Case study analysis of the Real-Time Mesoscale Analysis (RTMA) in the northern Gulf of Mexico

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- Description of research consortium CONCORDE and meteorology dataset archive
- RTMA overview
- RTMA validation
- Conclusions
- Future CONCORDE plans

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Manuel Pondeca, Steve Levine, and Runhua Yang
Environmental Modeling Center
IMSG and NOAA / NWS / NCEP

Consortium CONCORDE
Coastal River-Dominated Ecosystems

2015 CONCORDE is made possible by a grant from BP/The Gulf of Mexico Research Initiative (GoMRI)

Addresses the question:

How do the complex fine-scale biological, chemical, and physical structure and processes in coastal waters - dominated by pulsed-river plumes – control the exposure, impacts, and recovery from offshore spills?

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How do complex fine-scale structure and processes in coastal waters dominated by pulsed-river plumes control the exposure, impacts, and ecosystem recovery from offshore spills like the Deepwater Horizon release of 2010?

Physical distribution and ultimate fate of contaminants associated with the Deepwater Horizon incident (Theme 1)

Environmental effects of the contaminants on Gulf of Mexico ecosystems, and the science of ecosystem recovery (Theme 3)

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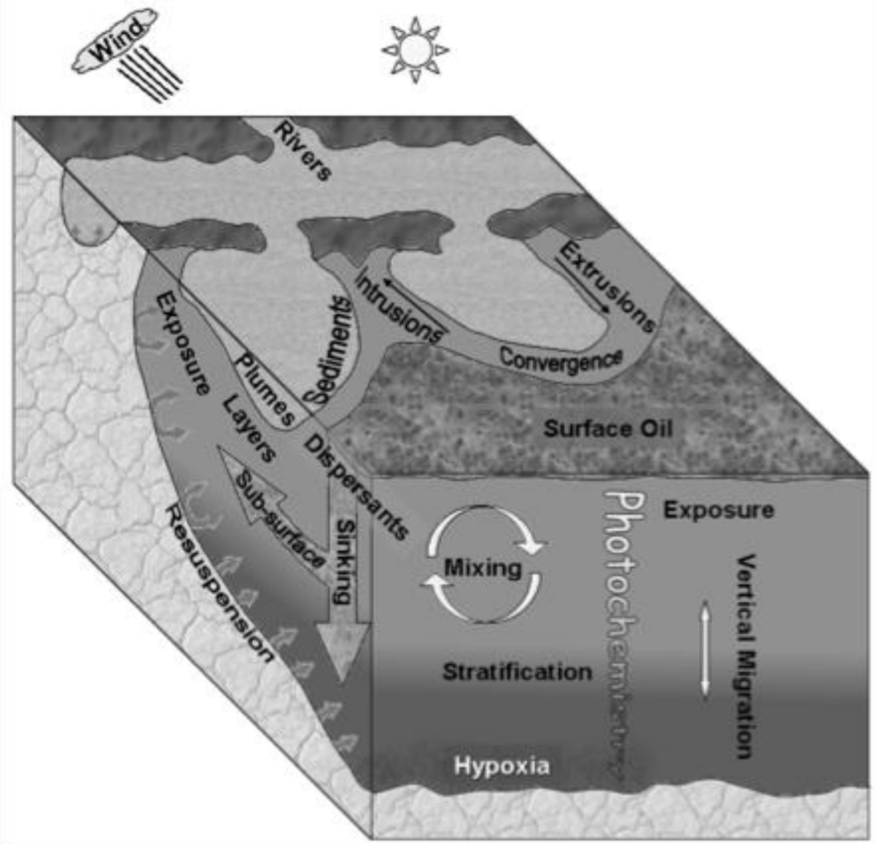
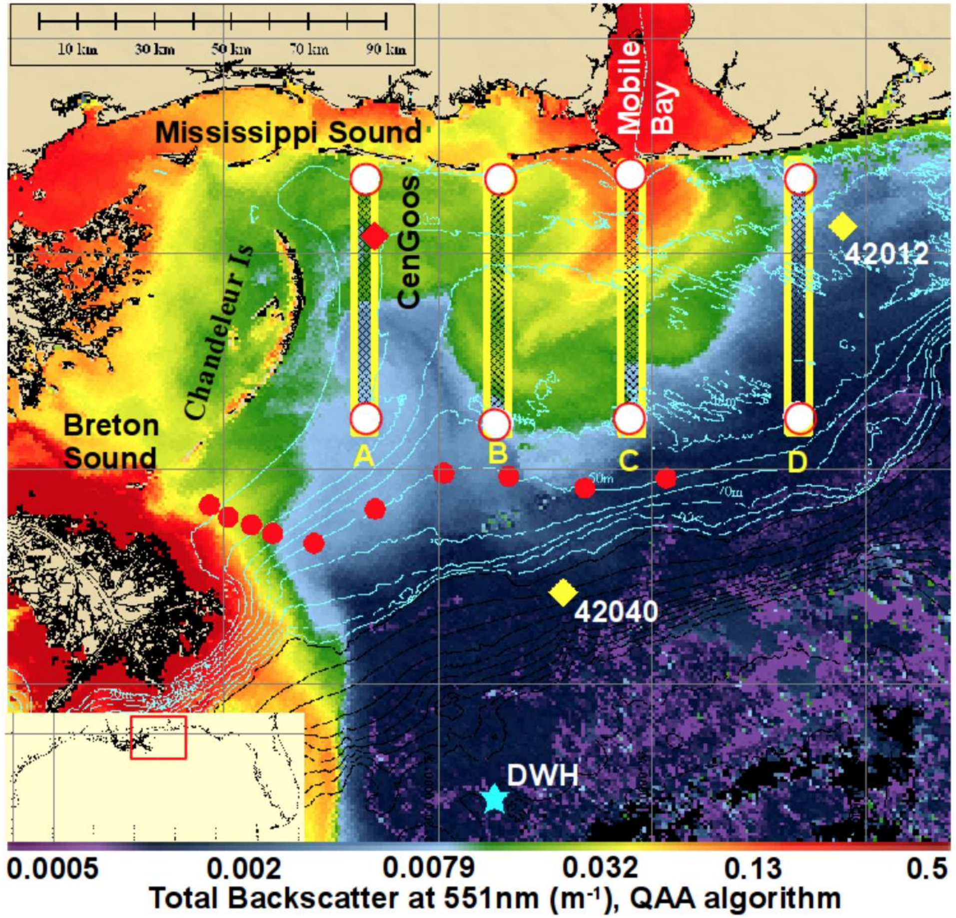
<u>Objective 1:</u> Characterize the distribution of planktonic organisms at relevant spatial and temporal scales as forced by the complex near shore physical environment and generating the setting for sub-surface ODS exposure.

<u>Objective 2:</u> Characterize the complex 4-D physical, geochemical, and bio-optical fields influenced by pulsed river discharge to characterize potential 3-D pathways of ODS to the coast, and mechanisms for enhanced interactions of ODS with plankton, suspended sediment and oil, which determine fate and toxic exposure, and informs synthetic biophysical-ecotoxicological models.

<u>Objective 3:</u> Generate a synthetic model that incorporates fine-scale 4-D biophysical processes that reveals exposure pathways reflective of DWH, and which will be portable to future spill scenarios impacting similar river-dominated coastal ecosystems.


Wind
Rivers
Extrusions
Intrusions
Sediments
Convergence
Exposure
Plumes
Layers
Surface Oil
Dispersants
Sub-surface
Resuspension
Sinking
Mixing
Photochemistry
Exposure
Vertical Migration
Stratification
Hypoxia


10 km 30 km 50 km 70 km 90 km
Mississippi Sound
Mobile Bay
CenGoos
Chandeleur Is
Breton Sound
A
B
C
D
42012
42040
DWH
0.0005 0.002 0.0079 0.032 0.13 0.5
Total Backscatter at 551nm (m-1), QAA algorithm

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Coastal River-Dominated Ecosystems

- Field programs:

  Recently completed a Fall 2015, Winter 2016, and Spring 2016 surveying campaign with two R/Vs and a small-boat excursion; focus is on chemistry, plankton, ocean dynamics, and meteorology forcing

  One more survey planned in Summer 2016

- Meteorology contribution from MSU is to:

  – *Provide and assess atmospheric forcing fields for hindcast ocean/biophysical models in Mississippi and Chandeleur Sound*
  – *Use RTMA and observations for CONCORDE case studies*

- It is necessary to validate the RTMA fields to assess strengths and weaknesses for these uses
- Few RTMA studies have been performed on the Gulf Coast nearshore regions

* *The Gulf of Mexico Research Initiative (GoMRI) is a ten-year $500 million commitment to study the effects of the Deepwater Horizon incident and the potential associated impact on the environment and public health. GoMRI's organization has overtones of an NSF structure.*

Archive generation for atmospheric forcing

- Model data (RTMA, NAM) is provided by NOAA's Operational Model Archive and Distribution System (NOMADS).
- Radar data is provided by NOAA's Hierarchical Data Storage System (HDSS). NCDC provides direct online access to these data though the HDSS Access System (HAS). This cannot be automated and has to be run manually, but weeks of data can be downloaded at once.
- High-resolution AVHRR SST data is provided by NOAA's Atlantic Oceanographic & Meteorological Laboratory (AOML). Alternatives under consideration.
- Some variables are converted to specific variables using FSU's COARE flux algorithm 3.0, for consistency with NRL's COAMPS.

Archive generation - Summary

The following are generated from different scripts, interpolated to 0.01 deg. RTMA is 2.5 km resolution. NAM is 12 km resolution.

1) NOMADS RTMA: pressure, air temperature, relative humidity, winds;
2) NOMADS NAM: Cloud fraction, shortwave radiation flux, longwave radiation flux (radiation not at 00, 06, 12, or 18Z are forecast fields);
3) NEXRAD radar from HAS: accumulated rainfall;
4) AVHRR: 5-day running mean of SST with QC for missing and bad data;
5) COARE Bulk Flux 3.0 algorithm: momentum stress, fluxes.

RTMA overview

2DVAR Grid Statistical Interpolation (GSI) with non-isotropic recursive filter

- A specially configured 2DVAR version of GSI which ingests HRRR 1-h forecast fields and perform a detailed surface analysis
- Key feature non-isotropic recursive filter package which allows more customization of corrections to the background field to better fit special surface features, such as terrain and coast lines.
- Uses surface, synoptic, ship, buoy, pre-approved mesonet, near-sfc satellite winds
- Result is a surface analysis that better matches the observed surface data, while providing a coherent field that best matches the various geographically-related features.

HRRR – High-Resolution Rapid Refresh

The HRRR is a NOAA real-time 3-km resolution, hourly updated, cloud-resolving, convection-allowing atmospheric model.

Radar data is assimilated in the HRRR every 15 min over a 1-h period.

Quality Control in RTMA

- ‘Gross error’ O-B check (relaxed by terrain, buddy check for temp)
- There is a provider and station-based reject/accept lists for <u>mesonets</u> (static, required RFC to change) (StationID based)
- Dynamic reject list (O-B last 6 hours)
- “Variational” nonlinear QC (problems with 2+ obs/hour/station)
- Data could also ‘fall on floor’ if not on “accept list, large time delays, etc.

RTMA references

GSI:

Wu, W.-S., R. J. Purser, and D. F. Parrish, 2002: Three-dimensional variational analysis with spatially inhomogeneous covariances. *Mon. Wea. Rev.*, **130**, 2905–2916.

RTMA:

De Pondeca, M. S. F. V., and Coauthors, 2011: The Real-Time Mesoscale Analysis at NOAA's National Centers for Environmental Prediction: Current status and development. *Wea. Forecasting*, **26**, 593–612.

Anisotropic Recursive Filters:

Purser, R. J., W.-S. Wu, D. F. Parrish, and N. M. Roberts, 2003a: Numerical aspects of the application of recursive filters to variational statistical analysis. Part I: Spatially homogeneous and isotropic Gaussian covariances. *Mon. Wea. Rev.*, **131**, 1524–1535.

Purser, R. J., W.-S. Wu, D. F. Parrish, and N. M. Roberts, 2003b: Numerical aspects of the application of recursive filters to variational statistical analysis. Part II: Spatially inhomogeneous and anisotropic general covariances. *Mon. Wea. Rev.*, **131**, 1536–1548.

Purser, R. J., 2005: A geometrical approach to the synthesis of smooth anisotropic covariance operators for data assimilation. NOAA/NCEP Office Note 447, 60 pp.

Analysis Error Estimation (Lanczos method):

Fisher, M., and P. Courtier, 1995: Estimating the covariance matrices of analysis and forecast error in variational data assimilation. ECMWF Tech. Memo. 220, 29 pp.

Basic Validation

Observations used for validation

- Used nearest neighbor RTMA with most appropriate land cover
- Wind observations converted to 10-meter height (when possible) and 1-minute average (when possible)
- Future validation will include WeatherFlow network (new platform installed at Ship Island, funded by CONCORDE)

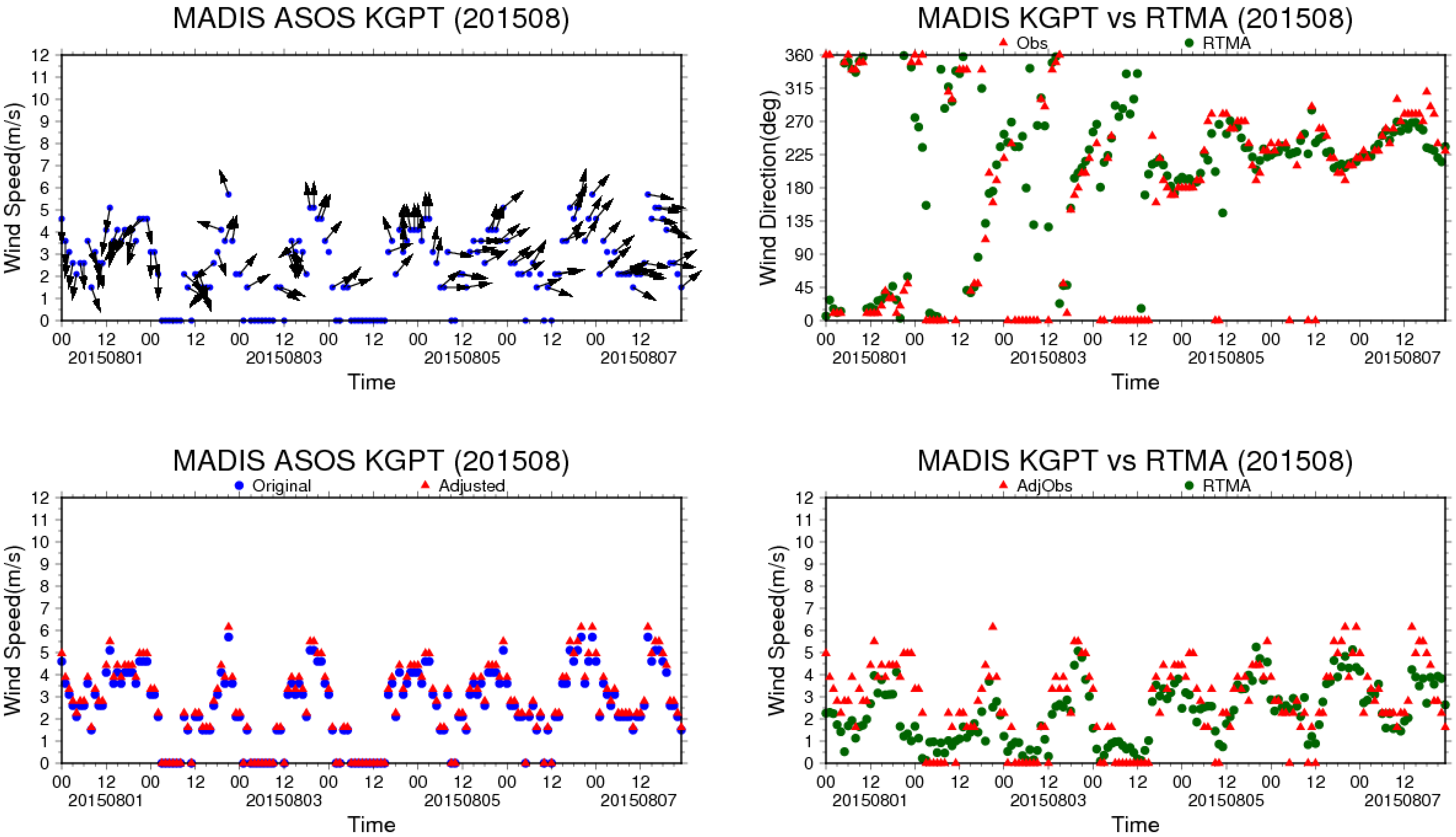
Temperature (C)							***Sample size***		
Station	May 2015		Aug 2015		Oct 2015		May	Aug	Oct
	Bias	*Abs Err*	*Bias*	*Abs Err*	*Bias*	*Abs Err*			
KMSY	-0.8	0.8	-0.4	0.7	-0.6	0.7	191	167	166
BBNL1	0.0	0.5	0.0	1.1	0.1	1.3	190	168	164
D6246	0.1	0.5	0.5	0.8	0.4	1.0	191	167	151
SHBL1	-0.1	0.4	-0.6	0.7	-0.7	0.9	12	8	111
NNHM6	-0.2	0.7	0.3	1.1	-0.1	1.2	187	168	167
KGPT	-0.5	0.6	-0.6	0.8	-0.5	0.8	191	168	167
42067	0.2	0.5	-0.2	0.5	NA	NA	47	53	NA
PTBM6	-1.7	1.9	-0.5	0.8	-0.1	0.8	191	168	167
DPIA1	-0.4	0.5	-0.2	0.4	0.1	0.4	178	168	166

Wind speed (ms⁻¹)							***Sample size***		
Station	May 2015		Aug 2015		Oct 2015		May n	Aug n	Oct n
	Bias	*Abs Err*	*Bias*	*Abs Err*	*Bias*	*Abs Err*			
KMSY	-1.9	1.9	-2.1	2.1	-1.7	1.7	187	157	154
BBNL1	0.6	0.8	0.0	0.7	0.0	0.5	188	115	114
D6246	1.6	1.9	0.4	1.2	0.5	1.2	164	161	150
SHBL1	-0.2	0.9	0.1	1.0	-0.7	1.2	164	155	140
NNHM6	1.1	1.2	1.2	1.3	1.1	1.2	170	118	115
KGPT	-2.2	2.2	-0.8	1.0	-2.1	2.1	171	135	130
42067	-0.6	1.3	-0.9	1.5	-0.1	1.1	46	53	13
PTBM6	0.2	1.2	-0.6	1.1	0.1	1.1	189	166	167
DPIA1	-0.1	1.0	0.7	1.5	-0.2	0.9	188	167	165

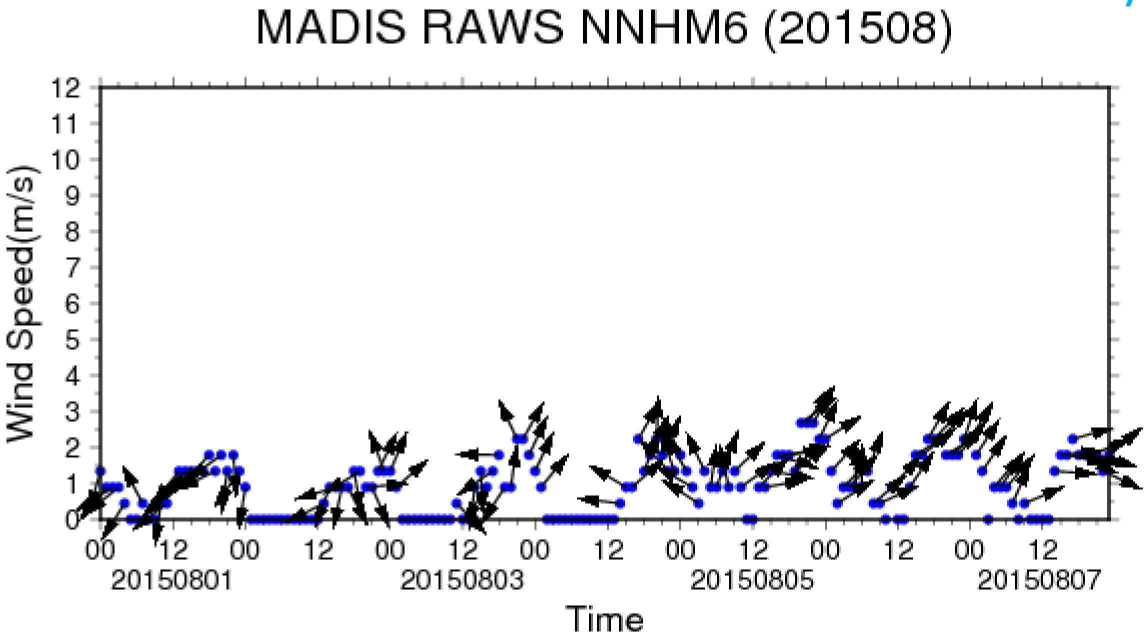
Wind direction (deg)							***Sample size***		
Station	May 2015		Aug 2015		Oct 2015		May n	Aug n	Oct n
	Bias	*Abs Err*	*Bias*	*Abs Err*	*Bias*	*Abs Err*			
KMSY	-3,7	12.0	-2.8	20.7	-3.0	18.2	185	155	151
BBNL1	20.6	24.7	15.3	32.8	23.7	32.5	188	115	114
D6246	12.5	14.0	2.4	25.6	6.2	21.3	164	161	150
SHBL1	7.1	10.7	14.7	29.3	2.6	16.3	164	155	140
NNHM6	14.8	17.9	-1.6	33.1	11.8	24.6	170	118	115
KGPT	4.4	9.1	-4.2	17.3	-0.3	14.4	169	128	127
42067	-2.7	10.4	-6.2	24.1	3.9	15.8	46	53	13
PTBM6	7.5	12.3	-8.7	22.8	6.2	14.7	189	166	167
DPIA1	4.8	12.4	8.2	21.3	9.3	14.4	188	167	165

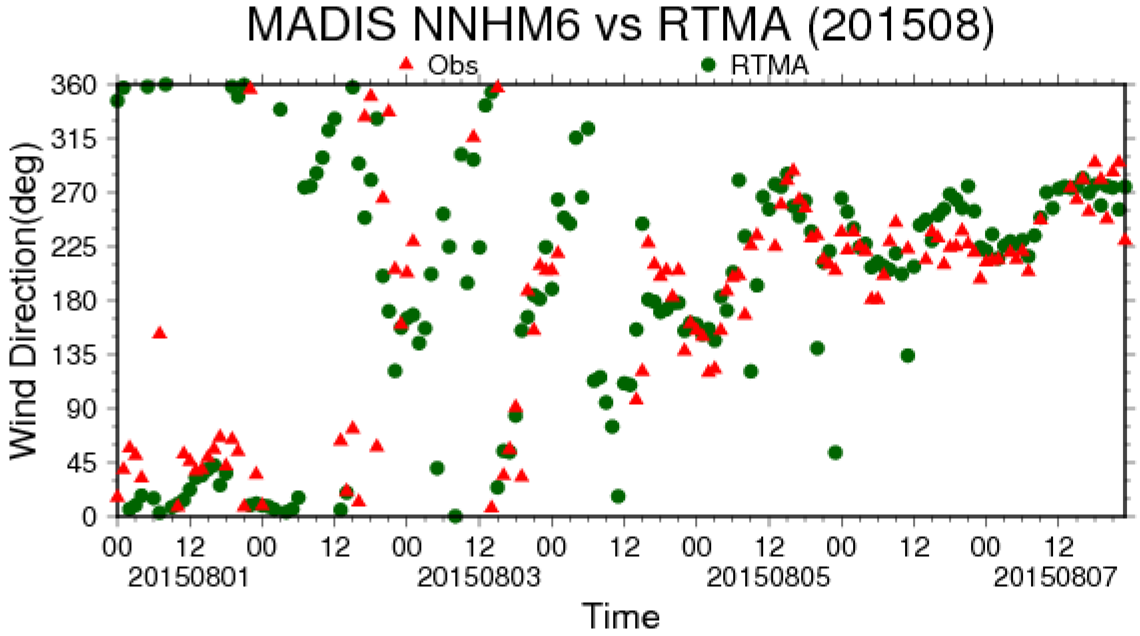
Aug Time series, wind

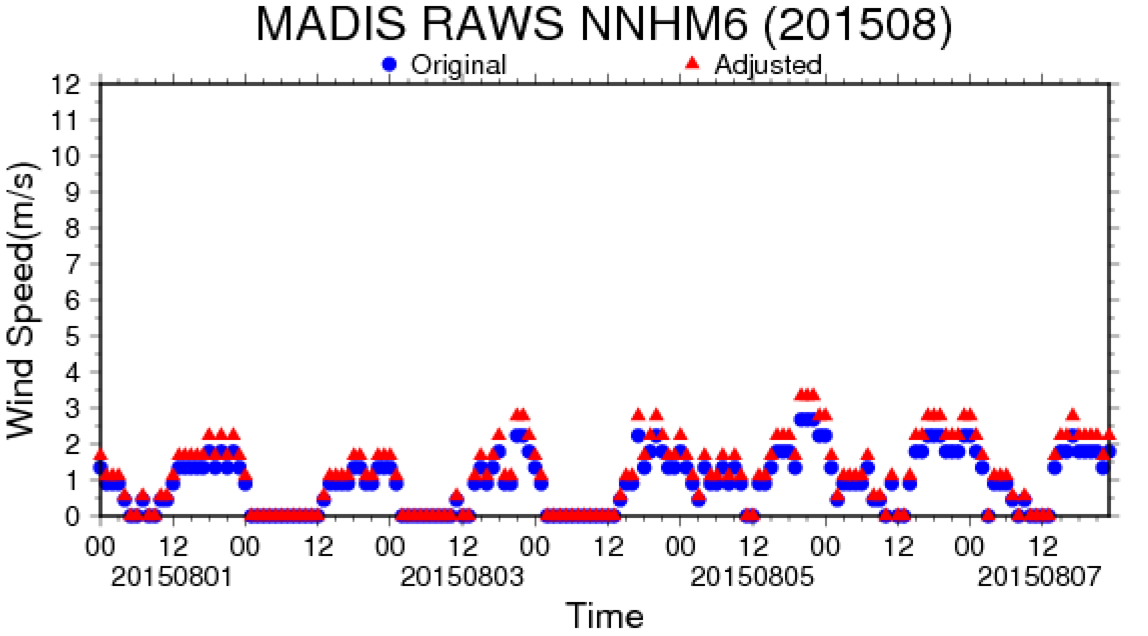
Most wind time series capture diurnal signal and magnitudes relatively well

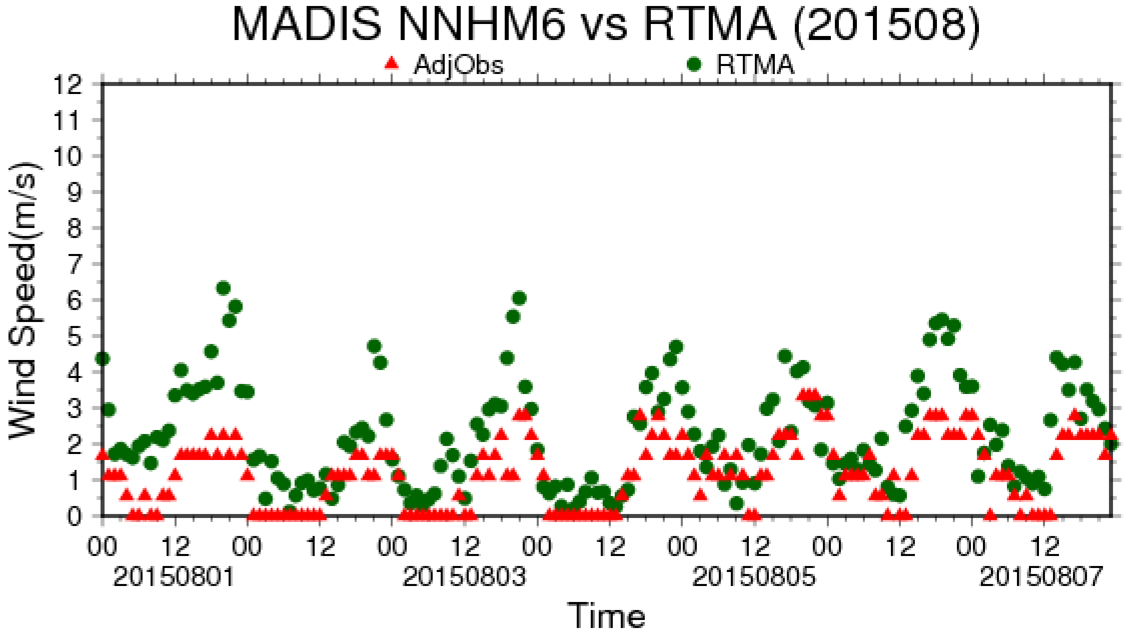


This station may not be on QC list

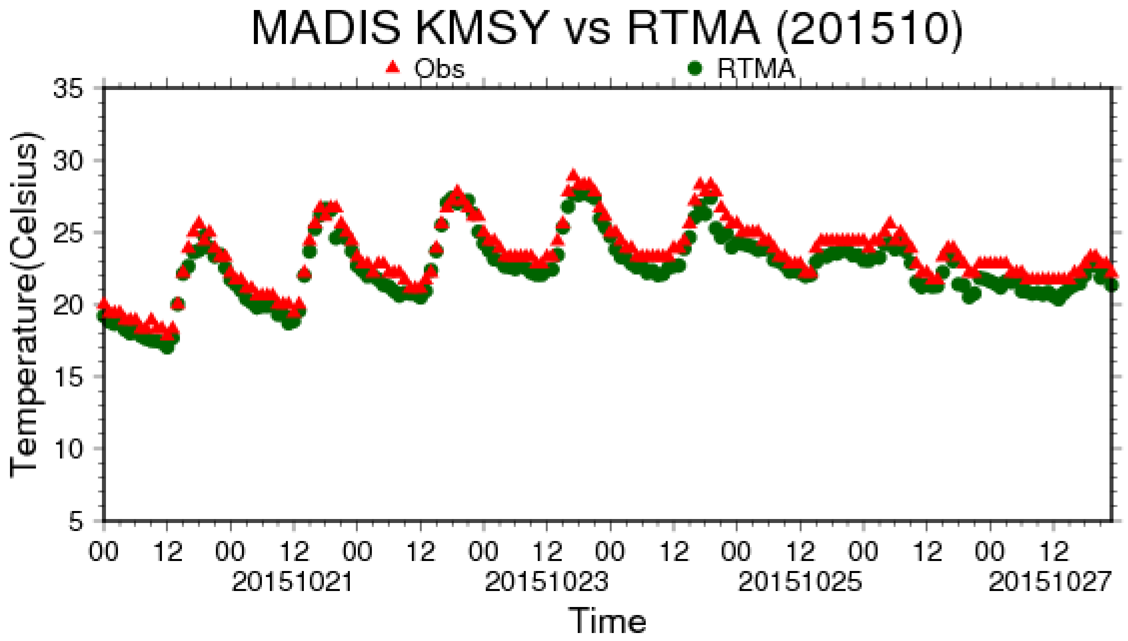




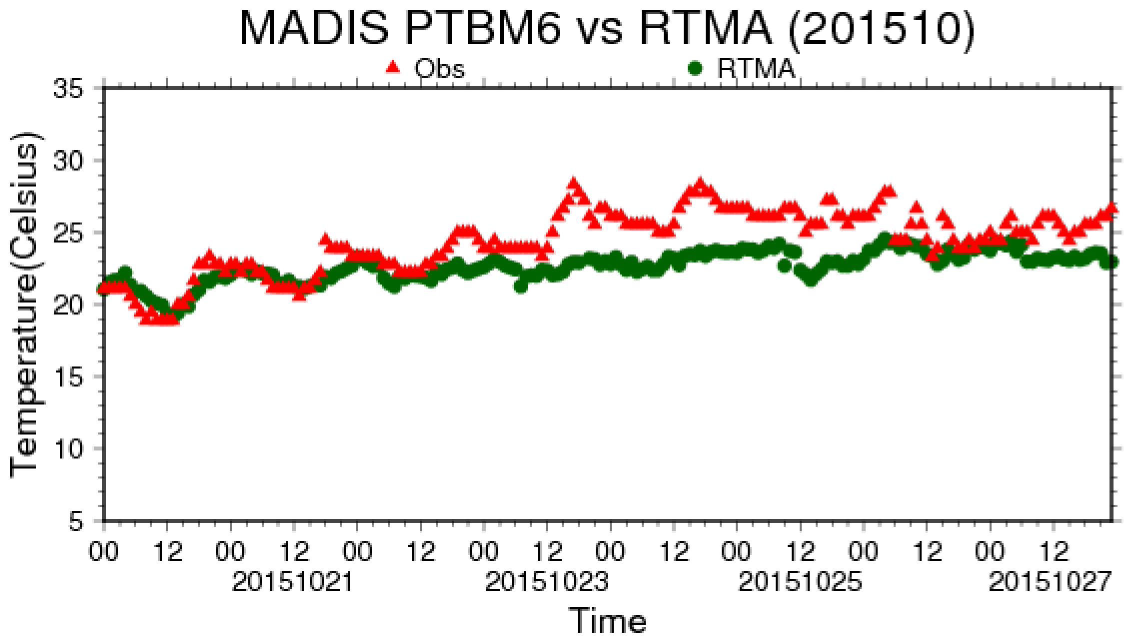




Aug Time series, temperature



Most temperature comparisons similar, match well

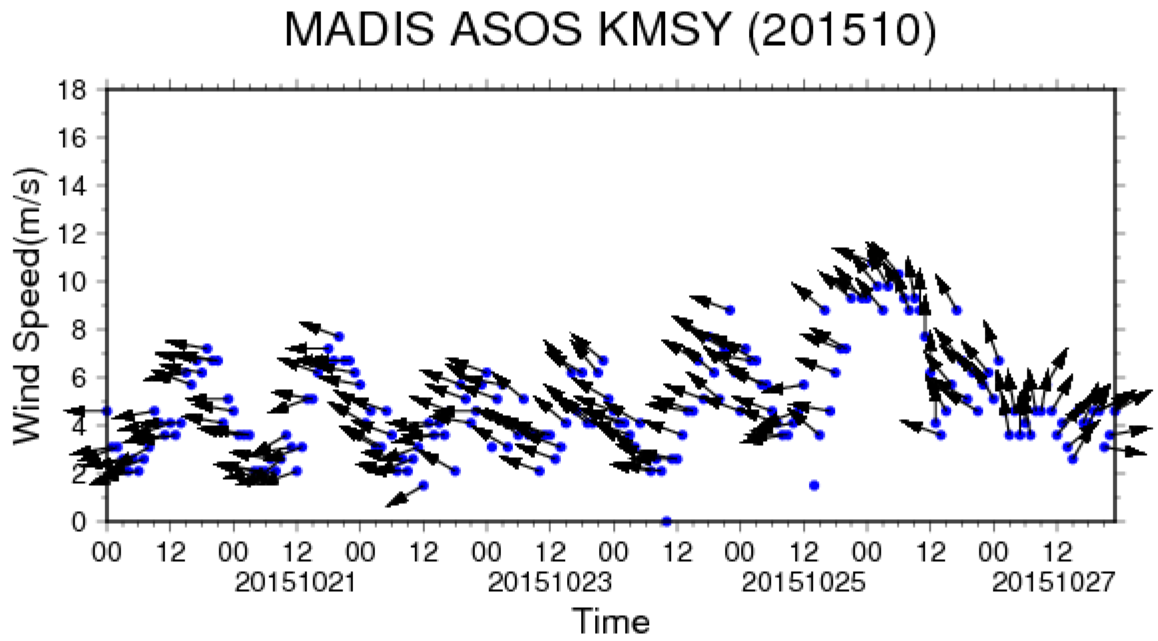


Station probably not on accept list

Oct Time series, wind (Patricia’s remnants)

Coincides with CONCORDE Fall cruises

Paper underway


MADIS ASOS KMSY (201510)
Wind Speed(m/s)
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2
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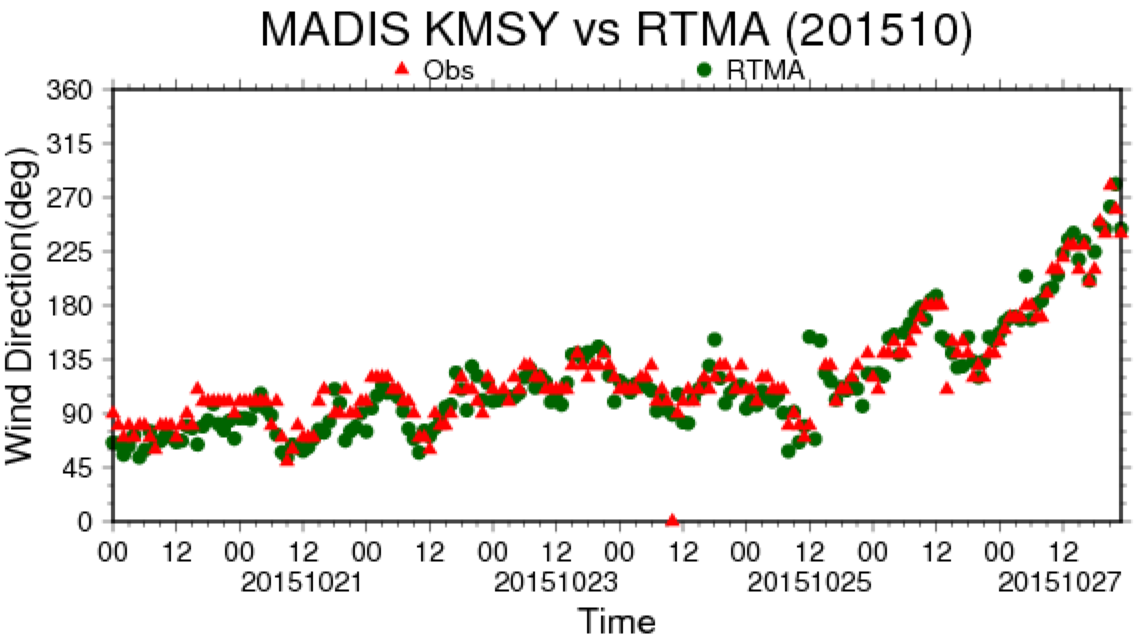
18
00 12 00 12 00 12 00 12 00 12 00 12 00 12
20151021
20151023
20151025
20151027
Time


MADIS KMSY vs RTMA (201510)
Obs
RTMA
Wind Direction(deg)
0
45
90
135
180
225
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315
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00 12 00 12 00 12 00 12 00 12 00 12 00 12
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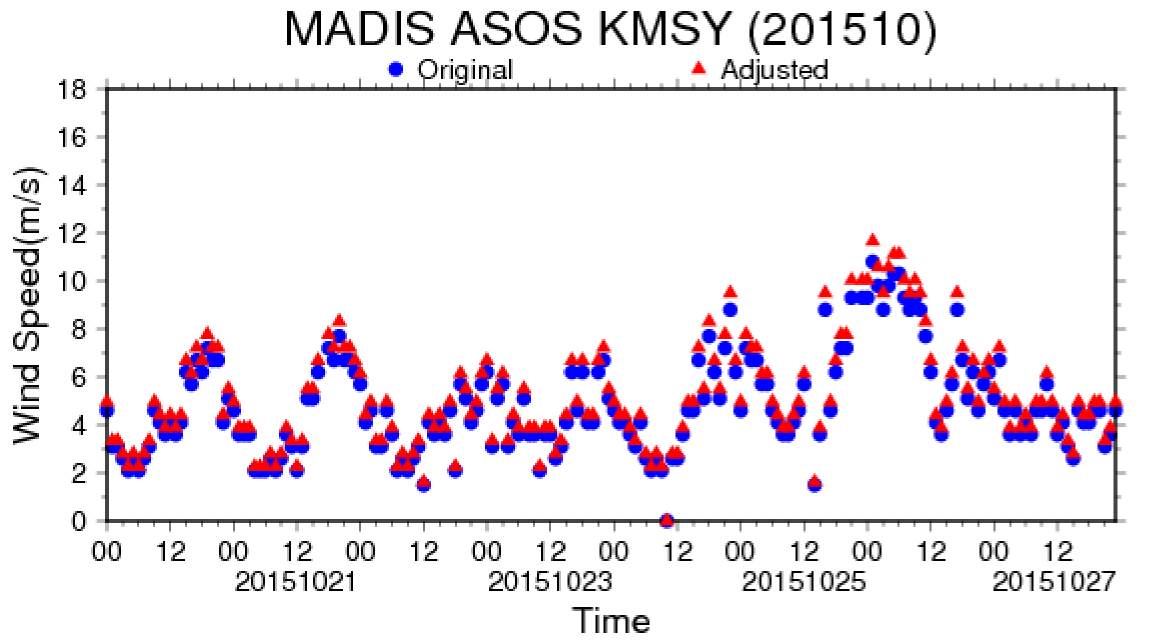
20151023
20151025
20151027
Time


MADIS ASOS KMSY (201510)
Original
Adjusted
Wind Speed(m/s)
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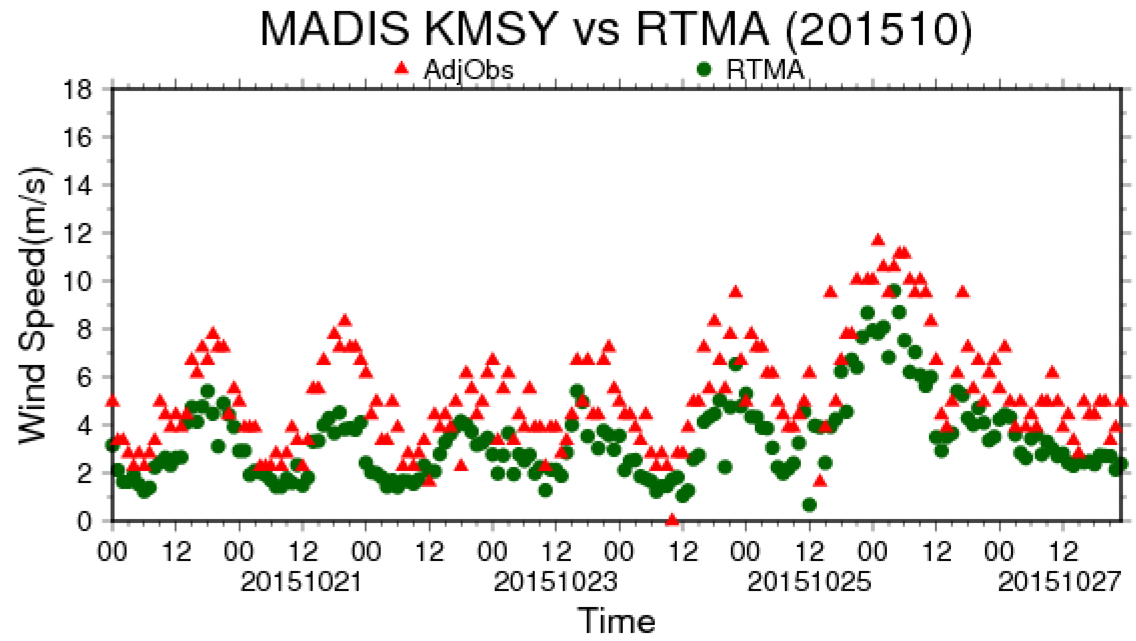
20151027
Time


MADIS KMSY vs RTMA (201510)
AdjObs
RTMA
Wind Speed(m/s)
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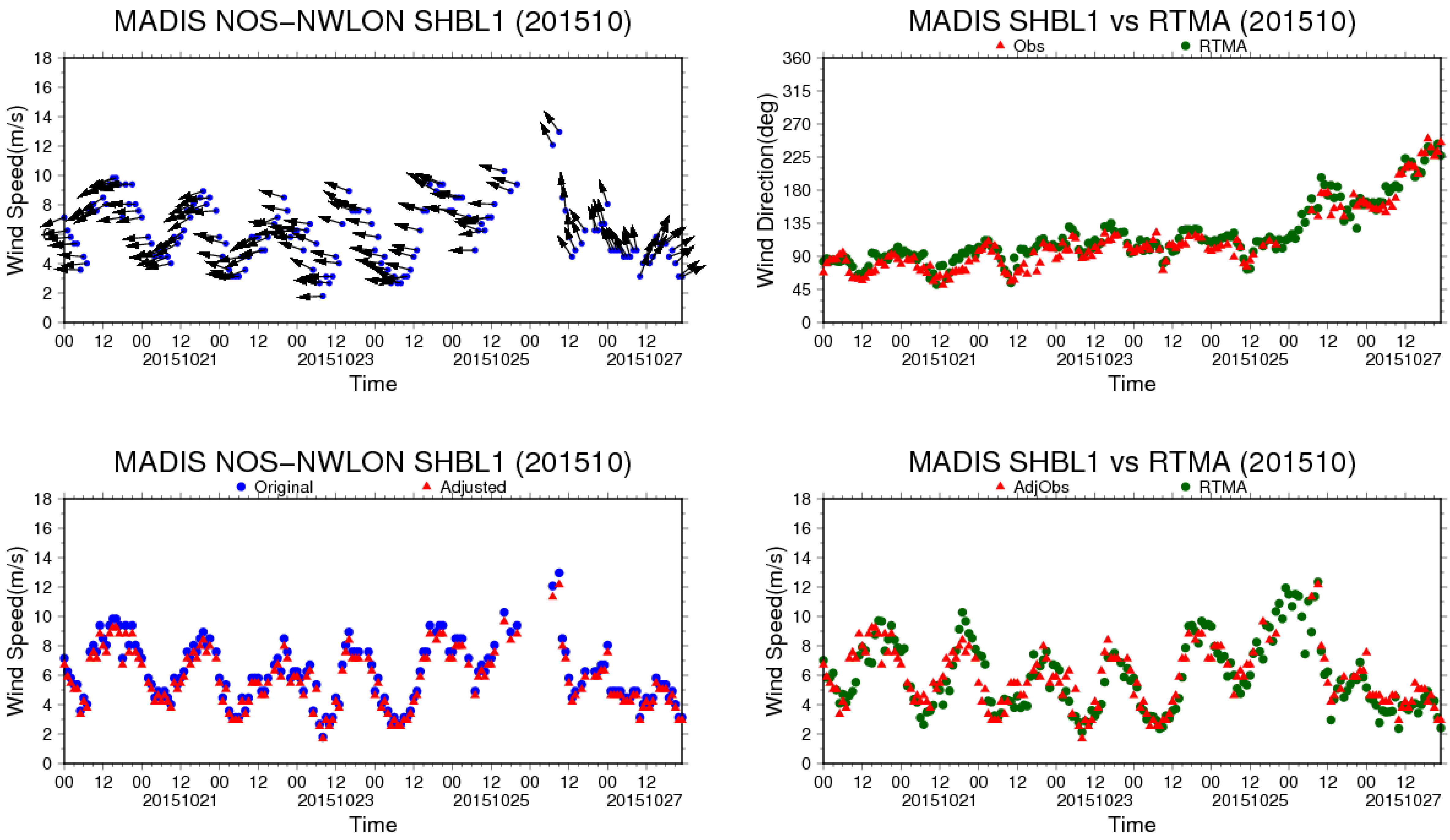
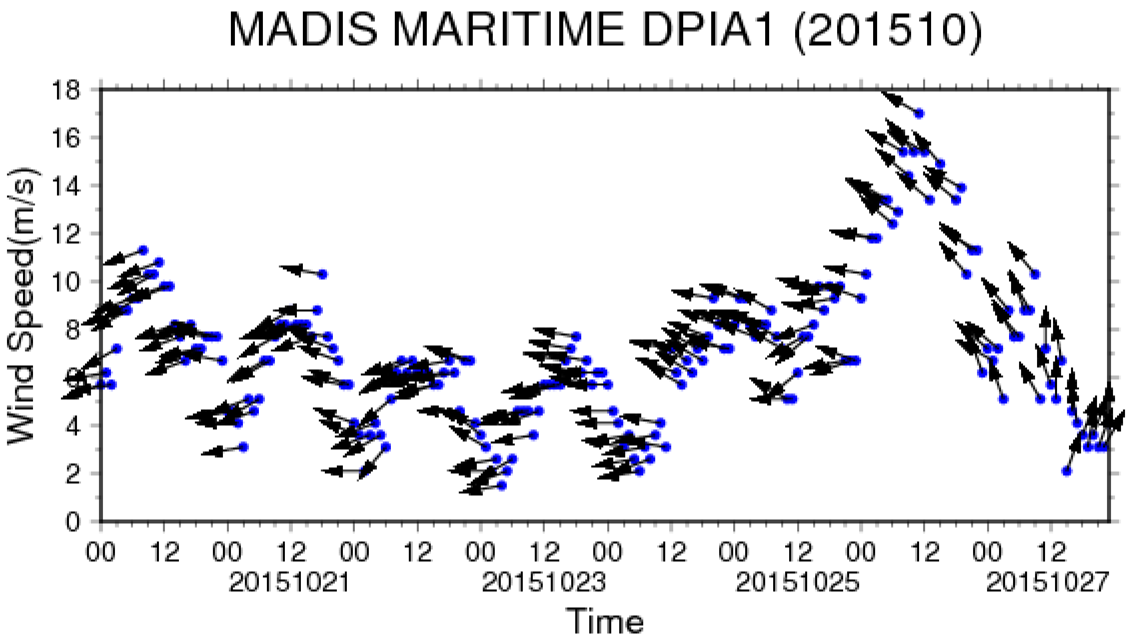
Time


MADIS NOS−NWLON SHBL1 (201510)
Wind Speed(m/s)
Time
20151021
20151023
20151025
20151027
MADIS SHBL1 vs RTMA (201510)
Obs
RTMA
Wind Direction(deg)
MADIS NOS−NWLON SHBL1 (201510)
Original
Adjusted
MADIS SHBL1 vs RTMA (201510)
AdjObs
RTMA



MADIS MARITIME DPIA1 (201510)
Wind Speed(m/s)
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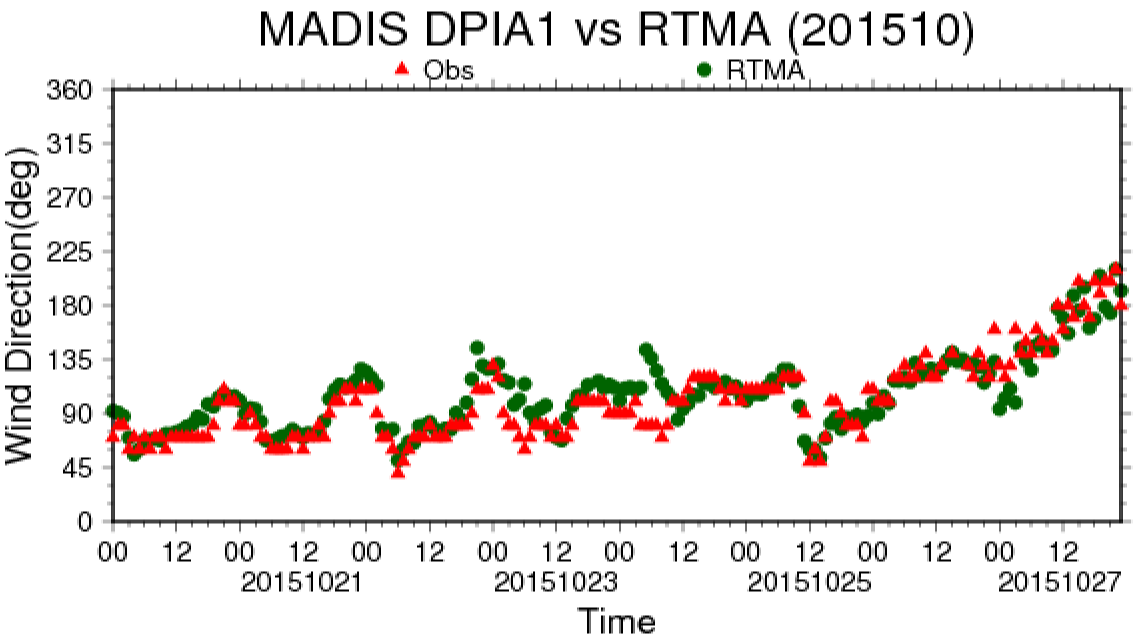
20151023
20151025
20151027
Time



MADIS DPIA1 vs RTMA (201510)
Obs
RTMA
Wind Direction(deg)
0
45
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20151021
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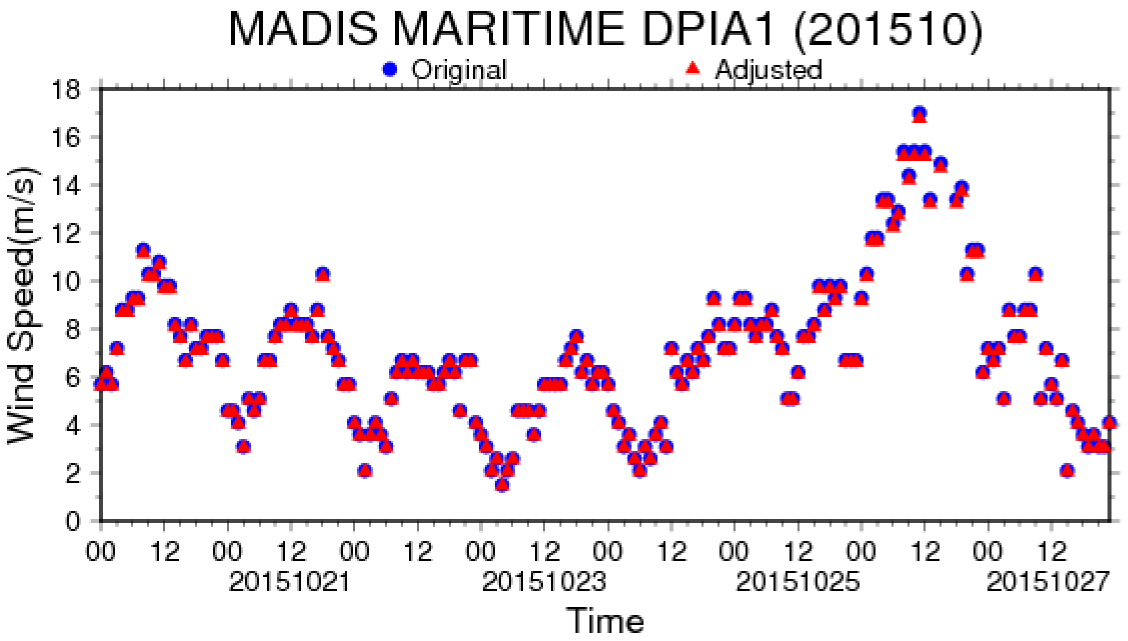
Time



MADIS MARITIME DPIA1 (201510)
Original
Adjusted
Wind Speed(m/s)
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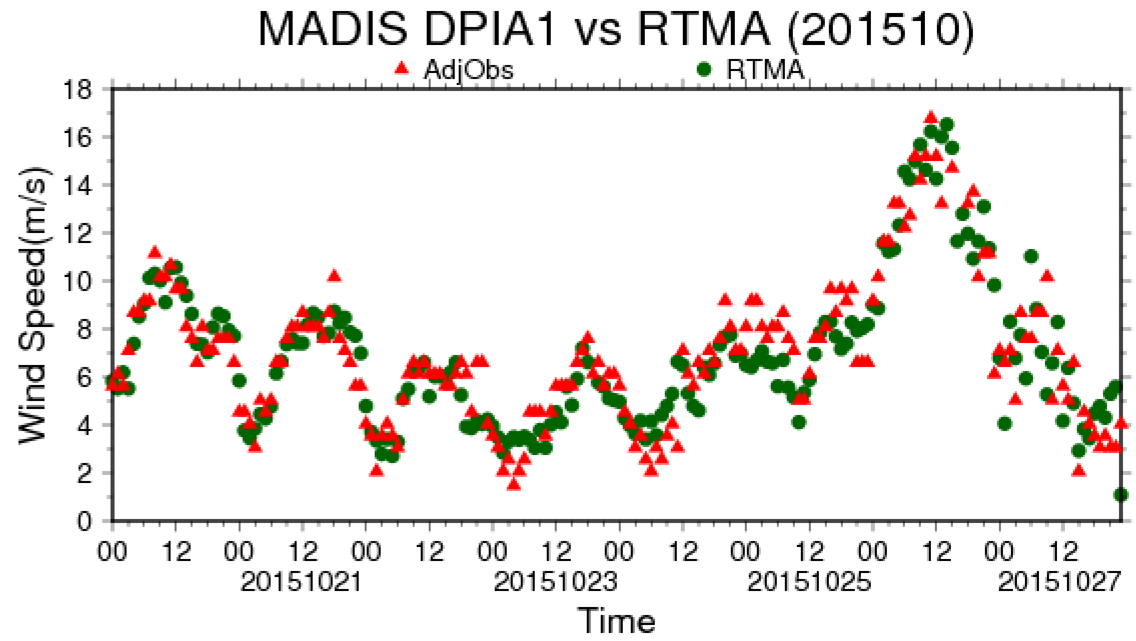
Time



MADIS DPIA1 vs RTMA (201510)
AdjObs
RTMA
Wind Speed(m/s)
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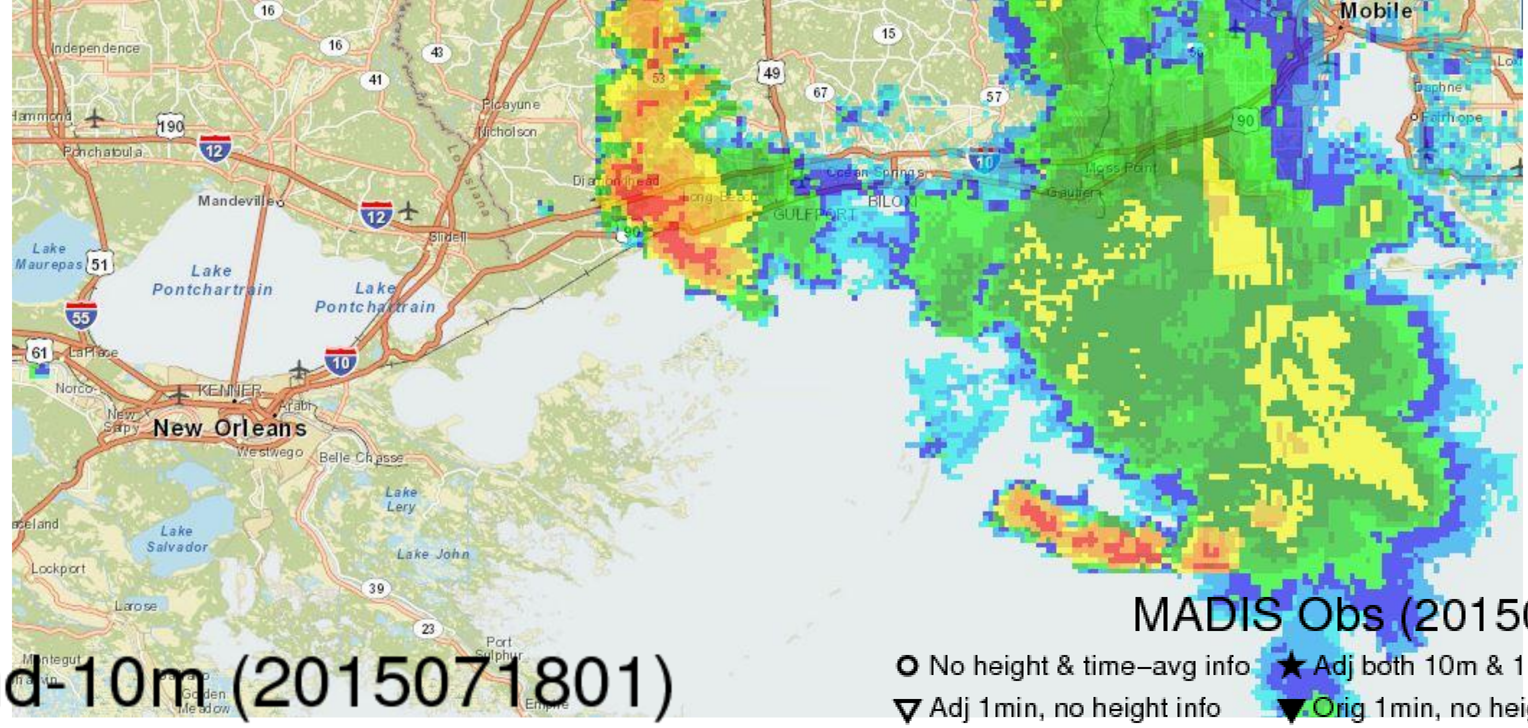
20151021
20151023
20151025
20151027
Time

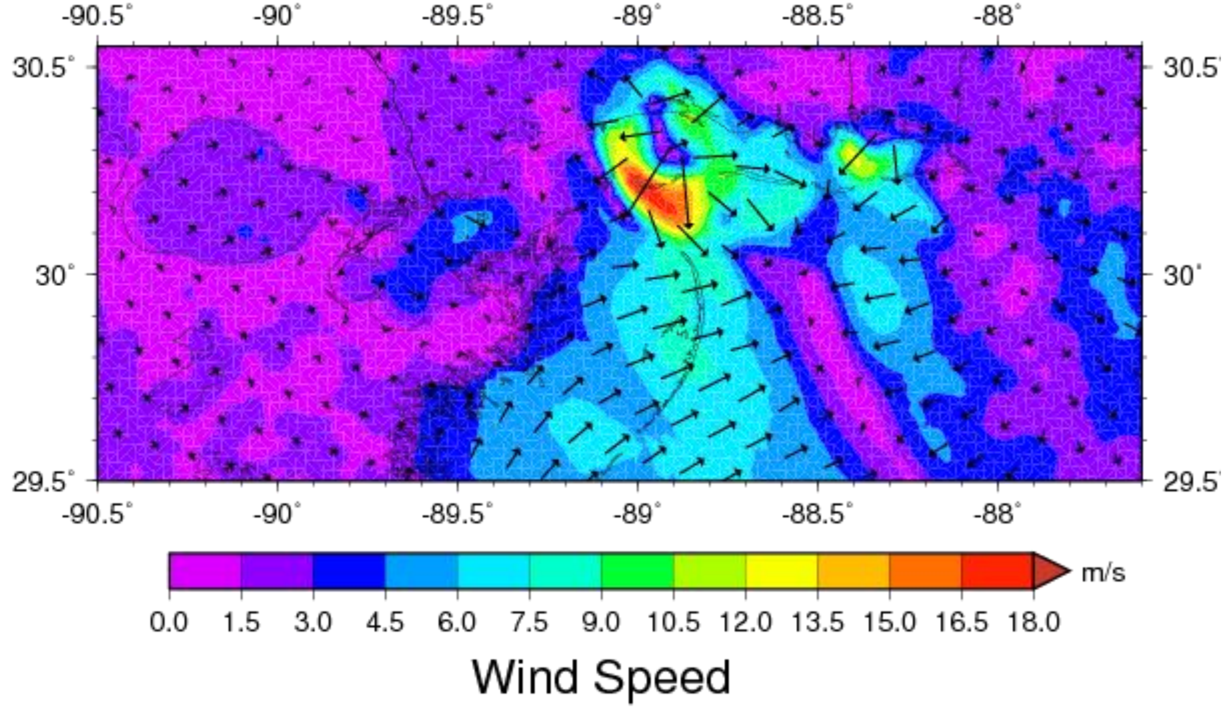
Also reasonably depicts 2D seabreeze structure compared to obs, but analysis still ongoing

Thunderstorm outflow boundary issues (from radar data assimilation?)

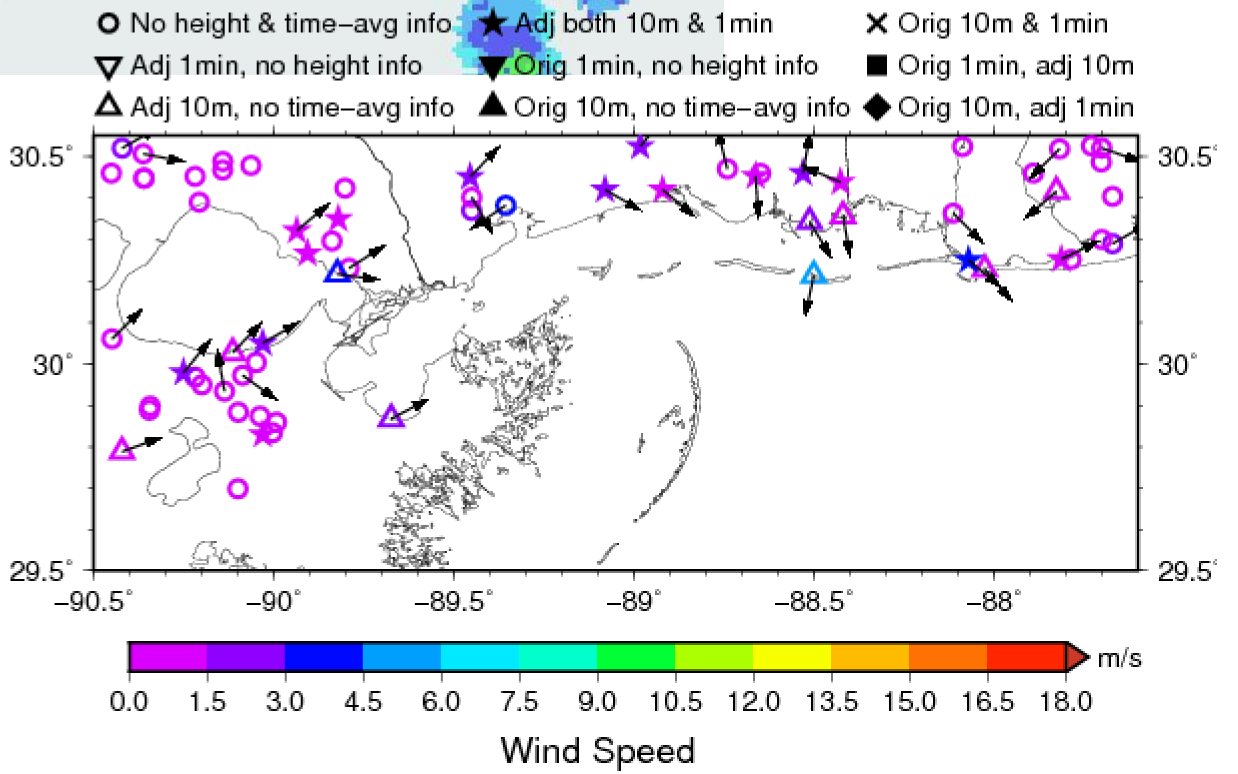
One motivation for visiting ESRL



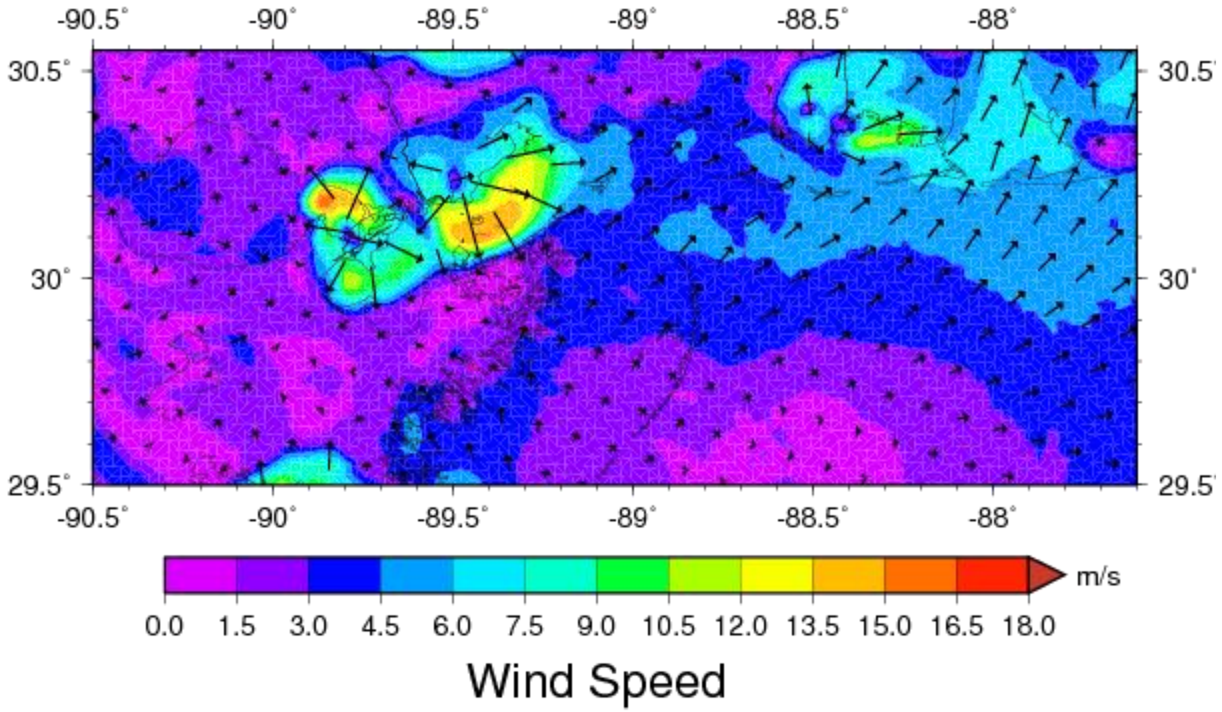
RTMA Wind-10m (2015071801)



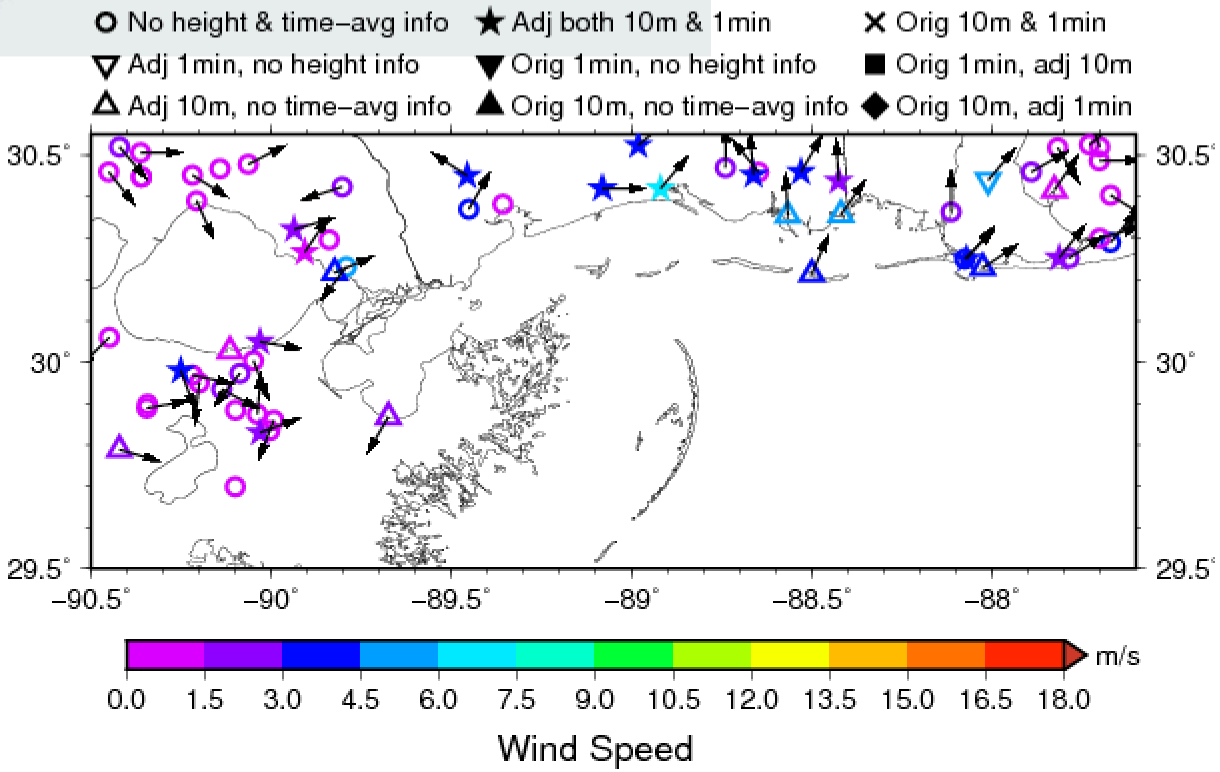
MADIS Obs (2015071801)



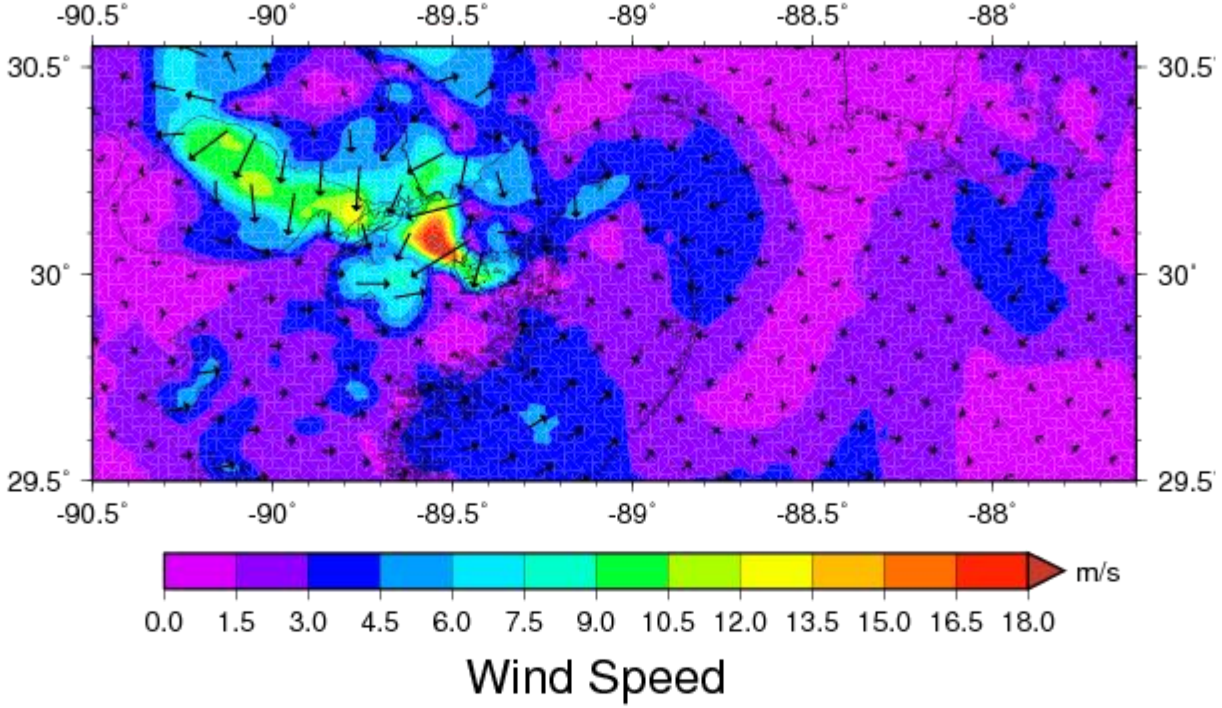
RTMA Wind-10m (2015071822)



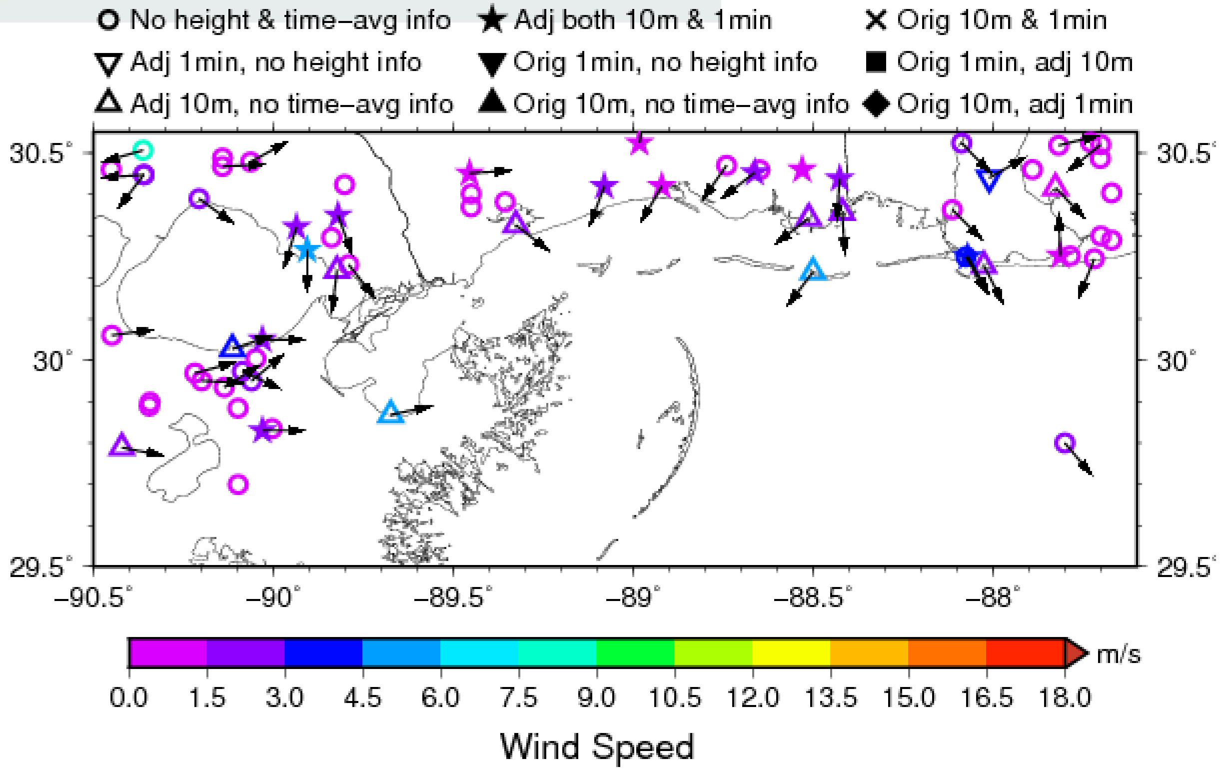
MADIS Obs (2015071822)



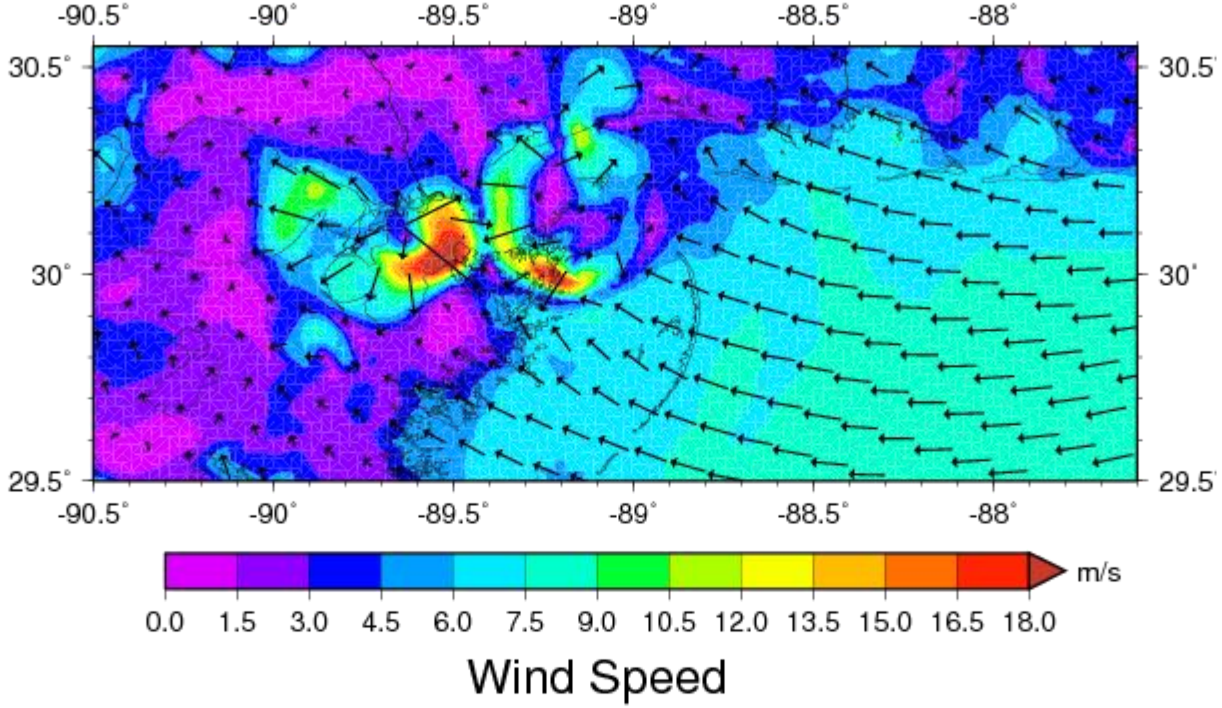
RTMA Wind-10m (2015090601)



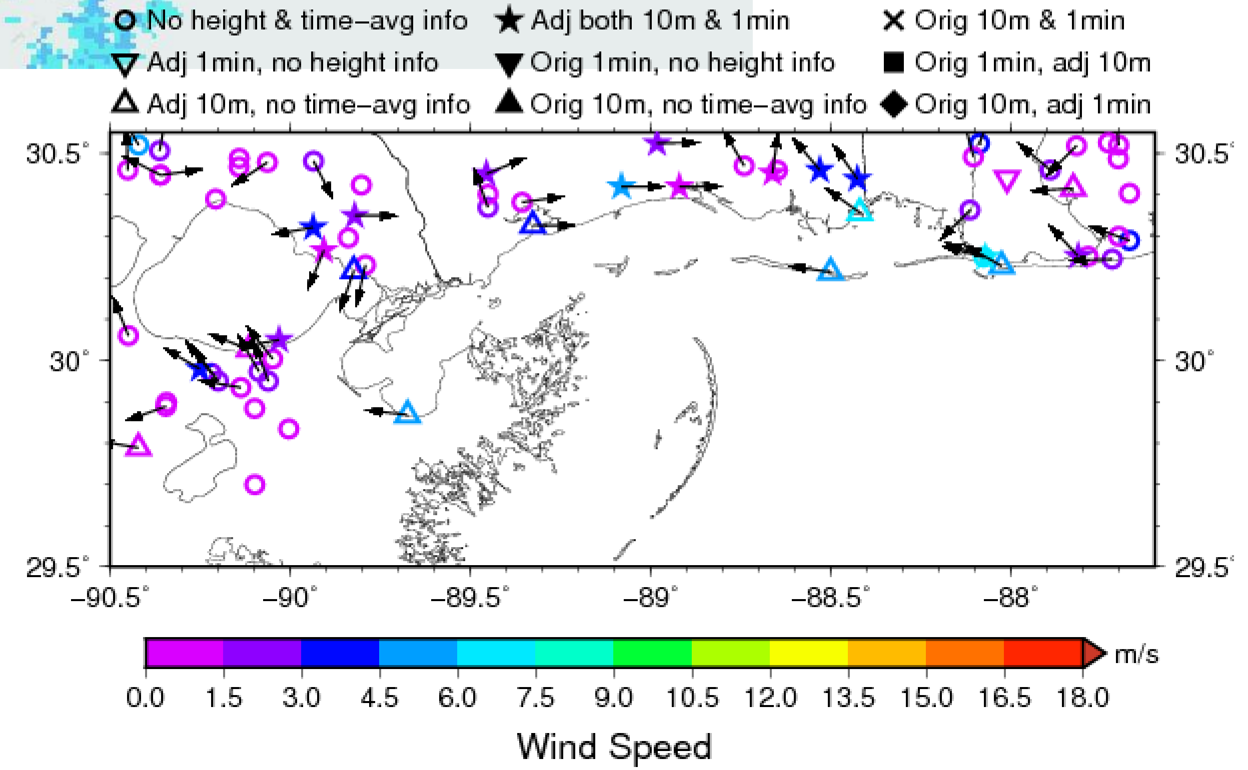
MADIS Obs (2015090601)



RTMA Wind-10m (2015090622)



MADIS Obs (2015090622)



Conclusions

1) RTMA wind and temperature reasonably matches observations in most cases
2) Some mesoscale platforms not in RTMA accept list. If the instruments meet WMO exposure standards and the instruments are reasonably accurate, we will formally request RTMA inclusion.
3) HRRR's ability to include outflow boundaries qualitatively matches most convective events, but magnitude and spatial patterns can be inaccurate

Visit is to understand how radar data is used in HRRR, and also to bring attention to the issue.

Future plans

A major objective is to generate a synthetic model that incorporates fine-scale 4-D biophysical processes that reveals exposure pathways reflective of DWH, and which will be portable to future spill scenarios impacting similar river-dominated coastal ecosystems.

Components include

- MSU Atmospheric reanalysis product
- NRL Model for boundary conditions
- ROMS-based applications with biogeochemical/lower trophic level model

Will facilitate

- Climatology studies for northern GOM
- Case studies for CONCORDE research cruises

Future interactions with the RTMA and HRRR team are being pursued, as well as more validation with WeatherFlow network