Radiative and Chemical Impacts of Stratospheric Aerosols from Volcanic Eruptions as Simulated in the NASA GEOS-5 Earth System Model

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Objective

Understand the perturbations to stratospheric dynamics and chemistry caused by the 1991 Mt. Pinatubo and Cerro Hudson volcanic eruptions

Evaluate GEOS-5 performance in simulating the stratospheric aerosol perturbation, and its radiative and chemical impacts

Goal is to have a model that supports a range of relevant chemistry-climate modeling applications (e.g., volcanic perturbations, geoengineering), as well as the interpretation of new stratospheric aerosol observations (e.g., OMPS-LP)

GEOS-5

GEOS-5 is the Goddard Earth Observing System model

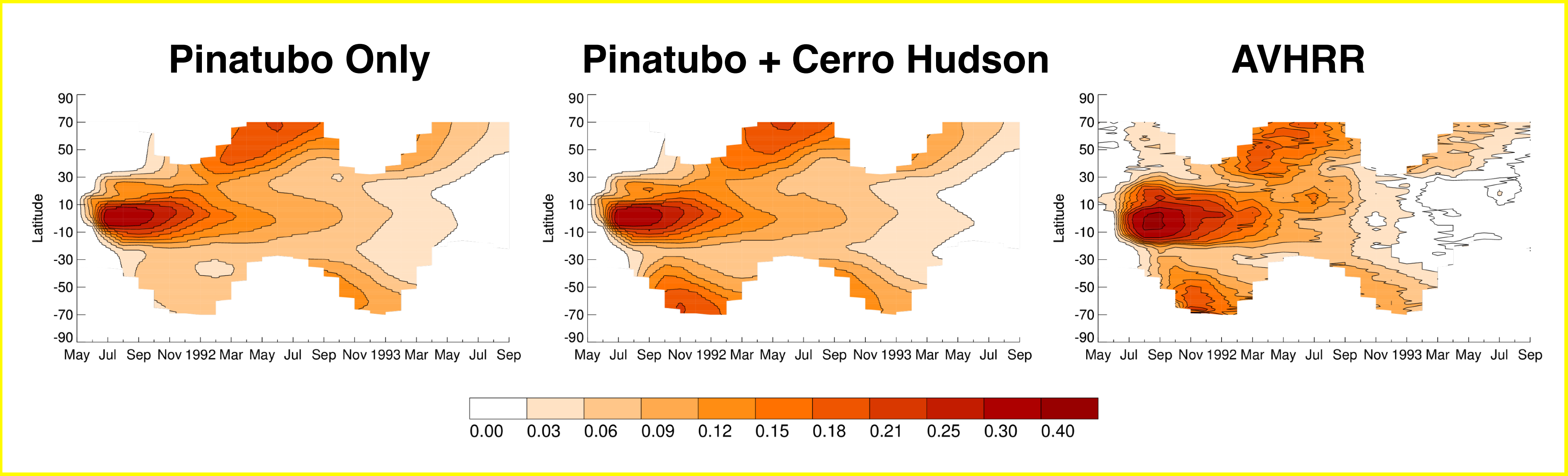
GEOSCCM version of GEOS-5 includes aerosol and chemistry mechanisms

- Applications to ozone and stratospheric transport assessments, chemistry-climate interactions studies

We have recently extended GEOSCCM to account for the chemical and radiative effects of stratospheric aerosols

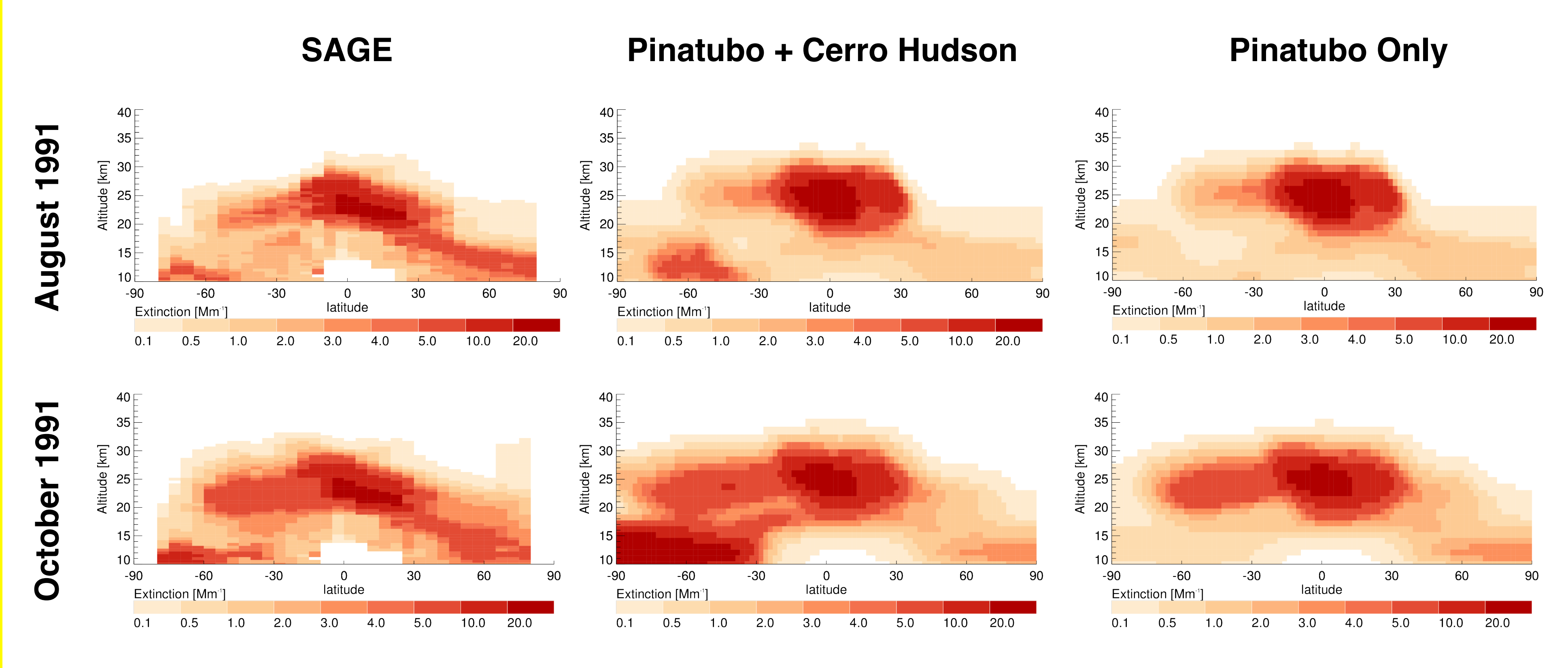
- Added OCS chemistry to produce natural background aerosols
- Two aerosol mechanisms: bulk (GOCART) and sectional (CARMA)
- Aerosols are radiatively coupled and provide input surface area to the stratospheric chemistry mechanism

AOD Time Series



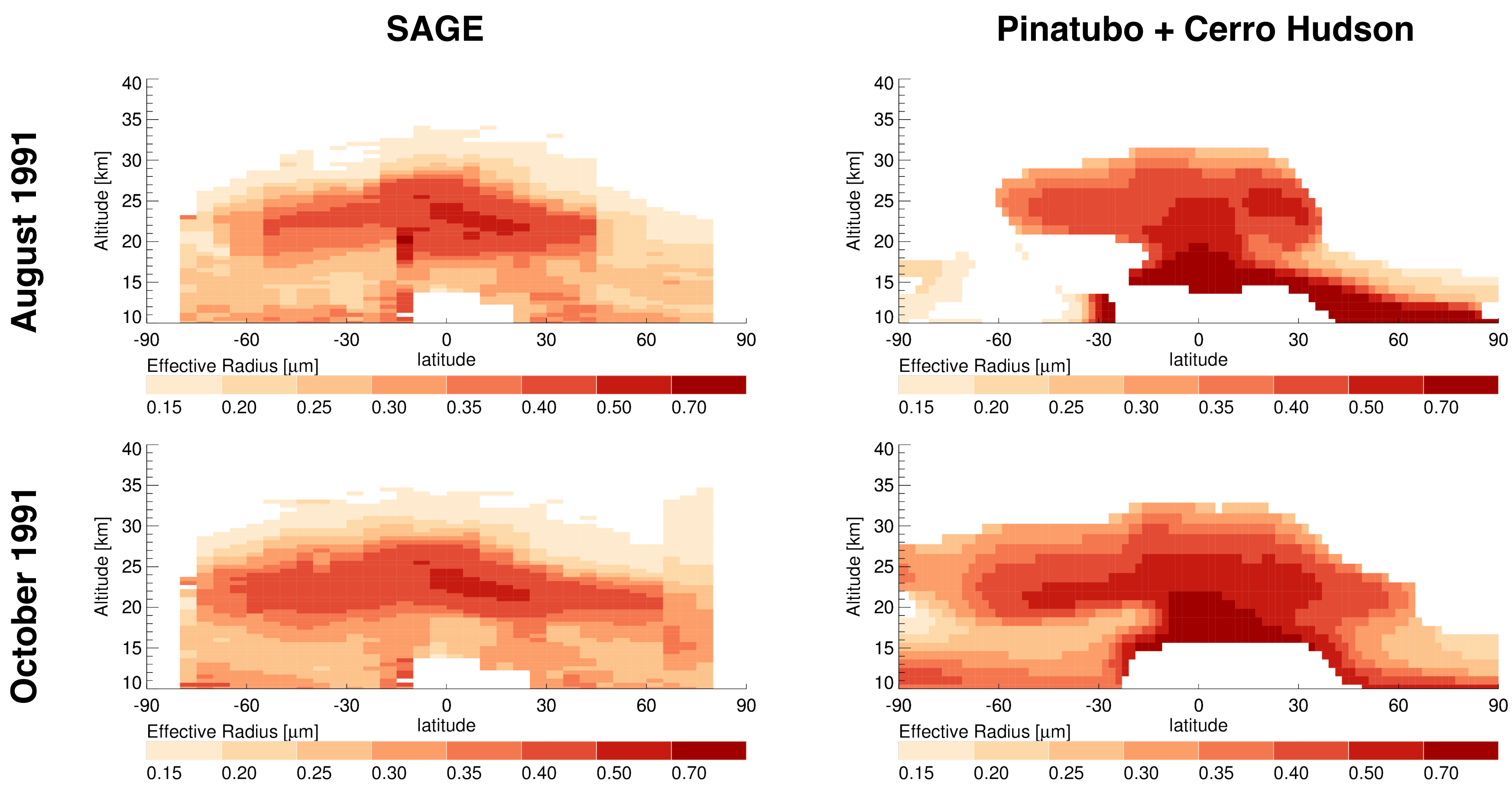
- Simulation details:
  - OCS produced sulfate + volcanic sulfate inputs only: Pinatubo main eruption (June 15) is 15 Tg SO_2 + 4 Tg sulfate at 18 - 22 km; Cerro Hudson (August 15) is 2.7 Tg SO_2 at 12.5 - 18 km
  - 72 vertical hybrid-sigma levels from surface to ~80 km
  - c48 horizontal resolution (cubed sphere, ~2° x 2.5°), 1991 - 1993
- AVHRR zonal mean time series with prior year AOD subtracted (i.e., attempt to construct stratospheric only AOD)
- Simulation results are shown for CARMA based model runs

Zonal Mean Extinction Profile



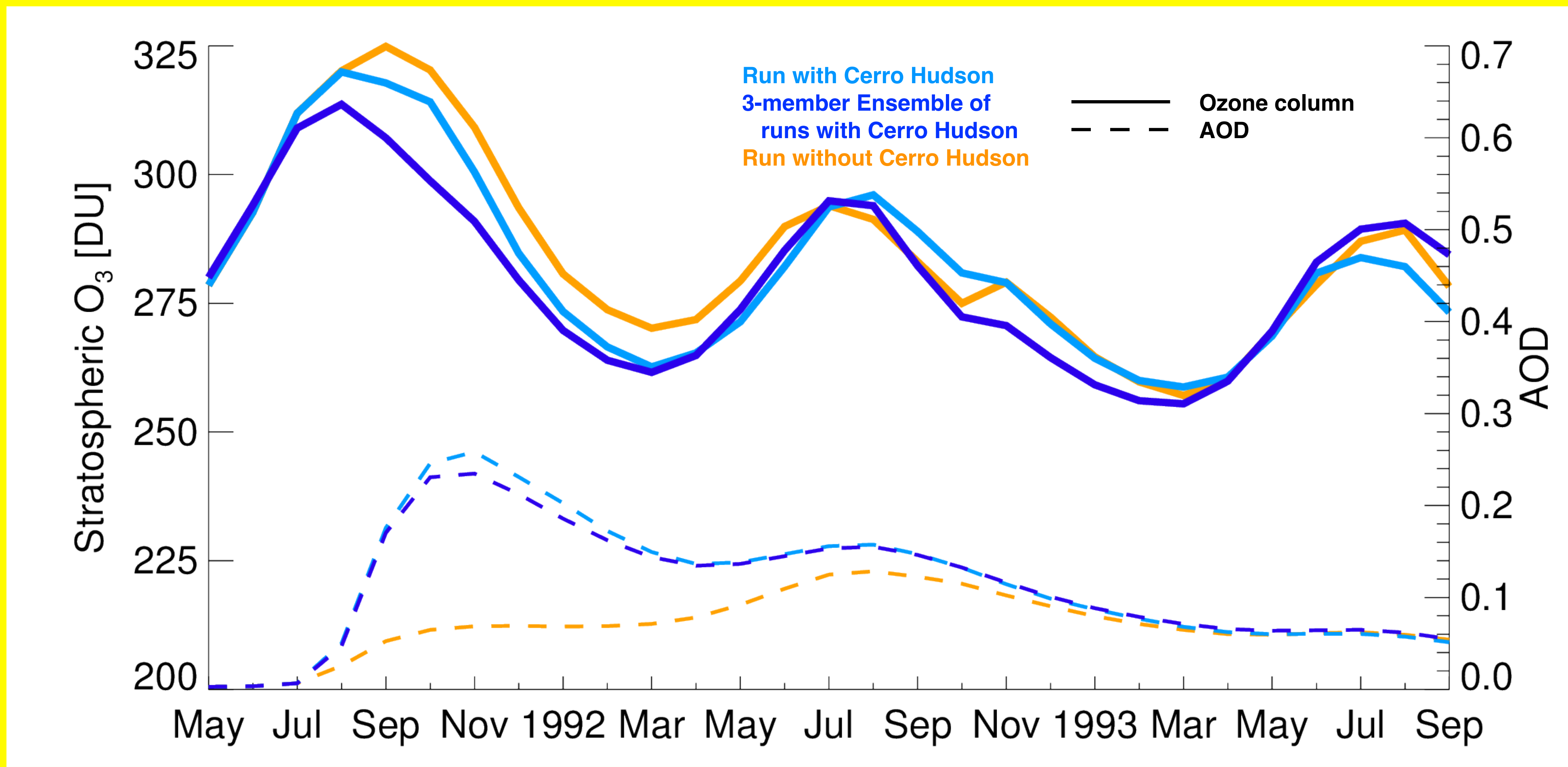
- Model picks up southward transport of Pinatubo plume, but not the northward transport
- Simulation including Cerro Hudson has 10 - 15 km altitude low latitude aerosol extinction as in the observations, not present in simulations without

Effective Radius



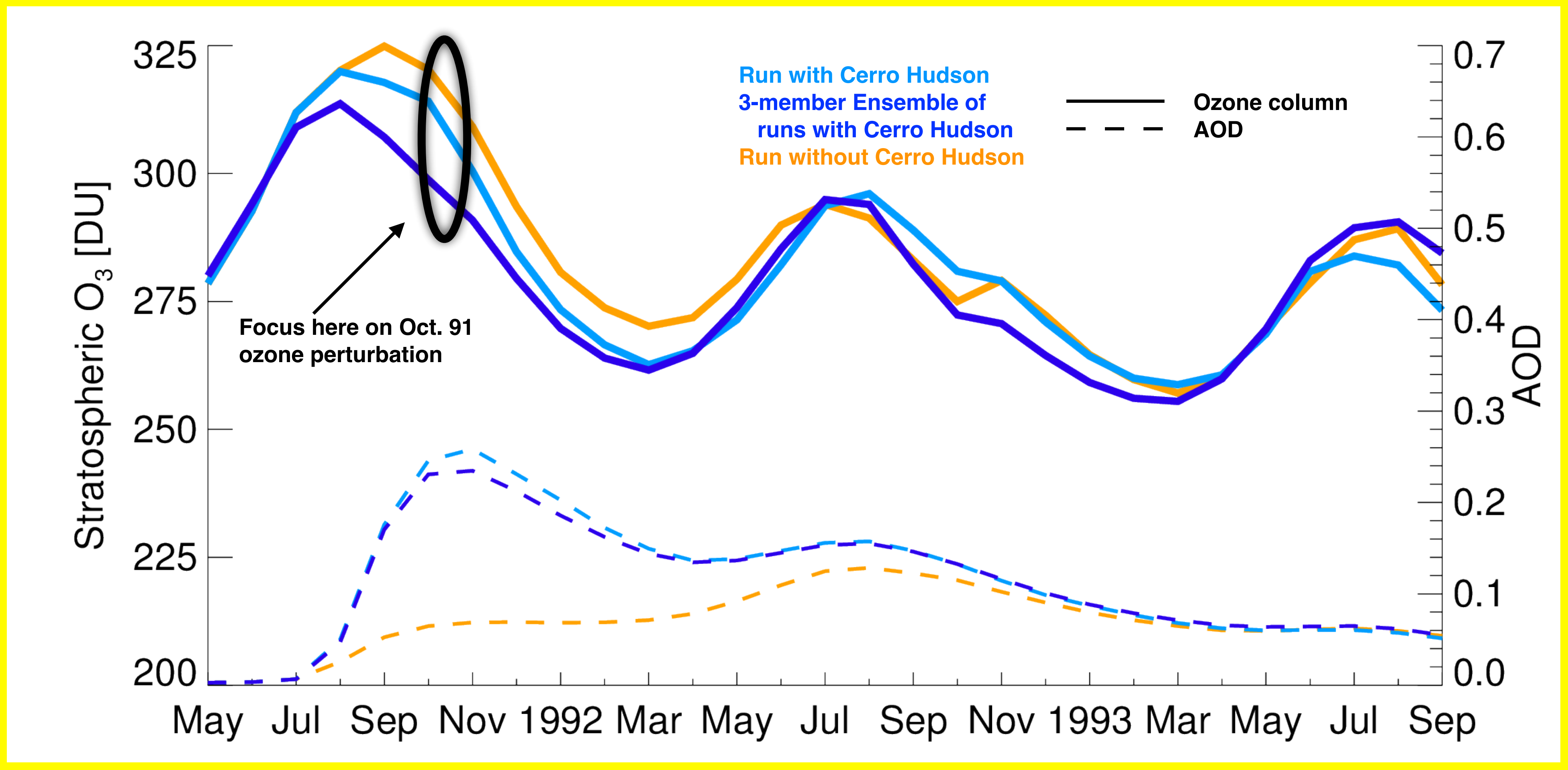
- Screened on zonal mean extinction coefficient > 1 Mm^{-1}

Ozone Impacts of Cerro Hudson



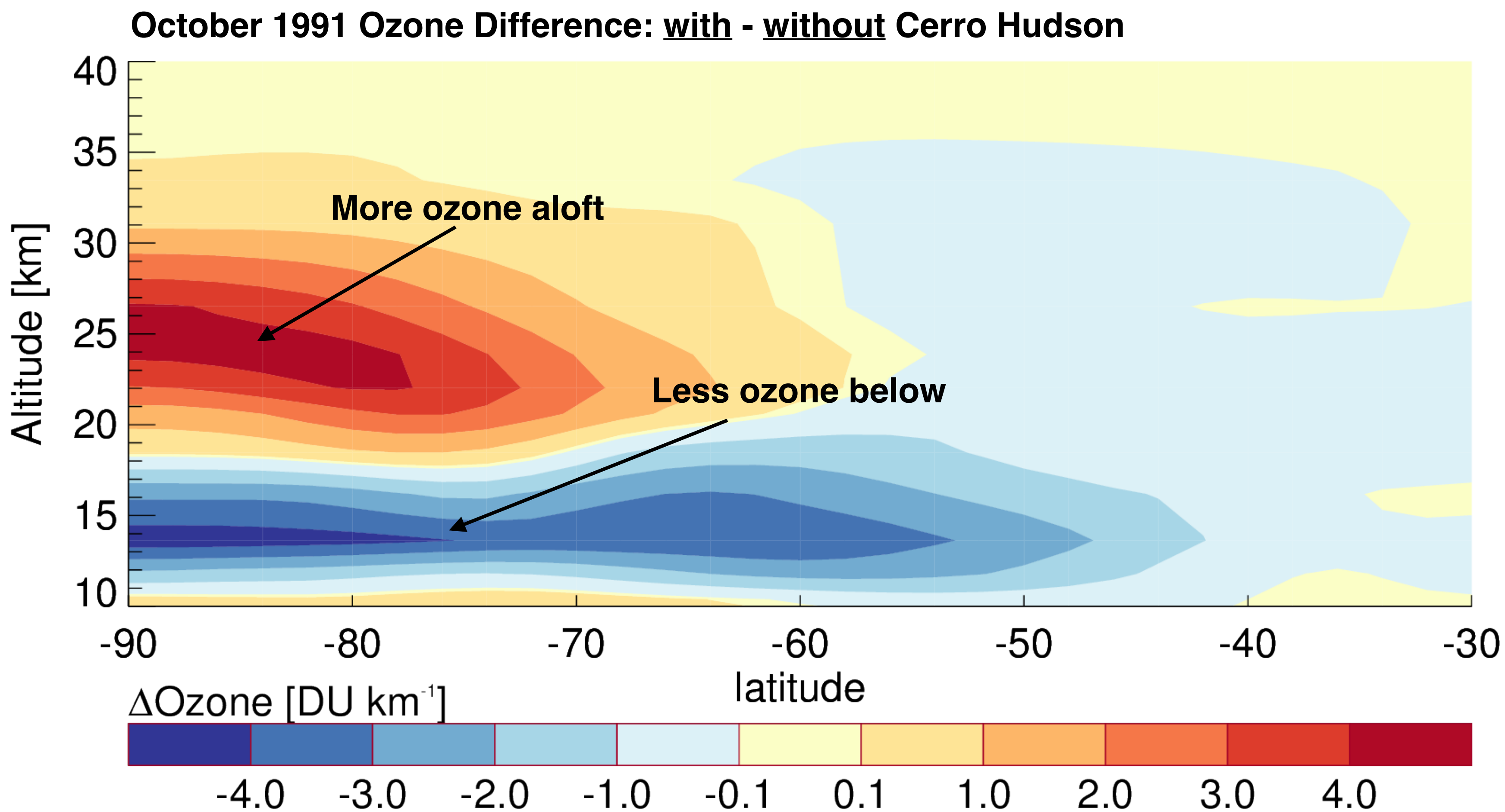
- Stratospheric column O_3 averaged poleward of 30° S

Ozone Impacts of Cerro Hudson

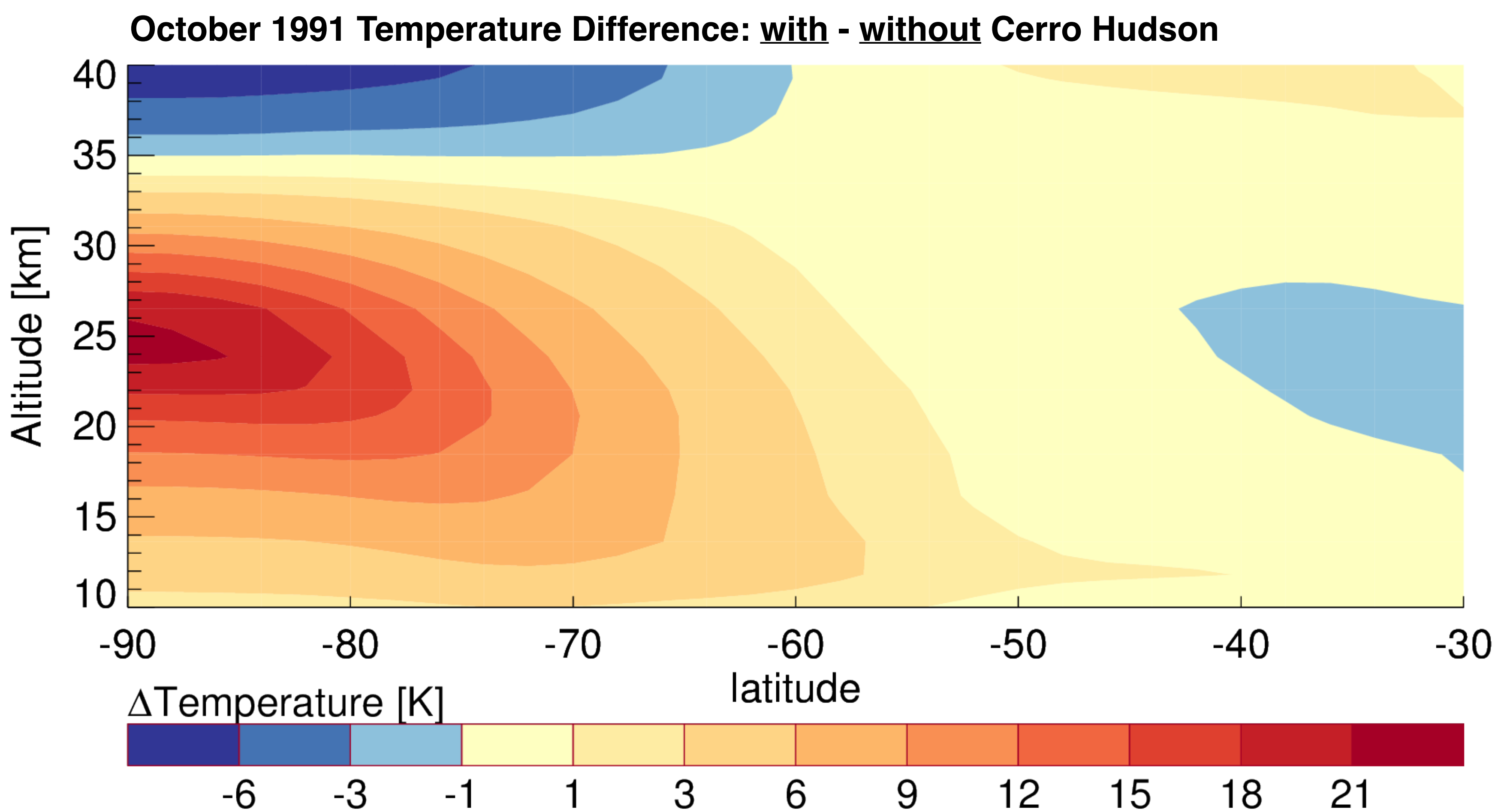


- Stratospheric column O_3 averaged poleward of 30° S

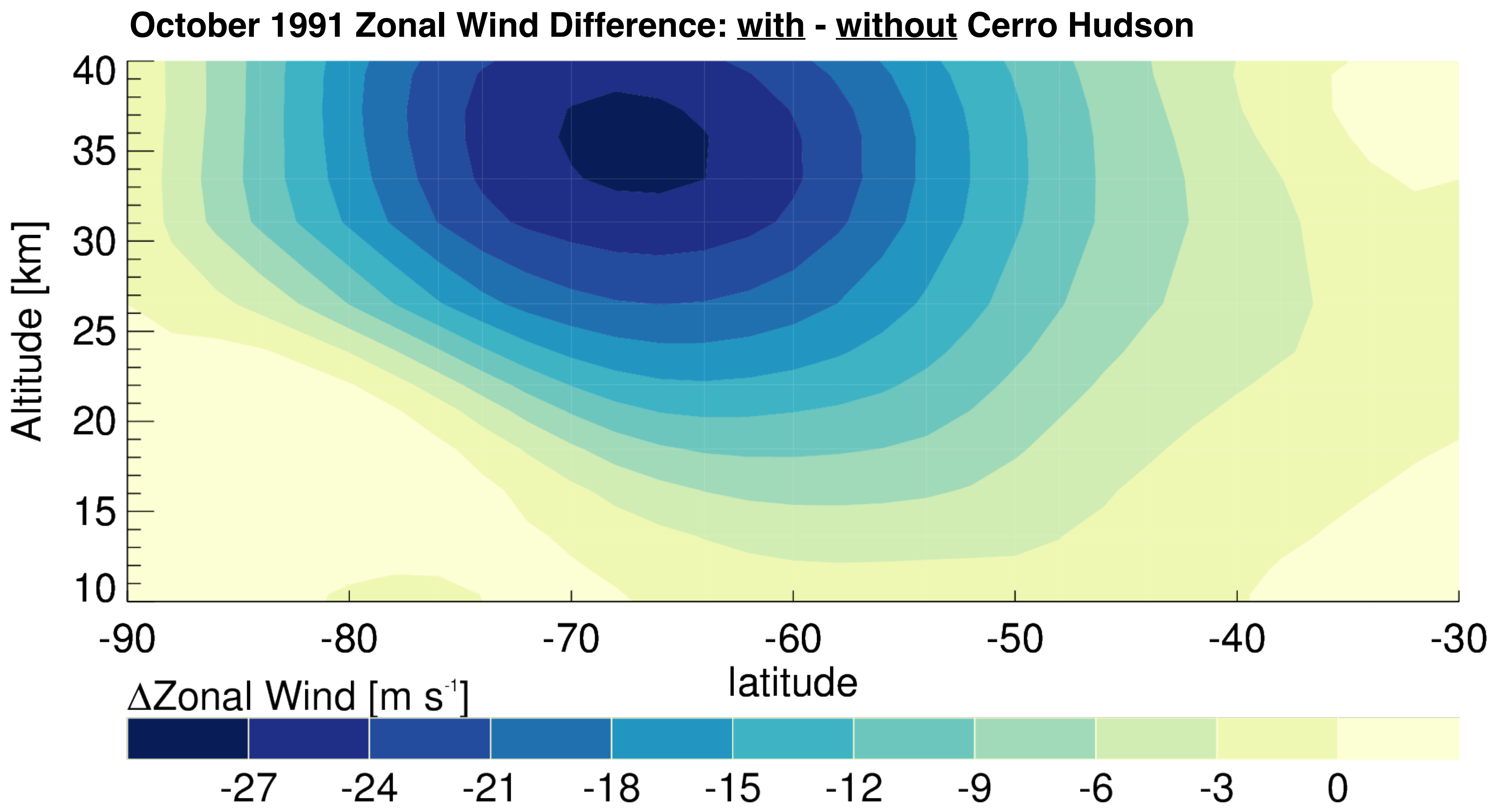
Zonal Mean Ozone Difference



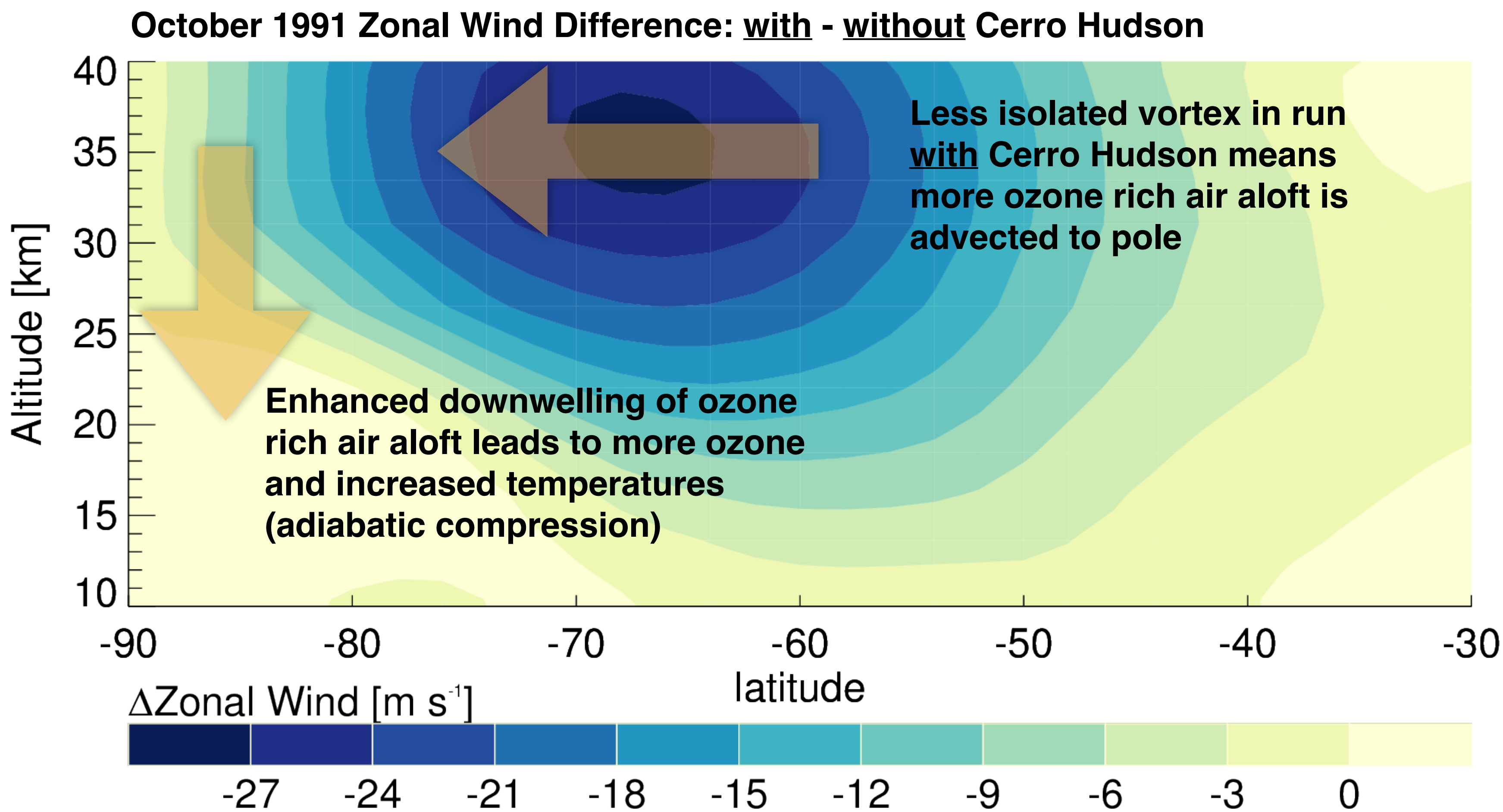
Zonal Mean Temperature Difference



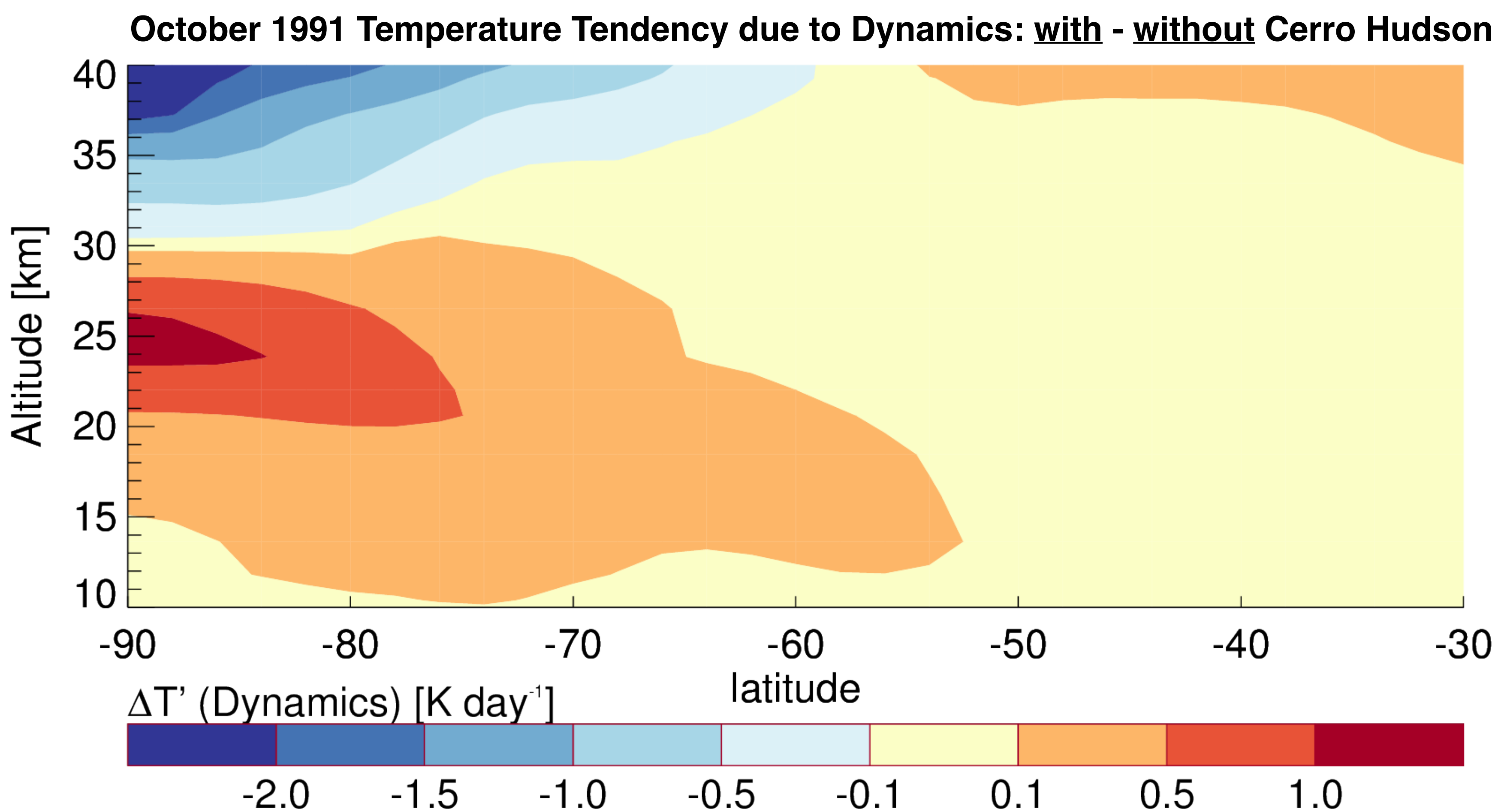
Zonal Mean Wind Difference



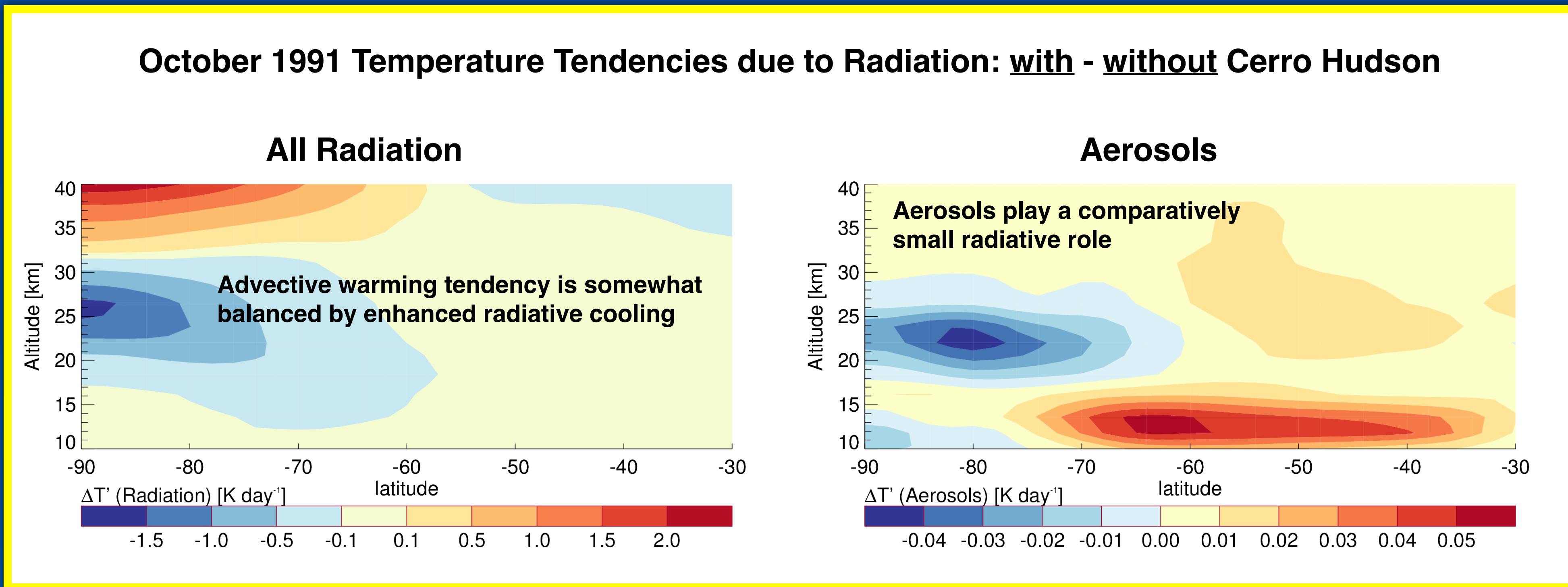
Zonal Mean Wind Difference



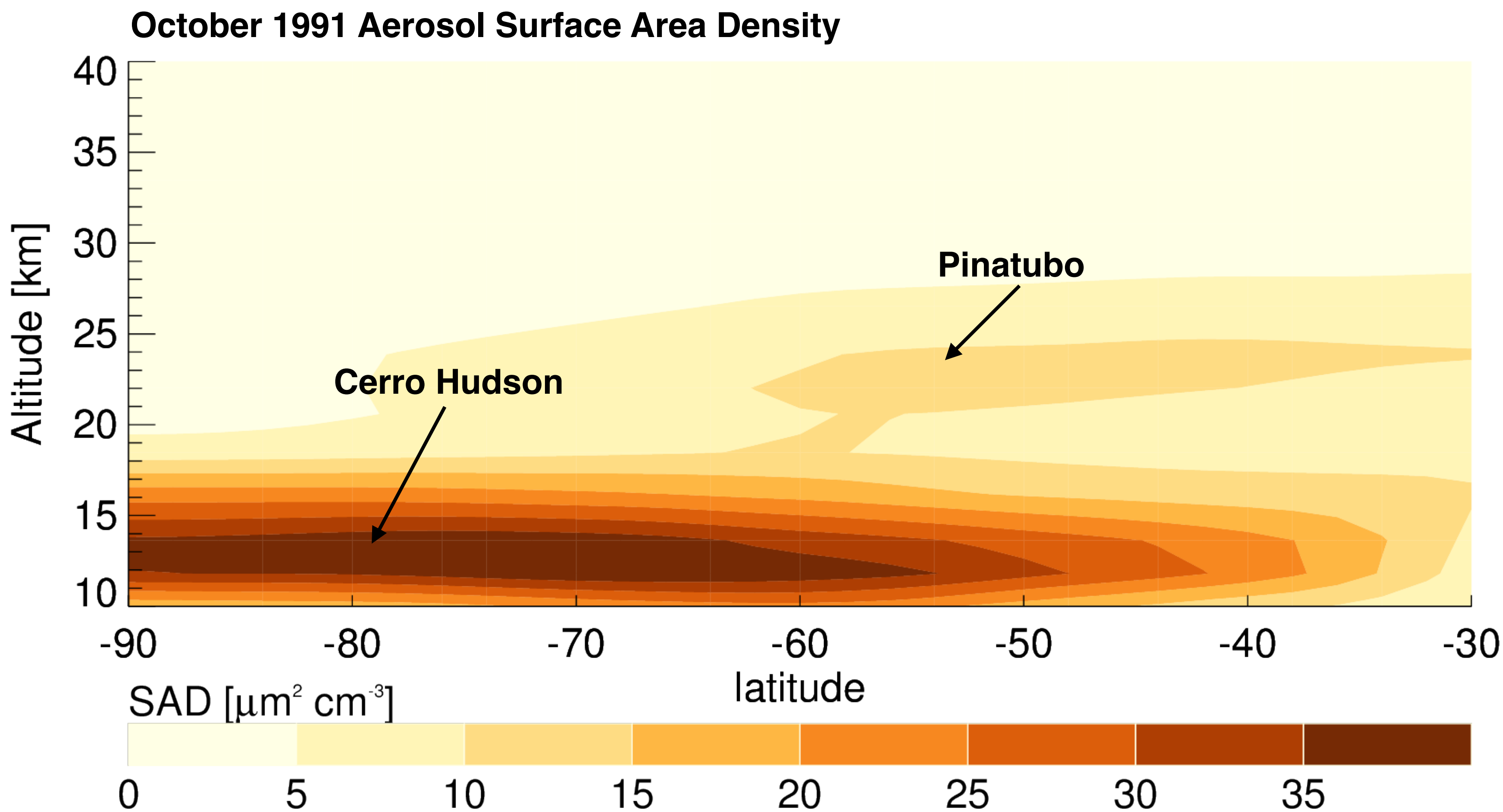
Dynamical Temperature Tendency



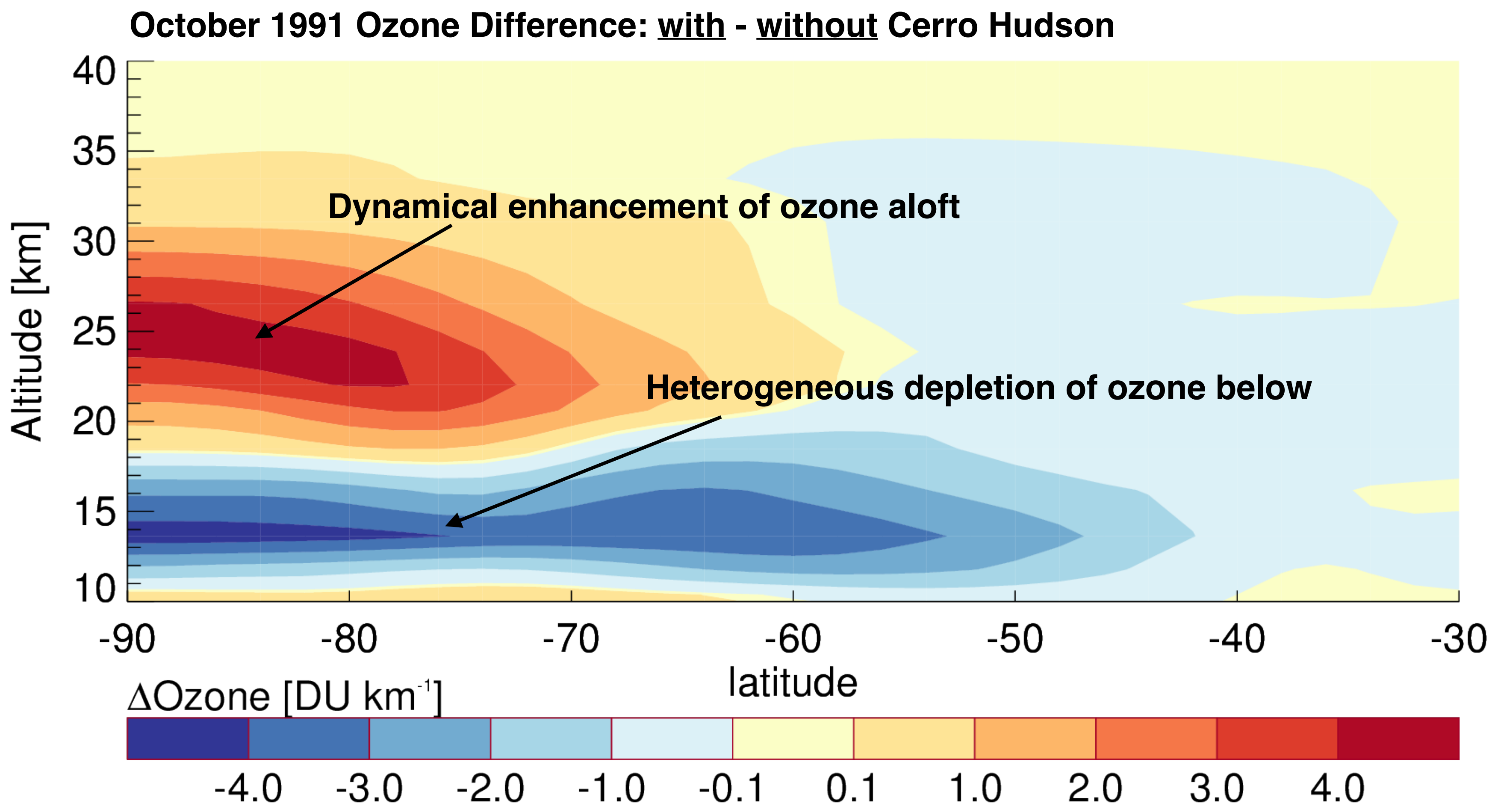
Radiation Temperature Tendency



Role for Aerosols



Zonal Mean Ozone Difference



Conclusions

- GEOS-5 simulation results show reasonable performance in simulating Mt. Pinatubo and Cerro Hudson volcanic aerosols
- We find less ozone in austral spring (October) 1991 in the simulations that include Cerro Hudson
- Simulations suggest significant depletion of ozone at 13 km due to heterogeneous chemistry occurring on Cerro Hudson aerosols, somewhat compensated by dynamical enhancement of ozone at 25 km
- We need to perform more simulations to assess the significance of our results