

Verification of Forecaster-Generated iCAST Thunderstorm Nowcasts and Comparison to Automated Thunderstorm Forecasts: Preliminary Results



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Environment
Canada

Environnement
Canada

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Canada

Outline

- Motivation for an area-based, met-object approach
- The iCAST prototype
- Data and methodology
- Verification results
- Discussion
- Summary



Motivation

From the ‘Next Generation Prediction System Group’ and the ‘Warning Re-Engineering Group’ requirements, we need:

- New nowcasting / warning tools that facilitate the best application of human’s skills and enable optimal use of technological progress to ensure effective human interaction
- To better define exactly how forecasters will use these new tools during a shift (‘concept of operations’)
- To automate product generation (to improve efficiency)
- New watch/warning products and dissemination approaches to provide improved, more impact-based decision support to Canadians and to public authorities
- To integrate wherever possible with NinJo



The iCAST prototype

- **interactive Convective Analysis and Storm Tracking (iCAST)**
 - *Research prototype* that attempts to find an optimal human-machine mix for convective nowcasting using an area-based, met-object approach
 - Allows intelligent combination of observations, numerical and statistical guidance in 4-D to enhance ADP
 - Intuitive database interaction tools allow forecasters to focus on the meteorology, product generation can be automated
 - Approaches for probabilistic and multimedia nowcasts / products being developed and evaluated
 - Real-time verification being included as a critical component
 - Developed with the implementation of concepts into NinJo in mind



What is meant by 'area-based'?

- Current forecast production paradigm is 'point based':
 - SCRIBE forecasts are modified by forecaster editing time series data at points
 - Over 1200 stations across Canada (grouping helps with efficiency)
- An area-based forecast production paradigm allows forecaster ADP in plan view
 - Very intuitive for the forecaster
 - Most forecaster training is area-based, not point-based (any?)
- NinJo workstation is mainly focused on area-based imagery:
 - Radar, satellite, surface obs, lightning,
 - Deterministic and ensemble NWP output
- US uses an area-based, grid-editing approach

What exactly are 'met objects'?

- Met-objects can be used to greatly simplify complex weather features:
 - **Points** – low pressure centre, storm cell
 - **Lines** – warm front, low-level jet, dryline, rain-snow boundary
 - **Areas** – precipitation, fog, ash, event-based warning
 - **Continuous fields** – surface-level temperature, wind, or pollutant concentration
 - **Tracks** – past, current and forecast locations of a feature, such as a thunderstorm or hurricane, connected through time



The area-based, met-object approach

- Enables ‘knowledge representation’ in the digital database using conceptual models as building blocks
- Very intuitive for forecasters, able to use extensive library of conceptual models
- Enhances ADP and ability to build consistent depiction sequence from inconsistent data
- No need to start from scratch each shift:
 - first-guess fields from obs and NWP
 - met-object database from previous shift can be used as ‘first guess’

The iCAST prototype

iCAST employs a three-level approach:

- 1) **Convective nowcasts in 3-6 hour time frame – ‘watch scale’**
- 2) **Mesoscale analyses each hour - before and during anticipated severe weather – ‘watch’ or ‘warning’ scale**
- 3) **Convective nowcasts focused on initiation / evolution of storms using forecaster-modified tracks – ‘warning scale’**

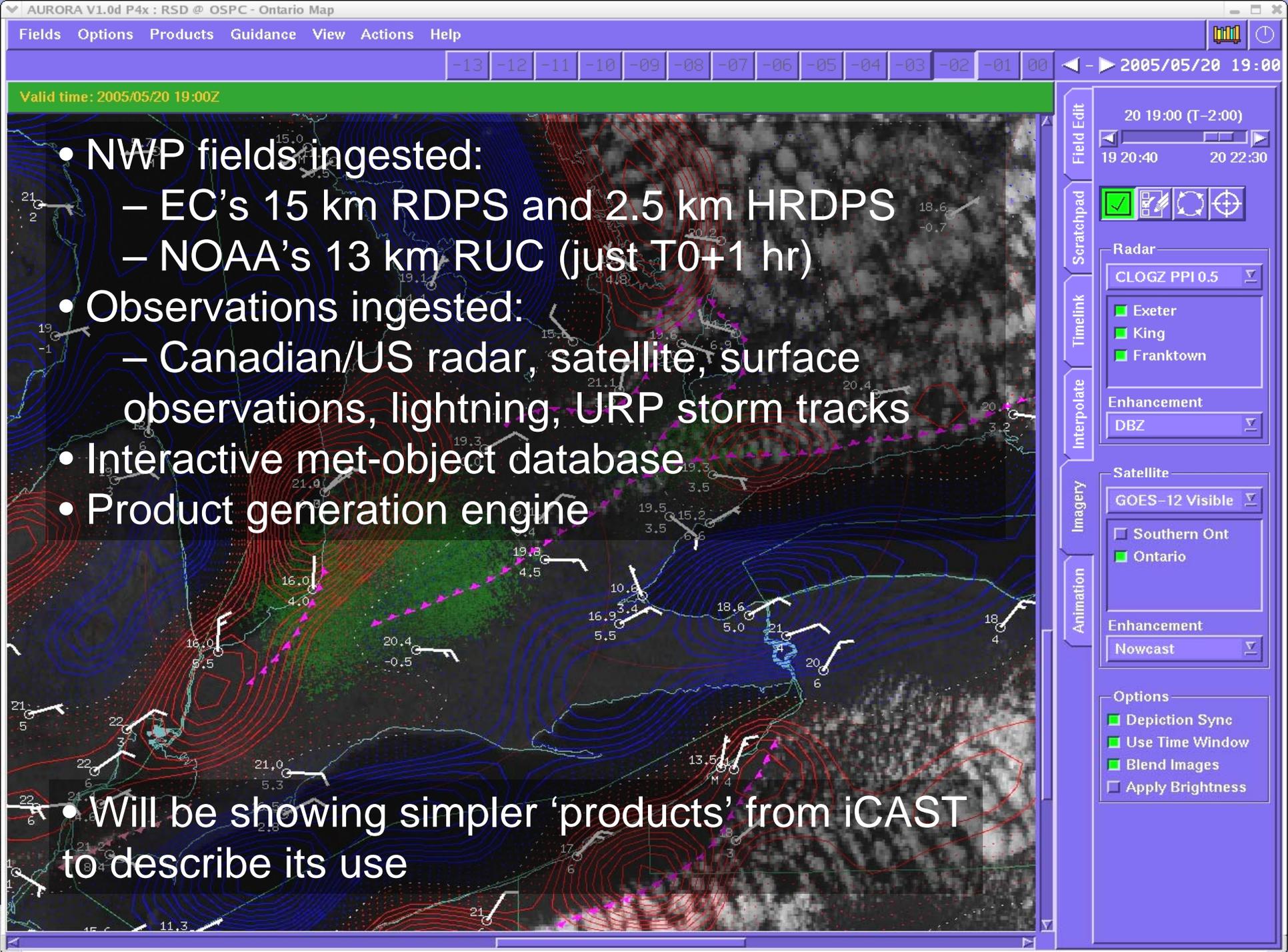


The iCAST prototype

iCAST employs a three-level approach:

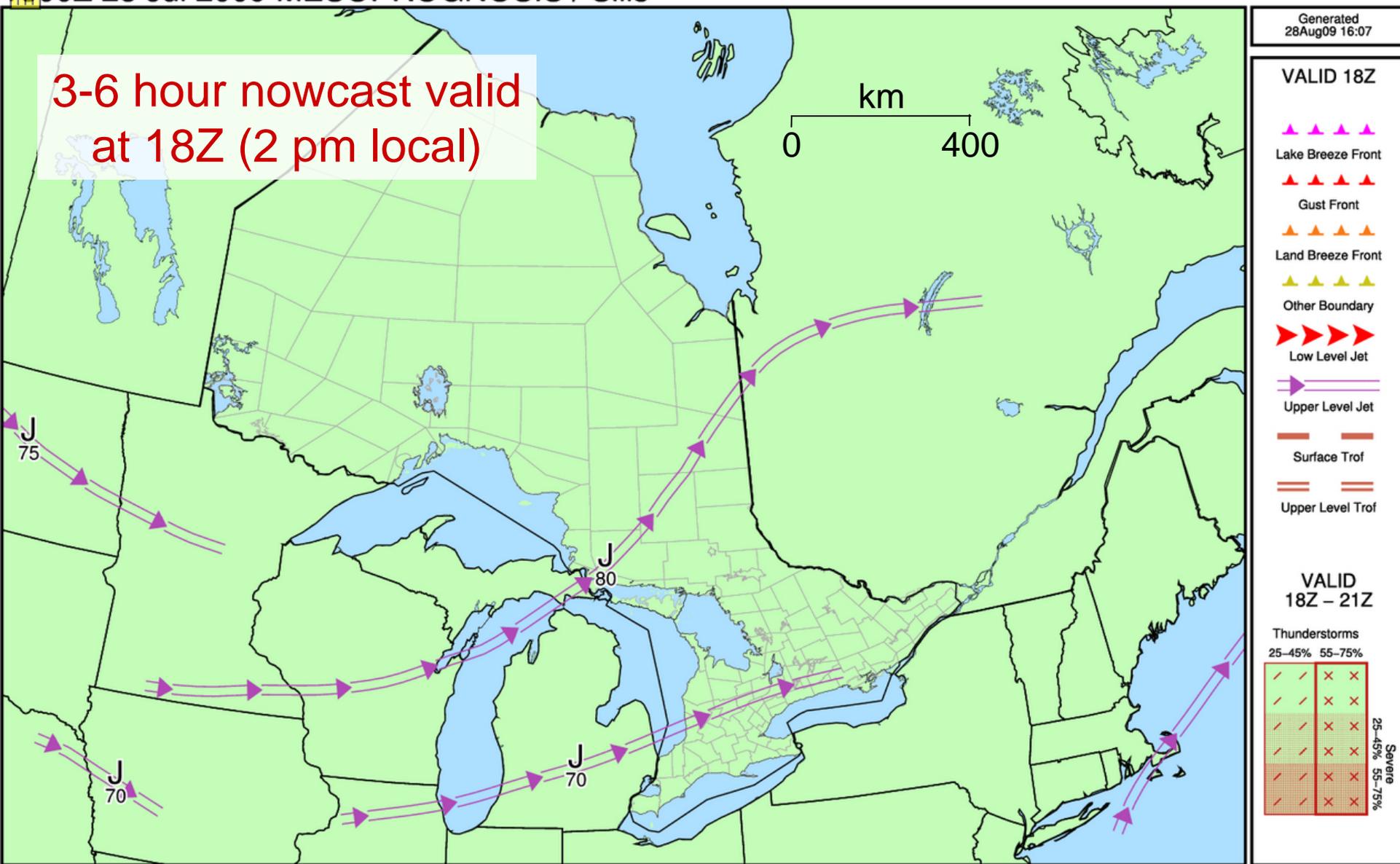
- 1) Convective nowcasts in 3-6 hour time frame – ‘watch scale’**
- 2) Mesoscale analyses each hour - before and during anticipated severe weather – ‘watch’ or ‘warning’ scale**
- 3) Convective nowcasts focused on initiation / evolution of storms using forecaster-modified tracks – ‘warning scale’**





- NWP fields ingested:
 - EC's 15 km RDPS and 2.5 km HRDPS
 - NOAA's 13 km RUC (just T0+1 hr)
- Observations ingested:
 - Canadian/US radar, satellite, surface observations, lightning, URP storm tracks
- Interactive met-object database
- Product generation engine
- Will be showing simpler 'products' from iCAST to describe its use

3-6 hour nowcast valid at 18Z (2 pm local)



- “Forecast Funnel”: weather features analyzed using NWP, extrapolated 12Z obs, and conceptual models from top down

1800Z 28 Jul 2009 MESOPROGNOSIS / Sills

Generated
28Aug09 16:24

VALID 18Z

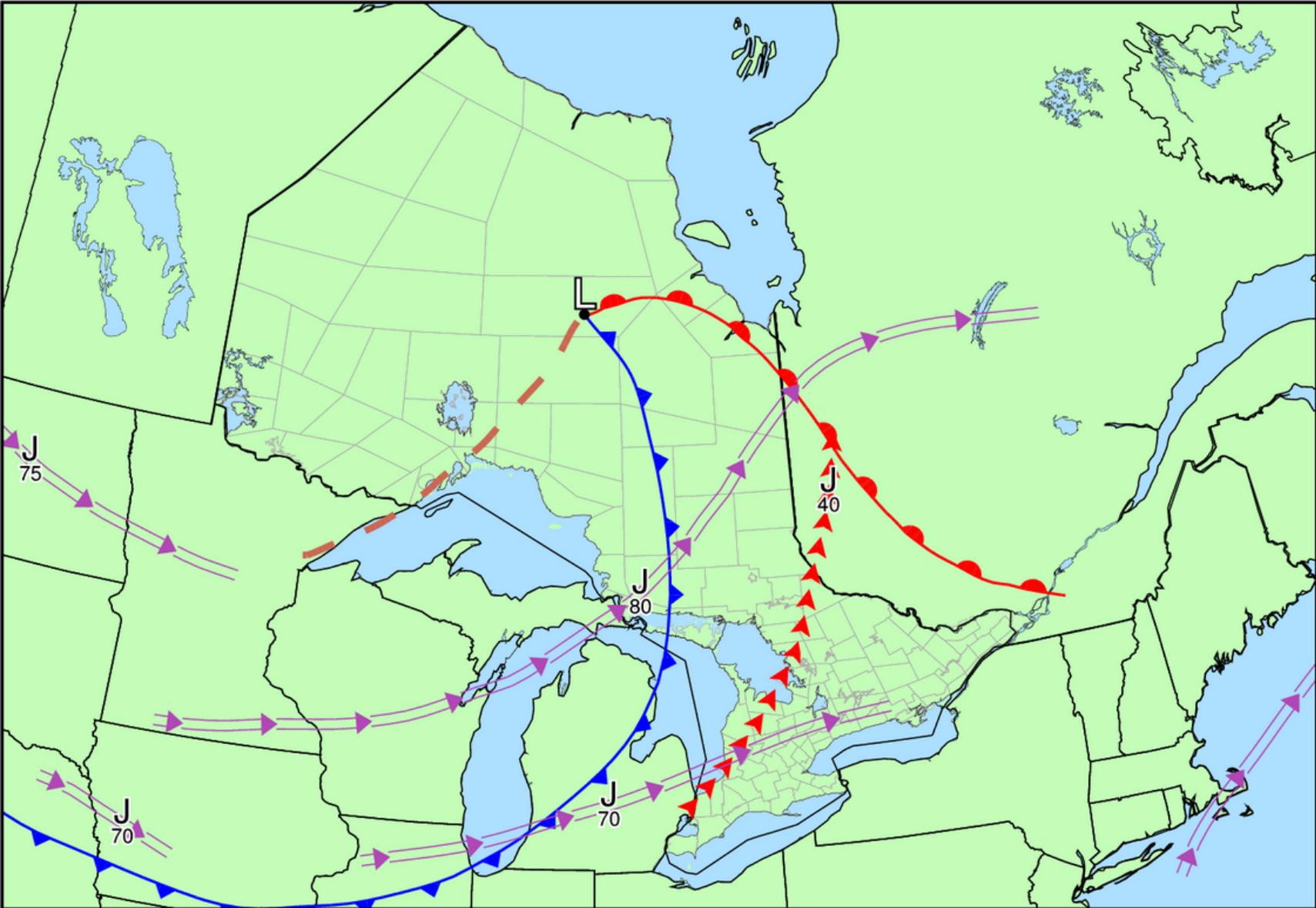
- ▲▲▲▲▲ Lake Breeze Front
- ▲▲▲▲▲ Gust Front
- ▲▲▲▲▲ Land Breeze Front
- ▲▲▲▲▲ Other Boundary
- ▶▶▶▶▶ Low Level Jet
- ▶▶▶▶▶ Upper Level Jet
- — — — — Surface Trof
- == == == == == Upper Level Trof

VALID 18Z - 21Z

Thunderstorms

25-45%	55-75%	Severe
/ / / / /	x x x x x	
/ / / / /	x x x x x	
/ / / / /	x x x x x	





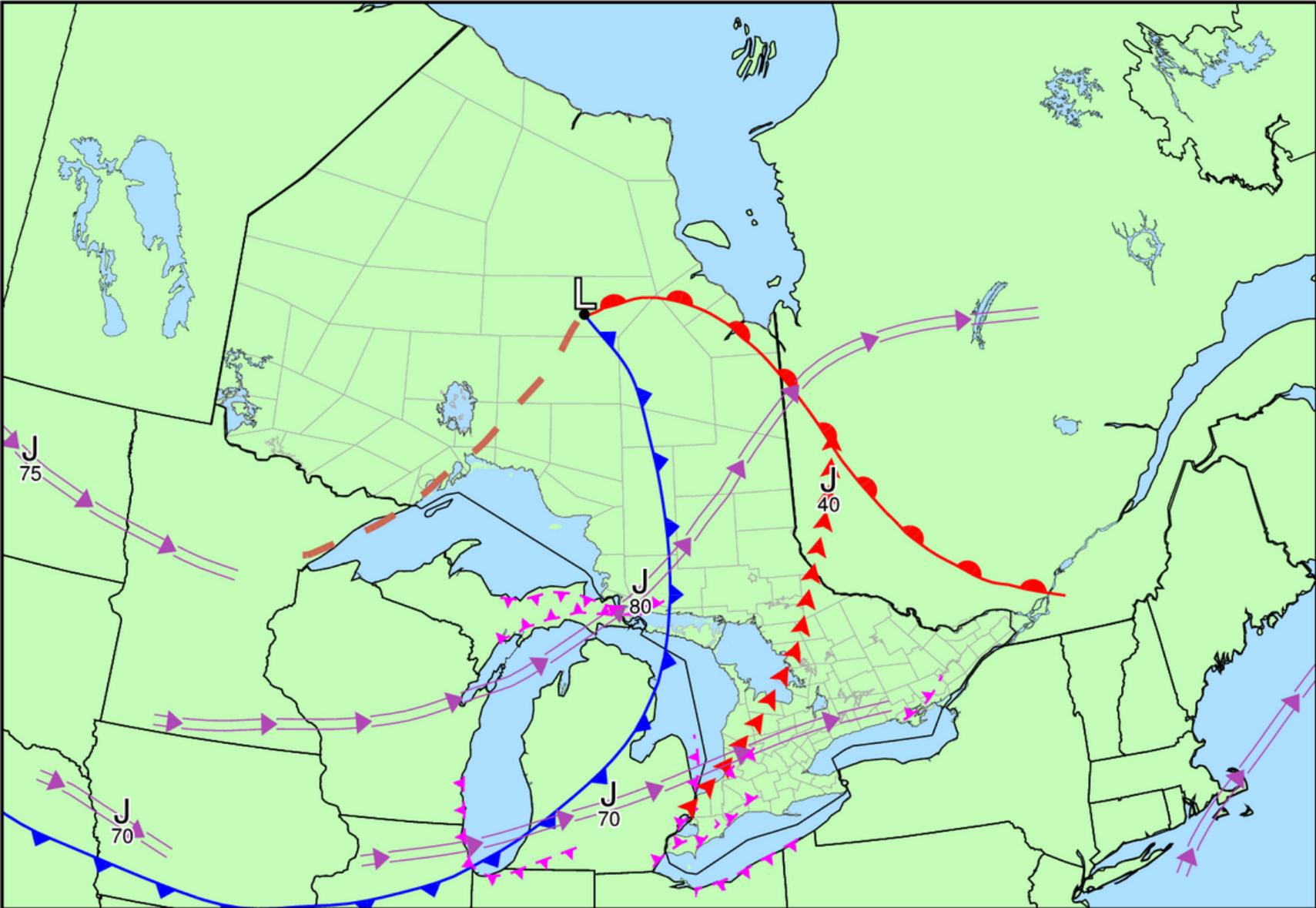
VALID 18Z

- ▲▲▲▲ Lake Breeze Front
- ▲▲▲▲ Gust Front
- ▲▲▲▲ Land Breeze Front
- ▲▲▲▲ Other Boundary
- ▶▶▶▶ Low Level Jet
- ▶▶▶▶ Upper Level Jet
- - - - Surface Trof
- == == Upper Level Trof

VALID
18Z - 21Z

Thunderstorms

25-45%	55-75%	Severe
/ / / /	x x x x	
/ / / /	x x x x	
/ / / /	x x x x	



VALID 18Z

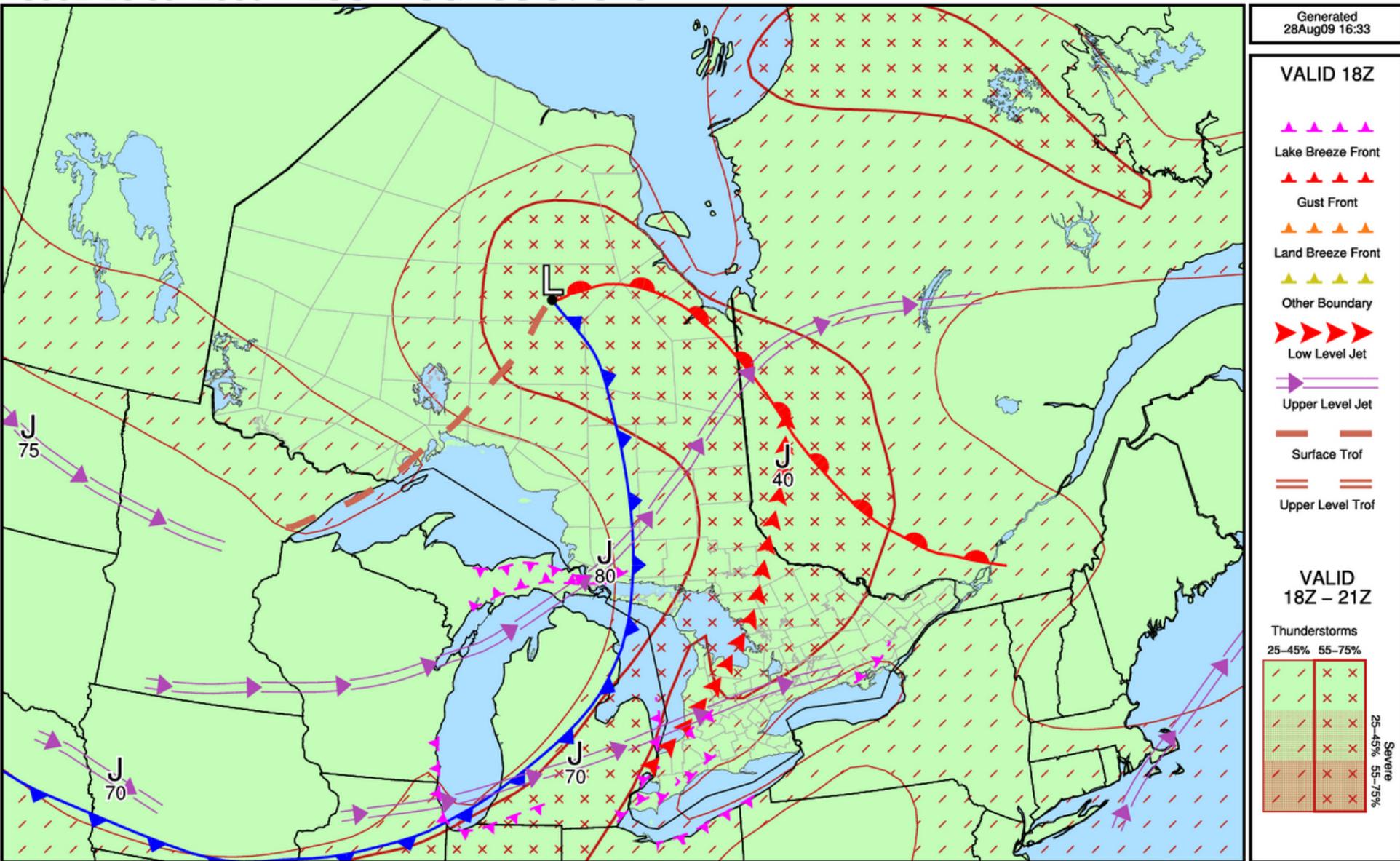
- ▲▲▲▲ Lake Breeze Front
- ▲▲▲▲ Gust Front
- ▲▲▲▲ Land Breeze Front
- ▲▲▲▲ Other Boundary
- ▶▶▶▶ Low Level Jet
- ▶▶▶▶ Upper Level Jet
- - - - Surface Trough
- - - - Upper Level Trough

VALID 18Z - 21Z

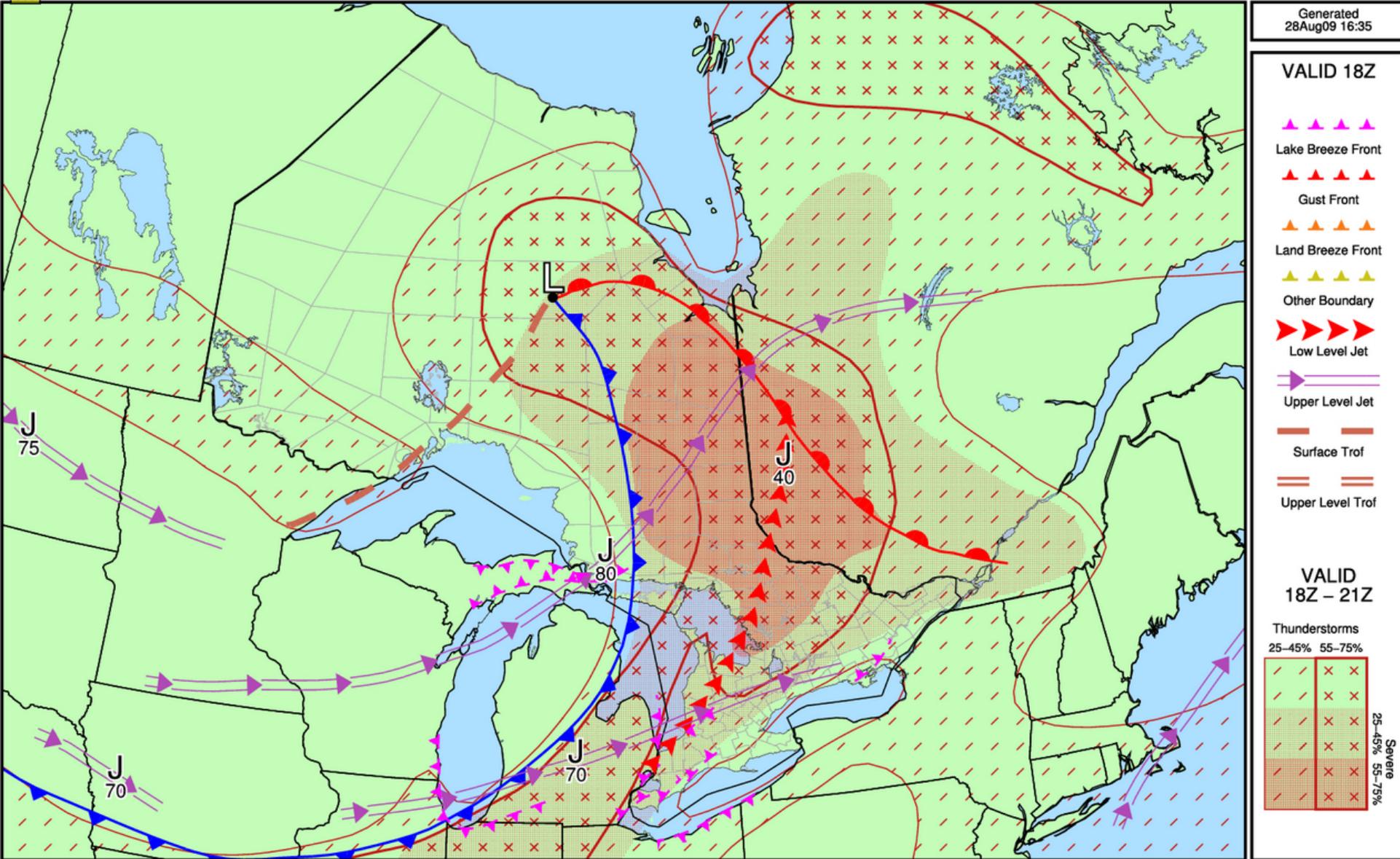
Thunderstorms

25-45%	55-75%
25-45%	55-75%
25-45%	55-75%
25-45%	55-75%
25-45%	55-75%

Savere



- Thunderstorm areas valid 18-21Z using numerical guidance, modified 12Z soundings, conceptual models, and history



- Severe storm areas valid 18-21Z using NWP, modified 12Z soundings, conceptual models, history, analogs, etc.

Verifying Thunderstorm Nowcasts

- **Research Support Desk, Summers 2009/2010**

- Used to develop thunderstorm nowcasting techniques and verification methodologies
- Developed 4-category thresholds for some techniques (e.g. IVV)

- **Research Support Desk, Summer 2011**

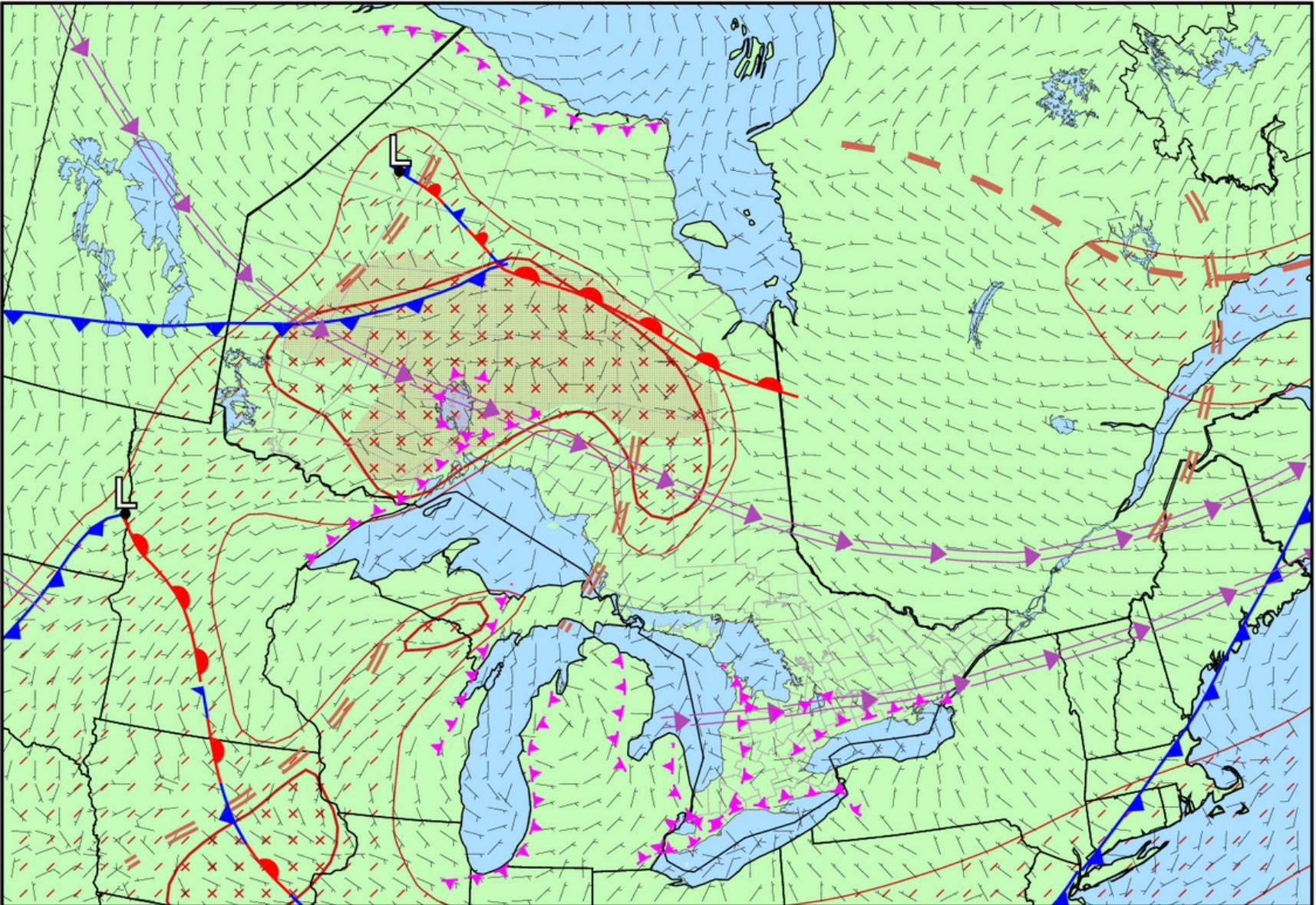
- Development and thresholds frozen
- Three meteorologists working RSD shifts focused on thunderstorm nowcasts and forecasts (Ashton, Kuhn and Sills)
- Four probability categories were defined: ‘none’, ‘chance’, ‘likely’, and ‘certain’



Verifying Thunderstorm Nowcasts

- RSD thunderstorm nowcasts are verified against NALDN lightning data
 - both cloud-to-ground and cloud flashes (limited) are used
 - detection efficiency is good even in far northern Ontario
- RSD thunderstorm nowcasts are compared to:
 - forecasts of climatology
 - HAL thunderstorm initiation and area (TIA) forecasts based on RDPS (GEM-REG) output
 - calibrated thunderstorm forecasts based on US SREF output





Generated 07Jul11 14:35

VALID 18Z

- ▲▲▲▲ Lake Breeze Front
- ▲▲▲▲ Gust Front
- ▲▲▲▲ Land Breeze Front
- ▲▲▲▲ Other Boundary
- ▶▶▶▶ Low Level Jet
- ▶▶▶▶ Upper Level Jet
- — — — Surface Trof
- — — — Upper Level Trof

VALID 18Z - 21Z

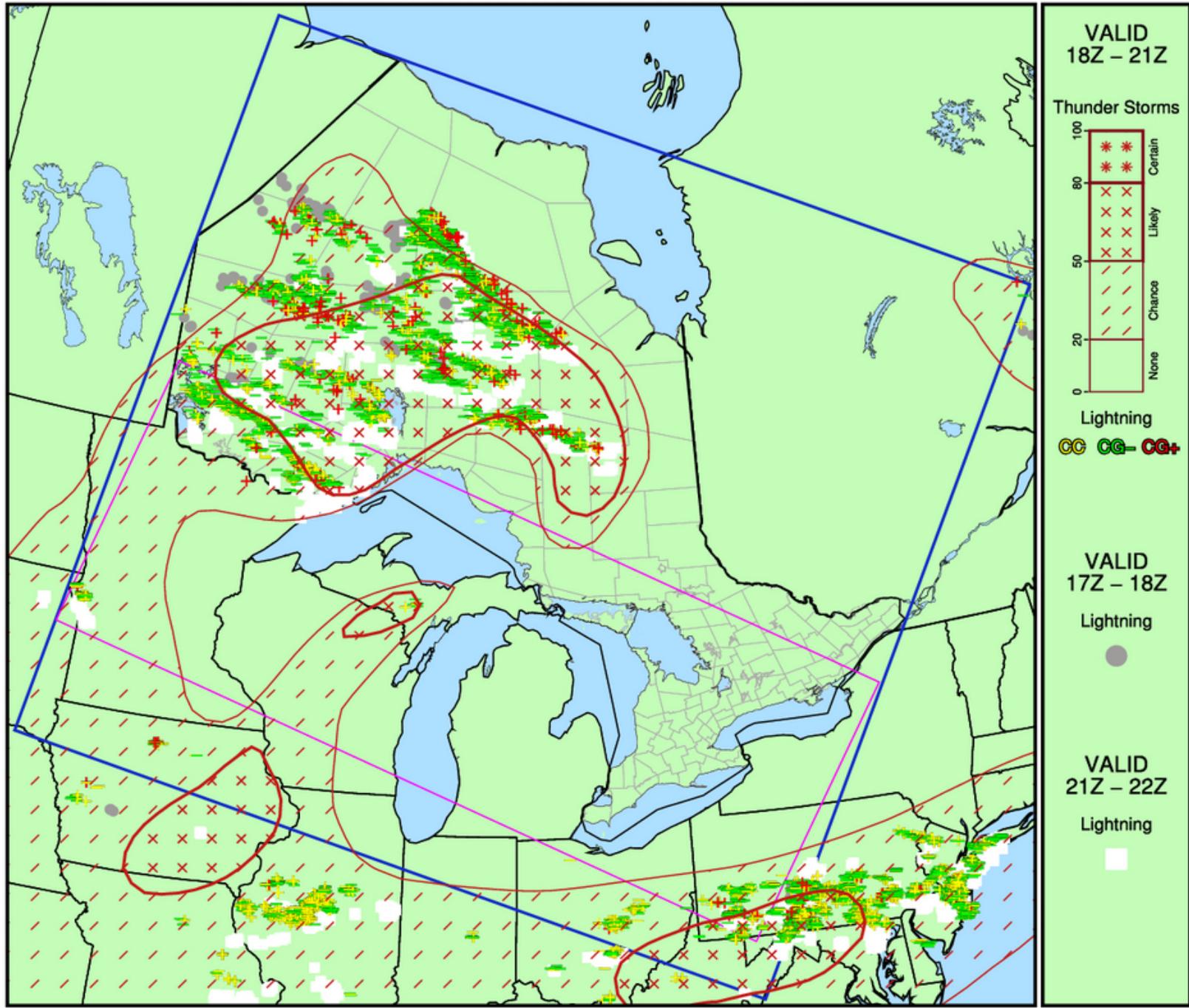
100%	***	***	Certain	100%
80%	xxx	xxx	Likely	80%
50%	xxx	xxx	Chance	50%
20%	xxx	xxx	None	20%
0%				0%

Thunder Storms

Severe Weather

IN NORTH, EXPCT TSRA IN OPEN WARM SECTOR AHEAD OF TWO VORT MAXES. CHC SVR OVER MOST OF THIS AREA DUE TO SHEAR 30-40 KNT, ALSO HAILCAST SHOWING POTENTIAL FOR 2-5 CM HAIL. CONVECTIVE MODE SHOULD BE MULTICELL. IN SOUTH, ONLY VIGOROUS LAKE BREEZES EXPCTD.

1800Z 07 Jul 2011 VERIFICATION / PROGNOSIS





RSD Nowcasts

- A time cut-off of 1630 UTC (12:30 pm local) was used to provide a minimum 3-hr nowcast for the midpoint of the 18-21 UTC period
- Majority of nowcasts were completed by 11 am or earlier
- Gave **68 days** with valid RSD nowcasts between May 29 and Sep 26, 2011
- Gridded on RDPS grid (14396 grid points)



RSD TI field ss

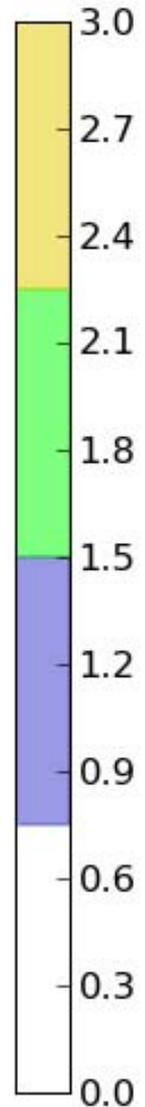
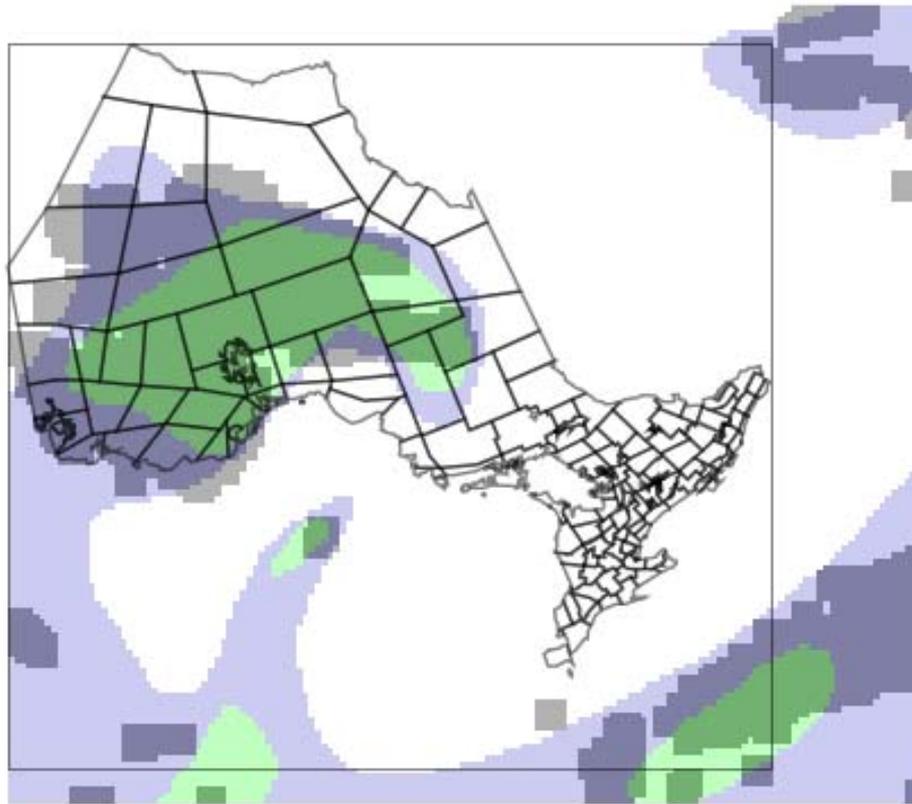
Time is: 2011:07:07:18 and next 3 hours.

CLDN gridded at: 75x75 sq km 17 to 22Z

Brier Skill Score: 0.4300 ROC Score: 0.7729

Purple
Green
Dark

Chance
Likely
Lightning



CHC: Lvl 0: POD= 0.897, FAR= 0.450, CSI= 0.518, HSS=0.574

LKLY: Lvl 1: POD= 0.463, FAR= 0.177, CSI= 0.421, HSS=0.522

CTN: Lvl 2: POD= 0.000, FAR= U, CSI= 0.000, HSS=0.000



TIA forecasts

- HAL in Edmonton has worked to develop automated thunderstorm initiation and area (TIA) forecasts derived from RDPS output
- Valid at each hour so, to compare with 3-hr RSD fields, the fields representing 18, 19 and 20 UTC were combined by taking the maximum value at each grid point





TIA forecasts

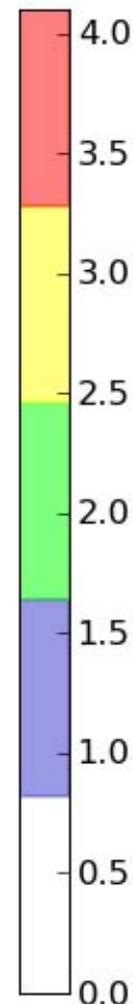
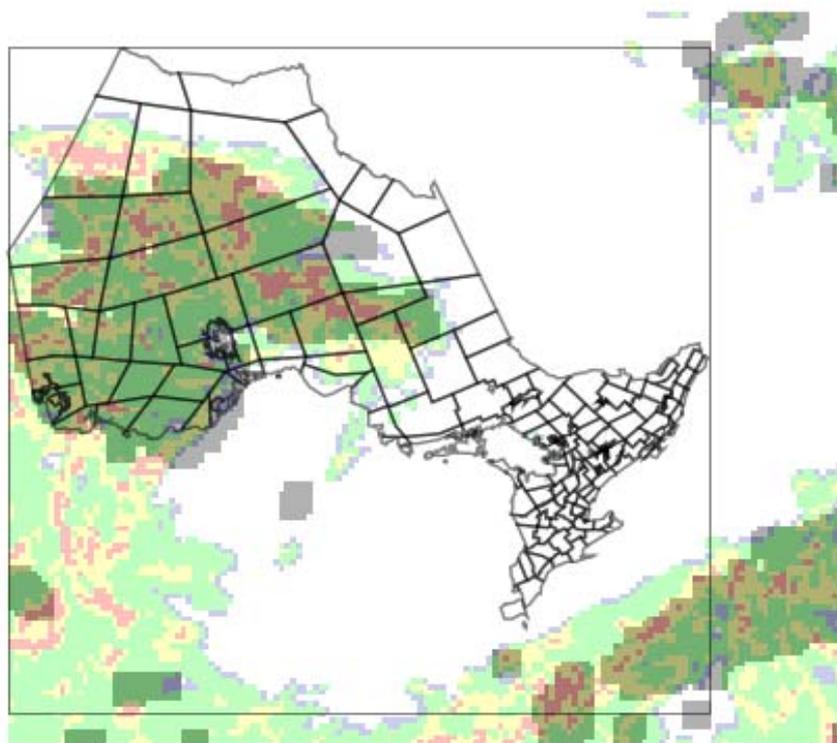
- OBTI - 'Objective TIA' thunderstorm forecast field uses four-level likelihood scale according to increasingly stringent thresholds of instability, convective inhibition, low-level convergence, and low-level wind shear
- Makes use of values from the Cloud Physics Thunderstorm Parameter (CPTP, Bright et al. 2005) calculated using RDPS data
- CPTP ≥ 25 mask is applied to better delineate areas with thunderstorm potential



HAL field of objective \bar{t}_i im
Merged grid at: 2011:07:07:18 to 20
CLDN gridded at: 75x75 sq km 17 to 22Z
Brier Skill Score: 0.2670 ROC Score: 0.6721

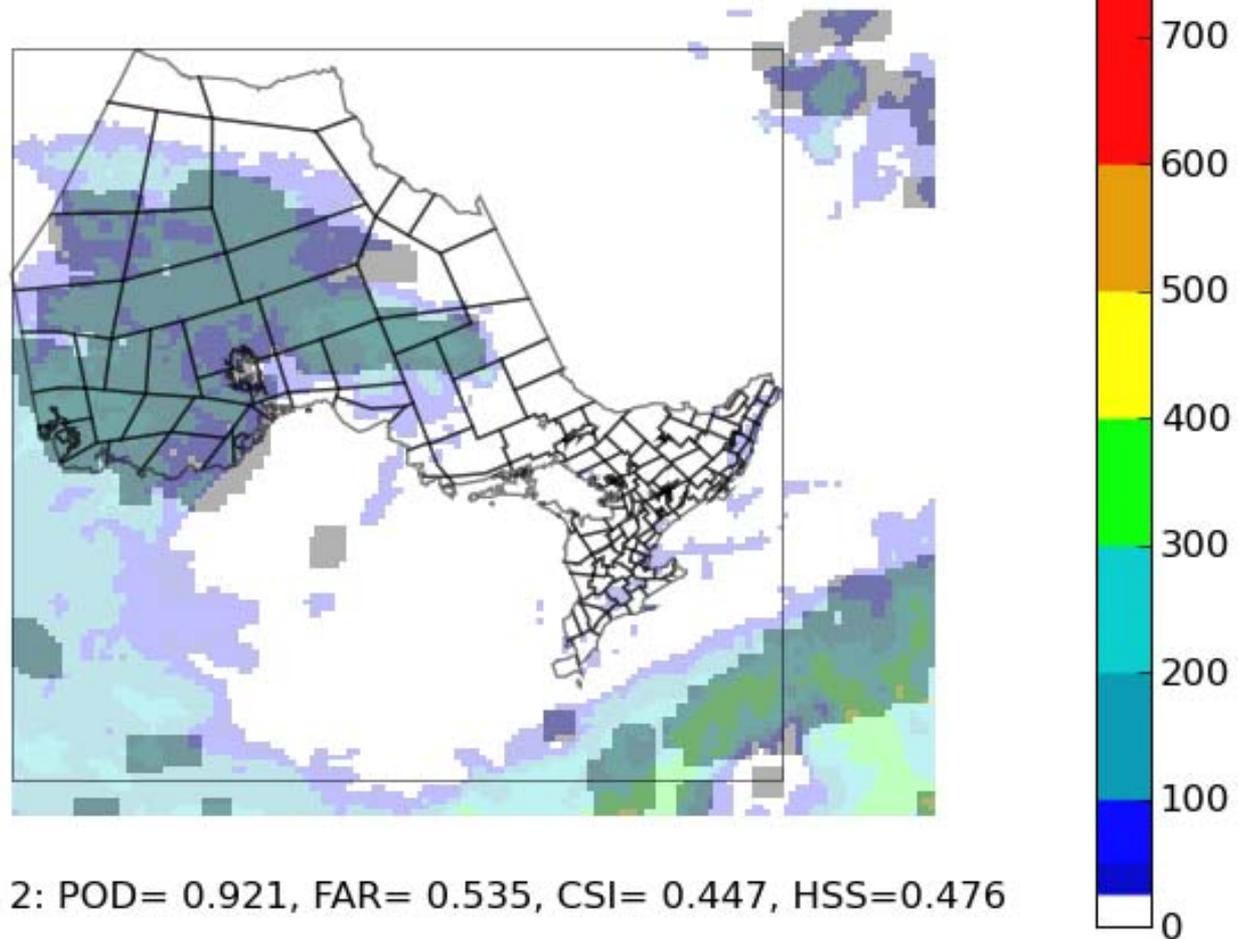
Green
Yellow
Red

Chance
Likely
Certain



CHC: Lvl 0: POD= 0.888, FAR= 0.504, CSI= 0.467, HSS=0.507
LKLY: Lvl 1: POD= 0.424, FAR= 0.459, CSI= 0.312, HSS=0.360
CTN: Lvl 2: POD= 0.105, FAR= 0.464, CSI= 0.096, HSS=0.116

HAL field ct cp_thunder_im
Merged grid at: 2011:07:07:18 to 20
CLDN gridded at: 75x75 sq km 17 to 22Z
Brier Skill Score: -0.1507 ROC Score: 0.6492





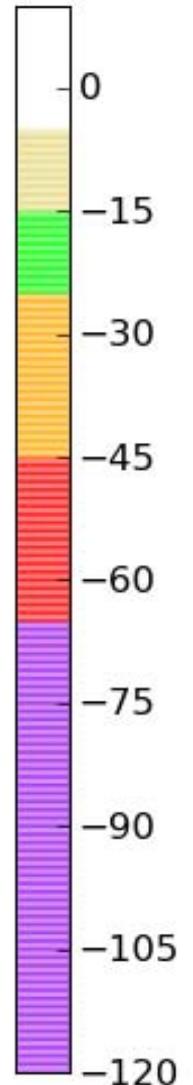
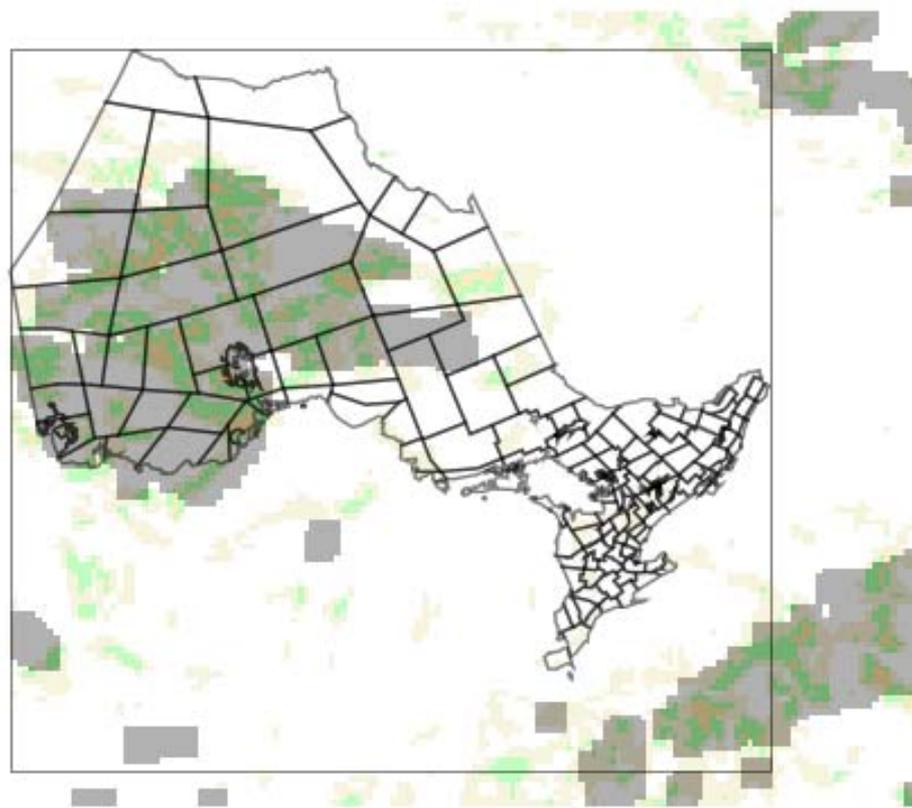
TIA forecasts

- IVV - 'Integrated Vertical Velocity' forecast integrates the RDPS vertical velocity at each model level from the surface to the mixed-layer equilibrium level for each grid point
- Idea to identify where strong upward vertical motions, near the surface and/or aloft, are likely to initiate and/or sustain deep moist convection
- Like OBTI, a CPTP ≥ 25 mask is applied to better delineate areas with thunderstorm potential



HAL field wc wwsum_cptp_im
Merged grid at: 2011:07:07:18 to 20
CLDN gridded at: 75x75 sq km 17 to 22Z
Brier Skill Score: 0.1970 ROC Score: 0.4568

≤ -5 Chance
 ≤ -25 Likely
 ≤ -45 Certain



CHC: Lvl 0: POD= 0.614, FAR= 0.512, CSI= 0.373, HSS=0.409
LKLY: Lvl 1: POD= 0.064, FAR= 0.201, CSI= 0.063, HSS=0.090
CTN: Lvl 2: POD= 0.000, FAR= U, CSI= 0.000, HSS=0.000



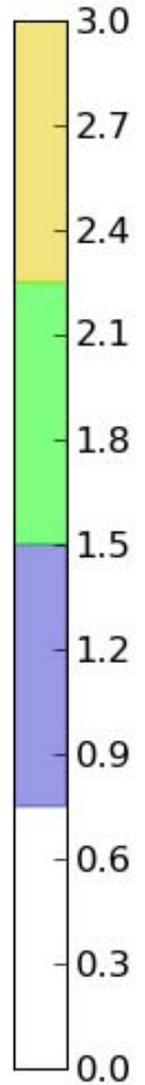
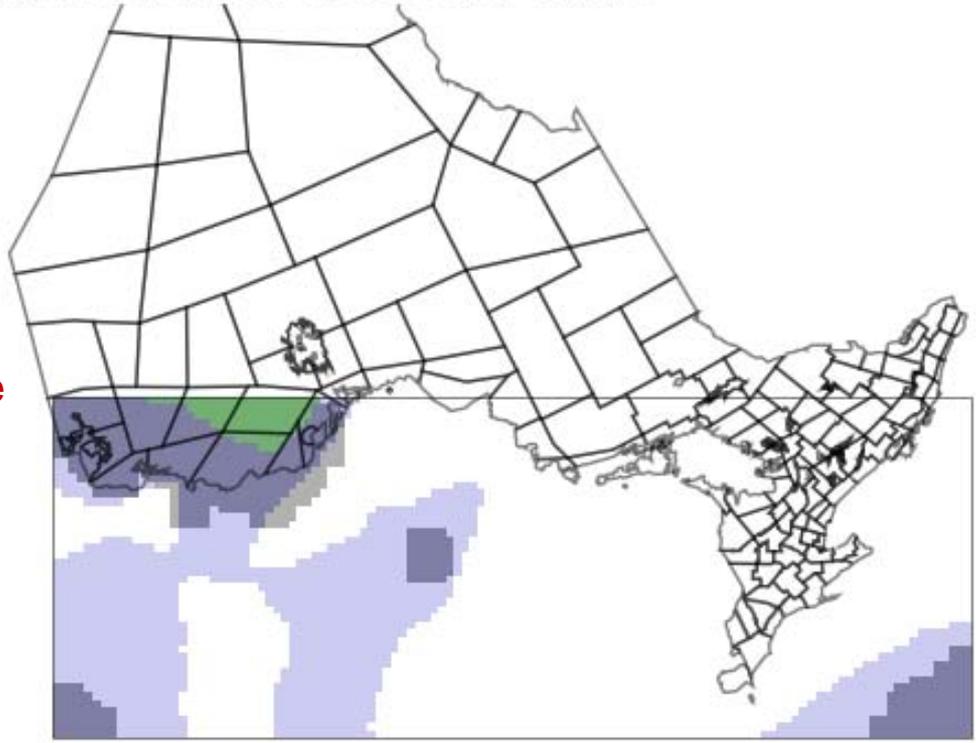
SREF Forecasts

- 3-hr calibrated thunderstorm forecasts based on post-processing of 21 members of the NCEP SREF system plus the operational WRF-NAM (total 22 members)
- Predictors are CPTP + 3-hr total precip
- Forecasts from the 03 UTC SREF run used
- SREF sample size 37 days
- Domain covers only parts of Ontario near the US border so sub-domain used



RSD TI field ti
Time is: 2011:07:07:21 and next 3 hours.
CLDN gridded at: 75x75 sq km 17 to 22Z
Brier Skill Score: 0.2587 ROC Score: 0.7230

10% (purple) Chance
40% (green) Likely
70% (yellow) Certain



CHC: Lvl 0: POD= 0.935, FAR= 0.625, CSI= 0.365, HSS=0.425
LKLY: Lvl 1: POD= 0.123, FAR= 0.000, CSI= 0.123, HSS=0.195
CTN: Lvl 2: POD= 0.000, FAR= U, CSI= 0.000, HSS=0.000

Verification Methodology

- Relaxed verification approach in space and time
 - Thunderstorm occurrence defined by at least one lightning flash within RDPS 15 km x 15 km grid cell
 - Influence of each lightning flash spread over 5 x 5 RDPS grids (75 km x 75 km box)
 - Boxes can overlap
 - Included one hour of lightning before and another after 18-21 UTC forecast period, so 5-hr period covering 17-22 UTC



Verification Methodology

- Comparisons made for both 00 UTC and 12 UTC RDPS runs:
 - RSD forecasters had only 00 UTC RDPS output for nowcasts, so this comparison made to see if forecasters were able to 'add value' to guidance
 - Comparisons to 12 UTC RDPS output made to see if updated guidance provides better thunderstorm forecasts

Verification Methodology

- Employed a system that allows categorical probability forecasts of binary events (thunderstorm vs. no thunderstorm)
- A good probability forecast system has:
 - resolution, reliability, sharpness
 - discrimination
 - skill
- To measure these attributes, used:
 - Attributes Diagram
 - Relative Operator Characteristic (ROC) score
 - Brier Skill Score
 - All are described in Wilks (2011)



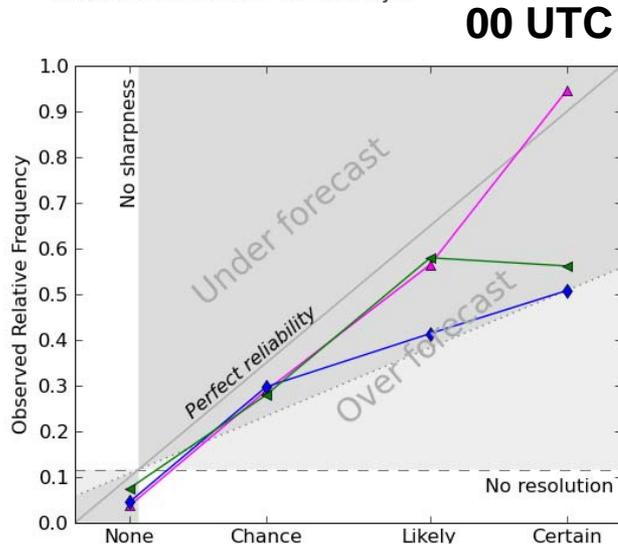
Results

- For larger HAL domain
- Based on both 00 UTC and 12 UTC RDPS output

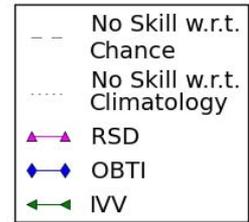
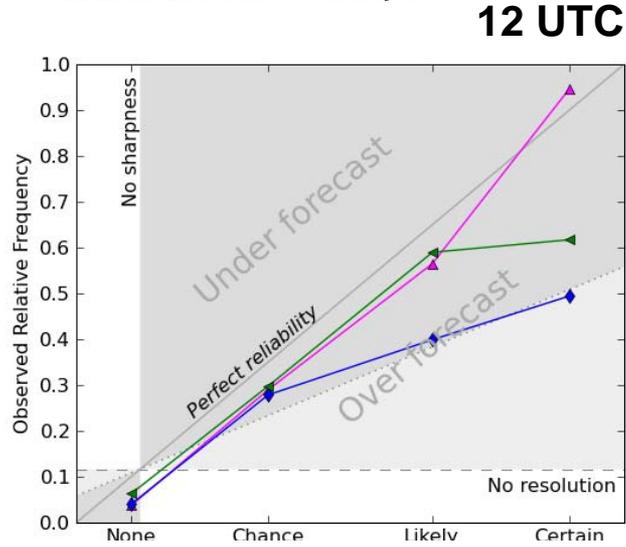


Attributes Diagrams

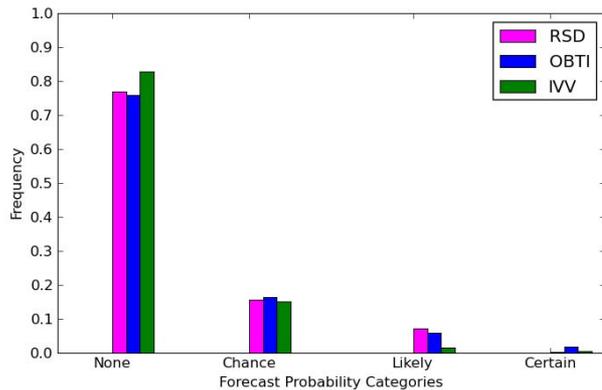
RSD-HAL Attributes Diagram
 Summer 2011 full stats excluding late issue days.
 Model runtime is 00Z. N = 68 days.



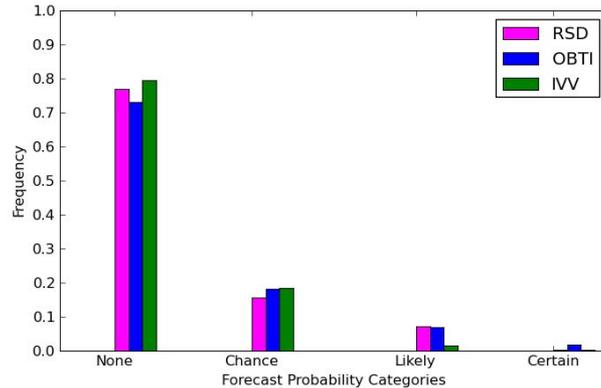
RSD-HAL Attributes Diagram
 Summer 2011 full stats excluding late issue days.
 Model runtime is 12Z. N = 68 days.



RSD-HAL Frequency Graph
 Summer 2011 full stats excluding late issue days.
 Model runtime is 00Z. N = 68 days.



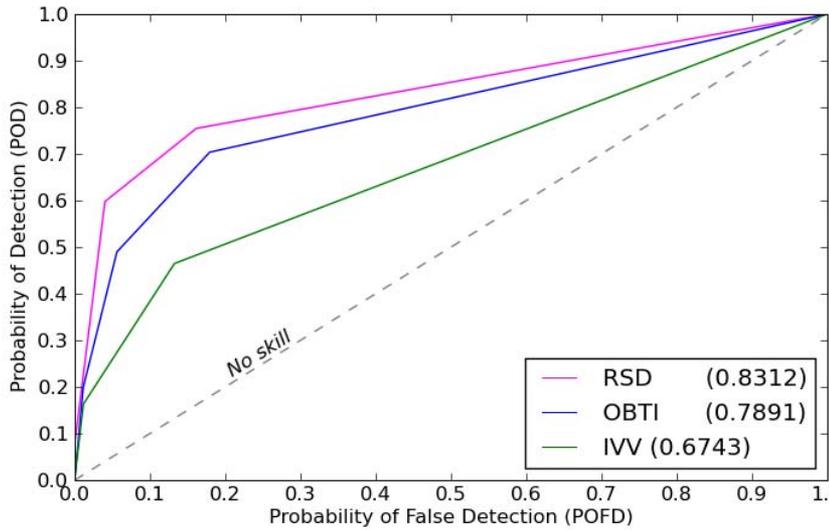
RSD-HAL Frequency Graph
 Summer 2011 full stats excluding late issue days.
 Model runtime is 12Z. N = 68 days.



ROC Diagrams

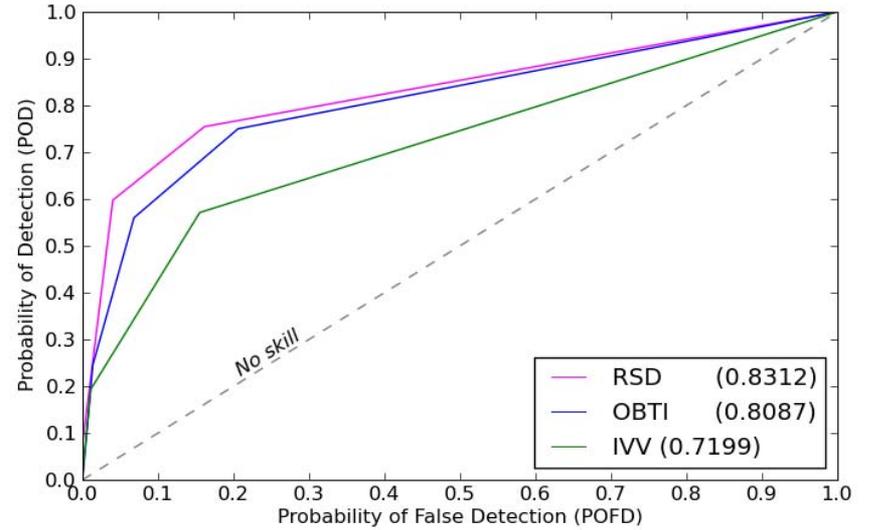
00 UTC

RSD-HAL ROC Curves
Summer 2011 full stats excluding late issue days.
Model runtime is 00Z. N = 68 days.



12 UTC

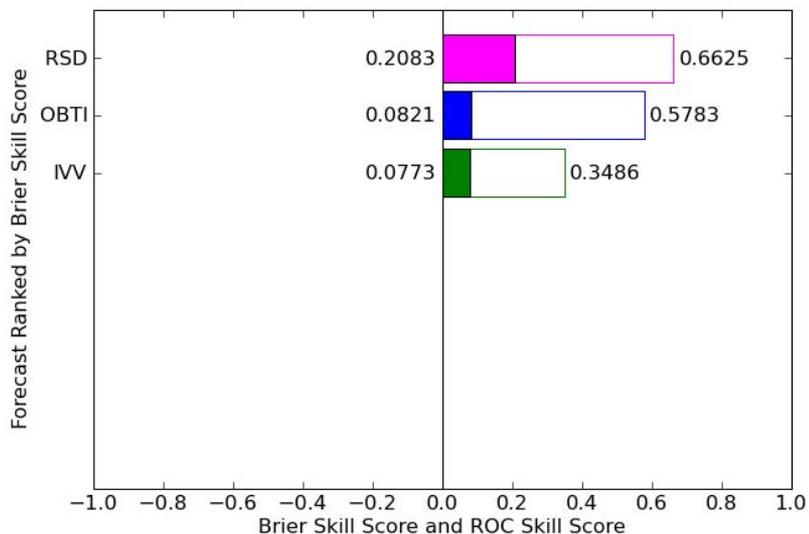
RSD-HAL ROC Curves
Summer 2011 full stats excluding late issue days.
Model runtime is 12Z. N = 68 days.



Brier Skill Score + ROC Score

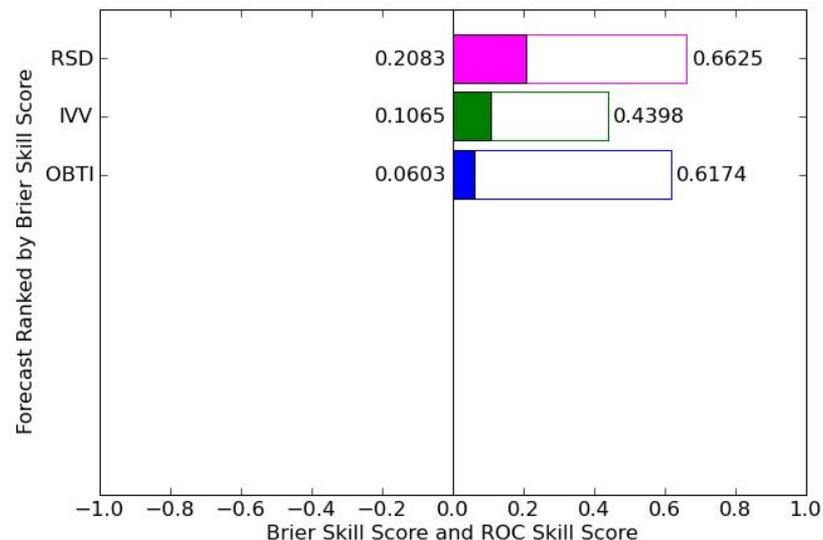
00 UTC

RSD-HAL Brier Skill Score Ranking Graph
Summer 2011 full stats excluding late issue days.
Model runtime is 00Z. N = 68 days.



12 UTC

RSD-HAL Brier Skill Score Ranking Graph
Summer 2011 full stats excluding late issue days.
Model runtime is 12Z. N = 68 days.





HAL Domain by Weather Regime

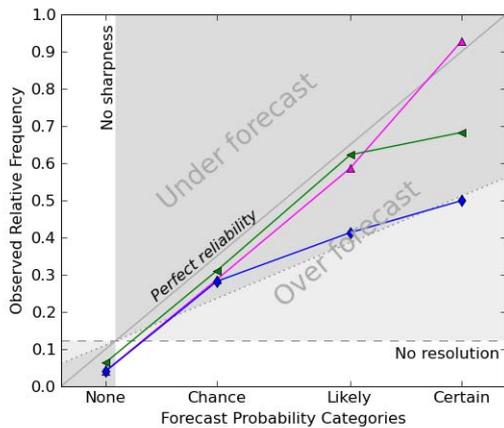
- Classified 68 sample days by regime
 - SSF – synoptic-scale fronts
 - MES – MCS and elevated storms
 - LCL – local forcing (mesoscale)
- Showing only 12 UTC run results



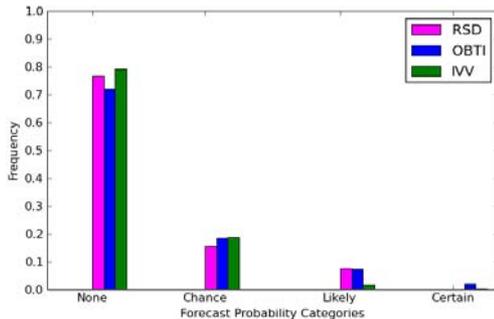
Attributes Diagrams

SSF

RSD-HAL Attributes Diagram
 Summer 2011 SSF stats excluding late issue days.
 Model runtime is 12Z. N = 33 days.

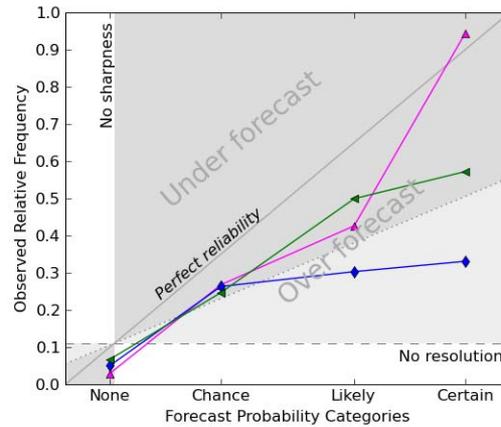


RSD-HAL Frequency Graph
 Summer 2011 SSF stats excluding late issue days.
 Model runtime is 12Z. N = 33 days.

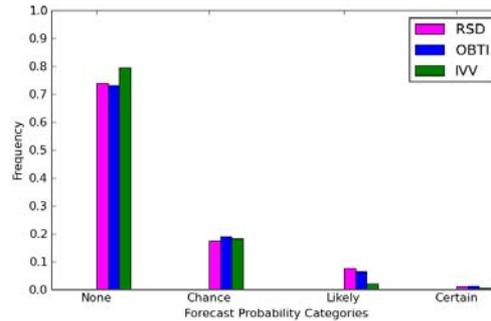


MES

RSD-HAL Attributes Diagram
 Summer 2011 MES stats excluding late issue days.
 Model runtime is 12Z. N = 15 days.

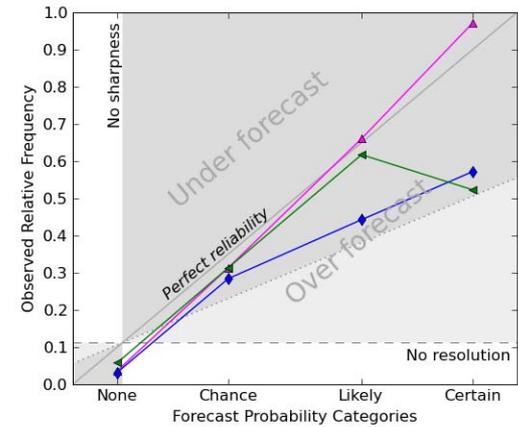


RSD-HAL Frequency Graph
 Summer 2011 MES stats excluding late issue days.
 Model runtime is 12Z. N = 15 days.

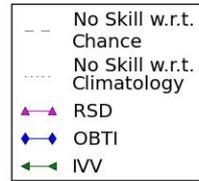
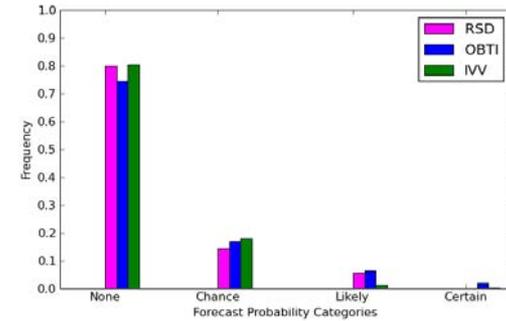


LCL

RSD-HAL Attributes Diagram
 Summer 2011 LCL stats excluding late issue days.
 Model runtime is 12Z. N = 20 days.



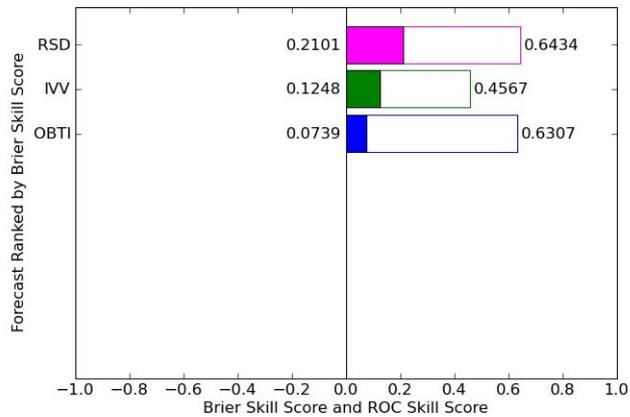
RSD-HAL Frequency Graph
 Summer 2011 LCL stats excluding late issue days.
 Model runtime is 12Z. N = 20 days.



Brier Skill Score + ROC Score

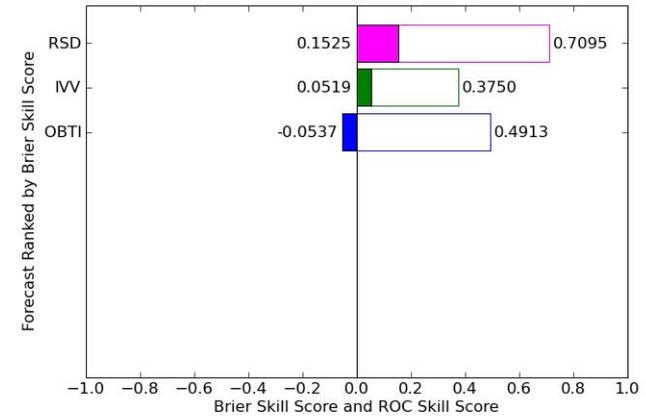
RSD-HAL Brier Skill Score Ranking Graph
Summer 2011 SSF stats excluding late issue days.
Model runtime is 12Z. N = 33 days.

SSF



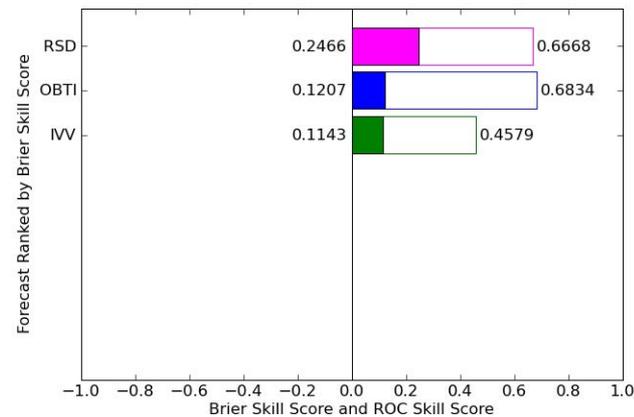
RSD-HAL Brier Skill Score Ranking Graph
Summer 2011 MES stats excluding late issue days.
Model runtime is 12Z. N = 15 days.

MES



RSD-HAL Brier Skill Score Ranking Graph
Summer 2011 LCL stats excluding late issue days.
Model runtime is 12Z. N = 20 days.

LCL

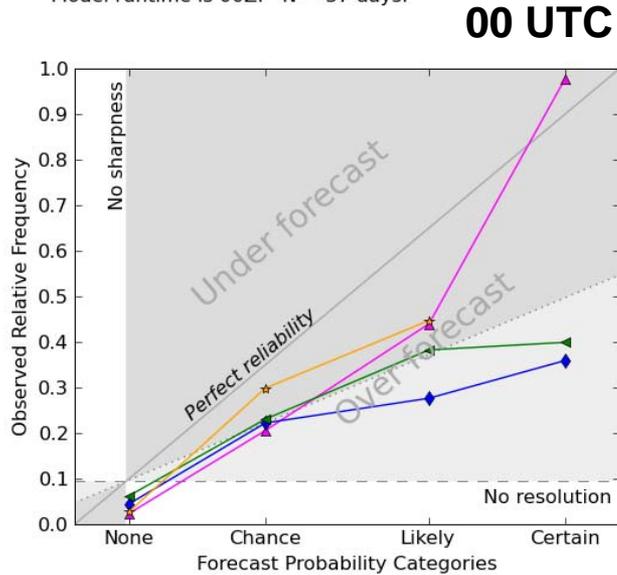


Results

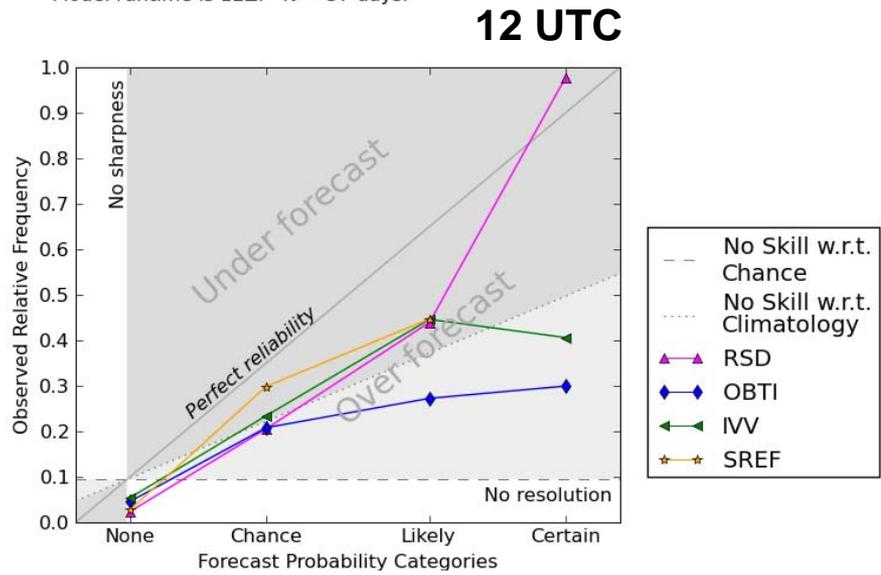
- For smaller SREF domain
- Based on 00 UTC and 12 UTC RDPS output
- Also 03 UTC SREF output

Attributes Diagrams

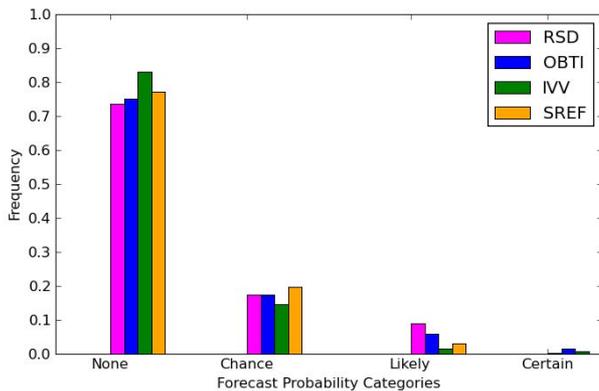
RSD-SREF-HAL Attributes Diagram
 Summer 2011 full stats excluding late issue days.
 Model runtime is 00Z. N = 37 days.



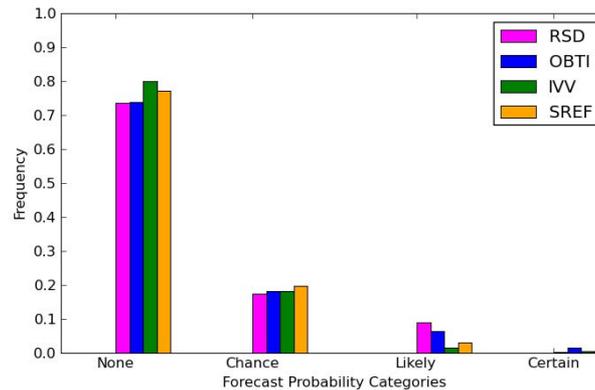
RSD-SREF-HAL Attributes Diagram
 Summer 2011 full stats excluding late issue days.
 Model runtime is 12Z. N = 37 days.



RSD-SREF-HAL Frequency Graph
 Summer 2011 full stats excluding late issue days.
 Model runtime is 00Z. N = 37 days.



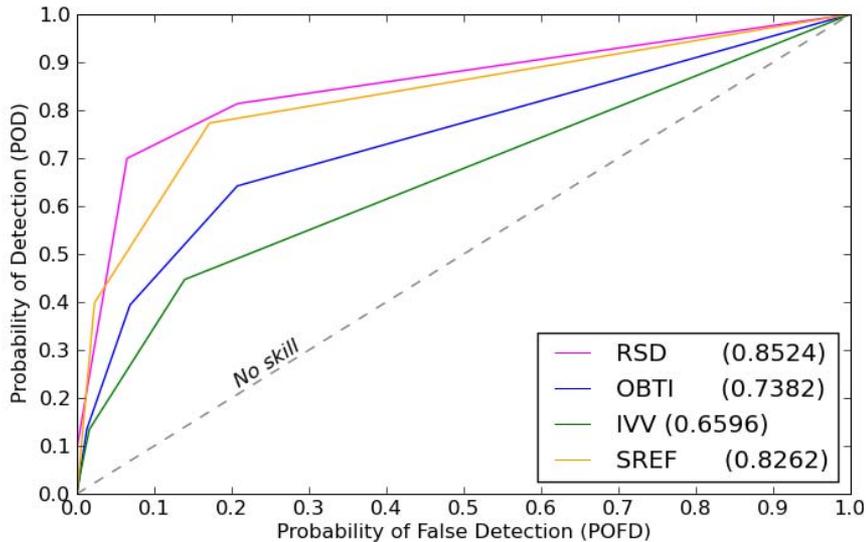
RSD-SREF-HAL Frequency Graph
 Summer 2011 full stats excluding late issue days.
 Model runtime is 12Z. N = 37 days.



ROC Diagrams

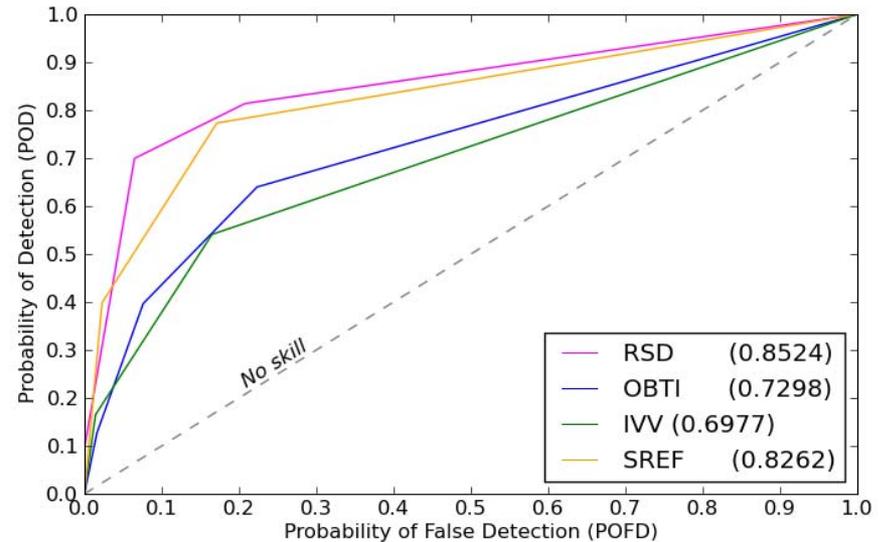
00 UTC

RSD-SREF-HAL ROC Curves
Summer 2011 full stats excluding late issue days.
Model runtime is 00Z. N = 37 days.



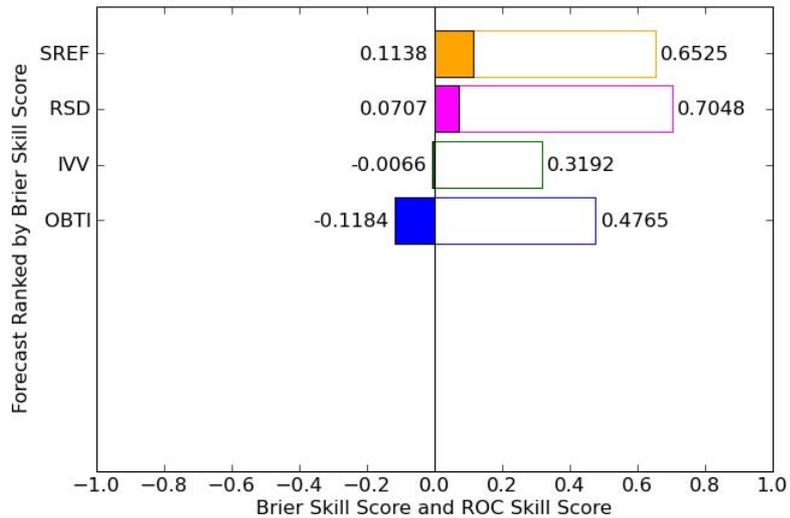
12 UTC

RSD-SREF-HAL ROC Curves
Summer 2011 full stats excluding late issue days.
Model runtime is 12Z. N = 37 days.

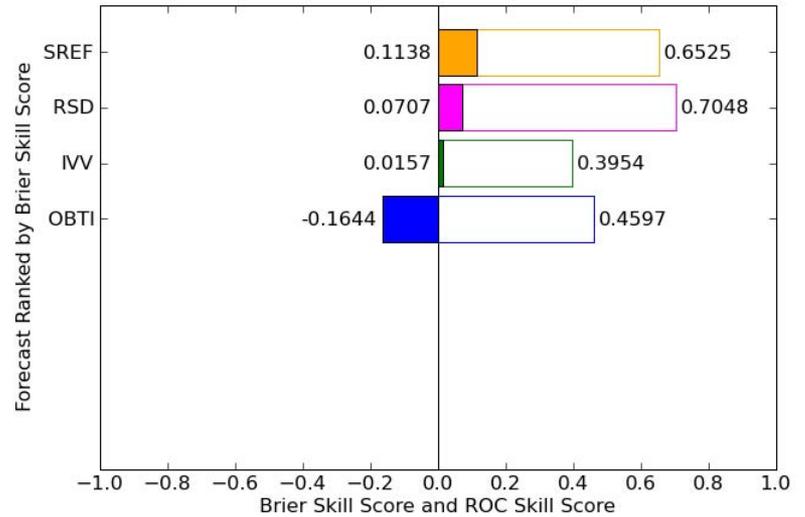


Brier Skill Score + ROC Score

RSD-SREF-HAL Brier Skill Score Ranking Graph
Summer 2011 full stats excluding late issue days.
Model runtime is 00Z. N = 37 days.



RSD-SREF-HAL Brier Skill Score Ranking Graph
Summer 2011 full stats excluding late issue days.
Model runtime is 12Z. N = 37 days.





SREF Domain by Weather Regime

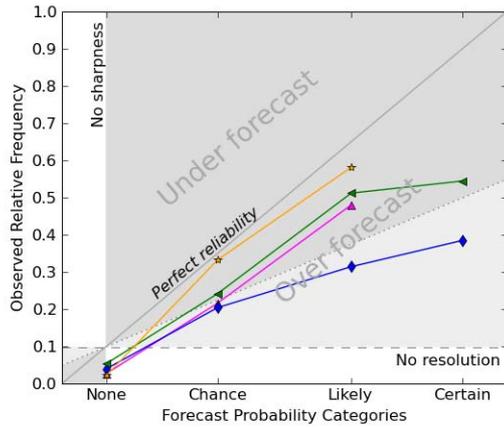
- Classified 37 sample days by regime
 - SSF – synoptic-scale fronts
 - MES – MCS and elevated storms
 - LCL – local forcing (mesoscale)
- Showing only 12 UTC run results



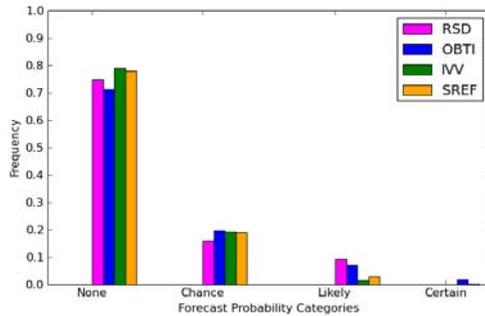
Attributes Diagrams

SSF

RSD-SREF-HAL Attributes Diagram
 Summer 2011 SSF stats excluding late issue days.
 Model runtime is 12Z. N = 20 days.

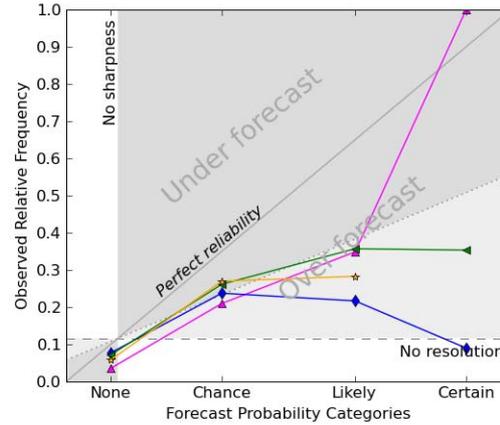


RSD-SREF-HAL Frequency Graph
 Summer 2011 SSF stats excluding late issue days.
 Model runtime is 12Z. N = 20 days.

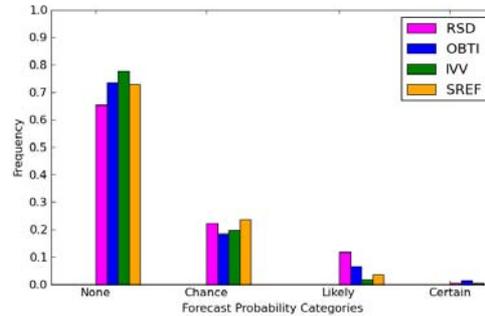


MES

RSD-SREF-HAL Attributes Diagram
 Summer 2011 MES stats excluding late issue days.
 Model runtime is 12Z. N = 9 days.

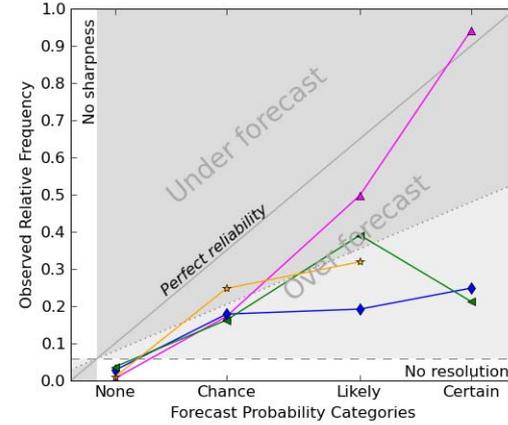


RSD-SREF-HAL Frequency Graph
 Summer 2011 MES stats excluding late issue days.
 Model runtime is 12Z. N = 9 days.

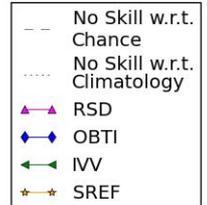
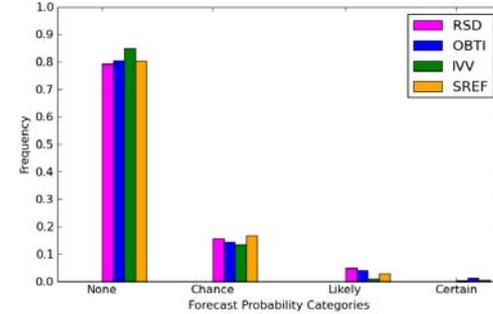


LCL

RSD-SREF-HAL Attributes Diagram
 Summer 2011 LCL stats excluding late issue days.
 Model runtime is 12Z. N = 8 days.



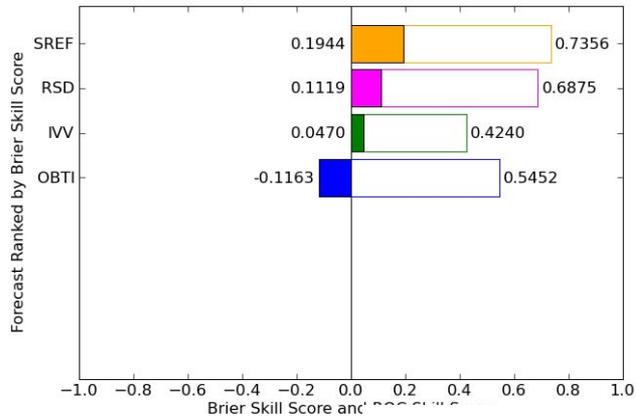
RSD-SREF-HAL Frequency Graph
 Summer 2011 LCL stats excluding late issue days.
 Model runtime is 12Z. N = 8 days.



Brier Skill Score + ROC Score

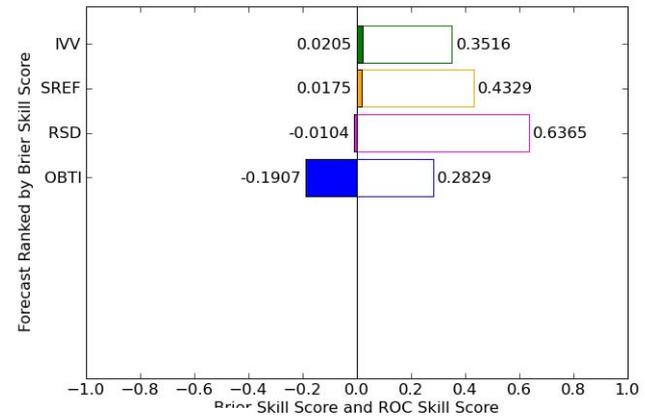
RSD-SREF-HAL Brier Skill Score Ranking Graph
Summer 2011 SSF stats excluding late issue days.
Model runtime is 12Z. N = 20 days.

SSF



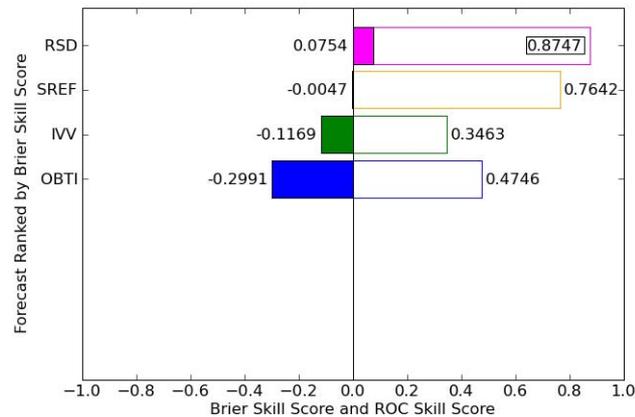
RSD-SREF-HAL Brier Skill Score Ranking Graph
Summer 2011 MES stats excluding late issue days.
Model runtime is 12Z. N = 9 days.

MES



RSD-SREF-HAL Brier Skill Score Ranking Graph
Summer 2011 LCL stats excluding late issue days.
Model runtime is 12Z. N = 8 days.

LCL





RSD Day 2 Forecasts

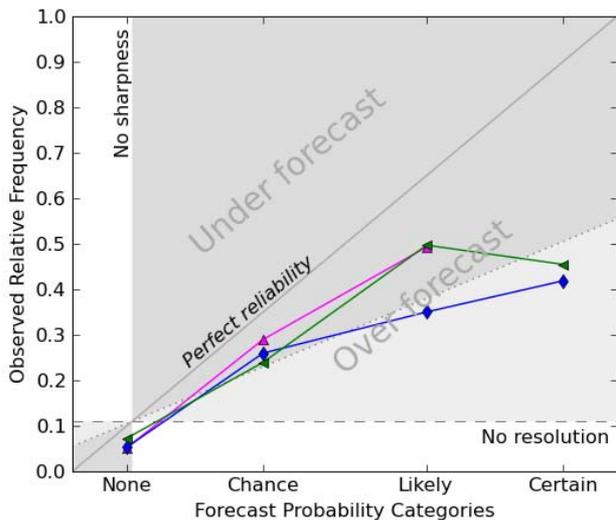
- **72 days** with valid RSD Day 2 forecasts between May 29 and Sep 26, 2011
- Used same verification methods to see if value can be added by forecaster using iCAST even into Day 2
- HAL domain
- 00 UTC and 12 UTC RDPS



Attributes Diagrams

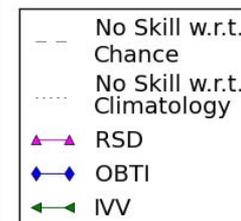
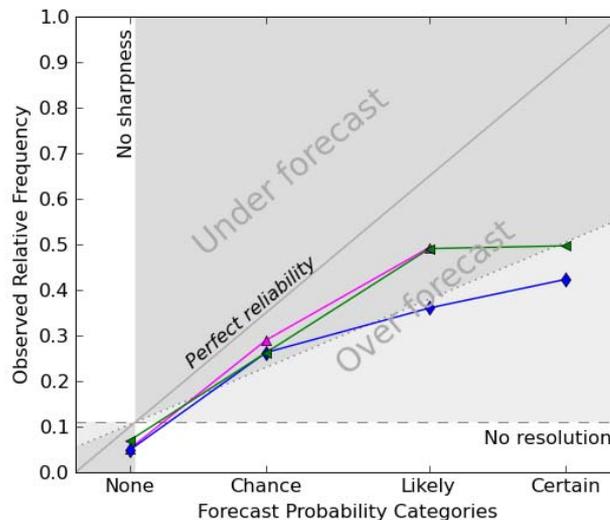
RSD-HAL Attributes Diagram
 Summer 2011 full stats.
 Model runtime is 00Z. N = 72 days.

00 UTC

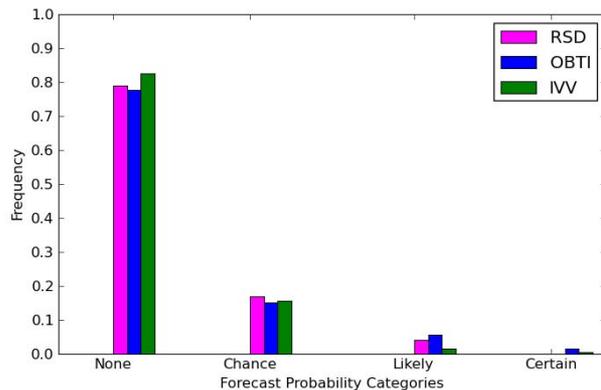


RSD-HAL Attributes Diagram
 Summer 2011 full stats.
 Model runtime is 12Z. N = 72 days.

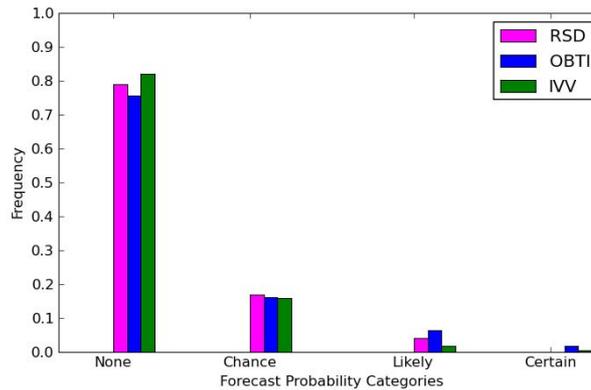
12 UTC



RSD-HAL Frequency Graph
 Summer 2011 full stats.
 Model runtime is 00Z. N = 72 days.



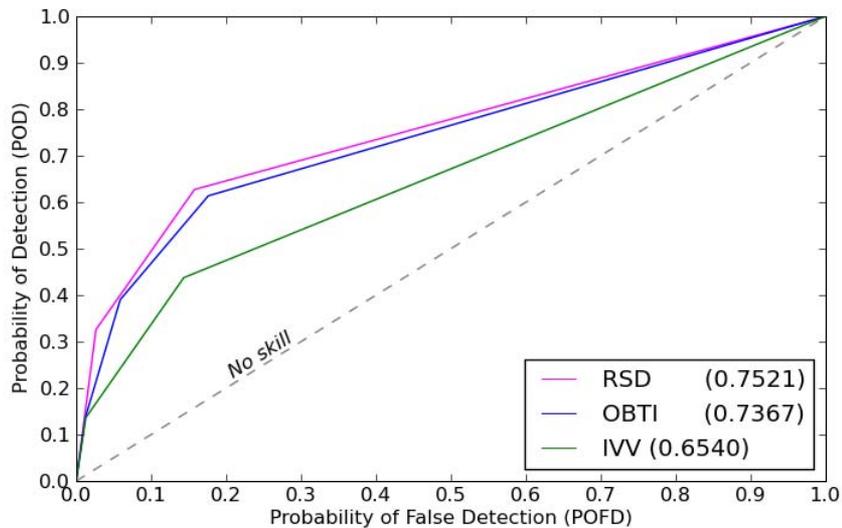
RSD-HAL Frequency Graph
 Summer 2011 full stats.
 Model runtime is 12Z. N = 72 days.



ROC Diagrams

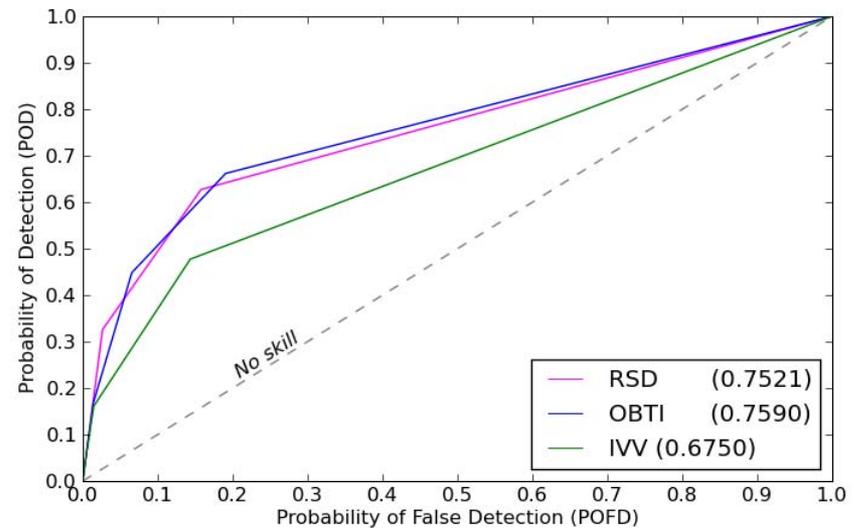
00 UTC

RSD-HAL ROC Curves
Summer 2011 full stats.
Model runtime is 00Z. N = 72 days.



12 UTC

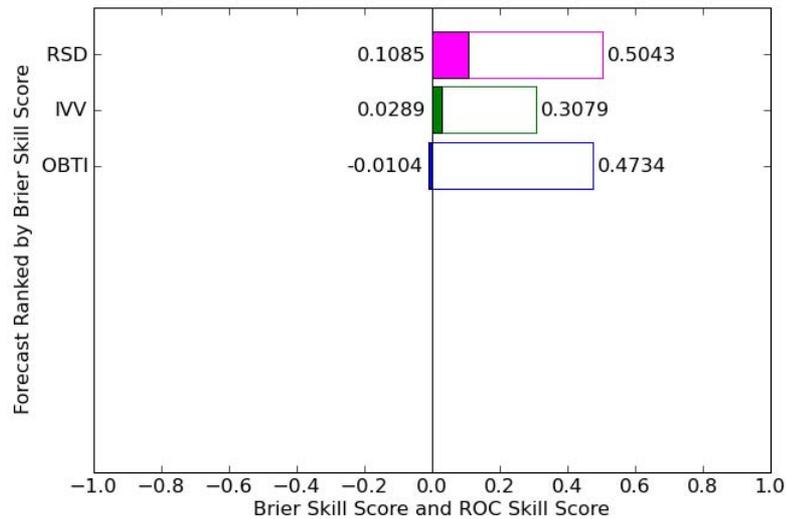
RSD-HAL ROC Curves
Summer 2011 full stats.
Model runtime is 12Z. N = 72 days.



Brier Skill Score + ROC Score

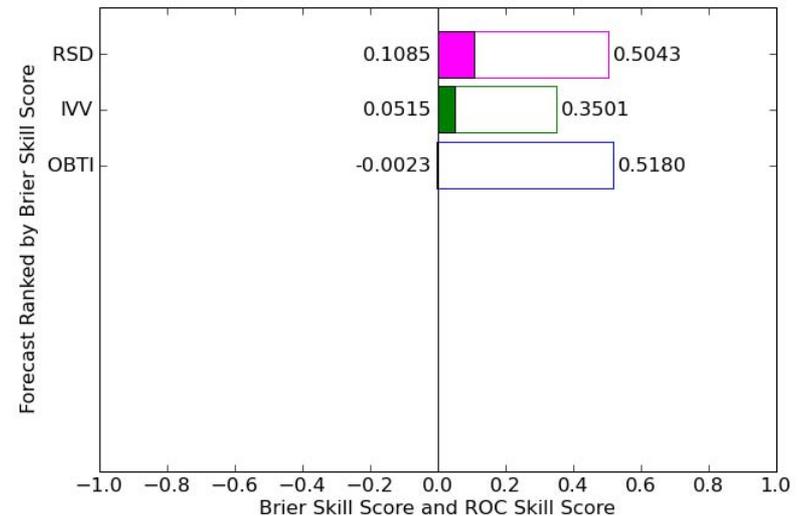
00 UTC

RSD-HAL Brier Skill Score Ranking Graph
Summer 2011 full stats.
Model runtime is 00Z. N = 72 days.



12 UTC

RSD-HAL Brier Skill Score Ranking Graph
Summer 2011 full stats.
Model runtime is 12Z. N = 72 days.



- Day 1 RSD BSS = 0.21, Day 2 RSD BSS = 0.11
- So still significant skill in Day 2 though about half as much as in Day 1



Results Summary

- RSD nowcasts appear to have:
 - significantly more skill than forecasts of climatology, even for Day 2
 - significantly more skill than RDPS-derived OBTI and IVV forecasts, even for Day 2
 - better discrimination than OBTI and IVV
 - better reliability than OBTI but less sharpness
 - better sharpness and discrimination than SREF, though slightly less skill
 - best results with local forcing i.e. mesoscale influences incorporated





Discussion

- Some evidence that the latest 12 UTC RDPS output is often not the best guidance for convective forecasts
 - occasionally even the Day 2 output is better
 - needs further study to understand why
- Benefit of using calibrated, ensemble output is clear
 - Still may be possible for forecasters to add value
 - Need to incorporate REPS data in future evaluations
- Need to calculate confidence intervals using ‘bootstrap’ method
- Need to find ways to compare operational Scribe and Burrows thunderstorm forecasting methods to iCAST





Summary

- The area-based, met-object approach is shown to produce skillful results for thunderstorm nowcasts, and even Day 2 forecasts
- Significant value is added to NWP guidance through the use of the iCAST prototype, especially when mesoscale features can be incorporated
- Calibrated, ensemble guidance is a valuable tool for convective forecasting
- Graphical 4-category probabilistic representations for thunderstorm forecasts present a viable approach for automated convective products



Acknowledgments

- Arnold Ashton, Robert Kuhn
- Emma Hung, Brian Greaves
- Neil Taylor
- Laurie Wilson, Martin Charron





References

- Bright, D. R., M. S. Wandishin, R. E. Jewell, and S. J. Weiss, 2005: A physically based parameter for lightning prediction and its calibration in ensemble forecasts. *Preprints, Conf. on Meteorological Applications of Lightning Data*, San Diego, CA, Amer. Meteorol. Soc., CD-ROM 4.3.
- Wilks, D. S., 1995: *Statistical Methods in the Atmospheric Sciences*. Academic Press, San Diego, CA, 467 pp.





Sensitivity Testing

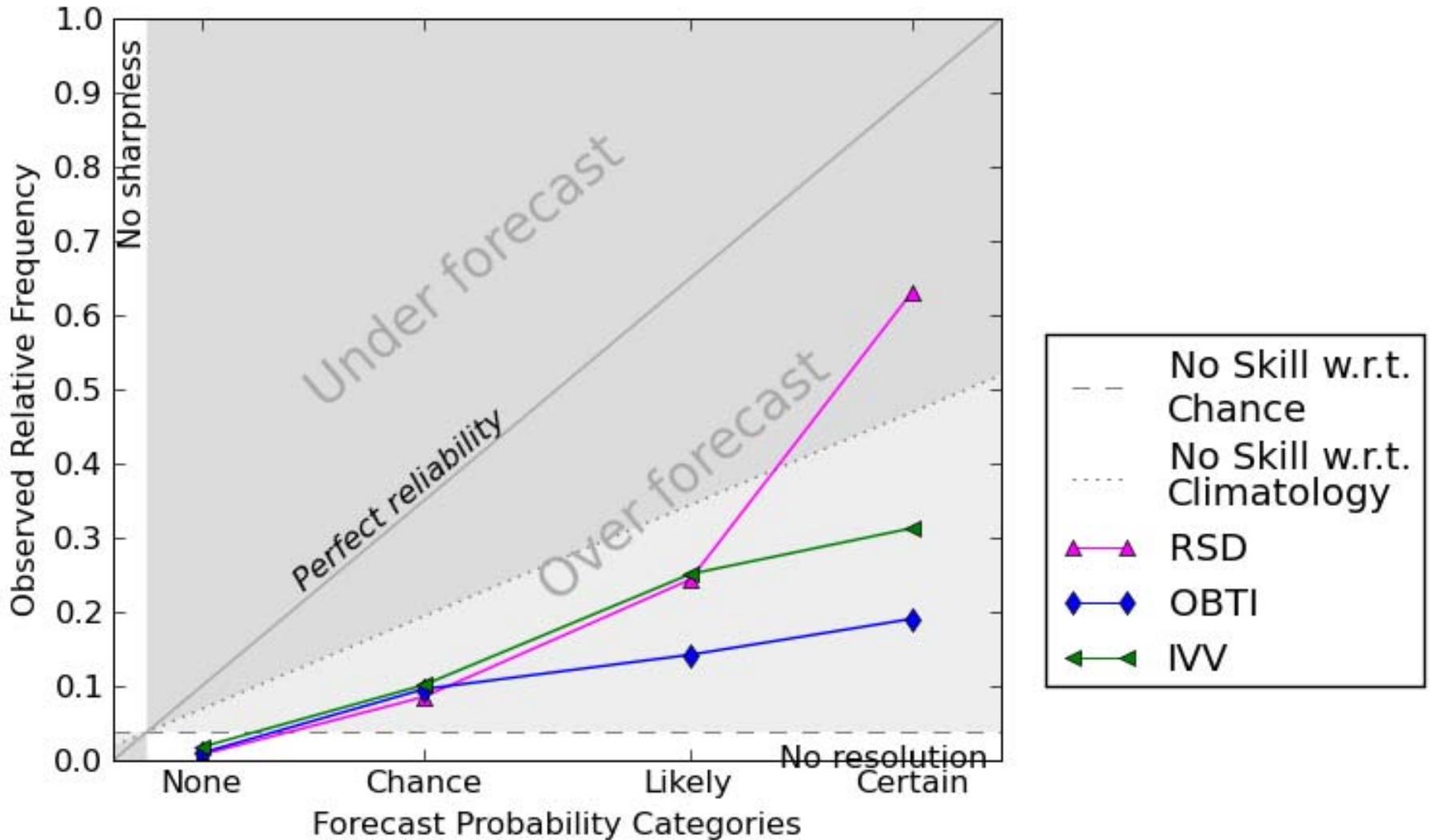
- Test effect of grid size
 - 15 km, 45 km, 75 km, 105 km boxes
- Test effect of lightning verification period
 - 18-21 UTC vs 17-22 UTC



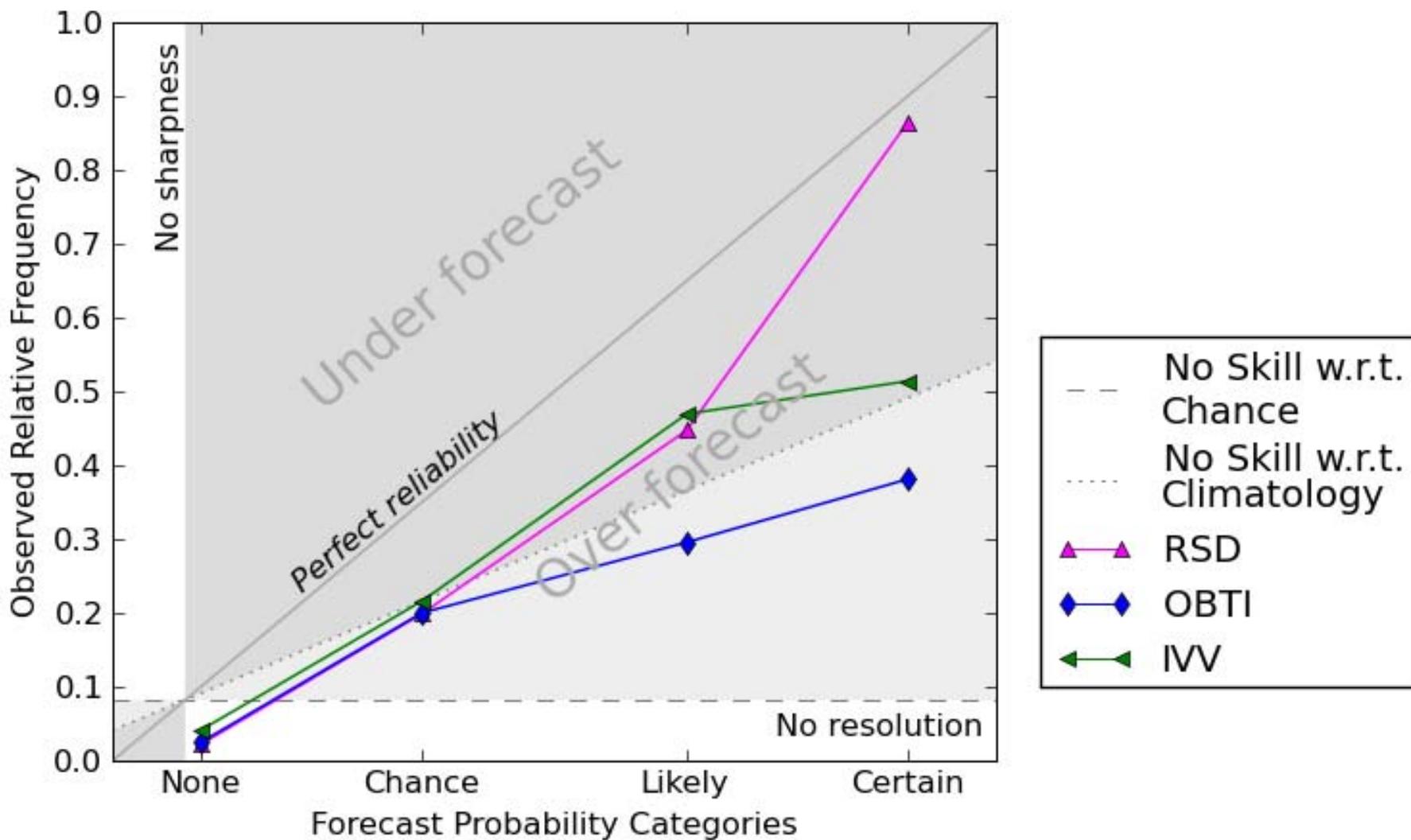
Effects of Grid Size

- Results shown are for 12 UTC RDPS runs over the 68 sample days during summer 2011

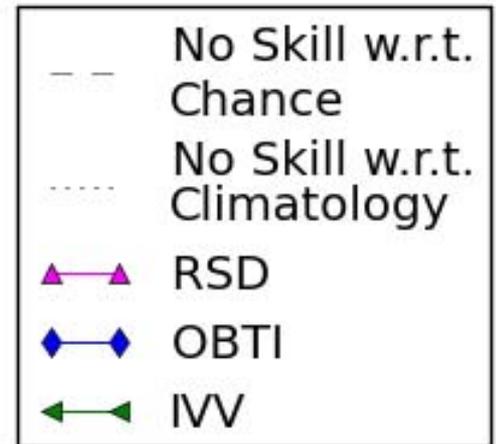
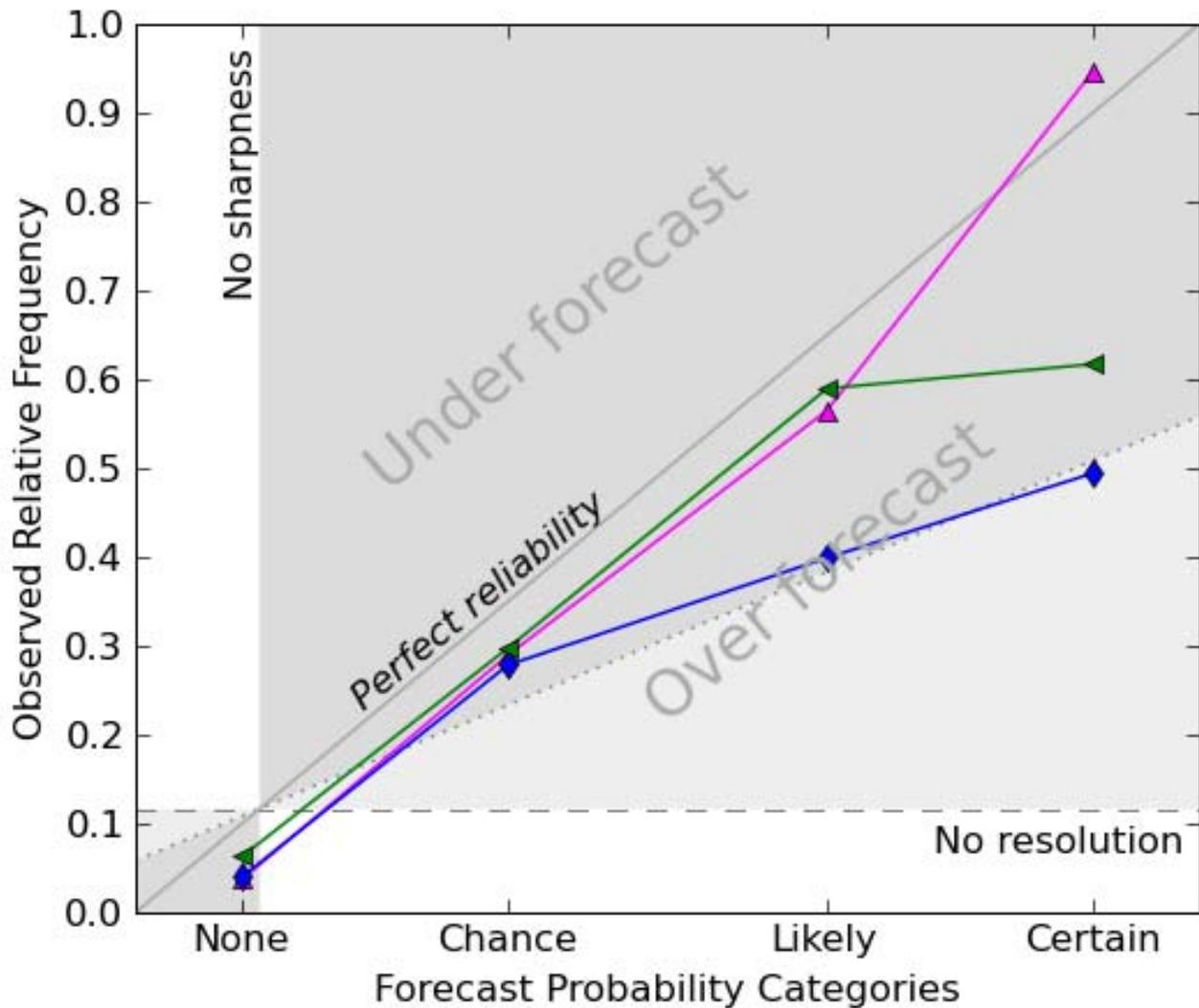
15 km x 15 km



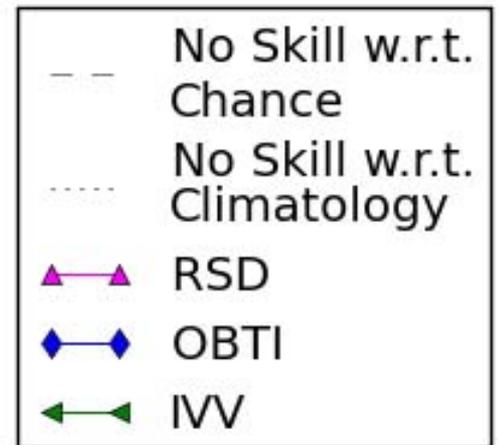
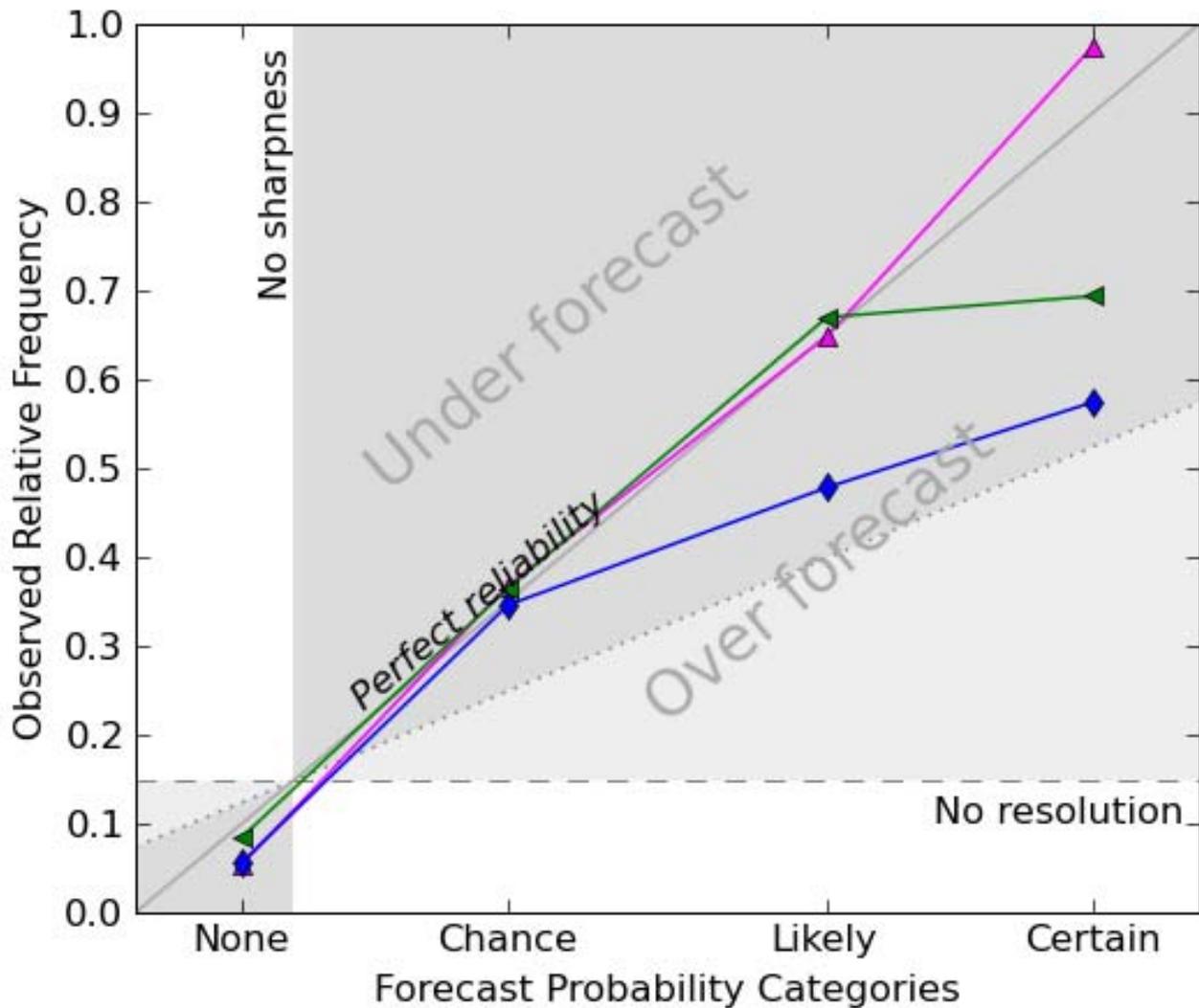
45 km x 45 km



75 km x 75 km (default)



105 km x 105 km



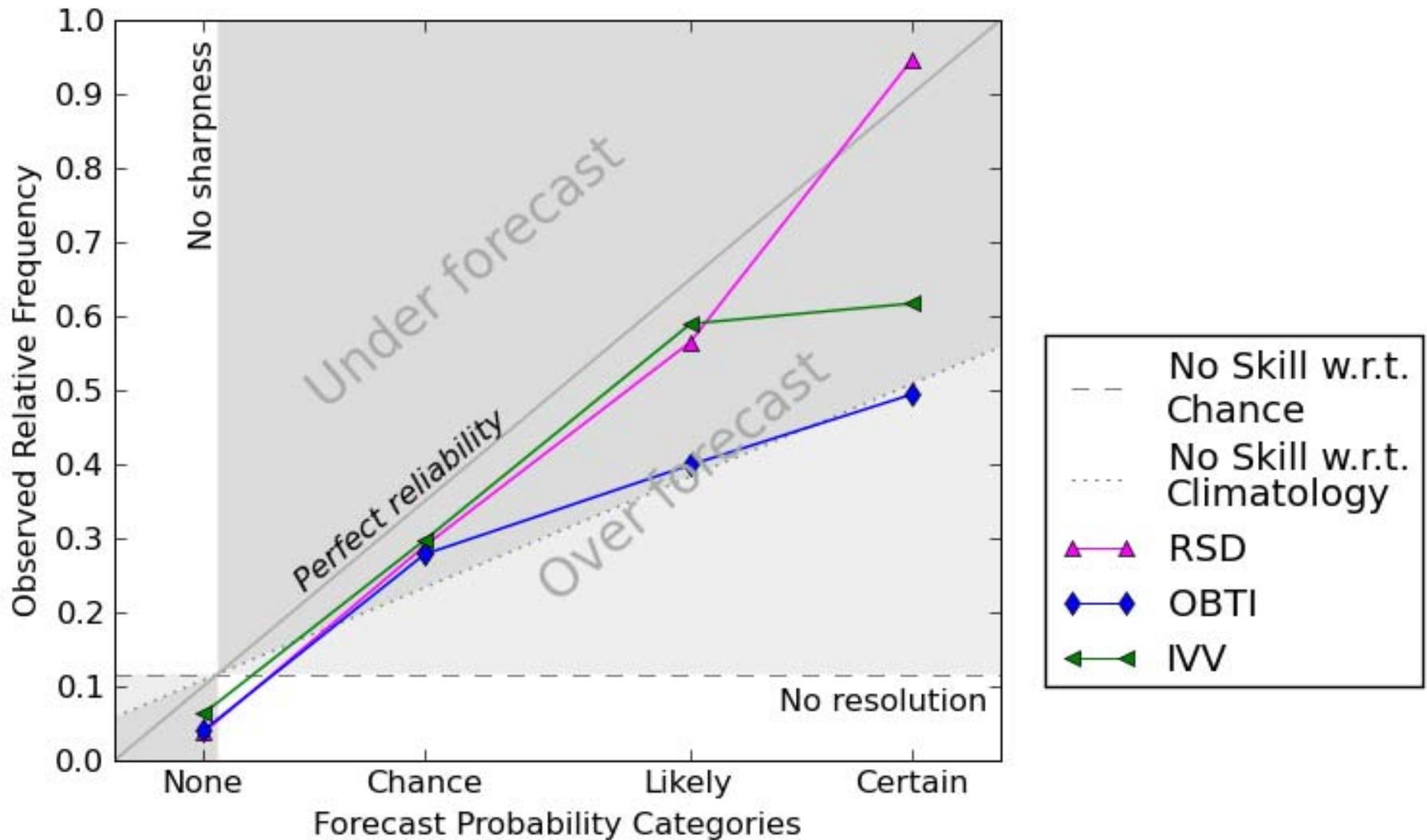


Effect of Lightning Verification Period

- Results shown are for 12 UTC RDPS runs over the 68 sample days during summer 2011



17-22 UTC Lightning (default)



18-21 UTC Lightning

