The Relative Contributions of ECMWF Deterministic and Ensemble Forecasts in an Automated Consensus Forecasting System

Brett Basarab, Bill Myers, William Gail, Jenny Shepard

Global Weather Corporation

ECMWF UEF Conference

June 7, 2018

Global Weather Corporation – GWC

Weather for the Connected World®

Based in Boulder, CO

Formed by **UCARF** (University Corporation for Atmospheric Research Foundation) to commercialize technology developed at **NCAR** (National Center for Atmospheric Research)
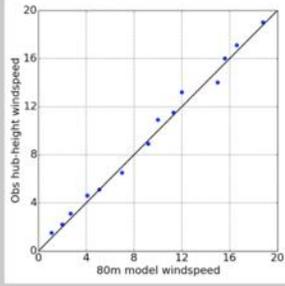
DICast: Dynamic, Integrated ForeCast System

## 1) Ingest raw forecasts and observations

| Weather Model 1	Weather Model 2	Weather Model 3	Weather Model 4	Weather Model 5

Observations ingest (temp, wspd, etc.)

Regression calculation: forecasts generated from available model inputs bias-corrected to observations

Dynamic MOS (DMOS) forecast generated: updated on past 90 day history

2) Forecast Integration

Forecast Weight Space
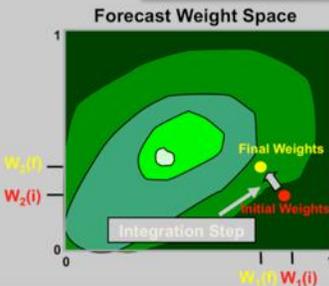
Dynamic weighting: DMOS forecasts weighted using fuzzy logic; optimal forecast derived

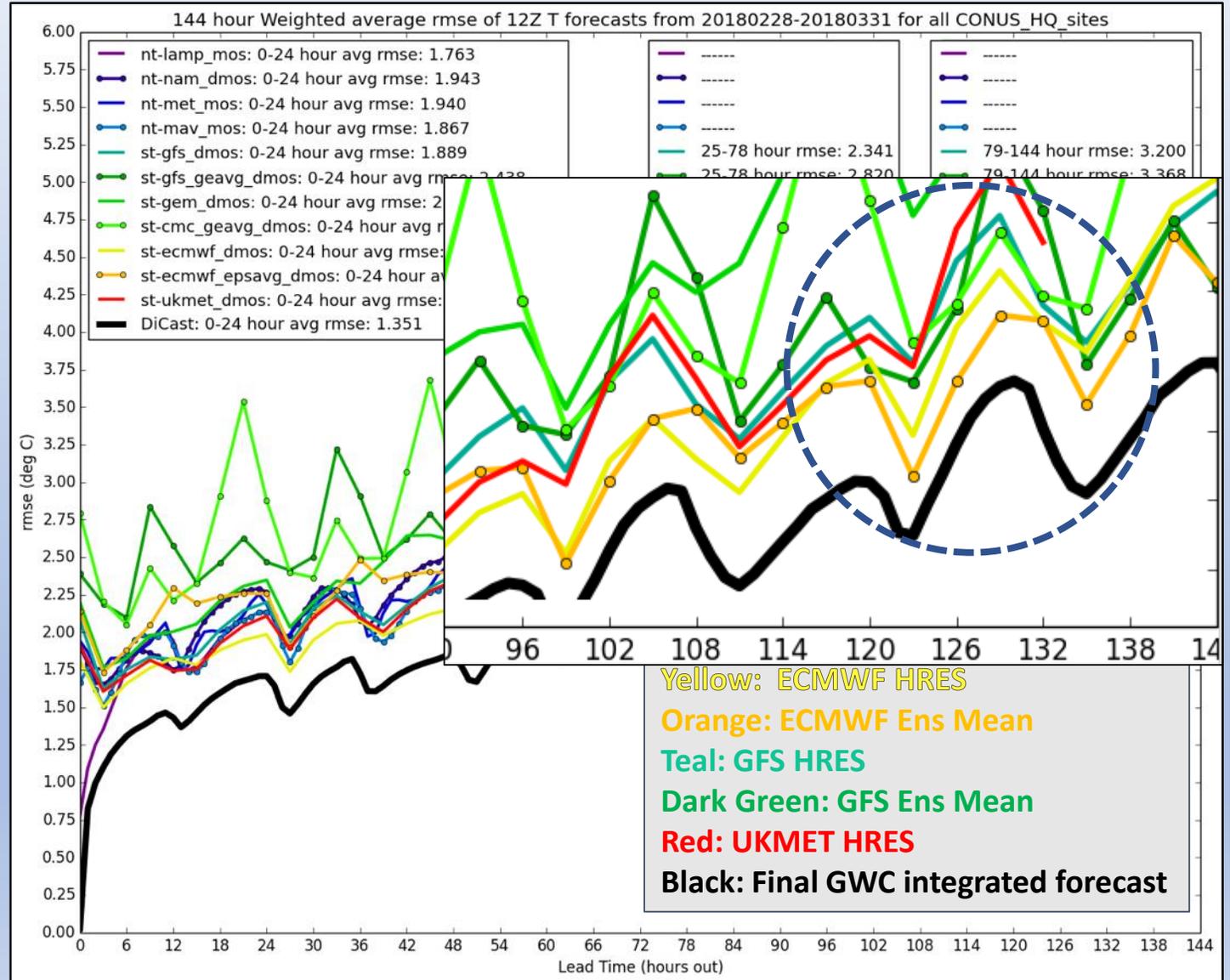## 3) Forward Error Correction (FEC)
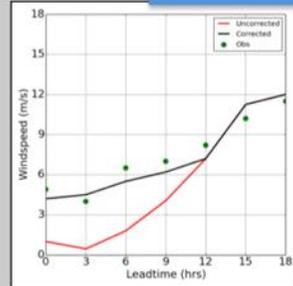
Forecast at **short lead times** corrected for consistency with observations

Point-based forecasting system – model data interpolated to locations of weather sensors (e.g., airports)

GWC Consensus Forecasting System

- GWC DICast forecast (black line) outperforms all component models

- GWC forecast accuracy possible due to high-quality model inputs from various national/international weather services

CONUS 12 UTC 2m temperature forecast RMSE: 20180228-20180331

144 hour Weighted average rmse of 12Z T forecasts from 20180228-20180331 for all CONUS_HQ_sites

Legend	0-24 hour avg rmse
nt-lamp_mos	1.763
nt-nam_dmos	1.943
nt-met_mos	1.940
nt-mav_mos	1.867
st-gfs_dmos	1.889
st-gfs_geavg_dmos	2.438
st-gem_dmos	2.
st-cmc_geavg_dmos	
st-ecmwf_dmos	
st-ecmwf_epsavg_dmos	
st-ukmet_dmos	
DiCast	1.351

25-78 hour rmse: 2.341
25-78 hour rmse: 2.820
79-144 hour rmse: 3.200
79-144 hour rmse: 3.368

Yellow: ECMWF HRES
Orange: ECMWF Ens Mean
Teal: GFS HRES
Dark Green: GFS Ens Mean
Red: UKMET HRES
Black: Final GWC integrated forecast

Experiment Outline

- Remove component input models to quantify change in final integrated forecast performance; thereby quantify benefit of individual component models

- Control system component models (Note: differs from GWC operational system)

Model Name	Description
ECMWF HRES	ECMWF Deterministic Forecast
ECMWF_EPSAVG	ECMWF Ensemble Prediction System Mean
GFS HRES	NCEP Global Forecast System Deterministic Forecast (GFS)
GFS_GEAVG	NCEP Global Forecast System Ensemble Mean (GEFS)
UKMET HRES	Met Office Global Deterministic Model
GEM HRES	CMC Global Environmental Model
CMC_GEAVG	CMC Ensemble Mean

Hypotheses

- **Removing HRES models will worsen performance at short- to medium-range (0-168 hours)**

- **Removing ensemble means has largest impacts at longer lead times (> 168 hours)**

- **Removing best-performing ECMWF forecasts should have the largest impact on final forecast performance**

Methodology

Models removed:
- ECMWF HRES
- ECMWF_EPSAVG
- GFS HRES
- GFS_GEAVG
- No ECMWF forecasts (NO_ECMWF)

Locations:
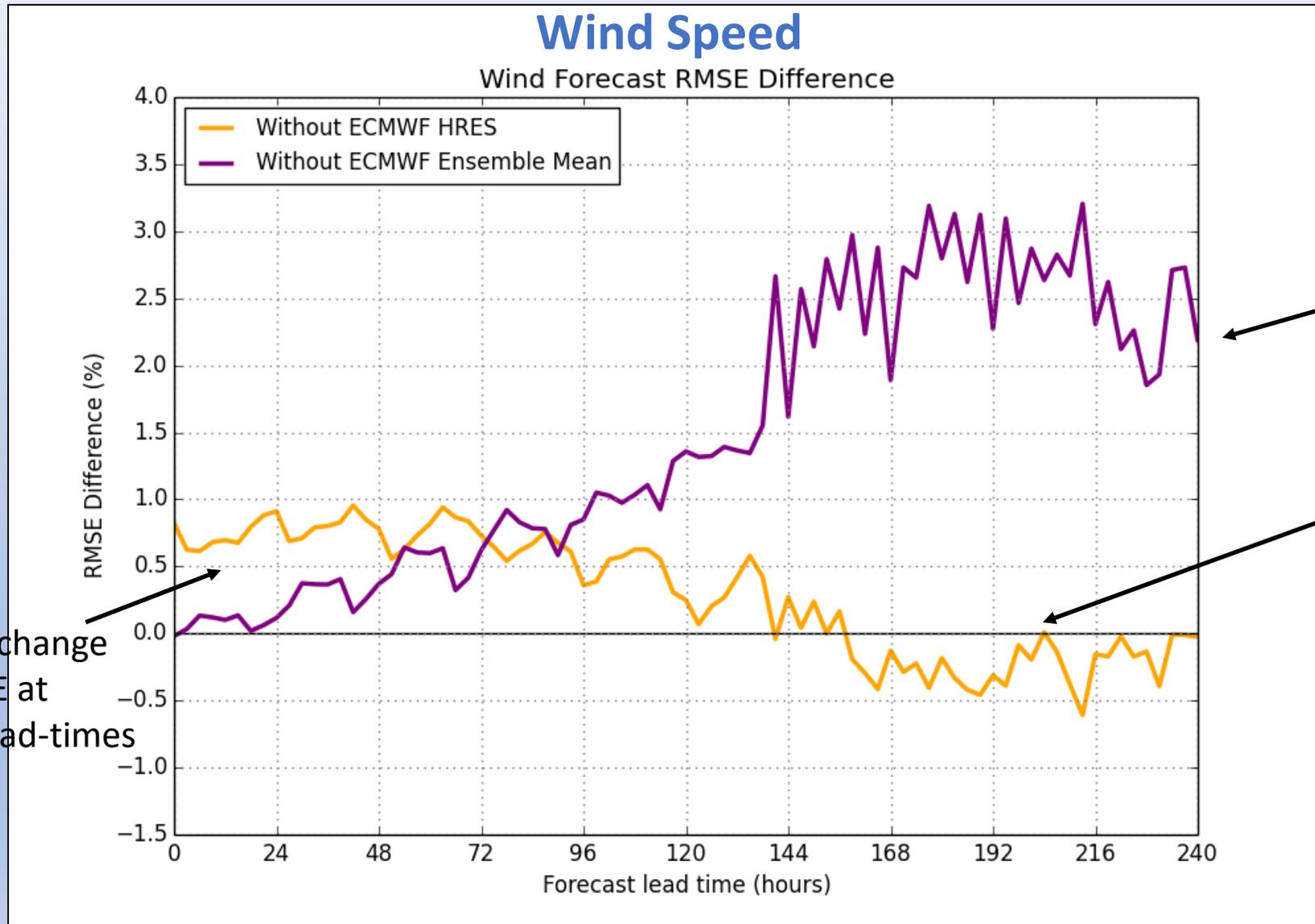- 1500 sites including most airport observing stations (METARS) in the CONUS

Forecast variables evaluated:
- 2m temperature (T)
- 2m dewpoint (dewpt)
- 10m windspeed (wind_speed)

Evaluation Period 20180201-20180430 (3 months)
- Forecasts integrated 20170801-20180430 (9 months)
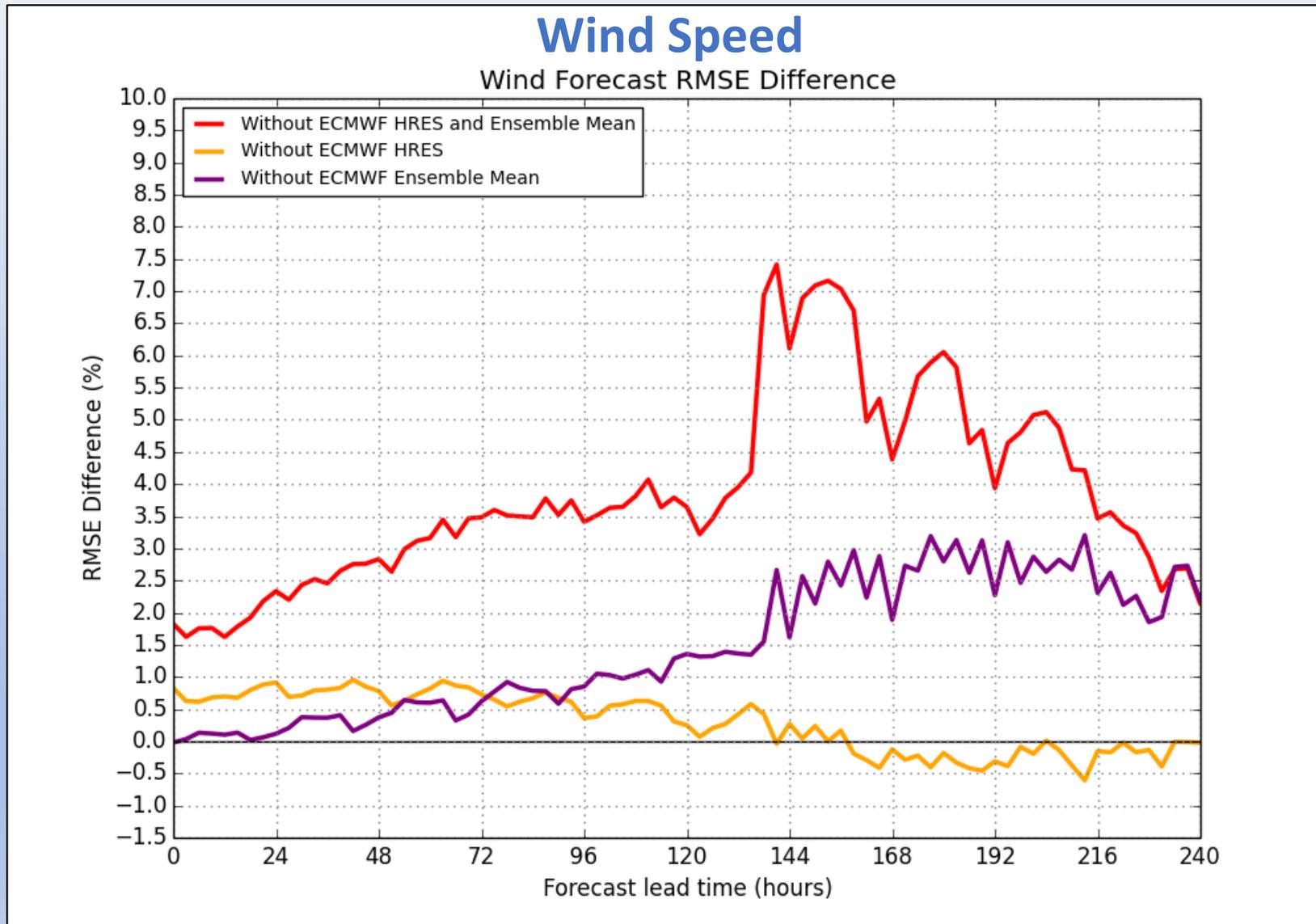
Results – ECMWF Forecasts

Wind Speed

Ensemble mean forecast most valuable past day 6

- Significant drop in deterministic forecast value past day 6
- Attributed to 6-hourly model data resolution necessitates non-ideal interpolation scheme

Similar change in RMSE at short lead-times

Results – No ECMWF Input

Wind Speed

- Effects of removing both ECMWF models not linear, but <u>compounded</u>

- Ensemble mean and deterministic forecast known to be <u>correlated</u>

- One can compensate for the other, but removing both significant worsens the forecast
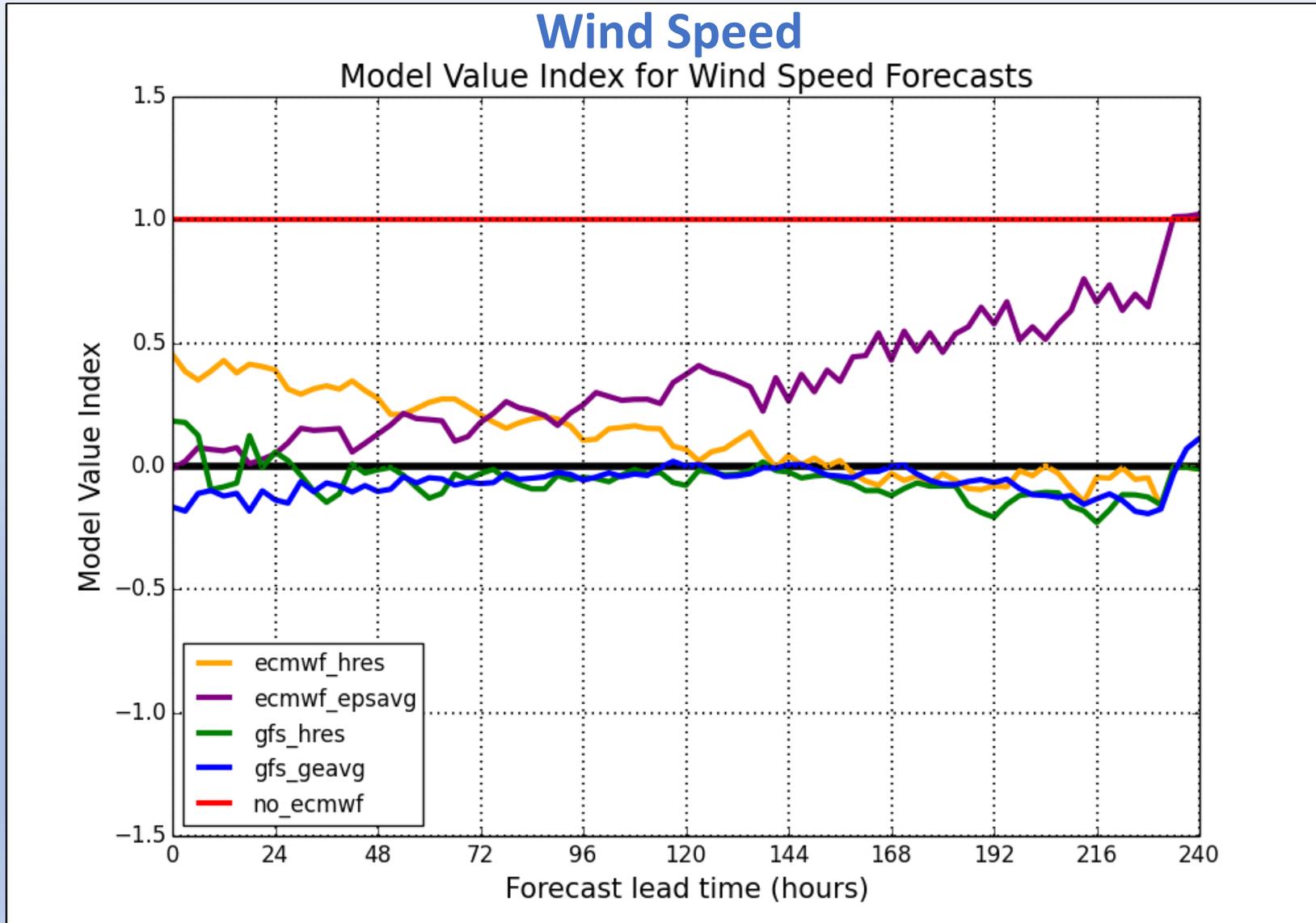
Quantifying Model Value

Define a Model Value Index (MVI):

- Change in RMSE ($\Delta RMSE$) in experimental forecasts compared to control forecast

- Normalize MVI to the change in RMSE excluding all ECMWF forecasts

- What is a single model's value compared to the entire ECMWF dataset?

$$MVI = \frac{\Delta RMSE_{imodel}}{\Delta RMSE_{no\_ecmwf}}$$

What is one model worth?

Wind Speed

Model Value Index for Wind Speed Forecasts

Legend:
- ecmwf_hres (orange)
- ecmwf_epsavg (purple)
- gfs_hres (green)
- gfs_geavg (blue)
- no_ecmwf (red)

x-axis: Forecast lead time (hours)
y-axis: Model Value Index

Model Value Index (MVI)

- Define change in RMSE ($\Delta RMSE$) compared to control system

$$MVI = \frac{\Delta RMSE_{imodel}}{\Delta RMSE_{no\_ecmwf}}$$

- ECMWF MVIs are initially similar, then diverge at longer lead times

- Greater value of the ensemble mean at long-range

- ECMWF forecasts <u>likely correlated</u> at short lead times, explaining limited impact of removing just one forecast

Model Value Index Summary

Short Range (0-48 hours)

Model Forecast – 2m Temperature	Average MVI
ECMWF HRES	0.16
ECMWF Ensemble Mean	0.22
GFS HRES	0.05
GFS Ensemble Mean	-0.08

Model Forecast – 2m Dewpoint	Average MVI
ECMWF HRES	0.13
ECMWF Ensemble Mean	0.14
GFS HRES	0.01
GFS Ensemble Mean	0.00

Model Forecast – 10m Wind Speed	Average MVI
ECMWF HRES	0.36
ECMWF Ensemble Mean	0.08
GFS HRES	0.00
GFS Ensemble Mean	-0.11

Medium Range (51-168 hours)

Model Forecast – 2m Temperature	Average MVI
ECMWF HRES	0.02
ECMWF Ensemble Mean	0.31
GFS HRES	0.02
GFS Ensemble Mean	-0.03

Model Forecast – 2m Dewpoint	Average MVI
ECMWF HRES	0.01
ECMWF Ensemble Mean	0.25
GFS HRES	0.01
GFS Ensemble Mean	0.03

Model Forecast – 10m Wind Speed	Average MVI
ECMWF HRES	0.11
ECMWF Ensemble Mean	0.29
GFS HRES	-0.05
GFS Ensemble Mean	-0.03

Long Range (171-240 hours)

Model Forecast – 2m Temperature	Average MVI
ECMWF HRES	-0.22
ECMWF Ensemble Mean	0.79
GFS HRES	-0.07
GFS Ensemble Mean	-0.14

Model Forecast – 2m Dewpoint	Average MVI
ECMWF HRES	-0.35
ECMWF Ensemble Mean	0.86
GFS HRES	0.15
GFS Ensemble Mean	-0.34

Model Forecast – 10m Wind Speed	Average MVI
ECMWF HRES	-0.05
ECMWF Ensemble Mean	0.65
GFS HRES	-0.12
GFS Ensemble Mean	-0.08

Conclusions

- ECMWF datasets crucial to produce a high-quality forecast:
  - ECMWF Ensemble Mean: highest value beyond day 6
  - ECMWF deterministic forecast: high value days 0-5
  - Correlated forecasts are beneficial: robustness of GWC system

- Averaging ensemble members is a simple means to provide significant additional forecast skill

- Correlation between ECMWF HRES and Ensemble mean results in comparable forecast quality when one removed, but not both

- GFS Ensemble Mean does not add significant value to integrated forecast; not all ensembles created equal!

Future Work

- This study informs how best to modify and optimize GWC's operational blend of models

- Expand preliminary study to longer time range covering multiple seasons; open to suggestions to improve model value metric and more rigorously quantify model value

- ECMWF Ensemble particularly valuable; GWC exploring addditional applications including probabilistic forecasts

- We look forward to ECMWF's continued emphasis on its ensemble system, as this is the most valuable input in GWC's forecasts

Thank You!