Sensitivity to Planetary Boundaries Layer Schemes in the WRF model: Air Quality applications in coastal areas of the Gulf Of Mexico

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Abstract

The near surface atmospheric concentration of pollutants (gases and particulate matter) in coastal areas depends on local sources (onshore and offshore), chemical reactions and transport which are highly variable spatially and temporarily. To enhance simulations of pollutant dispersion over sensible areas (cities and natural protected environments) it is important to appropriately set boundary layer processes from available model schemes. This study explore planetary boundary layer (PBL) parameterizations in the Weather Research and Forecasting (WRF) model at the western and central Gulf of Mexico in sensible areas (in Texas and Louisiana). This areas show frequent to sporadic events of high levels of pollutant concentrations particularly NAAQS . State of the art models like WRF offer enhanced physics and chemistry configurations improving predictions of contaminants.

This model sensitivity analysis presents a step forward in finding a fine configuration to represent regional coastal processes including sea breeze and urban heat island effects in the first 2 km above the surface. The fine spatial resolution of 4 km is proposed to resolve areas with high density of platforms from the offshore energy (oil and gas) production industrial sector.

Methods

- The WRF model configuration included Yonsei (YSU), Mellor-Yamada (MY) and Total Mass Flux (TEMF) planetary boundary layer options along with Kain-Fritsch (cumulus), Pleim-Xiu (land surface), Pleim-Xiu (surface layer), Dudhia (shortwave rad), GFDL (longwave rad), and Lin et al. (microphysics).
- Meteorological stations, buoys and IGRA radiosonde data are used to evaluate simulations at three domains of 12 km and 4 km over the Gulf of Mexico (Fig 1).
- We used the WRF during July 1 to August 31, 2006. In Houston, it is well known that ozone concentrations are higher in summer. Recent investigations (Bozlaker et al.,, 2013, Env. Sci. & Techn.) demonstrated simultaneous increments of particulate matter due to influence of transported dust.
- WRF evaluation was performed when continuous data is available. Some stations do not have two month data complete.
- For the data analysis on surface, by domain, were chosen two buoys offshore, two buoys near of coastal and, finally, two station inland.
- In the case of sounding data, were used two station for domain, one near of coastal, and the next one, inland.
- For results analysis of surface has been used coefficient correlation, while for radiosonde data has been used BIAS.

Figure 1: WRF domain and observation locations

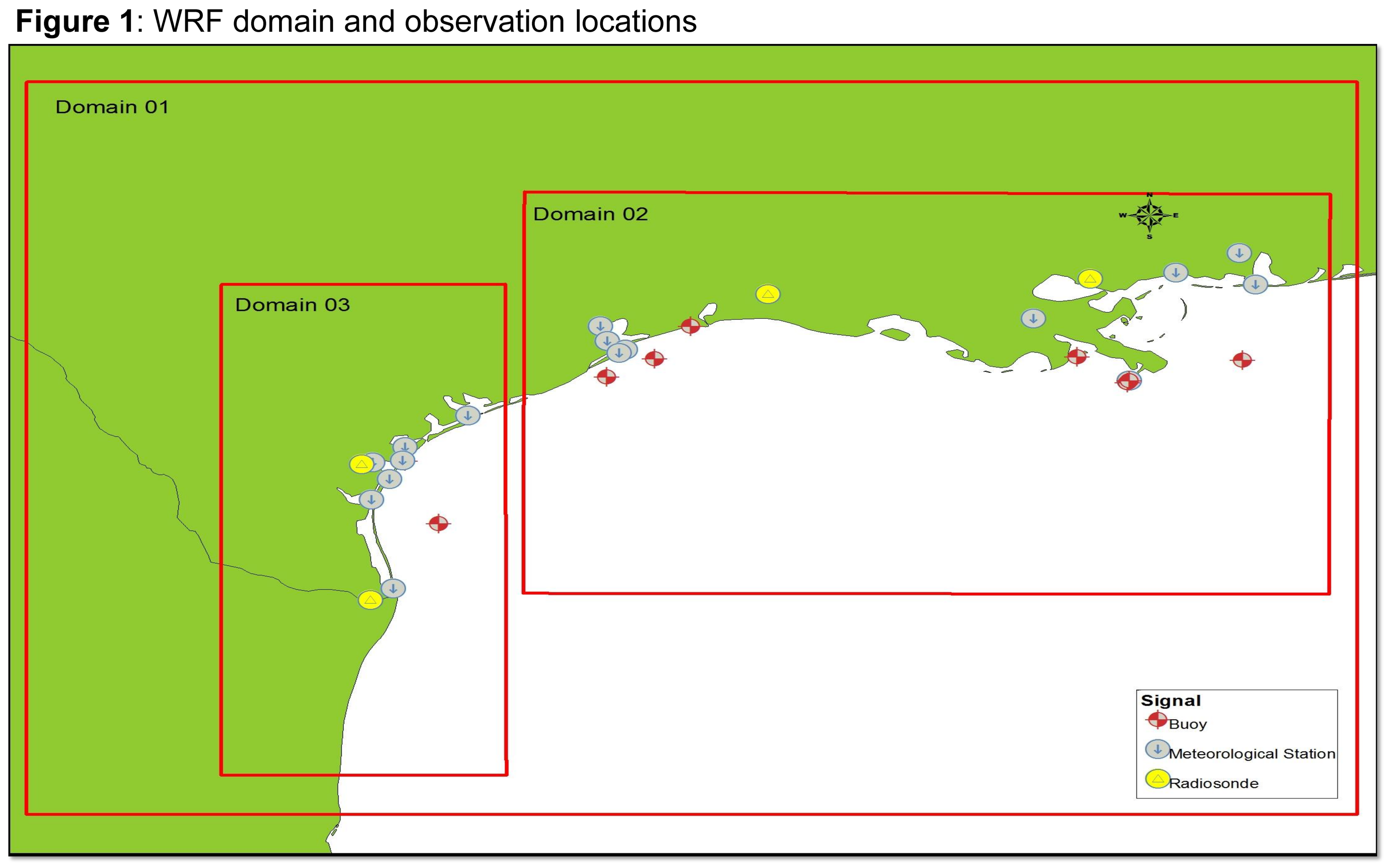


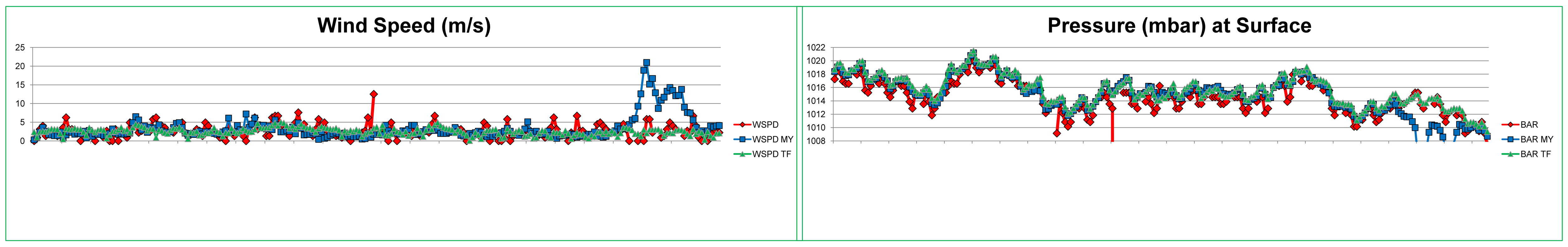
Table 1: data sources: IGRA radiosonde: http://www1.ncdc.noaa.gov/pub/data/igra/derived
Buoy data: http://www.ndbc.noaa.gov/
Meteorological data: http://www.ndbc.noaa.gov/

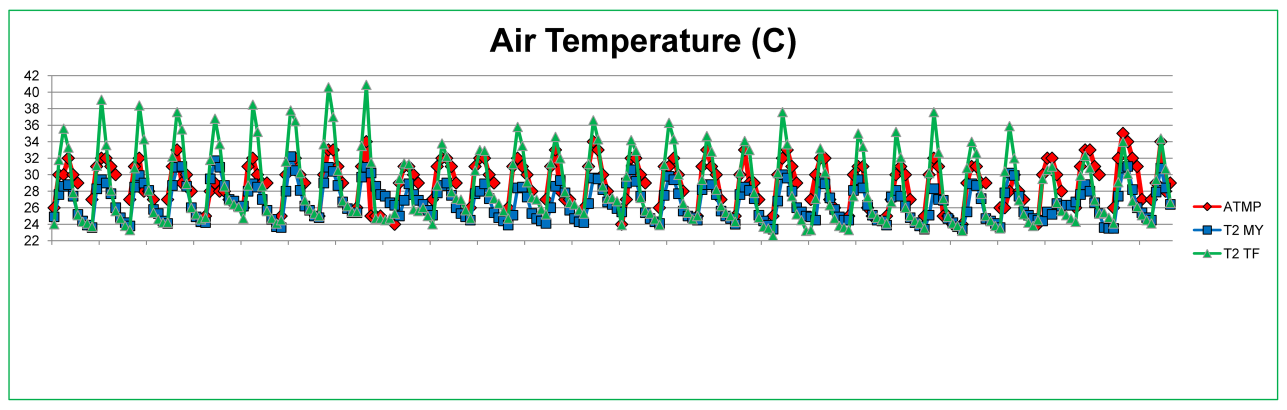
Latitude	Longitude	ID	Name	Type
30.416	-88.916	13820	KEESLER_AIR_FORCE_BASE	Meteorological
30.688	-88.245	13894	MOBILE_REGIONAL_AIRPORT	Meteorological
27.828	-97.050	42019	FREEPORT_TX	Bouy
26.968	-96.694	42020	CORPUS_CHRISTI	Bouy
29.232	-94.413	42035	GALVESTON_TX_22	Bouy
29.212	-88.207	42040	LUKE_OFFSHORE	Bouy
28.982	-94.919	42043	GA-252_TABS_B	Bouy
30.250	-88.075	8735180	Dauphin_Island	Meteorological
28.932	-89.407	8760922	Pilots_Station_East	Meteorological
29.788	-90.420	8762482	west_Bank_1	Meteorological
29.682	-94.985	8770613	Morgans_Point_TX	Meteorological
29.480	-94.918	8771013	Eagle_Point_TX	Meteorological
29.357	-94.723	8771341	Galveston_Bay_Entrance	Meteorological
29.310	-94.793	8771450	Galveston_Pier_21	Meteorological
28.452	-96.387	8773701	Port_OConnor	Meteorological
28.022	-97.047	8774770	Rockport	Meteorological
27.838	-97.073	8775237	Port_Aransas	Meteorological
27.812	-97.390	8775296	Texas_State_Aquarium	Meteorological
27.580	-97.217	8775870	Bob_Hall_Pier	Meteorological
27.295	-97.405	8776604	Baffin_Bay	Meteorological
26.077	-97.177	8779748	South_Padre_Island	Meteorological
28.905	-89.428	BURL1	SOUTHWEST_PASS	Bouy
29.263	-89.957	GISL1	Grand_Isle_LA	Bouy
28.932	-89.407	PSTL1	Pilot's_Station_East	Bouy
29.683	-94.033	SRST2	SABINE_PASS_TX	Bouy
30.330	-89.820	72233	Slidell	Radiosonde
30.120	-93.220	72240	LakeCharles	Radiosonde
25.920	-97.420	72250	Brownsville	Radiosonde
27.780	-97.510	72251	Corpus Christi	Radiosonde

The 85% of stations are in sea level and highest is Mobile Regional Airport at 65mts above sea level.

Meteorological Stations

Figure 2: time series at station 13820



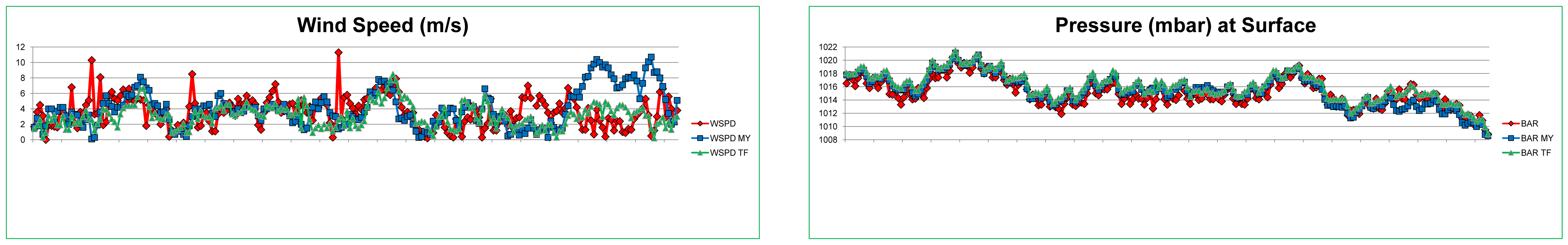


VARIABLE_SCHEME	13820		13894	
	RMSE	CorrCoef	RMSE	CorrCoef
BAR_MY	2.3	0.7	1.7	0.9
BAR_TF	1.6	0.9	2.0	0.9
BAR_YO	3.5	0.7	2.3	0.8
WD_MY	137.8	0.2	144.2	0.2
WD_TF	118.7	0.3	150.2	0.2
WD_YO	134.2	0.1	144.5	0.1
WSPD_MY	3.7	0.1	2.6	0.1
WSPD_TF	1.9	0.3	1.9	-0.3
WSPD_YO	3.7	0.7	3.4	0.0
ATMP_MY	2.8	0.7		
ATMP_TF	2.9	0.8		
ATMP_YO	2.5	0.7		

Table 2: statistics at stations 13820 and 13894

Buoy Stations

Figure 3: time series at station 42040



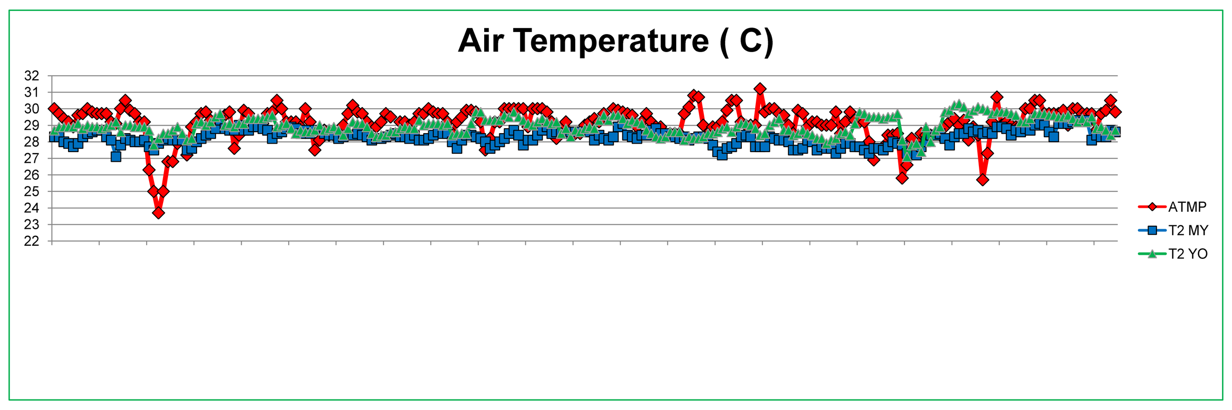


Table 3: buoy 42040 statistics

VAR_EXP	SRST2		BURL1		GISL1		PSTL1		42040	
	RMSE	CorrCoef	ERROR	CorrCoef	ERROR	CorrCoef	ERROR	CorrCoef	ERROR	CorrCoef
ATMP_MY	2.8	0.3	1.4	0.2	1.7	0.2	2.6	0.2	1.3	0.2
ATMP_TF	3.5	0.3	1.6	0.2	1.9	0.2	2.8	0.2	1.6	0.1
ATMP_YO	2.8	0.3	1.2	0.2	1.4	0.2	2.2	0.1	1.0	0.3
BAR_MY	1.4	0.9	0.9	0.9	1.2	0.9	0.5	0.9	1.1	0.9
BAR_TF	1.6	0.8	1.1	0.9	0.8	0.9	0.9	0.8	1.3	0.9
BAR_YO	5.0	0.5	10.2	0.5	9.8	0.4	0.7	0.6	6.5	0.8
WD_MY	93.1	0.3	81.3	0.5	95.1	0.5	130.0	0.2	104.7	0.3
WD_TF	85.9	0.4	80.7	0.5	78.2	0.5	138.6	0.1	90.6	0.5
WD_YO	110.0	0.2	105.7	0.3	120.5	0.3	153.0	-0.2	108.8	0.2
WSPD_MY	2.5	0.9	3.1	0.2	2.7	0.2	3.4	0.1	3.1	0.3
WSPD_TF	2.4	0.3	2.5	0.3	1.8	0.2	2.3	0.2	2.1	0.4
WSPD_YO	4.3	0.1	8.8	0.1	7.6	0.1	10.6	0.3	7.6	0.3

Radiosonde Stations

Figure 4: atmospheric profiles comparisson at station 72233 , Agoust 2006 at 12 UTC

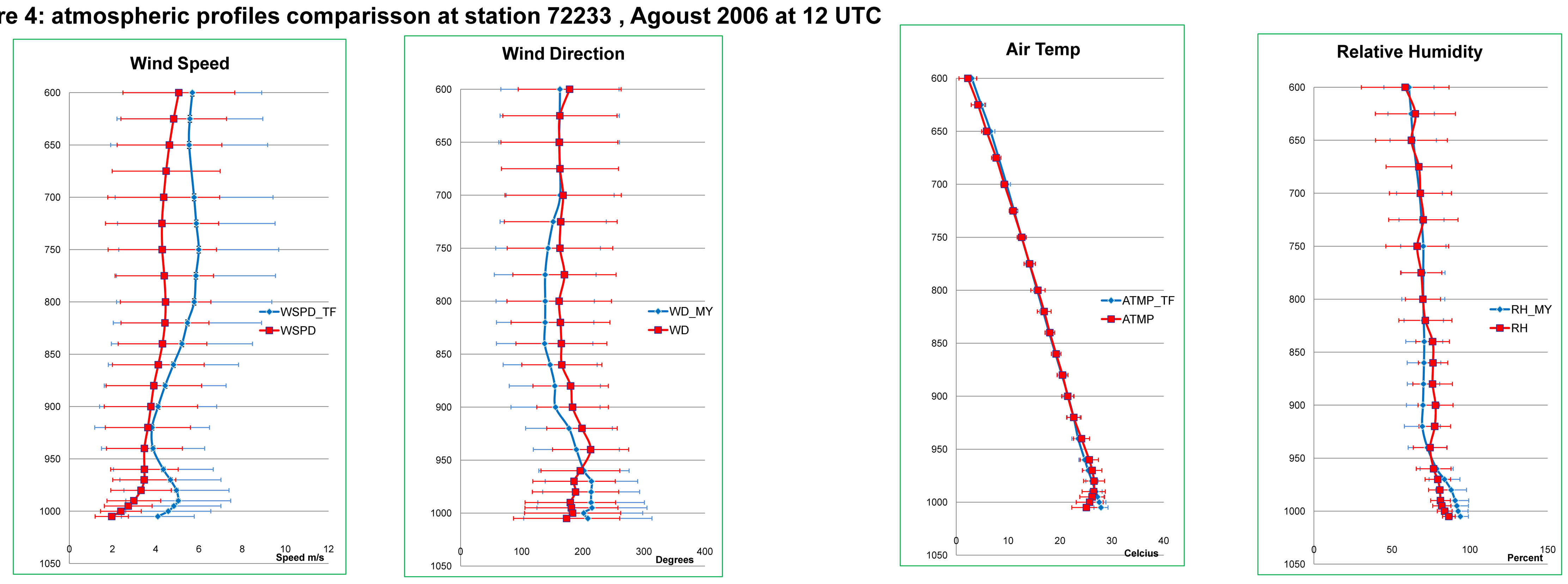


Table 4: stations 72233 and 72240, BIAS at 00 UTC and 12 UTC

00 UTC, BIAS

72233	MY	TF	YO
WSPD	1.13	0.21	4.21
WD	-6.84	2.54	-36.59
ATMP	0.36	0.20	0.66
HR	6.56	2.89	7.68

72250	MY	TF	YO
WSPD	-0.01	-0.75	3.28
WD	-7.03	1.99	-4.67
ATMP	0.56	-0.48	0.55
HR	-2.04	3.90	4.33

12 UTC, BIAS

72233	MY	TF	YO
WSPD	1.61	1.07	4.49
WD	-3.93	-8.51	-49.12
ATMP	0.53	1.06	0.86
HR	1.66	-4.05	1.65

72250	MY	TF	YO
WSPD	-0.06	-0.28	3.19
WD	4.68	-2.85	-6.99
ATMP	0.78	0.75	1.63
HR	-5.03	-4.37	-1.24

00 UTC, BIAS

72240	MY	TF	YO
WSPD	-0.19	-0.23	3.32
WD	9.07	-7.39	-29.91
ATMP	0.73	0.32	1.15
HR	-2.25	-3.81	-0.25

72251	MY	TF	YO
WSPD	-0.13	-0.56	1.16
WD	-0.81	3.35	-8.81
ATMP	0.66	-0.42	0.69
HR	-0.87	5.25	5.81

12 UTC, BIAS

72240	MY	TF	YO
WSPD	-0.60	-0.46	2.48
WD	-3.34	-14.45	-44.13
ATMP	0.89	1.27	1.58
HR	-4.07	-6.44	-1.28

72251	MY	TF	YO
WSPD	-0.90	-0.76	0.15
WD	-13.91	-13.37	-9.49
ATMP	0.89	0.99	0.99
HR	-5.08	-5.29	1.15

Preliminary discussion of results

A sample of data stations is presented here for a general preliminary discussion of results. The main work consists of a comprehensive sensitivity analysis of physics configuration at three different environmental settings: inland, shoreline, and offshore areas. Continuity and quality of observations are major constraints in this analysis. Data quality control is performed to assure an unbiased assessment of model performance.

Meteorological stations: The 13820 station is closest of the coastal while the 13894 is around 75km inland.

The WRF simulation has low skills in predicting Wind Speed (WSPD) and Wind Direction (WD), in the three physical configurations while the best simulated variables are the Pressure at surface (BAR) and the Air Temperature (ATMP) at 2mts.

Relative humidity (HR), not shown in Figure 2, obtained better results in the station 13894 with a correlation of 0.7 in the Mellor Yamada (MY) and Yonsei; while in 13820 the correlation is 0.5 in all three configurations. Overall, when comparing physical schemes in both domains, the best results are from total energy mass flux scheme followed by Mellor-Yamada scheme.

Buoys Offshore: Sample data analysis in Figure 3. WRF better performs in the Domain 3, for all variables, except in sea temperature.Mellor-Yamada had good skills predicting pressure at surface and in the dewpoint, while the total energy mass flux scheme has good performance in the other variables. Yoinsei hold lowest values in the correlation coefficient. For Sea temperature the three schemes show similar results.

Near to shore stations: There is not enough data in domain 2 to perform a quality analysis. Domain 03 contain data to evaluate model performance. It is found a variable behavior in the results. Mellor-Yamada have good results for pressure at surface and the dewpoint, while the total energy mass flux scheme has good performance in the other variables. For Sea temperature the three schemes show similar results.

Radiosonde Stations: Sample data analysis in Figure 4. There are two stations for each domain. Data at 00 UTC and 12 UTC have been analyzed using bias. The Mellor -Yamada scheme has tendency to overestimation in the Domain 02 at 00 and 12 UTC, while Domain 03 tend to underestimate observations with small bias.

The Total Energy Mass Flux scheme has a bivariate behavior. In station 72240 it overestimated the values at 00 UTC while in the 72250 has underestimated the values. During 12 UTC, show tendency to underestimate in both Domains. The Yonsei Scheme show has tendency to overestimate the values in both domains and has higher values of bias than the others.

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