Using water vapor flux as a predictor in precipitation forecast calibration along the U.S. West Coast

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Background

- ESRL/PSD working with Wes Junker and NCEP/EMC/HPC to evaluate reforecast products.
- ESRL + HPC experience with atmospheric rivers, suggests that for West-Coast heavy precipitation events, water-vapor flux important predictor of heavy precipitation.
- ESRL's experimental reforecast-based product for PQPF (www.cdc.noaa.gov/reforecast/narr) doesn't currently use water-vapor flux as a predictor.
- So, if we did use water-vapor flux, would it help?
- Ancillary question: is the analog-based procedure that we have been using the best for this situation?

NOAA’s reforecast data set

- **Model**: T62L28 NCEP GFS, circa 1998
- **Initial States**: NCEP-NCAR Reanalysis II plus 7 +/- bred modes.
- **Duration**: 15 days runs every day at 00Z from 19781101 to now. (*http://www.cdc.noaa.gov/people/jeffrey.s.whitaker/refcst/week2*).
- **Forecast data**: Selected fields (winds, hgt, temp on 5 press levels; precip, t2m, u10m, v10m, pwat, prmsl, rh700, heating). NCEP/NCAR reanalysis verifying fields included. Data saved on 2.5-degree grid. (Web form to download at *http://www.cdc.noaa.gov/reforecast*).
- **Verification / training data**: 32-km North American Regional Reanalysis 24-h accumulated precipitation (much finer scale than ~250 km reforecasts).
- **Proxy for water vapor flux** in this experiment: 850 wind velocity * precipitable water (pwat).

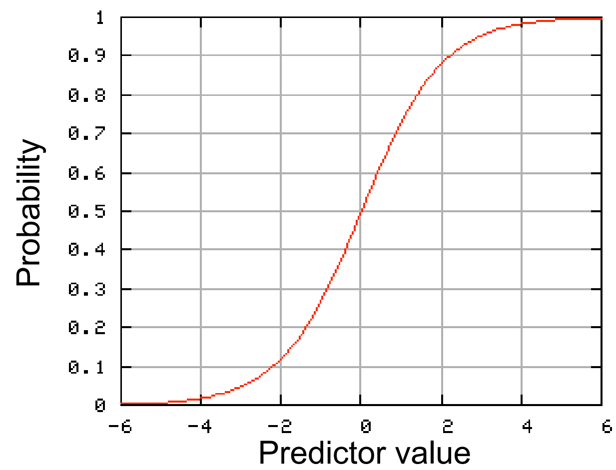
Forecast Calibration: (1) Logistic Regression

Given predictors $x_1, \ldots, x_N$ (such as the mean and water vapor flux), find regression coefficients

$\beta_0, \beta_1, \ldots, \beta_N$ for the equation

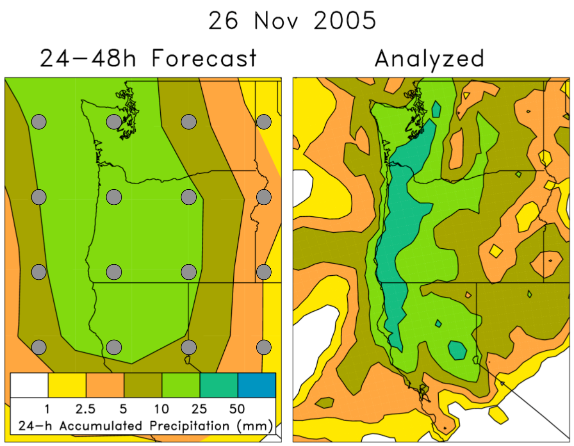
$$P\left(obs > T\right) = 1. - \frac{1}{1 - \exp\left(\beta_0 + \beta_1 x_1 + \ldots + \beta_N x_N\right)}$$

This generates an S-shaped curve (here for one predictor)

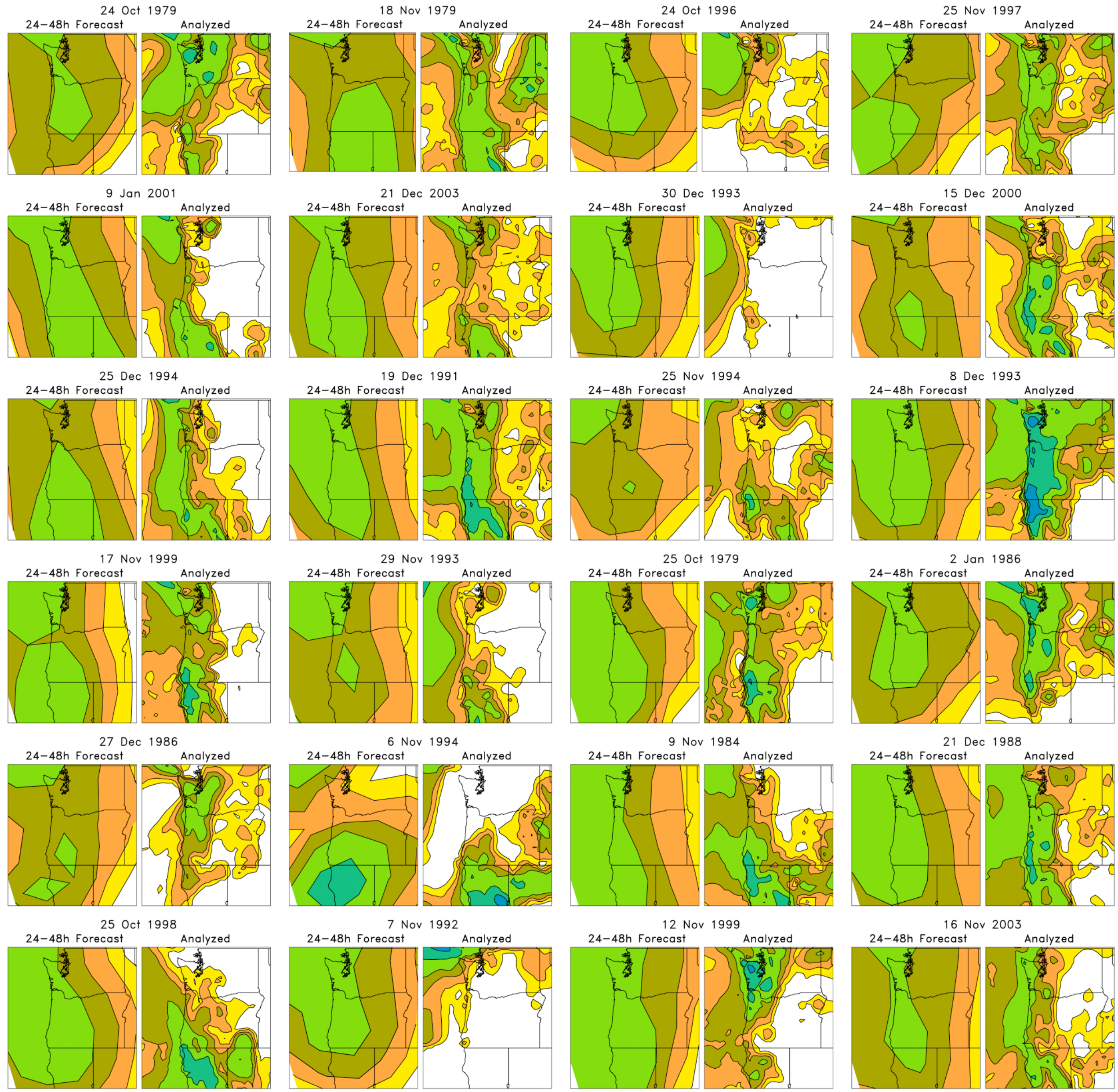


Forecast calibration: (2) analog technique

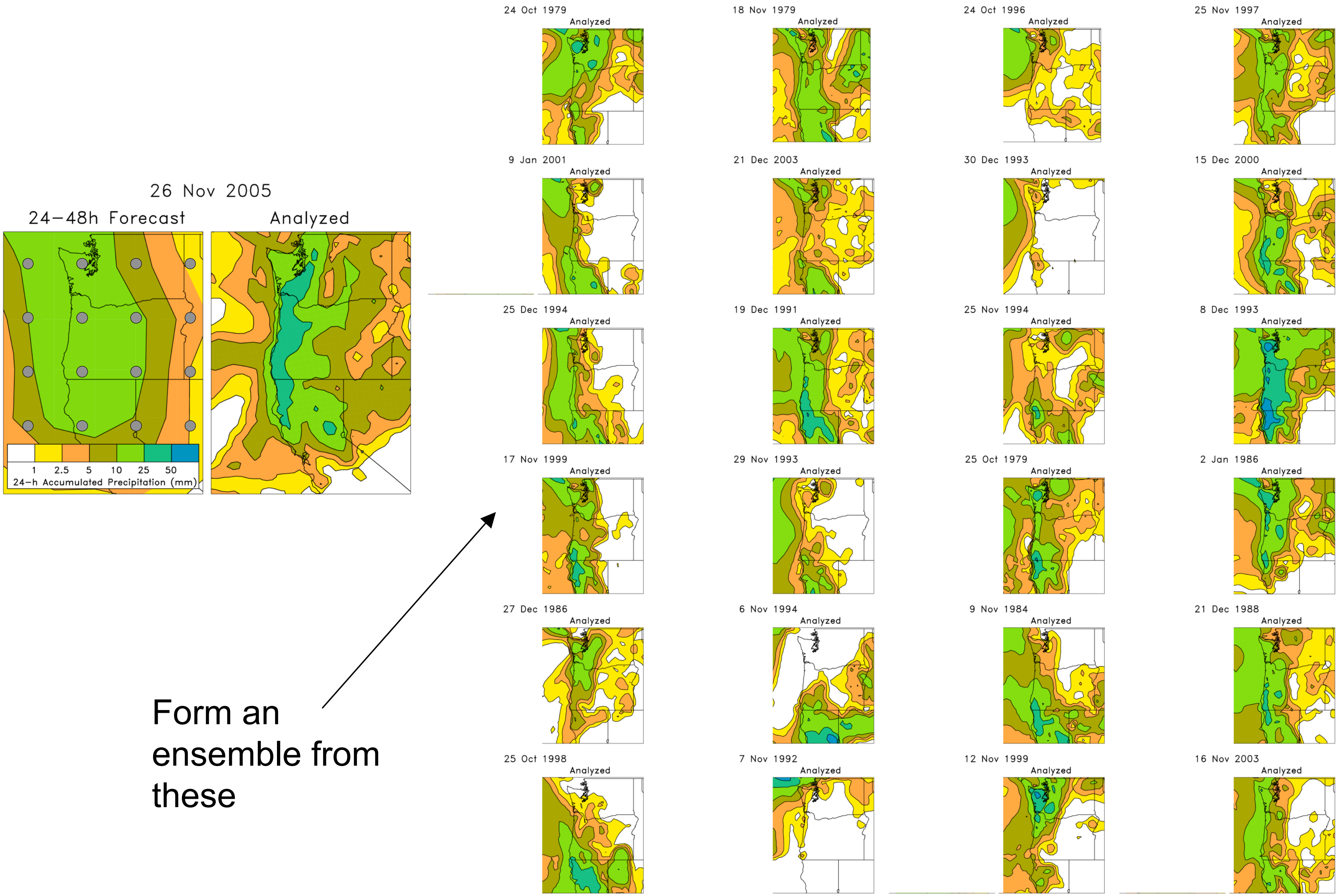
Today's ens. mean forecast + a posteriori analyzed precip.



On the left are old forecasts similar to today's ensemble-mean forecast. For making probabilistic forecasts, form an ensemble from the accompanying analyzed weather on the right-hand side.



Forecast calibration (2): analog technique



Form an ensemble from these

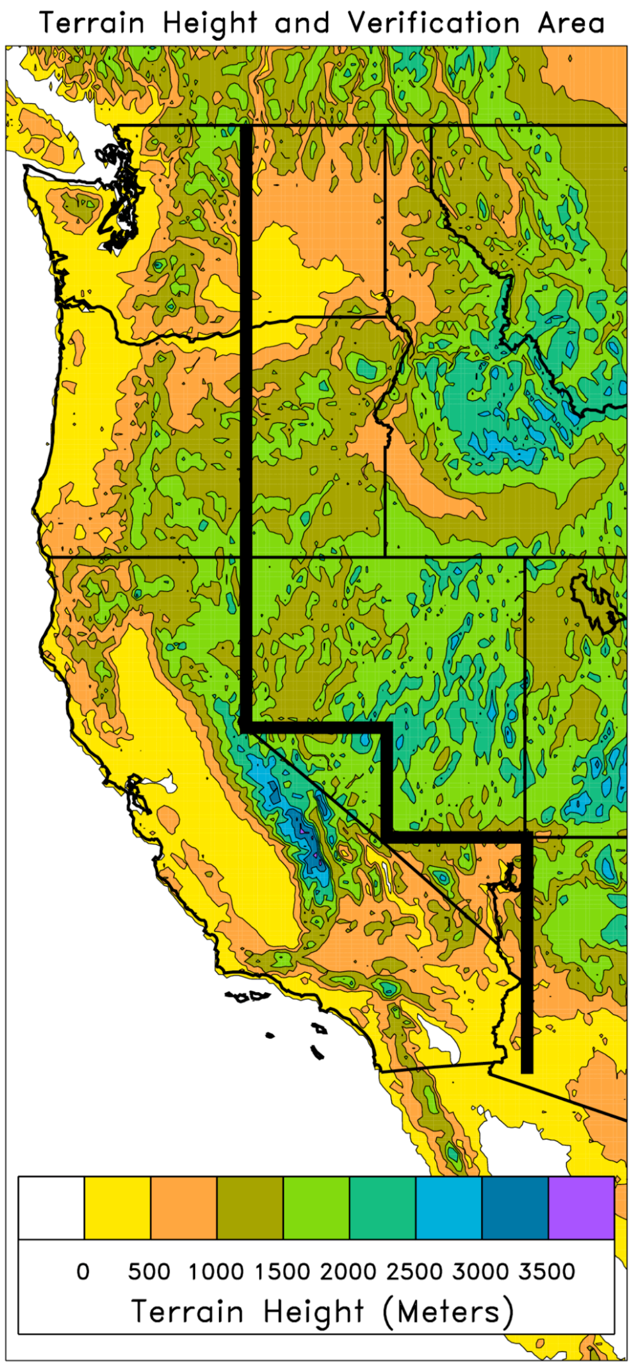
Four algorithms tested

(1) **Basic analog**: finds analogs to today's precipitation pattern. Observed weather associated with 25 closest analogs chosen. [see *MWR*, Nov 2006]

(2) **Precip + WV flux analog**: finds analogs based on precip and water vapor flux (UV850*Pwat). After normalization so max precip and flux the same magnitude, match based on 0.8*precip + 0.2*flux.

(3) **Basic logistic regression**: uses $\sqrt{}$(ens. mean precip) as sole predictor.

(4) **Precip + WV flux logistic regression**: uses $\sqrt{}$(ens. mean precip) and water-vapor flux as predictors.

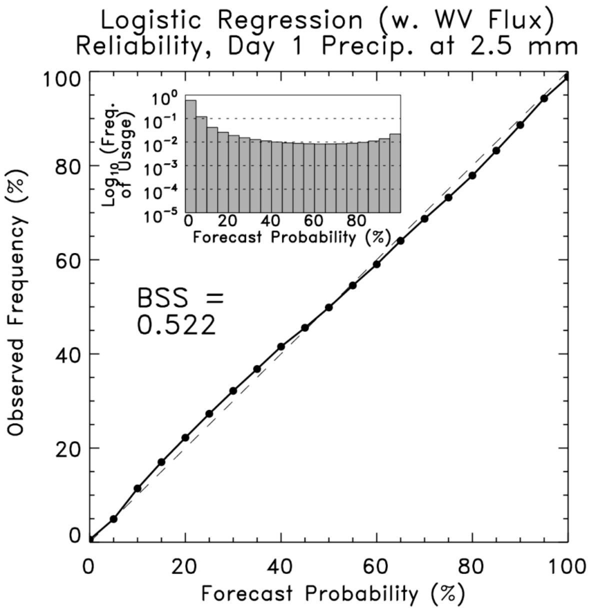


Forecast Domain

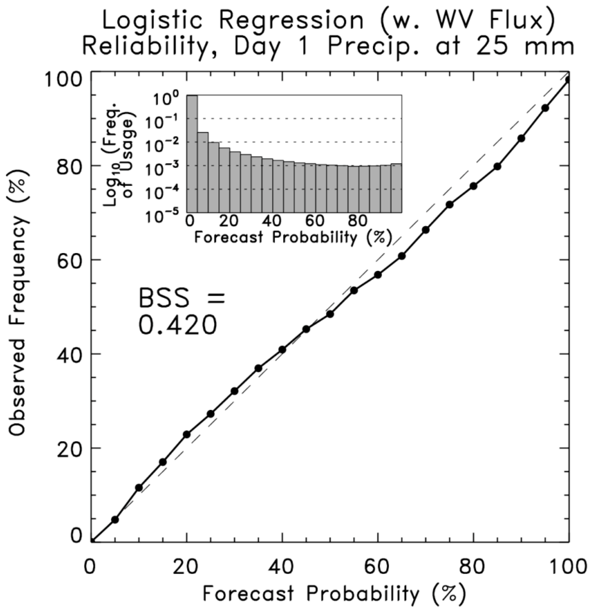
So we concentrate on precip in west-coast mountains, verify CONUS forecasts only west of heavy black line.

Reliability, Logistic Regression with Water Vapor Flux, Day 1

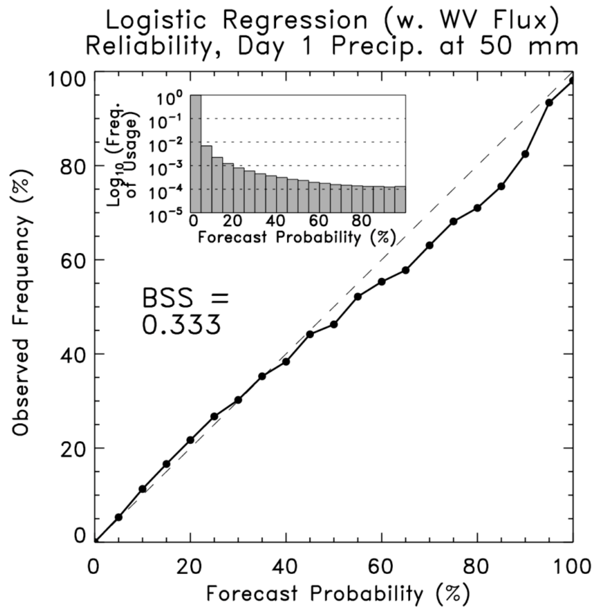
2.5 mm



25 mm



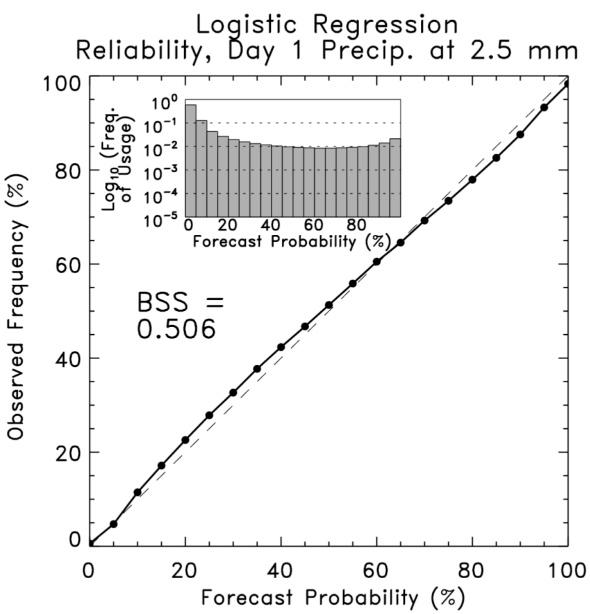
50 mm



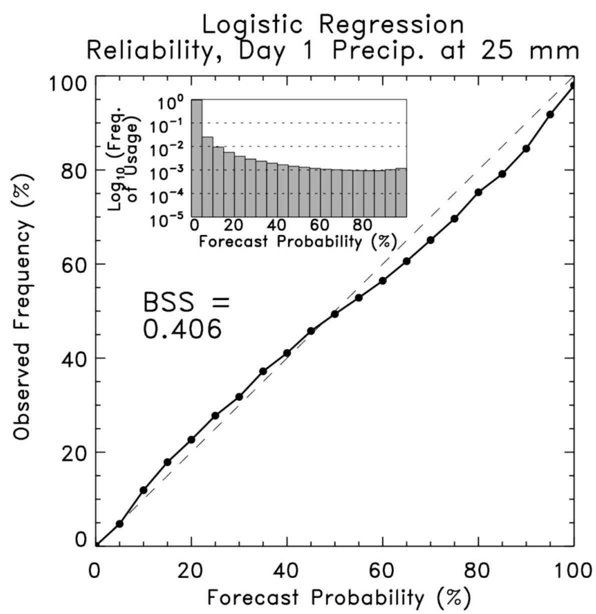
Slight over-forecast bias at high probabilities, high thresholds.

Reliability, Logistic Regression without Water Vapor Flux, Day 1

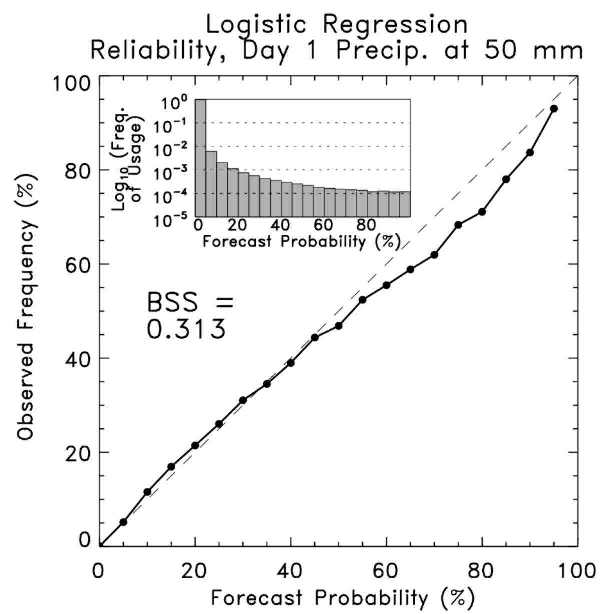
2.5 mm



25 mm

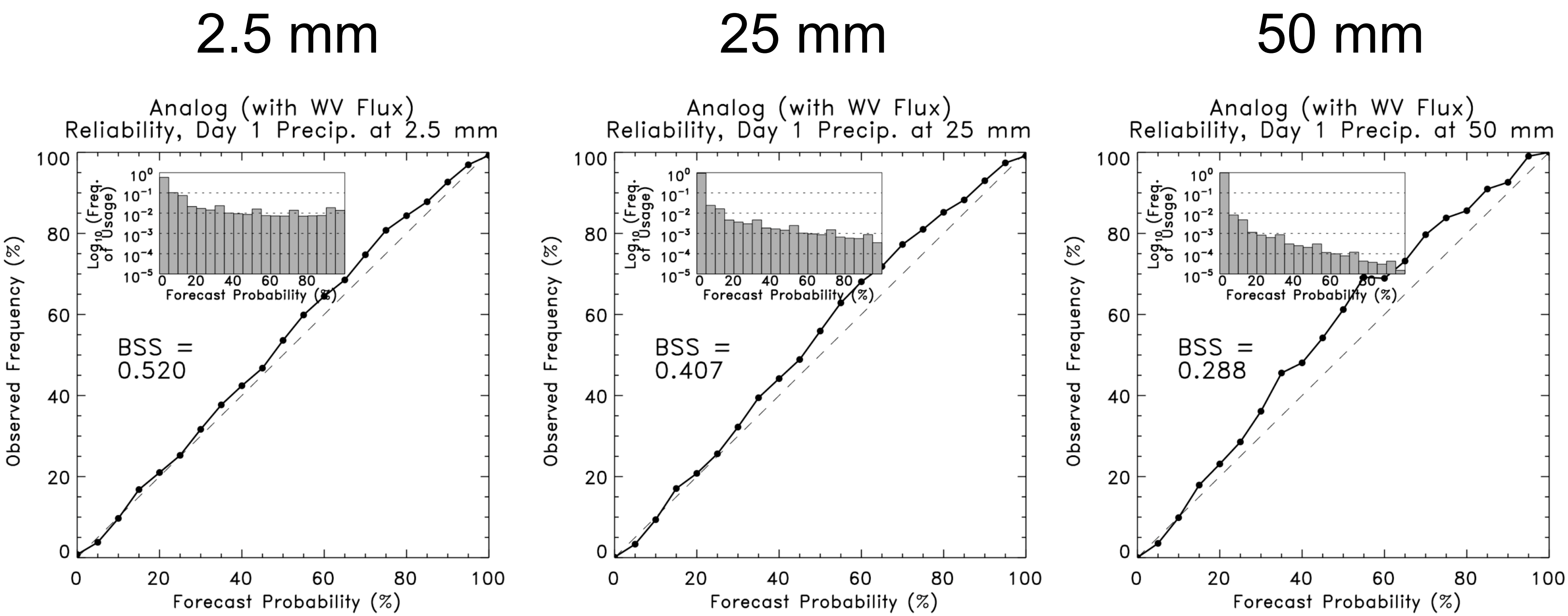


50 mm



Slight improvement with WV flux.

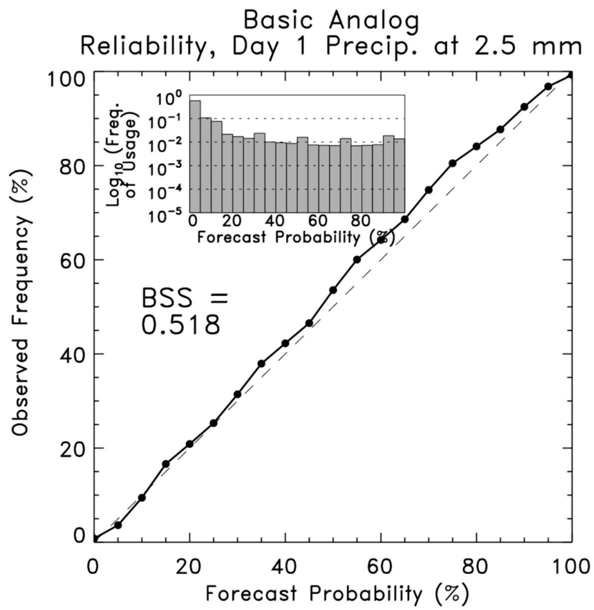
Reliability, Analog with Water Vapor Flux, Day 1



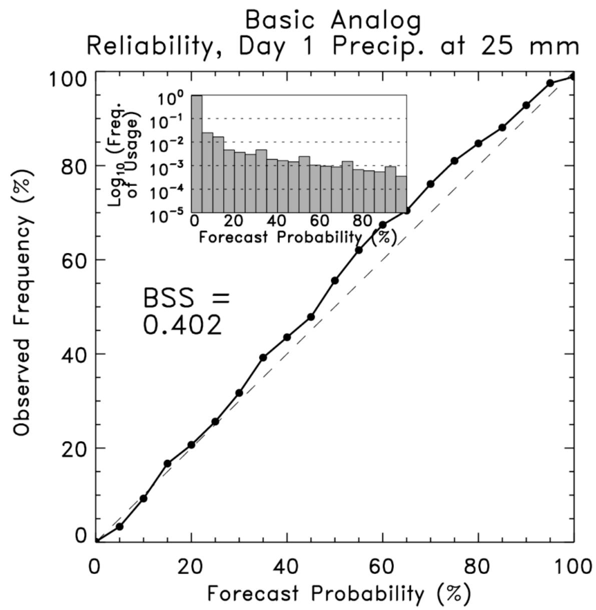
Here, an under-forecast bias for the analog relative to logistic regression.

Reliability, Analog without Water Vapor Flux, Day 1

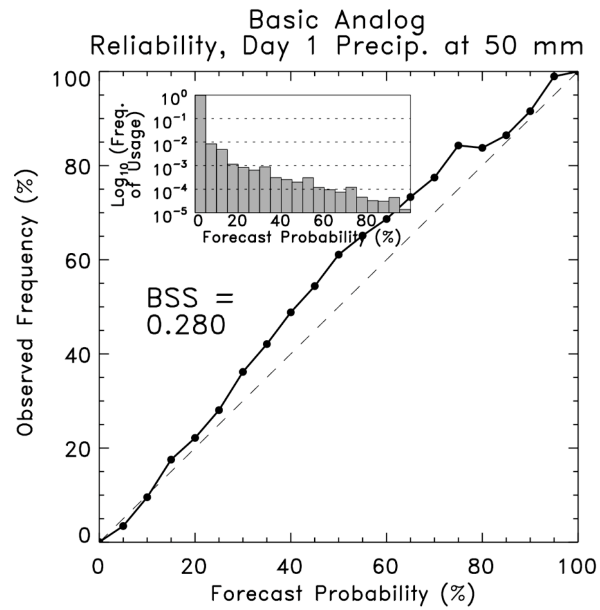
2.5 mm



25 mm

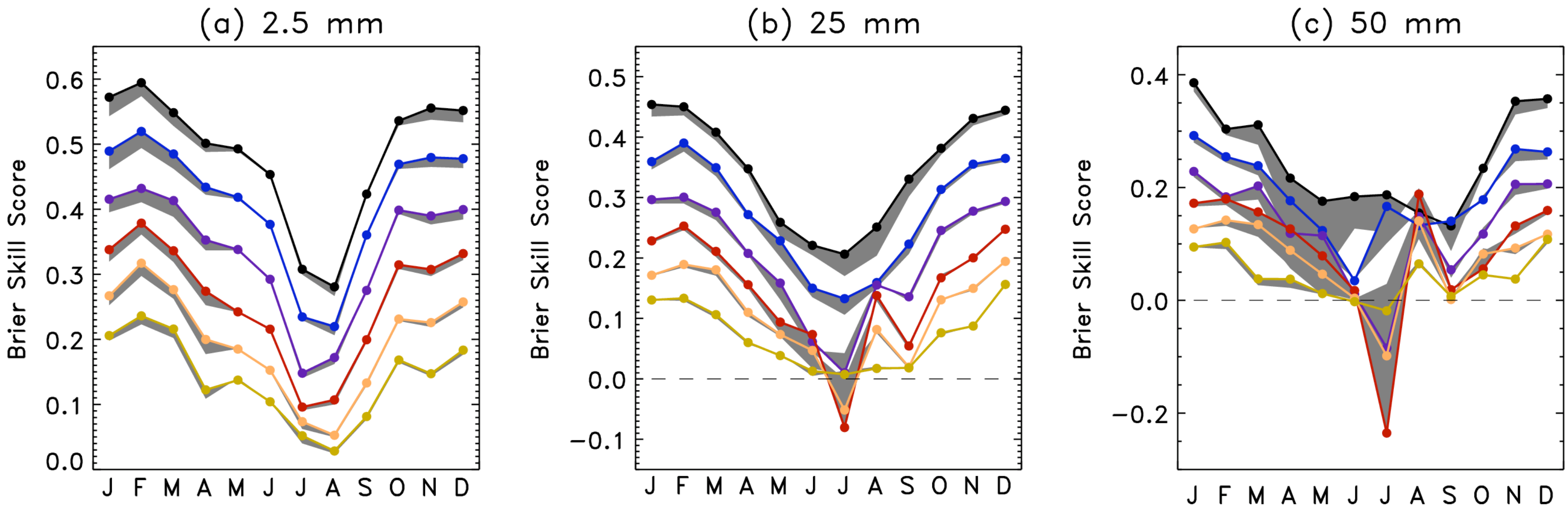


50 mm



Not much difference with/without WV flux.

Yearly Brier Skill Score, Logistic Regr. with & without WV flux

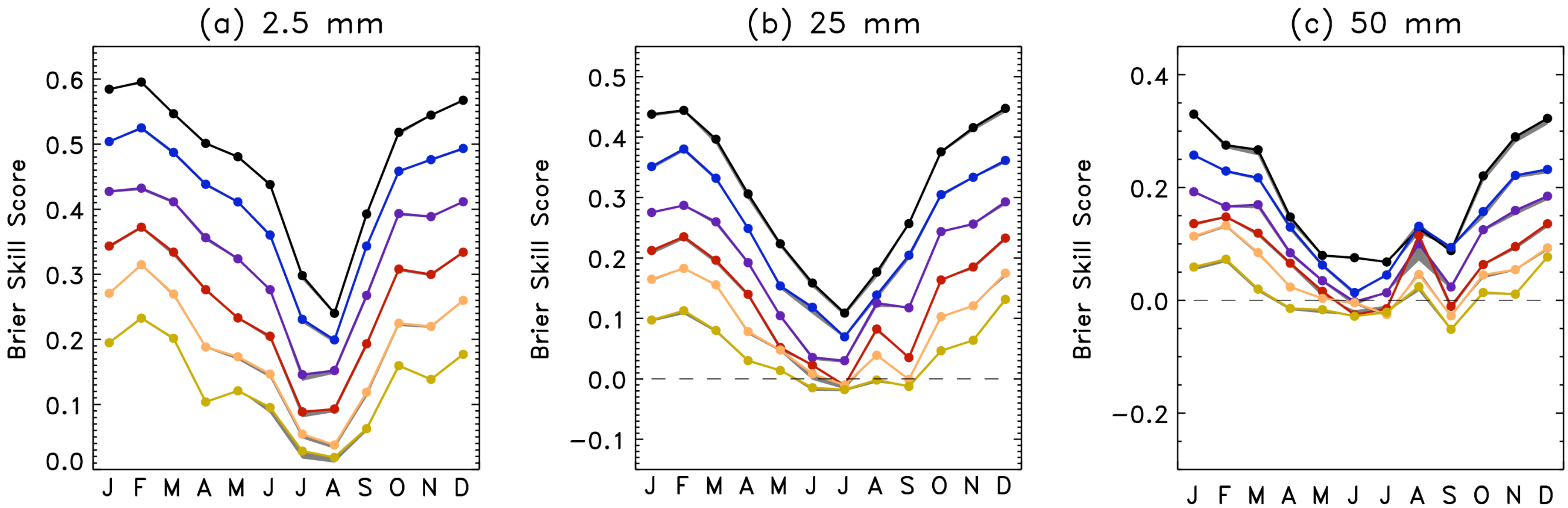


Solid lines denote skill of logistic regression including water-vapor flux. Shaded area indicates difference between this and logistic regression based only on the ensemble-mean precip.

For heavier events, more impact of WV flux in warm season. Is this because knowing whether precip. is due to large-scale transport viz. local convective instability is especially helpful?

Note: conventional method of calculating BSS is used here; I've found that this tends to exaggerate the actual skill (see Hamill and Juras, *QJRMS*, Oct. 2006).

Yearly Brier Skill Score, Analog with & without WV flux

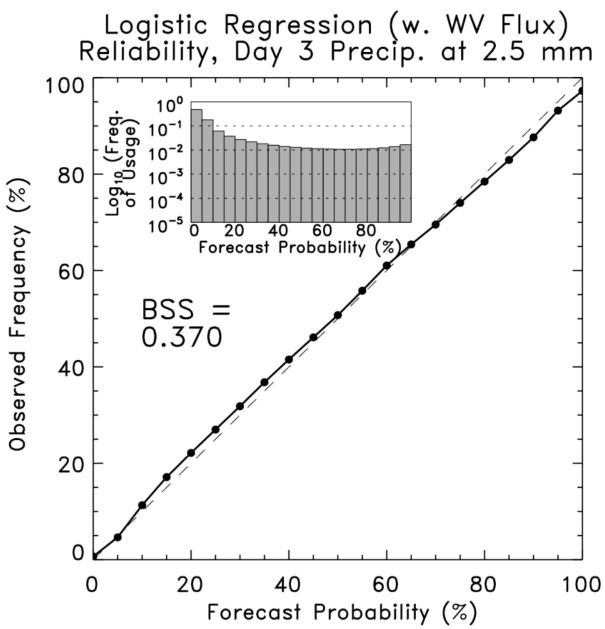


Solid lines denote skill of analog including water-vapor flux. Shaded area indicates difference between this and analog based only on the ensemble-mean precip.

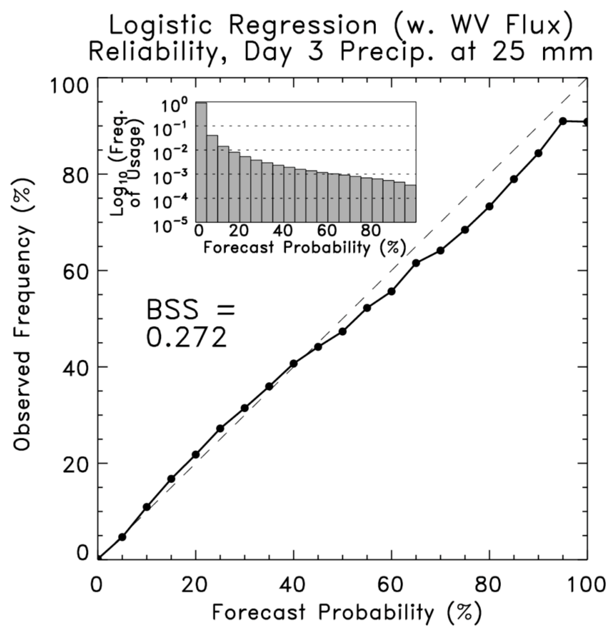
Note: conventional method of calculating BSS is used here; I've found that this tends to exaggerate the actual skill (see Hamill and Juras, *QJRMS*, Oct. 2006).

Reliability, Logistic Regression with Water Vapor Flux, Day 3

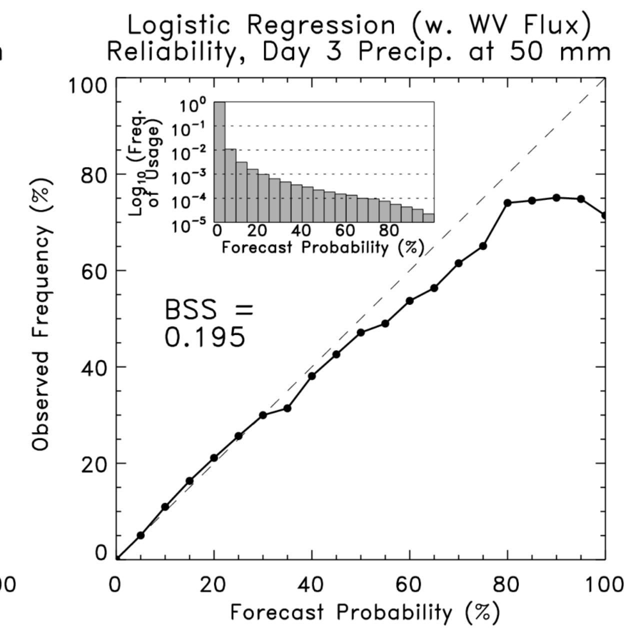
2.5 mm



25 mm

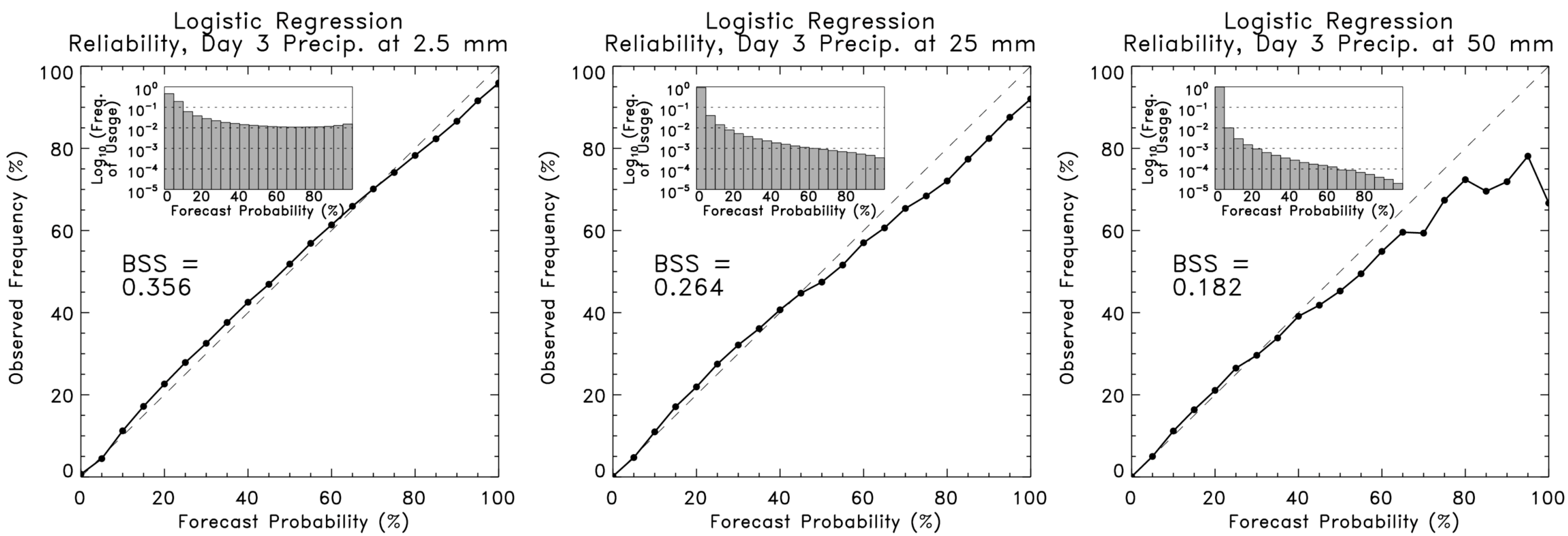


50 mm



Reliability, Logistic Regression without Water Vapor Flux, Day 3

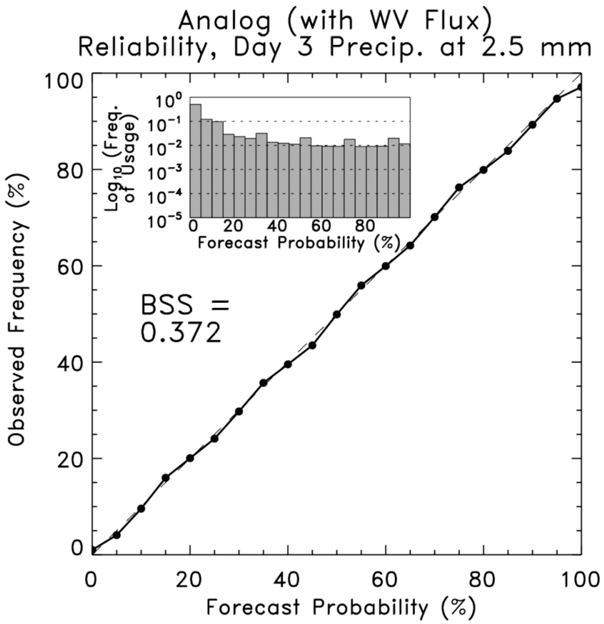
2.5 mm　　25 mm　　50 mm



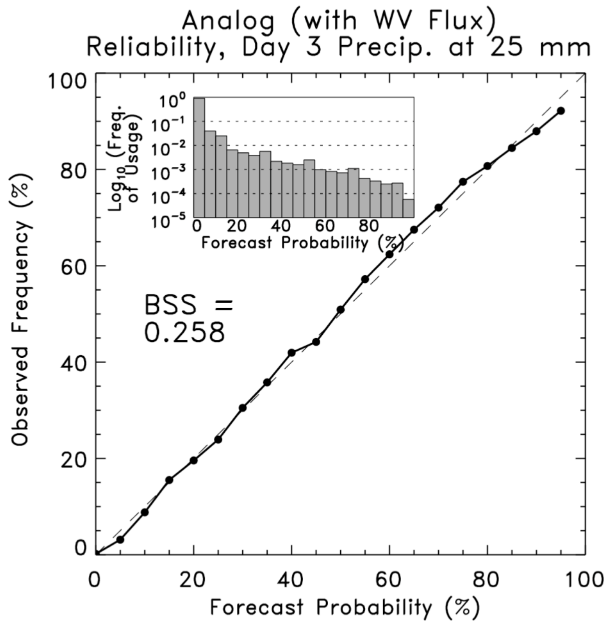
Small difference with/without. But "with" better.

Reliability, Analog with Water Vapor Flux, Day 3

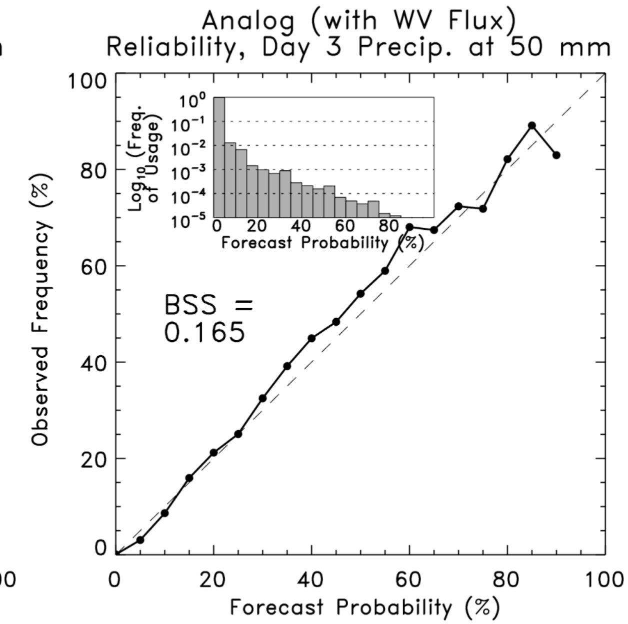
2.5 mm



25 mm



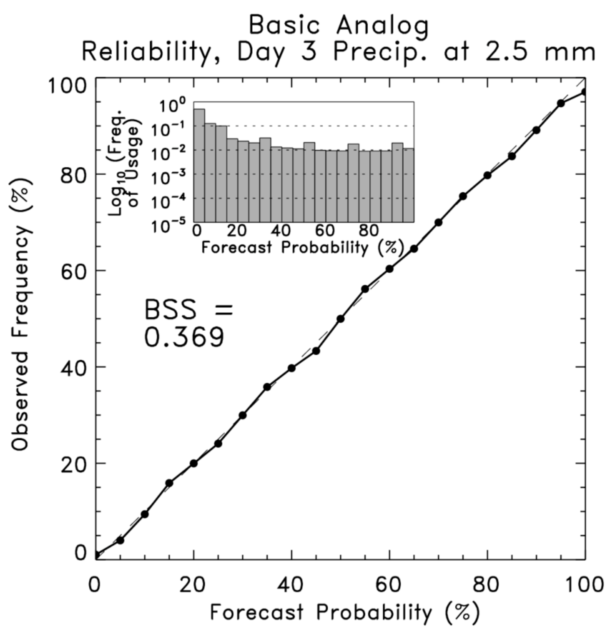
50 mm



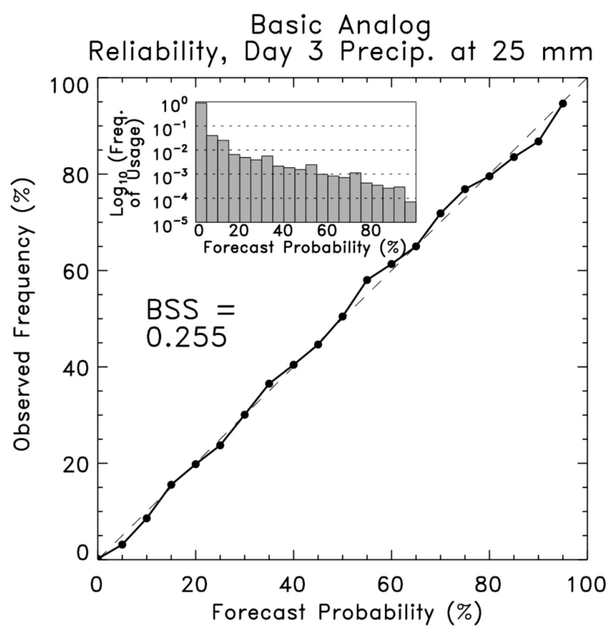
Increased skill of prior logistic regression relative to the analog at 50 mm comes from going out on a limb and issuing high probabilities slightly more often (and having them verify).

Reliability, Analog without Water Vapor Flux, Day 3

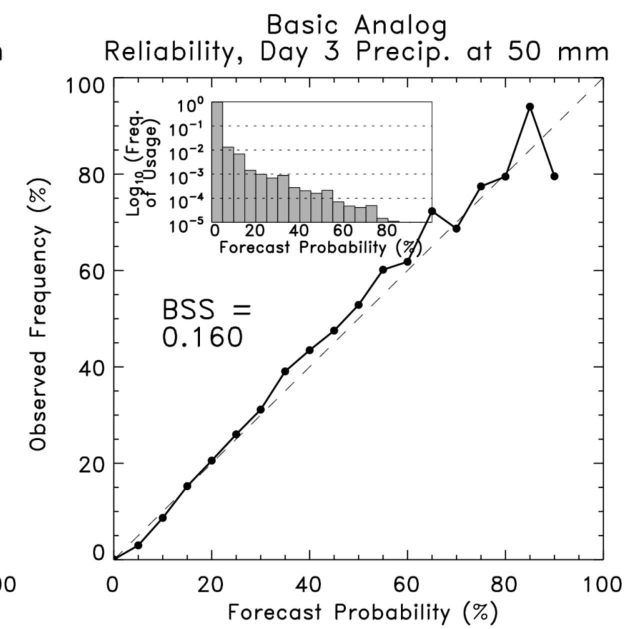
2.5 mm



25 mm

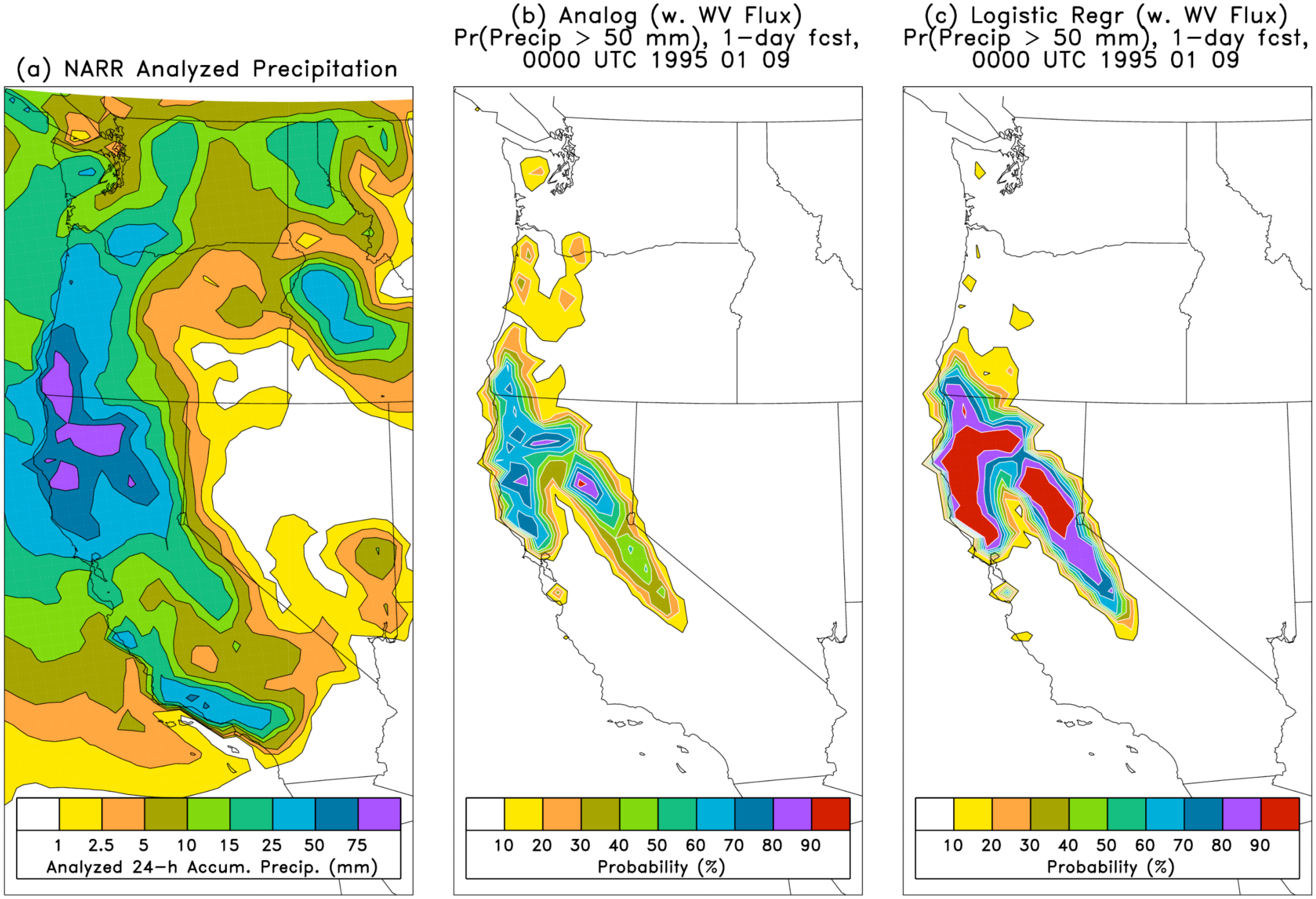


50 mm



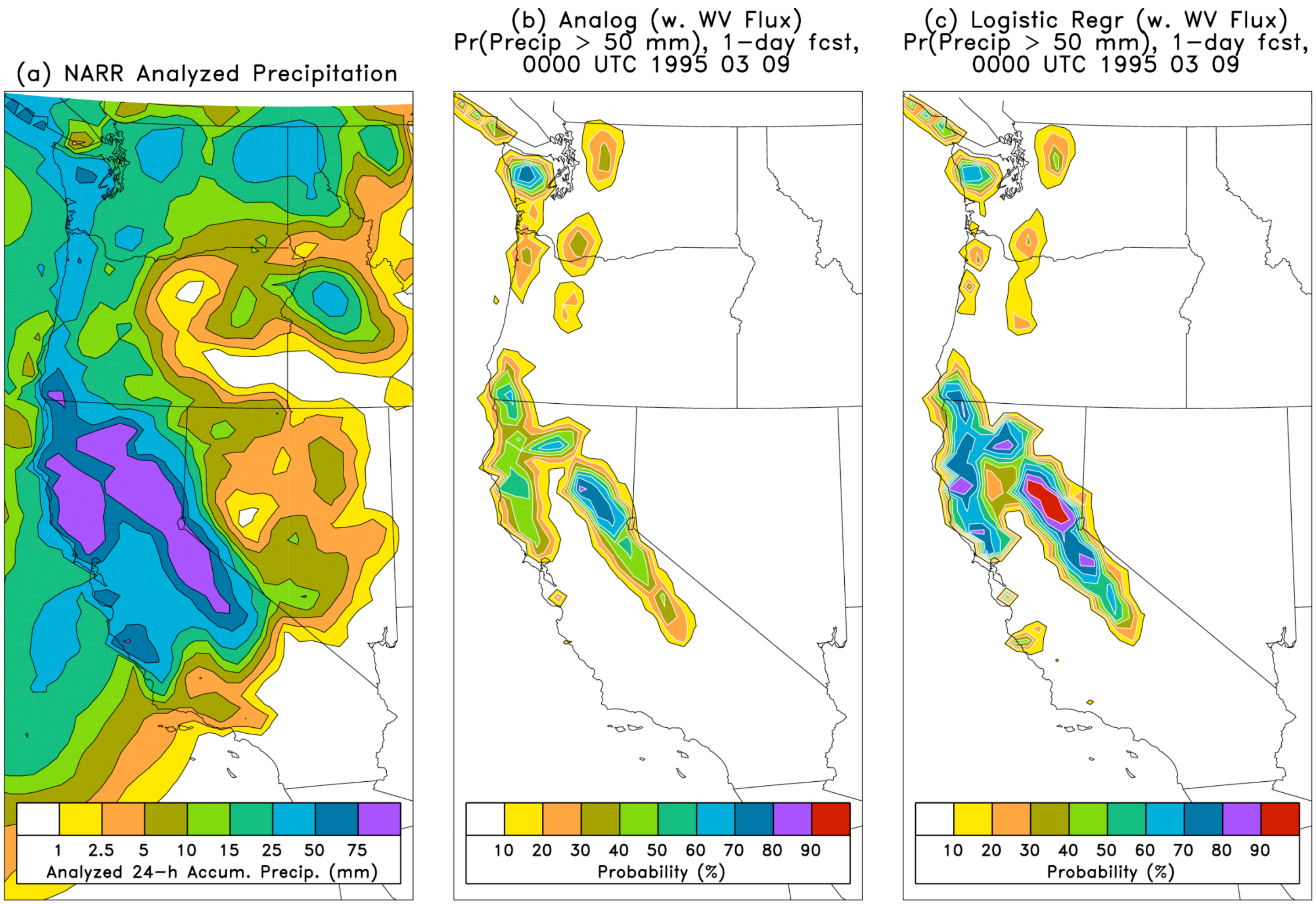
Not much difference for analog with/without WV flux.

Day-1 forecast, analog and logistic regression (with WV flux)

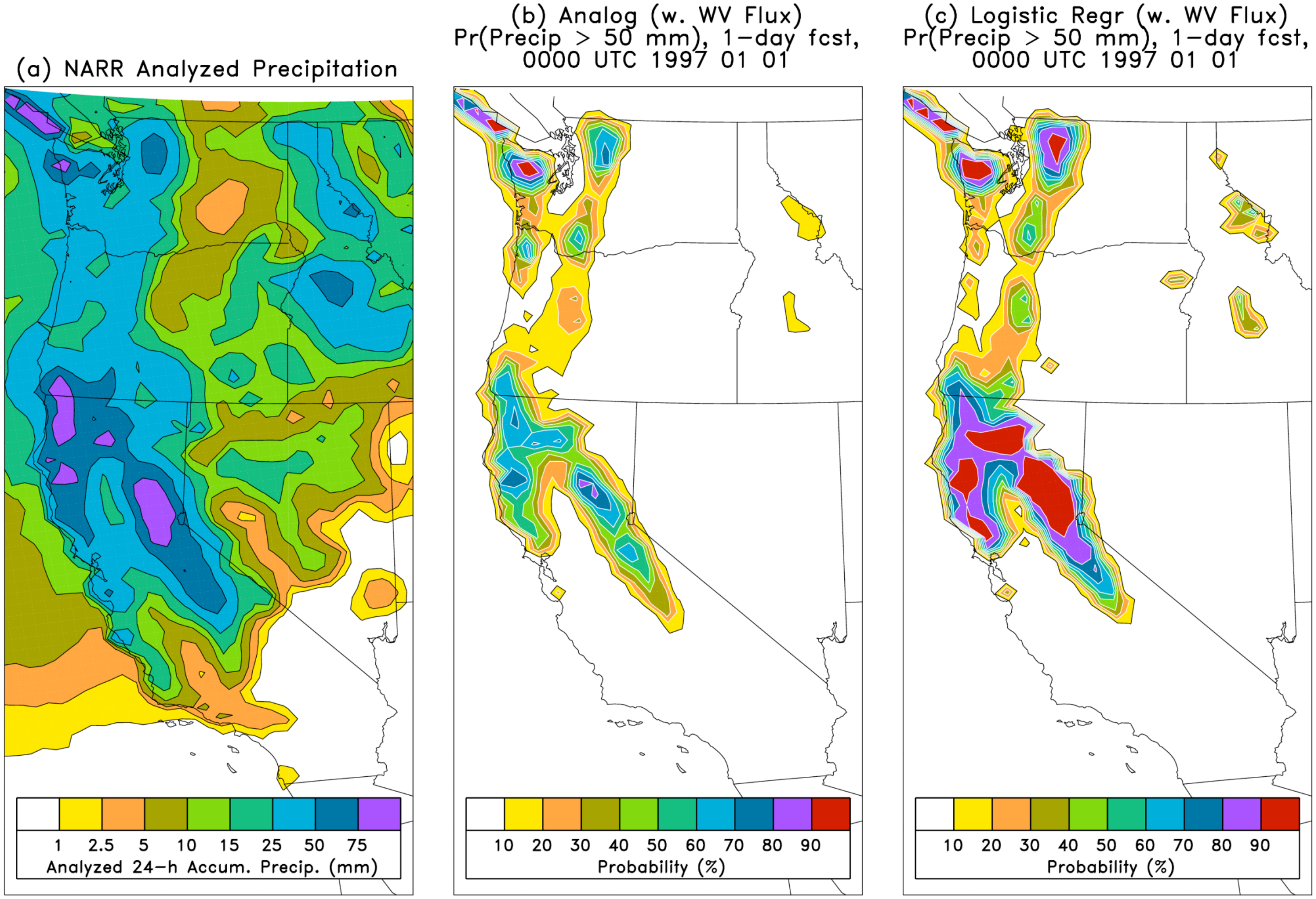


Notice accentuation of high probabilities with logistic regression.

Day-1 forecast, analog and logistic regression (with WV flux)

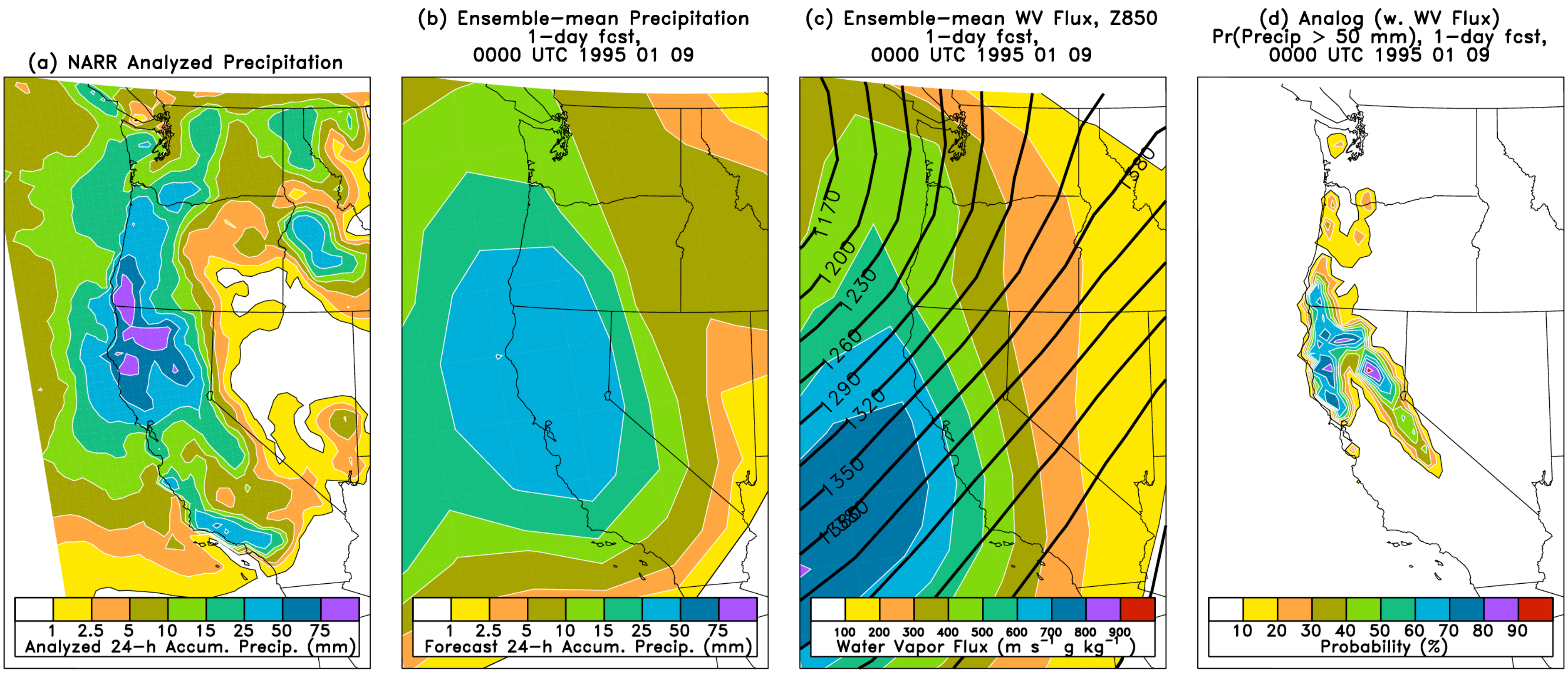


Day-1 forecast, analog and logistic regression (with WV flux)

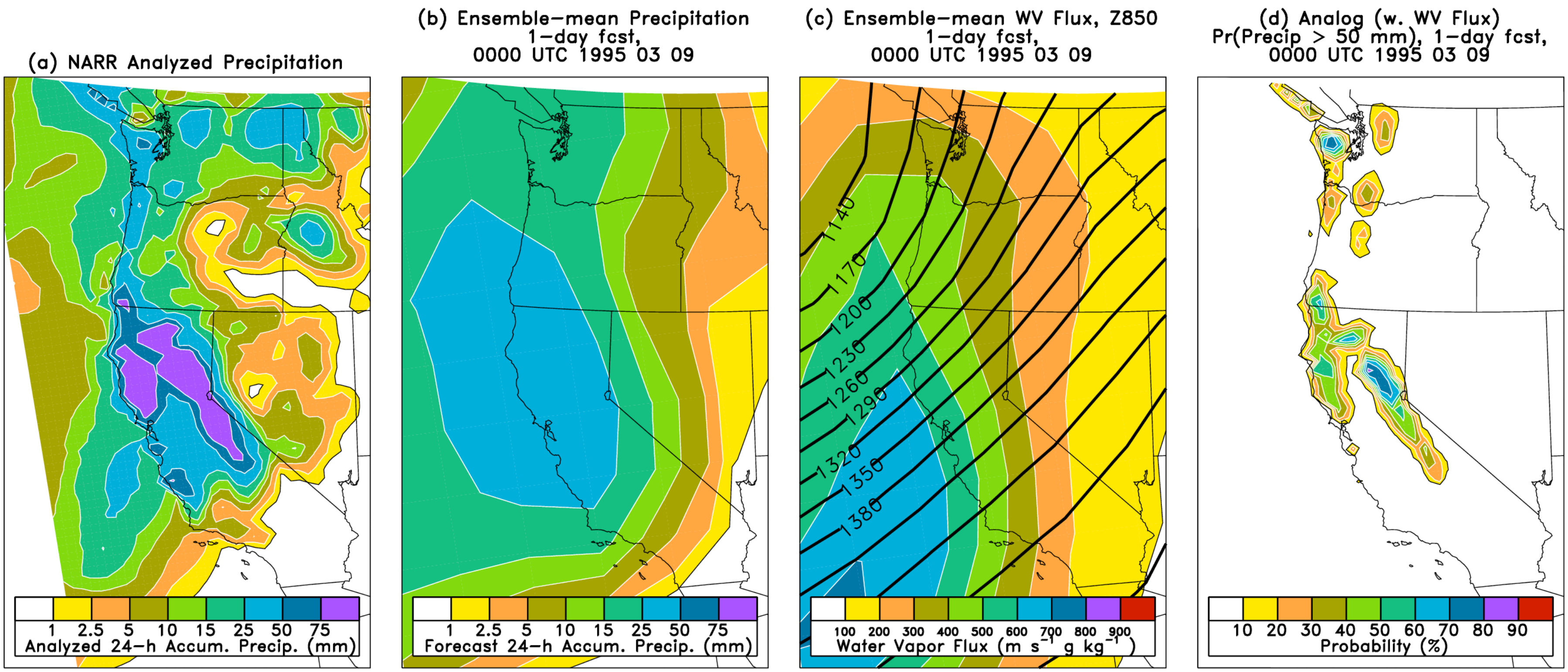


Again, logistic regression probabilities higher.

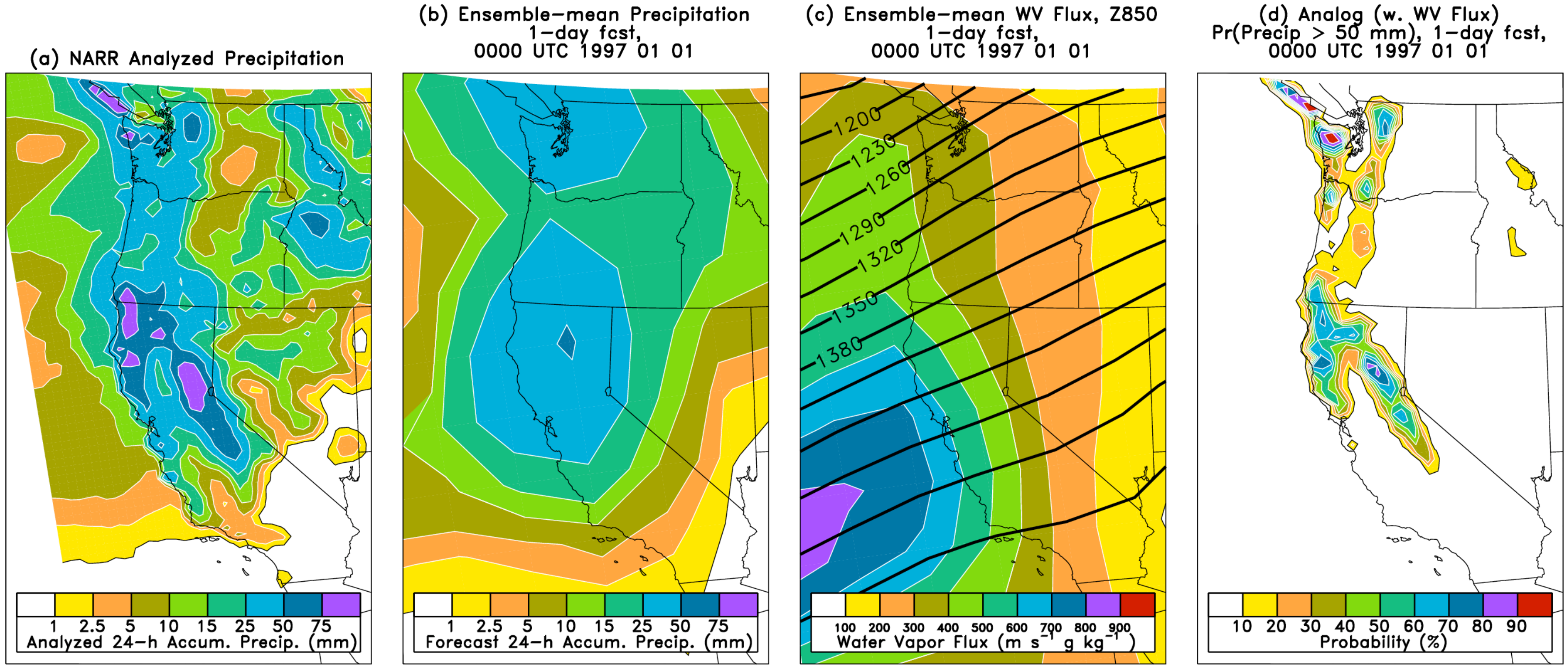
Water vapor flux and the day-1 precipitation forecasts



Water vapor flux and the day-1 precipitation forecasts



Water vapor flux and the day-1 precipitation forecasts



Water vapor appears to come in broader swaths in model forecasts than observed in atmospheric river research.

Discussion

(1) Why does the analog under-forecast, and the logistic regression over-forecast?

A: For extreme events, tough to find many good analogs. The chosen ones are likely to have drier forecasts, thus drier observed analogs. Conversely, logistic regression is "extrapolating the regression" into unknown parameter space, so would expect probabilities to be higher than those encountered with the training data.

(2) Why isn't water vapor more useful as a predictor?

A: Probably because the essential physics are already in the model. If the model is blowing a lot of moisture up a sloped terrain, it's going to precipitate in the forecast, so forecast precip field may contain most of the information already.

Conclusions

- Logistic regression preferable to analog technique for estimating probabilities of extreme events, even if skill scores ~ similar.
- Water vapor flux as an additional predictor has a small beneficial impact, larger with logistic regression than analog.
  - more impact in warm season.
- Will attempt (pending time and resources) to move our experimental products (www.cdc.noaa.gov/reforecast/narr) over to logistic regression

Selected reforecast references

Hamill, T. M., J. S. Whitaker, and S. L. Mullen, 2005: Reforecasts, an important dataset for improving weather predictions. *Bull. Amer. Meteor. Soc.*, **87**, 33-46.
http://www.cdc.noaa.gov/people/tom.hamill/refcst_bams.pdf

Hamill, T. M., and J. S. Whitaker, 2006: Probabilistic quantitative precipitation forecasts based on reforecast analogs: theory and application. *Mon. Wea. Rev.*, **134**, 3209-3229.
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Hamill, T. M., and J. Juras, 2006: Measuring forecast skill: is it real skill or is it the varying climatology? *Quart. J. Royal Meteor. Soc.*, in press.
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Hamill, T. M. and J. S. Whitaker, 2006: White Paper. "Producing high-skill probabilistic forecasts using reforecasts: implementing the National Research Council vision." Available at http://www.cdc.noaa.gov/people/tom.hamill/whitepaper_reforecast.pdf .