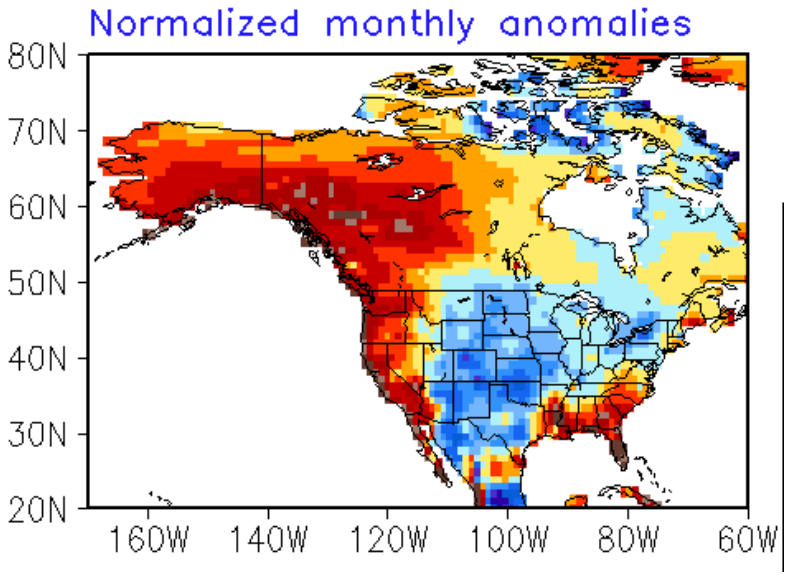
Subseasonal Prediction over the Western U.S.



Cliff Mass

Department of Atmospheric Sciences

University of Washington

Supported by the President of the U.S.

The **Obama Administration announced its intent to begin a coordinated U.S. effort, led by NOAA,** to initiate development of new extreme-weather outlooks in the 15-30 day range.

Subseasonal Definition for This Talk

- Forecasts for 1-7 weeks (7-45 days)

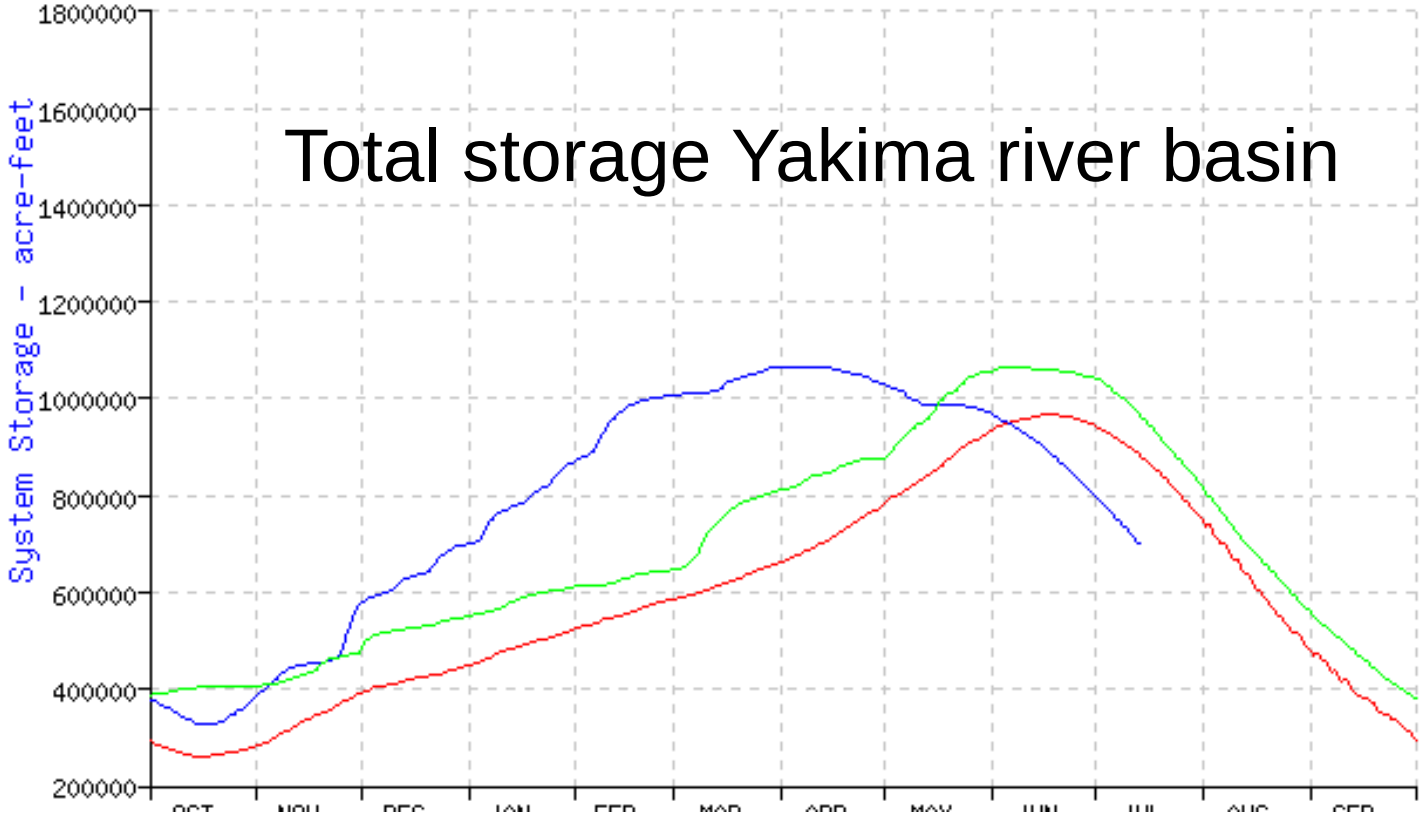
The Need for Subseasonal Prediction over the Western U.S.

- For flood preparation
- Dam and reservoir planning
- For agriculture management
- Preparation for wildfires
- Coastal fishery management (upwelling)
- And many more reasons….

Flood Control
Need a few weeks to safely lower dam/reservoirs levels

The Howard Hanson Dam Almost Failed in 2009: Endangering tens of thousands and tens of billions of dollars of assets

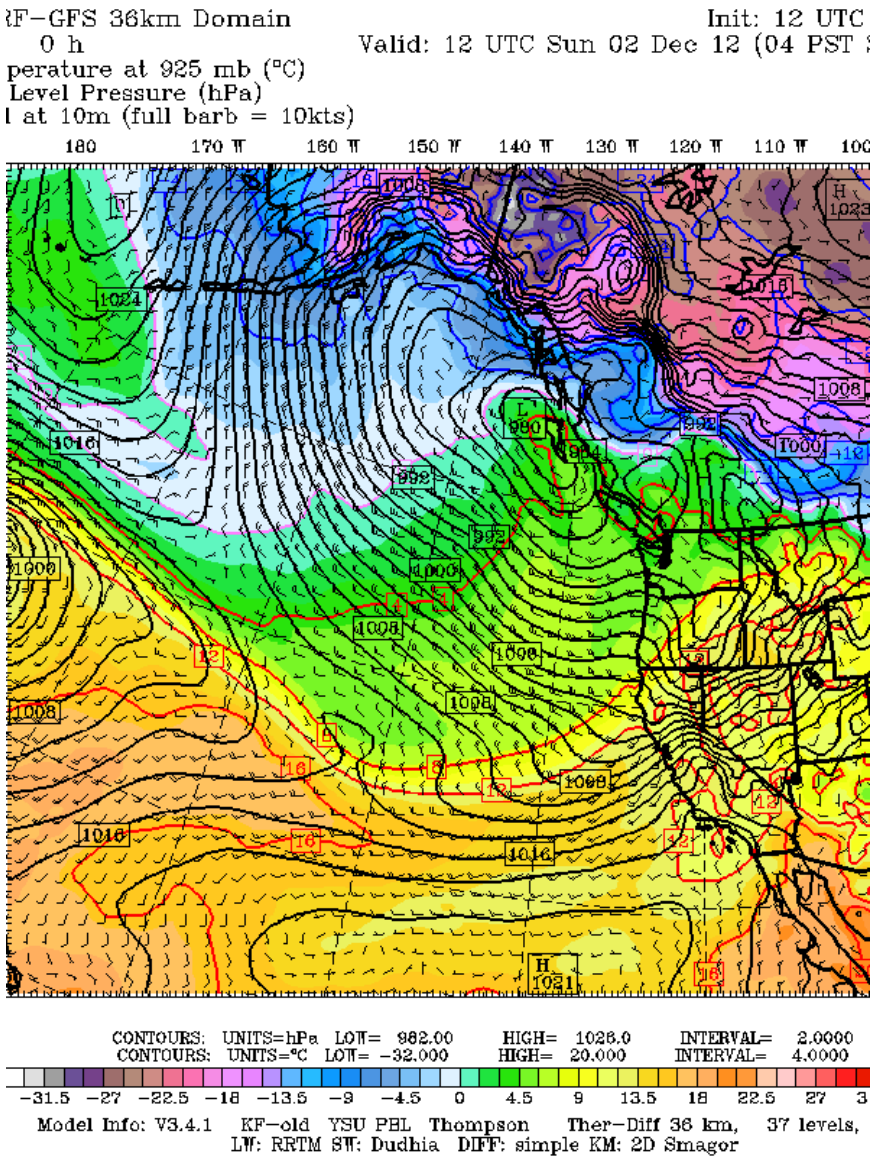
Reservoir Decisions: Store water for later or keep low for flood control?



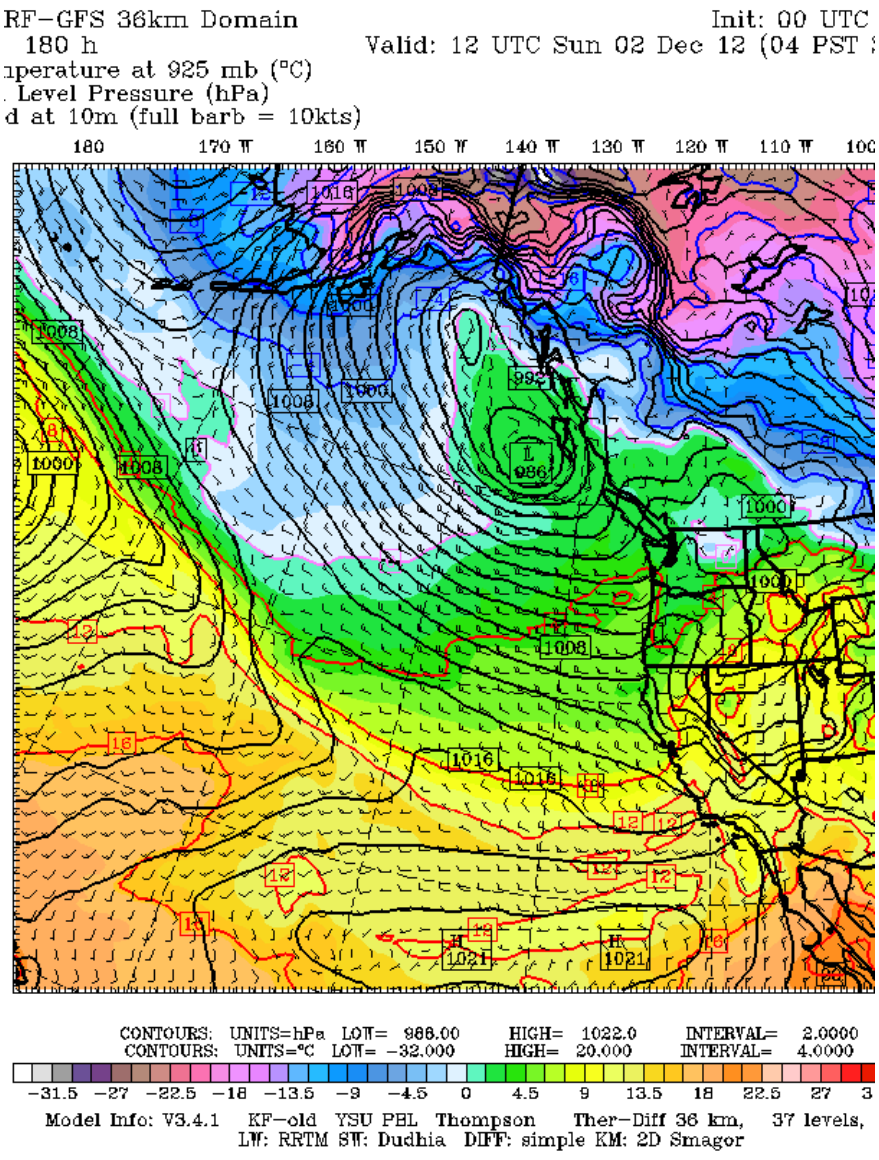
Subseasonal Prediction

- During the past decade it has become increasingly clear that deterministic and ensemble-based forecasts (GFS, ECMWF, UKMET) are often producinguseful skill extending into the second week.
- Superstorm Sandy was the poster child for this, but there are many more.

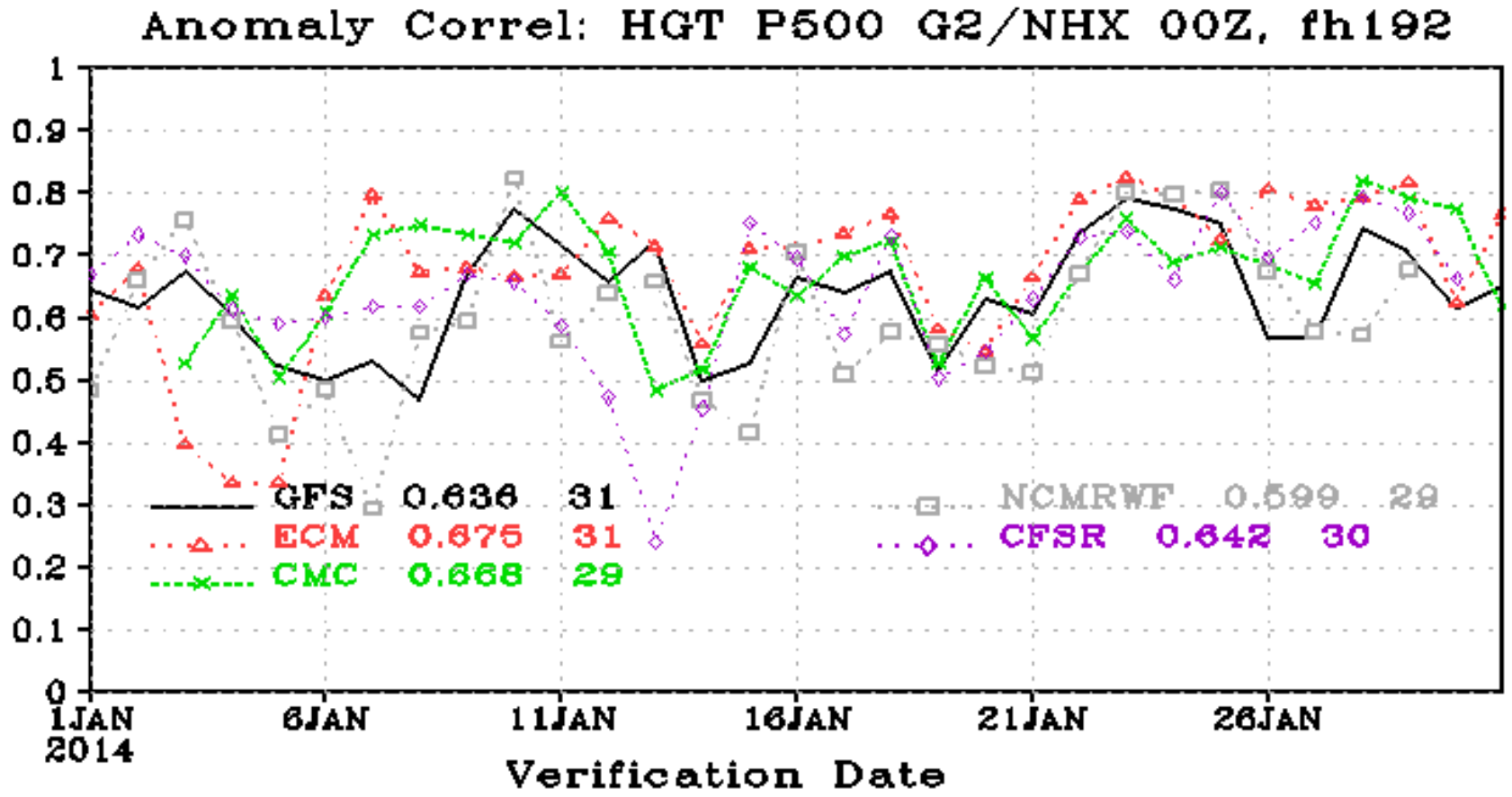
Observed



180 hr (7.5 days)

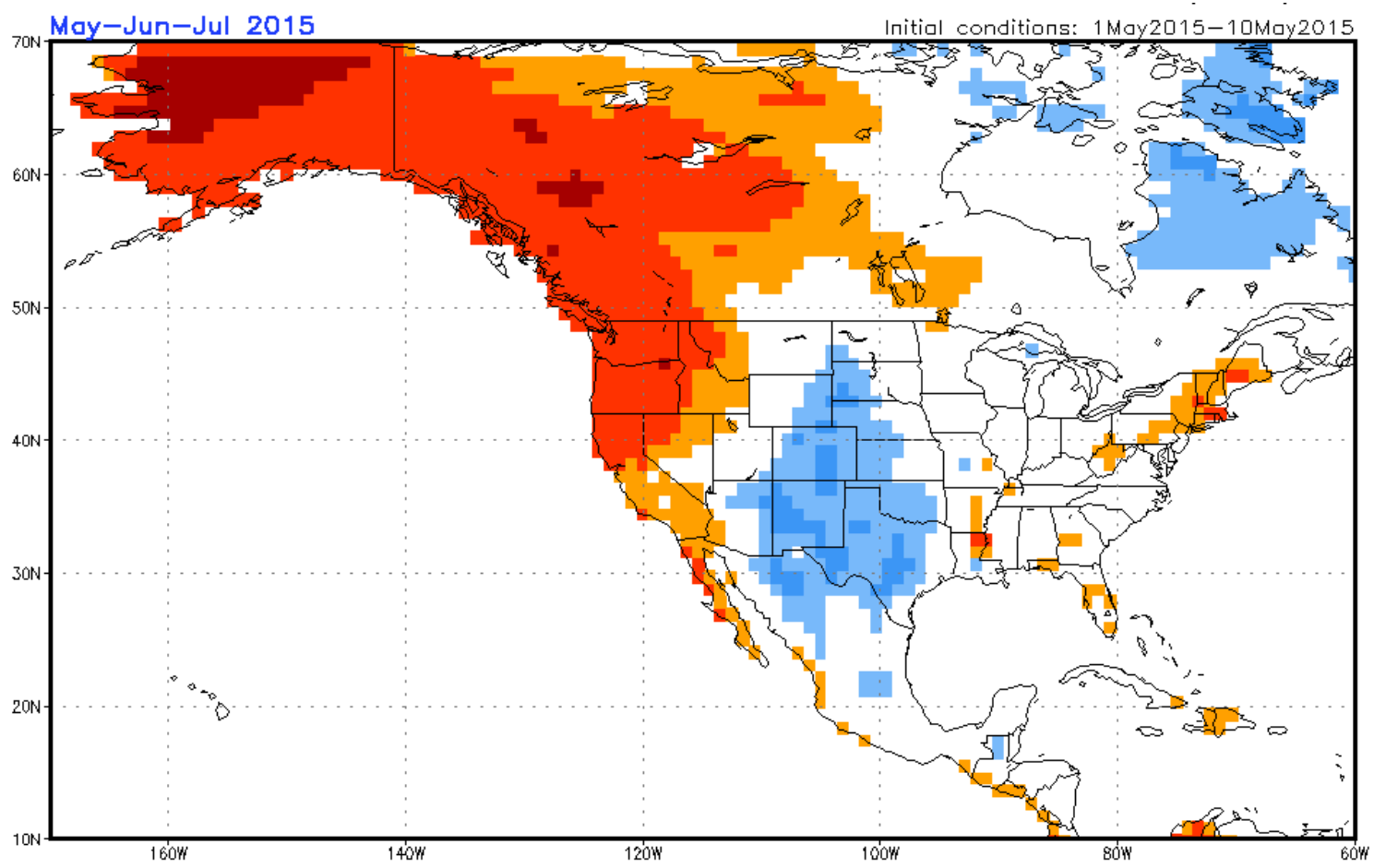


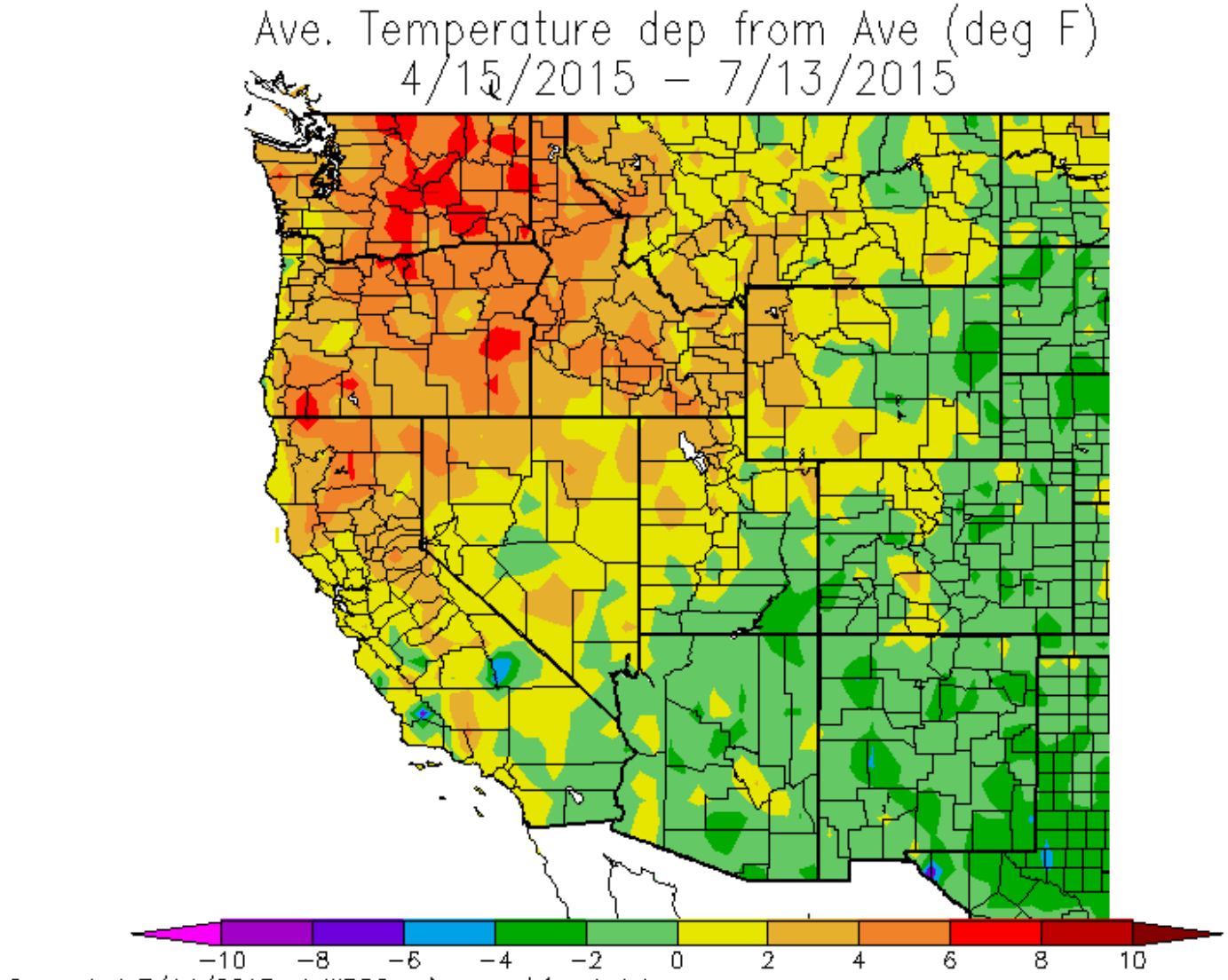
Frequent periods with .8 Anomaly Correlation at 8 days

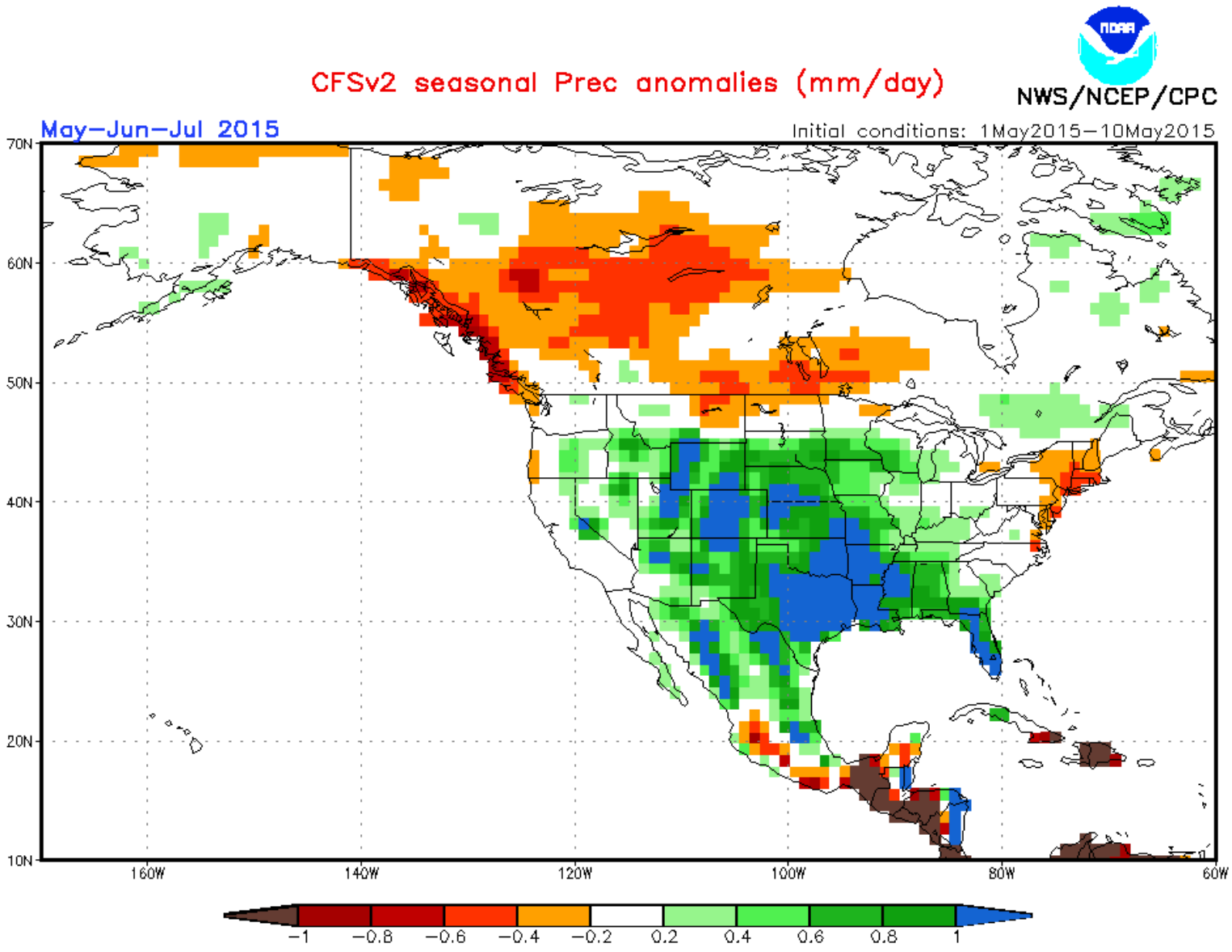


Extended Seasonal Models Like CFS Often Show Useful Skill Weeks to Months Ahead

2-m Temp (May-June-July)—Made in Early May

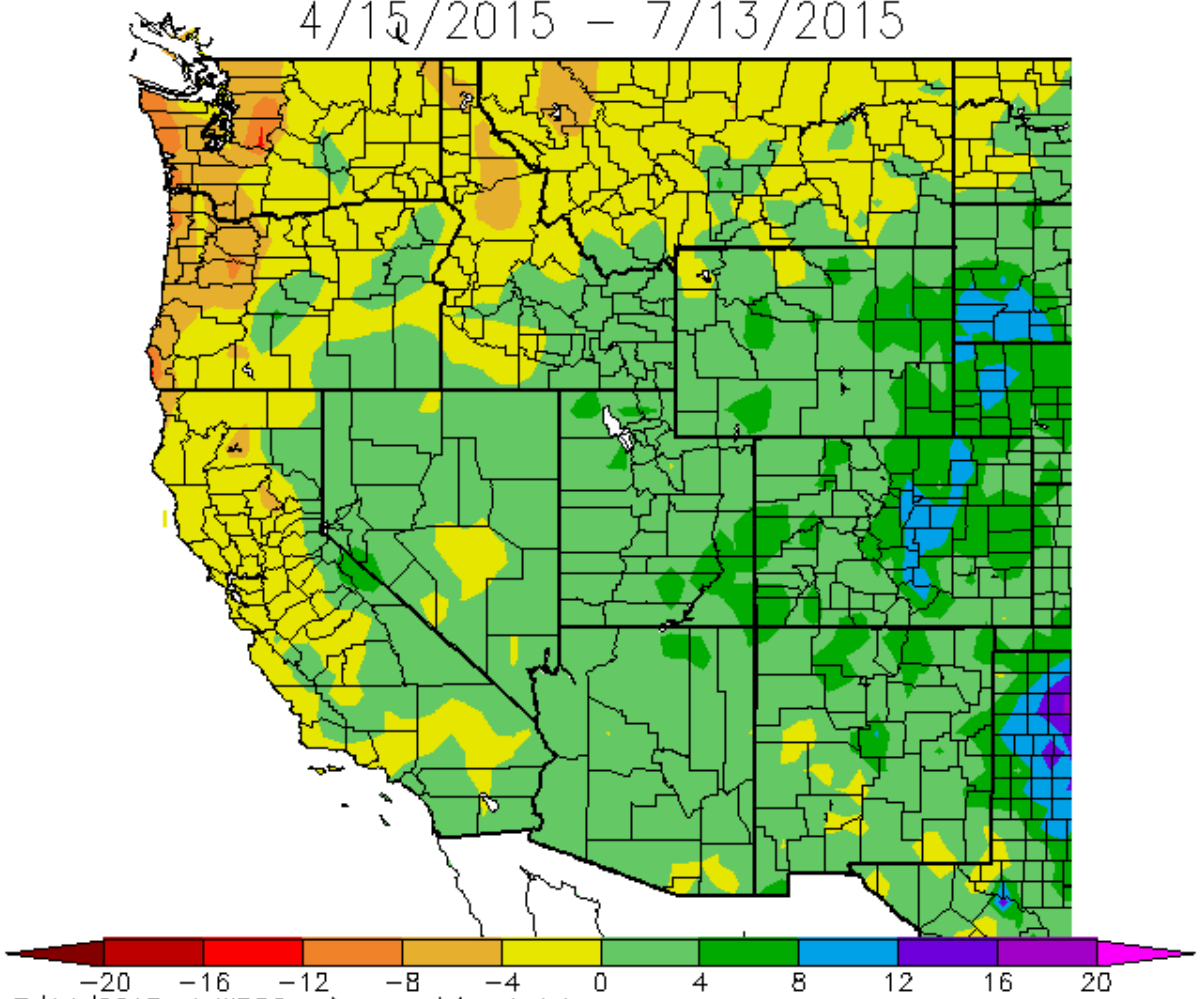



Ave. Temperature dep from Ave (deg F)
4/15/2015 – 7/13/2015
−10
−8
−6
−4
−2
0
2
4
6
8
10
Generated 7/14/2015 at WRCC using provisional data.
NOAA Regional Climate Centers


CFSv2 seasonal Prec anomalies (mm/day)
NWS/NCEP/CPC
May–Jun–Jul 2015
Initial conditions: 1May2015–10May2015
70N
60N
50N
40N
30N
20N
10N
160W
140W
120W
100W
80W
60W
−1
−0.8
−0.6
−0.4
−0.2
0.2
0.4
0.6
0.8
1

Precipitation Departure from Average (in.)

4/15/2015 – 7/13/2015



Generated 7/14/2015 at WRCC using provisional data.
NOAA Regional Climate Centers

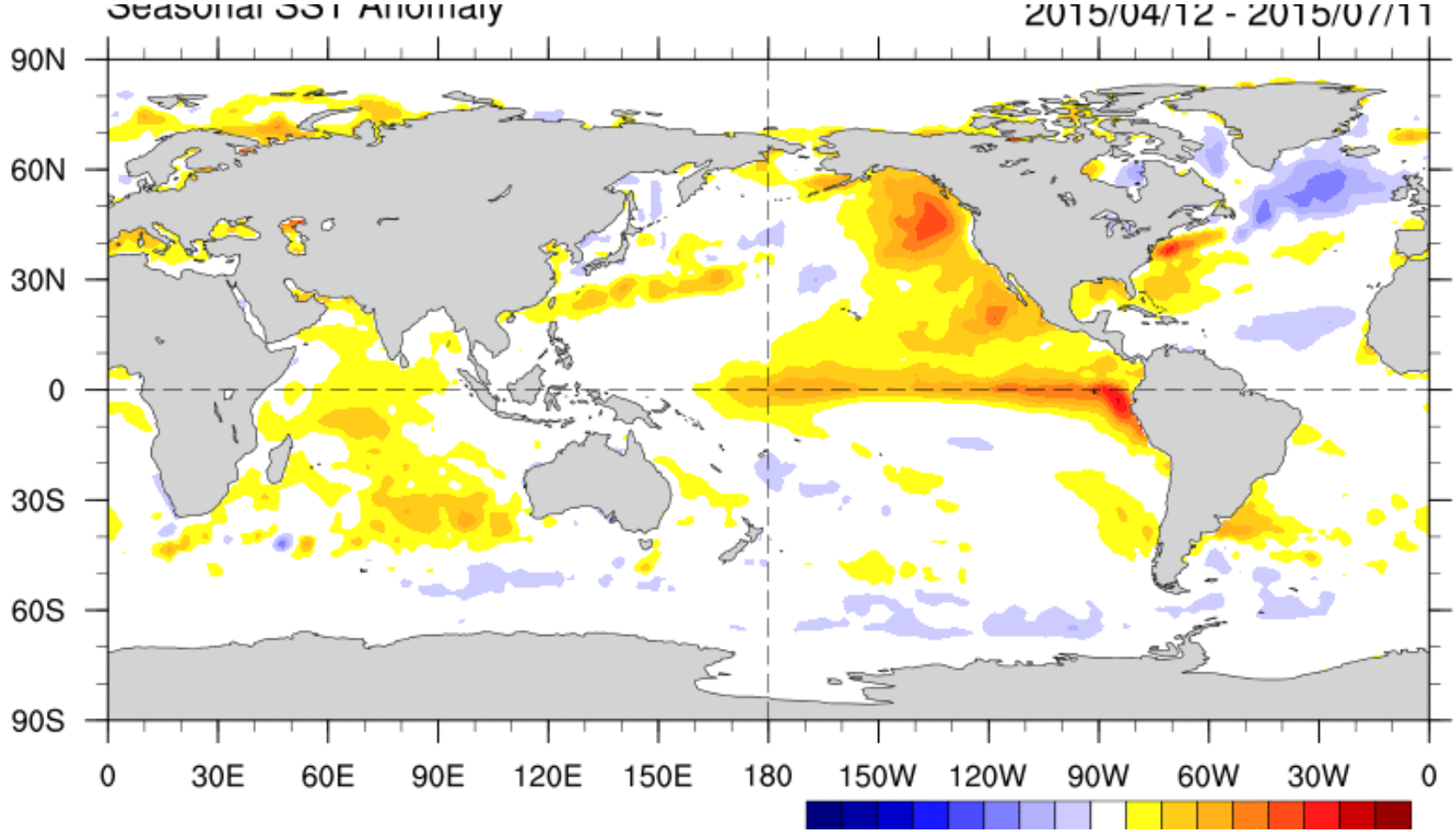
The promise of subseasonal forecast skill and the acute need inspired the UW Project that begun on May 1

But there is something else…

A Question

- Is the western U.S. an area of higher subseasonal predictability because of its proximity to the Pacific?
  - Strong connection to ENSO
  - Strong connections to MJO
  - Strong connection with relatively slowly varying Pacific Ocean

Example: the BLOB




INDESCRIBABLE...
INDESTRUCTIBLE!
NOTHING CAN STOP IT!
THE BLOB
STEVEN
McQUEEN
CORSAUT
ROWE
JACK H. HARRIS
IRVIN S. YEAWORTH JR.
THEODORE SIMONSON and KATE PHILLIPS

The Blob

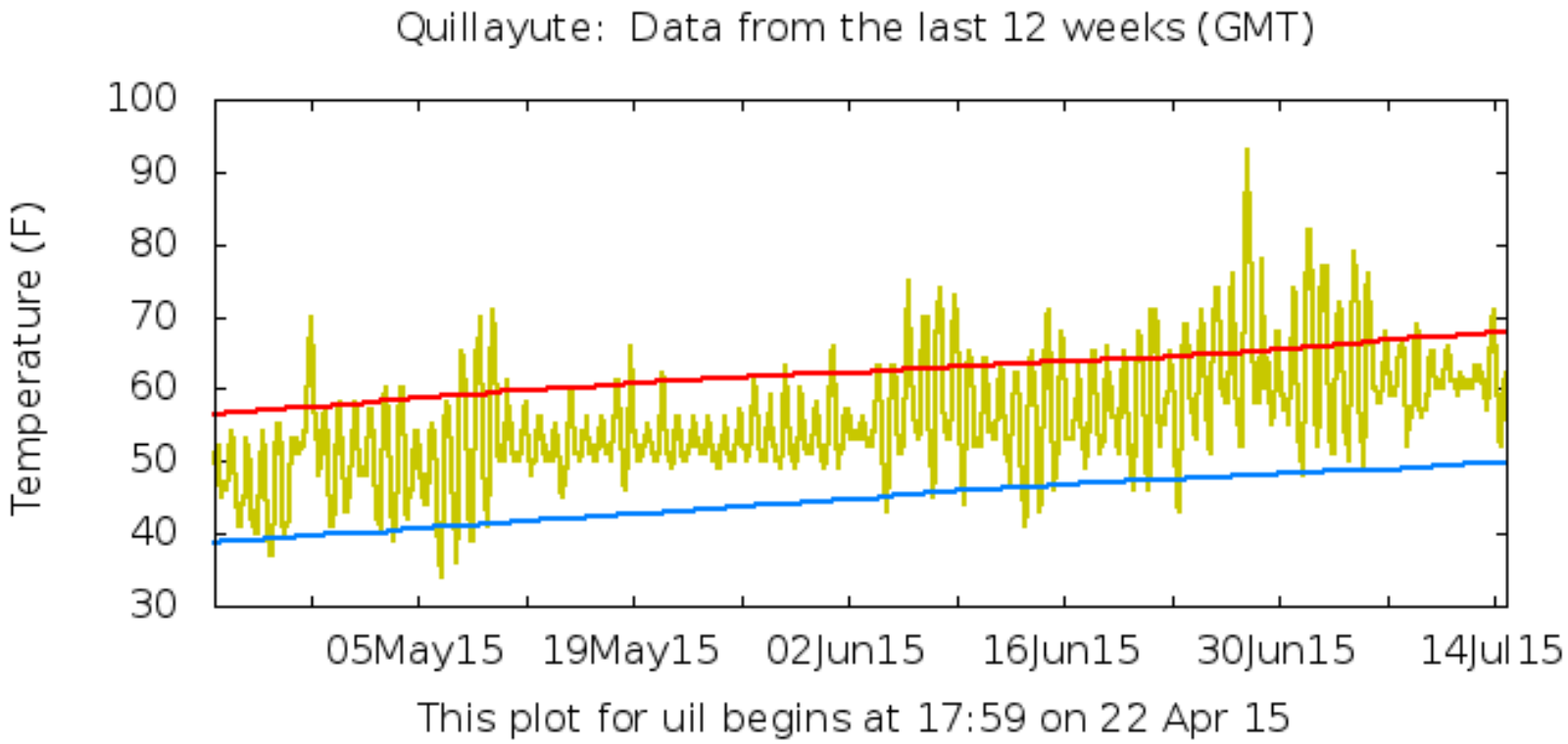
Geophysical Research Letters
AN AGU JOURNAL

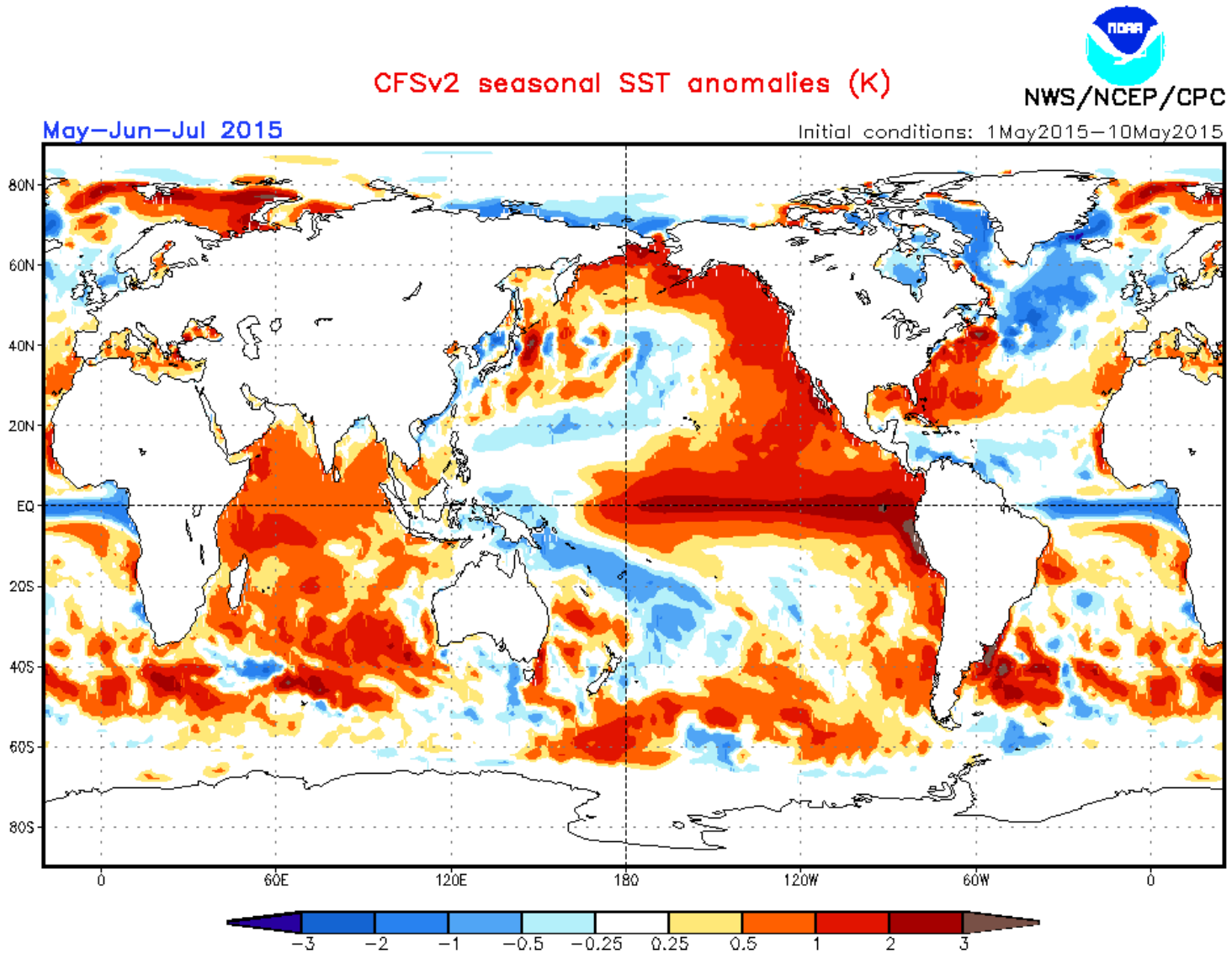
Research Letter

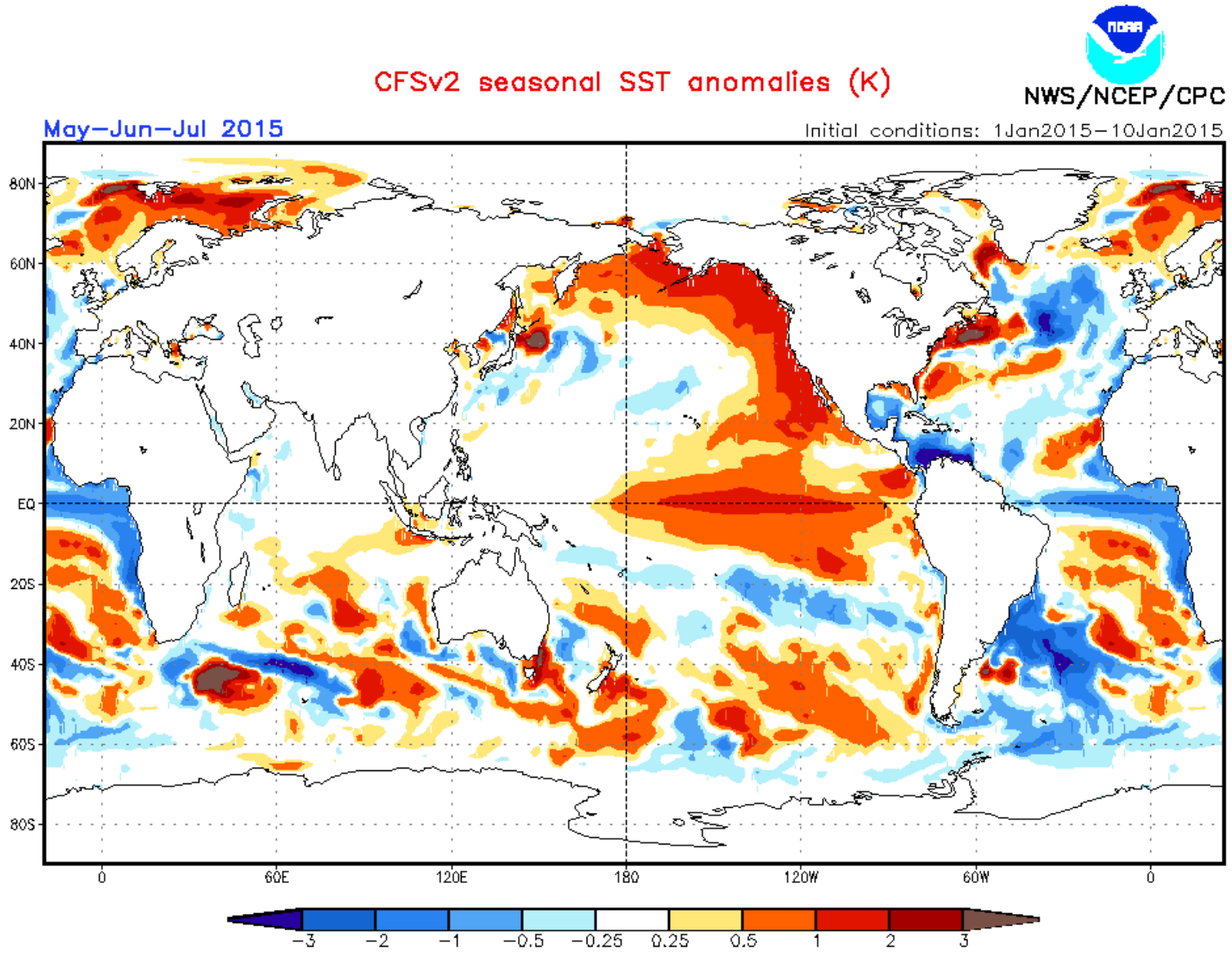
Causes and impacts of the 2014 warm anomaly in the NE Pacific

Nicholas A. Bond, Meghan F. Cronin, Howard Freeland, Nathan Mantua

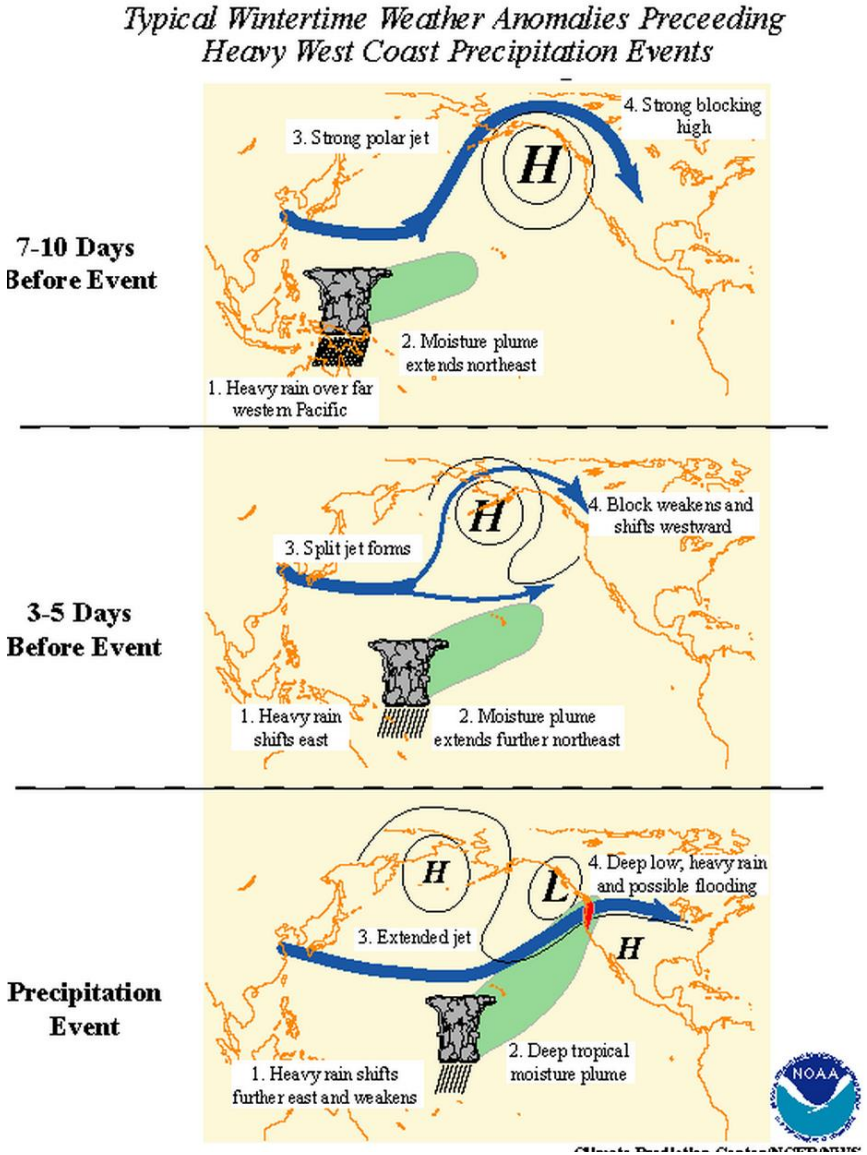
Surface Temperatures: Coastal Location




CFSv2 seasonal SST anomalies (K)
NWS/NCEP/CPC
May–Jun–Jul 2015
Initial conditions: 1May2015–10May2015
80N
60N
40N
20N
EQ
20S
40S
60S
80S
0
60E
120E
180
120W
60W
0
−3
−2
−1
−0.5
−0.25
0.25
0.5
1
2
3


CFSv2 seasonal SST anomalies (K)
NWS/NCEP/CPC
May–Jun–Jul 2015
Initial conditions: 1Jan2015–10Jan2015
80N
60N
40N
20N
EQ
20S
40S
60S
80S
0
60E
120E
180
120W
60W
0
−3
−2
−1
−0.5
−0.25
0.25
0.5
1
2
3

MJO and Atmospheric Rives



More Questions

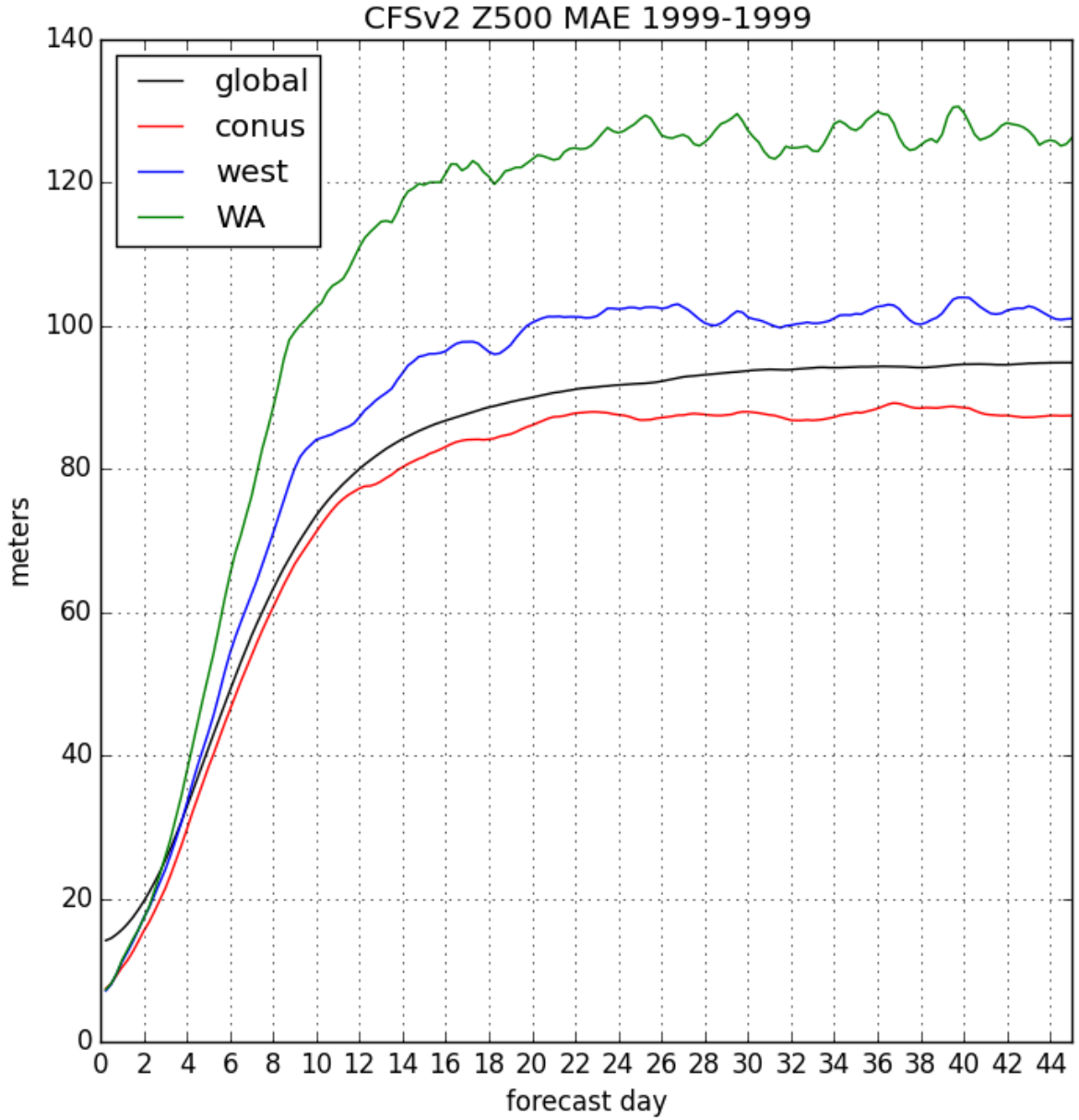
- How does CFS synoptic and surface parameter skill vary spatially, in this case…western NA?
- Are their areas where CFS is more skillful?
- How does skill change with averaging time and projection, season, synoptic situation.
- How can we create a useful ensemble of CFS forecasts?
- Can next-generation post-processing help?

Task 1: Evaluate CFS Synoptic Skill

- How does CFS synoptic skill vary in time over **western North America** for **various seasons**
- Does it vary spatially over the region?
- How does CFS vary with averaging time?
  - E.g., instantaneous, 1 day, 3 day, 7 day, two week, etc.. **Hypothesis: skill extends in time when averaging time longer**.
- Will examine multiple parameters

Task 1

- Will use either CFS zero hour forecast or NCEP reanalysis for gridded verification.
- Evaluate the skill of a CFS ensemble made by combining the 16 runs available daily
- Can use CFSv2 reforecast to secure a longer verification period (at least back to 1999).
- Can also verify CFS surface parameters (but will have serious resolution issues)


CFSv2 Z500 MAE 1999-1999
global
conus
west
WA
meters
forecast day
0
20
40
60
80
100
120
140
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44

Task 2: Post-processing of CFSv2 and its evaluation

- Can an ensemble of CFS forecasts be post-processed to improve skill?

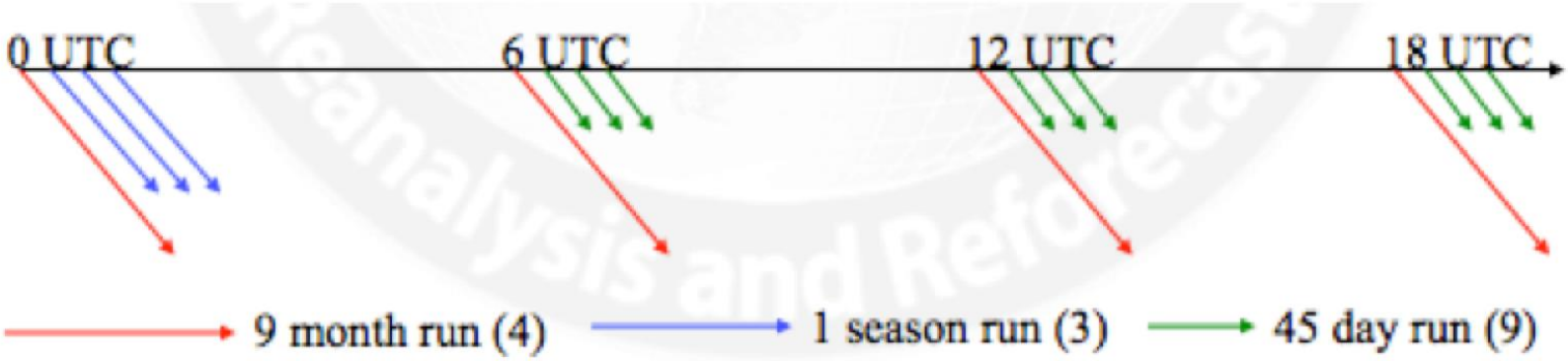


Figure 1: Operational CFSv2 configuration

Task 2: Experiment with EFA

- Can EFA (*Ensemble Forecast Adjustment*) be used to improve CFS forecasts (Madaus and Hakim 2015)?
- Observations taken after initialization time correct the subsequent forecast times. This approach exploits ensemble-estimated covariances in *both* space and time using an ensemble (ensemble of CFS forecasts).
- As the forecast proceeds, the difference between the ensemble forecasts and the observations are calculated, and the temporal covariances based on the ensemble of previous forecasts can be used to adjust the forecasts in the future

Task 2: Bayesian Model Averaging

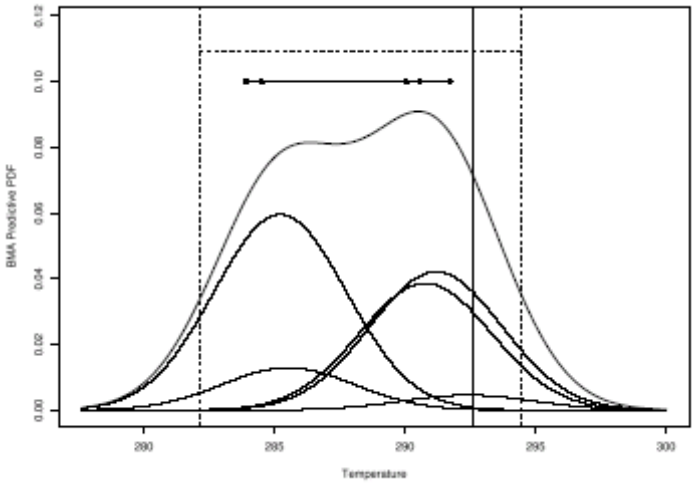
The BMA Model

- The predictive PDF is a mixture of PDFs, each one centered on one of the forecasts after bias correction.
- Let y be the observed value.
- Let $\tilde{y}_k$ be the kth forecast from the ensemble
- The BMA model is:

$$p(y|\tilde{y}_1, \ldots, \tilde{y}_K) = \sum_{k=1}^{K} w_k N(a_k + b_k \tilde{y}_k, \sigma^2)$$

where $w_k \geq 0$ and $\sum_{k=1}^{K} w_k = 1$.

- The model is estimated from a training set of recent data by maximum likelihood using the EM algorithm.



[c.f. Raftery et al. 2005, Mon. Wea. Rev.]

Bayesian Model Averaging (BMA)

- Reduces bias
- Weights model output based on past performance.
- Produces calibrated PDF.
- Lots of experience with BMA at the UW.

Using Bayesian Model Averaging to Calibrate Forecast Ensembles

ADRIAN E. RAFTERY, TILMANN GNEITING, FADOUA BALABDAOUI, AND MICHAEL POLAKOWSKI

Department of Statistics, University of Washington, Seattle, Washington

(Manuscript received 18 December 2003, in final form 29 September 2004)

Calibrating Multimodel Forecast Ensembles with Exchangeable and Missing Members Using Bayesian Model Averaging

CHRIS FRALEY AND ADRIAN E. RAFTERY

University of Washington, Seattle, Washington

TILMANN GNEITING

Universitat Heidelberg, Heidelberg, Germany

Probcast: Based on BMA

University of Washington Probability Forecast

Click a number on the table to select a new weather map; **click the weather map** or **fill in a zip code** to select a new location for the table. The yellow shows the current map; the star shows the current location.

Seattle, WA 98105 (47.66 N, 122.30 W) **City or Zip Code:** 98105 go

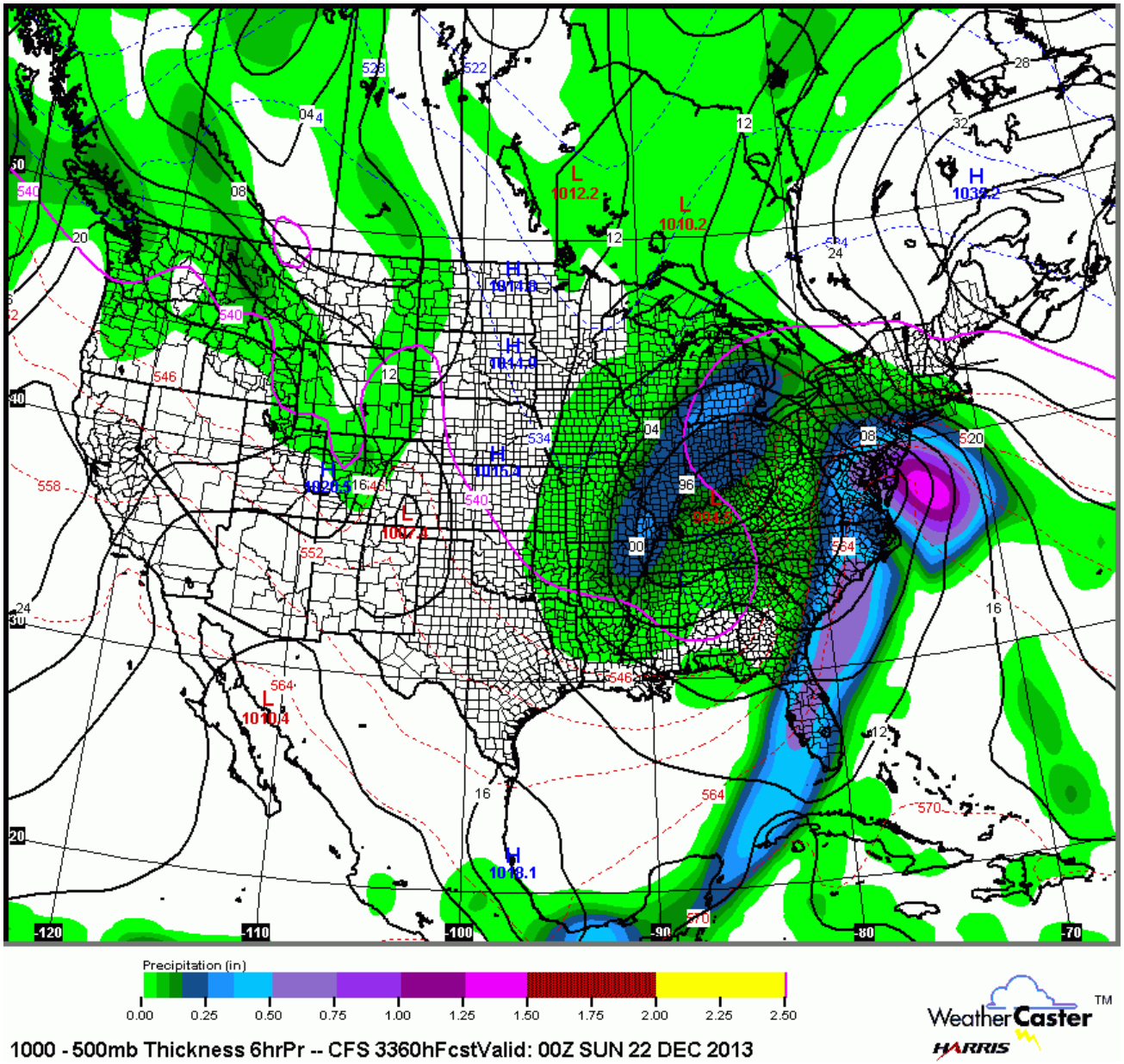
	Thu Jul 16	Thu Jul 16 Night	Fri Jul 17	Fri Jul 17 Night	Sat Jul 18
TEMP	Daytime High **77°** 10% chance greater than **82°** 10% chance less than **72°**	Nighttime Low **55°** Chance freeze: **0%** 10% chance greater than **60°** 10% chance less than **50°**	Daytime High **80°** 10% chance greater than **85°** 10% chance less than **75°**	Nighttime Low **59°** Chance freeze: **0%** 10% chance greater than **63°** 10% chance less than **54°**	Daytime High **87°** 10% chance greater than **92°** 10% chance less than **81°**
xPRECIP	Chance of Precip **5%** 10% chance **.0"** or more	Chance of Precip **5%** 10% chance **.0"** or more	Chance of Precip **5%** 10% chance **.0"** or more	Chance of Precip **5%** 10% chance **.0"** or more	Chance of Precip **5%** 10% chance **.0"** or more

Task 2: Dynamical Downscaling

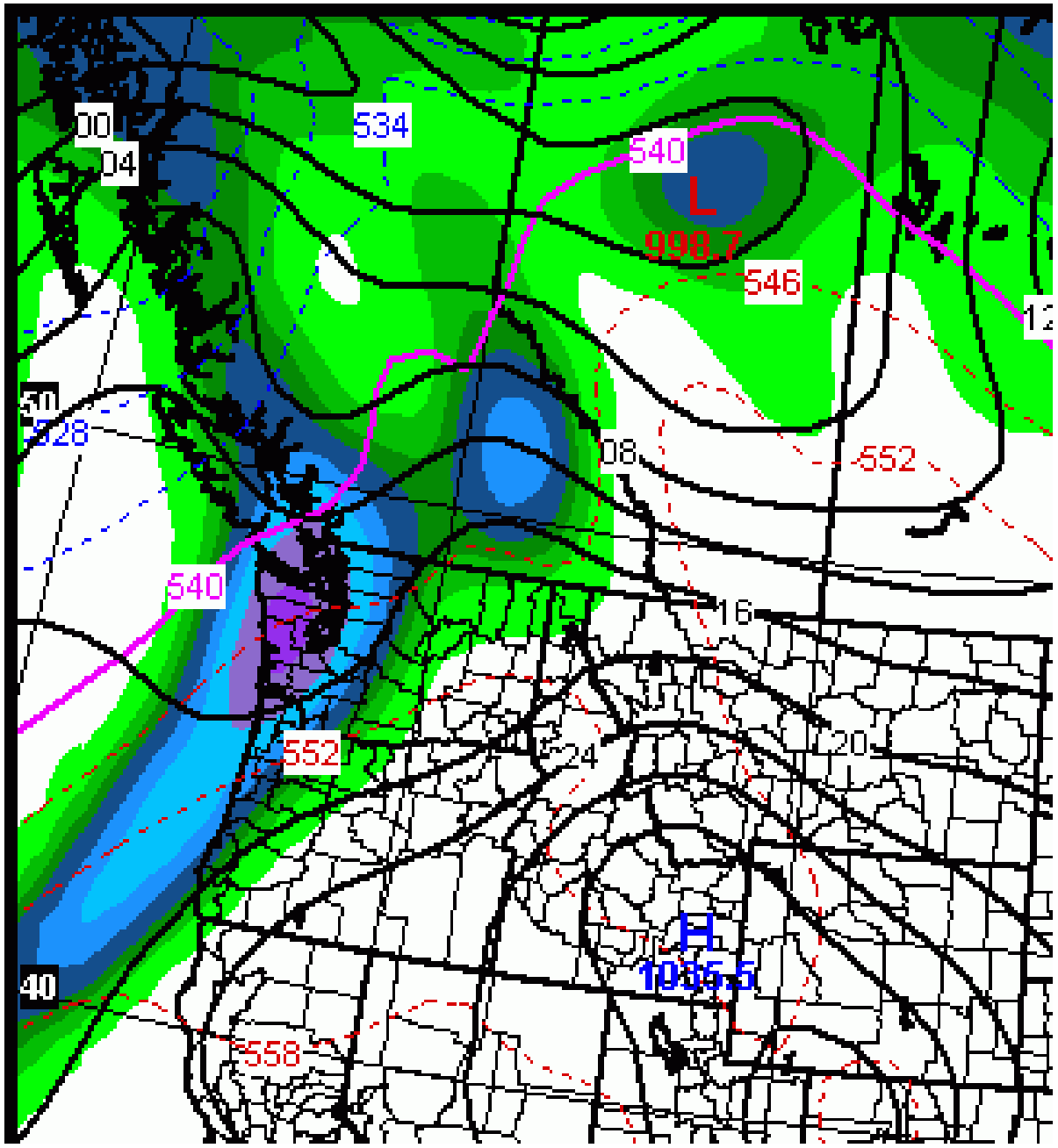
- The effective resolution of the CFS (~100 km) is sufficient to define the synoptic scale flow over the western U.S., **but too coarse to simulate most coastal and terrain-induced regional atmospheric mesoscale features**, such as orographically forced precipitation and coastally trapped southerly flow and thermal troughs

Dynamical Downscaling

- Thus, it is necessary to dynamically downscale WRF to at least 12-15 km grid spacing, **the resolution that appears necessary to realistically define the key mesoscale features of the western U.S.**

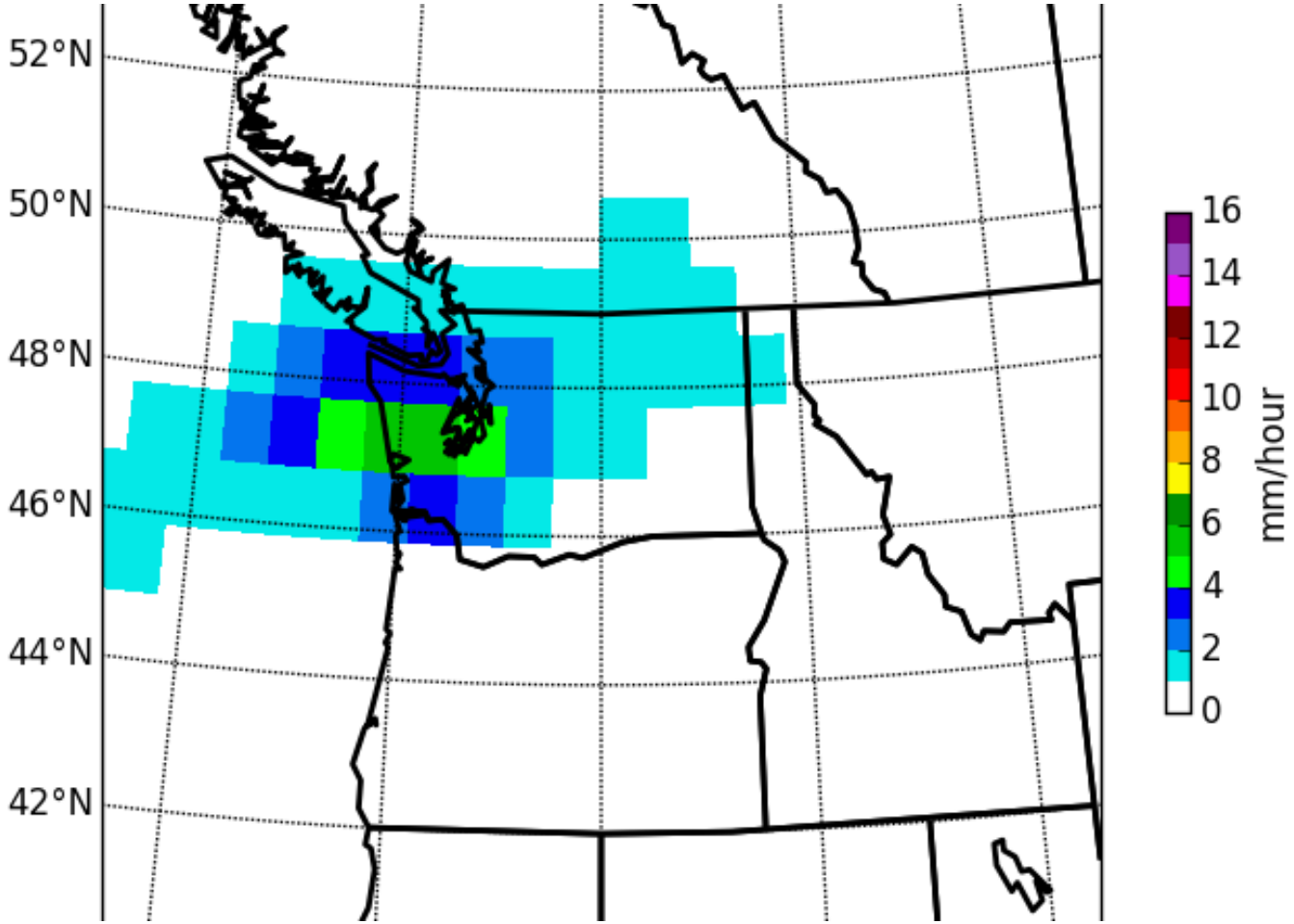

Precipitation (in)
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50
1000 - 500mb Thickness 6hrPr -- CFS 3360hFcstValid: 00Z SUN 22 DEC 2013
WeatherCaster
HARRIS

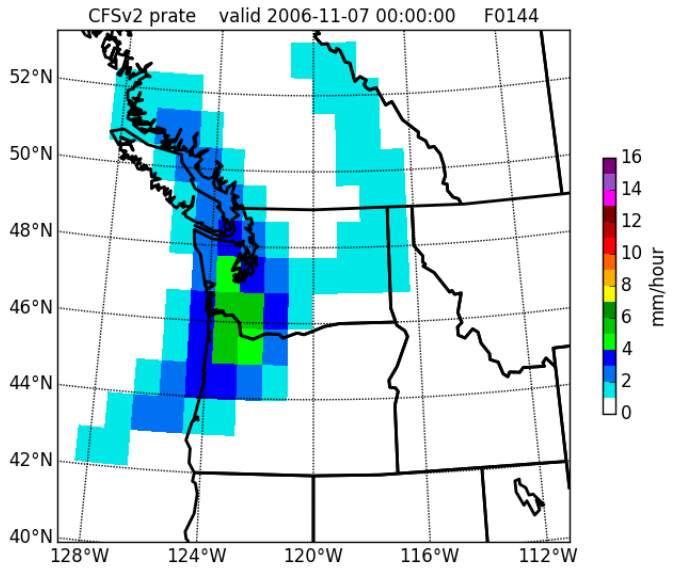
CFS

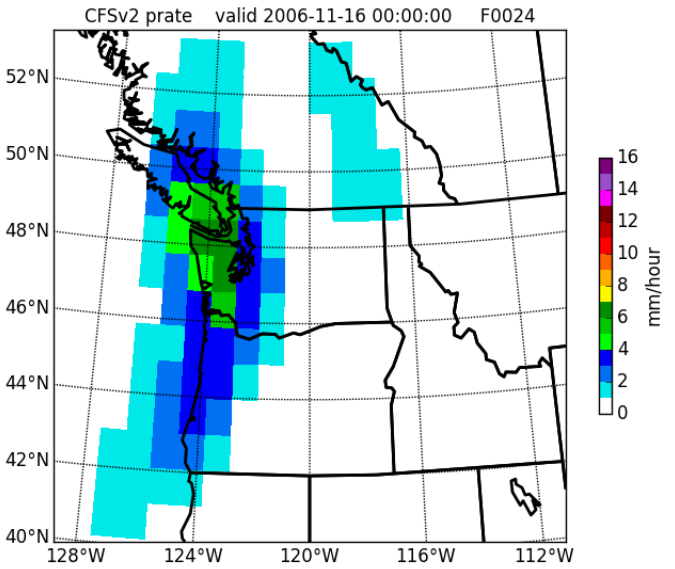


CFS

CFS Precipitation




CFSv2 prate valid 2006-11-07 00:00:00 F0144
52°N
50°N
48°N
46°N
44°N
42°N
40°N
128°W
124°W
120°W
116°W
112°W
16
14
12
10
8
6
4
2
0
mm/hour


CFSv2 prate valid 2006-11-16 00:00:00 F0024
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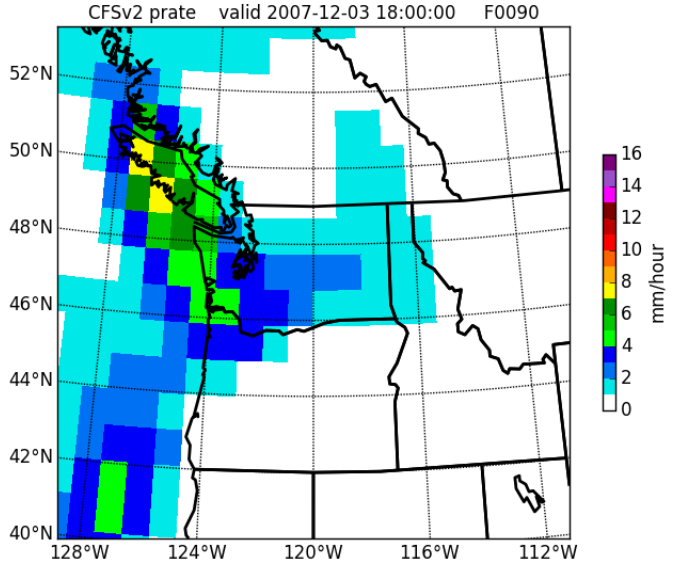
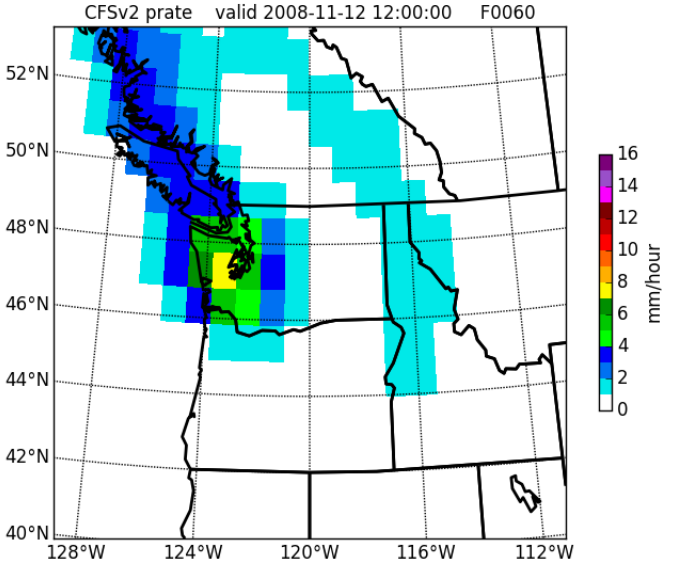
50°N
48°N
46°N
44°N
42°N
40°N
128°W
124°W
120°W
116°W
112°W
16
14
12
10
8
6
4
2
0
mm/hour


CFSv2 prate valid 2007-12-03 18:00:00 F0090
52°N
50°N
48°N
46°N
44°N
42°N
40°N
128°W
124°W
120°W
116°W
112°W
16
14
12
10
8
6
4
2
0
mm/hour


CFSv2 prate valid 2008-11-12 12:00:00 F0060
52°N
50°N
48°N
46°N
44°N
42°N
40°N
128°W
124°W
120°W
116°W
112°W
16
14
12
10
8
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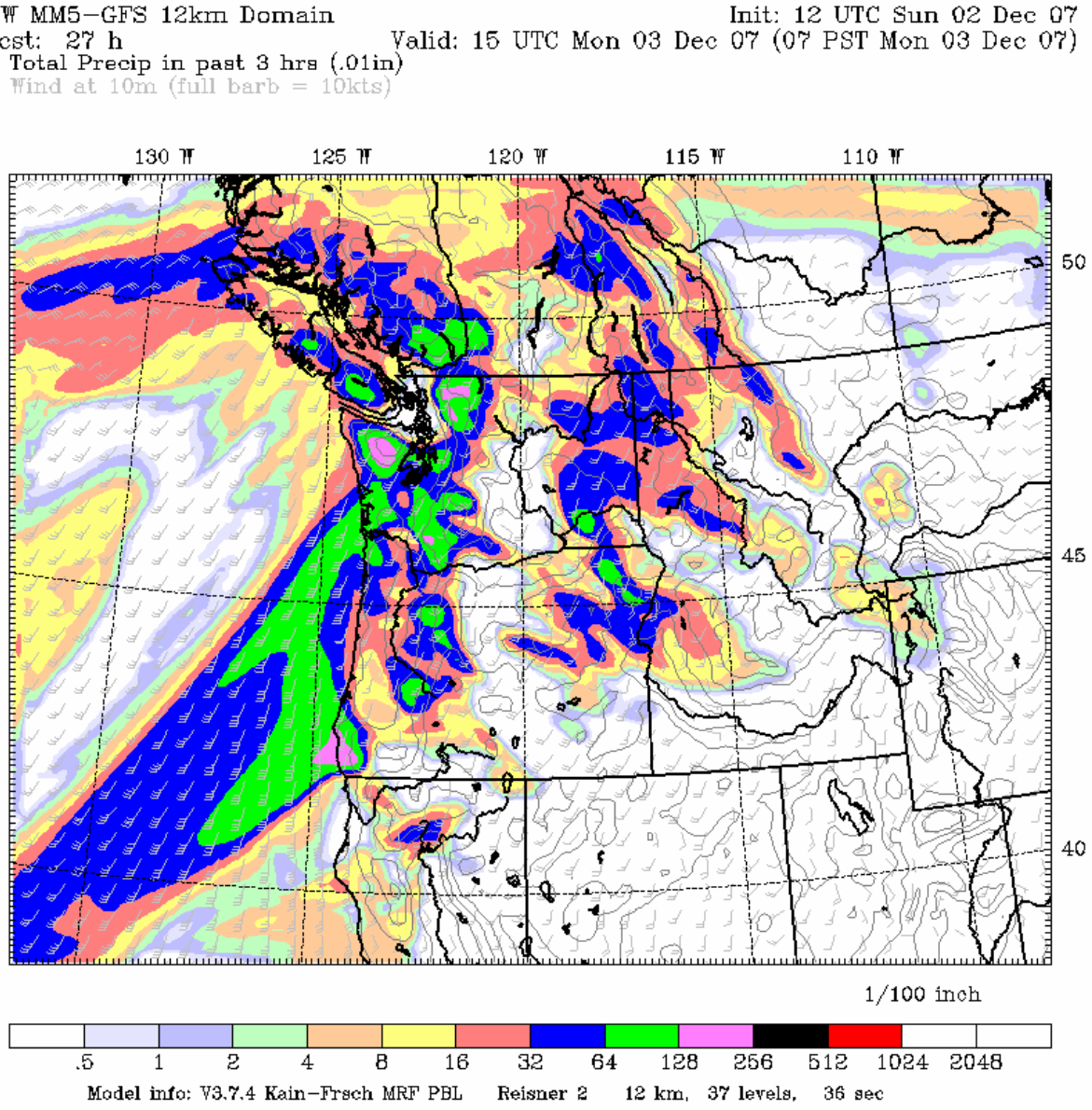
2
0
mm/hour

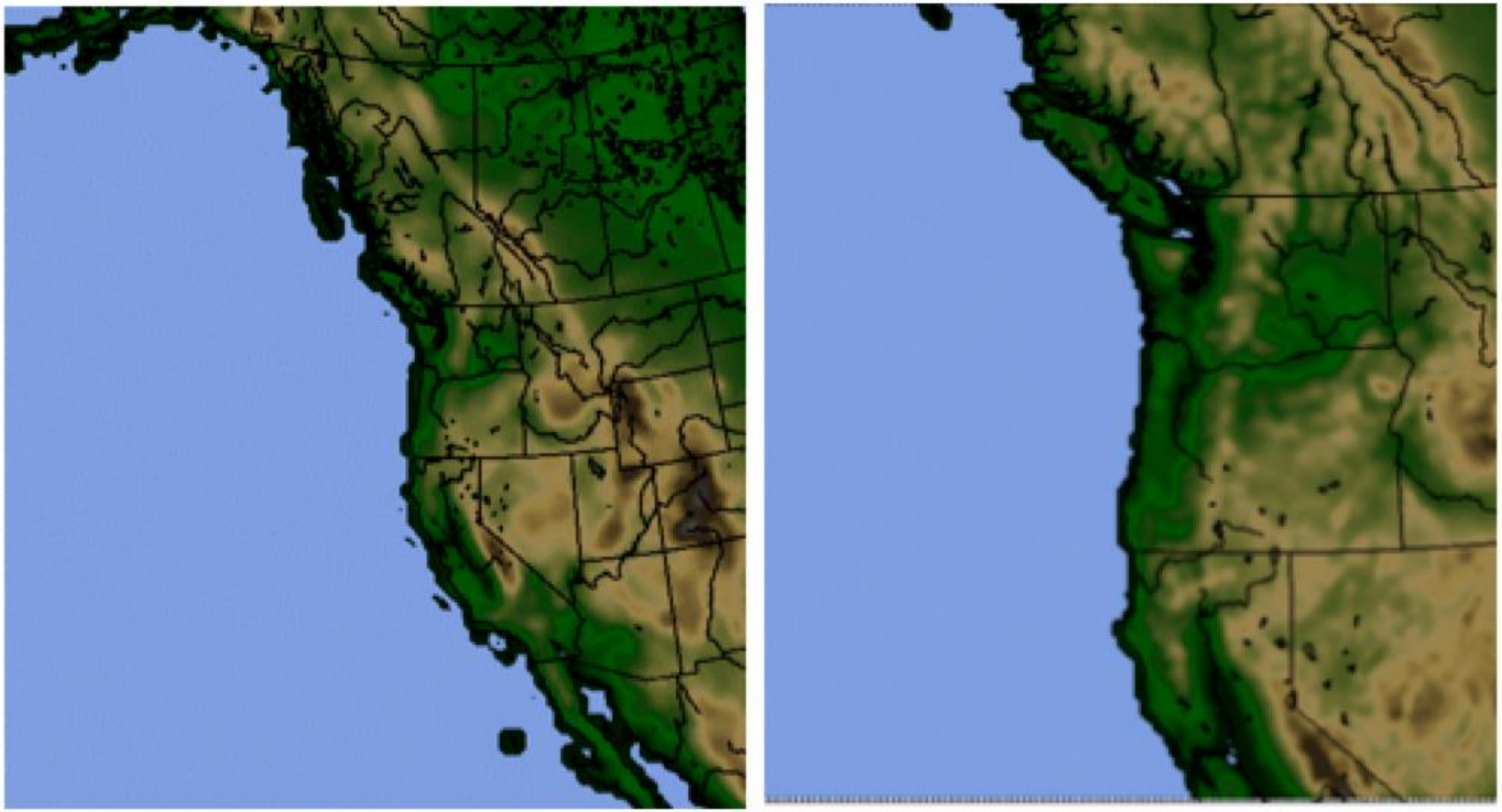

UW MM5-GFS 12km Domain
Init: 12 UTC Sun 02 Dec 07
Fcst: 27 h
Valid: 15 UTC Mon 03 Dec 07 (07 PST Mon 03 Dec 07)
Total Precip in past 3 hrs (.01in)
Wind at 10m (full barb = 10kts)
130 W
125 W
120 W
115 W
110 W
50
45
40
1/100 inch
.5
1
2
4
8
16
32
64
128
256
512
1024
2048
Model info: V3.7.4 Kain-Frsch MRF PBL Reisner 2 12 km, 37 levels, 36 sec

12-km WRF

Dynamical Downscaling

- If task 1 demonstrates that CFS (deterministic or ensemble-based) has extended **synoptic** skill, the output from the CFS model will be downscaled using the WRF ARW model at 36 and 12 km grid spacing.
- This system be will integrated for 45 days on a daily basis over at least a two-year period

36 and 12 km domains



Dynamical Downscaling

- The initialization and boundary conditions for the WRF forecasts will be based on either the ensemble mean of CFS or the CFS member closest to the mean of the four-member ensemble produced each day at 0000 UTC.
- Comprehensive verification using UW mesoscale verification system.
- Comparison to CFS forecasts.

Additions

- Compare NAEFS, GEFS, and GFS extended forecasts with CFS during first few weeks.
- Compare with NMME and IMME for weeks 2-6.

THE END