# Winter Ozone Chemistry and Snow Albedo Updates for CAMx


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## Western Air Quality Modeling Workshop

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# ACKNOWLEDGEMENTS


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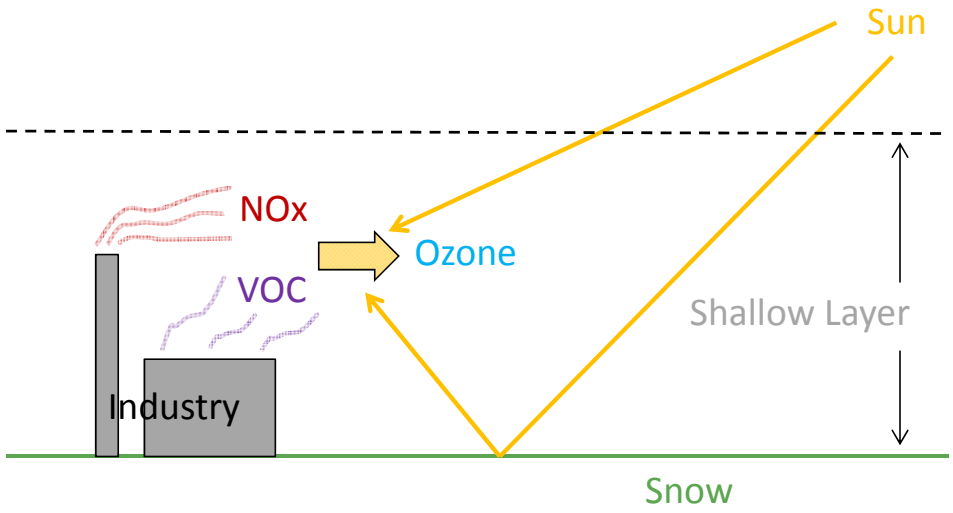
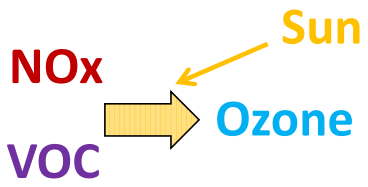
- Input from EPA Region 8
  - Gail Tonnesen
- Contributions from our technical staff
  - Bonyoung Koo, Jaegun Jung, Wei Chun Hsieh

# PROJECT PURPOSE

- This project looks to improve on two pieces of the difficult wintertime ozone modeling puzzle
  1) Atmospheric chemistry for western O&G basin conditions
  2) Treatment of snow cover

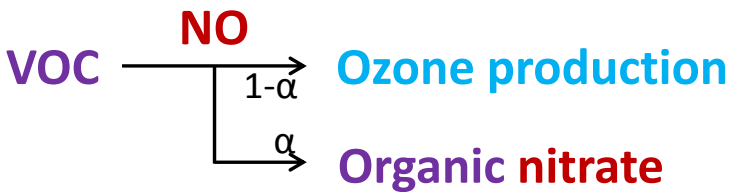


# ARE CHEMISTRY CHANGES NEEDED FOR WINTER OZONE?

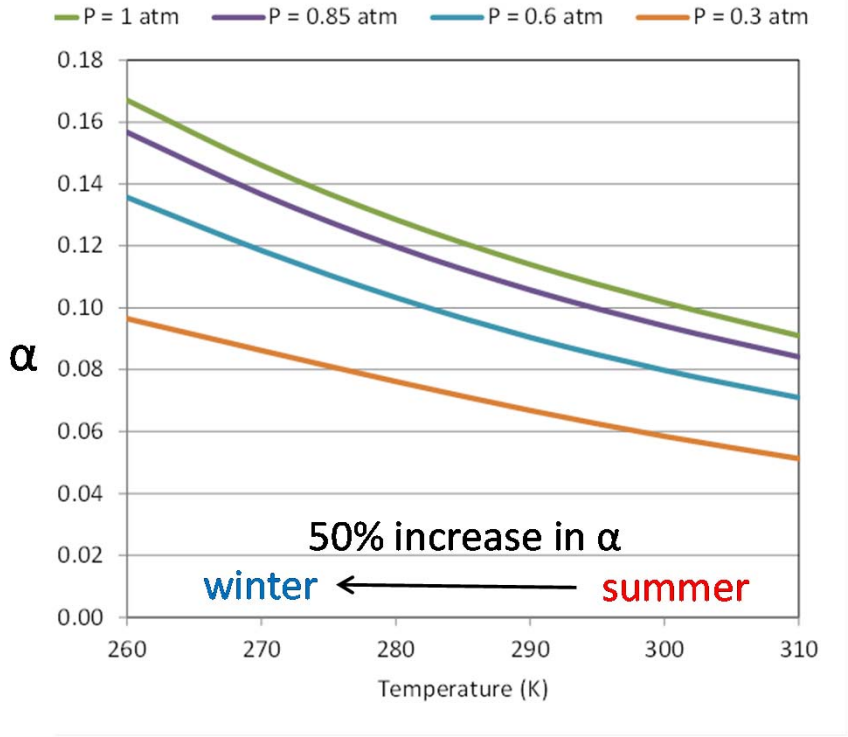



- Photolytic effect of sunlight
  - Little variation with temperature
- Chemistry of NOx and similar molecules
  - Cold conditions are understood
  - NOx chemistry is important for ozone from surface through stratosphere
- Chemistry of VOC
  - Models developed for summer ozone
  - There is potential for improvement
  - Focus on the most abundant VOCs in western US O&G basins: Alkanes

# ALKANE CHEMISTRY




- Fraction (α) of organic nitrate formed depends on temperature and pressure (altitude)
  - But models hold α constant
  - Including this dependency should improve winter chemistry modeling
  - Important for O&G basin conditions
- Dynamic branching ratio added to CB6 (r3)
  - This mechanism also added to CMAQ (Deborah Luecken, EPA)



# CAMx SNOW COVER TREATMENTS

- Surface UV reflectivity or “albedo”
  - Even shallow snow increases albedo by >10x
  - Old: albedo = 50% when any snow is present
  - New: albedo depends on snow cover (depth, age) and land cover type
- Atmospheric deposition to surface
  - Old: snow covers 80% of surface elements when any snow is present
  - New: snow cover consistent with albedo treatment
- Surface chemistry
  - Reactions on surfaces ***may*** be source of ozone precursors (e.g., HONO)
  - Old: no specific snow compartment
  - New: snow compartment added

# IMPROVEMENTS FOR SNOW ALBEDO

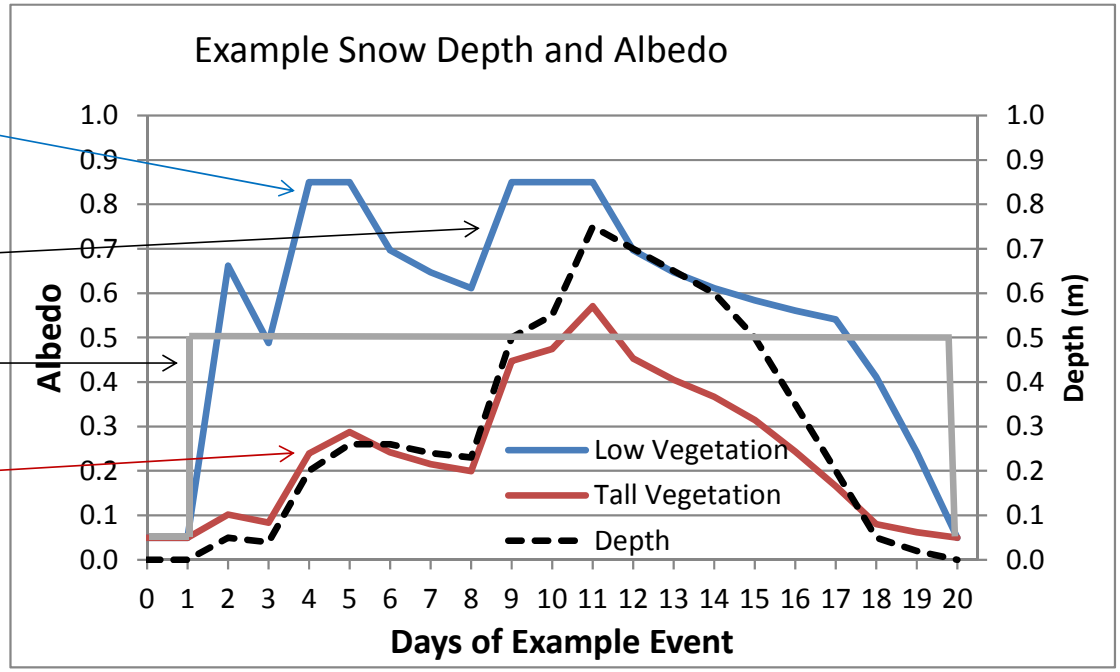
- Snow depth/cover and age/albedo functions from WRF/ARW meteorological model

Low vegetation covered faster/completely, maximizing snow albedo

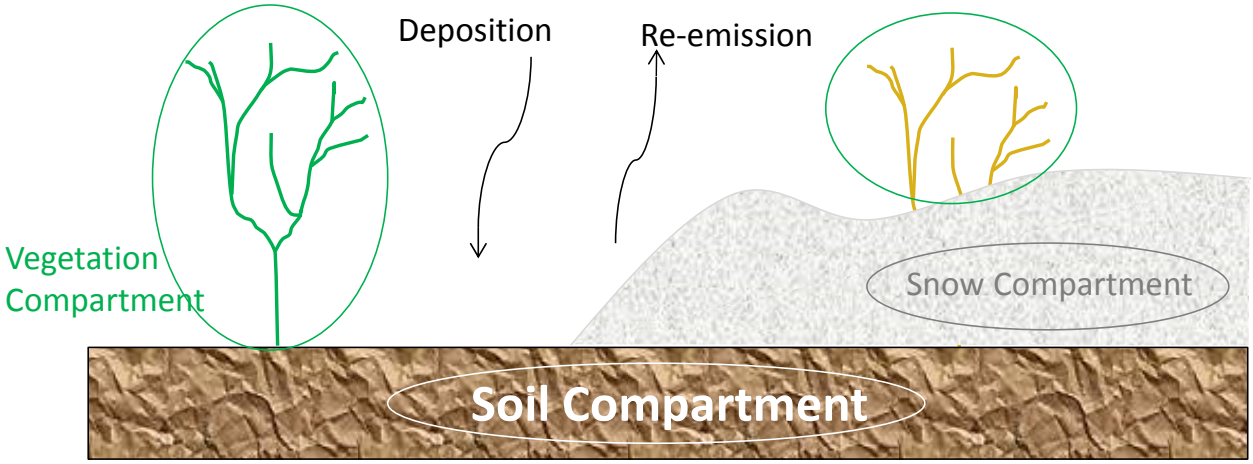
New snowfall increases snow depth and "freshens" the albedo

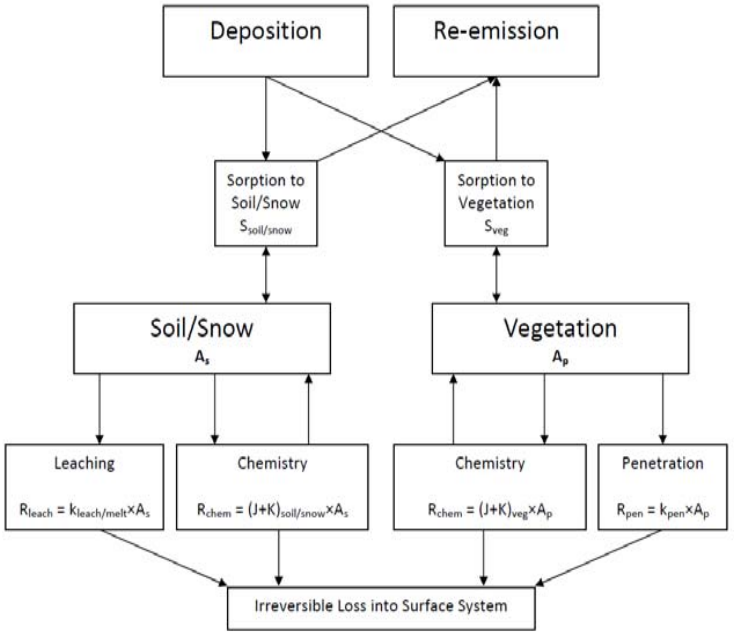
Original albedo assumption

Tall vegetation covered slower/incompletely, minimizing snow albedo



# SURFACE CHEMISTRY UPDATE

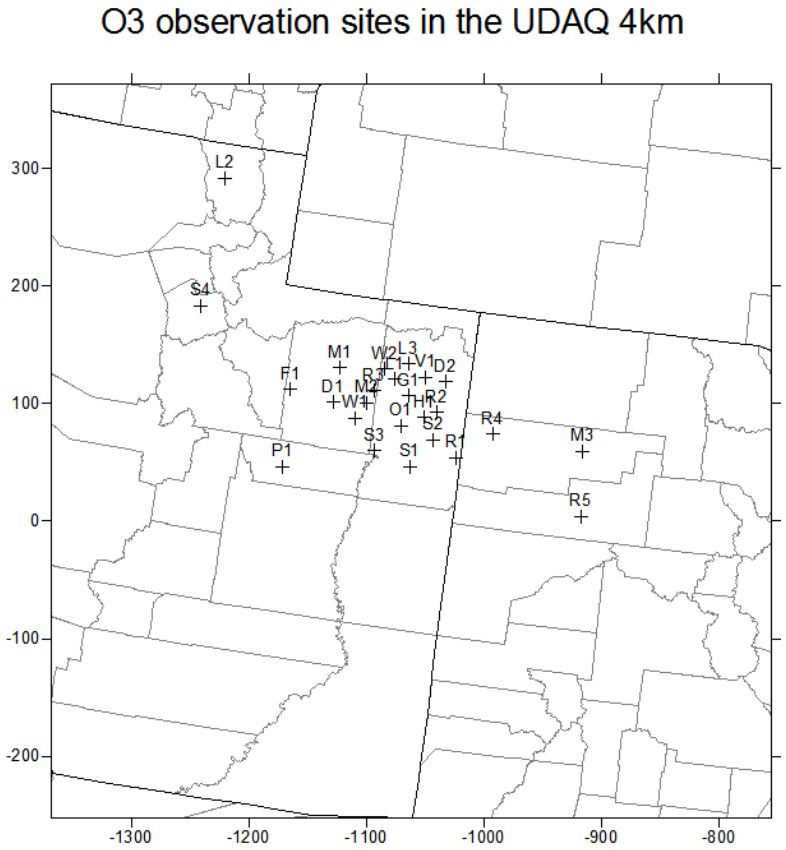



- Optional model component:
  - Two-way transfer between atmosphere and surface system
  - Chemical interactions among deposited material form products that re-emit
- Updated to include snow with soil and vegetation compartments
- Models need to account for snow surface-atmosphere chemistry interaction
  - May be an important contributor to atmospheric chemistry

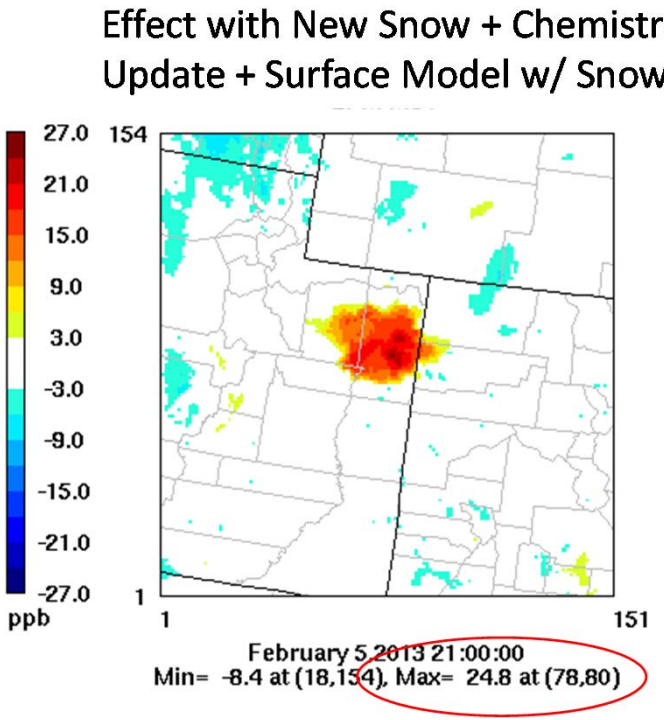
# EVALUATION IN UINTA BASIN

- Model:
  - CAMx v6.1
  - Add snow and CB6 chemistry updates
- Domain:
  - UDAQ 4-km grid
  - February 1-7, 2013
- Datasets:
  - UofU-derived meteorology
  - UDAQ-derived 2010 emissions (initial)
  - NEIv2/UDAQ-derived emissions (latest)
  - MOZART-derived boundary conditions
  - UBOS/NOAA 2013 measurements



# INITIAL OZONE SIMULATIONS

- Total effect of all model updates: 10-20 ppb $O_3$ **increase**
  - Snow albedo/deposition update: $O_3$ **increase**
  - Winter chemistry update: $O_3$ **decrease**
  - Surface chemistry update emitting heterogeneously-formed HONO: $O_3$ **increase**
- Surface chemistry configured for ***testing purposes only***!
  - Highly speculative, currently no conclusive evidence for a surface chemical pathway



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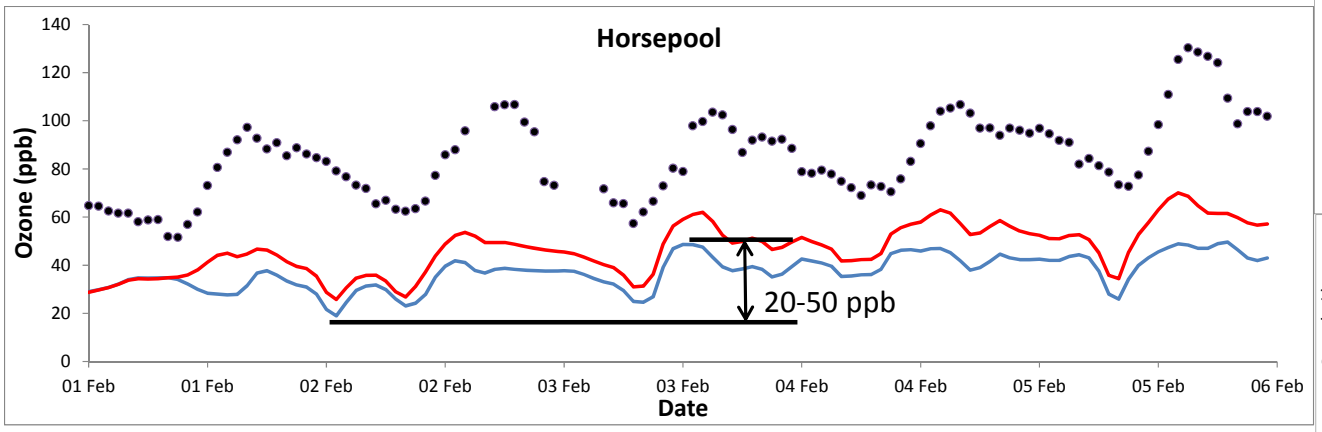
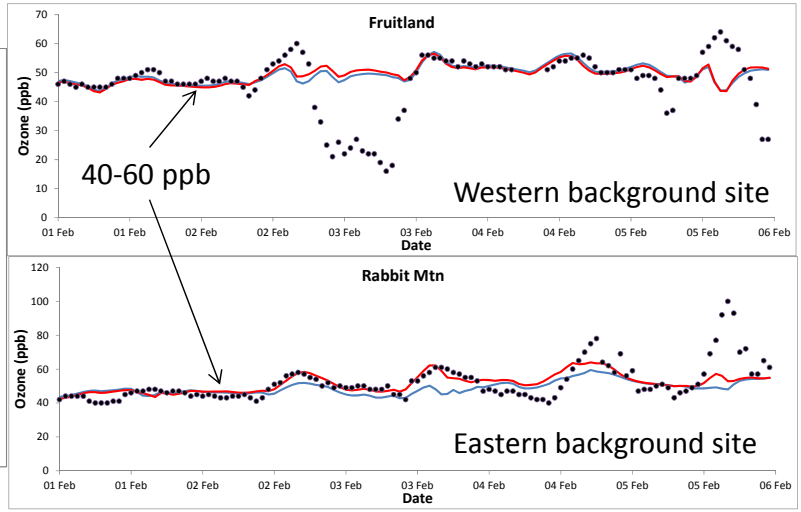


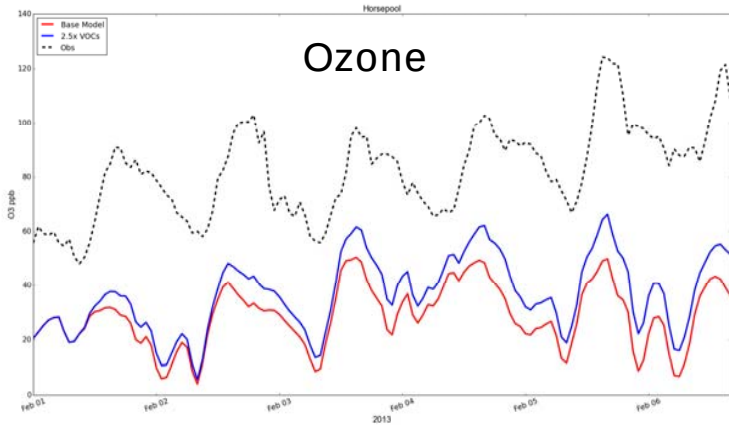

Original Model

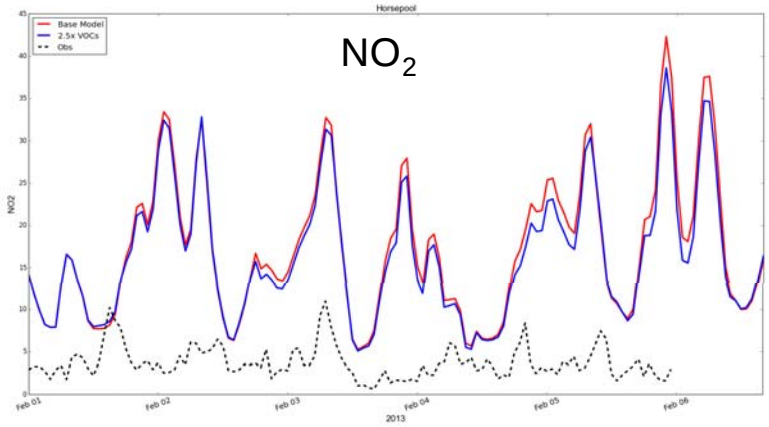
New snow + Chemistry Update + Surface Model w/ Snow

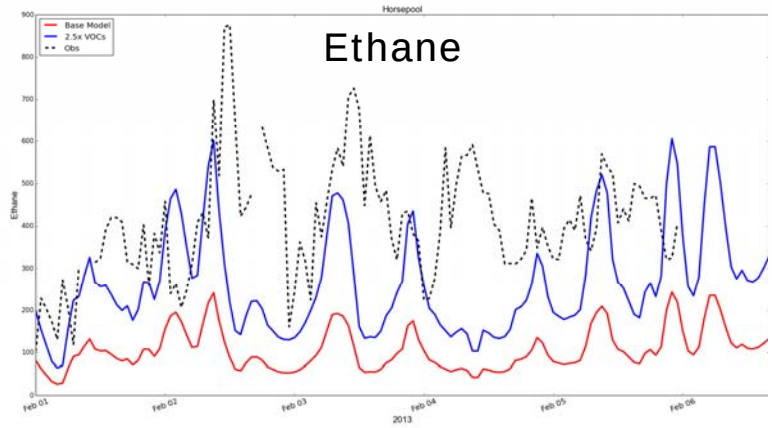
- $O_3$ is too low in the basin, but background is higher and well-simulated outside
  - $O_3$ is inhibited and suppressed
  - Comparisons to 2013 UBOS measurements confirm model is NOx-rich, VOC-poor

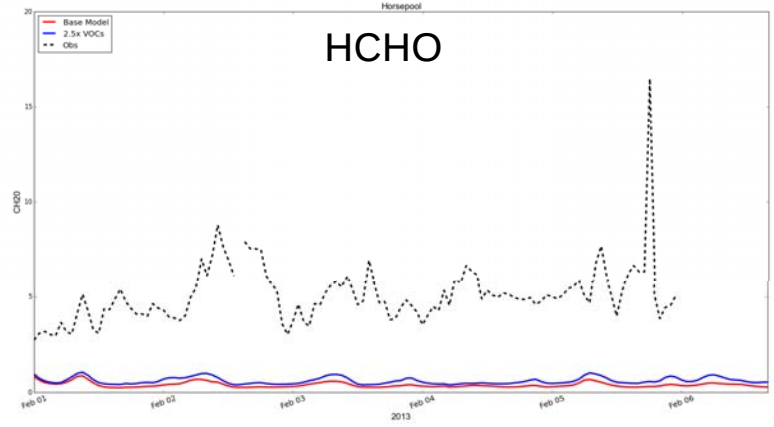
# LATEST OZONE SIMULATIONS (SO FAR)

- Base (CB6r3+snow)
- VOC×2.5
  - Little sensitivity
  - Squelched by NOx
  - Missing HCHO
- NOx inventory
  - Over-estimated?
  - Needs vertical distribution?

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# SUMMARY

- Model updates
  - Winter chemistry update
    - Cold temperature pushes NOx out of ozone cycle, reduces ozone
  - Snow albedo and deposition update
    - Higher albedo, reductions in deposition increase ozone
  - Snow surface chemistry
    - May be a source of emissions that increase ozone production
    - Complex, uncertain, inconclusive – more study needed
- Updates alone are insufficient to simulate ozone at measured levels
  - Similar to UDAQ's CMAQ sensitivity results
    - CMAQ: shallower mixing? Higher photolysis rates?
  - Needed improvements to emissions (NOx, VOC, HCHO)

# THANK YOU
# QUESTIONS?

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06/05/2015