Vertical ozone transport at Beltsville, MD

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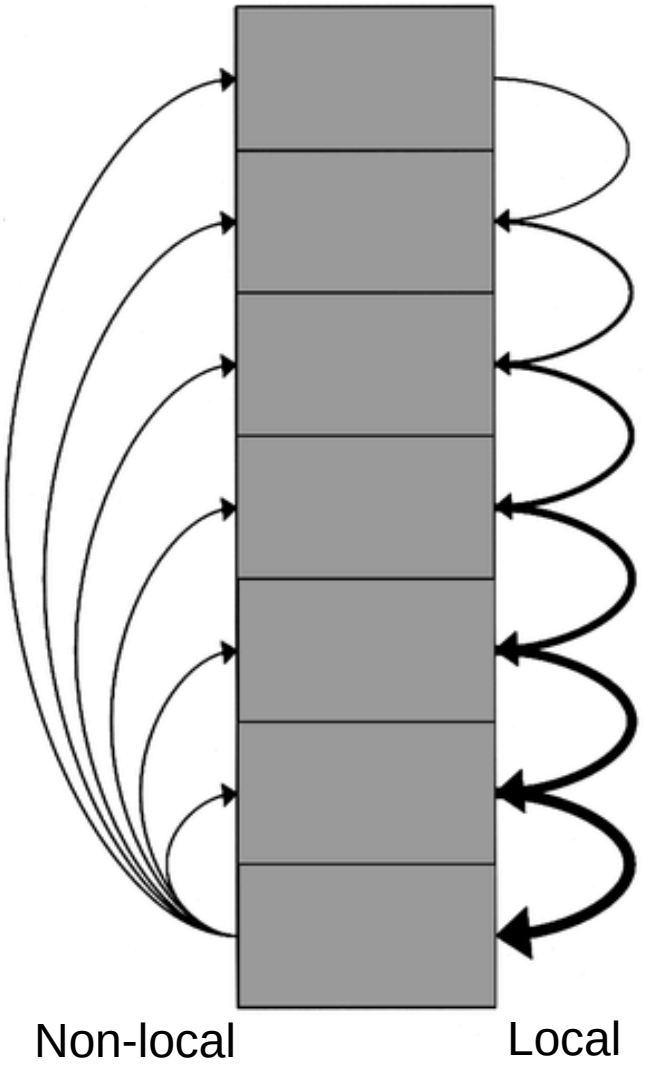
Three PBL schemes in WRF
MYJ, YSU, ACM2

- MYJ: local, down gradient, Kz
- YSU, ACM2: local+non-local

  (YSU implicit,

  ACM2 explicit)



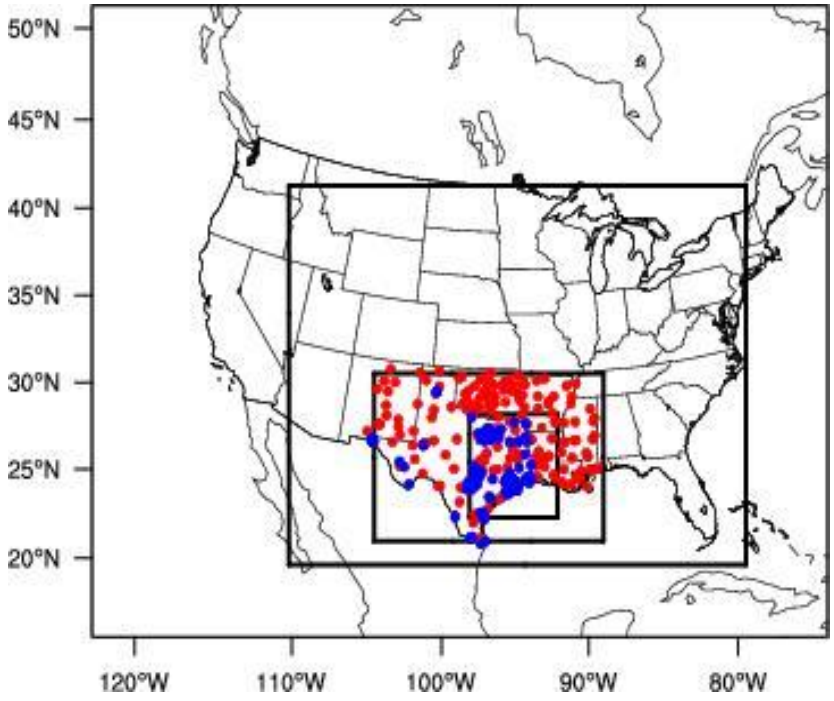
Configurations

Episode & Resolution

- Period: July – Sept., 2005
- Resolution: 108km, 36km, 12km, 4km
- Grids: 53×43, 97×76, 145×100, 166×184

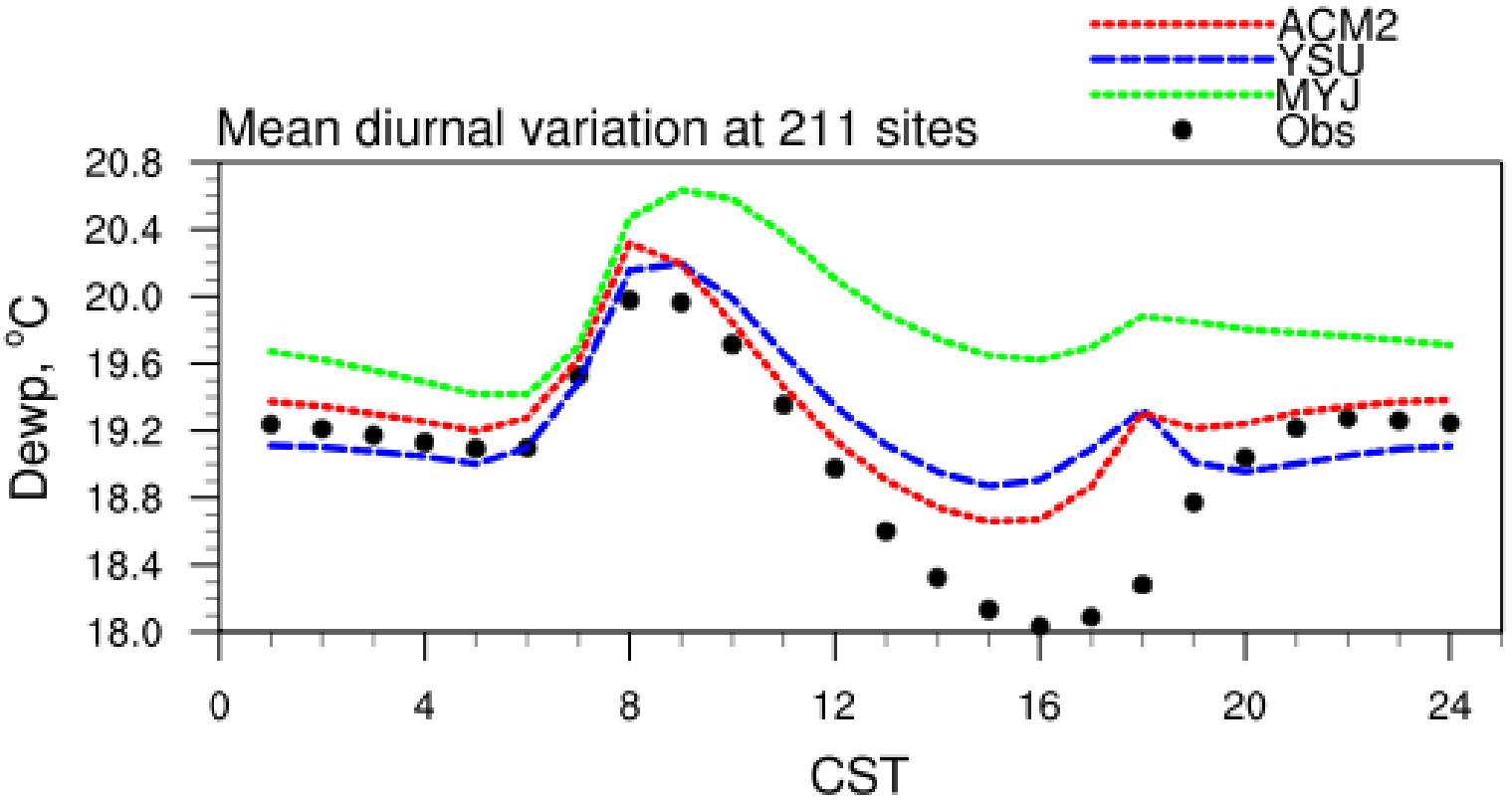
Model Configurations

- YSU, ACM2, MYJ PBL schemes
- WSM 6-class graupel scheme
- NOAH land-surface model (LSM)
- Dudhia short wave radiation
- RRTM long wave radiation
- Grell-Devenyi ensemble cumulus scheme



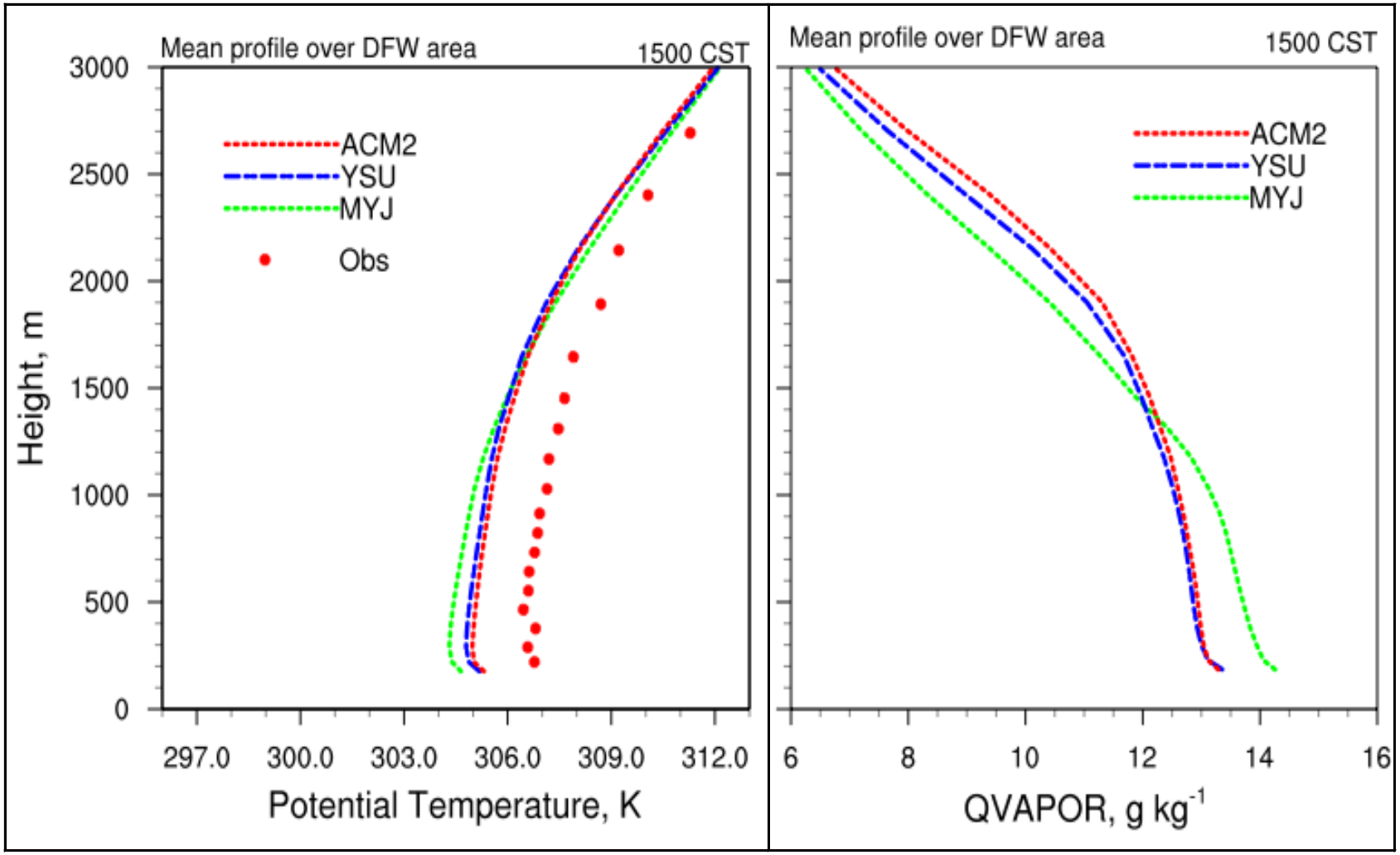
Domains and TCEQ, NWS/FAA sites

Daytime Convective BL (CBL)



MYJ gives the moistest biases near the surface.
Source: Hu, Nielsen-Gammon, and Zhang, 2010

Mean Profiles of T and Moisture



MYJ doesn't mix as high as YSU and ACM2 during daytime

Source: Hu, Nielsen-Gammon, and Zhang, 2010

Current Status of nighttime BL

- Comparing to daytime CBL, progress with modeling of the nighttime BL has been slower (Beare et al., 2006; Hong, 2010).
- Most studies of nighttime BL focused on the stable atmospheric surface layer. The residual layer (RL) is often treated as invariant with regard to ozone mixing ratio (Neu et al., 1994). Only few studies have investigated the exchange of ozone between NBL and RL.

Evolution of the Atmospheric BL

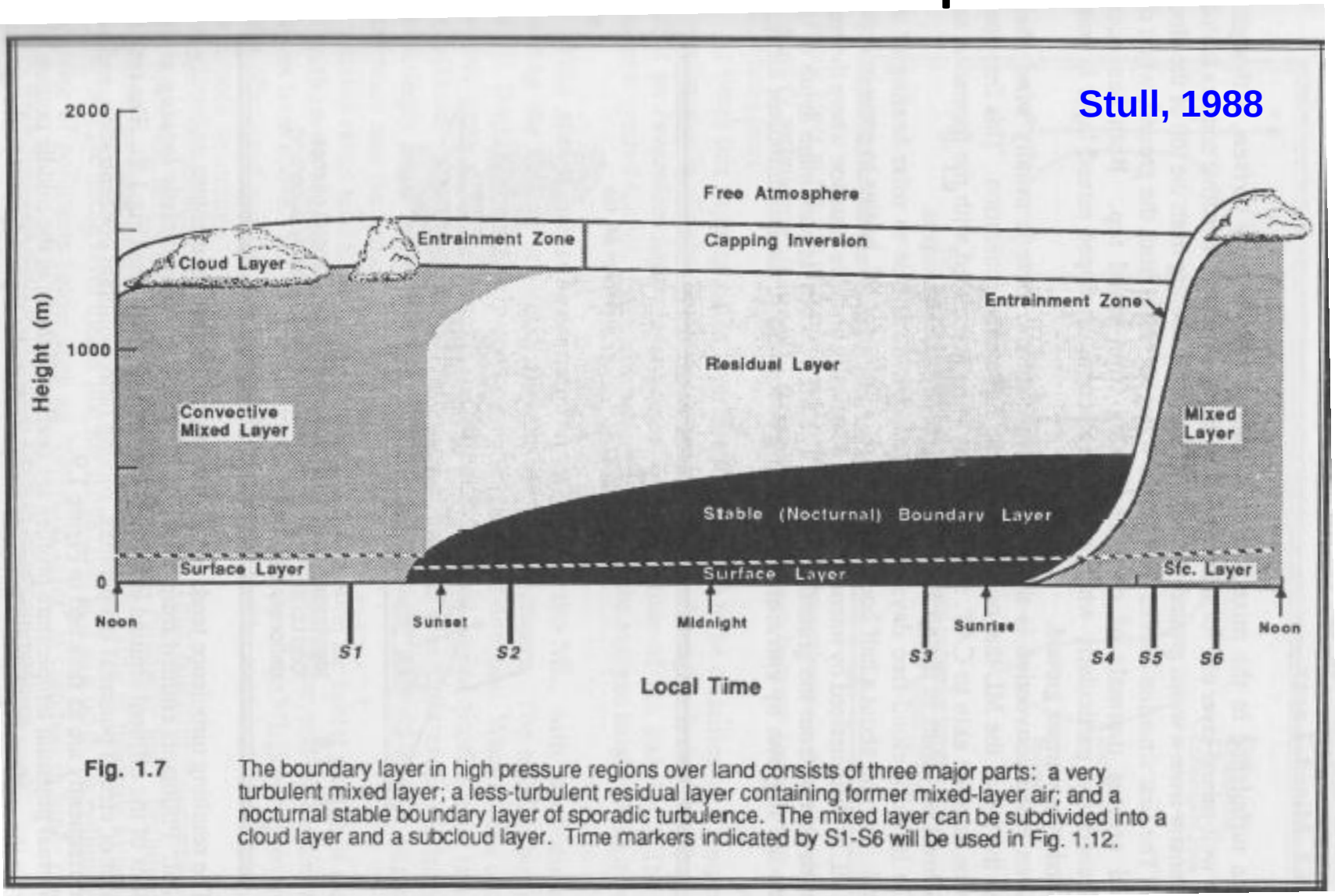
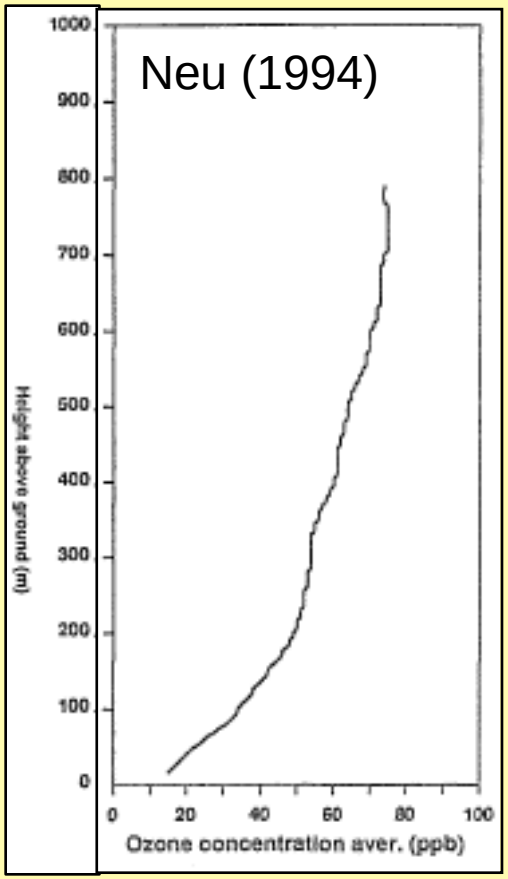
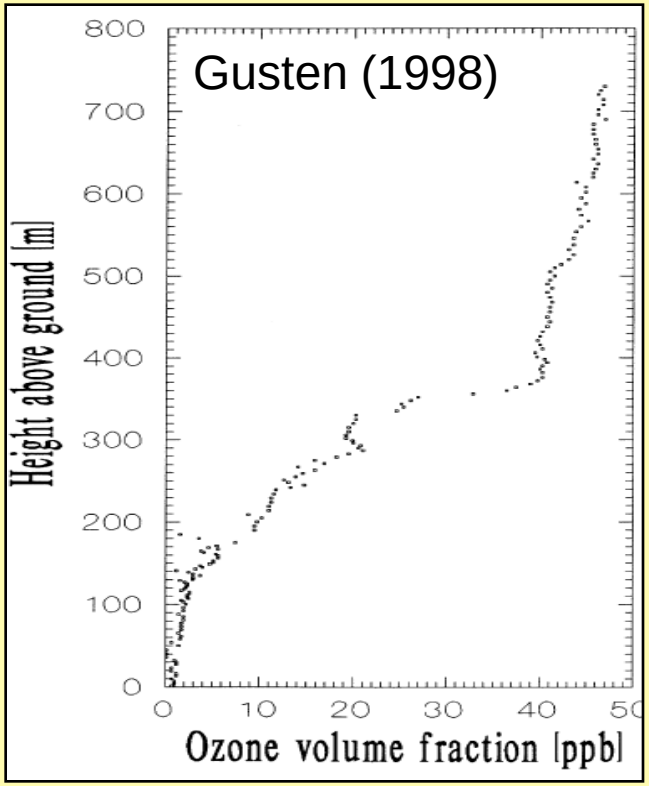
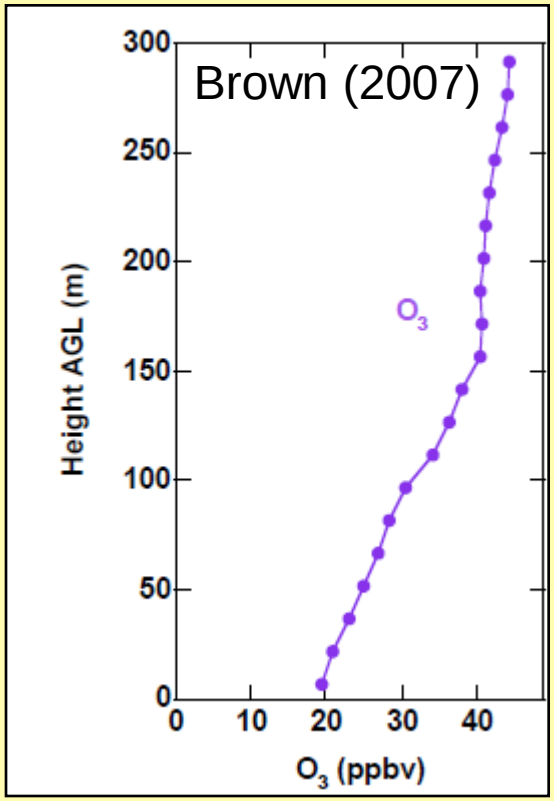


Fig. 1.7 The boundary layer in high pressure regions over land consists of three major parts: a very turbulent mixed layer; a less-turbulent residual layer containing former mixed-layer air; and a nocturnal stable boundary layer of sporadic turbulence. The mixed layer can be subdivided into a cloud layer and a subcloud layer. Time markers indicated by S1-S6 will be used in Fig. 1.12.

Nocturnal ozone variability near the surface







Importance of O_3 in RL

- Ozone mixed down from the RL contributes substantially to the maximum concentration near the surface during daytime (Neu et al., 1994; Zhang and Rao, 1999), thus the variation of O_3 in the RL is important. O_3 concentration was shown to be highly variable in the RL in Lower Fraser Valley, Canada (Salmond and McKendry, 2002).

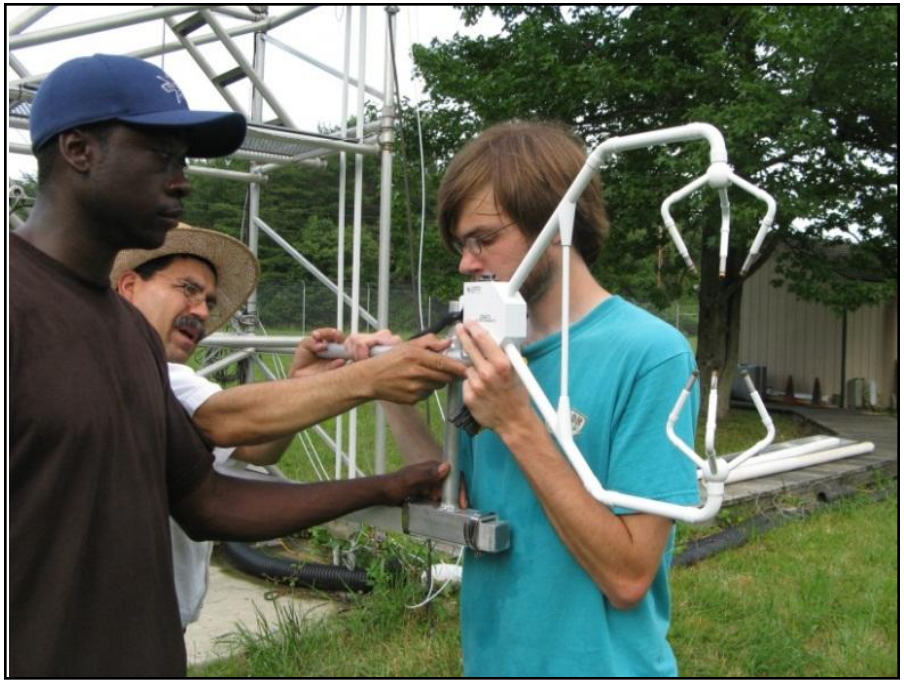
Objectives

- **Investigate the extent of the ozone variability in the residual layer at Beltsville, MD.**
- **Determine the nighttime vertical mixing in the residual layer.**
- **Establish the uncertainties associated with vertical ozone transport with WRF/Chem.**

Methods

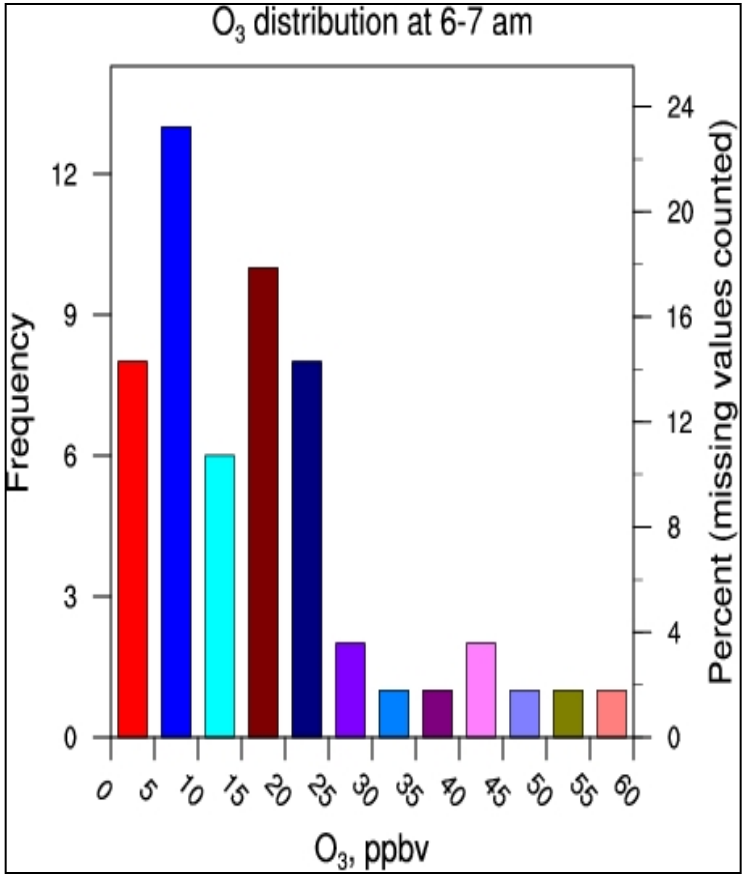
- Surface measurements and ozonesondes.
  - Our understanding of nighttime dispersion of pollutants has been limited by a focus of surface based measurements (Hastie et al., 1993). Extensive measurements of profiles of meteorological variables and ozone in Beltsville provide excellent dataset to investigate the ozone in RL and its vertical mixing.
- Model simulations with WRF/Chem.

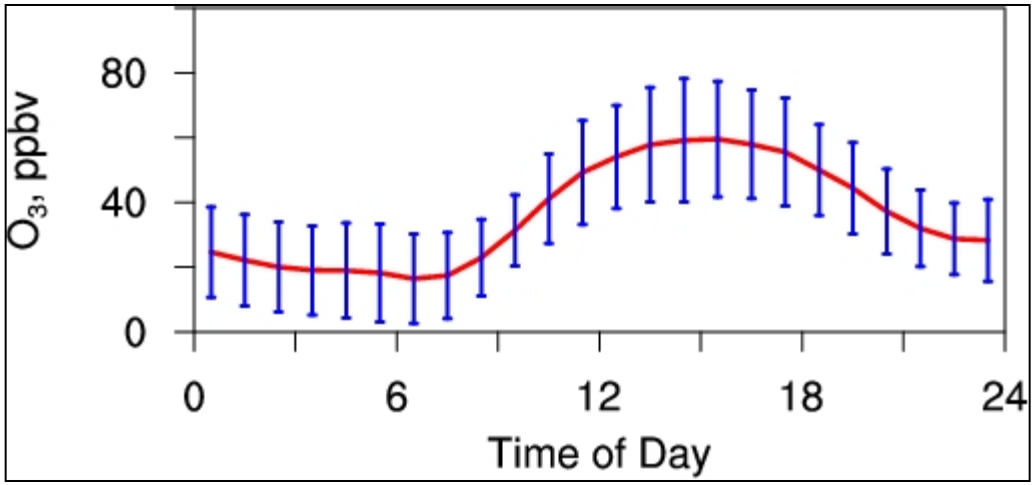
Measurement at Beltsville, MD

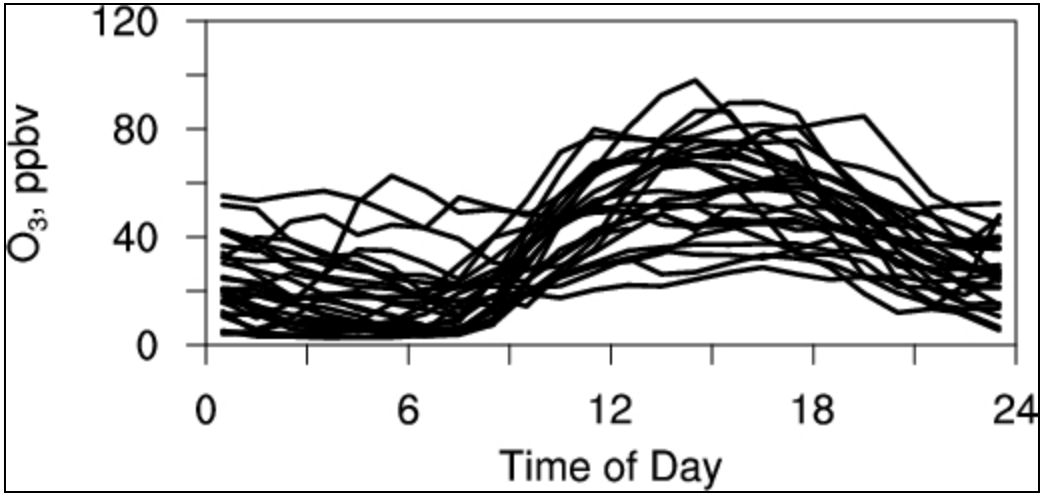


Ozone Time-series analysis

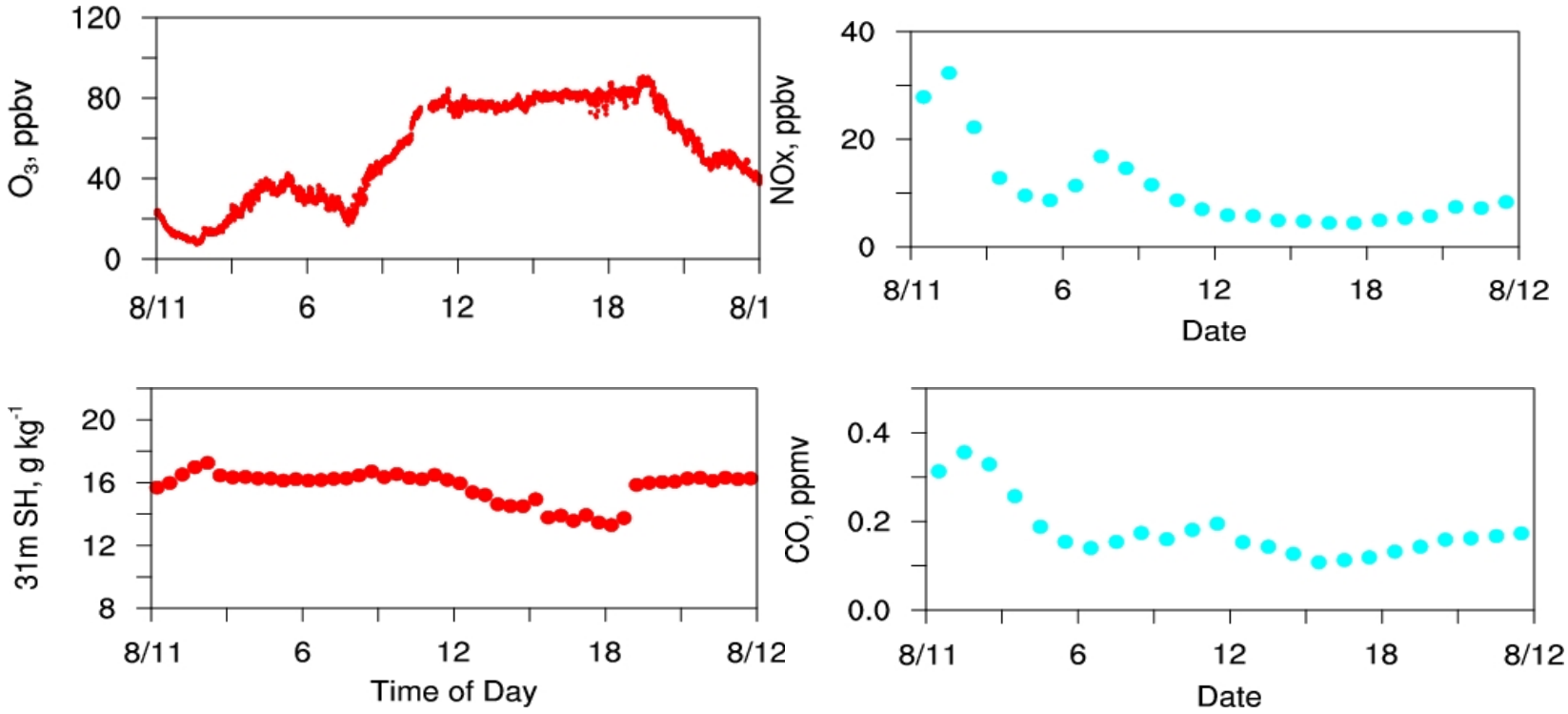
- Note outlier days







“Leaky Inversion”



Set up the WRF/Chem model for the mid Atlantic region

Resolution

- Resolution: 36km, 12km, 4km
- Grids: 100×78, 121×115, 160×157
- Vertical layers: 44 up to 100hPa

Model Initial Condition and Boundary Condition

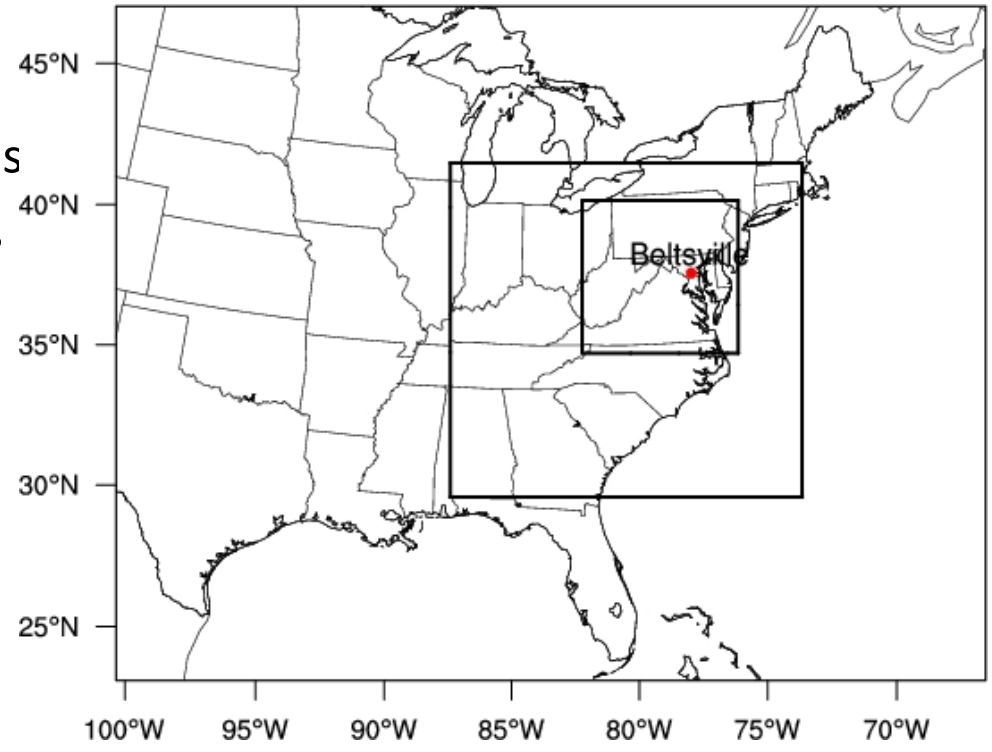
- MOZART4 output for chemical species
- FNL data for meteorological variables

Model Configurations

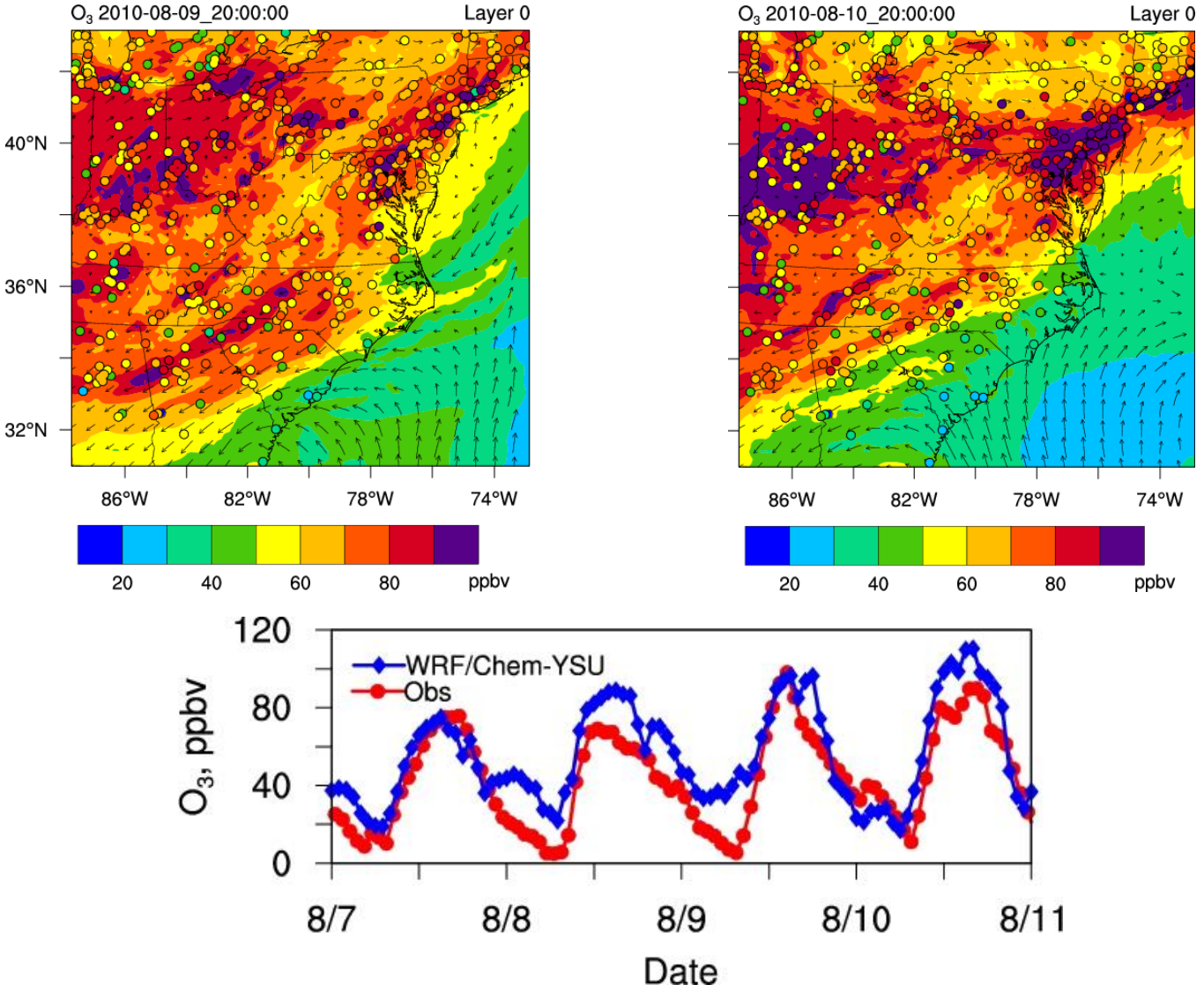
- Dudhia short wave radiation
- RRTM long wave radiation
- NOAH land-surface model
- YSU/ACM2/MYJ PBL scheme
- Monin-Obukhov surface scheme
- WSM6 microphysics
- Grell-Devenyi ensemble cumulus scheme (domain 1 and 2)
- RADM2/RACM gas phase mechanism

Emissions

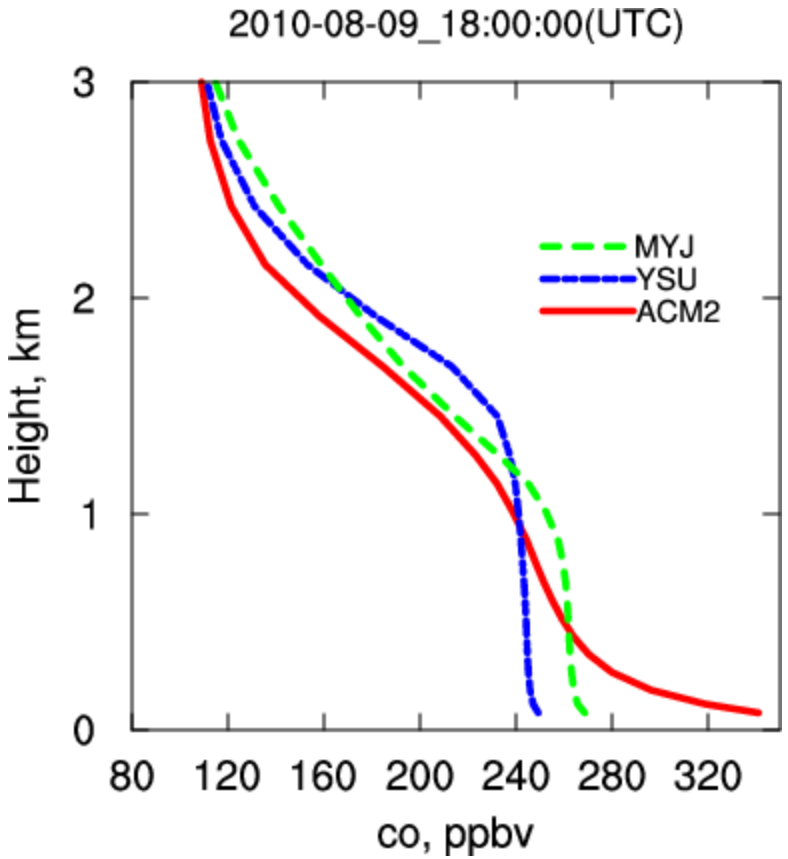
- National Emissions Inventory (NEI) 2005 inventory



Episode of August 9-10, 2010

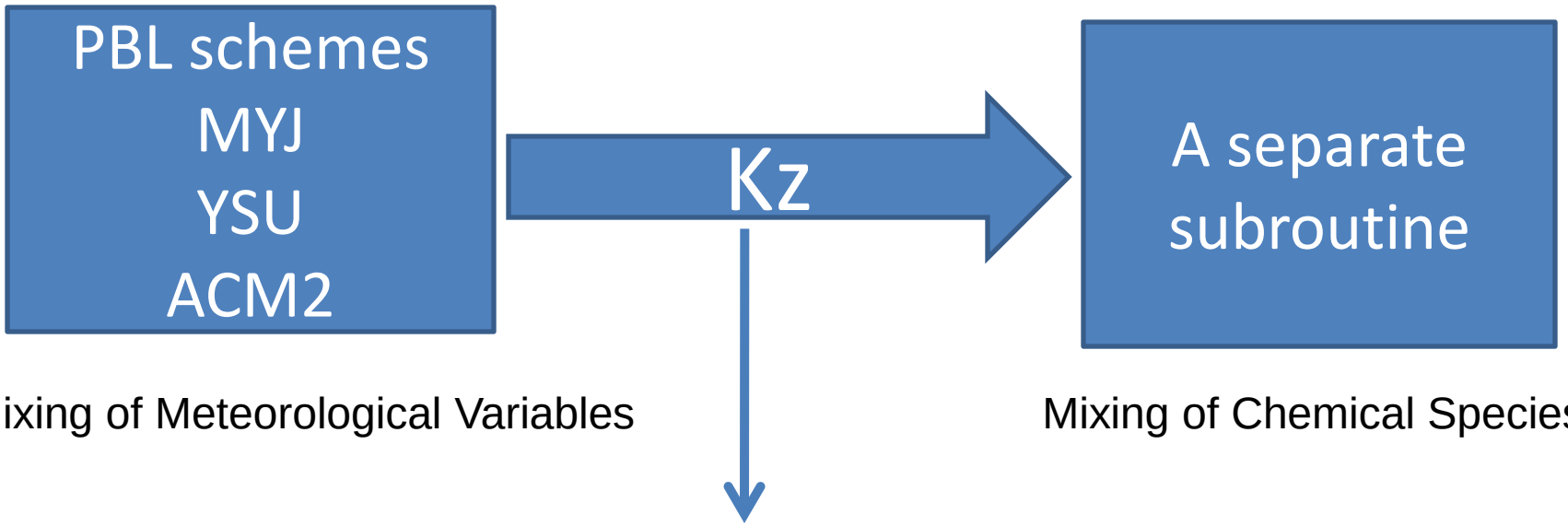


ACM2 not properly implemented?



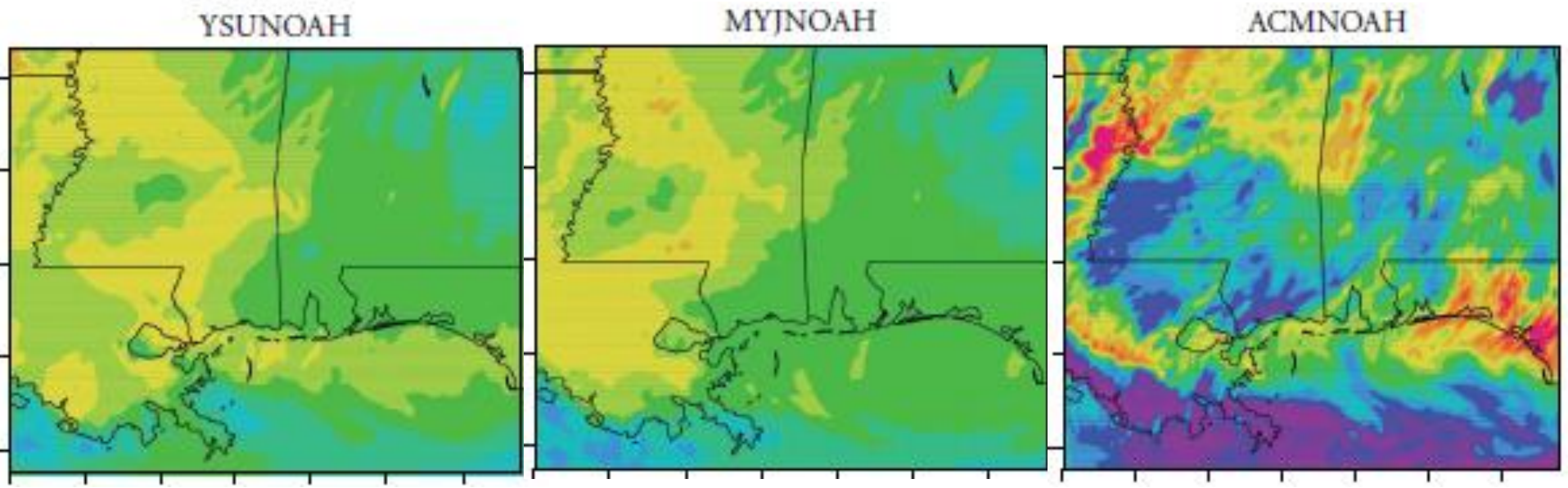
Current implementation of ACM2 in WRF/Chem is not able to simulate the vertical mixing of chemical species properly

Treatment of Vertical Mixing of Chemical Species



ACM2 does not diagnose Kz, thus no much mixing for chemical species

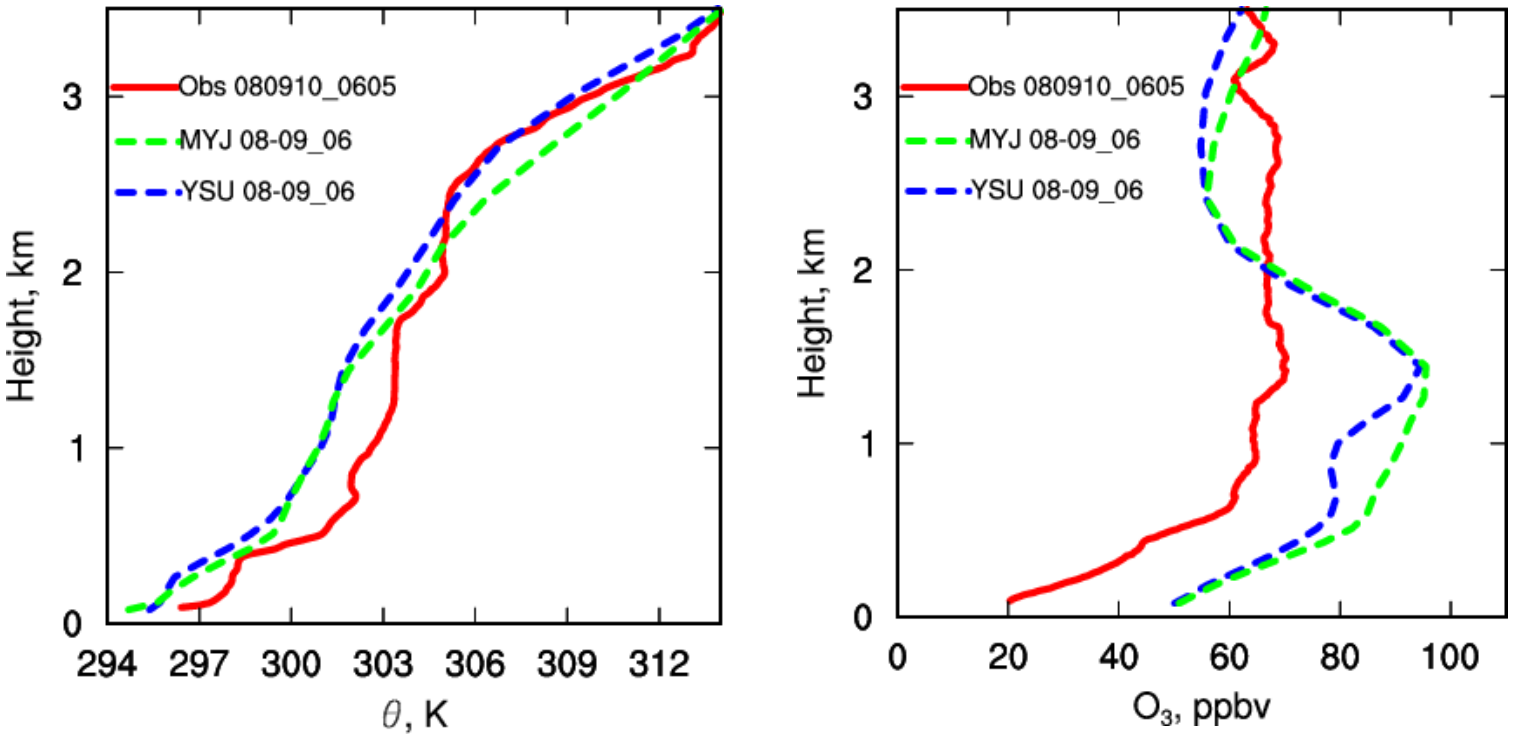
O_3 simulation using three PBL schemes



Yerramilli et al. (2010)

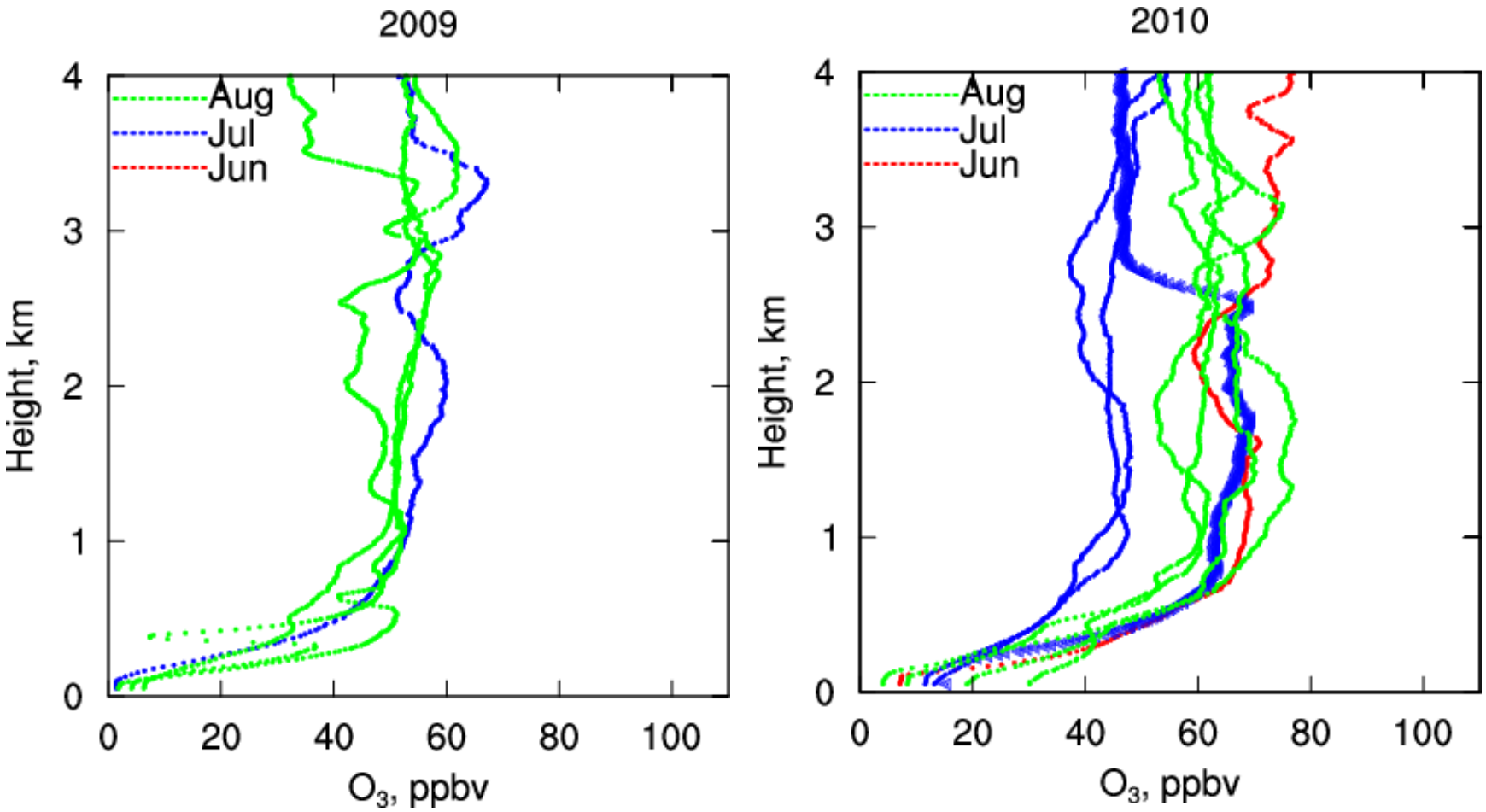
Current implementation of ACM2 in WRF/Chem is not able to simulate the vertical mixing of chemical species properly

Deficiency of Model at the top of RL?

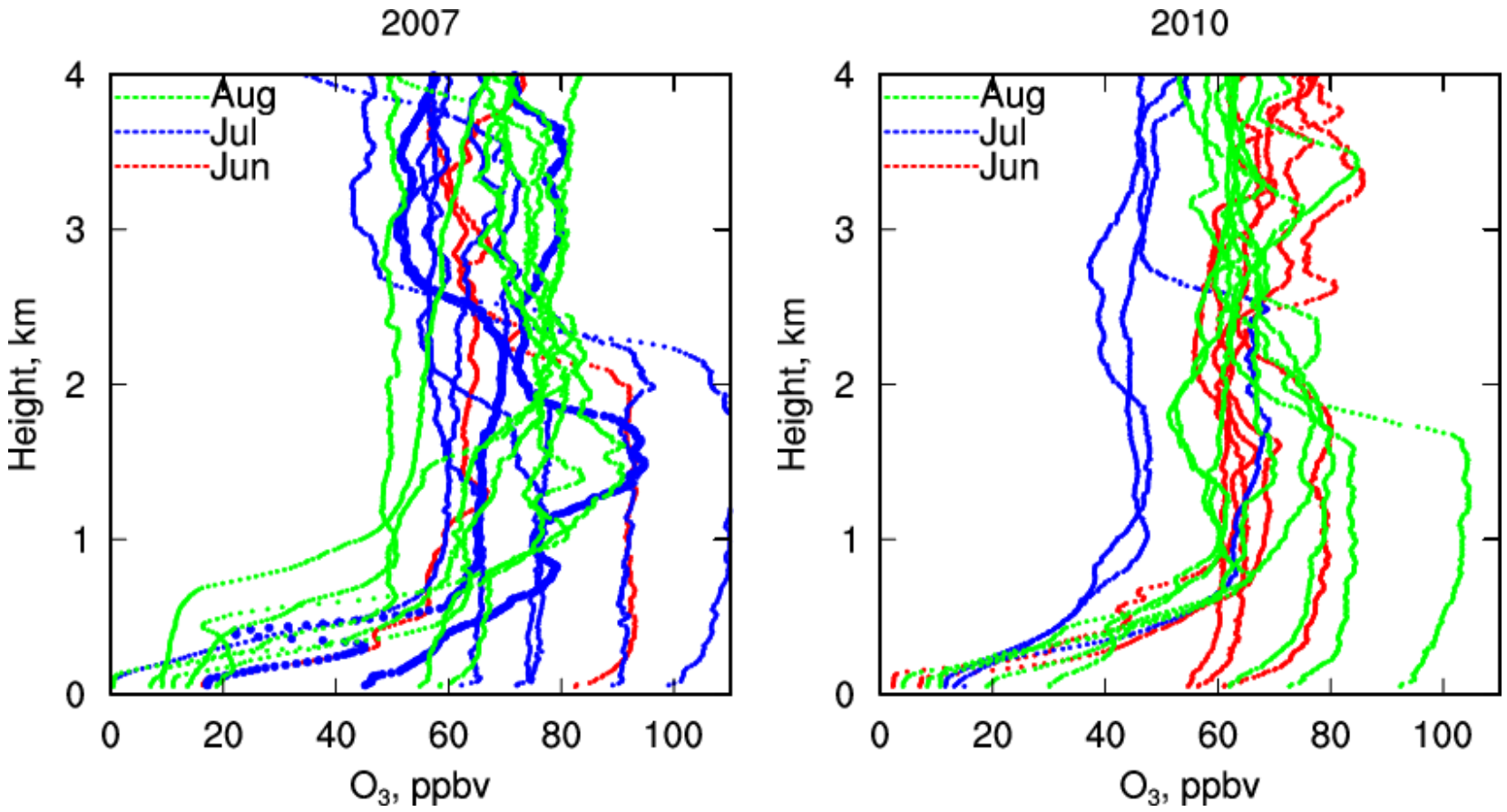


Strong gradient of O_3 between the RL and the free troposphere above from WRF/Chem; Too weak vertical mixing at those levels in the model?

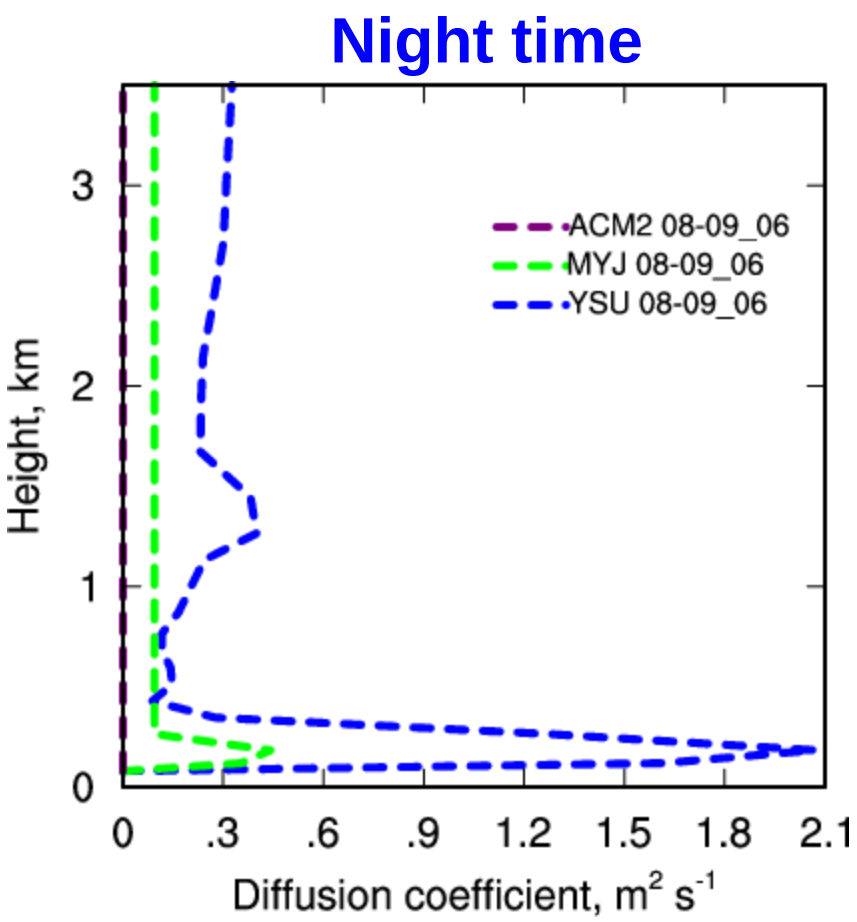
Nighttime O_3 profiles

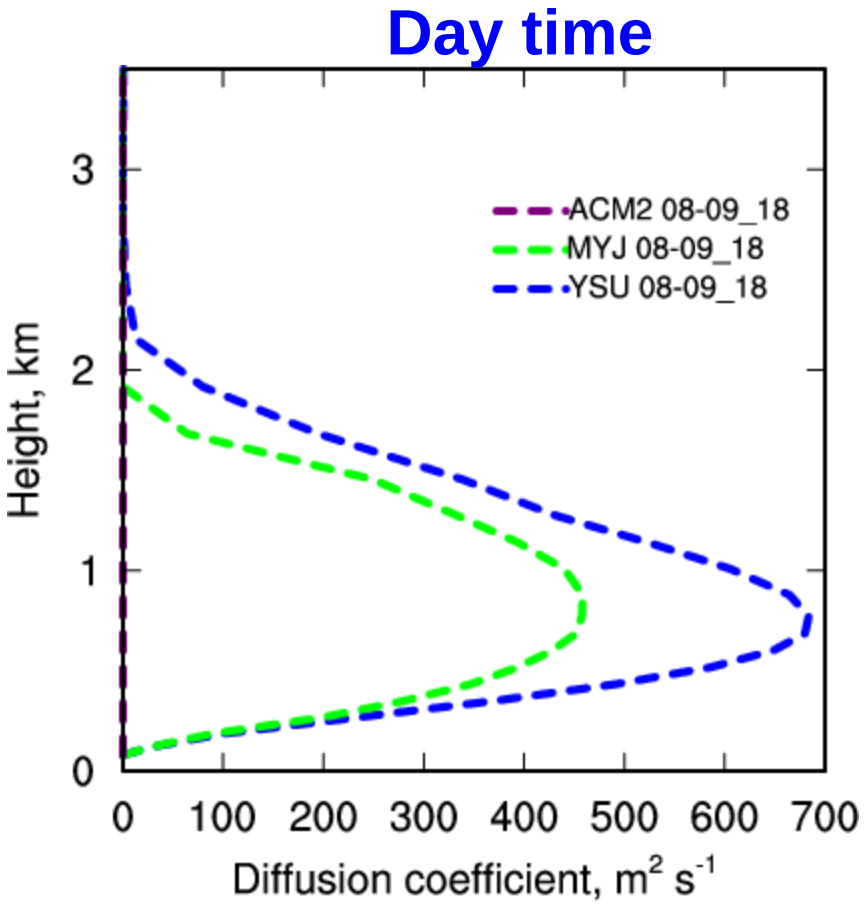


Large Variation of O_3 in RL

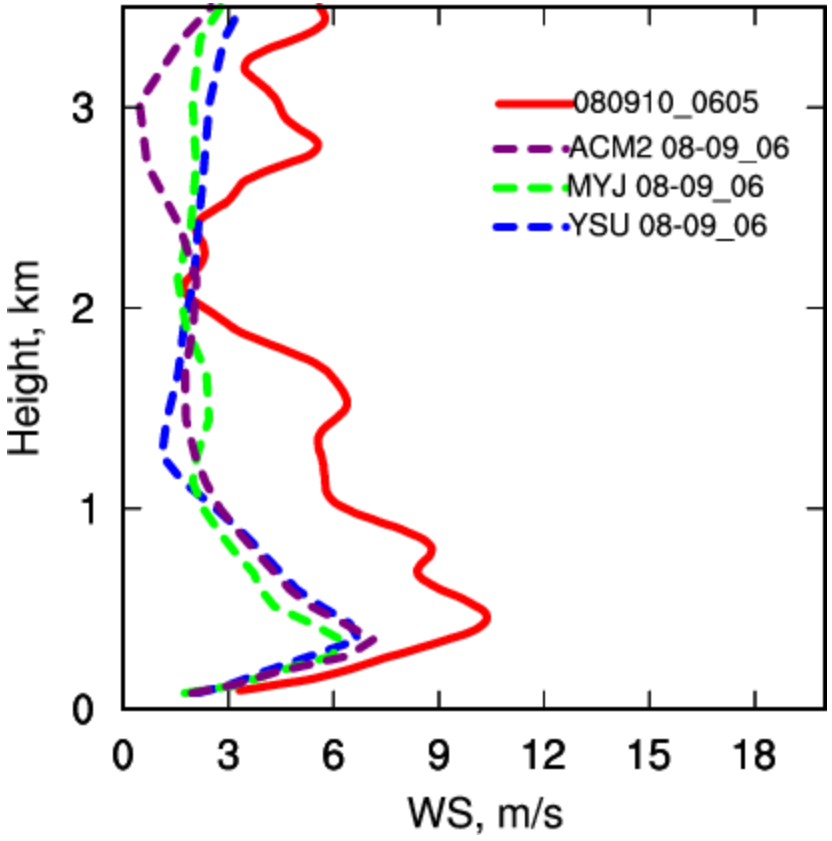


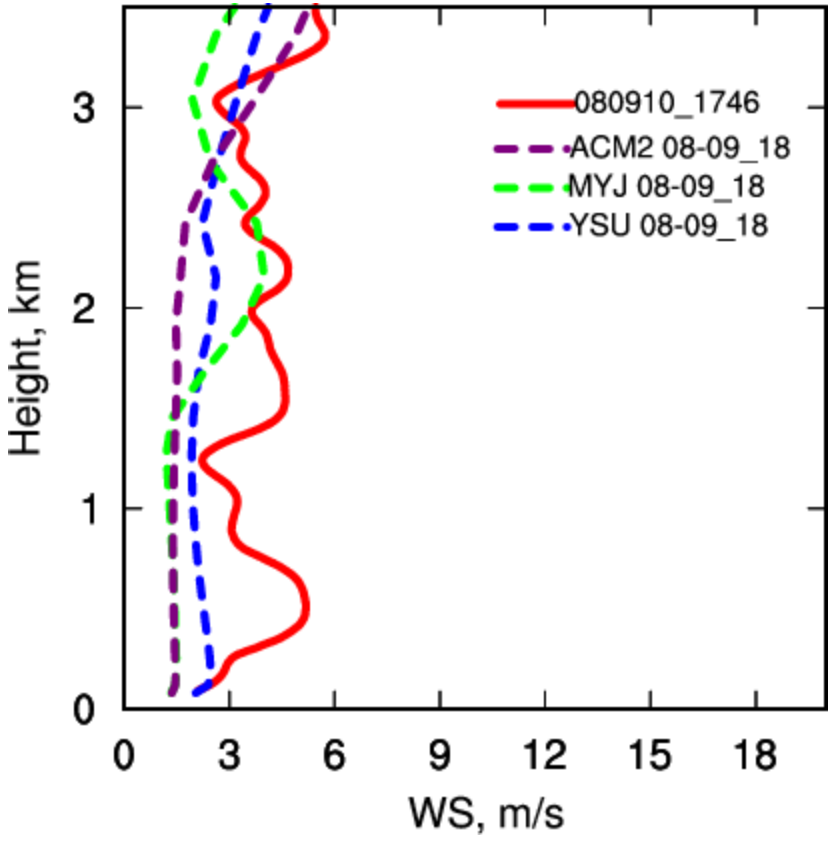
Profiles of eddy diffusivity





Profiles of Wind Speed



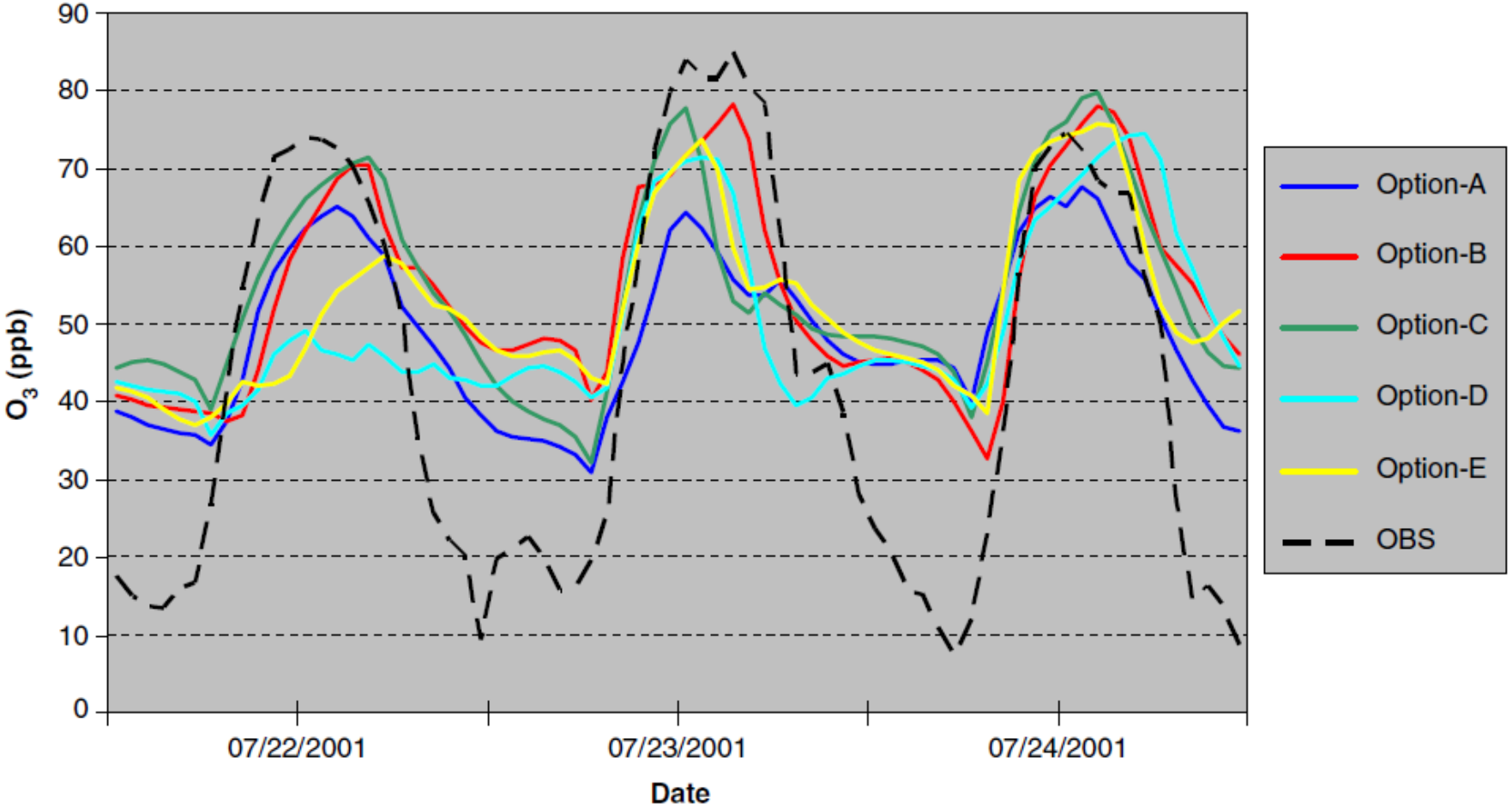


Low vertical mixing in the RL in the model is due to less wind variation?

Conclusions and Implications

- Ozone in the RL is highly variable.
- The strong ozone gradient between the RL and the free troposphere disappear during most of the nights. This is indicative of vertical mixing in the RL.
- Model cannot reproduce the vertical ozone profiles during nighttime, especially at the top of the RL.

Common problem in AQMs



CMAQ simulations (Mao et al., 2006)