Enhanced Predictability During Extreme Winter Flow Regimes

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ECMWF UEF | 2016

Reading, UK

June 6 – 9, 2016

Where does forecast verification occur today?

- Internal teams within NWP centers
- Media: TV broadcasters, print, web
- Social Media, Twitter / Facebook

Who is doing model forecast verification?

- Trained forecasters, gov't & commercial
- Your neighbor

High impact events

Why European forecasters saw Sandy's path first

US weather model is good, but lags behind the best.

by Scott K. Johnson - Dec 26, 2012 1:30pm EST

Satellite image of Hurricane Sandy.

NASA Earth Observatory

LATEST FROM ARS TECHNICA/UK


Labour backs "principle" of Tory government's Investigatory Powers Bill


EU net neutrality draft guidelines split the crowd—public told to wade in

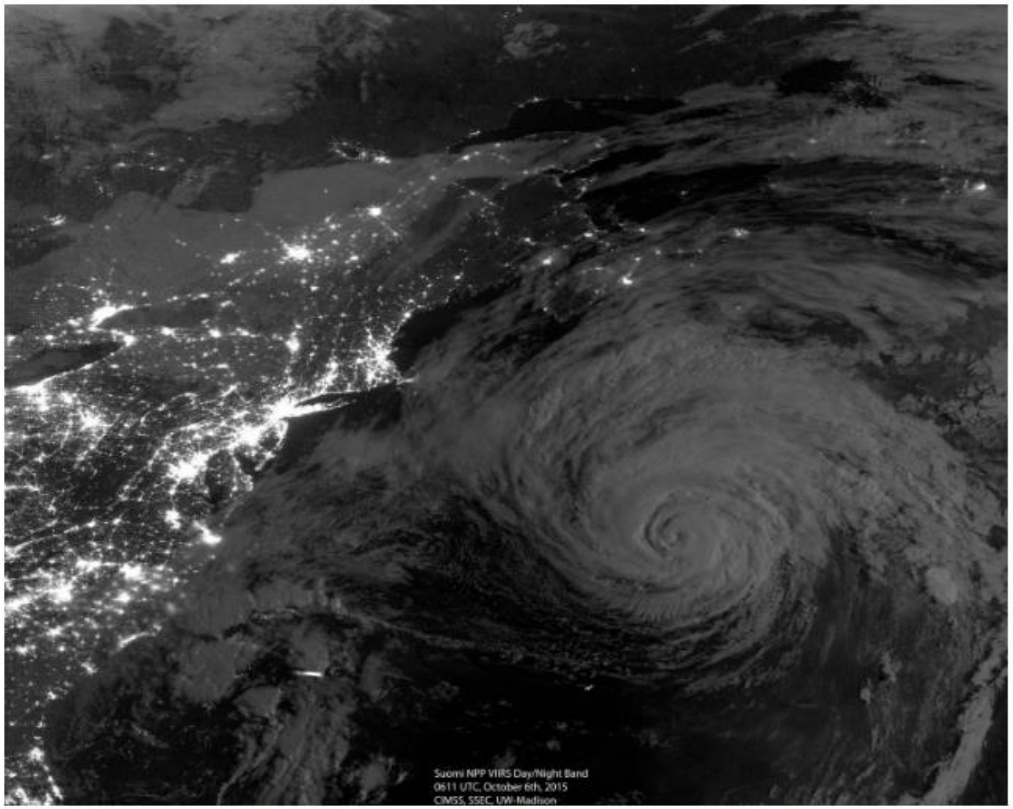

What a Brexit would mean for Europe's television channels


Google's AlphaGo AI will play Go against humanity's best

Capital Weather Gang

What the European model 'win' over the American model in Joaquin means for weather forecasting

By Jason Samenow October 6, 2015



Hurricane Joaquin (Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin-Madison)

Last week, on the biggest of stages, a weather forecast model from Europe proved superior to the principal U.S. model in its prediction for a hurricane threatening the United States.

Most Read

1 Traffic-weary homeowners and Waze are at war, again. Guess who's winning?
2 A six-month sentence in Stanford sexual assault case leads to a push to recall the judge
3 'I will not help you hide your money when you apply for financial aid' — and more straight talk from college admissions officers to parents
4 The 'heartbreaking' moment a dying mother begged her friend: 'Will you take my babies?'
5 'Which Way' is faster during SafeTrack's first surge — the Silver Line or one of the alternatives?

At a Glance

Mon.	Tue.	Wed.
–/87°	68°/85° 30%	61°/75°

Thu.	Fri.	Sat.
57°/76°	58°/78°	61°/83° 20%

Forecast by National Weather Service

National Airport | Dulles | BWI

PHYSICS TODAY

Europeans shine in weather forecasting

David Kramer

January 2016, page 22

PREVIOUS ARTICLE | ISSUES AND EVENTS | NEXT ARTICLE

The US global model lags the performance of two European competitors in predicting weather up to two weeks ahead.

GO TO SECTION...

Although Hurricane Joaquin passed well off the US East Coast in October, the storm had a different kind of impact: bringing into focus the outstanding performance of one of numerous global weather prediction models. The European Centre for Medium-Range Weather Forecasts (ECMWF) was the world's only major forecast simulation to pinpoint the hurricane's track several days out. Others, including the US Global Forecast System (GFS), had charted a course for Joaquin that was hundreds of miles to the west and showed that it would make landfall along the mid-Atlantic coast.

The exceptional performance of the ECMWF model had also been seen in 2012 when it was the only one to predict the left hook that brought Hurricane Sandy ashore in New Jersey. Other models had Sandy staying well out to sea.

Aerial view of the New Jersey coast in the aftermath of Hurricane Sandy. The global weather model from the European Centre for Medium-Range Weather Forecasts was the only one to correctly predict that the storm would make landfall there.

US AIR FORCE

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Europäisches Zentrum für mittelfristige Wettervorhersage | Centre européen pour les prévisions météorologiques à moyen terme

INTRODUCING 41R2: MOST ACCURATE AND HIGHEST-EVER RESOLUTION IN GLOBAL NUMERICAL WEATHER PREDICTION.

10 MARCH 2016

What has been announced today?

We're announcing a significant set of upgrades launched by the European Centre for Medium Range Weather Forecasts (ECMWF). The changes nearly halve the distance between global weather prediction points, substantially increasing the effective resolution of the forecast. As a result, ECMWF's numerical weather predictions, which are widely used by Europe's meteorological services, are more accurate, contain three times as much detail and can predict the weather up to half a day further ahead.

Key messages

- Most accurate global weather predictions at record-breaking resolution.
- Number of grid points tripled to 900 million in the high-resolution forecast, evenly distributed around the globe.
- Gain in predictability of up to half a day at same level of quality.

3600x 1801y 137L = 888M

Forecasts are about to get a lot more accurate: NOAA unveils new '4D' supercomputer model of the world's weather

- New model of global weather takes into account how weather systems evolve on a 3D spatial grid over time
- Dramatically improves accuracy of forecasts, and allows NOAA to see hourly forecasts for the next five days

By MARK PRIGG FOR DAILYMAIL.COM

PUBLISHED: 16:22 EST, 12 May 2016 | **UPDATED:** 21:45 EST, 12 May 2016

NOAA's premier forecast model goes 4-D

Weather | supercomputers modeling GFS

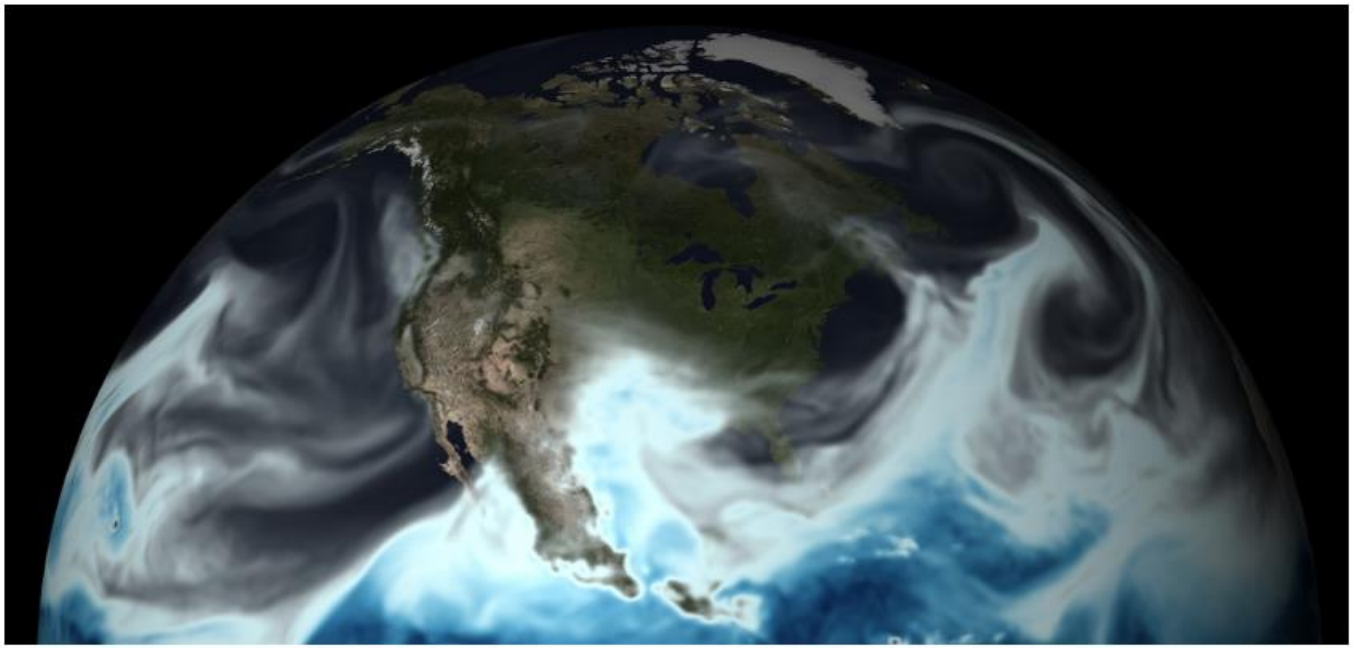
May 11, 2016 — NOAA's powerful new supercomputers paved the way for another upgrade to the U.S. Global Forecast System (GFS), NOAA's primary model for weather prediction.

NOAA's premier forecast model goes 4-D

Weather | supercomputers modeling GFS

SHARE

May 11, 2016 — NOAA's powerful new supercomputers paved the way for another upgrade to the U.S. Global Forecast System (GFS), NOAA's primary model for weather prediction.

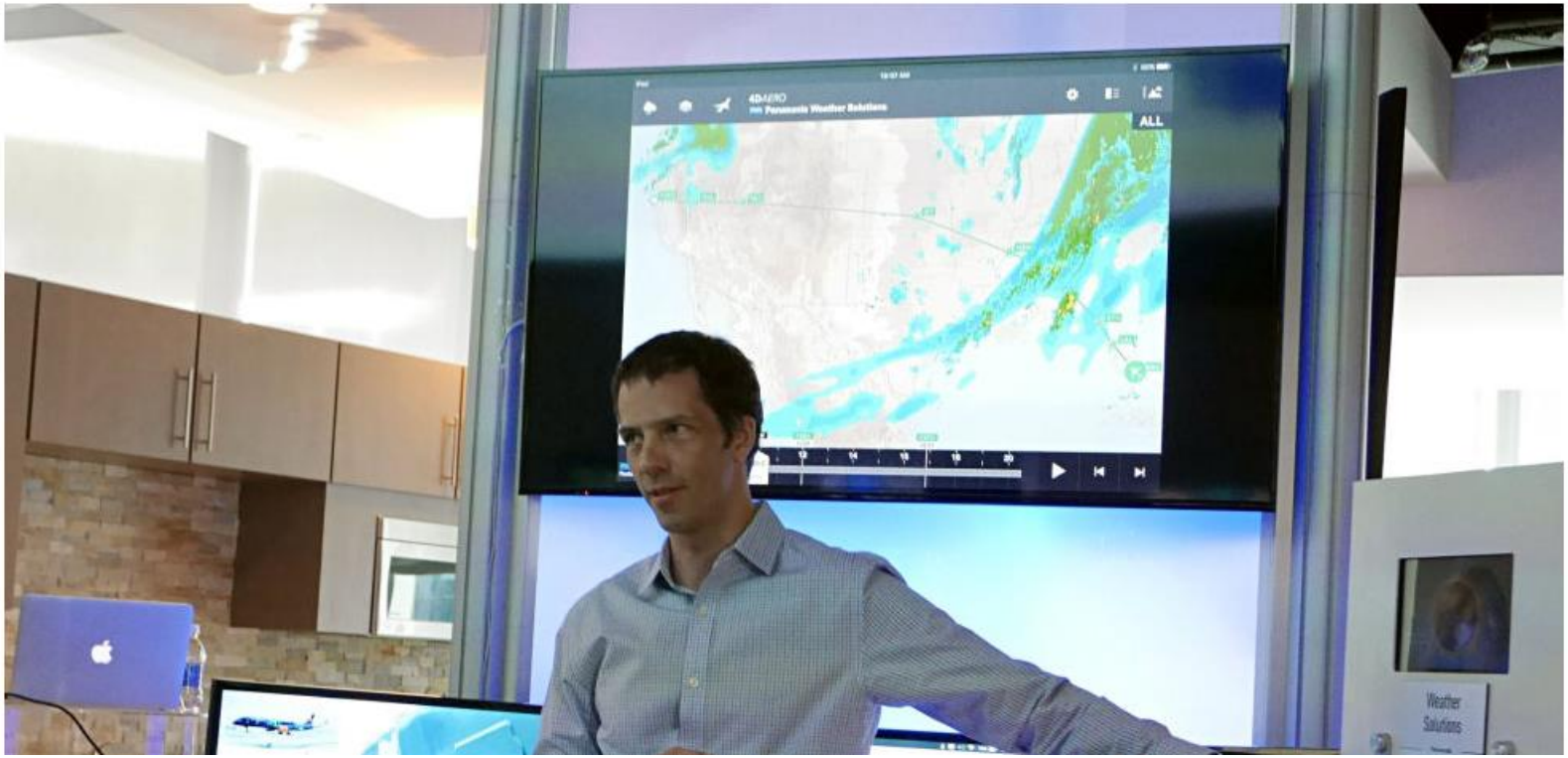


SCIENTIFIC METHOD / SCIENCE & EXPLORATION

TV maker Panasonic says it has developed the world's best weather model

The company says it has beaten the GFS for a while and now equals the ECMWF.

by **Eric Berger** - Apr 6, 2016 11:36am EDT



Comparison of Operational Suites

ECMWF

HRES Global model 0-10 days (2x)
EPS Ensembles 0 -15 days, 46 days
Seasonal 7-months (1 per mon)

NOAA

GFS global model 0 -16 days (4x daily)
GEFS ensembles 0–16 days (4x daily)
NAM (12-km) 0-84 hours (4x), *NAM-RR*
NAM 4-km Nest 0-60 hours (4x)
RAP 12-km (24x)
HRRR 3-km (24x), *HRRR-E*
CFSv2 climate forecast 0-270 days (4x)
HIRESW 4-km WRF-windows (2x)
SREF ensemble 16-km (4x)
RTMA/URMA analysis (24x)
WW3 Wave model (4x)
RTOFS global model (1x)
NDFD 2.5 km (48x)
National Water Model, Aerosols
HWRF hurricane model (4x)
WPC, SPC, NWS, NSIDC, OPC, Space …

Research Objectives

Framework & Goals

- Use current NWP deterministic & ensemble systems to analyze large-scale flow patterns and relate to medium-range forecast skill "dropouts"
- Diagnose causes of low-predictability flow regimes including dropouts: inadequate observations, large analysis uncertainty, and/or model error growth
- Link to skill of Teleconnection Indices such as AO/NAO, EPO, WPO and PNA

Definitions

- Forecast skill metrics: 5 or n-day 500 hPa geopotential anomaly correlation (NH: 20°-80°N),
- Forecast dropout: an individual or collection of several consecutive forecasts that have significantly lower 500 hPa geopotential anomaly correlation skill – compared to monthly/seasonal mean

  (AC < 0.8)
- Low-predictability regime: particular hemispheric-scale configuration of upper-level flow that leads to below average forecast skill

Anomaly Correlation: Definition

$$ACC = \frac{\sum_{m=1}^{M} f'_m o'_m}{\left[\sum_{m=1}^{M} (f'_m)^2 \sum_{m=1}^{M} (o'_m)^2\right]^{1/2}}$$

500-hPa geopotential height
Northern Hemisphere 20°-80° N

$f'_m = f_m - c_m$ Forecast anomaly from climatology* at each grid point (m)

$o'_m = o_m - c_m$ Analysis anomaly

- The AC is common forecast skill metric used by operational centers
- Forecasts with AC > 0.6 are considered as providing potential positive skill
- Not perfect metric, but used in concert w/ e.g. mean squared error

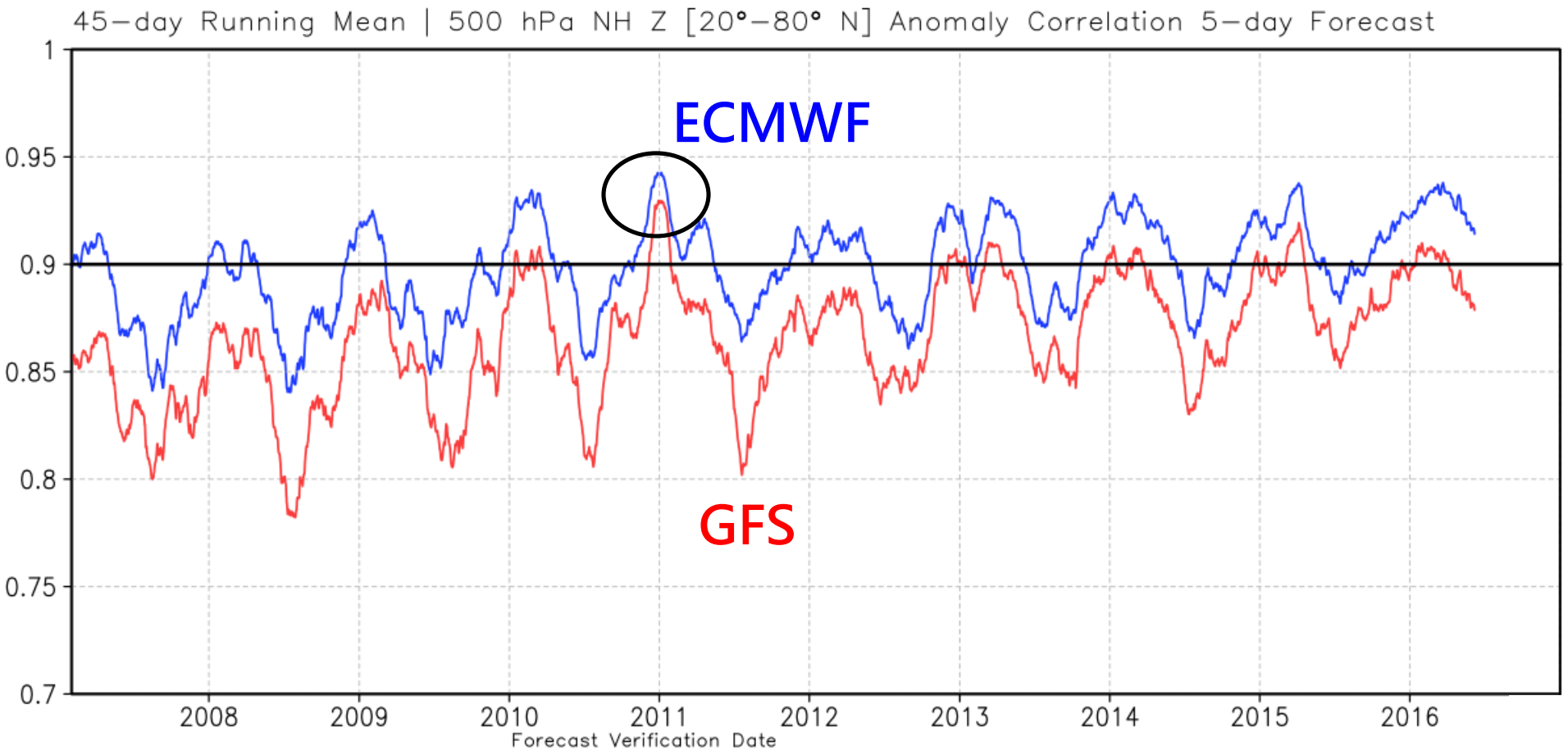
* ERA-Interim (reanalysis) 1981-2010 climatology

Archive of Analysis and Forecast Fields

- Historical record of analysis and forecasts from current NWP deterministic and ensemble systems
- Key is archive and/or "real-time" access to forecast products
- Valuable resource includes the EPS Reforecasts / Hindcasts or any frozen forecast model for post-processing purposes e.g. EFI, M-Climate

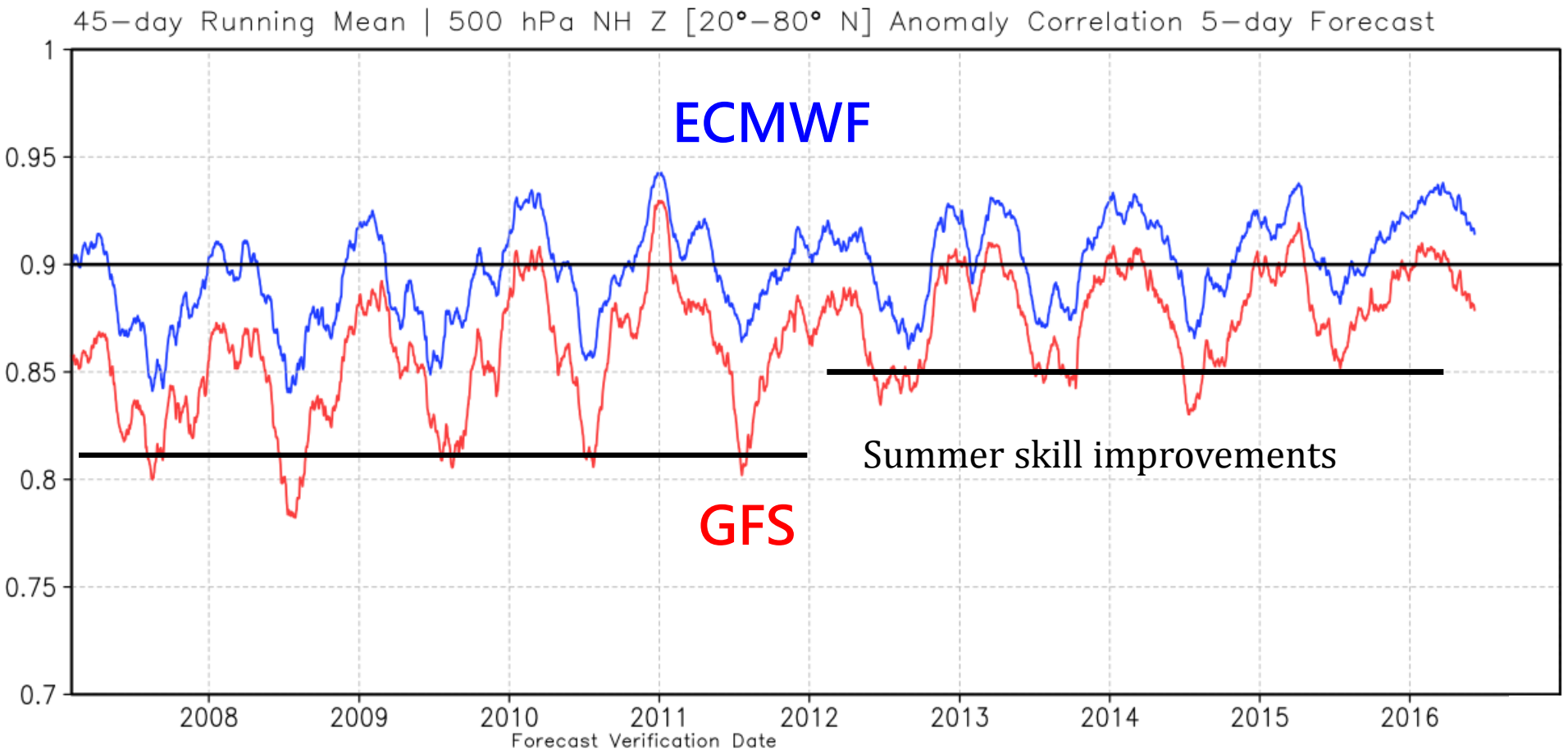
MODEL	TIME PERIOD	GRID/FIELDS	SOURCE
ECMWF HRES & EPS	Oct 2006-present	T799-T1279L137 Tco1279L137 ~9/18 km	WeatherBELL ECMWF MARS
NCEP GFS GEFS	Feb 2004-present	T382-T574L64 T1534L64 0.25°- 0.5° -1°	NOMADS/NCDC
NAVY NAVGEM	Jan 2004-present	T239-T319-T359 0.5°	NRL MONTEREY
*Forecasts verified against own analysis			

Anomaly Correlation: Forecast skill



Seasonal AC scores are highly correlated
NH Winter skill >> Summer Skill.
Both models showed record-high skill during winter 2010-2011

Anomaly Correlation: Forecast skill

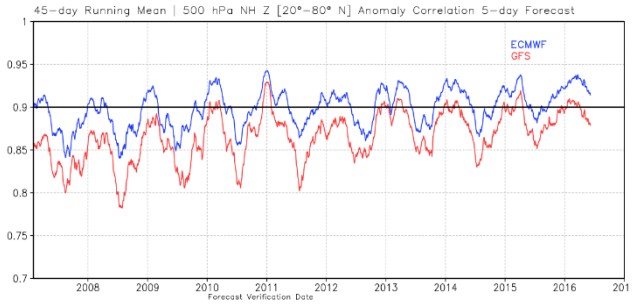


- Sustained improvement skill jumps mainly due to major model configuration changes:

Jan 26, 2010: ECMWF T799 → T1279 March 2016: 41r2

July 28, 2010: GFS T382 → T574 and physics major upgrade → T1534 → 4D-Hybrid EnVar May 11, 2016

Anomaly Correlation: Forecast skill



5-DAY NH Geopotential Height ECMWF vs GFS calendar year "Model Wars" in U.S.A. media

YEAR	GFS	ECMWF
2009	0.852	0.888
2010	0.872	0.904
2011	0.862	0.898
2012	0.871	0.900
2013	0.880	0.904
2014	0.875	0.905
2015	0.885	0.910
2016	YTD 0.894 12m 0.886	YTD 0.926 12m 0.915

NCEP May Upgrade:
4D-Var Hybrid EnKF
GFS gains have "leveled out"

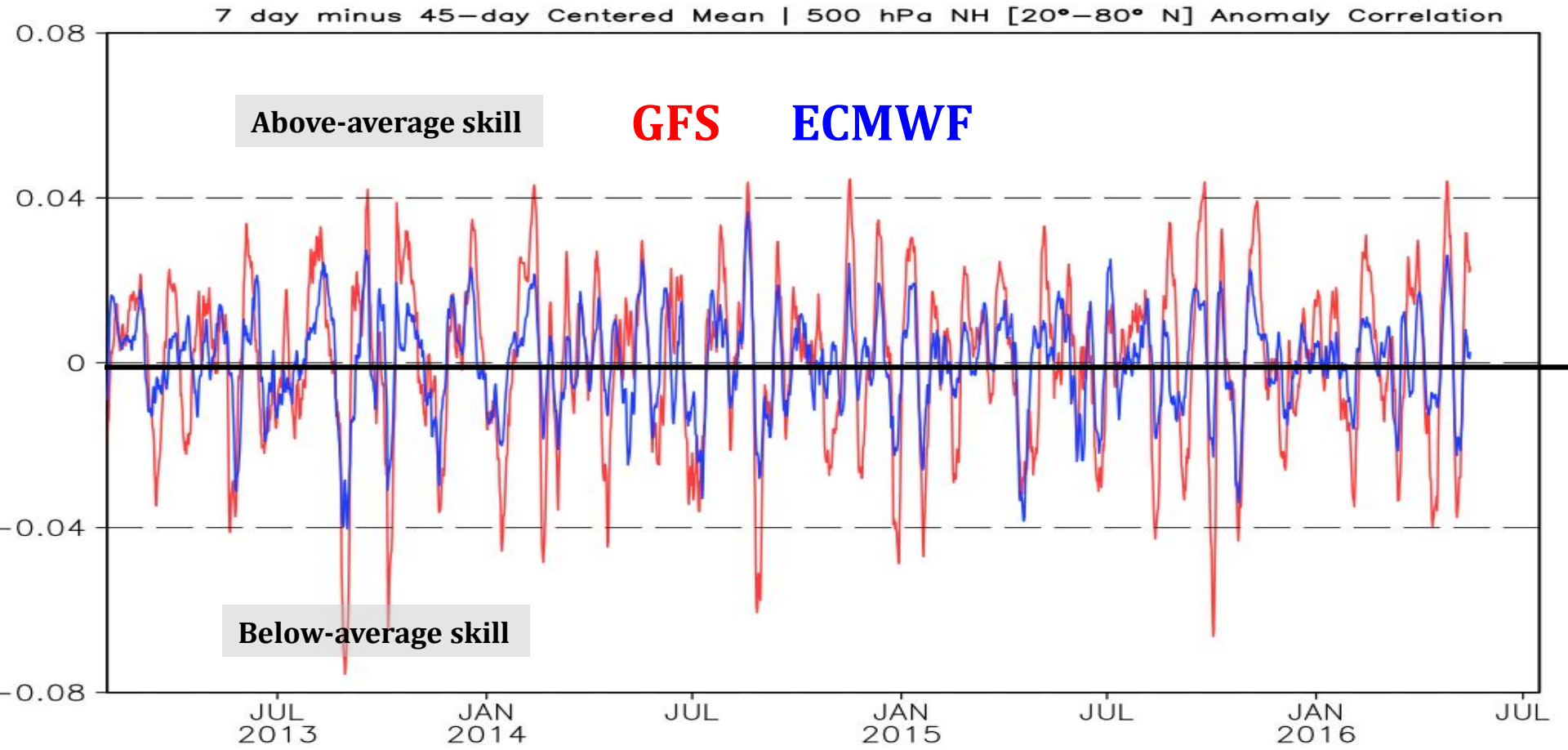
Cycle 42r1 significant Improvement

"Gap widened" by 20%
0.0025 → 0.03

On pace for 0.92

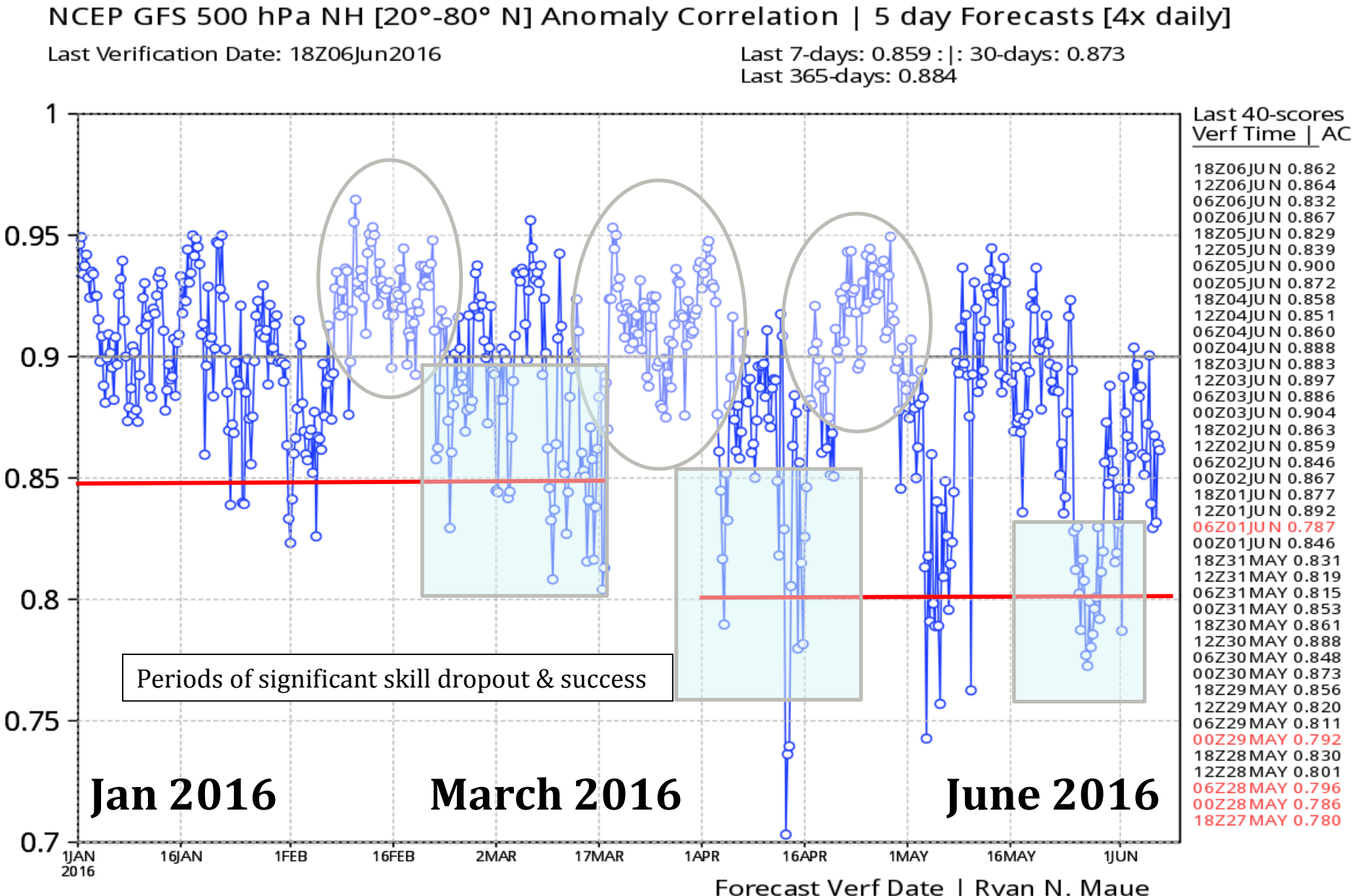
Predictive Skill Regimes

From N Hemi AC, ECMWF & GFS: Centered means of 45-days and 7-days are calculated
The 7-day ***minus*** 45-day mean represents a seasonally adjusted measure of skill

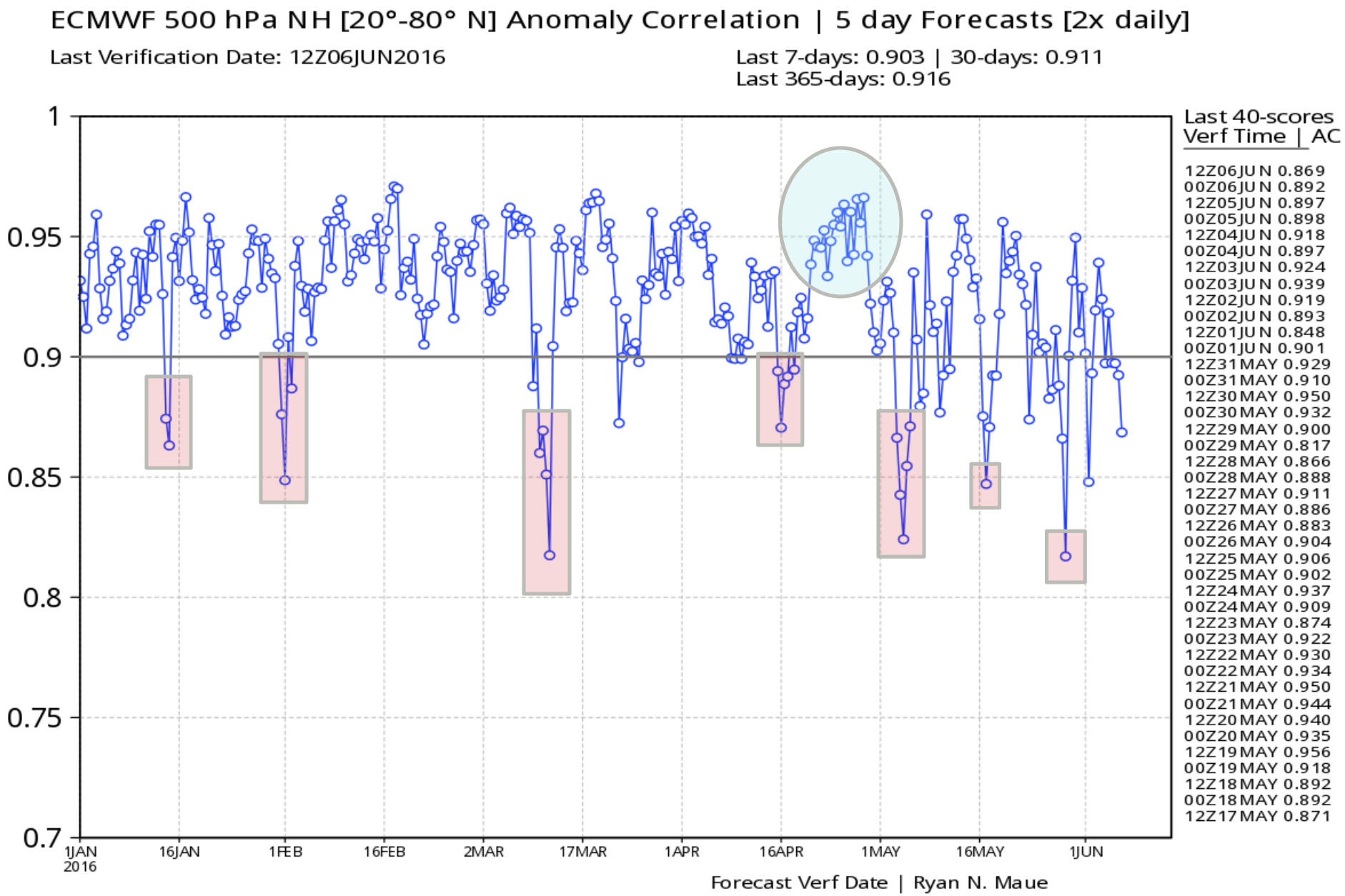


Models tend to have low and high skill on the same forecast(s)- but ECMWF skill drops off less than GFS

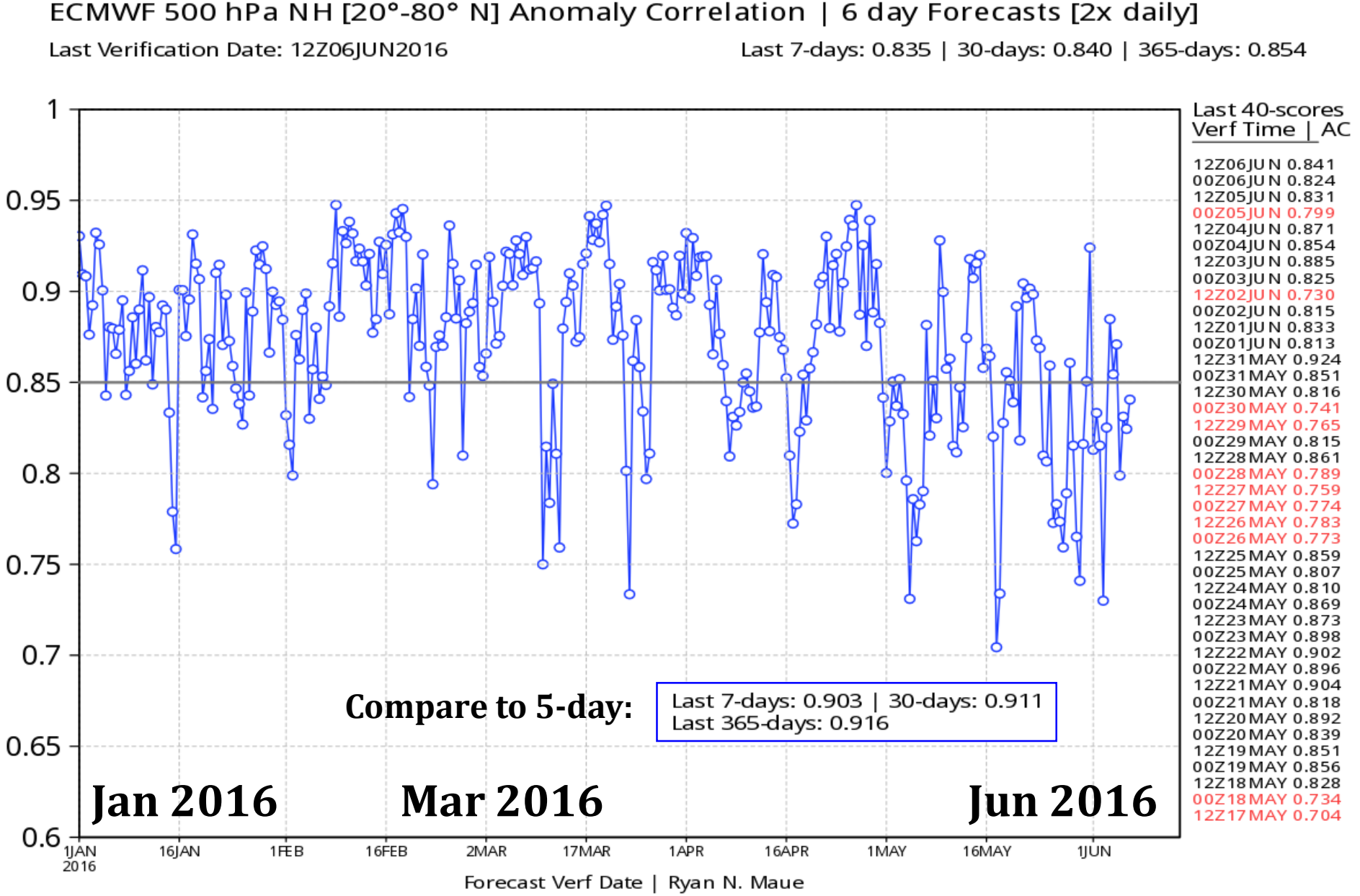
Anomaly Correlation: GFS recent skill



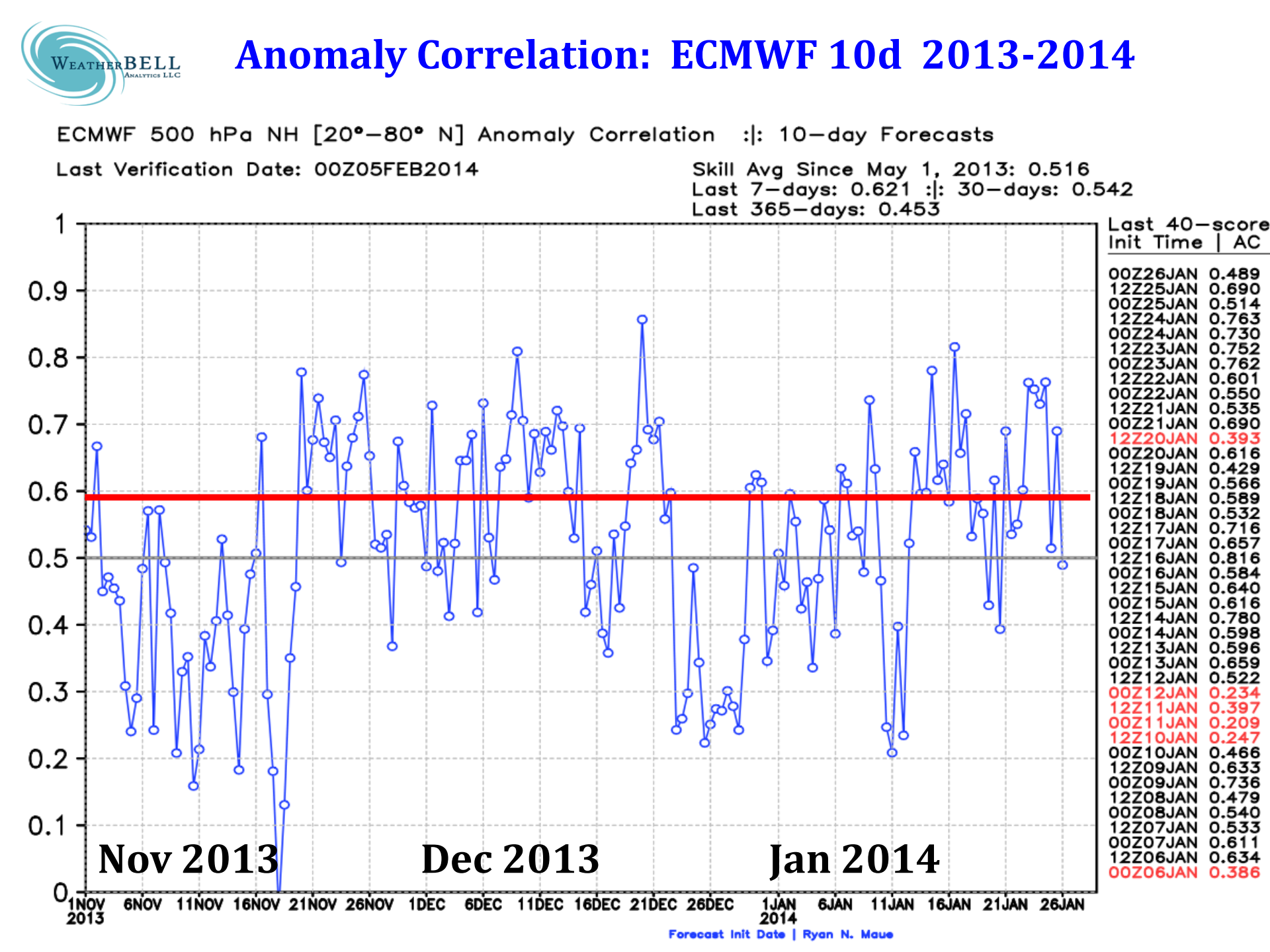
Anomaly Correlation: HRES ECMWF 5-day



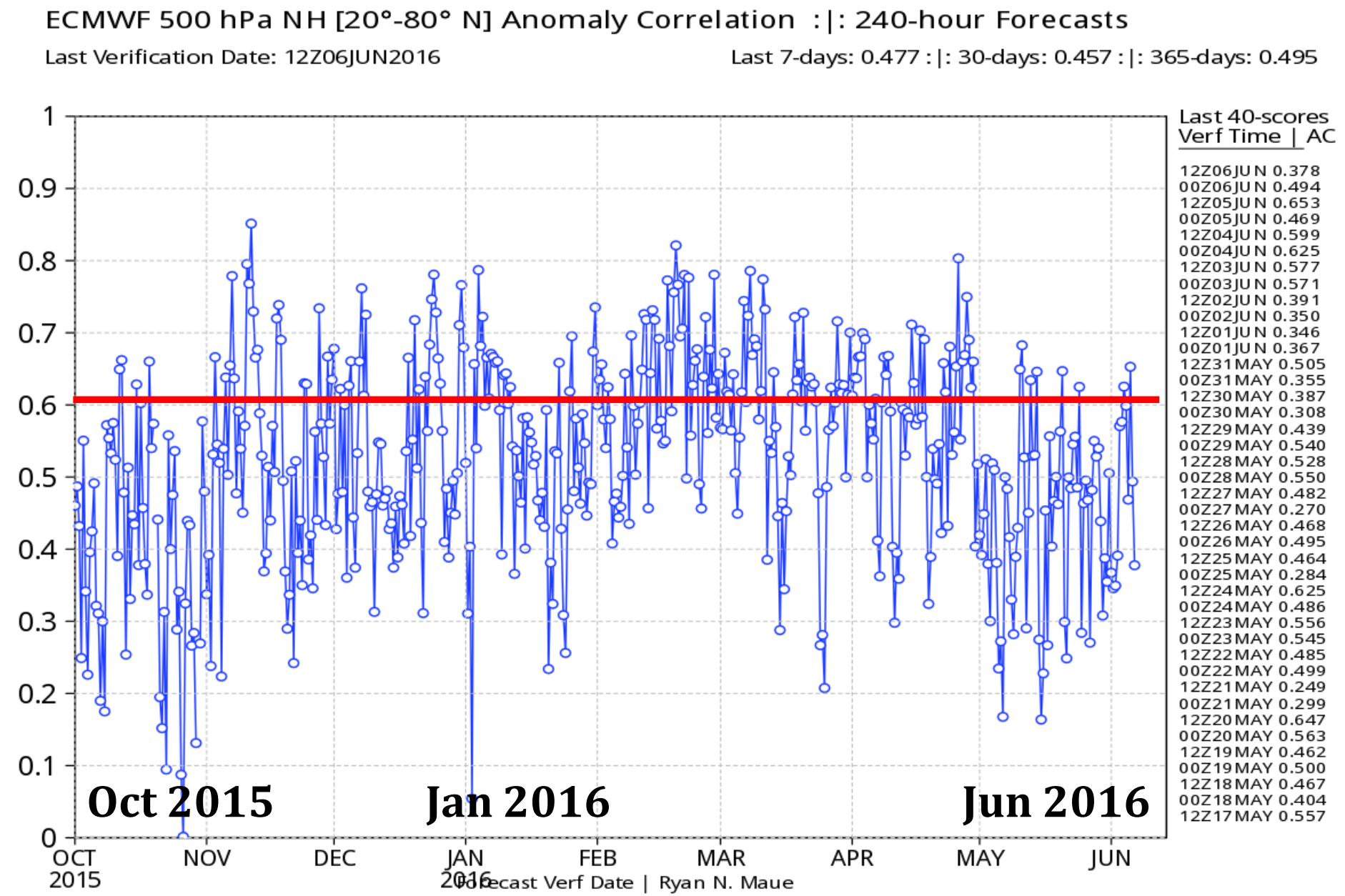
Anomaly Correlation: ECMWF 6-day



Anomaly Correlation: ECMWF 10d 2013-2014



Anomaly Correlation: ECMWF 10d 2015-2016



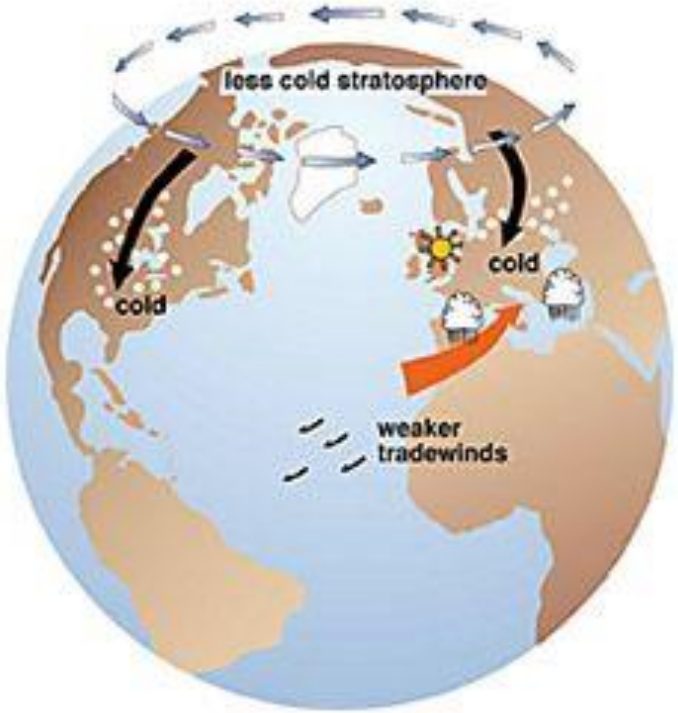
Example: Arctic Oscillation

- AO is the first EOF of sea-level pressure (1000 hPa geopotential height) variations north of 20°N latitude

- How do NWP systems perform during the **+** and **–** phase of the AO, as well as through *transitions* [e.g. Archambault et al. 2010**]** – during the Northern Hemisphere cold season?

POSITIVE PHASE

NEGATIVE PHASE

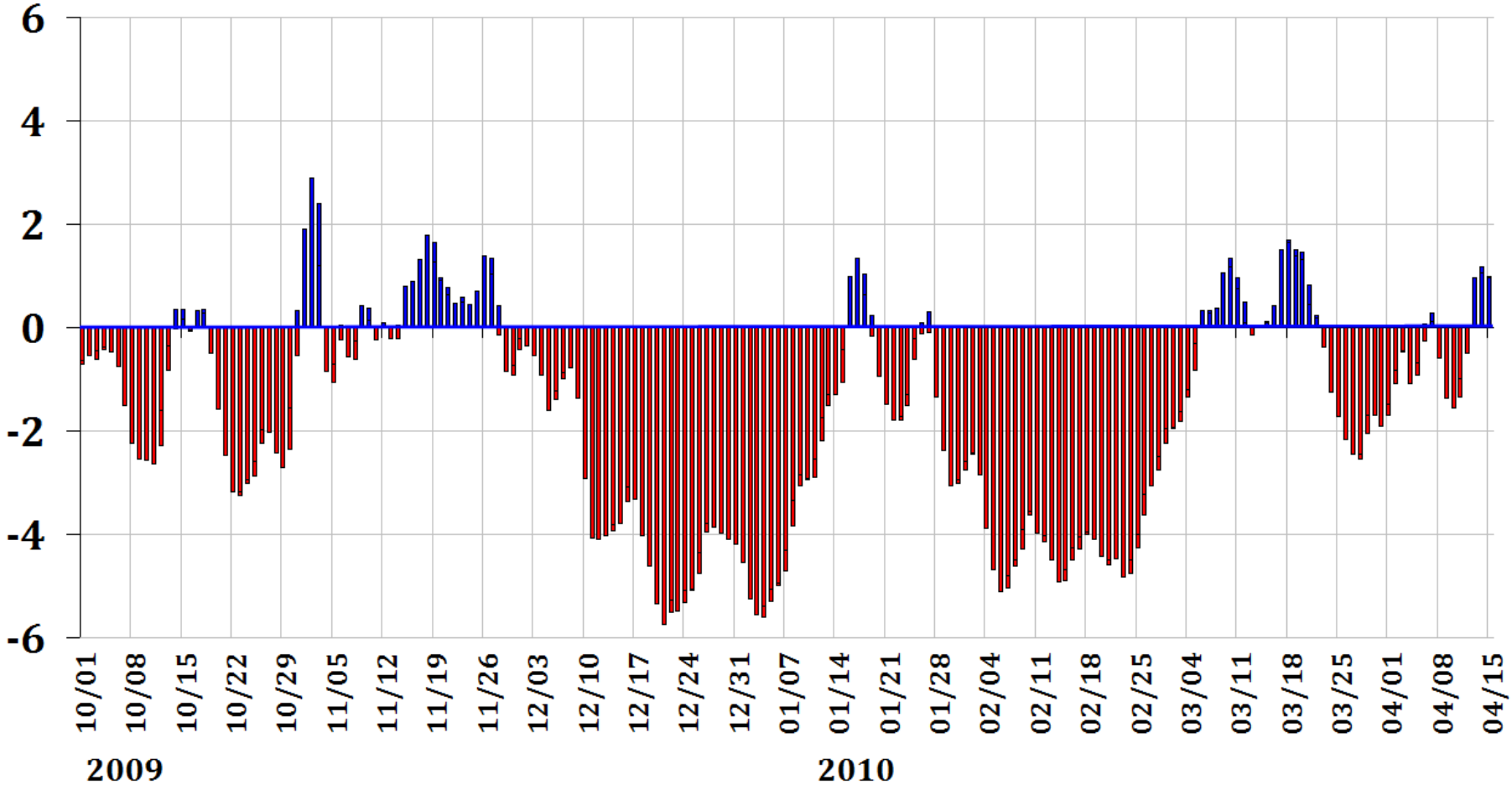


J. Wallace, University of Washington

Arctic Oscillation

Winter 2009 – 2010

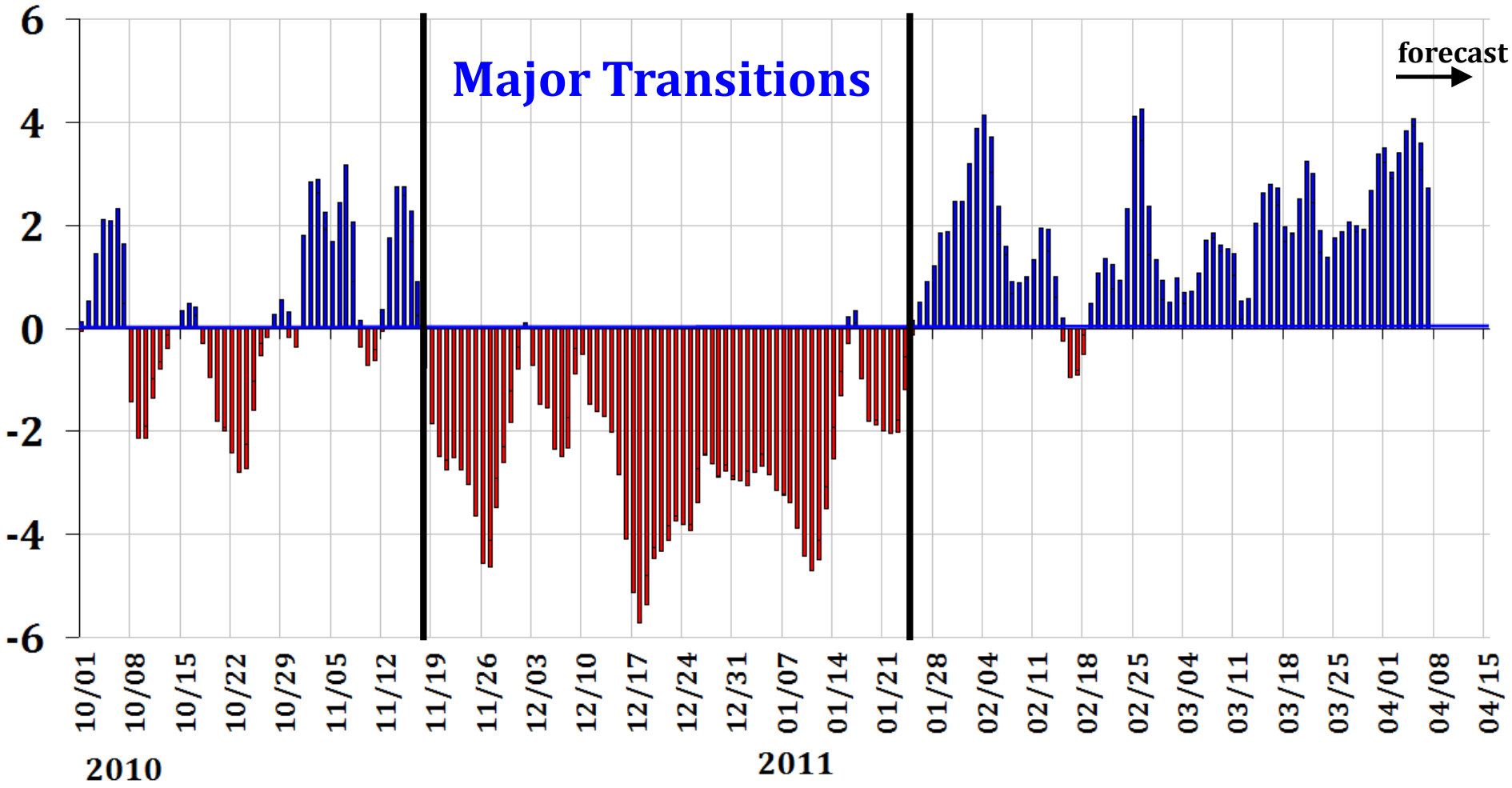
Sustained Negative AO



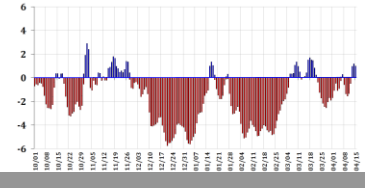
Arctic Oscillation

Winter 2010 – 2011

November – January Negative AO, followed by strong Positive



Arctic Oscillation



ECMWF – Winter 2009 – 2010

AC

500 hPa NH Anomaly Correlation

Arctic Oscillation Index

AO

Transitions

1
0.94
0.88
0.82
0.76
0.7
0.64

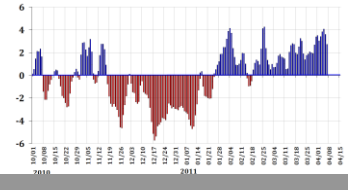
6
4
2
0
-2
-4
-6

10/01 10/08 10/15 10/22 10/29 11/05 11/12 11/19 11/26 12/03 12/10 12/17 12/24 12/31 01/07 01/14 01/21 01/28 02/04 02/11 02/18 02/25 03/04 03/11 03/18 03/25 04/01

Dec 2009

Feb 2010

Arctic Oscillation



ECMWF – Winter 2010 – 2011

500 hPa NH Anomaly Correlation

Arctic Oscillation Index

AC

AO

Lower Skill

Very High Skill

Lower Skill

1
0.96
0.92
0.88
0.84
0.8
0.76

6
4
2
0
-2
-4
-6

10/26 11/02 11/09 11/16 11/23 11/30 12/07 12/14 12/21 12/28 01/04 01/11 01/18 01/25 02/01 02/08 02/15 02/22 03/01 03/08 03/15 03/22 03/29 04/05 04/12

Dec 2010

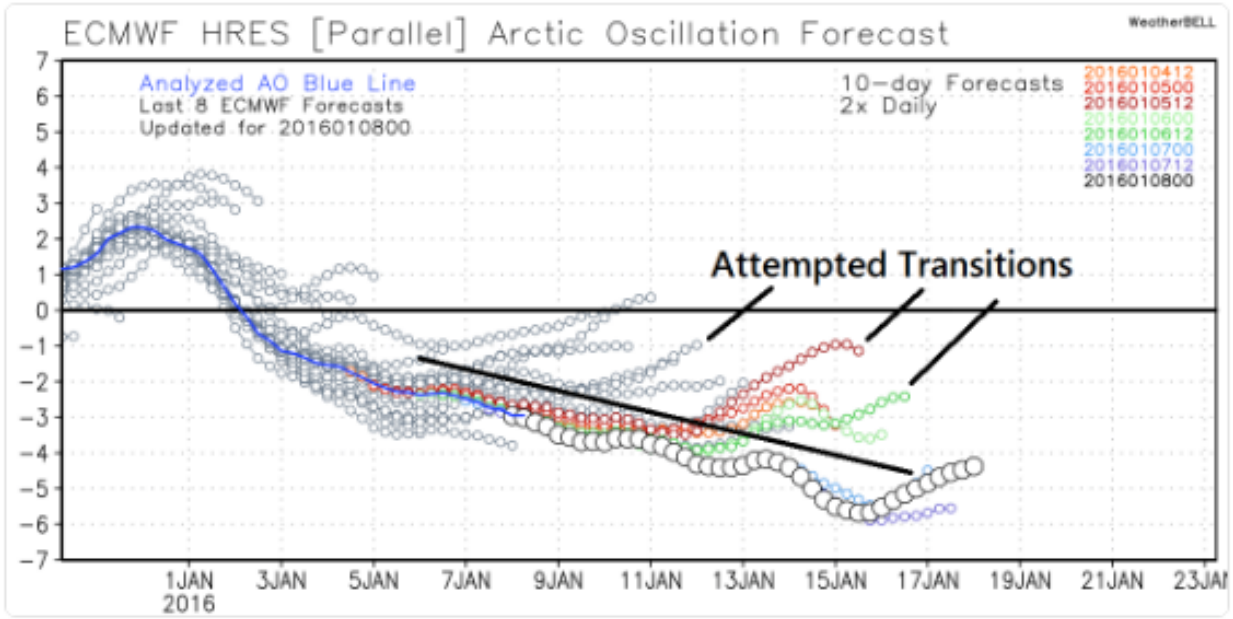
Feb 2011

Visualizing Arctic Oscillation Forecast Index

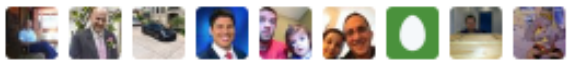
Ryan Maue
@RyanMaue

January 8, 2016

Visualize bias in global model using indices like AO ... EC parallel tried hard in medium range to be less negative

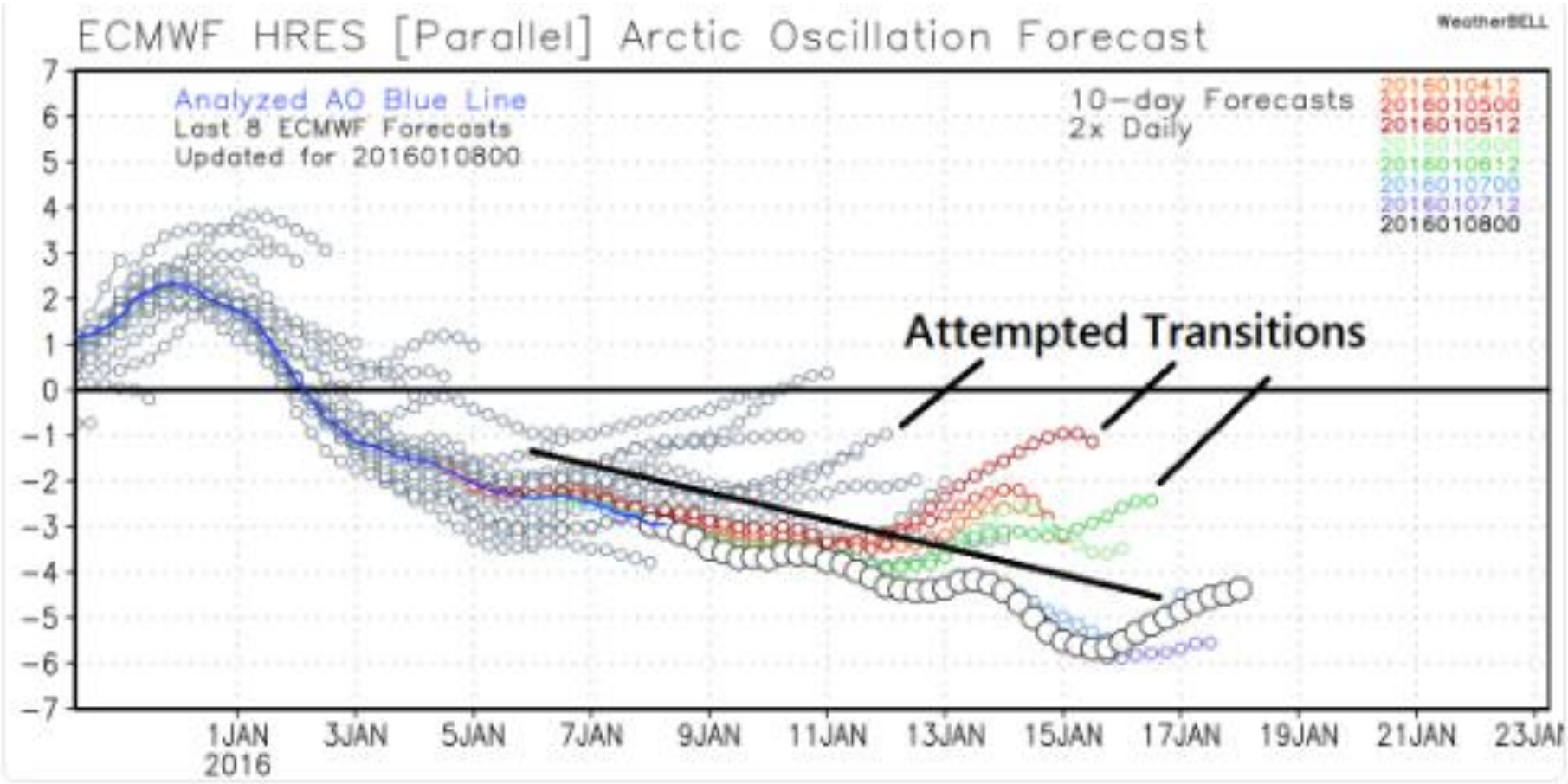


RETWEETS 13 LIKES 15



10:56 AM - 8 Jan 2016

Visualizing Arctic Oscillation Forecast Index

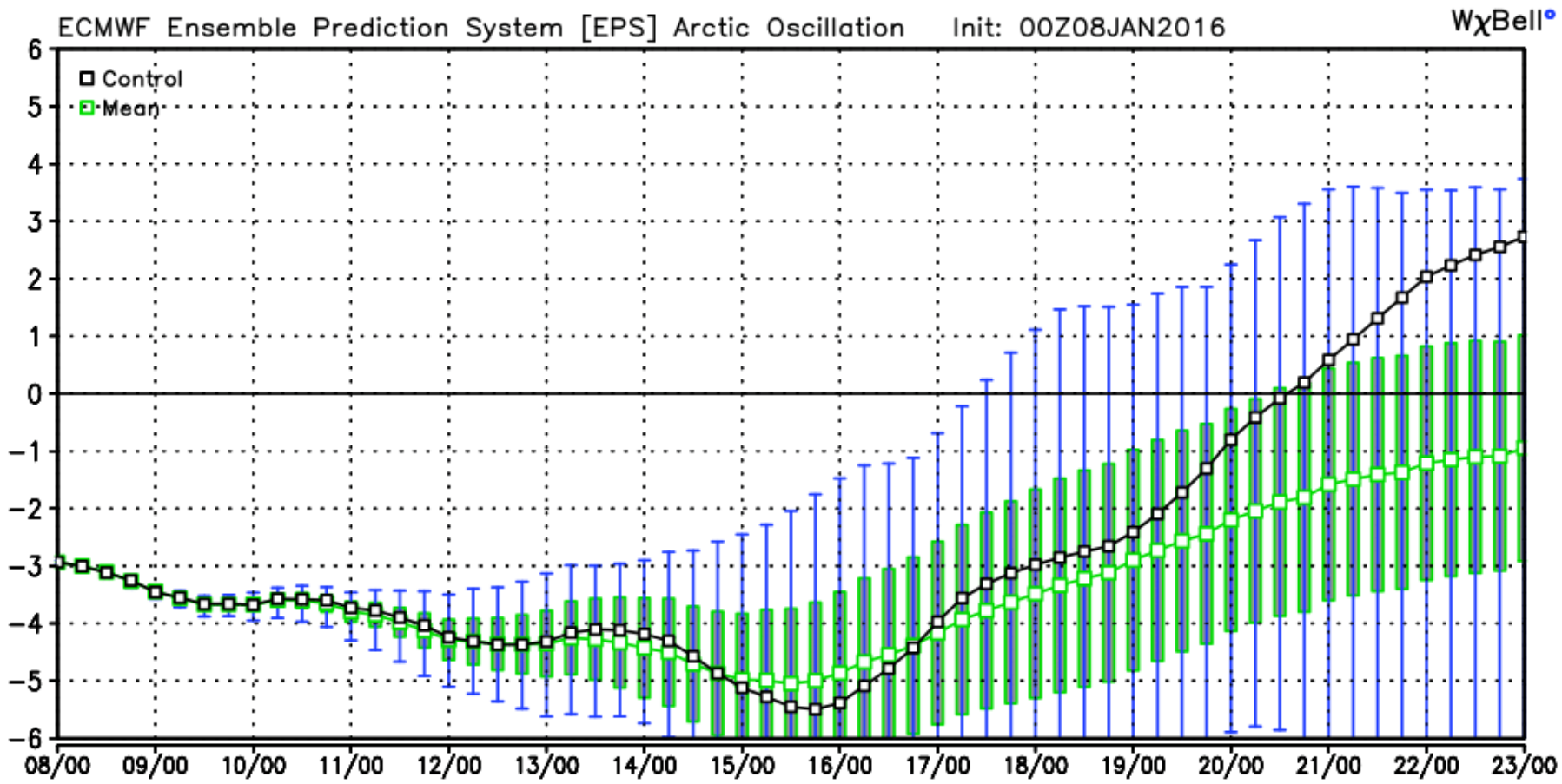


Bubbles

Analyzed AO, 10-day forecast bubbles

INIT: January 8, 2016 00z
HRES 41r2

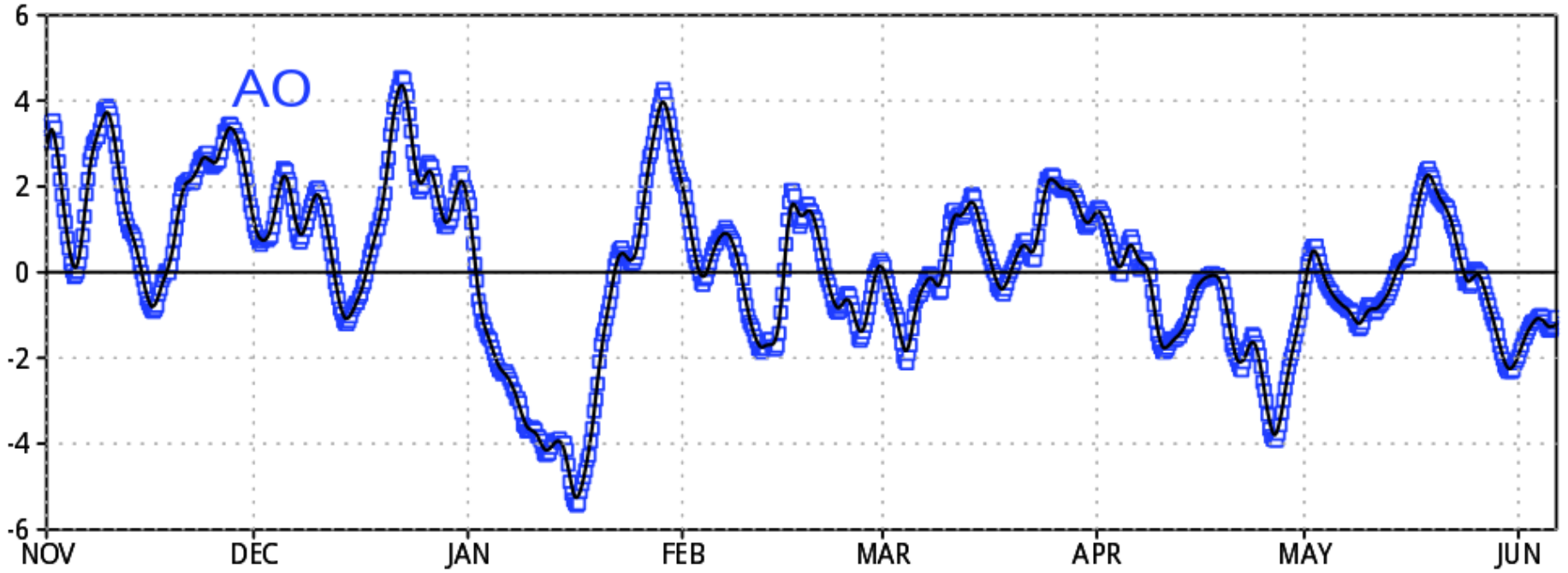
Visualizing Arctic Oscillation Forecast Index



Box & Whisker

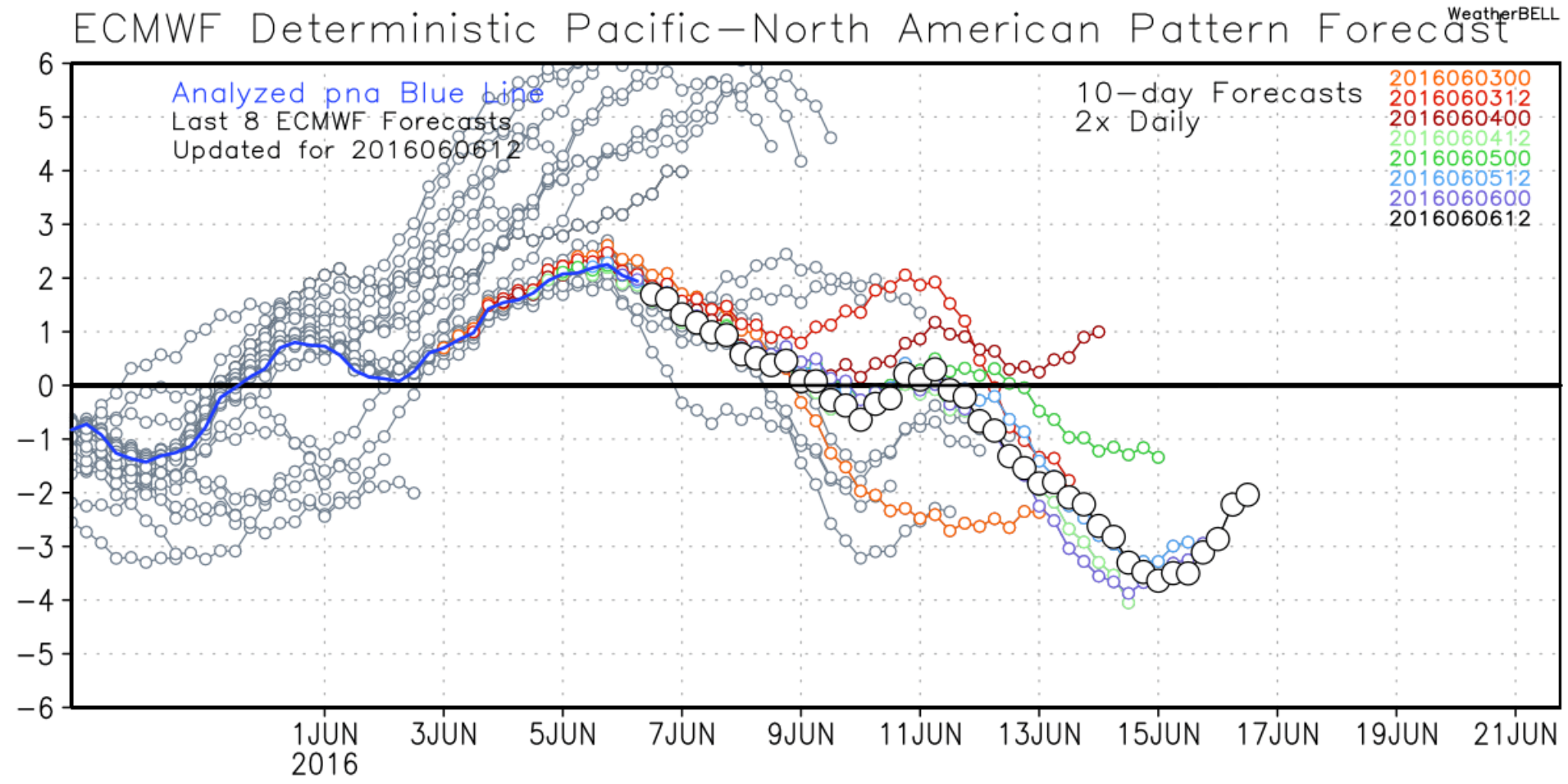
Forecast AO, 15-day EPS forecast, ensemble mean & distribution + control

Visualizing Arctic Oscillation Forecast Index



2015 2016

Visualizing PNA Forecast Index



Summary and Future Directions

- A decade archive of high-resolution operational center deterministic forecasts has been developed to study "dropouts" in medium-range forecast skill

- The models tend to "dropout" during the same forecasts, in "lower-predictability" flow regimes

- The Arctic Oscillation (AO) index is (to some extent) anti-correlated with medium-range forecast skill, as measured by the 5-day anomaly correlation of 500mb height

- Value of frozen model w/many years of data (~ 20) to evaluate model performance during particular large-scale flow regimes

- Value of multi-model & ensemble **forecast-forecast** correlations for medium-range extreme events

Acknowledgements

WeatherBELL Analytics [2012-present]

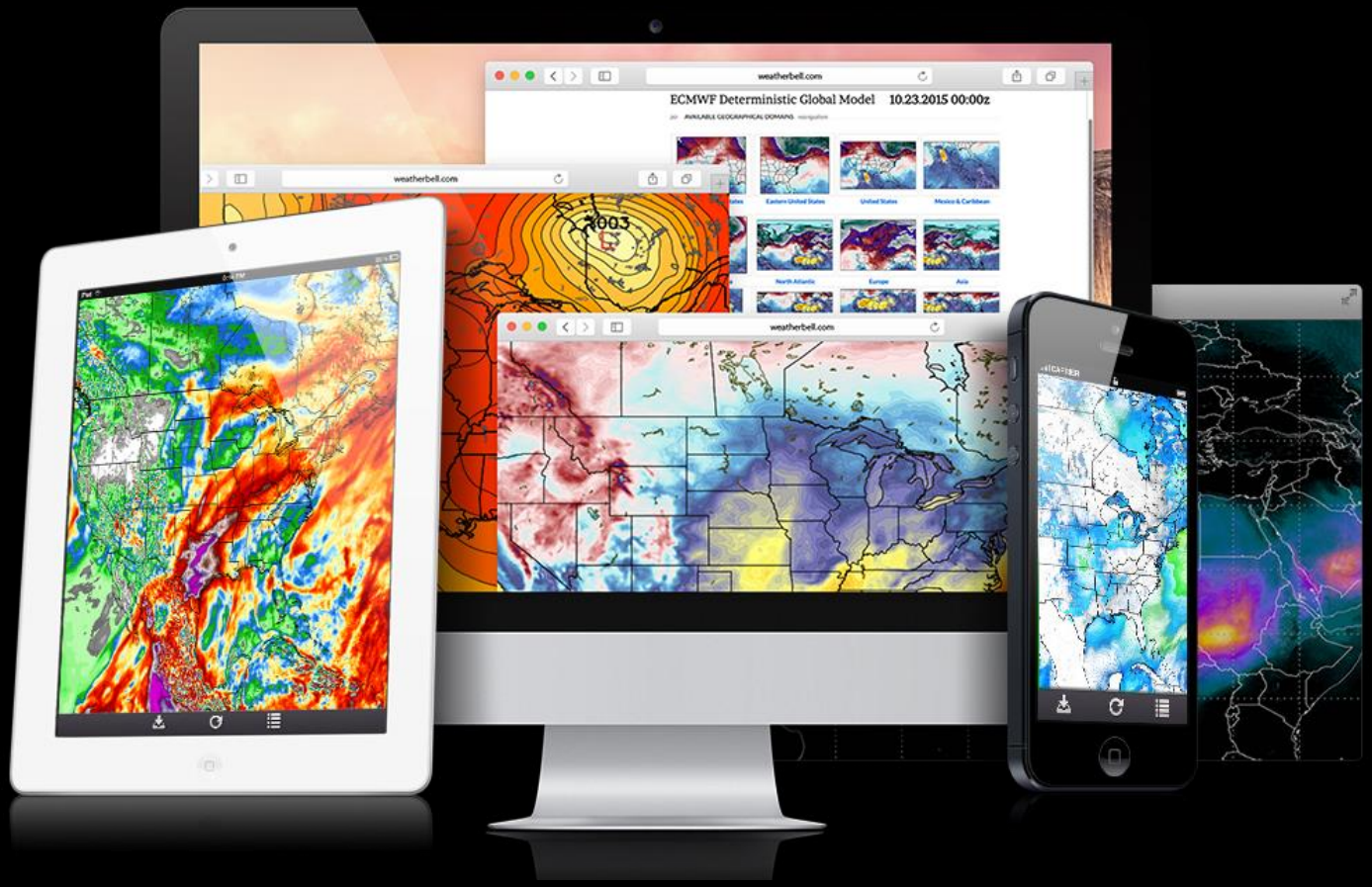
Data: ECMWF, NCEP/NOMADS, NRL-Monterey

NRC Postdoc at NRL Monterey [2010-2012]
advisor: Dr. Rolf H. Langland

Updated research work based on Langland and Maue (*Tellus A*, 2012):
Recent Northern Hemisphere mid-latitude medium-range deterministic forecast skill

Appreciation and Thanks to Dr. Ghelli and ECMWF!

WeatherBELL Models



http://models.weatherbell.com