Wind Forecasting Using the WRF-AWR Model

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What is WRF?

- **W**eather **R**esearch and **F**orecasting Model

- Mesoscale forecast model and data assimilation system

- Suitable for use in scales ranging from meters to thousands of kilometers
    - Operational
    - Research

- Two dynamics solvers:
    - Advanced Research WRF (ARW)
    - Nonhydrostatic Mesoscale Model (NMM)

ARW System

- Consists of the ARW dynamics solver with other components:
  - Initialization routines
  - Physics schemes
  - Data assimilation packages

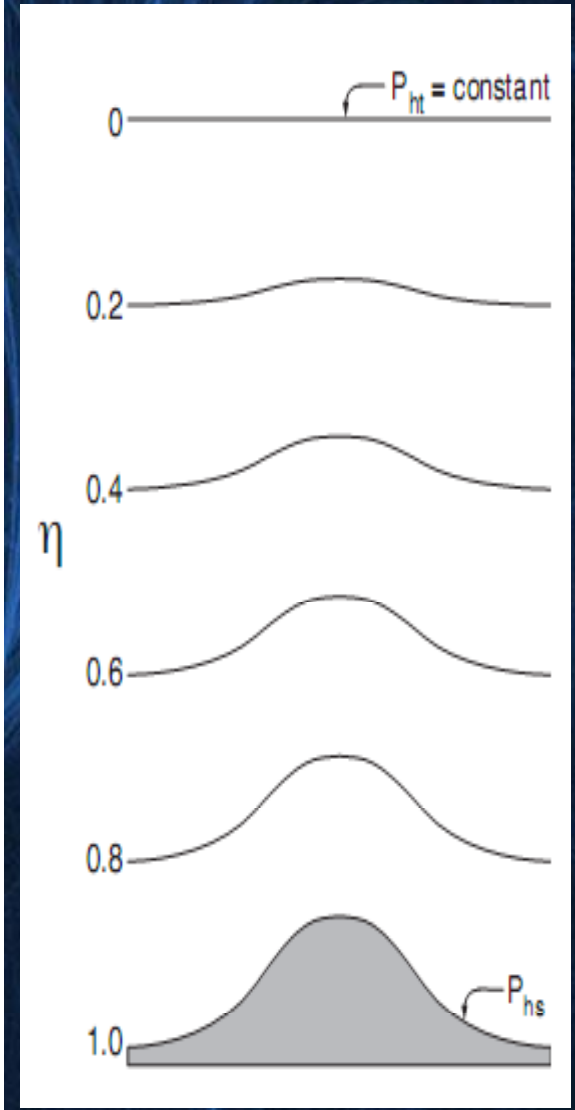
Major Features

- Fully compresible, Euler non-hydrostatic equations.

- Prognostic (time-varying) variables:
  - Velocity components *u, v, and w* in Cartesian coordinates
  - Perturbation potential temperature
  - Perturbation geopotential
  - Perturbation surface pressure of dry air

- Terrain-following hydrostatic-pressure vertical coordinate.

Terrain-following vertical coordinate



The lowest boundary geopotential (gz; z=height) specifies the terrain elevation, and we specify the lowest coordinate surface (P_{hs}) to be the terrain.

Since the vertical coordinate η is proportional to this lowest coordinate surface, we have a terrain-following coordinate.

The use of this coordinate system allows us to have a very realistic depiction of the topography in the model.

Initialization of the Model

- ARW can be run using interpolated data from either large-scale analysis or forecasts for real-data simulations.

- Initialization consists of two steps:
  - Running the WRF Pre-Processing System (WPS)
  - Running the ARW Pre-Processor (real)

- WPS prepares input to ARW for real-data simulations:
  - Defines simulation domain
  - Interpolates time-invariant terrestrial data to simulation grid
  - Interpolates time-varying meteorological fields from another model into simulation domain

Computational Domain

17.000° N – 19.000° N

64.000° W – 68.000° W

4 km spatial resolution

Time-Invariant Terrestrial Data

- Terrain elevation
- Latitude/Longitude
- Map rotation angle
- Annual mean temperature
- Coriolis parameters
- Albedo
- Land/water mask
- Vegetation/land-use type
- Vegetation greenness factor
- Soil texture category

Time-Varying Meteorological Fields

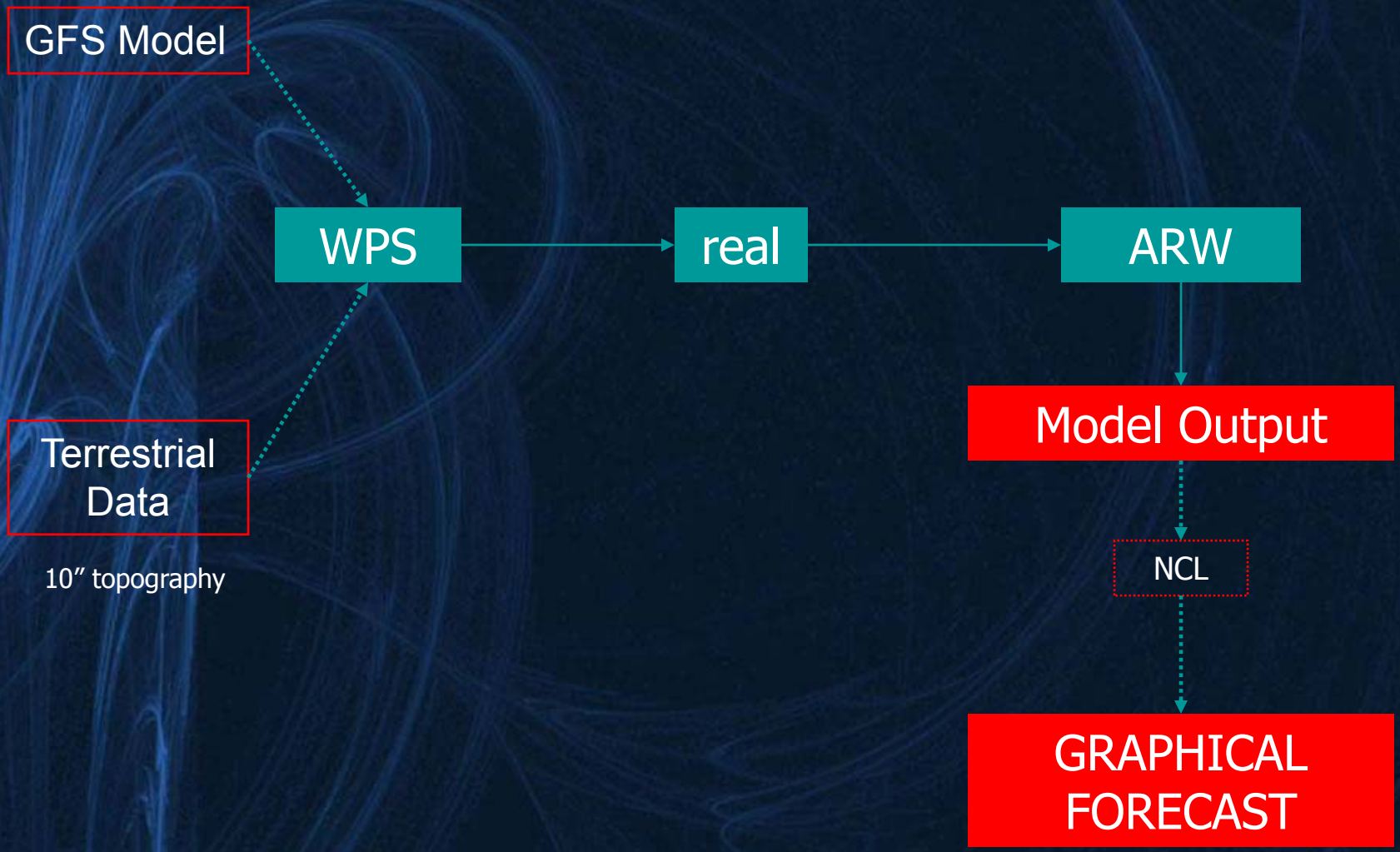
2D

- U, V wind components rotated to WRF grid
- U, V wind components interpolated into WRF grid
- Skin temperature
- Layers of soil temperature
- Soil Moisture

3D

- Potential temperature
- Mixing ratio

What do we do?


GFS Model
WPS
real
ARW
Model Output
Terrestrial Data
10″ topography
NCL
GRAPHICAL FORECAST

Graphical Forecast

- A forecast map is produced for the next 48 hours, at 3 hour intervals.

- The forecast map shows the wind field in two ways:
    - Contours: the colors indicate the wind speed (knots) according to the legend.
    - Wind Barbs: the inclination on the wind barb indicates the direction from where the wind is *coming*.

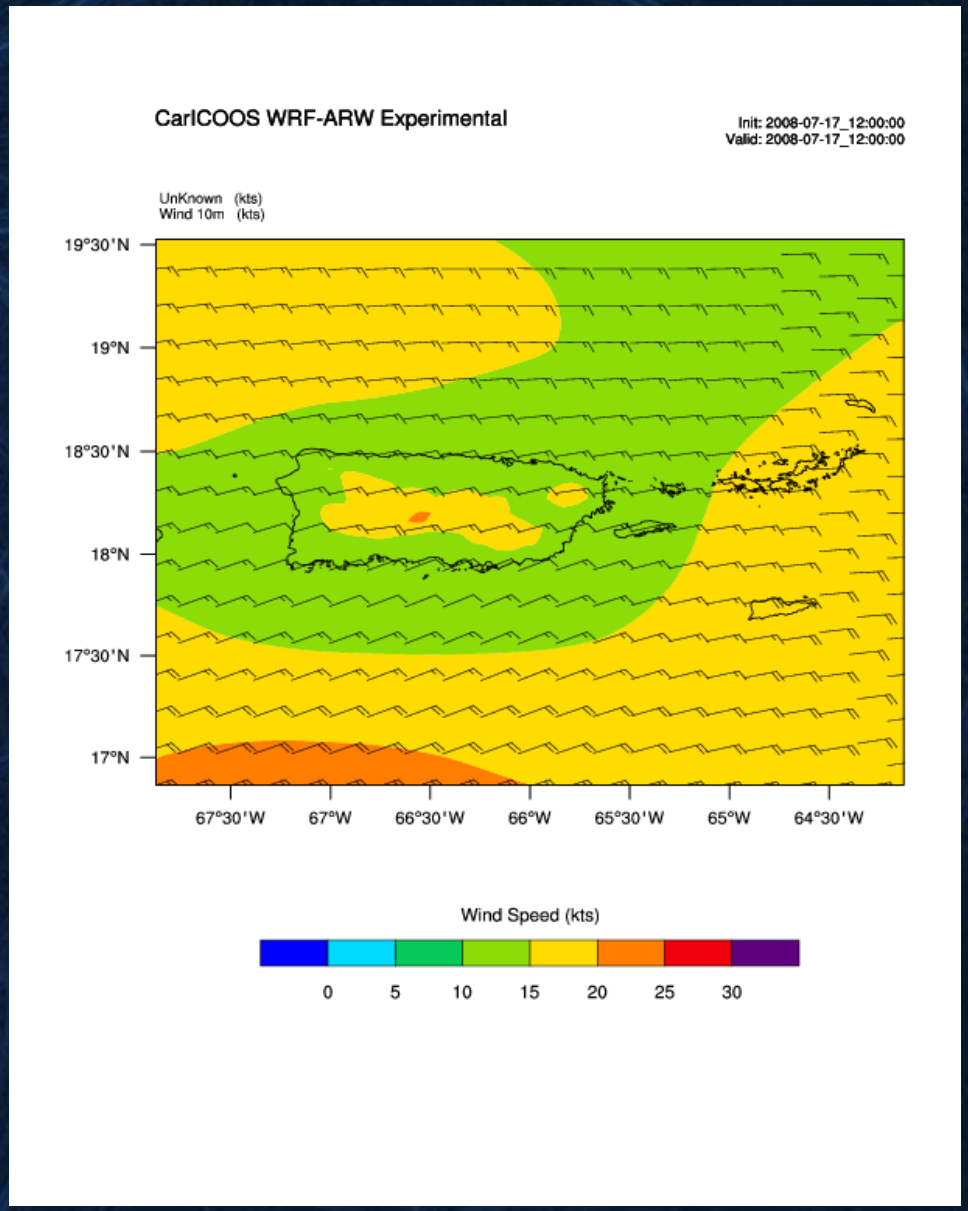
      The size of the barbs indicate the wind speed: the small barb is 5 knots and the large barb is 10 knots.

- The daily forecast map can be accessed at:

www.caricoos.org

Regions

- There are forecast maps available for the following areas:
    - **Puerto Rico**
        - San Juan
        - Arecibo
        - Mayaguez
        - Humacao
        - Vieques and Culebra
        - La Parguera, Lajas
        - South
        - South East
        - South West
    - **Virgin Islands**



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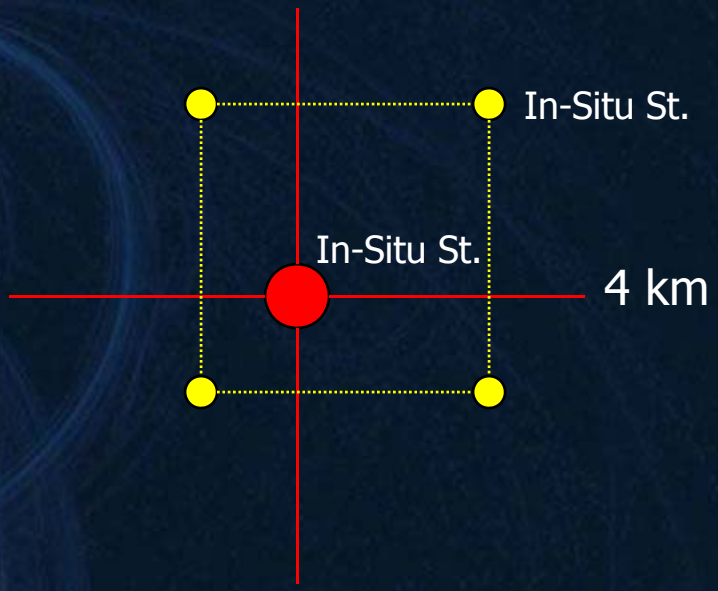
Validation

- Validation of the ARW is being done following the statistical analysis recommended by Wilmott, 1982.
    - Root Mean Square Error (RMSE)
    - Index of Agreement (IOA)

- The RMSE summarizes the mean differences between the forecast and the in-situ observations.

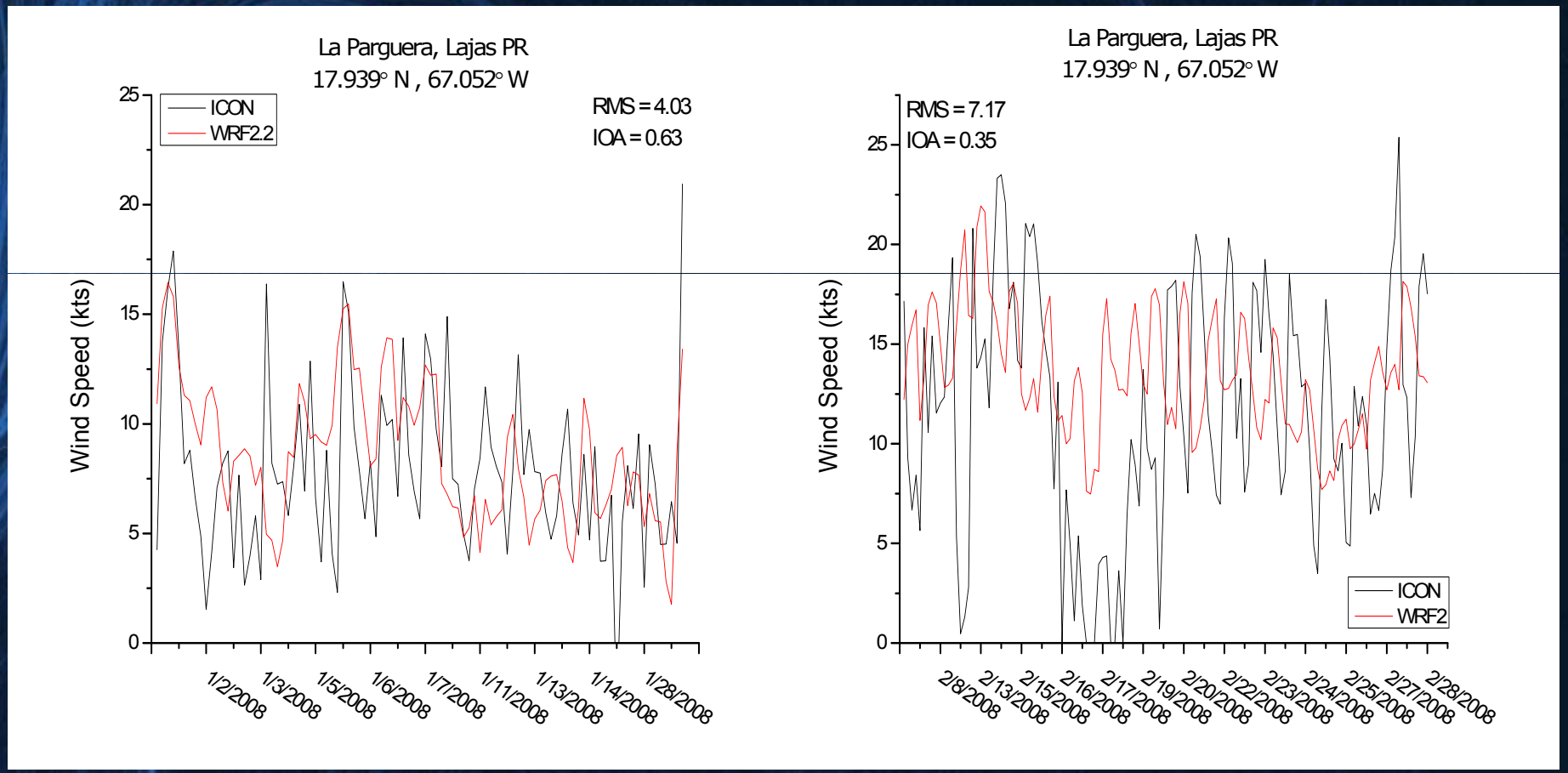
- The IOA is a measurement of the accuracy of a model in forecasting a given parameter.

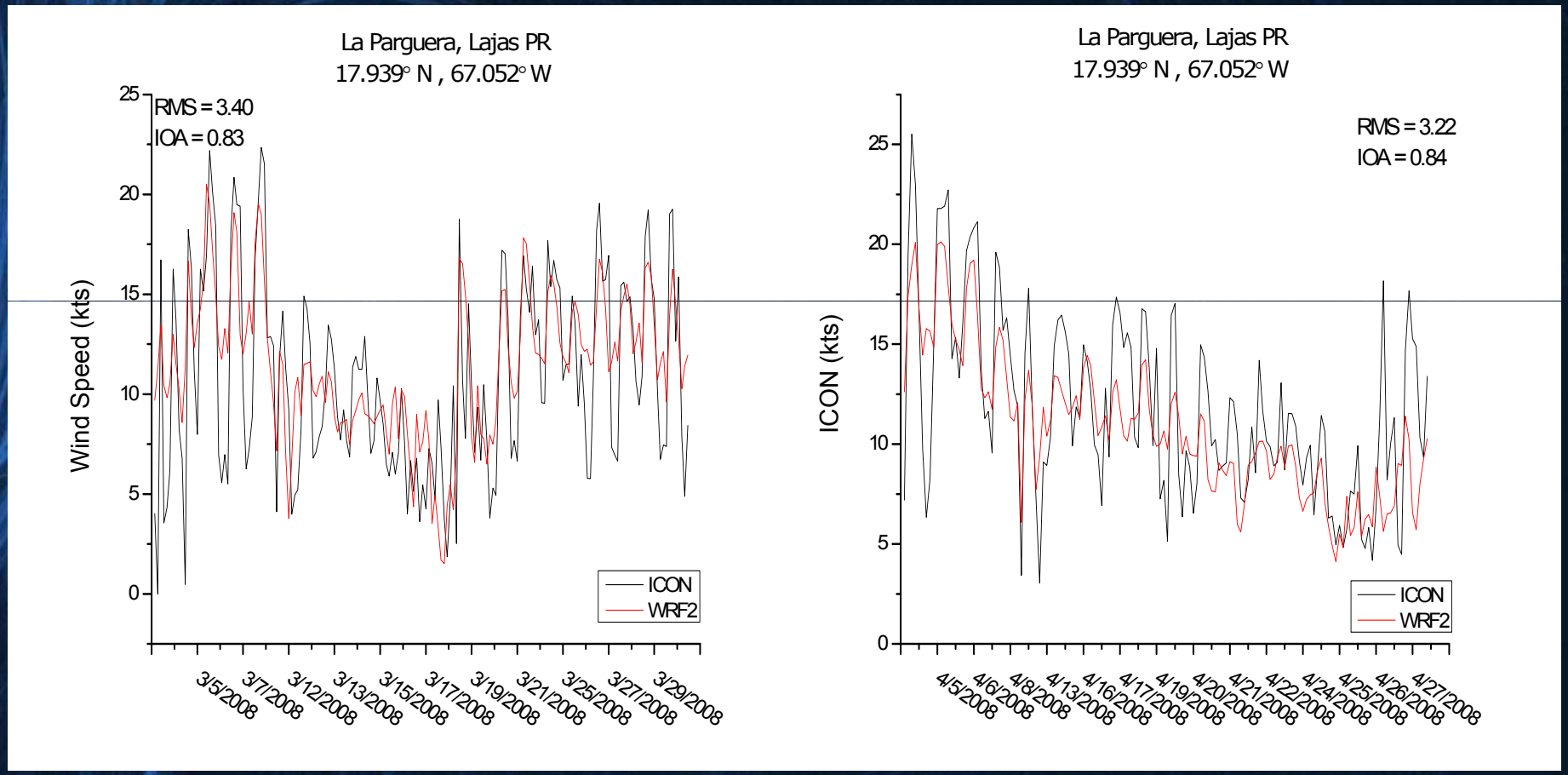
Validation Technique

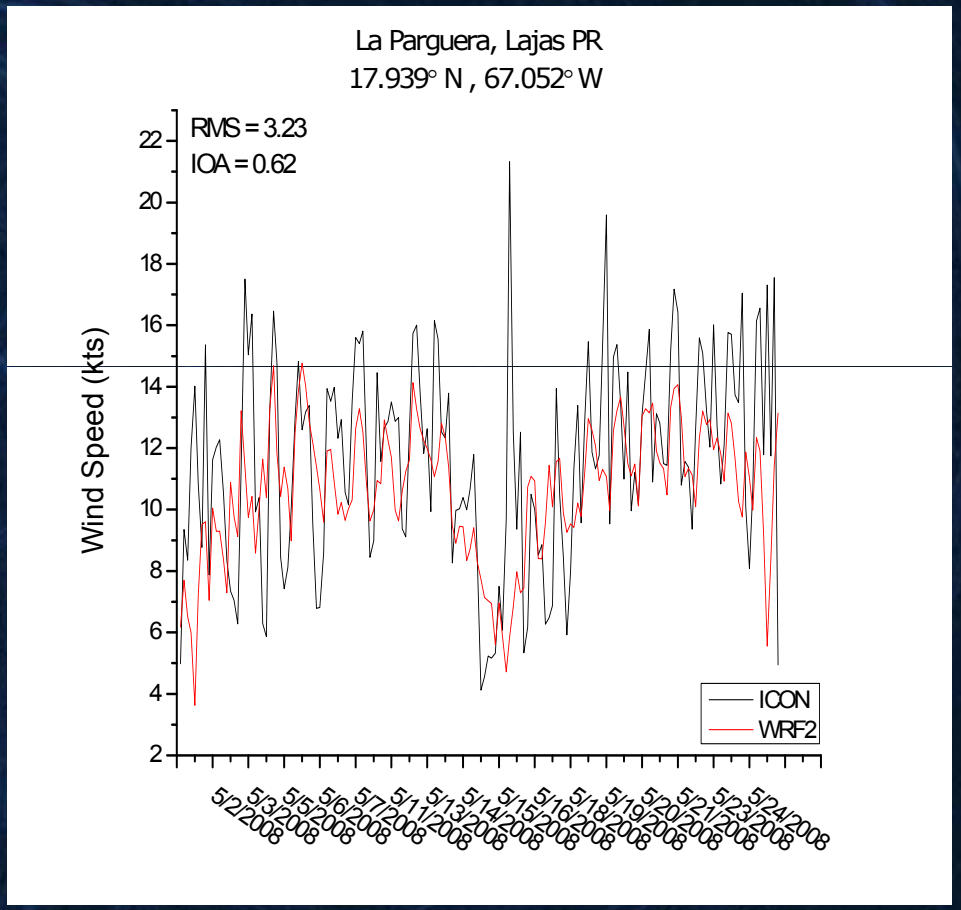


- For this presentation we use two in-situ stations:
  - ICON/CREWS buoy at Media Luna Reef, La Parguera
  - SJNP4 NOAA NOS buoy at San Juan

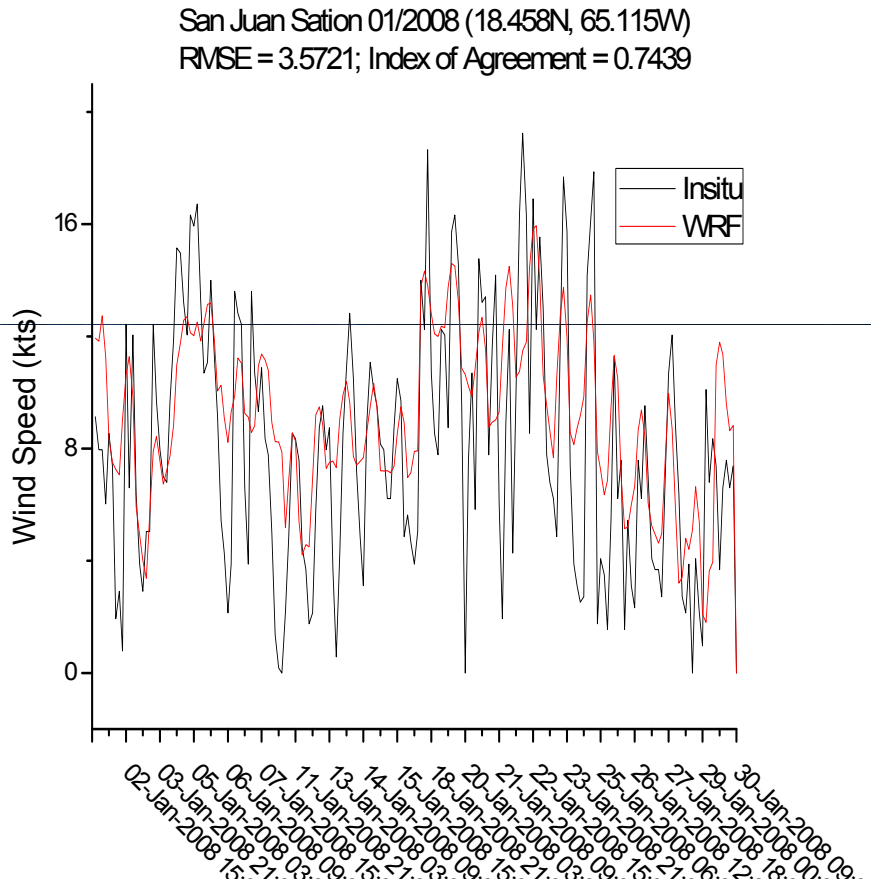
La Parguera

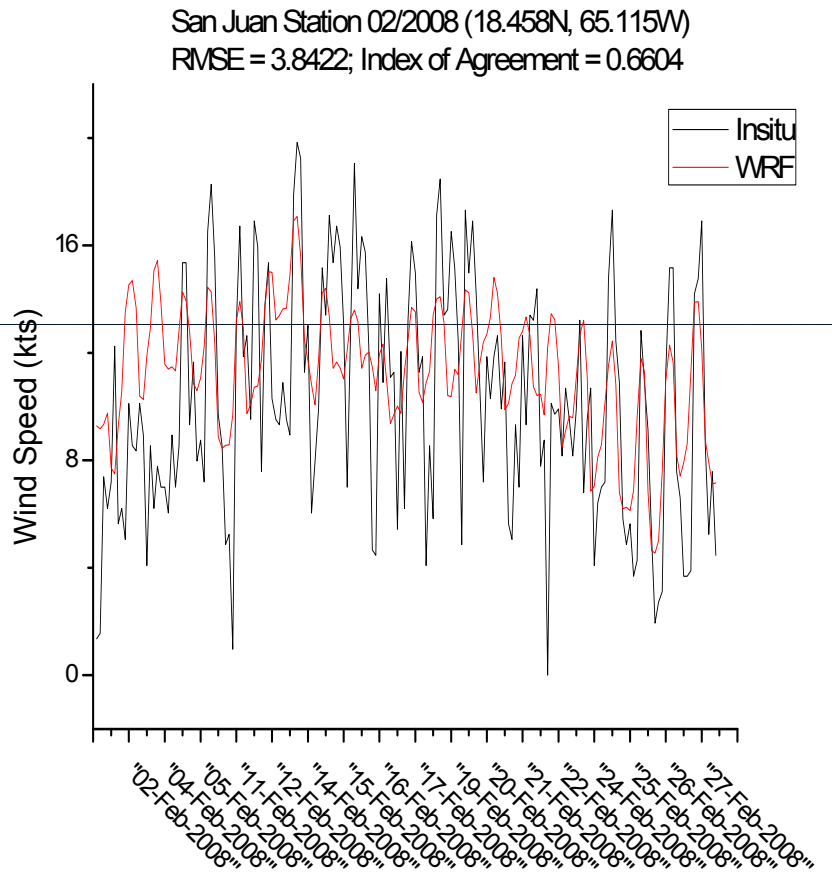

La Parguera, Lajas PR
17.939° N , 67.052° W
RMS = 4.03
IOA = 0.63
ICON
WRF2.2
Wind Speed (kts)
0
5
10
15
20
25
1/2/2008
1/3/2008
1/5/2008
1/6/2008
1/7/2008
1/11/2008
1/13/2008
1/14/2008
1/28/2008
La Parguera, Lajas PR
17.939° N , 67.052° W
RMS = 7.17
IOA = 0.35
ICON
WRF2
Wind Speed (kts)
0
5
10
15
20
25
2/8/2008
2/13/2008
2/15/2008
2/16/2008
2/17/2008
2/19/2008
2/20/2008
2/22/2008
2/23/2008
2/24/2008
2/25/2008
2/27/2008
2/28/2008

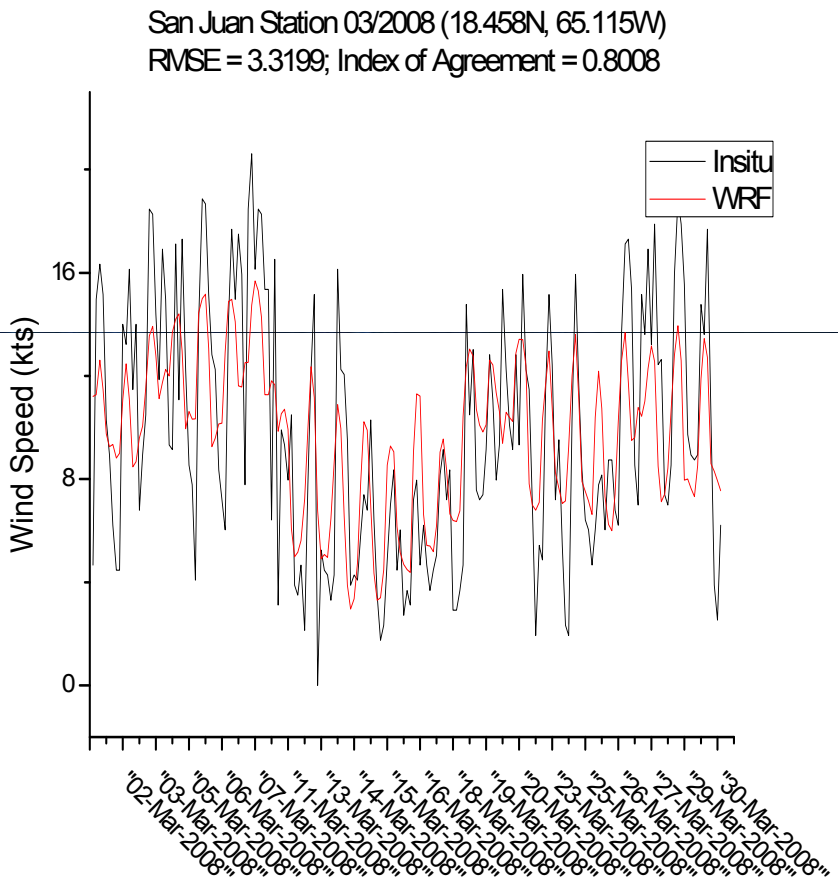

La Parguera, Lajas PR
17.939° N , 67.052° W
RMS = 3.40
IOA = 0.83
Wind Speed (kts)
ICON
WRF2
3/5/2008
3/7/2008
3/12/2008
3/13/2008
3/15/2008
3/17/2008
3/19/2008
3/21/2008
3/25/2008
3/27/2008
3/29/2008
La Parguera, Lajas PR
17.939° N , 67.052° W
RMS = 3.22
IOA = 0.84
ICON (kts)
ICON
WRF2
4/5/2008
4/6/2008
4/8/2008
4/13/2008
4/16/2008
4/17/2008
4/19/2008
4/20/2008
4/21/2008
4/22/2008
4/24/2008
4/25/2008
4/26/2008
4/27/2008

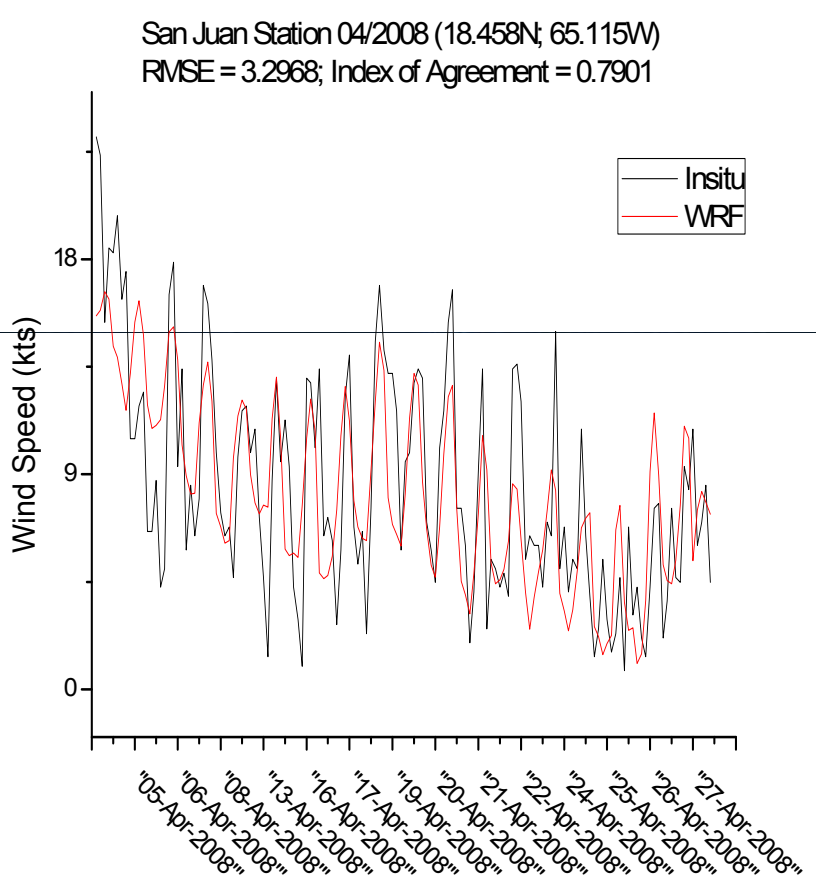

La Parguera, Lajas PR
17.939° N , 67.052° W
RMS = 3.23
IOA = 0.62
Wind Speed (kts)
22
20
18
16
14
12
10
8
6
4
2
ICON
WRF2
5/2/2008
5/3/2008
5/5/2008
5/6/2008
5/7/2008
5/11/2008
5/13/2008
5/14/2008
5/15/2008
5/16/2008
5/18/2008
5/19/2008
5/20/2008
5/21/2008
5/23/2008
5/24/2008

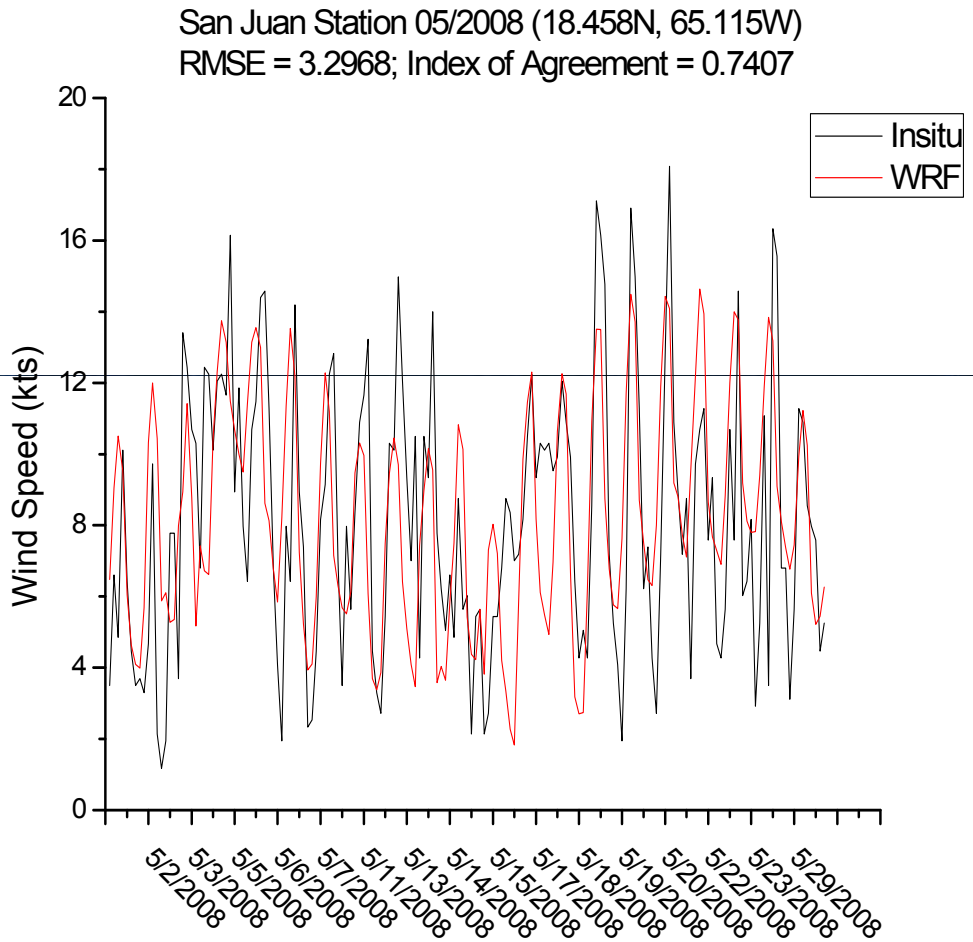
San Juan


San Juan Sation 01/2008 (18.458N, 65.115W)
RMSE = 3.5721; Index of Agreement = 0.7439
Insitu
WRF
Wind Speed (kts)
16
8
0
02-Jan-2008 15
03-Jan-2008 21
05-Jan-2008 03
06-Jan-2008 09
07-Jan-2008 15
11-Jan-2008 21
13-Jan-2008 03
14-Jan-2008 09
15-Jan-2008 15
18-Jan-2008 09
20-Jan-2008 15
21-Jan-2008 21
22-Jan-2008 03
23-Jan-2008 09
25-Jan-2008 15
26-Jan-2008 21
27-Jan-2008 06
29-Jan-2008 12
30-Jan-2008 00


San Juan Station 02/2008 (18.458N, 65.115W)
RMSE = 3.8422; Index of Agreement = 0.6604
Insitu
WRF
Wind Speed (kts)
16
8
0
"02-Feb-2008"
"04-Feb-2008"
"05-Feb-2008"
"11-Feb-2008"
"12-Feb-2008"
"14-Feb-2008"
"15-Feb-2008"
"16-Feb-2008"
"17-Feb-2008"
"19-Feb-2008"
"20-Feb-2008"
"21-Feb-2008"
"22-Feb-2008"
"24-Feb-2008"
"25-Feb-2008"
"26-Feb-2008"
"27-Feb-2008"


San Juan Station 03/2008 (18.458N, 65.115W)
RMSE = 3.3199; Index of Agreement = 0.8008
Insitu
WRF
Wind Speed (kts)
16
8
0
"02-Mar-2008"
"03-Mar-2008"
"05-Mar-2008"
"06-Mar-2008"
"07-Mar-2008"
"11-Mar-2008"
"13-Mar-2008"
"14-Mar-2008"
"15-Mar-2008"
"16-Mar-2008"
"18-Mar-2008"
"19-Mar-2008"
"20-Mar-2008"
"23-Mar-2008"
"25-Mar-2008"
"26-Mar-2008"
"27-Mar-2008"
"29-Mar-2008"
"30-Mar-2008"


San Juan Station 04/2008 (18.458N; 65.115W)
RMSE = 3.2968; Index of Agreement = 0.7901
Insitu
WRF
Wind Speed (kts)
18
9
0
"05-Apr-2008"
"06-Apr-2008"
"08-Apr-2008"
"13-Apr-2008"
"16-Apr-2008"
"17-Apr-2008"
"19-Apr-2008"
"20-Apr-2008"
"21-Apr-2008"
"22-Apr-2008"
"24-Apr-2008"
"25-Apr-2008"
"26-Apr-2008"
"27-Apr-2008"


San Juan Station 05/2008 (18.458N, 65.115W)
RMSE = 3.2968; Index of Agreement = 0.7407
Insitu
WRF
Wind Speed (kts)
20
16
12
8
4
0
5/2/2008
5/3/2008
5/5/2008
5/6/2008
5/7/2008
5/11/2008
5/13/2008
5/14/2008
5/15/2008
5/17/2008
5/18/2008
5/19/2008
5/20/2008
5/22/2008
5/23/2008
5/29/2008

Preliminary Conclusions

- The wind forecast generally follows the same pattern as the in-situ wind observations BUT:
  - Most peaks and lows are not well forecasted
  - ARW tends to underestimate peaks and overestimate lows
- Possible reasons:
  - Sub-grid processes
  - Lack of real-time observational data being fed into the model
  - Topographic shadowing, sea breeze
- Possible solutions:
  - Run model at higher spatial resolution (2km, 1km)
  - Use different parametrization and micro-physics schemes
  - Future implementation of WRF3 which includes shadowing effects

Future Work

- Increase spatial resolution of the model
  - Increase whole domain resolution to 2km, 1km

    Very computation time intensive
  - Use nested grids

    Keep whole domain at 4km resolution and run an area

    at 2km, 1km resolution

- Assimilate real-time observational data into the model
  - Ability to run an analysis on the ARW output, based on real-time observations and past model results.
  - After this analysis is done, an improved forecast is available.

Acknowledgements

- Scott Strippling – National Weather Service, San Juan

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Questions?