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Canada

On the Verification of Thunderstorm MetObjects During the 2015 Toronto Games

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WMO WWRP 4th International Symposium on Nowcasting and Very-short-range Forecasting (WSN16) , Hong Kong, China, 25-29 July 2016

Toronto 2015 Pan Am Games

- Large sporting event with over 6000 athletes from 41 Pan American countries.
- Main weather concern for organizers was lightning occurrence in outdoor events.
- Environment Canada provided site specific operational weather alerts.
- Experimental thunderstorm nowcasts were generated at a ‘Research Support Desk’ (RSD) operated by four science staff.

1. The Verification Experiment
2. Relaxation: Classical Scores
3. NWP-based MetObjects
4. MetObject-based Verification

The Verification Experiment

Goals:

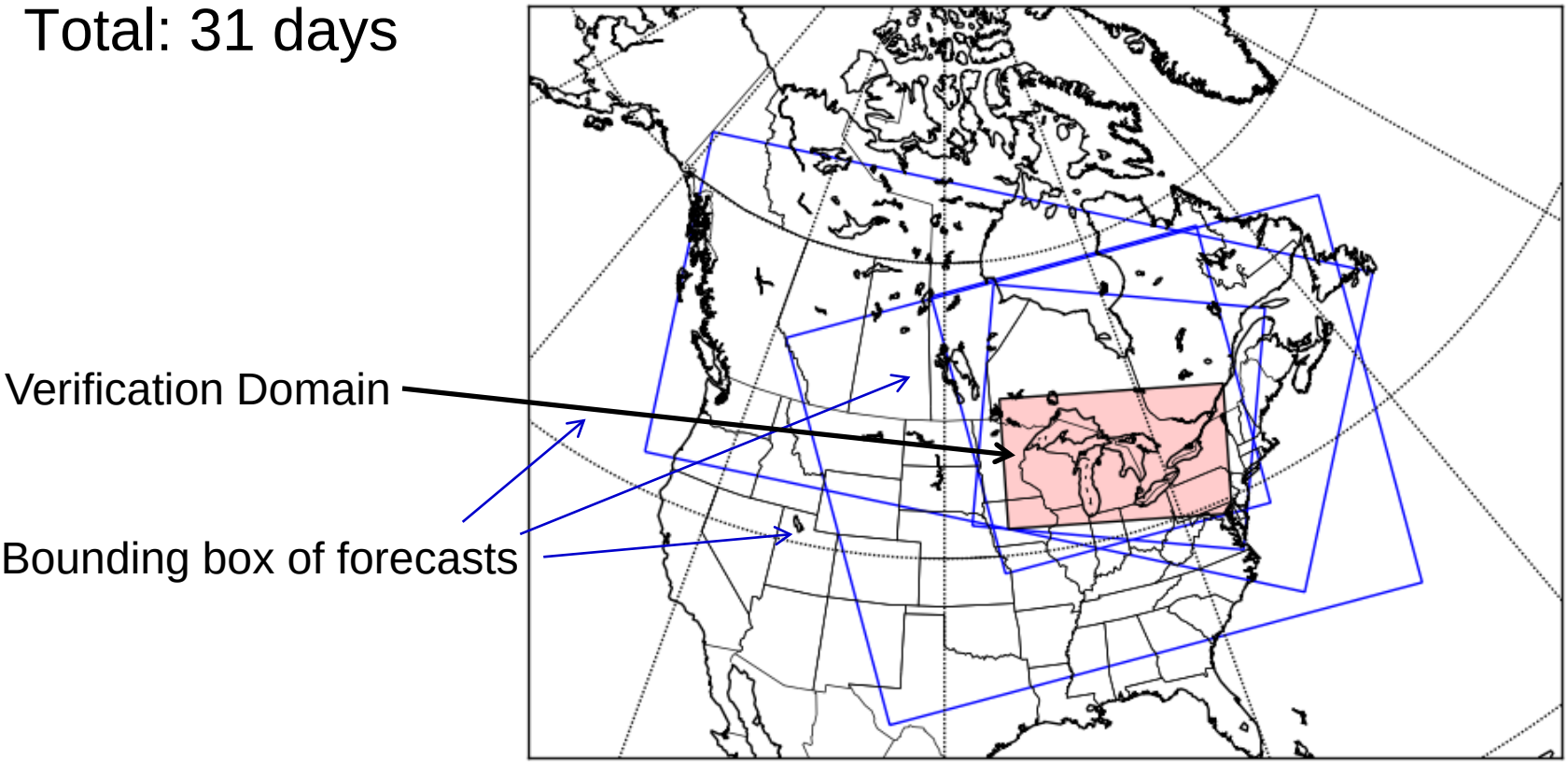
1) Intercomparison of different NWP-based thunderstorm nowcasts/forecasts and of a human-generated nowcast/forecast
2) Development of verification methodology to improve such intercomparison

Previous work:

Sills, D., N. Driedger and W. Burrows, 2012: Verification of forecaster-generated iCAST thunderstorm nowcasts and comparison to automated thunderstorm forecasts: preliminary results. *Extended Abstracts, 3rd World Weather Research Programme Symposium on Nowcasting and Very Short Range Forecasting,* Rio de Janeiro, Brazil, Paper 11.4.

Verification Domain

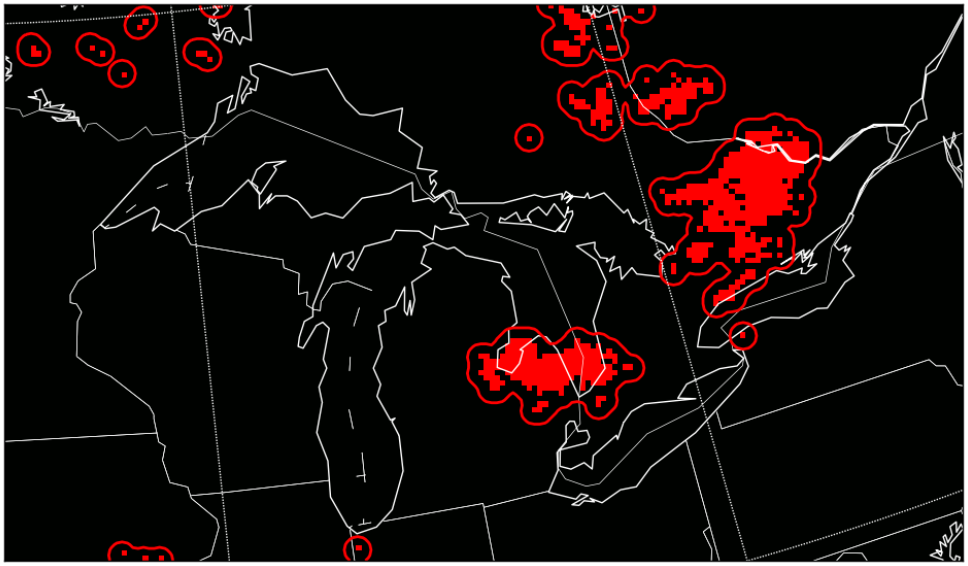
- Pan Am: July 9th-26th - ParaPan Am: August 8th-15th
- Plus few extra days in July-August 2015
- Total: 31 days



Observations

- CLDN: Canadian Lightning Detection Network (Vaisala + ECCC)
- Thunderstorm occurrence: “If you can hear the thunder…”

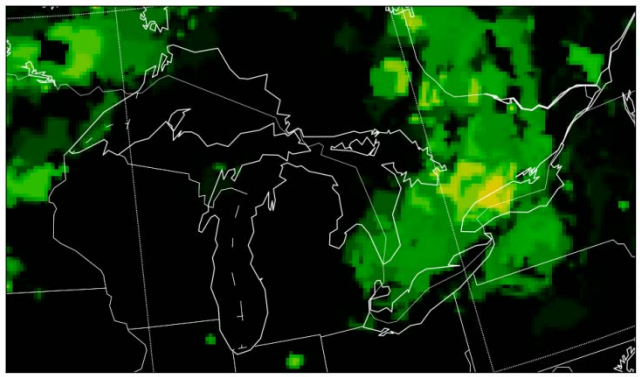
July 25, 2015, 18-21Z (2-5 pm)



- For verification purposes, we define thunderstorm occurrence as within 25km radius from lightning flashes

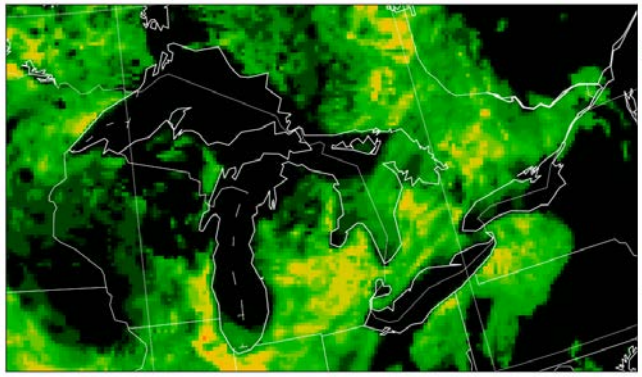
NWP-based Thunderstorm Forecasts

All forecasts are valid for July 25, 2015, 18-21Z. Runtime: 12Z. Issue time: 15Z.



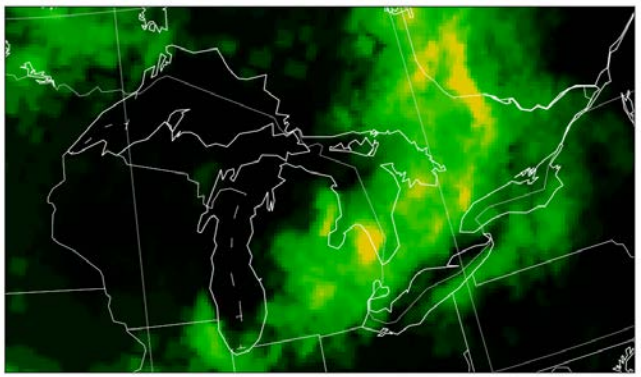
RDPS-Stat

Statistical post-processing of regional deterministic forecast (RDPS).
Source: Bill Burrows (ECCC-Edmonton)



RDPS-Sci

Calibrated post-processing of regional deterministic forecast (RDPS) based on latest thunderstorm initiation science.
Source: Neil Taylor (ECCC-Edmonton)

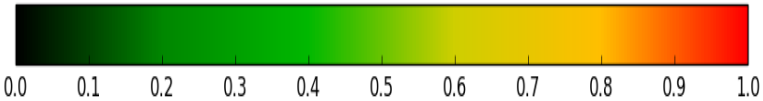


REPS-TI

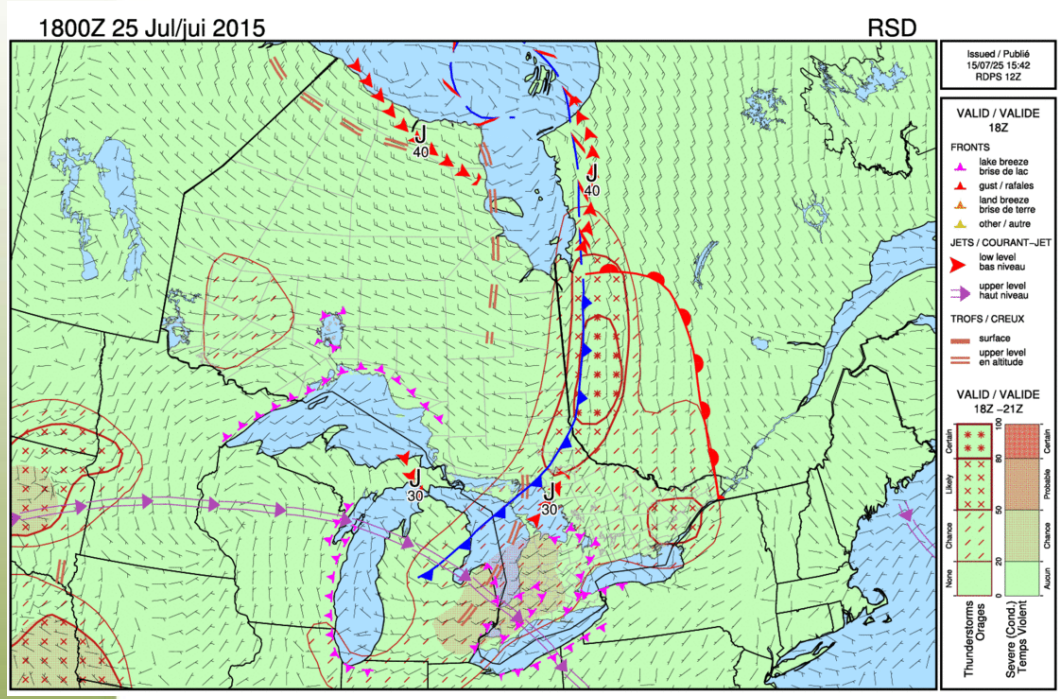
Calibrated regional ensemble thunderstorm forecast.
Source: Ron Frénette (ECCC-Montréal)

Taylor, N. M., W. R. Burrows and D. M. L. Sills, 2014: Post-processing of Canadian regional-scale NWP to develop first-guess forecasts of thunderstorm and severe weather threat areas. *Extended Abstracts, 27th AMS Conference on Severe Local Storms,* Madison, WI, Amer. Meteorol. Soc., Paper 7.

Thunderstorm probability:



Forecaster Generated MetObjects

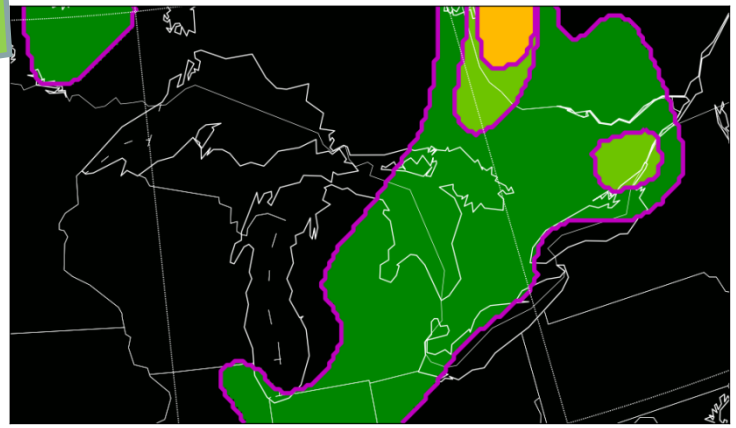


- RSD: human forecasters use prototype software for generation of MetObjects nowcasts
- MetObjects were based on combination of NWP nowcasts, observations including climatology, and conceptual models.

Sills, D. M. L., and N. M. Taylor, 2008: The Research Support Desk (RSD) initiative at Environment Canada: Linking severe weather researchers and forecasters in a real-time operational setting. *Preprints, 24th AMS Conference on Severe Local Storms,* Savannah, GA, Amer. Meteorol. Soc., Paper 9A.1

- MetObjects: Vector representation (points, lines, areas) of meteorological concepts with attributes
- Thunderstorm MetObjects: areas with severity (severe/non-severe) and probability attributes (chance/likely/certain).

MO-RSD:TS prob for non-severe
Issued at 15Z, valid 18-21Z



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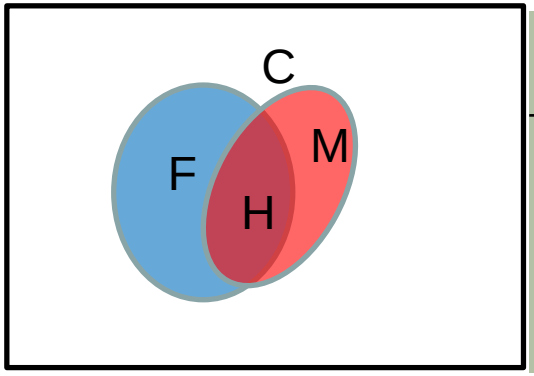
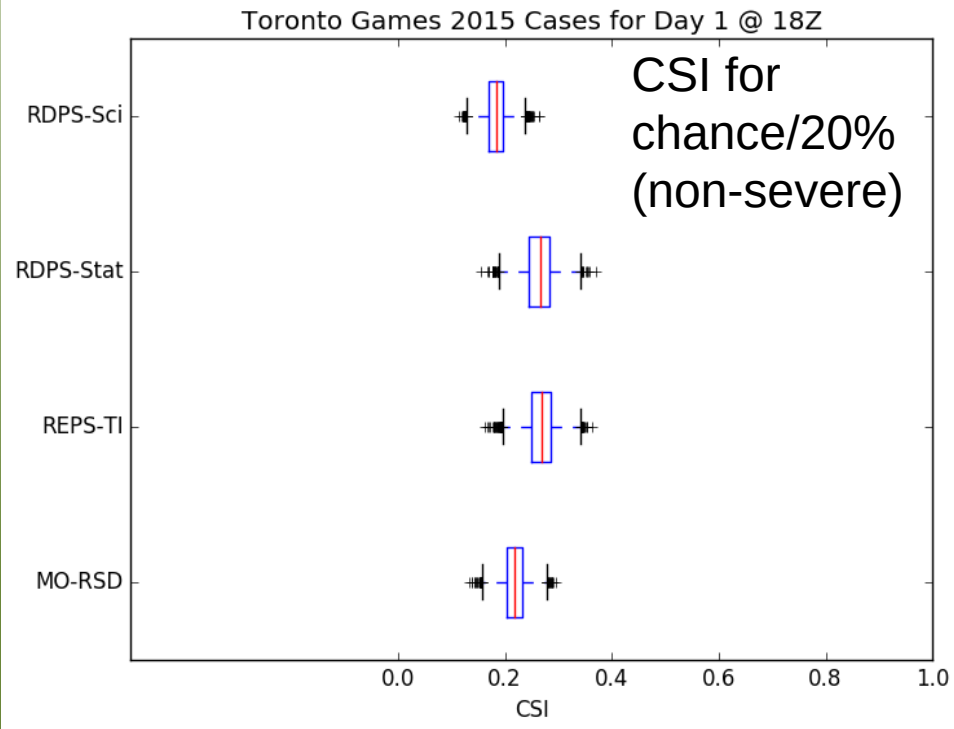
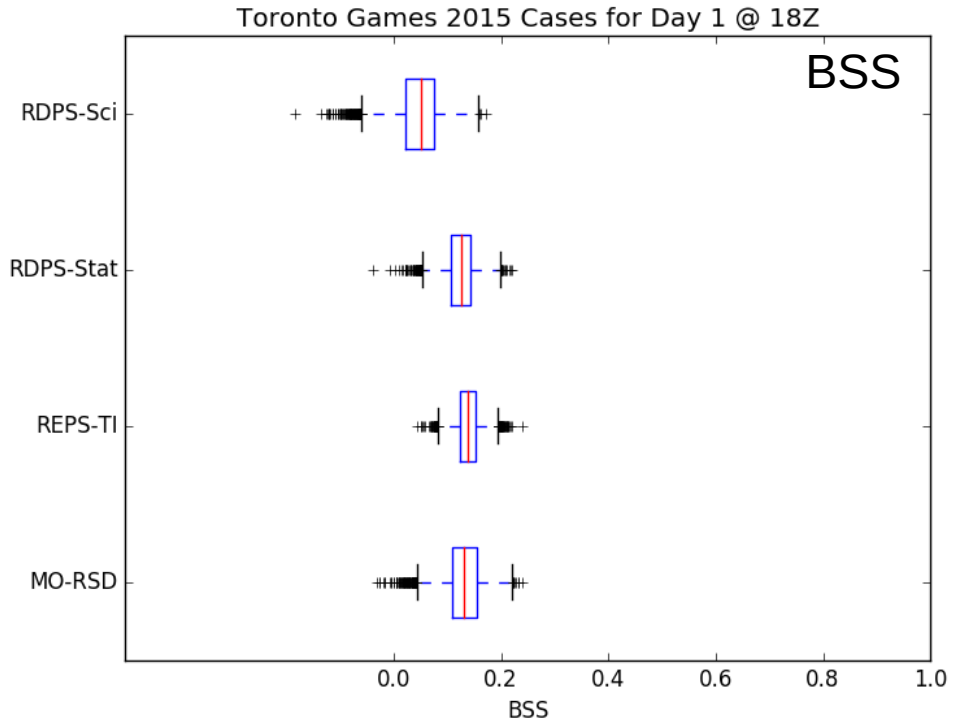
Classical Verification

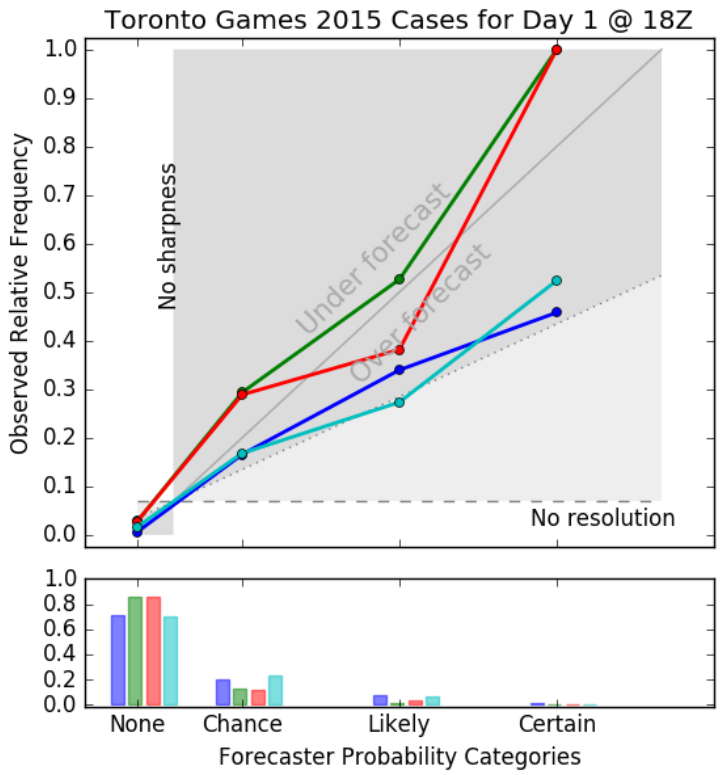


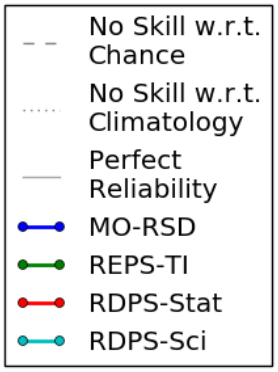
Contingency table	Observed	Not observed
Forecasted	H = #hits	F= #false alarms
Not forecasted	M = #misses	C = #correct negatives



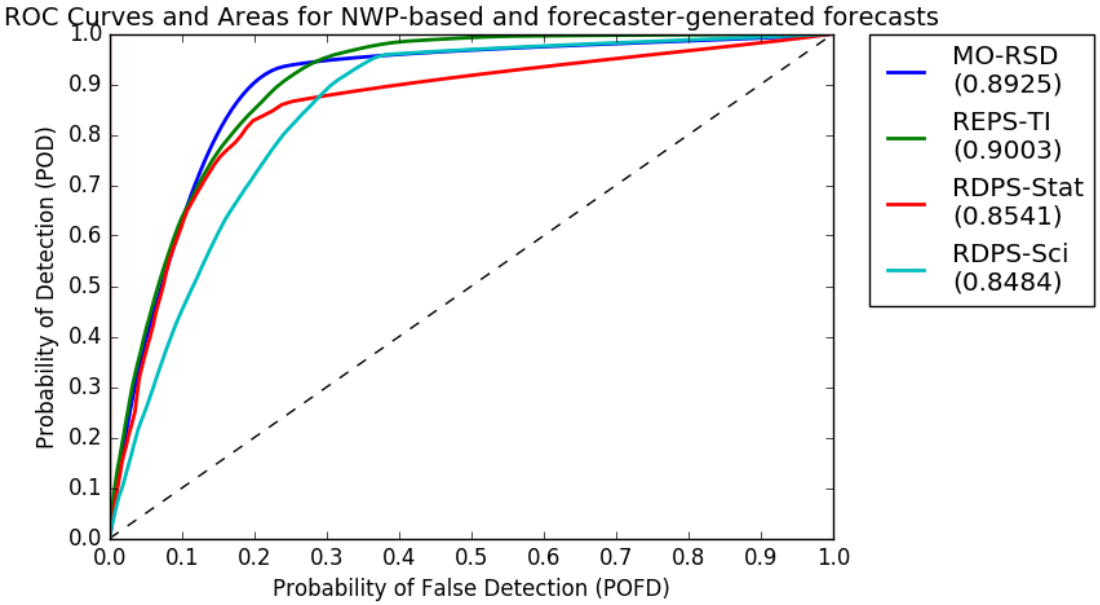


Reliability Plot and ROC Curve



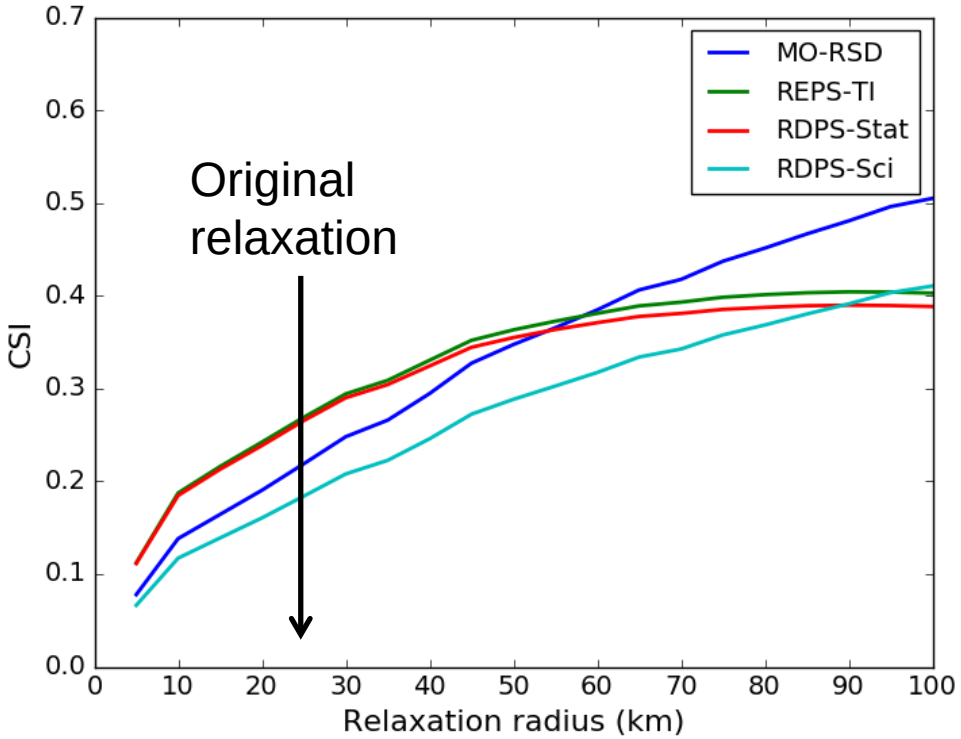


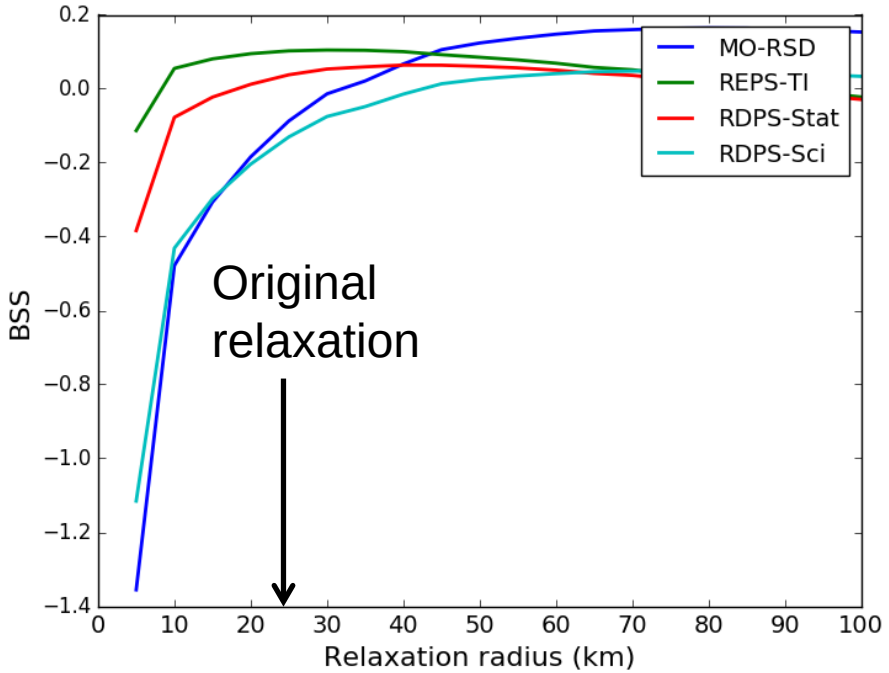
- MO-RSD and RDPS-Sci are over-forecasting
- MO-RSD and REPS-TI have best ROC scores



4-categories:
- None (0-20%)
- Chance (20-50%)
- Likely (50-80%)
- Certain (80-100%)

Sensitivity to Relaxation Parameter





Problem: Forecasts are sensitive to the relaxation parameter.
Solution: Bring all forecasts to the same scale (as MetObjects) so that they are robust to the choice of relaxation parameter

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NWP-based MetObjects

Goal: Find optimal smoothing and thresholds to transform NWP into MetObjects.

We use MO-RSD (human-generated) as the reference, so that all data have the same level of smoothness.

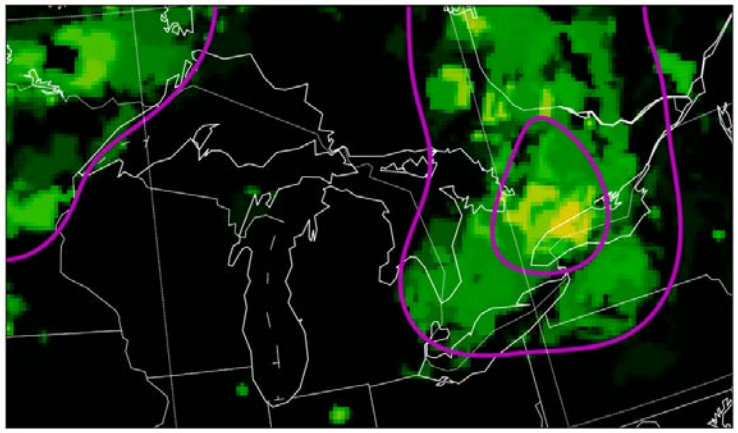
Decomposition of Brier's score into calibration and refinement term:

$$\underbrace{\frac{1}{K}\sum_{k}(f_k - o_k)^2}_{\text{Brier's score}} = \underbrace{\sum_{i} w_i(y_i - p_i)^2}_{\text{Calibration (squared bias)}} + \underbrace{\sum_{i} w_i p_i(1 - p_i)}_{\text{Refinement (variance)}}$$

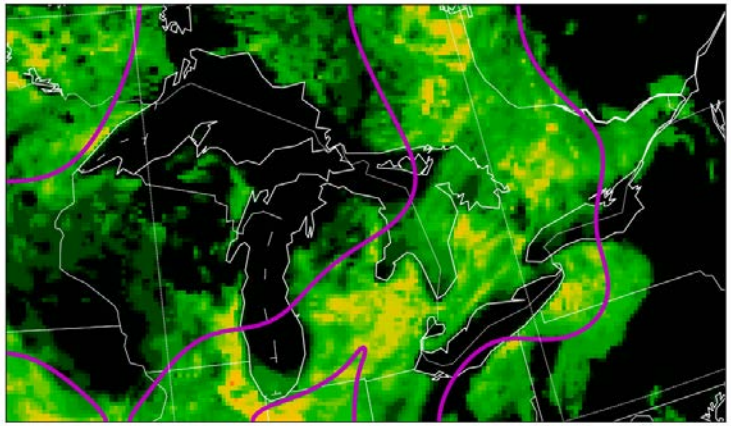
f_k: probabilistic forecast
o_k: binary "observation"
w_i: relative forecast frequency
y_i: value of binned probabilistic forecast
p_i: relative observational frequency given forecast value y_i

1) Find optimal smoothing for Chance category: minimize refinement term.
2) Find optimal thresholding for Chance/Likely/Certain categories: minimize calibration term.

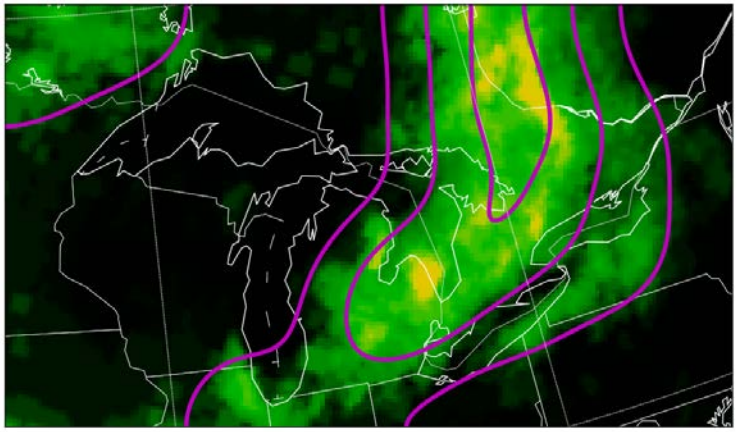
MetObject Extraction Example



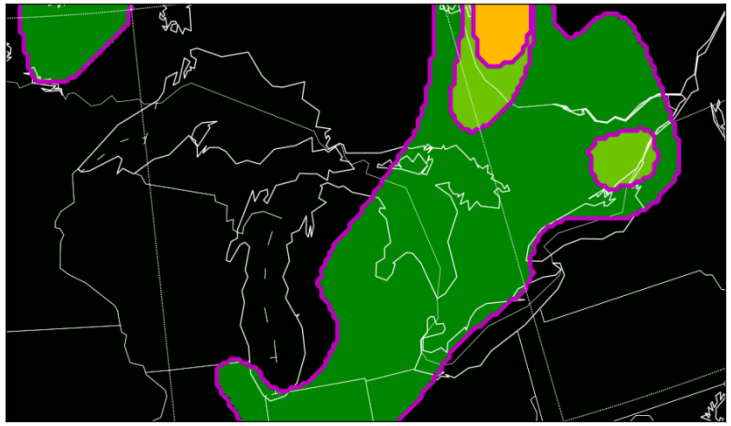
Statistical post-processing (RDPS-Stat)



Thunderstorm initiation (RDPS-Sci)

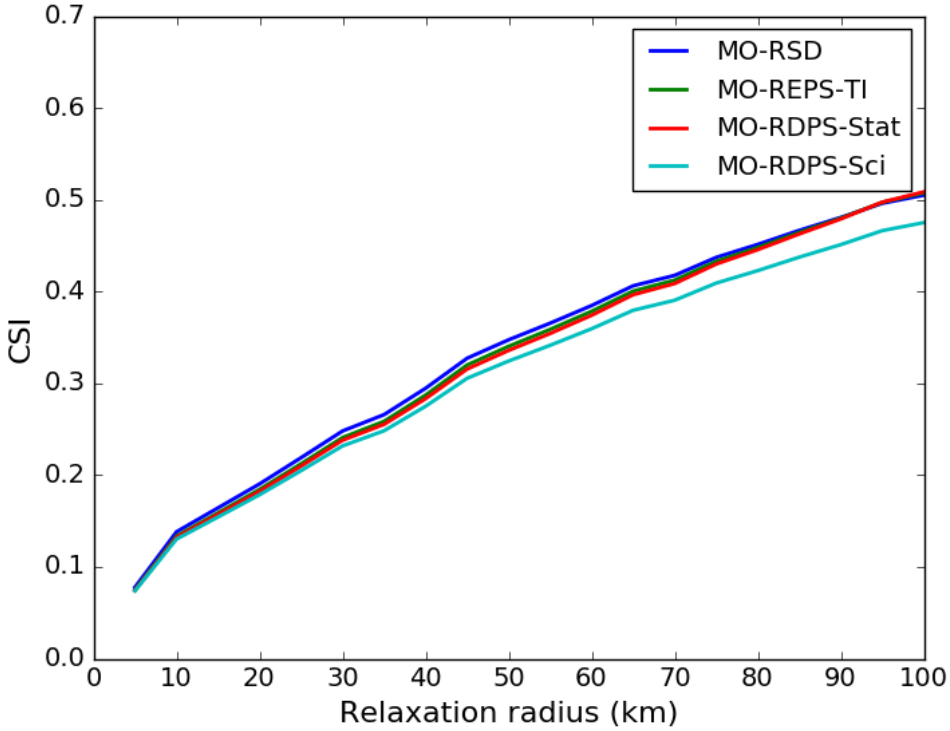


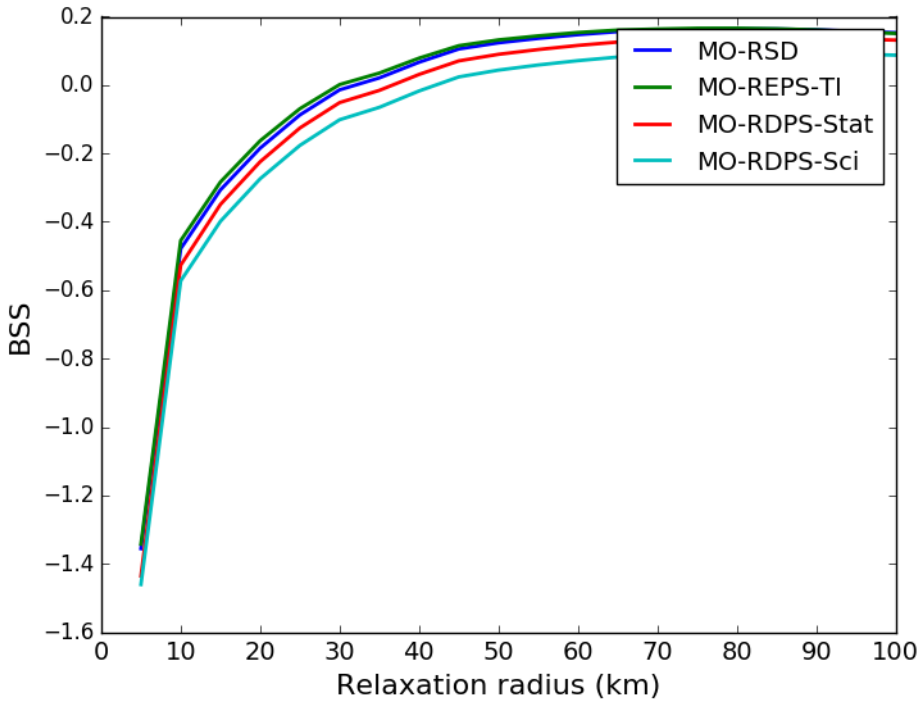
Calibrated ensemble (REPS-TI)



MO-RSD (human-generated)

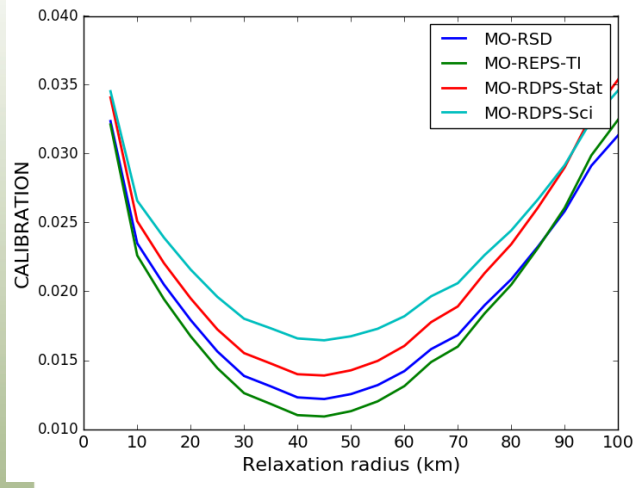
MetObject Classical Verification



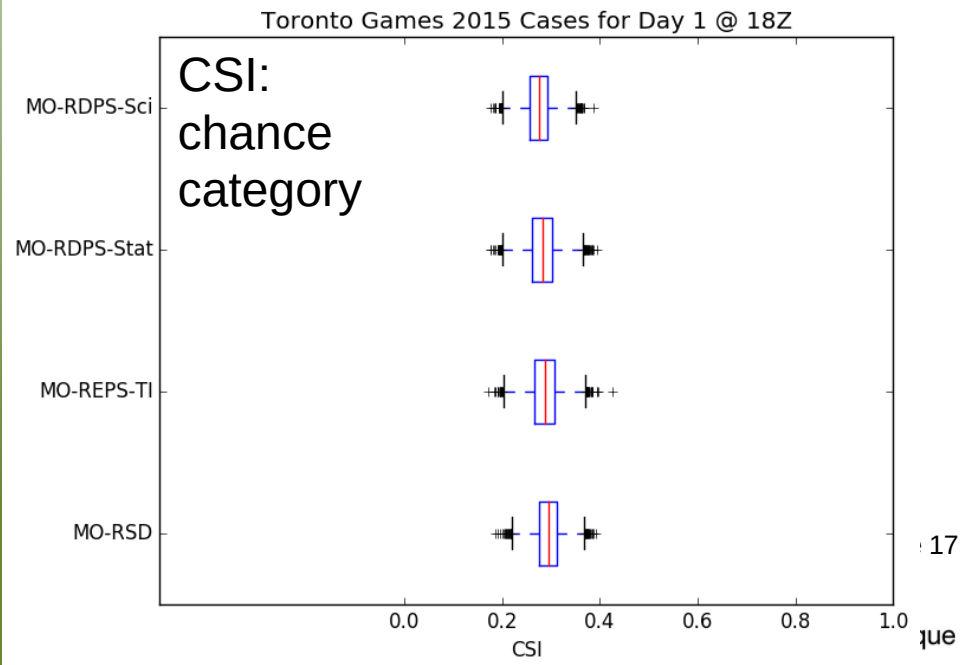


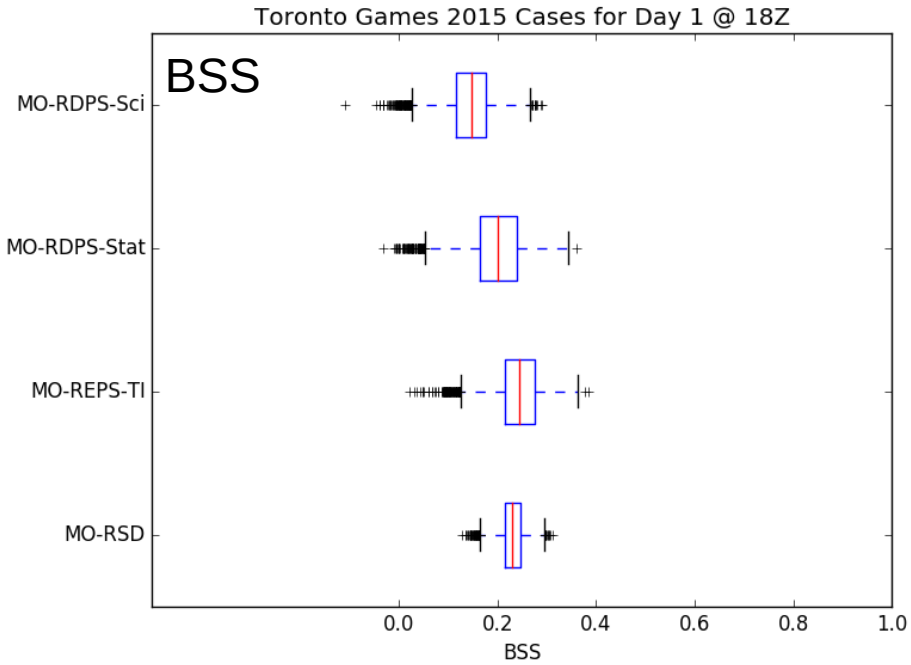
The relative order of the scores does not depend strongly on the relaxation parameter anymore.
The scores are also more similar.

Results for Optimal Relaxation



Same optimal relaxation parameter to minimize bias: 40 km





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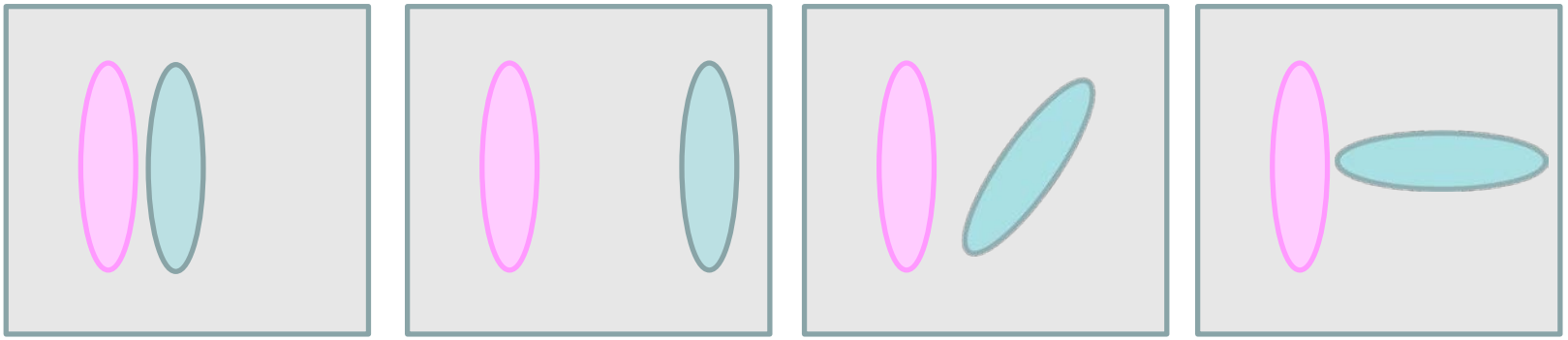
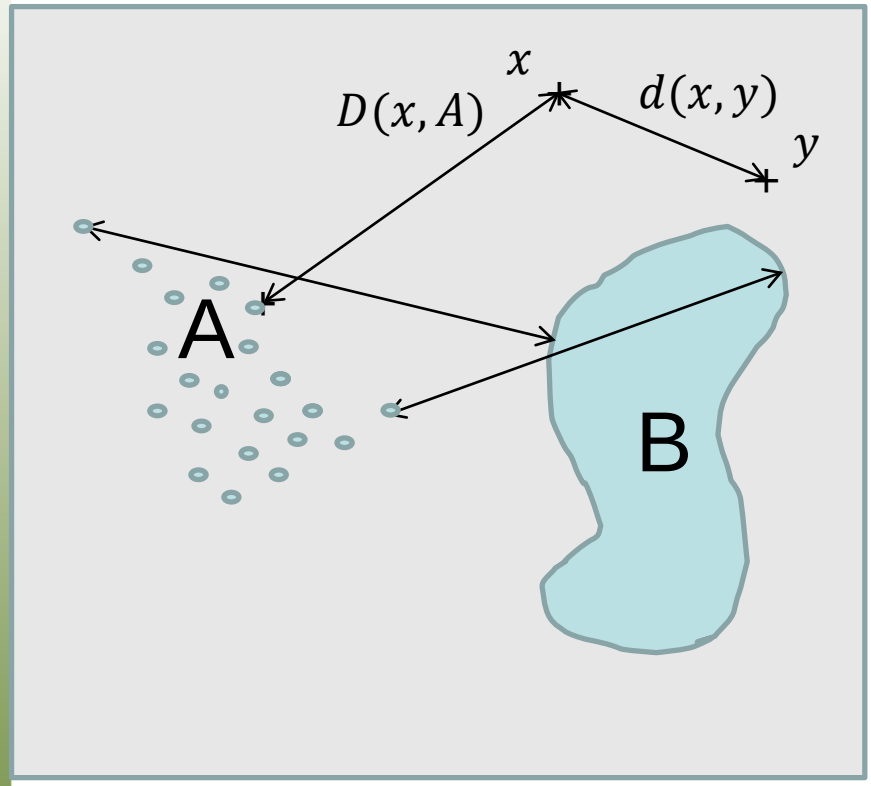
Double Penalty Problem

Which verification method better fits with our intuition of what is a good forecast?



They have all the same classical scores!

Distance Between Two MetObjects



X

Point-to-point distance for $x, y \in X$:

$$d(x,y) = \sqrt{\sum_i (x_i - y_i)^2}$$

Point-to-set distance for $x \in X, A \subset X$:

$$D(x,A) = \min_{a \in A} d(x,a)$$

Set-to-set distance (Hausdorff) for $A, B \subset X$:

$$H(A,B) = \max\left(\max_{a \in A} D(a,B), \max_{b \in B} D(b,A)\right)$$

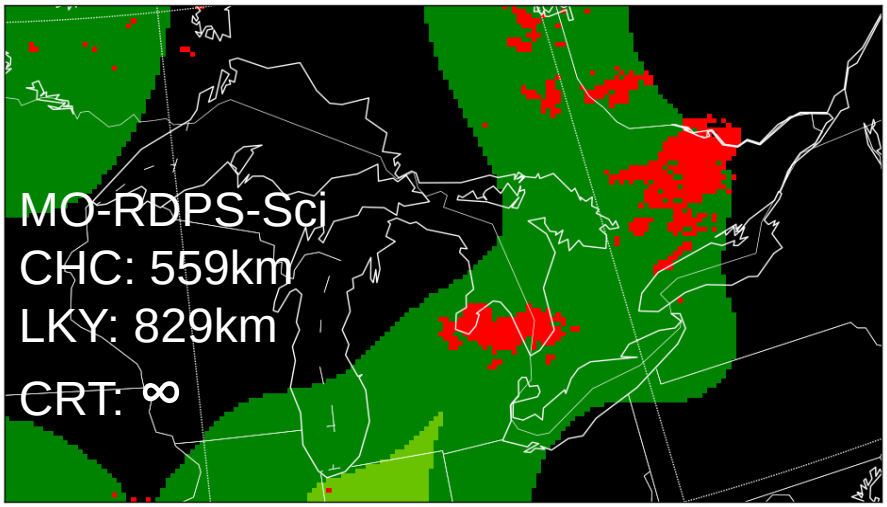
Set-to-set distance (generalized Hausdorff):
Replace min and/or max by power sums.

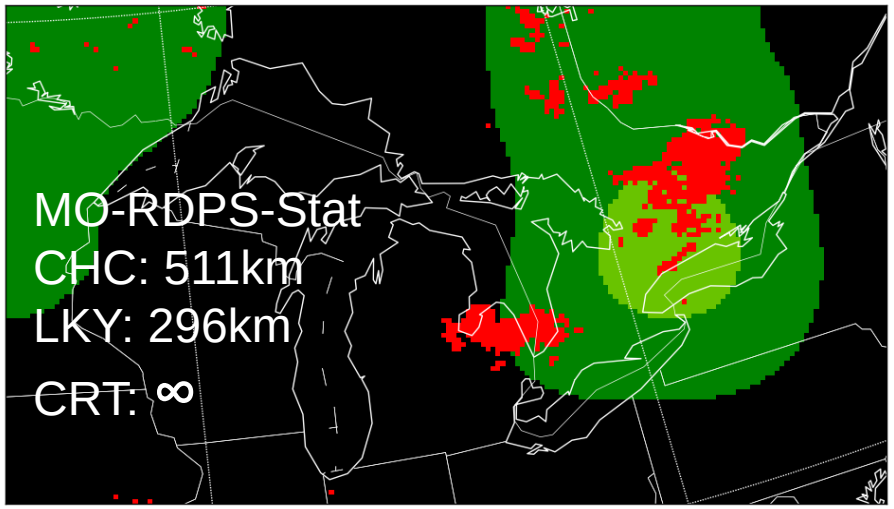
The geometry type of A and B can be areas, lines or cloud of points.

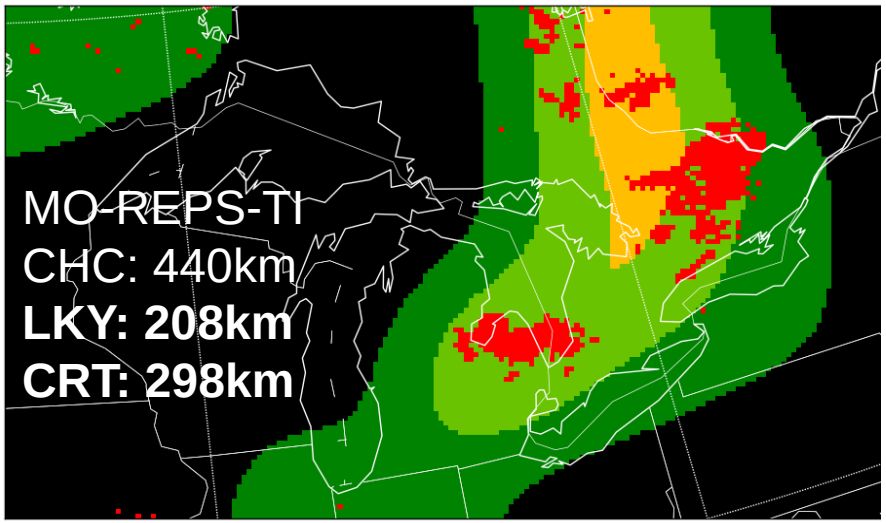
Brunet and Sills: *A generalized Distance Transform: Theory and Applications to Weather Analysis and Forecasting*, submitted to IEEE Transactions On Geoscience and Remote Sensing (2016)

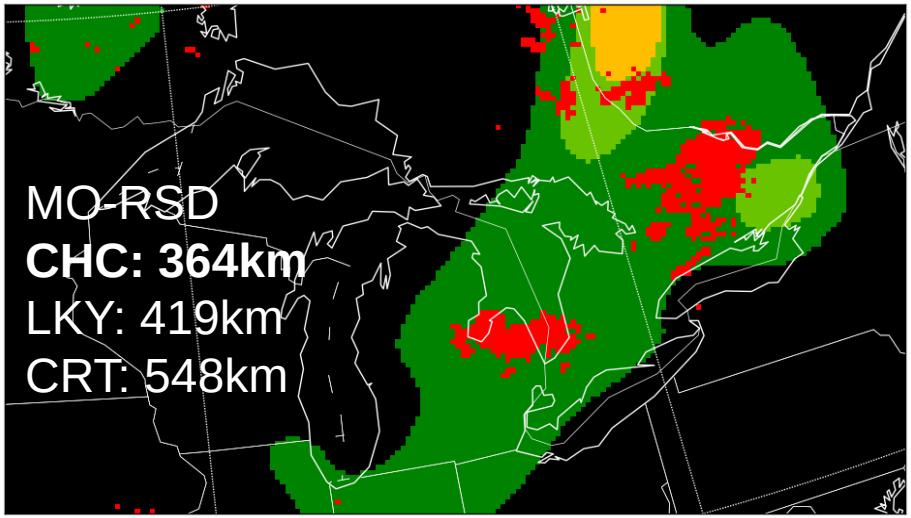
Distance-based Verification Example

CASE: July 25, 18-21Z









Conclusions

- Compared three NWP-based forecasts with human-generated forecast (MetObject) for thunderstorm nowcast with 3 hours lead time.
- REPS-TI forecast does best according to the classical scores, but the results are sensitive to the choice of relaxation parameter.
- Extracting MetObjects from NWP-based forecasts allows a comparison at the same scale and with the same calibration: REPS-TI and human-generated forecast (MO-RSD) come out on top with no statistically significant difference.
- The MetObject approach fits naturally an object-based verification paradigm. As an example, we demonstrate the computation of distance between MetObjects.

Questions or Comments?

Thank You!

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Caveats and Outlook

Caveats:

- The NWP-based MetObjects were computed in hindcast.
- The forecasters did not have access to the NWP-based MetObjects.
- Limited number of cases and of human forecasters.
- Trying to compare a 4-category forecast to continuous probabilistic forecasts.

Outlook:

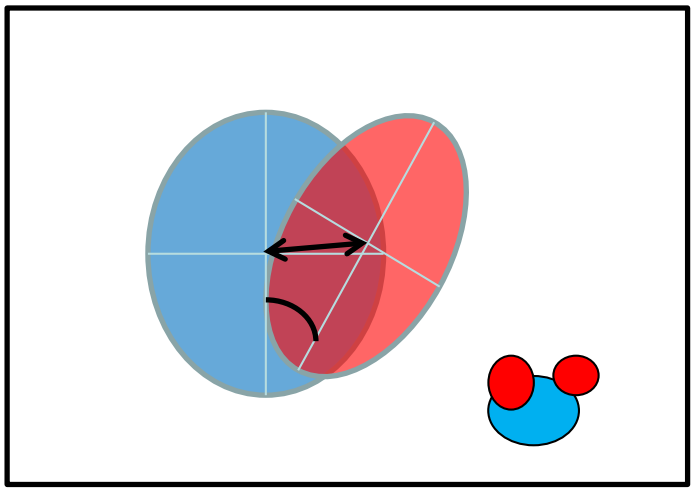
- Hard to settle the human VS machine forecaster controversy because of all the caveats, but getting closer to a rigourous methodology.
- Verification methods could also be extended for nowcasts based on persistence and extrapolation.
- Distance between MetObjects only one step into a full object-based framework, but distance can also be used for grouping and matching.
- The Toronto Panam 2015 Dataset will be shared Open Access, so a intercomparison of lightning nowcast can be possible.

QUESTIONS/COMMENTS?

- **Contact Dominique Brunet at Dominique.Brunet@canada.ca**

EXTRAS

Object-based verification



Group/match objects.
For each matched objects:
  Features extraction:
    Centroid, angle, aspect ratio, size
  Features/object comparison:
    Difference, log-ratio, distance
Summary or aggregation of pairwise scores