Verification of Eastern Pacific Cloud Forecasts

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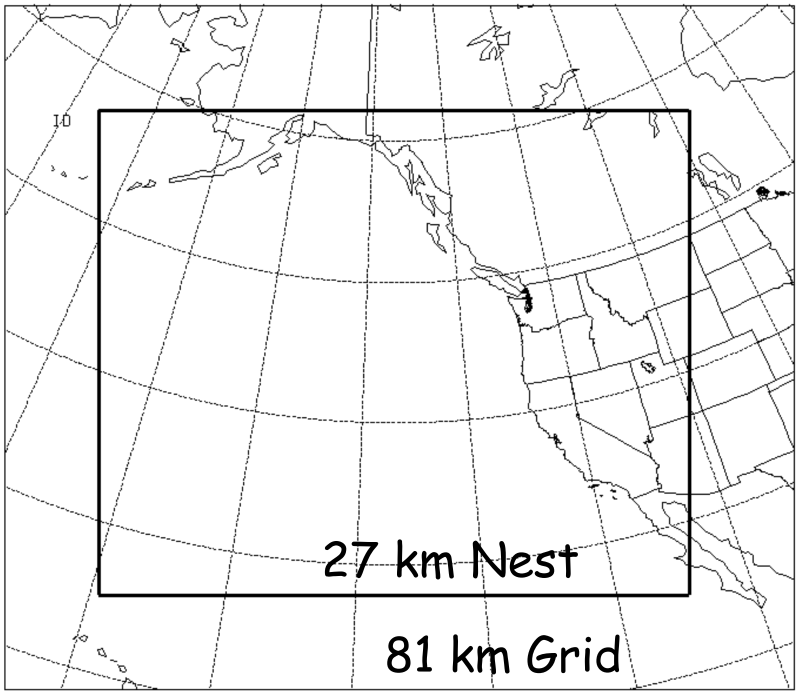
Outline

- Data and methods
- The challenge of cloud verification
- Composite verification
- Fuzzy verification
- Summary

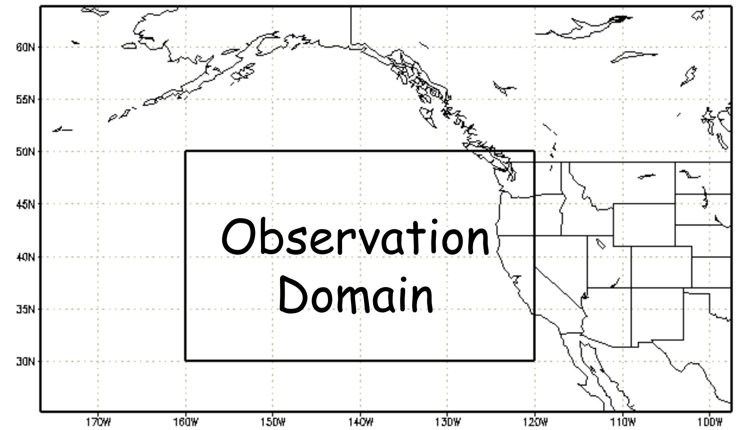
Forecast and Data Overview

Operational COAMPS®* Forecasts



- 30 levels
- 6-hour data assimilation cycle using NAVDAS 3-D Var
- Microphysics based on Rutledge and Hobbs
- Kain-Fritsch cumulus parameterization

Observations



- GOES satellite retrievals
  - Cloud top temperature
  - Cloud top height (based on NOGAPS) temperature profile
  - Liquid (includes ice) water path (daylight hours only)
  - Cloud type
- Subset area of forecast grid
- 4 km footprint interpolated to forecast grid
- Bias calibration performed
- Scores derived for Feb-May 2007

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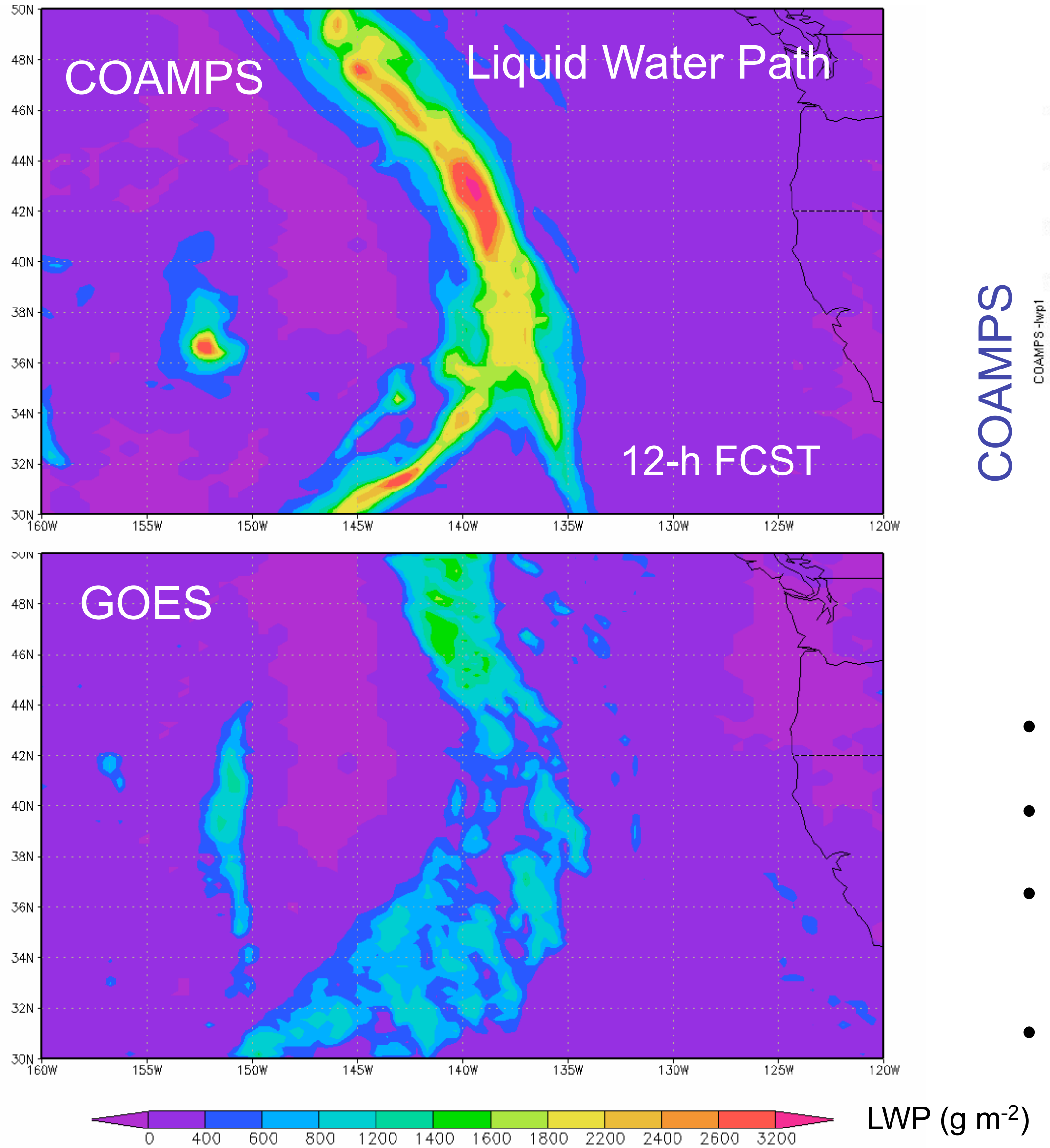
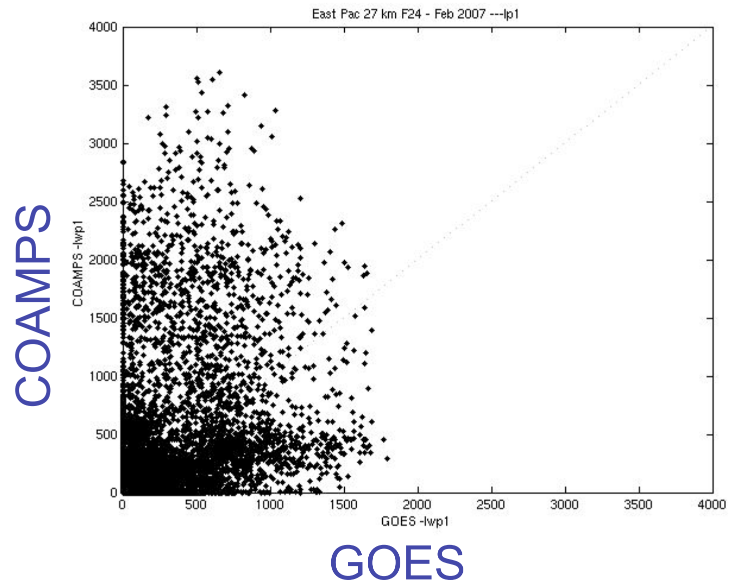
Is this a good Forecast?



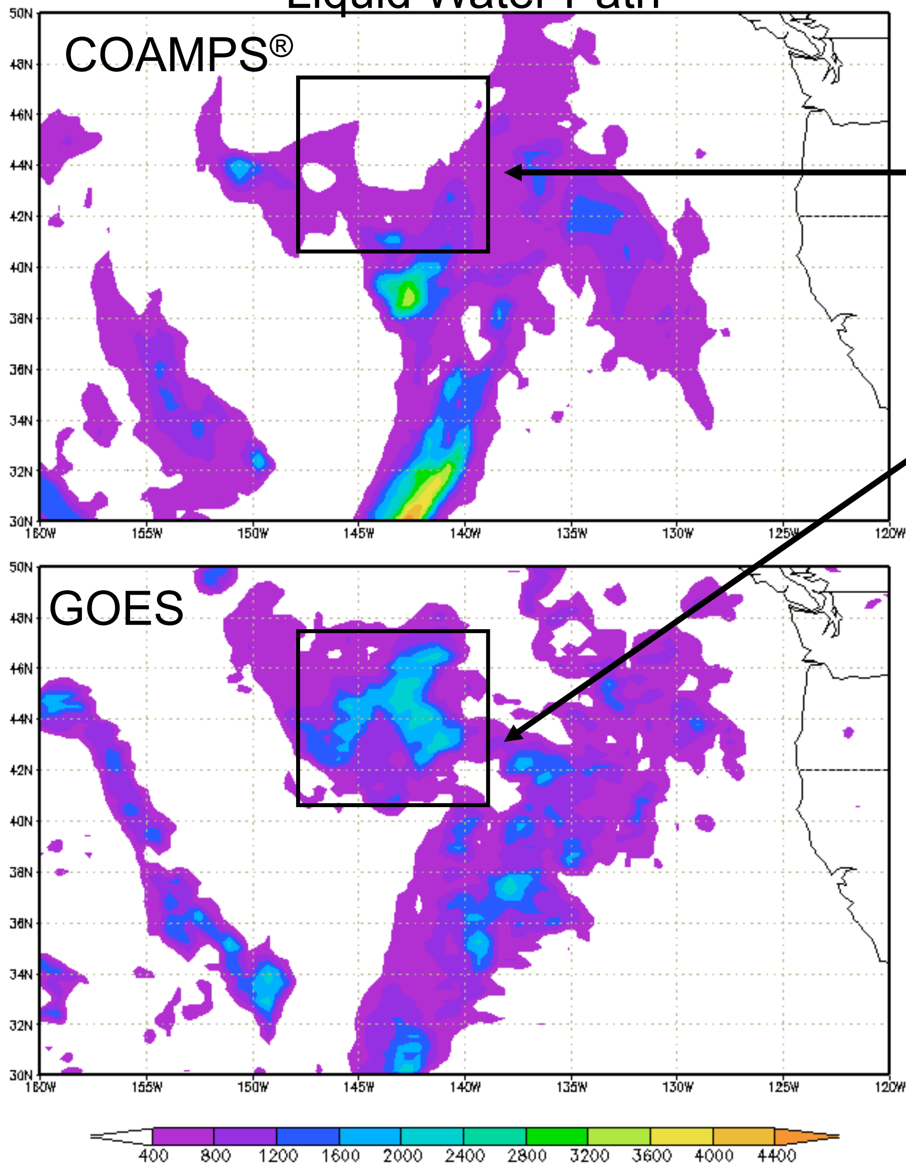
Point-to-Point Comparison



- General features well positioned
- Positive model bias
- Spatial error correlation not measured
- How to quantify this?

Composite (Event-based) Verification

Liquid Water Path



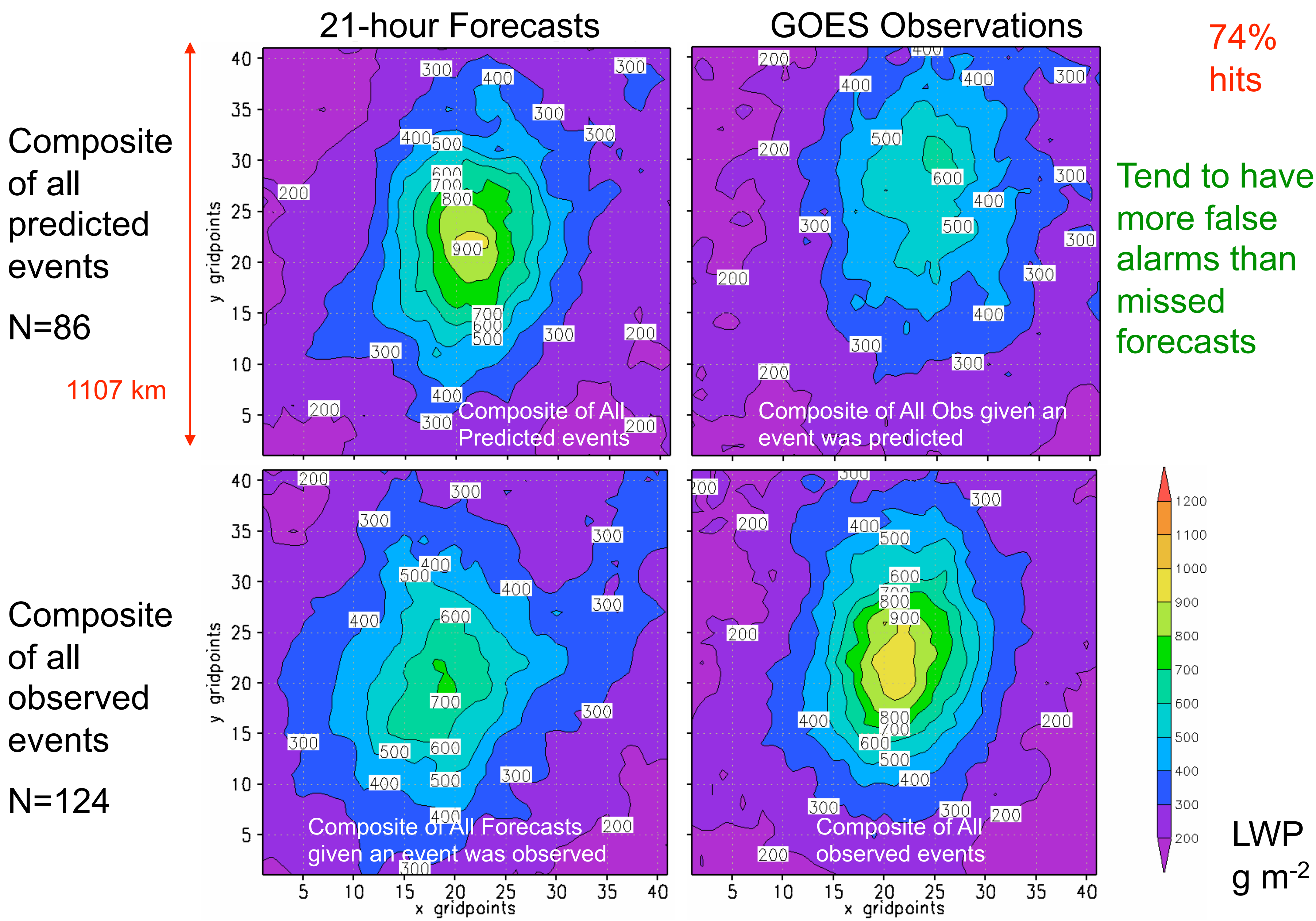
Event Statistics

- Collect samples of multiple events of similar scale
- Investigate systematic forecast errors

Method:

- Identify events of interest
  - all events with LWP ≥ 500 g m^{-2}
  - 100-600; 600-3000 points
- Composite all predicted events
- Composite all observed events

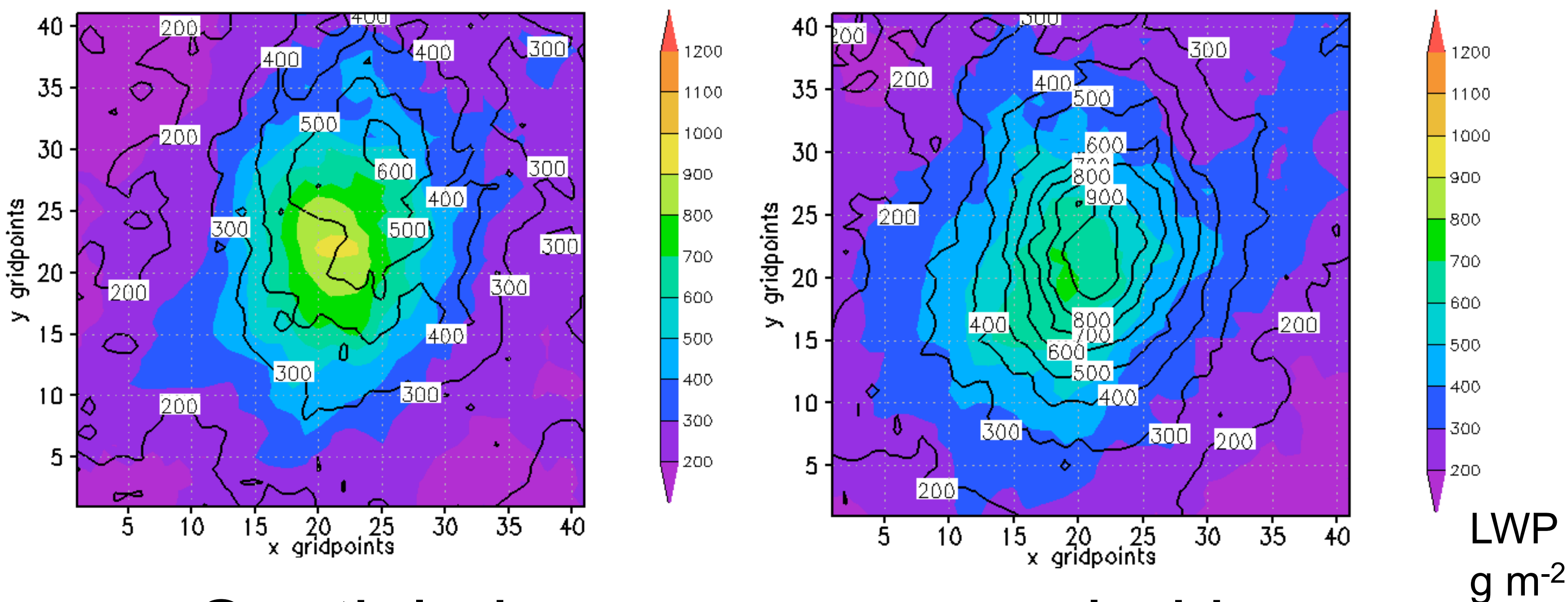
Small (~350 km) Events LWP ≥ 500 g m^{-2}



74% hits

Tend to have more false alarms than missed forecasts

Small (~350 km) Events LWP ≥ 500 g m^{-2}



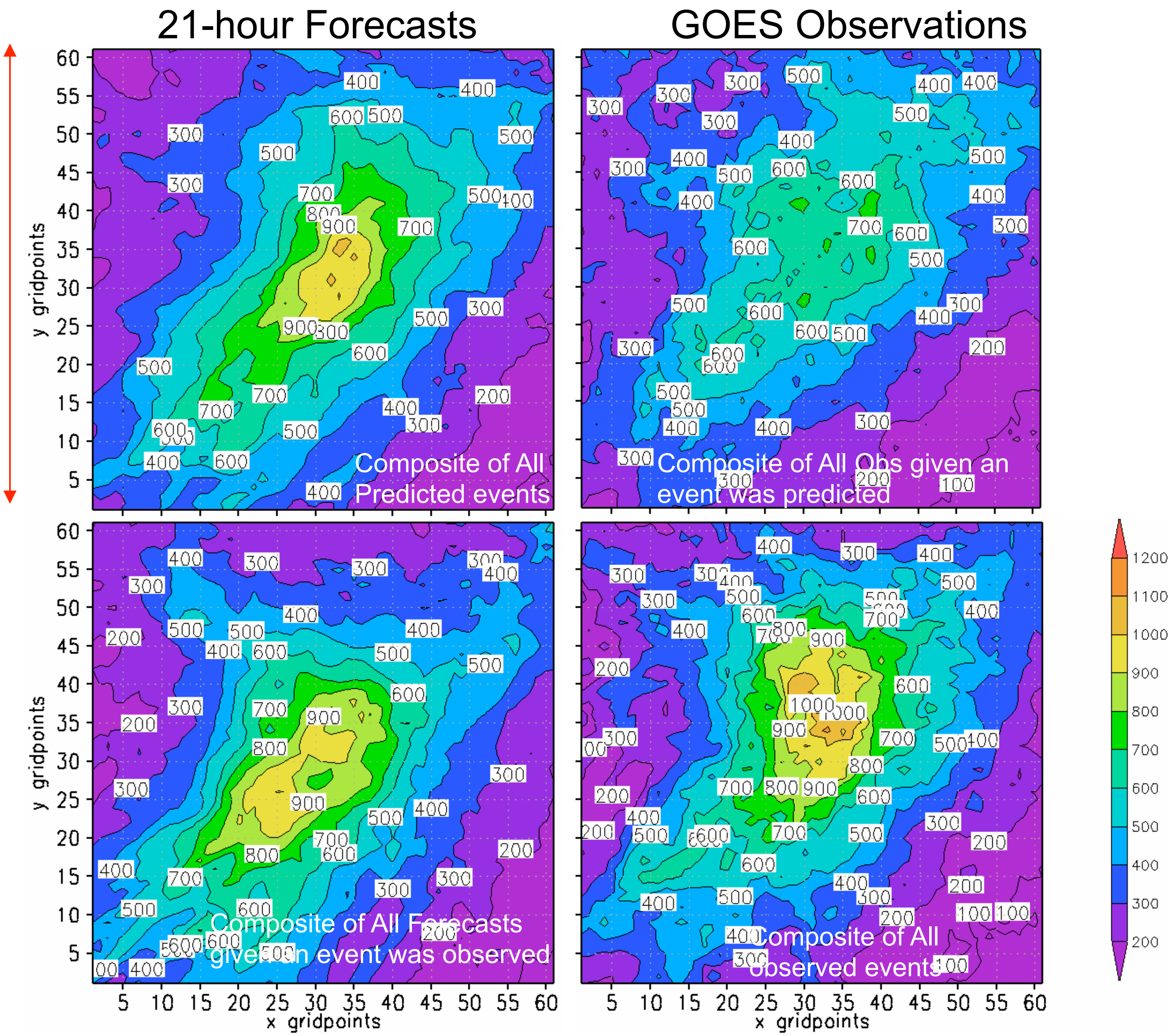
- Spatial phase errors revealed by overlaying distributions
- Must display predicted and observed events separately

Large (~1000 km) Events LWP ≥ 500 g m^{-2}

Composite of all predicted events

N=50

1647 km



80% hits

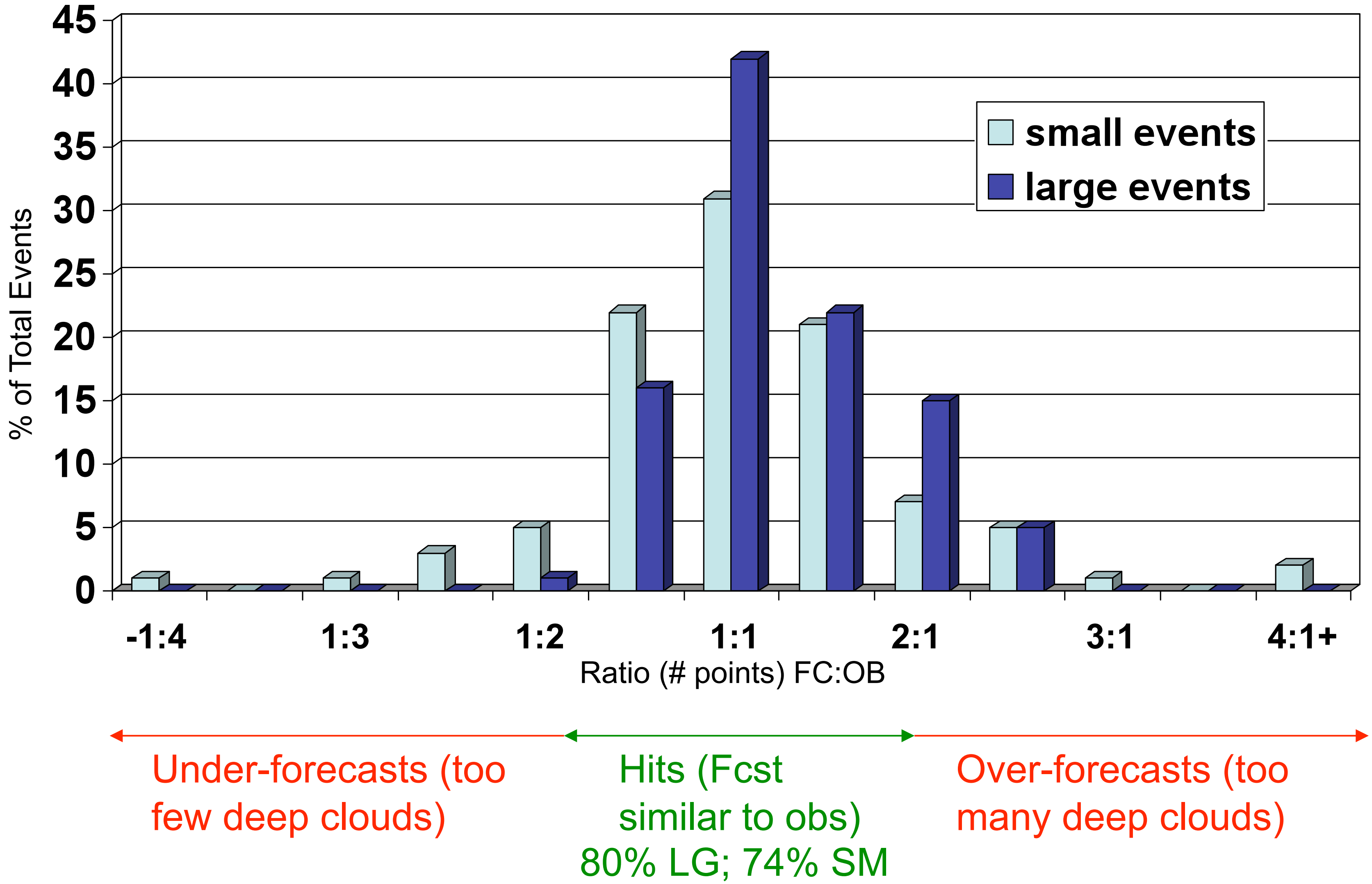
Composite of all observed events

N=38

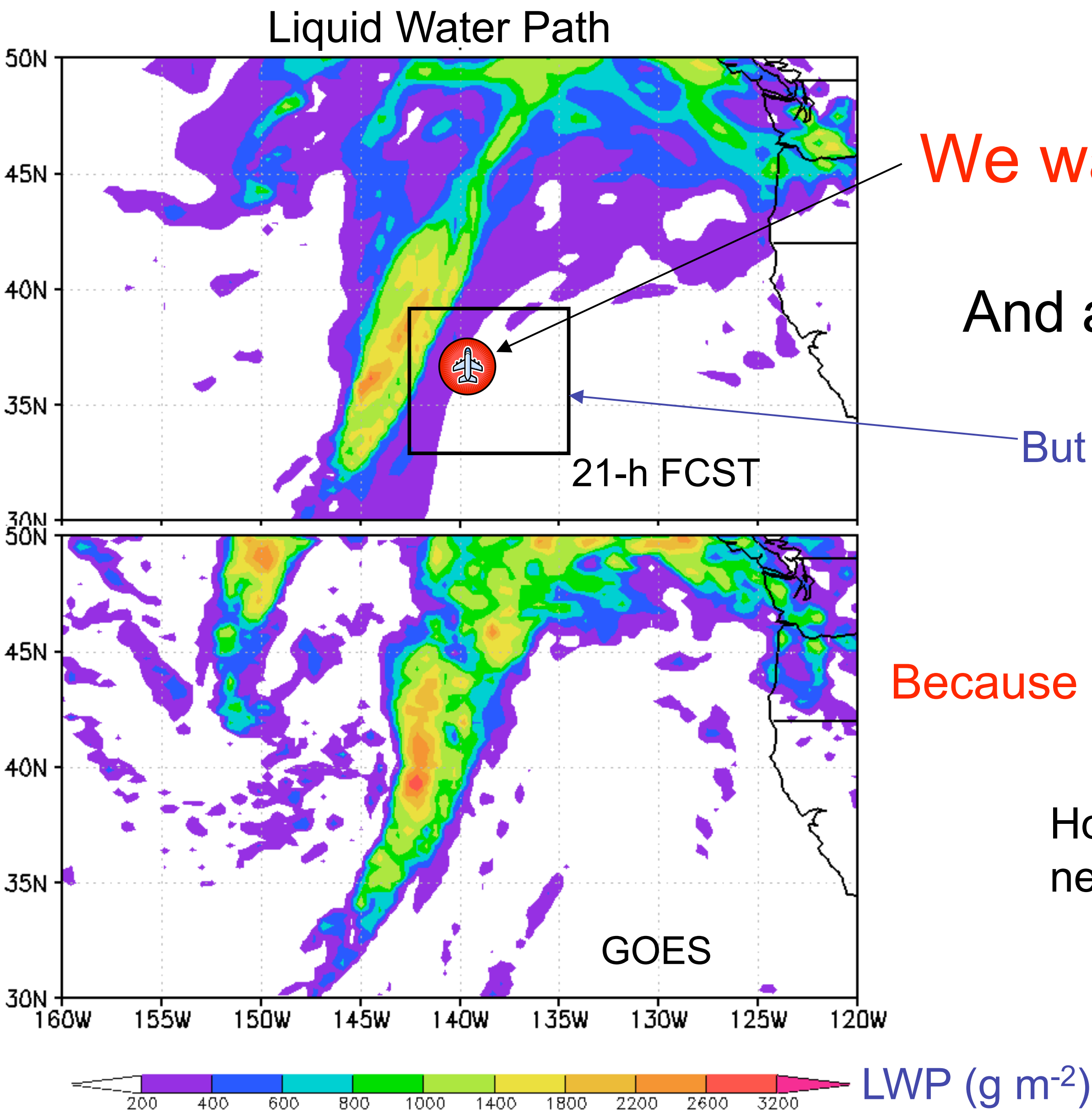
LWP g m^{-2}

Percentage of Events with Given Fcst:Obs Ratios

Feb-May 2007



Quantifying Uncertainty



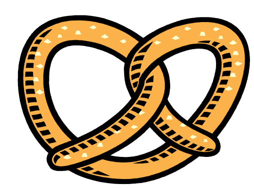
We want to go here

And avoid the front

But we're flexible…

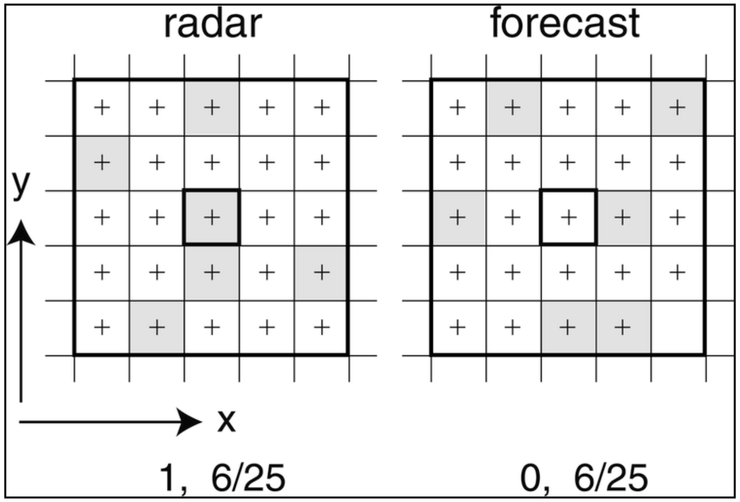
Because the forecast is not perfect

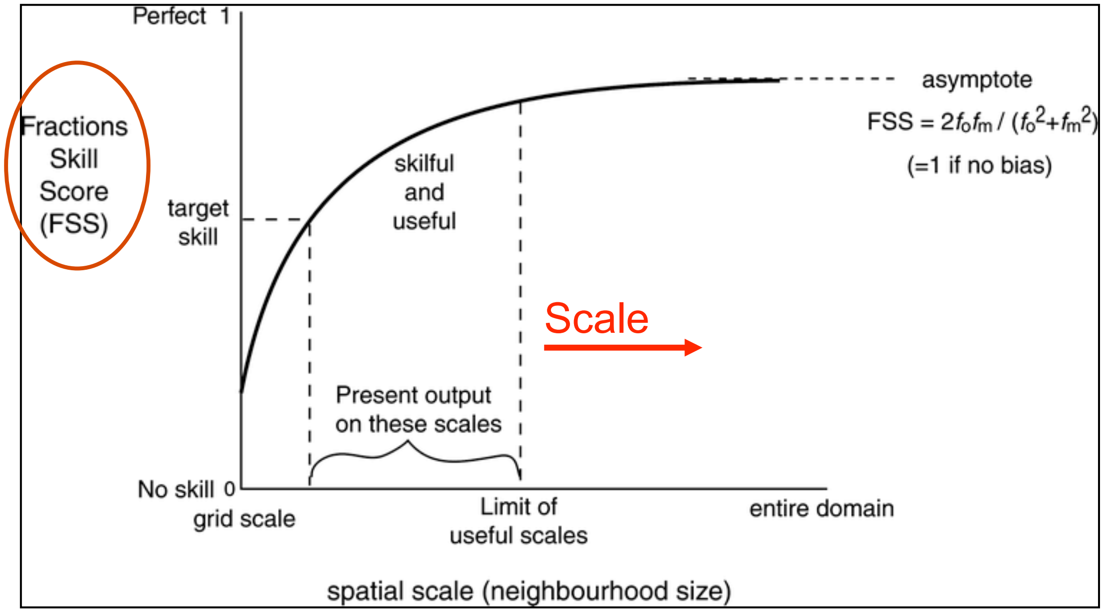
How flexible do we need to be?



Fuzzy Neighborhood Method

From Roberts and Lean (2008)

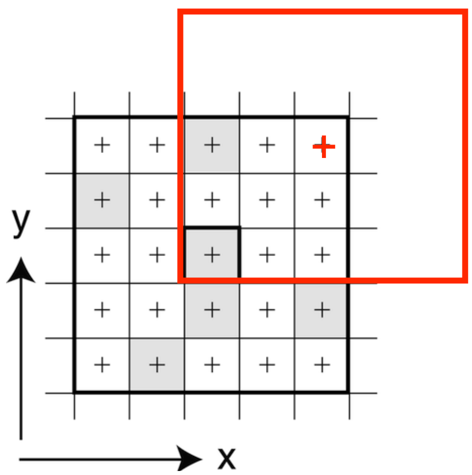




- Use threshold to create a binary field.
- Calculate Fractions Skill Score.
- FSS=1 (perfect) when forecast coverage=obs coverage.

Fuzzy Neighborhood Method

A Few Caveats



$$FSS_{(n)} = 1 - \frac{MSE_{(n)}}{MSE_{(n)ref}}$$

$$MSE_{(n)} = \frac{1}{N_x N_y} \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} (O_{(n)i,j} - M_{(n)i,j})^2$$

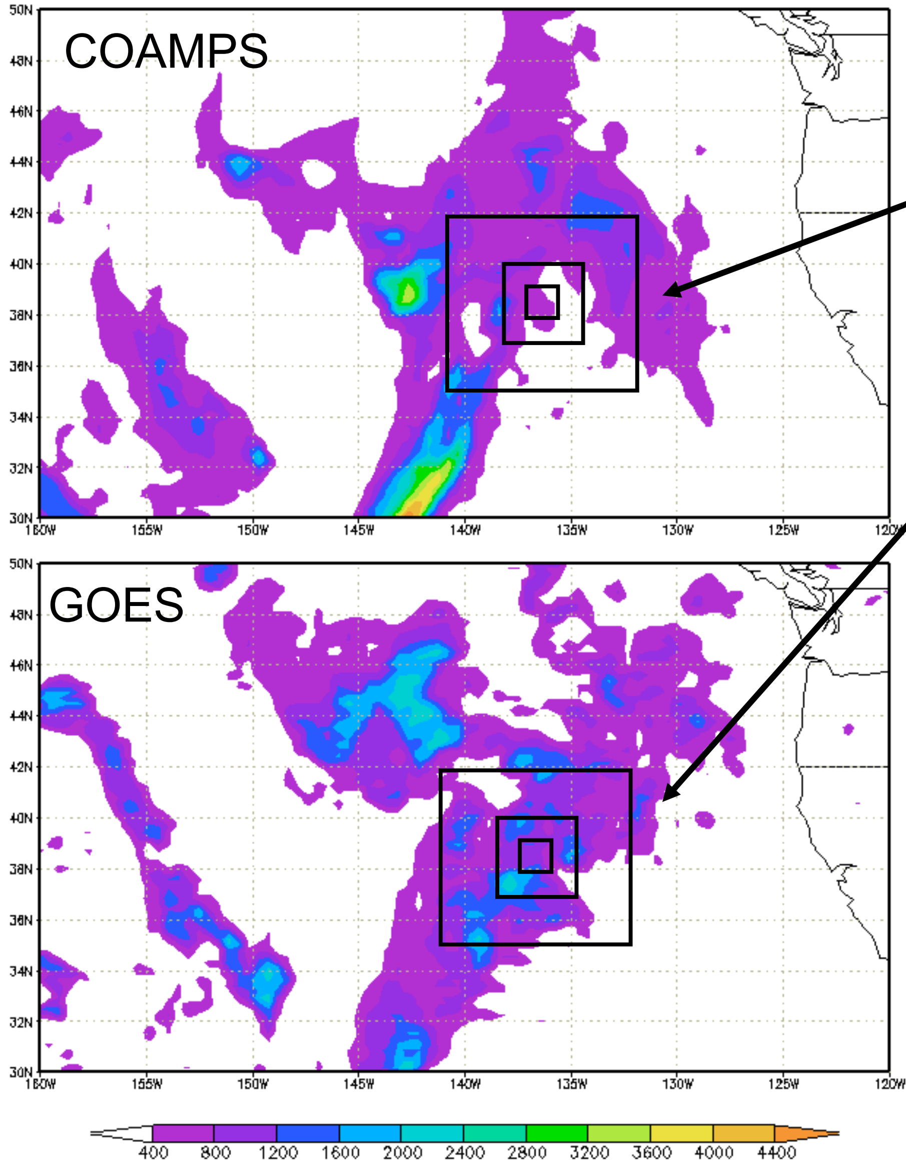
$$MSE_{(n)ref} = \frac{1}{N_x N_y} \left[\sum_{i=1}^{N_x} \sum_{j=1}^{N_y} O^2_{(n)i,j} + \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} M^2_{(n)i,j} \right]$$

- Large scale samples exceed grid bounds
- May cause aliasing

- Reference MSE not a true climatology
- Changes with each forecast
- Positive bias leads to large MSE_{ref} and improved FSS

Calculating Scale-Dependent Scores

Liquid Water Path



Fuzzy Statistics

- Collect samples at all points at multiple scales
- Determine the smallest scale to possess an acceptable error

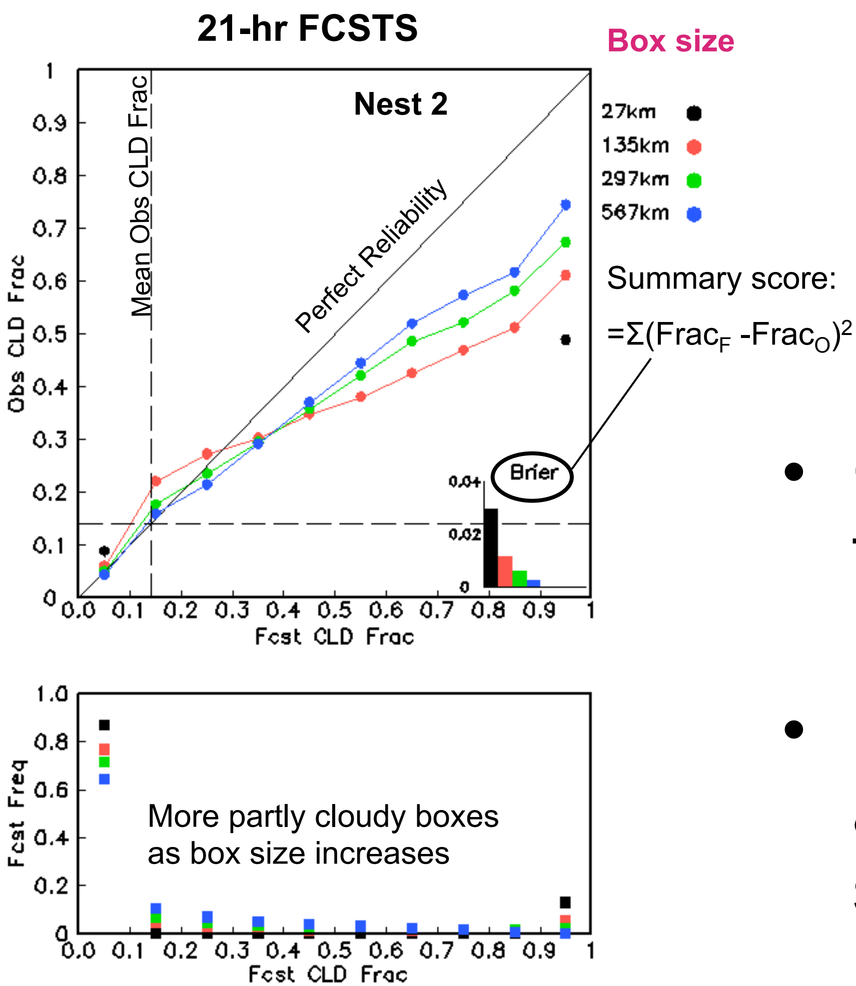
Method:

- Identify a threshold of interest
  - LWP ≥ 500 g m^{-2}
- Create binary field based on the threshold
- Examine the observed and predicted fractional coverage at each scale

Roberts and Lean (2008)

Forecast Uncertainty

Scale-Based Statistics

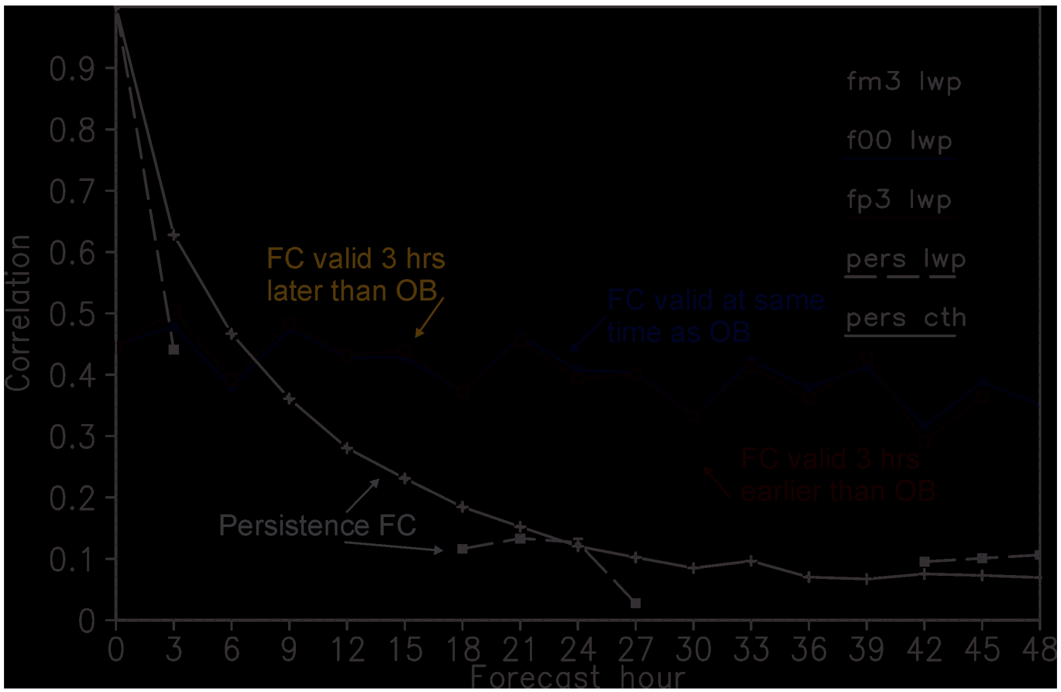


Results are best plotted using reliability diagrams.

- Compute average cloud fractions over increasingly large areas.
- Forecasts for large areas are more reliable but less spatially certain.

Timing Errors

LWP Correlations (Feb-Oct 2007)



- Compute lagged correlations at varying lead times
- Highest correlations indicate best agreement
- Similar to Ebert and Mcbride (2000) CRA method
- Could also use MSE

- +3 hr lag Fcst almost as good as 0 hr due to phase errors
- Model beats persistence after ~ 6-9 hours

Summary

- The characterization of mesoscale uncertainty is a challenging problem.
- Traditional methods do not account for spatial error correlation.
  - Good forecasts can have large errors.
  - Low spatial error correlations are desired.
- Composites provide useful performance information.
  - Focused on specific events.
  - Hard to characterize the entire forecast.
- Fuzzy verification provides useful statistical information.
  - Entire forecast solution is characterized.
  - Uncertainty is quantified over a range of scales.
  - Threshold value is required.