# Global Modeling of Air Quality

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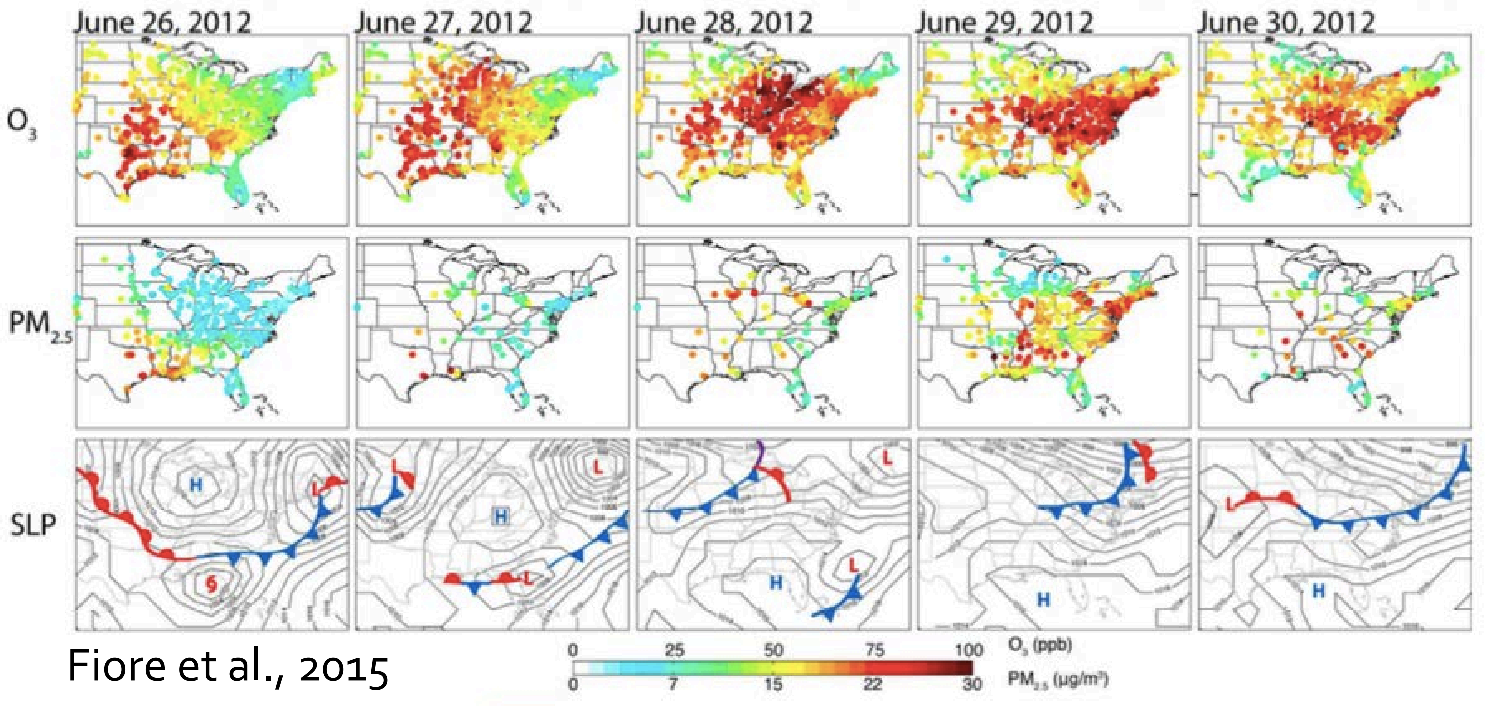
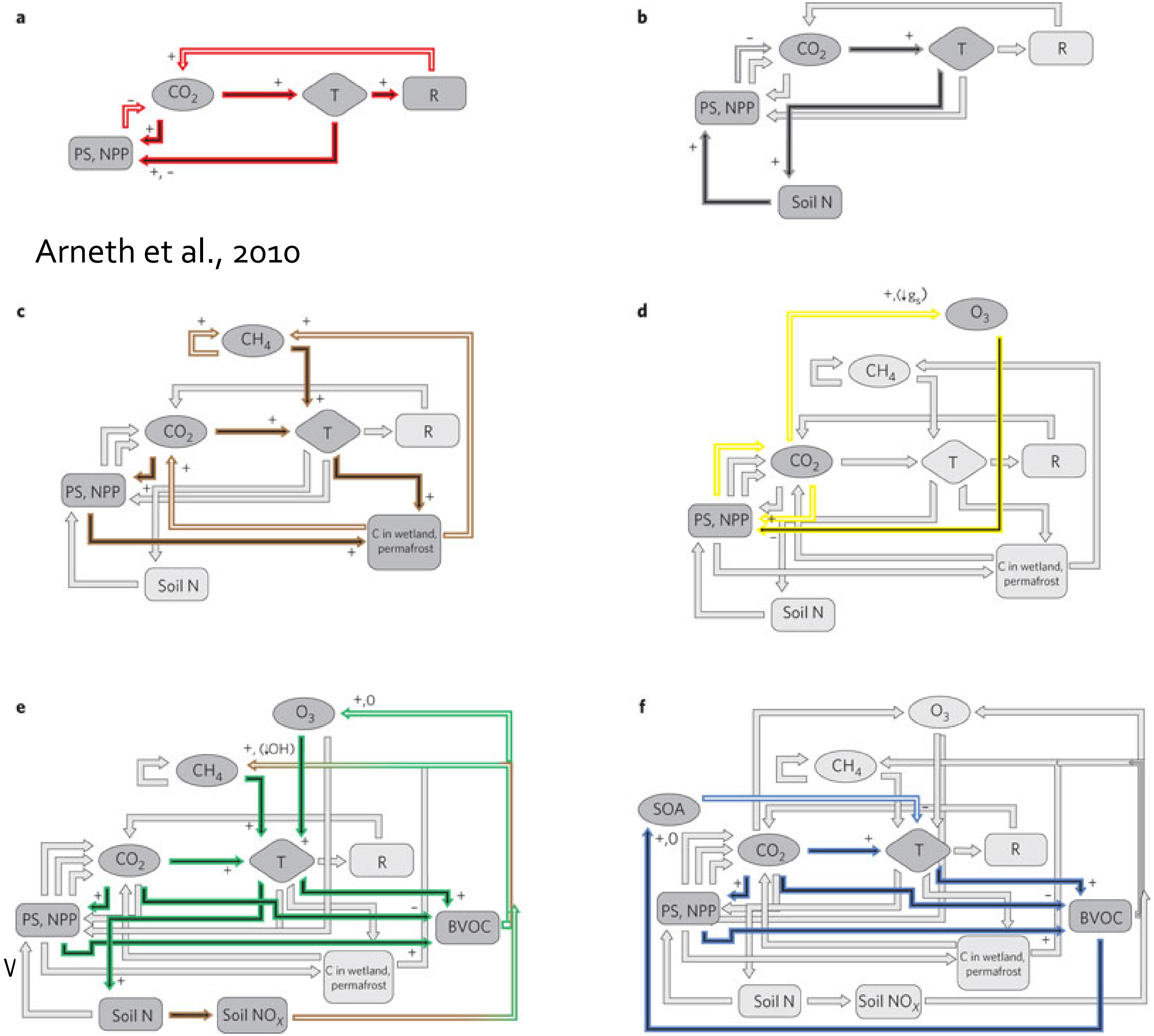



Fiore et al., 2015

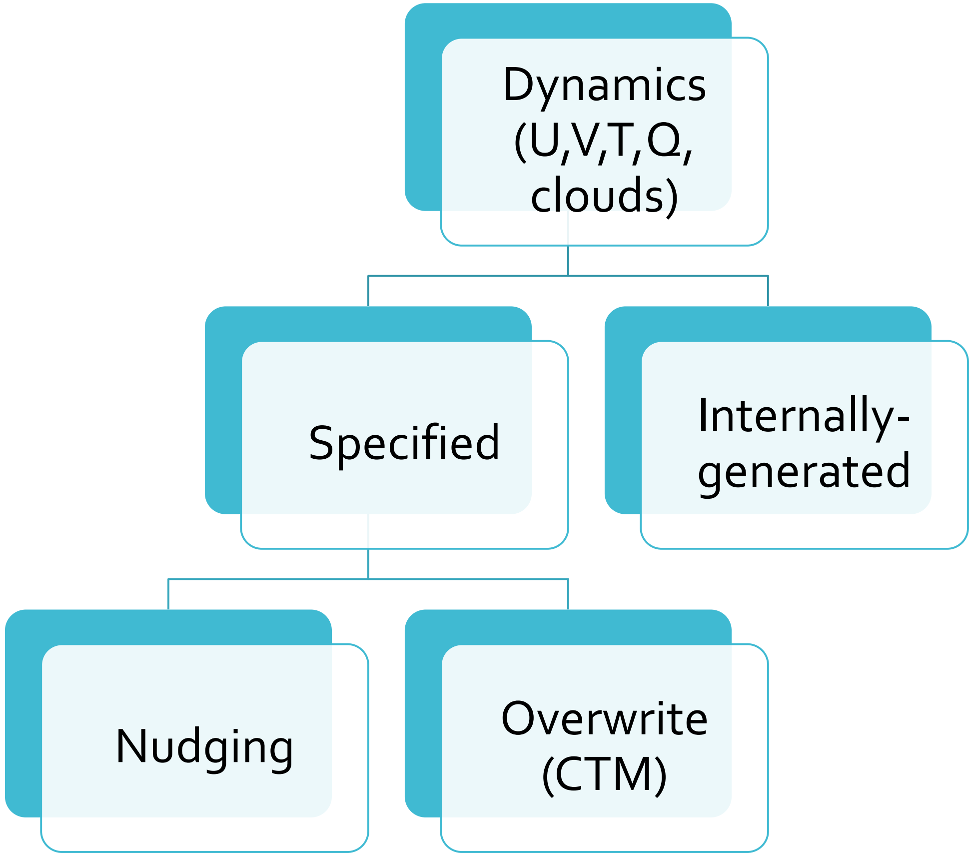
# Characteristics of Global Chemistry Modeling




Arneth et al., 2010

Jacob and V

# Types of global chemistry models

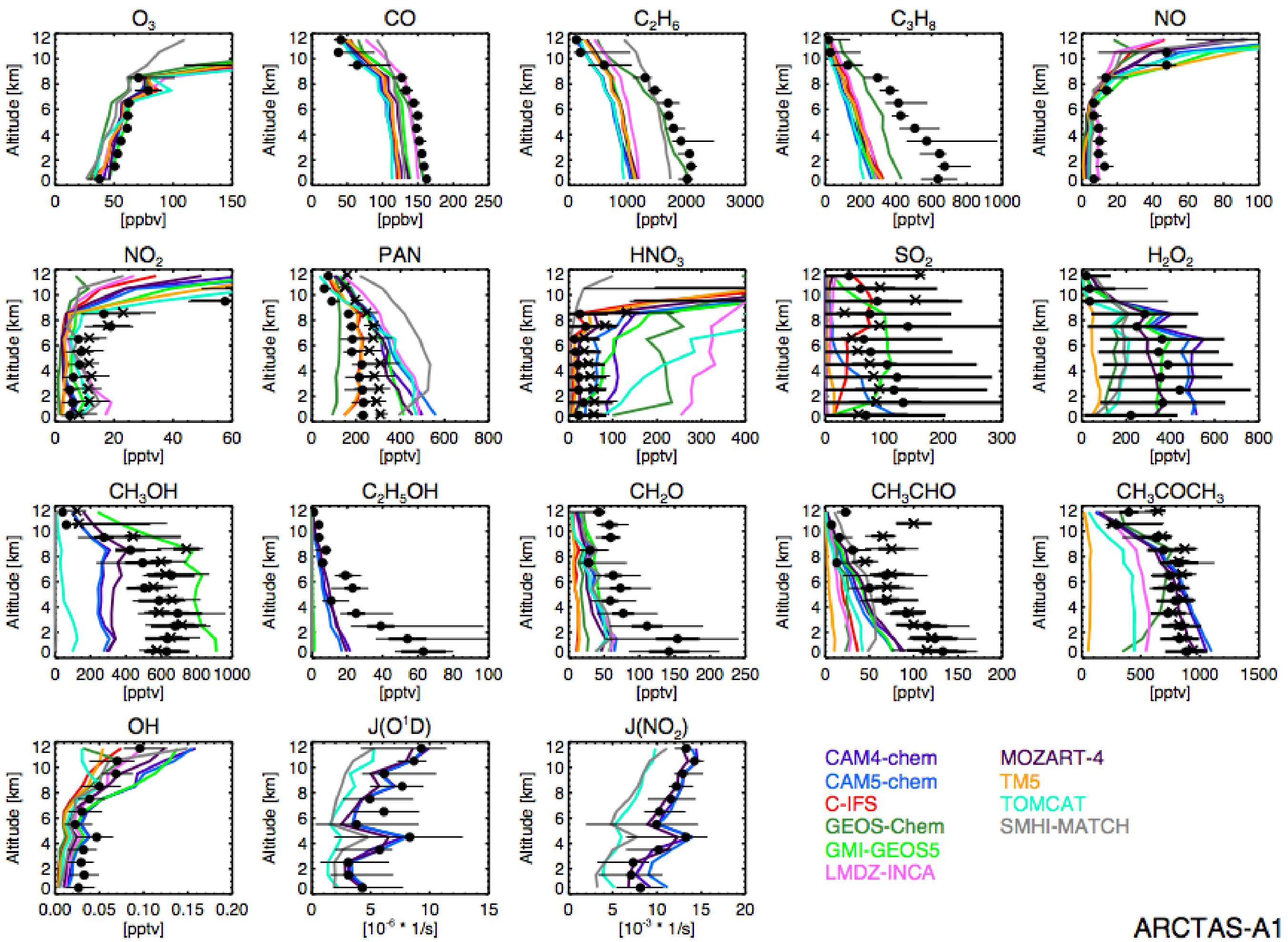



Typical configurations

- Horizontal resolution: 10s -100s km
- Vertical extent: ≈40-150 km (need stratosphere!)
- Timestep: 20-30 minutes
- Number of species (ACCMIP): 16-120
- Simulation periods: days to centuries

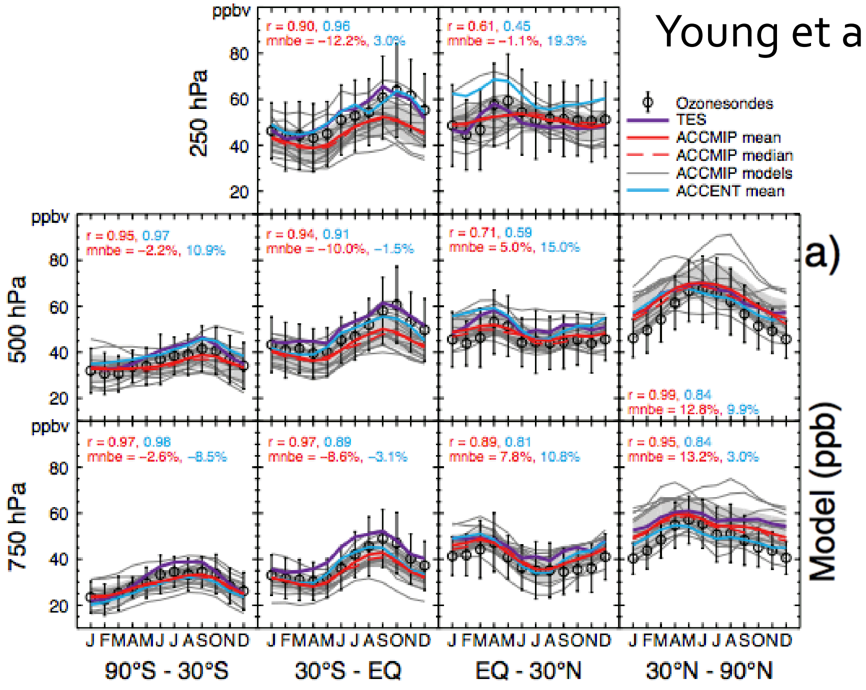
# Coarse grid and evaluation/assimilation issues

- Significant mismatch between model resolution and scale of observations, including most satellites
  - Representativeness
  - Averaging and variability

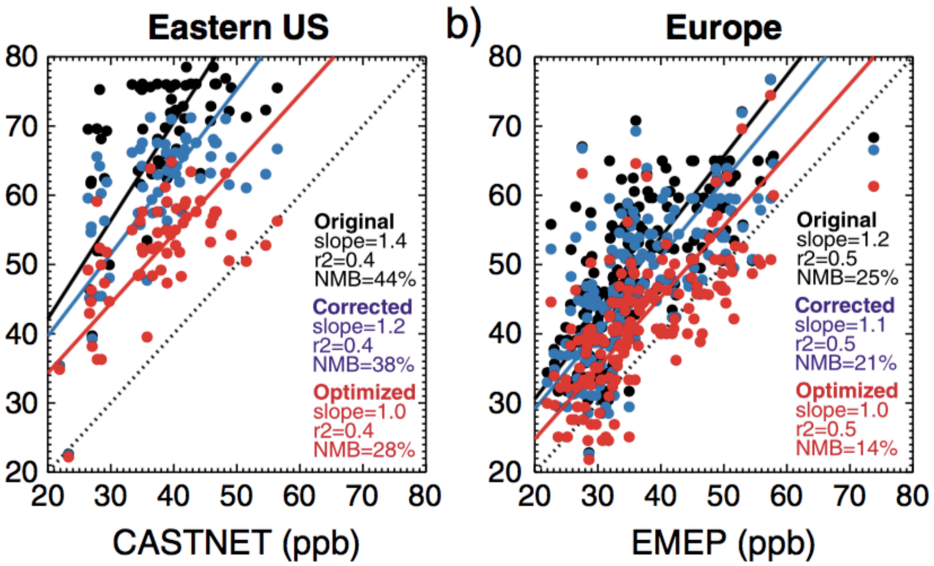



Emmons et al., 2015

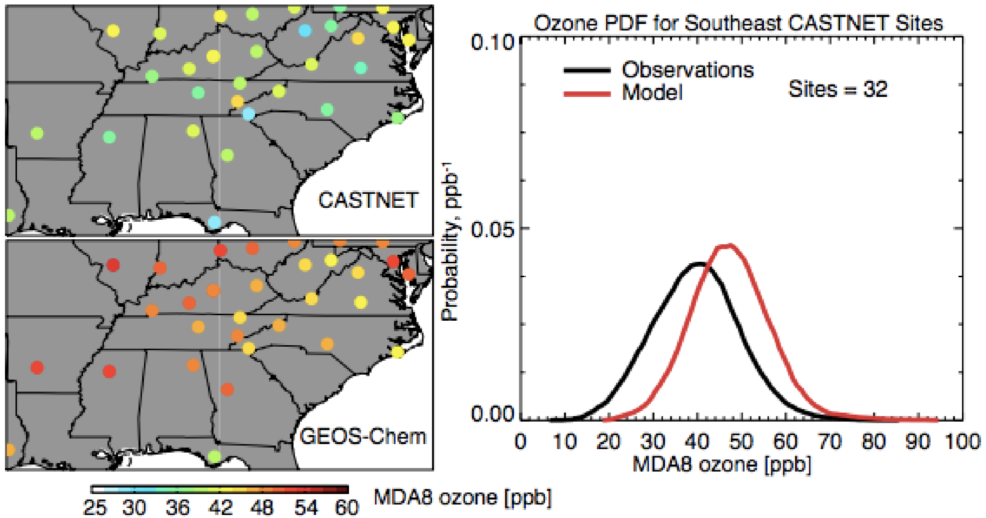
# How good are global models at simulating AQ?



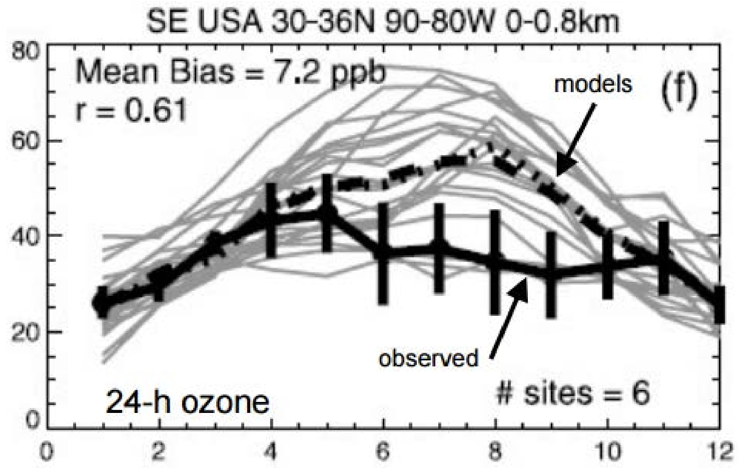

Young et al., 2013




ValMartin et al., 2014




Travis et al., 2016

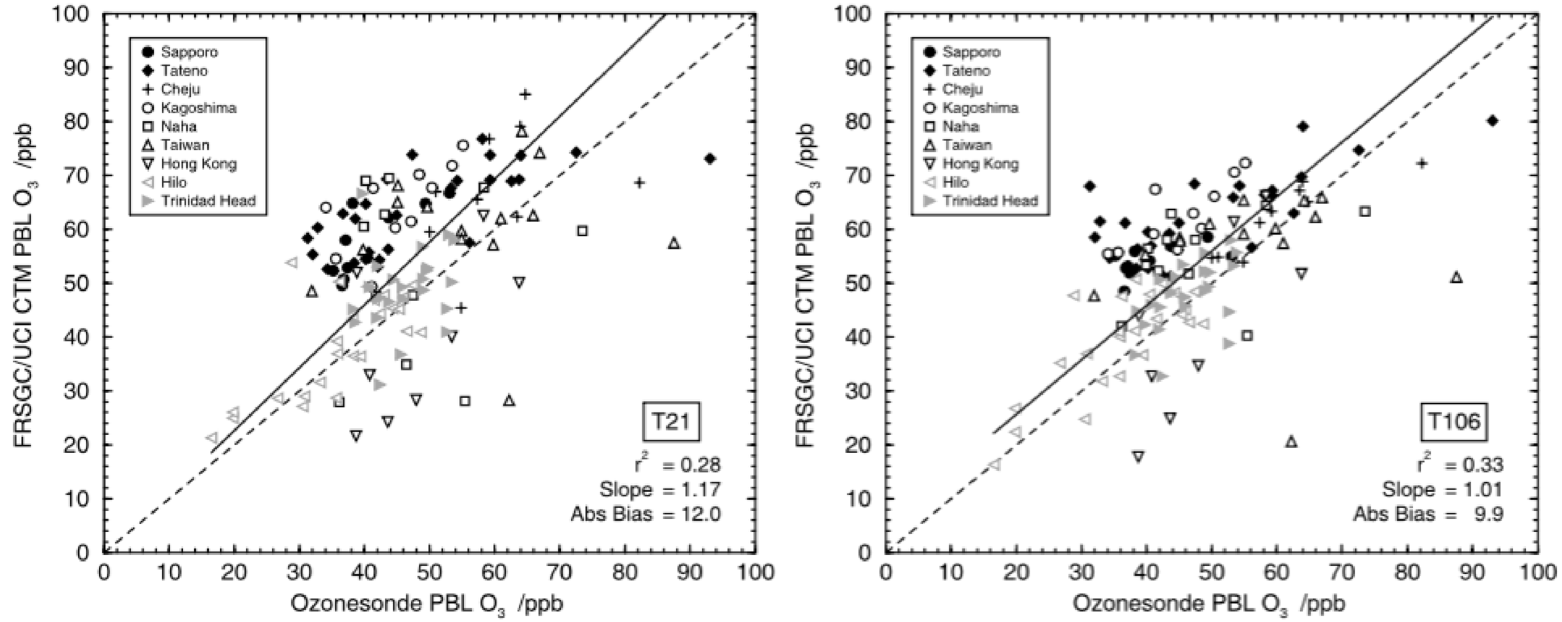



HTAP models; Fiore et al., 2009

# Regional *versus* global modeling: does resolution matter?

| | T21 | T42 | T63 | T106 |
|---|---|---|---|---|
| Mean $O_3$ burden, Tg | 294 | 284 | 278 | 275 |
| Gross production, Gg/day | 12,290 | 12,130 | 12,040 | 11,880 |
| Gross destruction, Gg/day | 12,120 | 11,650 | 11,450 | 11,290 |
| Net $O_3$ production, Gg/day | 169 | 480 | 594 | 583 |
| $O_3$ deposition, Gg/day | 2,090 | 2,210 | 2,250 | 2,300 |
| $O_3$ stratosphere/troposphere exchange, Gg/day | 2,000 | 1,760 | 1,670 | 1,730 |
| $O_3$ chemical lifetime,[a] days | 24.25 | 24.34 | 24.25 | 24.34 |
| $CH_4$ lifetime versus OH, years | 8.06 | 8.32 | 8.44 | 8.57 |

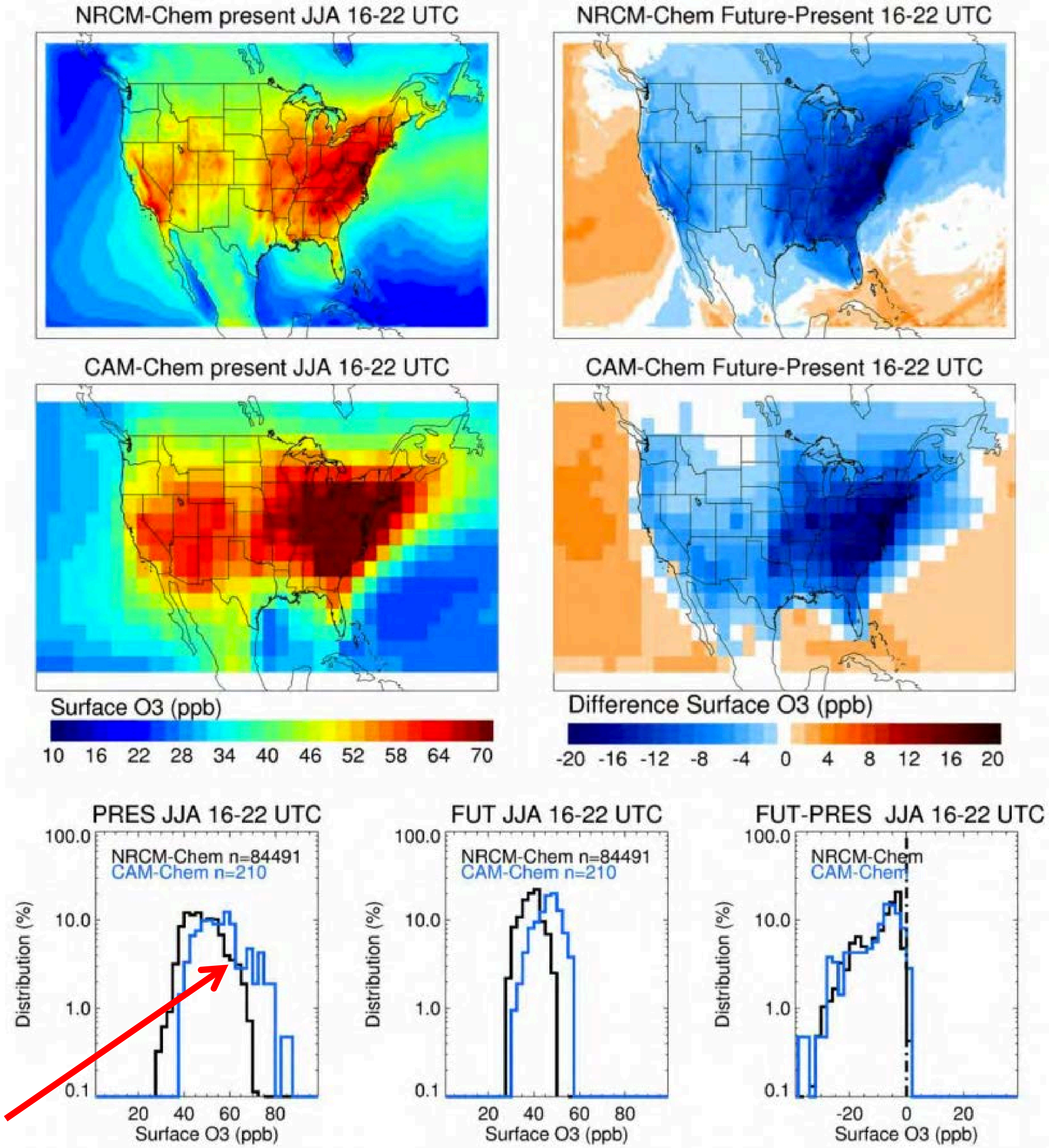
[a]Lifetime defined as burden divided by gross destruction.




Wild and Prather, 2006

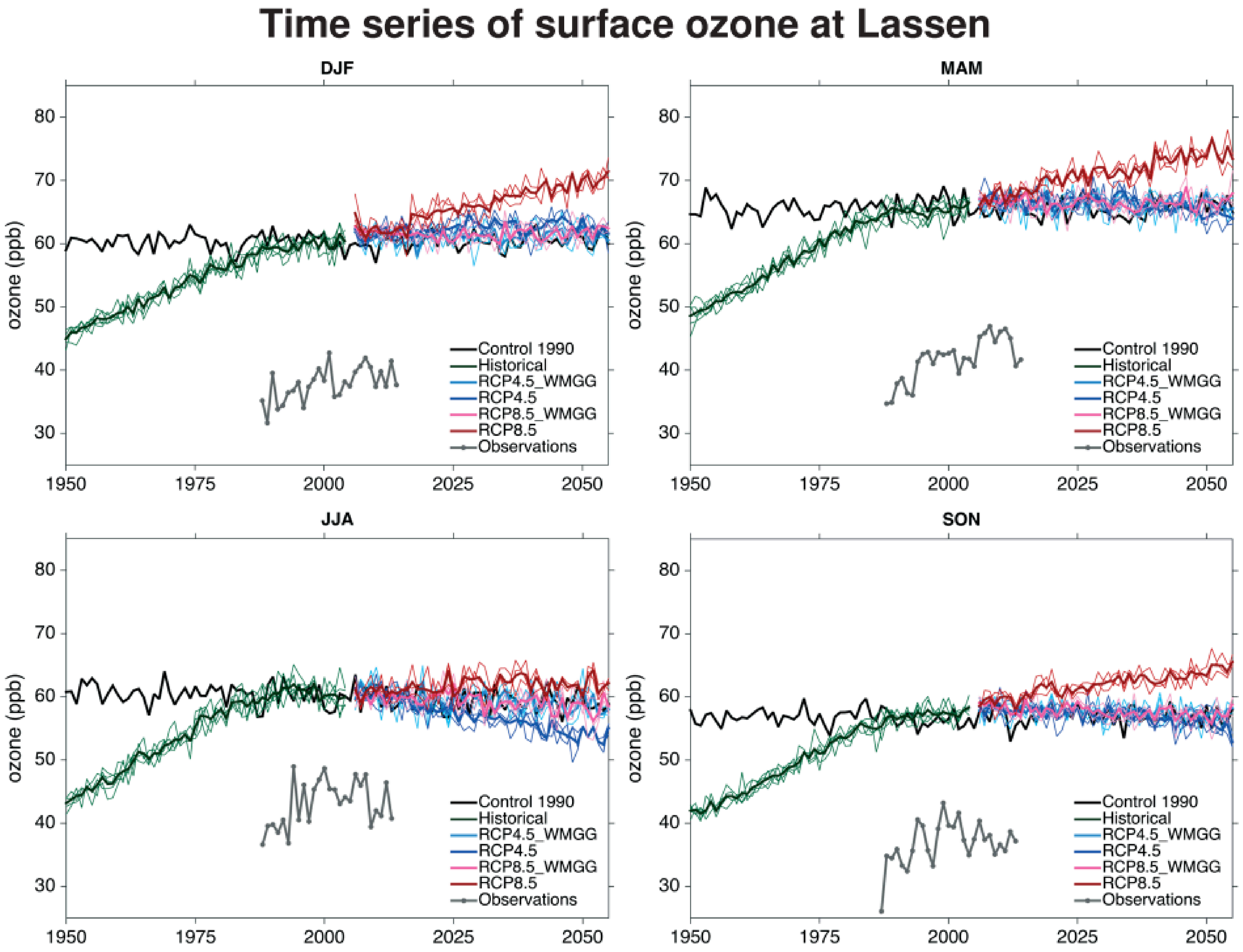
Pfister et al., 2014

# Regional *versus* global modeling: does resolution matter?



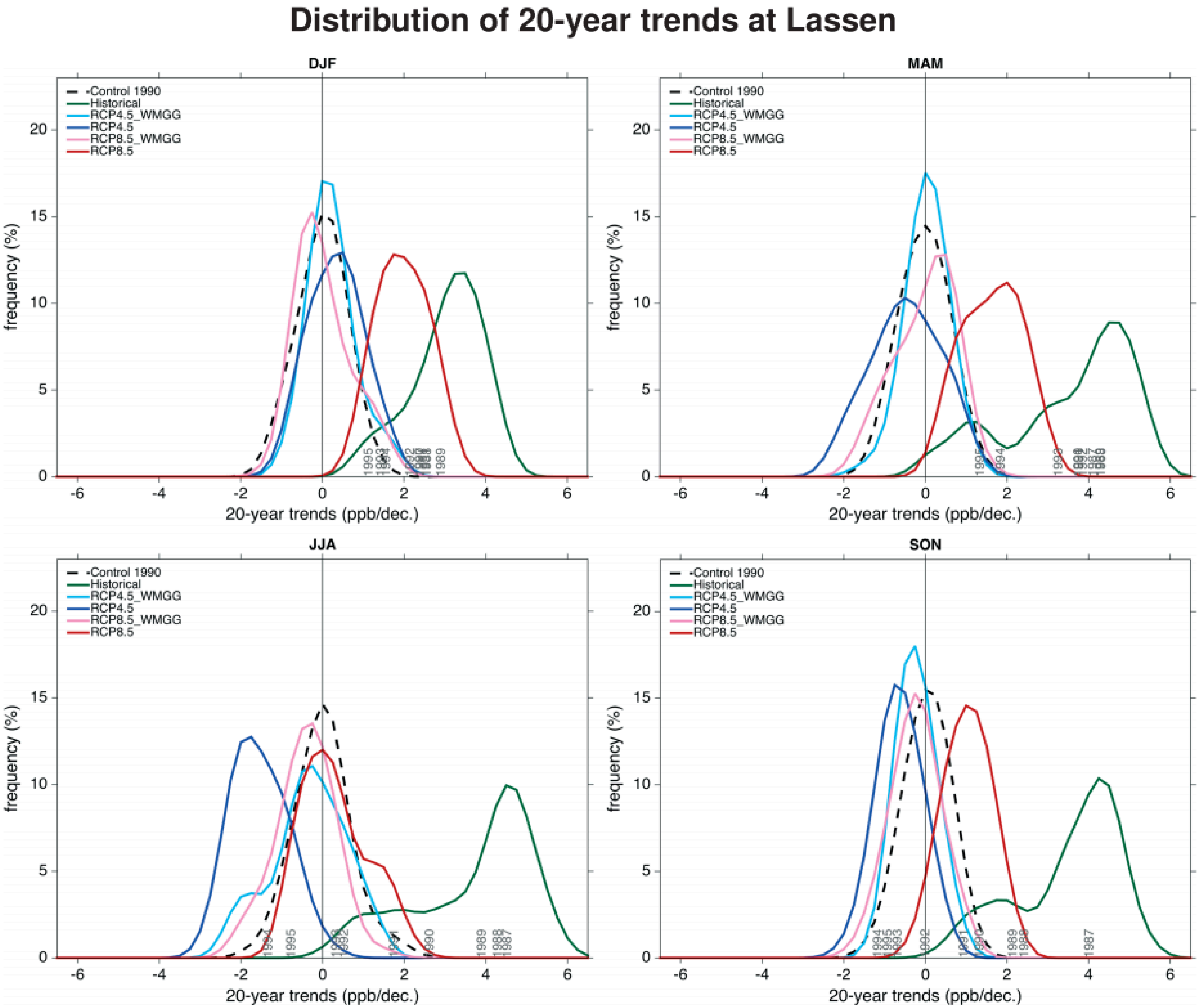

Positive bias

# Long-term trends: emissions *versus* transport



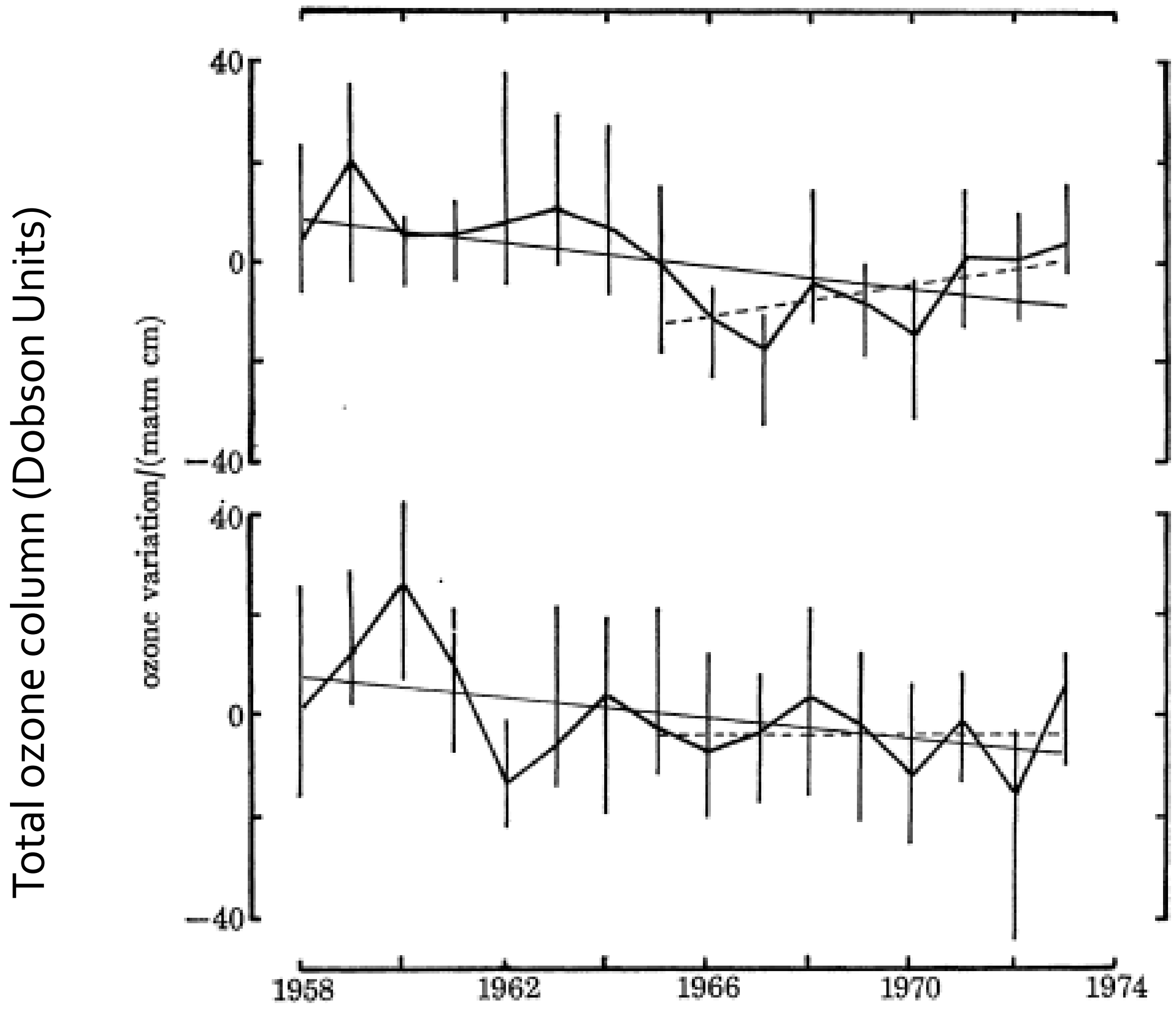

Barnes et al., 2016

# Long-term trends: emissions *versus* transport




Barnes et al., 2016

# Observations: living with short records and large internal variability




Farman, 1977

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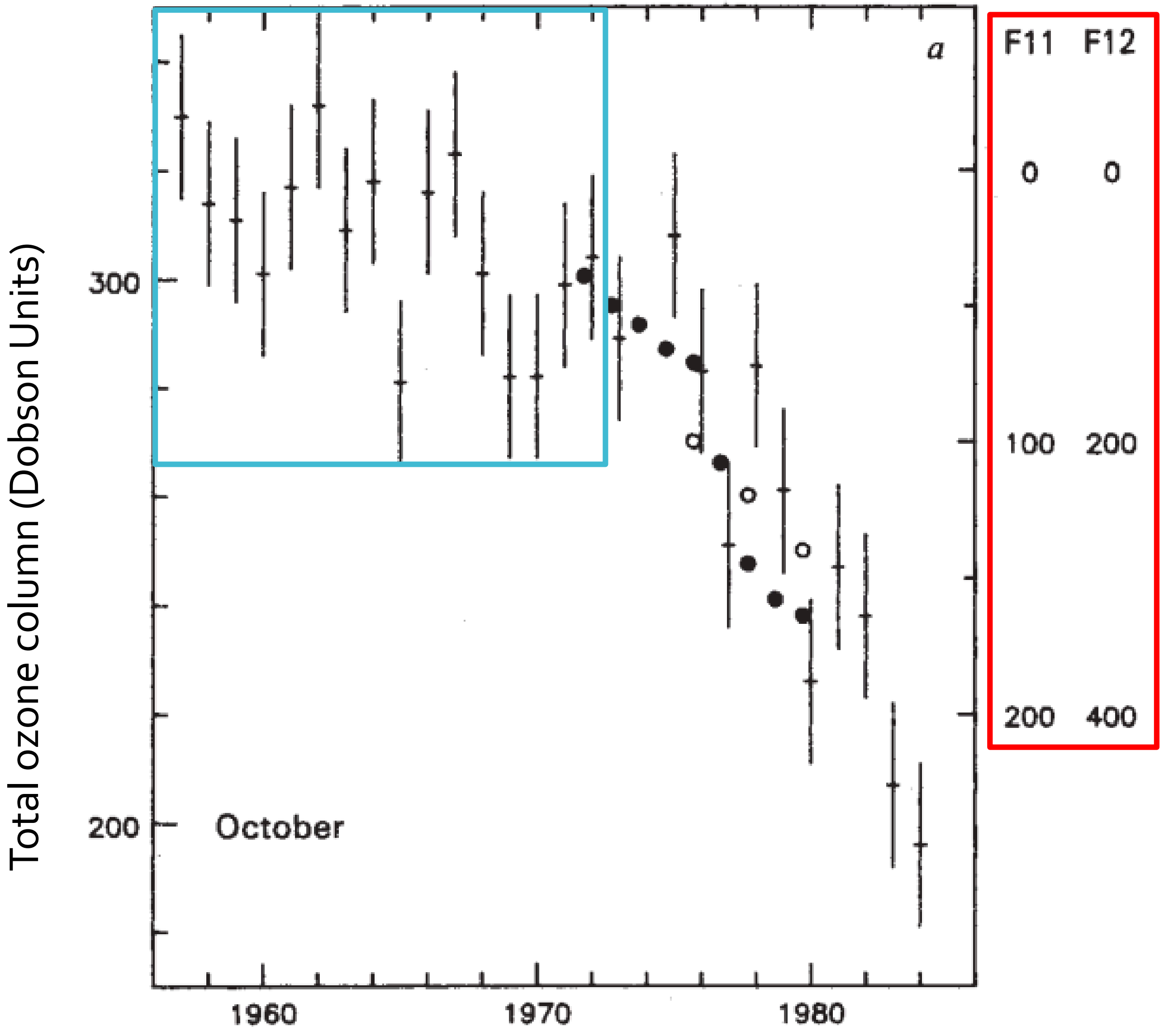
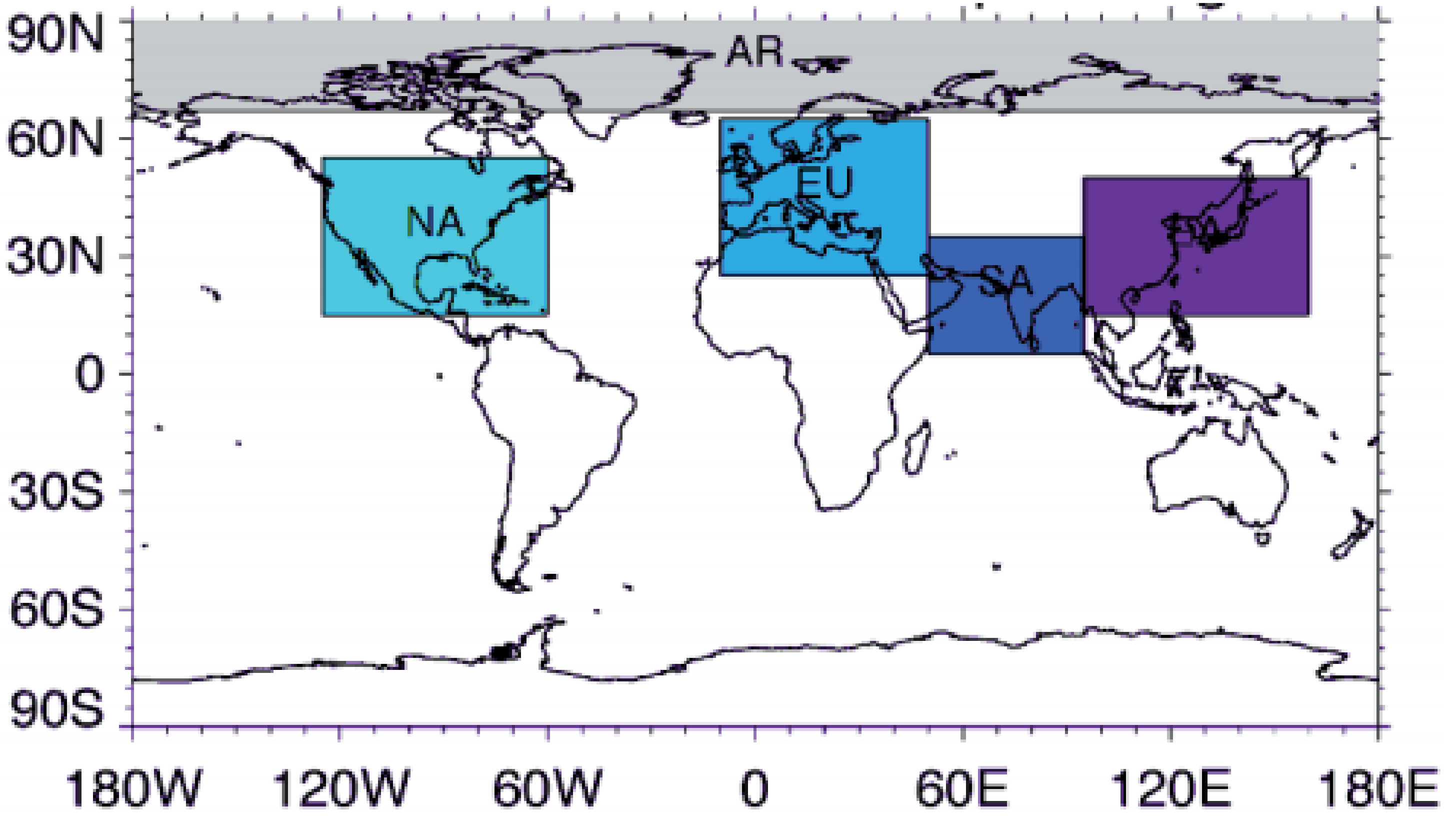


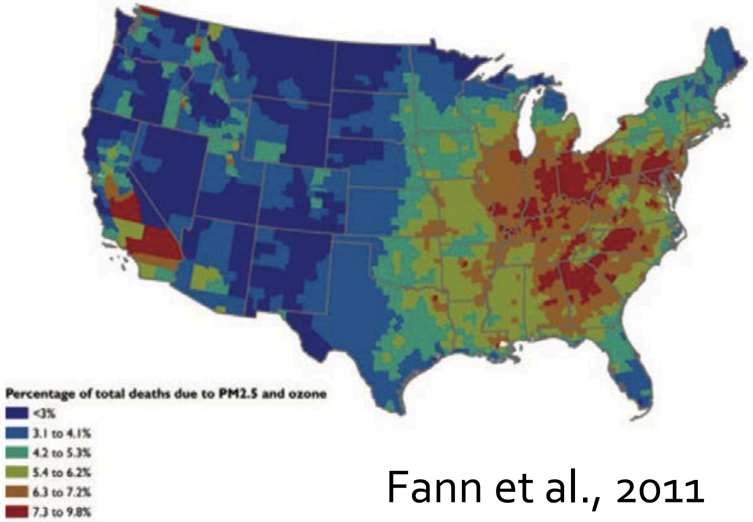

Farman et al., 1985

# Application: long-range transport and impact of emission reductions



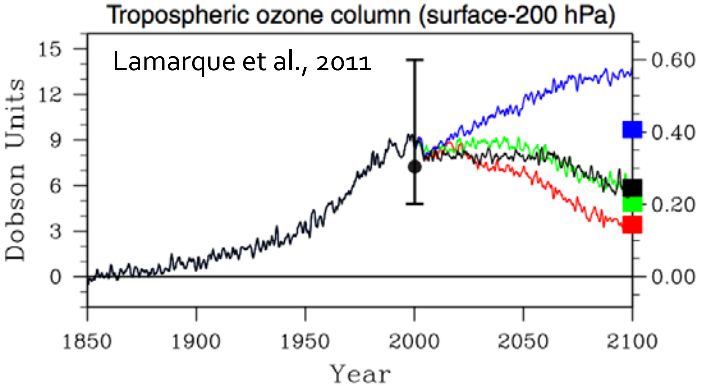

| | Receptor Region | | | |
|---|---|---|---|---|
| Source Region | NA | EU | EA | SA |
| *Annual mean decrease* | | | | |
| NA | 1.04±0.23 | **0.37±0.10** | **0.22±0.05** | **0.17±0.04** |
| EU | **0.19±0.06** | 0.82±0.29 | **0.24±0.08** | **0.24±0.05** |
| EA | **0.22±0.06** | **0.17±0.05** | 0.91±0.23 | **0.17±0.05** |
| SA | 0.07±0.03 | 0.07±0.03 | **0.14±0.03** | 1.26±0.26 |
| *Relative Annual Intercontinental Response (RAIR)* | | | | |
| | 32% | 43% | 40% | 32% |

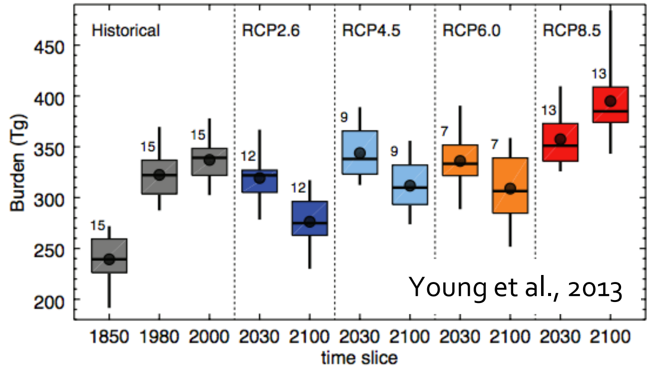
HTAP, 2010

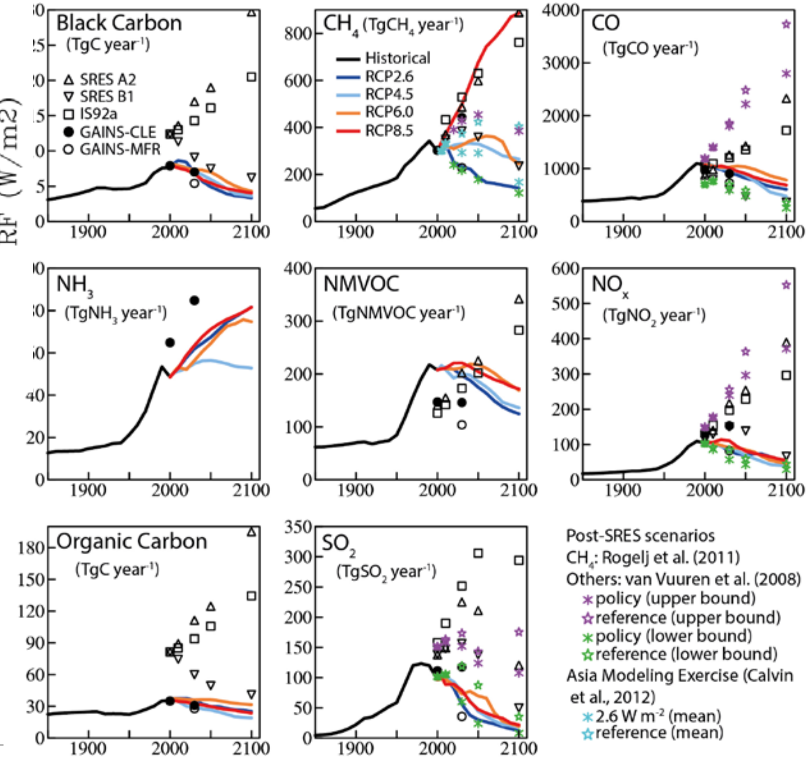



Fann et al., 2011

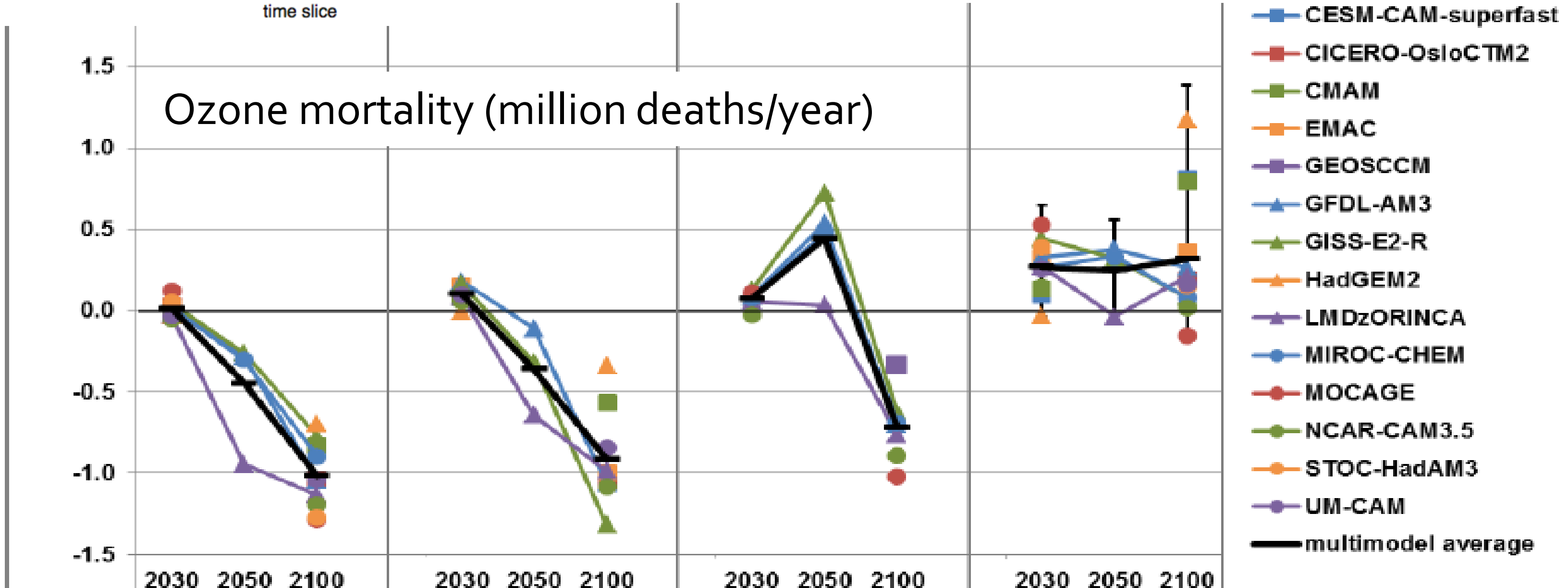
# Application: Long-term trends, climate forcing and mortality studies



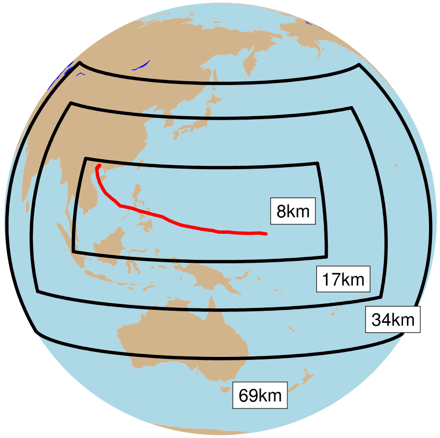

IPCC AR5, Ch. 8



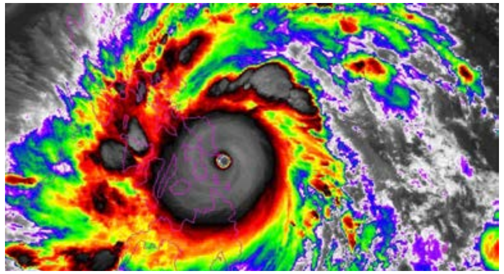

Silva et al., 2016

# Stretch-grid: getting more science done with lower computational cost

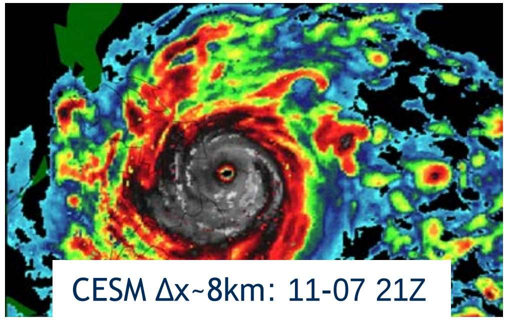
Spectral Element




From C. Zarzycki

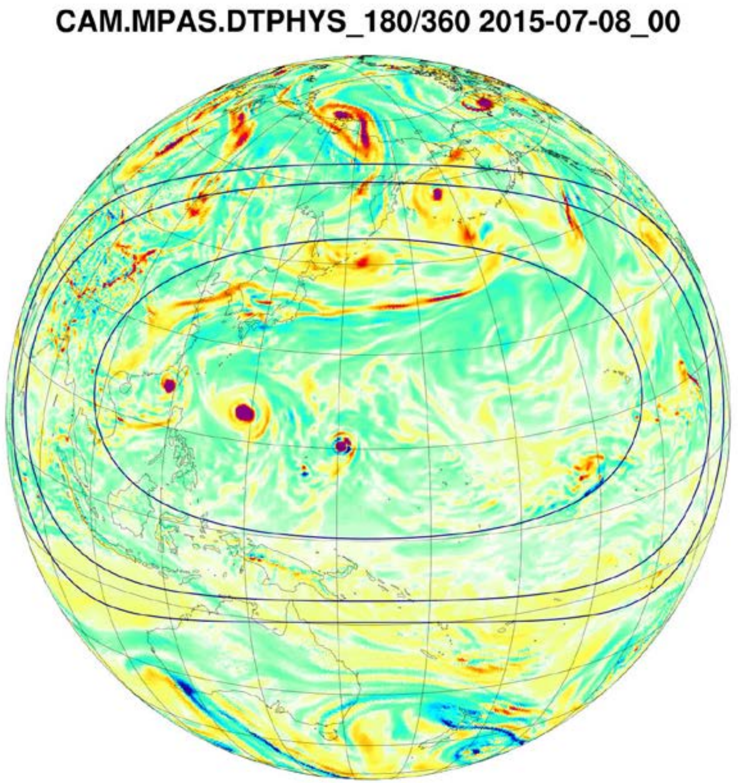


NOAA IR satellite obs: 11-07 21Z



CESM Δx~8km: 11-07 21Z

MPAS




CAM-MPAS coupled with ocean/ice model

500 hPa Vorticity, 15-60 km grid

From B. Skamarock

# Questions?