MODE Object Analyses of Integrated Water Vapor and Integrated Vapor Transport Fields

An HMT-DTC Collaboration Project

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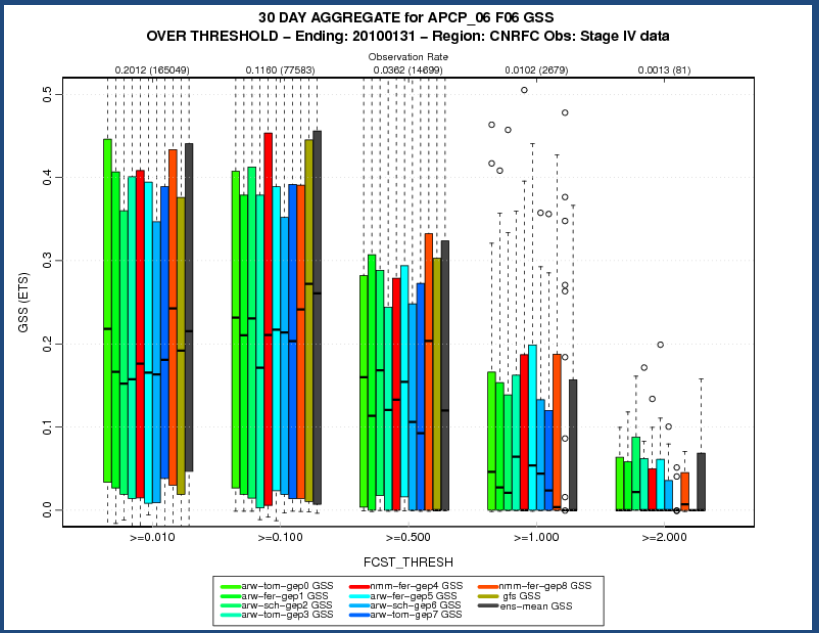
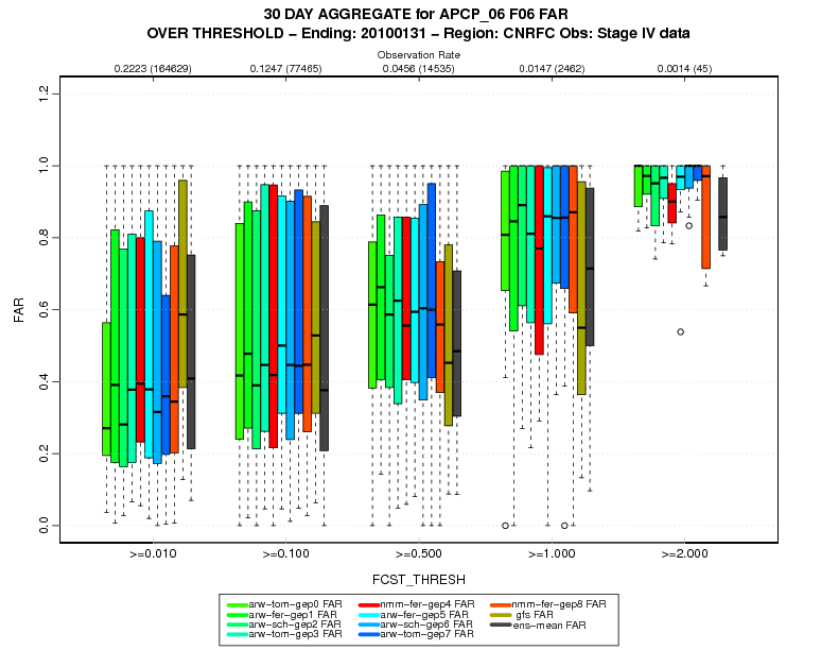
The Basic Problem

- Extreme event forecasts yield notoriously low skill scores.
  - Example: CNRFC Jan 2010

    30-day aggregate ensemble-member skill scores from MET Analysis: GSS and FAR
- Why is the skill so poor?
- How can the forecasts be improved?

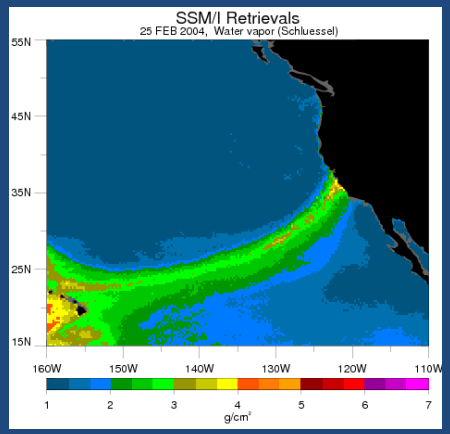




Extreme Events

Cool Season West Coast

- EEs are generally associated with Atmospheric Rivers (ARs)
  - ARs typically manifest along extratropical-cyclone polar cold-fronts
  - ARs bring large fluxes of low-level water vapor streaming on shore
    - Criteria for orographically induced AR extreme event
      - fluxes > 25 m/s cm
      - Upslope winds > 12.5 m/s
      - IWV > 2 cm



SSM/I IWV From Gary Wick

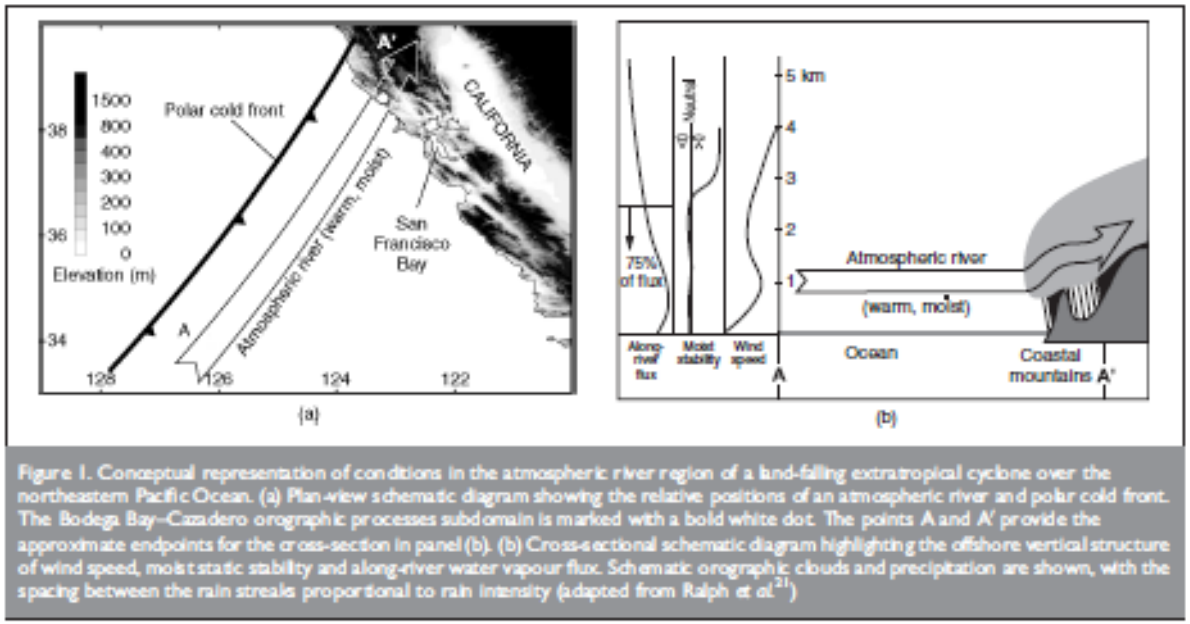
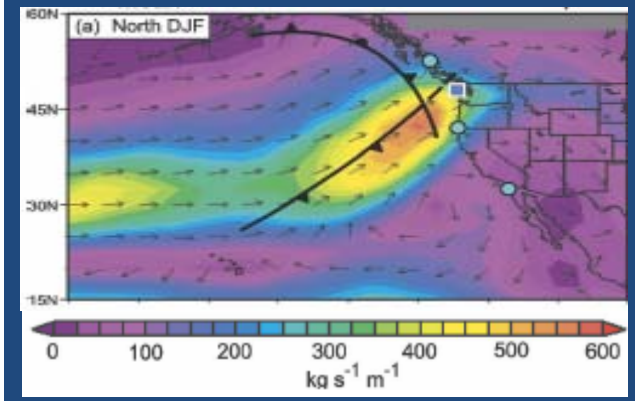


Figure 1. Conceptual representation of conditions in the atmospheric river region of a land-falling extratropical cyclone over the northeastern Pacific Ocean. (a) Plan-view schematic diagram showing the relative positions of an atmospheric river and polar cold front. The Bodega Bay–Cazadero orographic processes subdomain is marked with a bold white dot. The points A and A′ provide the approximate endpoints for the cross-section in panel (b). (b) Cross-sectional schematic diagram highlighting the offshore vertical structure of wind speed, moist static stability and along-river water vapour flux. Schematic orographic clouds and precipitation are shown, with the spacing between the rain streaks proportional to rain intensity (adapted from Ralph et al.[21])

Neiman et al., Water Management, p. 84, 2009



Seasonal Composite IVT fr. Neiman et al.,2008, J. Hydrom., p. 32

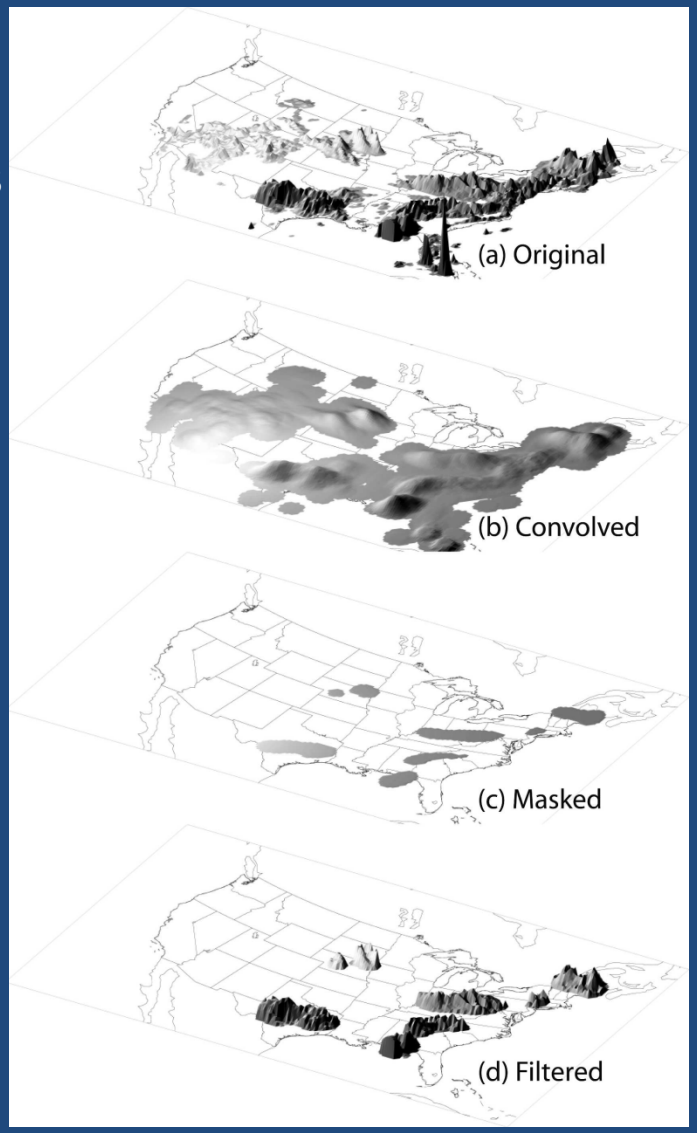
MODE Objects

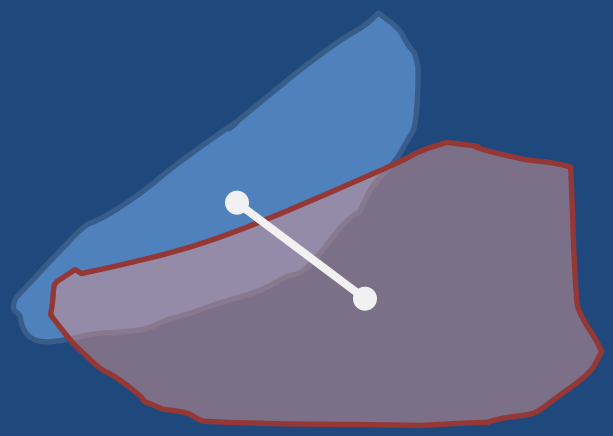
Original data field. Can be spiky at small scales, leading to many intermittent objects and difficulties in interpretation.

Appropriate smoothing before determining objects allows object scale control.

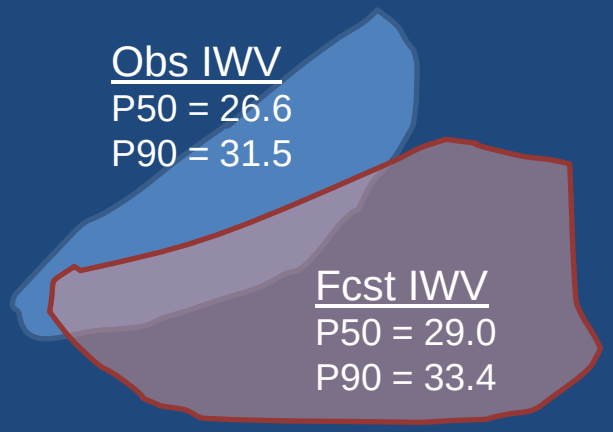
Smoothed values larger than a specified threshold are then associated with a masking value of 1, otherwise 0.

The contiguous **unsmoothed** values left after the masking populate the final objects.



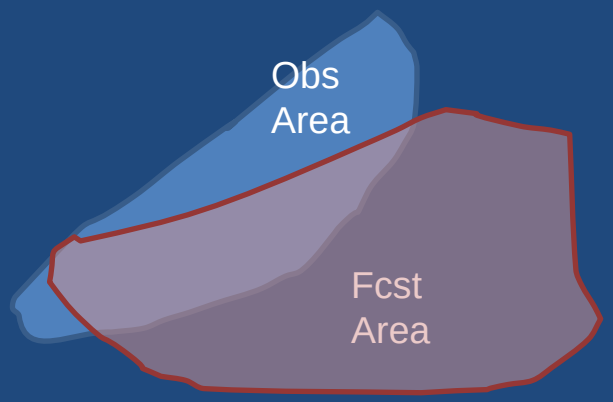


Centroid Distance: Provides a quantitative sense of spatial Displacement of AR core.
Small is good



P50 & P90 Int: Provides objective measures of Median (50th percentile) and near-Peak (90th percentile) intensities found in objects.
Ratio close To 1 is good

Area Ratio = $\frac{\text{Fcst Area}}{\text{Obs Area}}$

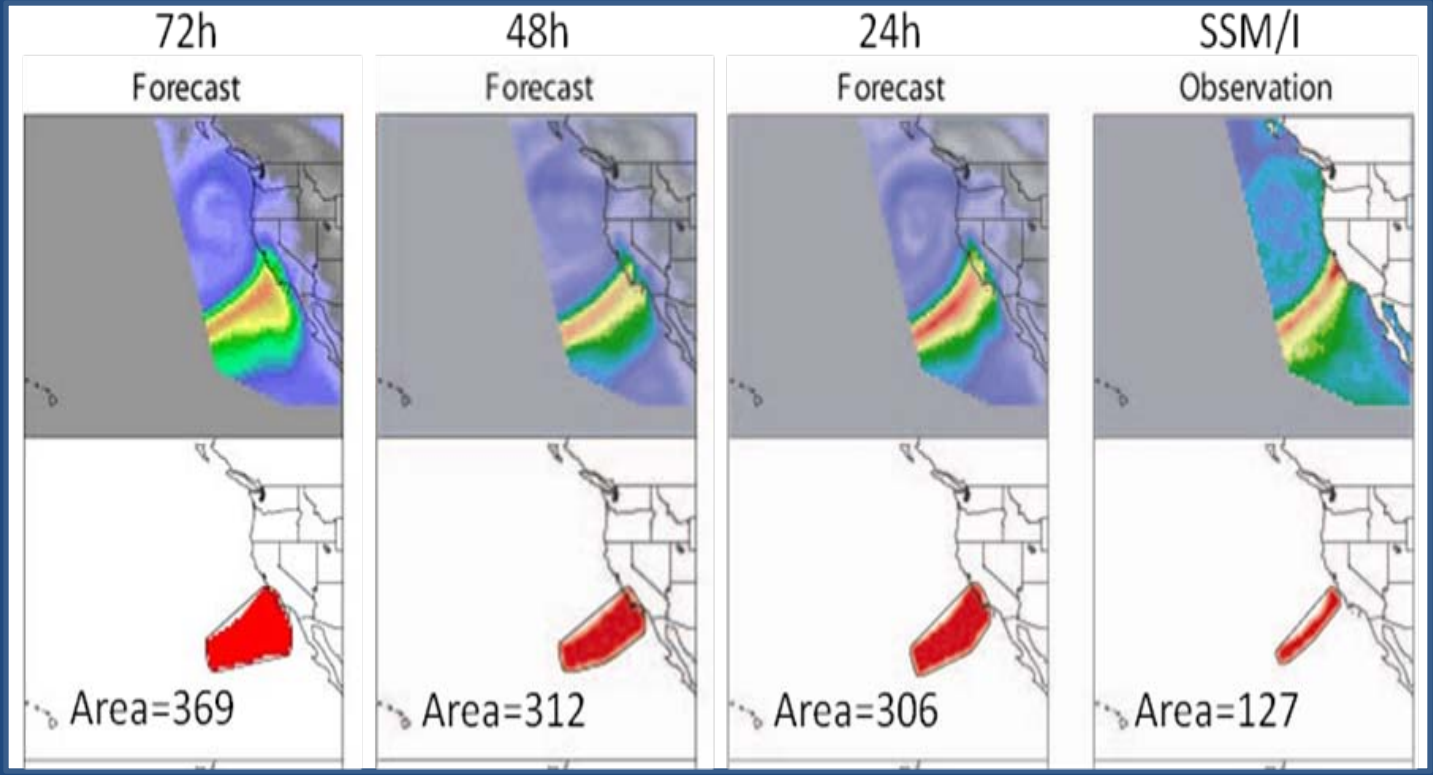


Area Ratio: Provides an objective measure of whether there is an over- or under-prediction of areal extent of AR.
Close to 1 is good

Use of MODE to show evolution of GFS IWV forecasts

Forecast width and location of AR landfall appear to be a function of forecast lead time.

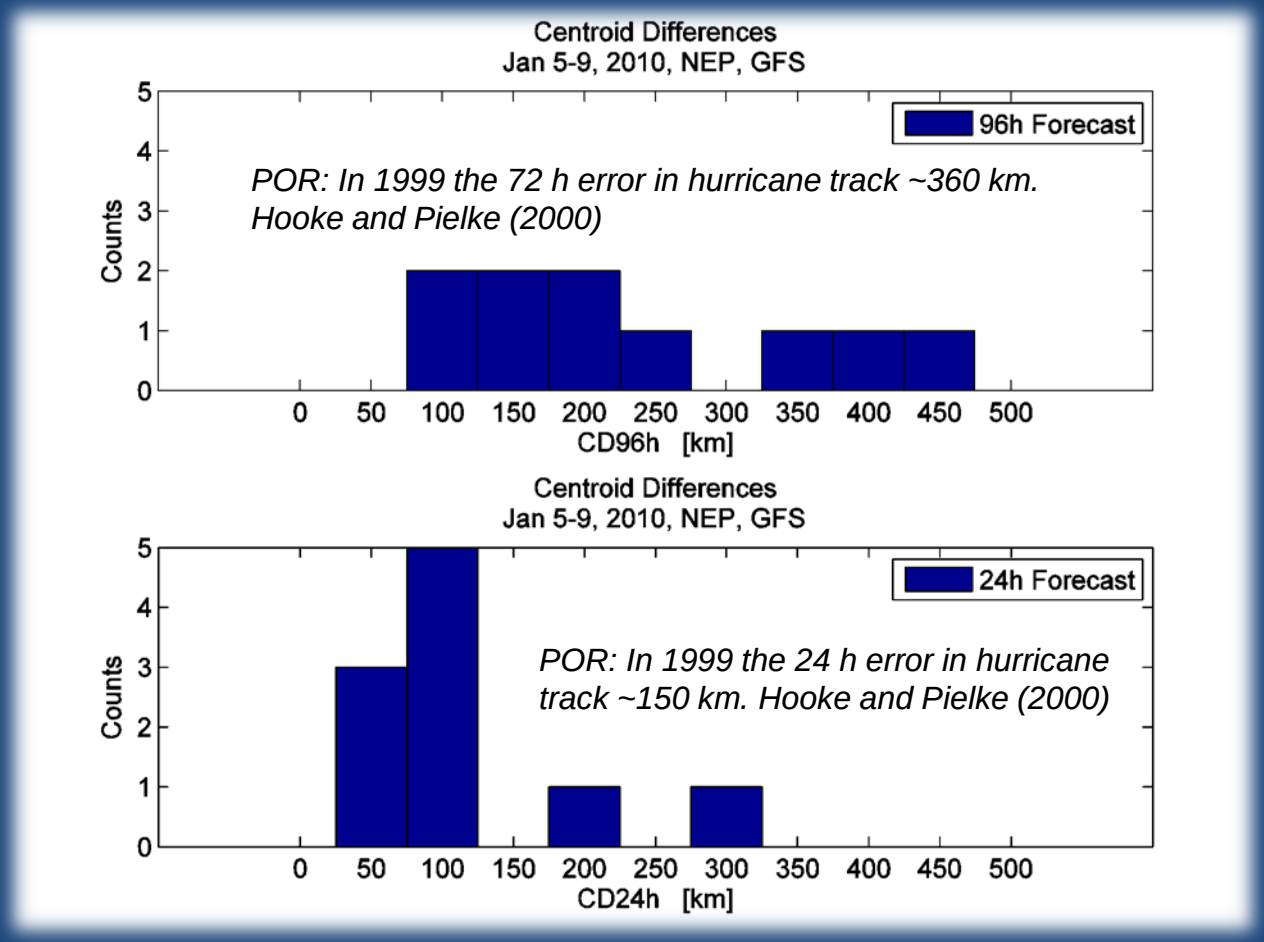
MODE Object Comparison of GFS Forecasts
with SSM/I Observation
Feb 25,2004

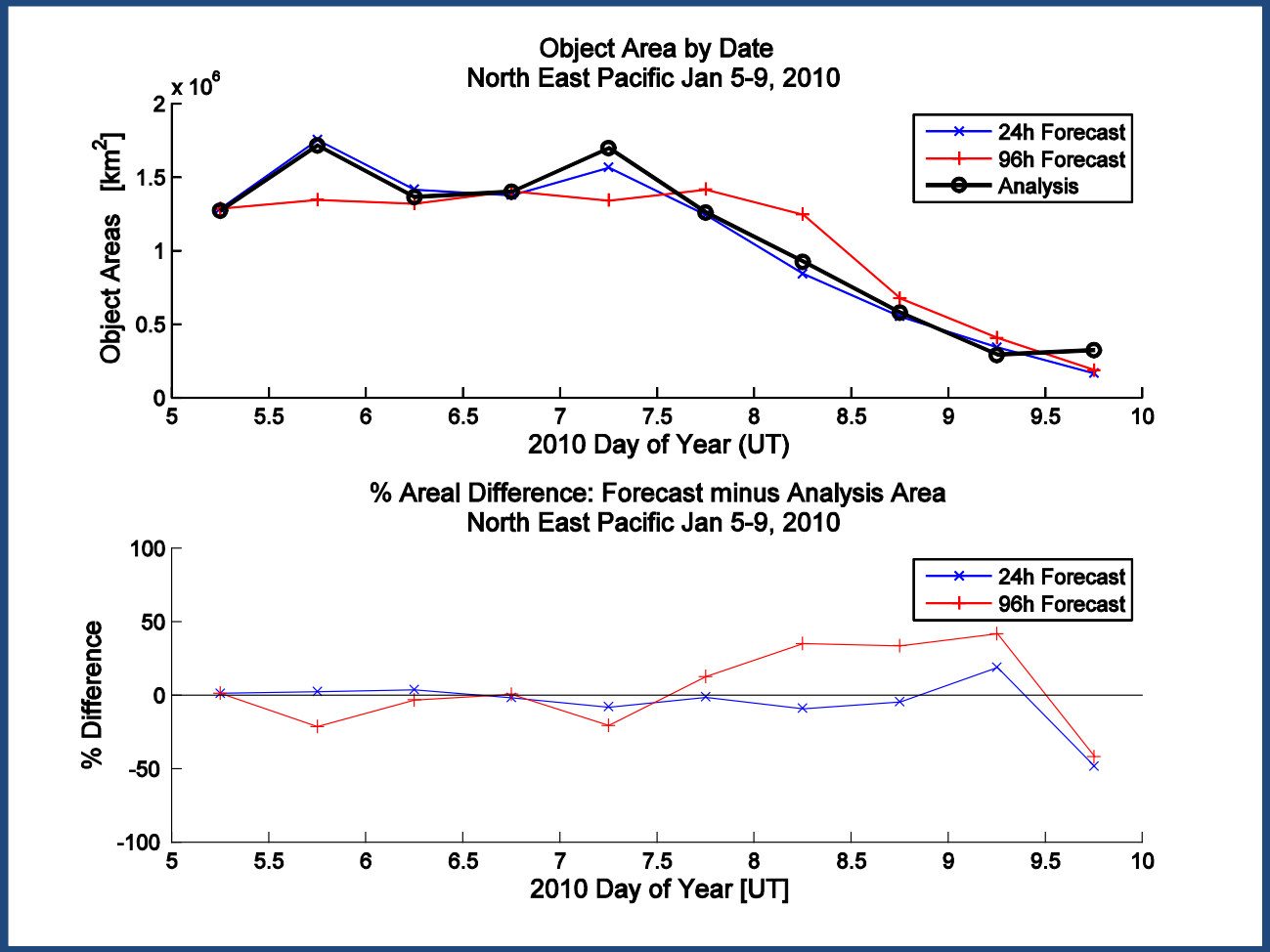


Distances between the forecast object centroids and the analysis centroids.

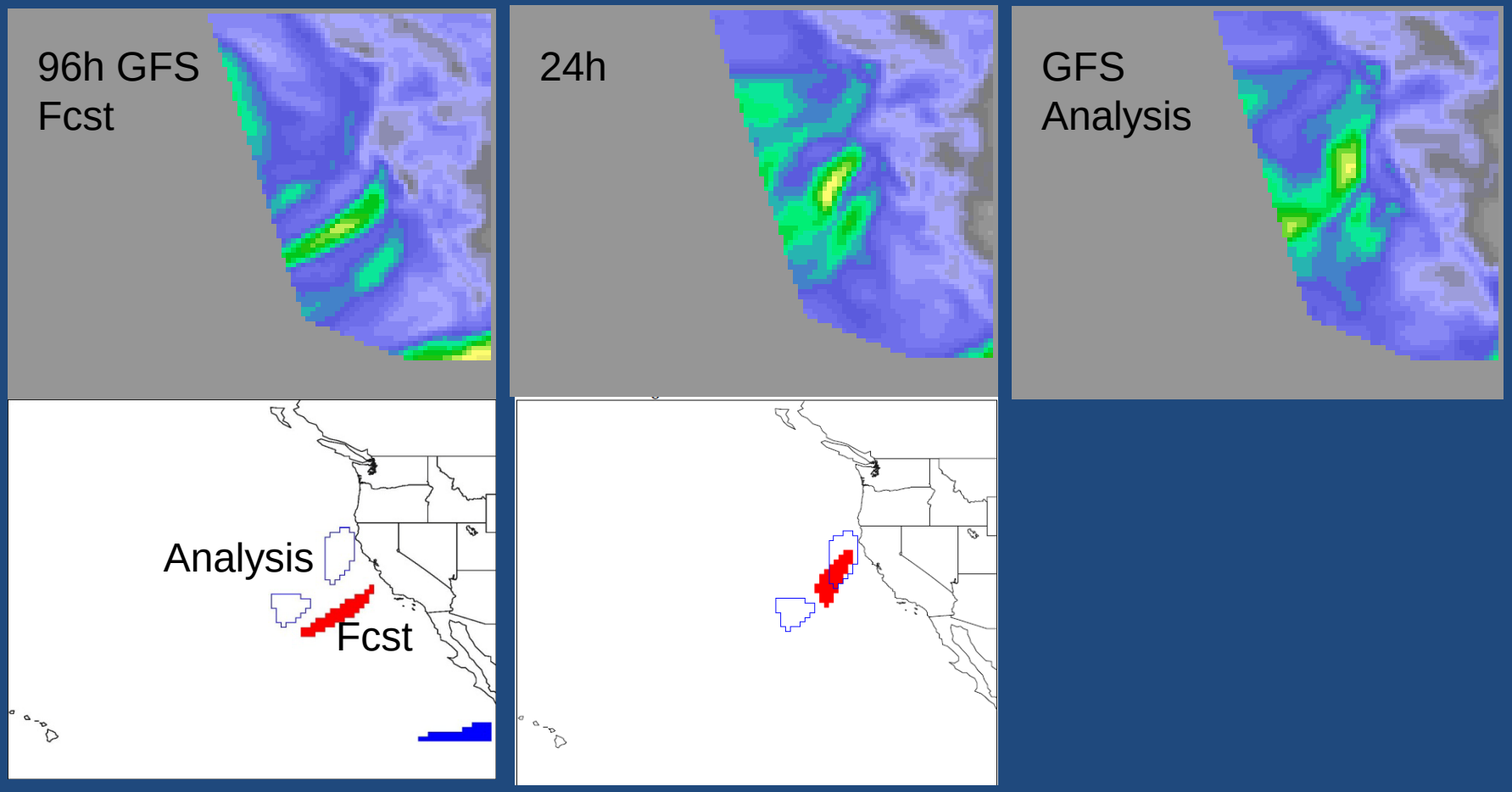
There is apparent marked improvement as the forecast lead time shortens.

Some of the distance error may be due to shape error caused by intensity differences.




Object Area by Date
North East Pacific Jan 5-9, 2010
x 10^6
Object Areas [km^2]
2
1.5
1
0.5
0
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
2010 Day of Year (UT)
24h Forecast
96h Forecast
Analysis
% Areal Difference: Forecast minus Analysis Area
North East Pacific Jan 5-9, 2010
% Difference
100
50
0
-50
-100
2010 Day of Year [UT]
24h Forecast
96h Forecast

North East Pacific GFS IWV, Jan 9, 2010, 18h UT



Focus on IVT

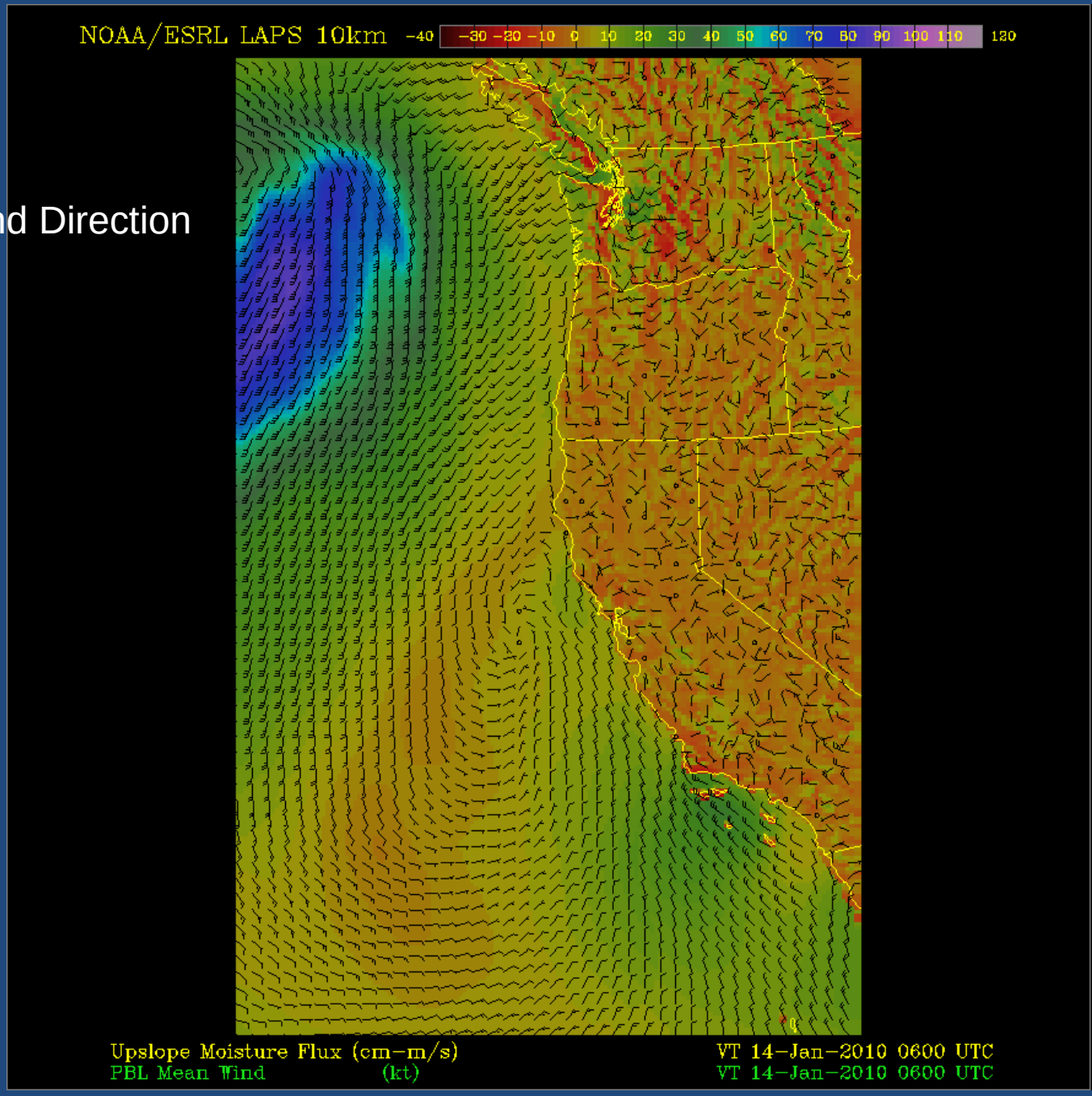
- Up to now we have compared SSM/I observations of IWV with those output by forecasts and analyses using GFS.
- Now we intend to focus on water vapor flux, a.k.a. Integrated Vapor Transport or IVT Because:
  - Knowledge of IVT strength and direction coupled with knowledge of the local terrain has been shown to be highly predictive of West-Coast cool-season extreme precipitation events.
    - E.g., Neiman et al., Water Management, 2009

LAPS Analysis
Moisture Flux and Wind Direction
Jan 14, 2010
0600 UTC

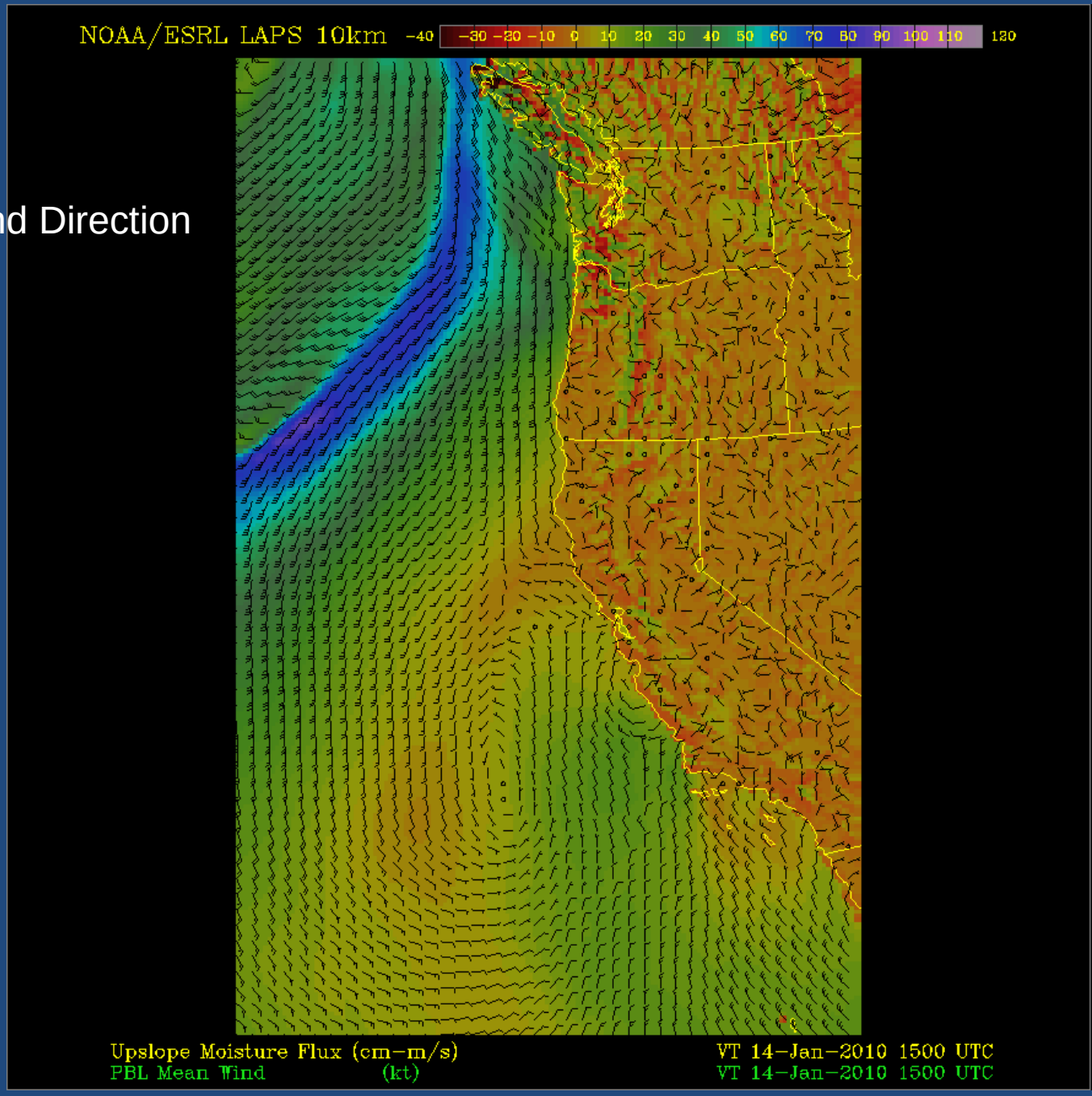
IVT is an excellent field for creating MODE objects.

Colors above dark green are above the 25 cm-m/s criterion for an extreme event.

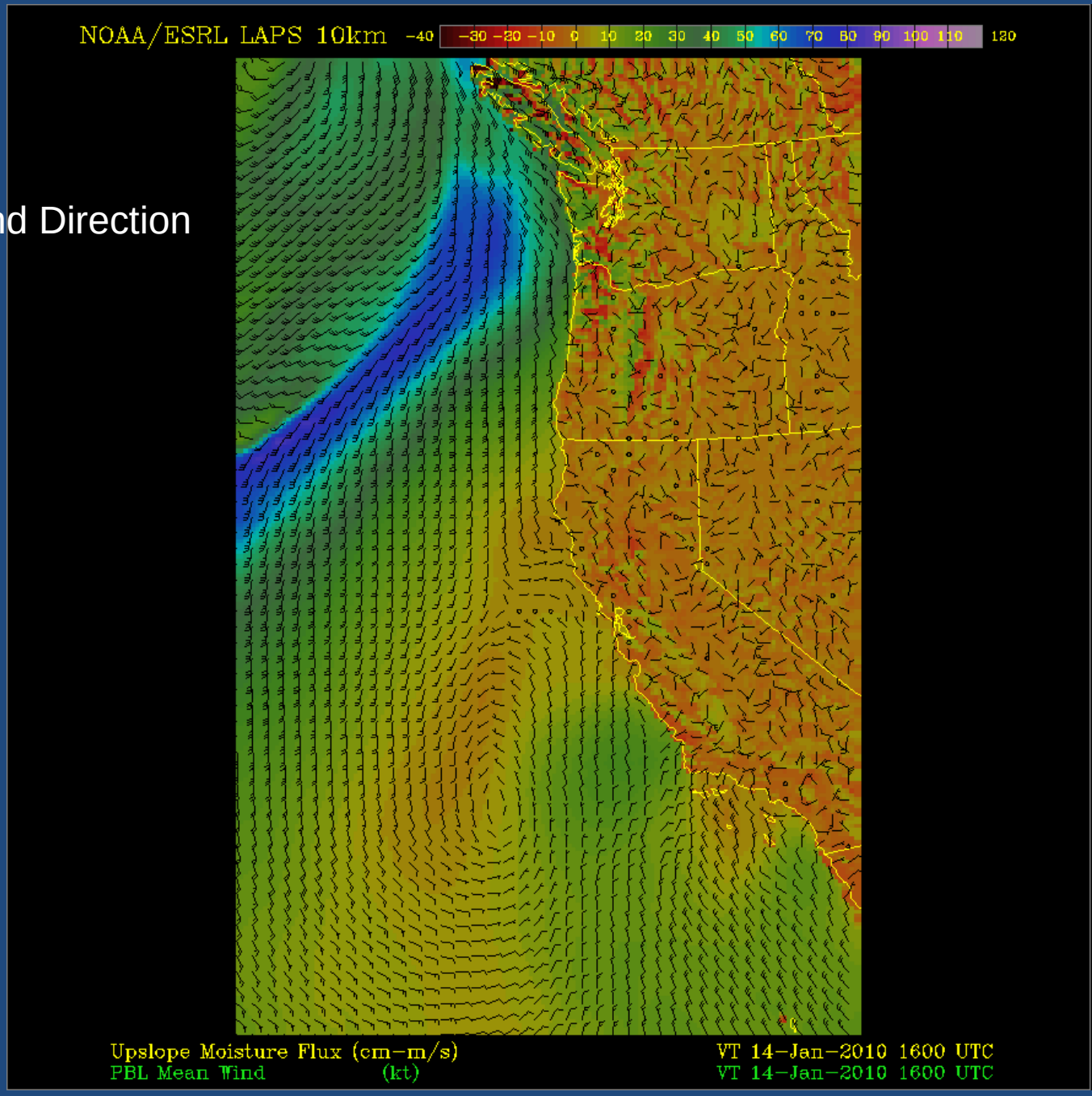
Over land the IVT intensity has been reduced to its upslope component



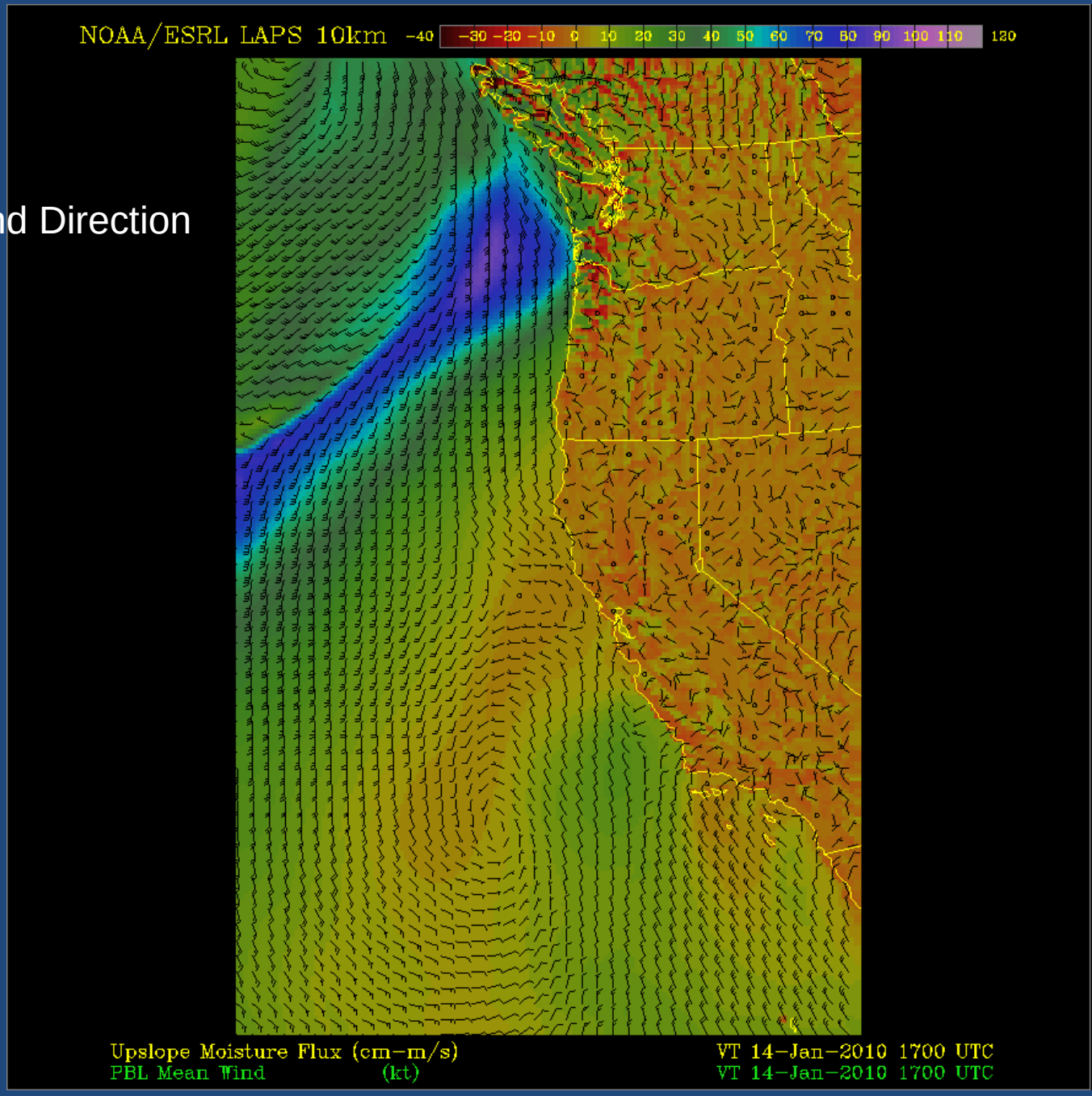
LAPS Analysis
Moisture Flux and Wind Direction
Jan 14, 2010
1500 UTC



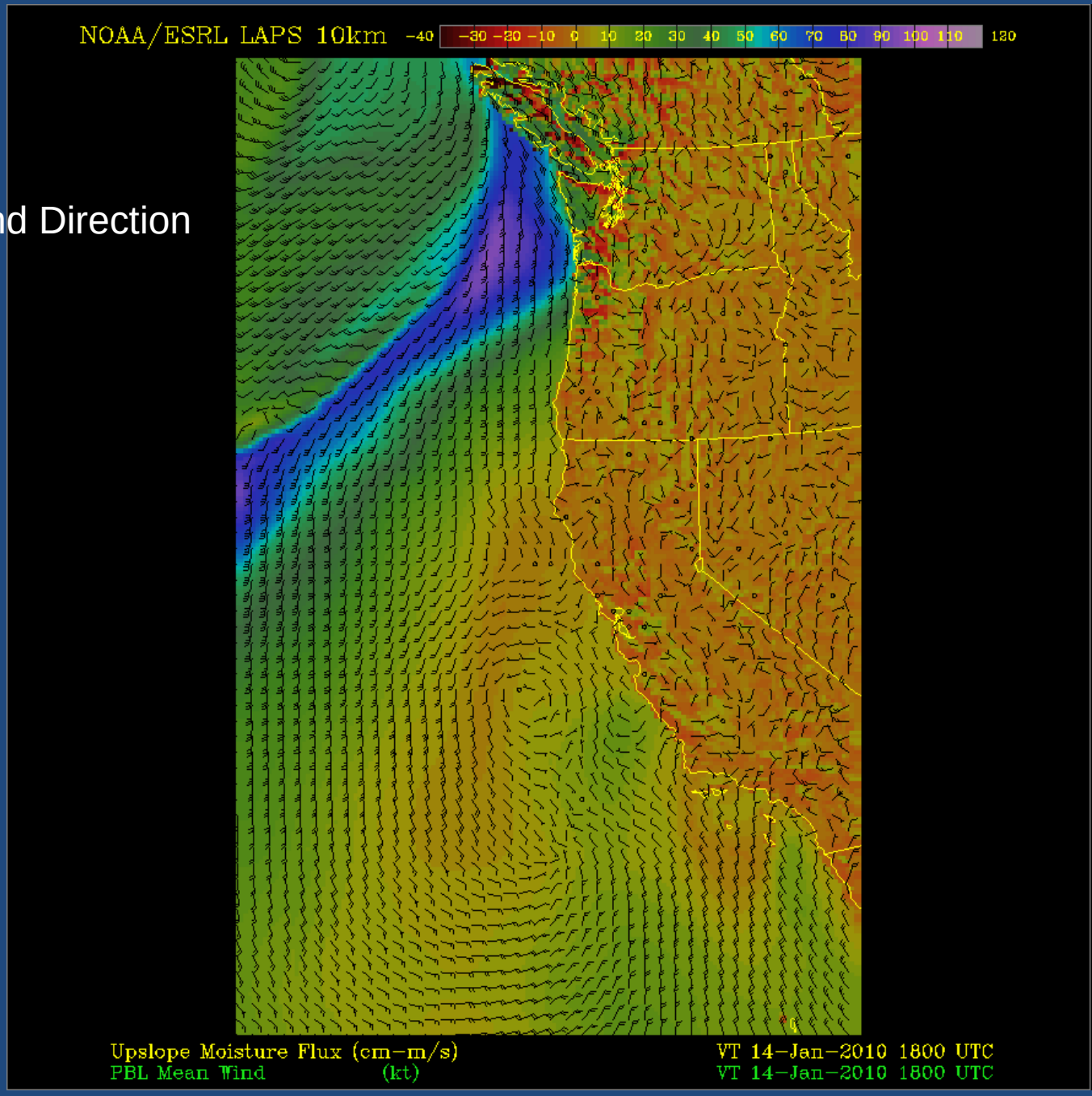
LAPS Analysis
Moisture Flux and Wind Direction
Jan 14, 2010
1600 UTC



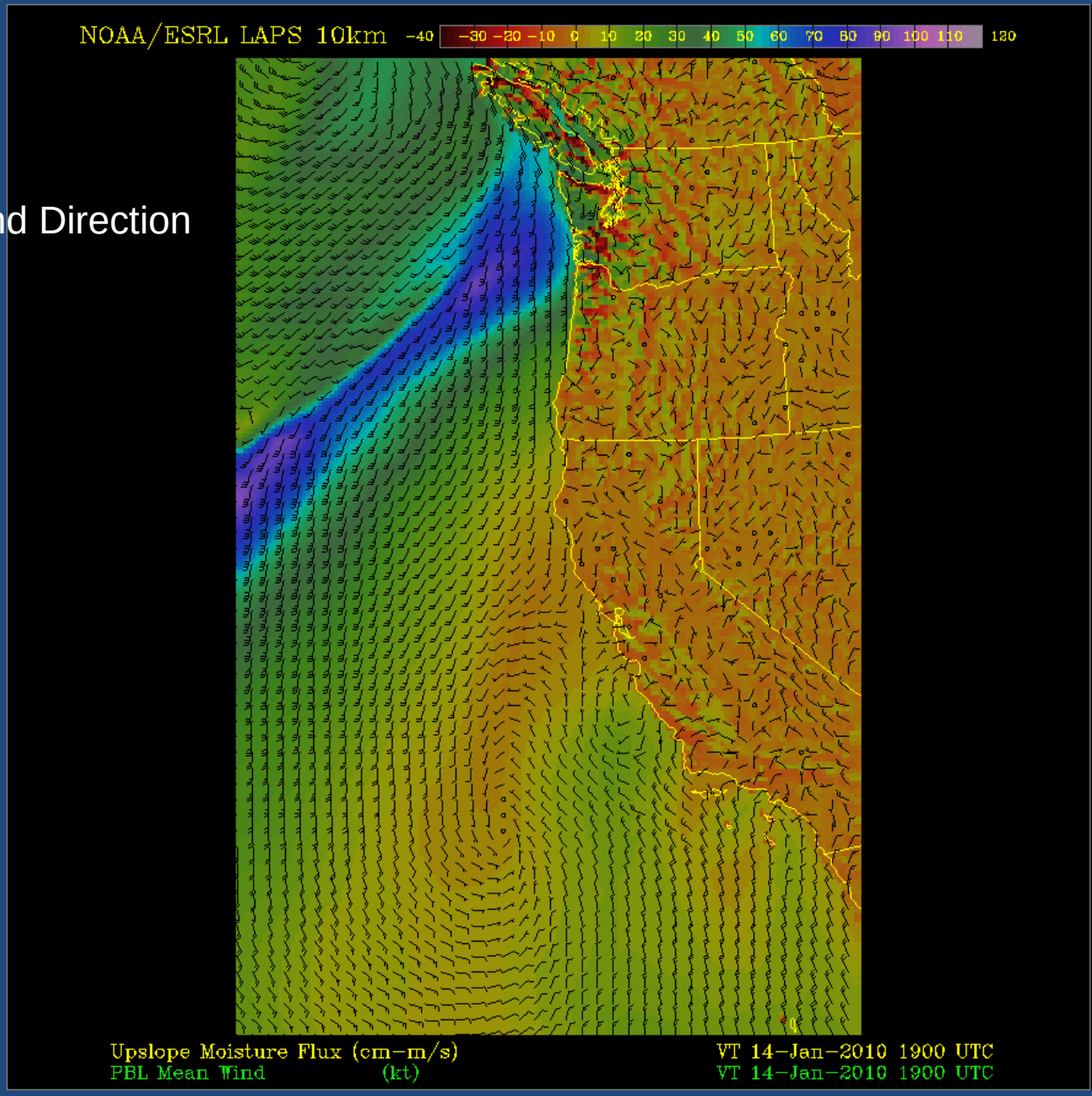
LAPS Analysis
Moisture Flux and Wind Direction
Jan 14, 2010
1700 UTC



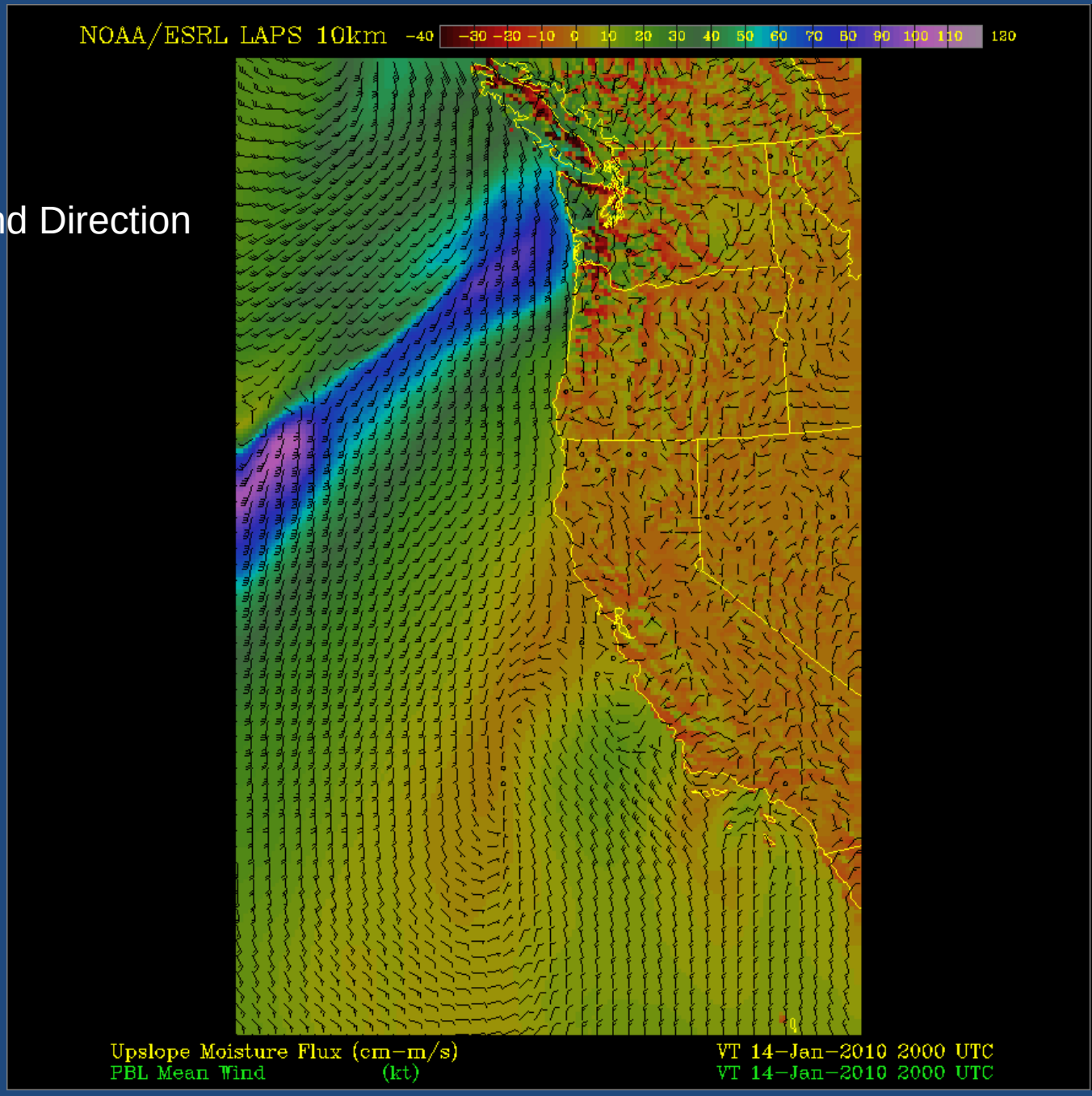
LAPS Analysis
Moisture Flux and Wind Direction
Jan 14, 2010
1800 UTC



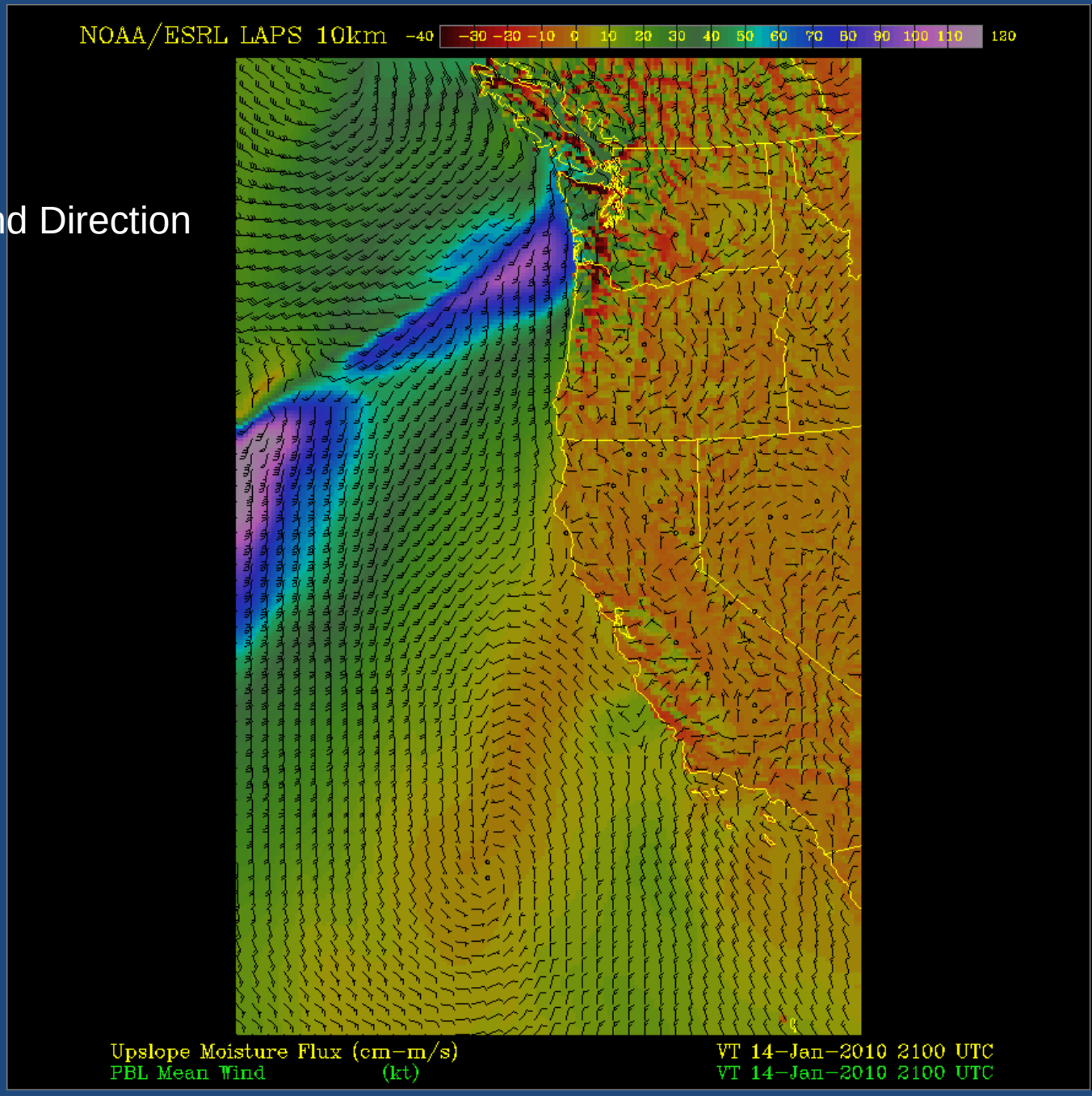
LAPS Analysis
Moisture Flux and Wind Direction
Jan 14, 2010
1900 UTC



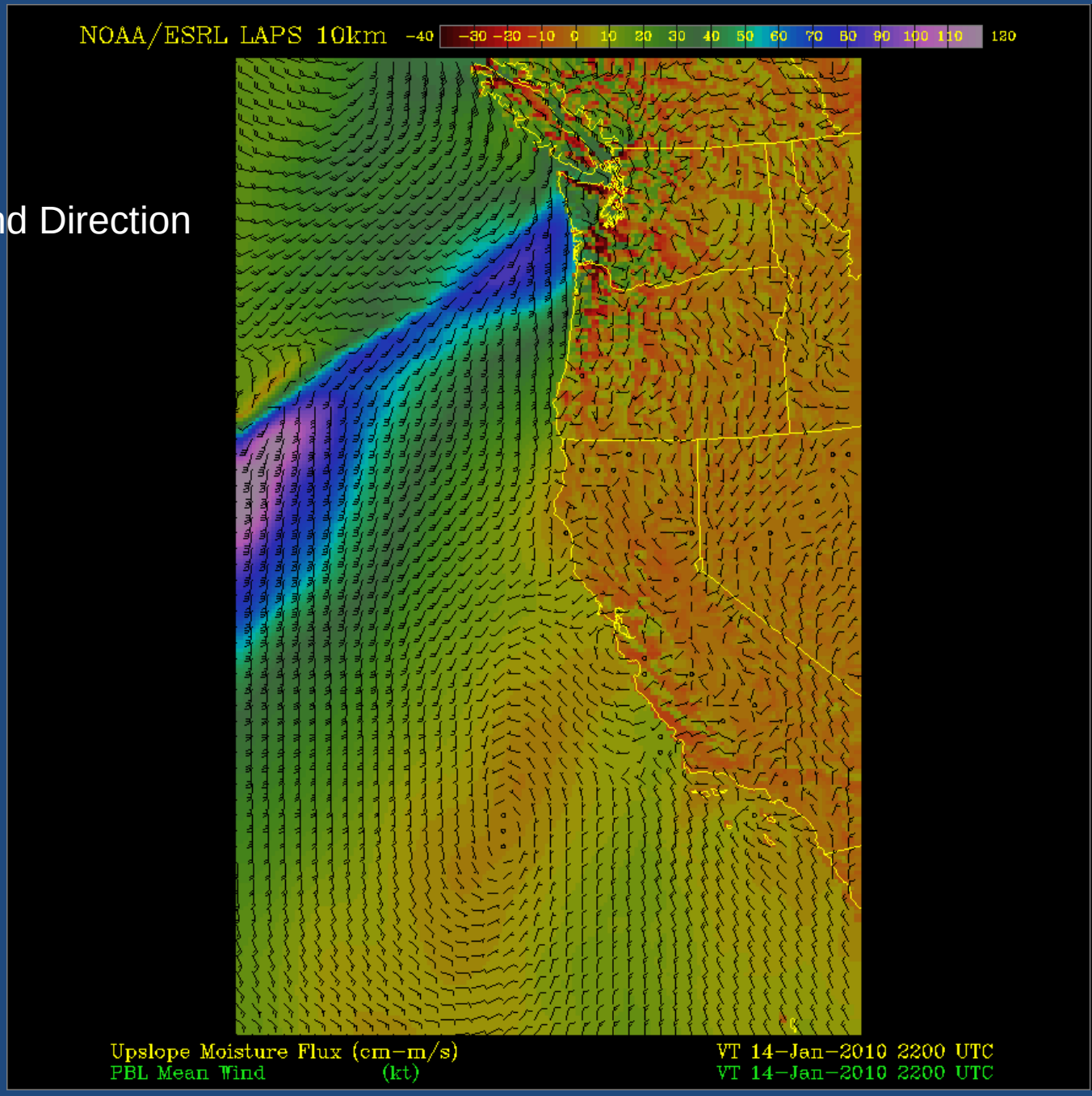
LAPS Analysis
Moisture Flux and Wind Direction
Jan 14, 2010
2000 UTC



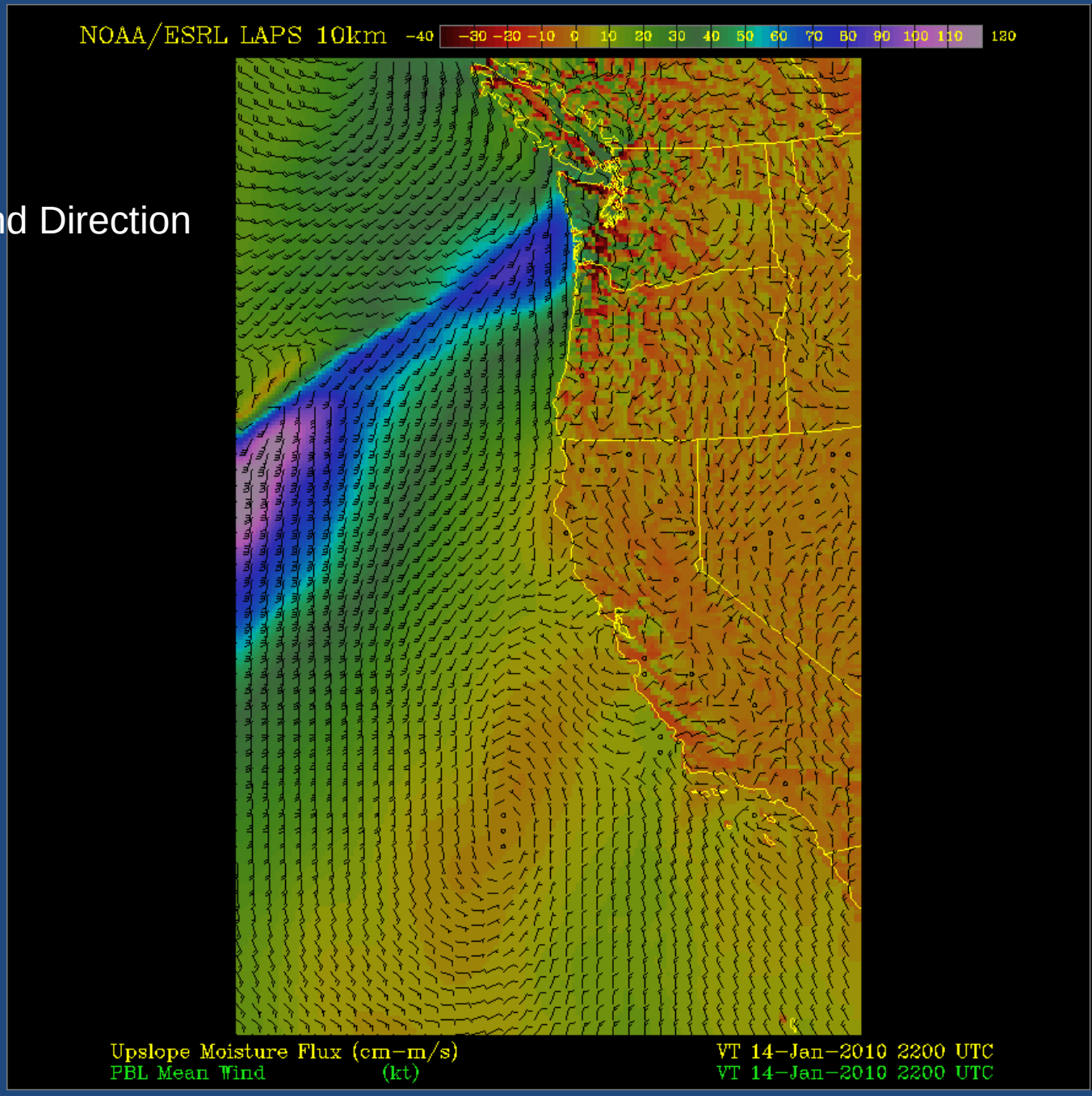
LAPS Analysis
Moisture Flux and Wind Direction
Jan 14, 2010
2100 UTC



LAPS Analysis
Moisture Flux and Wind Direction
Jan 14, 2010
2200 UTC



LAPS Analysis
Moisture Flux and Wind Direction
Jan 14, 2010
2200 UTC



- Summary
  - MODE objects, with some modification, are useful in diagnostic verification of AR forecasts.
    - Object methods like MODE allow performance studies on forecasts delineating uncertainties and biases related to:
      - location
      - Shape
      - intensity
    - These errors are difficult to diagnose by usual validation methods.
  - MODE can also be an efficient way to validate the performance of remote sensors, as it can quickly compare field measurements.
  - Application to IVT fields should illuminate any model biases due to uncertainties in wind and water vapor fields.

End