Spatial Verification of Atmospheric Rivers

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An HMT-DTC Collaboration Project

Funded by USWRP

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The Object Analysis Tool Used

MET/MODE

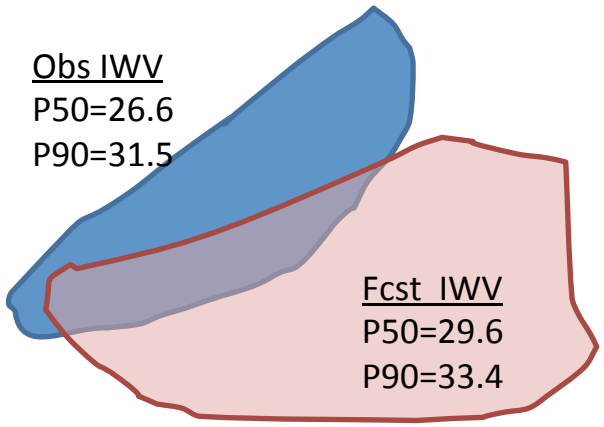
The **Model Evaluation Tools (MET) package** is a set of verification tools developed by the **Developmental Testbed Center (DTC)** for use by the numerical weather prediction community to help assess and evaluate the performance of numerical weather predictions.

MODE , the **Method for Object Based Diagnostic Evaluation,** is the **object analysis MET tool**. It is designed to make comparison of objects found in two grid-matched data fields natural, easy, and quantitative.

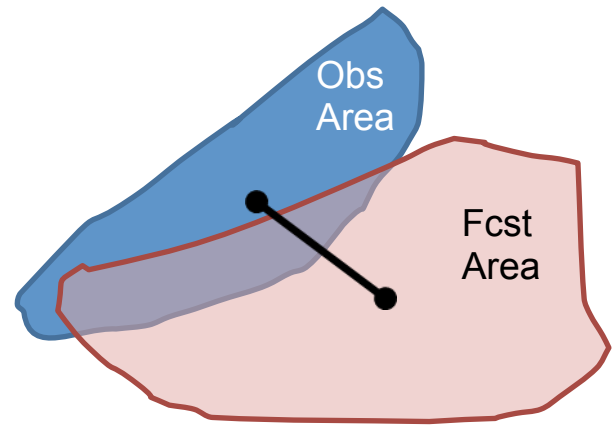
MODE Object Based Analysis

- Designed to run in real time as model postprocessor
- Spatial Verification
  - Location, Shape, and Intensity Errors
- Objective Definition of Events
- Multi-scale views
  - Maximizes diagnostic information
- Efficient
  - Statistical Summaries
    - Seasonal or Longer
  - Objective comparisons of ensemble members

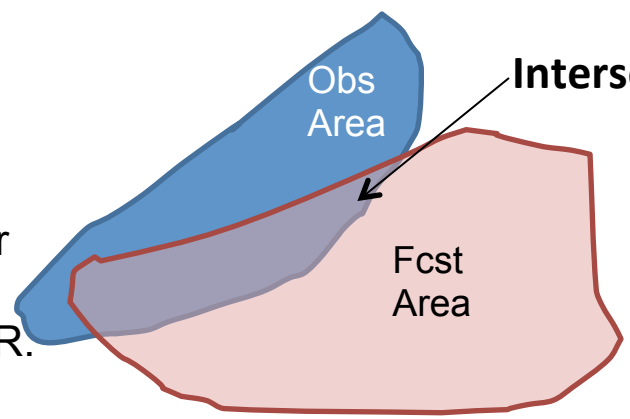
Objects and Matched Pairs Have Attributes. For example:



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



Centroid Distance: Provides a quantitative measure of spatial displacement of object centers.
Small is good

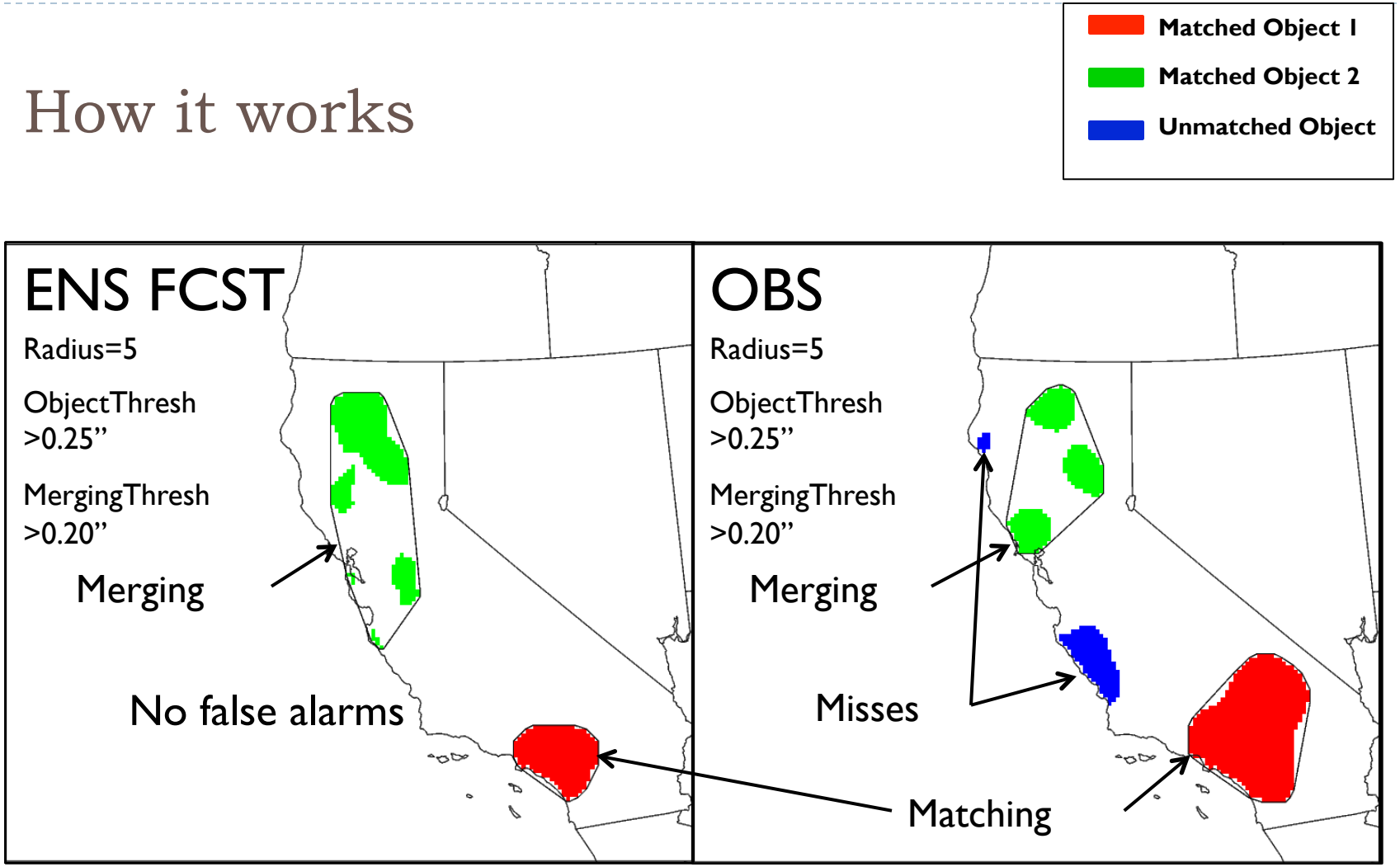


Area Ratio: Provides an objective measure of whether there is an over- or under-prediction of areal extent of AR.
Close to 1 is good

Intersection Area Ratio: The fraction of Obs Area overlaid by Fcst Area
Close to 1 is good

Object Oriented Method: MODE

How it works

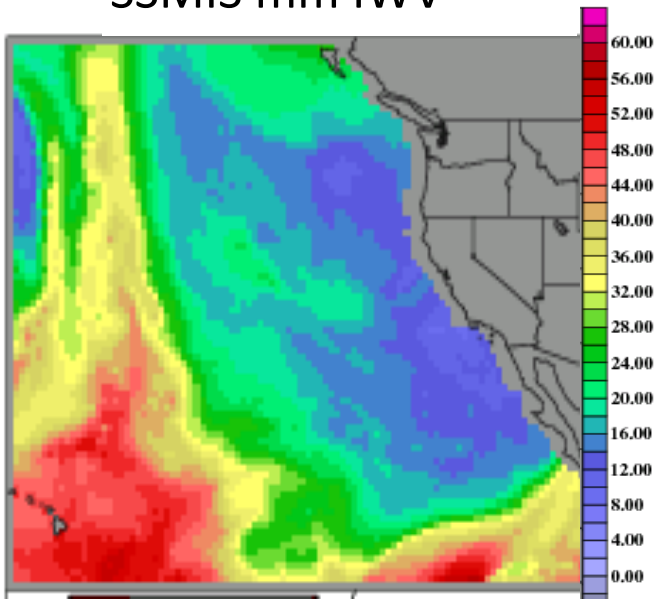


- HMT: APCP_06h Valid: 2010-02-06 18Z (F18)

Three Domains
Three Different Information Sets

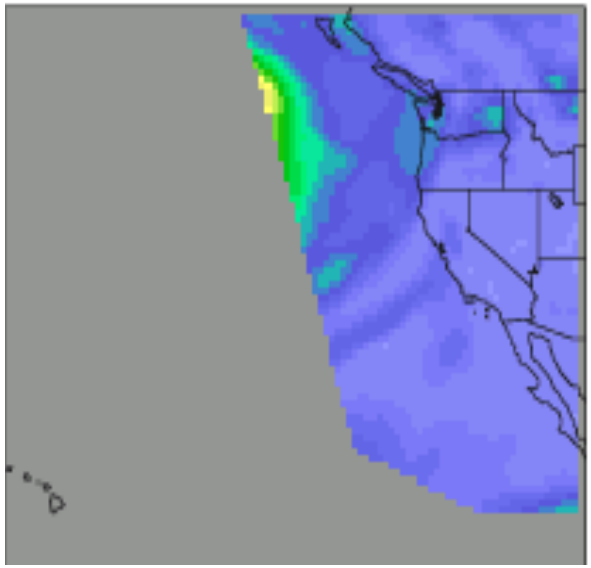
1) Northeast Pacific (NEP)

SSMIS mm IWV



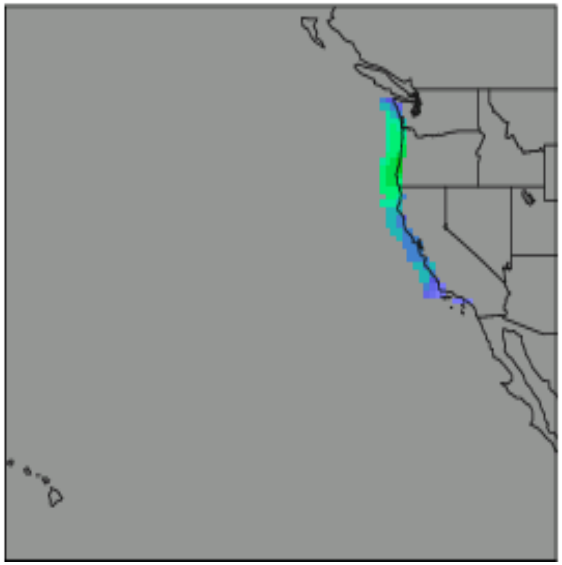
2) Near Coast

IVT 96h GFS Forecast



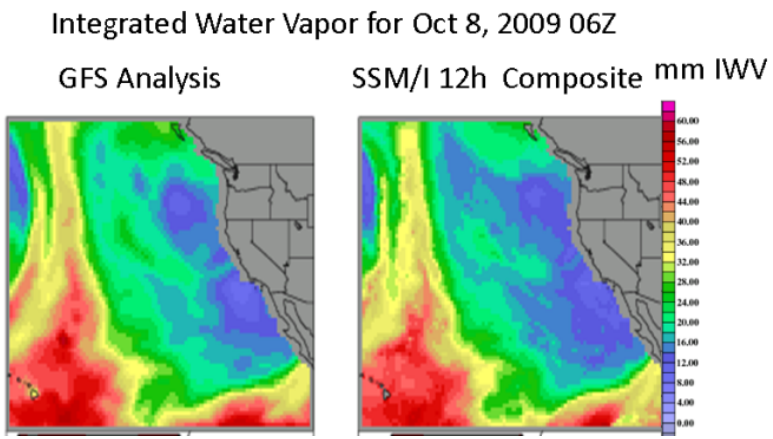
3) Coastal Strip

IVT: GFS 96 h Forecast



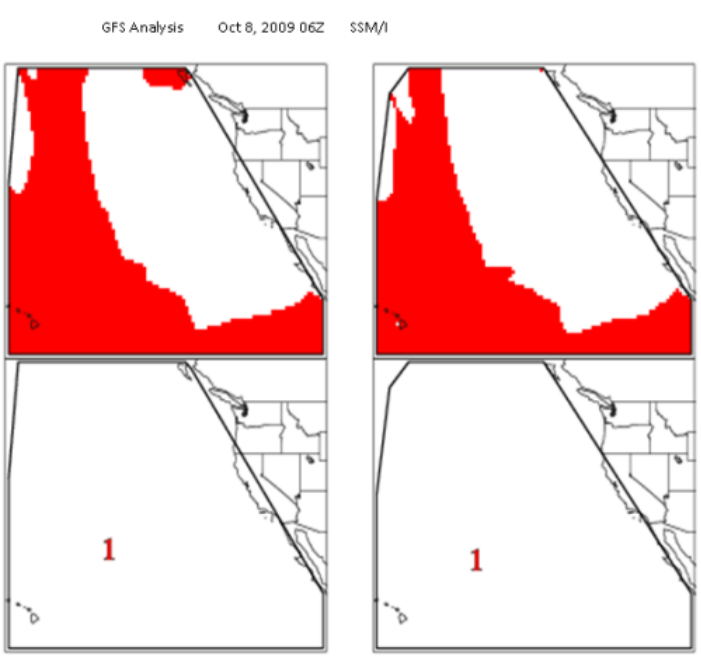
lat: 15N – 55N
lon: 160W – 110W
Grid Spacing: 0.5 degrees lat,lon

Domain 1: Northeast Pacific (NEP)



The synoptic scale NEP domain is large enough to meaningfully verify GFS integrated water vapor (IWV) fields against satellite (SSMIS) observations.

MODE assessments of the 'wetness' of the NEP may be useful to longer term (week or two) prognostications.



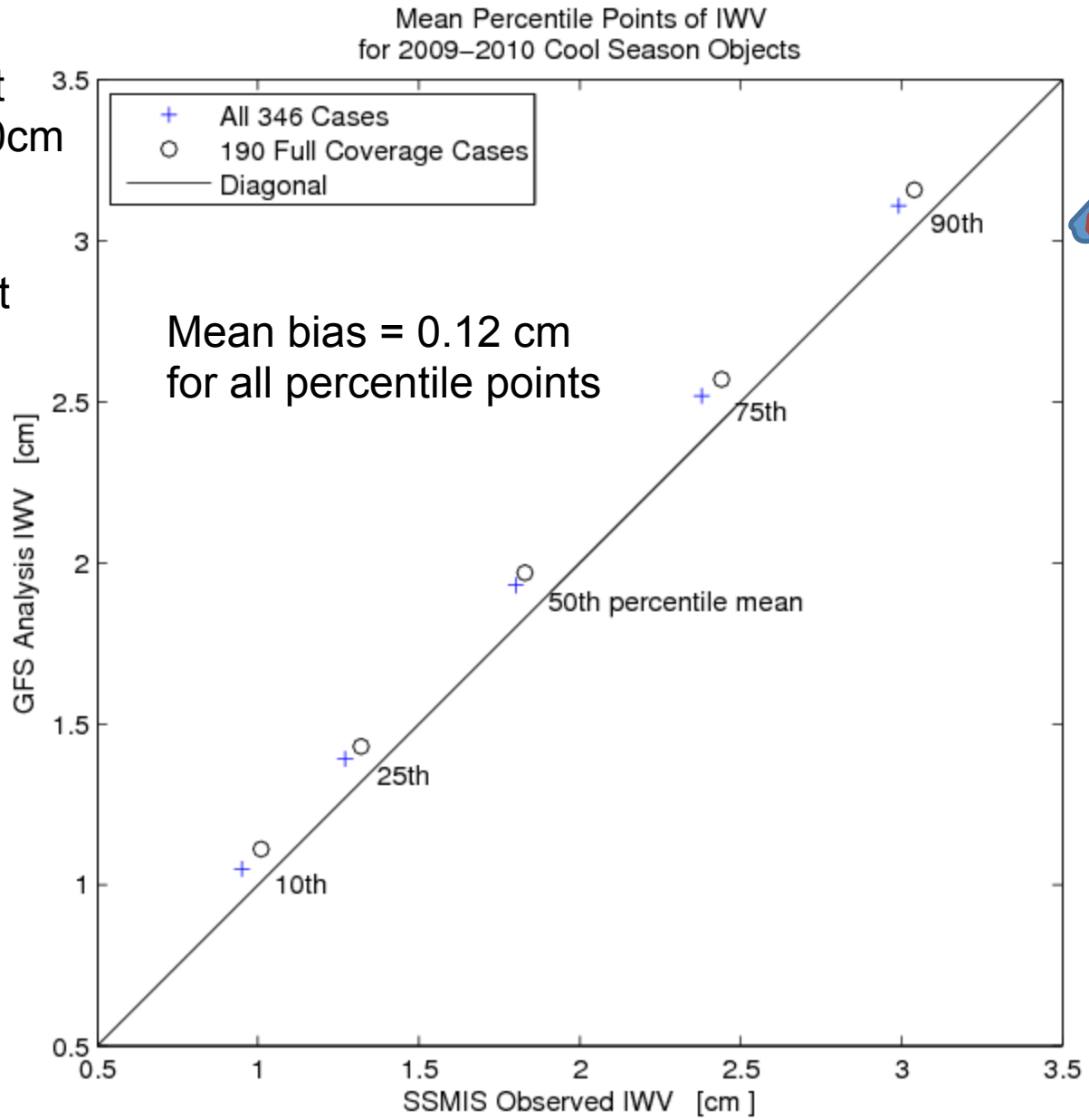
The GFS analysis and SSMIS 12 h composite objects shown here were found using a 2.5 cm IWV threshold.

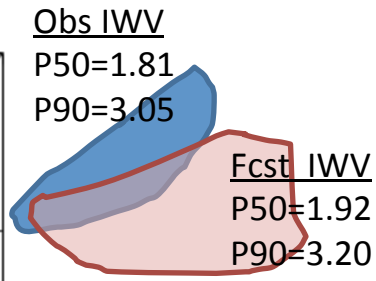
A DTC developed merging method was used to create 'cluster' objects. The goal is to compare objects in a way that approaches human intuitive methods.

Example 1: Bias Determination over the cool season

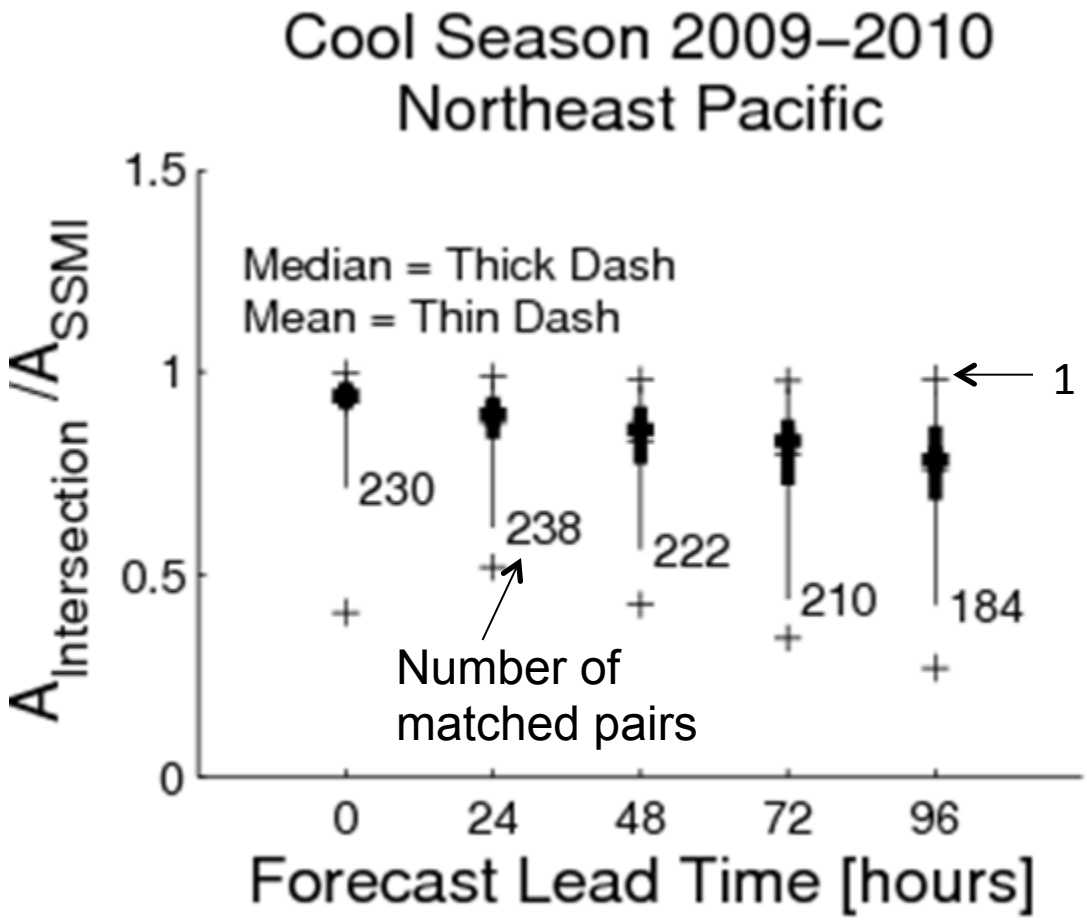
Set IWV object threshold = 0.0cm

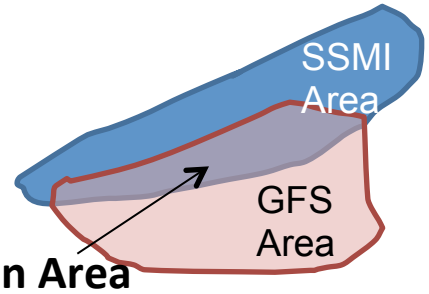
So that the resulting object covers the full domain.





Example 2: Deteriation of overlap with lead time. IWV threshold = 2.5 cm.





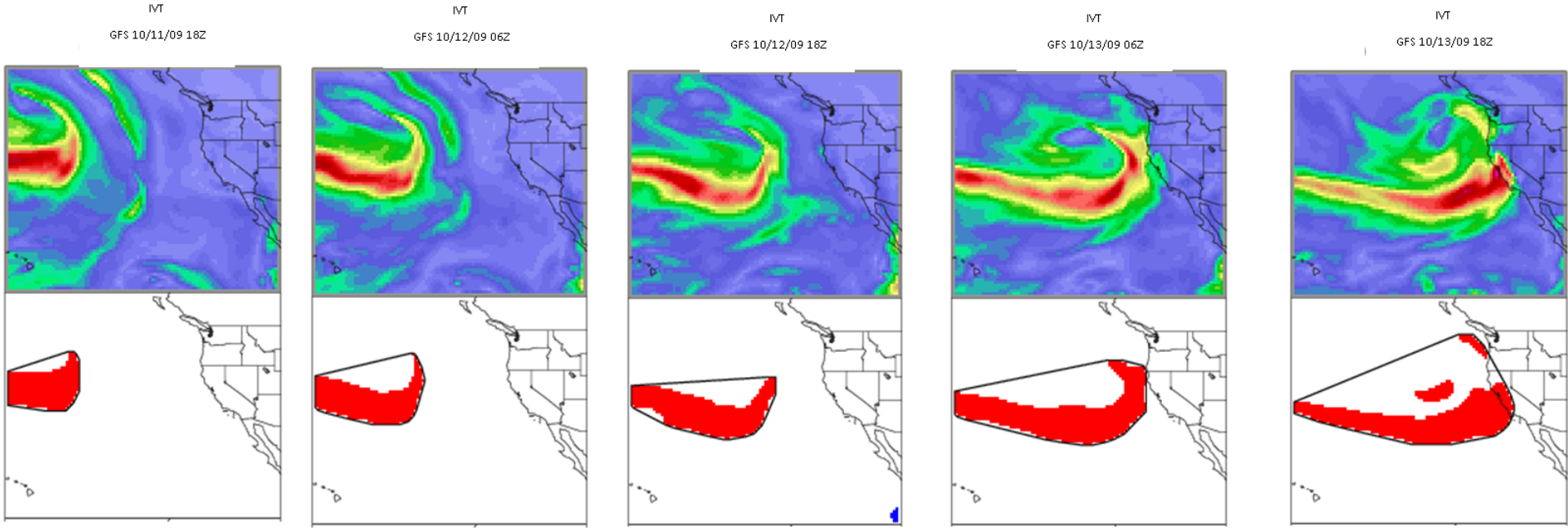
1 = Complete GFS overlap of SSMI

Deterioration in overlap with lead time is obvious.

Note also that the number of matched pairs decreases with lead time

Example 3: Tracking a Tropical Storm Related AR

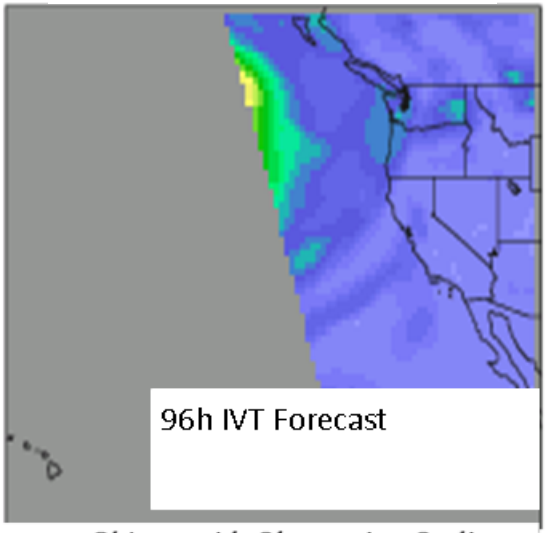
Object Threshold = 56 cm m/s



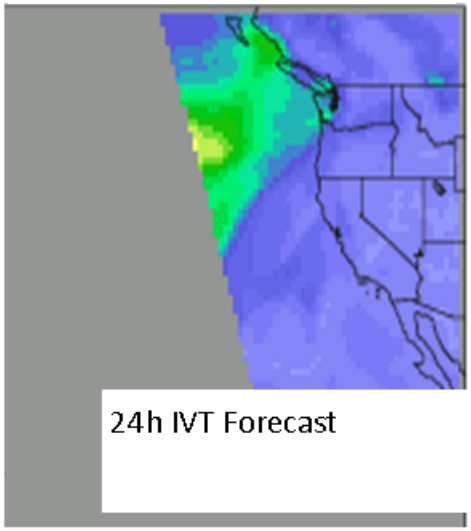
Domain 2: Strip ~1000 km from Coast

IVT = $Wind_{850mb}$ * IWV [cm m/s]

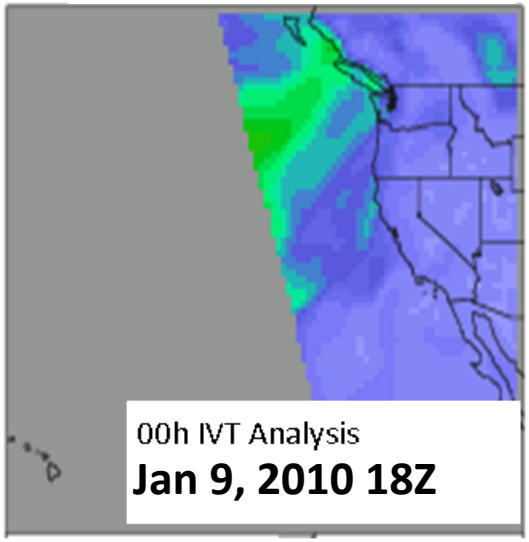
96h GFS IVT Forecast



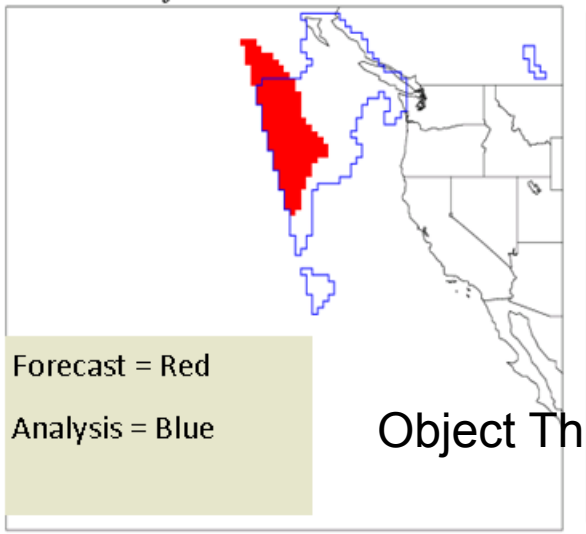
24h GFS IVT Forecast



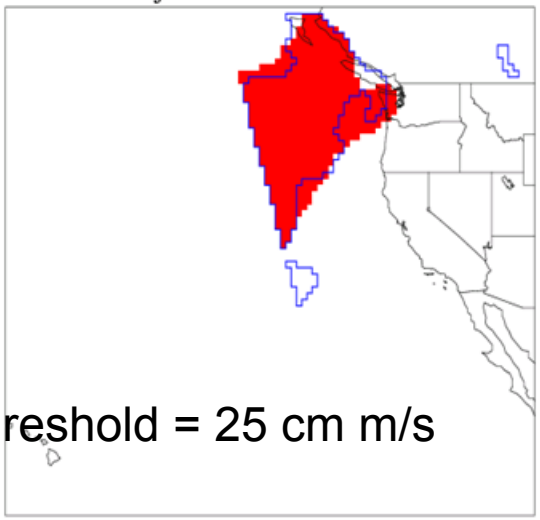
GFS IVT Analysis



Forecast Objects with Observation Outlines



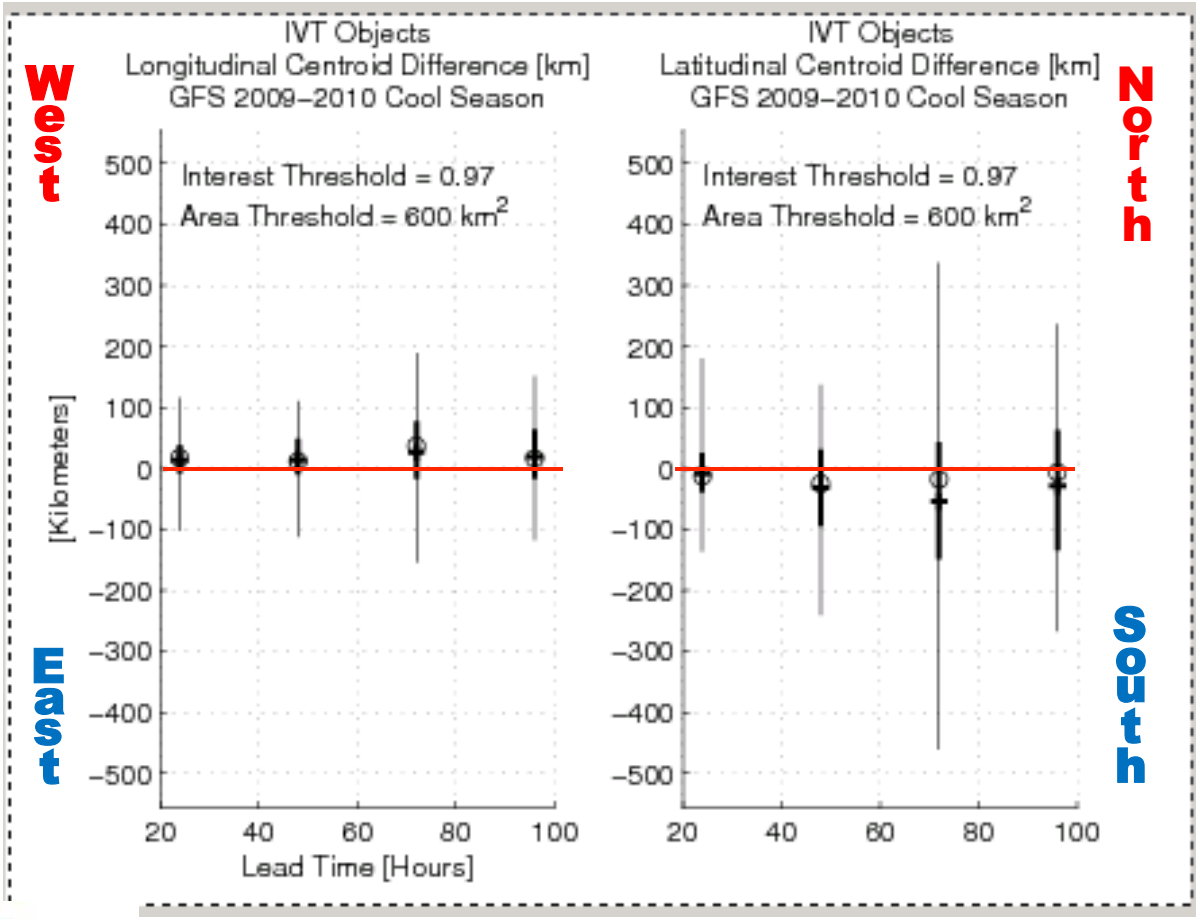
Forecast Objects with Observation Outlines



Object Threshold = 25 cm m/s

- **Helps with diagnosing model performance of landfall events**
- **Useful for qualitative analysis**
- **Fits with hi-res, smaller scale domains like LAPS.**
- **Object truncation a problem.**

Centroid Difference
Longitudinal and Latitudinal Bias?

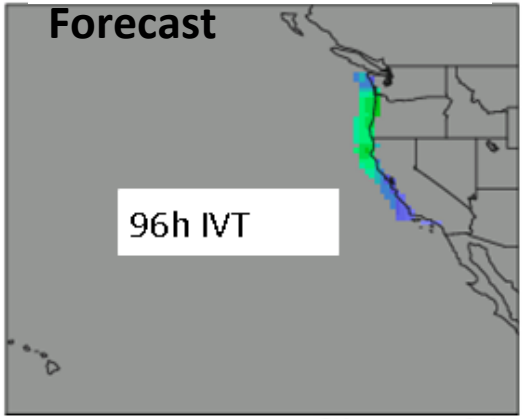


Direct use of currently available attributes must be done carefully in this domain due to object truncation.

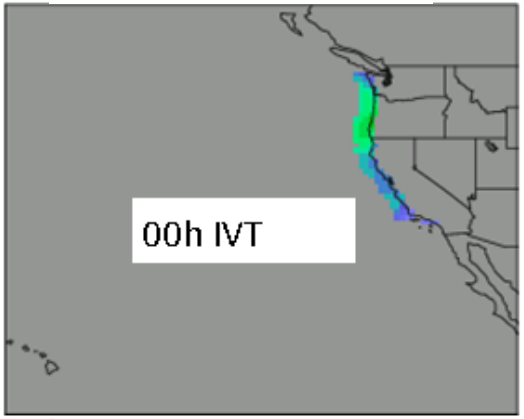
- **Centroid Difference provides *Qualitative* lead/lag information**
- **Development of special attributes would benefit *Quantitative* spatial error analysis**
- **Area attributes (not shown) should be interpreted with truncation in mind**

Domain 3: Longitudinally Narrow Coastal Strip

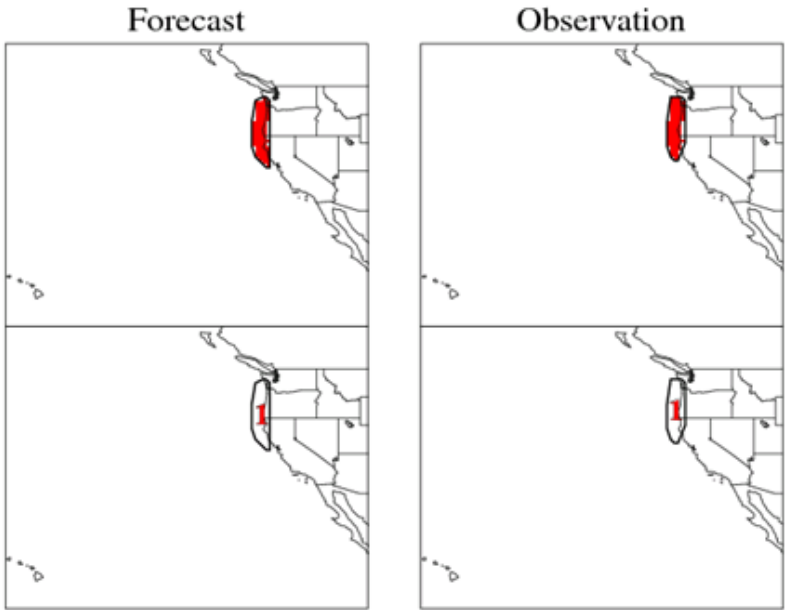
GFS 96 h IVT Forecast



GFS IVT Analysis



Cluster Object Information



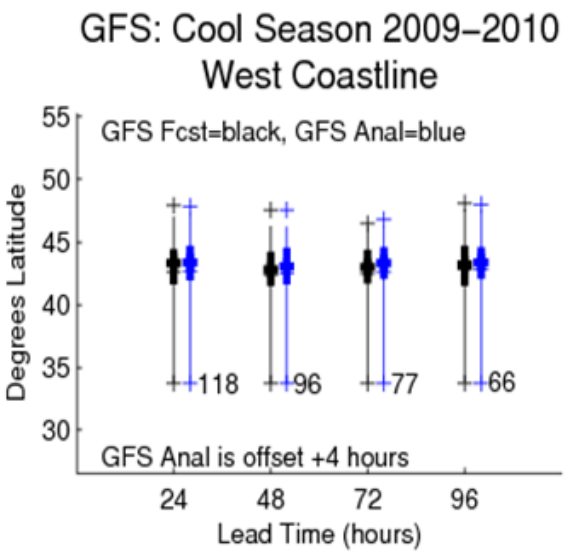
Objects found in this domain may serve as the definition of 'a landfall event'.

Attributes are intuitively interpretable:

- **Latitudinal centroid point is the coastal center of the event.**
- **With frequent (~hourly) data time of arrival, duration, and end time may be determined.**
- **The intensity and location of the event may be tracked in time.**

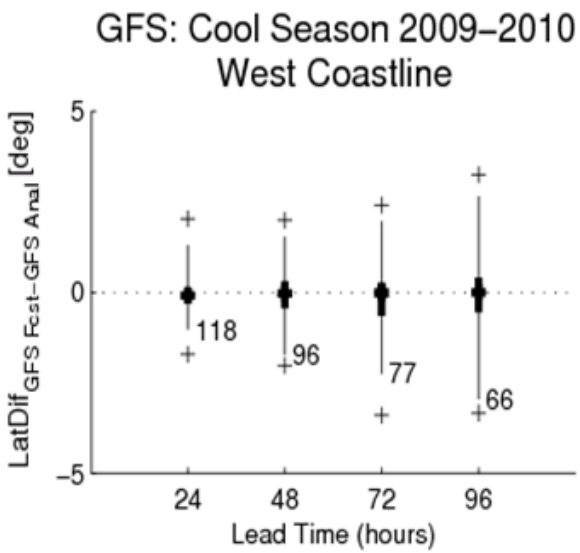
For Example: Some 2009-2010 Landfall Statistics

Coastal Strip IVT objects defined by a 25 cm m/s threshold

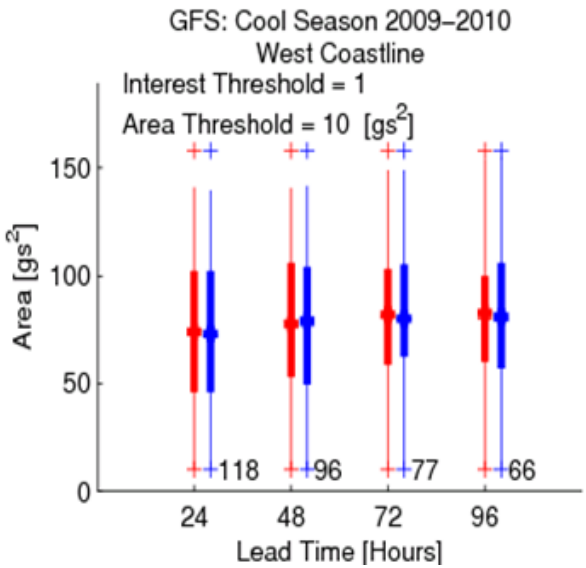


Greater than 50% of matched 'landfall' object centroids struck Oregon Coast (42-45 deg Lat.)

(Note: Long lasting objects resampled every 12 hours)



- No GFS fcst latitudinal bias vs GFS analysis out to 96 h lead time.
- Interquartile range of latitudinal centroid difference
  - 24h: +-0.25 deg.
  - 96h: +- 0.5 deg.



- Areas now translate to length along coast.
- Forecast areas statistically agree with analysis areas.
- Number of misses increase with lead time.

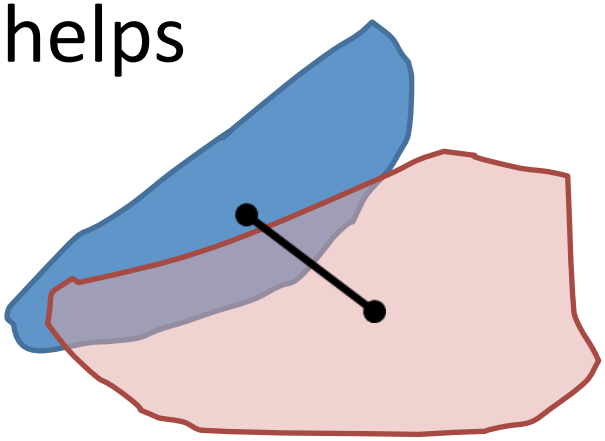
Next Steps

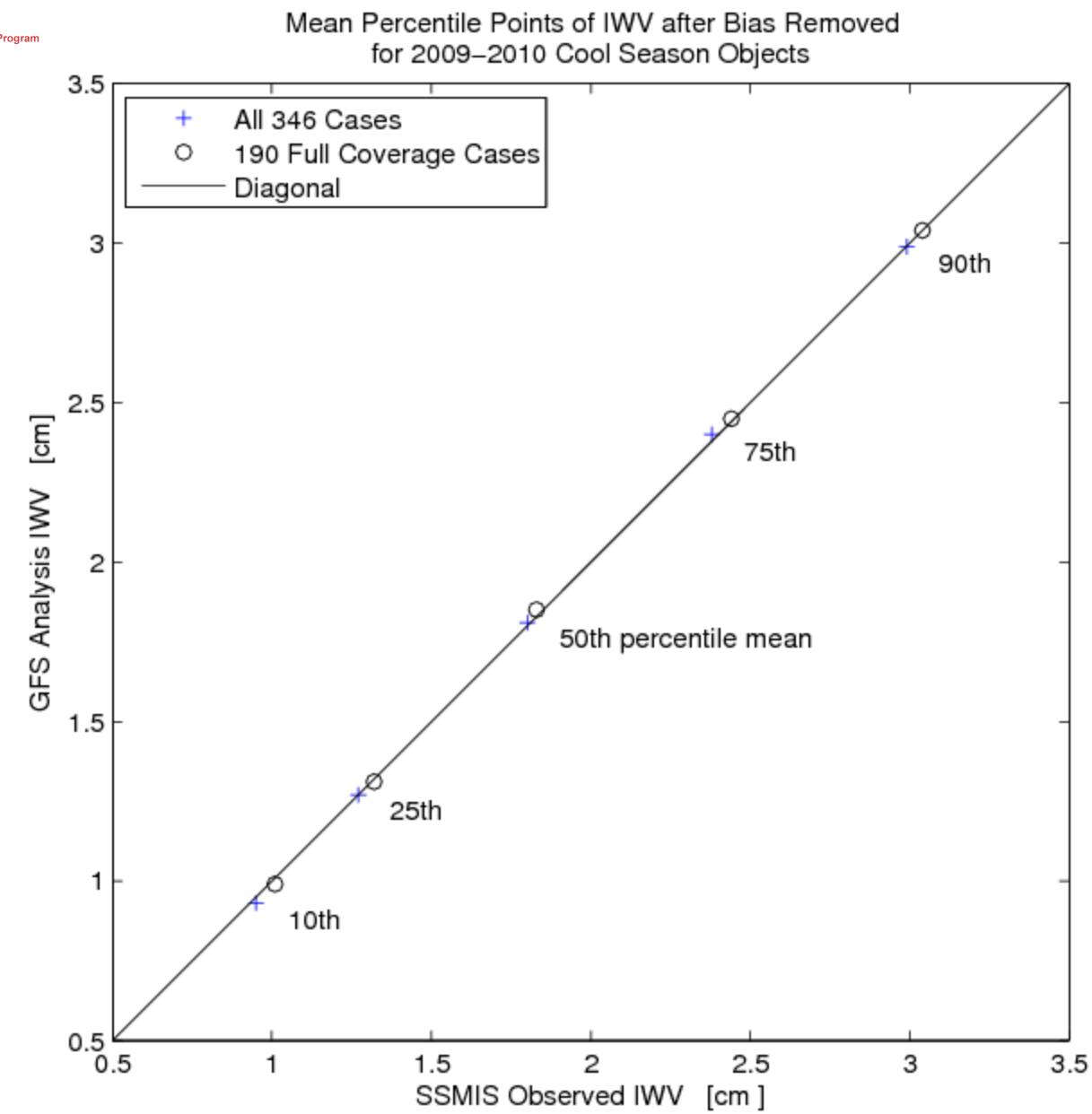
- For coastal strip domain: Incorporate time dimension utilizing more frequent (hourly) output. This should yield
  - Duration
  - Track
  - Landfall intensity vs Time and Latitude
    - i.e., a Hovmöller Diagram
- Include precipitation data field in the analysis
  - Correlations
  - Hits and Misses
  - Flux tool verification
- Apply MODE to ensemble verification and analysis
  - Model to Model Biases
  - Model to Model Spatial Uncertainty
  - Model to Model Intensity Uncertainty

Reiteration of Selected Attributes

Object or Event Based analysis helps separate error components:

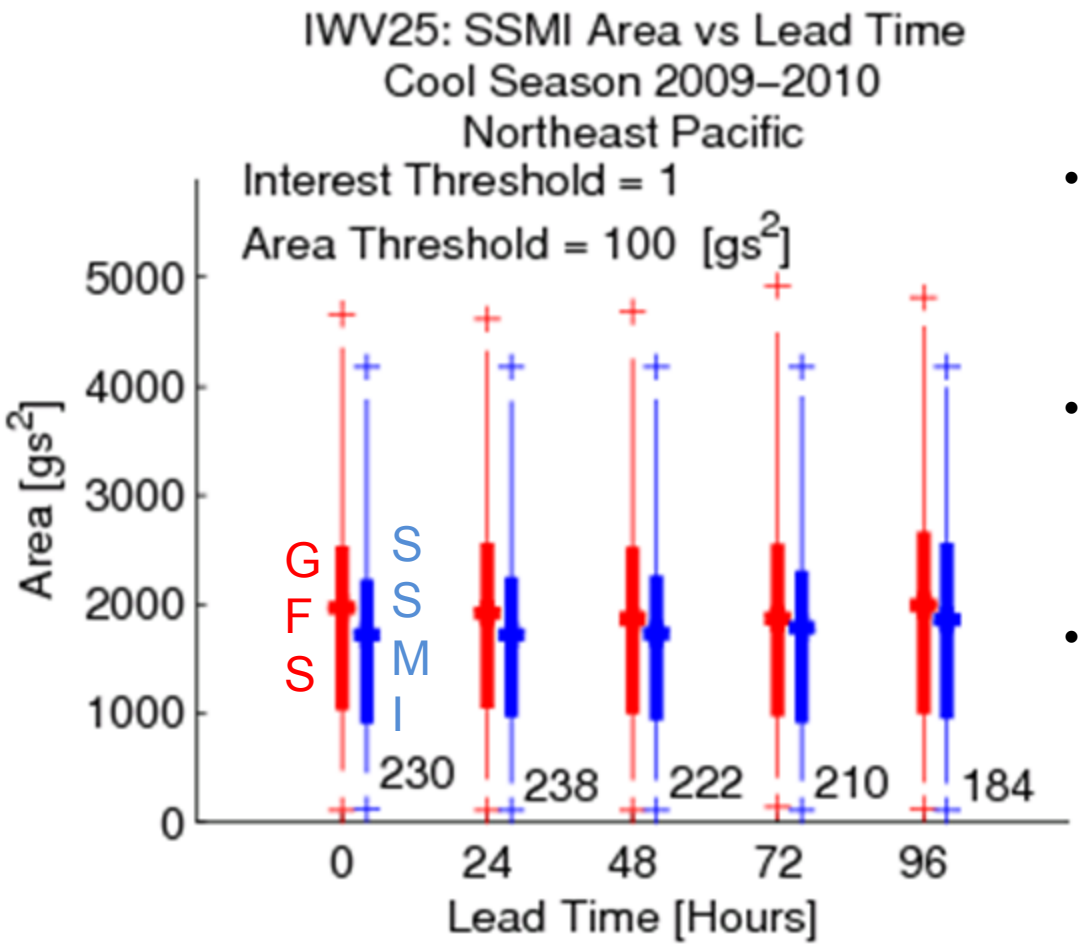
- Location Error
  - Centroid differences
  - Intersection Ratio
  - Area Ratios
- Intensity Error
  - Percentiles of object intensity
  - Total object intensity




Mean Percentile Points of IWV after Bias Removed
for 2009–2010 Cool Season Objects
All 346 Cases
190 Full Coverage Cases
Diagonal
90th
75th
50th percentile mean
25th
10th
GFS Analysis IWV [cm]
SSMIS Observed IWV [cm]
0.5
1
1.5
2
2.5
3
3.5

Object Areas vs. Lead Time

IWV Threshold = 2.5 cm



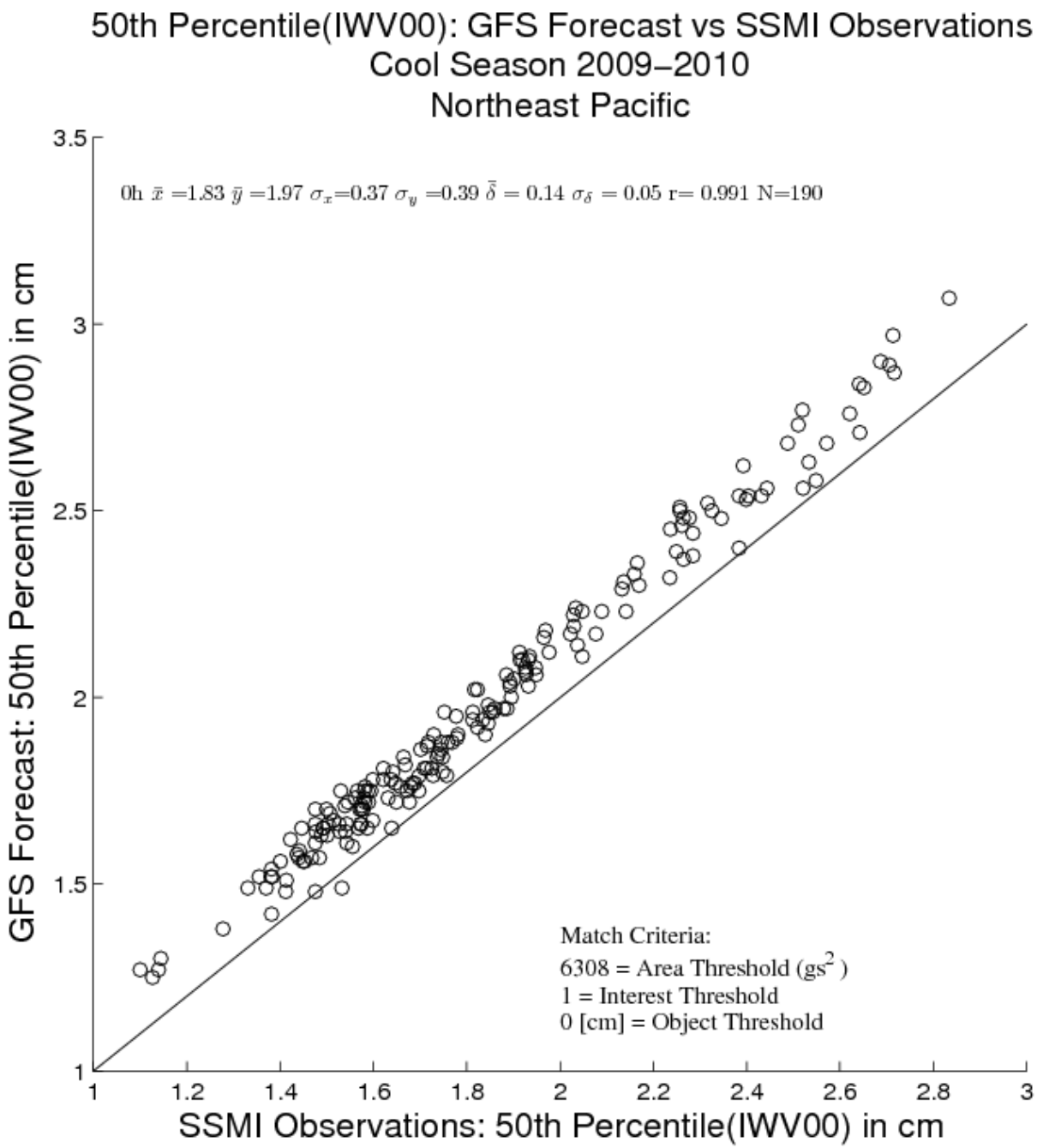
Legend

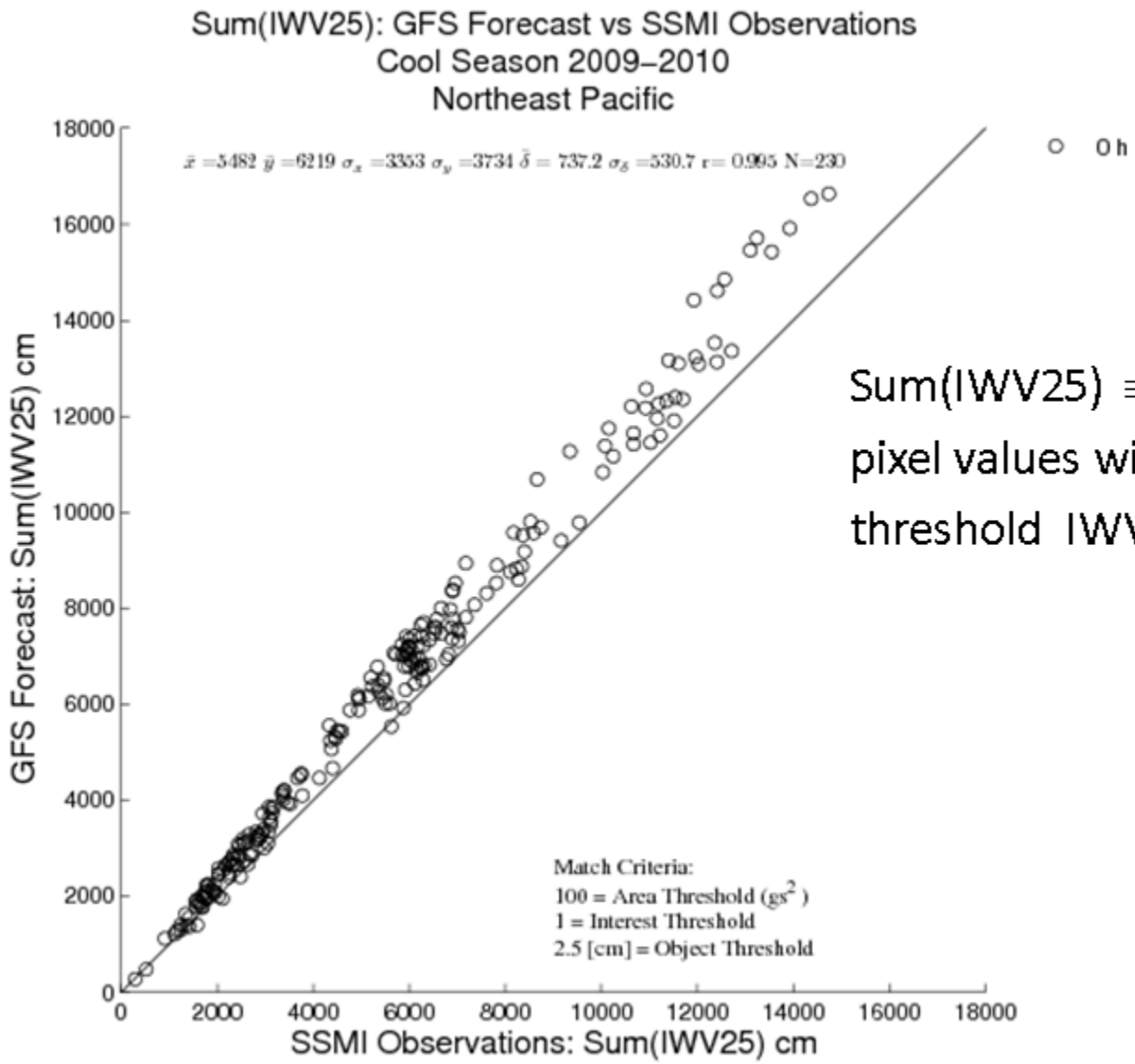
Median = Thick Bar, Mean = Thin Bar

Percentile Ranges: 2.5—97.5 = Thin line, 25—75 = Thick line

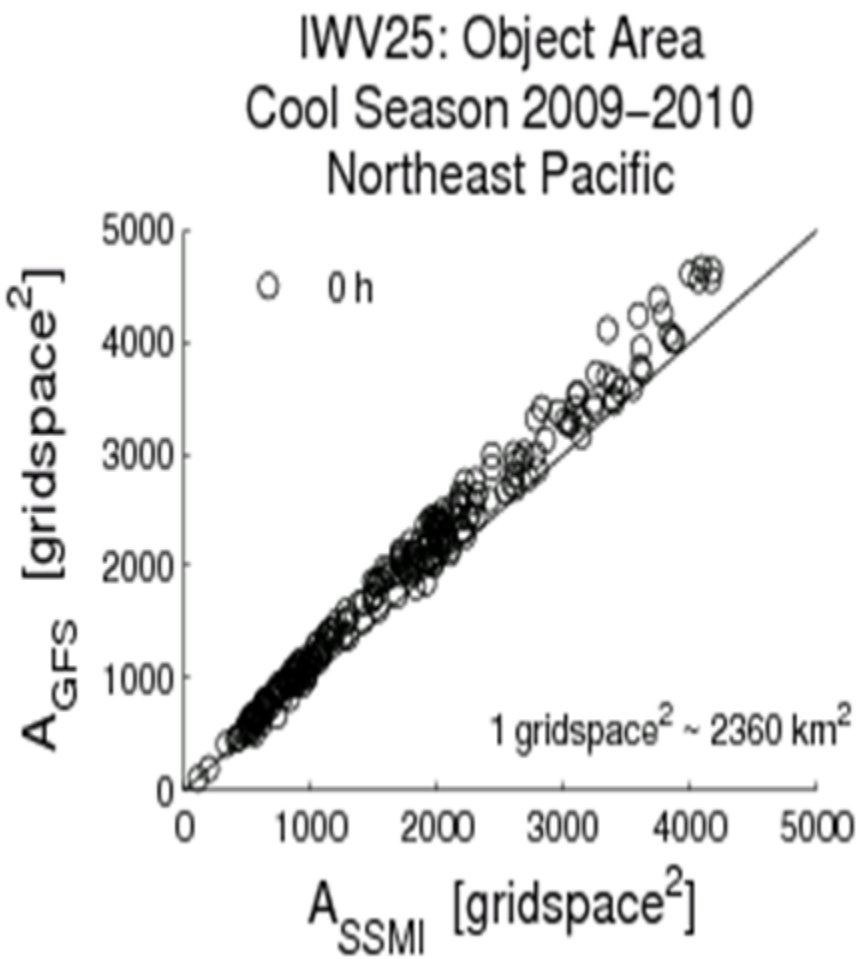
1 gs = 0.5 degrees latitude /longitude

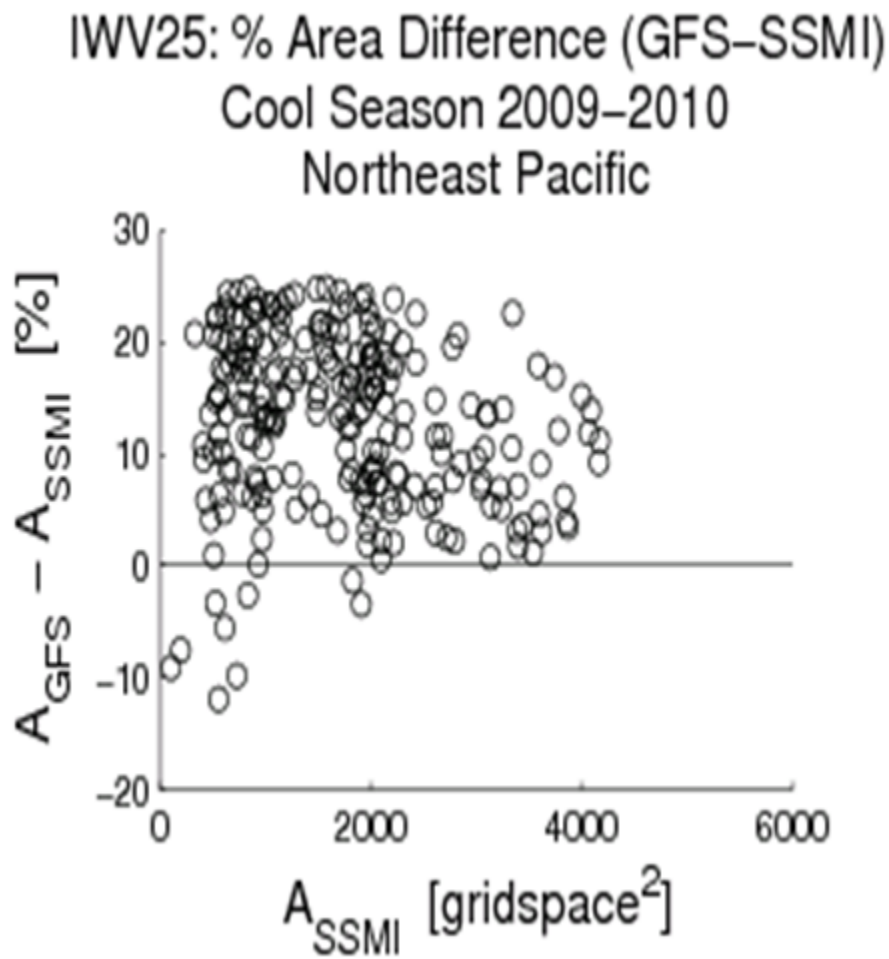
- The GFS object areas (red) tend to be larger than the SSMIS values (blue).
- 50% of the areas range roughly between 1000 and 2500 gs^2.
- The percentile-point differences in areas tend to be more noticeable for the larger areas.

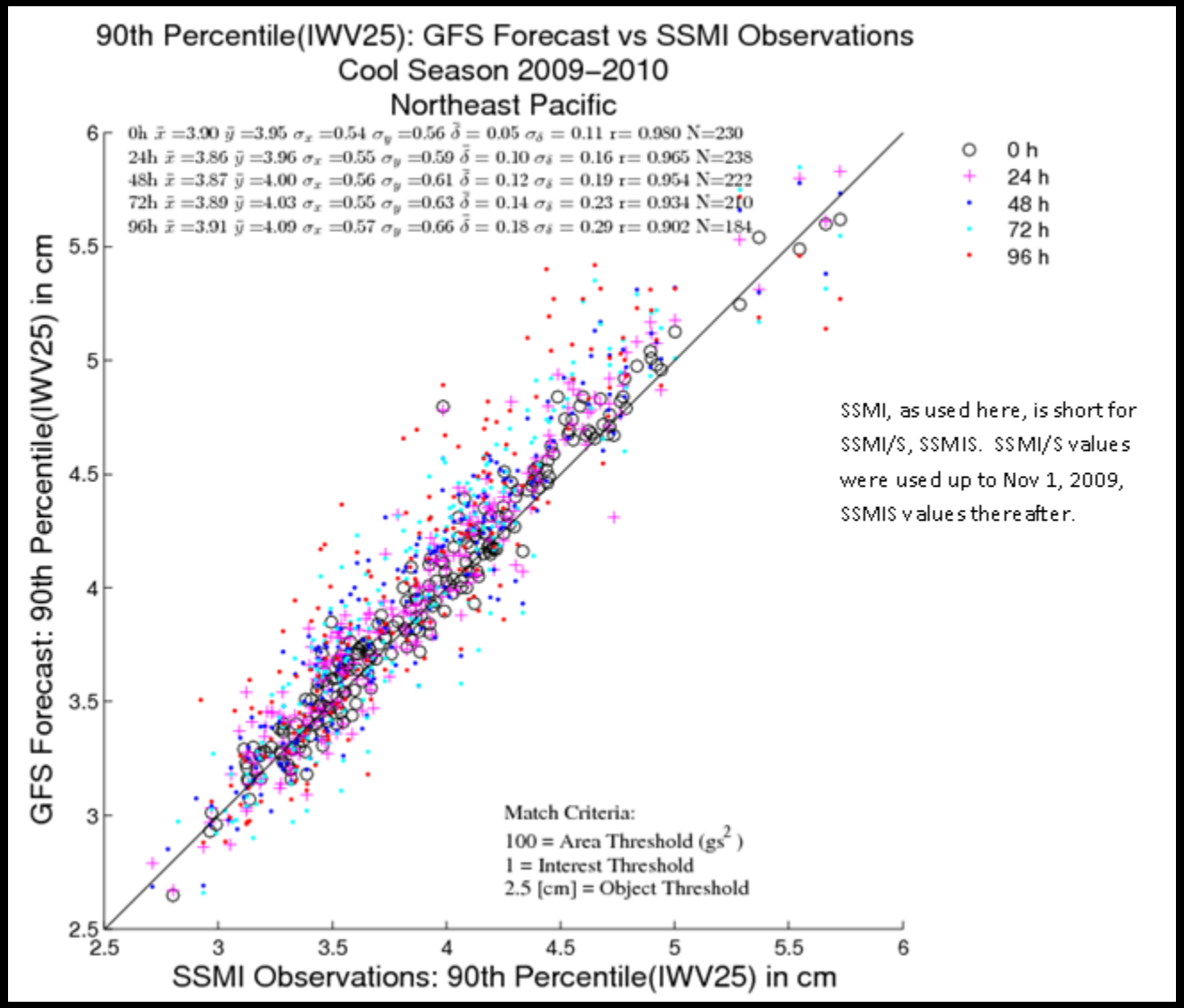

50th Percentile(IWV00): GFS Forecast vs SSMI Observations
Cool Season 2009–2010
Northeast Pacific
0h $\bar{x}$ =1.83 $\bar{y}$ =1.97 σ_x=0.37 σ_y =0.39 $\bar{\delta}$ = 0.14 σ_δ = 0.05 r= 0.991 N=190
Match Criteria:
6308 = Area Threshold (gs^2)
1 = Interest Threshold
0 [cm] = Object Threshold
GFS Forecast: 50th Percentile(IWV00) in cm
SSMI Observations: 50th Percentile(IWV00) in cm
1
1.5
2
2.5
3
3.5
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3



Sum(IWV25) ≡ Total of all IWV pixel values within a 25mm threshold IWV object.


IWV25: Object Area
Cool Season 2009–2010
Northeast Pacific
0 h
1 gridspace² ~ 2360 km²
A_GFS [gridspace²]
A_SSMI [gridspace²]
0
1000
2000
3000
4000
5000


IWV25: % Area Difference (GFS–SSMI)
Cool Season 2009–2010
Northeast Pacific
A_GFS – A_SSMI [%]
A_SSMI [gridspace²]
30
20
10
0
–10
–20
0
2000
4000
6000


90th Percentile(IWV25): GFS Forecast vs SSMI Observations
Cool Season 2009–2010
Northeast Pacific
0h $\bar{x}$ =3.90 $\bar{y}$ =3.95 σ_x =0.54 σ_y =0.56 $\bar{\delta}$ = 0.05 σ_δ = 0.11 r= 0.980 N=230
24h $\bar{x}$ =3.86 $\bar{y}$ =3.96 σ_x =0.55 σ_y =0.59 $\bar{\delta}$ = 0.10 σ_δ = 0.16 r= 0.965 N=238
48h $\bar{x}$ =3.87 $\bar{y}$ =4.00 σ_x =0.56 σ_y =0.61 $\bar{\delta}$ = 0.12 σ_δ = 0.19 r= 0.954 N=222
72h $\bar{x}$ =3.89 $\bar{y}$ =4.03 σ_x =0.55 σ_y =0.63 $\bar{\delta}$ = 0.14 σ_δ = 0.23 r= 0.934 N=210
96h $\bar{x}$ =3.91 $\bar{y}$ =4.09 σ_x =0.57 σ_y =0.66 $\bar{\delta}$ = 0.18 σ_δ = 0.29 r= 0.902 N=184
0 h
24 h
48 h
72 h
96 h
SSMI, as used here, is short for SSMI/S, SSMIS. SSMI/S values were used up to Nov 1, 2009, SSMIS values thereafter.
Match Criteria:
100 = Area Threshold (gs^2)
1 = Interest Threshold
2.5 [cm] = Object Threshold
GFS Forecast: 90th Percentile(IWV25) in cm
SSMI Observations: 90th Percentile(IWV25) in cm
2.5
3
3.5
4
4.5
5
5.5
6