Reaching Exposure-Relevant Scales: The Implementation of Full Chemistry into Regionally Refined CAM-chem

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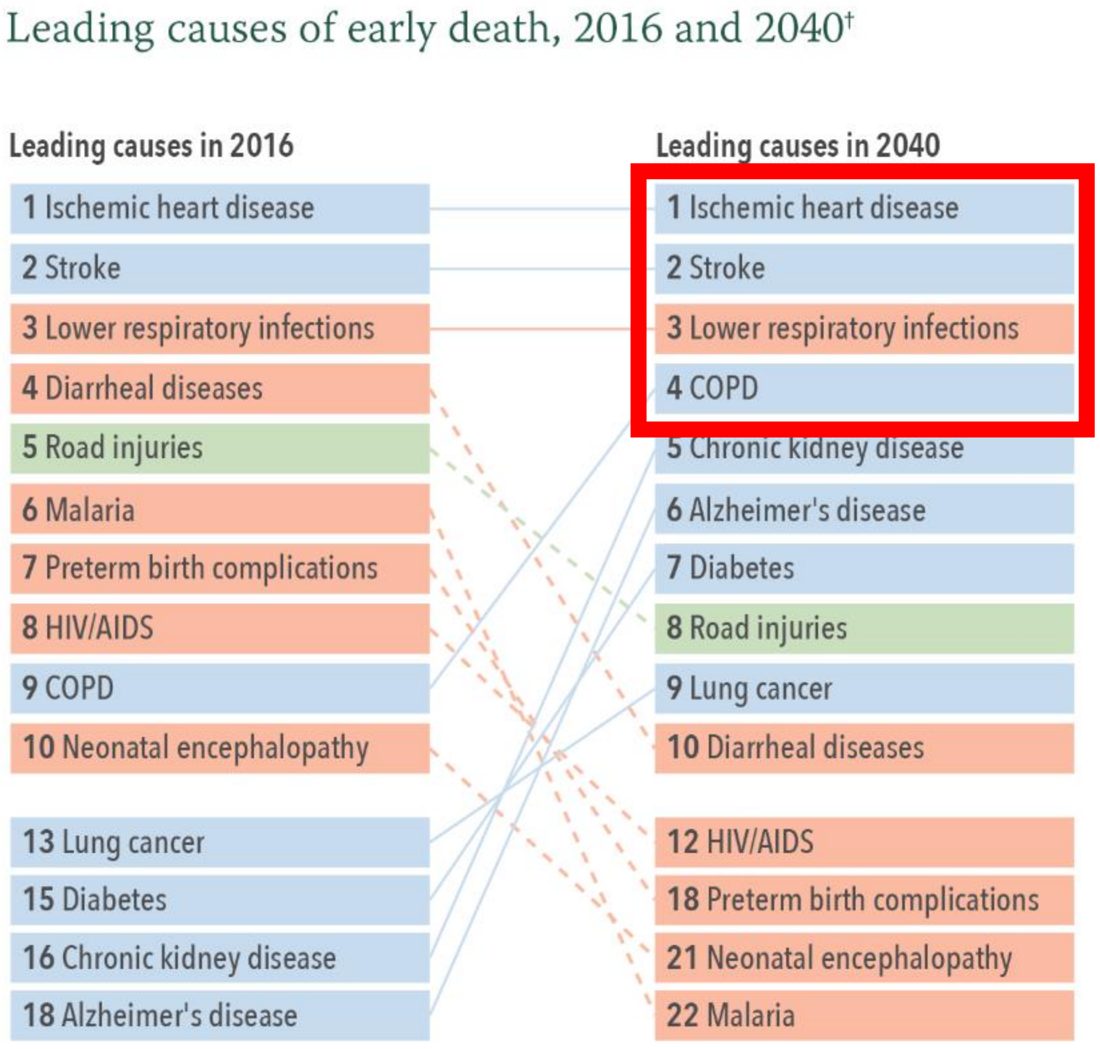
Motivation

Ambient air quality has an adverse effect on human health

Current Global Burden of Disease reports estimate that ~4 million premature deaths annually due to ambient air quality

This problem will persist moving further into the 21st century with the top four leading causes of death being impacted by exposure-related diseases

GBD 2018 Report on Forecasting life expectancy



Source: Foreman et al., 2018

Motivation

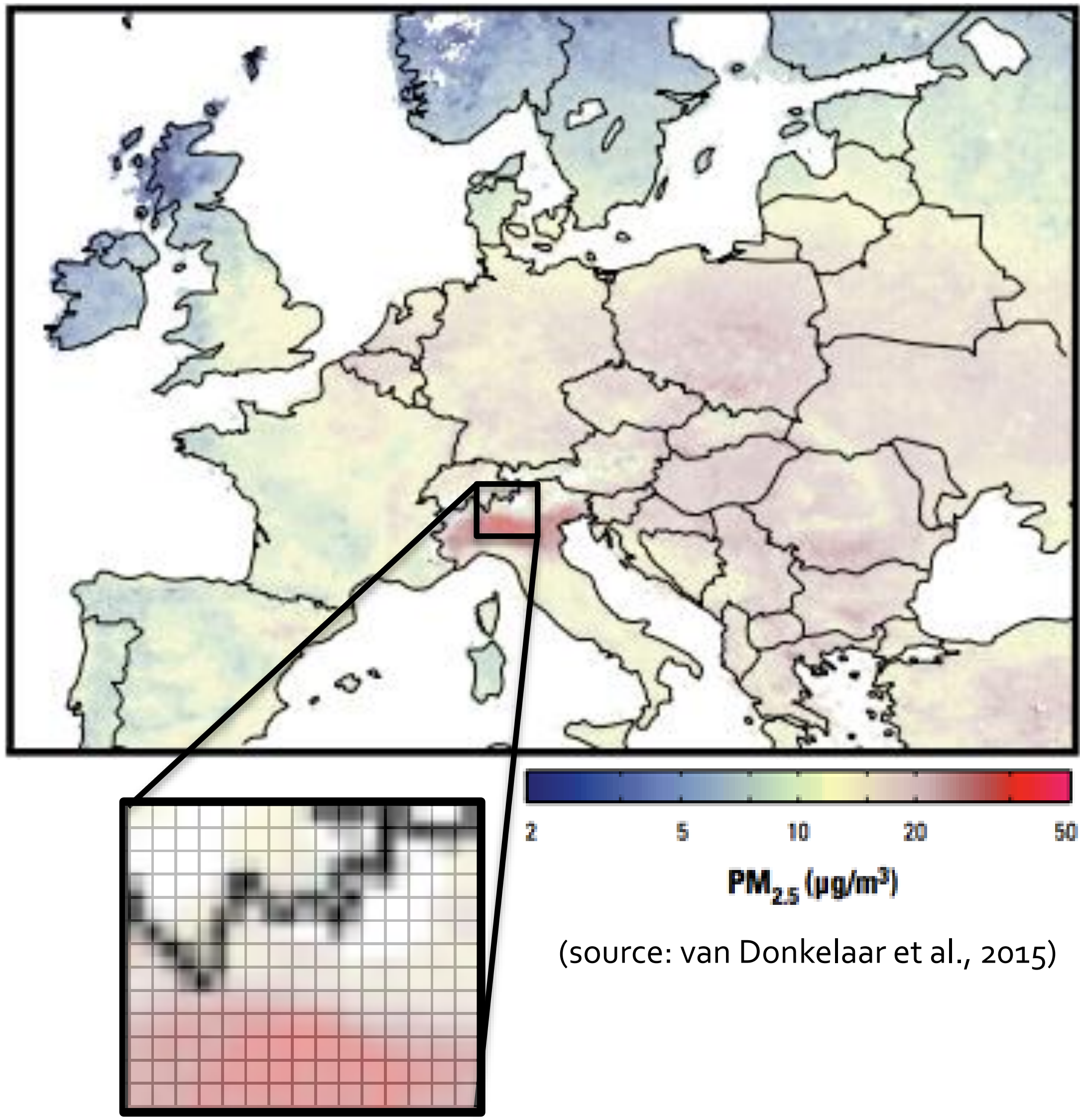
Models are becoming increasingly relevant as tools for estimating adverse human health impacts from air quality

- Models must be able to estimate ambient air quality at exposure-relevant scales (~10 km)

Current models used for analysis typically fall into two categories

- Chemical transport models
- Regional models

Both of these have drawbacks that need to be addressed for a complete health analysis



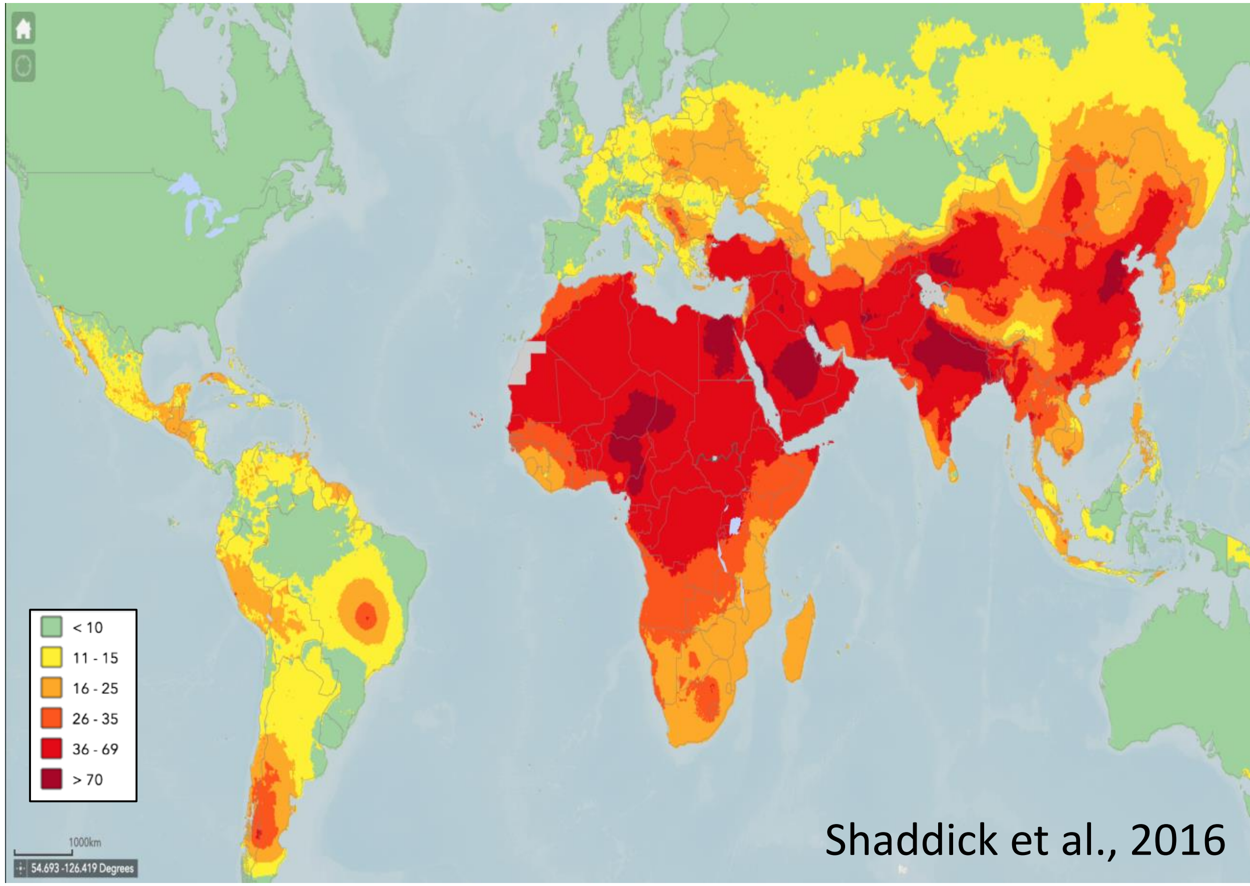
(source: van Donkelaar et al., 2015)

*representative grid, not to scale

Motivation

Current dataset used for the GBD reports uses the following information:

- Ground-based monitor observations
  - 9,690 sites
- Ensemble model estimates of $PM_{2.5}$
  - GEOS-Chem, TM5, and TM5-FASST
  - GC uses satellite obs to distribute within grid cell
- Population data from GPWv4
- Other factors such as land use and topography
  - Needed to correct satellite data products



Shaddick et al., 2016

Motivation

For next-generation of NCAR models, one goal is to align with the needs of the health community.

Needs:

Higher resolution (from ~100 km to ~10 km)

Maintain function as state-of-the-science atmospheric chemistry model

Maintain function as a high-top chemistry-climate model

Maintain functionality as a coupled global Earth System Model

Computationally efficient

Ability to forecast

- Seasonal cycles
- Near-term (10-14 days)

These goals led to the proposed development of the Multi-Scale Infrastructure for Chemistry and Aerosols (MUSICA) model

Model Setup

CAM-chem SE (ne30)

- ATM_GRID: ne30np4
  - cam6 physics
  - MOZART T1 w/ simple VBS SOA & MAM4 aerosols
- LND_GRID: ne30np4
  - clm5.0:BGC w/ prognostic crops
- ICE_GRID: ne30np4
- OCN_GRID: ne30np4
- ROF_GRID: r05

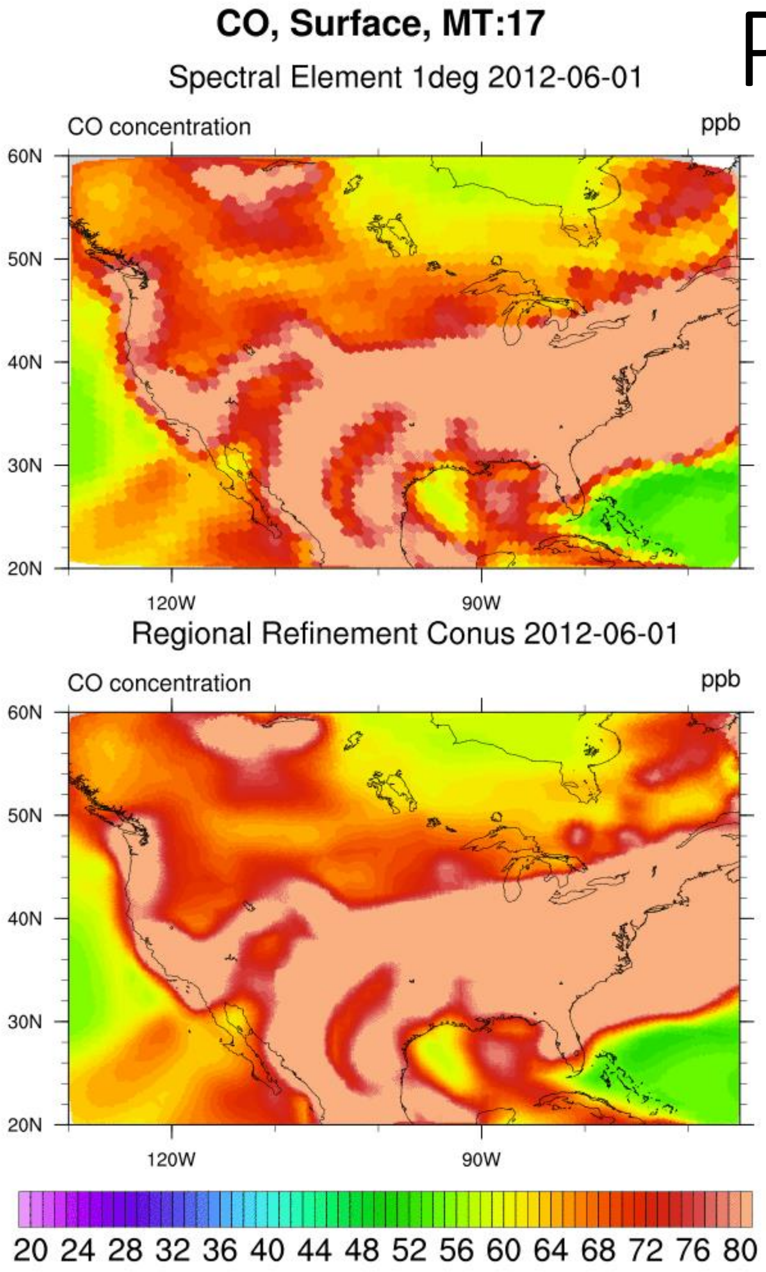
CAM-chem SE RR (CONUS.ne30x8)

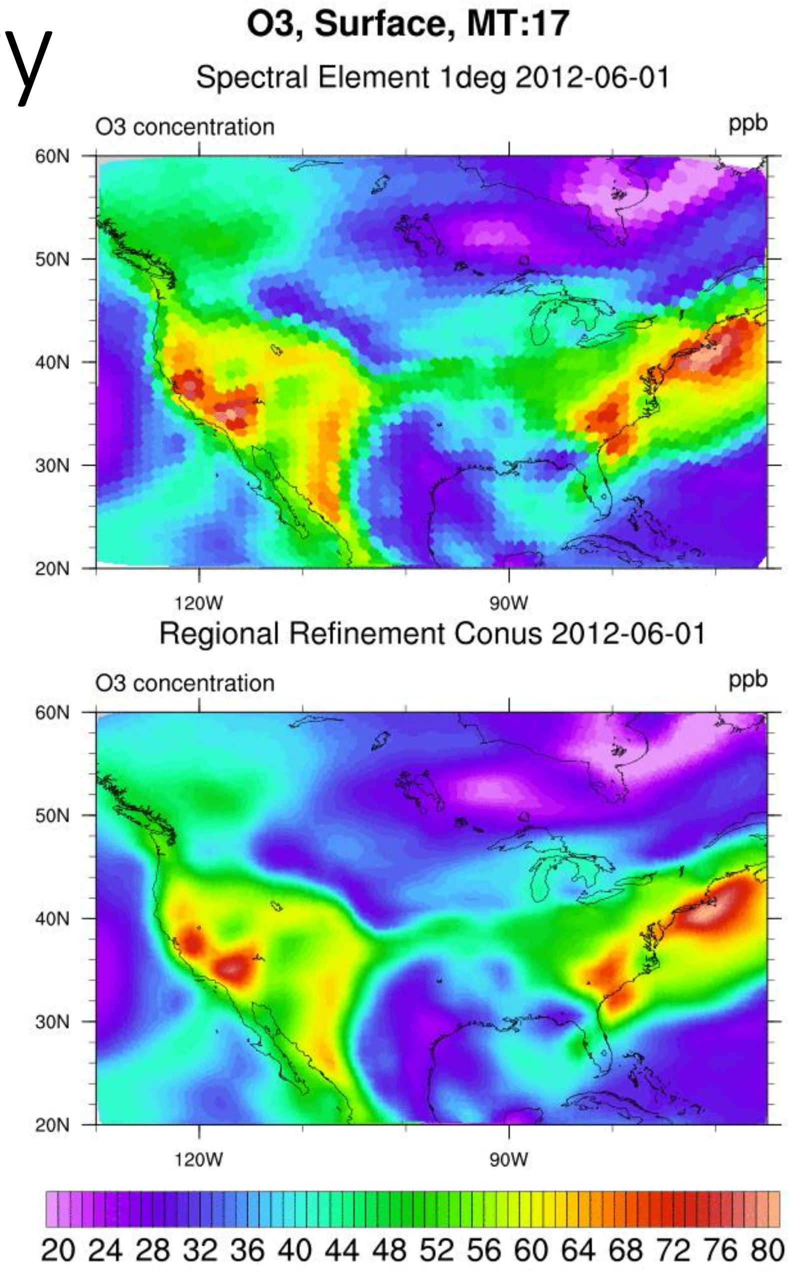
- ATM_GRID: ne0np4CONUS.ne30x8
  - cam6 physics
  - MOZART T1 w/ simple VBS SOA & MAM4 aerosols
- LND_GRID:ne0np4CONUS.ne30x8
  - clm5.0:BGC w/ prognostic crops
- ICE_GRID: tx0.1v2
- OCN_GRID: tx0.1v2
- ROF_GRID:r8th

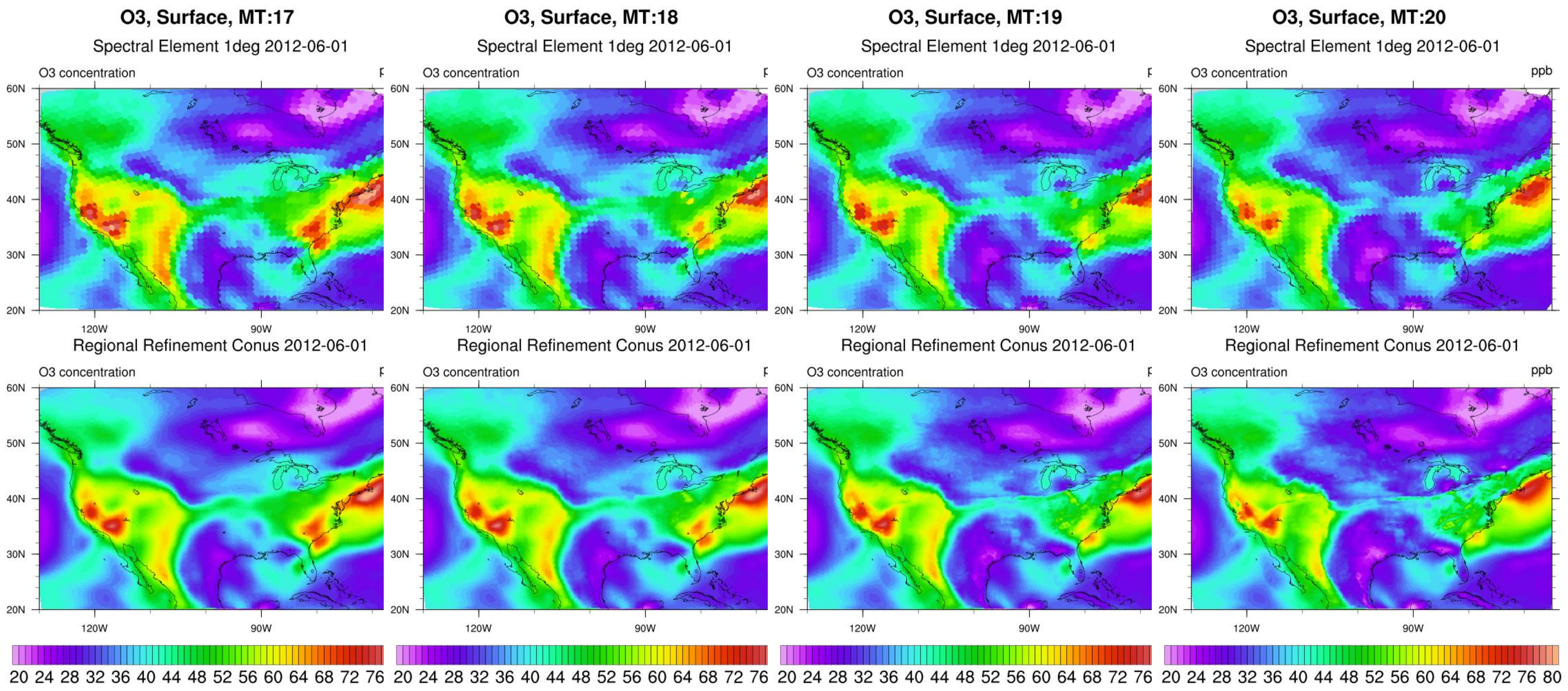
Identical emissions used in both cases, CMIP6 anthropogenic and biomass burning with online emissions form MEGAN for biogenics

All simulations run from the same setup (2 year spinup in CAM-SE (2010-2012))

Preliminary Results



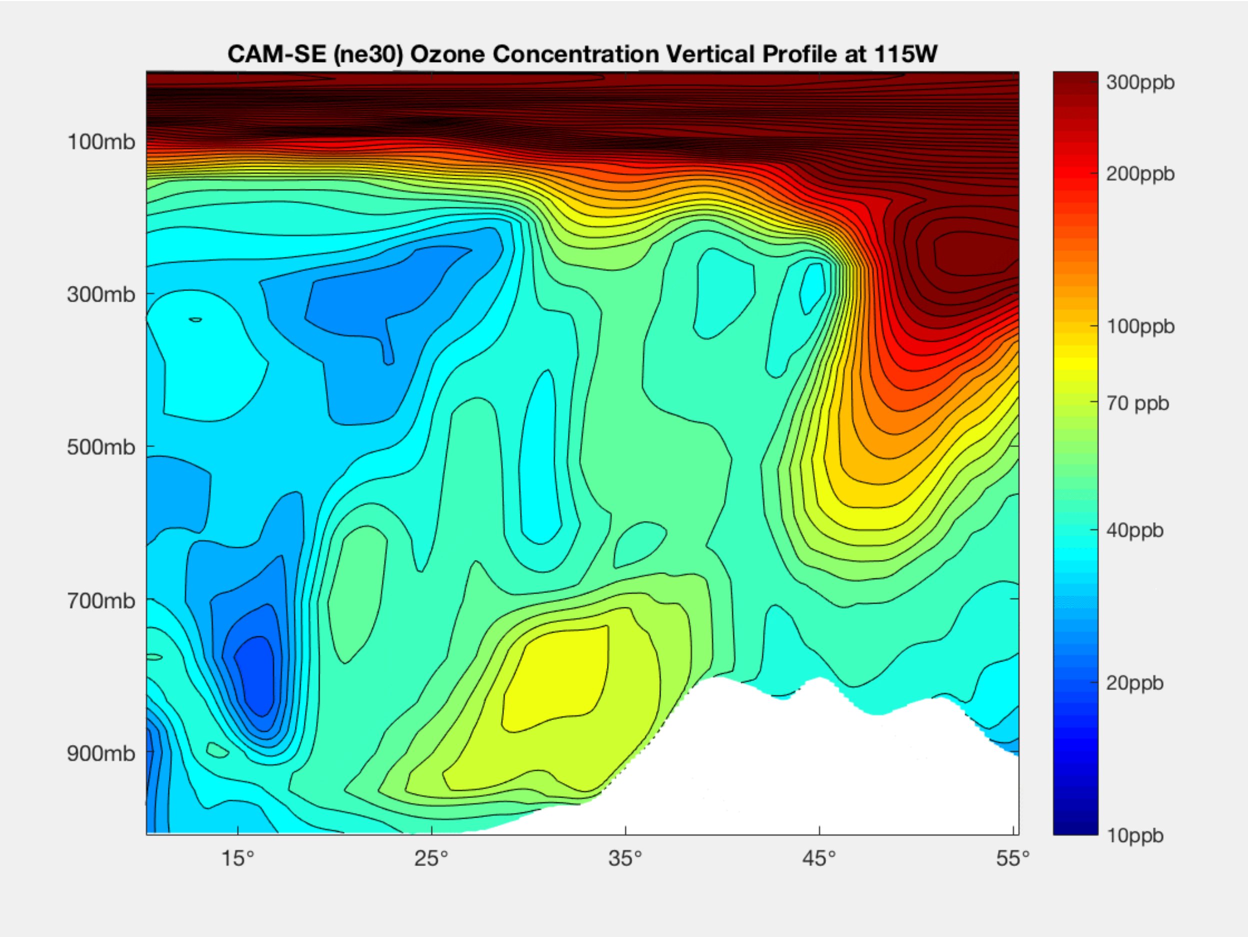




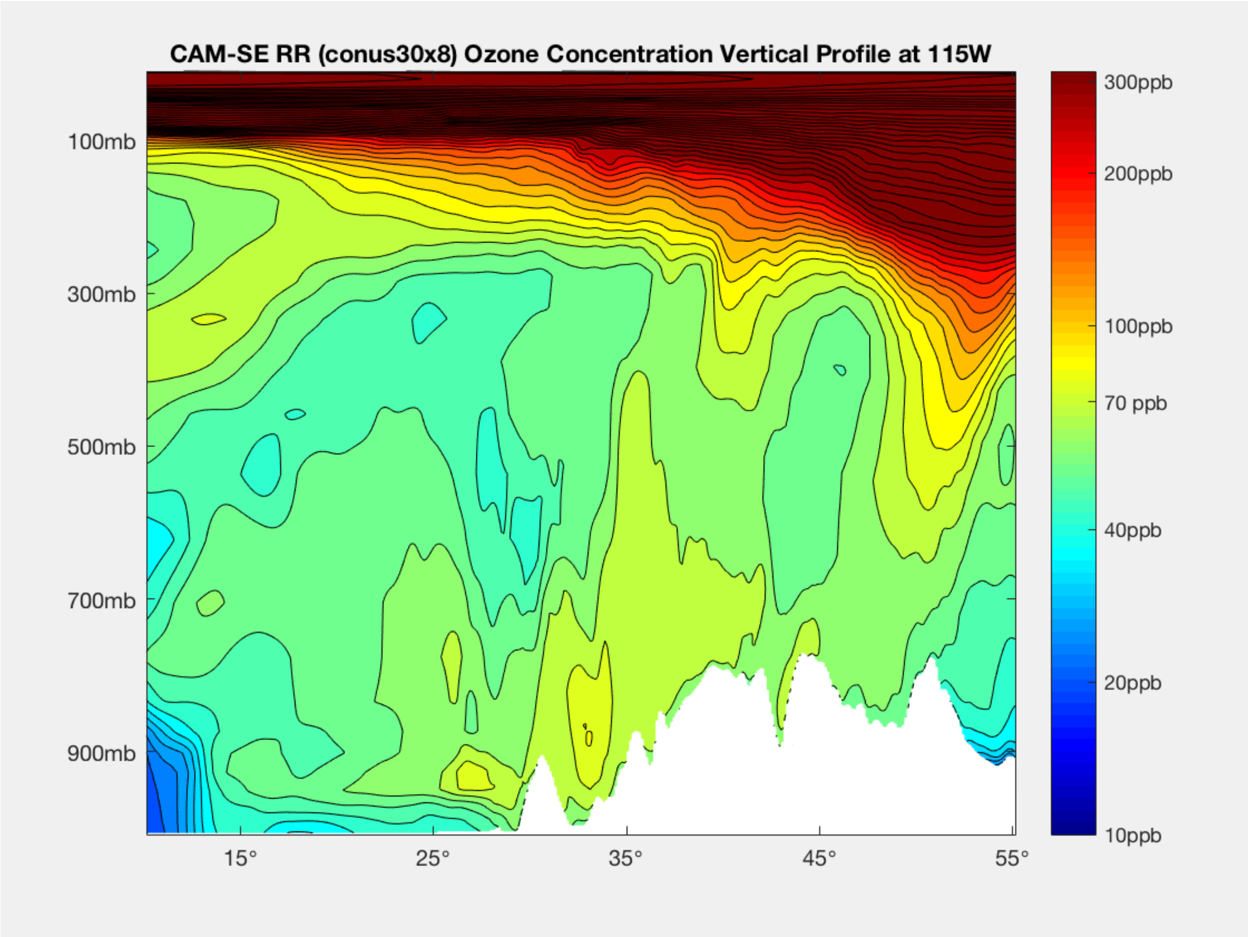
Both simulations use the same IC file from an SE ne30np4 run. Within the first several hours we start to see improved resolution in the SE RR case

June 2012 Daily Avg Concentrations at 115W

CAM-SE (ne30)



CAM-SE RR (conus30x8)

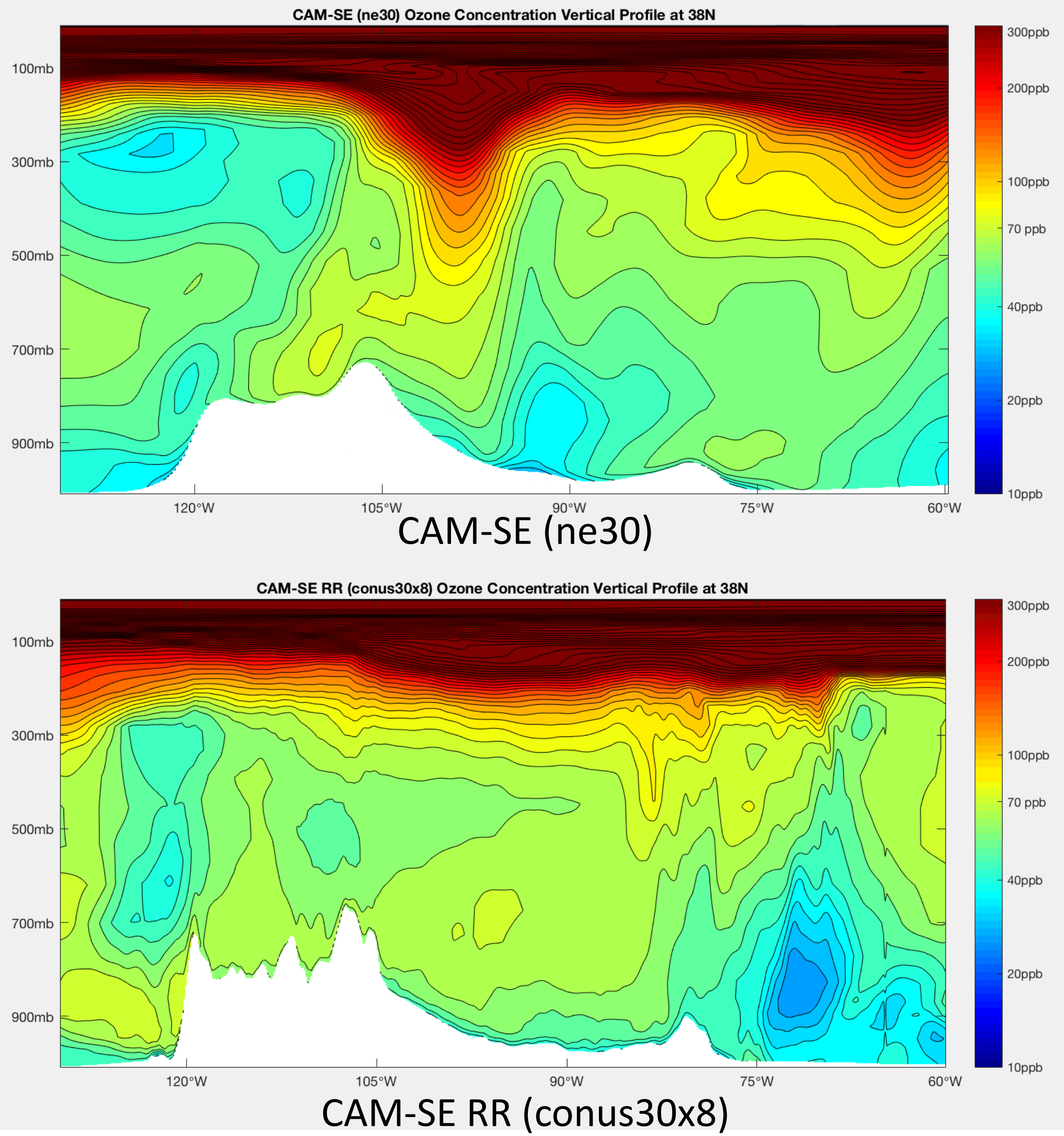


Here the improvement in vertical resolution becomes very apparent. The smoothing of pressure levels often puts us in a different regime for dynamics and vertical transport

June 2012 Daily Avg Concentrations at 38N

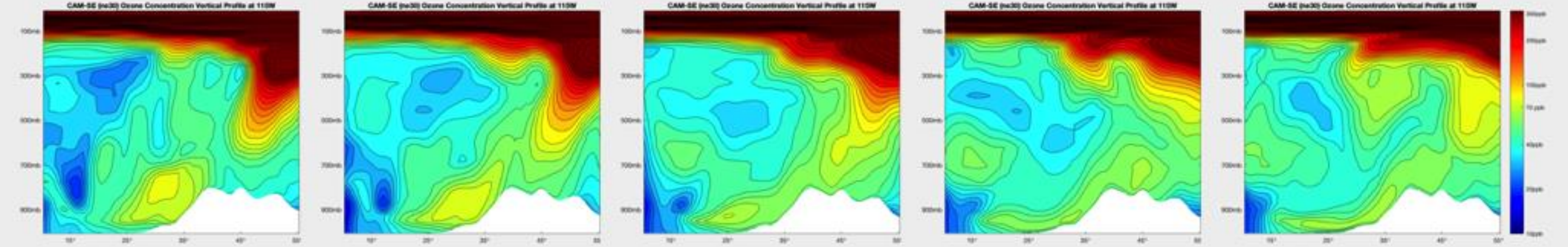
E-W Transects make this behavior even more apparent and show potential stratospheric intrusions of ozone.

What is within the range of acceptable behavior in the model and is higher horizontal (and pressure) resolution driving this?

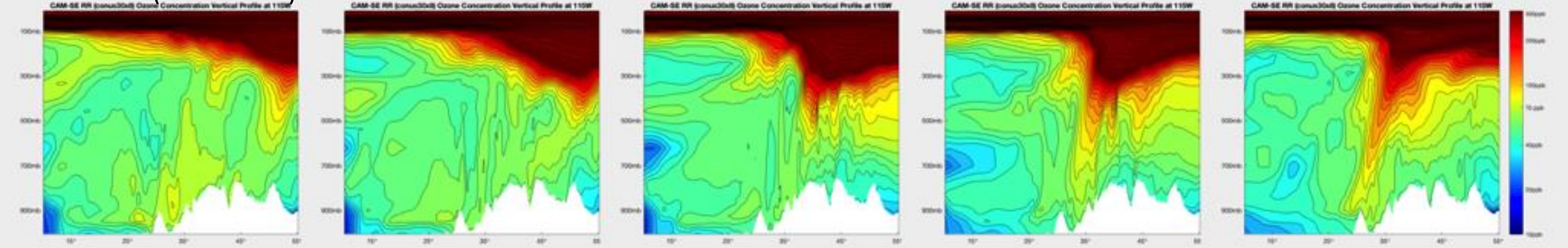


June 2012 Daily Avg Concentrations at 115W

CAM-SE (ne30)



CAM-SE RR (conus30x8)



1JUN 2JUN 3JUN 4JUN 5JUN

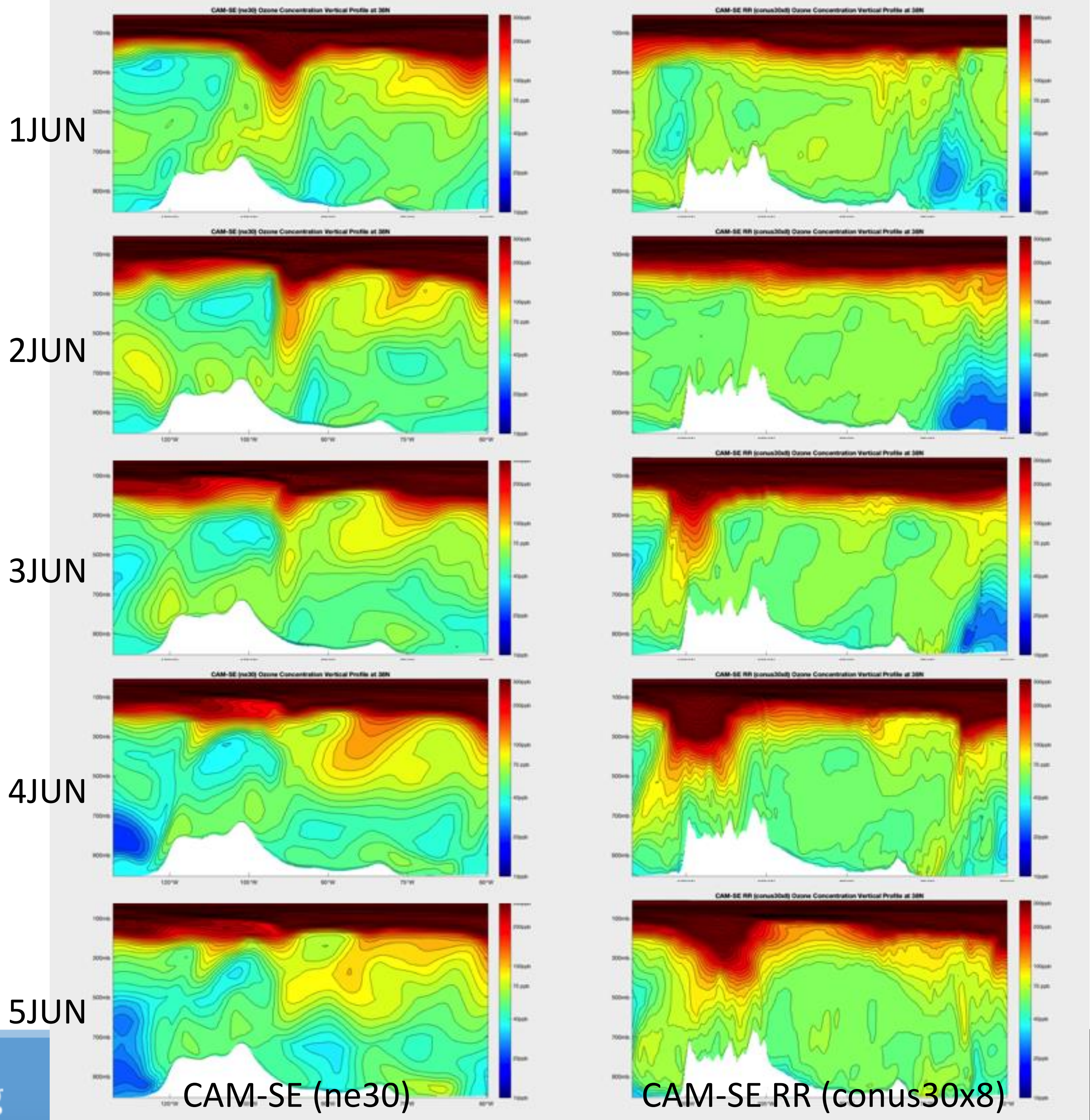
These plot show significant stratospheric intrusions in the CAM-SE RR case, while they are not present in the CAM-SE case

Unsure if this is within the range of reasonable behavior but clearly needs further investigation

Vertical Ozone Profiles

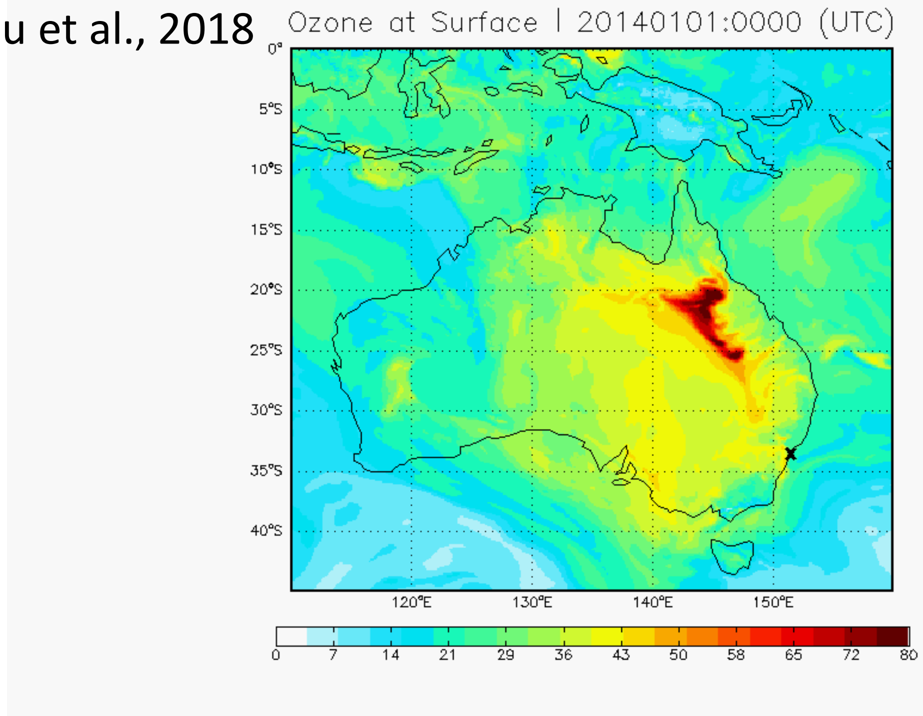
June 2012 Daily Avg Concentrations at 115W

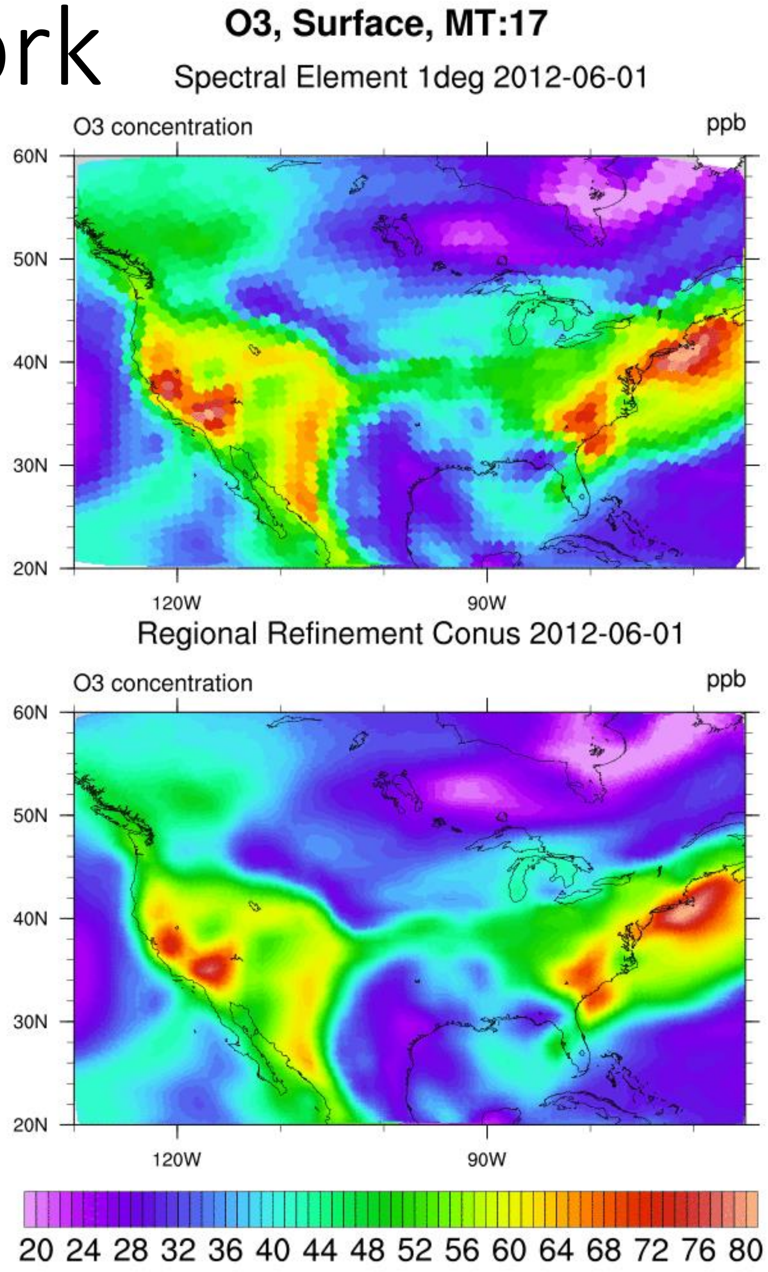
We see the same behavior, albeit a bit more pronounced on the E-W plot. Some event on June 3rd causes a sharp intrusion of stratospheric ozone that persists for several days.



Comparison to similar framework

GEOS-Chem in 12.5 km GEOS-5 Nature Run
Hu et al., 2018





Current development and next steps

- Tune scale-dependent dynamics parameterizations
- Finalize implementation of high resolution emission (NEI 2014)
- Test other regions of interest
  - GBD regions, KORUS-AQ, Europe, ect.
- Validate model using 2012 as comparison year for observations
- Other chemistry items may be discussed in the session tomorrow