Chemical/Dynamical Interactions and Consequences for Climate

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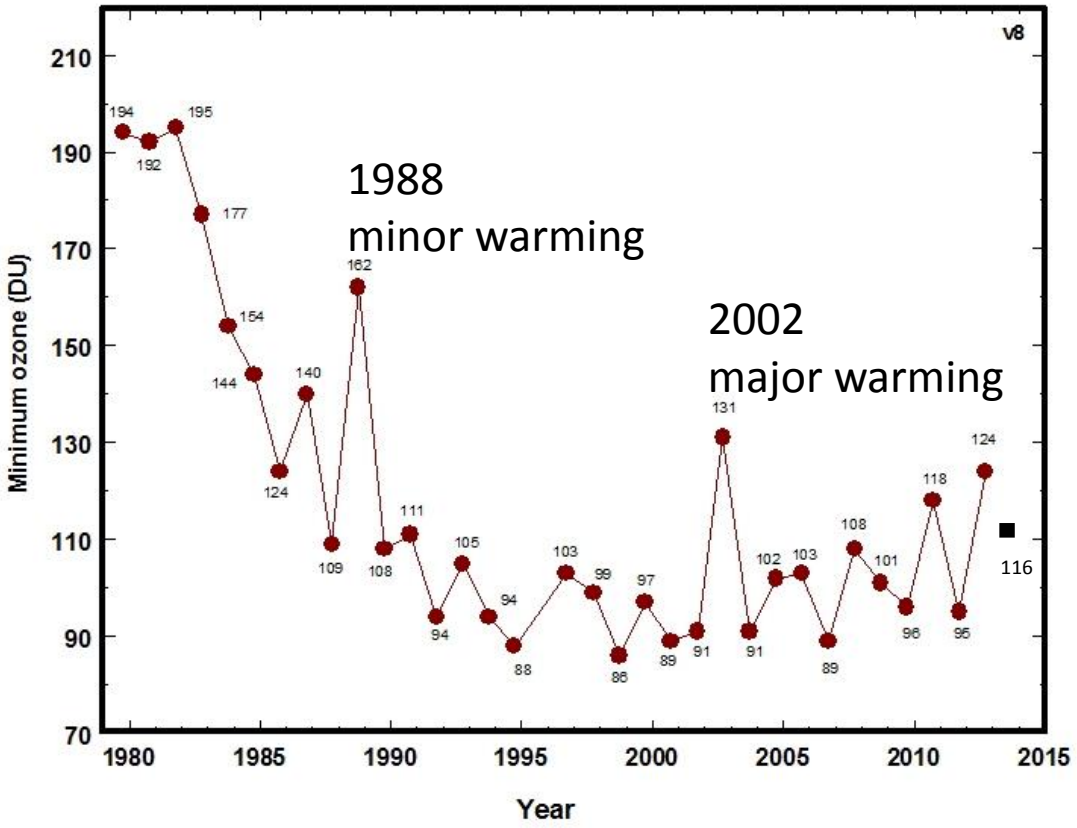
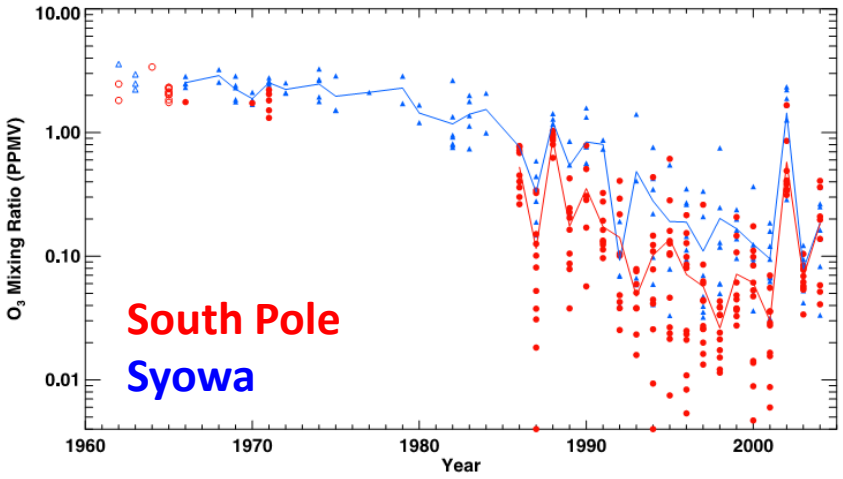
Antarctic Minimum Total Ozone



Variability of Antarctic Ozone

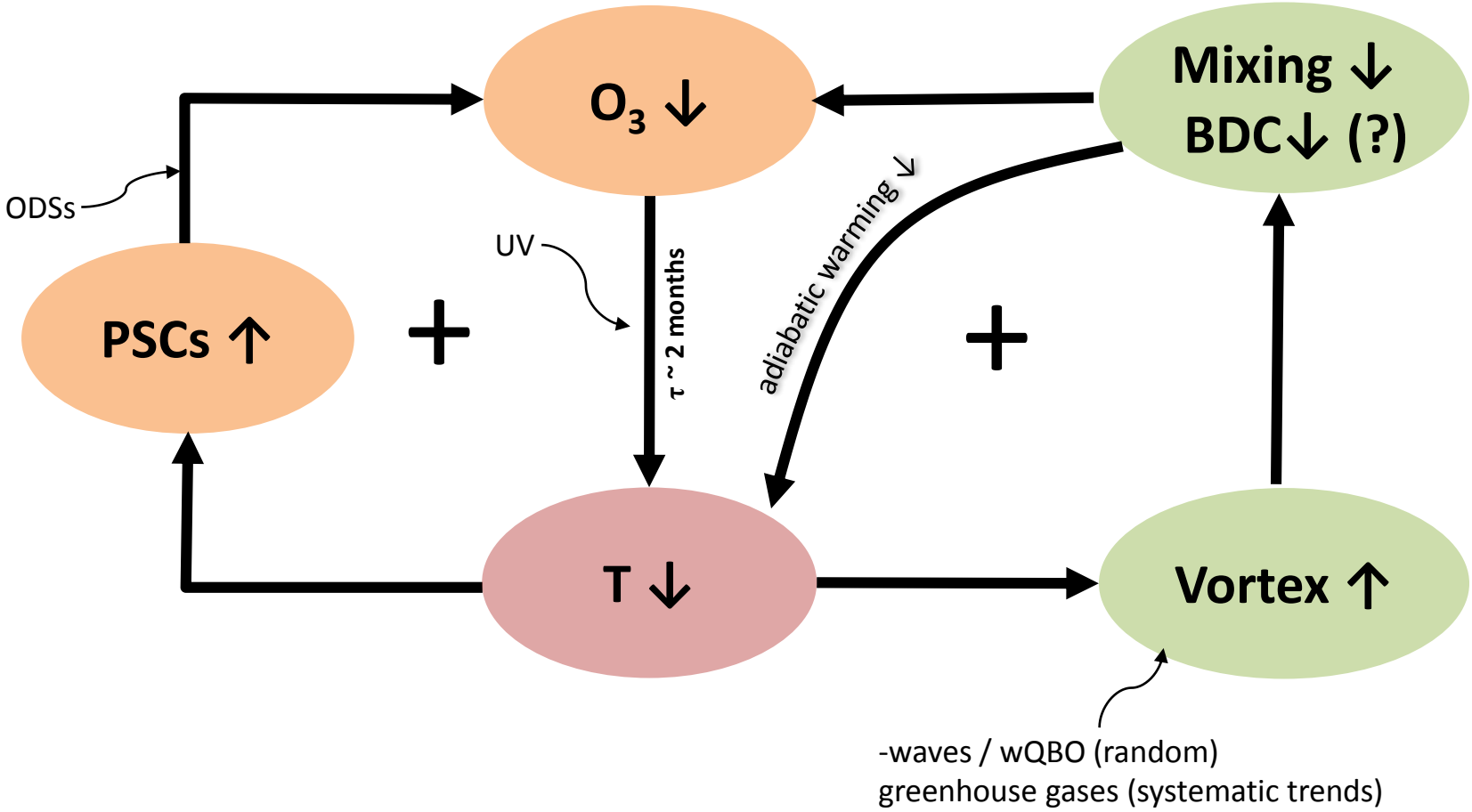


Solomon et al. 2005

pre-1980: little variability

much increased day-to-day and interannual variability

Feedback


O_3 ↓
Mixing ↓
BDC↓ (?)
ODSs
UV
τ ~ 2 months
adiabatic warming ↓
PSCs ↑
+
+
T ↓
Vortex ↑
-waves / wQBO (random)
greenhouse gases (systematic trends)
Photo-Chemical (PC)
Dynamical-Chemical (DC)

Basic Strategy

- Hypothesized positive feedbacks should
  - increase persistence on intraseasonal time scales, and
  - increase variability on interannual time scales.

- Feedback response = results from

  (models with feedbacks) minus

  (models in which feedbacks are turned off)

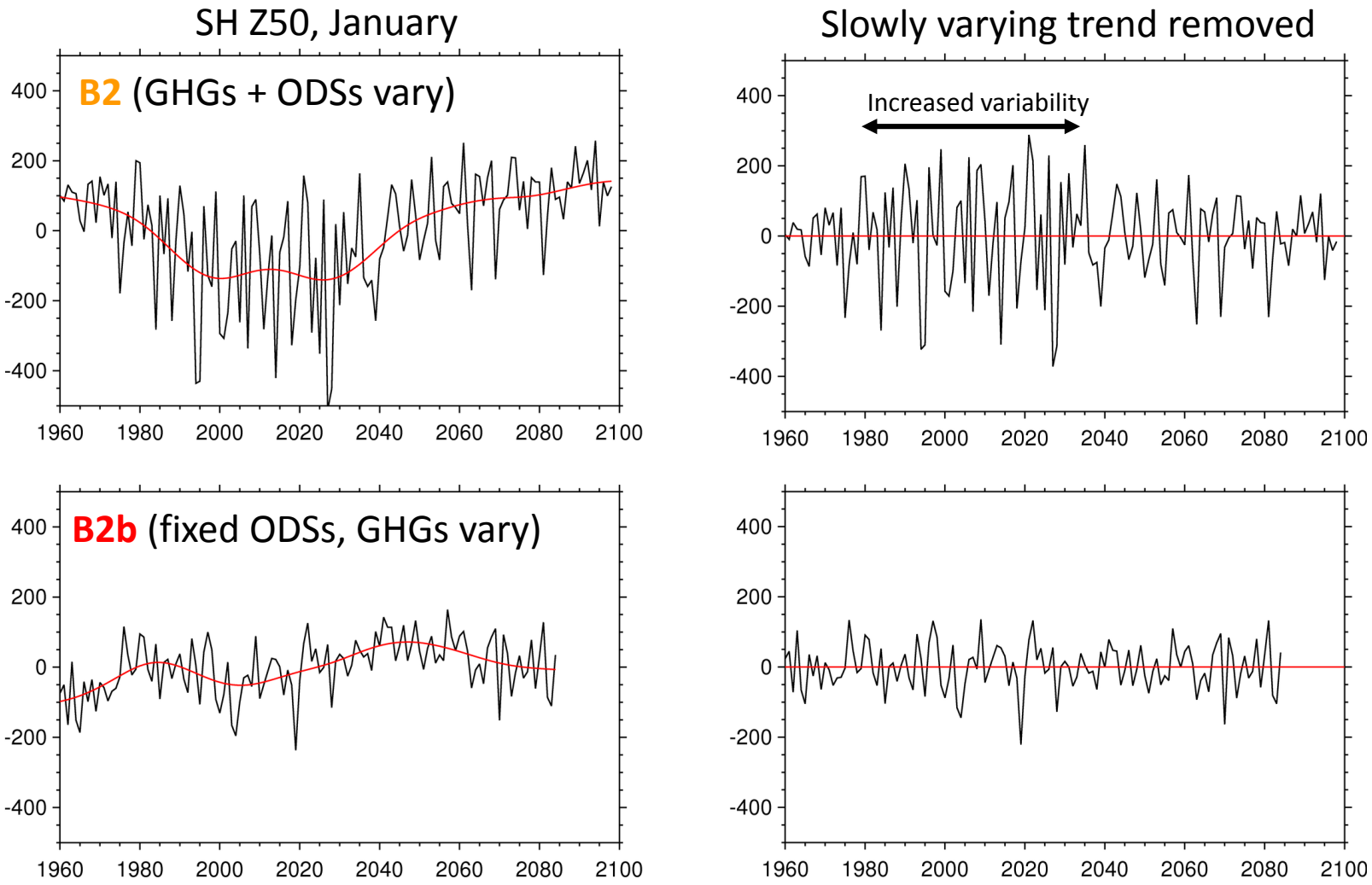
CCMVal-2

- Coupled chemistry-atmosphere models; multi-model means of 5 common models
- Transient simulations: 1960-2100

name	forcings	factors
B2	varying GHGs and ODSs	DC + PC + ↑CO_2
B2b	1960 ODSs	DC + ↑CO_2
B2c	1960 GHGs	DC + PC

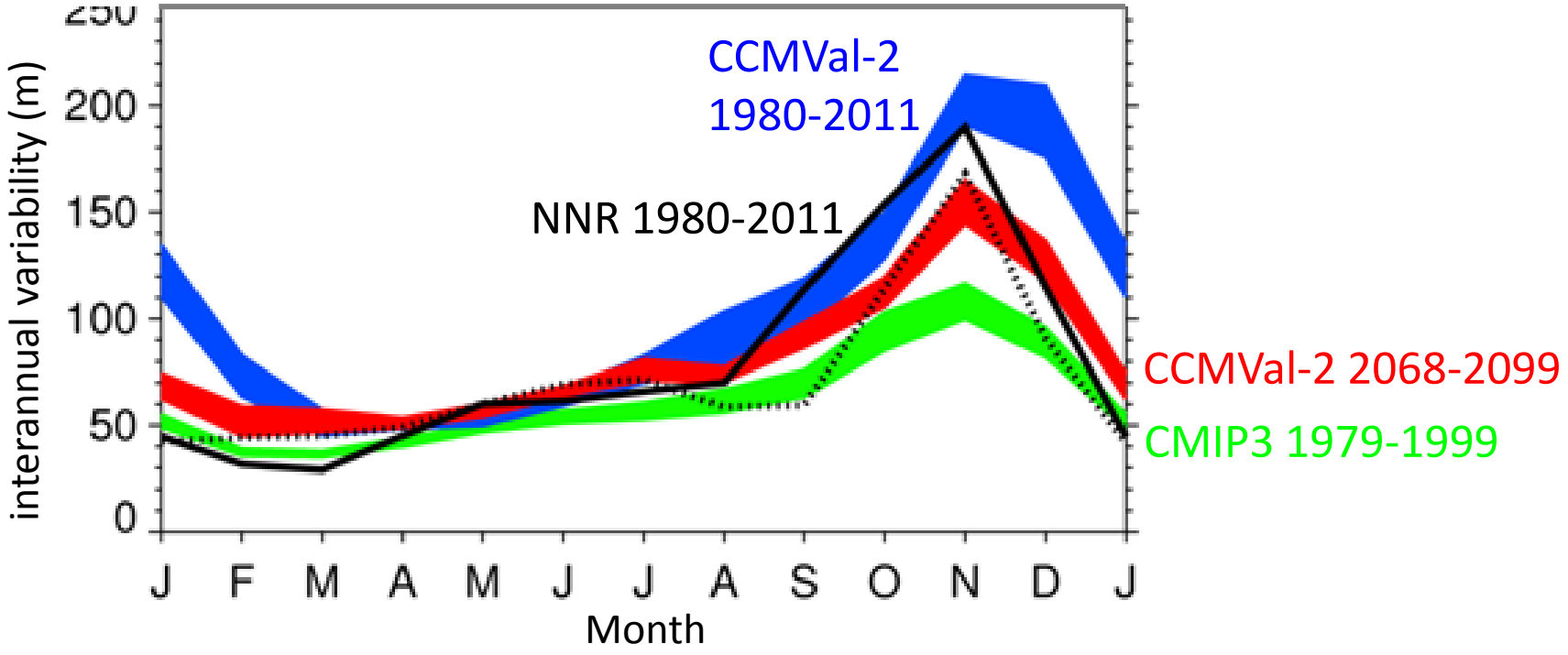
SAM (Z50)

CCMVal-2 model



SAM (Z50) Interannual Variability

Ozone depletion vs. ozone recovery period



GFDL-CM3

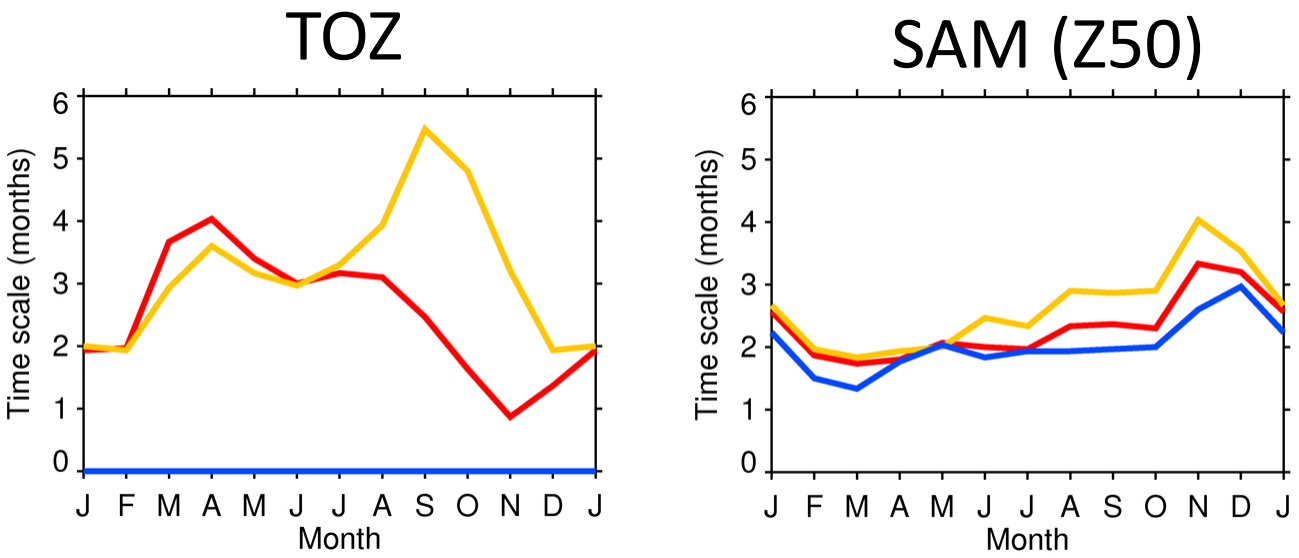
- Coupled chemistry-climate model
- Long time-slice simulations (500-2000 years)

name	forcings	factors
CTRL	1860	DC
DEPLO3	1990 CO_2 and ODSs	DC + PC + ↑CO_2
FIXO3	1860, fixed ozone	-

- Caveats
  - DEPLO3 has no Arctic ozone depletion
  - DEPLO3 has changing CO_2
  - FIXO3 has more SSWs (46%) than CTRL (36%) or DEPLO3 (35%)

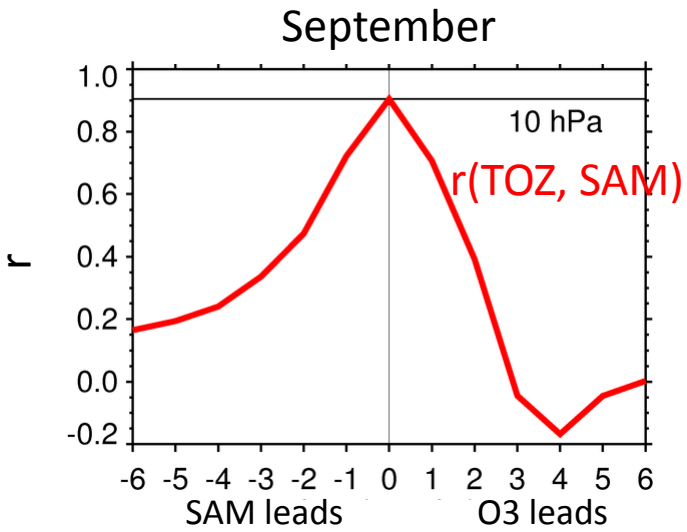
SH: Persistence

FIXO3
CTRL
DEPLO3



- TOZ and SAM anomalies last for several months
- On average, TOZ has longer time scale than SAM
- **PC** strongly increases TOZ persistence
- **DC** influence is noticeable

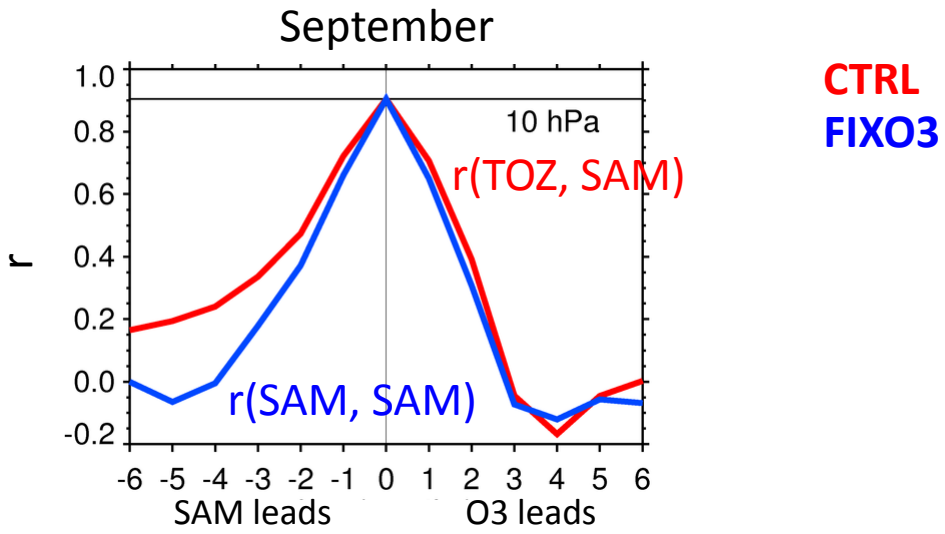
Cross-Correlation: TOZ & SAM10



CTRL

- Correlations between TOZ and SAM are strongly positive, in particular during austral spring
- Correlations are larger when SAM leads TOZ
- Correlations are larger in DEPLO3 than in CTRL (not shown)

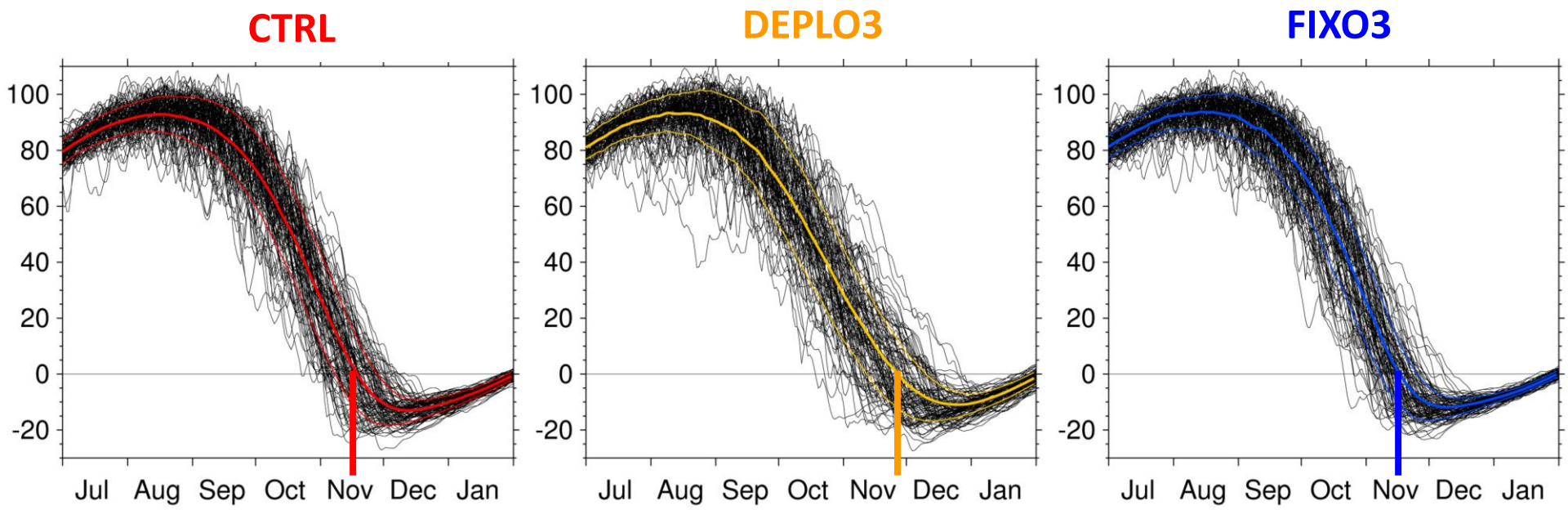
Cross-Correlation: TOZ & SAM10



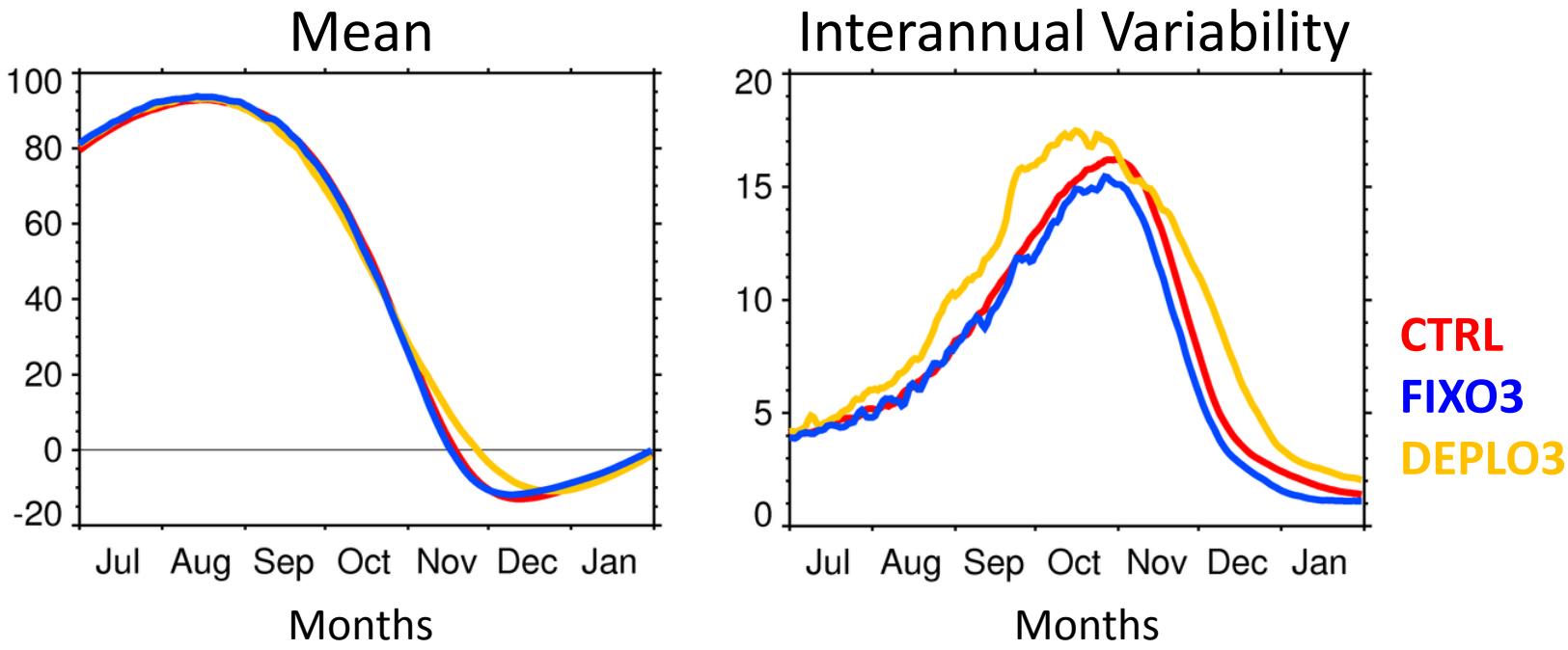
- Correlations between TOZ and SAM are strongly positive, in particular during austral spring
- Correlations are larger when SAM leads TOZ
- Correlations are larger in DEPLO3 than in CTRL (not shown)
- Correlations are larger than auto-correlation of SAM in FIXO3 (= no-feedback null-hypothesis)

Polar Vortex: U10 @ 60°S

First 100 years each

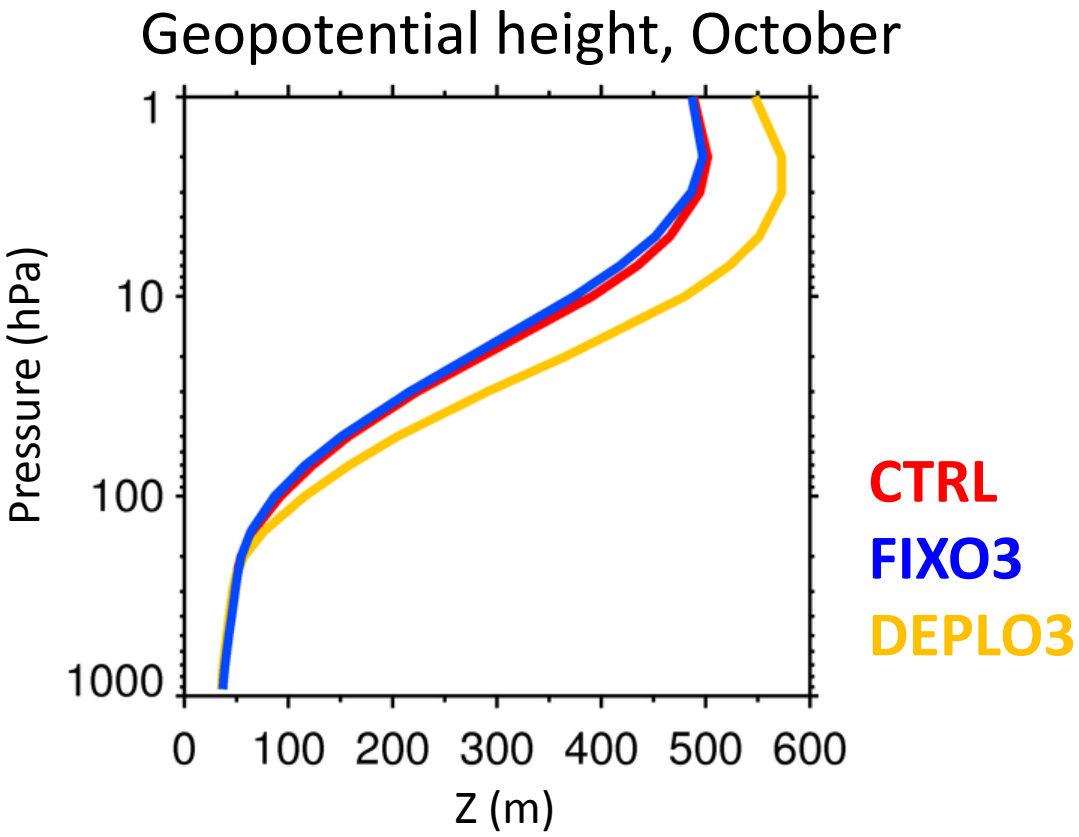


Polar Vortex: U10 @ 60°S

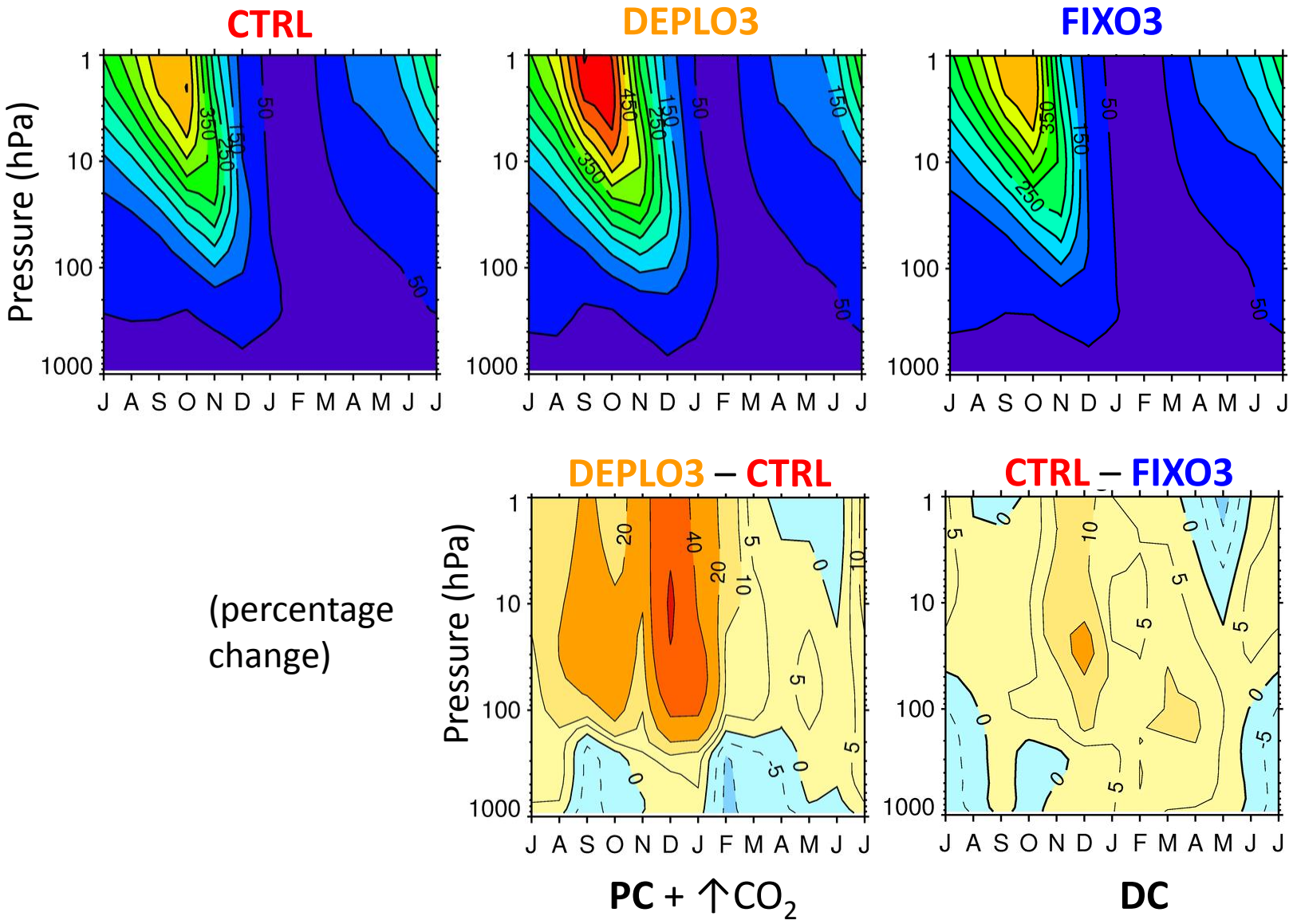


SAM Interannual Variability

GFDL-CM3



SAM Interannual Variability

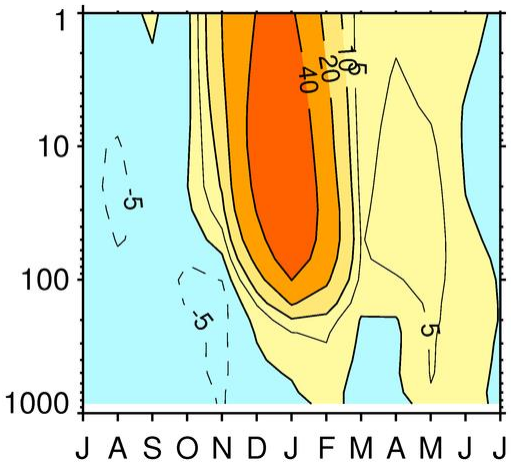


SAM Interannual Variability Change

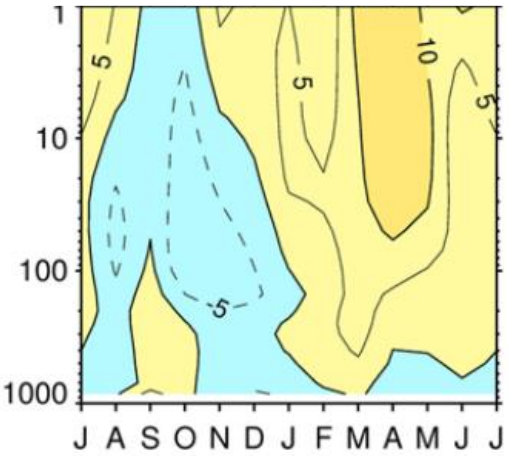
CCMVal-2 vs. GFDL-CM3

(percentage change)

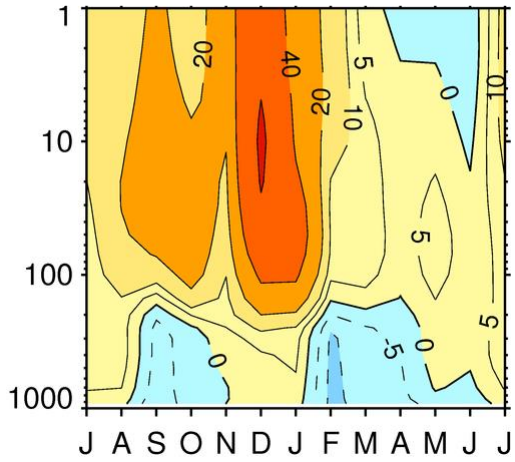
B2 – B2b: **PC**



B2 – B2c: ↑CO_2



DEPLO3 – **CTRL**: **PC** + ↑CO_2

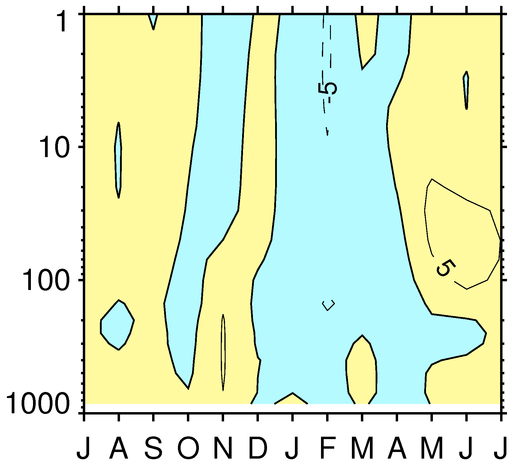


NAM Interannual Variability Change

CCMVal-2 vs. GFDL-CM3

(percentage change)

B2 – B2b: **PC**



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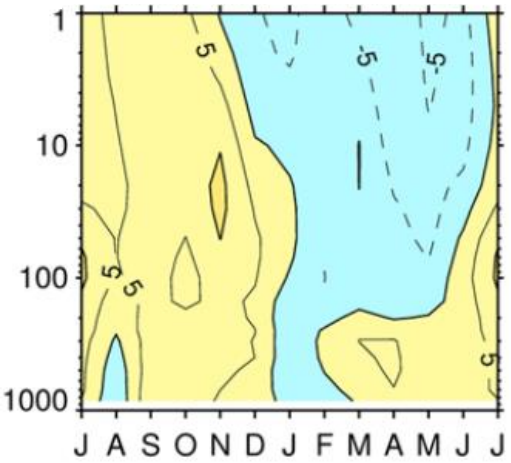

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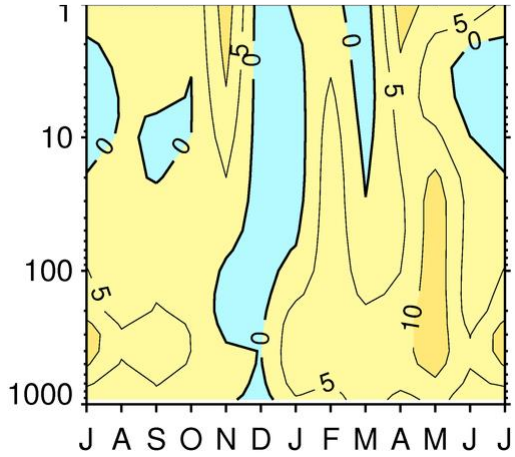

Conclusion

- Our results are consistent with the hypothesized feedbacks
  - feedbacks increase Antarctic climate variability
    - up to 80% in stratosphere
    - 5% in troposphere
  - photo-chemical feedback (PC) strongly amplifies dynamical-chemical feedback (DC)
- Anthropogenic ozone depletion increases climate variability
  - impact on sea ice variability and detectability of trends
- Models without interactive chemistry underestimate natural climate variability