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Sensitivity of WRF Surface Fluxes to PBL and LSM Parameterizations During Persistent Cold Air Pools

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American Meteorological Society – Boundary Layers and Turbulence Meeting

Salt Lake City, Utah, USA

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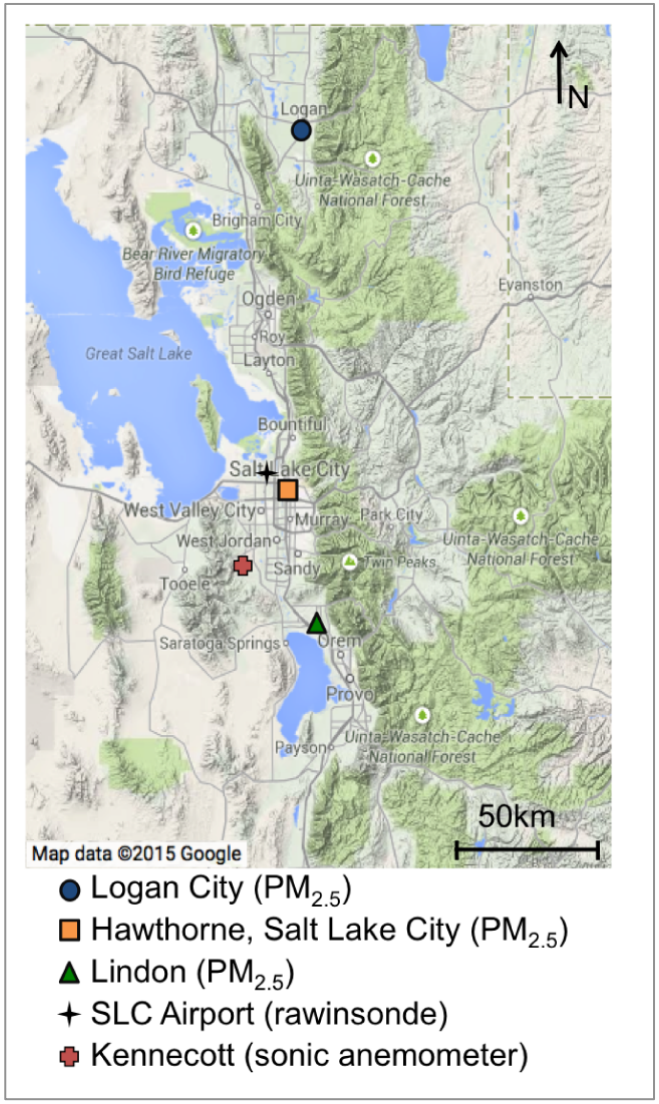
Cold Air Pool (CAP)
Salt Lake Valley, Utah, USA



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Wintertime Air Pollution: Cold Air Pool

13 Feb 2004 (CAP)

18 Feb 2004 (Mix Out)

21 Feb 2004 (CAP)

- Stable atmospheric boundary layers
- Decrease in boundary layer height
- Inhibited mixing
- **Leads to an increase in pollutant concentrations!**

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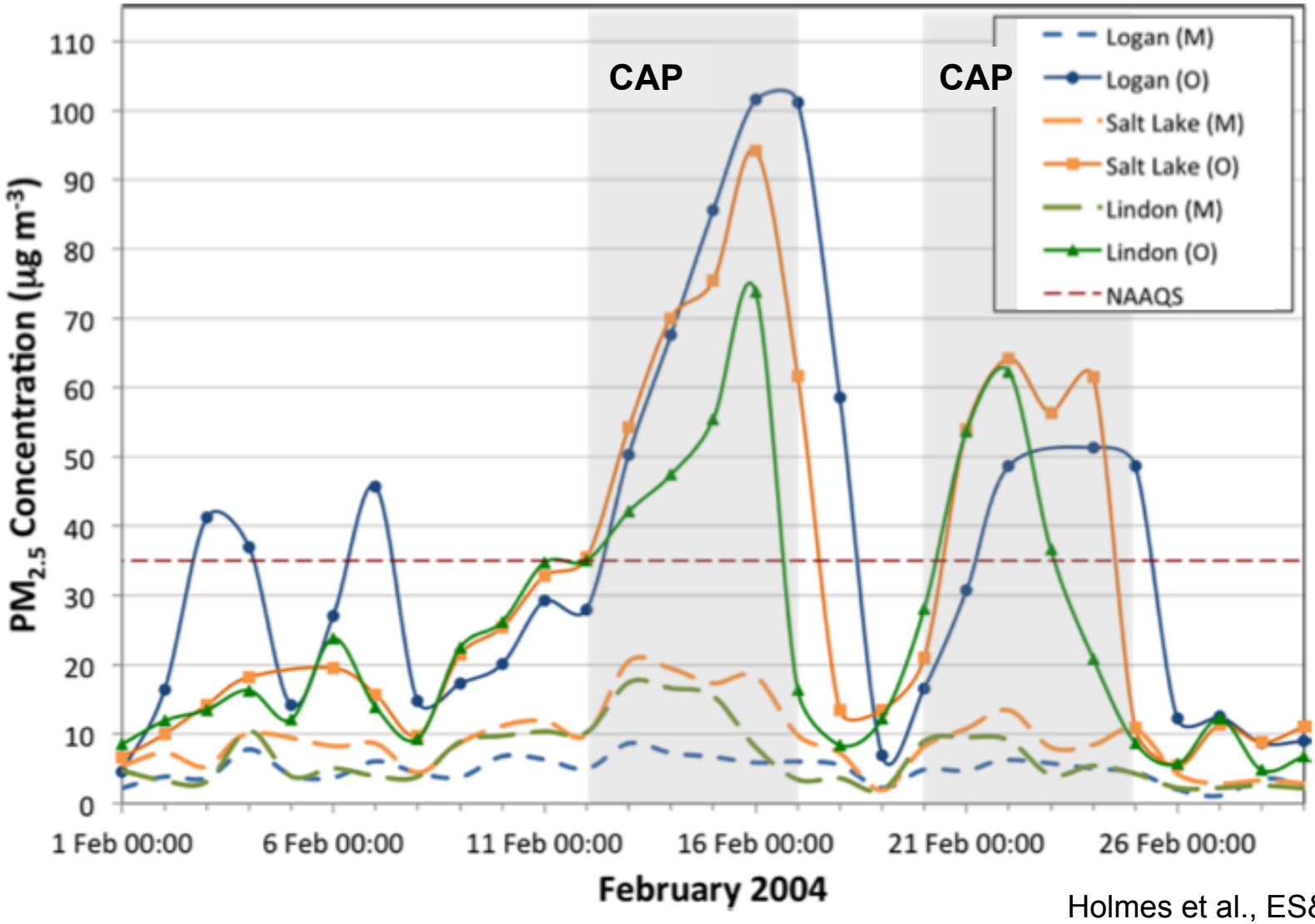
Particulate Matter: Observations vs. Model



Holmes et al., ES&T, 2015

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Objectives and Hypotheses

Objectives

- Quantify surface fluxes during wintertime CAPs

  Holmes, H. A., Sriramasamudram, J. K., Pardyjak, E. R., & Whiteman, C. D. (2015) *Environmental science & technology*, 49(22), 13206-13214.

- Compare obs to numerical weather prediction (NWP) results
- *Use NWP results in chemical transport model*

Hypotheses

- Modeled will over estimate surface fluxes compared to observations during all time periods
- NWP model will not predict the decrease in atmospheric turbulence during wintertime CAPs

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Approach

- Measure turbulence and surface fluxes using a fast response sonic anemometer
- Use NWP model to simulate meteorological conditions
- Sensitivity testing of planetary boundary layer (PBL) and land surface model (LSM) schemes in NWP
- Collect $PM_{2.5}$ mass concentrations form regulatory monitoring networks in northern Utah
- *Model air quality using a chemical transport model to investigate air pollution concentrations*

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Numerical Weather Prediction Model

Weather Research & Forecasting (WRF) v3.7.1

- NCEP North American Regional Reanalysis: 32km
- 3 Nested Domains: 12km, 2.4km, 480m
- 30 Vertical Levels: 10 in first 1,000m AGL
- Surface and Upper Air Nudging: OBSGRID
  - Surface: T, u, v, q
  - Vertical, all levels: u, v
  - NCEP ADP surface and upper air weather data
- Land Use Classification: USGS 24-category data

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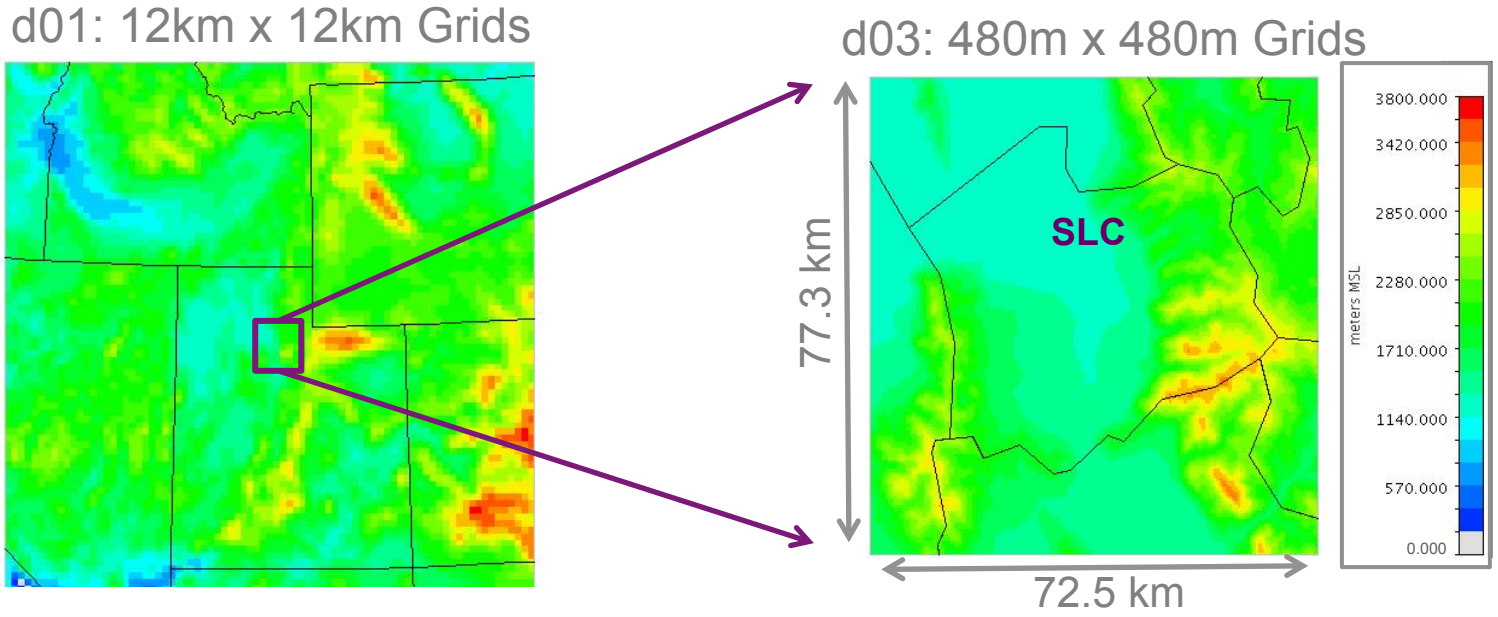
WRF Physics Options

- **Cloud Microphysics:** Lin
- **Longwave Radiation:** Rapid Radiative Transfer Model
- **Shortwave Radiation**: Dudhia
- **Cumulus Parameterizations**: Kain-Fritsch
- **Cloud Fraction Option:** Xu-Randall



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Sensitivity Testing: PBL, LSM, Surface Physics

Planetary Boundary Layer, Surface Physics, Land Surface

1. ACM2, Pleim-Xiu, Pleim-Xiu (with soil nudging) [PLX]
2. YSU, Monin-Obukhov Similarity, Noah [YSU]
3. MYJ, Monin-Obukhov Janjic Eta Similarity, Noah [MYJ]
4. BouLac, Monin-Obukhov Similarity, Noah [BLC]

Combination based on what the PBL model developers intended the configuration to be!

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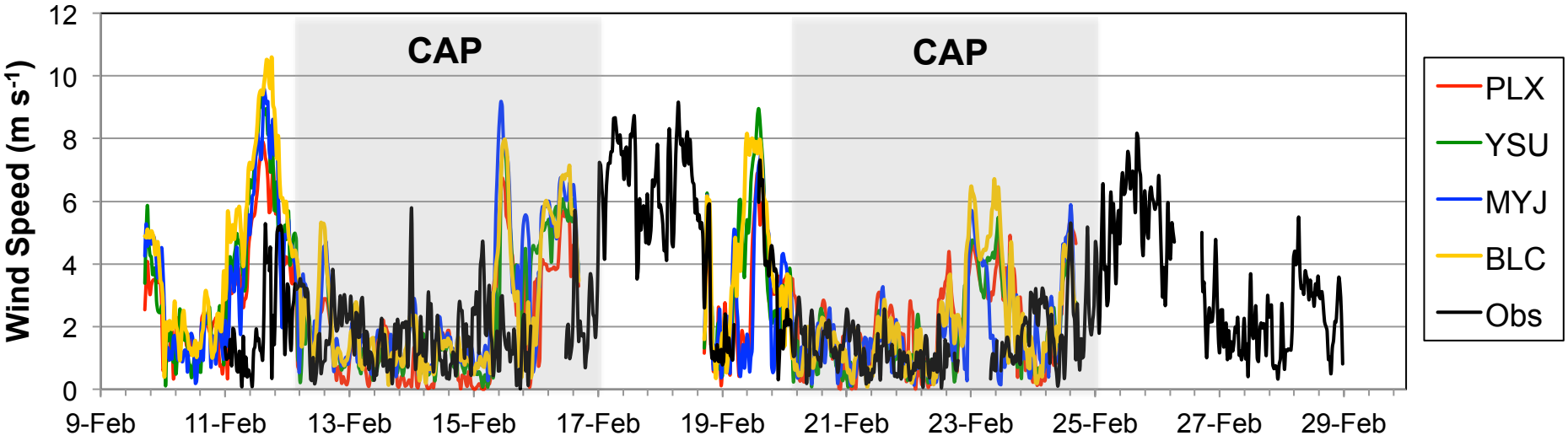
Wind Speed



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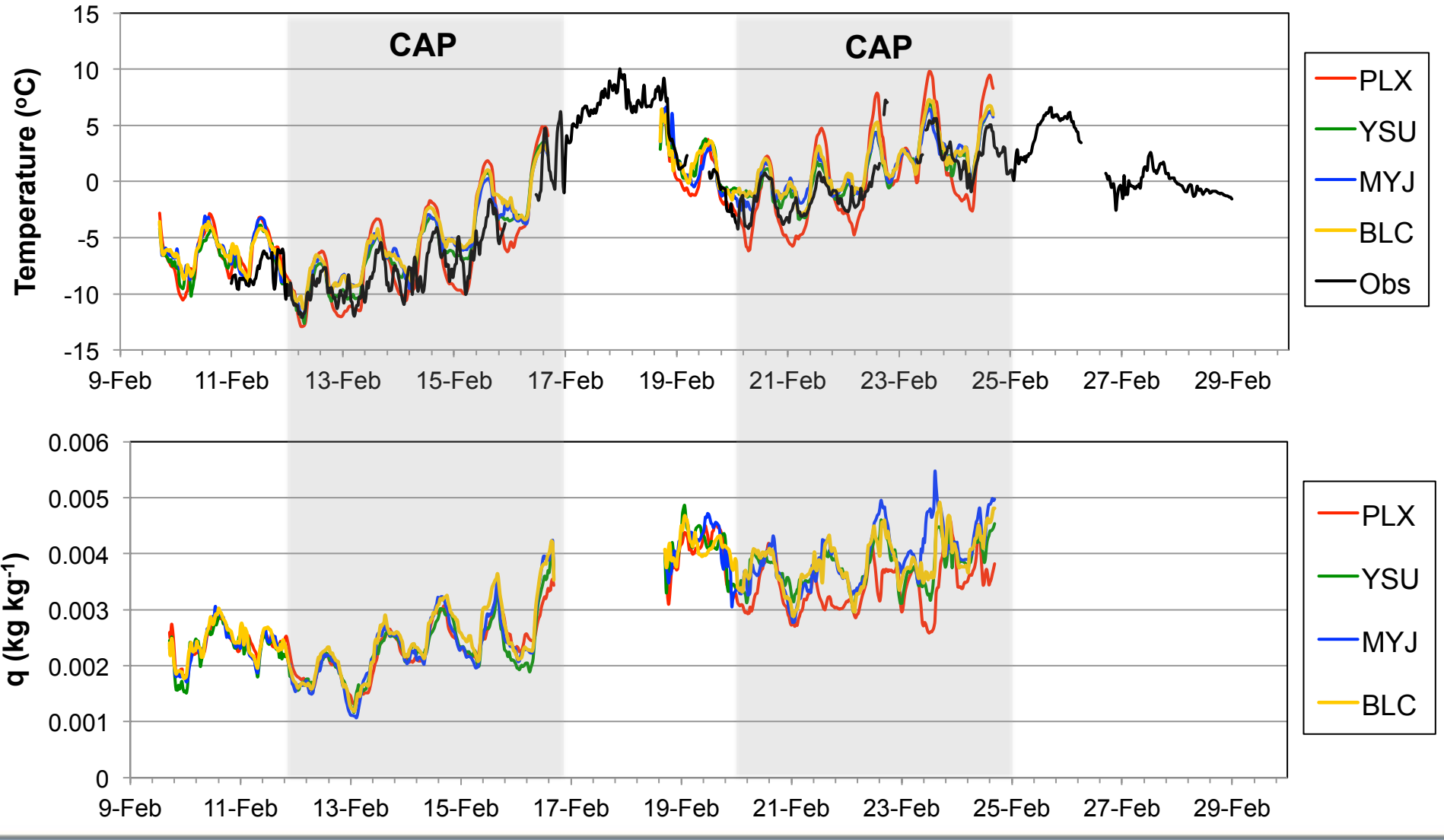
Temperature and Humidity



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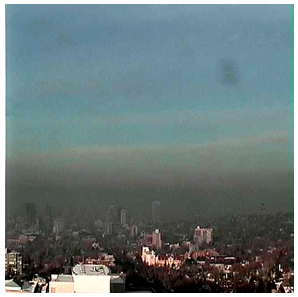
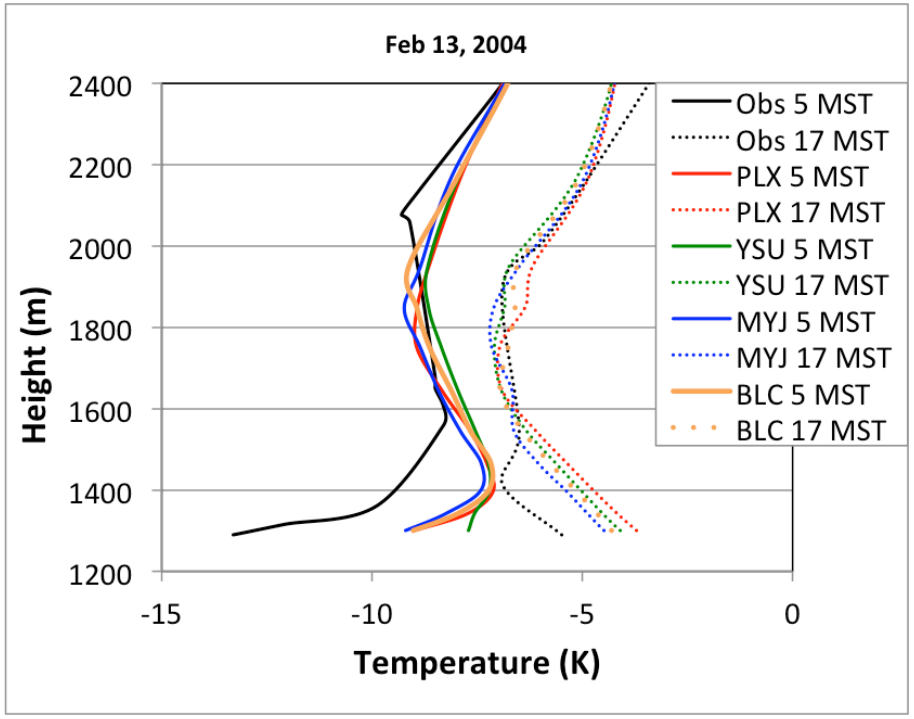
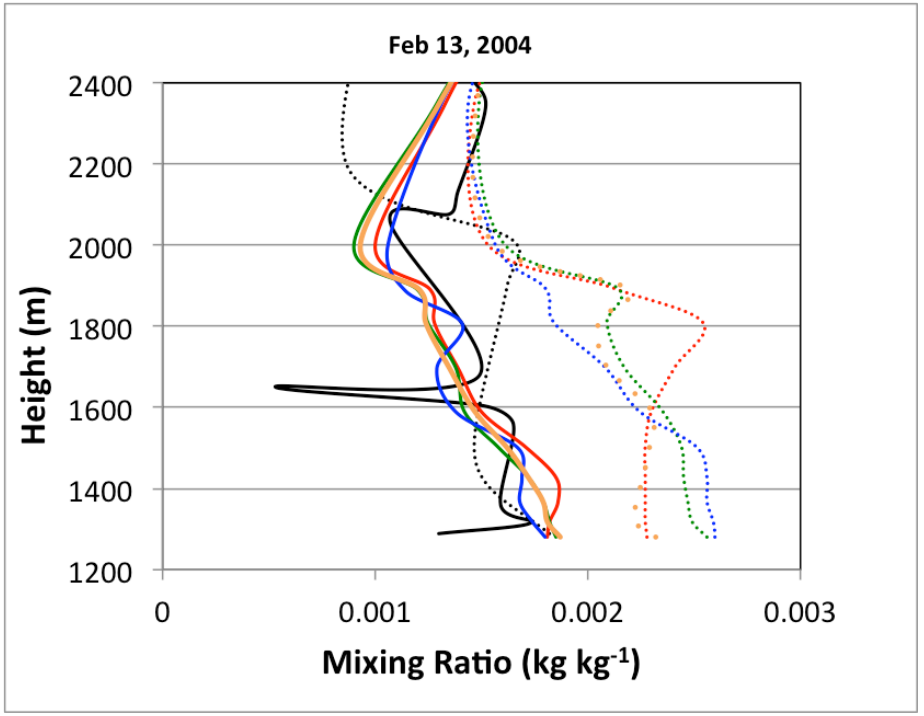
Vertical Profiles: Dry CAP



13 February 2004

- Surface based inversion
- Snow on ground
- No clouds





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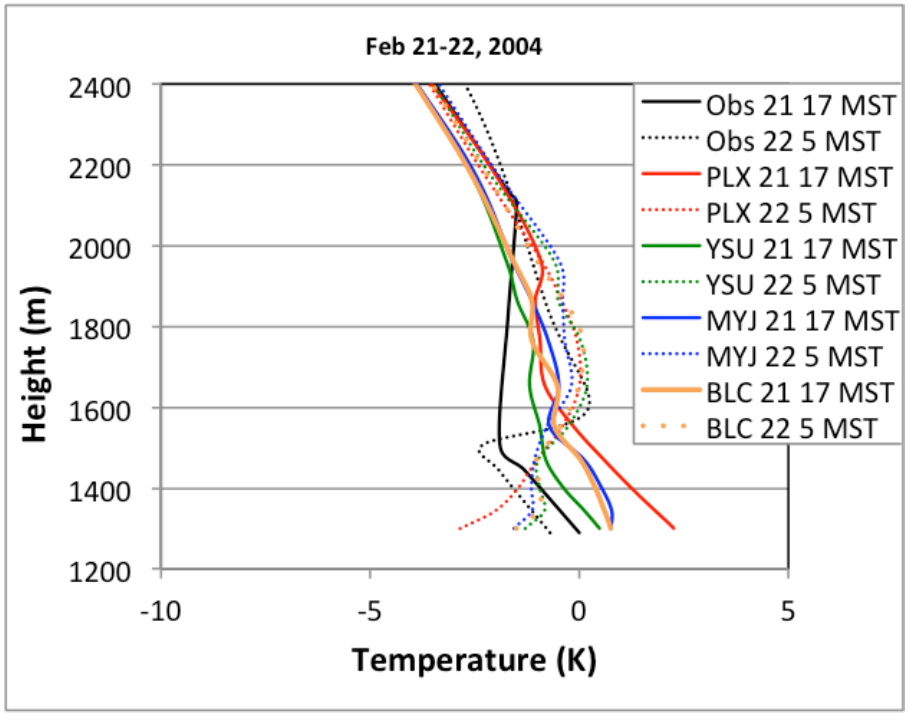
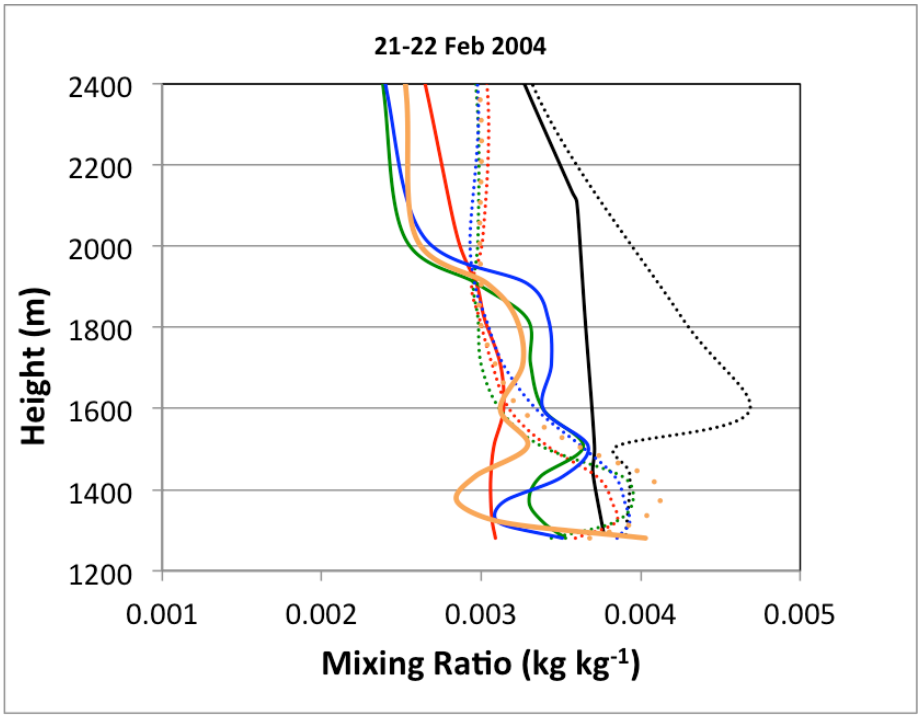
Vertical Profiles: Cloudy CAP

21 February 2004

- Surface mixing + elevated inversion
- No snow on ground
- Layer of stratus clouds





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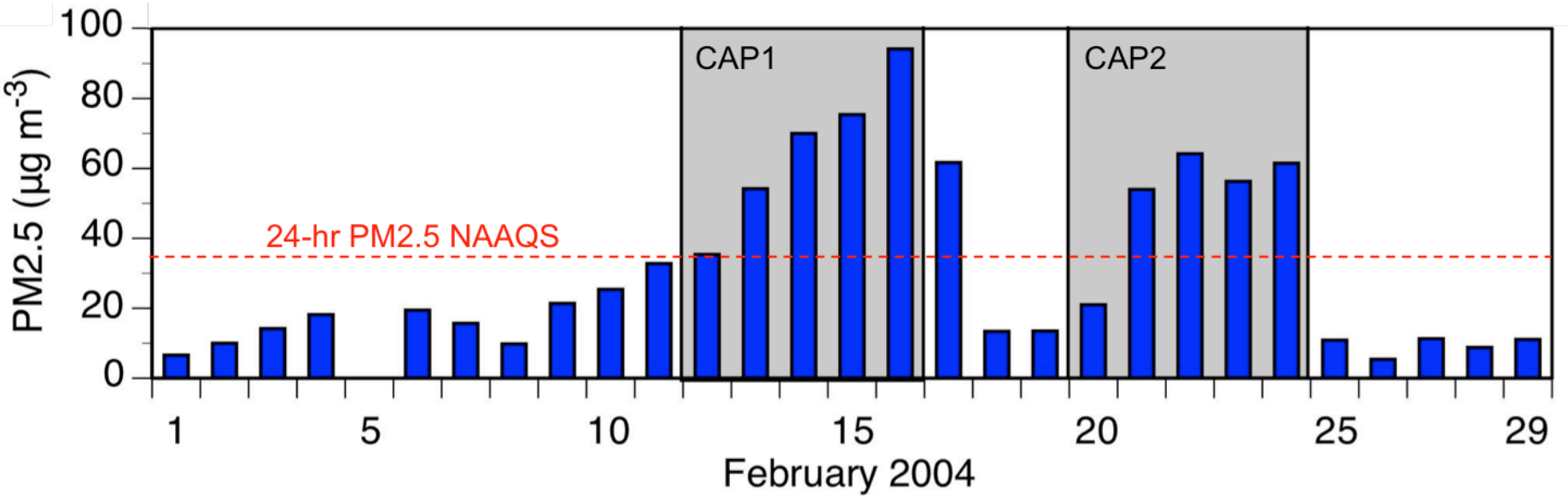
Particulate Matter Accumulation



Two Persistent Cold Air Pools

12-16 February (CAP1), Dry CAP [12.3 μg m^{-3} day^{-1}]

20-24 February (CAP2), Cloudy CAP [9.6 μg m^{-3} day^{-1}]

Holmes et al., 2015

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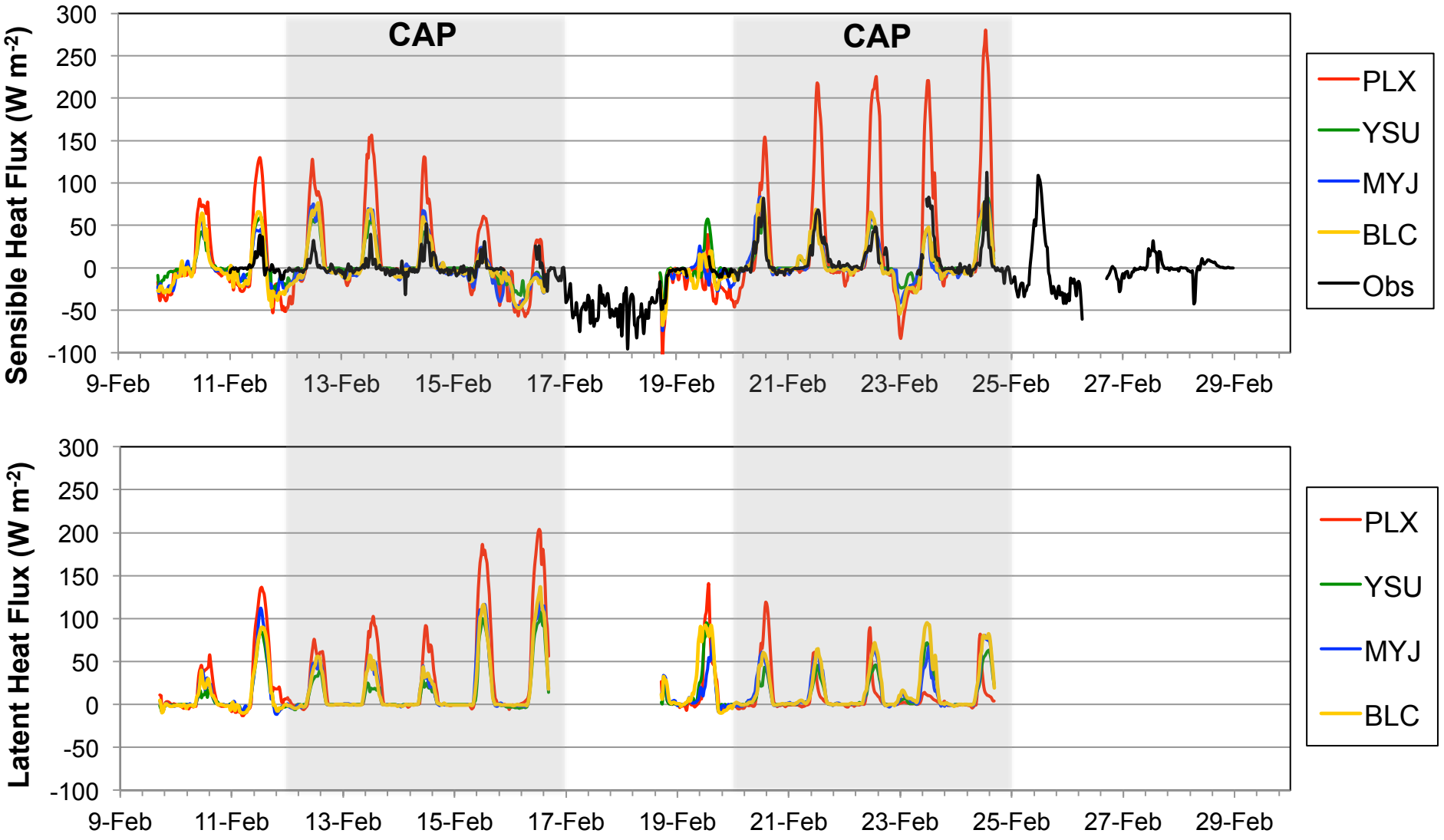
Sensible and Latent Heat Fluxes



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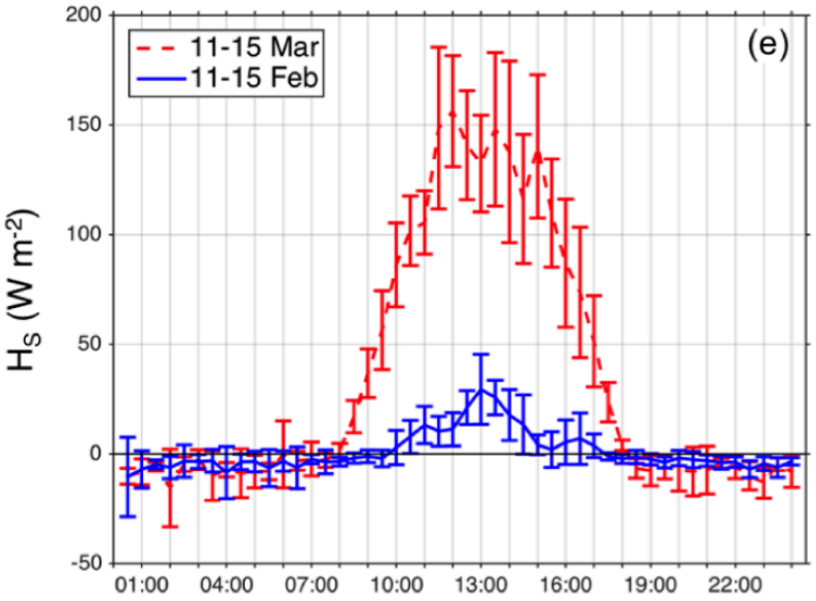
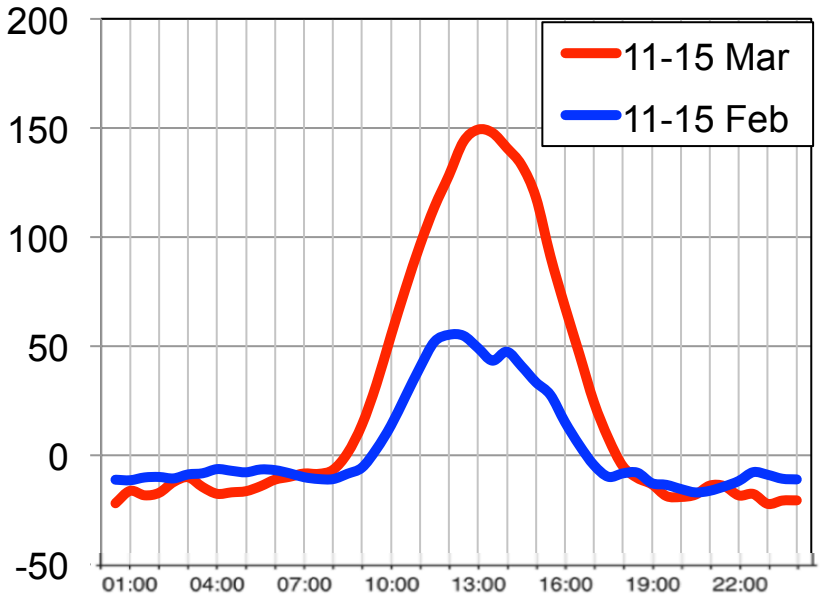
Sensible Heat Flux
CAP *versus* non-CAP

OBSERVATIONS



MYJ



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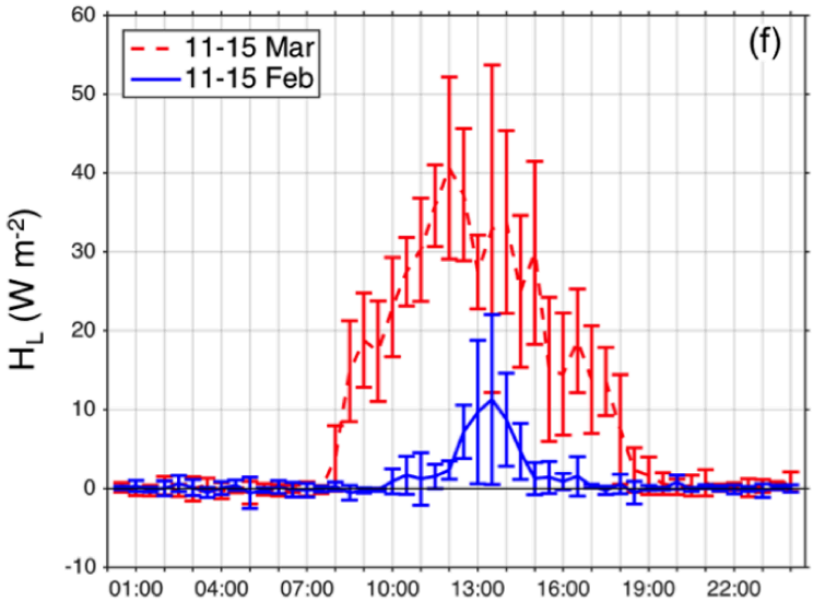
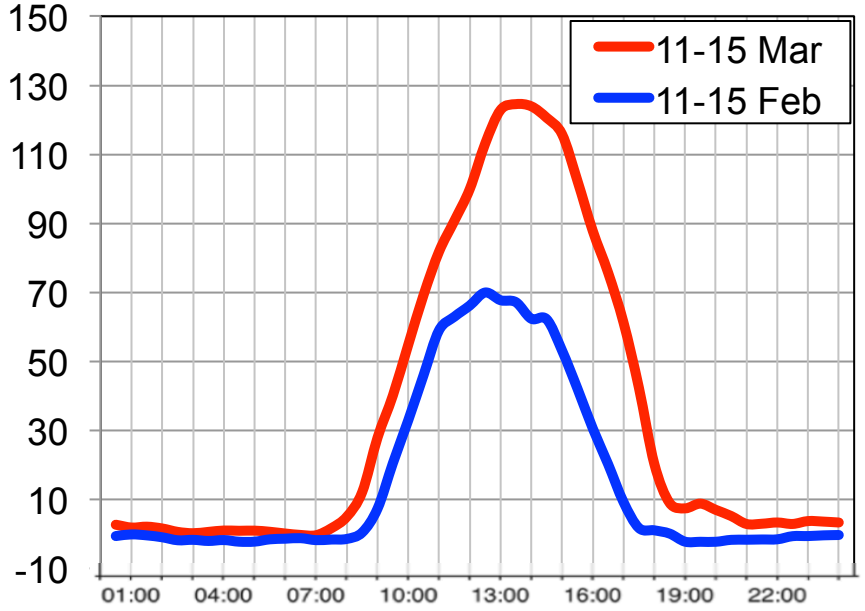
Latent Heat Flux
CAP *versus* non-CAP

OBSERVATIONS



MYJ



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Summary

- Elevated PM during wintertime in complex terrain is due to both physical and chemical processes in the atmosphere
- WRF captures the mesoscale CAP formation, but does not capture the microscale physics
- CAP surface fluxes are over estimated in simulation results
- Sensible heat flux during non-CAP agrees better with obs
- Simulation results do not capture the cloudy CAP event, likely due to fog issues in the mesoscale model

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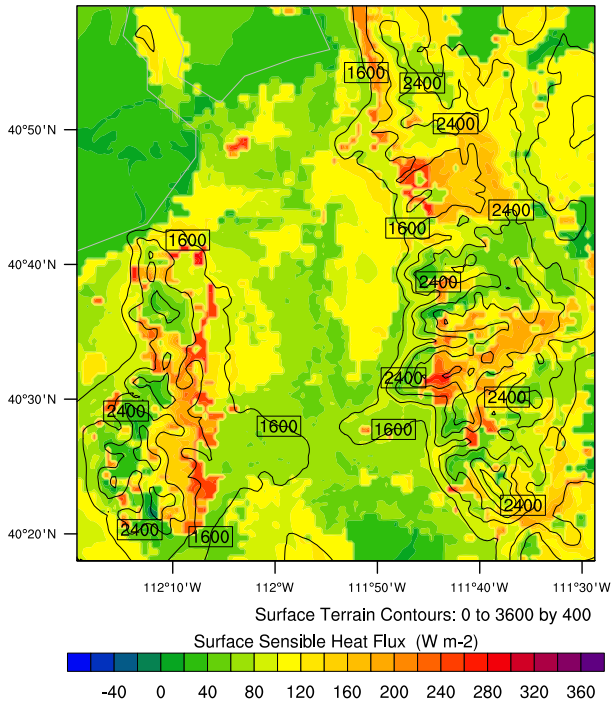
Future Work

- Plot friction velocity data
- Investigate surface heterogeneity differences
- Sensitivity of PBL/LSM in chemical transport model
- Simulate more recent time periods (e.g., PCAPS)
- Incorporate improved land use data form MODIS

Sensible HF
13 Feb 2004
11:00 MST
PLX



Sensible HF
13 Feb 2004
11:00 MST
MYJ