Weather Research and Forecasting Model Wind Sensitivity Study at Edwards Air Force Base, CA

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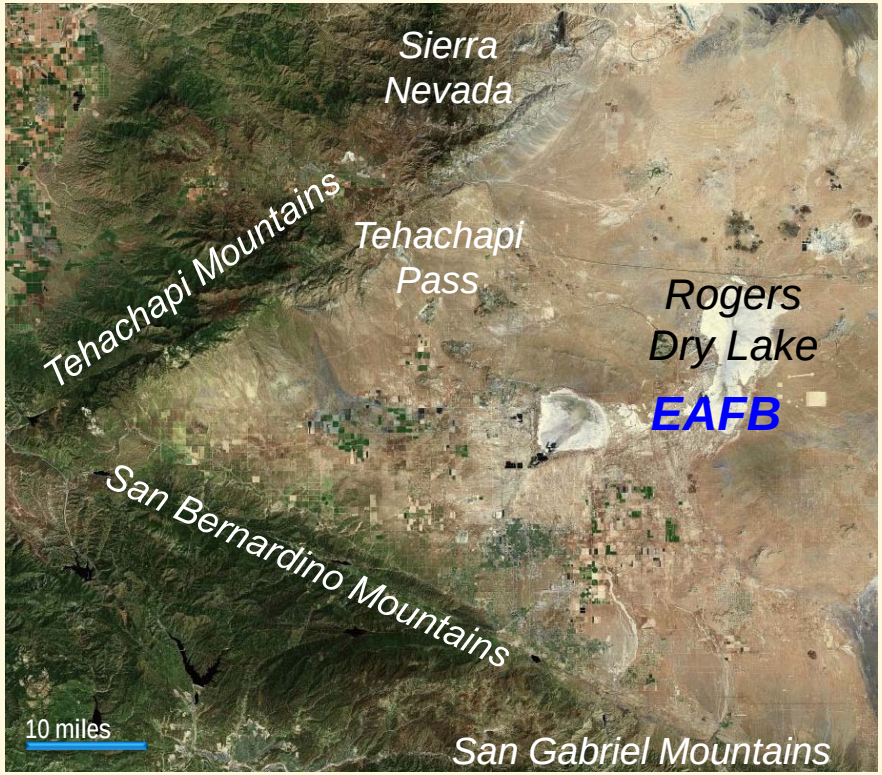
Outline

- Background
- Project Goal
- Wind Cycling Explained
- Data
- Model Configuration
- Subjective Analysis
- Objective Analysis
- Summary/Conclusions

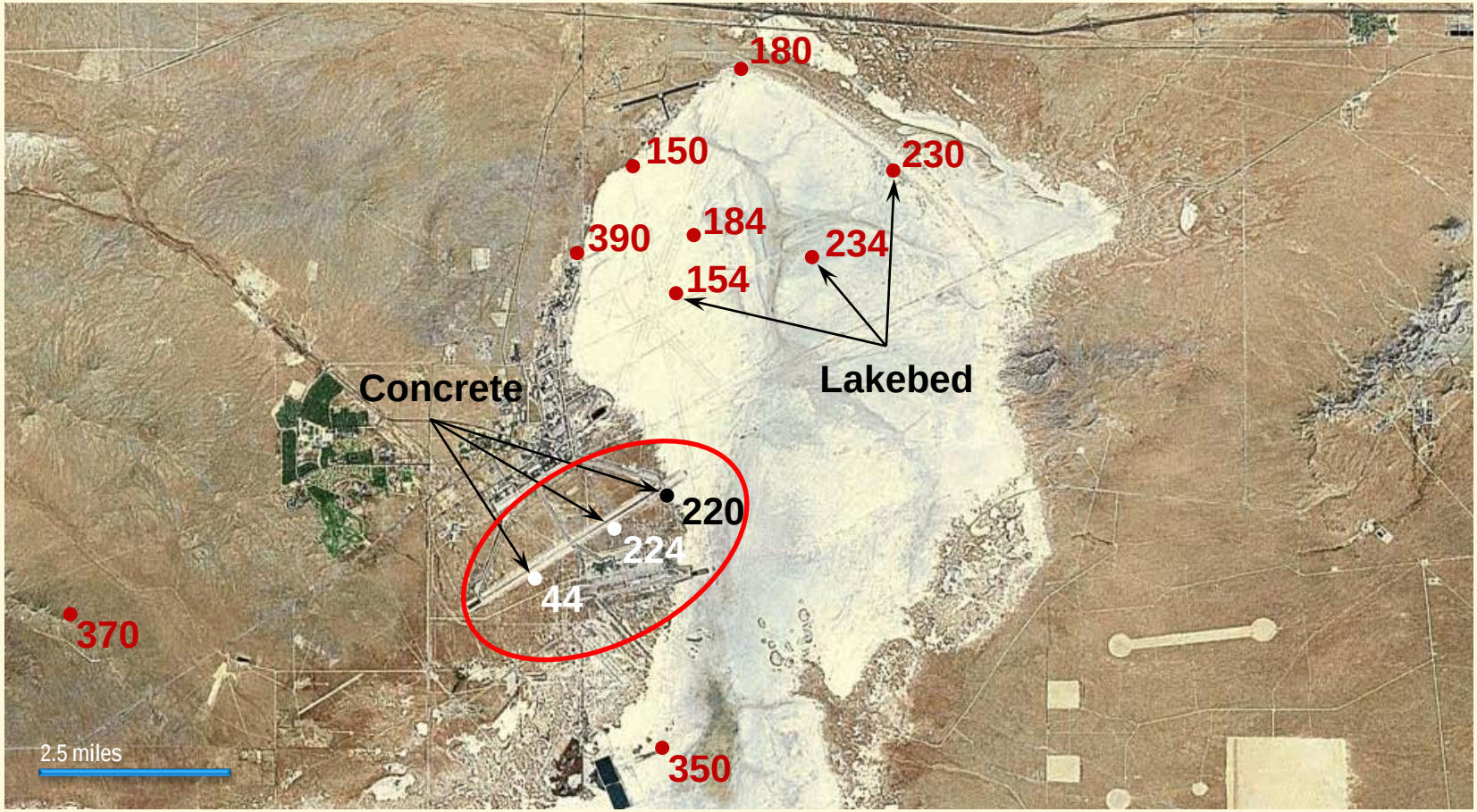
Background

- Space Shuttle landings at Edwards AFB (EAFB)
  - When weather conditions at KSC violate Flight Rules
- Complex terrain
  - Wind speeds and directions oscillate among towers near EAFB runway
  - Forecasting surface winds challenging for Spaceflight Meteorology Group (SMG)



Project Goal

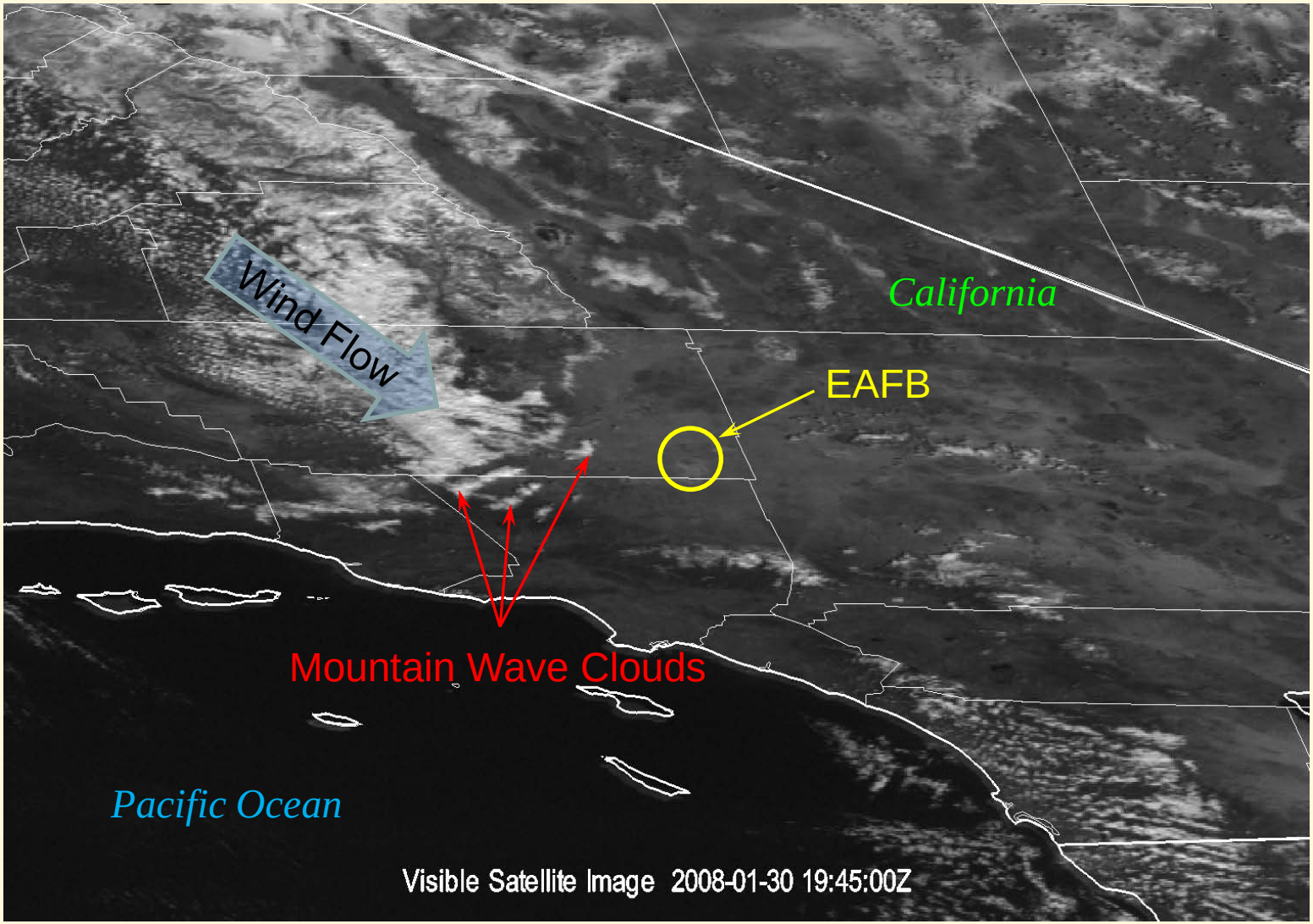
Determine the skill of different WRF model configurations in forecasting “wind cycling” cases at EAFB



EAFB Wind Cycling

- An oscillation in wind speed and/or wind direction among the wind tower network near the EAFB runway complex
- Wind speed and direction reported from the towers near the concrete runway are noticeably different than that reported from towers near the lakebed runway
- Duration 90 minutes up to 4 hours or longer
- Prevailing wind is northwest or west-northwest
- Has occurred when mountain wave clouds are observed

EAFB Wind Cycling



Data

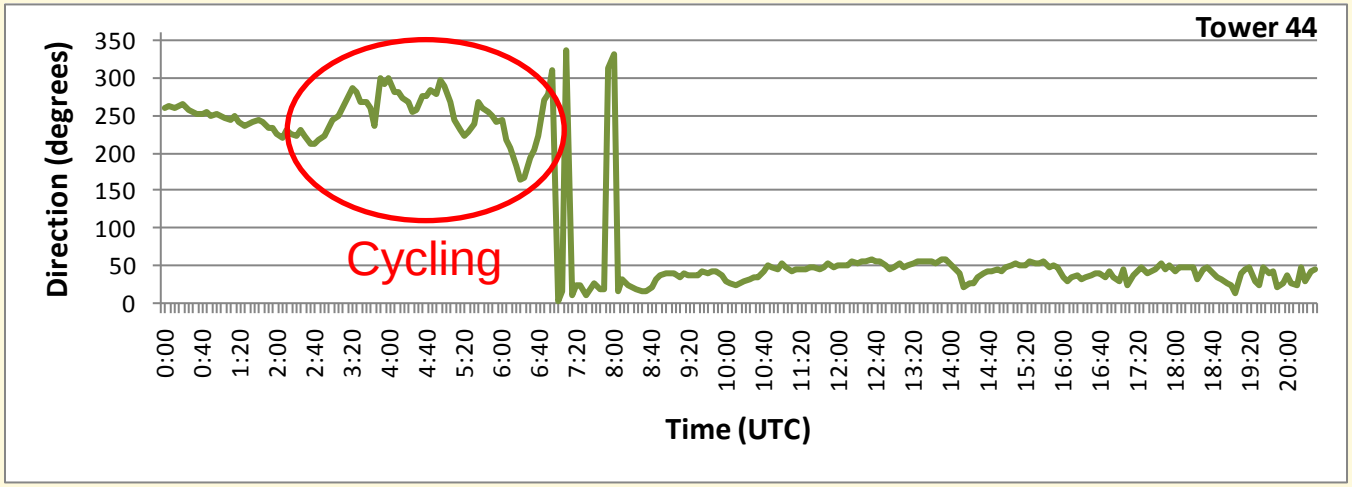
- Period of Record
  - Dec 2006 to Jul 2008
- Candidate days
  - Seven cycling cases
  - Two null cases

List of the all wind cycling candidate days, null cases, start of the wind cycling event, and the end of the event.

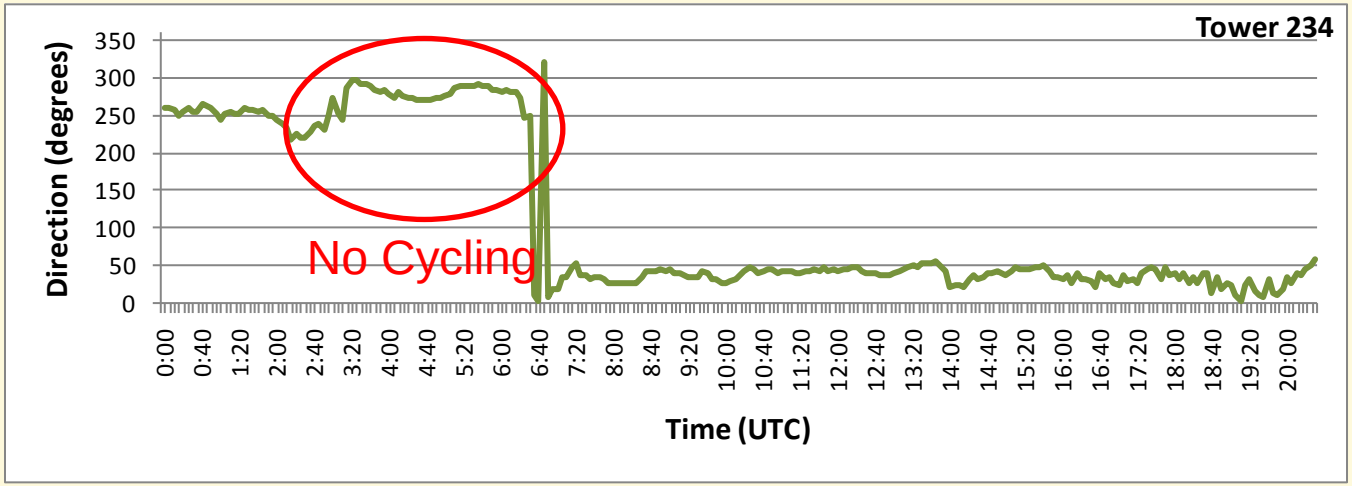
Candidate Day	Start of Event	End of Event
22 Dec 2006	0900 UTC	1800 UTC
30 Jan 2008	1030 UTC	1330 UTC
14 Feb 2008	0300 UTC	0700 UTC
5 Mar 2008	0000 UTC	1000 UTC
4 Jun 2008	1100 UTC	2000 UTC
7 Jun 2008	0200 UTC	1300 UTC
30/31 Jul 2008	1900 UTC	0100 UTC
9 Jun 2007	NULL CASE	
1 Nov 2007	NULL CASE	

Cycling Example – Wind Direction

Concrete Runway



Lakebed Runway

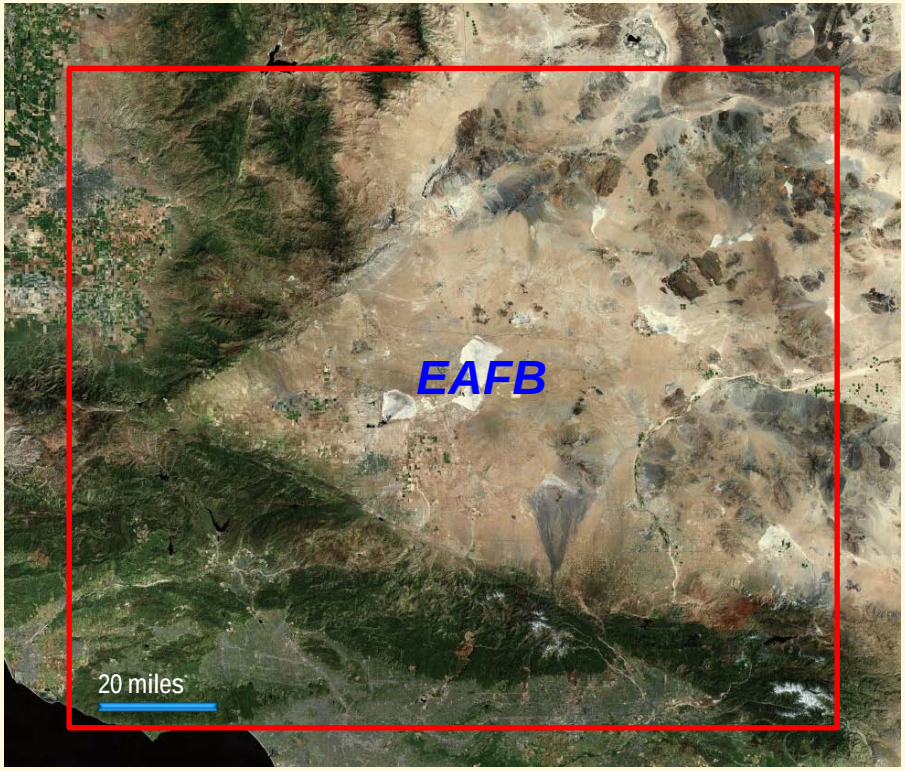


Model Configuration

- Weather Research and Forecasting (WRF) Model
  - Two dynamical cores
    - Advanced Research WRF (ARW)
    - Non-hydrostatic Mesoscale Model (NMM)
  - Two “hot start” options
    - Local Analysis and Prediction System (LAPS)
    - Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS)
  - Physics options
    - Yonsei University planetary boundary layer (PBL) scheme and NCAR/Penn State MM5 similarity surface layer scheme
    - Mellor-Yamada-Janjic PBL scheme and ETA similarity surface layer scheme
    - NCEP Global Forecast Systems (GFS) PBL and NCEP GFS surface layer scheme

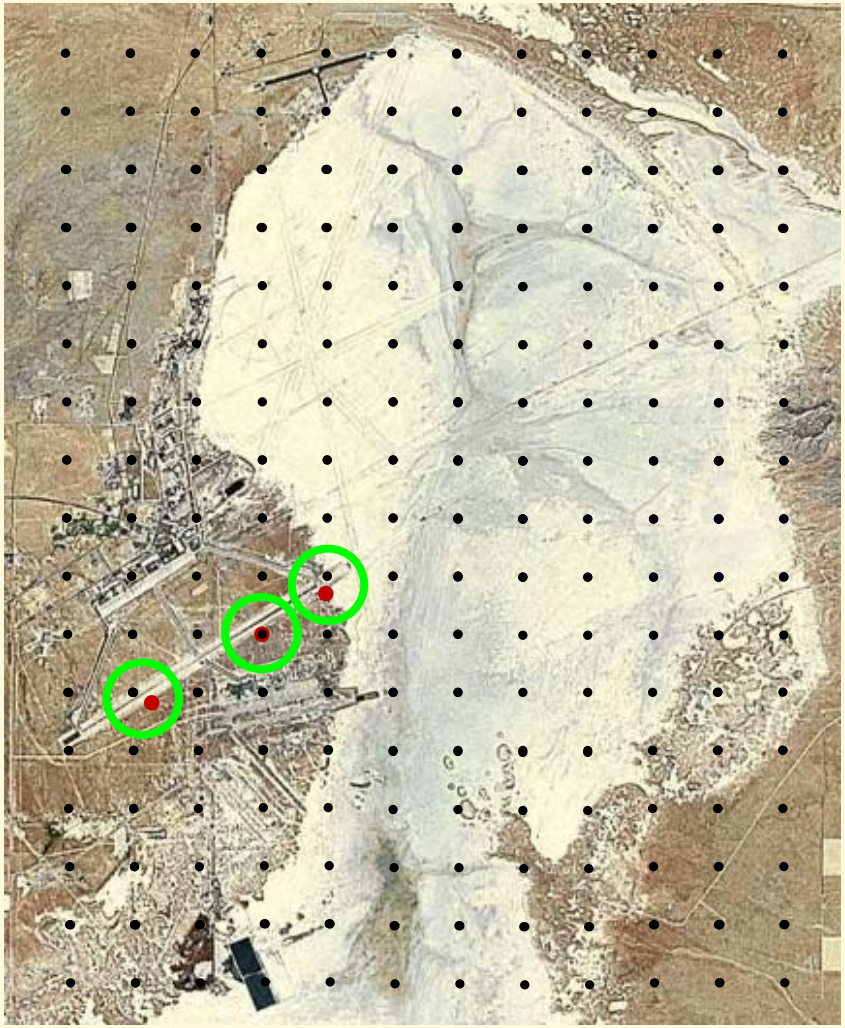
Model Configuration

- WRF Setup
  - 1-km horizontal grid
  - 51 irregularly spaced vertical sigma levels
  - Integrated over 12 hr
  - Runs began 1-3 hr prior to cycling event start
- NAM boundary conditions
  - 12-km horizontal grid
  - 42 vertical levels



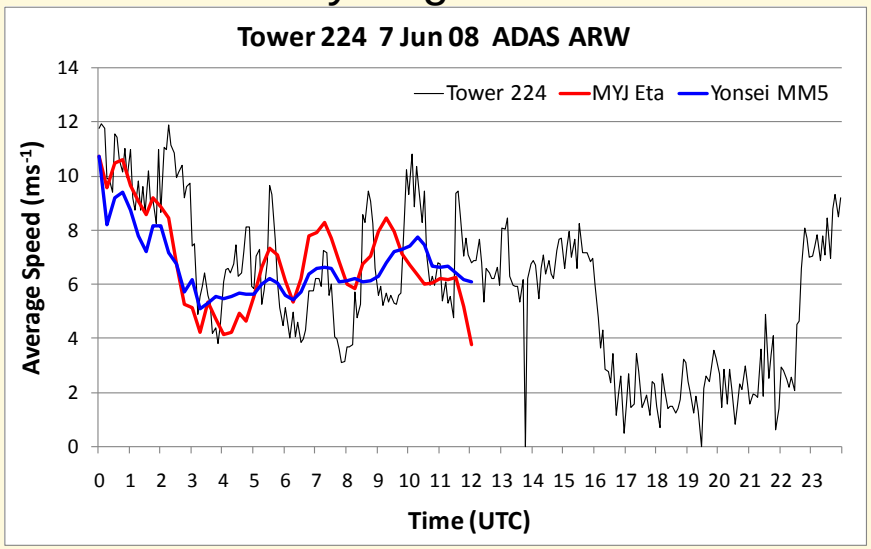
Subjective Analysis

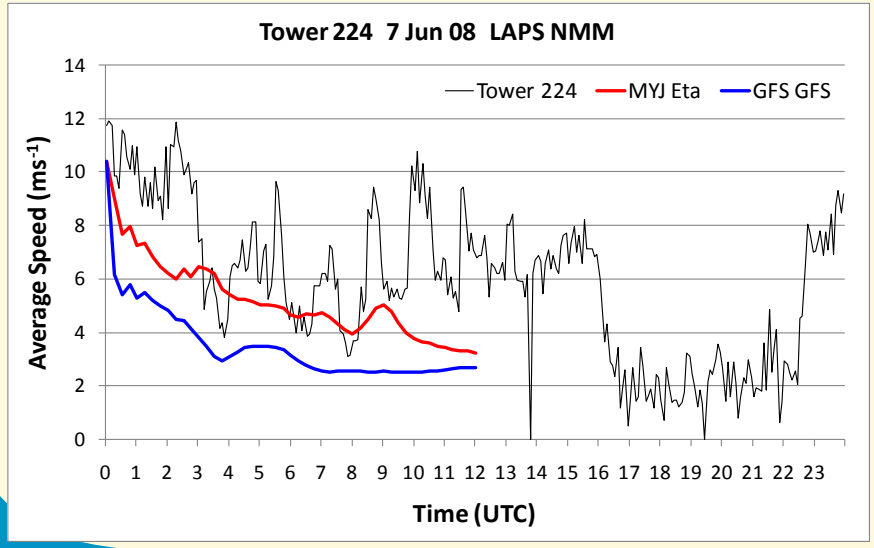
- Goal: Determine if model could predict timing and/or magnitude of wind cycling
  - Compared observed to forecast wind speed
  - Tower location and nearest model grid point



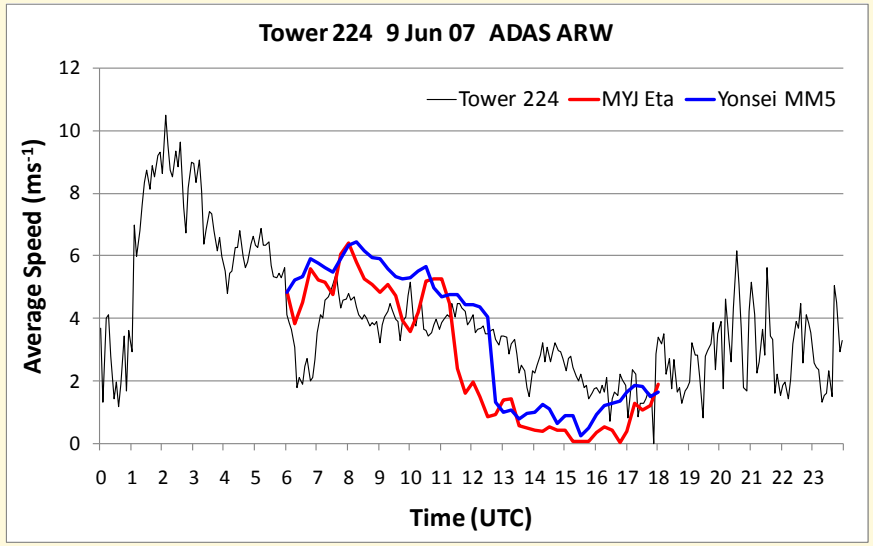
Subjective Analysis

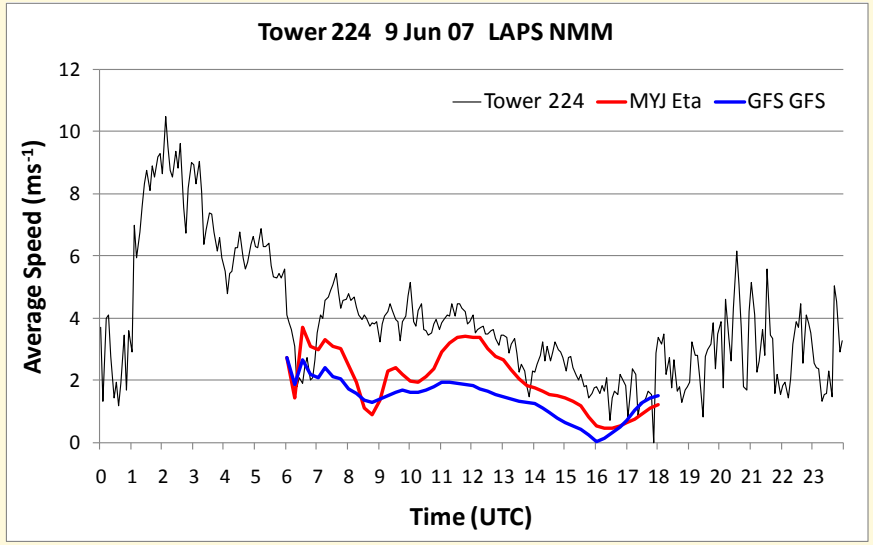
Cycling Case





Null Case

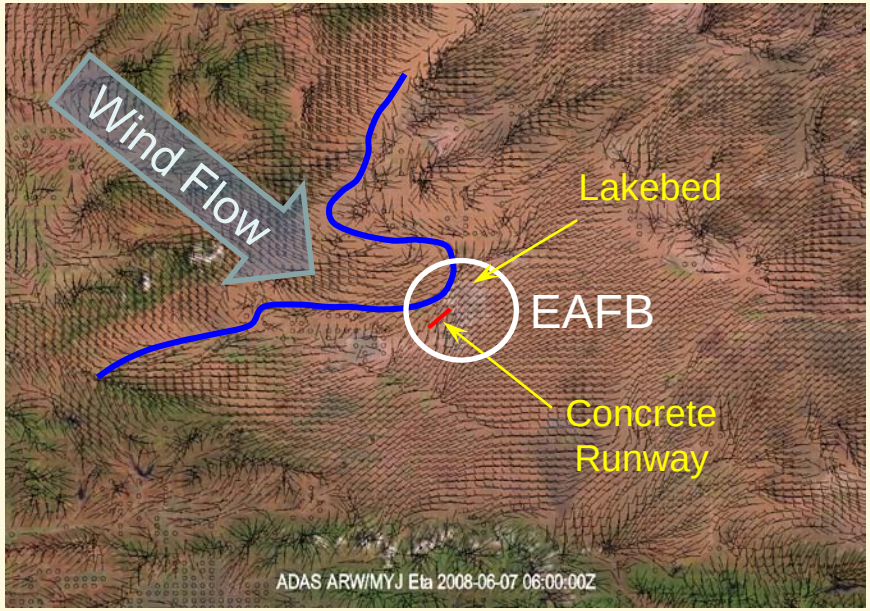




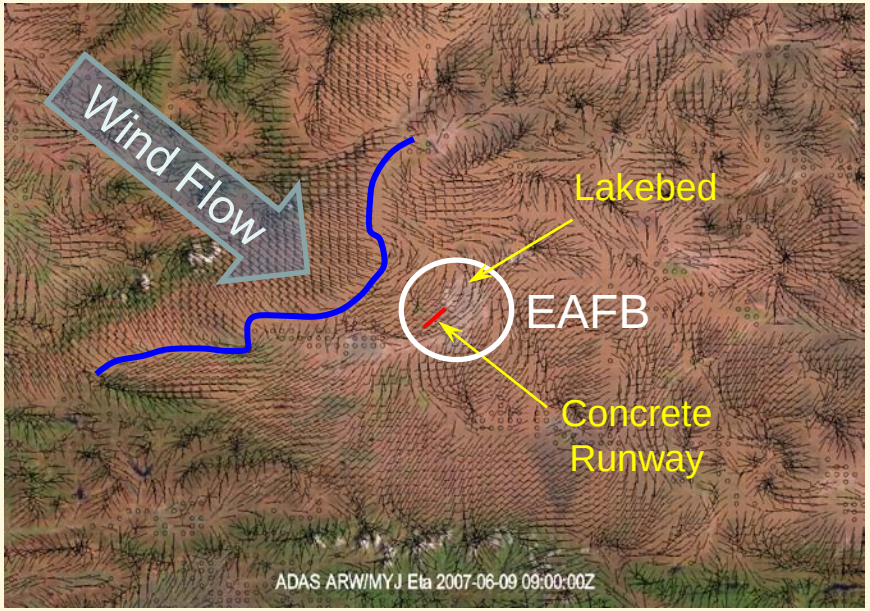
Subjective Analysis

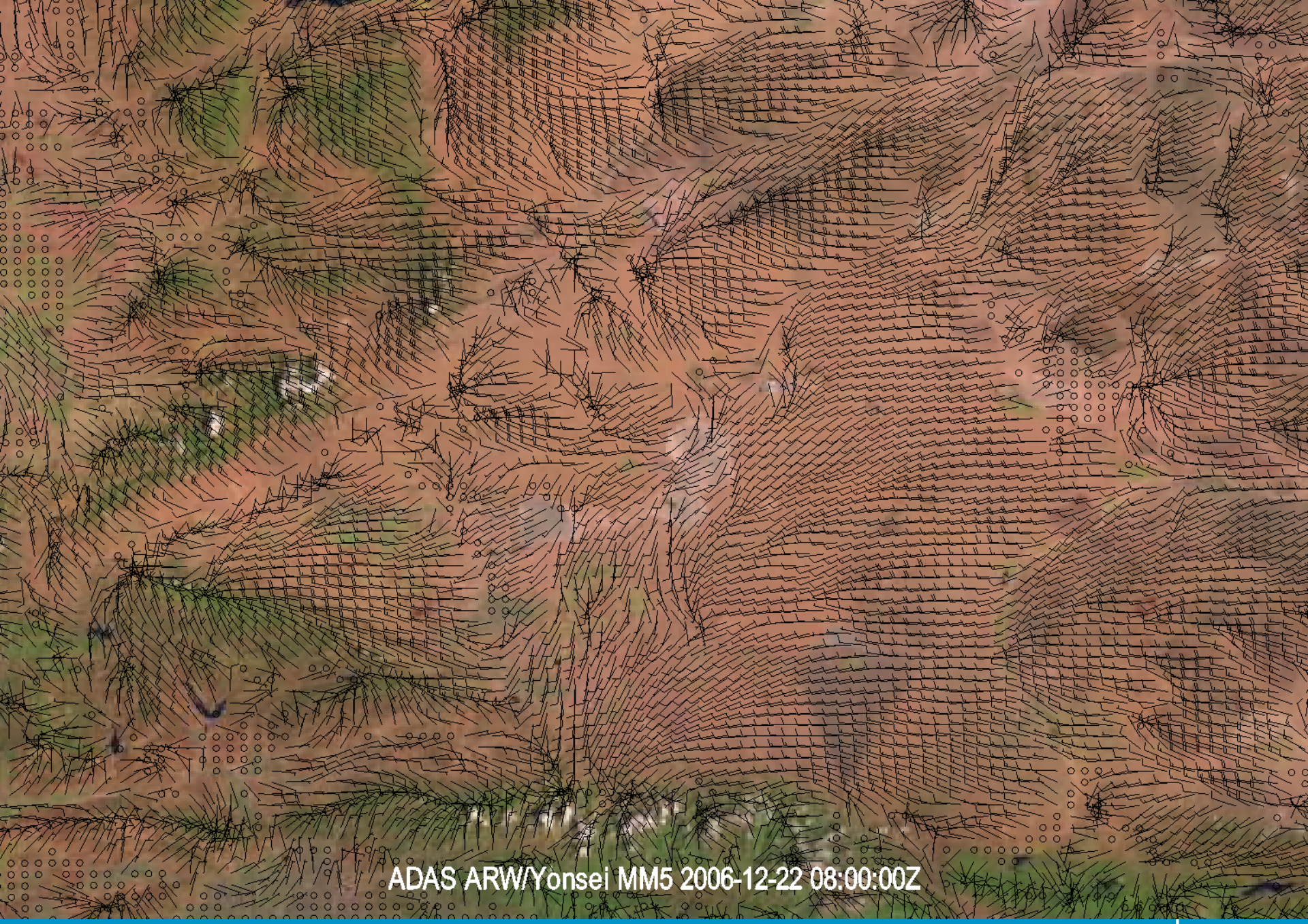
- Determine if the model could provide forecasters with an indication of a wind cycling event
  - Assessed model on wind cycling and null case days
  - Trend of model forecasts over entire domain

Cycling Case



Null Case




ADAS ARW/Yonsei MM5 2006-12-22 08:00:00Z

Objective Analysis

- Goal: Use the Model Evaluation Tools (MET) software to compare forecast to observed wind speed and direction
  - Developed by NCAR Developmental Testbed Center
  - Compared 12 towers to corresponding model grid points
- Used MET statistics to show how well model performed overall – not if cycling was captured
  - Wind speed
    - Forecast versus observed mean
    - Mean error
    - Pearson Correlation Coefficient (PCC)
  - Wind direction
    - Mean error
    - PCC

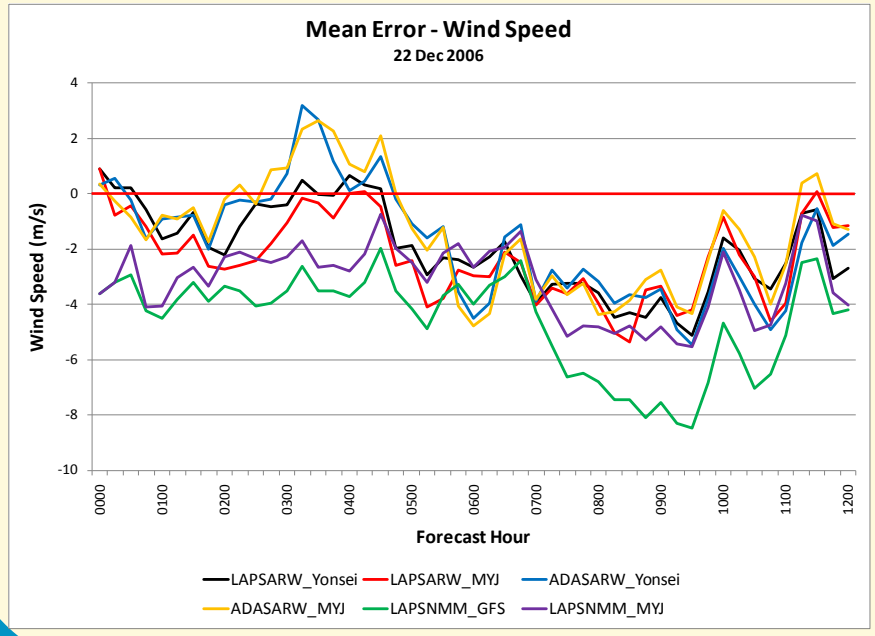
$$\bar{f} = \frac{1}{n}\sum_{i=1}^{n}(f_i) \qquad \bar{o} = \frac{1}{n}\sum_{i=1}^{n}(o_i)$$

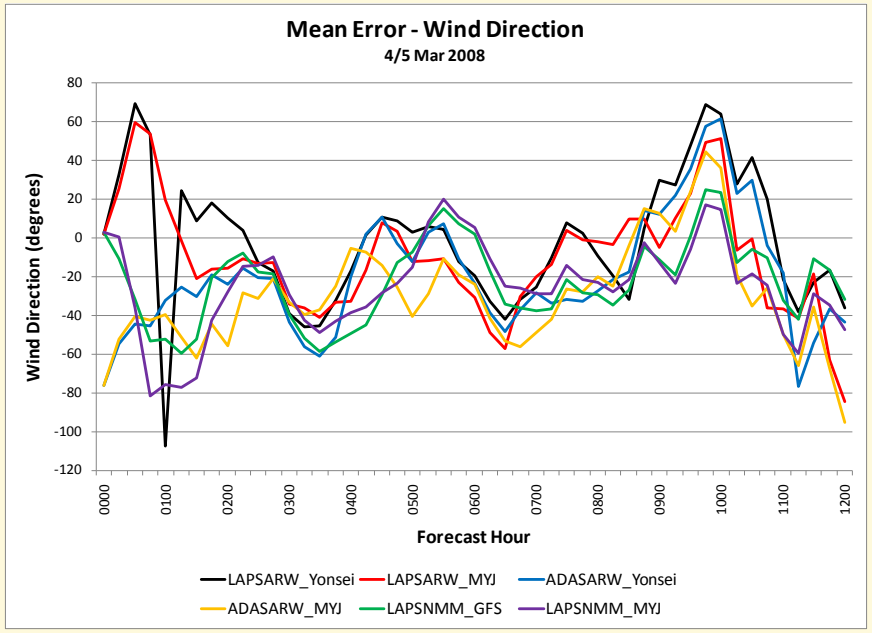
$$ME = \frac{1}{n}\sum_{i=1}^{n}(f_i - o_i) = \bar{f} - \bar{o}$$

$$r = \frac{\sum_{i=1}^{n}(f_i - \bar{f})(o_i - \bar{o})}{\sqrt{\sum_{i=1}^{n}(f_i - \bar{f})^2 \sum_{i=1}^{n}(o_i - \bar{o})^2}}$$

Objective Analysis

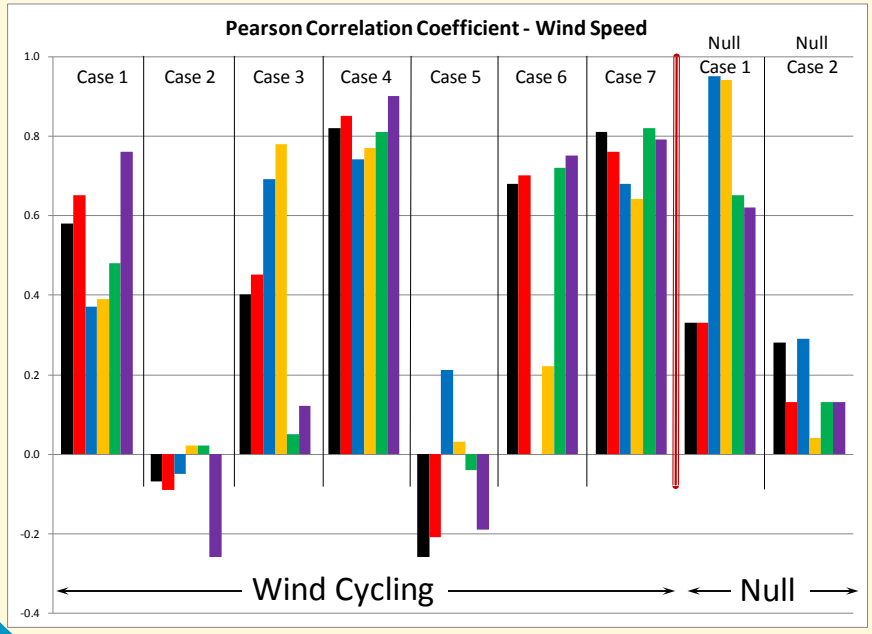
- All model configurations under-predicted wind speed throughout the forecasts for all wind cycling case days
- All model configurations were clustered throughout the forecast indicating they all captured or all missed the same shifts in wind direction

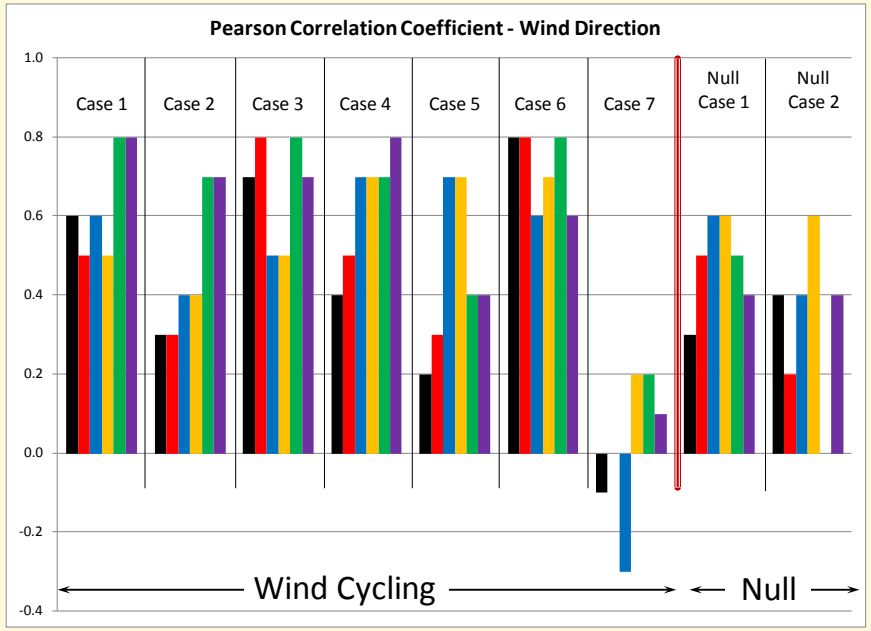




Objective Analysis

- Model configuration was able to capture the fluctuations in wind speed maximums and minimums
- The model was better able to capture shifts in wind direction for the wind cycling days than for the null cases





Summary and Conclusions

- Space Shuttle must sometimes land at EAFB instead of KSC
- EAFB complex terrain creates a challenge for SMG forecasters during westerly flow due to “wind cycling”
- Determined skill of different WRF configurations
- Subjective and objective analyses results
  - Overall ARW outperformed NMM
  - Largest impact: changing model core
  - Least impact: changing model physics
  - Model differentiated between cycling and null cases
  - Model does no better forecasting wind speeds for null than cycling cases
- Recommend ADAS or LAPS with ARW core and MYJ PBL scheme