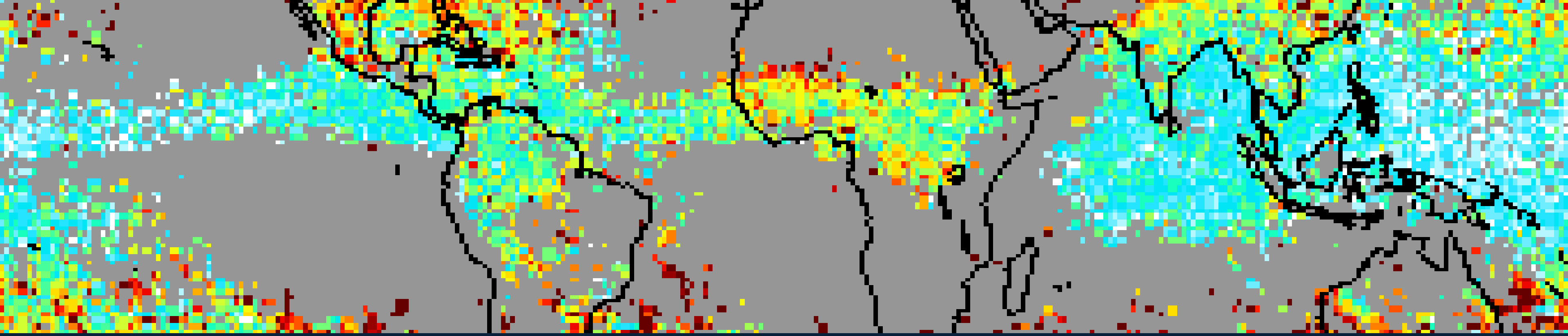

Analysis of Ozone in Cloudy Versus Clear Sky Conditions

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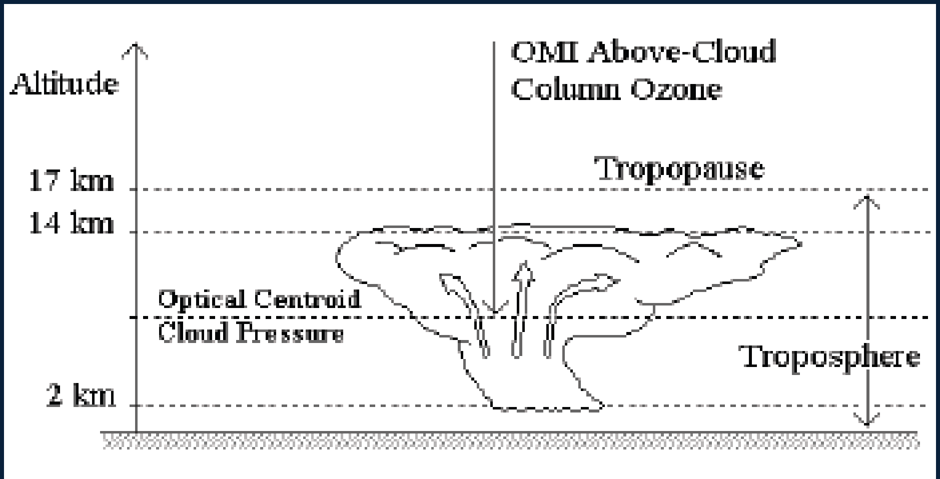
GESTAR

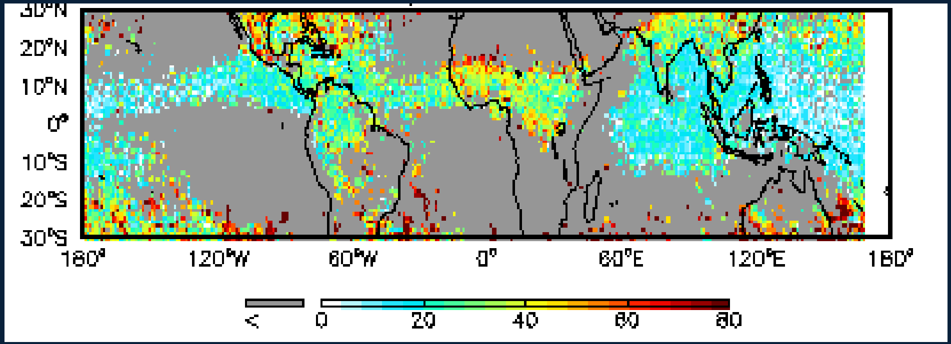
Introduction

- Convection
  - lifts low ozone air from the marine boundary layer to the mid & upper troposphere
  - Contributes to S-shaped ozonesonde profiles in the tropics
  - lifts NO_x & hydrocarbons from the polluted boundary layer → O_3 production
  - Associated with lightning NO_x emissions
- How important is O_3 production versus the O_3 transport due to convection?
- How has the impact of convection on upper tropospheric ozone changed over time?

OMI/MLS in-cloud O_3

- Observations of ozone under cloudy versus clear-sky conditions provide insight on how convection influences ozone
- Ziemke et al. [2009] calculate O_3 inside tropical deep convective clouds by subtracting the MLS stratospheric column from the OMI above-cloud column





Satellite observations give us broad spatial coverage over the tropics to extend our understanding of ozone under clear versus cloudy conditions

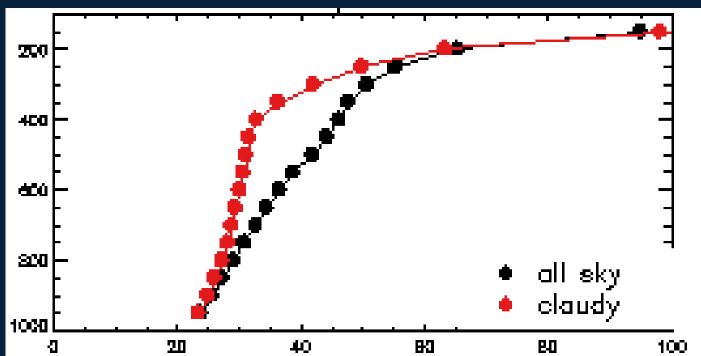
Model Evaluation & Analysis

- Can we evaluate chemistry climate models (CCMs) with the OMI/MLS in-cloud ozone?
- Can we use CCMs to interpret in-cloud ozone?
- Challenges:
  - Clouds in free-running CCM don't align with the obs
  - Model resolution (1 or 2 degree) much larger than a cloud, so gridbox isn't completely cloudy
- Solution:
  - bin model output according to a cloudiness threshold of 40% at 350-400hPa
  - Composite July days over multiple years
- Examples from multi-year GEOS-5 CCM hindcasts, focusing on July

All Sky vs. Cloudy Profiles

Tropical O_3

Pressure (hPa)

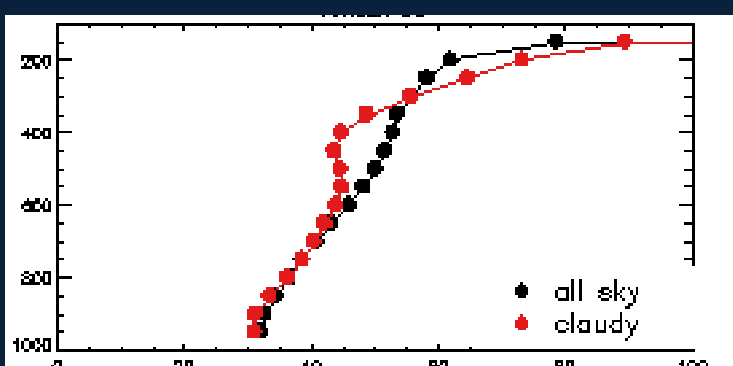


O_3 (ppb)

- Simulated ozone profiles are more vertically uniform under cloudy conditions, leading to lower concentrations in the mid-troposphere
- Use 400 hPa level to compare with obs since this is where separation is large
- Over polluted regions, CO profile shows lofting of pollution in cloudy conditions

African O_3

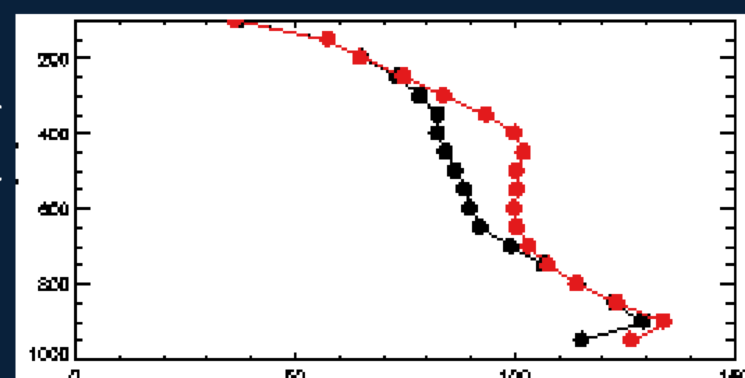
Pressure (hPa)



O_3 (ppb)

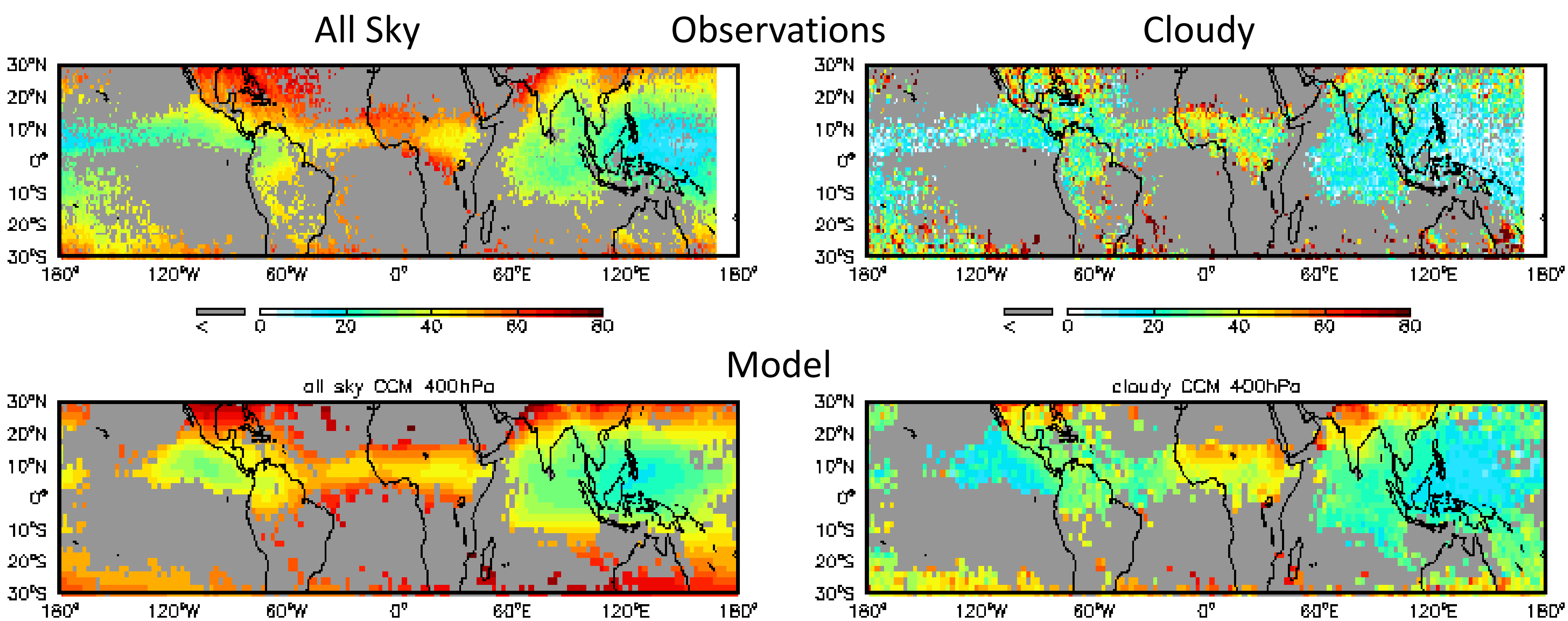
African CO

Pressure (hPa)



CO (ppb)

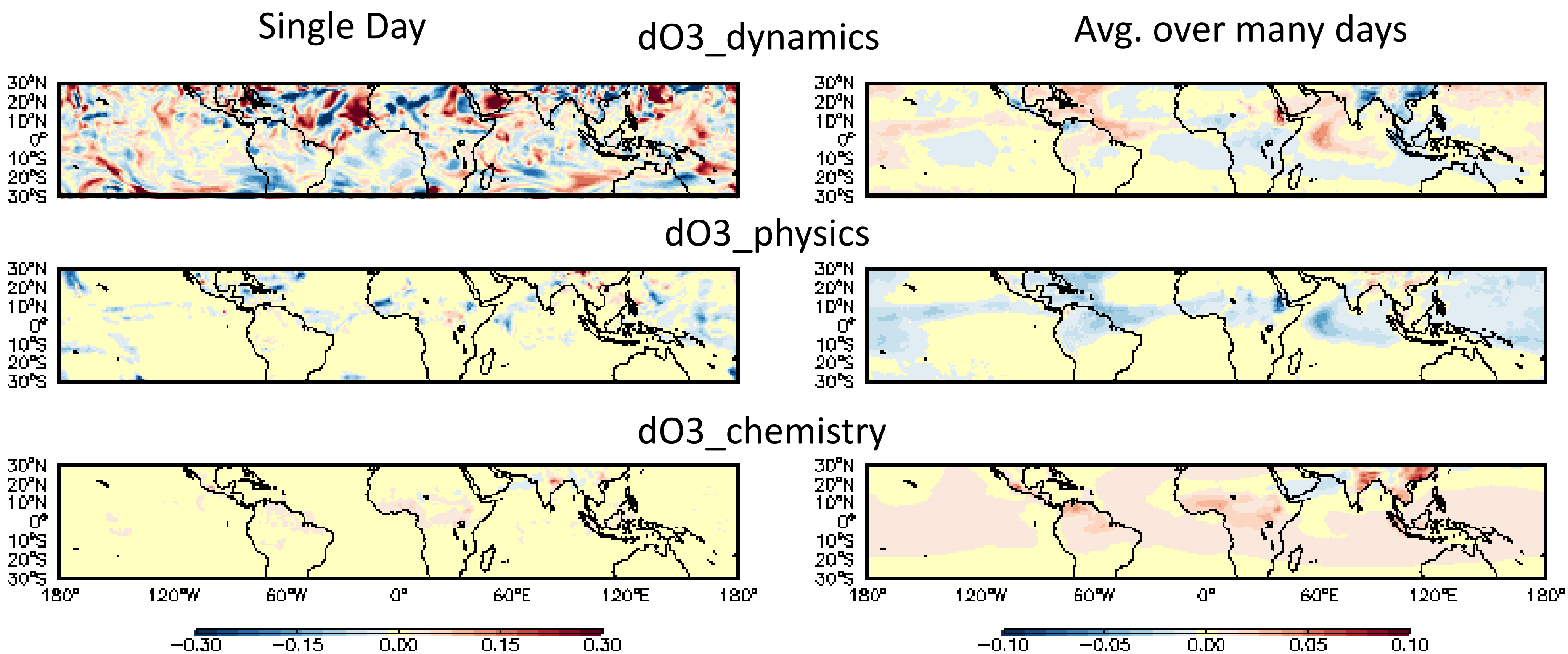
All Sky vs. Cloudy O_3 Maps



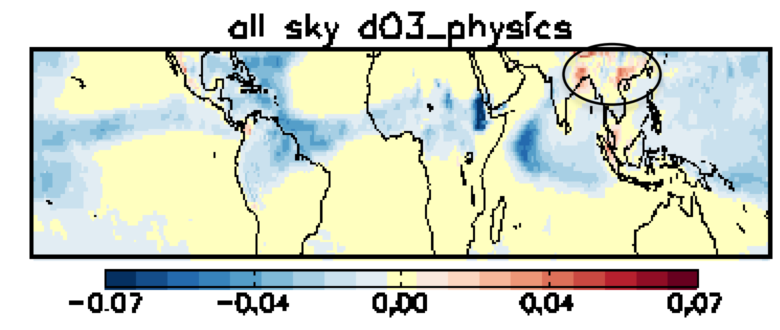
- Cloudy O_3 lower than All Sky O_3 throughout tropics in both observations and model
- East-West gradients in ozone well-simulated

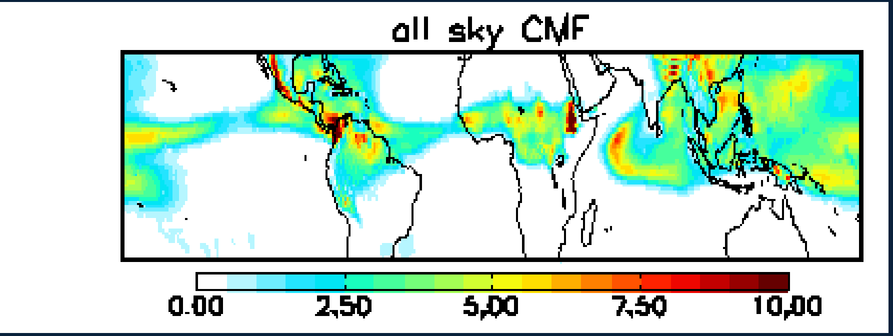
Dynamics, Convection, & Chemistry

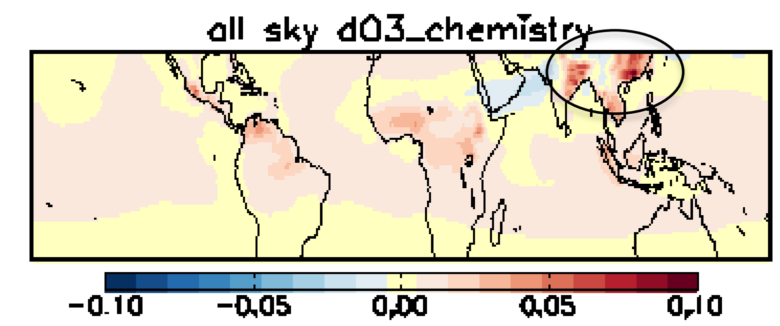
- Model diagnoses O_3 tendency due to large-scale dynamics, physics (convection), & chemistry at 400 hPa:
  - Daily mean: dynamics dominates
  - Multi-July average: competition between terms

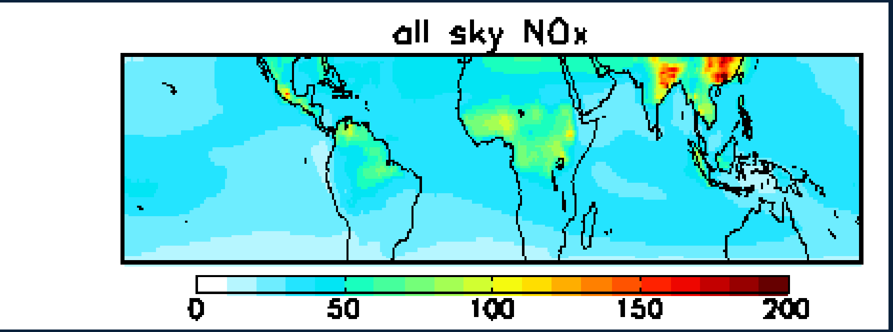


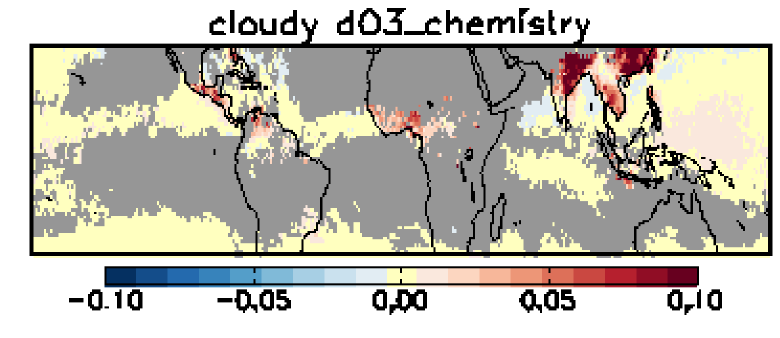
Distribution of Tendencies

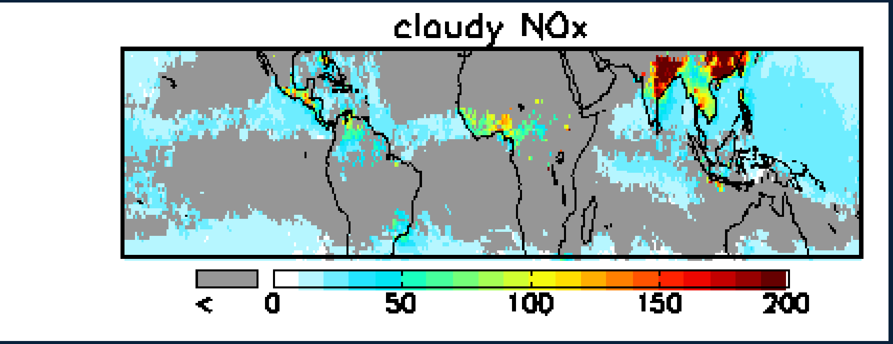






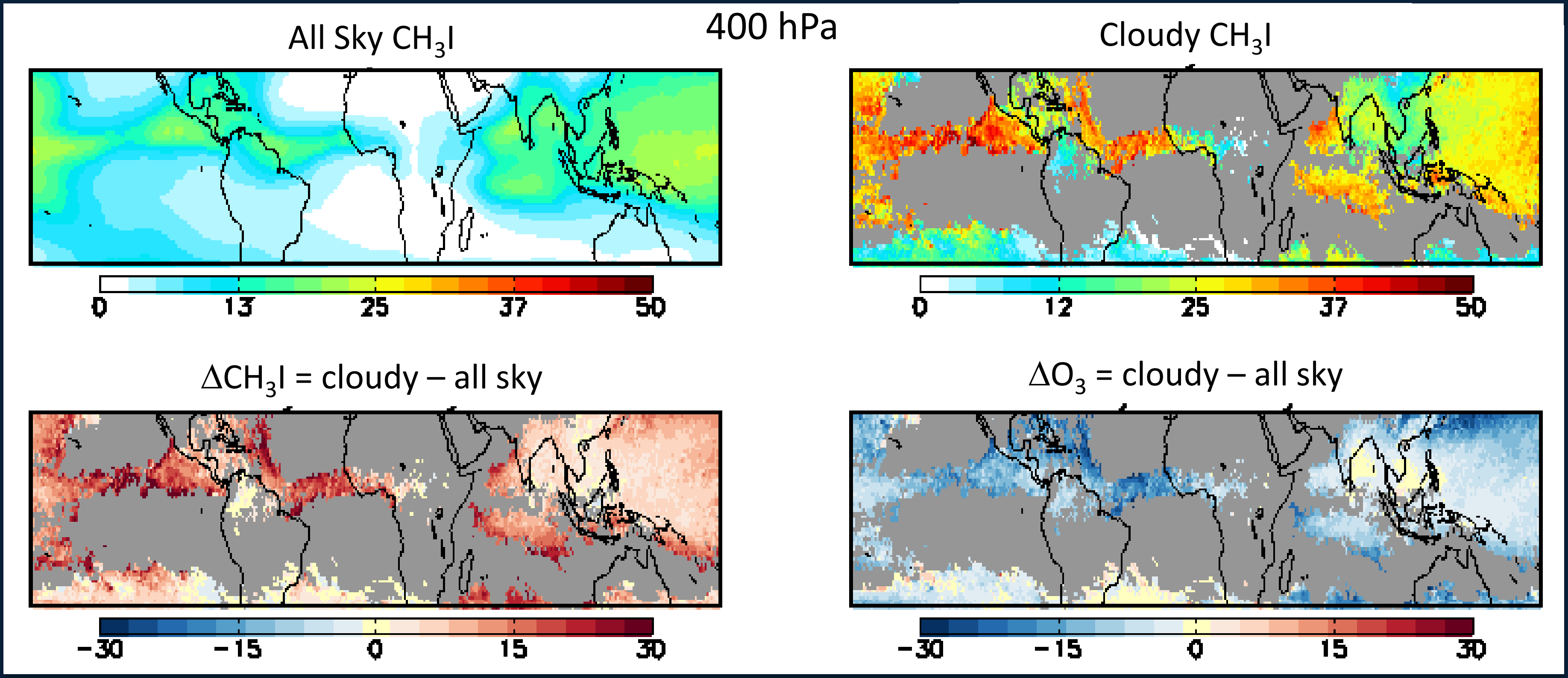




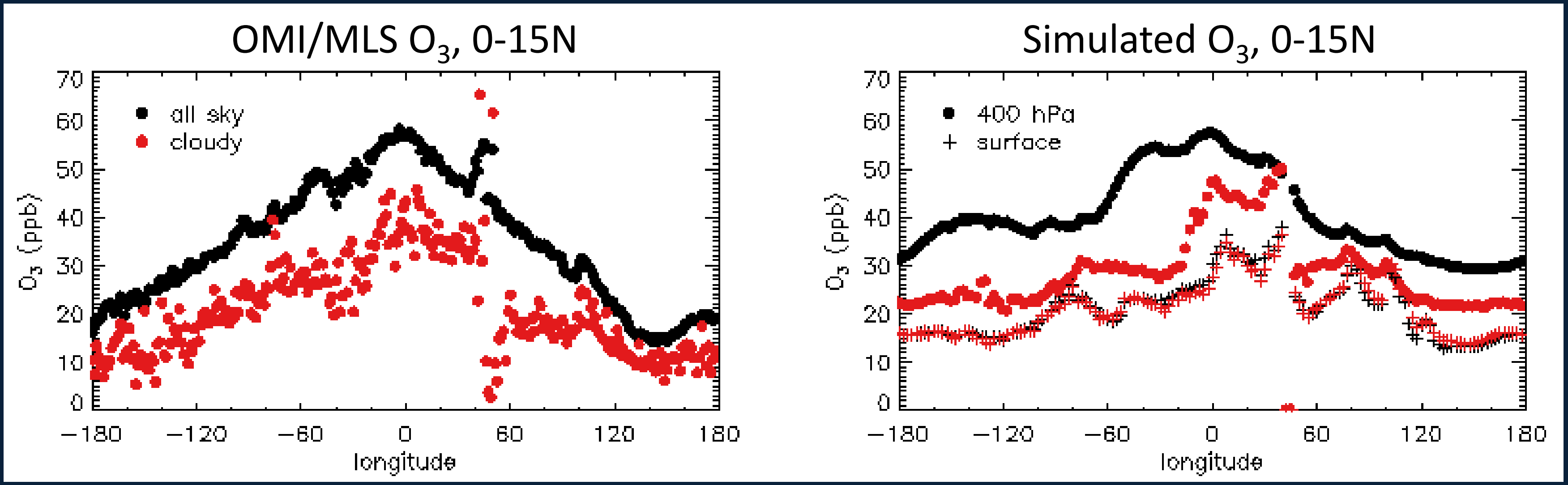


Net Effect of Marine Convection

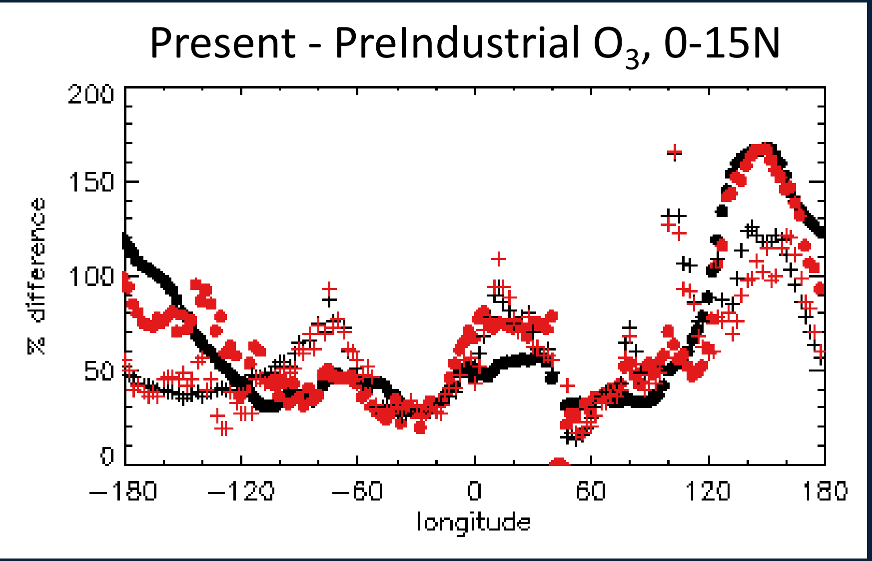
- Convection is localized and maps of convective mass flux are noisy
- CH_3I is a tracer of marine convection, gives smoother picture
- Cloudy vs. all-sky differences in simulated CH_3I anticorrelate (r=-0.7) with O_3 differences



Pre-Industrial to Present Changes



- Simulation captures observed steep jump in cloudy-sky O_3 at the east coast of Africa
- All-sky & cloudy O_3 increased by comparable percentages since 1860s (larger absolute change in all-sky) in most regions
- Larger % increase in cloudy-sky O_3 over Africa where change in lightning NO_x is large



Conclusions & Future Work

- Simulated 400 hPa O_3 for days with cloud fraction > 0.4 comparable to OMI/MLS in-cloud O_3
- Convection leads to lower ozone for "cloudy" days, but chemical production is enhanced for cloudy conditions over polluted regions
- Similar pre-industrial to present % increases in cloudy and all-sky O_3, with some regional differences

Future Work:

- Quantify role of lightning versus surface NO_x emissions
- Calculate pre-industrial to present change in O_3 tendencies due to convection and chemistry