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Verification of the NCAR-Xcel Ensemble-RTFDDA system for Wind Energy Prediction

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13th WRF Users Workshop, Boulder, CO
25 - 29 June 2012

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

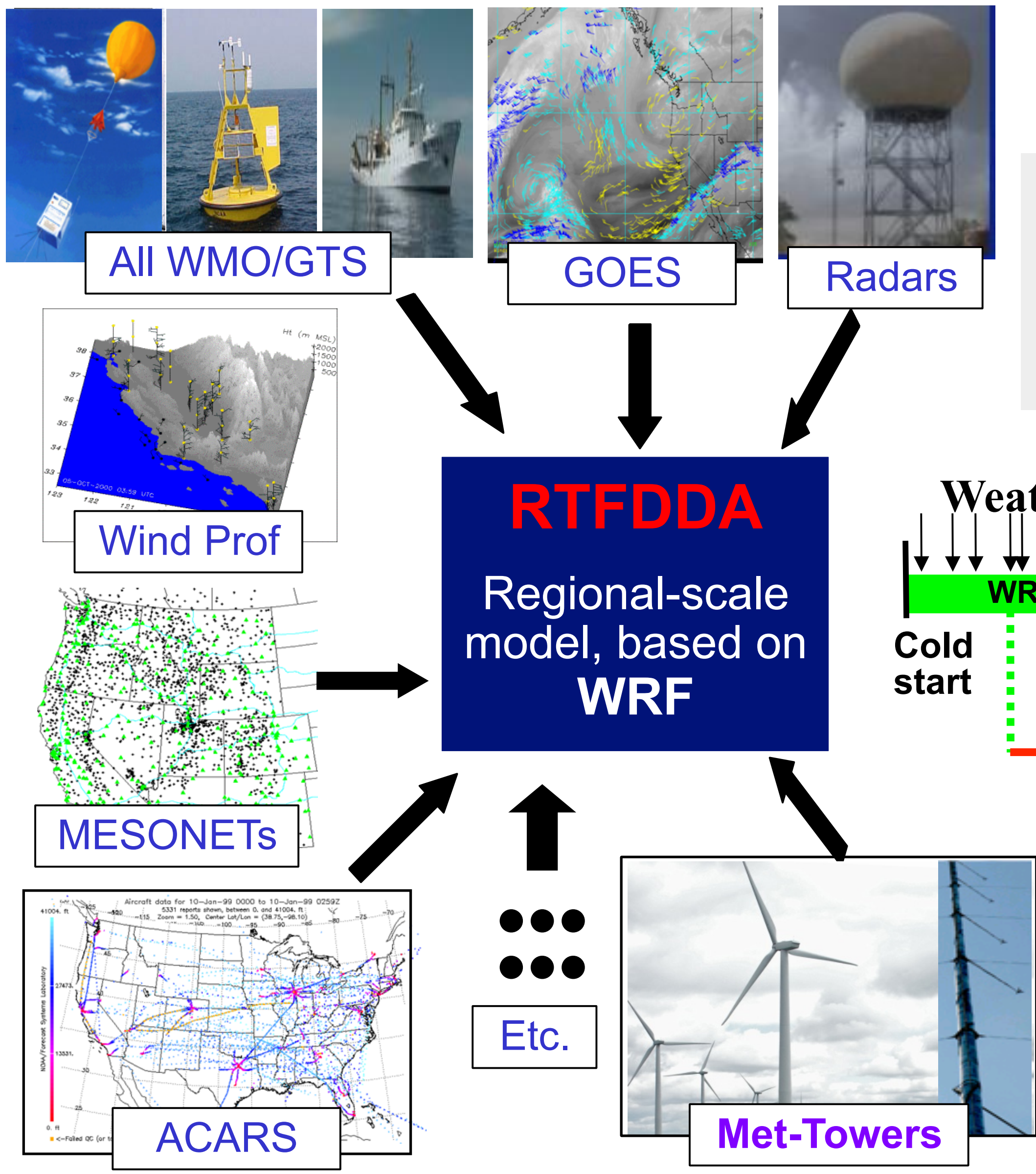
Motivations

- Since April 2010, E-RTFDDA implemented for Xcel energy, to support wind power forecasting
- Extends the predictability of the mesoscale weather processes, improves the wind and power trend prediction from the single deterministic model forecasting and provides probabilistic information for the timing and magnitude of wind

Outline

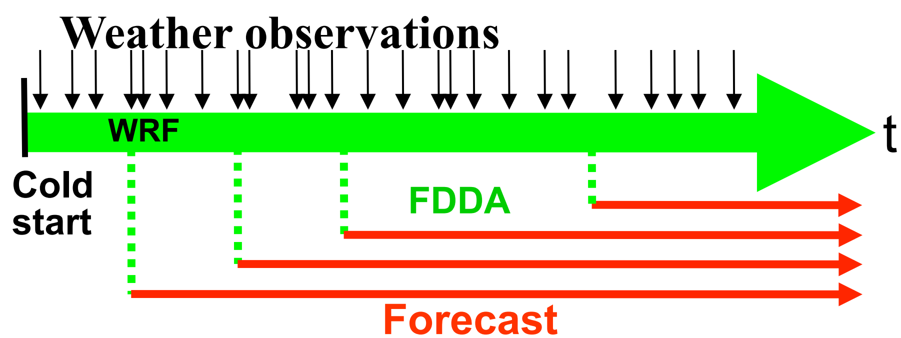
1) E-RTFDDA Modeling System
2) Verification of SPD at three wind farms
3) Evaluation of WRF physics settings
4) Statistical bias correction/Calibration

RTFDDA - 4D Continuous DA and Forecasting

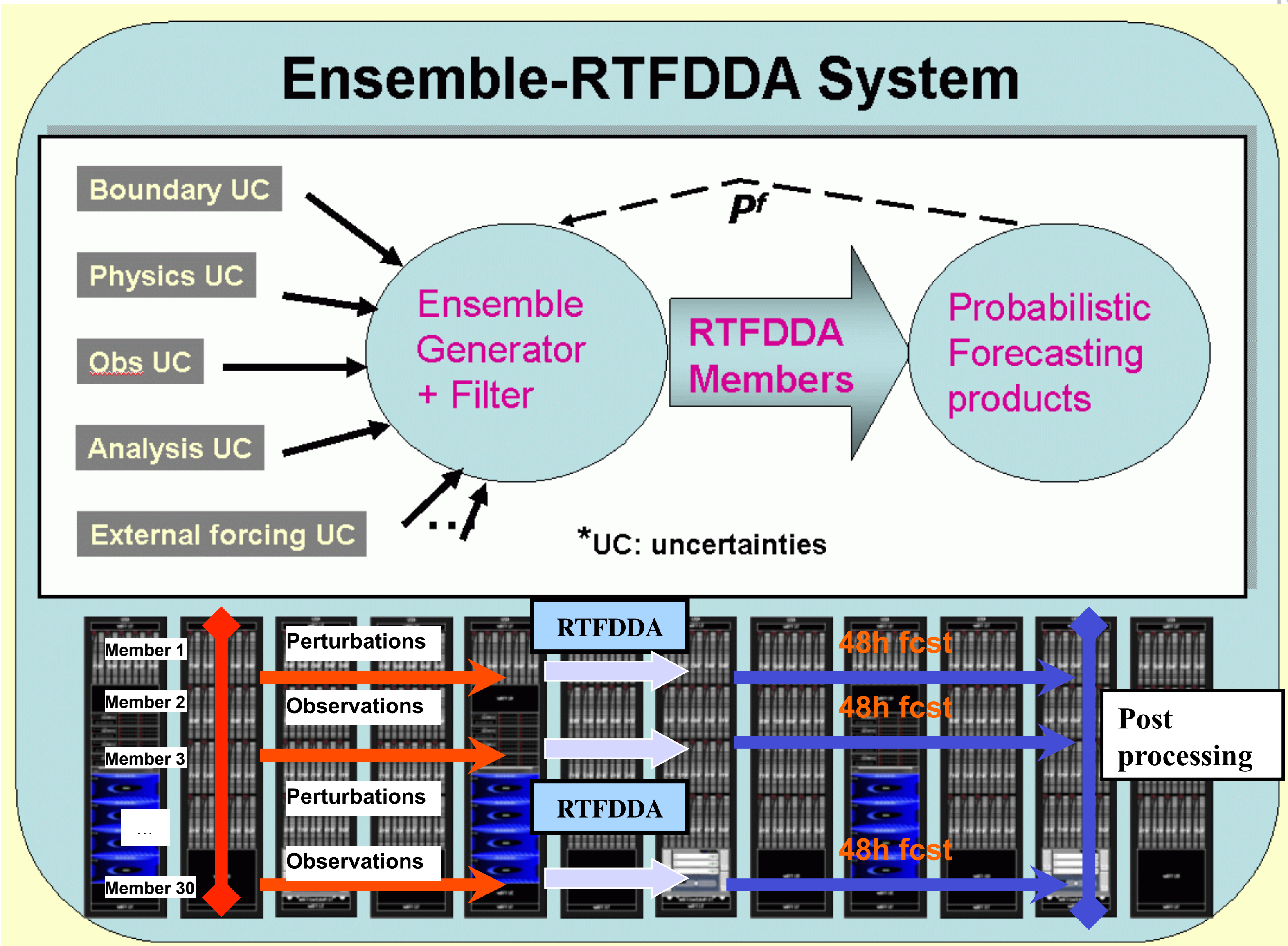


4 cycles a day

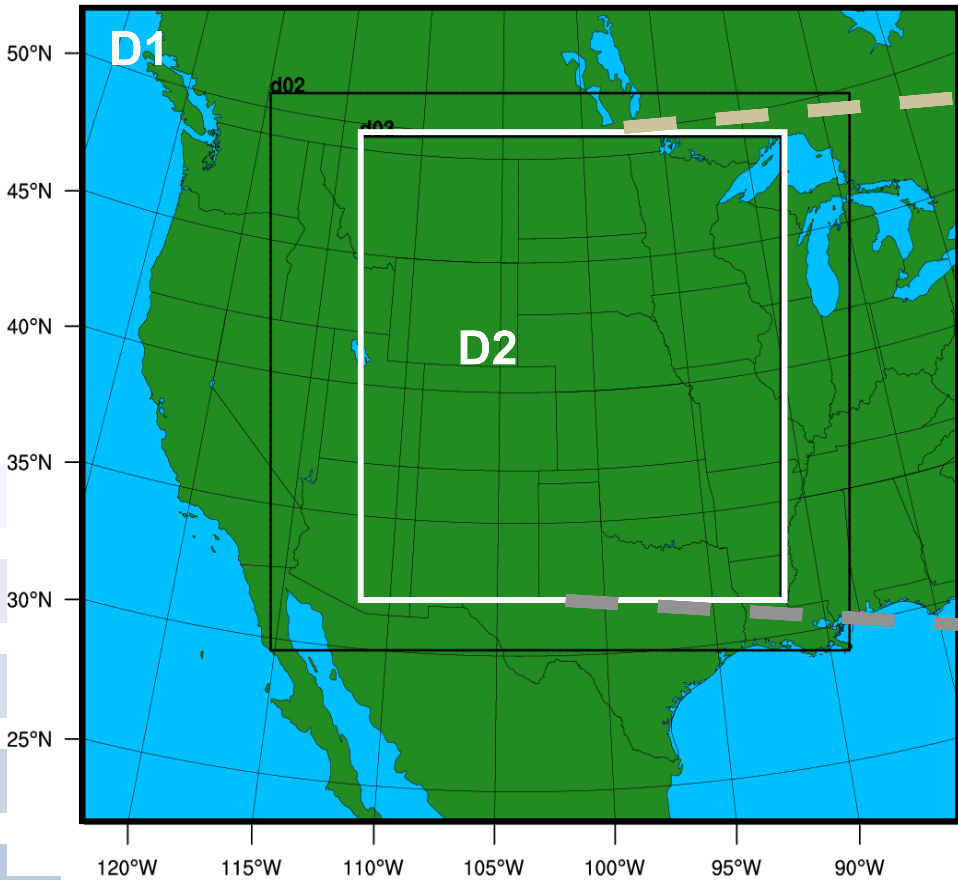
- 6-hour FDDA analysis
- 48 hour forecast

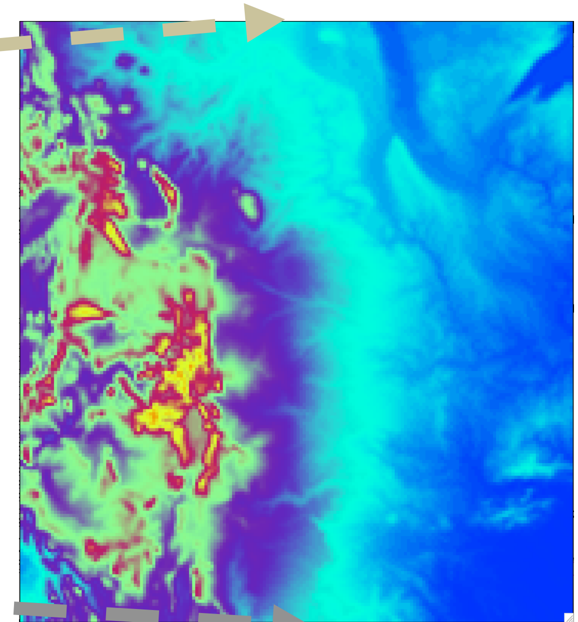


RTFDDA → E-RTFDDA



Xcel E-RTFDDA Model Domains





30 members,
6h cycle,
48h forecast

D1: 30 km

D2: 10 km

37 vertical levels with 12 levels in the lowest 1-km

30 members, 6h cycles, 48h forecasts

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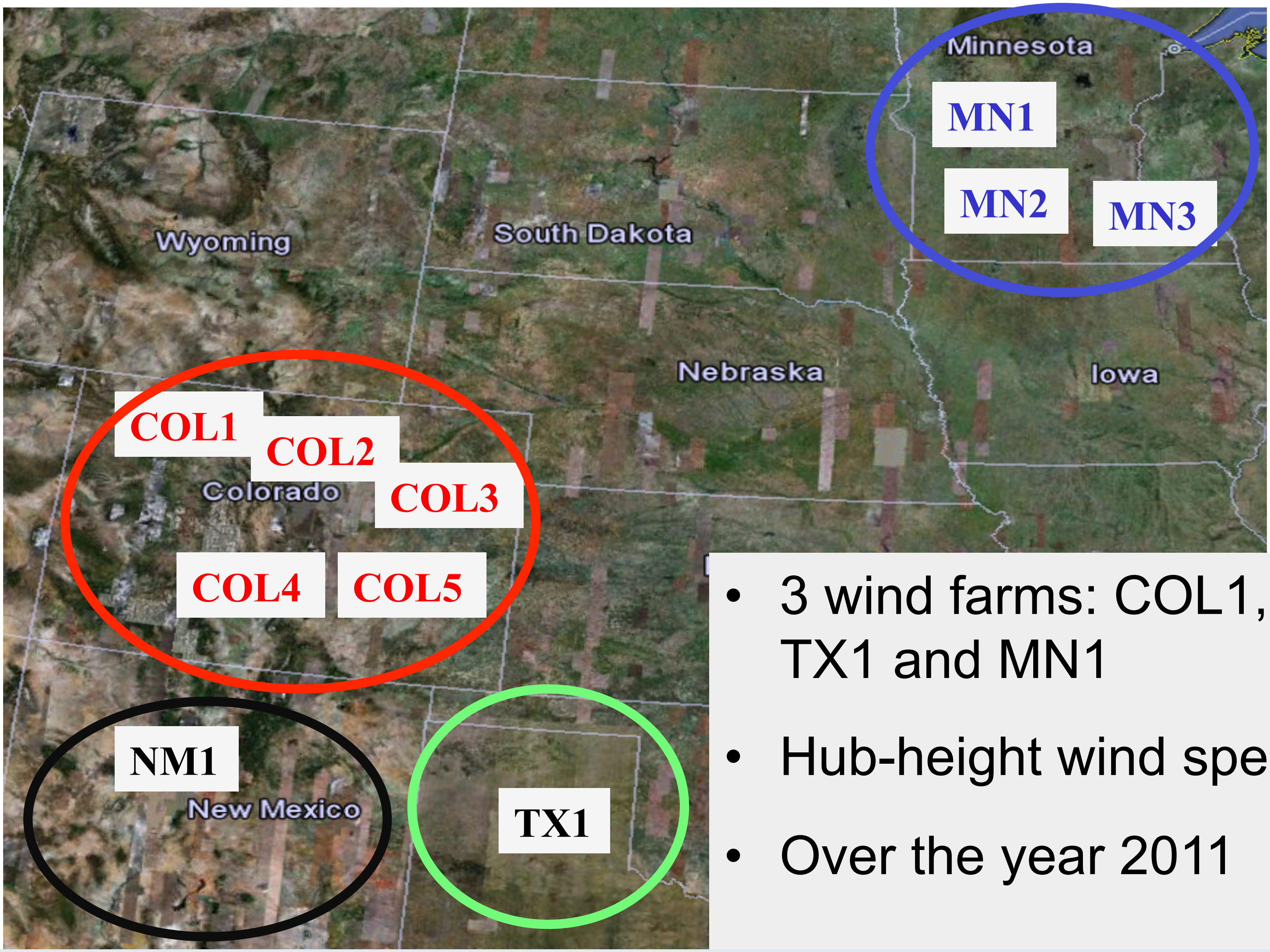
E#	LBC	WRF Members (15)
1	NAM	Control: WRF baseline physics
2	GFS	Control: WRF baseline physics
3	NAM	SLAB land surface
4	NAM	MYJ PBL
5	NAM	MYJ PBL + GD Cumulus
6	NAM	WMS6 microphysics
7	NAM	GD cumulus
8	GFS	Thomason microphysics
9	GFS	MYJ PBL + WMS5 microphysics
10	GFS	MYJ PBL
11	GFS	MYJ PBL + GD Cumulus
12	GFS	BMJ cumulus
13	GFS	BMJ cumulus in 3.3 km grid
14	GFS	GD cumulus in 3.3 km grid
15	GFS	KF cumulus in 3.3 km grid

E#	LBC	MM5 Members (15)
16	NAM	Control: MM5 baseline physics
17	GFS	Control: MM5 baseline physics
18	NAM	Simple cloud-effect radiation
19	NAM	ETA TKE PBL
20	NAM	Kain-Fritsch cumulus
21	NAM	Goddard microphysics
22	GFS	Betts-Miller cumulus
23	GFS	Reisner 3-ice microphysics
24	GFS	CCM2 radiation
25	GFS	GFS LBC Phase-uncertainty 1
26	GFS	Symmetric perturb to Member 25
27	GFS	GFS LBC Phase-uncertainty 2
28	GFS	Symmetric perturb. to Member 27
29	GFS	Correlated sounding perturbation
30	GFS	Symmetric perturb. to Member 29

Xcel Wind Farms



- 3 wind farms: COL1, TX1 and MN1
- Hub-height wind speed
- Over the year 2011

Statistics of the ensemble mean

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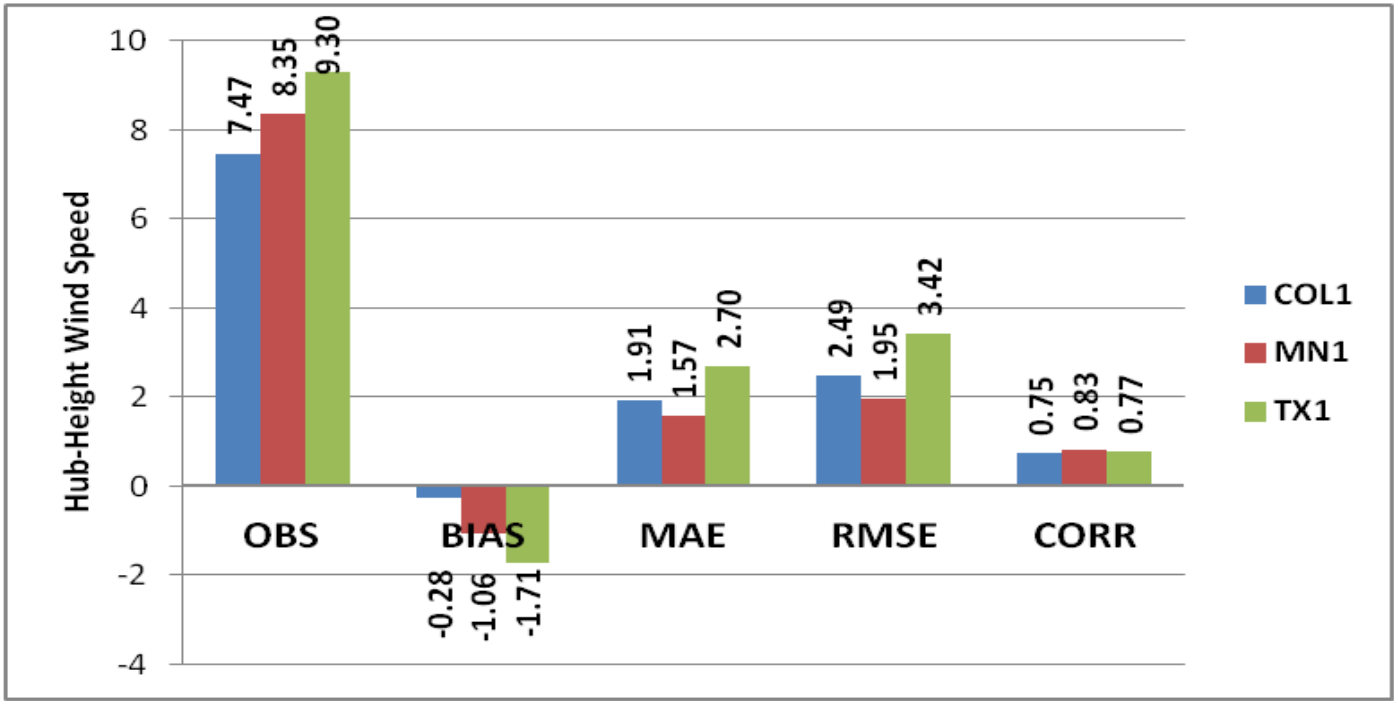


- Over the year 2011
- 0-24h forecast
- Ensemble mean

Under-estimation of wind-speed

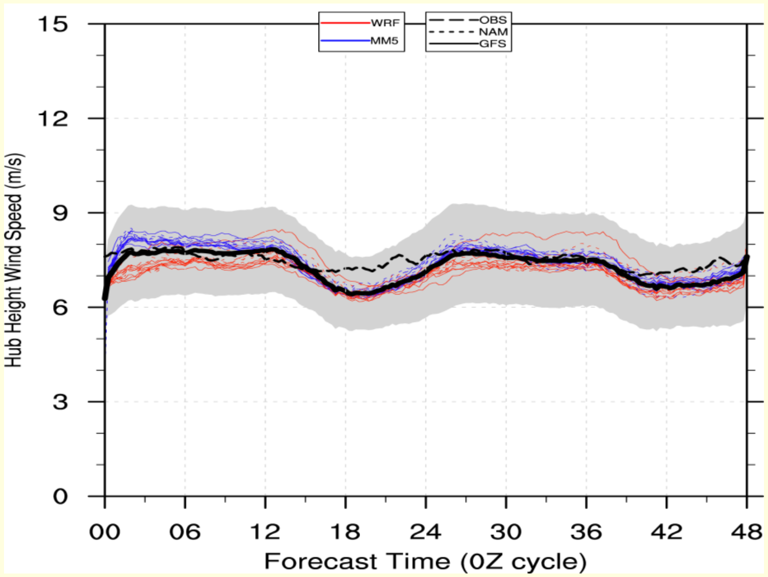
Overall good correlation

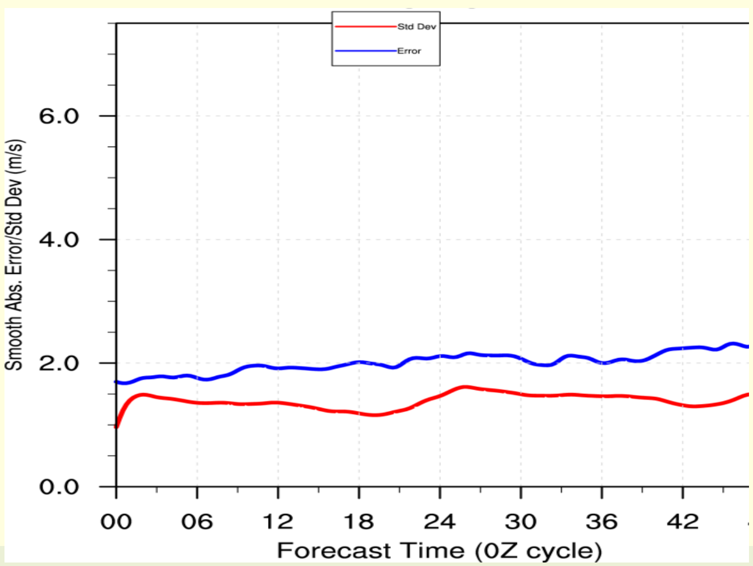
Better statistics than deterministic run

TX1, MN1: underestimate higher winds

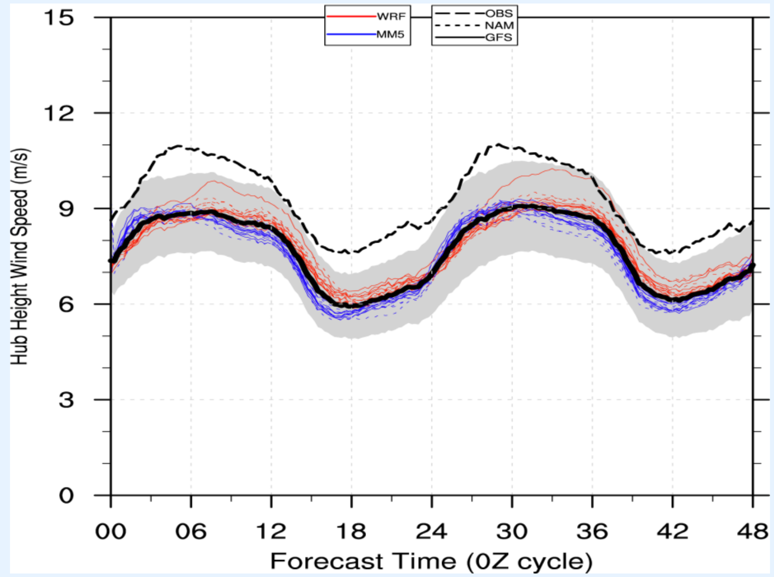
Ensemble Verication

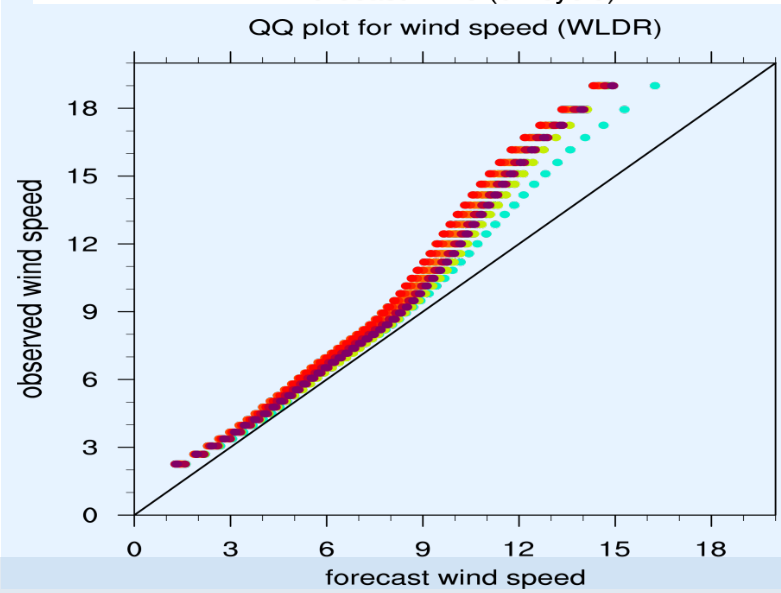
COL1



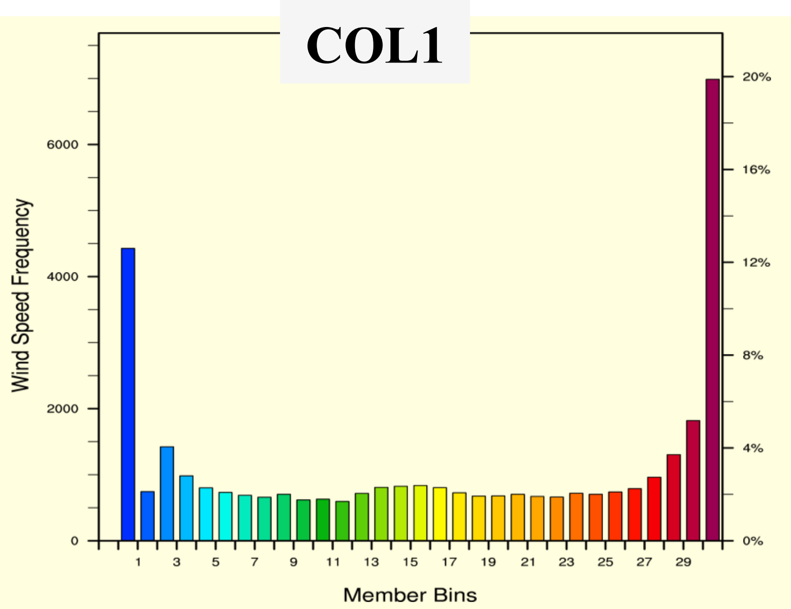


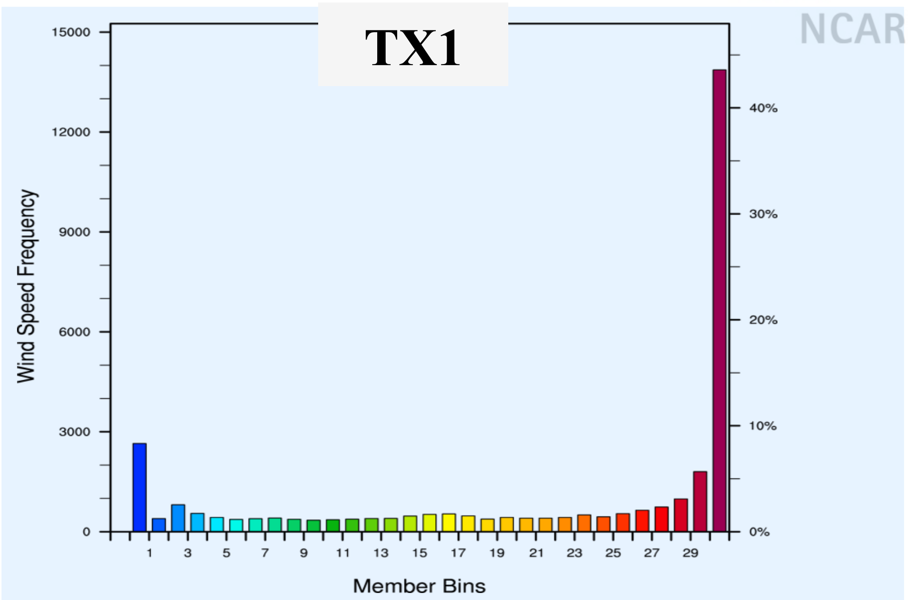
TX1

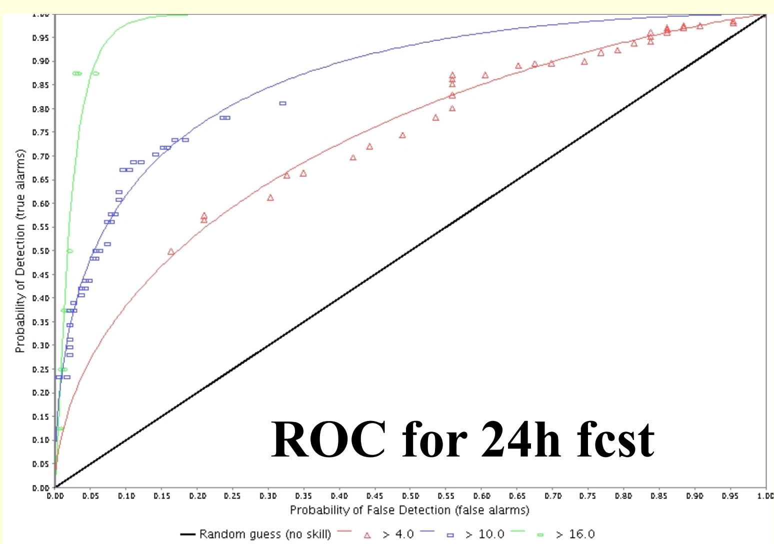


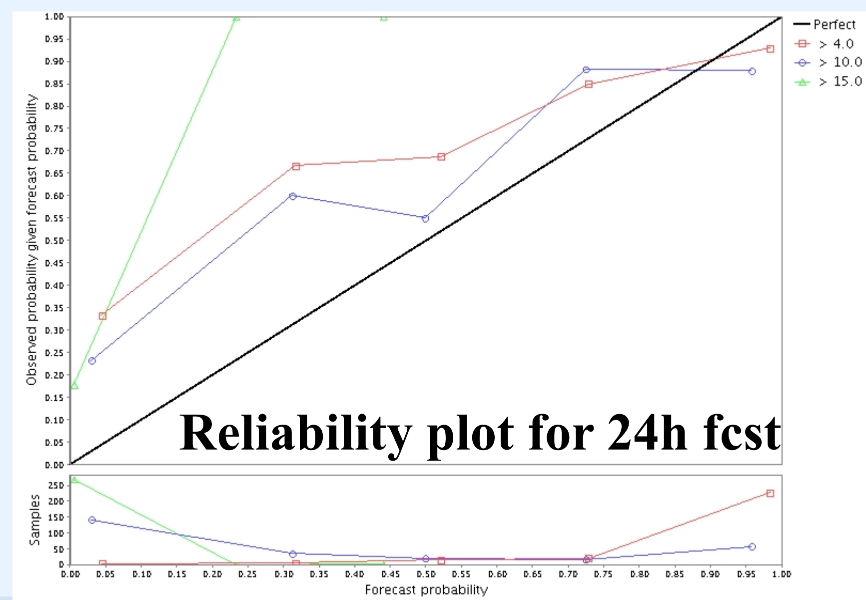


Ensemble Verification

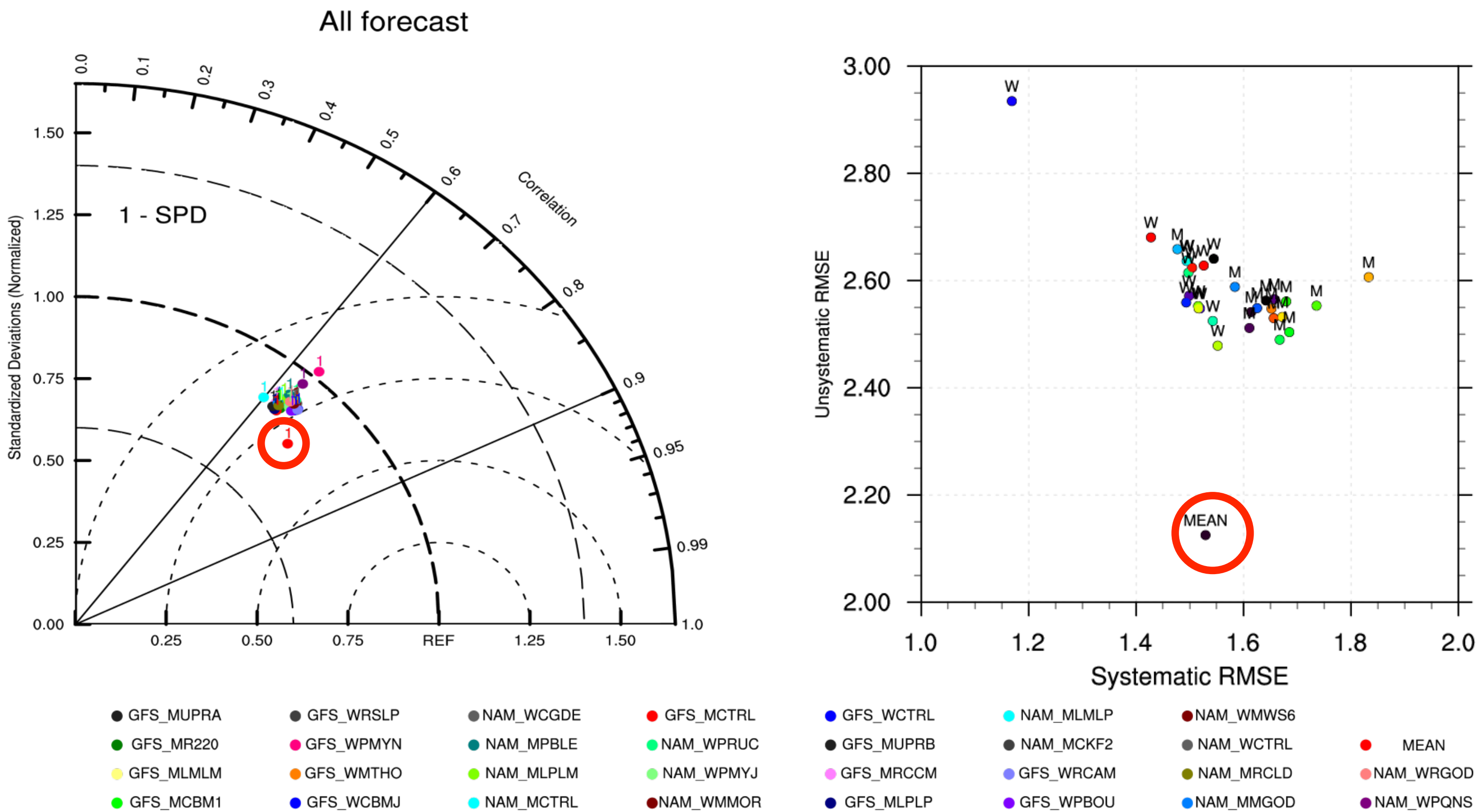


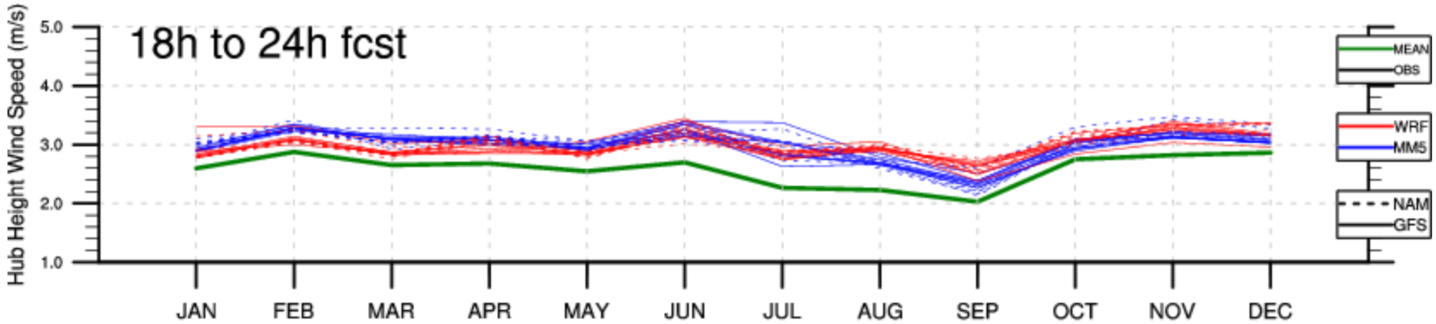




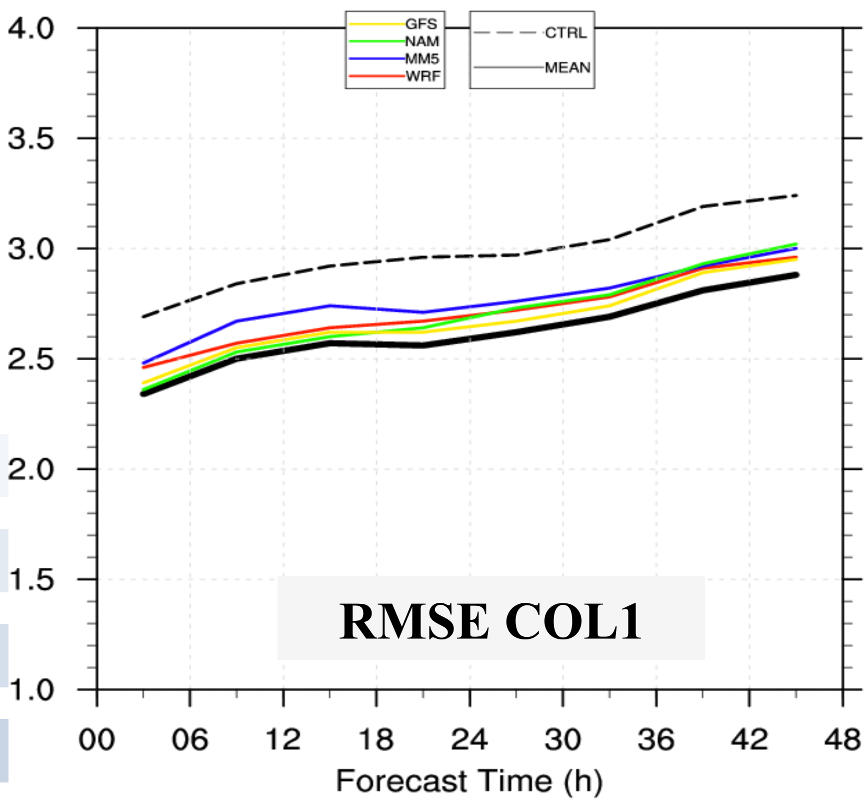


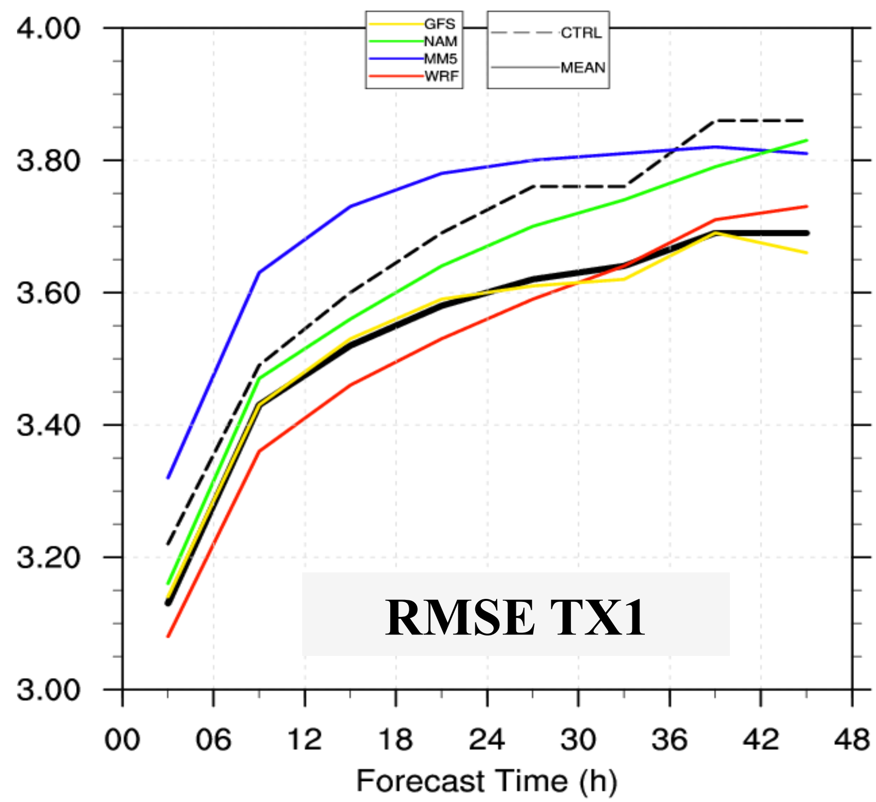
Verification of Ensemble Members





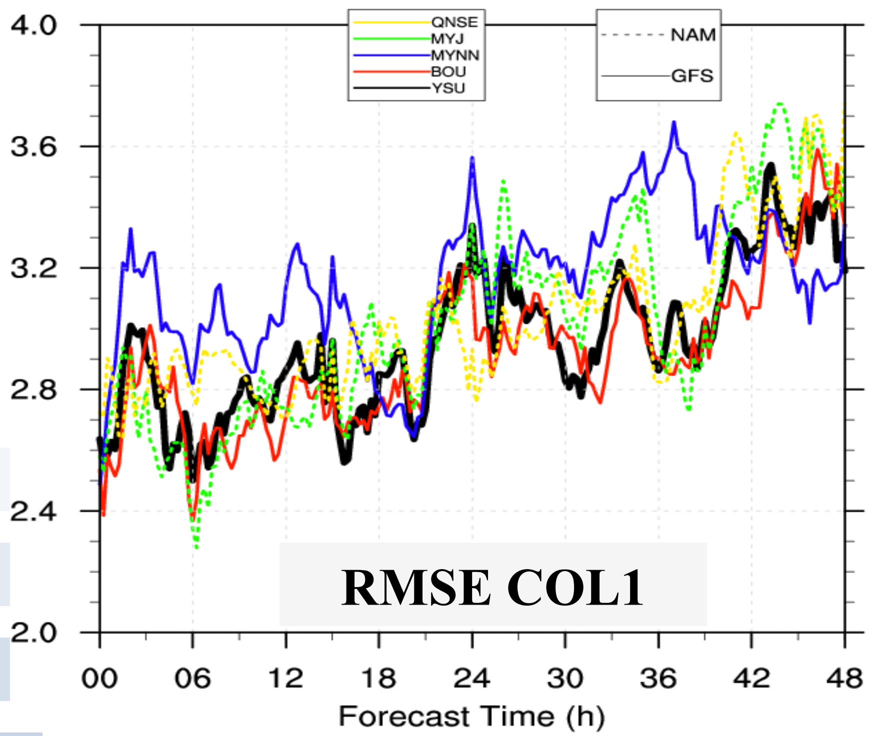
Model Comparison

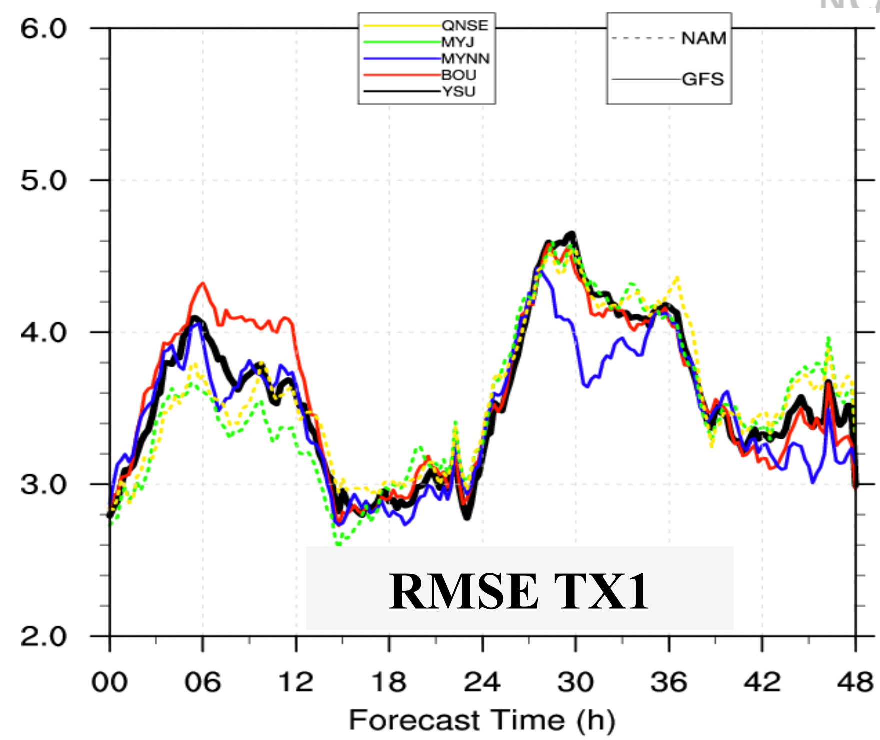




Low differences for COL1.
Low NAM/GFS differences. GFS better for MN1 and TX1.
Lowest underestimation for WRF for MN1 and TX1.

PBL Schemes Comparison





For COL1, YSU/BOU lowest errors/MYNN highest.
For TX1, MYJ lowest errors/BOU highest.
YSU (daytime) and MYJ (nighttime) lowest errors on average.
Low differences for the Microphysics/Cumulus schemes (not shown)

Statistical Bias Correction Schemes

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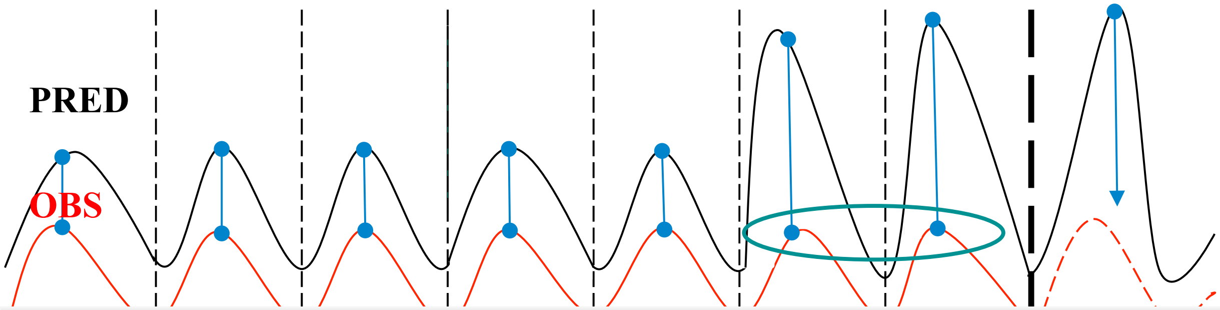


This correction is applied independently at each observation location, for a given forecast time and for each member

(work by: Luca Delle Monache)

KF-weight

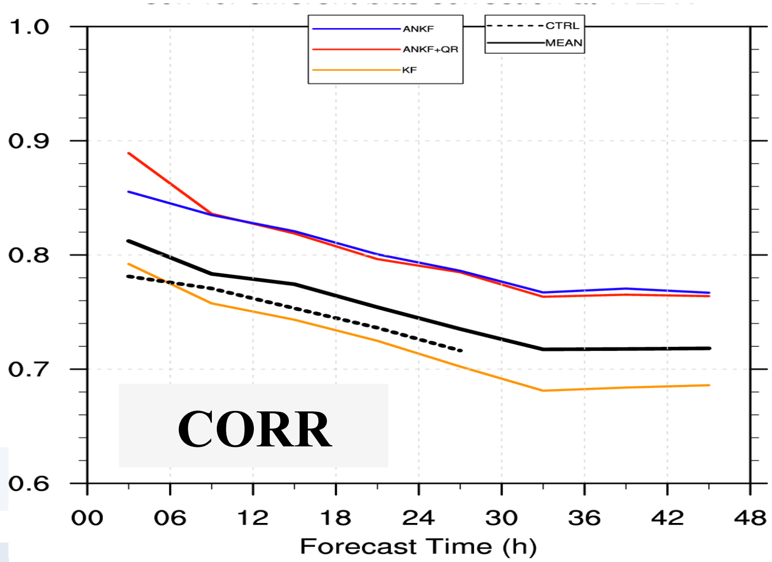
Apply Quantile Regression on the ANKF corrected ensemble

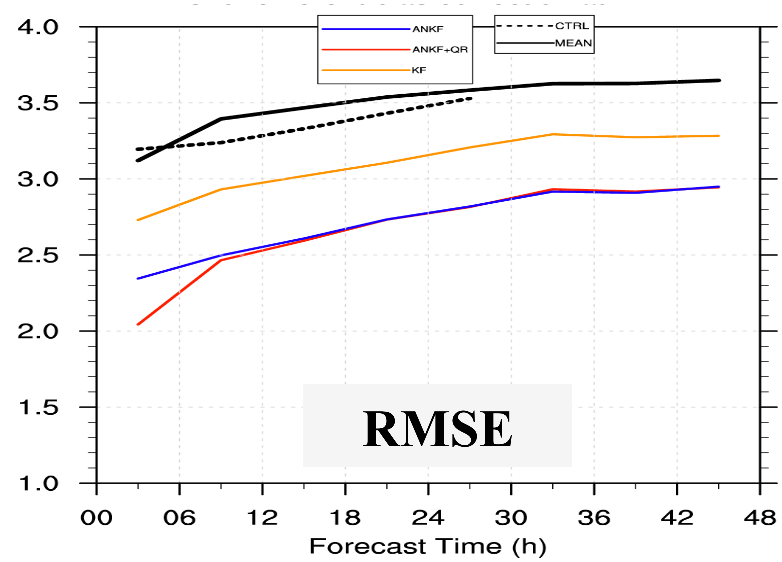
Fitting SPD quantiles using QR conditioned on:

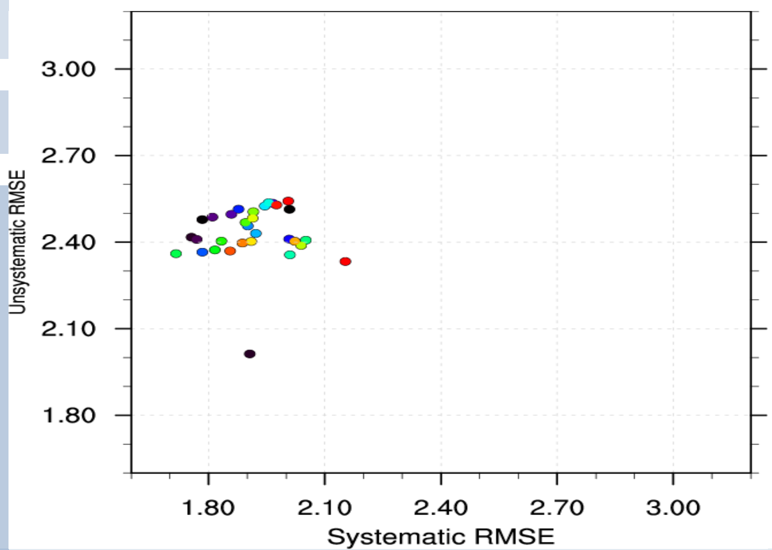
- Ranked forecast ensemble
- Ensemble mean
- Ensemble median
- Ensemble standard deviation
- Persistence

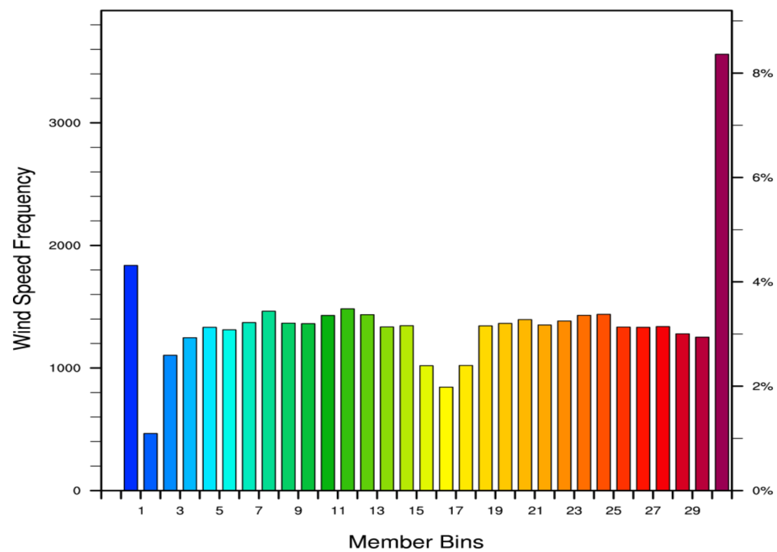
(work by: Tom Hopson)

Verification after Correction/Calibration









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Summary

❖ E-RTFDDA system has been developed for Xcel Energy for Wind Power forecasting since April, 2010. This study investigates the wind forecast characteristics at Wind Farms and post-processing approaches. It is found that:

1. Underpredict hub-height (60 – 80m AGL) wind speeds at all the farms and underestimate strong wind events (low-level jet at TX1);
2. Ensemble underdispersive, lack resolution, but good skill;
3. Differences between NAM and GFS LBC are small. WRF members show lower errors than MM5.
4. On average, YSU and MYJ perform the best.
5. Applying a statistical bias correction (ANKF) and a quantile regression improves the forecasts: lower bias, better spread and skill;
6. Future work: improve statistical bias correction and verification of the ramp events…

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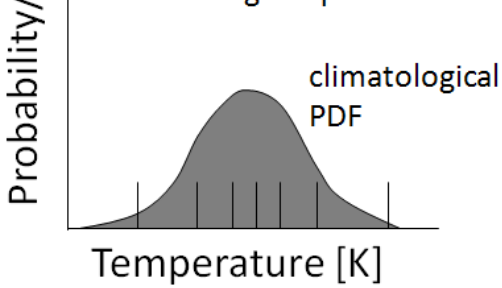
Thank you…

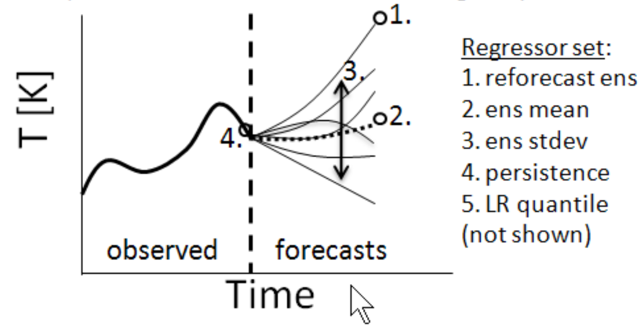
QUESTIONS?

Step I: Determine climatological quantiles

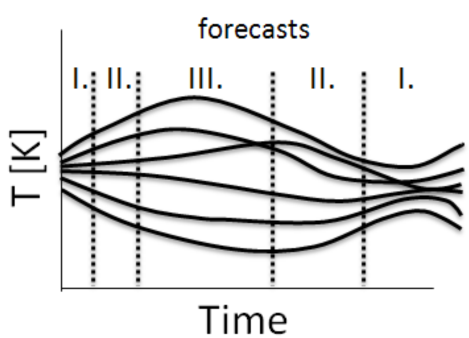


Step 2: For each quan, use "forward step-wise cross-validation" to iteratively select best subset

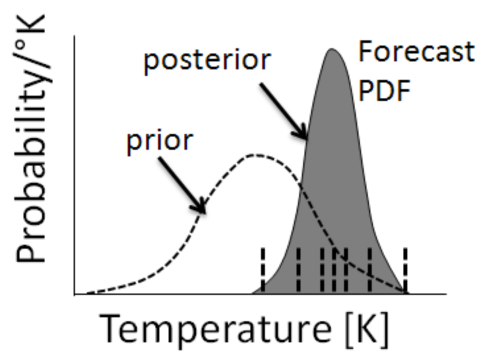
Selection requirements: a) QR cost function minimum,
b) Satisfy binomial distribution at 95% confidence
If requirements not met, retain climatological "prior"



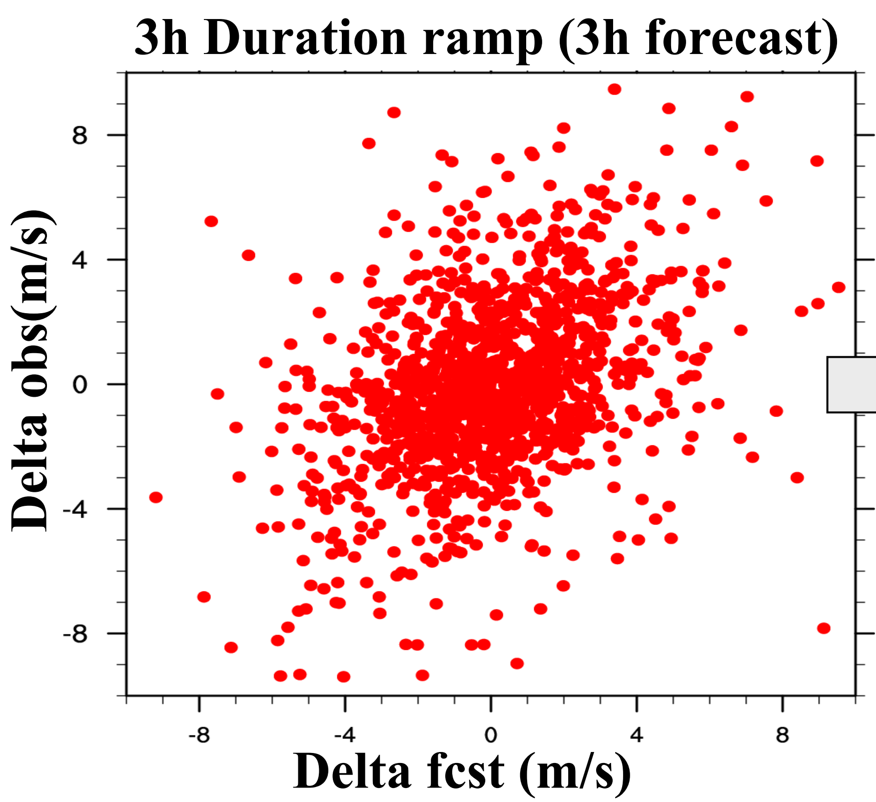
Step 3: segregate forecasts into differing ranges of ensemble dispersion and refit models (Step 2) uniquely for each range

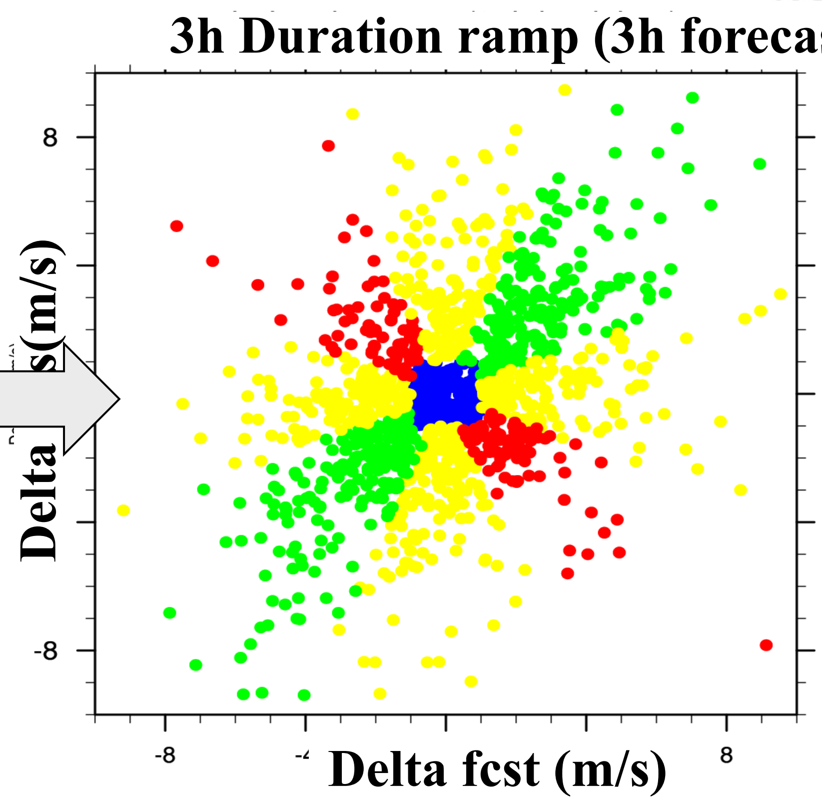


Final result: "sharper" posterior PDF represented by interpolated quans



Forecast of ramp events: TX1



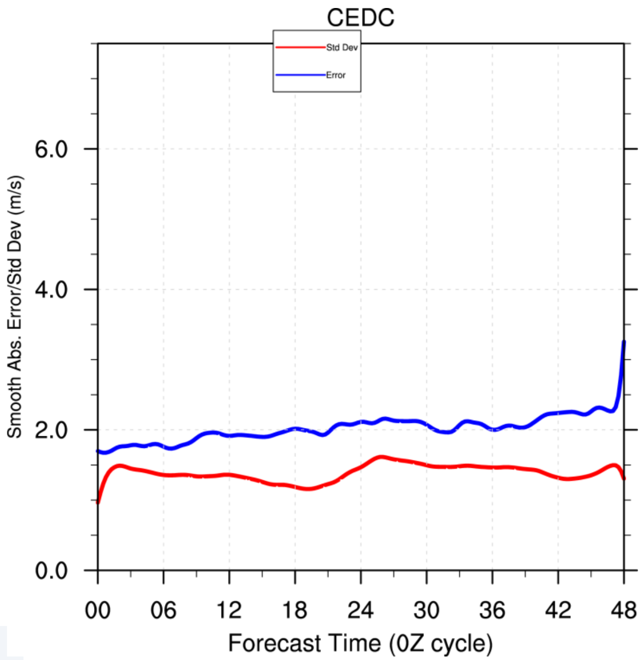


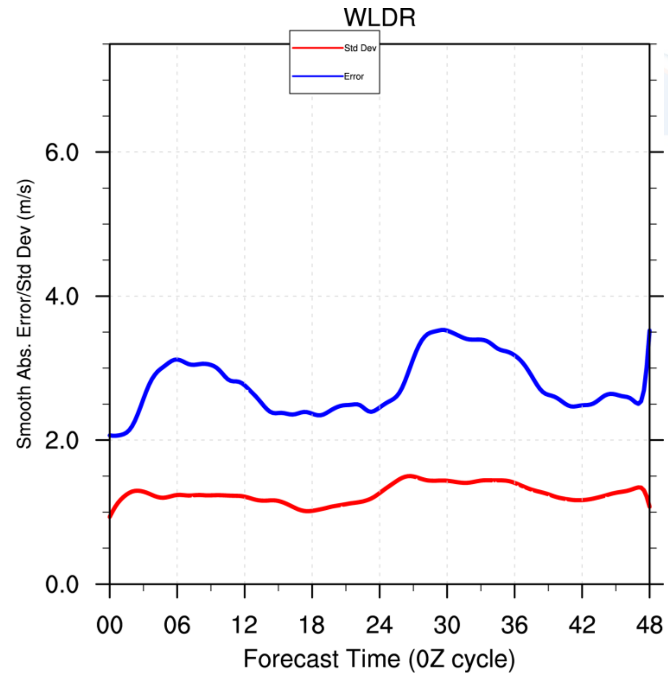
Observation

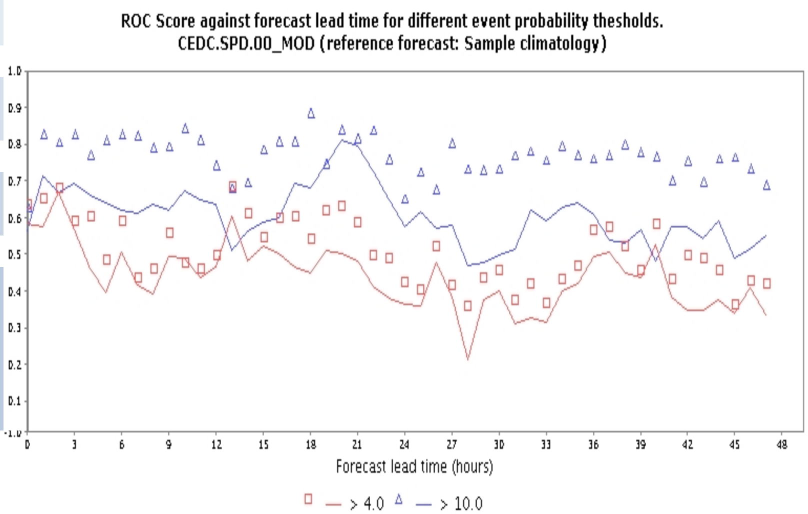
Forecast	Up	Neutral	Down
Up	**16%**	10%	5%
Neutral	12%	**14%**	11%
Down	6%	11%	**15%**

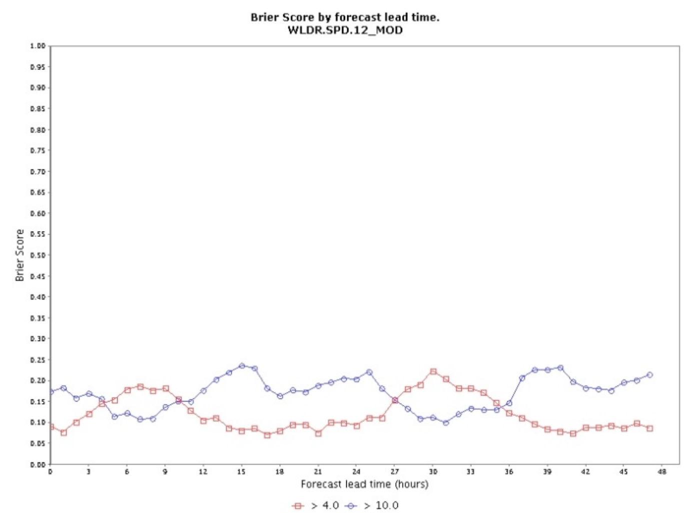
Percent Correct: 45%

(work by: Matt Pocernich)


CEDC
Std Dev
Error
Smooth Abs. Error/Std Dev (m/s)
0.0
2.0
4.0
6.0
00 06 12 18 24 30 36 42 48
Forecast Time (0Z cycle)


WLDR
Std Dev
Error
Smooth Abs. Error/Std Dev (m/s)
0.0
2.0
4.0
6.0
00 06 12 18 24 30 36 42 48
Forecast Time (0Z cycle)


ROC Score against forecast lead time for different event probability thesholds.
CEDC.SPD.00_MOD (reference forecast: Sample climatology)
Forecast lead time (hours)
> 4.0
> 10.0


Brier Score by forecast lead time.
WLDR.SPD.12_MOD
Brier Score
Forecast lead time (hours)
> 4.0
> 10.0