Numerical Modeling of Wintertime Cold Air Pools in the Uinta and Salt Lake Basins

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Basin Topography and Meteorology Vary

- Snow cover critical, particularly in Uinta Basin
- Salt Lake Basin not as deep and more prone to pollution mix-out
Detailed Meteorology Associated with Poor Winter Air Quality Difficult to Simulate

Stable capping layer

Mixing

High pressure

Clouds

Transport

Polluted layer

Snow Cover and Land Use
Improving WRF Cold Air Pool Simulations

- Land use and snow cover
- Initialization and observational nudging
- Low clouds
- Stable stratification, mixing/winds
Land Use and Snow Cover

• Snow analyses for thin and rapidly changing lower elevations difficult

• Spatially inhomogeneous snow fall, snowpack aging, and melt rates

• Ice fog deposition effects

• Snow physics models undeveloped for shallow snowpack

• In situ data used to correct snow fields (UBWOS, PCAPS)
- Concentrations in FULL simulation 15-30% greater than NONE
- Areal extent of region exceeding NAAQS 6 times larger in FULL
- CMAQ sensitivity to Uinta Basin oil and gas emissions inventory updates (Lance Avey, Utah) Thursday talk (yesterday)
**CAPs Highly Sensitive to Land Use**

- Subtle land use differences result in significant changes in CAP evolution
- WRF model has 3 land use options
- National Land Cover Database (NLCD 2006)
- MODIS 2001
- USGS (default)
- 3 Versions of reality—they can’t all be right!
WRF CAP Sensitivity to Land Use

9 Day Average 2-m Temperature Difference
USGS minus NLCD

Average 2 m Temperature Difference from 1/1/2011 to 1/10/2011 (degC),
USGS Run - NLCD Run
Spatially and Temporally Variable Albedo in the Salt Lake Valley

Hourly Albedo, IOP 5

1-8 January 2011

PCAPS
Persistent Cold-Air Pool Study
Observational Nudging

*Four-dimensional data assimilation* method that uses dynamical relaxation to adjust toward *observations* and analyses

- Analysis nudging for the atmosphere above PBL: NAM data, nudged for u/v/T/Q for all three domains
- Observational nudging at surface: data from MODIS sites + AirNowTech(Ouray and Redwash sites), nudged u/v/T for inner domain
The Challenges of Observational Nudging

• Air Quality community for the most part has found observational nudging to improve simulations

• Active area of research (e.g, Li et al. WRF CMAQ nudging during the DISCOVERAQ 2013 Texas Campaign)

• A challenge is that nudging can limit available meteorological data to validate model results

• Atmospheric nudging was found to worsen overall CAP meteorology in Utah State Simulations
Poster:
FDDA (nudging) impacts on WRF-CMAQ model performance in simulating winter $O_3$ formation in Uintah Basin
Trang Tran$^1$, Huy Tran$^1$, Erik Crosman$^2$
WRF CAP Sensitivity to Initialization Time

Identical simulations started 1 day apart

Run Beginning 12/31/2010 - Run Beginning 01/01/2011
(Average Temperature Difference, degC)
WRF Cloud and Fog Modifications

- Microphysics modifications (Thompson) in lowest 15 model layers (~500m):
  - Turned off cloud ice sedimentation
  - Turned off cloud ice autoconversion to snow

→ Results in ice-phase dominated low clouds/fog vs. liquid-phase

LES: $\Delta X = 0.250$ km

PBL: YSU $\Delta X = 1.33$ km

Toxic soup continues...

Crosman and Horel 2015, in preparation for BLM

Time to exercise!
Summary

• 4 key areas for modeling improvements
• PCAPS data set helpful in validating complex CAP situations
• Lots of areas for further development
Selected CAP Publications


