Annual WRF Simulations for the Utah Bureau of Land Management's Air Resource Management Strategy (ARMS) Air Quality Modeling

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Background and Goals

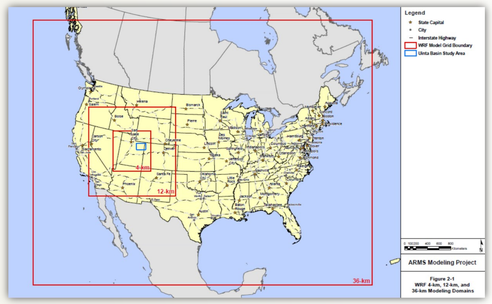
In recent years, several episodes of elevated fine particulate matter ($PM_{2.5}$) and ozone concentrations have been observed in the Uinta Basin in northeast Utah, where significant oil and gas development activities are occurring. These episodes typically occur during wintertime cold pool stagnation events.

The ARMS Modeling Project is a cumulative assessment of potential future air quality impacts associated with predicted oil and gas activity in the Uinta Basin, and will provide a reusable modeling platform suitable for air quality management decisions affecting the Uinta Basin.

To support ongoing photochemical grid modeling efforts, AECOM and STI conducted annual meteorological model simulations with the Weather Research and Forecast (WRF) model for 2010 for three nested modeling domains (36-km, 12-km, and 4-km grid resolutions).

Uinta Basin study area for the ARMS Modeling Project.

Because this air quality management tool will be used by stakeholders during all seasons, adequate meteorological and air quality model performance must be demonstrated throughout the year under a variety of conditions. We performed several WRF sensitivity experiments for February and July to determine the preferred configuration for the annual simulation. This poster presents key findings from these sensitivity tests.



WRF domains for the ARMS Modeling Project.

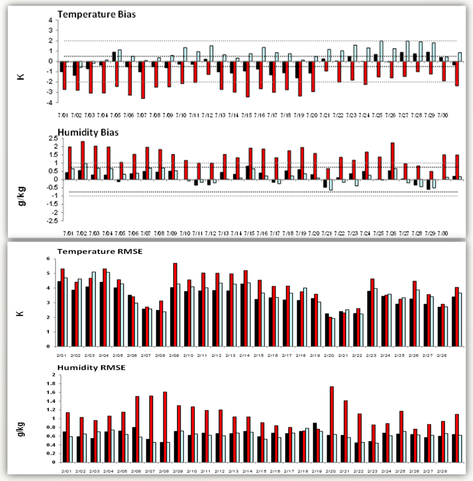
Land Surface Model Sensitivity

We evaluated three land surface models (LSM):

1. **Pleim-Xiu** LSM coupled with the Asymmetric Convective Model version 2 (ACM2) planetary boundary layer (PBL) scheme.
2. **Noah-MP** LSM with default configurations, coupled with the Mellor-Yamada-Janjic (MYJ) PBL scheme.
3. **Unified Noah** LSM coupled with the MYJ PBL scheme.

Noah-MP performed poorly in the winter, despite more advanced snow physics. Additional testing of the Noah-MP settings is required to improve model performance.

The Noah-MP land surface model was not used for the ARMS Modeling Project.



Daily temperature and humidity model performance for the LSM sensitivity experiments. The top two images show biases from the summer sensitivity, while the bottom two images show root mean square errors (RMSE) for the winter sensitivity.

PBL Model Sensitivity

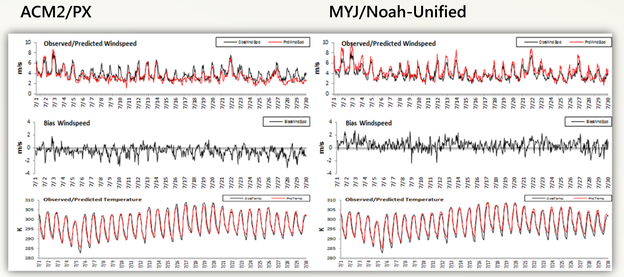
We evaluated three PBL schemes:

1. ACM2 coupled with the Pleim-Xiu LSM (ACM2/PX).
2. MYJ coupled with the Unified Noah LSM (MYJ/Noah).
3. Quasi-Normal Scale Elimination (QNSE) scheme coupled with the Unified Noah LSM.

ACM2/PX generally performed best in winter, while MYJ/Noah performed best in summer. The large negative wind speed bias for the summer ACM2 run was of particular concern.

Separate WRF configurations were selected for the annual simulation: one for summer and another for winter.

ACM2/PX | MYJ/Noah-Unified



Observed (black) and predicted (red) wind speed, wind speed bias, and temperature for the summer sensitivity experiments for the WRF 4-km domain.

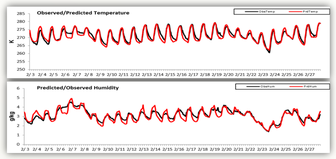
Statistical Benchmarks and Model Performance for the BLM WRF 4-km Domain for February and July

Parameter	Statistics	Statistical Benchmark (Tesche 2002)	Statistical Benchmark Complex Terrain	February ACM2/PX	February MYJ/Noah	February QNSE-EDMF/Noah	July ACM2/PX	July MYJ/Noah	July QNSE-EDMF/Noah
Wind Speed (m/s)	RSME	≤ 2	≤ 2.5	1.83	2.22	2.2	2.16	2.48	2.54
	Bias	± 0.5		-0.59	0.21	0.14	-0.6	0.44	0.46
	IOA	≥ 0.6		0.56	0.55	0.54	0.59	0.61	0.6
Wind Direction (deg)	Bias	± 10		3.58	4.09	1.78	1.48	4.29	1.04
	Gross Error	≤ 30	≤ 55	58.66	59.3	60.63	55.6	55.19	55.54
Temperature (K)	Bias	± 0.5	± 2	-0.05	0.5	0.19	-0.34	0.85	0.09
	Gross Error	≤ 2	≤ 3.5	2.71	2.87	2.88	2.4	2.6	2.49
	IOA	≥ 0.8		0.89	0.87	0.86	0.94	0.93	0.93
Humidity (g/kg)	Bias	± 0.75	± 1	-0.1	0.11	0.15	0.2	0.17	-0.12
	Gross Error	≤ 2	≤ 2	0.52	0.5	0.51	1.29	1.39	1.19
	IOA	≥ 0.6		0.8	0.82	0.8	0.75	0.74	0.79

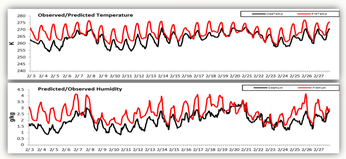
Model performance statistics for the WRF 4-km domain for the February and July sensitivity experiments. Green values indicate the best configuration for a particular parameter and statistic.

Uinta Basin Model Performance

WRF model performance was unusually poor in the Uinta Basin, despite the use of data assimilation with special observations from the Uinta Basin.



Observed (black) and predicted (red) temperature and moisture for the WRF 4-km domain for February 2010.



Observed (black) and predicted (red) temperature and moisture for the Uinta Basin study area for February 2010.

Buddy Check Test in WRF OBSGRID

We found that the Buddy Check quality assurance (QA) test in WRF OBSGRID was rejecting valid temperature observations in areas with complex terrain. Rejected observations were subsequently omitted from the WRF data assimilation process. We deactivated the Buddy Check test, but retained the other OBSGRID QA tests.

With Buddy Check

```
20100211010000
40.6000 -110.4300
                    LKFU1                    MADIS
                    3079.    F    F    1
 -99999.000  98304.000 -888888.000 -888888.000  3078.500     0.000
-888888.000 -888888.000 -888888.000 -888888.000 -888888.000 -888888.000
-888888.000 -888888.000  -99999.000     0.000 -888888.000 -888888.000

20100211010000
40.1726 -110.4930
                    UTSTV                    MADIS
                    1744.    F    F    1
 -99999.000  98304.000 -888888.000 -888888.000  1743.500     0.000
-888888.000 -888888.000    -0.437     0.000     0.120     0.000
-888888.000 -888888.000  -99999.000     0.000 -888888.000 -888888.000
```

Without Buddy Check

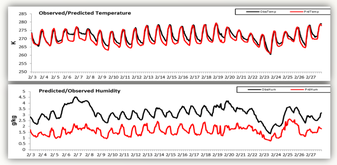
```
20100211010000
40.6000 -110.4300
                    LKFU1                    MADIS
                    3079.    F    F    1
 -99999.000  32768.000 -888888.000 -888888.000  3078.500     0.000
  263.650     0.000 -888888.000 -888888.000 -888888.000 -888888.000
-888888.000 -888888.000  -99999.000     0.000 -888888.000 -888888.000

20100211010000
40.1726 -110.4930
                    UTSTV                    MADIS
                    1744.    F    F    1
 -99999.000  32768.000 -888888.000 -888888.000  1743.500     0.000
  263.850     0.000    -0.437     0.000     0.120     0.000    74.374     0.000
 -99999.000     0.000 -888888.000 -888888.000
```

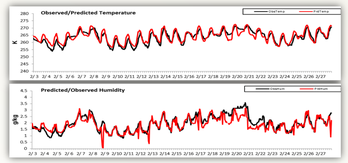
temperature

elevation

Disabling the Buddy Check improved model performance for temperature and moisture in the Uinta Basin, but degraded model performance for moisture in the 4-km domain.



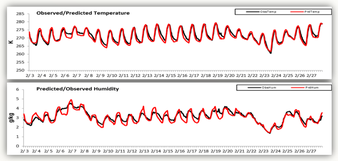
Observed (black) and predicted (red) temperature and moisture for the WRF 4-km domain for February 2010.



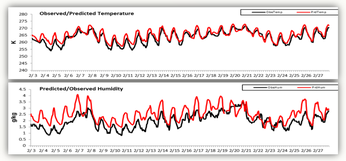
Observed (black) and predicted (red) temperature and moisture for the Uinta Basin study area for February 2010.

Moisture Nudging

To regain suitable model performance for moisture in the 4-km domain, we turned off observation nudging for relative humidity while disabling the Buddy Check Test.



Observed (black) and predicted (red) temperature and moisture for the WRF 4-km domain for February 2010.



Observed (black) and predicted (red) temperature and moisture for the Uinta Basin study area for February 2010.

Conclusions

- Based on sensitivity experiments, two configurations were selected for the ARMS Modeling Project annual WRF simulation—one for winter and another for summer. These configurations yielded acceptable model performance in the annual simulation.
- WRF successfully reproduced Uinta Basin cold-pool stagnation events without compromising model performance for other areas and seasons.
- Poor model performance in the Uinta Basin was rectified by deactivating the OBSGRID Buddy Check test.
- Modelers should understand the effect of default WRF settings on their results, as well as the behavior of WRF's data QA tests.

For more information

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Poster presented by Kenneth Craig (kcraig@sonomatech.com) at the 12th Annual CMAS Conference, October 28-30, 2013, Chapel Hill, NC (STI-5707).