Wind Forecasting Using the WRF-AWR Model

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What is WRF?

- **Weather Research and Forecasting 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 compressible, 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 \(\eta\) 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**

**Terrestrial Data**

- 10” topography

**Model Output**

**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**
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.
- 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, Lajas PR
17.939° N, 67.052° W

RMS = 3.40
IQA = 0.83

La Parguera, Lajas PR
17.939° N, 67.052° W

RMS = 3.22
IQA = 0.84

Wind Speed (kts)

ICON (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
3/23/2008
3/25/2008
4/5/2008
4/6/2008
4/8/2008
4/13/2008
4/16/2008
4/17/2008
4/19/2008
4/20/2008
4/22/2008
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
San Juan Station 01/2008 (18.458N, 65.115W)
RMSE = 3.5721; Index of Agreement = 0.7439

San Juan Station 02/2008 (18.458N, 65.115W)
RMSE = 3.8422; Index of Agreement = 0.6604

Wind Speed (kts)
San Juan Station 03/2008 (18.458N, 65.115W)
RMSE = 3.3199; Index of Agreement = 0.8008

San Juan Station 04/2008 (18.458N; 65.115W)
RMSE = 3.2968; Index of Agreement = 0.7901

Wind Speed (kts) vs. Time (days)

- Insitu
- WRF

Wind Speed (kts) vs. Time (days)
San Juan Station 05/2008 (18.458N, 65.115W)
RMSE = 3.2968; Index of Agreement = 0.7407
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
- Carlos M. Anselmi – Marine Sciences Department
Questions?