Air quality urban simulations using WRF-Chem:

analysis of the grid resolution, urban land use classification and urban parametrization effects.

Ana Carla Fernandez, and Yunha Lee

Laboratory for Atmospheric Research
Civil and Environmental Engineering
Washington State University

Future works from the last AIRQUEST meeting

✓ Explore the impact of UCM and WUDAPT land use on air quality over Spokane: Run WRF-Chem BEP UCM with WUDAPT classification.

✓ Apply Ndown or nested domains to avoid unrealistic boundary influences on the model domain.
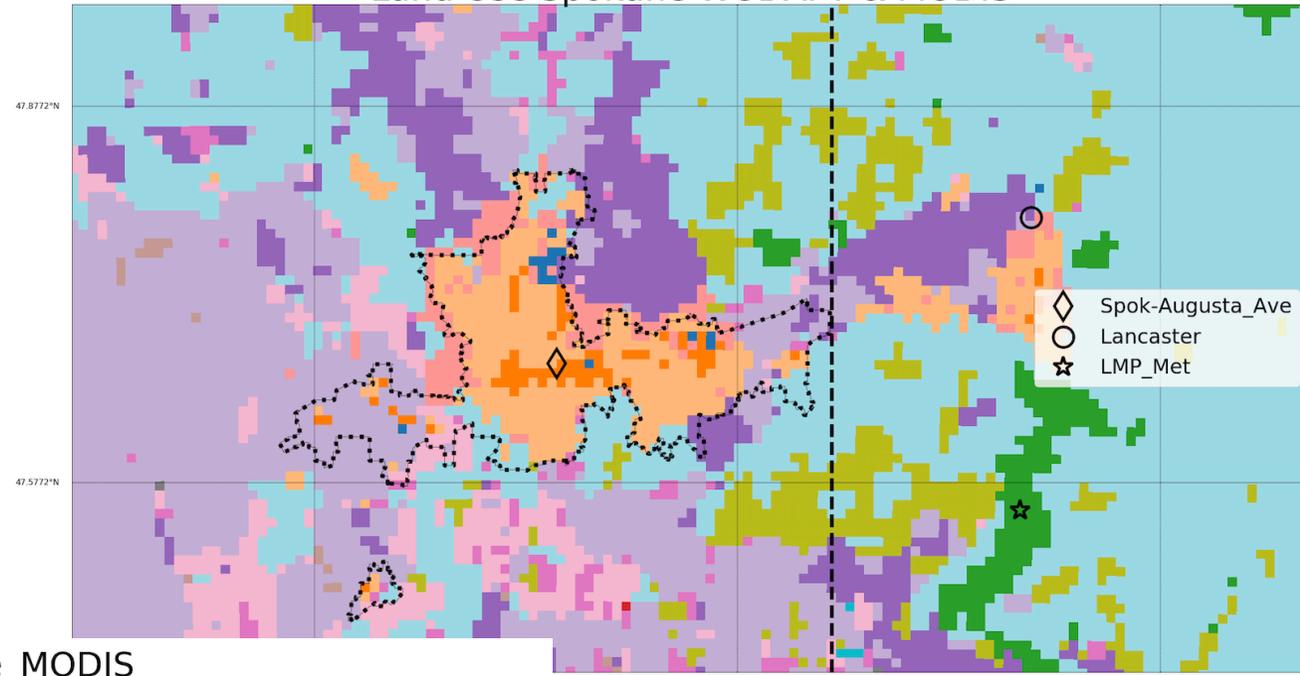
Model Configuration

- One-way 3 Nested Domain using Ndown(nested down).

- **Resolution**:
    - d01 – 12km
    - d02 – 4km
    - d03 – 0.8km.

- **Boundary and initial conditions:**
    - GFS-ANL (meteorological) and CAM_CHEM(chemical) with 1 x 1 grade of resolution every 6 hours.

- **Chemistry**: MOZART & MOSAIC.

- **Emissions:**
    - **Anthropogenic emissions**: NEI 2014.
    - **Biogenic emissions**: MEGAN.
    - **Biomass burning emissions**: FINN.

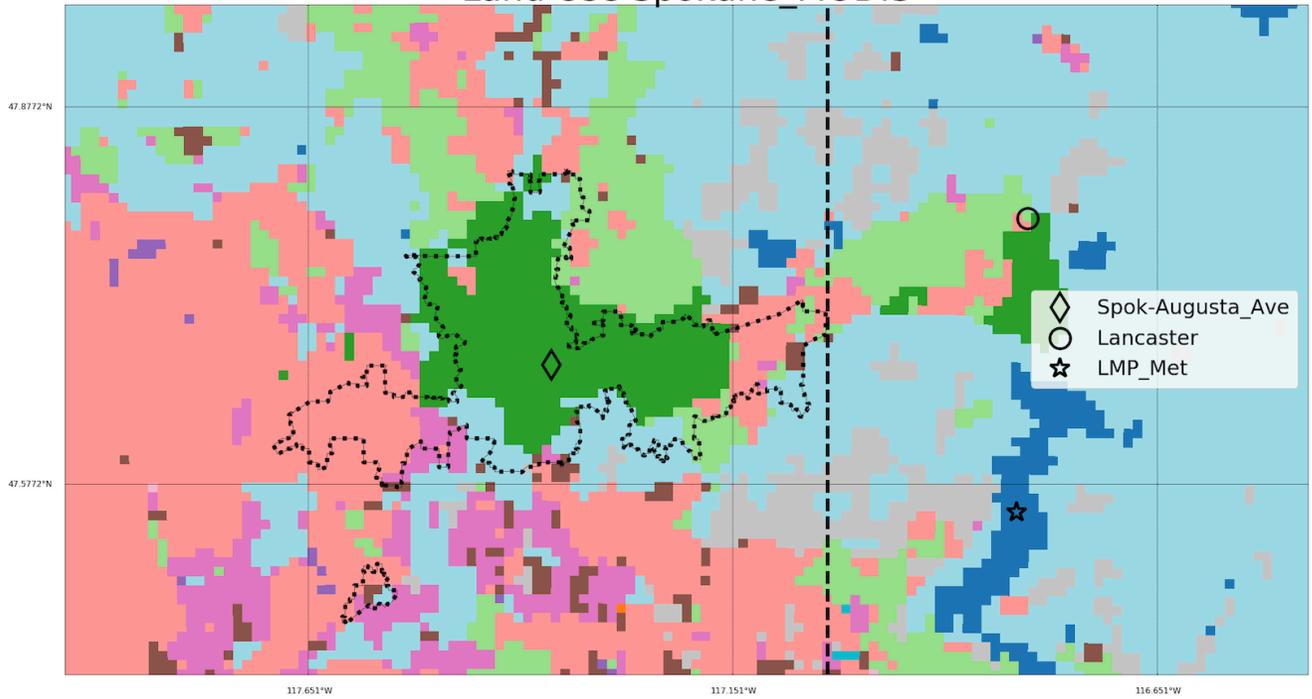- **Simulation Period:** 2017, August 31st to September 6th
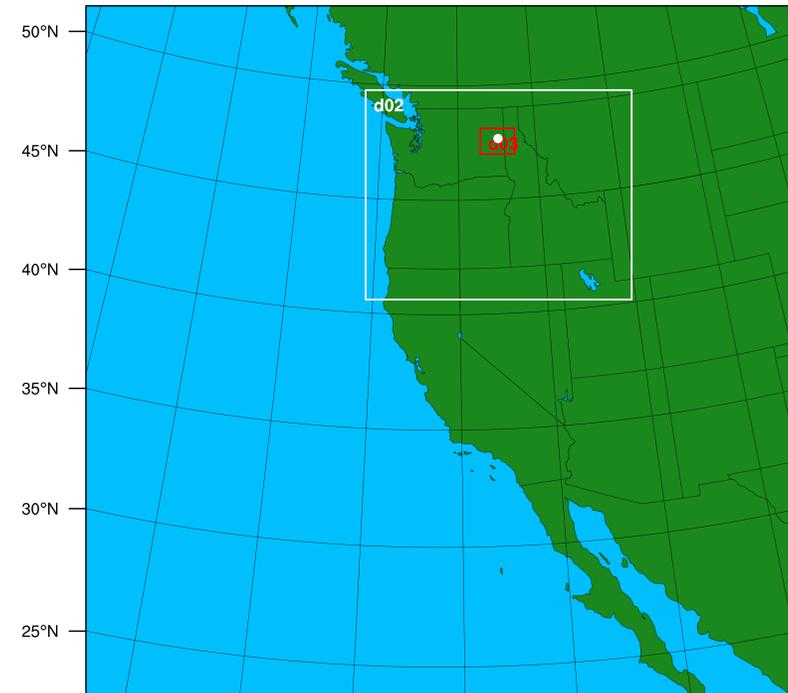
	BASE	**WUDAPT**	**BEP**
Urban Coupled Option	Noah LSM & Urban Bulk Parametrization	Noah LSM & Multi-layer BEP UCM	Noah LSM & Multi-layer BEP UCM
Land Use	MODIS	WUDAPT & MODIS	MODIS

Land use Differences on domain d03

Land Use Spokane WUDAPT & MODIS

Legend (top map):
- Heavy industry
- Large low-rise
- Open low-rise
- Water
- Barren or Sparsely Vegetated
- Cropland/natural vegetation
- Croplands
- Grasslands
- Savannas
- Woody Savannas
- Open Shrublands
- Closed Shrublands
- Mixed Forests
- Deciduous Broadleaf Forest
- Evergreen Broadleaf Forest
- Evergreen Needleleaf Forest

Markers:
- Spok-Augusta_Ave
- Lancaster
- LMP_Met

Land Use Spokane_MODIS

Legend (bottom map):
- Water
- Barren or Sparsely Vegetated
- Urban and Built-Up
- Croplands
- Grasslands
- Savannas
- Woody Savannas
- Open Shrublands
- Closed Shrublands
- Mixed Forests
- Deciduous Broadleaf Forest
- Evergreen Broadleaf Forest
- Evergreen Needleleaf Forest

Markers:
- Spok-Augusta_Ave
- Lancaster
- LMP_Met

Modeling strategy

	BASE	WUDAPT	BEP
Urban Coupled Option	Noah LSM & Urban Bulk Parametrization	Noah LSM & Multi-layer BEP UCM	Noah LSM & Multi-layer BEP UCM
Land Use	MODIS	WUDAPT & MODIS	MODIS

BASE vs WUDAPT:

To investigate the impact of urban land use classification on urban meteorology and air quality over the Spokane area
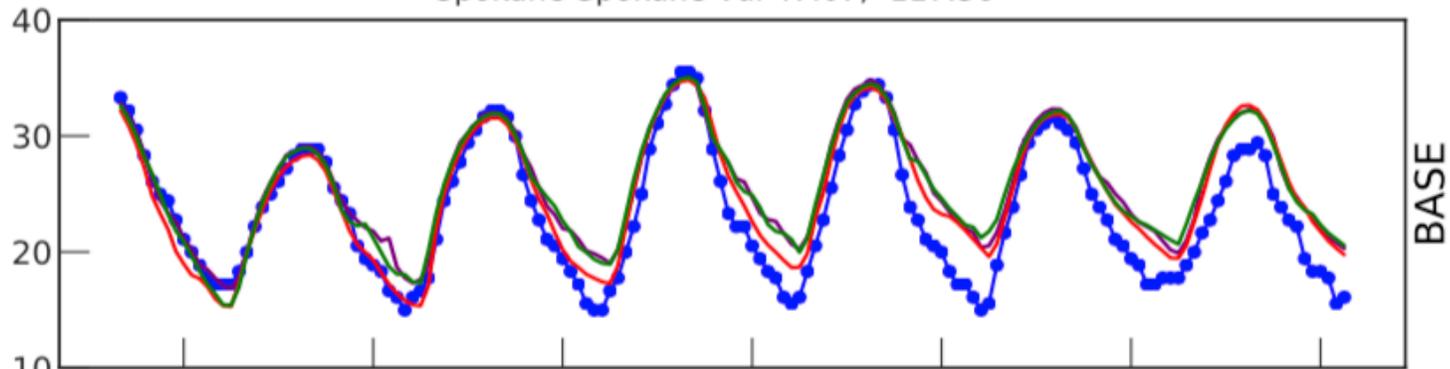
WUDAPT vs BEP:

To investigate the effect of Urban Canopy Models parametrization on urban meteorology and air quality over the Spokane area.
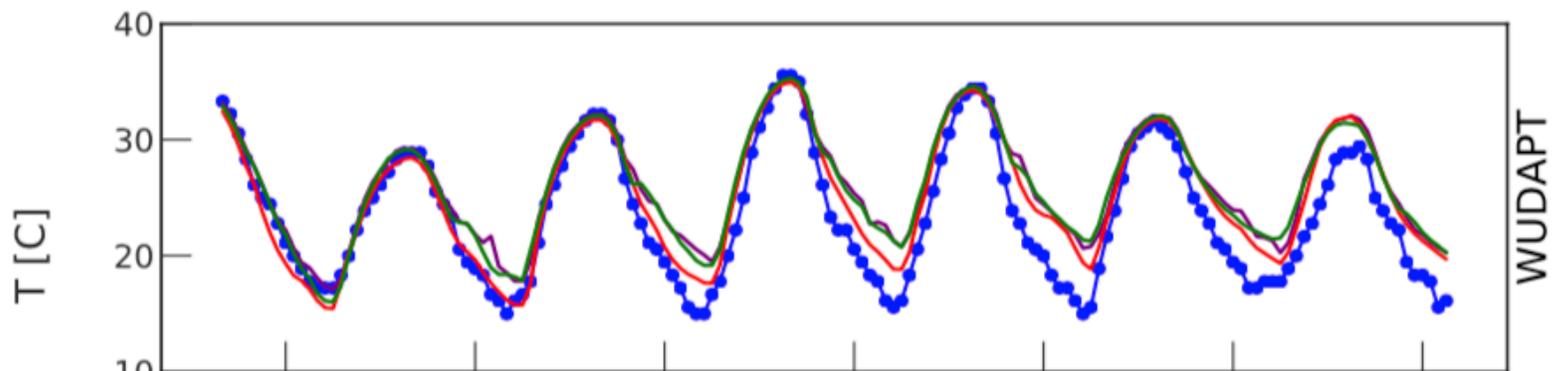
Domains intercomparison:

Effect of resolution on each comparison.
d01 vs d02 vs d03

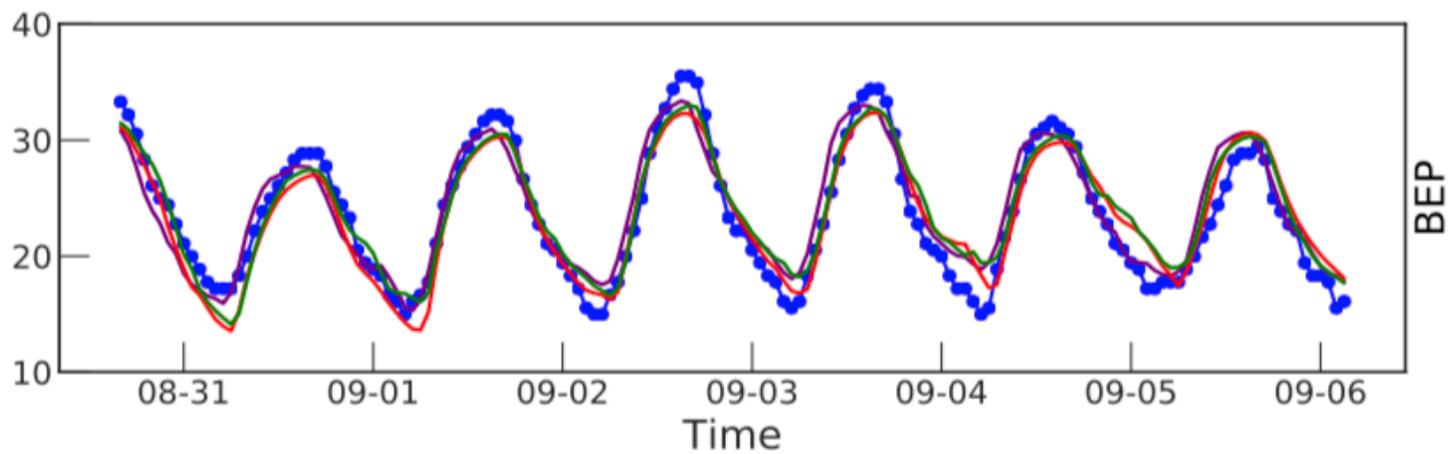# Results

'Spokane-Spokane Val 47.67, -117.36

BASE

	NMB	NME	RMSE	R^2
d01	6	8	2	0.88
d02	9	10	3	0.87
d03	10	10	3	0.89

WUDAPT

	NMB	NME	RMSE	R^2
d01	6	8	2	0.89
d02	10	11	3	0.89
d03	11	11	3	0.9

BEP

	NMB	NME	RMSE	R^2
d01	0	7	2	0.88
d02	2	6	2	0.9
d03	2	7	2	0.89

BASE_d01   BASE_d02   BASE_d03

WUD_d01   WUD_d02   WUD_d03

BEP_d01   BEP_d02   BEP_d03

15.0   16.5   18.0   19.5   21.0   22.5   24.0   25.5   27.0   28.5

T2 C
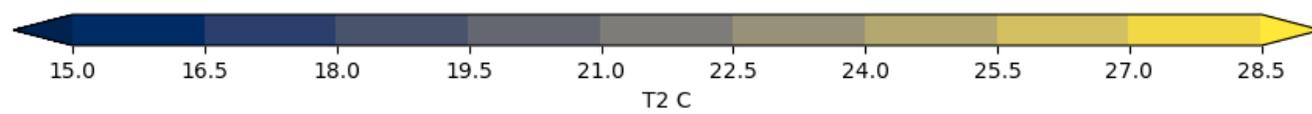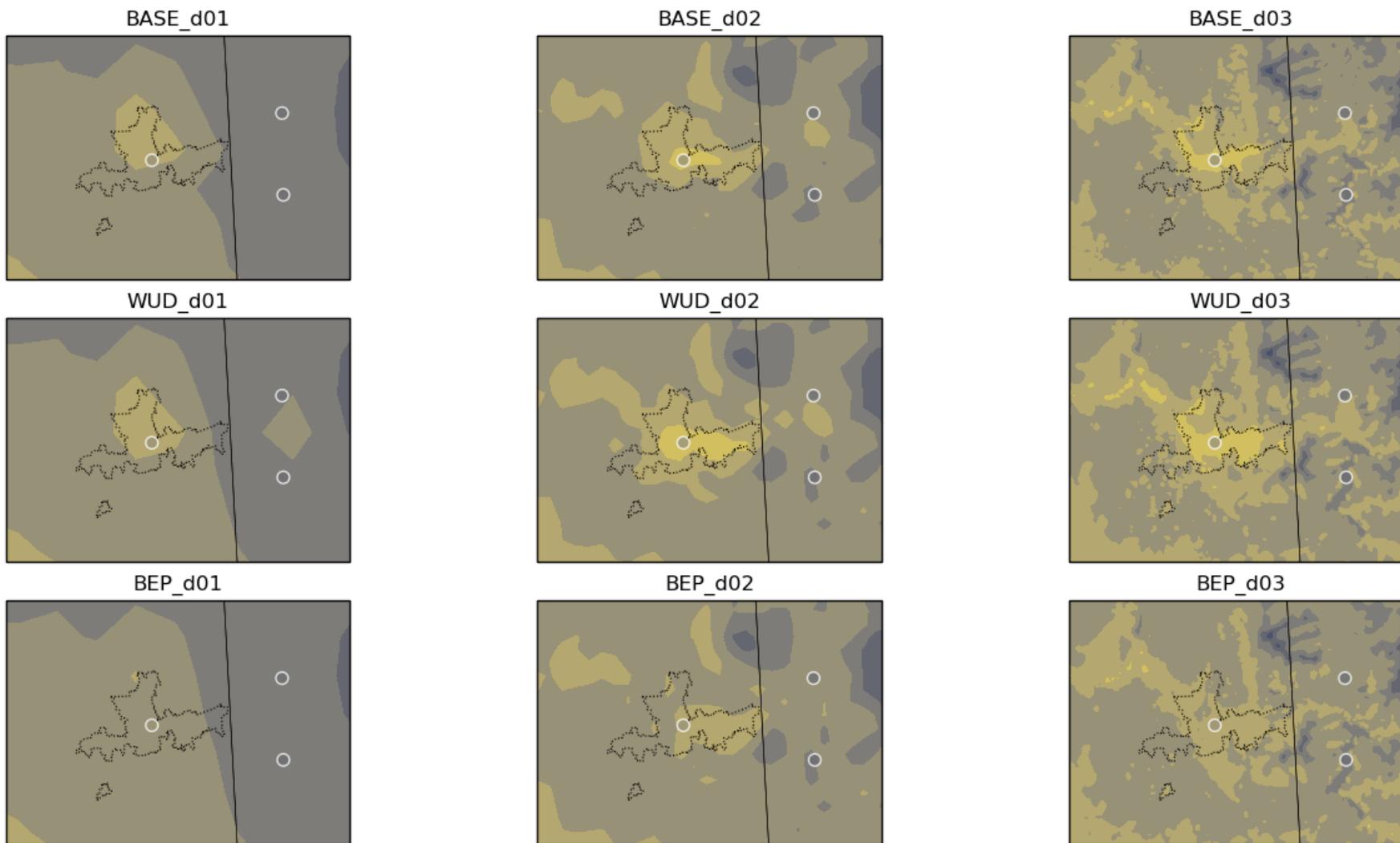
'Spokane-Spokane Val 47.67, -117.36
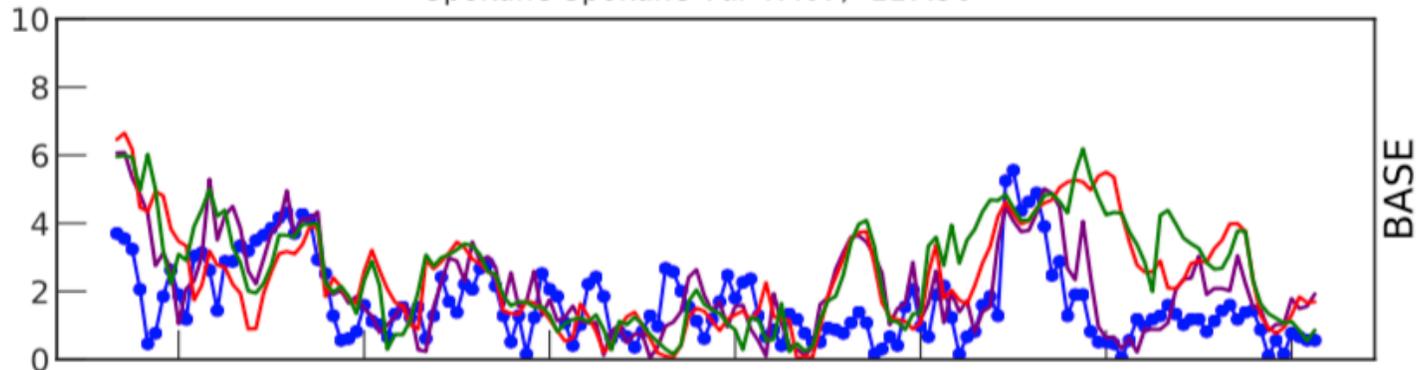
BASE

	NMB	NME	RMSE	R^2
d01	46	82	2	0.1
d02	56	85	2	0.13
d03	28	56	1	0.39
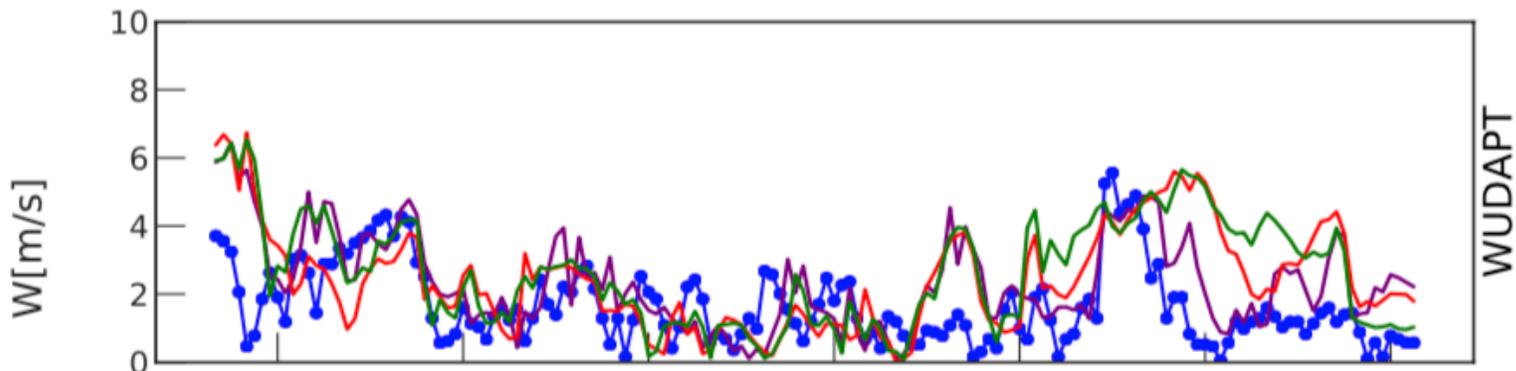
WUDAPT

	NMB	NME	RMSE	R^2
d01	47	86	2	0.07
d02	59	86	2	0.11
d03	41	65	1	0.28

BEP
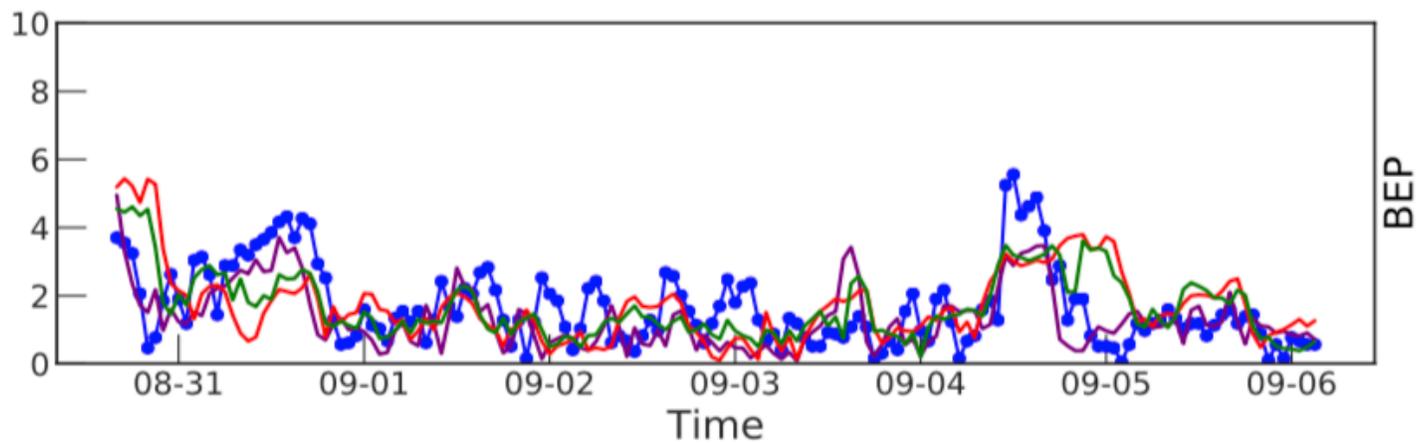
	NMB	NME	RMSE	R^2
d01	3	63	1	0.08
d02	0	50	1	0.22
d03	-20	47	1	0.37

obs   d03   d01   d02

BASE_d01   BASE_d02   BASE_d03

WUD_d01   WUD_d02   WUD_d03

BEP_d01   BEP_d02   BEP_d03

0.0   0.6   1.2   1.8   2.4   3.0   3.6   4.2   4.8   5.4

wspd10 m/s
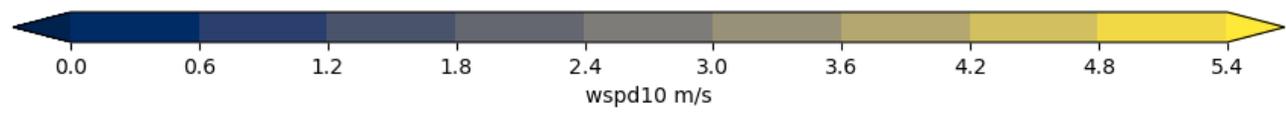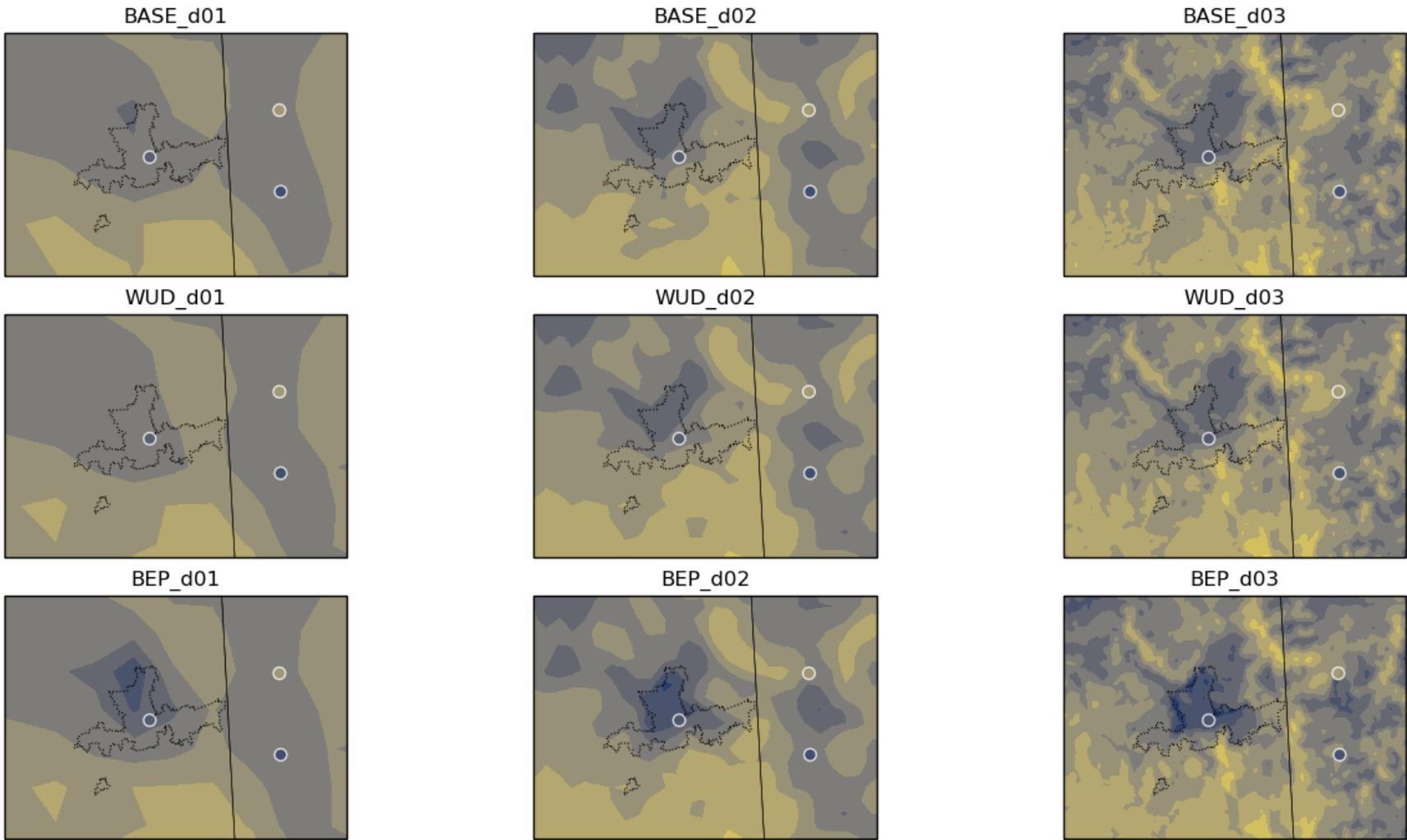
47.42, -117.53
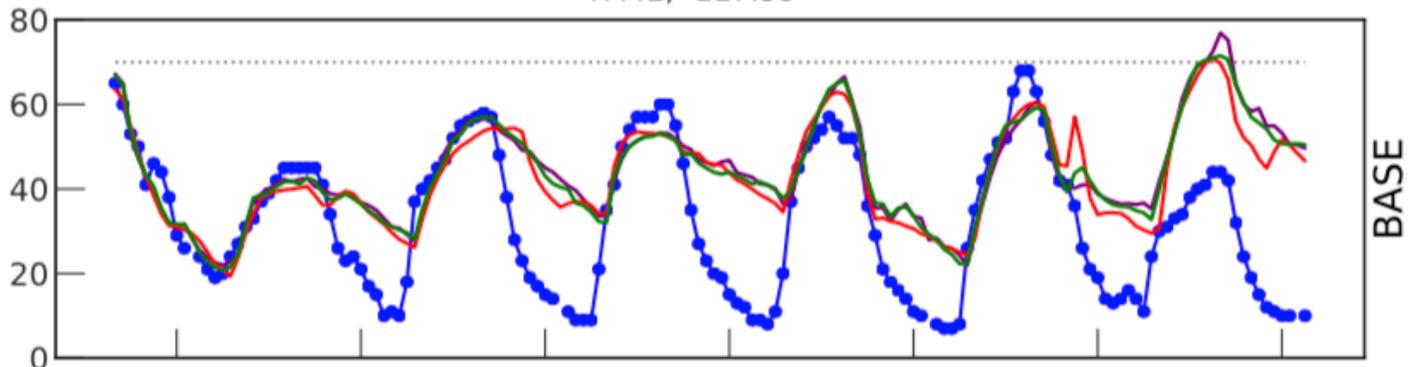
	NMB	NME	RMSE	R^2
d01	32	40	17	0.39
d02	35	42	18	0.34
d03	36	43	19	0.3
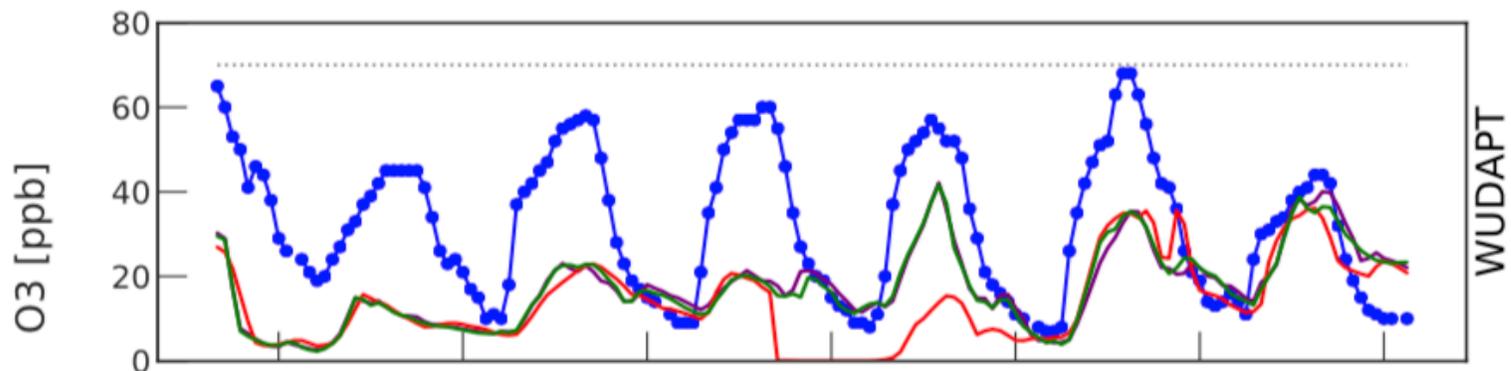
	NMB	NME	RMSE	R^2
d01	-57	60	24	0.21
d02	-47	53	21	0.23
d03	-46	53	21	0.2
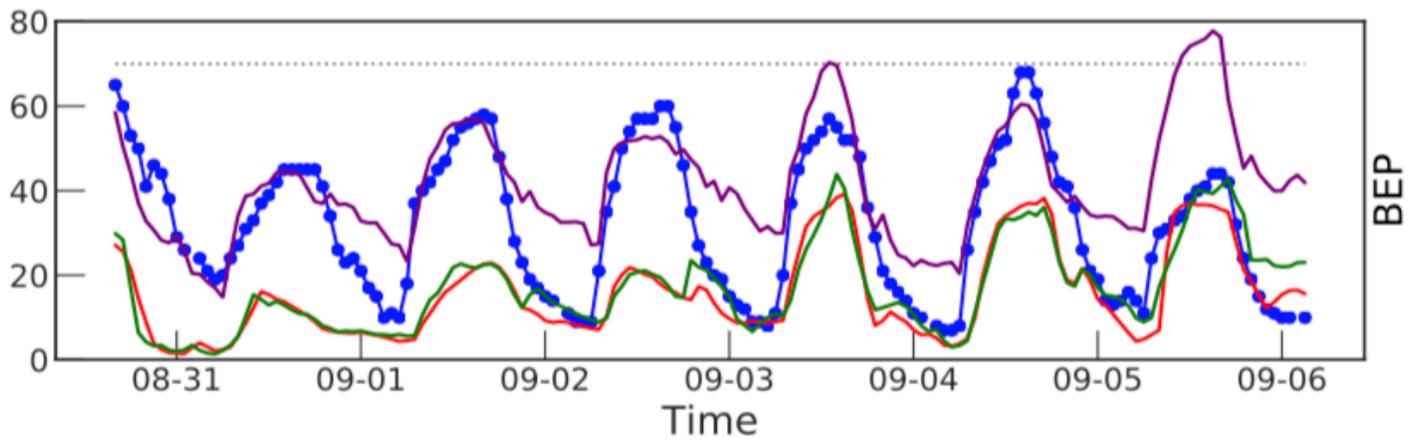
	NMB	NME	RMSE	R^2
d01	-52	53	21	0.43
d02	-48	52	21	0.28
d03	29	38	16	0.47

	BASE_d01	BASE_d02	BASE_d03
WUD_d01	WUD_d02	WUD_d03
BEP_d01	BEP_d02	BEP_d03

o3 ppb
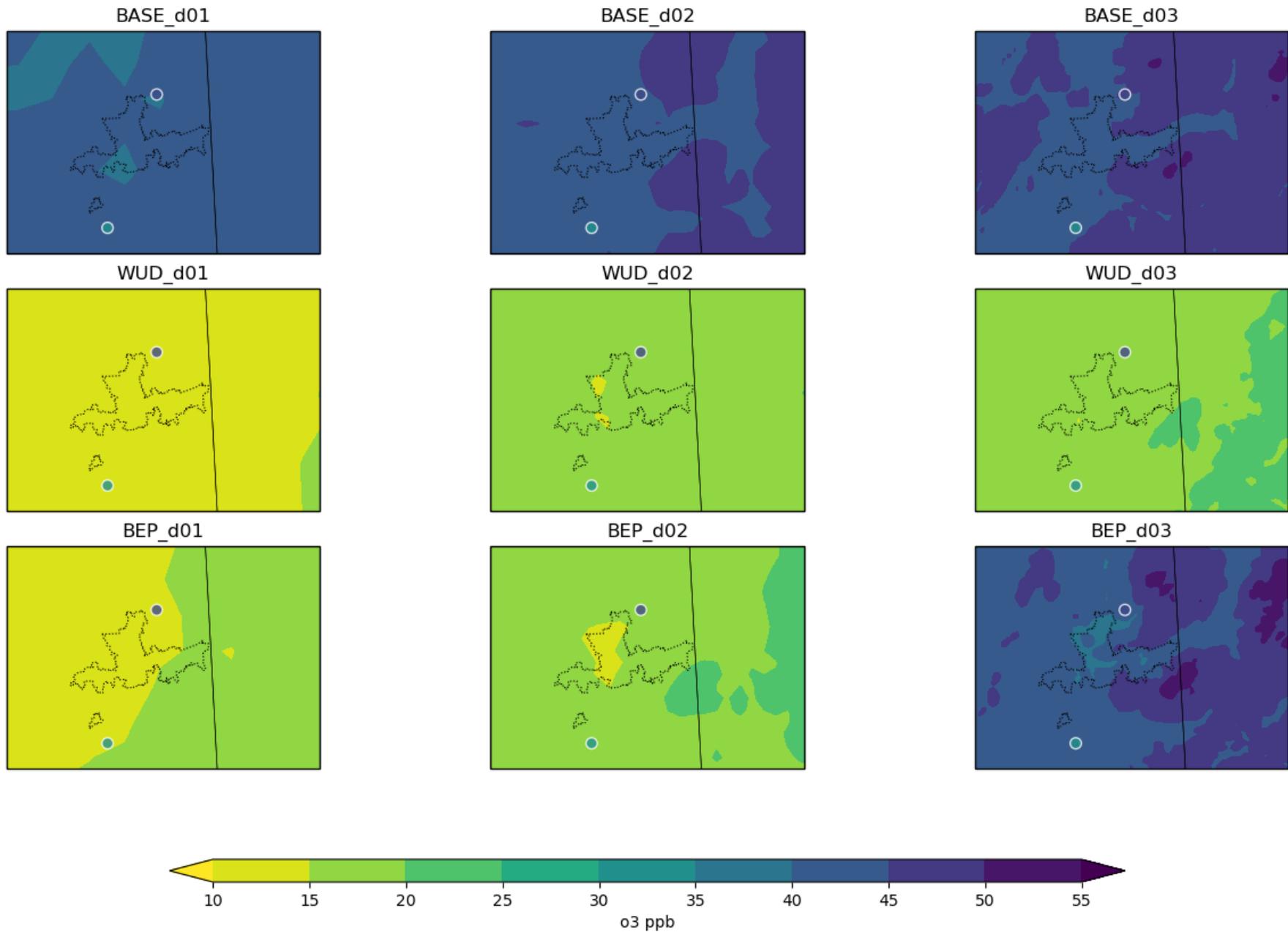
'Spokane-Spokane Val 47.67, -117.36
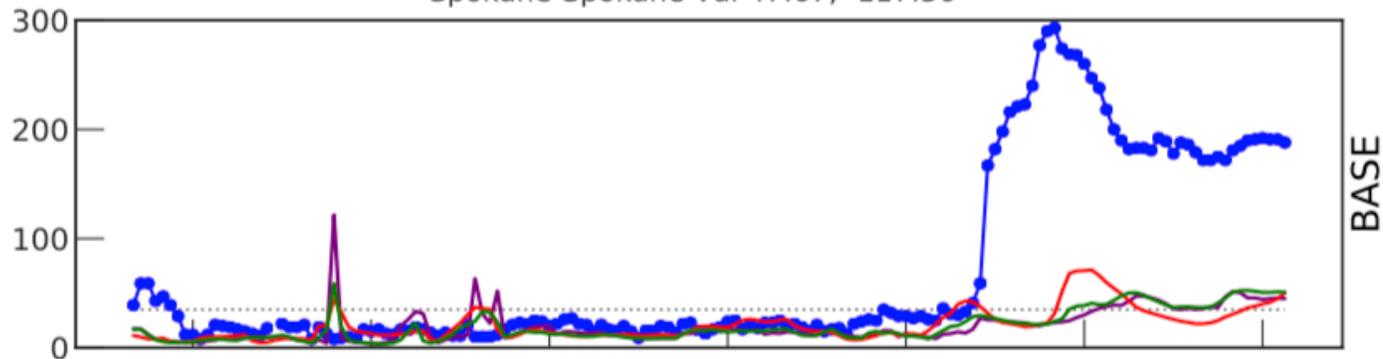
BASE

	NMB	NME	RMSE	R^2
d01	-69	73	90	0.45
d02	-71	74	90	0.55
d03	-71	76	92	0.3
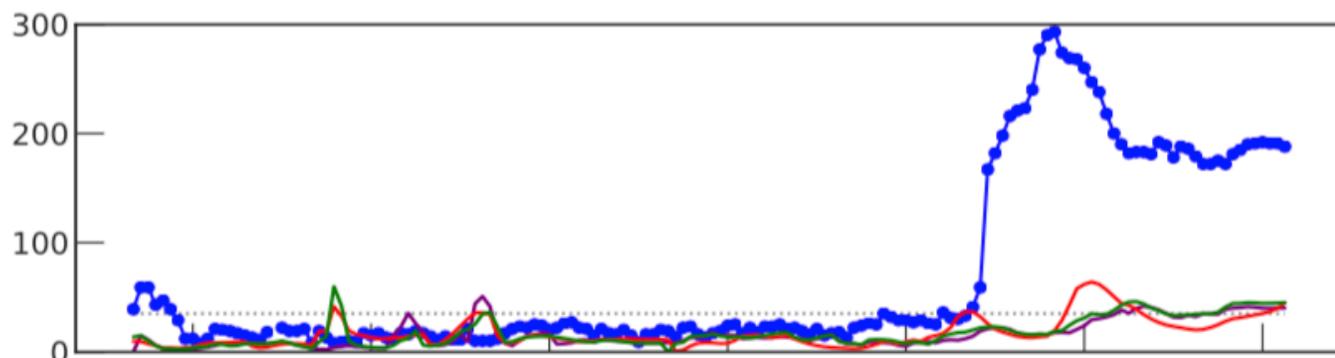
WUDAPT

	NMB	NME	RMSE	R^2
d01	-74	78	93	0.41
d02	-74	77	93	0.43
d03	-76	79	95	0.41

BEP
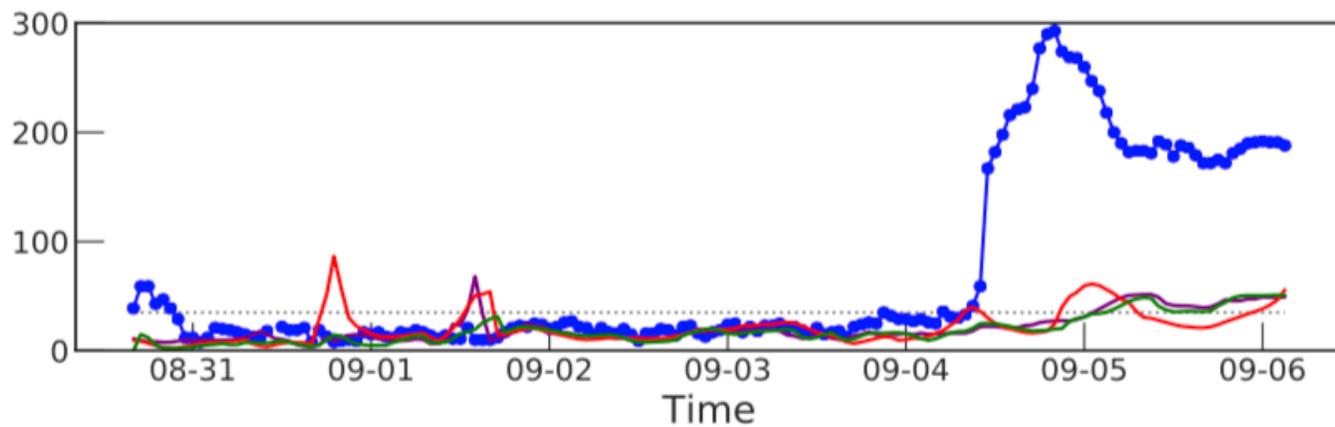
	NMB	NME	RMSE	R^2
d01	-68	76	92	0.23
d02	-72	74	92	0.51
d03	-70	72	90	0.51

PM2.5 [ug m-3]

Time

PM2.5_NAAQS   obs   d03   d01   d02
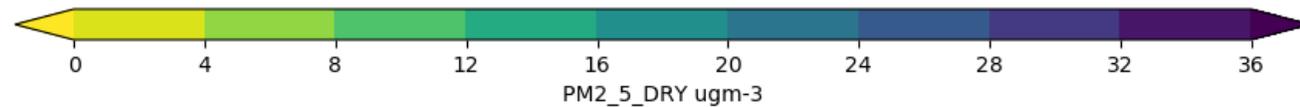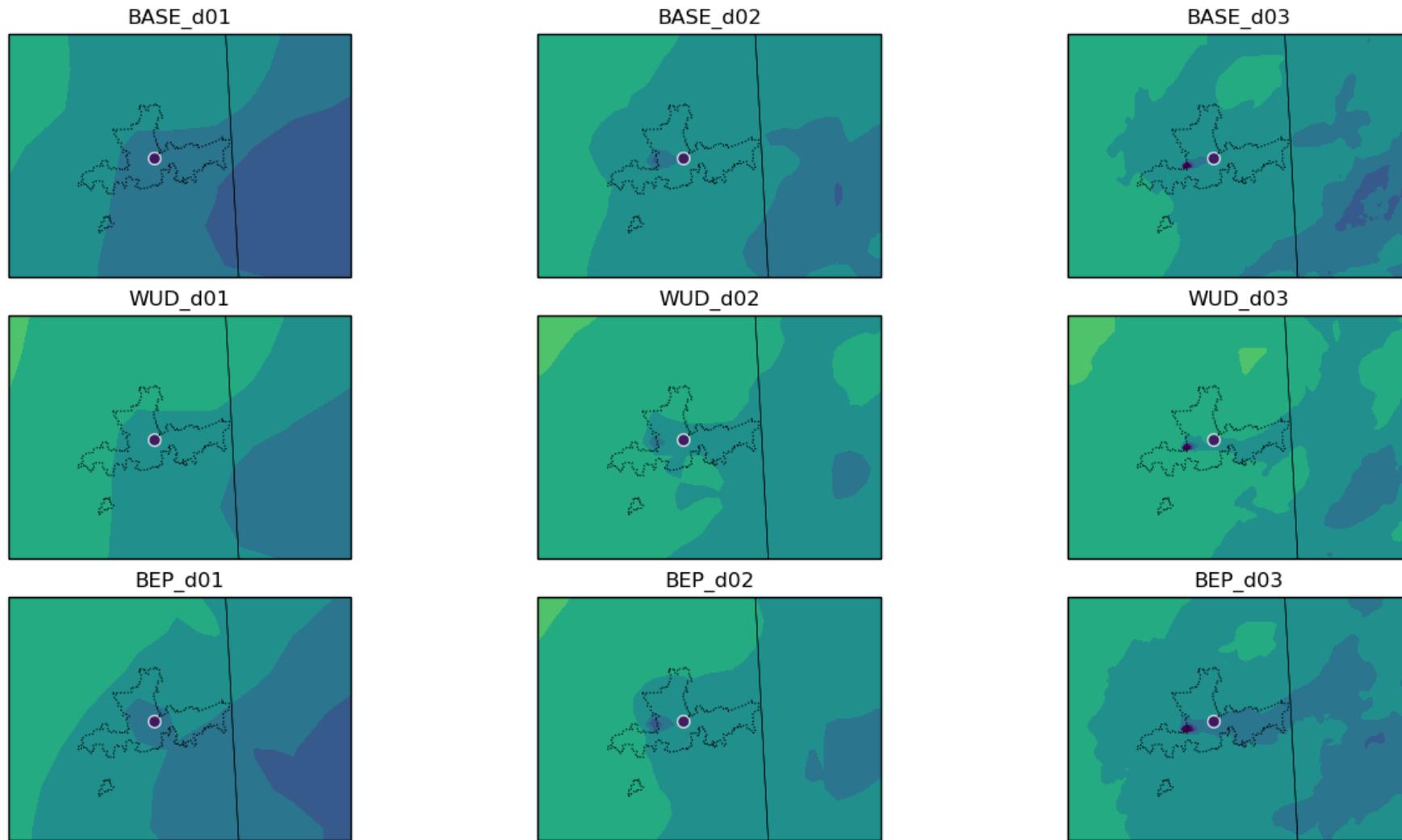
BASE_d01   BASE_d02   BASE_d03

WUD_d01   WUD_d02   WUD_d03

BEP_d01   BEP_d02   BEP_d03

0   4   8   12   16   20   24   28   32   36

PM2_5_DRY ugm-3

BASE vs WUDAPT:

- Switching from the MODIS urban land use to the WUDAPT urban land use in WRF over Spokane results in:

  - **Temperature at 2m**: no significative differences between cases when compared to observations and some minimal differences on the spatial distributions (higher values within the city limits compared to rural areas).

    - Higher resolution results in a more detailed temperature pattern distributions, however there is not a significant effect when compared to observations.

  - **Wind speed**: lower values within the city limits compared to surrounding areas, which make the predictions closer to the observations, but still overpredicting them.

    - Higher resolution results in a more detailed wind speed pattern distributions, however there is not a significant effect when compared to observations.

BASE vs WUDAPT:

- Switching from the MODIS urban land use to the WUDAPT urban land use in WRF over Spokane results in:

  - **Ozone:** both models slightly reproduce the daily cycle pattern. Compared to observations, WUDAPT underpredict and BASE case overpredict them. Both cases simulate uniform distributions concentrations within the city limits.

    - Higher resolution **not** results in a more detailed concentrations pattern distributions, however there is not a significant effect when compared to observations.

  - **PM2.5:** Both cases underpredict concentrations values, being the WUDAPT case the one that underestimate the most.

    - Higher resolution results in a more detailed concentrations pattern distributions, however there is not a significant effect when compared to observations.

WUDAPT vs BEP:

- Switching from the Bulk urban parametrization to the BEP urban canopy model in WRF over Spokane results in:

  - **Temperature at 2m**: when compared to observations, BEP model performed better than WUDAPT case.

    - Higher resolution results in a more detailed temperature pattern distributions, however there is not a significant effect when compared to observations.

  - **Wind speed**: BEP simulate lower values within the city limits compared WUDAPT case. BEP predictions underestimate the observations but still its simulation values are closer to observation than WUDAPT case.

    - Higher resolution results in a more detailed wind speed pattern distributions, BEP case for domain d02(4km) performs better compared to the other domains.

WUDAPT vs BEP:

- Switching from the Bulk urban parametrization to the BEP urban canopy model in WRF over Spokane results in:

  - **Ozone:** BEP model reproduces better the daily cycle pattern compare to WUDAPT model. Compared to observations, BEP overpredict those values while WUDAPT underpredict them. WUDAPT case simulates a more uniform spatial distribution within the city limits whereas BEP model simulates more heterogeneous patterns.

    - Higher resolution **not** results in a more detailed concentrations pattern distributions for WUDAPT case but it does affect to the BEP model. Compared to observations BEP d03 performs better compared to the other domains.

  - **PM2.5:** Both cases underpredict concentrations values, being the WUDAPT case the one that underestimate the most.

    - Higher resolution results in a more detailed concentrations pattern distributions, however there is not a significant effect when compared to observations.

Thanks