Verification of nowcasting methods in the context of high-impact weather events for the Canadian Airport Nowcasting (CAN-Now) project

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The CAN-Now Project

- The Canadian Airport Nowcasting project (CAN-Now) will deliver all-season forecasts of aviation related parameters out to 6 hours.
- Nowcasts are generated for Toronto Pearson Airport (YYZ) by blending numerical weather point forecasts from the GEM Regional and LAM models with observational data from on-site instruments.

This Verification Study

- Airport critical weather events occurring during the last two years at YYZ were identified from hourly observations.
- Model forecasts, both raw and modified by local nowcasting corrections were compared with extrapolated observations and persistence during these critical weather events between June 2007 and April 2009

Data Sources: NWP

Model	GEM Regional	GEM (LAM) East
Source	CMC	CMC
Resolution	15 km	2.5 km
Model runs	00, 12 UTC	12 UTC
Forecast hours studied	0 – 23h	0 – 23h
Time steps	30 min	5 min

- On-hour MOLTS data; NN at Pearson
- 3 hour spin up REG, no spin up for the LAM
- Variables: 2 m temperature and relative humidity, 10 m wind speed and direction, ceiling derived from NU ≥ 1% (REG only)

NU = GEM 2D Cloud Amount fraction

Data Sources: Observations

Hourly surface observations come from the Environment Canada Data Archives

The variables extracted were: temperature, relative humidity, ceiling, visibility, wind speed and direction.

One Minute data come from a large suite of CAN-Now instruments at Pearson Airport

The variables measured are: temperature, relative humidity, ceiling, wind speed and direction

Nowcasting Methods

Local area corrections are made to the REG and LAM model using:

- **Error persistence**
  Model error (model minus observation) at current time is persisted into the future. (Equivalent to the r=1 in the reduced model changes method; equation 1)
- **Reduced model changes**
  Observations are adjusted by a factor r = 0.5 of the model change, equation (1)

$$O_{k+p} = O_k + r(m_{k+p} - m_k) \quad \text{……….} \quad \text{(equation 1)}$$

O_{k+p} is predicted value at time p into the future, O_k is observed value now, m_k is model value now, m_{k+p} is model value at time p, r is a reduction factor. Here r = 0.5 was used (but optimal values could be determined empirically for each variable type)

- **Error prediction (events)**
  Least squares filter correction with the coefficients determined by minimizing the mean square errors over the event data set.
- **Error prediction (all data)**
  Least squares filter correction with the coefficients determined by minimizing the mean square errors over the full data set.

The corrected models are compared to:

- **Observation trend**
  A linear extrapolation out to the forecast lead time based on the average trend over an equivalent past time
- **Observation persistence**

Selection of Airport Critical Events

Event types and times were identified from the hourly observation data using the following criteria:

- **Fog + Visibility ≤ 3 miles** (defines crossover to IFR)
  133 events, 506 event points
- **Snow + Visibility ≤ 3 miles** (defines crossover to IFR)
  171 events, 568 event points
- **Wind speed ≥ 20 knots** (defines crossover to "caution")
  378 events, 965 event points
- **Ceiling ≤ 1000 ft** (defines crossover to IFR)
  305 events, 1324 event points

Minimum event length = 1 hour; Maximum intra-event gap allowed = 1 hour; 6 hours was added before and after each event to capture the prelude and postlude of the event.

Verification Results

Event: Wind speed ≥ 20 knots
Mean Absolute Errors for REG Wind Speed (m/s)

Forecast Lead Time: hours	0.5	1	2	3	4	5	6
Raw model	1.62	1.62	1.62	1.62	1.62	1.62	1.62
Error persistence	0.61	0.98	1.43	1.63	1.76	1.85	1.93
Reduced model changes	0.57	0.93	1.39	1.66	1.88	2.07	2.24
Observation trend	0.65	1.22	2.12	2.74	3.29	3.81	4.39
Observation persistence	0.59	1.00	1.59	2.03	2.42	2.76	3.06
Error prediction (all)	0.53	0.88	1.27	1.40	1.46	1.52	1.55
Error prediction (events)	0.54	0.89	1.29	1.43	1.49	1.51	1.49

- Error prediction performs best to 6 hours
- Raw model performance is similar after 3 hours

Event: Fog + Visibility ≤ 3 miles
Mean Absolute Errors for REG RH (%)

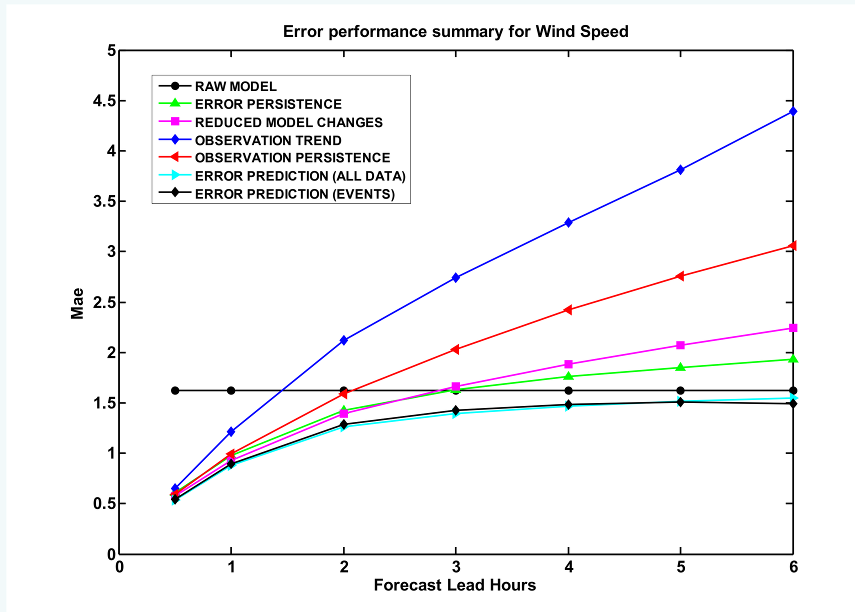
Forecast Lead Time: hours	0.5	1	2	3	4	5	6
Raw model	4.96	4.96	4.96	4.96	4.96	4.96	4.96
Error persistence	1.62	2.64	4.12	5.20	6.01	6.60	7.04
Reduced model changes	1.37	2.27	3.77	5.02	6.08	6.99	7.71
Observation trend	1.48	2.62	4.93	7.46	10.06	12.80	15.48
Observation persistence	1.34	2.33	4.20	5.94	7.51	8.91	10.10
Error prediction (all)	1.56	2.52	3.79	4.56	4.98	5.19	5.28
Error prediction (events)	1.54	2.49	3.63	4.27	4.61	4.77	4.86

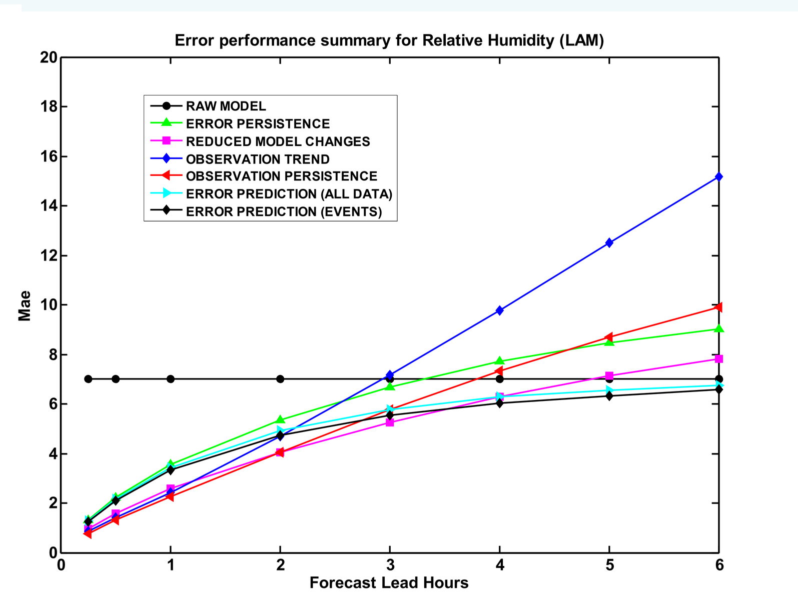
- Obs persistence performs best to 1 hour
- Error prediction performs best from 2 to 6 hours
- Raw model performance is similar after 4 hours

Event: Fog + Visibility ≤ 3 miles
Mean Absolute Errors for LAM RH (%)

Forecast lead time: hours	0.25	0.5	1	2	3	4	5	6
Raw model	7.02	7.02	7.02	7.02	7.02	7.02	7.02	7.02
Error persistence	1.32	2.22	3.57	5.35	6.68	7.74	8.48	9.03
Reduced model changes	0.96	1.59	2.59	4.05	5.25	6.29	7.14	7.81
Observation trend	0.86	1.40	2.43	4.69	7.18	9.79	12.51	15.16
Observation persistence	0.78	1.30	2.27	4.06	5.77	7.32	8.71	9.90
Error prediction (all)	1.28	2.17	3.44	4.91	5.78	6.28	6.56	6.74
Error prediction (events)	1.25	2.10	3.33	4.74	5.54	6.04	6.33	6.57

- LAM mae > REG mae
- Obs persistence performs best to 2 hours
- Error prediction performs best from 4 to 6 hours
- Raw model performance is similar after 4 hours





REG CEILING < 1000 feet (305m)

	A	B	C	D	Total	POD	FAR	TSS	PC	FBI	THR
Full data set	681	655	438	7481	9255	0.61	0.08	0.53	0.88	1.19	0.38
Event times, no timing leeway	681	360	438	1548	3027	0.61	0.19	0.42	0.77	0.93	0.46
Event times, 60 min timing leeway	796	360	323	1548	3027	0.71	0.19	0.52	0.77	1.03	0.54

GEM REG correctly forecasts low ceilings for about half of the low-ceiling events (Threat score THR ~0.5)

REG WIND > 20 knots (10 m/s)

	A	B	C	D	Total	POD	FAR	TSS	PC	FBI	THR
Full data set	327	211	582	27730	28850	0.36	0.01	0.35	0.97	0.59	0.29
Event times, no timing leeway	329	178	375	3231	4113	0.47	0.05	0.42	0.87	0.72	0.37
Event times, 30 min timing leeway	367	178	337	3231	4113	0.52	0.05	0.47	0.87	0.77	0.42

GEM REG generally underestimates the frequency of high wind speed events (Frequency bias index FBI < 1).

SUMMARY

- Methods that blend model and observations perform best after ~ 1 hour and on average perform better than the raw model at all times; however, this advantage is greatly reduced by ~ 6 hours.
- Observational (persistence and trend) methods perform best during the first 30 min to 1 hour. Often other methods perform equally well during this time. This is in contrast to the results of seasonal verification for winter temperatures (CMOS 2008) in which observation persistence out performed other methods at all forecast lead times. (This result is perhaps not surprising since the "non-events" have been excluded from the present analysis)
- Comparison of REG and LAM variables:
  - Temperature: mae REG is less than mae LAM (1.5°C and 2.1°C)
  - RH: mae REG is less than mae LAM (5% and 7 %)
  - Wind speed: mae for REG and LAM are the same (1.6 m/s)
  - Verification of ceiling was performed only for REG.
- Specific dichotomous (yes/no contingency table) analysis showed that GEM Regional correctly forecasts low ceilings (<1000 ft) for about half of the events GEM Regional generally underestimates the frequency of high wind speed events (> 20 knots)
- Ongoing work:
  - Exploring a combination of objective and subjective methods to identify significant events and regime onset as indicated by a combination of changes over a group of variables.