

Tropospheric cloud properties at Davis, Antarctica (69S) and at Hobart, Australia (43S) measured with Rayleigh lidar

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Clouds remain one of the highest priorities to resolve in climate change projection due to their very large uncertainties. Little is known about Antarctic clouds compared to other regions, yet they are crucial for a correct understanding of the ice sheet mass balance and surface radiative balance. The incorrect representation of Southern Ocean clouds also creates uncertainties in future projections of the Antarctic via atmospheric transport processes. There is a paucity of ground-based measurements in these regions compared with other latitudes.

As a first step toward quantifying various cloud properties in the southern high latitudes, a Rayleigh lidar at Davis, Antarctica (69S, 78E) has been making campaign-based observations of clouds for the last few years, initially focussing on upper tropospheric cirrus clouds. Radiosondes and a co-located wind-profiling radar provide additional data with which to characterise the clouds and the environment in which they exist. We present a case study of thin cirrus in the wintertime upper troposphere and examine its presence in the context of the mesoscale meteorology. During spring 2012, a new polarization system was deployed to Davis, allowing observations of cloud phase. We construct an initial spring climatology of cloud parameters, including cloud top height, cloud phase, cloud temperature and optical depth.

Recently we have begun development of a small polarized lidar system at Hobart (43S, 147E). We will present initial results from these observations at Hobart, including observations of ice and water clouds and the beginnings of a cloud climatology. We discuss our future plans for extending the suite of instruments at Davis to fully characterise clouds in coastal East Antarctica and the Southern Ocean so as to provide various parameters for climate and forecast model evaluation.

In situ measurements of stratospheric aerosols from a new light optical aerosol counter with particle characterization capabilities

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The understanding of the processes that control stratospheric aerosols and their variability needs to be improved especially to better capture the interaction between these high altitude aerosols and the climate system. A new SPARC initiative, Stratospheric Sulphur and its Role in Climate (SSiRC) has been very recently created to address this issue.

A new generation of aerosol counter, called LOAC (Light Optical Aerosol Counter) which is of interest for the scientific objectives of SPARC-SSiRC, has been developed in the frame of a cooperation between French scientific laboratories (CNRS), the Environnement-SA and MeteoModem companies and the French Space Agency (CNES). LOAC is a small optical particle counter/sizer of ~250 grams, having a low electrical power consumption. The measurements are conducted at two scattering angles. The first one, at 12°, is used to determine the aerosol particle concentrations in 19 size classes within a diameter range of ~0.3-50 µm. At such an angle close to forward scattering, the signal is much more intense and the measurements are the least sensitive to the particle nature. The second angle is at 60°, where the scattered light is strongly dependent on the particle refractive index and thus on the nature of the aerosols. The ratio of the measurements at the two angles is used to discriminate between the main types of particles, in particular liquid droplets, mineral particles and soot.

The high launching reactivity of meteorological balloon launches of LOAC has allowed us to foresee further advances in the characterization of aerosol physical properties in the middle atmosphere, of their natural variability from various sources (such as volcanic plumes) and of potential anthropogenic effects, a philosophy which can be similar to the recurrent ozone soundings.

Since 2011, we have operated LOAC in various environments (Arctic, Tropics, mid-latitudes). The results obtained during these balloon flights and related campaigns will be presented firstly to highlight the capabilities of the instrument to detect the concentrations of different aerosols, i.e. cloud droplets, carbonaceous aerosols from polluted areas, mineral particles from sand episodes across the Mediterranean sea (CHARMEX project), volcanic sulphate aerosols in the troposphere (Etna site). Then, from the various balloon flights of the last version of LOAC conducted in 2013 at mid-latitude, we will present the observations of stratospheric aerosols in this period free of volcanic influence. We will particularly point out the variability of the sulphate and solid particle content up to altitudes above 30 km in terms of concentrations and size distributions. We will discuss the possibility to detect meteoric particles.

These new observations have several implications relevant for the SSiRC scientific objectives such as 1) documenting the seasonal variability of background aerosols using in situ instruments and 2) providing the necessary aerosol parameters to validate or drive simulations from Climate-Chemistry models and investigate the radiative impact of stratospheric aerosols.

Science highlights from the GCOS Reference Upper Air Network (GRUAN)

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Measurements of primary state variables of the troposphere and stratosphere are typically made to provide the input required by numerical weather prediction models. These same measurements then also constitute the primary source for meteorological reanalyses and climate analyses. The balloon-borne, ground-based and satellite-based systems used to make these measurements often undergo changes in instrumentation, data processing methods, retrieval techniques, and calibration. These changes are often poorly documented and very seldom are measurement series reprocessed to ensure long-term homogeneity of the climate data record. Such unphysical discontinuities in measurement records not only confound the detection and attribution of climate change signals, but can also lead to deterioration of the quality of meteorological reanalyses.

To address this specific deficiency of the global climate monitoring network, the World Meteorological Organization (WMO) and the Global Climate Observing System (GCOS) called for the establishment of a new state-of-the-art global network of high quality measurements of essential climate variables in the upper atmosphere. The establishment of GRUAN (GCOS Reference Upper Air Network) is now underway and 16 sites participating in the implementation phase of GRUAN are providing, or are about to start providing, reference quality measurements that adhere to GRUAN operating protocols. In addition to improving the data required for the detection and attribution of changes in climate in the troposphere and stratosphere, these measurements are expected to be valuable either as input to global meteorological reanalyses, or to validate reanalyses data products.

The latest scientific results from GRUAN will be presented including how GRUAN data can best be exploited for scientific studies, the use of GRUAN data for satellite calibration, the scientific bases underlying the intended design of the network, as well as the outcomes of studies performed to determine optimal measurement scheduling. The presentation will also highlight the protocols that have been established to ensure that measurements are of reference quality, what measurement systems are (and will be) operating at GRUAN sites, what data products are expected to flow from those systems, and an overview of the data currently flowing from GRUAN sites. A focus of the presentation will be to describe the value of GRUAN measurements to the global climate monitoring community and in particular how the robust derivation of measurement uncertainties on all GRUAN measurements enhances their scientific utility.

Attribution of direct ozone radiative forcing to spatially resolved emissions

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Quantifying the dependence of ozone direct radiative forcing (DRF) on the mixture and spatial distribution of precursor emissions is a key step towards understanding the impact of air quality standards on climate. We show how a combination of satellite observations of ozone and its radiative effect in conjunction with an adjoint chemical transport model to determine the ozone DRF due to global, anthropogenic NO_x, CO, and non-methane hydrocarbons (NMHC) emissions regionally at 2x2.5° resolution. We show that 8% of the ozone DRF from the sum of all these emissions can be attributed to 15 regions, which are predominantly located in China and the United States (US). To achieve an equivalent reduction in ozone DRF, necessary emission reductions for each precursor vary intra-continently by a factor of 3–10 and globally by over an order of magnitude. The contribution of NO_x emissions to ozone DRF relative to CO and NMHC emissions within individual regions varies globally by nearly a factor of two.

Long term changes in the polar vortices

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As the amount of halogens in the stratosphere is slowly declining and the ozone layer slowly recovers it is of interest to see how the meteorological conditions in the vortex develop over the long term since such changes might alter the foreseen ozone recovery. In conjunction with the publication of the WMO Antarctic and Arctic Ozone Bulletins, WMO has acquired the ERA Interim global reanalysis data set for several meteorological parameters. This data set goes from 1979 - present. These long time series of data can be used for several useful studies of the long term development of the polar vortices. Several "environmental indicators" for vortex change have been calculated, and a climatology, as well as trends, for these parameters will be presented. These indicators can act as yardsticks and will be useful for understanding past and future changes in the polar vortices and how these changes affect polar ozone depletion. Examples of indicators are: vortex mean temperature, vortex minimum temperature, vortex mean PV, vortex "importance" (PV*area), vortex break-up time, mean and maximum wind speed. Data for both the north and south polar vortices have been analysed at several isentropic levels from 350 to 850 K. A possible link between changes in PV and sudden stratospheric warmings will be investigated, and the results presented.

How well can we model polar spring ozone variability in a CCM?

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Chemistry-climate models (CCMs) are important tools for the assessment of chemistry-climate interactions, including ozone issues. For example CCMs are used to attribute past changes and to simulate the future development of the stratospheric ozone layer. Their ability to capture the full range of interannual variability is crucial for our assessment of uncertainties in future projections. One important measure of variability is the range of polar ozone amounts that can be modelled.

Two intrinsically linked elements determine polar ozone amounts in spring: meridional transport and chemical loss. Both effects accumulated over the preceding months and determine ozone anomalies in spring. However the duration and occurrence frequency of low stratospheric temperatures is guiding both processes. Consequently a lack of modelled high-latitude ozone variability can be caused by deficits in the chemistry and/or a lack of range in temperature variability. Feedbacks exist, because temperatures depend on changes in long-lived greenhouse gases, ozone and dynamical changes.

To test the chemical component in the UK's chemistry-climate community model (UMUKCA) (<http://www.ukca.ac.uk/>) we use the nudged configuration specifying ERA-Interim meteorological fields over the period 1979 – present. We utilise the newly compiled ESA Ozone Climate Change Initiative (CCI) (<http://www.esa-ozone-cci.org/>) merged total ozone record for the period 1996 – 2011 in the validation. Focusing on extreme years, 1997 and 2011 in the northern hemisphere and 2002 in the southern hemisphere, we investigate how the modelled ozone anomalies deviate as a function of month from the observed ones.

We conclude that the studied model set-up is capable of capturing the extreme ozone anomalies observed in the last decades and that the limiting factor in modelling ozone variability/extremes is the range of meteorological (temperature) variability in the underlying climate model. With this in mind we conclude that uncertainties caused by internal variability are quite likely underestimated in ozone projections, because the range of modelled variability in the free running model version seems commonly too small.

Validation of fresh water fluxes in HOAPS and ERA-Interim reanalysis data over sea

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Variations of ocean surface salinity, influencing ocean currents, are caused to a large extent by the surface freshwater fluxes, which are established by the difference between precipitation and evaporation. But even to date they are difficult to assess. So the relative paucity of evaporation or associated latent heat flux measurements and uncertainties in empirical approaches lead to large uncertainties of evaporation products over the ocean (e.g. Large and Yeager, 2009). Measuring precipitation over the ocean is also a challenging task. However, the progress in satellite technology has provided the possibility to retrieve global data sets from space, including precipitation, with sufficient accuracy (Levizzani et al., 2007). On the other hand Andersson et al. (2011) pointed out that even state-of-the-art satellite retrievals and reanalysis data sets still disagree on global precipitation with respect to amounts, patterns, variability, and temporal behavior. These uncertainties have consequences not only for ocean modeling but, for example, also for modeling of the washing out of aerosols by rain. That calls for a validation of evaporation and precipitation fields.

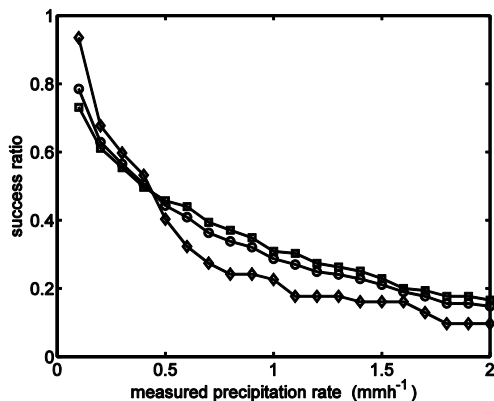


Fig.1: Success ratio of HOAPS precipitation against measurements (all \circ , only rain \square , only snow \diamond) as a function of minimum measured precipitation rate.

In the present study we use three years of precipitation measurements onboard several research vessels and parameterized latent heat fluxes from R/V *Polarstern* to validate the HOAPS-S subset data (Hamburg Ocean Atmosphere Parameters and fluxes from Satellites) and ERA-Interim reanalysis data, mainly for the Atlantic area. The parameterization of latent heat fluxes is based on turbulence measurements performed on Atlantic transects onboard *Polarstern* during the recent years.

The statistical analysis of precipitation data follows the recommendations given by the World Meteorological Organisation for binary forecasts. It came out that the number of observations is sufficient to compare mean precipitation, too. Some of the results are that the success ratio of HOAPS precipitation against measurements (Fig.1) reaches values of about 0.8,

indicating a good performance of the HOAPS' algorithm, and a mean precipitation rate, which is about 15% lower than observed. The HOAPS latent heat fluxes show also a negative bias compared to both, observations and ERA-Interim reanalysis data, which can be attributed to uncertainties in estimated air temperatures and humidities.

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Observations of vertical profile of Ozone from SCIAMACHY

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The Scanning Imaging Absorption spectroMeter for Atmospheric CHartographY, SCIAMACHY is a national contribution to the ESA Envisat, which was launched on 28th February in 2002 into a sun synchronous orbit in descending node, having a 10:00 equator crossing time. ESA lost contact with Envisat on 8th April 2012. SCIAMACHY makes measurements of the back scattered, reflected and emitted solar electromagnetic radiation, contiguously between 214 and 2380 nm in 8 channels at spectral resolutions between 0.2 and 1.4 nm. In each orbit solar occultation in the northern hemisphere is followed by alternate nadir and limb observations with lunar occultation being undertaken for about 6 months of the year around full moon in the southern hemisphere. The limb measurements on inversion yield vertical profiles the following:

- UT/LS and stratosphere: O₃, NO₂, BrO, H₂O, polar stratospheric clouds and aerosol in the stratosphere
- mesosphere O₃, polar mesospheric/ noctiluscent clouds, and mesopause temperature,
- mesosphere and lower thermosphere, the metal atoms emissions from meteoritic clouds and molecular and atomics emissions.

In addition the solar and lunar occultation yields vertical profiles of O₃, NO₂, BrO and aerosol. The presentation addresses the time series of the data products, in particular O₃ Gebhardt et al 2013) and aerosol, retrieved from SCIAMACHY: the origin of the observed changes being a focus.

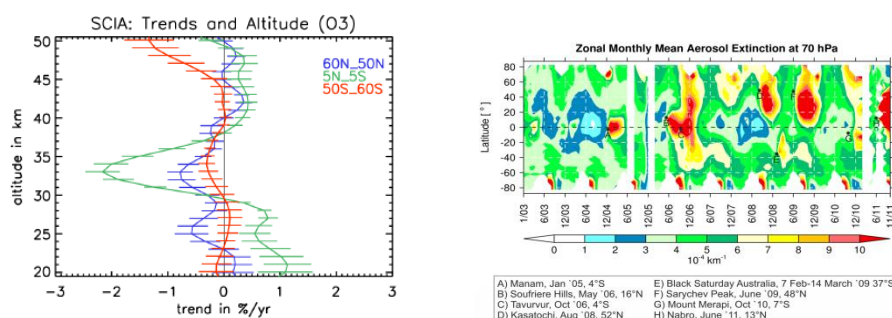


Figure 1 O₃ linear trends derived from SCIAMACHY limb observations.

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Changes in South Pacific Blocking and the Influence on New Zealand and Antarctica

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A paper by Dean and Stott (2009, J.Clim) demonstrated that the increasing trend in New Zealand temperatures over the past 50 years could be attributed to increased anthropogenic greenhouse gas concentrations, but only if a recent trend to more southerly flows over New Zealand was first removed from the observations. This represented an example of coupled climate models failing to adequately simulate a regional circulation change, whether forced, or due to under-representation of natural variability. Here we investigate the cause of this trend using reanalysis datasets, a PLS regression analysis, and a blocking high index derived from Rotated EOFs two and three of Southern Hemisphere monthly mean surface pressure (Renwick, 1998, J.Clim). This analysis shows that the most likely explanation for the southerly trend is the significant decreasing trend for blocking in the south-west (SW) Pacific (figure 1). We have previously used seventy simulations of the 20th Century from the CMIP3 archive to show that models are unable to produce such a large trend in SW Pacific blocking, but do reproduce the trend in south-east (SE) Pacific blocking. Here we extend this analysis to the coupled models available in the CMIP5 archive, as well as those from the C20C experiment, and finally coupled chemistry models that participated in the CCMVAL experiment. This additional range of models gives insight into possible causes of the model failure. In particular we consider in detail new simulations of the fully coupled atmosphere/ocean/chemistry model HadGEM3-UKCA, which shows promising improvements in circulation variability. Because of the contrasting results for the east and west Pacific we investigate the role that tropical convective anomalies might have played in modulating South Pacific blocking via mid-latitude teleconnections. Finally we consider the relationship between these observed changes in south Pacific blocking and the Amundsen sea low, and in turn the implications for recent sea ice variability in the South Pacific region of Antarctica.

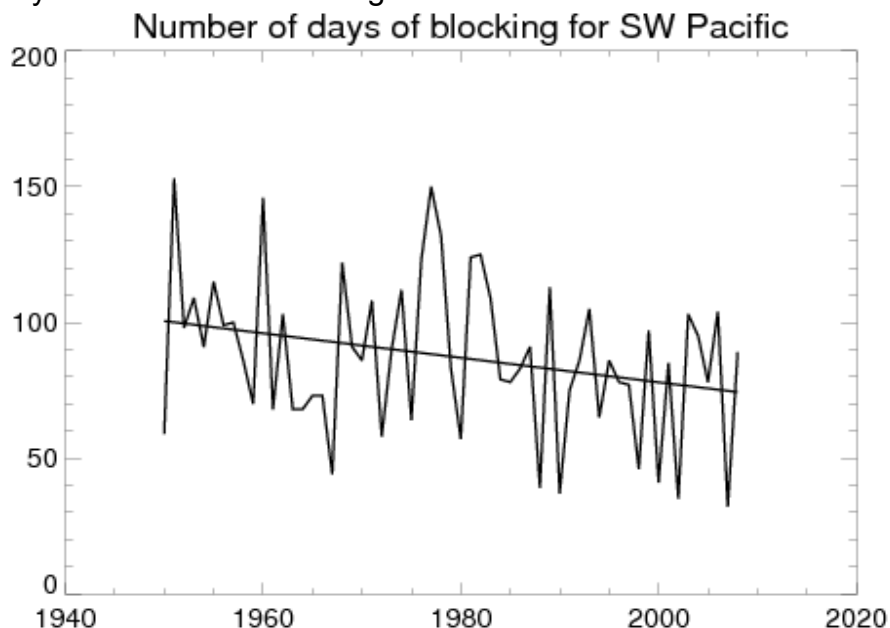


Figure 1. The number of days of SW Pacific Blocking per year from the 20th Century Reanalysis. The best fit linear trend is -4.5 days per decade with a p value of 0.03.

Stratospheric O₃ changes during 2001–2010: the small role of solar flux variations in a CTM and a CCM

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Solar spectral fluxes (or irradiance) measured by the SOLar Radiation and Climate Experiment (SORCE) show different variability at ultraviolet (UV) wavelengths compared to other irradiance measurements and models (e.g. NRL-SSI, SATIRE-S). Some modelling studies have suggested that stratospheric/lower mesospheric O₃ changes during solar cycle 23 (1996–2008) can only be reproduced if SORCE solar fluxes are used. We have used a 3-D chemical transport model (CTM), forced by meteorology from the European Centre for Medium-Range Weather Forecasts (ECMWF) and a 3-D chemistry climate model (CCM) to simulate middle atmospheric O₃ using three different solar flux datasets (SORCE, NRL-SSI and SATIRE-S). Simulated O₃ changes are compared with Microwave Limb Sounder (MLS) and Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) satellite data. Modelled O₃ anomalies from all solar flux datasets show good agreement with the observations, despite the different flux variations. The off-line CTM reproduces these changes through dynamical information contained in the analyses. A notable feature during this period is a robust positive solar signal in the tropical middle stratosphere due to changes in stratospheric dynamics. Ozone changes in the lower mesosphere cannot be used to discriminate between solar flux datasets due to large uncertainties and the short time span of the observations. Overall this study suggests that, in a CTM, the UV variations detected by SORCE are not necessary to reproduce observed stratospheric O₃ changes during 2001–2010. But this uniqueness in a solar signal could not be confirmed with the CCM simulations.

On the accuracy of stratospheric meteorological reanalyses using wind measurements at high altitude in the stratosphere,

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This study is motivated by the improvement of the knowledge of stratospheric dynamics and the evaluation of the ability of models to represent wind variability in the stratosphere. To do that, 327 balloons (opened stratospheric balloons operated by CNES agency) flights trajectories were retrieved from 1989 to 2011. Balloons are considered as perfect tracers at high altitude. We deduce from the balloons trajectories zonal and meridional wind to provide a unique database in the altitude range [25-40] km. The collected data covers various seasons and different locations: Polar region (launch base at Kiruna (67.9°lat, 23.1°lon)) mid-latitudes (Gap (44.4°lat, 6.0°lon) and Aire-sur-Adour (43.7°lat, -0.25°lon) in France) and Tropics (Hawaii (19.1°lat, -155.8°lon), Teresina (-5.1°lat, -42.9°lon) and Bauru (-22.4°lat, -49.0°lon) in Brazil, Niamey (13.5°lat, 2.1°lon) in Niger).

We performed comparisons between wind measurements and ERA–interim reanalysis (Dee et al., 2011) from ECMWF (European Centre for Medium-Range Weather Forecasts). Biases obtained are in agreement with the results of Hertzog et al. (2004) focusing on polar vortex conditions, in the altitude range [15-20] km.

We will present the systematically evaluation of the accuracy of the ERA–interim reanalyses up to 40 km and performed in several geophysical conditions (polar vortex, spring and summer turn around in polar region, mid-latitude circulation in spring and autumn, and in the tropic East and West phase of the Quasi Biennale Oscillation).

We identify large discrepancies: above 30 km in Polar region, in the altitude range [20-30] km at mid-latitudes and above 30 km in the tropics where a large wave activity is recorded.

Winds measured at high levels are distributed in well defined layers with thickness sometimes lower than 100 m. They are more variable in direction and intensity than those calculated by the model. The wind variability is characterized by the probability density function of several parameters (number of layers, thickness, wind direction and speed variability) as a function of altitude.

Results presented will help for better understanding and improving the stratospheric circulation representation used by the models. This is one of the major issues for the stratosphere in the context of climate change.

On the consistency of the evolution of dynamics, temperatures and tracers in the TTL and lower stratosphere from the 1980's to the present in observations

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Satellite observations now provide a global record of about 3 decades of atmospheric temperature and chemical composition. Here, we focus on the evolution of the tropical tropopause layer (TTL) and tropical lower stratosphere (TLS). Trace gas distributions often reflect atmospheric dynamics and transport, and changes therein over time. Conversely, radiatively active trace gases and aerosol have an impact on the temperature structure (and hence also on atmospheric dynamics) and variations therein over time. We ask the question to what extent observations of temperatures, radiatively active trace gases and aerosol, and atmospheric dynamics (as represented in reanalyses) provide a coherent and quantitatively correct picture of the evolution of the TTL and TLS, and whether an integrated perspective can constrain uncertainties and errors in each of the variables. Of particular interest here is the observed non-monotonic cooling in the TLS, the very large uncertainty in temperature trends around tropopause levels, and possible changes in the Brewer-Dobson circulation and Quasi-Biennial Oscillation. We emphasise the connection with the evolution of the underlying troposphere, specifically also the possibility of a common anomaly centered around the year 2000, and the importance of the two major volcanic eruptions (El-Chichon and Pinatubo).

SPARC Reanalysis Intercomparison Project (S-RIP)

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The SPARC community has been using reanalysis datasets to understand atmospheric processes and variability, and to validate climate and chemistry-climate models. Currently there are eight global atmospheric reanalysis datasets available (NCEP/NCAR, NCEP/DOE, ERA-40, ERA-Interim, JRA-25/JCDAS, MERRA, NCEP-CFSR, and 20CR) and four more will be available soon (JRA-55, ERA-20C, ERA-SAT, and MERRA-2). The SPARC Reanalysis Intercomparison Project (S-RIP) is an emerging SPARC activity that was proposed in 2012 (Fujiwara et al., 2012; Fujiwara and Jackson, 2013). The goals of S-RIP are to create a communication platform between the SPARC community and reanalysis centres, to understand current reanalysis products, and to contribute to future reanalysis improvements.

The results will be published in a SPARC report. The first four “basic” chapters of the report are the Introduction¹, Description of the Reanalysis Systems², Climatology and Interannual Variability of Dynamical Variables³, and Climatology and Interannual Variability of Ozone and Water Vapour⁴. The following seven “advanced” chapters are: The Brewer-Dobson Circulation⁵, Stratosphere-Troposphere Coupling⁶, The Extra-tropical Upper Troposphere and Lower Stratosphere⁷, The Tropical Tropopause Layer⁸, The Quasi-Biennial Oscillation and Tropical Variability⁹, Polar Processes¹⁰, and The Upper Stratosphere and Lower Mesosphere¹¹. The final chapter is the Synthesis Summary¹². A key aspect of the synthesis will be to highlight appropriate and inappropriate uses of reanalysis datasets.

In this contribution, we will introduce the rationale of the report and the chapters and show some initial intercomparison results.

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S-RIP website: <http://www.woa.ees.hokudai.ac.jp/~fuji/s-rip/>

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Connections between the TTL and sea surface temperatures: interannual variability and trends

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Satellite data and chemistry-climate models are used to investigate the forcing of variability in the tropical lower stratosphere and upper troposphere. The observations show significant zonal variations in the upper tropospheric (UT) and lower stratospheric (LS) tropical temperature trends (with largest UT warming and LS cooling over the Indo-Pacific region). Chemistry-climate models are used to demonstrate that SST trends are driving the zonal asymmetry, and that the anomalous circulation set up by the changing SSTs has led to zonal structure in the ozone and water vapor trends near the tropopause, and subsequently to less water vapor entering the stratosphere.

Chemistry-climate model experiments are also used to demonstrate that seasonality and the location of the peak warming of SSTs dictate the response of stratospheric water vapor to El Nino, with the response varying with season and between different variants of the El Nino. The difference in water vapor in the lower stratosphere between the central and eastern El Nino events is around 0.3 ppmv, while the difference between the winter and spring responses exceeds 0.5 ppmv.

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A Proposed WCRP/SPARC Project on Fine-Scale Atmospheric Structures and Processes

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A new WCRP/SPARC project is proposed on fine-scale atmospheric structures and processes. This new, proposed project has its origins from existing research uses of the US high vertical-resolution radiosonde data that have been accessed through the SPARC Data Center. In particular the outline for this proposed project were formulated in an international workshop on Research Applications of High Resolution Radiosonde Data, which was held in Stony Brook, NY, USA, during the period May 27-29, 2013. Funding for this workshop was through the US National Science Foundation, WCRP/SPARC, and Stony Brook University. The project vision is not only to improve understanding of fine-scale atmospheric structures and processes that have already been studied using these data, such as gravity waves, turbulence, the tropopause, and the planetary boundary layer, but also to realize the full potential of high resolution sounding data in new research areas. This project's proposed activities would be the following: to provide advocacy and guidance for a proposed High Vertical Resolution Sounding Data Archive; to increase the availability of high vertical-resolution radiosonde and other data taken worldwide; to promote scientific investigations through workshops and coordinated communications; and to enable collaborative publications, reviews, and regional studies using such data.

This paper will give some history of SPARC's previous efforts that have led to this proposed project as well as examples of studies in diverse areas that have utilized the US high vertical-resolution radiosonde data, and give more details about this proposed project.

Quantifying the Summertime Austral Jet Stream and Hadley Cell Response to Stratospheric Ozone and Greenhouse Gases

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The impact of anthropogenic forcing on the austral jet stream and Hadley Cell in summer is assessed across three comprehensive climate model datasets, the Chemistry Climate Model Validation Activity 2 (CCMVal2) and Coupled Model Intercomparison Projects, Phases 3 and 5 (CMIP3,5). Changes in stratospheric ozone and greenhouse gases impact the troposphere in this season, and a simple framework based on temperature trends in the lower polar stratosphere and upper tropical troposphere is developed to separate their effects. It suggests that Southern Hemisphere circulation trends are driven by changes in upper troposphere/lower stratosphere temperature gradients: the subtropical and extratropical jets respond similarly when the tropics warm or the polar stratosphere cools. The mean circulation response to greenhouse gases and ozone is fairly comparable across the three multimodel datasets; consistent with previous studies, ozone has dominated changes in recent decades, while in the future, ozone and greenhouse gases will largely offset each other.

The multimodel mean perspective, however, masks considerable spread between individual models. Uncertainty resulting from differences in temperature trends is separated from differences in the circulation response to a given temperature change. Both sources of uncertainty contribute equally to model spread. Uncertainty in temperature trends is dominated by differences in the polar stratosphere, not the tropics, suggesting that reducing uncertainty in models' climate sensitivity may not narrow the spread in subtropical and extratropical circulation trends in this season. Rather, the ozone forcing must be constrained. Even if the temperature trends were perfectly known, however, models' "circulation sensitivity," differences in the response of the circulation to the same thermal forcing, must be addressed in order to narrow spread in climate projections.

Detection of Volcanic Aerosol with Envisat MIPAS

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It is known that volcanic eruptions can inject significant amounts of sulfur dioxide and volcanic ash directly into the stratosphere. Most sulfur dioxide and ash, however, is injected into the troposphere and only a fraction of it can make its way into the stratosphere. The transport pathways of the volcanic aerosol and its impact on climate are still discussed. Volcanic eruptions also provide unique point sources of aerosol that can be used as a tracer to study circulation patterns. Global and altitude resolved time series of observations provide a valuable source of information to trace volcanic aerosol. We introduce new aerosol detection methods for the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) and present case studies for ash and sulfate aerosol dispersion.

MIPAS is an infrared limb sounding instrument that provides day and night measurements with a vertical sampling of 1.5 km in the upper troposphere (down to 5 km) and lower stratosphere. Due to the long viewing path through the atmosphere it is very sensitive to cloud and aerosol layers. We developed detection methods for volcanic ash and sulfate aerosol. The detection methods basically rely on the different spectral behaviour of ice and volcanic aerosol. With the help of radiative transfer simulations including scattering on aerosol and cloud particles we identified the detectable particle size and concentration ranges as well as the detection accuracy in the vertical. The new methods allow us to detect volcanic aerosol layers and to discriminate sulfate aerosol and ash from ice clouds. This enables us to trace volcanic emissions in the stratosphere as well as the troposphere.

Regarding the volcanic ash detection method we discuss the 2011 eruption of the Puyehue. The eruption injected large amounts of volcanic ash into the troposphere and lower stratosphere. We traced the ash as it was distributed widely in the southern hemisphere and observed its descent during the following three months (Griessbach et al., 2012).

The Nabro eruption in 2011 mainly injected sulfur dioxide into the atmosphere. We can trace the sulfate aerosol on a daily basis starting one day after the initial eruption until the beginning of 2012. In the first two weeks we observe the sulfate aerosol circulating around the Asian monsoon with the highest detection altitudes already above 380 K. Our MIPAS observations combined with backward trajectories imply that the aerosol entered the Asian monsoon circulation gradually from an outer circulation ring. We also observe several wave breaking events (29 June, 16 July) where sulfate aerosol is shed off the monsoon circulation and moves north beyond 70 N.

Detecting and tracing volcanic aerosol vertically resolved on a global scale is of particular interest to SPARC. Enhanced stratospheric aerosol after volcanic eruptions is known to have an impact on climate. Especially the Nabro case study offers the unique opportunity to study the transport processes in the Asian monsoon region that is discussed to be one of the main transport pathways to the stratosphere. With our MIPAS aerosol measurements we can contribute essential new information to the canon of already existing information.

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Peak Anomalies in Stratospheric NO₂ over Russia Related to the 2011 Ozone Hole in the Arctic

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In this work we analyze data of long-term ground-based spectrometric measurements of the column NO₂ content at Russian stations of Zvenigorod (55.7° N, 36.8° E, Moscow region), Tomsk (56.5° N, 85° E, Western Siberia), and Zhigansk (66.8° N, 123.4° E, Eastern Siberia). Column NO₂ data for Zvenigorod and Zhigansk are publicly available at the NDACC web site (<http://ndacc.org>). Additionally we retrieve NO₂ vertical profiles at Zvenigorod by solving an inverse problem. We have found extreme negative NO₂ anomalies in the winter-spring period of 2011 over the three stations (Fig. 1). The peak NO₂ decrease was about 40%. One-episode NO₂ anomaly was observed at Zvenigorod in the end of March while three episodes were observed at Tomsk and Zhigansk in the end of January, the end of February and in March (Zhigansk) or April (Tomsk). Trajectory analysis shows that the 2011 anomalies in NO₂ were caused by transport of stratospheric air from the area of the ozone hole observed that season in the Arctic. The anomalies in column NO₂ were accompanied by negative anomalies in total ozone and stratospheric temperature.

Negative anomalies in column NO₂ were also observed in winter-spring periods in other years. Usually they were also due to transport from the polar region. However extremely low NO₂ contents were observed in 2011. Figure 2 compares NO₂ vertical profiles over Zvenigorod corresponding to the NO₂ anomalies in the end of March 2010 and in the end of March 2011 (noted by vertical broken lines in Fig. 1). The shapes of the profiles above the NO₂ maximum are similar to each other. However the profiles in 15-25 km layer differ from each other. NO₂ in this layer is less abundant in the 2011 anomaly than in the 2010 anomaly. Therefore the difference between the column NO₂ contents in the March anomalies of 2010 and 2011 over Zvenigorod is caused by the NO₂ deficit below the NO₂ maximum, which probably results from the denitrification of the Arctic stratosphere in the end of winter 2011 due to polar stratospheric clouds.

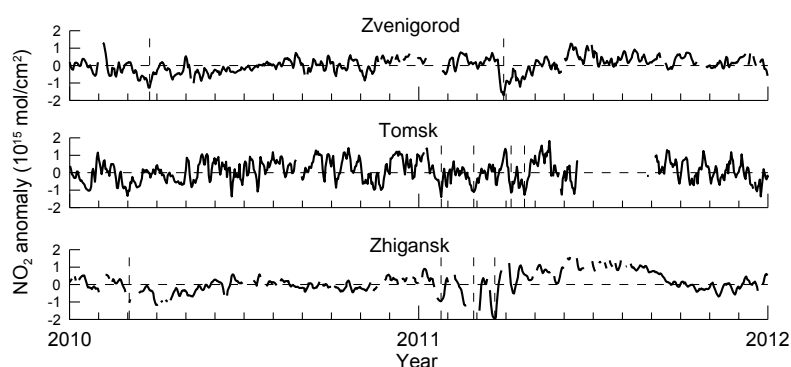


Fig. 1. Column NO₂ anomalies over Zvenigorod, Tomsk, and Zhigansk in 2010-2011. Peak anomalies are shown by vertical broken lines

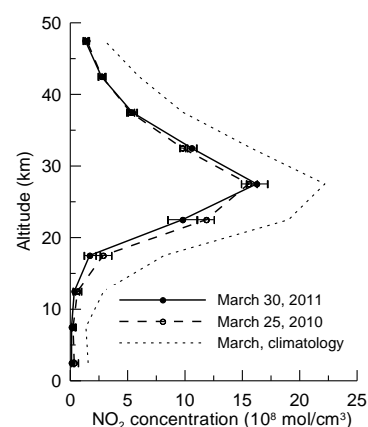


Fig. 2. NO₂ profiles at Zvenigorod for the 2010 and 2011 anomalies, and the climatological profile

Past Ozone Profile Changes analyzed by statistical modeling of suitable long-term measurements

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Stratospheric concentrations of ozone depleting substances in mid-latitudes have slowly decreased since mid-1990s due to the successful implementation of the Montreal Protocol (1987) and the subsequent enforcements. Comprehensive analysis of changes in global profile ozone changes is a suitable method to quantify the beneficial effect of the Montreal Protocol on the ozone layer. The global picture needs to be based on merged satellite ozone series since no satellite instrument covers the entire period when ozone depleting substances started to affect stratospheric ozone in the 1970s. Ground-based instruments allow to quantify long-term profile ozone changes at individual sites.

The work presented here results from the SI2N activity which is an international initiative supported by SPARC, International Ozone Commission (IO3), IGACO-O3/UV of GAW (Global Atmosphere Watch) and NDACC (Network for the Detection of Atmospheric Composition Changes) demonstrating the bottom-up character of the project. SI2N work has assessed the knowledge of the changes in the vertical distribution of ozone, including a thorough assessment of the quality of the large number of measurements data sets, the ways in which datasets are merged from multiple data sets and the statistical analysis.

In this presentation long-term profile ozone changes are analysed using multiple regression models (using proxies such as QBO and solar cycle). We will compare results of the piecewise linear trend (PWLT) modeling with results using Equivalent Effective Stratospheric Chlorine (EESC) as proxy for chemical ozone depletion. The different merged satellite ozone profile series regarding ozone profile changes are compared as function of latitude, altitude and seasonality and they will be evaluated by long-term ground-based series at selected sites. Particular attention will be devoted to the comparisons of the tropical and extratropical regions and the asymmetry of Northern and Southern extratropics. The results will provide important information for comparison with numerical simulations.

SI2N Overview Paper - Measurements Or Where Do I Find the Perfect Ozone Profile Data?

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The peak of chlorofluorocarbon (CFC) concentrations in the stratosphere was reached in the mid to late 1990s. Since then the detection and attribution of the ozone layer recovery and evolution in measurement time series is one of the main focal points of stratospheric ozone research. Answering these questions requires a critical examination of the pattern and time sequence of ozone change with an accurate knowledge of the spatial (geographical and vertical) and temporal ozone response. For such examination, it is critical that the quality of the measurements used be as high as possible and that the measurement uncertainties are well quantified.

In preparation for the 2014 United Nations Environment Programme (UNEP)/World Meteorological Organization (WMO) Scientific Assessment of Ozone Depletion the SI2N initiative was created to evaluate the available long-term ozone profile data sets for measurement stability, uncertainty characteristics, and ultimately their suitability for ozone recovery studies. Some of the data sets have been improved based on the findings of this initiative, with updated data versions now being available.

This summary presents an overview of these stratospheric ozone profile measurement data sets (ground- and satellite-based) that are available for ozone recovery studies, the measurement techniques employed in obtaining them, their geographical and vertical coverage, layer density, the length of their time series, their native units and their overall measurement uncertainties. In addition, the latest data versions are briefly described (including changes to previous data versions as well as different retrievals available for measurements from the same satellite instrument).

Changes in the Polar Vortex: Effects on Antarctic Total Ozone Observations at Various Stations and Antarctic Surface Climate Characteristics

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October mean total column ozone data from four Antarctic stations form the basis for understanding the evolution of the ozone hole since 1960. While these stations show similar emergence of the ozone hole from 1960 to 1980, the records are divergent in the last two decades. The effects of long-term changes in vortex shape and location are considered by gridding the measurements by equivalent latitude. A clear eastward shift of the mean position of the vortex in October with time is revealed, which changes the fraction of ozone measurements taken inside/outside the vortex for stations in the vortex collar region. After including only those measurements made inside the vortex, ozone behavior in the last two decades at the four stations is very similar. This suggests that dynamical influence must be considered when interpreting and intercomparing ozone measurements from Antarctic stations for detecting ozone recovery and ozone-related changes in Antarctic climate. As a next step, changes in Antarctic surface temperature and sea ice extent will be related to the observed changes in the polar vortex and possible connections evaluated.

Highlights of the SPARC Data Initiative: Part I

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This contribution will present Part I of the research highlights of the SPARC Data Initiative. The main objectives of the SPARC Data Initiative were to compile and compare climatologies of trace gas and aerosol observations available since 1979 from a multi-national suite of limb-viewing satellite instruments. The zonal monthly mean climatologies, which were produced in a common format include the observations of 25 different atmospheric constituents obtained from 19 different instruments.

We here focus on the evaluations of the long-lived trace gases H₂O, CH₄, N₂O, CO, and HCl, some shorter-lived species (ClO, BrO, and CH₂O), as well as aerosol. The results highlight new evaluation methods and the advances in our understanding of these data sets, and also discuss their limitations or usefulness for merging and trend analysis. Lessons learned and an outlook on the future of the SPARC Data Initiative will also be provided.

Solving the stratospheric water vapour entry puzzle

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Water vapour is the most important natural greenhouse gas in the atmosphere and provides a positive feedback to the climate forcing from CO₂. The greenhouse effect from water vapour is strongest in the upper troposphere and lower stratosphere (UTLS), where the lowest temperatures are found and where strong gradients in concentration across the tropopause exist. Water vapour is also a key constituent in atmospheric chemistry. It is the source of the cleansing agent of the atmosphere, hydroxyl (OH), which controls the lifetime of shorter-lived pollutants, stratospheric and tropospheric ozone, and other long-lived greenhouse gases such as methane.

Despite the importance of water vapour to chemistry and the radiative balance of the atmosphere, its observed long-term changes are not well understood mostly due to inadequate quality of the available observations. In particular, comparisons with long-term changes in tropical temperatures that are known to largely control stratospheric water vapour entry values are inconsistent leading to an unresolved puzzle. We here use a new approach combining water vapour observations from different limb-viewing satellite instruments and the information on modelled water vapour fields from a nudged chemistry-climate model (CMAM30) as transfer function in order to produce a long-term time series (or climate data record). This time series is then evaluated in order to infer and explain observed trends in stratospheric water vapour, reveal shortcomings in data sets, and also resolve apparent discrepancies between satellite observations and in-situ measurements from balloon-borne water vapour measurements.

On the dynamical characterization of the stratosphere using multi-scale analysis of N₂O, CH₄, O₃ and HNO₃ high resolution measurements.

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Small-scale turbulent processes are still poorly understood and parameterized in numerical models. In this study, we investigate mixing processes associated with turbulent processes by performing multi-scale analysis of high resolution trace species vertical profiles in the middle atmosphere, measured by the SPIRALE balloon-borne instrument in the middle atmosphere.

SPIRALE is a spectrometer with six tunable laser diodes for in situ measurements of trace gas species from the upper troposphere to the middle stratosphere (~34 km height). This instrument provides concentration of several trace gas species with a vertical resolution of ~5 m. SPIRALE has flown in tropical region (Teresina, 5.0°S/42.5°W, Brasil), at mid-latitudes (Aire sur l'Adour, 43.5°N/0.2°W; Gap, 44.3°N/6.0°E, France) and in Arctic region (Esrang, 67.5°N/21.0°E), and at different seasons, over the last 10 years.

The aim of this work is to evaluate the vertical turbulent diffusivity as a function of altitude, latitude and season. We will show preliminary results obtained by performing wavelet decompositions at different vertical scale, and roughness calculations, of N₂O, CH₄, HNO₃, and O₃ vertical profiles.

Comparison of the Cameroon Weather Synoptic Stations Rainfall Data with TRMM Datasets: Intra and inter annual Rainfall variability.

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Climatic hazards, associated with heavy precipitations and droughts greatly impact on the modification of socio-economic planning and livelihoods in the world, especially in developing countries where populations are highly vulnerable. With shifting seasons, increasing water scarcity, and potentially more frequent and intense extreme events (IPCC, 2007, 2010), climate change is bringing a series of disaster and livelihood impacts to the poorest and most vulnerable countries and communities, and is placing development assistance at risk. Over the past decades, progressively more attention has been given to converging Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) (Tom et al., 2010). The Cameroon (2N-14N and 9E-16E) Government is actually developing a wide program for DRR and CCA and needs regional climate modelling assistance. For instance climate modelling, to be consistent, requires deep validation using observational data. Generally, models results are validated based on direct comparison with rain gauge data or reanalysis data over the region of interest, but the spatial repartition of synoptic weather stations in Cameroon is sparse and heterogeneous as the meteorological observation network is seriously deteriorating. Furthermore, the number of stations has decreased from 1300 stations in 1968-1980 to least than 250 stations at the beginning of the year 1991. The aim of this study is to evaluate how accuracy are the 3B43 TRMM data by a direct comparison with the available National Meteorological Department (NMD) data and to show whether synoptic weather stations data (rain gauge) could be replaced by these datasets in Cameroon for models validation. Annual rainfall distribution showed that TRMM 3B43 is slightly underestimated in the Sahel, Savannah and Highlands zones whereas it is overestimated in the mono-modal and bi-modal forest zones. Bias is generally most pronounced in the bi-modal forest zone. In general, the study showed that 3B43 closely matches rain gauge data, suggesting that the goal of the algorithm was largely achieved as stated by (Debo and Kenji, 2003) and therefore can be used as reference data for validating forecast simulations as a replacement of gauge data. We also noticed the rainfall inter and intra annual variability which can be assigned to motion waves (Lenouo and Mkankam, 2008). For instance, the best agreements with rain gauge data are obtained for the Cameroon northern zone rather than for its southern counterpart leading to two majors climatic regions in Cameroon: the North region with the rainy season in JJA and the South region with the rainy season ranging from May to November.

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Spatio-temporal characteristics of convective gravity wave momentum flux derived from HIRDLS and SABER satellites in the stratosphere over Asian Summer Monsoon region

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Due to recently increased interest of the influence of the stratosphere on tropospheric weather and the inclusion of the stratosphere in the IPCC models, also gravity waves (GWs) as a major error source for climate modeling receives increased attention. One of the most important GW sources is deep convection. In particular, in the subtropics and tropics convective gravity waves (CGWs) are very important for driving the equatorial stratospheric semi-annual oscillation (SAO) and quasi-biennial oscillation (QBO). However, there remain still many open questions with respect to the detailed mechanisms, dominant scales and total momentum flux related to CGWs. This is, to a large extent, due to the lack of CGW observations. In the current study the absolute values of gravity wave momentum flux (GWMF) derived from global temperature measurement by the satellite instruments High Resolution Dynamics Limb Sounder (HIRDLS; 2005-2007) and Sounding of the Atmosphere using Broadband Emission Radiometry (SABER; starting 2002) are used to investigate the spatio-temporal characteristics of CGW over Asian Summer Monsoon region (5°N-40°N, 60°E-150°E). The results show that enhanced GWMF values generally appear in April and maintain till October in the lower stratosphere. The position of maximum GWMF values follows the deep convection centers during this period: In early summer GWs peak over India, in August and September the pattern shifts to the East. The intensity of the observed GWMF is also influenced by the background wind. In particular, the QBO modulates the interannual variability. This is investigated with supporting ray-tracing modeling.

SMILES diurnal variation climatology of strato- and mesospheric trace gases: O₃, HCl, HNO₃, ClO, BrO, HOCl, HO₂, and temperature

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We have made a climatology of the diurnal variation of short-lived atmospheric compounds, such as ClO, BrO, HO₂, and HOCl, as well as longer life time longer-lived species: O₃, the hydrogen chloride isotopes H³⁵Cl and H³⁷Cl, and HNO₃ from measurements by the Superconducting SubMillimeter9 wave Limb-Emission Sounder (SMILES) on International Space Station (ISS). We performed the observation with very low noise on the emission spectrum for measuring of vertical profiles of atmospheric compositions with altitude range from the lower stratosphere to the lower thermosphere (20 – 100 km), thus observing at all local times due to a non-sun-synchronous orbit of ISS.

The diurnal variation climatologies are based on data periods of two months. Consideration of the SMILES time-space sampling patterns with respect to the averaging coordinates is a key issue for climatology creation. Biases induced by inhomogeneous sampling are minimized by carefully choosing the size of averaging bins. The sampling biases of the diurnal variation climatology of ClO and BrO are investigated in a comparison of homogeneously sampled model data versus SMILES sampled model data from the stratospheric Lagrangian chemistry and transport model ATLAS. Mostly the relative error is in the range of 0 – 20%.

The diurnal variation climatologies of short-lived atmospheric composition were obtained for the first time. The SMILES climatology data sets are available via the SMILES data distribution home page. https://smiles-p6.nict.go.jp/products/research_latitude-longitude.jsf

Evolution of Atmospheric Sulfur dioxide (SO₂) Column Densities over Pakistan during last decade of Pakistan

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This study emphasize on evolution of atmospheric Sulfur dioxide (SO₂) column densities obtained from satellite observation over Pakistan during the time period of 2004 – 2012. The level-2 data product of Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) instrument onboard ENVISAT (Bovensmann *et al.*, 1999) retrieved by using by using Differential optical absorption spectroscopy (DOAS) (Khokhar et al., 2008; 2005; Van Roozendaal, 1999; Richter, 1998; Eisinger and Burrows, 1998; Perner and Platt, 1979) technique were used.

Spatio-temporal distribution of SO₂ column densities along with the seasonal variation over main cities and regions of Pakistan has been discussed in this paper.

The Nabro volcano eruption in 2011 had caused high SO₂ columns over East Africa, Middle East and South Asian region. Satellite images exhibited the transported SO₂ pollution over Pakistan during this event.

Temporal trend in SO₂ column densities was calculated and significance of the data sets was tested with statistical analysis. An overall increase of about 70% in SO₂ column densities over Pakistan during the timer period of 2004-2012 has been calculated. This study with spatial and temporal analyses of SO₂ pollution in the atmosphere of Pakistan by using satellite observation has been presented first time.

A climatological Perspective of Water Vapour at UTLS Region over Different

Global Monsoon Regions: Observations Inferred from AURA-MLS and Reanalysis Data

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AURA-MLS observations of eight years from 2004-2011 have been utilized to understand the hydration and the dehydration mechanism over the northern and the southern hemispheric monsoon (NH and SH) regions. The monsoon regions considered are the Asian Summer Monsoon (ASM), East Asian Summer Monsoon (EASM), Amazon Monsoon (AM), North African Monsoon (NAM), South American Monsoon (SAM) and the Australian Monsoon (AUM). The annual cycle of water vapour as expected shows maxima over NH during June-August and during December-February over the SH. The time taken by the air parcels over the NH monsoon regions is found to be different compared to that over the SH monsoon regions. The analysis shows the concentration of water vapour in the upper troposphere and the lower stratosphere (UTLS) has not changed over these eight years in both the hemispheres. The Probability Density function (PDF) shows a unimodal Gaussian distribution over all the monsoon regions except AUM where bimodal distribution is observed. The PDF's also shows a wider distribution over the AM region compared to the other monsoon regions. The analysis shows that the direct overshooting by convection plays only a negligible role in transport to the stratosphere. Analysis of the UTLS water vapour with temperature and ice water content shows that the AM is hydrating the stratosphere compared to all the other monsoon regions where the water vapour is getting dehydrated. Thus it is envisaged that the present results will have important implications in understanding the exchange processes across the tropopause over the different monsoon regions and its role in stratosphere chemistry.

Quasi-Stationary Rossby Waves in the Southern Extratropics: An Examination of Meteorological Reanalyses and Climate Model Simulations

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Large-scale zonal asymmetries in the climatological spatial pattern of atmospheric variables such as geopotential height, temperature, and trace gas concentration are primarily dictated by the characteristics of quasi-stationary Rossby waves (QSWs). These waves are mainly forced by spatial inhomogeneities in surface temperature (particularly associated with land-sea contrasts), orography, and large-scale latent heat release, and are in turn affected by transient eddies and changes in the meridional and vertical gradient of temperature.

Here we examine meteorological reanalyses and climate model simulations to quantify variability and change in the QSW patterns in the troposphere and stratosphere of the Southern Hemisphere extratropics. The primary motivation for this study is to examine how well climate models simulate the climatological phase and amplitude of the low-order QSW modes, particularly in light of potential model biases in the temperature of the Southern Ocean and the distribution of Antarctic sea ice, and long-term changes in greenhouse gases and stratospheric ozone. We use atmosphere-ocean (AO) climate model simulations from the Climate Model Intercomparison Project (CMIP) and chemistry-climate model simulations from the SPARC Chemistry-Climate Model Validation Activity (CCMVal) and the SPARC/IGAC Chemistry-Climate Model Initiative (CCMI).

In reanalysis data (e.g. ERA-Interim) of the satellite era (from 1979), we find significant trends in the longitude and amplitude of QSW wave-1 and wave-2 patterns in the Antarctic lower stratosphere during spring and summer, that appear in part related to ozone change. Climate models with interactive stratospheric chemistry generally perform better at reproducing the observed trends than AO models. We discuss the observed trends and performance of the climate models for the southern extratropics, and diagnose characteristics of the models that result in the best agreement with the observed QSW behaviour.

Brewer-Dobson circulation diagnosed from JRA-55

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JMA completed the new reanalysis, JRA-55 and will release it to the society, soon. Brewer-Dobson circulation (BDC) diagnosed from JRA-55 is compared with that from JRA-25 and ERA-interim. The intensity of the climatological northern cell of BDC in JRA-55 is weakened from JRA-25 in all season, moreover the intensity of the southern cell in JRA-55 is increased from JRA-25 in southern winter. As a result, the climatological seasonality of BDC diagnosed from JRA-55 becomes similar to that from ERA-interim. It is considered that BDC diagnosed from JRA-55 considerably improved through remedies of the thermodynamic balance of GCM and advancement of data assimilation schemes.

The inter-annual variation of the northern cell of BDC in JRA-55 is well consistent with that in JRA-55C, which is a family reanalysis assimilating conventional observations only. In other words, the inter-annual variation of the northern cell of BDC in JRA-55 is little affected by changes of the satellite observations at least during the period from 1973 to 1996. The northern cell was strengthened from 1960 to 1980, but it was slightly weakened since 1980. The inter-annual variation in JRA-55 is agreed well with that in ERA-interim. On the other hand, the southern cell indicates a strengthening trend from 1960 to 2010 in JRA-55, although the southern cell of ERA-interim indicates a weakening trend.

The climatological BDC of JRA-55 is stronger than that of JRA-55AMIP which is the same model simulation experiment as used in JRA-55 Data assimilation system under the same boundary conditions of SSTs and the greenhouse gases. The difference may be closely related to the reproducibility of QBO. Although QBO is reproduced in reanalyses, both of JRA-55 and JRA-55C, QBO is not reproduced in JRA-55AMIP. The systematic error of the climatological zonal mean zonal wind of JRA-55AMIP is similar spatial to a specific QBO phase. The weakening of BDC in JRA55-AMIP may be partially explained by the QBO-phase dependence of BDC.

Understanding the Global Distribution of HCFC-22 in the Upper Troposphere and Lower Stratosphere

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The annual springtime minimum in stratospheric ozone over the Antarctic is primarily caused by catalytic reactions of ozone and chlorine. Anthropogenic chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are major sources of this chlorine. Since the implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987, HCFC-22 has been the primary replacement for CFCs, since its shorter lifetime leads to a much lower ozone depletion potential. Rising atmospheric concentrations of HCFC-22 are causing concern due to its strong global warming potential. To understand the atmospheric distribution of HCFC-22, its seasonal variability and inter-hemispheric gradient, we use a combined measurement/model approach using satellite observations and model simulations. In particular, we use zonal mean comparisons and joint probability density functions to explore the behaviour of HCFC-22 in the upper troposphere and lower stratosphere.

The observations used in this study were obtained by the Atmospheric Chemistry Experiment Fourier transform spectrometer (ACE-FTS). The ACE-FTS is the primary instrument on board the Canadian SCISAT mission, capable of measuring key CFC and HCFC species. The altitude distribution from the ACE-FTS profiles provides information that is complementary to the in situ ground-based measurements that are used to monitor these species but are confined to the lower troposphere. To understand the ACE-FTS measurements, we use the Canadian Middle Atmosphere Model (CMAM), which has been used extensively as a free-running chemistry-climate model. To assess chemical processes in the CMAM, a twenty-year run has been produced where the dynamics of the model have been nudged to the ERA Interim reanalysis (the CMAM20 run). Halocarbons in the CMAM are grouped for ease of calculation; therefore, a direct comparison to measurements is complicated by varied mixing and chemical timescales within each group. For example, the HCFC-22 group combines HCFC-22 with four other HCFCs. Therefore, an HCFC-22 tracer was added in parallel to the grouped species while ensuring that there is no delivery of reactive halogens into the model when it breaks down. The parallel HCFC-22 has a hemispherically-defined lower boundary condition, appropriate chemistry and is advected as a tracer.

To compare the representation of HCFC-22 in the CMAM20 run, the model outputs on both 6-hourly and monthly timescales have been sampled at each occultation location. The zonal mean comparisons with CMAM20 agree well with some evidence of too rapid transport within the stratosphere. The use of HCFC-22:N₂O joint probability density functions has allowed a diagnosis of the chemistry and transport characteristics in the CMAM20 stratosphere.

Climate data record of carbonyl sulfide (COS) in the Southern Hemisphere

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Carbonyl sulfide (COS) is the most abundant and long-lived sulfur containing source gas in the non-polluted atmosphere. Due to the paucity of atmospheric measurements of COS, our understanding of the dominant global sources and sinks of COS is incomplete. This incomplete knowledge has resulted in uncertainties in global COS budgets and the drivers of long-term trends in COS. While COS likely provides an important source for stratospheric sulfate aerosol (SSA), there is some debate regarding the relative contributions of different sulfur containing source gasses, such as COS and sulfur dioxide (SO₂), to SSA. To address these knowledge gaps, and in particular to close the COS budget and quantify trends in COS, long-term measurements of COS are required. Here we present COS columns and COS vertical profiles retrieved from the databases of Fourier Transform Infrared (FTIR) spectra measured at Lauder (New Zealand) and Wollongong (Australia) with the goal of establishing a climate data record of COS in the Southern Hemisphere. In addition to quantify trends in COS these databases are used to investigate COS variability and seasonal cycles. These databases extend from 1997 to 2012 and are therefore ideally suited for this purpose. This presentation will describe the FTIR spectra measurements and retrieval algorithm used to derive total and partial columns of COS. This COS climate data record has been constructed to meet the needs of the Global Climate Observing System (GCOS).

Vertical dependence of breakpoint occurrence at the selected European ozonsonde stations
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Abstract

This poster deals with vertical dependence of breakpoint occurrence at the European ozonsonde stations up to 30 km in the period 1979-2011. We used data from the following stations: Hohepeissenberg, (Germany), Payerne (Switzerland), Uccle (Belgium), Lindenberg (Germany) and Legionowo (Poland). At each station and each season we computed 1-km wide height intervals of ozone concentration up to 30 km. We explore the statistical method for breakpoint searching and we are interested in the time position of breakpoints. We use one or two breakpoints in each height interval and season. We expect in the stratosphere the breakpoints will be situated about mid-90s and it will be very interesting to find the position of the second breakpoint

A climatology of potential vorticity filaments and related exchange between the tropics and extratropics in the lower stratosphere

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The global atmospheric re-analysis product ERA-Interim from the European Centre for Medium-Range Weather Forecasts is used to investigate lower stratospheric potential vorticity (PV) structures and exchange of air masses between the tropics and the extratropics from 1979 to 2011. A climatology of PV filaments and cutoffs above the subtropical jet stream is presented on isentropic surfaces from 350 to 500 K. The recently developed concept of the strongest isentropic gradients in the dynamical fields of PV and wind speed is applied to mark a dynamically relevant PV contour on every isentropic surface. An Eulerian algorithm is then used to identify filaments and cutoffs of this PV contour and a trajectory-based technique to study the exchange across this contour. The combination then allows quantifying the significance of the PV filaments and cutoffs for the isentropic exchange across this dynamically relevant boundary.

The presented climatology extends already existing climatologies of cross-tropopause exchange connected with PV streamers into the lower stratosphere. This analysis is particularly relevant for the assessment of the chemical impact of the lower branch of the residual circulation. The climatology of PV filaments reveals a seasonal cycle with a higher frequency in summer than in winter in both hemispheres. During winter, intrusions are completely suppressed on isentropic surfaces above 400 K in line with the activity of the polar vortices. Global highest frequency of PV filaments is found between 380 and 440 K in northern hemispheric summer simultaneous with dynamics of the Asian anticyclone. In general, PV filaments in equatorward direction are more frequent than in poleward direction.

The quantification of the mass fluxes associated with these PV structures identifies different atmospheric transport pathways between the tropics and extratropics with strong geographical variability. In the northern hemispheric summer, strongest PV filaments connected with severe exchange are preferentially located above the North Pacific. An atmospheric pathway is identified that transports air masses around the Asian anticyclone from northern toward southern Asia and the Indian ocean. In the southern hemispheric summer, highest frequency of PV filaments connected with severe air mass exchange is located above the South Pacific. This atmospheric pathway transports air masses from above the Indian ocean in eastward direction around the Antarctic toward the South Pacific.

Brewer-Dobson circulation in the ERA-Interim: increase or decrease?

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The Brewer-Dobson circulation in the ERA-Interim has been investigated with Lagrangian diabatic and kinematic trajectories and calculations of effective diffusivity. The calculated ages and the age spectrum show patterns which are very similar to those obtained in the GEOSCCM model. The best agreement with the observations, including in the polar regions, is obtained with diabatic trajectories after discarding all parcels travelling above 0,5 hPa. It is noticeable that kinematic versus diabatic age of air exhibits an old bias in the lower southern stratosphere below 25 km and a young bias in the mid northern stratosphere above 25 km. There is a trend in the ERA-Interim age of air which is negative in the lower stratosphere and positive above 25 km. This result is at odd with most CCM which predict an intensification of the whole Brewer-Dobson circulation. The residual circulation decreases in the ERA-Interim and is over compensated by an increased meridional mixing in the lower stratosphere. This suggests an opposite evolution of the shallow and deep branches of the Brewer-Dobson circulation. We will present more results investigating whether the ERA-Interim trend is due to biases in the observation system or the model, and comparing ERA-Interim with MERRA

Stratospheric Aerosol over Lauder, New Zealand

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Lidar observations of the stratosphere and upper troposphere from Lauder (45° S, 170° E) have been made since November 1992. The data series to February 2009, using a single instrument to measure backscatter at 532 nm, provides a uniform data record from the Pinatubo aftermath through recent stratospheric aerosol change. The data correlate well with backscattersonde measurements and with SAGE data in the years to 2000. The upper tropospheric record shows an annual spring maximum attributable to tropical biomass burning. The stratospheric aerosol burden after the Pinatubo eruption declined with an e-folding time of about 1.4 years, to a minimum integrated backscattering coefficient (IBC) of about $1.4 \times 10^{-4} \text{ sr}^{-1}$. In the decade to 2009, stratospheric IBC increased at a rate of around 4% per year. This trend correlates well with satellite observations.

In February 2009 the Lauder aerosol lidar system was upgraded to a dual-wavelength (1064 and 532 nm system) that also measures depolarisation, similar to the CALIOP lidar system on the CALIPSO satellite. The upgraded Lauder system measures cirrus and tropospheric aerosol by day in support of ground-based near-IR FTS measurements for GOSAT validation, for which cloud and aerosol scattering is an important factor. The Lauder aerosol lidar was also used to characterise the aerosol from the June 2011 eruption of Puyehue-Cordón Caulle in Chile.

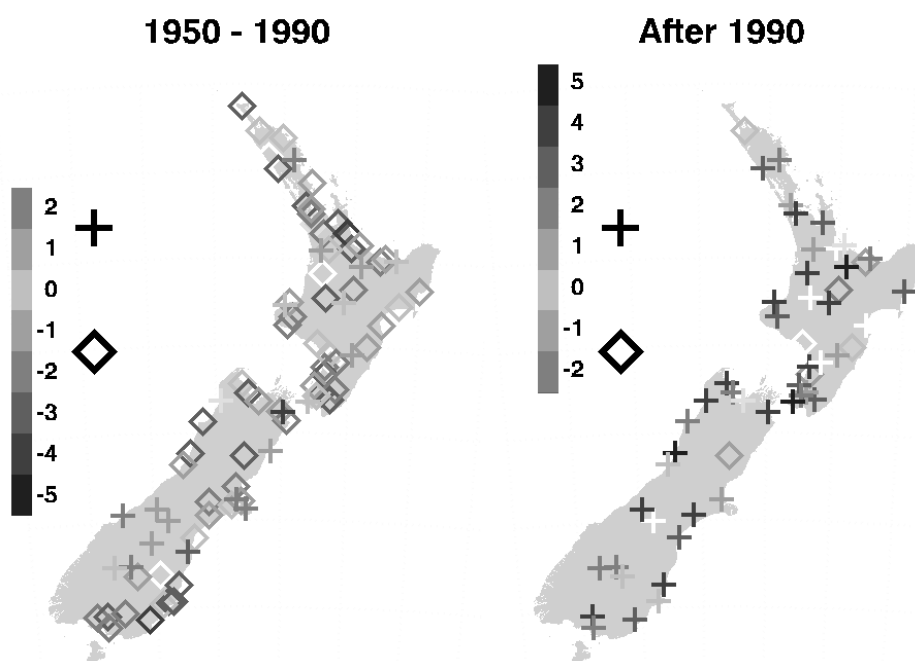
In addition, the new lidar system continues the night-time stratospheric aerosol measurements for NDACC. Here, we report on the long-term observation of stratospheric aerosols over Lauder, the recent trend, and sensitivity to assumed air density profile and to the normalisation height.

Global Dimming and Brightening in New Zealand

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Numerous papers in the international literature on global dimming and brightening confirm that substantial changes in global irradiance have occurred over decadal time scales. The predominant pattern is of declining global irradiance from around 1960 to 1990, and a reversal after that time. In many parts of the world, the trends have been attributed to anthropogenic pollution, especially of aerosols or their precursors, leading to reduced atmospheric transmission by any of the well-known mechanisms. In this context, New Zealand data are of considerable interest. Pyranometer data from four long-term sites show a downward trend up to 1990, with a reversal at three of them after that time. How much can be attributed to the direct aerosol effect is uncertain from the pyranometer data, but aerosol optical depth data from Lauder show too little aerosol for this to be a substantial component. A comparison with much longer records of sunshine hours shows that there was a trend of increasing cloudiness to around 1990, and a decline since then, consistent with the global pattern, as reported and published in 2008. Here I review the time series of both pyranometer and sunshine hours, and update them with recent data.



Trends in sunshine hours, expressed as the decadal change in percentage of maximum possible hours.

Vertical ozone variability and decadal trend over Beijing from ozonesonde observation

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In this work, the decadal variations of ozone vertical distribution over Beijing were investigated. The ozone profiles used here were measured with a Global Positioning System ozonesonde sensor (GPSO3) between 2002 and 2012 at regular intervals, once a week over Beijing, the only ozonesonde station routinely making measurements once per week in North China from 2002 to the present.

From the ten years ozonesonde observation, we can derive that the decadal trend of upper troposphere and lower stratospheric column O_3 (9–15 km layer) is 2.0 %/yr for a mean level of 40 DU. The decadal trend of tropospheric column O_3 is 3.0 %/yr for a mean level of 53 DU. The decadal trend of low tropospheric column O_3 (0–3 km layer) is 3.0 %/yr for a mean level of 17 DU. The seasonal variations show that there are remarkable ozone trend within low troposphere, which could attribute to the photochemical production of O_3 during summer.

SPARC Reanalysis Intercomparison Project (S-RIP): Climatology and Interannual Variability of Dynamical Variables

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The SPARC Reanalysis Intercomparison Project is evaluating the earlier and more recent reanalyses with focus upon the stratosphere. The reanalyses evaluated include the NCEP/NCAR(R1), NCEP/DOE(R2), NCEP-CFSR, ERA-40, ERA-Interim, JRA-25, JRA-55, MERRA. This in-depth report will include a chapter devoted to the climatology and interannual variability of the dynamical variables in these reanalyses. This information is crucial for understanding how the stratosphere has been changing over the past several decades. These data sets are utilized by climate modelers to validate their models. Information about when and where the reanalyses have greatest agreement and disagreement help determine the uncertainties the modelers have to contend with.

This presentation will focus upon the similarities and differences of the various reanalyses' climatologies of thermal and dynamic variables (T, u, v, etc) and their long term anomalies and trends. There is an evolution of the quality of data assimilated from 1979 to present and how the reanalyses use these observations. We will discuss how these differences impact the resulting climatologies, anomalies, and trends. We will show how well the various reanalyses agree with each other with respect to season, latitude, and height. We will also evaluate how the reanalyses replicate other long term temperature data sets like the MSU channel 4 in the lower stratosphere and the three SSU channels in the middle and upper stratosphere. We then will offer explanations as to why there may be differences and if the differences are rectifiable.

Variability and linear changes of stratospheric water vapour

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Water vapour is one of the most important trace constituents of the Earth's atmosphere. As the most important greenhouse gas in the troposphere and lower stratosphere any long-term change of its concentration in this altitude region has important implications for our climate. The balloon-borne observations at Boulder indicate several changes in the lower stratospheric water vapour budget since measurements started in 1980. Many aspects of the observed behaviour remain poorly understood. Here we combine observations from two satellite instruments, HALOE and MIPAS, to study in detail the variability and linear changes of stratospheric water vapour on a global scale in the period time 1991 - 2012. In the first part we focus on technical details, i.e. on our approach to combine the data sets as well as the detection of trend breaks that are characteristic for the water vapour time series. Then we discuss and attribute the distribution of annual, semi-annual and QBO variations along with the multiple linear changes that have occurred. The results will be compared with model simulations that have been carried out in the framework of the German SHARP (Stratospheric Change and its Role for Climate Prediction) initiative that aims towards a better understanding of the stratospheric changes that occurred in the past and the relevant processes of importance for our future climate.

What Drives Southern Hemisphere Tropical Expansion?

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Tropical expansion, a poleward shift in the location of the subtropical dry zone, has been observed using a variety of metrics in both hemispheres. While the response is robust across the different datasets, the rate of expansion remains unclear; trend estimates range from about 0.1 to 2.0 degrees latitude per decade, with many between 0.5 and 1.0 degrees per decade. Uncertainties in the data sources (including reanalyses) and methodologies contribute to this spread. Several climate forcings have been hypothesized to lie behind this expansion, including greenhouse gases, stratospheric ozone depletion and aerosol. See Lucas et al [2013] for a comprehensive review.

Lucas et al. [2012] used radiosonde-based tropopause observations to estimate an expansion of the Southern Hemisphere (SH) tropics of 0.4 degrees latitude per decade from 1979 to 2010. These results, while broadly consistent with reanalysis-based estimates using the same methodology, indicate the possibility of discontinuities in the reanalysis-based record, particularly the state-of-the-art ERA Interim reanalysis. These stem in part from changes in the satellite-based observation system, particularly after 2002. As analysed in Lucas et al [2012], the radiosonde-based data are believed to be free of these sorts of artificial changes.

The results from the radiosonde data show considerable interannual and decadal variability in the annual position of the tropical edge. Using multiple linear regression, approximately 60% of the variance in the observational results can be explained by considering ENSO, volcanic aerosol, SH average temperature and the size of the Antarctic ozone hole. Of the factors chosen in this statistical analysis, the proxy for ozone forcing explains ~30-60% of the trend since 1979. Volcanic aerosol accounts for ~20% and ENSO about 10%; these factors are both comparatively short-lived and their overall effect on the long-term trend is a result of the period chosen. Global or SH temperature, a proxy for greenhouse gas forcing, accounts for the remaining 10-40% of the trend.

To ascertain the reality of this finding, rates of tropical expansion from 'historical' simulations from the NCAR Community Climate System Model version 4 (CCSM4) are analysed using a similar tropopause-based methodology. Model results from historical 'full-forcing' runs are compared to 'single-forcing' simulations using ozone, greenhouse gas, anthropogenic aerosol or natural forcings to estimate the relative contribution of each of these factors to the overall trend. Three-member ensembles are used for each simulation; the period from 1960 to 2005 is analysed. Overall, the model slightly underestimates the observed trend (0.25 degrees/decade). Ozone and greenhouse gases are the dominant drivers behind expansion, with a slightly larger effect ascribed to ozone. Considering only the period since 1979, natural forcing, presumably from volcanic aerosol, plays a significant role, largely reducing the contribution from greenhouse gas forcing.

In both observations and simulations, tropical expansion can be attributed to a combination of factors, primarily ozone depletion and greenhouse gas. Natural factors, particularly volcanic eruptions, play a variable role depending on the choice of starting time for the trend calculation. Since the beginning of the modern observational record, natural factors have been of increased importance. As ozone recovery proceeds over the next few decades, the rate of SH tropical expansion and its corresponding climate impacts are unclear, as the tendencies of ozone and greenhouse gas forcing will be acting in opposite directions. Future globally significant volcanic eruptions could further confound this issue.

Lucas, C., H. Nguyen and B. Timbal, 2012: An observational analysis of Southern Hemisphere tropical expansion. *J. Geophys. Res.*, **117**, D17112, doi:10.1029/2011JD017033

Lucas, C, B Timbal and H Nguyen, 2013: The expanding tropics: A critical assessment of the observational and modelling studies. Submitted to *Wiley Interdisciplinary Reviews – Climate Change*.

A Critical Comparison of Tropical Expansion Metrics

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Tropical expansion, a poleward shift in the location of the subtropical dry zone, has been observed using a variety of metrics in both hemispheres. While the response is robust across the different datasets, the rate of expansion remains unclear; trend estimates range from about 0.1 to 2.0 degrees latitude per decade, with many between 0.5 and 1.0 degrees per decade. Also unclear is the degree of asymmetry in the expansion between the hemispheres. Uncertainties in the data sources (including reanalyses) and methodologies contribute to this spread. These uncertainties limit our understanding of the causes and impacts of tropical expansion both now and into the future. Lucas et al [2013] provides a comprehensive review.

Here, we compare and contrast the position and temporal trends of the tropical edge as defined from several different metrics. These metrics include definitions based on outgoing longwave radiation (OLR), tropopause heights from radiosonde- and reanalysis-based studies, precipitation based definitions and the subtropical edge of the Hadley cell as defined by the isobaric mass streamfunction. Estimates from both hemispheres are examined. The objectives are to examine the commonalities and differences in tropical expansion defined from the various methodologies and to identify the source(s) of any differences. Are these differences inherent in the estimates because of the 'different physics' involved, or are there flaws in the data or methodology used? Knowledge of these differences helps to build a comprehensive and coherent picture of tropical expansion.

In some cases, the results indicate that the data processing methodology used are in error. For example, expansion estimates based on OLR are flawed because of equatorial crossing time biases in the satellite data, particularly in the NH. Removal of these biases effectively eliminates the trends observed in the uncorrected datasets. The trends in these data are often among the strongest reported. Some modelling studies have suggested that the changes in OLR in a changing climate should be relatively small.

Other metrics indicate that the datasets themselves may be flawed, particularly the reanalyses. In the SH, the Hadley cell-based tropical edge from the majority of reanalyses show significant breakpoints in 1990 and 1998, suggestive of inhomogeneities in those products. Tropopause height metrics from reanalyses and radiosonde also show differences. In particular, significant differences in the behaviour of the ERA Interim in both the NH and SH after 2002 are identified, although not at all latitudes. These are hypothesized to be the result of changes (improvements) to the satellite observing system. While the timing of the suggested inhomogeneities in the reanalyses is not consistent across the different metrics, the results reinforce the idea that the reanalysis products may not be suitable for the determination of long-term climate trends.

In all cases, the 'edge of the tropics' from one metric does not directly align with those defined from others. This is a consequence of the 'different physics' used in determining the position of the edges. For example, the global subtropical minimum in precipitation lies roughly 5-10 degrees equatorward of the positions of the other metrics. Despite this, the edges derived from different metrics show a reasonable degree of correspondence on interannual timescales. This suggests that the metrics are adequately capturing the dynamics of changing global climate system.

From these results, we hypothesize that the 'true' tropical expansion trend likely lies towards the smaller end of the range that has been previously reported. This work helps to resolve the discrepancies between modelled and observed results of tropical expansion, which in turn allows for to better identification of the forcings and mechanisms behind tropical expansion. Considerable work (by the community) remains to identify the sources of inhomogeneities in reanalysis products and how to best account for these shortcomings.

Lucas, C, B Timbal and H Nguyen, 2013: The expanding tropics: A critical assessment of the observational and modelling studies. Submitted to Wiley Interdisciplinary Reviews – Climate Change.

Using trace gas measurements to quantify horizontal and vertical motion at the poles

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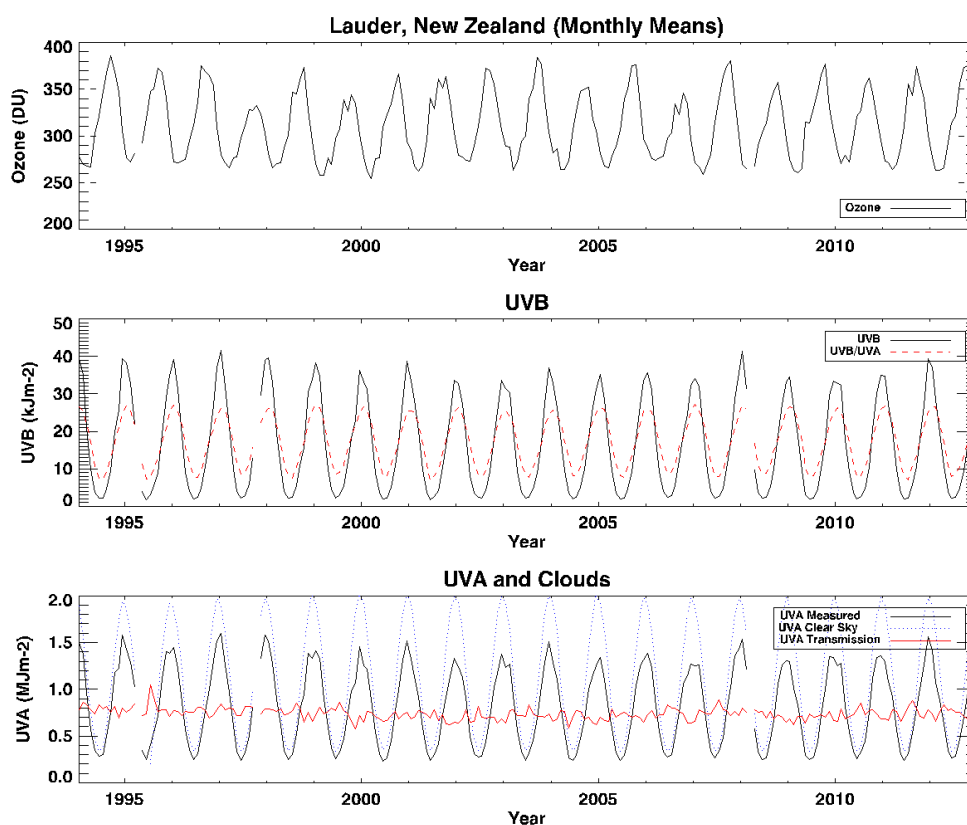
Atmospheric transport and the resultant mixing potentially has a strong impact on the strength of the Energetic Particle Precipitation Indirect Effect (EPP IE) observed in the polar regions. A large number of studies have examined atmospheric tracers to examine horizontal and vertical transport in the middle atmosphere. The aim of this study is to utilize observations of Carbon monoxide (CO), Nitrous Oxide (N₂O) and Methyl chloride (CH₃Cl) from the EOS-MLS instrument onboard the Aura Satellite to examine horizontal and vertical transport in the middle atmosphere and determine the potential for examining the magnitude of this modulating effect. We initially focus on using the probability distribution function (PDF) of the tracer data to identify the locations of transition regions (or transport barriers) in the stratosphere and mesosphere. We then utilise reanalyses data to perform a domain filling scheme on the tracer observations – this procedure allows us to produce high resolution maps which can be used to quantify filamentary leak structures. A tracer PDF derived quantification of coherent regions is then used in the calculation of descent and ascent rates within the polar vortex. We also apply the techniques identified to MIPAS observations of trace gases to examine their universality.

Long Term Changes in UV in New Zealand Due to Ozone Depletion: Comparison with Variability from Other Causes and at Other Places

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New Zealand has a long association with research related to SPARC activities, based on measurements undertaken at the Lauder, Central Otago NDACC site (45°S, 170°E, altitude 370 m). Spectral UV irradiance measurements, which meet the demanding standards of NDACC, have been undertaken continuously since the late 1980s. These are complemented by a wide range of trace gas measurements, including ozone, and measurements of aerosol extinctions. Previous studies have shown the peak UVI values at Lauder can be 40% greater than at corresponding latitudes in the Northern Hemisphere (McKenzie et al. 2006). This arises because of differences in ozone, air-clarity, and seasonal changes in Earth-Sun separation. In the context of SPARC, changes in UV due to factors related to climate change, such as changes in cloud cover, are also relevant. We extract monthly and annual doses of UV-B (280-315 nm), which is strongly affected by ozone extinctions, and UV-A (315-400 nm), which is not affected by ozone extinction, from spectral irradiance measurements at Lauder over the last 20 years. Because of the success of the Montreal Protocol, effects of ozone change on UV at this mid-latitude site are minor. The main variability in UV is due to seasonal changes in SZA. Year to year changes in cloud cover are also important. Although changes in aerosol are not important at Lauder, they can have a large contribution at more polluted sites. The relative importance of differences in aerosol, altitude and surface albedo are demonstrated by comparison between the data at Lauder and other NDACC sites.



Non-linear Statistical Model of Changes of Total Ozone with the Help of Neural Networks. A Case Study: Hradec Kralove, Czech Republic, 1961-2010

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Empirical studies of the most dominant factors influencing total ozone are often based on regression models. Linear multiregression models have been widely used mainly due to their simplicity, but their linearity is a drawback as the real physical relations between explanatory variables (predictors) and total ozone (predictand) are non-linear. For this reason, non-linear multiregression models may provide better results but their development is more difficult as the model performance is strongly dependent on expected shape of non-linear relations.

Neural networks belong to artificial intelligence systems. Among others, they are able to solve very complex non-linear multiregression tasks. Their advantage is that they do not need any a-priori information about the shape of predictors-predictand relations as they are able to “learn” these relations directly from the data. The biggest disadvantage is that the final (trained) neural network is not expressed as a fixed relation but as a network of highly interconnected linear and simple non-linear transformations of the signal. For this reason it is difficult to analyze directly the physical appropriateness of the model and its careful validation is needed.

In the case study we used neural networks for building of non-linear model of monthly means of total ozone for Hradec Kralove station. Adjusted and homogenized time series of monthly total ozone means (1961-2010) were used as predictand. Model predictors were selected from a large set of possible explanatory variables (UT/LS parameters from ERA-40 and ERA-Interim reanalyses and their vertical profiles between 300 and 10 hPa, solar activity, AOD - aerosol optical depth, EESC, NINO indices, QBO) with the help of both stepwise regression and genetic algorithm methods. MLP (Multilayer Perceptron) neural network was used to build the model. For generalization purpose the cross-validated ensemble of 99 individual neural networks was trained and their average was considered to be the final model.

The results of final neural model were better than performance of linear models, namely as for standard deviations of residuals (2-3% in November-January, 1-2% in other months). Correlations between modeled and observed values varied from 0,82 in November to 0,98 in February. The sensitivity analysis indicated strong influence of temperature or temperature-related parameters in UT/LS and tropopause pressure. A weaker but detectable influence of humidity parameters has been found in LS. Among “forcings”, EESC clearly exhibits strong influence while the influence of solar variability is weaker. AOD influence is episodic but also clearly detectable. Moreover, the model allowed for separation and quantification of the influence of individual explanatory variables or their groups on total ozone, its variability and trends. The relation between long-term trends of UT/LS parameters and climate change was indicated while short-term UT/LS changes were found to be related mainly to several climatic indices (mostly to Arctic Oscillation, East Atlantic Oscillation and East Atlantic/Western Russia Oscillation).

Neural networks turned out to be very good tool for diagnostic studies of total ozone, due to their intrinsic non-linearity and their ability to “learn” even very complex non-linear relations directly from the data.

Latest BrO, HO₂ and HOCl Observations from the EOS Microwave Limb Sounder

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This study describes updated middle atmosphere BrO, HO₂, and HOCl estimates from the EOS Microwave Limb Sounder on the Aura satellite. BrO is of particular importance, as it is the dominant form of bromine in the stratosphere, a significant contributor to chemical ozone loss, and one whose importance is set to increase in the light of declining stratospheric chlorine levels. HO₂ is also of interest because odd hydrogen (HO_x = OH + HO₂ + H) chemistry controls the atmospheric ozone destruction at heights above around 40 km. Lastly, although HOCl is not a major player in the ozone budget, it does play some role in the chemical ozone destruction.

MLS BrO, HO₂ and HOCl observations have weak signal to noise, necessitating significant averaging and specifically optimized retrieval algorithms for the best results. A detailed description of the retrieval methodology, error budget, and a comparison with expectations are presented. We infer a 2005 yearly total inorganic Br_y using the measured MLS BrO to be 20 ± 4.5 pptv, which implies a contribution from very short lived substances to the stratospheric bromine budget of 5 ± 4.5 pptv. We compare HO₂ and HOCl profiles with photochemical model simulations testing different kinetic parameters to investigate the “HO_x dilemma” and uncertainties in the HOCl rate formation.

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Multimodel attribution of the Southern Hemisphere Hadley cell widening: Major role of ozone depletion

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It has been suggested that the Hadley cell has been widening during the past three decades in both hemispheres, but attribution of its cause(s) remains challenging. By applying an optimal fingerprinting technique to 7 modern reanalyses and 49 coupled climate models participating in the CMIP3 and CMIP5, here we detect an influence of human-induced stratospheric ozone depletion on the observed expansion of the Hadley cell in the Southern Hemisphere (SH) summer. The detected signal is found to be separable from other external forcings that include greenhouse gases (GHGs), confirming a dominant role of stratospheric ozone in the SH summer climate change. Our results are largely insensitive to observational and model uncertainties, providing additional evidence for a human contribution to the atmospheric circulation changes.

The Impact of Stratospheric Resolution for Detection and Attribution of Atmospheric Temperature Trends

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A comparison of temperature trends in the free atmosphere over the past 50 years is performed, comparing: 1. coupled ocean-atmosphere models with atmosphere-only models, and 2. high-top (lid at 84km) and low-top (lid at 40km) versions of HadGEM2. It is shown that atmosphere-only models compare more favourably with observations than coupled models, and this comes from a better representation of surface temperature trends. Furthermore, it is shown that a well resolved stratosphere can result in a more robust detection of natural and anthropogenic climate change signals, although the attribution remains consistent with non-stratosphere resolving models.

The Morphology of the Polar Vortices on Mars and Earth from Atmospheric Reanalyses

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Fundamental causes of stratospheric polar vortex variability and the associated surface teleconnections remain poorly understood. Mars could provide additional case studies to understand polar vortex dynamics if the Martian polar vortices were found to be a suitable analogy to those on Earth. Due to the recent development of the first publicly available Martian reanalysis data set (MACDA) it is timely to perform such a comparison. In this study the MACDA data set is compared with terrestrial MERRA reanalysis data set, with a specific focus on the structure and evolution of the polar vortices. It is found that on Mars there are large differences between the polar vortices in both hemispheres, and that these arise due to the elliptical nature of the Martian orbit. Specifically it is found that the Martian polar vortices are annular in nature, and that the northern hemisphere vortex is far stronger than its southern counterpart. While the differences in vortex strength are also reported on Earth, the contrast is not as large. Distinctions are also apparent in terms of the climatological vertical structure of the vortices between the two planets, in that the Martian polar vortices are observed to decrease in size at higher altitudes, whereas on Earth the opposite is observed. Finally, it is found that the Martian vortices are less variable throughout winter compared to Earth, especially in terms of the vortex geometry. During a specific dust storm on Mars (Martian year 26), a decrease in the strength of the northern polar vortex is observed as well as an equatorward displacement of the vortex air mass which shares characteristics of sudden stratospheric warmings on Earth.

Assimilation of Geodetic Monitoring Data as a Dynamical Constraint in Atmosphere Models

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Atmospheric angular momentum (AAM) is a global quantity that reflects the distribution of mass and winds in the atmosphere, especially tropospheric jets, the NAO, sudden stratospheric warmings, and the MJO. It is a useful tool to measure the agreement or disagreement between atmospheric models and reanalysis sets. In fact, it has been shown (Paek and Huang 2012) that major reanalysis datasets can substantially disagree in this metric, even though they are strongly constrained by various observations. AAM is moreover a quantity that can be observed, in the form of Earth Rotation Parameters (ERPs), i.e. the angles of polar motion and the Earth's rotation rate. These parameters are observed frequently and at high precision, and, at timescales of weeks to years, primarily reflect the exchange of angular momentum between the Earth and the atmosphere. These observations make it possible to apply AAM as a constraint on atmospheric models, via data assimilation of observed ERPs.

This study investigates the dynamical constraint imposed by ERP/AAM observations on an atmospheric model, using perfect-model assimilation experiments with the Community Atmosphere Model 5 (CAM5) and an Ensemble Square Root Filter (EnSRF) within the Data Assimilation Research Testbed (DART, Anderson et al. 2009). The Earth rotation observations differ fundamentally from "standard" meteorological observations in that they represent global integrals of the wind and pressure field. Nevertheless, these data can be used to constrain the state because the ensemble filter statistically models the relationship between local changes in the wind and pressure fields, and changes in their global integral. Thus, the misfit between modeled and observed Earth rotation variations can constrain the modeled state in a way that is complementary to more standard, local observations (such as radiosonde data). In particular, Earth rotation observations help to reduce error in the modeled tropospheric jets (Fig. 1), as well as the mass distribution at midlatitudes (Fig. 2). This work highlights the usefulness of previously unused data as an additional constraint upon climate models.

High Altitude Airships as a Platform for Atmospheric Composition Observations

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Over the last decade, telecommunications companies, military programs, and other interested parties have worked toward developing autonomous high altitude, solar-powered, maneuverable lighter-than-air vehicles known as airships. These airships would reside at an altitude of ~20 km and station keep for periods of weeks to months to even years, thus providing wireless communications and surveillance capabilities at a cheaper cost than satellites. A recent Keck Institute for Space Studies (KISS) workshop examined the potential for using airships as a platform for Earth and space sciences. We discuss the challenges of developing such a platform, its potential for remote sensing of atmospheric composition, and the advantages over conventional high-altitude balloons and spacecraft. We provide an overview of the current developments in airship technology in the U.S., an analysis of the physical and chemical characteristics of the stratosphere that impact airship design, and a vision for a semi-stationary observing platform focusing on air quality, convection, and upper troposphere / lower stratosphere dynamics and chemistry.

The SPARC Data Initiative: Comparison of upper troposphere / lower stratosphere ozone climatologies from limb-viewing instruments and the nadir-viewing Tropospheric Emission Spectrometer (TES)

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We present the first comprehensive intercomparison of currently available satellite ozone climatologies in the upper troposphere / lower stratosphere (UTLS) region (~300-70 hPa), which has been performed as part of the Stratospheric Processes and their Role in Climate (SPARC) Data Initiative. One of the biggest challenges in intercomparing satellite measurements is accounting for differences in vertical resolution, and this is particularly difficult in the UTLS region, where there are strong vertical gradients as well as a great deal of small-scale vertical structure in trace gas distributions. One way to overcome differences in vertical resolution is to provide a consistent basis for comparison by smoothing all of the measurements with the observational operator of the instrument with the coarsest vertical resolution. This allows for identification of systematic differences in the large scale vertical and horizontal distribution of a trace gas as well as in its temporal variability. The Tropospheric Emission Spectrometer (TES) instrument is the only nadir-viewing instrument in this Initiative, as well as the only instrument with a focus on tropospheric composition. TES ozone has ~6-7 km vertical resolution and is well-characterized with respect to in situ observations in the UTLS region. We apply the TES observational operator to the ozone measurements from the more highly vertically resolved limb-viewing instruments and assess differences in the large-scale structure and variability of UTLS ozone as measured by the different instruments. We find that most of the limb-viewing instruments are positively biased with respect to TES over much of the UTLS region, with the largest relative biases in the tropics. There is relatively good agreement regarding the timing and magnitude of the ozone seasonal cycle and interannual variability among the instruments in the extratropics, but in the tropics there are significant differences between them. This analysis provides an important first step in understanding the similarities and differences between satellite measurements of this region, which plays a critical role in chemistry-climate interactions. Future work will focus on more sophisticated comparisons of level 2 data, utilizing techniques that minimize the effects of differences in sampling and resolution.

Towards a combined IASI/TES record of ozone: validation and first results

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Ozone is the third most important anthropogenic greenhouse gas and a significant pollutant at the surface affecting human and plant health. Rapidly increasing Asian emissions of ozone precursors, land-surface changes from burning, and decreasing surface emissions in Europe and North America have resulted in unknown changes to the distribution of tropospheric ozone. Satellite-borne instruments provide the means for global and continuous monitoring of this important trace gas. High spectral resolution infrared radiance measurements, such as those from the Tropospheric Emission Spectrometer (TES) on the NASA Aura satellite (launched in 2004), and the Infrared Atmospheric Sounding Instruments (IASI), on the MetOp-A and MetOp-B satellites (launched in 2006 and 2012 respectively) can be used to derive vertical information of tropospheric ozone. Together, these instruments now present a record spanning more than nine years. As part of efforts to assess consistency between the TES and IASI data records, a retrieval for ozone from IASI radiances, building on the data processor for TES, is under development as a collaboration between NASA JPL and NCAR. Using a priori information consistent with TES retrievals, the optimal estimation approach is applied to IASI radiances in order to obtain vertical distributions of ozone. This presentation shows the characterisation of these IASI ozone retrievals with respect to the vertical distribution of the uncertainties and sensitivities as well as validation with coincident ozonesonde profiles. Further comparisons with TES are presented and observed trends in ozone over Asia, North America, and Europe described.

Splicing SAGE-II and GOMOS measurements to create a long-term stratospheric ozone climate data record

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Climate data records provide the basis for evaluating past changes in climate and assessing our current understanding of climate change. A long-term (1979-2012) climate data record of stratospheric ozone with high vertical resolution was created by merging two datasets: SAGE-II (Stratospheric Aerosol and Gas Experiment) and GOMOS (Global Ozone Monitoring by Occultation of Stars) ozone measurements.

Both instruments provide high vertical resolution measurements of ozone profiles which were interpolated onto a 1 km altitude grid. To remove offsets and drifts between the SAGE-II and GOMOS ozone measurements, coincidences were identified in the time period of overlap between the two datasets between 2002 and 2005 according to pre-defined time, latitude, longitude and altitude coincidence criteria. The latitude-time difference field was statistically modelled using Legendre polynomials in latitude and Fourier expansions in season to capture the climatological annual mean difference pattern between SAGE-II and GOMOS data in the overlap period.. The difference field was then applied to the whole GOMOS dataset so that it could be spliced onto the end of the SAGE-II record, thereby providing a high vertical resolution, long-term climate data record of stratospheric ozone. The resultant ozone data record was validated through comparisons with other vertically resolved global ozone databases, such as that derived from SBUV measurements.

Balloon-borne match measurements of mid-latitude cirrus clouds

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Single measurements of a cloudy air mass provide only a snapshot from which the evolution of an ice cloud or the persistence of ice supersaturation cannot be judged. We introduce here the “cirrus match technique” (Cirisan et al., 2013) to obtain information of the evolution of clouds and their saturation ratio. The aim of these coordinated balloon soundings is to analyze the same air mass twice. To this end the standard radiosonde equipment is complemented by a frost point hygrometer “SnowWhite” and a particle backscatter detector “COBALD” (Compact Optical Backscatter Aerosol Detector). We present the results of matching a cirrus cloud to within 2-15 km, realized in June 2010 over Payerne, Switzerland, and a location 120 km downstream close to Zurich. A thick cirrus was detected over both measurement sites. By means of comprehensive microphysical modelling driven by COSMO regional weather model analyses we show that in order to quantitatively reproduce the measured particle backscatter ratios, the small-scale temperature fluctuations not resolved by COSMO must be superimposed on the trajectories. The stochastic nature of the fluctuations is captured by ensemble calculations. Possibilities for further improvements in the agreement with the measured backscatter data are investigated by assuming a very slow mass accommodation of water on ice, the presence of heterogeneous ice nuclei, or a wide span of (spheroidal) particle shapes. However, the resulting improvements from microphysical refinements are moderate and comparable in magnitude with changes caused by assuming different regimes of temperature fluctuations for clear sky or cloudy sky conditions, highlighting the importance of a proper treatment of the subscale fluctuations. The model yields good agreement with the measured backscatter over both sites and reproduces the measured saturation ratios with respect to ice over Payerne. Conversely, the 30% in-cloud supersaturation measured in a massive, 4-km thick cloud layer over Zurich cannot be reproduced, irrespective of the choice of meteorological or microphysical model parameters. The measured supersaturation can only be explained by either resorting to an unknown physical process, which prevents the ice particles from consuming the excess humidity, or – much more likely – by a measurement error, such as a contamination of the sensor housing of the SnowWhite hygrometer by a precipitation drop from a mixed phase cloud just below the cirrus layer or from some very slight rain in the boundary layer. This uncertainty calls for in-flight checks or calibrations of hygrometers under the extreme humidity conditions in the upper troposphere.

A New Balloon-borne Submillimetre Limb Sounding Radiometer

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We propose concept and design for a balloon-borne submillimetre limb sounding radiometer. The instrument is tailored for high sensitivity measurements of the Upper Troposphere/Lower Stratosphere (UT/LS) region to address several open scientific questions regarding interaction mechanisms in this climate-critical region. The radiometer will consist of two receivers. The first one, a Schottky diode receiver, will be operated uncooled, while the second one, a SIS receiver, will be cooled to below 4K. The expected stand time for the SIS will be up to 7 days in order to plan for even long duration flights over the Atlantic ocean. Circumpolar flights would be an additional option for this instrument, dependent on permission from the Russian authorities. The instrument will perform passive limb-sounding observations utilizing a single beam scanning across the UT/LS. The instrument package (funding provided) will be borne on either a specifically designed gondola platform or be integrated with a project sharing similar observation requirements.

The radiometer concept as well as the platform should be highly modular in order to enable extra payload, i.e. other scientific equipment. In that way the radiometer could be used as a test bed for new components while the platform and gondola modularity enables to adjust for varying payloads and specific flight plans. The modularity should include not only a scalable geometry of the gondola but also a flexible power supply, telemetry and attitude control.

The scientific targets are water and ozone isotopologues as well as chemical tracers and substances involved in the polar stratospheric ozone loss. Microwave limb sounding instrumentation is insensitive to all but thick clouds and would allow us to obtain high quality vertically well resolved observations of atmospheric minor species in this climate-critical UT/LS region and to study photo-chemical processes and reaction mechanisms in the presence of upper tropospheric cirrus or polar stratospheric clouds.

Limb ozone profile intercomparison of ozone_cci data products

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As part of ESA's climate change initiative (CCI) on ozone an essential climate variable (ECV) data product have been created. The harmonized limb ozone profiles are required in producing the merged ozone data. As a first step the various data sets, statistical methods and detailed consistency checks are done to characterise and compare the data. Investigation include bias and drift analysis, and signature of short term variability. Such a diagnosis is useful to identify strengths and weaknesses of each of the data set that may vary in time.

Evaluating transport in the middle atmosphere using ERA-Interim analyses

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Results of model simulations of long-term tracer transport in the middle atmosphere using ERA-Interim analyses are presented using the 3D model KASIMA. KASIMA combines meteorological analyses with a mechanistic model covering a vertical range from the lower stratosphere up to the lower thermosphere. Several artificial tracers have been implemented in the model simulating trace gases as SF₆, CO₂, N₂O and H₂O, often used to derive transport properties in the middle atmosphere from observations. Simulating the whole period of ERA-Interim from 1979 up to present, we compare observations of these tracers from the MIPAS instrument on the ENVISAT satellite for the period 2002-2012 together with in-situ measurement from several campaigns with the model results to characterise the transport properties of the simulations.

Long-term changes in winter stratospheric circulation in CMIP5 Scenarios Simulated by the Climate System Model FGOALS-s2

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Abstract

Diagnosis of changes in the winter stratospheric circulation in the Fifth Coupled Model Intercomparison Project (CMIP5) scenarios simulated by the Flexible Global Ocean-Atmosphere-Land System model, second version spectrum (FGOALS-s2), indicates that the model can generally reproduce the present climatology of the stratosphere and can capture the general features of its long-term changes during 1950–2000, including the global stratospheric cooling and the strengthening of the westerly polar jet, though the simulated polar vortex is much cooler, the jet is much stronger, and the projected changes are generally weaker than those revealed by observation data. With the increase in greenhouse gases (GHGs) effect in the historical simulation from 1850 to 2005 (called the HISTORICAL run) and the two future projections for Representative Concentration Pathways (called the RCP4.5 and RCP8.5 scenarios) from 2006 to 2100, the stratospheric response was generally steady, with an increasing stratospheric cooling and a strengthening polar jet extending equatorward. Correspondingly, the leading oscillation mode, defined as the Polar Vortex Oscillation (PVO), exhibited a clear positive trend in each scenario, confirming the steady strengthening of the polar vortex. However, the positive trend of the PVO and the strengthening of the polar jet were not accompanied by decreased planetary-wave dynamical heating, suggesting that the cause of the positive PVO trend and the polar stratospheric cooling trend is probably the radiation cooling effect due to increase in GHGs. Nevertheless, without the long-term linear trend, the temporal variations of the wave dynamic heating, the PVO, and the polar stratospheric temperature are still closely coupled in the interannual and decadal time scales.

Reference:

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STUDY OF TEMPERATURE PROFILES OBSERVED DURING AN UNUSUAL DEPLETION OF OZONE OVER NDACC STATION OF RÍO GALLEGOS (51 ° 55'S, 69 ° 14'W) - ARGENTINA ON NOVEMBER 2009

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Since June 2005, the CEILAP group with the support of JICA Japan International Cooperation Agency (JICA) and cooperation with French and Japanese researches has carried out systematic measurements of ozone profile and UV radiation in the southern part of Argentina (51 ° 55'S, 69 ° 14'W) using a Differential Absorption lidar (DIAL), this place has been called Atmospheric Observatory of Southern Patagonia (OAPA). After 2006 other products were retrieved in addition to the ozone profiles from the DIAL measurements, such as stratospheric aerosols and temperature profiles using the off-wavelength signal at 355 nm. As a part the systematic observations at southern continent using stratospheric Rayleigh Lidar we have detected an unusual temperature profiles on November 2009 where a depletion of the ozone number density in the southern hemisphere was detected (de Laat *et al.*, 2010). We present the comparison of these profiles measured during November 13-14, 2009. They have been compared with the NCEP mean profiles in Río Gallegos for the period 2005-2011. We have found a warming in the upper stratosphere with a temperature anomaly of 25 K around 36 km when the temperature was compared with the NCEP mean profile. We presents in this work complementary analysis from models and satellite instruments to improve the analysis

Reference:

-Extreme sunbathing: Three weeks of small total O3 columns and high UV radiation over the southern tip of South America during the 2009 Antarctic O3 hole season

de Laat, A. T. J., R. J. van der A, M. A. F. Allaart, M. van Weele, G. C. Benitez, C. Casiccia, N. M. Paes Leme, E. Quel, J. Salvador, and E. Wolfram (2010), *Geophys. Res. Lett.*, 37, L14805, doi:10.1029/2010GL043699

Observations of Methyl Chloride and Methanol in the Upper Troposphere / Lower Stratosphere from the Aura Microwave Limb Sounder

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We exploit the unmatched scope of the 9-year data record from the Microwave Limb Sounder (MLS) aboard NASA's Aura satellite to investigate the spatial, seasonal, and interannual variations in the distributions of methyl chloride (CH_3Cl) and methanol (CH_3OH) in the upper troposphere / lower stratosphere (UTLS). Methyl chloride is by far the largest natural carrier of chlorine to the stratosphere, and its importance in stratospheric ozone chemistry is expected to increase as anthropogenic halocarbons decline in response to emission regulations. Like carbon monoxide (CO), CH_3Cl is a marker of pollution from biomass burning that can be lofted to the UTLS very rapidly by deep convection. The climatological seasonal cycle in CH_3Cl reflects variability in regional fire activity and other surface sources as well as convection, and anomalous CH_3Cl enhancements in the tropical upper troposphere are linked to specific episodes of intense burning. Methanol is the second most abundant organic molecule in the atmosphere (after methane). Its primary source is plant growth, but it is also emitted during biomass and biofuel burning. Through its reaction with the hydroxyl radical it influences the oxidizing capacity of the atmosphere, with consequent impact on the global budget of tropospheric ozone. Here we introduce new measurements of CH_3OH from Aura MLS and compare its observed behaviour with that of other species measured by MLS, including CO and CH_3Cl .

Program of the Antarctic Syowa MST/IS Radar (PANSY)

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The PANSY radar is the first Mesosphere-Stratosphere-Troposphere/Incoherent Scatter (MST/IS) radar in the Antarctic region. It is a large VHF monostatic pulse Doppler radar operating at 47 MHz, consisting of an active phased array of 1,045 Yagi antennas and an equivalent number of transmit-receive (TR) modules with a total peak output power of 500 kW. The first stage of the radar was installed at Syowa Station (69°00'S, 39°35'E) in early 2011, and is currently operating with 228 antennas and modules. This paper reports the project's scientific objectives, technical descriptions, and the preliminary results of observations made to date. The radar is designed to clarify the role of atmospheric gravity waves at high latitudes in the momentum budget of the global circulation in the troposphere, stratosphere and mesosphere, and to explore the dynamical aspects of unique polar phenomena such as polar mesospheric clouds (PMC) and polar stratospheric clouds (PSC). The katabatic winds as a branch of Antarctic tropospheric circulation and as an important source of gravity waves are also of special interest. Moreover, strong and sporadic energy inputs from the magnetosphere by energetic particles and field-aligned currents can be quantitatively assessed by the broad height coverage of the radar which extends from the lower troposphere to the upper ionosphere. From engineering points of view, the radar had to overcome restrictions related to the severe environments of Antarctic research, such as very strong winds, limited power availability, short construction periods, and limited manpower availability. We resolved these problems through the adoption of specially designed class-E amplifiers, lightweight and tough antenna elements, and versatile antenna arrangements. Although the radar is currently operating with only about a quarter of its full designed system components, we have already obtained interesting results on the Antarctic troposphere, stratosphere and mesosphere, such as gravity waves, multiple tropopause associated with a severe snow storm in the troposphere and stratosphere, and polar mesosphere summer echoes (PMSE).

Sato, K., et al., Program of the Antarctic Syowa MST/IS Radar (PANSY), J. Atmos. Solar-Terr. Phys., submitted and revised.

Geopotential Height and Geostrophic Wind from Radio Occultation Data

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An accurate knowledge of the spatial and temporal distribution of winds is crucial to understand dynamics and chemistry of the atmosphere. While traditional measurements e.g., from radiosondes, dropsondes, or LIDAR mainly provide data over the continents in the Northern Hemisphere, coverage in the Southern Hemisphere and over oceans is poor. More homogeneous sampling is obtained from satellite measurements but most of these data suffer from low vertical resolution. Global Positioning System (GPS) Radio Occultation (RO) measurements have the potential to overcome these problems as they provide global soundings with a very high vertical resolution (from near 100 m in the lower troposphere to approximately 1.5 km in the stratosphere). These measurements provide accurate and precise information about the thermodynamic state of the atmosphere, which can be utilized to study atmospheric dynamics.

In contrast to other satellite measurements, geopotential height from RO is not derived from temperature and pressure data but from accurate knowledge of the refraction probed by the GPS signals and the position and velocity vectors of the satellites involved. In the middle and upper troposphere the observational error of geopotential height from RO is estimated to be approximately 10 m, or smaller after some averaging.

Radio occultation data are continuously available since 2001. After the launch of the Formosat-3/COSMIC and Metop-A satellites in 2006 the number of RO profiles increased significantly up to 3000 profiles per day. We will use profiles from multiple RO missions from 2006 to 2012 to calculate monthly mean geopotential height fields and associated geostrophic winds at a range of pressure levels in the upper troposphere and lower stratosphere at 5° x 5° latitude/longitude resolution.

We will discuss monthly mean geopotential height fields and geostrophic winds, their annual cycle and their interannual variability related to the El Niño-Southern Oscillation phenomenon. Uncertainty estimates will be provided using ECMWF analysis fields. The high vertical resolution of the RO data will be utilized to thoroughly investigate the dynamical behavior close to the tropopause.

Temperature variability in the upper troposphere and lower stratosphere observed with GPS radio occultations

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The radio occultation (RO) technique uses GPS signals received aboard low Earth orbiting satellites for atmospheric limb sounding. Temperature profiles are derived with high vertical resolution. Due to its long-term stability, all-weather capability and global coverage the GPS RO technique offers the possibility for global monitoring of the tropopause and temperature structure in the upper troposphere and lower stratosphere (UTLS) region. Each, the German CHAMP (2001-2008), TerraSAR-X (since 2008) and TanDEM-X (since 2011), and the U.S./German GRACE (since 2006) missions provide between 150-200 occultation measurements daily.

Based on these datasets a global increase of the tropopause height of about 7 m/year is detected between 2001 and 2012 linked to a global upper tropospheric warming and a lower stratospheric cooling.

Regional trend differences are discussed with the focus to the tropical tropopause region where a warming is observed between 17 and 21 km during the last decade. Possible reasons will be discussed. The warming near the tropical tropopause observed during the last decade in contrast to cooling in the past decades possibly indicating a trend changepoint that will also be addressed.

The derived GPS RO trends will be compared with UTLS temperature and tropopause height trends from ERA interim data for the same time period as well as with long-term climatologies reported in the literature.

Validation of Thermodynamic Profiles from MIPAS, GOMOS, and Radiosondes against Radio Occultation Reference Datasets

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In the context of calibration/validation activities for ESA atmospheric missions, a project of the WEGC prepares and provides long-term radio occultation (RO) reference data from a variety of RO missions (in total up to about 2500 profiles per day). Applications of the data include use in climate change and variability studies, in the monitoring of trends in data from other spaceborne instruments, in routine validation of atmospheric satellite data products, in the validation of retrieval algorithms, in atmospheric process studies, and in bridging temporally separated space missions. The project ensures the provision of correlative RO data suitable for in-depth examination of tropospheric and stratospheric fundamental state profiles, such as of temperature, pressure, and humidity as function of altitude. This undertaking is highly worthwhile since the unique combination of global coverage, high accuracy and vertical resolution, long-term stability, and virtual all-weather capability makes, in the free atmosphere, the validation with RO data preferable to other methods.

The presentation will discuss the setup of the project on multi-mission validation by RO at the WEGC, and the quality and availability of the reprocessed RO datasets. We will then focus on the discussion of results of the multi-year validation of temperature and pressure profiles over the upper troposphere and lower stratosphere (UTLS) from Envisat MIPAS data against colocated RO processed at WEGC. We will also provide results of temperature and density validation of Envisat GOMOS data against the RO data. In addition, temperature and humidity profiles from a high-quality radiosonde dataset (Vaisala sondes, ERA-Interim archive) are inter-validated against the RO dataset. We show how these results help to obtain quantitative estimates on the quality of the data (e.g., systematic error bounds) and on the utility of RO to serve as reference data for the targeted validation and climate monitoring applications.

Comparison of ozone profiles between Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) and worldwide ozonesonde measurements – some issues in ozonesonde measurements

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We compared ozone profiles measured by the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) with those taken at worldwide ozonesonde stations. SMILES performed high-sensitivity measurement of minor species in the middle atmosphere for the observation period from 12 October 2009 to 21 April 2010. To validate the quality of the SMILES version 2.1 ozone data for 16–30 km, 500 ozonesonde profiles were compared with the coincident SMILES ozone profiles. The agreement between SMILES and ozonesonde measurements was good within 6%–8% for 20–30 km at mid- and high latitudes, but degraded below 20 km. Moreover, at low latitudes, the SMILES ozone data showed larger values (~7%–20% for 20–26 km) than those at mid- and high latitudes. To investigate this difference we examined the following possibilities in the ozonesonde system. (i) Bias in the pressure measurement of radiosondes that are equipped with ozonesondes. (ii) Bias owing to the ozonesonde's response time.

During the SMILES observation period, we looked into ozonesonde profiles from the Soundings of Ozone and Water in the Equatorial Region (SOWER) campaign. They used the ECC ozonesonde with the Vaisala RS80 radiosonde that measures pressure using a pressure sensor. These ozonesondes were launched with the frost-point hygrometer (CFH) with which the GPS sensor is equipped. To compare the geometric heights between the RS80-derived and the GPS-derived ones, we found the former is usually higher about 250–300 m at 30 km than the latter; this can produce a negative bias in pressure about 5%, and in ozone mixing ratio this bias yields ~2% smaller values in the mid- stratosphere and ~4% smaller ones in the lower stratosphere.

To investigate another possibility we tried to apply a time-lag correction to the ozonesonde profiles based on the ozonesonde's response time. The response time was estimated from ozonesonde measurements with ascending and descending profiles showing clear difference, by using the time-lag correction method to minimize the difference between the ascending and descending profiles. The ozonesonde's response time is generally assumed to be within 20–30 s, and our estimation from this method also shows a similar value around 28 s on average, suggesting an appropriate use of the time-lag correction method. By applying this correction to the original profiles, we found a negative bias of the ozonesonde measurement more than 7% at 20 km in the equatorial latitude where the vertical gradient of ozone is steep. The corrected ozonesonde profiles by taking into the above two factors showed better agreement with the SMILES data, but it is not perfect. Though there may be other problems with the SMILES data, we suggest that such issues related to the ozonesonde system could create a negative bias, particularly in the lower stratosphere at equatorial latitudes.

Spatial Patterns of Summer Precipitation around the Himalayas and the Mountainous Western Coast of India and Myanmar Revealed by TRMM

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Southern slope of the Himalayas and the mountainous western coast of India and Myanmar are the areas of the heaviest precipitation of the south Asian summer monsoon. In these areas, narrow mountain ranges are an important organizing agent anchoring intense monsoon precipitation on the windward sides. The process related to the interaction of topography and precipitation is analyzed utilizing the 13-year (1998–2010) high resolution (0.05°) Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) data.

In the central Himalayas, two significant rainfall peaks appear during summer monsoon, along the southern flank of the foothills at 500 m, as well as the southern flank of the higher terrain approximately at 2000 m. The former rainfall peak is attributed to fewer heavy rainfall events, and the latter to frequent, weak, but persistent rainfall. It is suggested that the atmosphere is insufficiently moist to trigger convections during the pre-monsoon season, and sufficiently moist during summer monsoon season. The convections over the Sub-Himalayas may moisten the middle layer, and the water vapor in the atmosphere condenses because of the forced lifting along the slope, forming the second rainfall band. The total rain amount is primarily determined by the frequency of rain. The rain-conditioned rain rate along the slope monotonically decreases with elevation. This shows that the precipitation occurs because of forced lifting.

Over the mountainous western coast of India and Myanmar, maximum rainfall zone forms along a tight line on the windward side of the coastal mountains and propagating towards offshore. This is in contrast to the widely held view that this convection is centered over the open ocean as implied by coarse resolution datasets. Further, the most frequent and broader rainfall maxima, by far, is seen over the western coast of Myanmar. The rain top is also higher over the Myanmar West Coast than that over the Western Ghats, probably because of the moisture conditions in the eastern Bay of Bengal. It is suggested that, interaction of the low-level southwesterly moisture flow with the western coastal mountains of India and Myanmar in an important element of south Asian monsoon climatology.

Keywords: rainfall, mountains, orographic forcing, TRMM

Role of Planetary Boundary Layer and Cumulus Convection Parameterization Schemes in Mesoscale Simulation of Bay of Bengal Cyclones

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Tropical cyclones (TCs) are one of the deadliest and costliest natural hazards of the world. The disaster due to these severe storms can be reduced by providing more accurate prediction of the track and intensity of the storm. As far as single model forecast is concern, high resolution mesoscale model is expected to provide the best possible forecast of tropical cyclones. The forecast skill of a mesoscale model depends on the appropriate representation of the physical processes in the model. In this study, the sensitivity of Planetary Boundary Layer (PBL) and cumulus convection parameterization schemes on mesoscale simulation of landfalling Bay of Bengal cyclones is investigated. For this purpose two severe storm Sidr (2007) and Aila (2009) is simulated using WRF-ARW model. Thirty numerical simulations are conducted for each of the two cyclones with double nested domain with horizontal resolutions 27 Km and 9 Km with combination of six cumulus convection and five PBL parameterization schemes. The model is integrated for 99 hours and 51 hours for Sidr and Aila case respectively. The initial and boundary conditions for the model are derived from the NCEP Final analysis at one degree resolution. The model simulated results viz, track and intensity is compared with the best-fit datasets from the India Meteorological Department (IMD) and precipitation is compared with TRMM estimates. The model simulated results show that the simulations are sensitive to the choice of different cumulus convection and PBL parameterization schemes in the model. The minimum model simulated mean vector displacement errors during the whole simulation period are 90 Km and 49 Km for Sidr and Aila respectively. The location and time of landfall of the storms are also fairly simulated by the model with minimum landfall position error is 22 Km & zero Km and minimum landfall time error is 1 hour & 1 hour for Sidr and Aila respectively. Overall, the combination of the parameterization schemes of asymmetric convective model for PBL and Kain-Fritsch for cumulus convection produced the best simulation in terms of track and intensity of the storm. The comparisons of the intensities and structures of the simulated severe storms and inner core structures in the planetary boundary layer are also discussed.

Key words: Planetary boundary layer, cumulus convection, numerical simulation and parameterization schemes.

Reanalysis versus reality: a case study of snow on Antarctic sea ice

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Reanalysis data is widely used in climate research. However, in polar regions ground-truth measurements are sparse. For MERRA (Rienecker et al., 2011), previous authors have identified issues with Antarctic precipitation values (Bromwich et al., 2011; Cullather and Bosilovich, 2011). In this presentation for McMurdo Sound, Antarctica in 2009 we compare MERRA reanalysis snow values with measurements made on sea ice directly by personnel during the austral winter. It is shown that total snow accumulation using MERRA data was less than that measured directly at the site. The implications of this for climate studies are shown through the use of the Bitz and Lipscomb (1999) thermodynamic sea ice model (BL99). During the period when purely atmospheric heat conduction drove sea ice growth, the MERRA snow values lead to BL99 modelling thicker sea ice than was actually measured.

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The Fine-scale Structure of the Global Lapse-Rate Tropopause Derived from COSMIC GPS Radio Occultation Measurements

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The spatiotemporal structure of the lapse-rate tropopause (LRT) is examined by using state-of-the-art Global Positioning System (GPS) radio occultation measurements from the Constellation Observing System for Meteorology, Ionosphere and Climate/Formosa Satellite Mission 3 mission (COSMIC). The high temporal and spatial resolutions of the data reveal the detailed structure of tropopause properties such as pressure (P-LRT), temperature (T-LRT), and sharpness (S-LRT) and their relationships to upper tropospheric and lower stratospheric processes.

The overall results are generally in good agreement with previous studies. The climatology of all three tropopause properties shows largely homogeneous structure in the zonal direction: noticeable asymmetries are found only in the tropics and the Northern Hemisphere extratropics during boreal winter owing to localized tropospheric processes. This contrasts with the seasonal cycles of tropopause properties which are significantly influenced by stratospheric processes such as the Brewer-Dobson circulation, the polar vortex, and the radiative processes near the tropopause. On intraseasonal time scales, P-LRT and T-LRT exhibit significant variability over the Asian summer monsoon and the subtropics where double tropopauses frequently occur. In contrast, S-LRT shows maximum variability in the tropics where P-LRT and T-LRT have minimum variability, possibly a consequence of vertically propagating waves. The tropopause properties derived from COSMIC observations are further applied to evaluate tropopause data directly available from the NCEP-NCAR Reanalysis (NNR). Although the NNR tropopause data have been widely used in climate studies, they are found to have significant and systematic biases, especially in the subtropics. This suggests that the NNR tropopause data should be treated with great caution in any quantitative studies.

Comparison of ozone concentrations in the UTLS as measured by ozone sondes and commercial airliners (MOZAIC)

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Ozone is a strong greenhouse gas with maximal radiative forcing of surface temperature to changes in vertical ozone distribution close to the tropopause. Ozone sondes have been launched at selected sites since the late 1960s. They measure highly-resolved ozone profiles that can be used to construct ozone climatologies (e.g. for comparison with numerical simulations) and to deduce long-term ozone changes. However, the reliability of long-term tropospheric trends deduced from Brewer Mast sondes (mainly flown at European sites in previous decades) has recently been questioned.

Since 1994, ozone in the upper troposphere-lower stratosphere (UTLS) has also been continuously monitored by measurements from regular aircraft as part of the project MOZAIC (Measurement of Ozone and Water Vapor by Airbus in Service Aircraft Program). In this study, a method was developed to systematically compare ozone measurements from MOZAIC derived at flight altitude (largely in the mid-latitude UTLS) with ozone sonde data from various launch sites. This is achieved by identifying the same air masses using trajectory analysis. The method was tested extensively (including comparison of matches of the same air masses sampled by two MOZAIC aircraft) and an uncertainty of $\pm 2\%$ is determined for the MOZAIC measurements. Most of the ozone sonde data in the northern extra-tropics show encouraging agreement for the period after 1998 (in the order of 5-10%, consistent with laboratory studies). Prior to this, however, discrepancies are much larger. Potential reasons for these discrepancies will be discussed in the presentation.

Atmospheric temperature trends from GPS radio occultation records

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Observations for atmospheric climate monitoring and change detection have to meet stringent quality requirements. Conventional observations from weather satellites and balloons require demanding homogenization and calibration processes for the construction of climate records since they were originally not intended to serve climate monitoring needs. Intensive efforts have been put into reconciling differences in atmospheric temperature trends from radiosondes, microwave sounding records, and climate model data. Though basic agreement confirmed a tropospheric warming and stratospheric cooling, the uncertainties in trend rates and its vertical structure remain large in the upper troposphere and lower stratosphere (UTLS).

A relatively new atmospheric record is available from radio occultation (RO) observations based on signals of the Global Positioning System (GPS), providing a global and continuous data set of key climate variables for the UTLS since 2001. The measurements are based on precise atomic clocks and feature accuracy, long-term stability, and consistency across RO missions. The consistency implies that RO measurements from different satellites can be combined without any intercalibration. Best data quality is achieved from about 5 km to 30 km altitude. Profiles of bending angle, refractivity, pressure, geopotential height, and temperature are retrieved at a high vertical resolution of about 0.5 km to 1.5 km in the UTLS. Due to these characteristics RO qualifies as climate benchmark data type to investigate atmospheric climate change.

In this study we use the newly reprocessed RO record of WEGC over the full period 2002 to 2012, including data from the CHAMP, GRACE, Formosat-3/COSMIC, and MetOp satellites. We first briefly recall the demonstrated and remarkable utility of RO for UTLS climate monitoring and then focus on the investigation of temperature trends in the tropical UTLS. Vertically resolved temperature anomalies and trends will be presented and compared to those of recent radiosonde records and global climate models. In addition, layer average temperatures will be compared to records of the Advanced Microwave Sounding Unit (AMSU) and the Stratospheric Sounding Unit (SSU) for the lower- to mid-stratosphere channels. Overall we aim at providing deeper insight into recent anomalies and trends in the tropical UTLS based on the RO reference data record.

An Updated Retrieval of Ozone Profile Information from the Australian Dobson Observational Network

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Ozone vertical profile information can be estimated through an inversion of a Dobson Umkehr intensity ratio curve. The Umkehr technique measures the intensity ratio pair of ultra-violet wavelengths, typically between solar zenith angles of 60° and 90°. The retrieval algorithm then employs a forward model and inversion technique to obtain low vertical resolution information of ozone. The retrieval algorithm being developed is similar to Petropavlovskikh et al. (2005). However, the ray-tracing forward model incorporates interactive refraction; and the retrieval algorithm will use data taken at all solar zenith angles (SZA), which will change from measurement to measurement, instead of first fitting a spline through the data and working to a standard set of SZAs. The inverse method used is an optimal estimation technique, based off Rodgers (2000).

Dobson Umkehr measurements over the Australian sites of: Melbourne, Brisbane, Darwin, Hobart, Perth and Macquarie Island are retrieved and analysed. The data for these sites ranges from early 1962 to the present day for the sites of Melbourne, Darwin and Brisbane; 1969 – present for Perth; 1962 - 1999 for Macquarie Island and from 1969 – 1991 for Hobart. This project includes the digitisation of Australian Dobson paper records, and the re-formatting of all data records into a raw form, with no normalisation to standard Umkehr angles for the retrieval process.

Previously, Australian Umkehr data has not been retrieved for Australian sites after the year 2000. Thus, using the updated algorithm, the Dobson time series over Australia will be extended and completed. We present analysis of stratospheric ozone climatology and trends over Australia using the retrieved Dobson and Umkehr total column measurements. We also present preliminary comparisons with the retrieval algorithm developed by Petropavlovskikh et al. (2005).

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Diurnal variation of HO₂ over wide vertical region, from stratosphere to thermosphere, observed by SMILES

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HO₂ radical plays an important role in the atmospheric chemistry with its strong oxidizing capability. But there have been no report of the direct observation of photochemical behavior including diurnal variation in upper atmosphere. In this study, we report the first wide vertical range observation of HO₂ diurnal variations over range from stratosphere to thermosphere obtained by the observation of Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) from the Japanese Experiment Module (JEM) onboard the International Space Station (ISS).

SMILES has high-sensitive detectors for atmospheric limb emission in the submillimeter-wave 600 GHz range including the HO₂ transition frequency at 649.70 GHz. Observation period is during 12 October 2009 and 21 April 2010. The latitudinal range of observation covers from 65° N to 38° S.

NICT SMILES product was used for this study. Figure 1 shows the SMILES HO₂ diurnal variations as a function of solar zenith angle (SZA) at 10° intervals in the stratosphere (29.0-49.0 km) and mesosphere (53.0-79.5 km) in equatorial region (20° N-20° S). In general, HO₂ gradually increases and decreases after the sunrise and after sunset, respectively, and has a maximum peak at SZA of 0°. This is due to the reaction with O(¹D) atoms, which are generated predominantly from the photolysis of O₃. We found unpredicted behavior of HO₂ at the 79.5 km. At this altitude, the HO₂ peak was observed at SZA of 90° in the diurnal variation. Different chemical mechanisms might happen for HO₂ diurnal variation above the mesosphere.

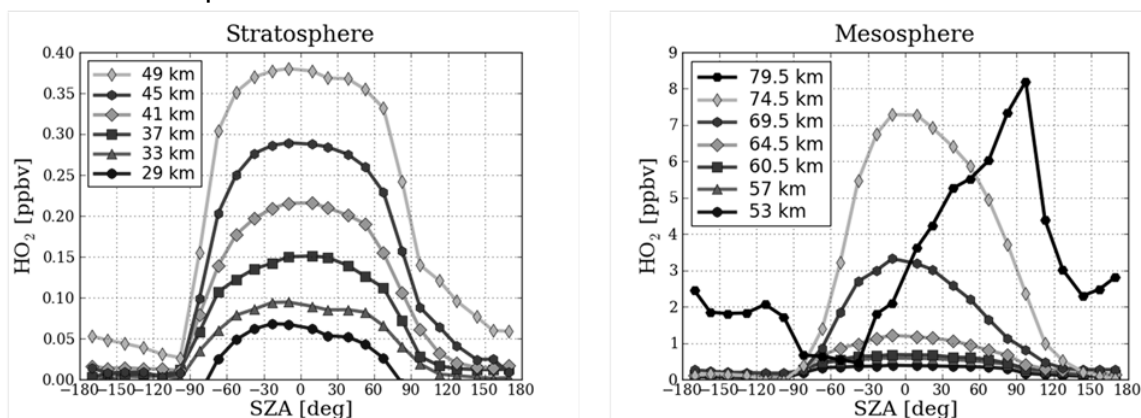


Figure 1. HO₂ diurnal variations from the SMILES observations for the equatorial region in the stratosphere (left panel) and mesosphere (right panel) at the altitude from 29.0 km to 79.5 km. The HO₂ volume mixing ratio is determined by averaging the observed 18885 profiles between February and March 2010. The data were selected according to the goodness of the fit of retrieval analysis and the measurement sensitivity. The horizontal axis represents the SZA where negative values are used to indicate the local time before the noon for descriptive purpose.

Highlights of the SPARC Data Initiative: Part II

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This contribution will present Part II of the research highlights of the SPARC Data Initiative. The main objective of the SPARC Data Initiative is a comprehensive inter-comparison of atmospheric satellite climatologies of chemical tracers and aerosol extending from the upper troposphere to the middle mesosphere. The zonal monthly mean climatologies, which were produced in a common format include the observations of 25 different atmospheric constituents obtained from 19 different instruments. The initiative assesses the quality of the available data sets and highlights similarities and differences between them, taking account of sampling limitations and biases.

We here focus on the evaluations of the long-lived trace gases O₃, CFC-11, CFC-12, HF, SF₆ and the short-lived nitrogen species NO, NO₂, HNO₃, HNO₄, N₂O₅ including the chemical families NO_x and NO_y. The evaluations of the trace gas climatologies include zonal monthly mean comparisons investigating the latitudinal and vertical structure of the various data sets. Additionally, the seasonal cycle, time series of deseasonalized trace gas anomalies and explicit diagnostics such as the quasi-biennial oscillation and the Antarctic ozone hole are evaluated. An assessment of the range of measurements as an estimate of the systematic uncertainty in our knowledge of the middle atmosphere mean state is derived for all trace gases. Our results highlight the advances in our understanding of these data sets, and also discuss their limitations or usefulness for merging and trend analysis. Lessons learned and an outlook on the future of the SPARC Data Initiative will be given.

Toward standardization of the SAGE-series data products: SAGE II 7.0

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The series of Stratospheric Aerosol and Gas Experiments (SAGE I, II, and III) and their predecessor the Stratospheric Aerosol Measurement (SAM II) are space-based solar occultation instruments that have provided over 26 years of ozone and aerosol data (1978-2005) which have been a cornerstone in studies of ozone trends and climate change. During this time, our understanding of the best practices for processing these data from instrument level data to the final data products has evolved considerably. On the other hand, the application of these practices has not been uniformly applied among the various missions particularly the earlier ones. Recently, the SAGE team has embarked on an effort to standardize the algorithms between instruments to the highest extent possible. This includes relatively obvious changes such as using uniform absorption cross sections for ozone and nitrogen dioxide and auxiliary data (e.g., T/p data from MERRA) to advanced tools used to reduced measurement noise in the intermediate line-of-sight transmission product. The first application of this process resulted in the release of SAGE II 7.0 in December 2012. Herein, we will discuss the changes in the algorithms from V6.2 to V7.0 discussing the major changes and their impact on the science data products. In general, significant improvements to the ozone and water vapor products are observed with smaller impacts on aerosol and nitrogen dioxide. We will also discuss on the on-going process of producing updated versions for SAM II, SAGE I, and SAGE III/Meteor 3M and how this effort will impact the upcoming SAGE III/ISS mission.

The SAGE III's mission aboard the International Space Station

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The Stratospheric Aerosol and Gas Experiment (SAGE III) is being prepared for a flight on the International Space Station (ISS) beginning in 2015. Since the instrument was constructed in the early 2000s, the instrument undergoing extensive testing and refurbishment prior to deliver to ISS. In addition, the project will also refurbish the ESA-provided Hexapod which is a high-accuracy pointing system developed to support ISS external payloads particularly SAGE III. SAGE III refurbishment also includes the replacement of the neutral density filter that has been associated with some instrument performance degradation during the SAGE III mission aboard METEOR/3M mission (2002-2005). In this presentation, we will discuss SAGE III - ISS refurbishment including results from Sun-look testing, revisions to the science measurements, and discuss expected measurement accuracies in part by examining SAGE III - METEOR/3M measurement data quality. We will also discuss potential mission science goals enabled by the mid-inclination ISS orbit. No dedicated field campaign for SAGE III validation is anticipated. Instead, validation will most rely on a collaborative effort with international groups making in situ and ground-based measurements of aerosol, ozone, and other SAGE III data products. A limited balloon-based effort with a yet-to-be-determined validation partner will also be in the planning stages.

Dynamical and Chemical Effects of Quasi-biennial Oscillation and Stratospheric Semiannual Oscillation on Tracer Transport in the upper Stratosphere

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Using satellite observations together with a chemistry-climate model (CCM), the effect of the stratospheric semiannual oscillation (SAO) and quasi-biennial oscillation (QBO) on the stratospheric tracer transport is investigated. It is found that QBO and SAO have a significant impact on tracer distributions in the stratosphere. The local vertical downwelling associated with SAO westerlies in the upper equatorial stratosphere is mainly responsible for the double peak structure in tracer distributions in the upper stratosphere, although the double peak structure is also modulated by the QBO phases. Both the observational evidence (Vincent and Alexander, 2000) and our modeling results (Shu et al., 2013) suggest that the equatorial long-lived tracer mixing ratio near the stratopause was significantly influenced by interannual variation in the gravity waves and enhanced lower stratospheric gravity wave activity can strength the SAO westerlies. Finally, the analysis reveals that the QBO and SAO can also affect stratospheric tracer distributions indirectly through dynamical processes. However, the altitude of greatest chemical destruction anomalies associated with the SAO and QBO is below the trough of the double peak in CH₄ distributions in the stratosphere.

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Trends in Total Column Ozone from Australian and New Zealand Dobson Sites

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The Southern Hemisphere mid-latitudes, particularly the area around south-eastern Australia and New Zealand, has been suggested as one of the regions where ozone recovery might first be detected, due to the combination of a strong impact of stratospheric halogen on ozone and relatively low dynamic variability¹. Here, we present total column ozone data from four long-term Dobson sites located in Australia and New Zealand: Brisbane (153°E 27°S), Perth (116°E 32°S), Melbourne (145°E 38°S) and Lauder (170°E 45°S). Brisbane, Melbourne and Perth are operated by the Bureau of Meteorology and Lauder by NIWA, however the instrumentation at Lauder and Perth is automated and supported by NOAA for measurements of the Umkehr effect which can be analysed to produce ozone profiles. All four time-series are traceable to the World Standard Dobson through a documented sequence of regular intercomparisons.

Ozone values in August to October, when the maximum in the annual cycle occurs, are well-correlated from year to year across all four sites, with close to half the variance explained by the phase of the QBO.

After applying a three-year running mean to reduce the impact of the QBO and random dynamic influences, Melbourne and Lauder both display negative trends before the mid 1990s and positive trends afterwards, in both autumn (February-March-April) and spring (August-September-October). The relative magnitude of the decreasing and increasing ozone trends are consistent within uncertainties with the ratio of the increasing and decreasing trend in EESC before and after this time. The decrease in Perth is similar to Melbourne and Lauder at both times of year but has only been followed by an increase in spring and not autumn. We do not detect meaningful trends at Brisbane. The significance of these trends are calculated using the standard cumulative sum of residuals (CUSUM) method.

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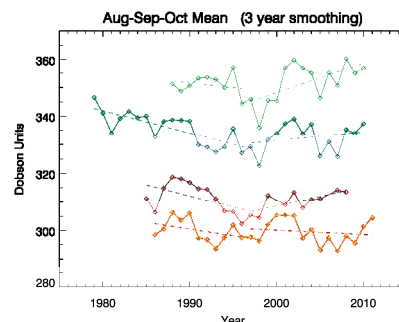


Figure 1 – Mean August to October total column ozone by year for the four sites: Lauder (green), Melbourne (blue), Perth (red) and Brisbane (yellow), with a three year running mean applied. The dashed line shows the pre-1997 and post-1997 linear trend.

Study of stratospheric water vapour and ozone time-series using data from Odin and other satellites

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The aim of the work is to provide an overview of the recent evolution of the key stratospheric species water vapour and ozone. We extend the historical satellite time-series of O₃ and H₂O from SAGE and HALOE, available until 2005, to present day by using data from Odin (launched in 2001) and more recently launched satellites such as Envisat (2002-2012), ACE (2003-), and Aura (2004-).

Comparison and combination of various satellite time-series provides first of all a critical test of the quality of the different satellite data sets. The study provides then an update concerning the expected long term recovery of stratospheric ozone as well as on the most recent evolution of strato-mesospheric water vapour in the tropics and at middle and high latitudes. It is still challenging to detect small changes in the global abundances of ozone and water vapour which are hidden behind a large natural variability manifested for example through seasonal, semi-annual, annual and biennial oscillations and by slow modulations caused by the 11 year cycle of solar activity. The time-series and trends of ozone can be compared to relevant observations of temperature and key species of the chlorine and nitrogen chemical families. In contrast, the amount of water vapour in the stratosphere is mainly controlled by the abundance of methane in the stratosphere and by the quite variable Lagrangian cold point temperature in the tropical tropopause layer. For example, a drop of the zonal mean TTL temperature minimum of over 3K was recently observed from mid-2011 to mid-2013, leading to a decrease of water vapour entering the stratosphere by roughly the same magnitude as observed more than a decade earlier during the year 2000. Odin observations of water vapour in the 375K-425K layer of potential temperature (16.5km-18.5km in terms of altitude) show a decrease which is consistent with the predicted temperature sensitivity of 0.19ppmv/K .

Results of this work will contribute to ongoing international activities such as the SPARC "Water Vapour Assessment" and the SI2N (SPARC/IO3C/IGACO-O3/NDACC) "Initiative on Past Changes in the Vertical Distribution of Ozone". Odin is a Swedish-led satellite project funded jointly by Sweden (SNSB), Canada (CSA), Finland (TEKES), France (CNES), and the European Space Agency (ESA).

MIPAS databases: the current status and future plans

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The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) was a limb emission spectrometer which globally measured vertically resolved distributions of temperature and many trace species. The data product generated by IMK and IAA includes H₂O, O₃, N₂O, NO₂, NO, HNO₃, N₂O₅, HNO₄, HCN, ClONO₂, ClO, HOCl, CFC-11, CFC-12, HCFC-22, CH₄, C₂H₂, C₂H₆, acetone, CO, PAN, SF₆, formic acid, acetic acid, OCS, SO₂ and others. These data are widely used in the scientific community for purposes of climate research, atmospheric chemistry, and others. While some users prefer to work with the original data, there are several further data bases based on these data which are custom-tailored to the specific requirements of particular user communities. Among these are the MIPAS climatologies created for the SPARC Data Initiative (Hegglin and Tegtmeier 2011) or the homogenized MIPAS ozone data created within the framework of the ESA Climate Change Initiative (Sofieva et al., 2013). A typical characteristics of these MIPAS data - and all remotely sensed data retrieved using a numerical constraint - is that these data include some form of prior information, which adds complication to the quantitative work with these data. The problem is that the altitude resolution and content of prior information depends on the atmospheric state, which can lead to artefacts in trends, artefacts in annual cycles, and limited comparability to modelled data or other measurements. Limitations of the classical remedies against these problems will be critically discussed, and maximum likelihood retrievals will be revisited for generation of user-friendly data products.

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Using FTIR Measurements of Stratospheric Composition to Identify Mid-Latitude Polar Vortex Intrusions Over Toronto

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Using eleven years of trace gas measurements made at the University of Toronto Atmospheric Observatory (TAO, 43.66°N, 79.40°W), and Environment Canada's Centre for Atmospheric Research Experiments (CARE, 44.23°N, 79.78°W), along with derived meteorological products, we identify a number of polar intrusion events, which are excursions of the polar vortex or filaments from the polar vortex extending down to mid-latitudes. These events are characterized by enhanced stratospheric columns (12-50 km) of hydrogen fluoride (HF) and diminished stratospheric columns of nitrous oxide (N₂O), and by a scaled potential vorticity above 1.2 vu. The events comprise 10% of winter/spring (November to April inclusive) Fourier transform infrared (FTIR) spectroscopic measurements from January 2002 to March 2013, and we find a minimum of two, and maximum of nine events in a given year, with four events per year being the average. The events are confirmed by Modèle Isentrope du transport Méso-échelle de l'Ozone Stratosphérique par Advection (MIMOSA) and Modern-Era Retrospective Analysis for Research and Applications (MERRA) potential vorticity (PV) maps, and Global Modelling Initiative (GMI) N₂O maps. During polar intrusion events, the stratospheric ozone (O₃) columns over Toronto - which are in agreement with the Optical Spectrograph and InfraRed Imaging System (OSIRIS) satellite instrument - are usually greater than when there is no event. However, we find six cases out of 46 where chemical O₃ depletion within the polar vortex led to a reduction in stratospheric O₃ columns over this major metropolitan area.

We have thus identified a dynamical cause for most of the winter/spring variability of stratospheric trace gas columns observed at our mid-latitude site. While there have been a number of prior polar intrusion studies, this is the first study to report in the context of eleven years of ground-based column measurements, providing insight into the frequency of mid-latitude polar vortex intrusions, and observations of upper-stratospheric (25-50 km) intrusions. It is also the first to present HF measurements during polar intrusions, which was found to be an excellent tracer for their identification.

Impact of polar vortex on ozone profiles in the Atmospheric Observatory of South Patagonia, Río Gallegos, Argentina

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The Atmospheric Observatory of Austral Patagonia (OAPA) is a remote sensing site located near the Río Gallegos city in South Patagonia (51° 55'S, 69° 14'W), in subpolar region affected by the polar vortex. It is a convenient monitoring site of the atmosphere in the southern hemisphere especially for ozone studies. This site is operating a differential absorption lidar instrument (DIAL) for the measurement of ozone vertical distribution. This instrument is part of Network Data for Atmospheric Composition Change (NDACC). The altitude range of the ozone measurement is 14-45 km, which provides the opportunity to monitor the perturbations due to the passage of stratospheric polar air over Río Gallegos. Since 2005, systematic stratospheric ozone profile measurements have been carried on in this experimental site. The position of the station with respect to the polar vortex was analyzed from the use of equivalent latitude maps. We identified three major perturbation related to the ozone hole on the stratospheric ozone profile record in Río Gallegos: extension of the polar vortex towards the station during late winter, passage of the ozone hole over the station in middle spring and dilution process during late spring. All these three processes change the shape of the stratospheric ozone profile and produce variation in the total ozone column over the OAPA. These perturbations in the middle atmosphere induce change in solar UV radiation at ground surface of great importance for the health of people leaving in the area. In this article, we review the main conclusions regarding the observation of stratospheric ozone profiles and surface UV radiation measurements in the OAPA for the period 2005-2012, including the analysis of the exceptional final warming of November 2009 vortex breakdown (Wolfram, et al, 2012).

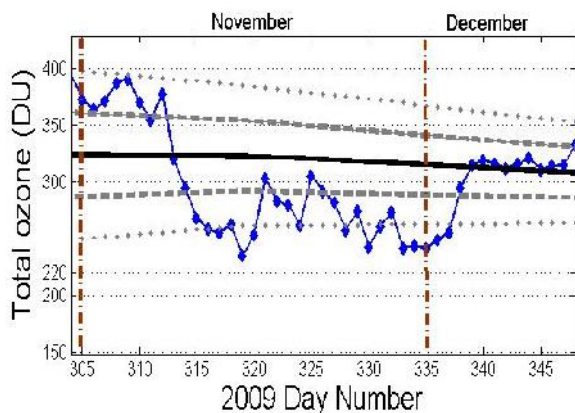


Fig 1. Temporal evolution of total ozone for Río Gallegos site (blue line) with the climatological daily mean of total ozone (black line). Gray dash line correspond to to ± 1 SD and dotted gray line corresponds to ± 2 SD.

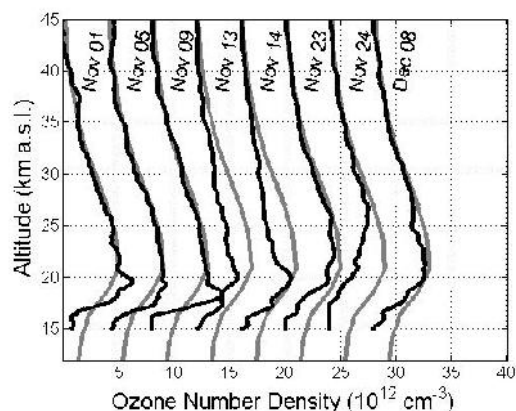


Fig 2. Lidar ozone profiles measured in OAPA (black lines) from November 1 to December 13, 2009. For comparison of vertical ozone profile shape change, November climatological Fortuin and Kelder ozone profile is included (gray line). The profiles have been offset successively by $4 \times 10^{12} \text{ cm}^{-3}$.

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Decadal Record of Satellite Carbon Monoxide Observations

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Atmospheric carbon monoxide (CO) distributions are controlled by anthropogenic emissions, biomass burning, chemical production, transport and oxidation by reaction with the hydroxyl radical (OH). Quantifying trends in CO is therefore important for understanding changes related to all of these contributions. Here we present a comprehensive record of satellite observations from 2000 through 2011 of total column CO using the available measurements from nadir-viewing thermal infrared instruments: MOPITT, AIRS, TES and IASI. We examine trends for CO in the Northern and Southern hemispheres along with regional trends for E. China, E. USA, Europe and India. Measurement and sampling methods for each of the instruments are discussed, and we show diagnostics for systematic errors in MOPITT trends. We find that all the satellite observations are consistent with a modest decreasing trend around -1%/year in total column CO over the Northern hemisphere for this time period. Decreasing trends in total CO column are observed for the United States, Europe and E. China with more than 2 σ significance. For India, the trend is also decreasing, but smaller in magnitude and less significant. Decreasing trends in surface CO have also been observed from measurements in the U.S. and Europe. Although less information is available for surface CO in China, there is a decreasing trend reported for Beijing. Some of the interannual variability in the observations can be explained by global fire emissions, and there may be evidence of the global financial crisis in late 2008 to 2009. But the overall decrease needs further study to understand the implications for changes in anthropogenic emissions.

CH₄ emissions estimates from tropical and subtropical fires using Aura TES CH₄ and Terra MOPITT CO profiles

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Methane is the second most important greenhouse gas and has been increasing at approximately 0.4% (~8 ppb/year relative to ~ 1850 ppb background) per year since 2006. This rise is equivalent to an approximately 18 Tg/year excess source that could be due to a number of processes. Attributing the processes and sources controlling methane are critical for predicting future response of atmospheric methane to a changing climate. In any given year, methane from fire emissions represent approximately 5% to 20% of the global methane emissions of approximately 550 Terragrams and significantly affects inter-annual variability of atmospheric methane. Greater than 60% of fire emissions occur in the tropics and sub-tropics (between 30 S to 30 N) with the remaining fire emissions mostly in boreal regions. Unfortunately the current surface network is challenged to place constraints on these methane emissions because fire emissions can be quickly lofted into the free troposphere and diluted before being transported back to the surface. Current satellite measurements using reflected sunlight measurements to quantify total column methane are challenged to quantify methane from fires because of the use of CO₂ (also emitted by fires) as a reference gas for the total column retrieval, because aerosols increase uncertainty of reflected sunlight measurements, and because of the lack of a co-measured CO measurement to identify air parcels affected by the fire. Aura TES (thermal IR based) methane observations, with sensitivity from the top of the boundary layer to the tropopause have the error characteristics (< 1% precision and < 0.5% accuracy after bias correction) and sensitivity within fire plumes to quantify tropical and subtropical fire emissions. In this talk we use Aura TES CH₄ and CO as well as TERRA MOPITT CO profile measurements to quantify the role of tropical fires on atmospheric methane from 2006 through 2010.