Stratospheric processes and impacts

Pu Lin

Geophysical Fluid Dynamics Laboratory Review

October 29-31, 2019

The stratosphere: A unique component of the climate system

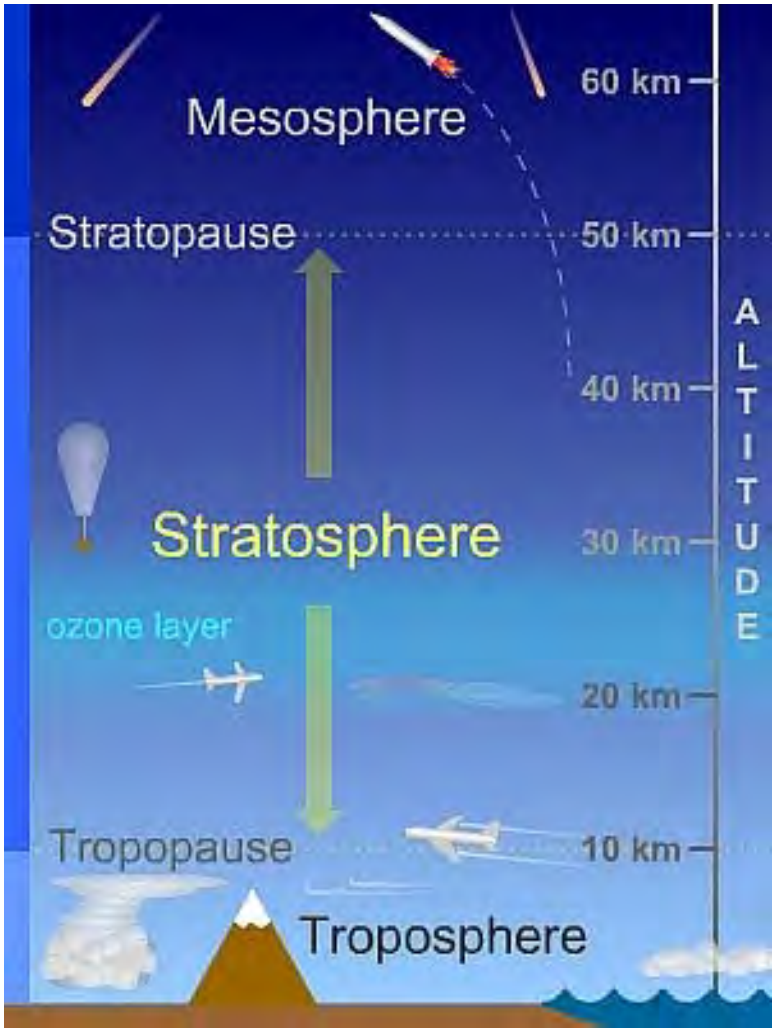
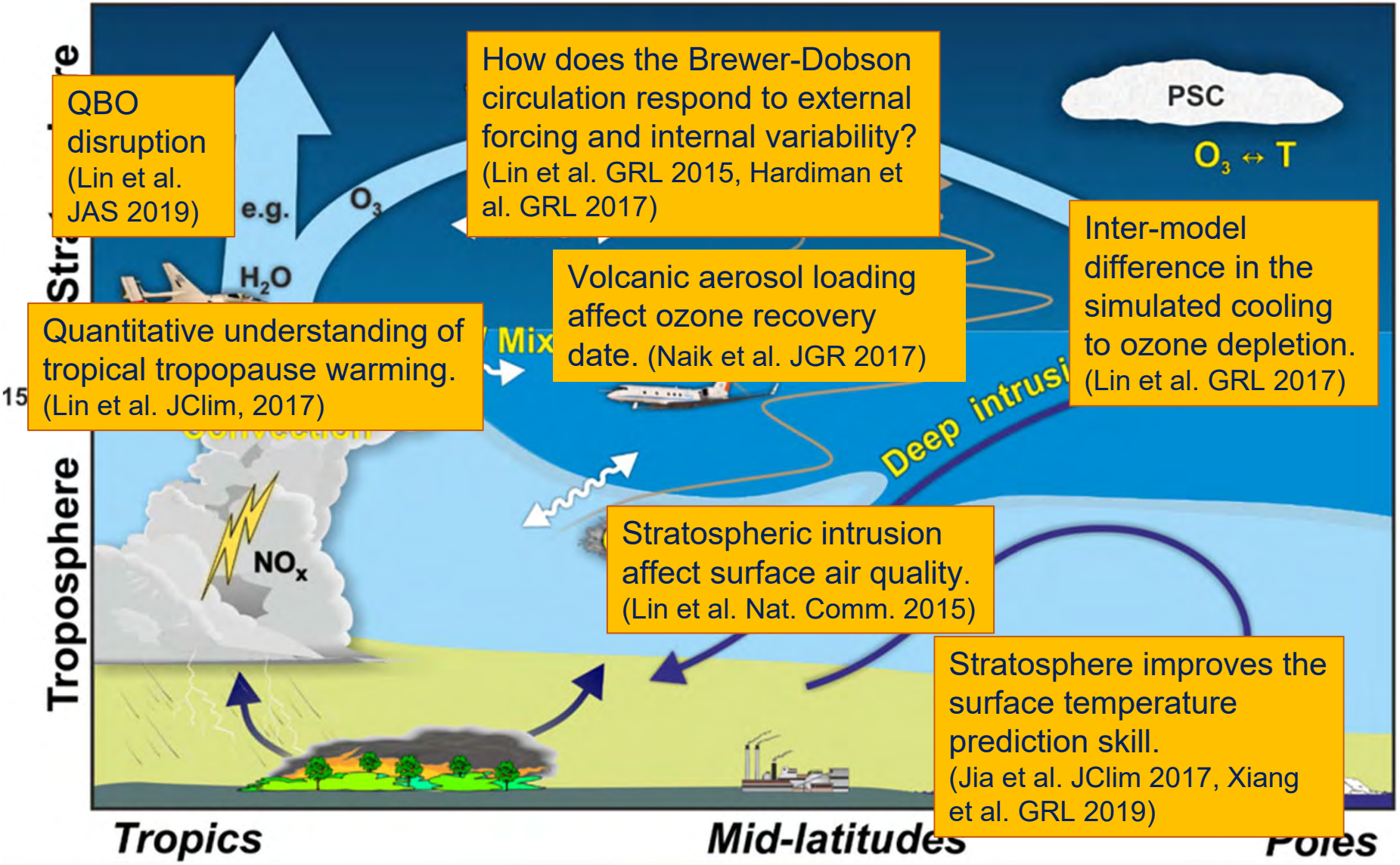


Image Credit: UCAR

- Additional validation for basic theories.
- Significant influence on weather and climate in the troposphere and at the surface.
  - Stratospheric species can directly alter the tropospheric and surface radiation balance.
  - Dynamical coupling between the stratosphere and the troposphere.
  - Composition changes from stratosphere-troposphere exchange.

Recent stratospheric studies at GFDL



QBO disruption (Lin et al. JAS 2019)

How does the Brewer-Dobson circulation respond to external forcing and internal variability? (Lin et al. GRL 2015, Hardiman et al. GRL 2017)

Inter-model difference in the simulated cooling to ozone depletion. (Lin et al. GRL 2017)

Volcanic aerosol loading affect ozone recovery date. (Naik et al. JGR 2017)

Quantitative understanding of tropical tropopause warming. (Lin et al. JClim, 2017)

Stratospheric intrusion affect surface air quality. (Lin et al. Nat. Comm. 2015)

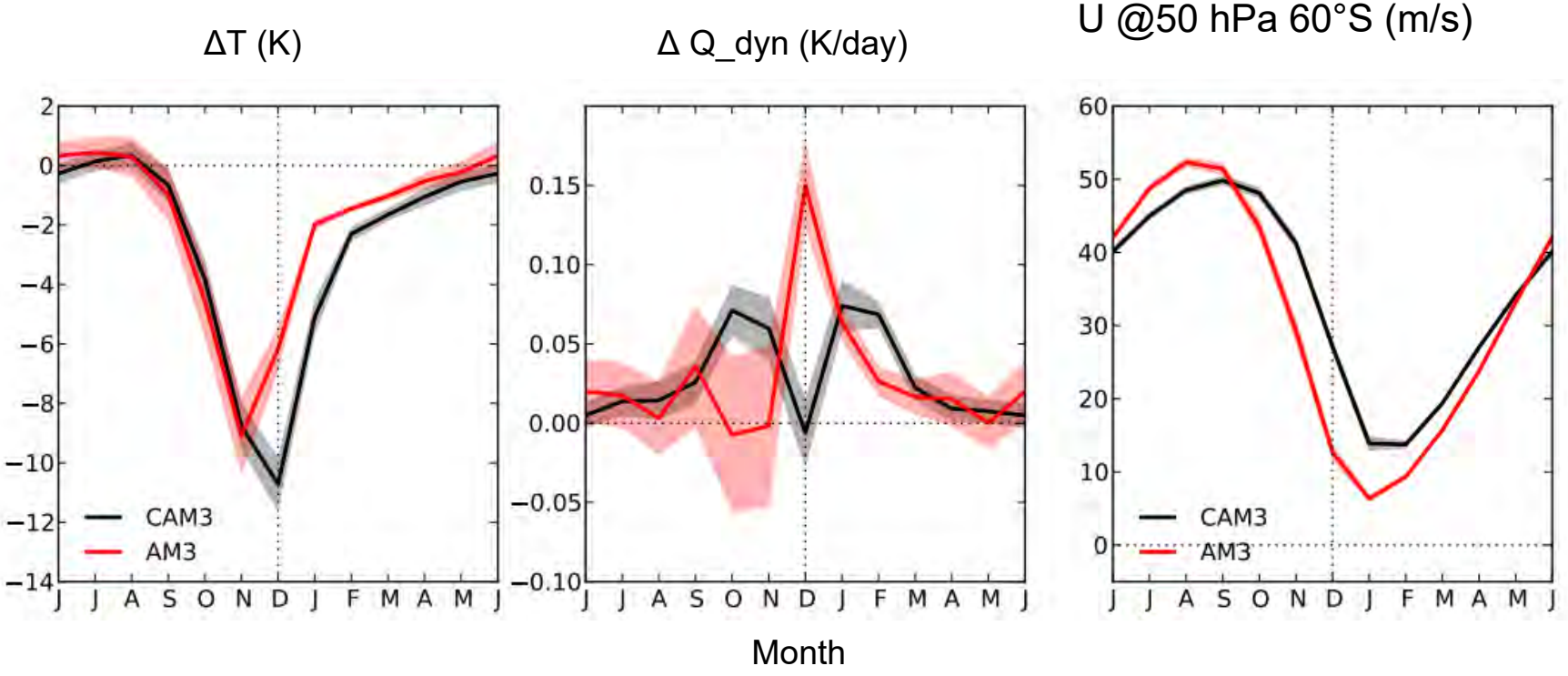
Stratosphere improves the surface temperature prediction skill. (Jia et al. JClim 2017, Xiang et al. GRL 2019)

Image Credit: IKE-7

Simulated Response to Ozone Depletion

Responses to identical ozone depletion @100 hPa 60°S-90°S

Strat. polar vortex climatology
U @50 hPa 60°S (m/s)

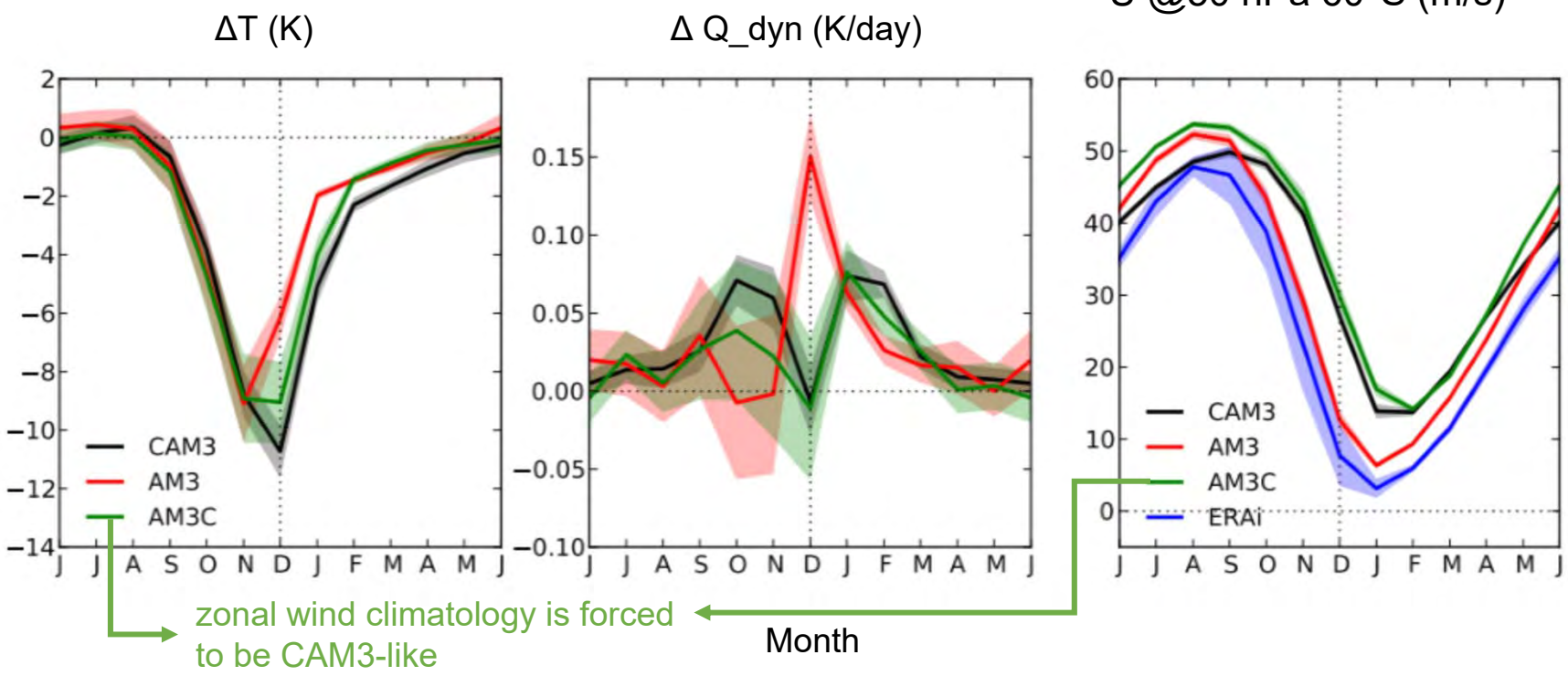


- Stratospheric cooling in response to ozone depletion consists of both radiative and dynamical components.
- Dynamical component drives the inter-model difference.
- Dynamical component is affected by the polar vortex seasonality.

Simulated Response to Ozone Depletion

Responses to identical ozone depletion @100 hPa 60°S-90°S

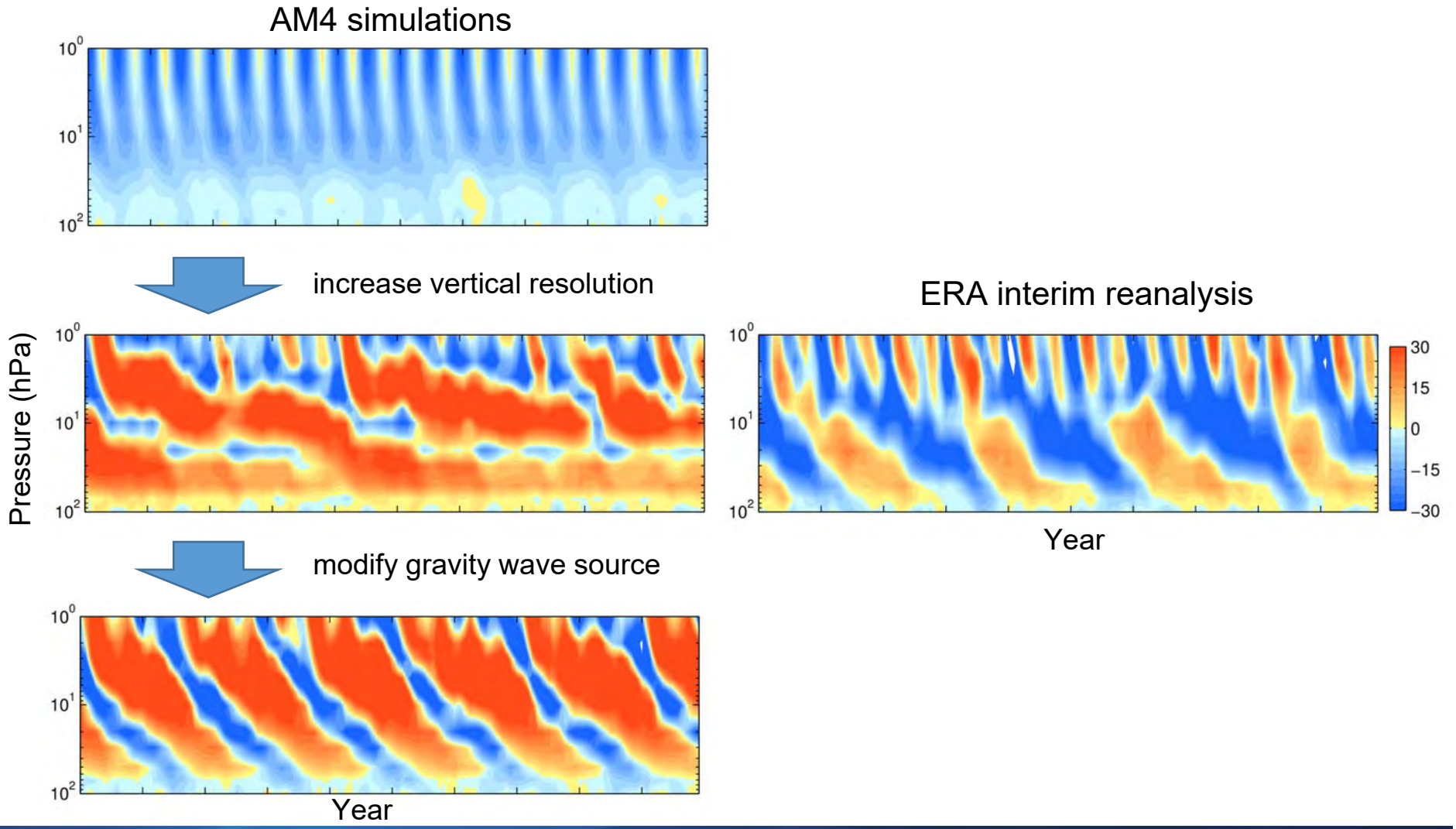
Strat polar vortex climatology
U @50 hPa 60°S (m/s)



- Zonal wind climatology serves as a better observational constrain.
- Delayed southern polar vortex breakdown, a common model bias, implies an overestimation of the response to ozone depletion.

Higher resolution and more physical representation

Zonal mean zonal wind at the equator



Future Plans & Challenges

- Interaction between convection and circulation
  - redesign the parameterization for the convective gravity waves.
  - correct bias in the large-scale equatorial waves.
  - utilize the convection-resolving simulations.
- Stratospheric aerosol
  - better resolve the transport across tropopause.
  - better representation of the volcanic aerosol.
- Potential benefit for prediction at the surface
  - preliminary results confirms the benefits (see poster by Liwei Jia and talk by Baoqiang Xiang).
  - better understanding of the mechanism.

Summary

- GFDL models are capable of simulating the essential radiative, dynamic, thermodynamic and chemical processes in the stratosphere.
- Simulated response to ozone depletion depends on the zonal wind climatology.
- Other activities: QBO disruption, tropical tropopause warming, the Brewer-Dobson circulation, ozone recovery, stratospheric intrusion, stratospheric contribution to surface prediction.
- Higher resolution and more physical simulations create new research opportunity.

Publication

- Lin, P., I. Held and Y. Ming, 2019: The early development of the 2015/2016 Quasi-Biennial Oscillation disruption. J. Atmos. Sci., 76, 821-836.
- Xiang, Baoqiang, S.-J. Lin, M. Zhao, N. C. Johnson, X. Yang, and X. Jiang, 2019: Subseasonal week 3-5 surface air temperature prediction during boreal wintertime in a GFDL model. GRL., 46, 416-425.
- Lin, P., D. Paynter, L. Polvani, G. J. P. Correa, Y. Ming and V. Ramaswamy, 2017: Dependence of model-simulated response to ozone depletion on stratospheric polar vortex climatology. Geophys. Res. Lett., 44, 6391-6398.
- Jia, L., X. Yang, G. Vecchi, R. Gudgel, T. Delworth, S. Fueglistaler, P. Lin, A. Scaife, S. Underwood and S.-J. Lin, 2017: Seasonal prediction skill of northern extratropical surface temperature driven by the stratosphere. J. Clim., 30, 4463-4475.
- Hardiman, S., P. Lin, A. Scaife, N. Dunstone and H.-L. Ren, 2017: The influence of dynamical variability on the observed Brewer-Dobson circulation trend. Geophys. Res. Lett., 44, 2885-2892.
- Lin, P., D. Paynter, Y. Ming and V. Ramaswamy, 2017: Changes of the tropical tropopause layer under global warming. J. Clim., 30, 1245-1258.
- Naik, V., L. Horowitz, M. D. Schwarzkopf, and M. Lin, 2017: Impact of volcanic aerosols on stratospheric ozone recovery, J. Geophys. Res., 122, 9515-9528.
- Lin, P., Y. Ming and V. Ramaswamy, 2015: Tropical climate change control of the lower stratospheric circulation. Geophys. Res. Lett., 42, 941-948.
- Lin, M., A. M. Fiore, L. W. Horowitz, A. Langford, S. J. Oltmans, D. W. Tarasick, and H. E. Rieder, 2015: Climate variability modulates western US ozone air quality in spring via deep stratospheric intrusions. Nat. Comm., 6, 7105.