Modeling Air Quality during Wintertime Stagnation Events in Idaho's Treasure Valley using the WRF-CMAQ Modeling System

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Background & Motivation

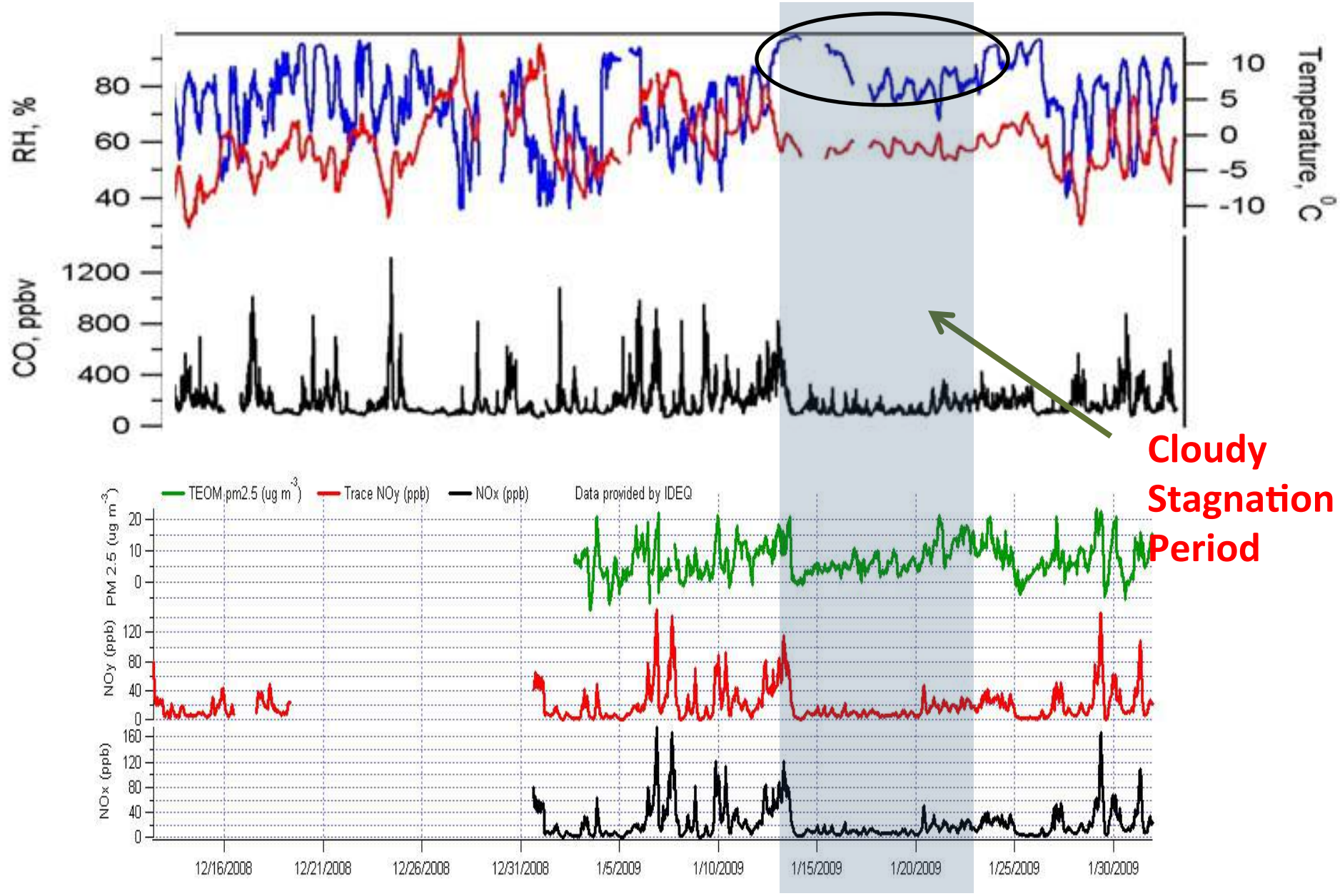
- Wintertime wood burning and other emissions lead to significant air quality concerns in the Pacific Northwest, leading to recent studies:
  - Treasure Valley Study (Jan 2009)
  - Yakima Study (Jan 2013)

- The 'typical' clear sky wintertime inversions and valley topography can together cause unfavorable dispersion conditions. On the other hand, during stagnant cloudy or foggy periods we have observed relatively clean conditions, though nitrate and other secondary species remain.

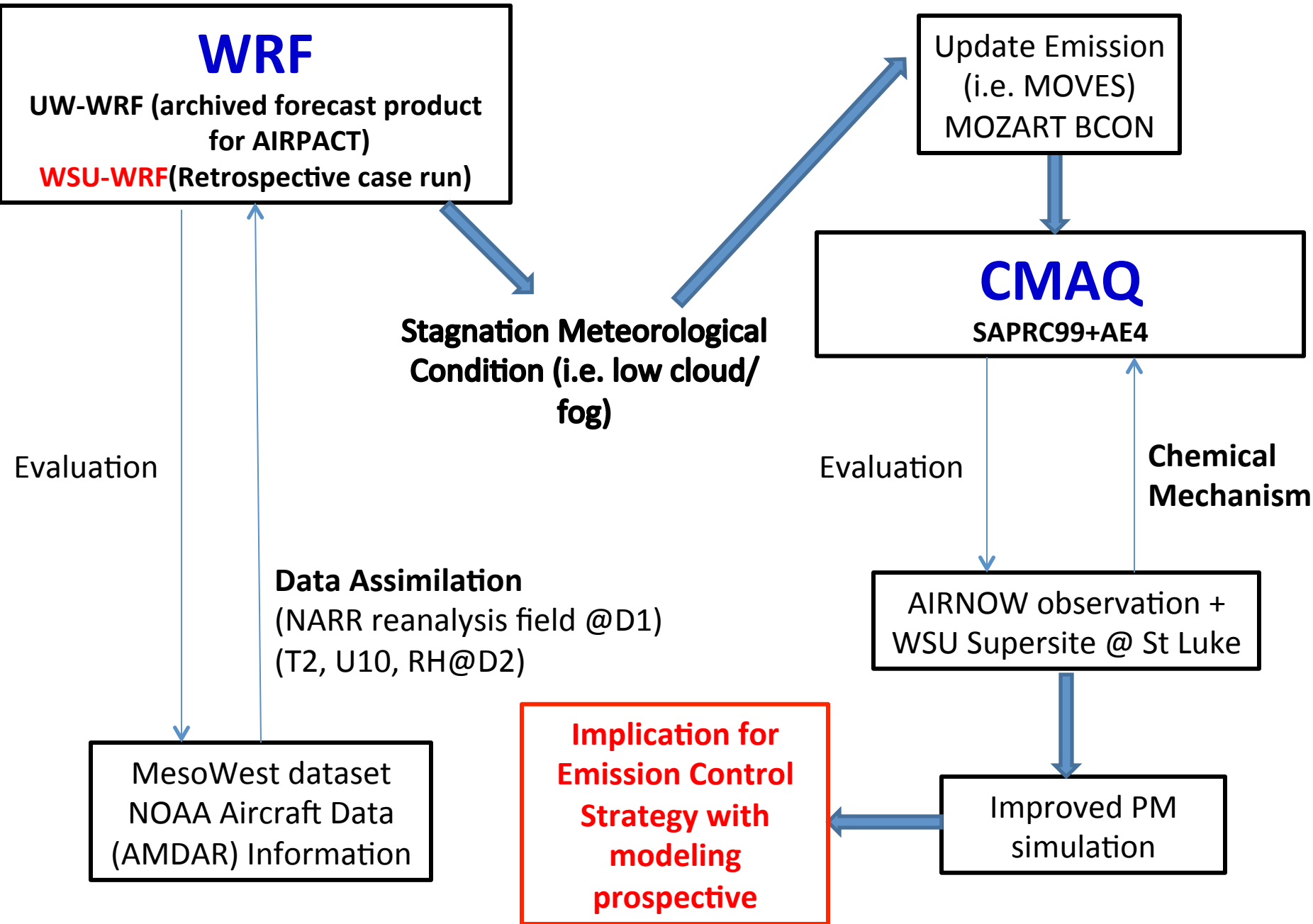
  Meteorology impact .vs. Chemistry impact?

- Science Questions:
  - Can **WRF** capture this clear and cloudy stagnation periods?
  - Can **CMAQ** reliably simulate wintertime pollution events?

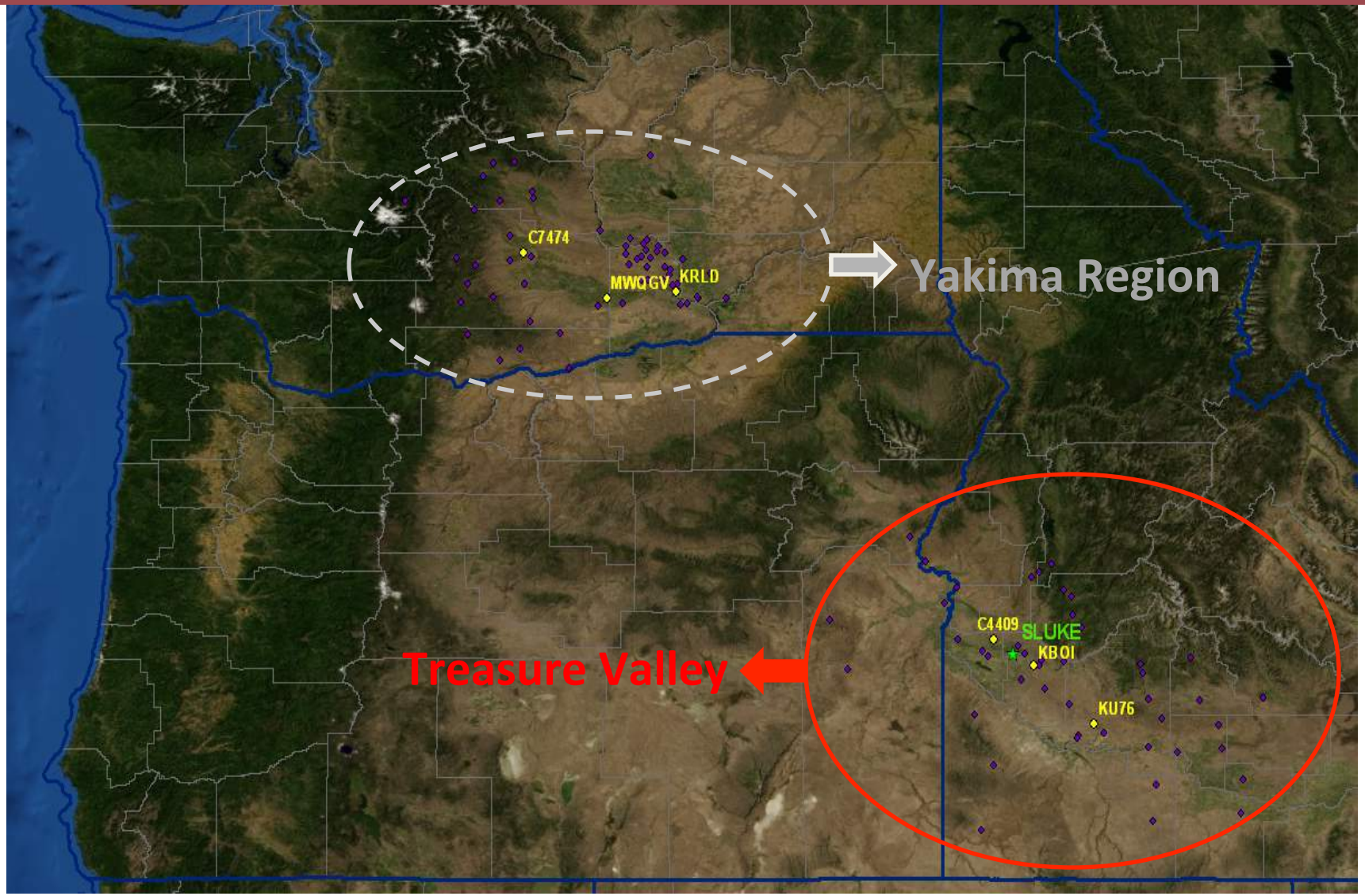
Observations @ St Luke's Site



Modeling Approach using WRF-CMAQ

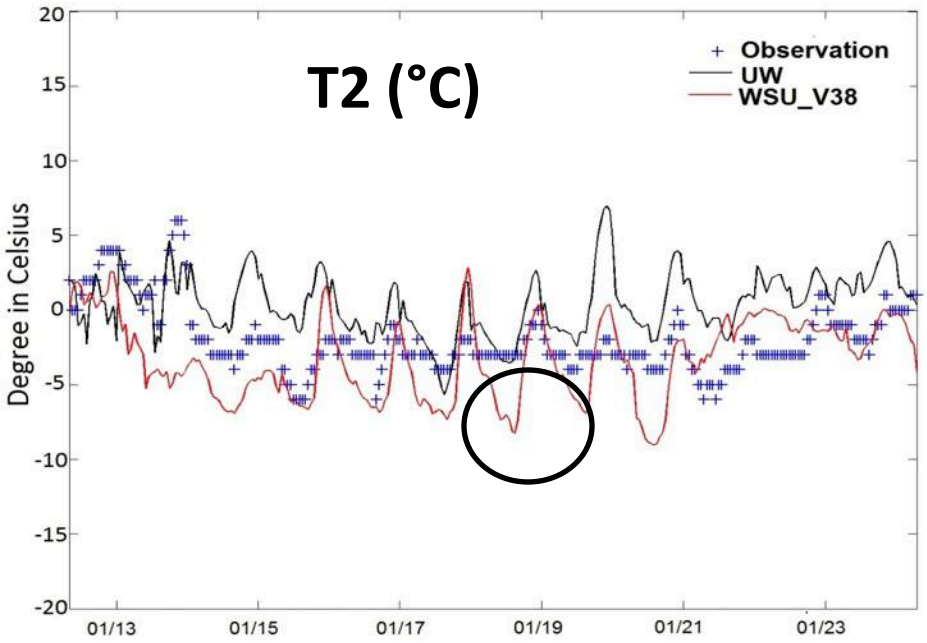


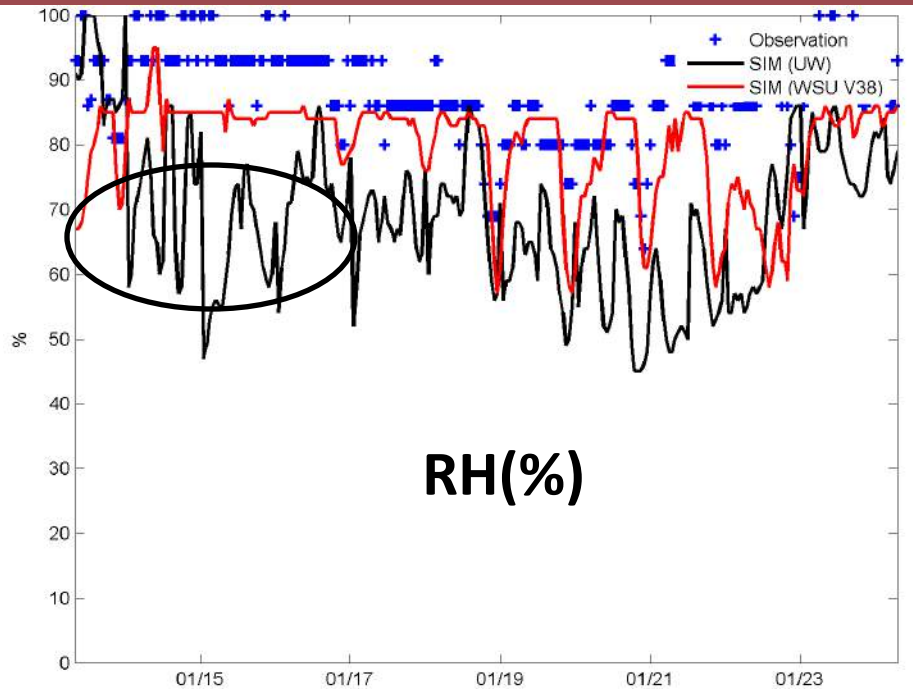
Sites Used for Assimilation and Evaluation in WRF (D2)

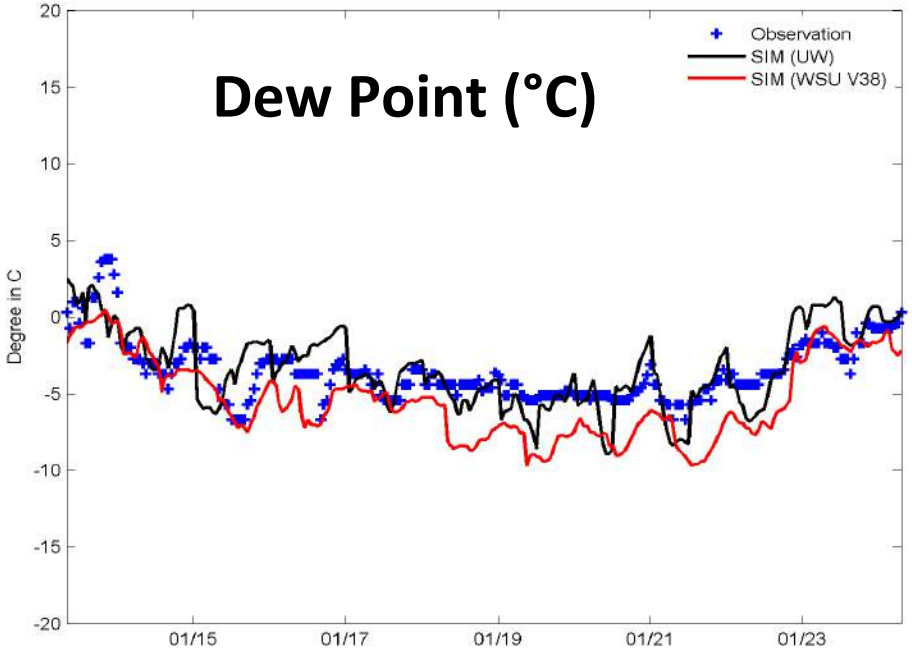


- T2, U10, and moisture from **104** MesoWest stations near two study regions were assimilated
- Seven independent sites (including St. Luke's) near Boise and Yakima were used for model evaluation

WRF Performance in temperature and moisture







- WSU WRF has a cold bias in the simulated temperature (related to the land-surface scheme);
- Underestimation of RH in the UW-WRF simulation may lead to less liquid water available for aqueous-phase reactions.

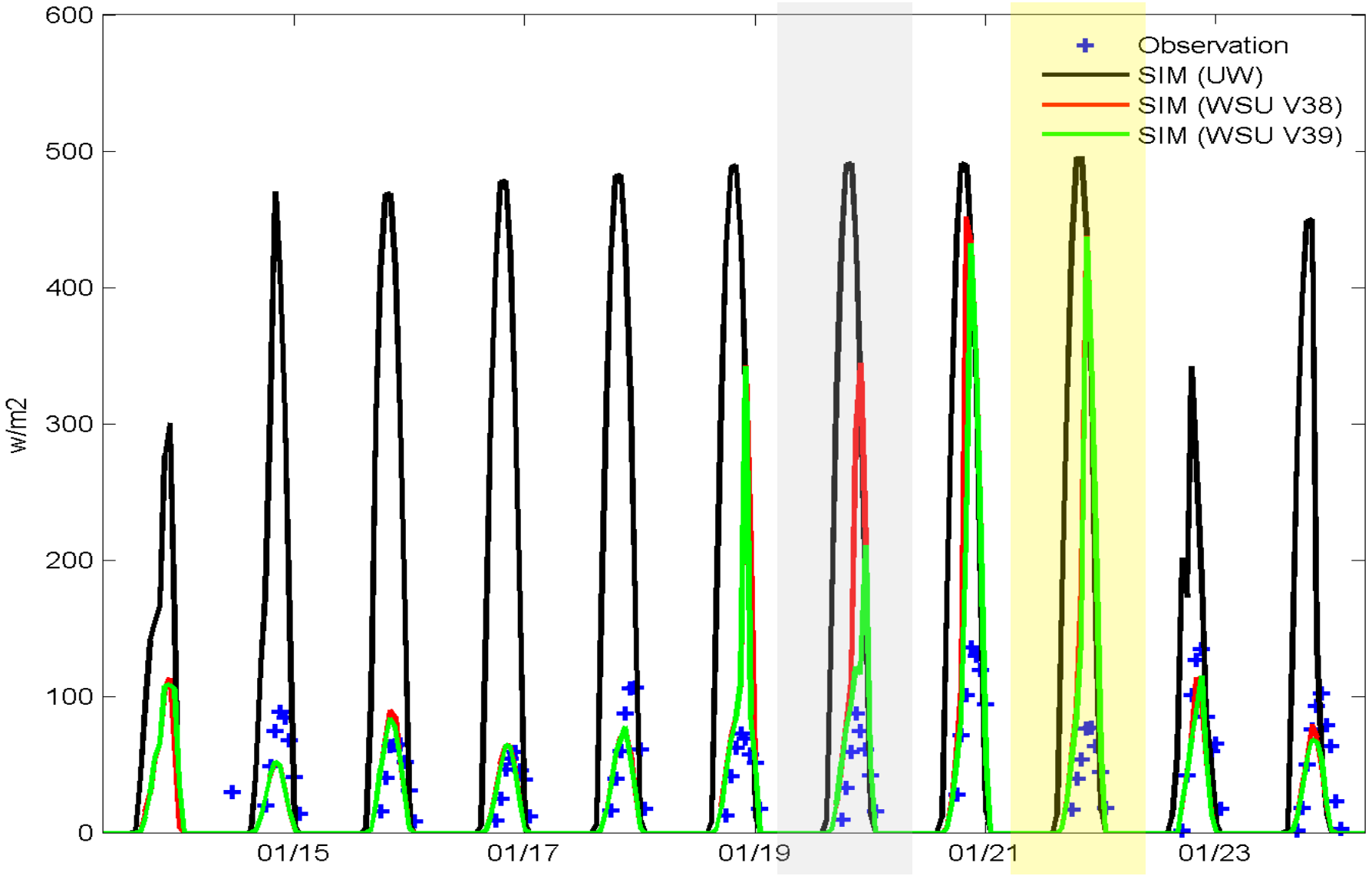
WRF Performance

	OBS_AVE	SIM_AVE	R	RMSE	NMB	NME
Dew Point_UW (°C)	1.5	0.8	0.1	2.1	-102.3	121.7
Dew Point_WSU_V38(°C)	1.5	0.3	0.7	2.5	-171.4	171.4
Radiation_UW(W/m^2)	55.1	240.2	0.158	273	362.3	394.5
Radiation_WSU_V38(W/m^2)	55.1	70.3	0.529	82.37	34.21	86.69
RH_UW(%)	85.5	69.1	0.5	19.0	-19.1	19.5
RH_WSU_V38(%)	85.5	81.7	0.4	8.9	-4.3	8.2
T2_UW (°C)	1.5	2.3	-0.1	2.4	36.4	133.9
T2_WSU_V38 (°C)	1.5	0.9	0.6	2.7	-162.5	179.8
U10_UW(m/s)	2.0	1.9	0.1	1.4	-1.3	58.7
U10_WSU_V38(m/s)	2.0	1.6	0.1	1.2	-12.7	48.7

UW MCIP
WSU V38 MCIP

- Assimilated Low T2 -> Low Dew Point -> High RH
- Assimilated wind speed is lower during stagnation period
- Significant change in terms of ground incoming solar radiation @ St Luke's site -> Cloud formation?

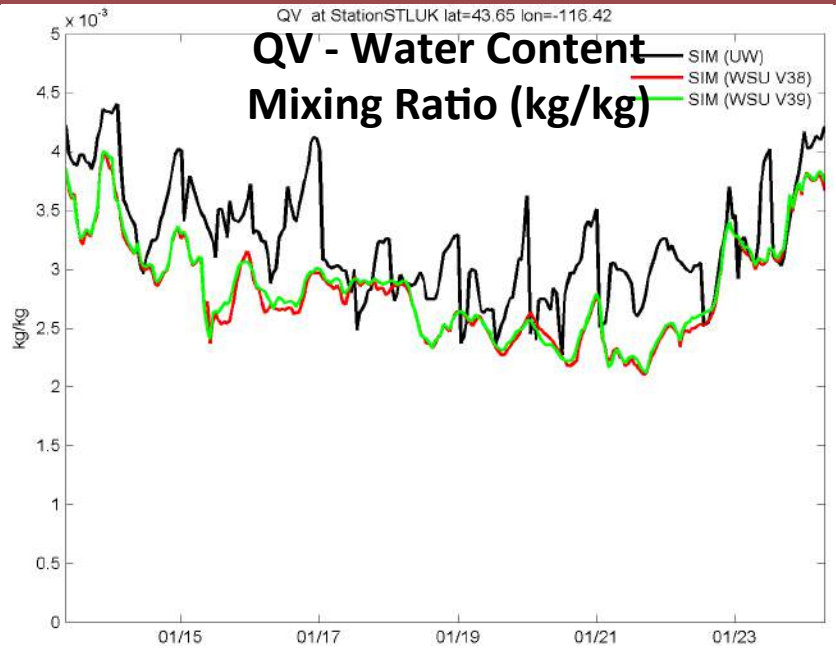
Catching the Surface Fog in Treasury Valley

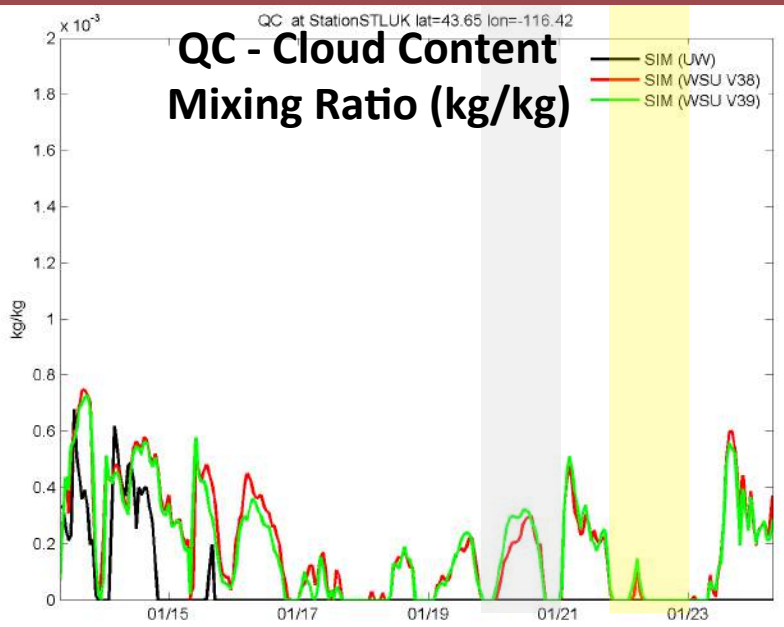


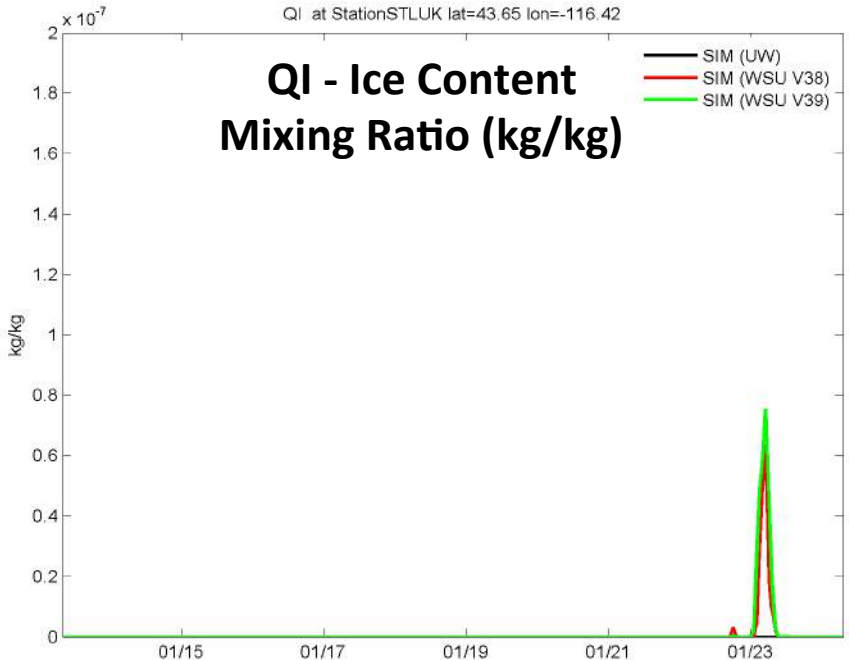
CASE I. Jan 20, additional vertical layer leads to significant change in radiation

CASE II. Jan 22, no major change for radiation

Change of Ground Resolved Water Content

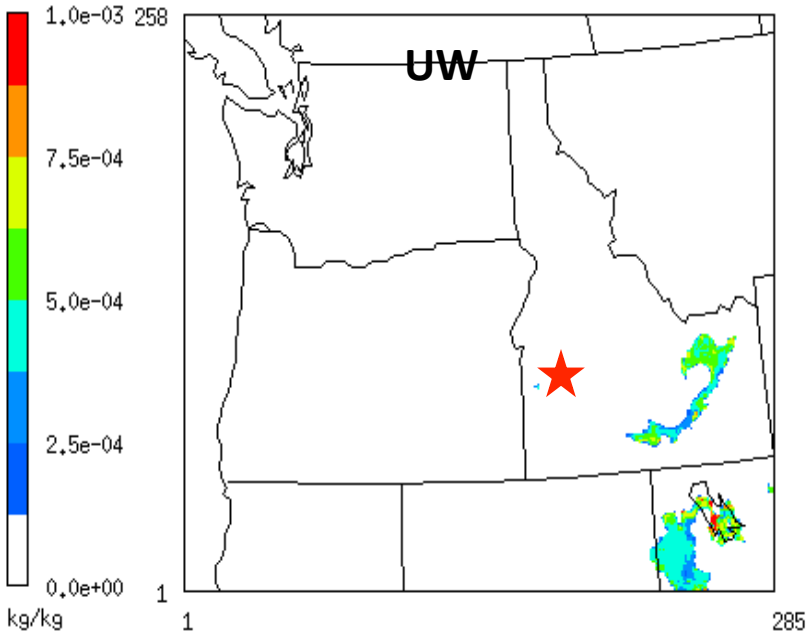


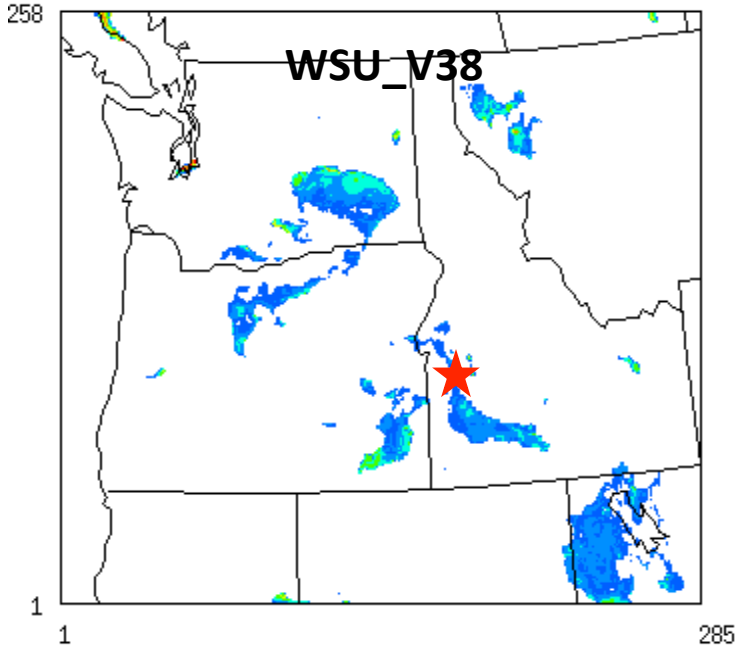


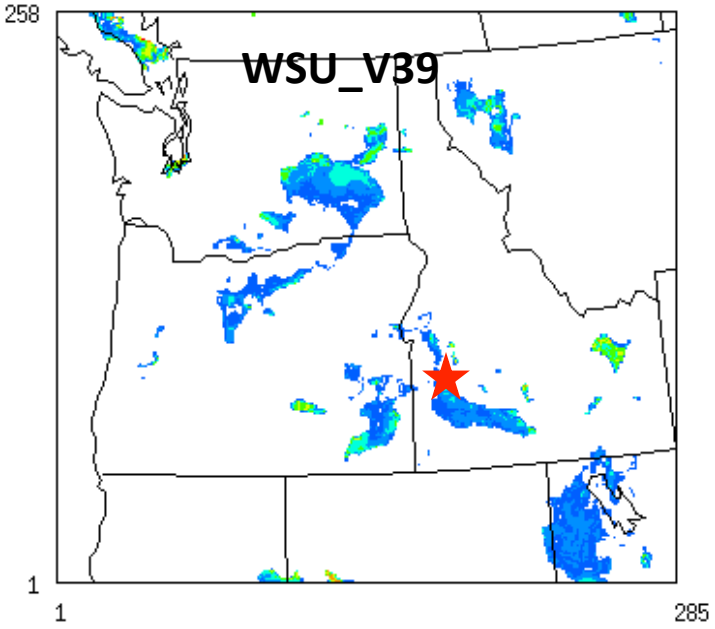


- @ St Luke's site, WSU WRF resolves much more ground cloud appearance and some isolated ice appearance

Spatial Distribution of QC in CASE I



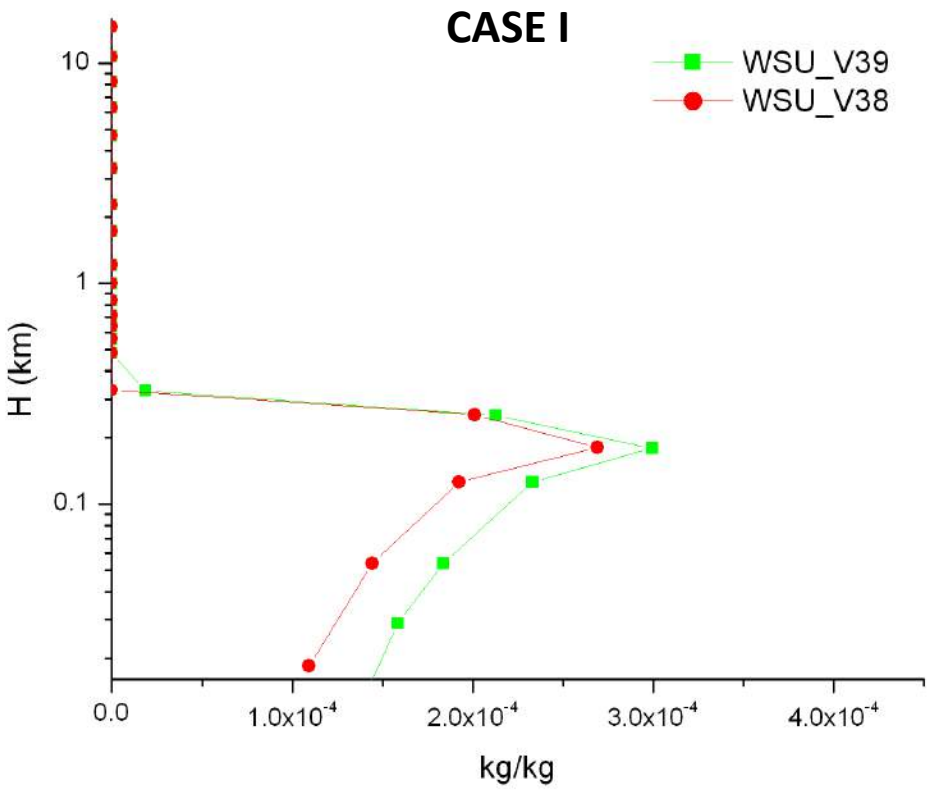


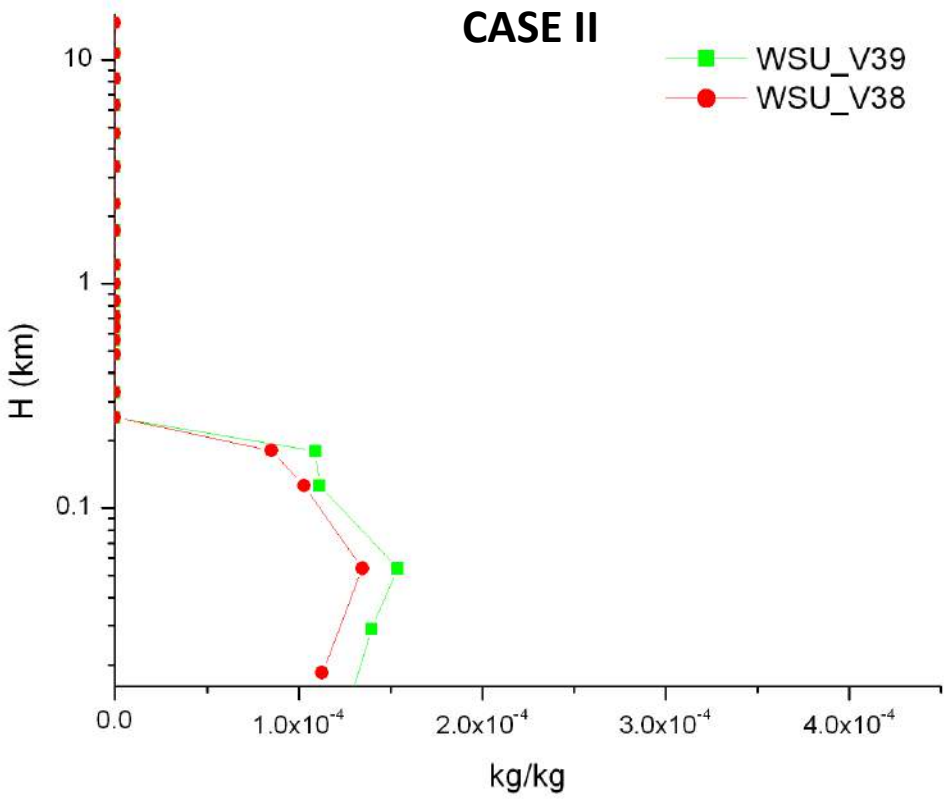


- More ground cloud/fog were resolved using finer vertical resolution

(snapshot @ 11UTC Jan 20, 2009)

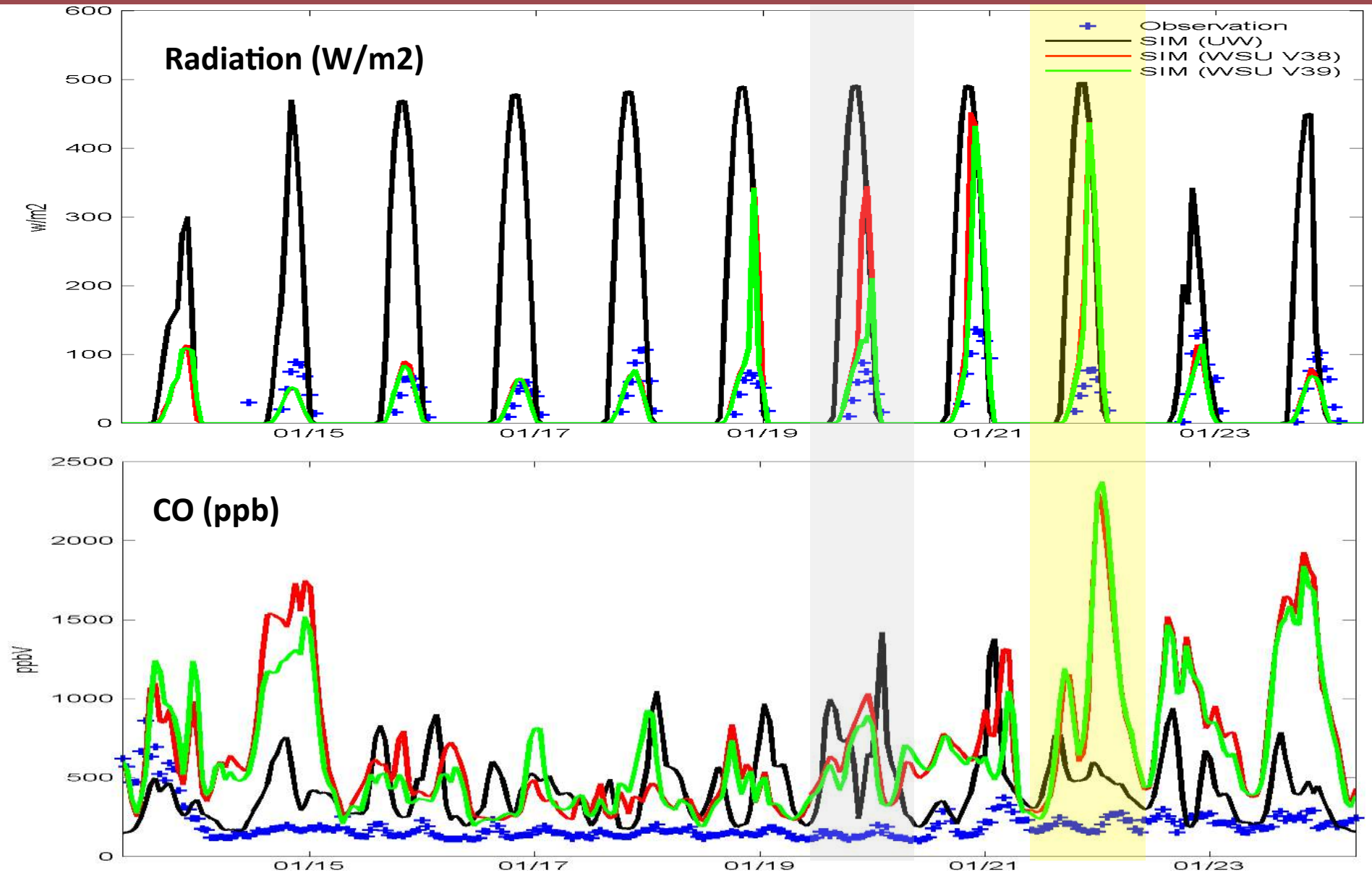
Vertical profile of cloud mixing ratio



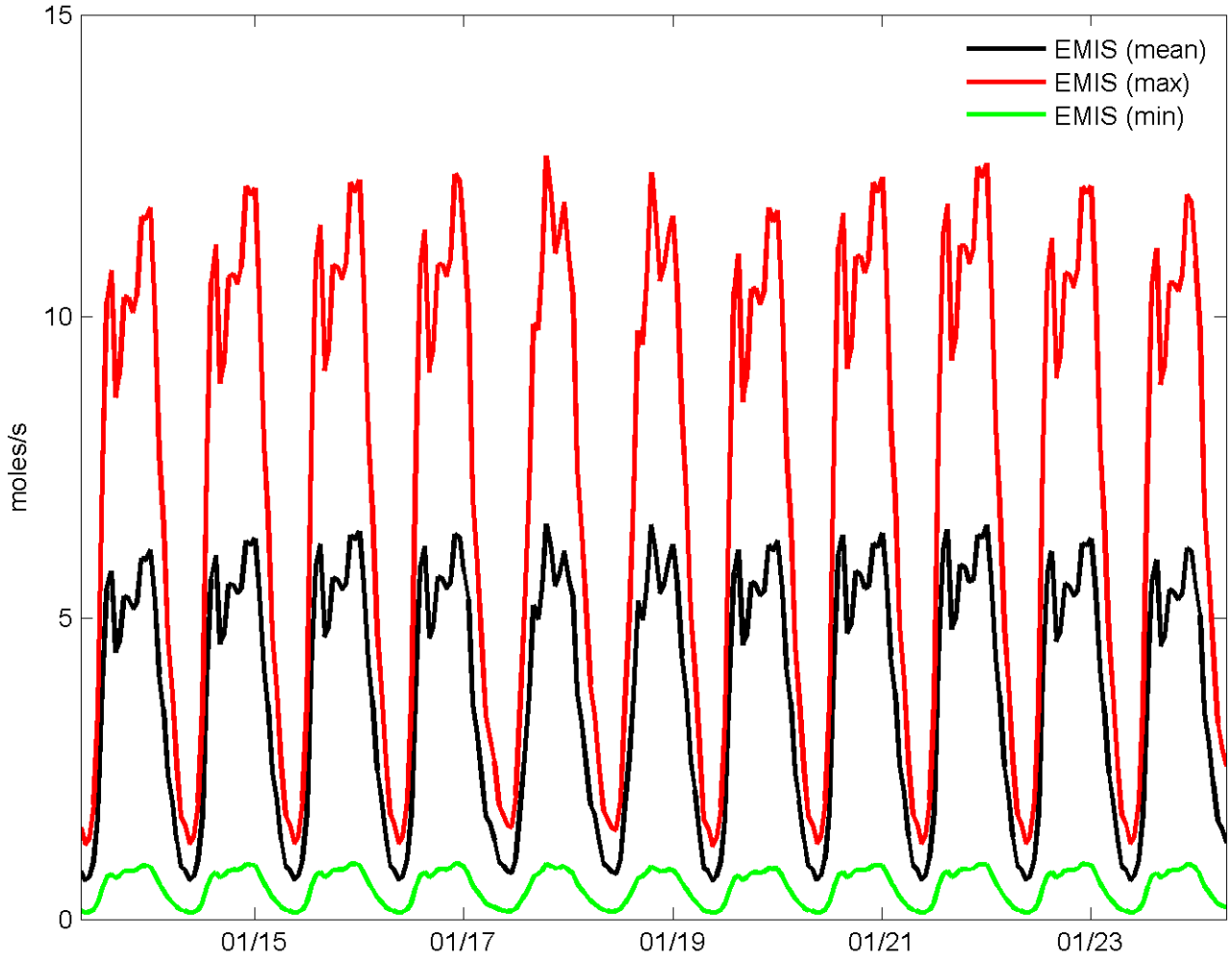


- The difference of resolved daily mean Qv profile may be associated with the difference of incoming radiation for WRF run V38 and V39

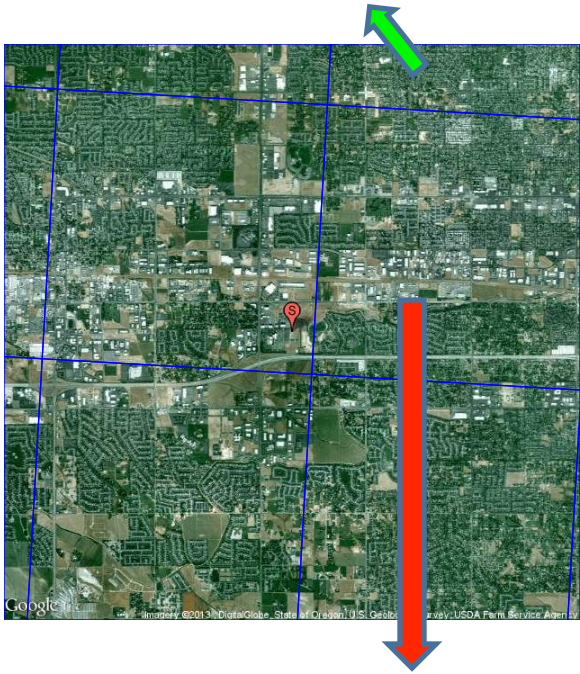
CO Simulation @ St Luke



CO Emission “footprint” near St. Luke’s



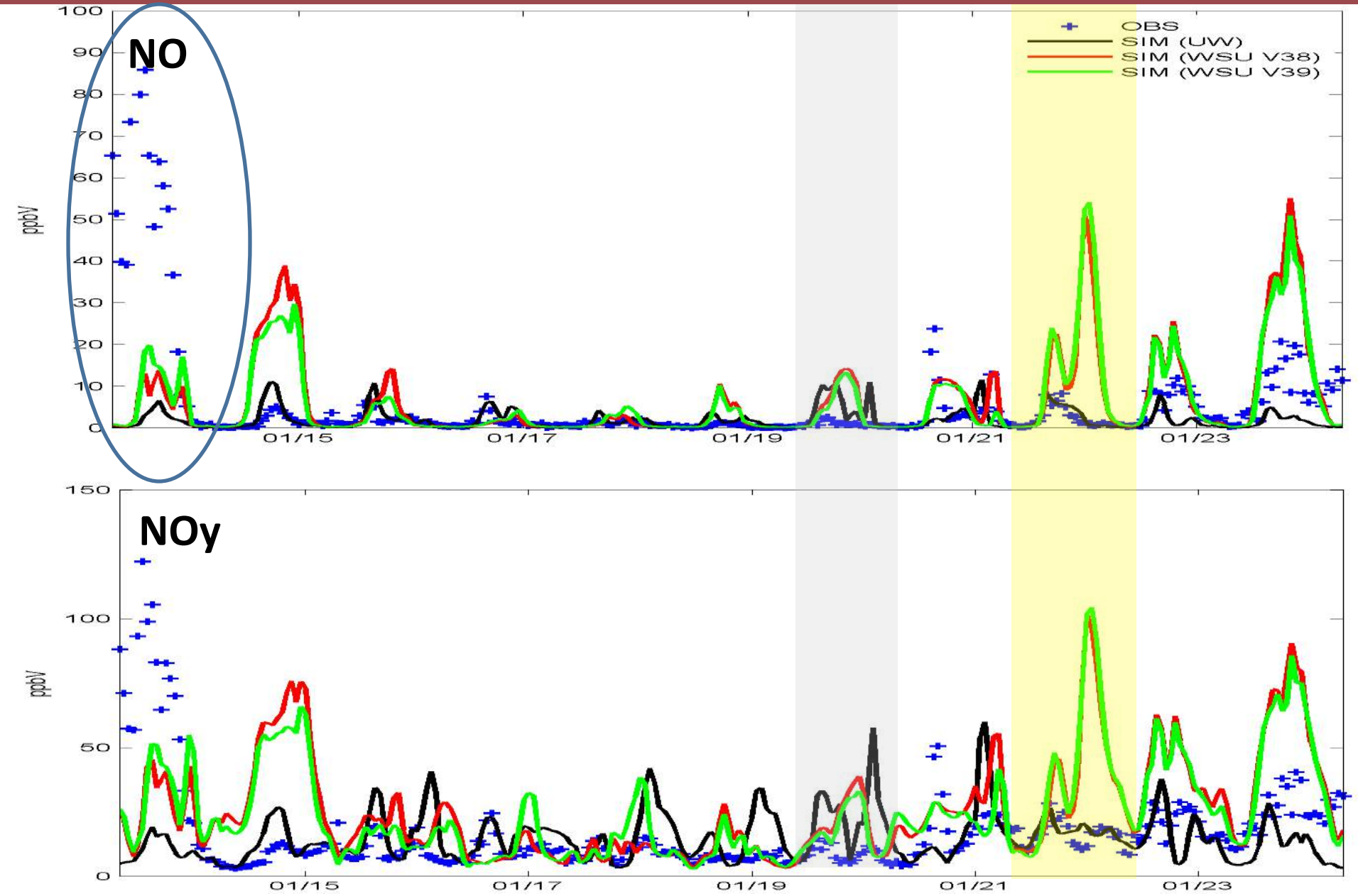
Min Emission Grid
Peak value~1 moles/s



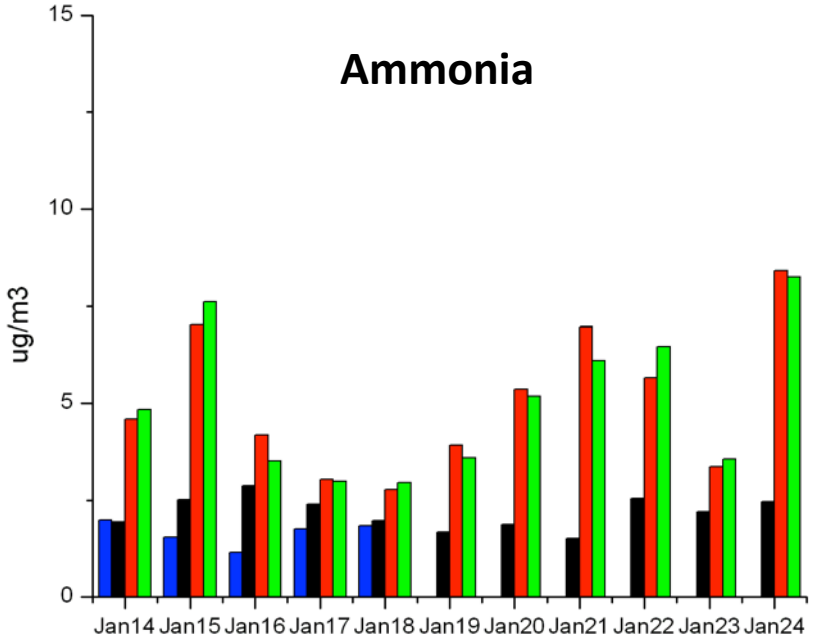
Max Emission Grid
Peak value~12 moles/s

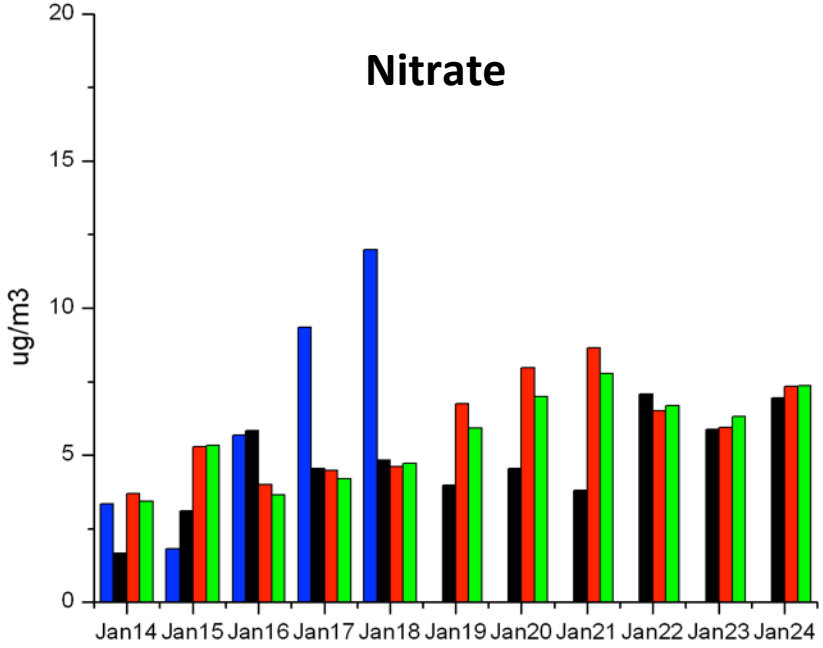
Emission with same diurnal variation but highly heterogeneous in terms of spatial variation, hence the receptor concentration highly depend on wind direction and upwind source.

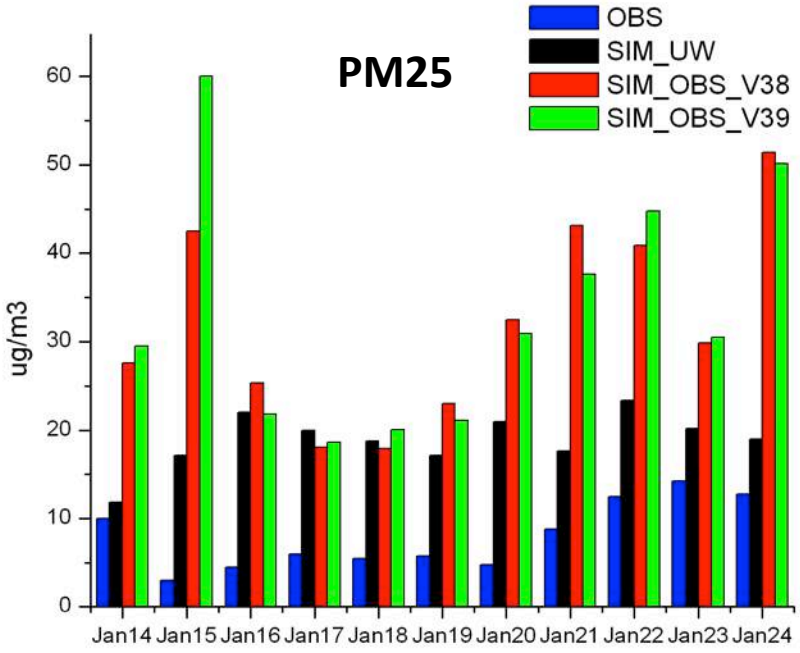
NOx Simulation @ St Luke



PM Simulation @ St Luke







- Hard to differentiate the impact of different meteorological fields (V38 .vs. V39) to ground concentration

Summary and Future Work

- Retrospective WRF with data assimilation produces better metrological fields for CMAQ over valley during winter time, at least some of the time.

- Increasing the near-surface vertical model resolution helps to capture the near surface fog formation, but is still imperfect.

- CMAQ results using assimilated WRF fields follow the pollutants daily variation trend. However, the impact of finer vertical resolution to surface concentration is not informative with current try.

- Future work will expand the simulation period, explore the concentration difference in 3D fields, and tuning the nitrate formation mechanism.

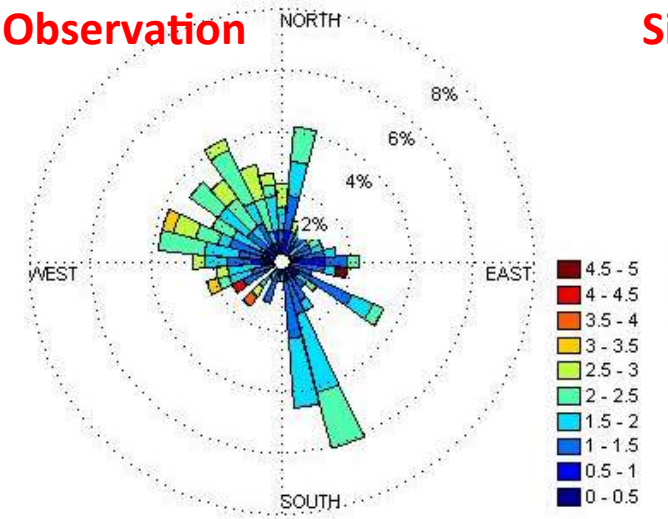
Backup slides

WRF Configuration Differences between UW and WSU

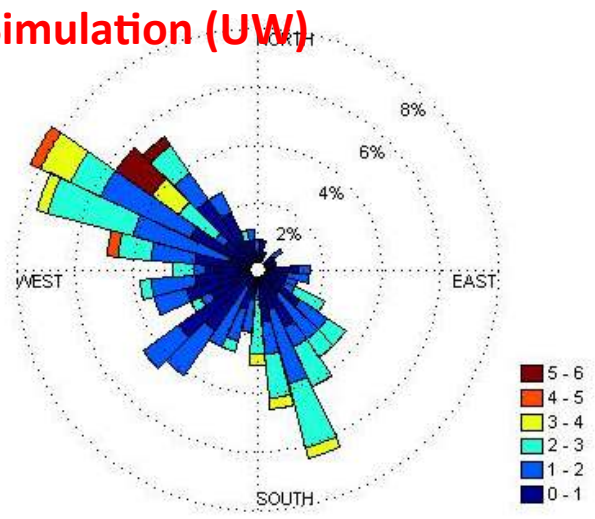
	UW-WRF (archived)	WSU-WRF (V38 or V39)
Purpose:	Forecast product	Retrospective case study
WRF Version:	WRF-ARW V3.1.1	WRF-ARW **V3.4.1**
Domain resolution:	D1(36km)-D2(12km)-D3(4km)	D1(12km)-D2(4km) with same domain coverage
Vertical Layer:	38 layers with first eta layer @ 0.995 (~39m)	**38** or **39** layers with first eta Layers @ 0.995 (~39m) or 0.997 (~23m), respectively
Boundary Conditions:	NCEP GFS forecast	NARR reanalysis fields
Radiation scheme:	RRTM (Transition effect with 2009012212)	RRTM
Microphysics scheme:	Thompson	Thompson
PBL scheme:	YSU	YSU
Land-surface scheme:	5 layer thermal-diffusion	5 layer thermal-diffusion
Cumulus scheme:	Kain-Fritsch	Kain-Fritsch
Assimilation:	No	Temperature, wind, moisture from NARR in D1 T2, U10 and RH from Mesowest in D2

Wind Performance during the Stagnation Period

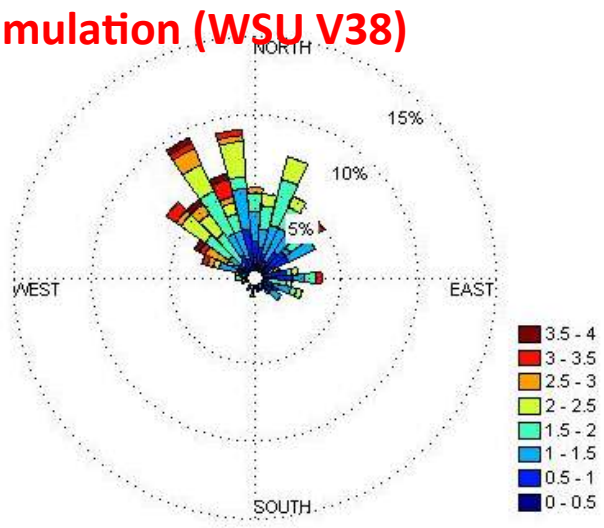
Observation

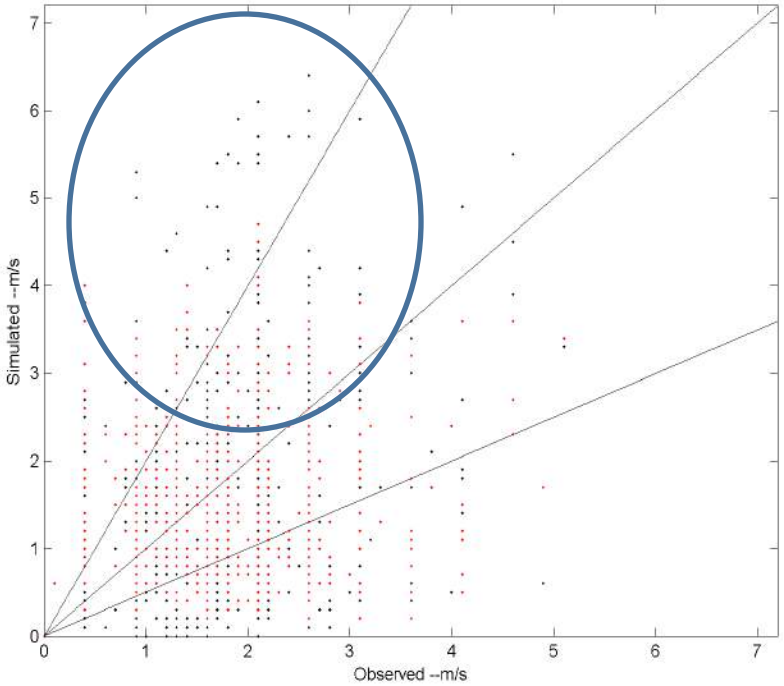


Simulation (UW)



Simulation (WSU V38)

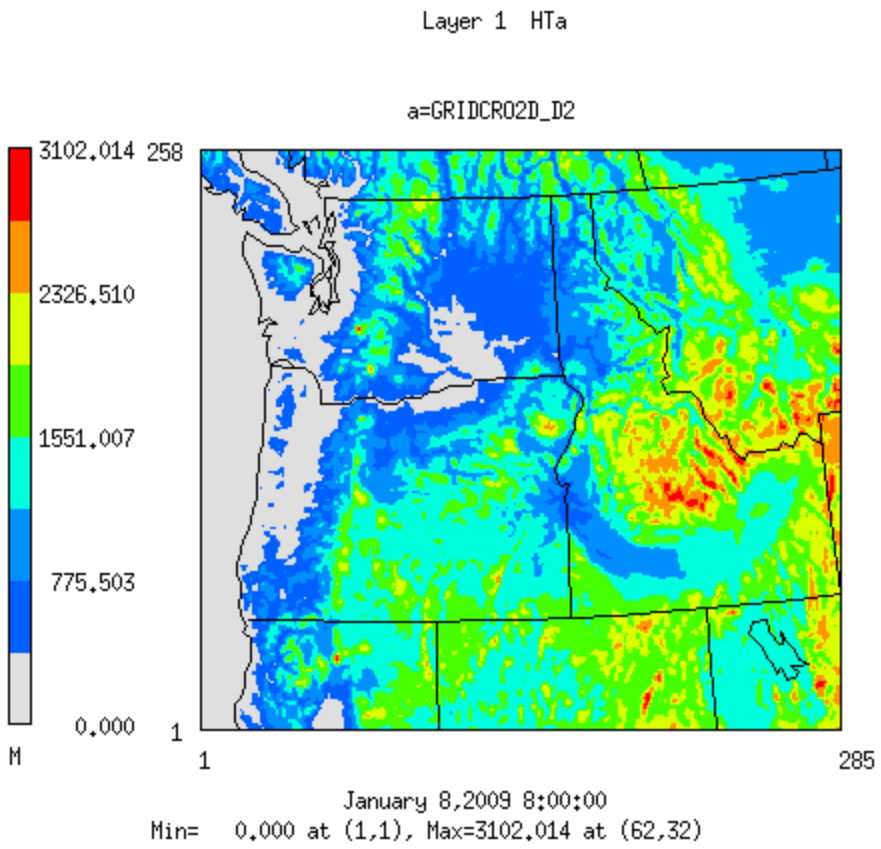




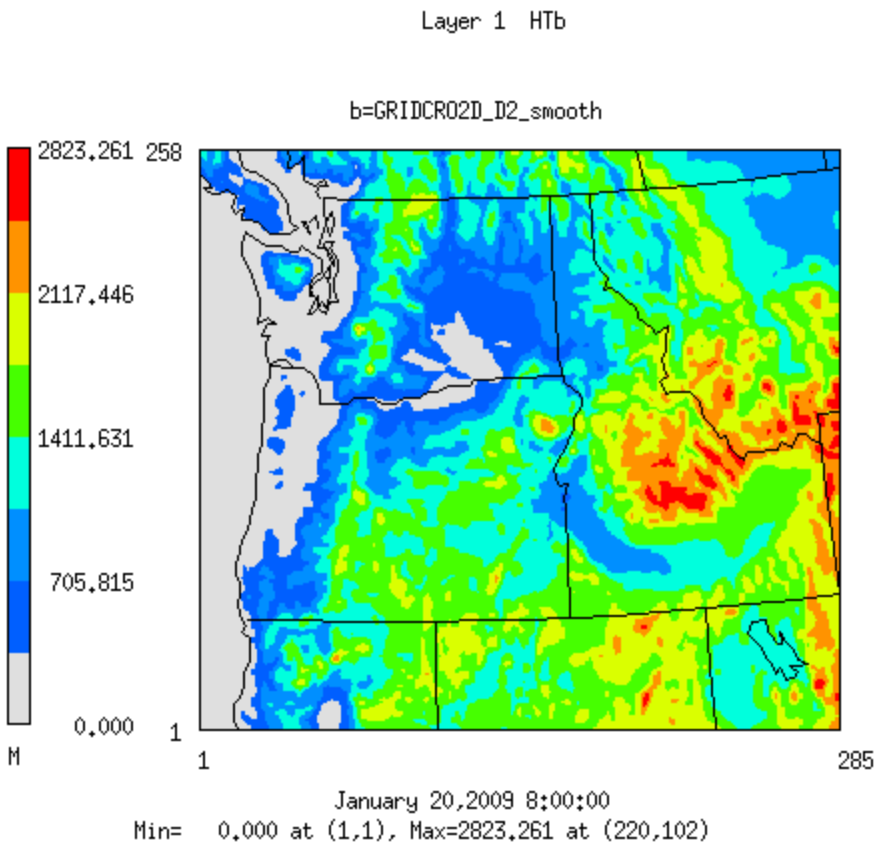
- Data assimilation can improve the wind overestimation in UW-WRF during the stagnation period.

The different terrain height outputs from WPS using terrain smoothing

Original



After smoothing



Max HT decrease from 3102 m to 2823 m, the gradient is decreased