The Future of Statistical Post-Processing

Western Region Considerations

- **Complex terrain**

- **Large areas void of conventional data (over both land and water)**

- **Remotely sensed data (satellite and GOES-R), multi-radar/mutli-sensor analysis, high-resolution data assimilation**

- **Quality control (QC) of observations**

- **Point vs area observations**

- **Training and utilization issue with forecasters**

- **The number of statistical post-processing methods**

- **Difficult for forecasters to track, understand, and utilize**

- **Application of ensembles and related post-processing still largely web based**
  - **Putting the forecasting into context: Anomalies / EFI / Confidence / Probabilities**
- **Reforecasting**
  - **Applications from global to meso- and storm-scale ensembles**

WR STID

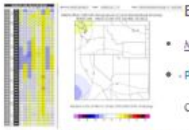
Forecast Confidence Toolkit

- Multi-year effort to make better use of models/ensembles to improve forecast/DSS messaging
- Worked with WR SOO/DOHs to identify top set of analysis tools - https://sites.google.com/a/noaa.gov/nws-wr-stid/projects/forecast-confidence

Bottom line -- forecasters can use better science based tools to examine model trends

This and the following slides from Andy Edman & WRH Sci. & Tech. Integration Branch (STID)

Large-Scale Pattern Tools

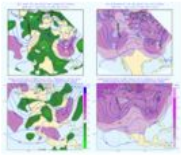


Ensemble Situational Awareness Table

- Main Page (now publicly accessible)
- Penn State Anomaly Page

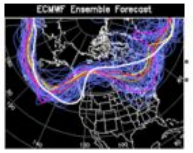
Contact/training: Randy Graham

- Provides a framework for quickly identifying significant events in the forecast.
- NAEFS ensemble mean fields are compared to the 1979-2009 CFSR reanalysis climatology to highlight potentially significant features in the forecast.
- The NAEFS ensemble consists of a control run and 20 perturbed members from each of the Canadian and GEFS models.
- Only presents the ensemble mean-- no explicit confidence information.
- Large anomalies in an ensemble mean at long lead times suggest a higher likelihood of significant events, but not if the model is underdispersive or "overconfident"
- See the Projects Page for more details.



STID Ensemble Graphics

- Main Page (now publicly accessible)
- Contact/training: Trevor Alcott
- Gathers several confidence tools (normalized spread, GFS deterministic versus GEFS ensemble, model climate QPF, ensemble IVT) in one place.
- Normalized spread is especially tricky, and can highlight strong gradients or pattern changes rather than low predictability.



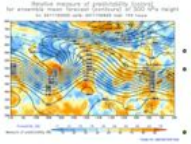
ECMWF Ensemble Graphics

- HPC Spaghetti Plots
- ECMWF Normalized Spread Maps

Contact/training: Donny Dumont

USING THESE PLOTS

- Spaghetti plots compare the ECMWF ensemble members, GEFS ensemble members, and both control runs. Verification is plotted for times in the past.
- Normalized spread is the standard deviation (spread) in the current forecast divided by the average spread at this forecast hour for model runs over the last 30 days. Values greater than 1 indicate higher than normal spread and suggest lower than normal confidence.
- Always remember that only a PERFECT ensemble shows a 1:1 spread-to-skill relationship.

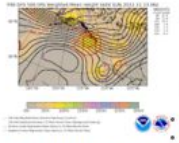


Relative Measure of Predictability

- NCEP RMOP Loop
- About RMOP

Contact/training: Andy Taylor

- RMOP in a given region indicates how much spread the GEFS emseble members have relative to spread over the last 30 days.
- Example... 90% RMOP: current GEFS at this forecast hour is more tighly clustered than 90% of forecasts at this hour over the past 30 days. 55% probability: 55% of GEFS forecasts at this hour with 90% RMOP have verified close to observations.
- High values of RMOP: ensemble has narrowed in on a solution. High values of probability: that solution might actually occur.
- High values of both RMOP and probability should increase confidence.
- Only the ensemble mean is plotted, which will wash out smaller scale features when there is timing/spatial uncertainty.
- High values of RMOP with low probabilities indicate that the GEFS is confident but you should not be!



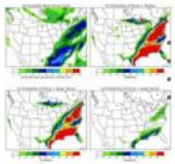
modTrend

Site w/Eastern Domain
Training Video (Mar 2013)

Contact/training: Paul Iniguez

- Black contours are weighted 500 hPa heights using an exponential decay function.
- Red (blue) contours depict positive (negative) linear trend of past 10 deterministic GFS runs.
- Color shading is residual spread (linear trend signal removed) of past 10 deterministic GFS runs.

Impact Probabilities and Forecast Analogs

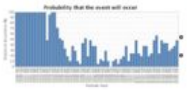


GEFS Reforecast Analogs

- QPF Analogs and EFI
- New High-Res QPF Analogs
- Z500/T850/T2
- Teleconnections

Contact/training: Trevor Alcott
Data outages: Reforecast Admin

- Reforecast analogs are used to calibrate the real-time GEFS forecast, which shows considerable skill over raw ensemble probabilities.
- Uses a GEFS reforecast dataset covering 1984 to 2012 at ~50km (~70 km) resolution for days 1-8 (8-16).
- Precipitation forecasts are subject to the quality of the NARR reanalysis precipitation (32-km resolution).

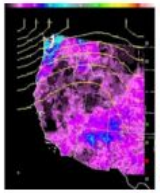


NCEP / EMC Ensemble Tools

- NAEFS / GEFS / SREF Graphics
- NOMADS Probability Tool

Contact/training: JJ Brost

- Show the raw probability of exceeding various thresholds (% of 21 GEFS members).
- Point-based and plan view graphics available. One-stop shop for raw ensemble mean/spread data and probabilities.
- Use raw ensemble probabilities at your peril. Particularly for high precipitation thresholds, these uncalibrated values are unreliable in complex terrain.

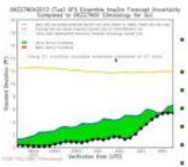


WR Pattern Recognition Tool

Pattern Climo Page

Contact/training: Bill Rasch

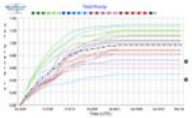
Identifies pattern similar to the current GFS or ECMWF forecast, from a set of 12 pre-defined patterns.
Click on a pattern to see the climatological PoPs for that pattern
Limited to the deterministic GFS/ECMWF solutions
Small set of patterns, few apply in summer.



Confidence in Surface Fields

- FSU Confidence Plots

- Can help to establish confidence in localized sensible weather from a large-scale ensemble.
- Compares de-baised climatological GEFS spread to spread in the current GEFS forecast
- Similar to normalized spread plots, but spread is compared to climatology rather than last 30 days of forecasts.
- Plan-view and point-based plots for 2-m temperature, wind speed and other surface variables.
- Low-resolution fields, no post-processing.
- Low spread does not always imply high skill.

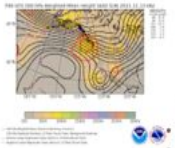


Plume Diagrams

- SPC Interactive SREF Plumes
- CFS 45-day Plumes Page

- Time series plots of all SREF ensemble members at a point
- Useful fields: 10m winds, precip/snow accumulations
- The SREF has 21 members that are all variations of the WRF model. 3 different cores, 7 initial condition perturbations each. 16 km resolution.
- This is not MOS and is not bias-corrected. As such, WRF configurations typically overpredict wind speed and underpredict the diurnal range of temperature, although this varies from event to event.

SREF Probability Plots



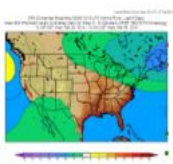
modTrend

Site w/Eastern Domain
Training Video (Mar 2013)

Contact/training: Paul Iniguez

- Black contours are weighted 500 hPa heights using an exponential decay function.
- Red (blue) contours depict positive (negative) linear trend of past 10 deterministic GFS runs.
- Color shading is residual spread (linear trend signal removed) of past 10 deterministic GFS runs.

- Pros: Objective indication of GFS trend. Strong trends enhance certainty of emerging solutions. Low certainty forecasts easily identified through high spread with no trend.
- Cons: Available only for GFS (no NAM due to short [84hr] forecast period and no ECMWF due to lack of runs [only every 12 hours]). Trends are not to be extrapolated.

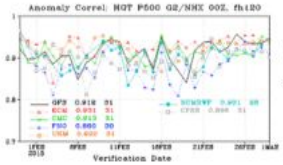


Climate Forecast System Ensemble

Week 3-6 Forecasts Graphics
About the CFS

Contact/training: Tom Hultquist (SOO - MPX)

- 20-member CFS ensemble contains 00,06,12,18 UTC runs for the last 5 days.
- Some of the only operational guidance available beyond week 2.
- Limited verification data available. The CFS output is something to start looking at and evaluating, but be careful not to take these (or any) long-range forecasts at face value until we know more about the biases and skill of the forecast system.

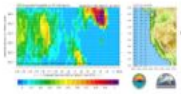


Model Verification Pages

- NCEP Deterministic Models
- NCEP Ensemble Verification
- Ensemble SA Table Verification

Contact/training: Trevor Alcott

Atmospheric River Identification Tools (*See browser issues at the top of the page if you have any problems viewing the links*)

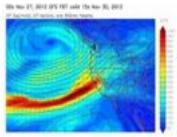


Atmospheric River Diagnostics and Forecasts

- Atmospheric River Forecasts

Contact/training: Jon Rutz
Contact/suggestions: Jay Cordeira

- Links to the Plymouth State / CW3E AR Portal.
- A variety of deterministic and ensemble-based forecast confidence tools focusing on atmospheric rivers over the northeastern Pacific.



WRH Atmospheric River Plots

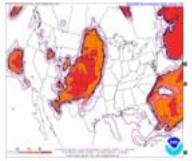
- IWV Transport

Contact/training: Jon Rutz or Trevor Alcott

- Depictions of GEFS ensemble mean and GFS deterministic IWV transport for the Western US.

Updated 1.15.14 by Trevor Alcott (trevor.alcott@noaa.gov) Added link to new extended range CIPS guidance.

- Time series plots of all SREF ensemble members at a point
- Useful fields: 10m winds, precip/snow accumulations
- The SREF has 21 members that are all variations of the WRF model. 3 different cores, 7 initial condition perturbations each. 16 km resolution.
- This is not MOS and is not bias-corrected. As such, WRF configurations typically overpredict wind speed and underpredict the diurnal range of temperature, although this varies from event to event.



SREF Probability Plots

- SPC Plots
- NCEP Aviation Page

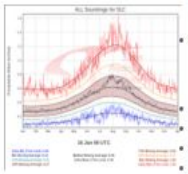
- SPC does some post-processing of the 21 SREF members here.
- Useful fields: calibrated thunderstorm probability, Fire Weather joint probabilities, CAPE/Shear and other combined convective probabilities, PQPF.
- Click on the forecast hour for d(prog)/dt graphics.
- Basic surface fields are not calibrated or bias-corrected. 16-km resolution is insufficient in complex terrain.

CIPS Guidance

- CIPS Analog Page
- Extended Range GEFS Analogs
- NAM Consistency (NEW!)
- GFS Consistency (NEW!)

Contact/training: CIPS Staff

- Identifies 15 past NARR analyses that are similar to the current NAM and GFS forecast.
- Initial page shows the list of dates sorted by how well they match the forecast pattern.
- Plots show the probabilties of exceeding various precipitation, snowfall and temperature thresholds. Example: 50% probability of >12" snowfall at a point means that on more than half of the 15 past dates with similar patterns, at least 12" of snow fell at that point (based on COOP data).
- Western US domain moves based on the pattern.
- Based on deterministic NAM/GFS solutions. Builds confidence in the impacts, but only assuming that the model forecast is good.
- Precipitation/snowfall probabilities use smoothed COOP data, not PRISM. Terrain is not well represented.



National RAOB Climatology

- SPC Sounding Climatology Page

Contact/training: Trevor Alcott

- Although not explicitly a forecast confidence tool, can be very useful for placing forecast values in context.
- Seasonal/monthly/daily climatologies (standard deviations and percentiles) for many sounding variables
- Covers the entire RAOB period of record (back to the 1950s at many sites).
- No forecast information.

Short-Term / High-Res Tools

SPC Storm Scale Ensemble of Opportunity (SSEO)

- SPC SSEO

Contact/training: Trevor Alcott

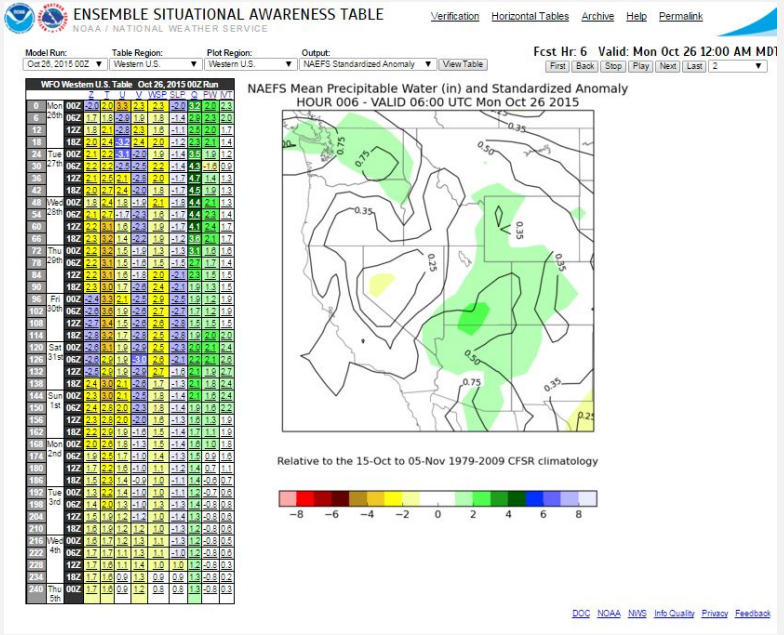
- Provides probabilistic guidance based on available high-resolution, convection-allowing models including NAM CONUS Nest, ARW/NMM CONUS, NSSL WRF

WR STID

Ensemble Situational Awareness Web Page

- Compares GEFS/NAEFS to model and real climatology to tease out major events to improve forecast lead time and provide improved scientific basis for DSS -- http://ssd.wrh.noaa.gov/satable/
- Includes real time verification – web site migrating to IDP this year

Bottom line -- forecasters can use better tools to examine model trends to create better forecast and DSS messaging



ENSEMBLE SITUATIONAL AWARENESS TABLE

NOAA / NATIONAL WEATHER SERVICE

Model Run: Oct 26, 2015 00Z | Table Region: Western U.S. | Plot Region: Western U.S. | Output: GEFS QPF M-Climate | View Table

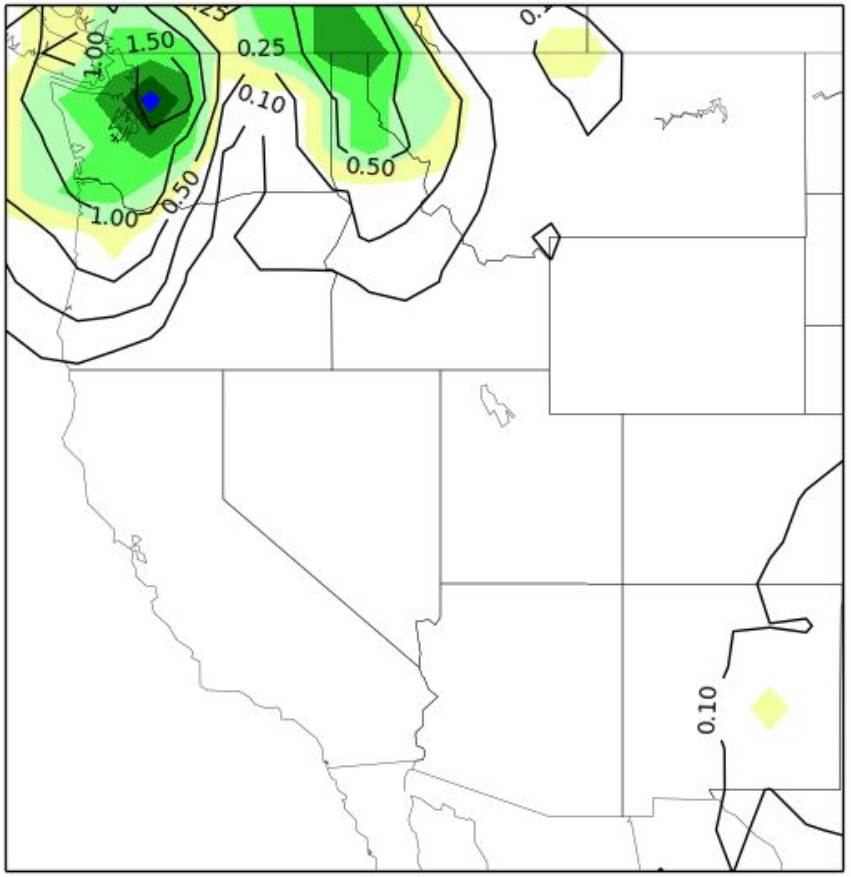
Fcst Hr: 144 Vali

First Back Stop

WFO Western U.S. Table Oct 26, 2015 00Z Run

			6-h	12-h	24-h	48-h	72-h
6	Mon 26th	06Z	97.7				
12		12Z	92.4	95.0			
18		18Z	95.9	93.2			
24	Tue 27th	00Z	96.1	96.1	94.3		
30		06Z	91.8	96.7	95.6		
36		12Z	94.9	93.1	95.7		
42		18Z	<90	91.6	94.7		
48	Wed 28th	00Z	<90	<90	<90	93.2	
54		06Z	92.7	<90	<90	93.7	
60		12Z	<90	90.0	<90	93.3	
66		18Z	<90	<90	<90	91.6	
72	Thu 29th	00Z	<90	<90	<90	<90	90.8
78		06Z	<90	<90	<90	<90	91.4
84		12Z	92.6	90.3	90.0	<90	91.6
90		18Z	94.9	94.6	92.5	<90	<90
96	Fri 30th	00Z	92.8	95.1	94.3	<90	<90
102		06Z	97.5	97.4	95.7	91.1	<90
108		12Z	92.8	96.0	96.5	92.4	<90
114		18Z	97.9	97.4	96.4	93.1	<90
120	Sat 31st	00Z	99.5	99.6	98.6	95.9	90.1
126		06Z	98.6	99.1	99.2	96.9	94.5
132		12Z	99.5	99.2	99.2	97.2	97.0
138		18Z	99.3	99.7	99.4	97.7	98.5
144	Sun 1st	00Z	99.2	99.7	99.8	99.0	98.6
150		06Z	99.2	99.0	99.5	99.1	98.9
156		12Z	98.7	99.0	99.0	99.4	98.9
162		18Z	97.8	98.4	99.0	99.7	98.9
168	Mon 2nd	00Z	97.5	98.1	99.3	99.7	99.3
174		06Z	97.1	97.6	99.1	99.6	99.5
180		12Z	97.0	97.5	98.8	99.5	99.6
186		18Z	95.6	97.5	97.8	99.5	99.8
192	Tue 3rd	00Z	97.9	97.9	98.1	99.3	99.6

GEFS Mean QPF (in) and M-Climate percentile
120-144-h forecast valid
00Z Sat Oct 31 2015 to 00Z Sun Nov 01 2015



relative to GEFS reforecasts initialized
11-Sep to 10-Dec (1985-2012)

ENSEMBLE SITUATIONAL AWARENESS TABLE

NOAA / NATIONAL WEATHER SERVICE

Model Run: Oct 26, 2015 00Z | Table Region: Western U.S. | Plot Region: Western U.S. | Output: GEFS M-Climate Return Interval | View Table

Fcst Hr: 6 Valid: Mon Oct 26 12:00 AM MDT

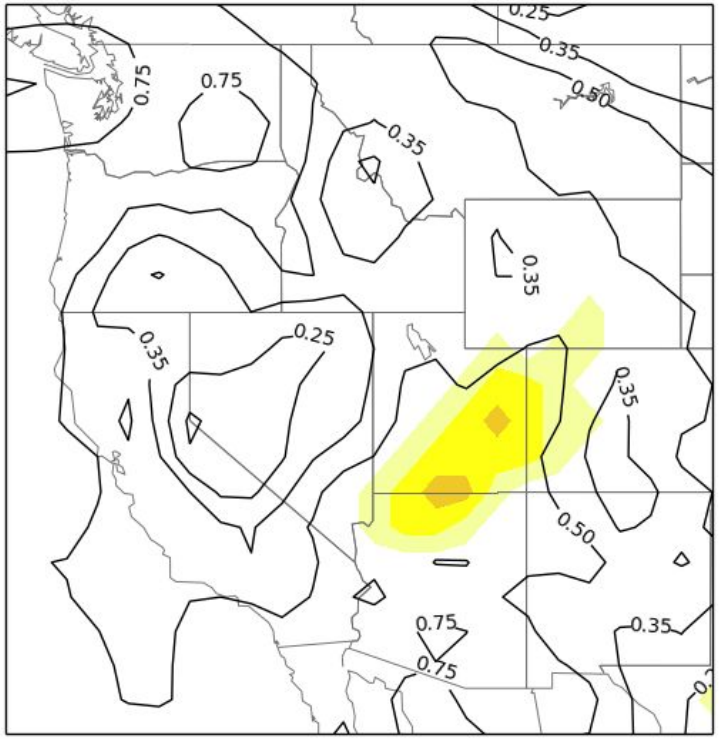
First | Back | Stop | Play | Next | Last | 2

WFO Western U.S. Table Oct 26, 2015 00Z Run

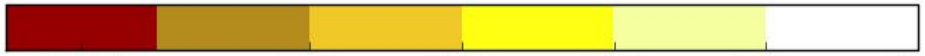
			Z	T	SLP	PW
0	Mon 26th	00Z	0-1	0-1	1	30
6		06Z	0-1	0-1	0-1	5
12		12Z	0-1	0-1	0-1	5
18		18Z	0-1	0-1	0-1	2
24	Tue 27th	00Z	0-1	0-1	0-1	5
30		06Z	0-1	0-1	0-1	5
36		12Z	0-1	0-1	0-1	1
42		18Z	0-1	0-1	0-1	2
48	Wed 28th	00Z	0-1	0-1	0-1	2
54		06Z	0-1	0-1	0-1	2
60		12Z	0-1	0-1	0-1	5
66		18Z	0-1	0-1	0-1	2
72	Thu 29th	00Z	0-1	0-1	0-1	2
78		06Z	0-1	0-1	0-1	2
84		12Z	0-1	0-1	1	1
90		18Z	0-1	0-1	1	0-1
96	Fri 30th	00Z	1	0-1	2	0-1
102		06Z	5	0-1	2	2
108		12Z	2	0-1	5	1
114		18Z	5	1	10	5
120	Sat 31st	00Z	2	1	5	10
126		06Z	10	2	0-1	5
132		12Z	2	2	0-1	5
138		18Z	30	2	0-1	2
144	Sun 1st	00Z	2	5	1	2
150		06Z	30	2	5	2
156		12Z	2	2	1	1
162		18Z	10	2	1	1
168	Mon 2nd	00Z	1	2	1	1
174		06Z	5	1	1	1
180		12Z	0-1	1	1	0-1
186		18Z	2	1	1	0-1
192	Tue 3rd	00Z	0-1	5	2	0-1

GEFS Mean Precipitable Water (in) and M-Climate Return Interval

HOUR 006 - VALID 06:00 UTC Mon Oct 26 2015



Approximate frequency of occurrence in
15-Oct to 05-Nov, 6-h GEFS reforecasts (1985-2012):



outside M-climate | 1 day every 10 y | 1 day every 5 y | 1 day every 2 y | 1 day per year | every day

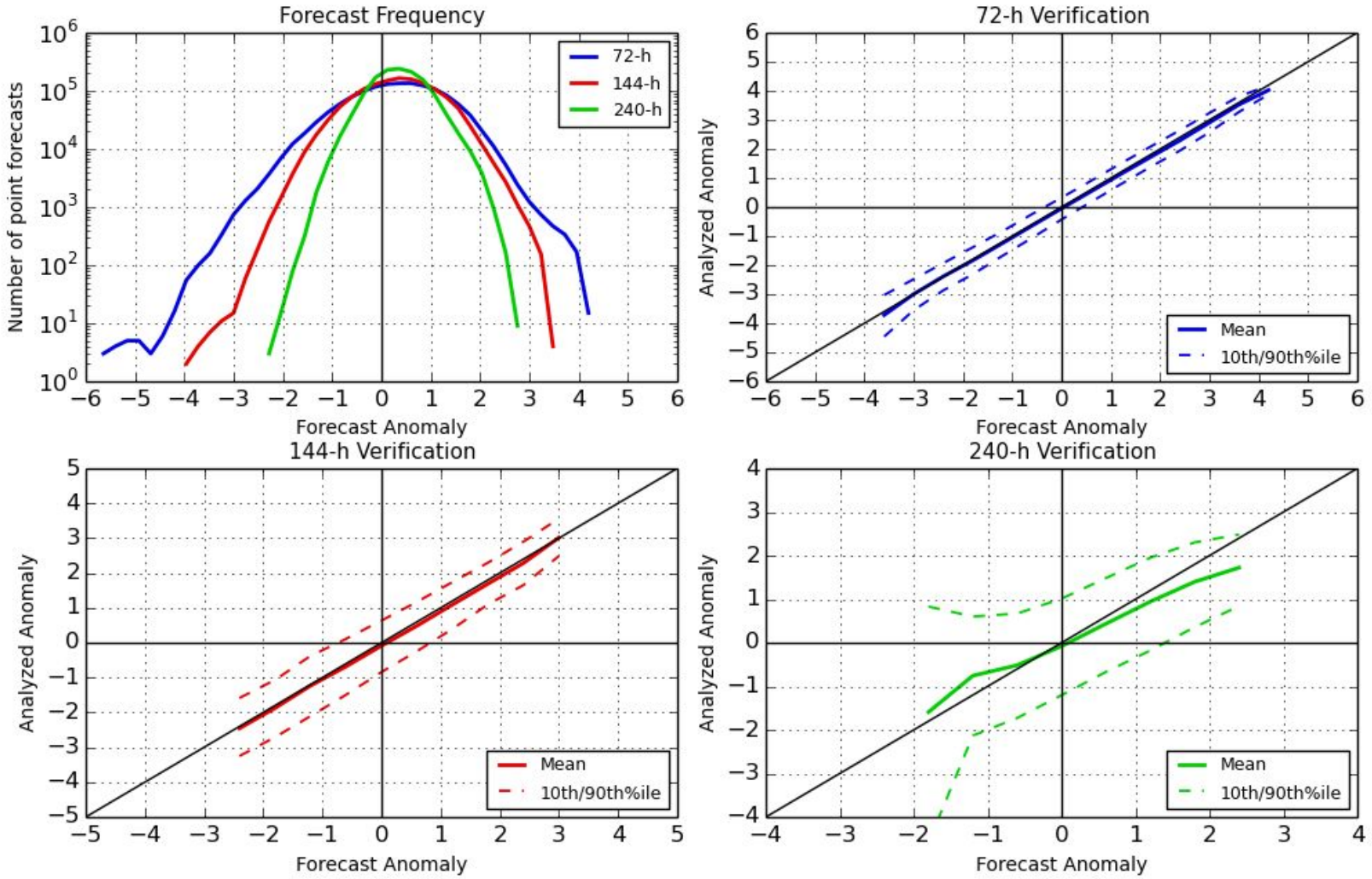
WRH NAEFS VERIFICATION

NOAA / NATIONAL WEATHER SERVICE

Type: Standardized Anomaly | Parameter: 500-hPa Height | Region: North America | Period: Past 90 Days | Show Plot

NAEFS Ensemble Mean Verification - North America Domain
500-hPa Geopotential Height (06/08/2015 - 09/06/2015)

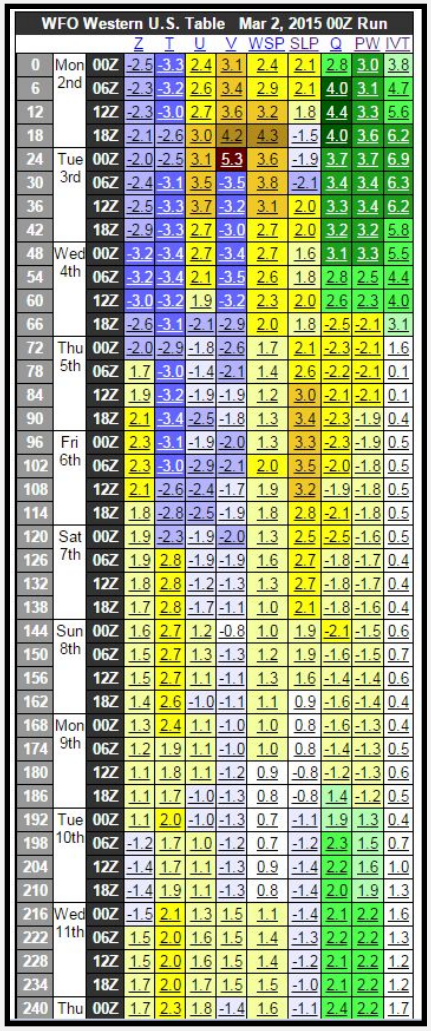
trevor.alcott@noaa.gov



Forecast Confidence Science Push

- Goal is to:
  - Better anticipate when we should have more confidence to extend lead times and allow for improved IDSS
  - Provide field with tools to better utilize deterministic model solutions when developing their confidence

- Next Steps:
  - Integrate approach with information from partners to better serve their needs for confidence and IDSS
  - Continue using opportunities to reinforce use and adaptation of tools into culture
  - **DSS is only as good as our content!**



WFO Western U.S. Table Mar 2, 2015 00Z Run

			Z	T	U	V	WSP	SLP	Q	PW	IVT
0	Mon 2nd	00Z	-2.5	-3.3	2.4	3.1	2.4	2.1	2.8	3.0	3.8
6		06Z	-2.3	-3.7	2.6	3.4	2.9	2.1	4.0	3.1	4.7
12		12Z	-2.3	-3.0	2.7	3.6	3.2	1.8	4.4	3.3	5.6
18		18Z	-2.1	-2.6	3.0	4.2	4.3	-1.5	4.0	3.6	6.2
24	Tue 3rd	00Z	-2.0	-2.5	3.1	5.3	3.6	-1.9	3.7	3.7	6.9
30		06Z	-2.4	-3.1	3.5	-3.5	3.8	-2.1	3.4	3.4	6.3
36		12Z	-2.5	-3.3	3.7	-3.2	3.1	2.0	3.3	3.4	6.2
42		18Z	-2.9	-3.3	2.7	-3.0	2.7	2.0	3.2	3.2	5.8
48	Wed 4th	00Z	-3.2	-3.4	2.7	-3.4	2.7	1.6	3.1	3.3	5.5
54		06Z	-3.2	-3.4	2.1	-3.5	2.6	1.8	2.8	2.5	4.4
60		12Z	-3.0	-3.2	1.9	-3.2	2.3	2.0	2.6	2.3	4.0
66		18Z	-2.6	-3.1	-2.1	-2.9	2.0	1.8	-2.5	-2.1	3.1
72	Thu 5th	00Z	-2.0	-2.9	-1.8	-2.6	1.7	2.1	-2.3	-2.1	1.6
78		06Z	1.7	-3.0	-1.4	-2.1	1.4	2.6	-2.2	-2.1	0.1
84		12Z	1.9	-3.2	-1.9	-1.9	1.2	3.0	-2.1	-2.1	0.1
90		18Z	2.1	-3.4	-2.5	-1.8	1.3	3.4	-2.3	-1.9	0.4
96	Fri 6th	00Z	2.3	-3.1	-1.9	-2.0	1.3	3.3	-2.3	-1.9	0.5
102		06Z	2.3	-3.0	-2.9	-2.1	2.0	3.5	-2.0	-1.8	0.5
108		12Z	2.1	-2.6	-2.4	-1.7	1.9	3.2	-1.9	-1.8	0.5
114		18Z	1.8	-2.8	-2.5	-1.9	1.8	2.8	-2.1	-1.8	0.5
120	Sat 7th	00Z	1.9	-2.3	-1.9	-2.0	1.3	2.5	-2.5	-1.6	0.5
126		06Z	1.9	2.8	-1.9	-1.9	1.6	2.7	-1.8	-1.7	0.4
132		12Z	1.8	2.8	-1.2	-1.3	1.3	2.7	-1.8	-1.7	0.4
138		18Z	1.7	2.8	-1.7	-1.1	1.0	2.1	-1.8	-1.6	0.4
144	Sun 8th	00Z	1.6	2.7	1.2	-0.8	1.0	1.9	-2.1	-1.5	0.6
150		06Z	1.5	2.7	1.3	-1.3	1.2	1.9	-1.6	-1.5	0.7
156		12Z	1.5	2.7	1.1	-1.1	1.3	1.6	-1.4	-1.4	0.6
162		18Z	1.4	2.6	-1.0	-1.1	1.1	0.9	-1.6	-1.4	0.4
168	Mon 9th	00Z	1.3	2.4	1.1	-1.0	1.0	0.8	-1.6	-1.3	0.4
174		06Z	1.2	1.9	1.1	-1.0	1.0	0.8	-1.4	-1.3	0.5
180		12Z	1.1	1.8	1.1	-1.2	0.9	-0.8	-1.2	-1.3	0.6
186		18Z	1.1	1.7	-1.0	-1.3	0.8	-0.8	1.4	-1.2	0.5
192	Tue 10th	00Z	1.1	2.0	-1.0	-1.3	0.7	-1.1	1.9	1.3	0.4
198		06Z	-1.2	1.7	1.0	-1.2	0.7	-1.2	2.3	1.5	0.7
204		12Z	-1.4	1.7	1.1	-1.3	0.9	-1.4	2.2	1.6	1.0
210		18Z	-1.4	1.9	1.1	-1.3	0.8	-1.4	2.0	1.9	1.3
216	Wed 11th	00Z	-1.5	2.1	1.3	1.5	1.1	-1.4	2.1	2.2	1.6
222		06Z	1.5	2.0	1.6	1.5	1.4	-1.3	2.2	2.2	1.3
228		12Z	1.5	2.0	1.6	1.5	1.4	-1.2	2.1	2.2	1.2
234		18Z	1.7	2.0	1.7	1.5	1.5	-1.0	2.1	2.2	1.2
240	Thu	00Z	1.7	2.3	1.8	-1.4	1.6	-1.1	2.4	2.2	1.7

EX: WRH Forecast Conf. Email

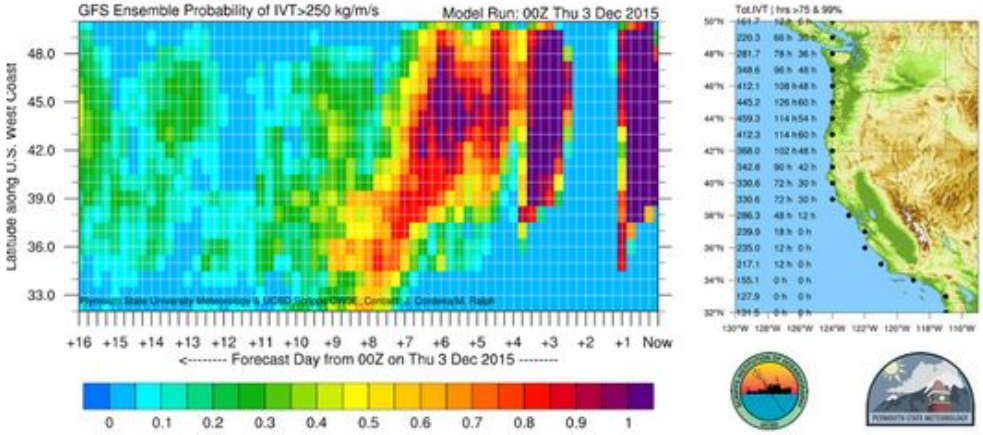
Forecast Confidence: Upcoming Wet Pattern for Pacific Northwest STID (WRH) x

Jonathan Rutz - NOAA Federal <jonathan.rutz@noaa.gov> 12/3/15

to _NWS, Bill, Brian, Jim, mralph, WR, WYNDAM

Hi everyone,

Our forecast confidence tools are highlighting a prolonged wet pattern for the Pacific Northwest (PacNW) with multiple landfalling atmospheric rivers (ARs) during the next 7-10 days. The "AR Landfall Tool", available from the AR Portal, summarizes the situation nicely, with multiple waves of enhanced water vapor transport reaching the PacNW coast during this period. This shows the probability of AR conditions (i.e., fraction of GEFS members with integrated water vapor transport > 250 kg m-1 s-1) at a given place and time. We have the current event, a second event centered near day 3, and a third event that is expected to (100% GEFS probabilities) impact the PacNW and may (50-80% probabilities) impact California as well.



The third event, in particular, looks to be a fairly potent AR as it makes landfall along the PacNW coast with integrated water vapor transport pushing 1250 kg m-1 s-1 (according to the deterministic GFS).