

Surface Ozone and Climate Change

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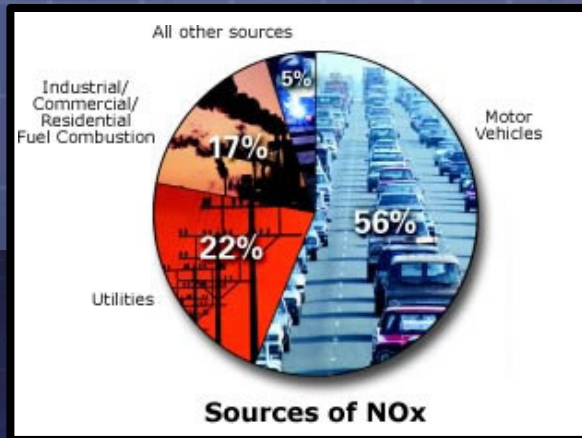
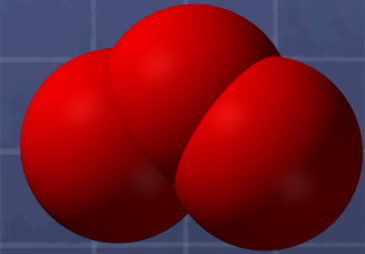
July 31, 2013



CMMAP Summer Internship



What is ozone?



(Source: EPA)



(Source: USDA)

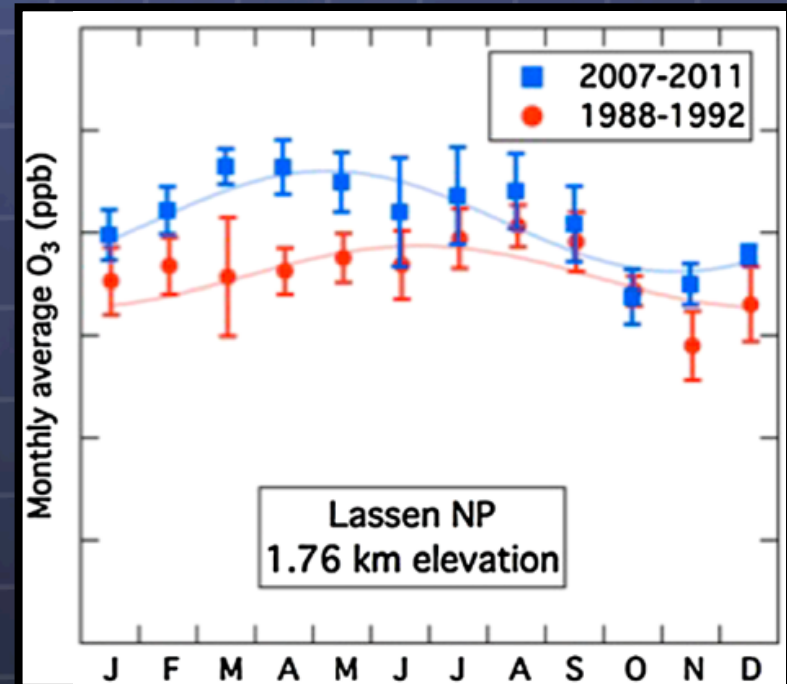
- 🌐 **Bad O₃ = Nitrogen Oxides (NO_x) + sunlight**
- 🌐 **Peak of ozone pollution in summertime.**
- 🌐 **Too much leads to health problems, crop damage.**

Motivation

- 🌍 How will surface ozone respond to climate change in the future?
- 🌍 Are emission changes or meteorology changes the biggest factors?

Motivation

- 🌐 Research done by Parrish et. al using site data.
- 🌐 Seasonal cycle of ozone shifts.

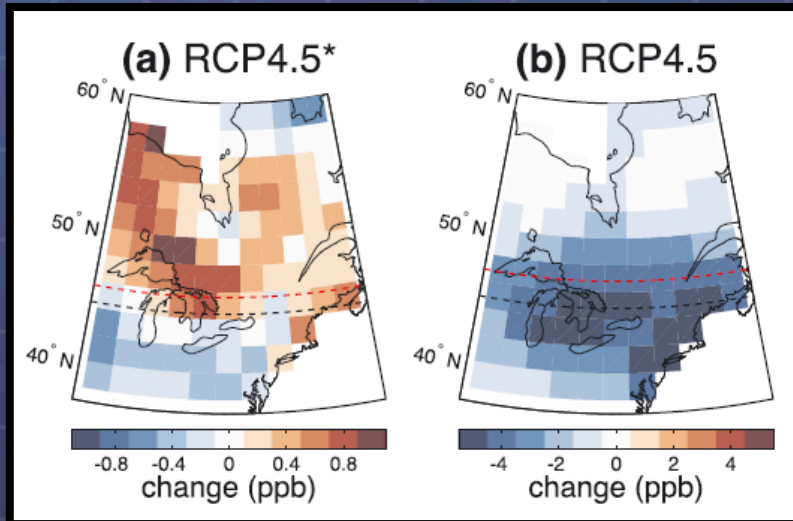


(Source: Parrish et. al, 2013)

Will there be a shift in the future?

What is causing the shift?

Motivation



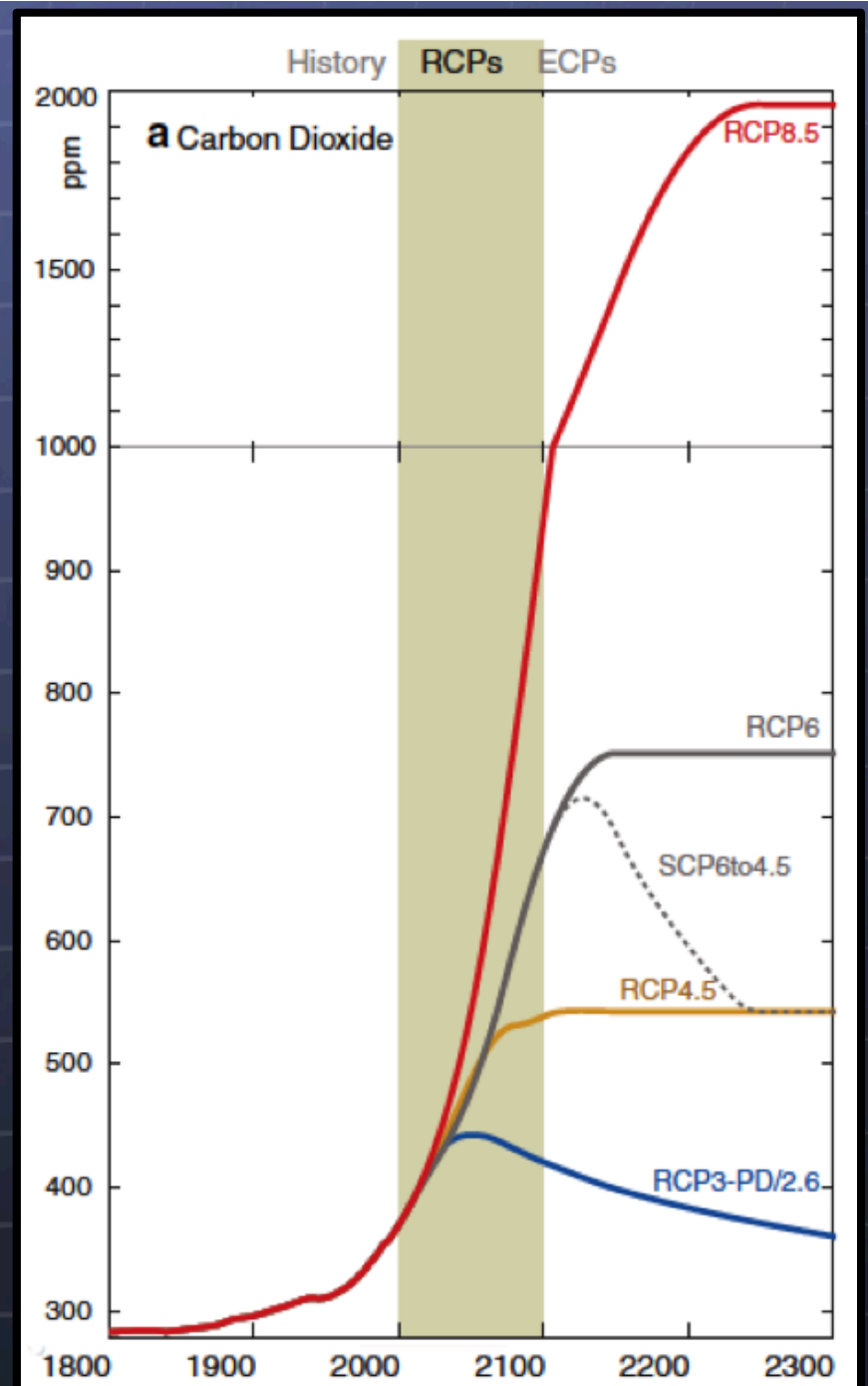
(Source: Barnes & Fiore, 2013)

- 🌍 Research done by Barnes & Fiore
- 🌍 Pole-ward shift of jet stream
- 🌍 Ozone variability correlated to location of midlatitude storms

What is driving the variability and amount of ozone in other regions?

Background

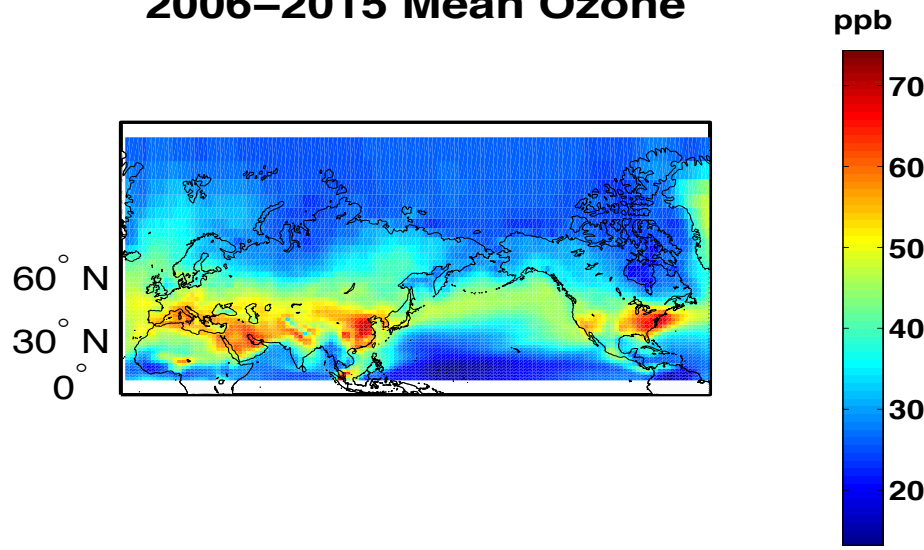
- Model used: GFDL Coupled Chemistry Climate Model (CM3) from IPCC's Coupled Model Intercomparison Project (CMIP5).
- RCP: Representative Concentration Pathway
- 4.5*: Aerosol and ozone precursor emissions held fixed at 2005 levels.
- Three-member ensembles averaged together.
- Our focus: Surface O₃ and 500mb zonal winds 2006-2100



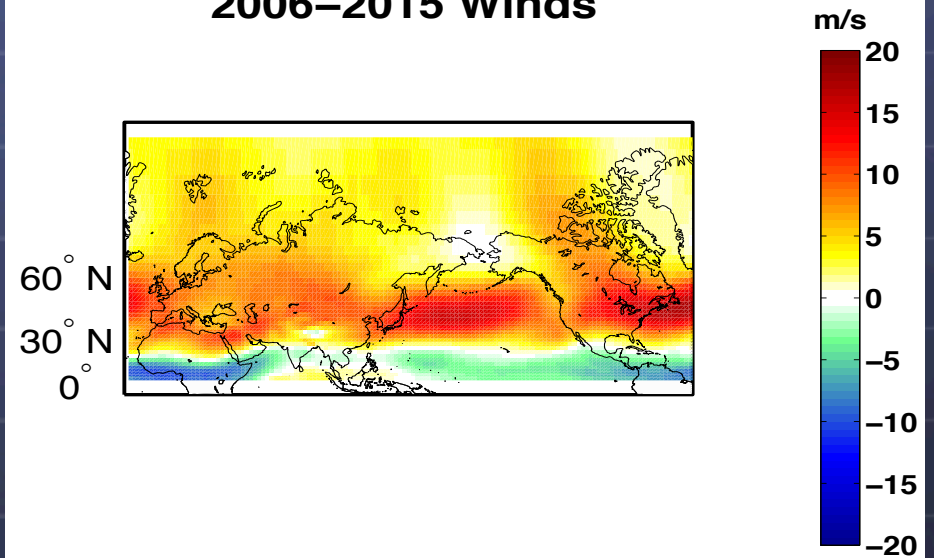
(Source: Meinshausen, Smith et. Al, 2013)

Climate Today

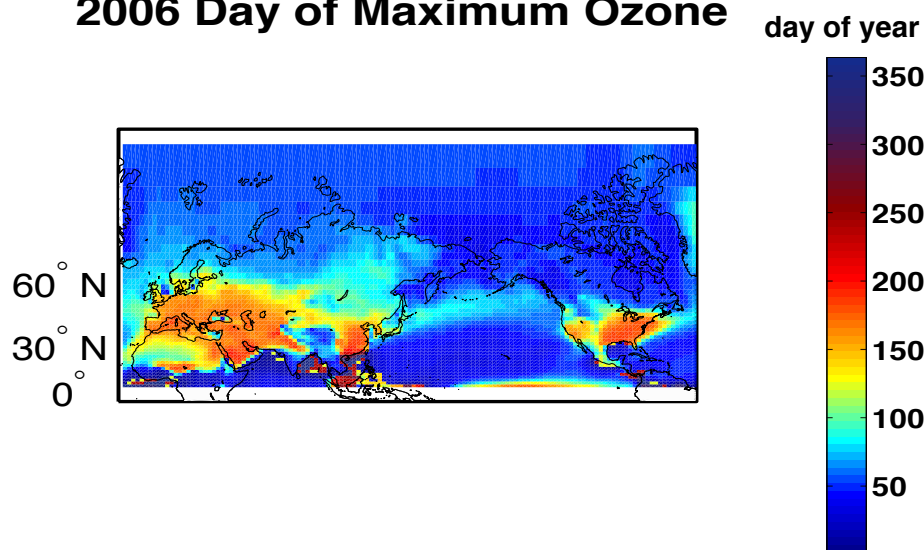
2006–2015 Mean Ozone



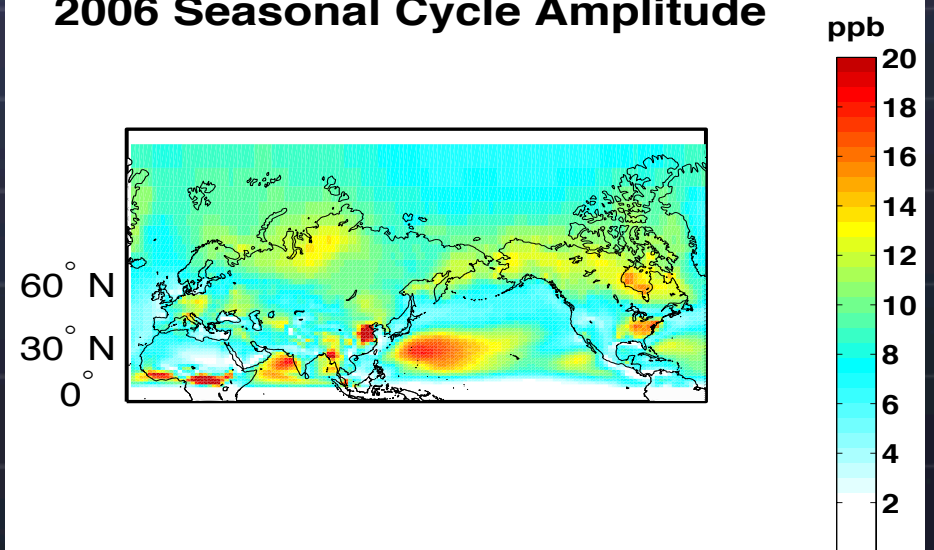
2006–2015 Winds



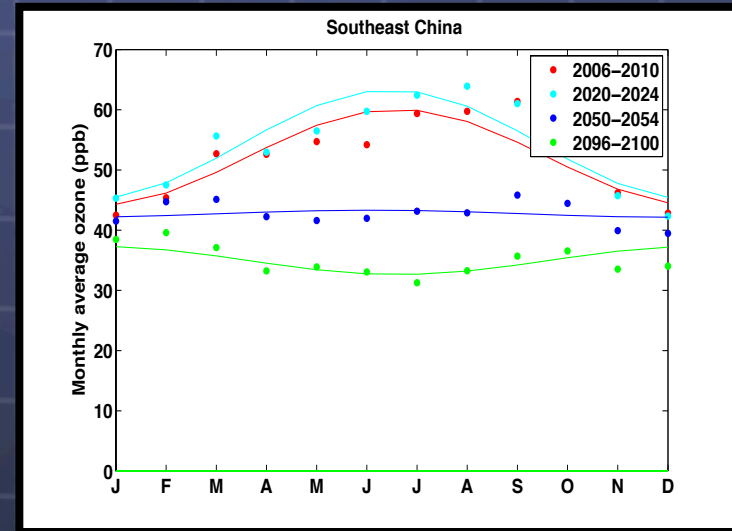
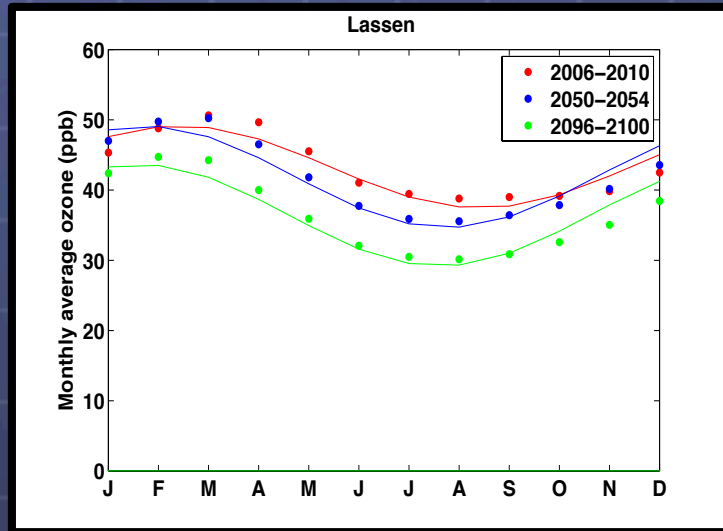
2006 Day of Maximum Ozone



2006 Seasonal Cycle Amplitude



Ozone Seasonality

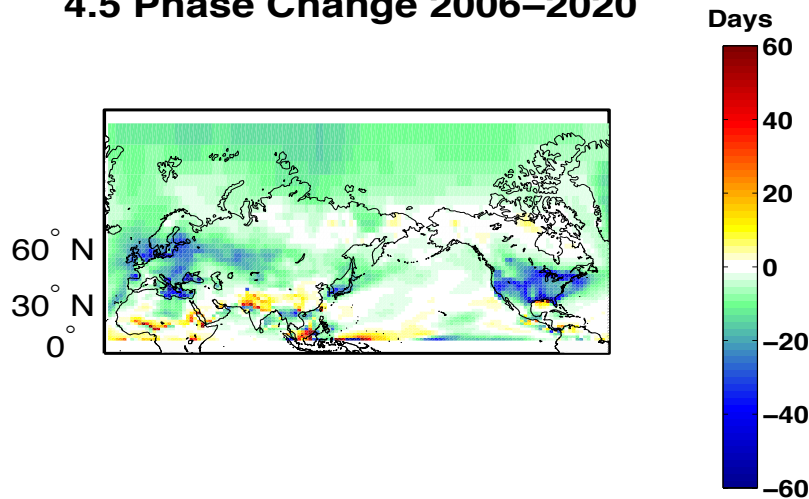


- 🌐 Monthly average values fit to sine wave.
- 🌐 Phase shift seen as well as decreasing Amplitude.

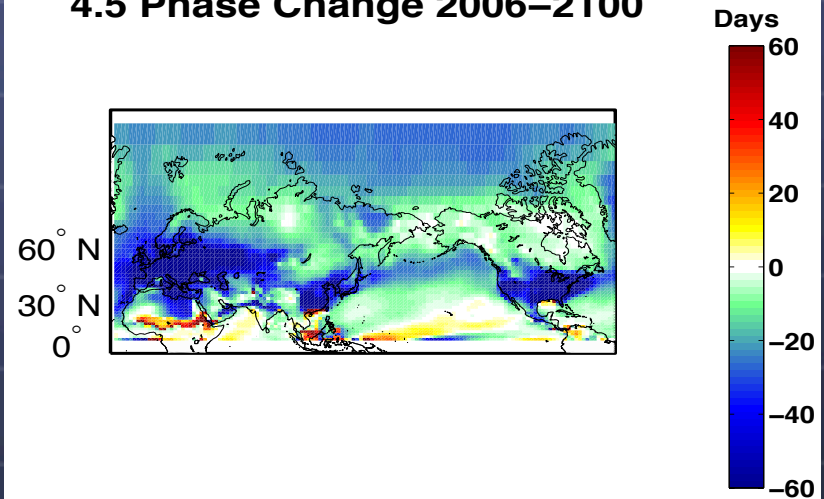
Is this primarily emissions-driven?

Ozone Seasonality: 4.5

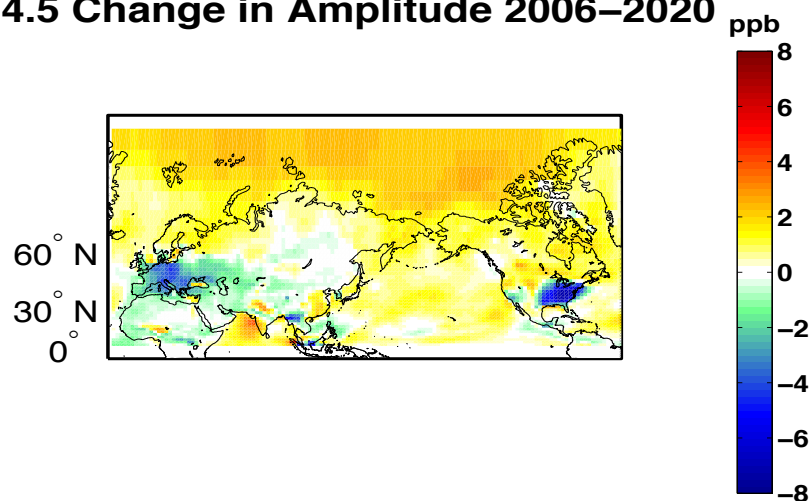
4.5 Phase Change 2006–2020



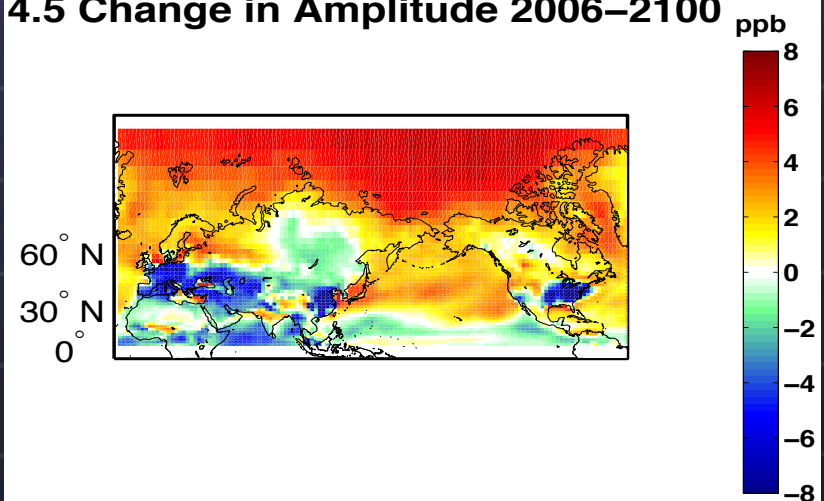
4.5 Phase Change 2006–2100



4.5 Change in Amplitude 2006–2020

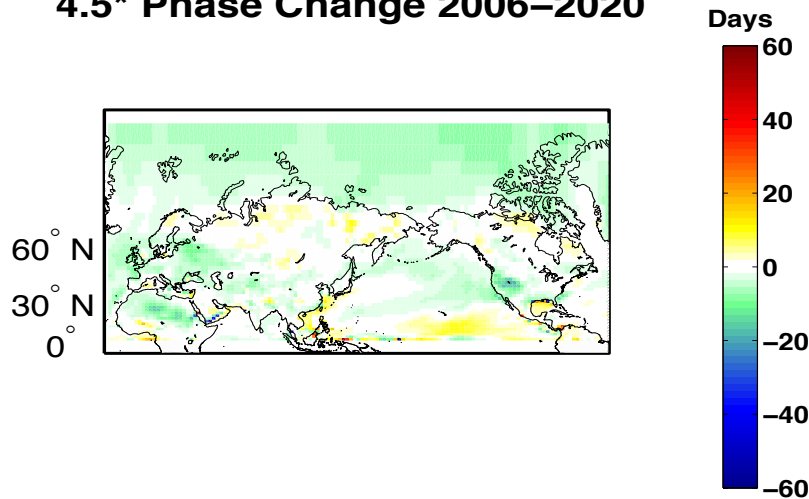


4.5 Change in Amplitude 2006–2100

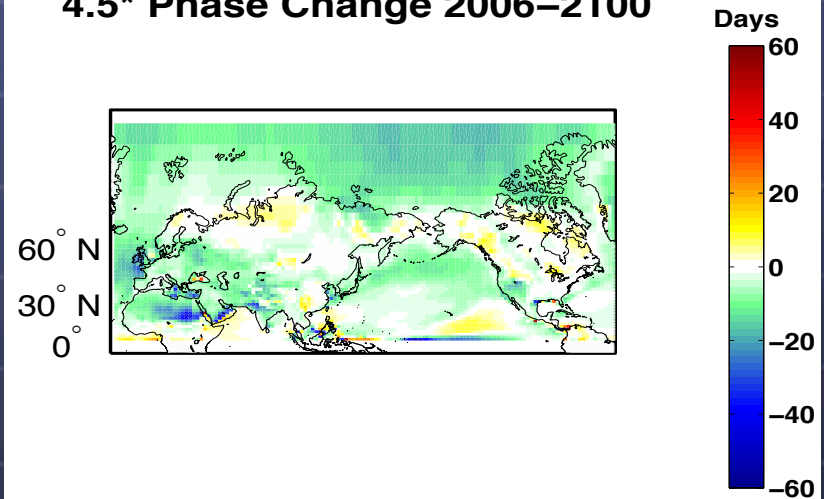


Ozone Seasonality: 4.5*

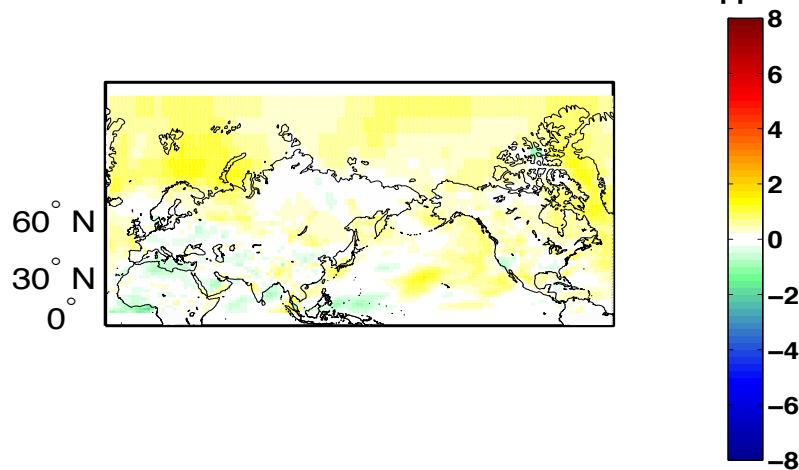
4.5* Phase Change 2006–2020



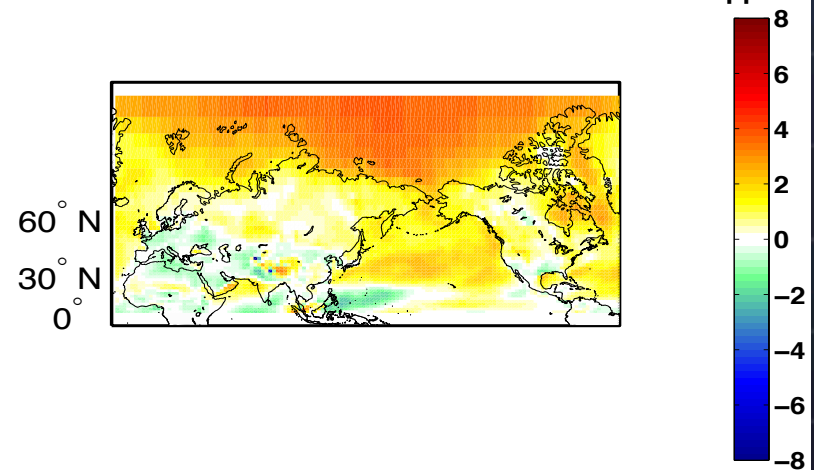
4.5* Phase Change 2006–2100



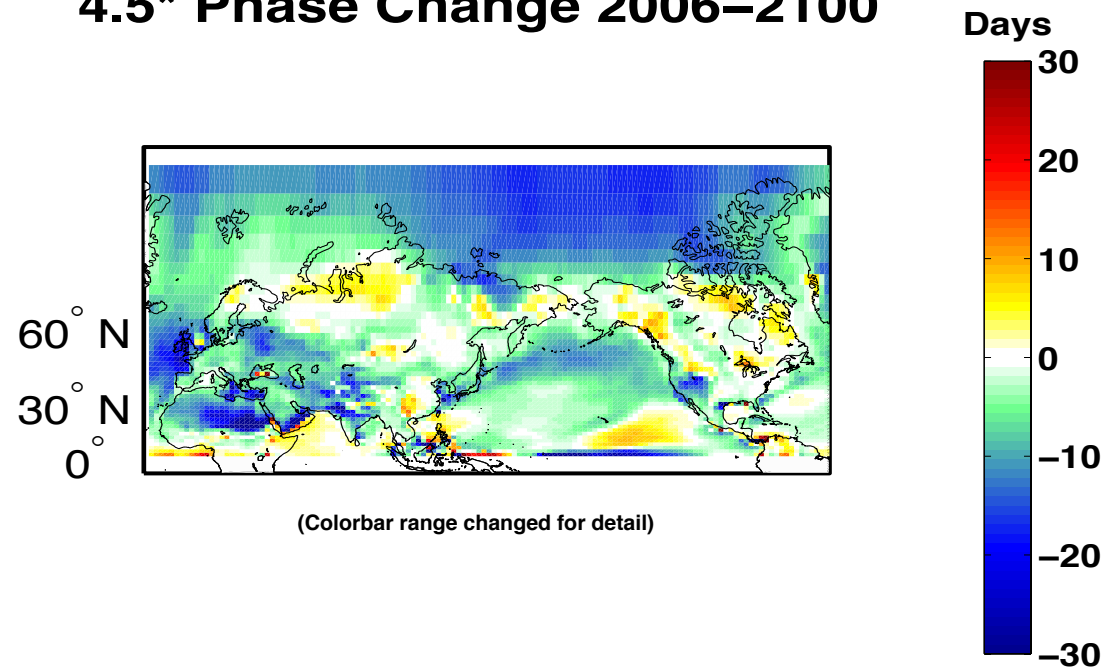
4.5* Change in Amplitude 2006–2020 ppb



4.5* Change in Amplitude 2006–2100 ppb



4.5* Phase Change 2006–2100

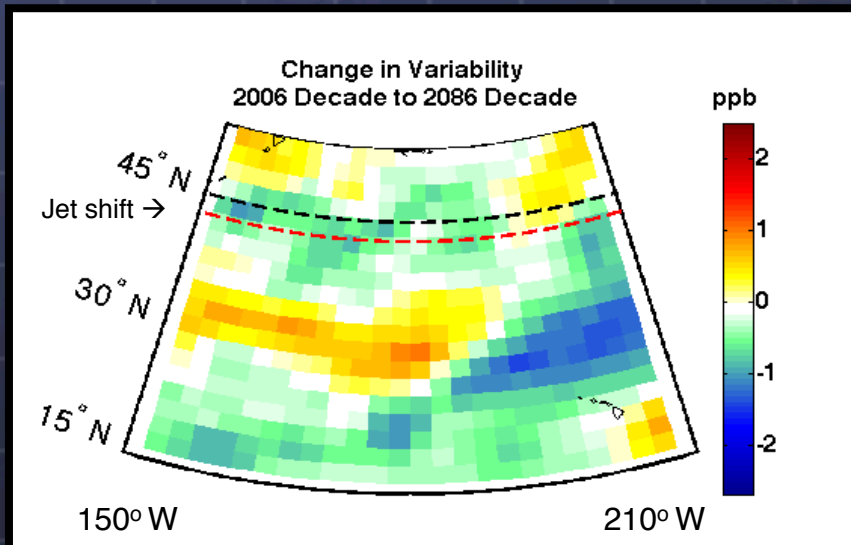
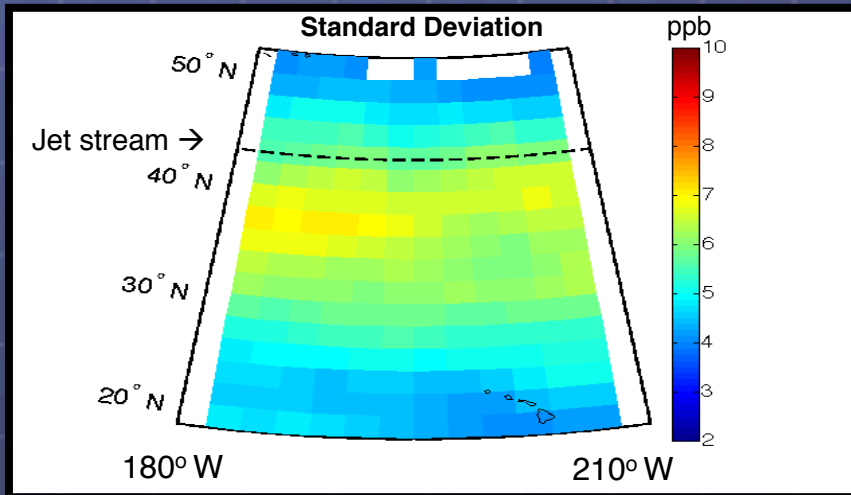


- 4.5: Changes in emissions will decrease amplitude of cycle. Old minima become new maxima.
- 4.5*: Without emission changes, cycle shifts and peaks earlier.

What about long-term changes in surface O₃ in summertime?

Ozone and the Jet Stream

Ozone Variability



(1 ensemble of 4.5* plotted.)

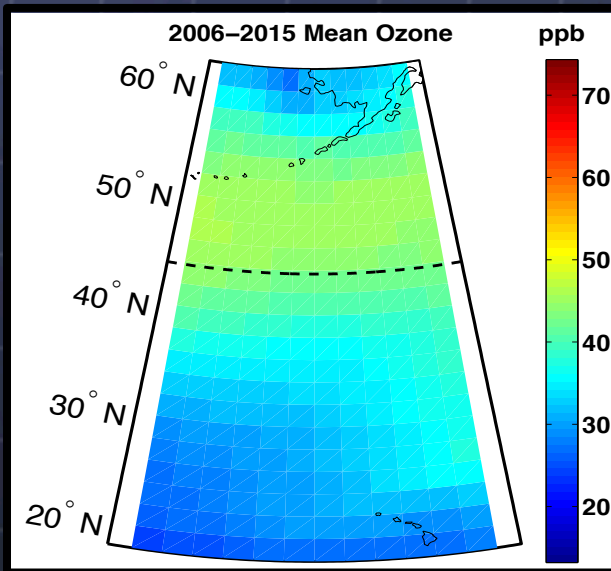
- Focus: Pacific Region
- Standard deviation of anomalies taken per decade.
- Variability shifts over time.
- Shift not directly correlated with winds BUT definitely influenced by circulation.

Do winds influence
MEAN OZONE over Pacific?

Ozone and the Jet Stream

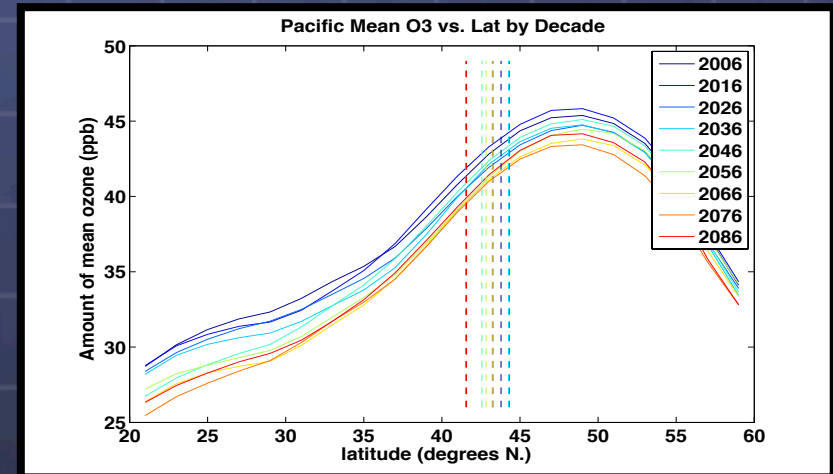
Mean Ozone

- Amount of ozone decreases per decade in both scenarios.
- Jet nearly aligned with peak.

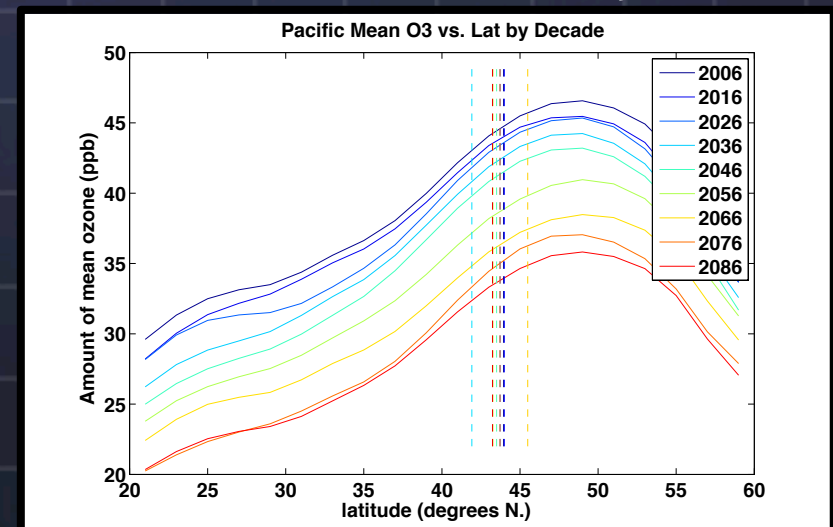


(1 ensemble of 4.5* plotted.)

4.5* Mean Ozone Profile by Decade



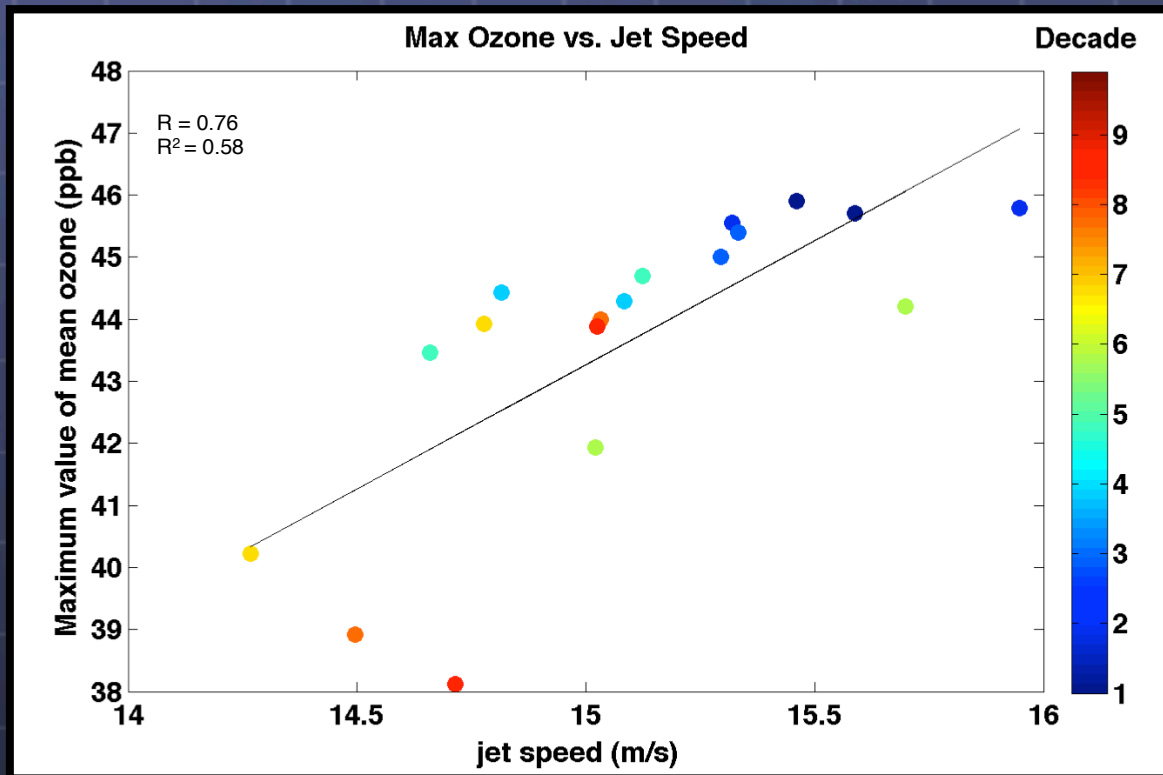
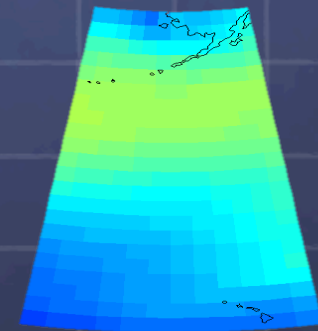
4.5 Mean Ozone Profile by Decade



(1 ensemble of plotted.)

Ozone and the Jet Stream

Mean Ozone

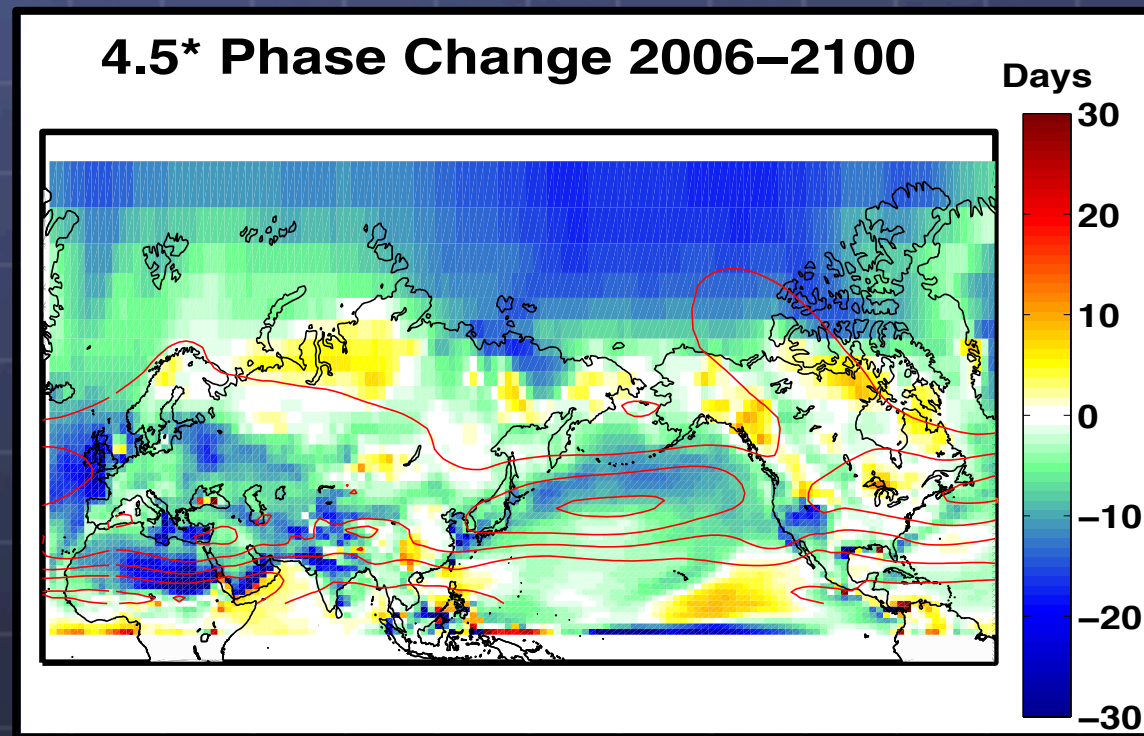


- 4.5 AND 4.5* scattered.
- Year-to-year short-term relationship holds up.

- Amount of ozone is correlated to jet speed.
- Jet speed seems to decrease decade by decade.

Ozone and the Jet Stream

Seasonal Cycle



- 🌐 Over oceans, phase change patterns appear to be correlated with winds!
- 🌐 Further research required to understand why.

Conclusions

- With *AND* without changes in emissions, mean ozone decreases over Pacific.
- Smaller jet speeds linked to less surface ozone over Pacific.
- With *AND* without changes in emissions, ozone seasonality changes.
 - The amplitude of the seasonal cycle depends on emissions.
 - Shift of seasonal cycle appears to be aligned with winds.



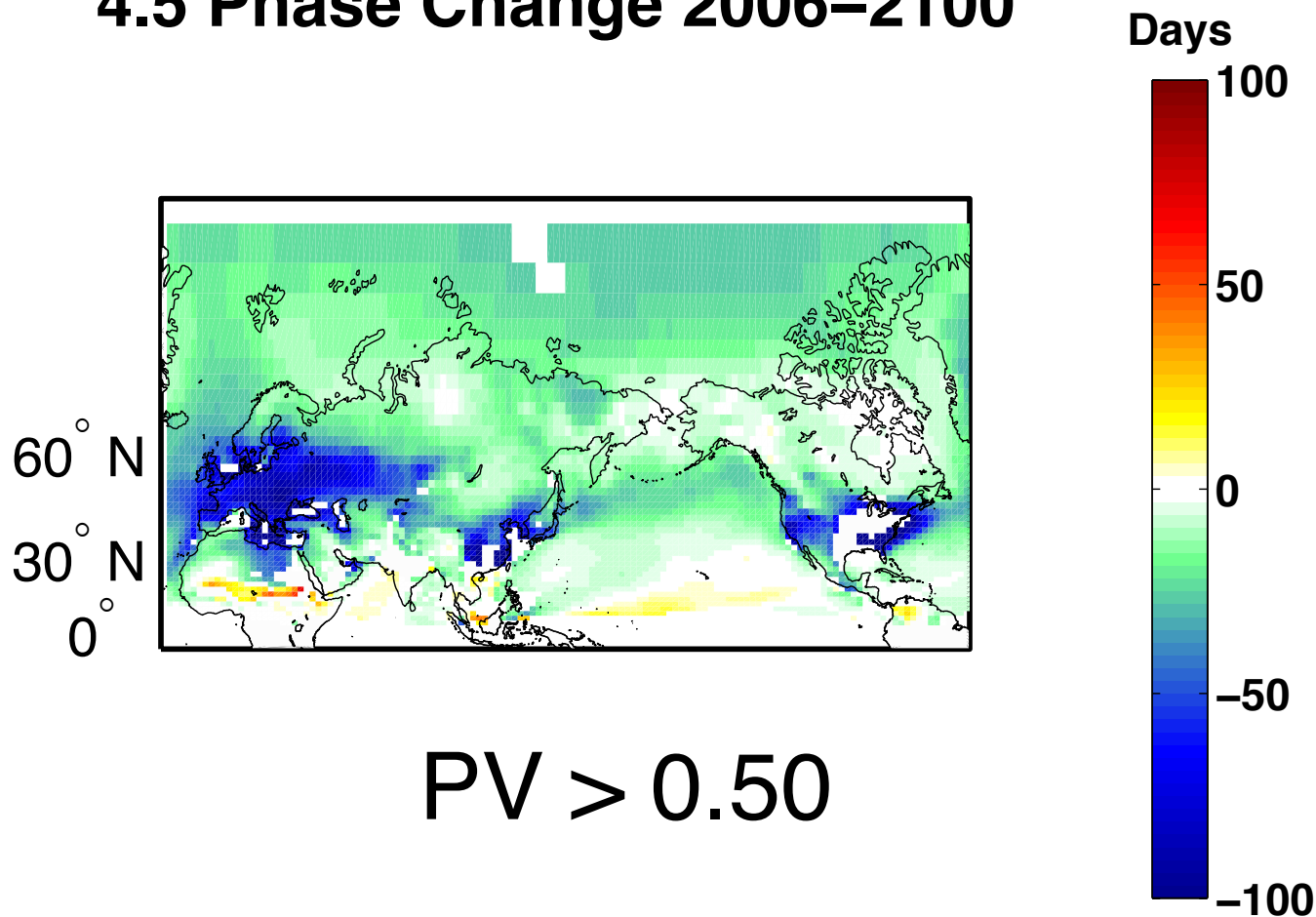
Questions?

Further Work

- 🌐 Understanding how winds are linked to seasonal cycle change in 4.5*.
- 🌐 Understanding transport of NO_x from Asia: is it changing?
- 🌐 Getting a better idea of ozone's response to climate change throughout the atmosphere, not just at surface.

Appendix

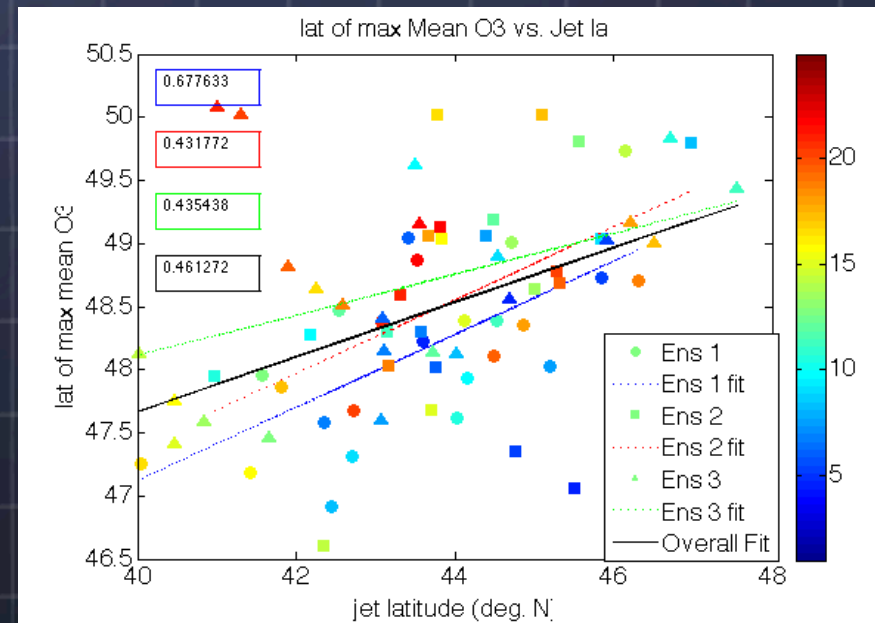
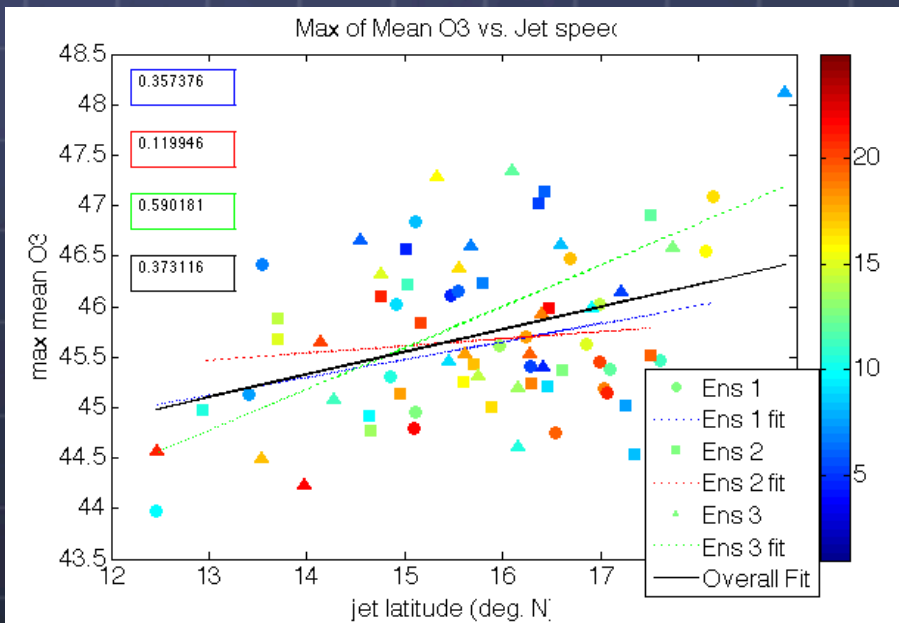
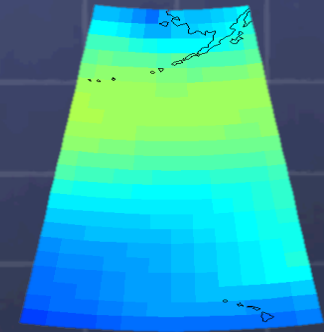
4.5 Phase Change 2006–2100



Ozone and the Jet Stream

Mean Ozone

- Amount of ozone DOES correlate year-to-year in time frame of minimal climate change.
- Latitude of max ozone vs. latitude of jet ONLY correlates year-to-year.



References

- Barnes, E. A., and A. M. Fiore (2013), Ozone variability, jet, and climate change, *Geophys. Res. Lett.*, 40, 1-6.
- Meinshausen, M., et. al (2011), The RCP greenhouse gas concentrations and their extensions from 1765 to 2300, *Climatic Change*, 109, 213–241.
- Parrish, D. D., et. al (2013), Changing ozone seasonal cycle, *Geophys. Res. Lett.*, 40, 1631-1636.