Winter Weather Nowcasting

by

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Canadian Airport Nowcasting (CAN-Now) Acknowledgements

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- **Search and Rescue New Initiatives Fund**
- **NAV CANADA**
- **Environment Canada**

People
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Laura Huang[1], Jason Milbrandt[2], Ruping Mo[4], Roy Rasmussen[7],
Janti Reid[1], Trevor Smith[4], Ron Stewart [8], and Donghai Wang[9]

[1] Cloud Physics and Severe Weather Research Section, Environment Canada
[2] Recherche en prévision numérique, Environment Canada
[3] Weather Decision Technologies, Oklahoma, USA
[4] Meteorological Service of Canada, Environment Canada
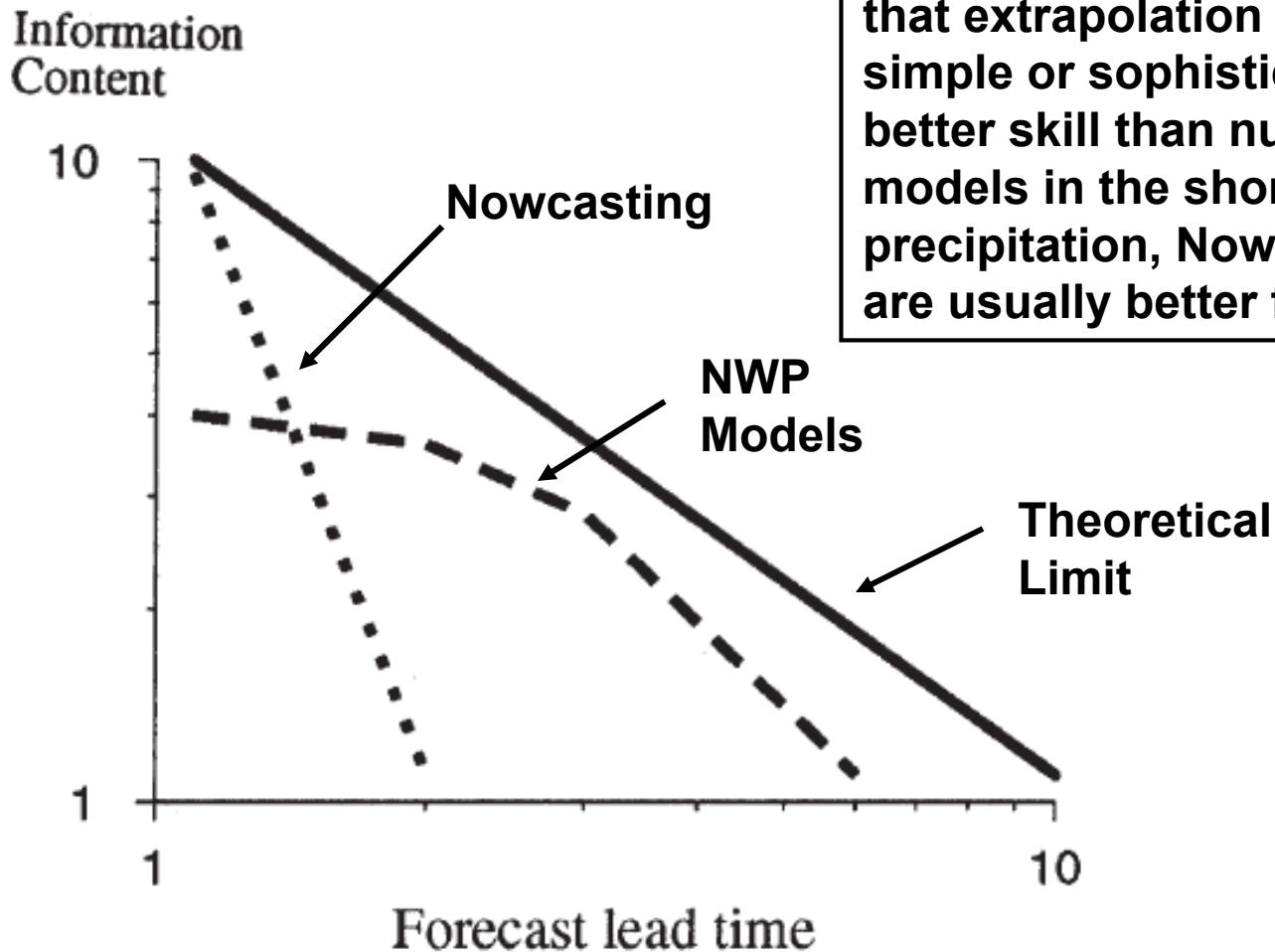[5] National Severe Storms Laboratory, Norman, Oklahoma, USA
[6] Central Institute for Meteorology and Geodynamics (ZAMG), Austria
[7] National Center for Atmospheric Research, Colorado, USA
[8] Department of Environment and Geography, University of Manitoba
[9] Chinese Academy of Meteorological Science, China

The main idea behind Nowcasting is that extrapolation of observations, by simple or sophisticated means, shows better skill than numerical forecast models in the short term. For precipitation, Nowcasting techniques are usually better for 6 hours or more.

Information Content

Nowcasting

NWP Models

Theoretical Limit

Forecast lead time

Figure 1. Schematic representation of the loss of information content in forecasts as a function of lead time. The solid line represents the theoretical limit of predictability. The dashed line represents NWP models and the dotted line nowcasting methods.

From Golding (1998) Meteorol. Appl., 5, 1-16

Objectives
Canadian Airport Nowcasting (CAN-Now)

- To improve short term forecasts (0-6 hour) or Nowcasts of airport severe weather.

- Develop a forecast system which will include routinely gathered information (radar, satellite, surface based data, pilot reports), numerical weather prediction model outputs, and a limited suite of specialized sensors placed at the airport.

- Forecast/Nowcast products will be issued with 1-15 min resolution for most variables.

- Test this system, and its associated information delivery system, within an operational airport environment (e.g. Toronto and Vancouver International Airports).

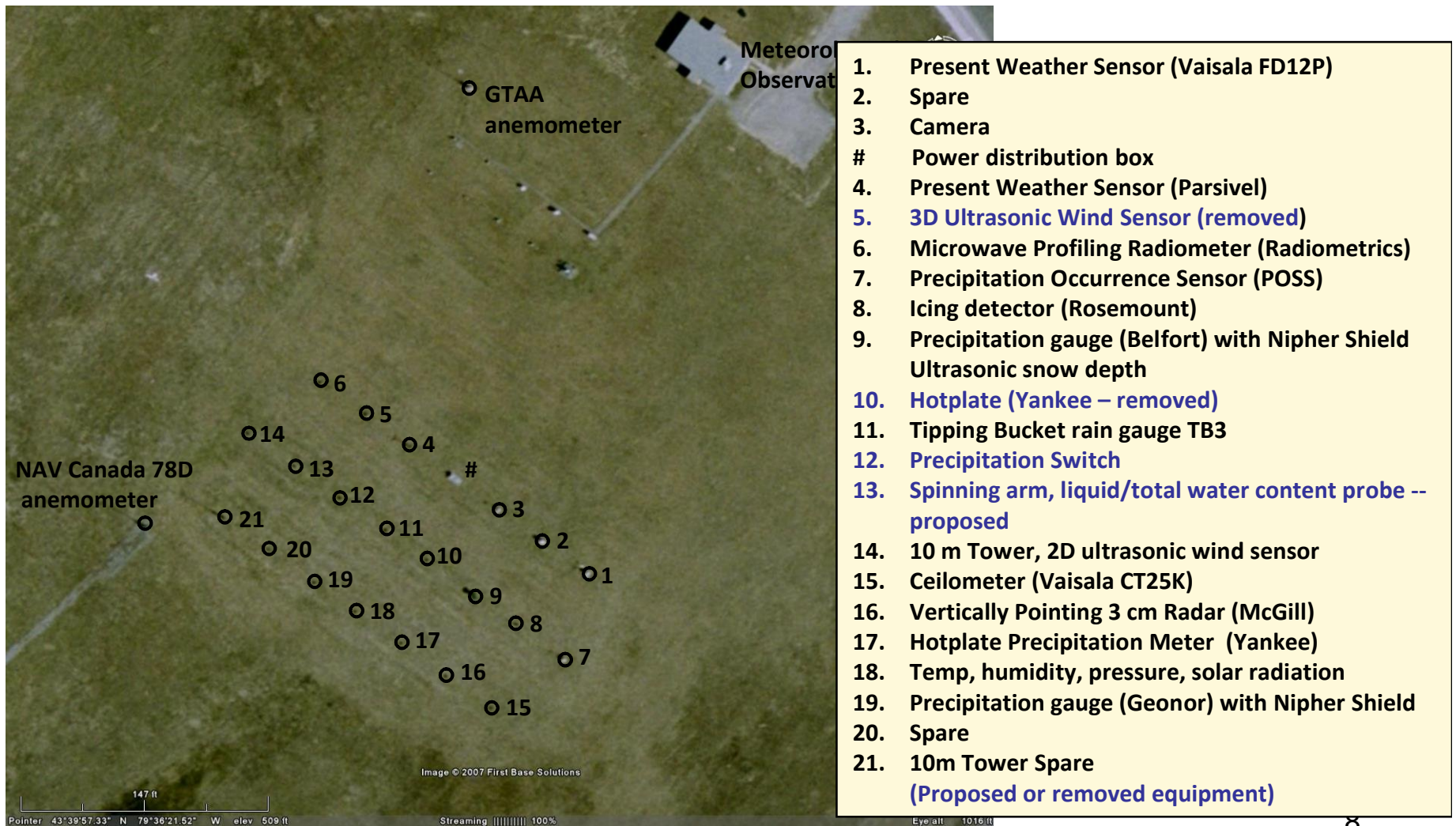# Variables for Airport System

- **Snow and rain events**
- **Freezing precipitation and ice pellets**
- **Frost**
- **Blowing snow**
- **Icing aloft**
- **High winds/gusts**
- **Wind shifts/shear**
- **Turbulence**
- **Lightning**
- **Low ceilings**
- **Low visibility and fog**
- **Convective cells**
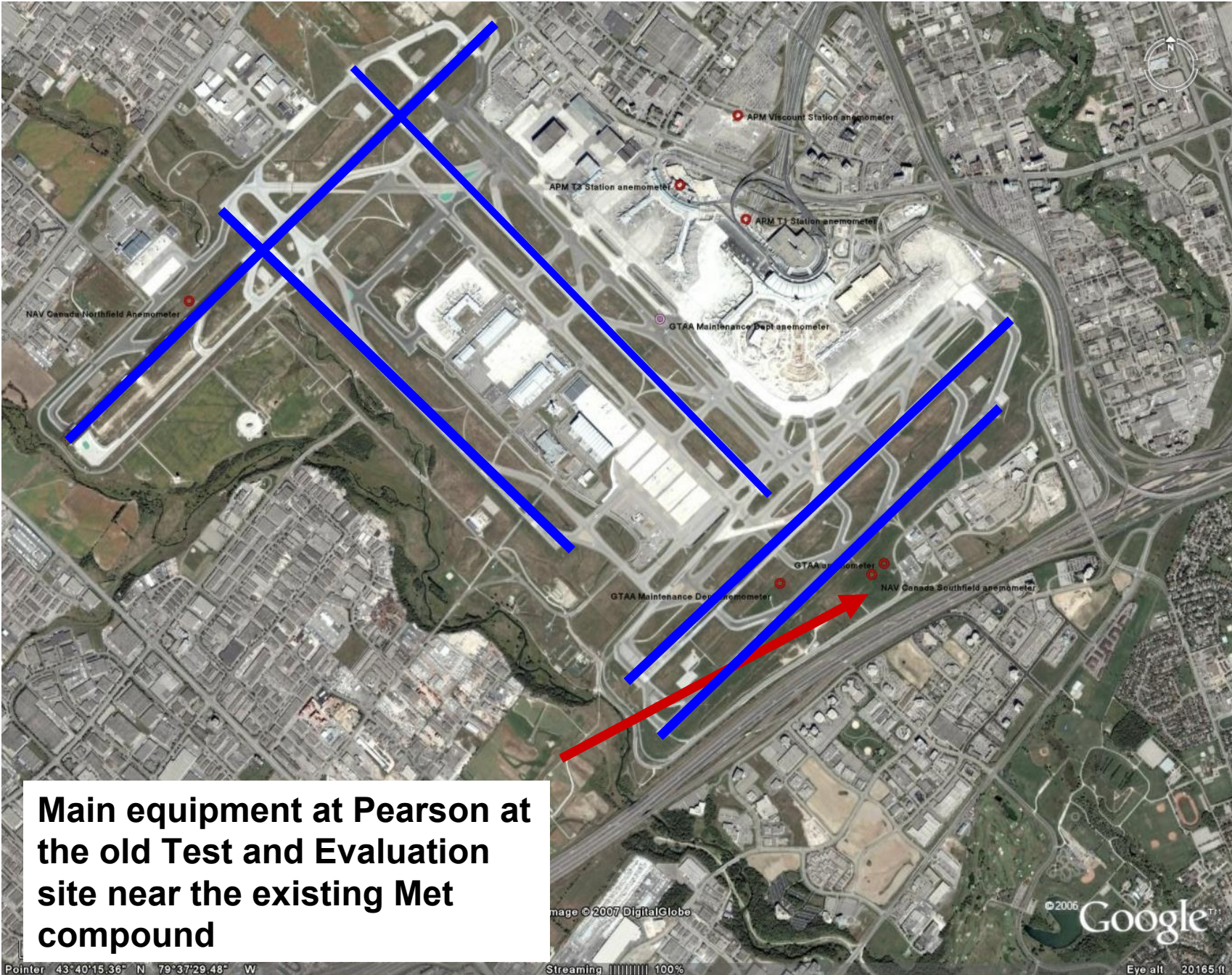
Main equipment at Pearson at the old Test and Evaluation site near the existing Met compound

Pearson Instrument Site

- 21 instrument bases with power and data feeds.
- 10m apart; rows 15m apart

1. Present Weather Sensor (Vaisala FD12P)
2. Spare
3. Camera
#. Power distribution box
4. Present Weather Sensor (Parsivel)
5. 3D Ultrasonic Wind Sensor (removed)
6. Microwave Profiling Radiometer (Radiometrics)
7. Precipitation Occurrence Sensor (POSS)
8. Icing detector (Rosemount)
9. Precipitation gauge (Belfort) with Nipher Shield Ultrasonic snow depth
10. Hotplate (Yankee – removed)
11. Tipping Bucket rain gauge TB3
12. Precipitation Switch
13. Spinning arm, liquid/total water content probe -- proposed
14. 10 m Tower, 2D ultrasonic wind sensor
15. Ceilometer (Vaisala CT25K)
16. Vertically Pointing 3 cm Radar (McGill)
17. Hotplate Precipitation Meter (Yankee)
18. Temp, humidity, pressure, solar radiation
19. Precipitation gauge (Geonor) with Nipher Shield
20. Spare
21. 10m Tower Spare
(Proposed or removed equipment)

Ex-AWOS Site

Vancouver Int'l Airport

Image © 2007 DigitalGlobe
© 2007 Europa Technologies

Web Site

- A Web site has been created at: http://www.canadian-airport-nowcasting.org/

- The data on this site is accessible only with a user name and password. The site is currently active.

Canadian Airport Nowcasting

Airports Overview

CAN-Now (West) | **CAN-Now (East)**

| Crosswind0 ▾ | 21:40 (NOW) ▾ | ☐ Wx-Cams |

✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈
CYYZ	KBUF	KCLE	KDTW	CYHM	CYGK	CYXU	CYUL	KIAG	CYYB	CYOO
✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈
CYOW	KPIT	KROC	CYAM	CYSB	KSYR	CYTS	CYKZ	CYTZ	CYTR	CYQG

LEGEND

✈	GREEN	OK
✈	BLUE	Check
✈	YELLOW	Check
✈	ORANGE	Caution
✈	RED	Stop
✈	BLACK	Data Unavailable

CAN-Now Project Blog

☑ Case Studies
☑ Site Updates and Feedback
☑ Statistical Evaluations
☑ Present Weather Discussion
☑ Uncategorized

Situation Chart changes - Observations on 'Now'
Category: Site Updates and Feedback
Thu, 27 May, by Bob Crawford

Lightning Forecast System
Category: Uncategorized
Wed, 26 May, by Bob Crawford [1]

Vertically Pointing Radar VPR back at CYYZ
Category: Uncategorized
Fri, 21 May, by Janti Reid [2]

Low Ceiling Forecasts at Squamish and Whistler
Category: Uncategorized
Tue, 18 May, by gissac

GEM Model Winds
Category: Uncategorized

Situation Chart for CYYZ

TAF Plus

Rwy: ☑ 05/23 ☑ 06/24RL ☑ 15/

Thresholds

CYYZ METEOROLOGICAL NOWCAST : VALID AT 2009-05-28 16:30 UTC

	16:30	16:40	16:50	17:00	17:10	17:20	17:30	17:40	17:50	18:00	18:10	18:20	18:30	19:30	20:30	21:30	22:30
	NOW	+10m	+20m	+30m	+40m	+50m	+1h	+1:10h	+1:20h	+1:30h	+1:40h	+1:50h	+2h	+3h	+4h	+5h	+6h
RWY 05/23 WI	110 04G12	120 04G12	120 04G12	120 04G11	120 04G11	120 05G11	120 05G11	120 05G11	120 05G11	120 05G11	130 05G07	130 05G04	130 05	140 06	140 06	120 05	120 03
RWY 06/24RL	110 04G12	120 04G12	120 04G12	120 04G11	120 04G11	120 05G11	120 05G11	120 05G11	120 05G11	120 05G11	130 05G07	130 05G04	130 05	140 06	140 06	120 05	120 03
RWY 15/33RL	110 04G12	120 04G12	120 04G12	120 04G11	120 04G11	120 05G11	120 05G11	120 05G11	120 05G11	120 05G11	130 05G07	130 05G04	130 05	140 06	140 06	120 05	120 03
VISIBILITY	P6SM	P6SM	P6SM	P6SM	P6SM	5/8SM	5/8SM	3/4SM	3/4SM	3/4SM	1SM	1 1/8SM	1 1/4SM	P6SM	P6SM	P6SM	P6SM
CEILING	000	000	000	000	000	000	000	001	003	004	004	004	004	004	004	000	000
SHEAR/TURB																	
PRECIP														T	T	T	0008
TSTM & LTNG						LTNG DIST	LTNG DIST	LTNG DIST	LTNG DIST	LTNG DIST	LTNG DIST						
ICING																	220

Thresholds

CYYZ OPERATIONS NOWCAST : VALID AT 2009-05-28 16:30 UTC

|	16:30	16:40	16:50	17:00	17:10	17:20	17:30	17:40	17:50	18:00	18:10	18:20	18:30	19:30	20:30	21:30	22:30
	NOW	+10m	+20m	+30m	+40m	+50m	+1h	+1:10h	+1:20h	+1:30h	+1:40h	+1:50h	+2h	+3h	+4h	+5h	+6h
WX-ONLY AAR	18	18	18	18	18	18	18	22	62	62	62	62	62	62	62	18	18
CAT LEVEL	IIIa	IIIa	IIIa	IIIa	IIIa	IIIa	IIIa	II	I	I	I	I	I	I	I	IIIa	IIIa
RWY 05/23 CO																	
RWY 06/24RL																	
RWY 15/33RL																	

Prototype Display Contains

- Bar chart at 10 min resolution for first two hours, then one hour resolution for next 4 h.
- Bar changes colour to attention (yellow) to red (alert) status. Remains green if everything OK. Bars main contain some text (e.g. T, RH, Visibility, Ceiling, Precipitation Type, etc).
- If chart changes colour, you can click and obtain more information as to why. Either graphs or text from forecaster.
- A text message from the forecaster outlining significant features has been included (TAF Plus)
- Besides significant weather variables, the ability to include AAR, Runway Friction, etc, is included
- An area chart showing all the YYZ alternates has been prepared. The airports are colour coded to indicate all OK (green), up to red (below limits).
- Some graphical charts are available, including radar, satellite, lightning, etc.

2-hour Nowcast Lightning Flash Tracks (Red Line) Ending Sun/dim 0015Z 26 Apr 2009 Regional GEM
for each flash observed in 15 min period 2200Z 25/04/2009 - 2215Z 25/04/2009
Flashes observed in this period (red circles)   Flashes observed in previous >15-30 mins (orange circles)
Flashes observed in previous >30-45 mins (yellow circles)   Flashes observed in previous >45-60 mins (blue circles)

Thanks to Bill Burrows
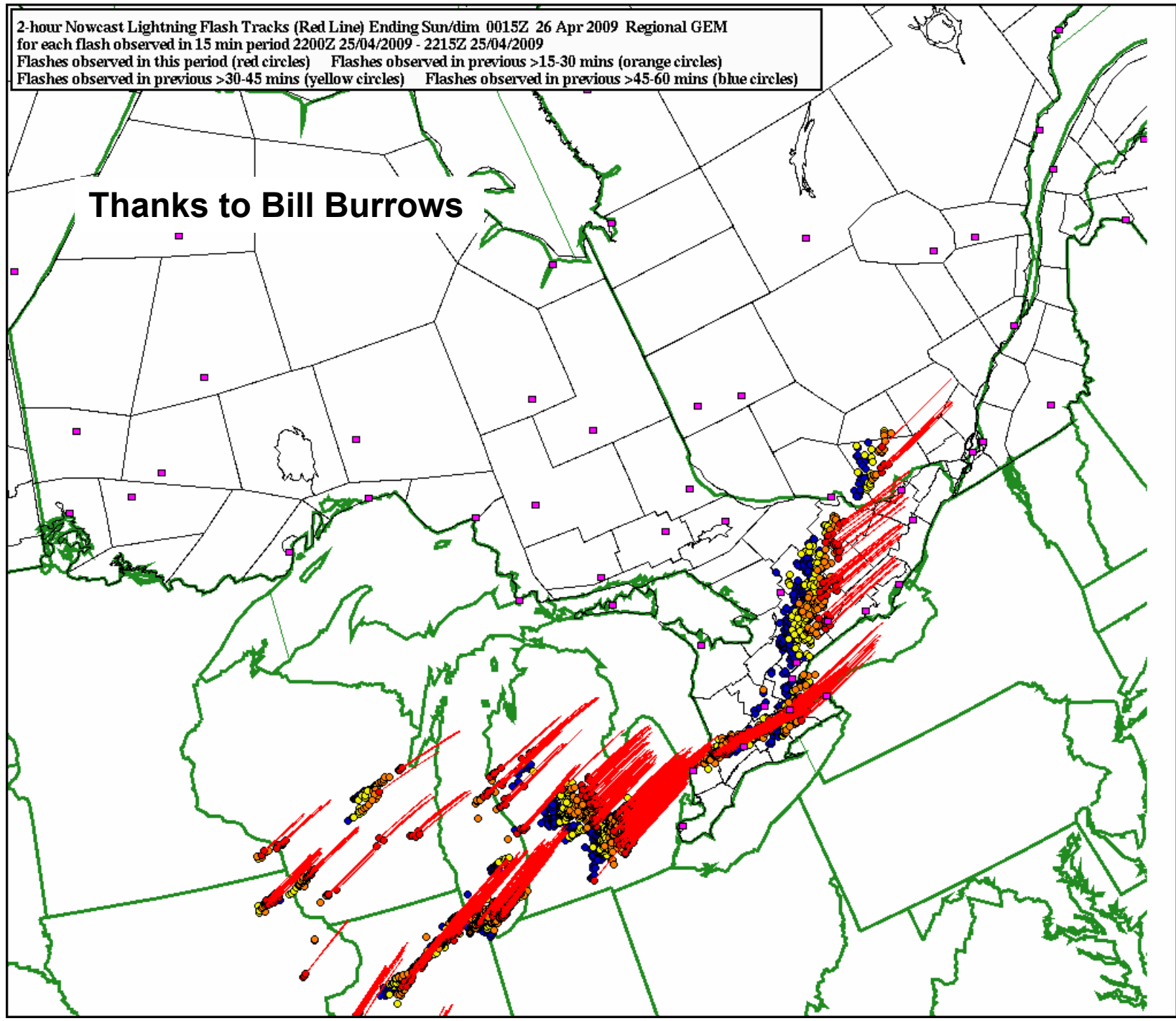
Thresholds as applied on Situation Chart

Crosswinds:
Dry RWY (precipitation rate $\leq$ 0.2 mm/h and visibility $\geq$ 1 SM):
    x-wind (knots) < 15   :   GREEN
15 $\leq$ x-wind (knots) < 20 :   YELLOW
20 $\leq$ x-wind (knots) < 25 :   ORANGE
    x-wind (knots) $\geq$ 25   :   RED   (NOT PERMITTED)
Wet RWY (precipitation rate > 0.2 mm/h or visibility < 1 SM):
    x-wind (knots) < 5   :   GREEN
  5 $\leq$ x-wind (knots) < 10 :   YELLOW
10 $\leq$ x-wind (knots) < 15 :   ORANGE
    x-wind (knots) $\geq$ 15   :   RED   (NOT PERMITTED)

Visibility:

    vis (SM) $\geq$ 6   :   GREEN   (VFR)
  3 $\leq$ vis (SM) < 6   :   BLUE   (MVFR)
½ $\leq$ vis (SM) < 3   :   YELLOW   (IFR)
¼ $\leq$ vis (SM) < ½   :   ORANGE   (BLO ALTERNATE)
    vis (SM) < ¼   :   RED   (BLO LANDING)

Ceiling:

ceiling (ft) $\geq$ 2500 :   GREEN   (VFR)

1000 $\leq$ ceiling (ft) < 2500 :   BLUE   (MVFR)

400 $\leq$ ceiling (ft) < 1000 :   YELLOW   (IFR)

150 $\leq$ ceiling (ft) < 400 :   ORANGE   (BLO ALTERNATE)

ceiling (ft) < 150 :   RED   (BLO LANDING)

Shear & Turbulence:

momentum flux FQ (Pa) < 0.75 :   GREEN   (LGT)

0.75 $\leq$ mom. flux FQ (Pa) < 1.5 :   YELLOW   (MOD)

mom flux FQ (Pa) $\geq$ 1.5 :   RED   (SEV)

eddy dissipation rate ($m^{2/3}$/s) < 0.3 :   GREEN   (LGT)

0.3 $\leq$ EDR ($m^{2/3}$/s) < 0.5 :   YELLOW   (MOD)

EDR ($m^{2/3}$/s) $\geq$ 0.5 :   RED   (SEV)

eddy dissipation rate ($m^{2/3}$/s) < 0.3 :   GREEN   (LGT)

0.3 $\leq$ EDR ($m^{2/3}$/s) < 0.5 :   YELLOW   (MOD)

EDR ($m^{2/3}$/s) $\geq$ 0.5 :   RED   (SEV)

If the windspeed (relative to surface wind direction) exceeds, any of the following

level[2] (~125m/410ft) - level[0] >= 25 kts

level[4] (~325m/1060ft) - level[0] >= 40 kts   :   RED

level[5] (~440m/1440ft) - level[0] >= 50 kts

Precipitation:

rate (mm/h) > 7.5 :	RED	(HEAVY)
2.5 < rate (mm/h) ≤ 7.5 :	ORANGE	(MODERATE)
0.2 < rate (mm/h) ≤ 2.5 :	YELLOW	(LIGHT)
0 < rate (mm/h) ≤ 0.2 :	GREEN	(TRACE)
rate (mm/h) = 0 :	GREEN	(NO PRECIP)

TSTM & LTNG:

Lightning Distance ≤ 6 SM	RED	(TS)
Lightning Distance ≤ 10 SM	ORANGE	(VCTS)
Lightning Distance ≤ 30 SM	YELLOW	(LTNG DIST)
Lightning within area (> 30 SM)	YELLOW	
Lightning forecast map received	GREEN	(NO LTNG FCST)

ICING:

TWC < 0.1 g/m3 or TT ≥ 0°C	GREEN	
TWC ≥ 0.1 g/m3 where TT < 0°C	YELLOW	(POTENTIAL ICING)

CAT-level:

RVR (ft) < 600	RED	(NOT PERMITTED)
600 ≤ RVR (ft) < 1200 -or- ceiling (ft) < 100	: RED	(CAT IIIa)
1200 ≤ RVR (ft) < 2600 -or- 100 ≤ ceiling (ft) < 200	: ORANGE	(CAT II)
2600 ft ≤ RVR < 3 SM -or- 200 ≤ ceiling (ft) < 1000	: YELLOW	(CAT I)
3 ≤ RVR (SM) < 6 -or- 1000 ≤ ceiling (ft) < 2500	: BLUE	(MVFR)
RVR (SM) ≥ 6 -and- ceiling (ft) ≥ 2500	: GREEN	(VFR)

RWY Condition:

precipitation rate (mm/h) > 0.2   : ORANGE   (Possible WET rwy)

precipitation rate (mm/h) ≤ 0.2   : YELLOW   (Possible DRY rwy)

Wx Only AAR:

Cell colour is based on meteorological conditions – same as CAT-level

Meteorologically-limited theoretical maximum AAR determined from
  look-up table of documented AAR values based on runway configuration
  and meteorological conditions (CAT-level).

Runway configuration determined solely from crosswind thresholds for maximum
  potential capacity.

Progress to Develop Smart Nowcast Products

- Adaptive Blending Observations and Models (ABOM)
- Automated selection of best model (INTW)
- Graphical TAFs
- Kalman Filter and Nowcasting

ABOM: Adaptive Blending of Observation and Model
Smooth transition between modes depending on recent history

This method reduces to:
- **Observation persistence when r = s = 0**
- **Error persistence when s = 0, r = 1**
- **Pure obs trend when r = 0**
- **Blended model-obs for all other r and s**

Prediction at lead time p

Current observation

$$\hat{V}_{k+p} = V_k + s_p\Delta\text{trend} + r_p(m_{k+p} - m_k)$$

Change predicted by obs trend

Change predicted by model
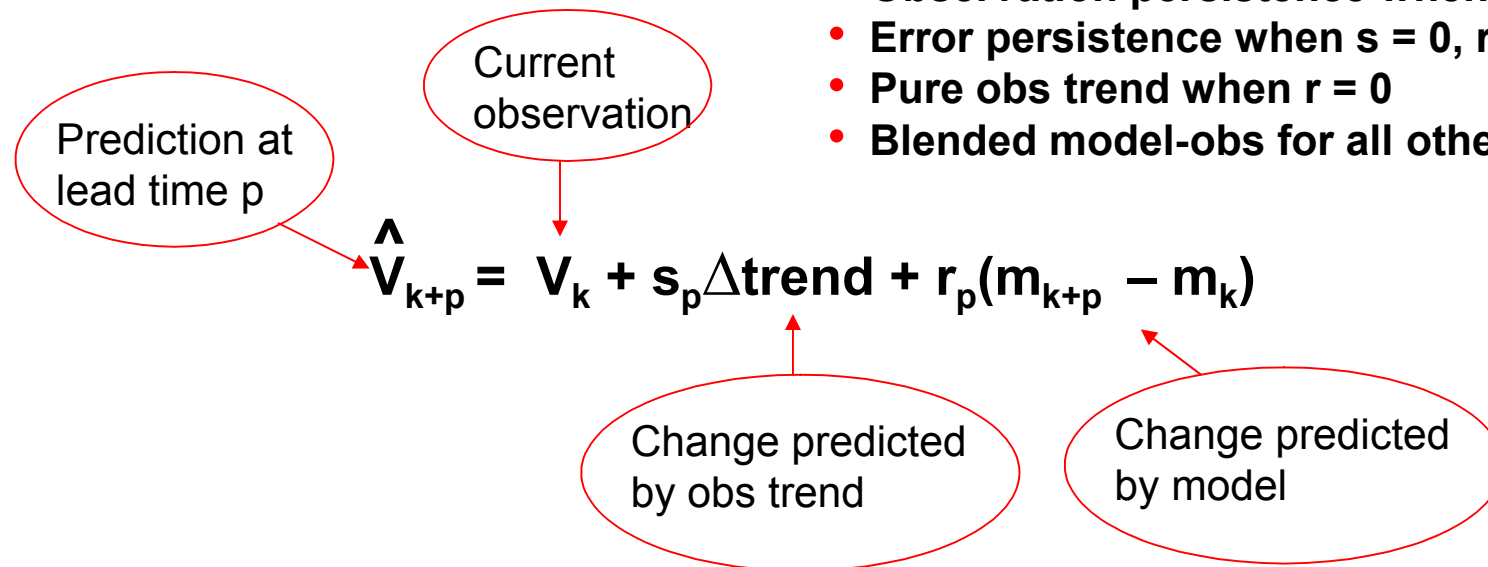
- The coefficients s and r are obtained by calibrating over the past 8 hours using a multivariate regression analysis to give the best fit and errors in the fit
- s and r are expected to be different for each forecast lead time, p

Integrated Weighted Model INTW

- INTW generation
    - Check NWP model performance - calculate statistics for past 6 hours
    - Assign weight to each NWP model based on model performance
    - Adjust weight
    - Perform variational and dynamic bias correction
    - Generate integrated forecasts by blending forecasts from NWP models with corresponding weights
- The system is reusable for:
    - different input models
    - different weather forecasting parameters
- During SNOW V10, 1 km **LAM** and 15 km **REG** were selected to generate INTW. For CAN-Now 2.5 km **LAM**, 15 km **REG**, and 13 km **RUC** were used.

Example of Nowcast Products
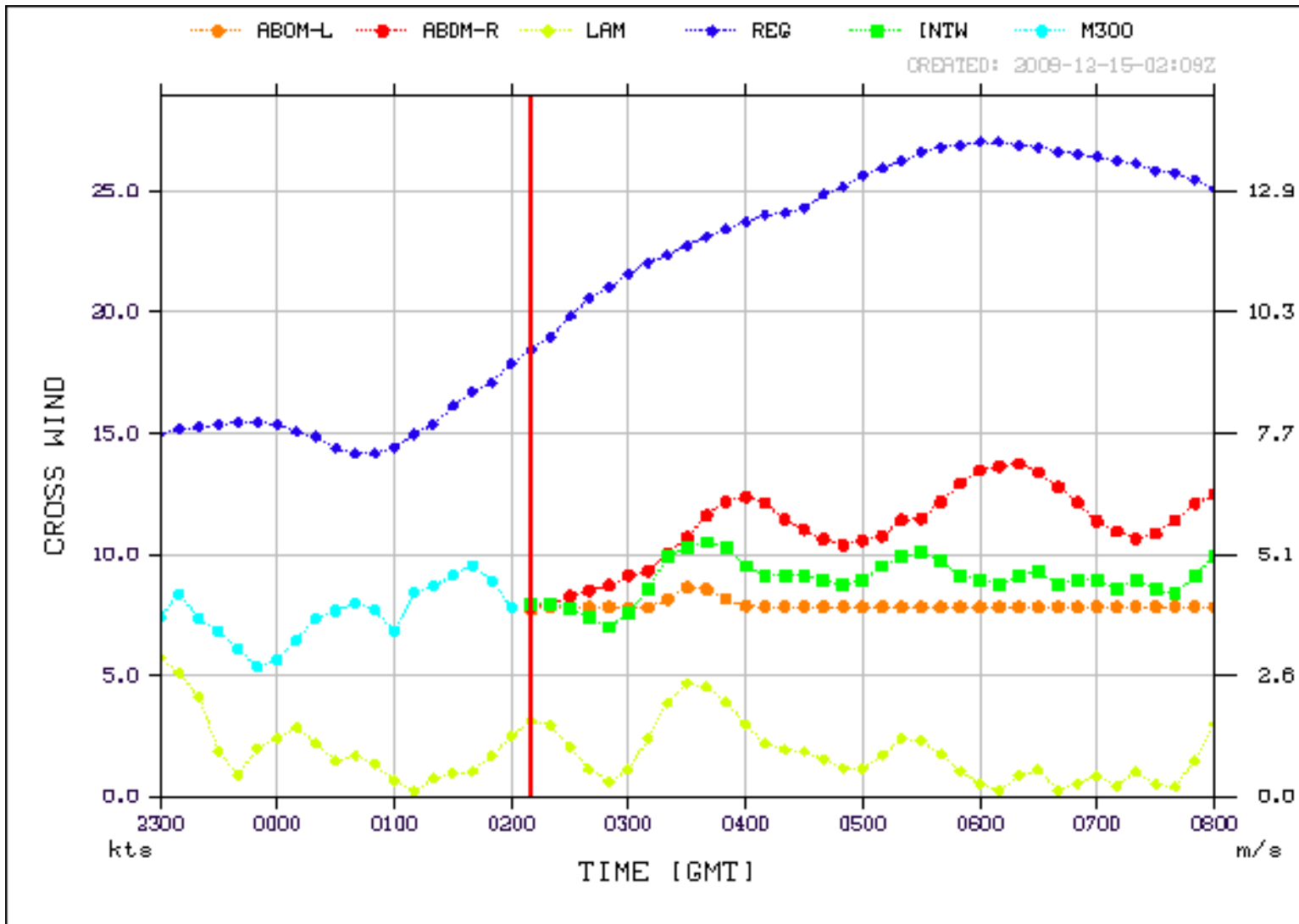
Nowcasting Error Tables for ABOM_LAM at CYVR

View MAE for: ABOM_REG | ABOM_LAM | INTW | KALF_REG | KALF_LAM

Mean Absolute Error (MAE) for valid times in the past 6 hours by forecast lead time																	
Model Run Time: 2009-12-09 16:30 GMT																	
	0m	10m	20m	30m	40m	50m	1h	1h10m	1h20m	1h30m	1h40m	1h50m	2h	3h	4h	5h	6h
TEMP [C]	N/A	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.7	0.9	1.2	1.7
RH [%]	N/A	1.7	2.5	2.8	3.1	3.4	3.7	3.9	4.1	4.2	4.3	4.3	4.4	4.8	6.9	10.5	16.0
WINDSPD [m/s]	N/A	0.3	0.4	0.5	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.4	1.6
WINDDIR [deg]	N/A	5.3	5.9	5.9	5.6	5.8	5.4	6.3	7.1	7.1	7.2	7.2	7.4	9.8	10.6	17.4	21.7
CEILING* [cat]	N/A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
VIS* [cat]	N/A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GUST [m/s]	N/A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XWIND 1 [m/s]	N/A	0.4	0.5	0.5	0.5	0.6	0.6	0.5	0.6	0.5	0.6	0.5	0.5	0.4	0.7	1.0	0.8
XWIND 2 [m/s]	N/A	0.4	0.5	0.5	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.7	0.6	0.7	0.9	0.7
XWIND 3 [m/s]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Mean Absolute Error (MAE) for past 6 hours used in INTW method				
Model Run Time: 2009-12-09 16:30 GMT				
	REG	LAM	RUC	INTW
TEMP [C]	1.1	2.2	2.2	1.2
RH [%]	17.7	23.7	9.8	3.6
WINDSPD [m/s]	0.4	1.6	2.2	1.1
WINDDIR [deg]	81.3	6.1	101.6	28.7
GUST [m/s]	0.0	6.7	6.3	6.6
XWIND 1 [m/s]	0.7	2.2	3.2	0.7
XWIND 2 [m/s]	0.6	1.8	2.5	1.3
XWIND 3 [m/s]	N/A	N/A	N/A	N/A
File generated on December 09 2009 16:38 GMT				

Error Analysis Done in Real Time

Main Goals of SNOW-V10
Related to Nowcasting in Complex Terrain
(Developed at March 08 Workshop)

- **To improve our understanding and ability to forecast/nowcast low cloud, and visibility;**

- **To improve our understanding and ability to forecast precipitation amount and type**;

- **To improve forecasts of wind speed, gusts and direction;**

- **To develop better forecast system production system(s).**

- **Assess and evaluate value to end users;**

- **To increase the capacity of WMO member state**s (Training component).

Participating Groups

Observing Systems and Associated Nowcast Systems
- EC Region OAN Sites
- EC Research Sites
- UBC (McKendry) and U. Manitoba (Stewart)
- NCAR WSDDM System + (Rasmussen)
- BOM STEPS System (Seed)
- NSSL Radar (Forsyth)
- FMI (Koistinen)

Modeling Systems
- EC Research Models
- WDT (Carpenter)
- China (Donghai Wang)
- Austria INCA (Haiden)
- Germany (Bott)
- Switzerland (Mueller)

Verification
- EC Team
- NCAR (Brown)

The Winter Olympic Challenge

Steep topography, highly variable weather elements in space and time
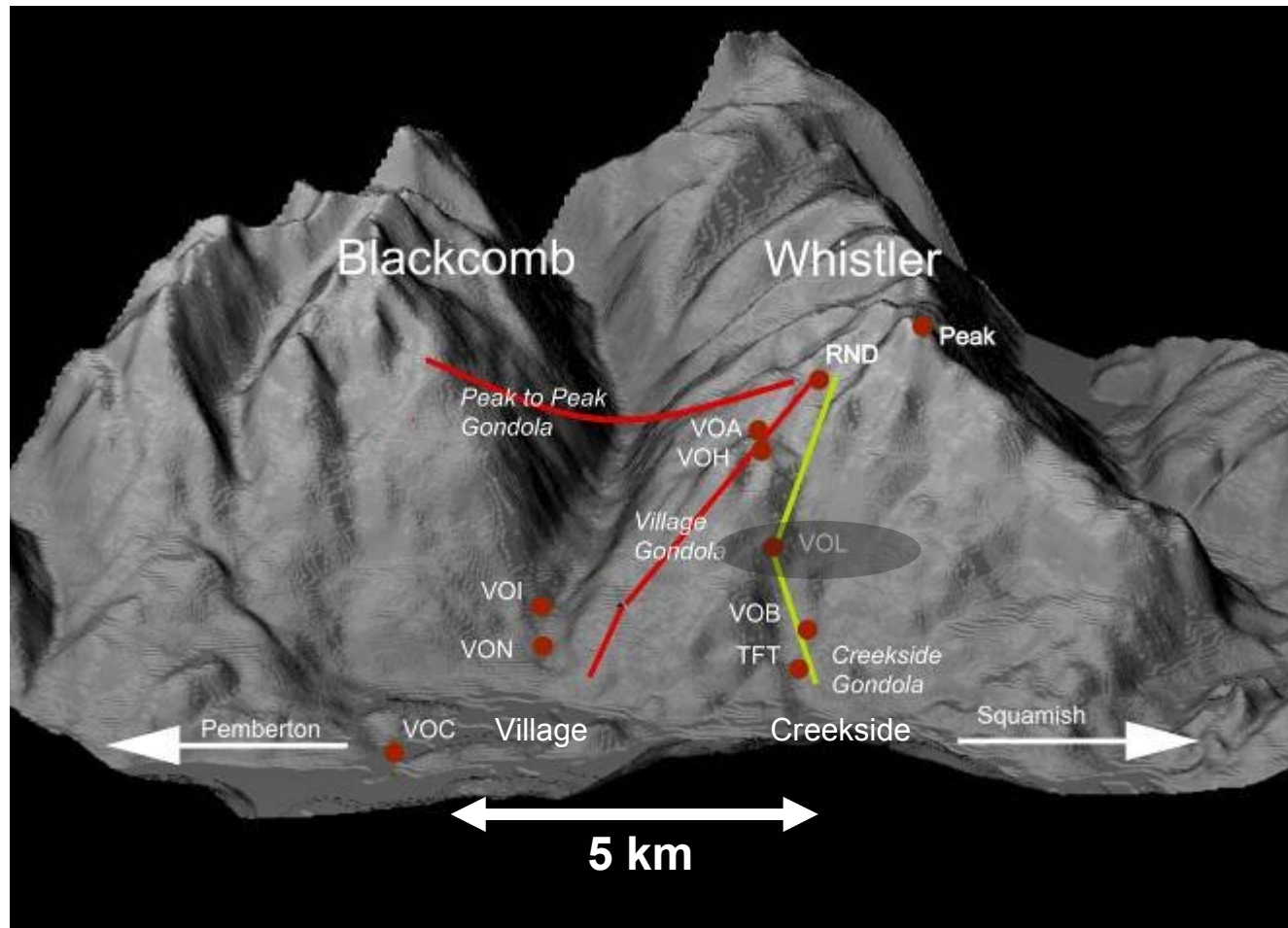
Cypress Mountain
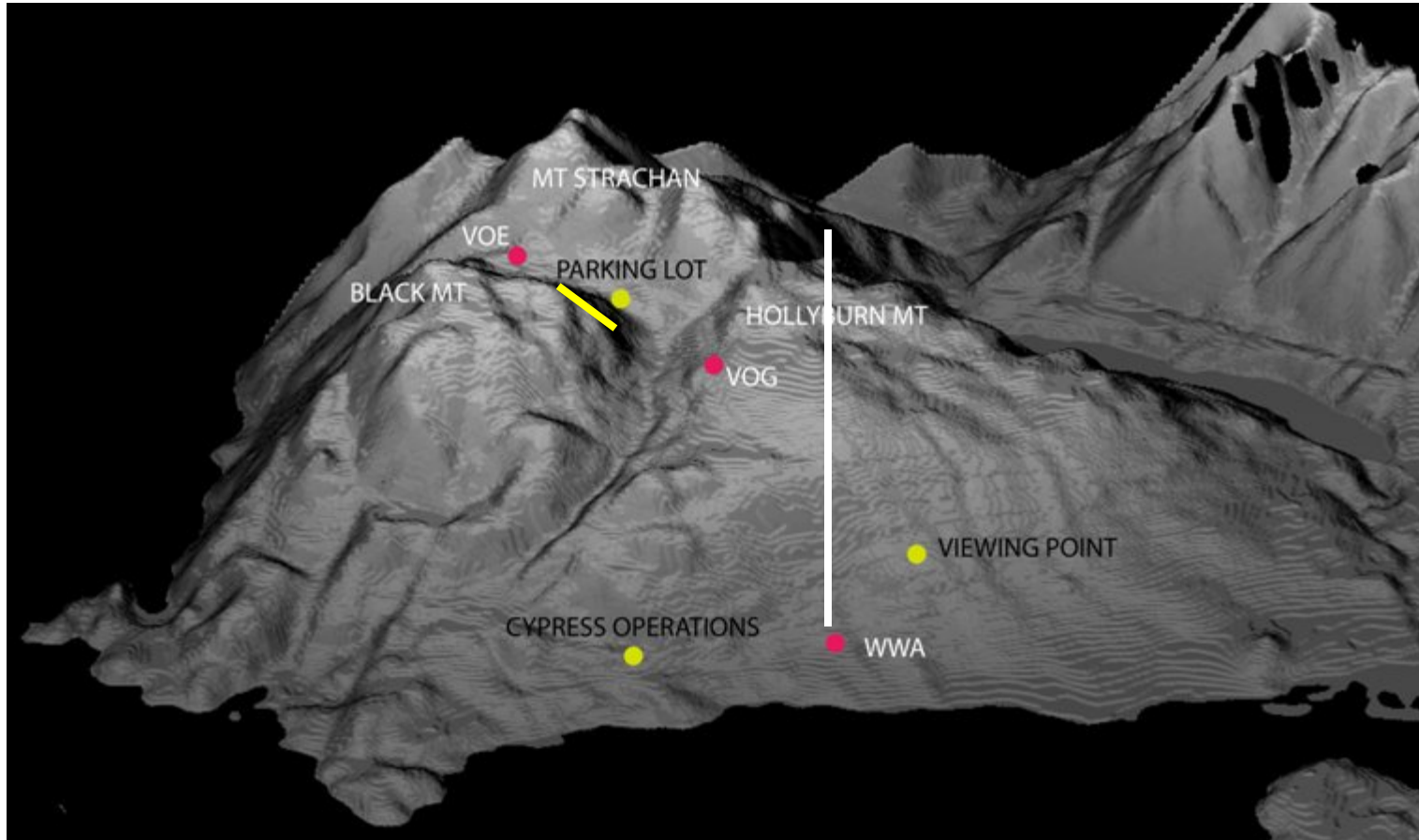
Summary of Instruments

- Callaghan scanning C-Band Radar located near Whistler.
- NOAA/OU X-Band Dual- Polarization Radar located at Canada/U.S. Border south of Vancouver.
- Vertically Pointing X-Band Radars were located at TFT, RND and WWA.
- A 915 MHz Boundary Layer Wind Profiler located at Squamish Airport (WSK).
- A profiling microwave radiometer located at Timing Flats (TFT)
- A rawindsonde system located at Nesters (VOC).
- Ceilometers located at YVR, WWA, TFT, WSK, WGP, and VOG,
- Recording visibility meters located at VOA, VOL, RND, VOT, VOG and YVR.
- Hot Plates located at YVR, VOG, RND, VOA, VOL and TFT
- Present weather sensors, either the Vaisala FD12P, Parsivel or POSS located at VOA, VOL, VOD, WWA, WSK, YVR, TFT, VOT, RND, and VOG,
- A 3D anemometer located at the ski jump (VOW).
- Temperature, relative humidity and GPS sensors were installed on the Whistler Village to Roundhouse Gondola, and the Whistler to Blackcomb gondola.
- The Roundhouse site, near the helipad, was instrumented with a significant list of equipment. as an extension of the Fog Remote Sensing and Modeling Project (FRAM) (Gultepe et al., 2009).
- Special surface sites measuring temperature and humidity were installed by UBC up Whistler Mountain
- Snow Density measurements were made at some selected sites, mainly VOA, VOL RND and VOC after significant snowstorms.
- Snow Photographs were made continuously at RND as a special project during some intensive periods and then irregularly outside those periods.
-

Summary Charts for 12 Feb to 21 March 2010

Visibility CDF Feb 12 to Mar 21 2010

Legend:
- VOT FD12P
- VOL PARS
- VOL FD12P
- VOA FD12P
- RND FD12P
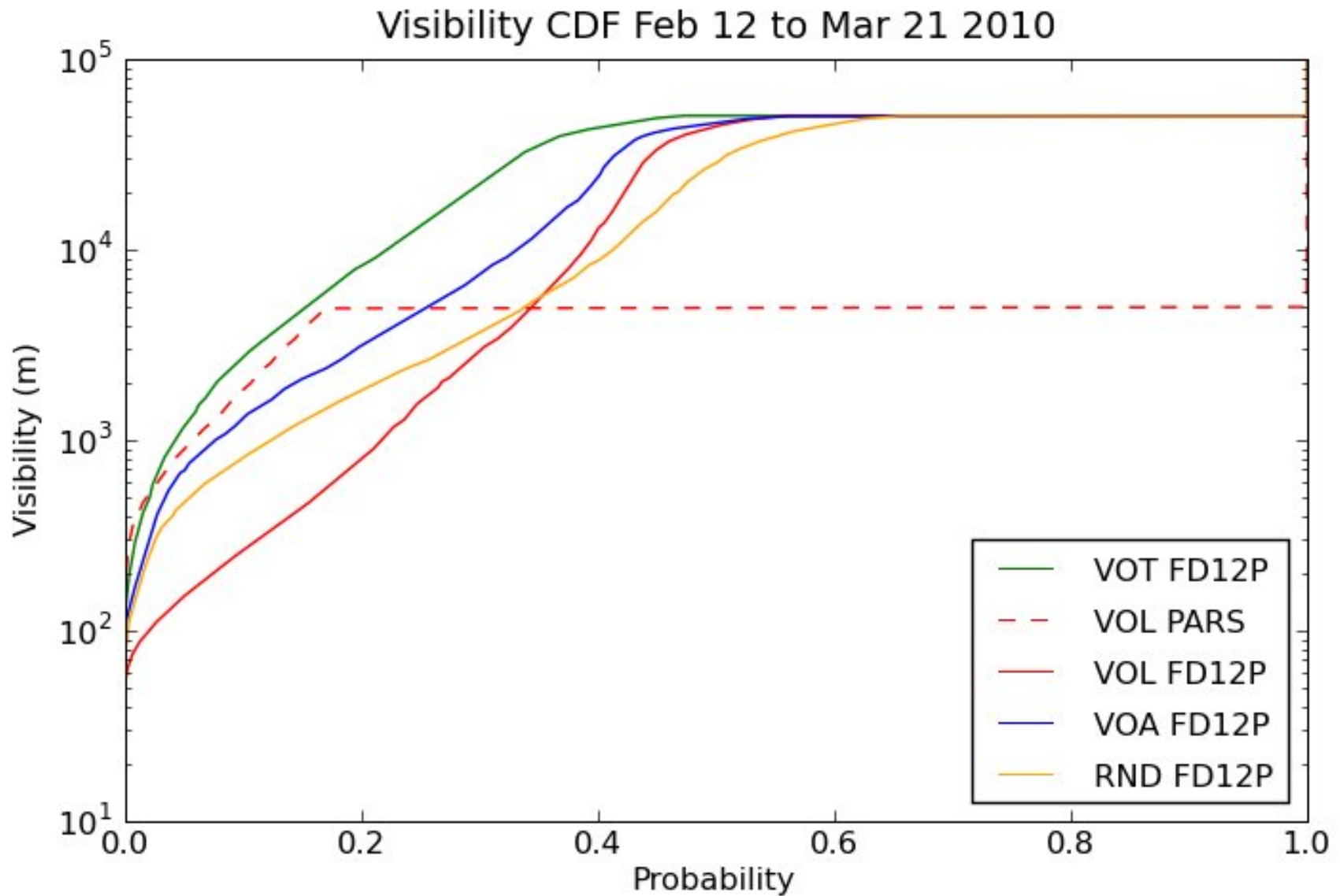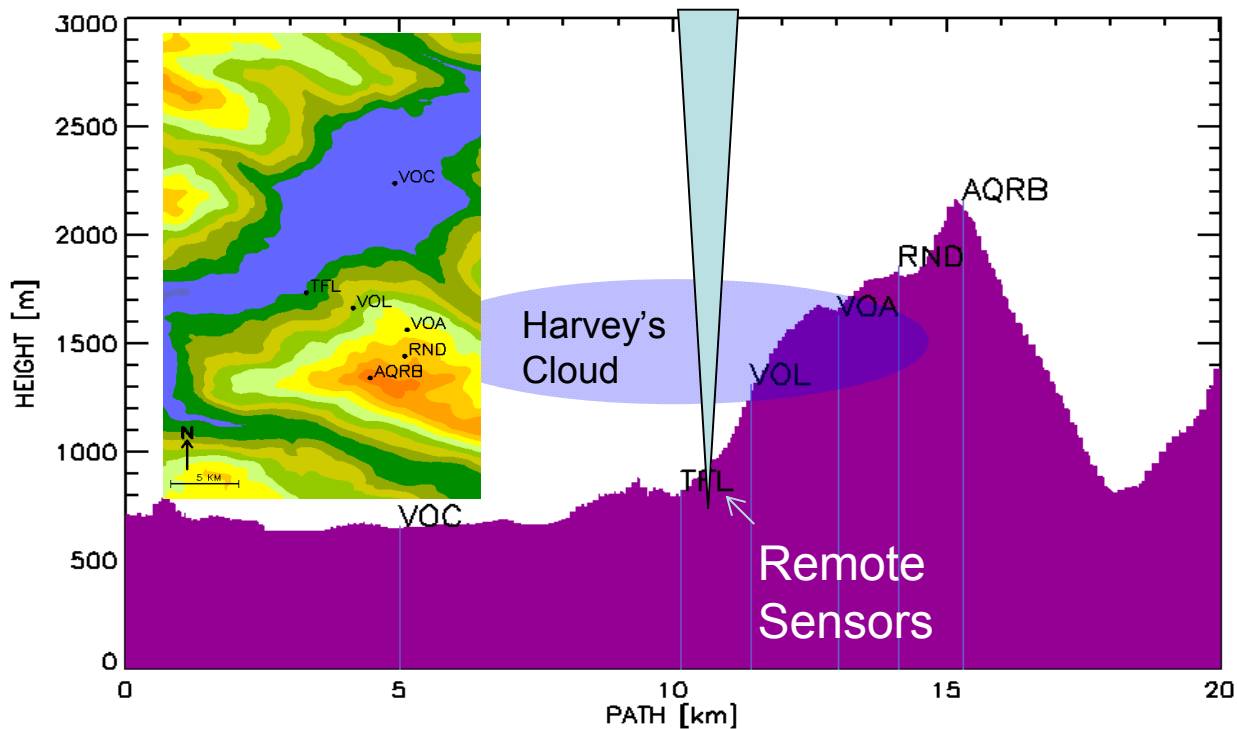
Equipment on Whistler mountain provided good data for forecasters and help in understanding weather processes
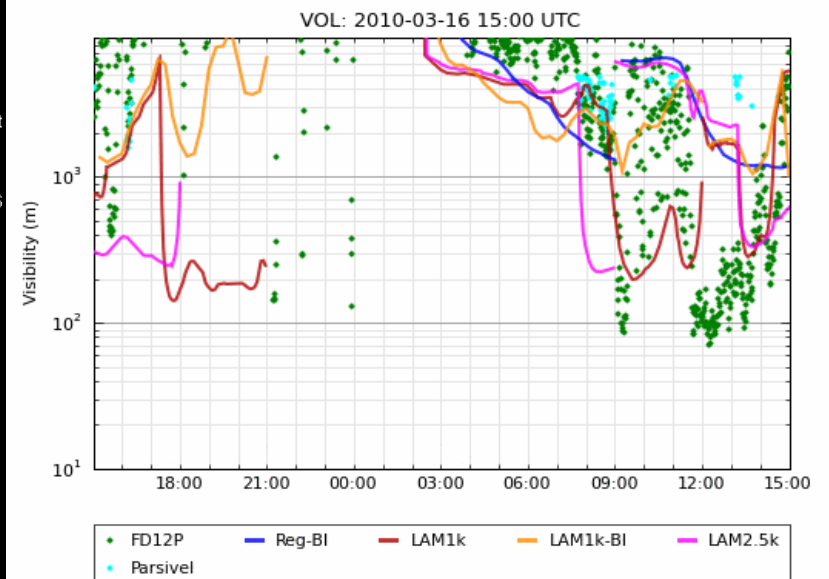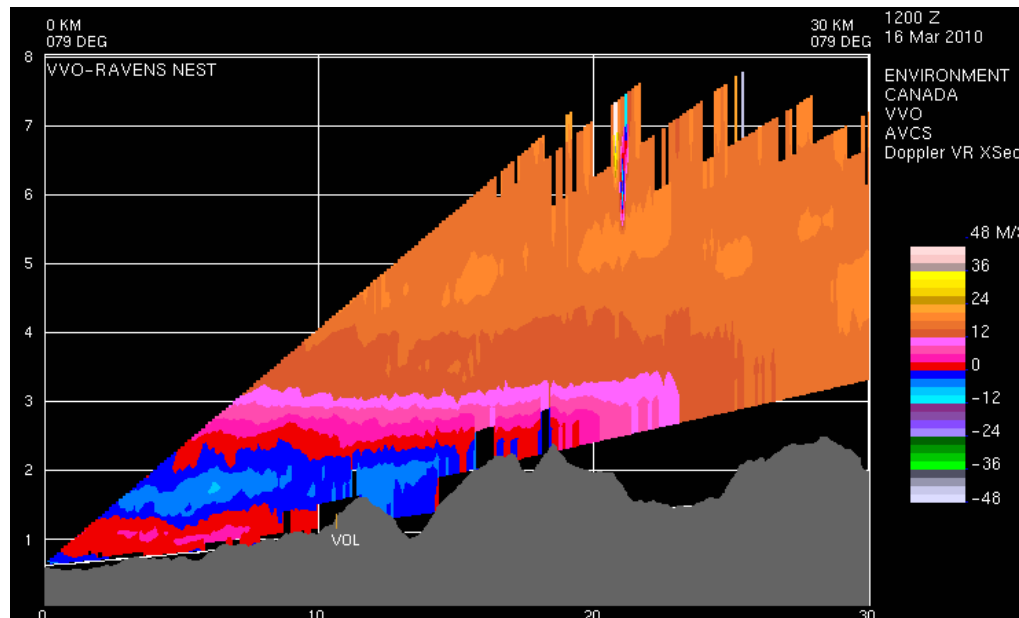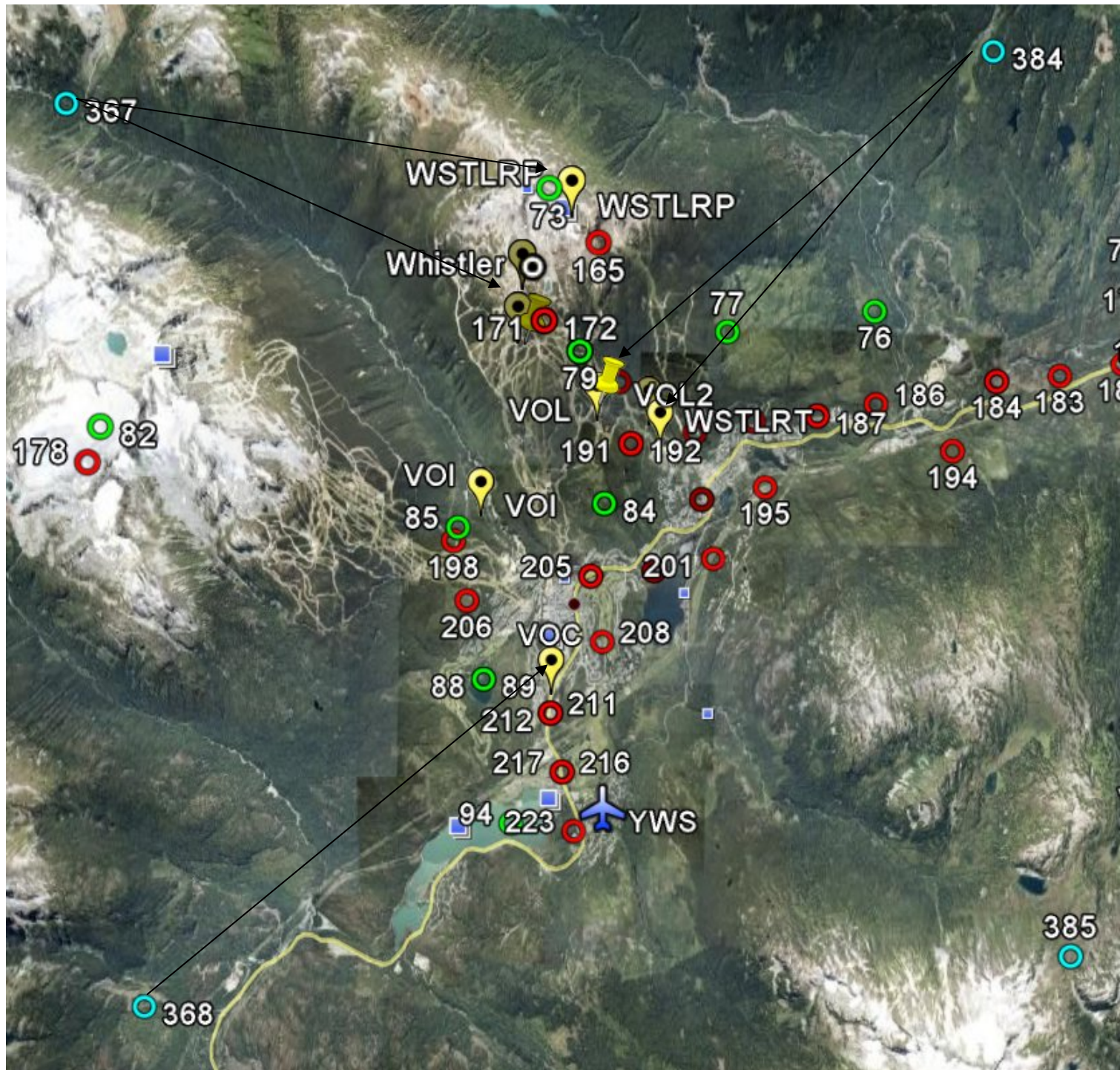
Canadian Models Used in SNOW-V10

| Model Name	Organization	Country	Spatial Resolution	Temporal Resolution Available	Times of Day Run (UTC)	Length of Forecst (hours)	General Description
ABOMLAM1km	Environment Canada	Canada	1 Km	15 min	Every 15 min	Max 6 h	Adaptive Blending of Observation and Models using GEM LAM1k
ABOMREG	Environment Canada	Canada	15 km	15 min	Every 15 min	Max 6 h	Adaptive Blending of Observation and Models using GEM Regional
INTW	Environment Canada	Canada	1 and 15 km	15 min	Every 15 min	Max 6 h	INTegrated Weighted Model using LAM1k, GEM Regional and Observations
LAM1k	Environment Canada	Canada	1 km	30 s (Model), 15 min (Tables)	11 and 20 UTC	19 h	Limited-Area version of GEM model
LAM2.5k	Environment Canada	Canada	2.5 km	1 min (Model), 15 min (Tables)	06 and 15 UTC	33 h	Limited-Area version of GEM model
REG	Environment Canada	Canada	15 km	7.5 min (Model), 15 min (Tables)	00, 06, 12, 18 UTC	48 h	Regional version of GEM (Global Environmental Multiscale) model

Other Countries Models Used in SNOW-V10

Model Name	Organization	Country	Spatial Resolution	Temporal Resolution Available	Times of Day Run (UTC)	Length of Forecst (hours)	General Description
CMA	Chinese Meteorological Administration	China	15 km & 3 km	1 hour	00 and 12 UTC	48 h & 24 h	CMA GRAPES-Meso NWP model
WDTUSL	Weather Decision Technologies and NanoWeather	USA	pointwise or 100 m grid		02, 08, 14, 20 UTC	48 h	Surface layer model nested in NAM. Works particularly well in quiescent condistions..
WSDDM	National Center for Atmospheric Research (NCAR)	USA	Radar Resolution	10 min (based on radar update)	Every 10 min	2 hours	Nowcast based on storm tracking of radar echo using cross correlation and real-time calibration with surface precipitation gauges.
ZAMGINCA	Central Institute for Meteorology and Geodynamics (ZAMG)	Austria	1 km	1 hour	Every hour	18 hours	The *Integrated Nowcasting Through Comprehensive Analysis* (INCA) system uses downscaled ECMWF forecasts as a first guess and applies corrections according to the latest observation.
ZAMGINCARR	Central Institute for Meteorology and Geodynamics (ZAMG)	Austria	1 km	15 min	Every 15 min	18 hours	The precipitation module of INCA combines raingauge and radar data, taking into account intensity-dependant elevation effects. The forecasting mode is based on displacement by INCA motion vectors, merging into the ECMWF model through prescribed weighting.
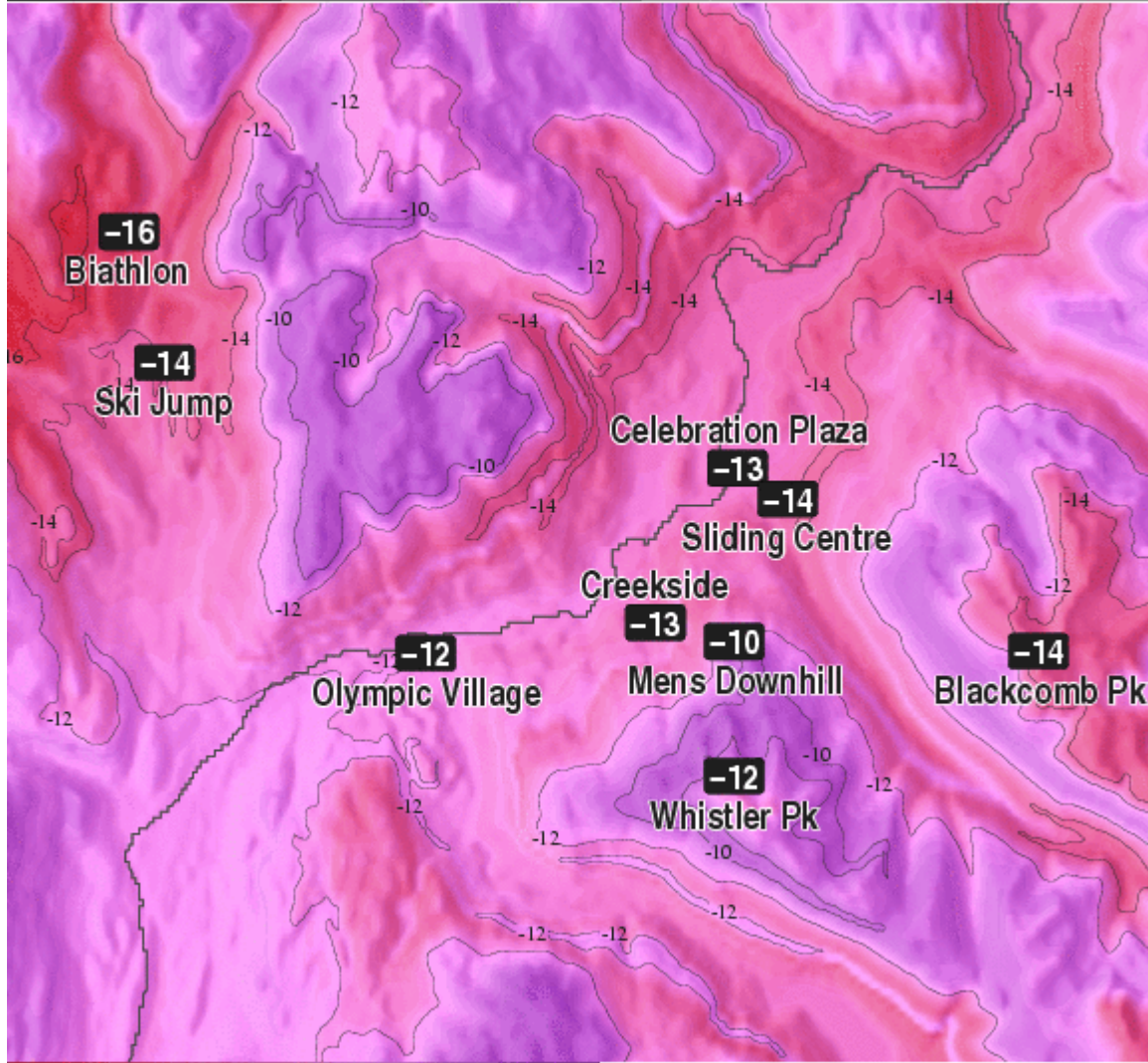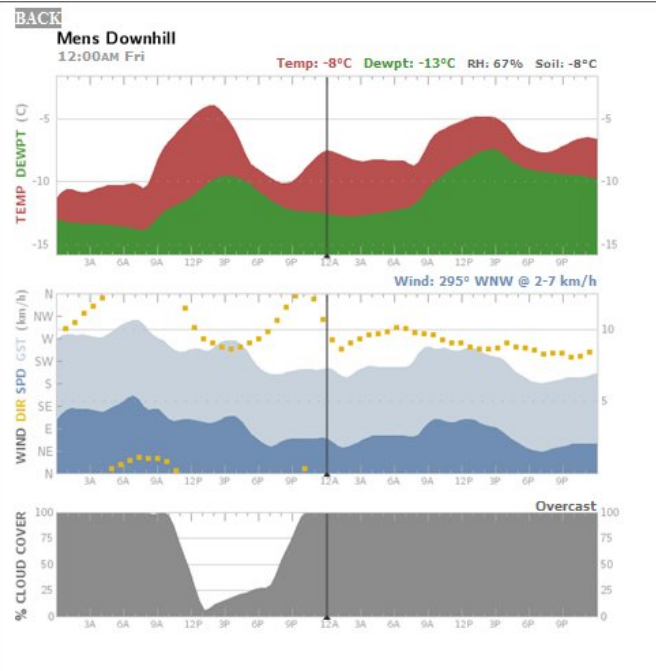
Weather Decision Technologies (WDT) Products for Vancouver 2010

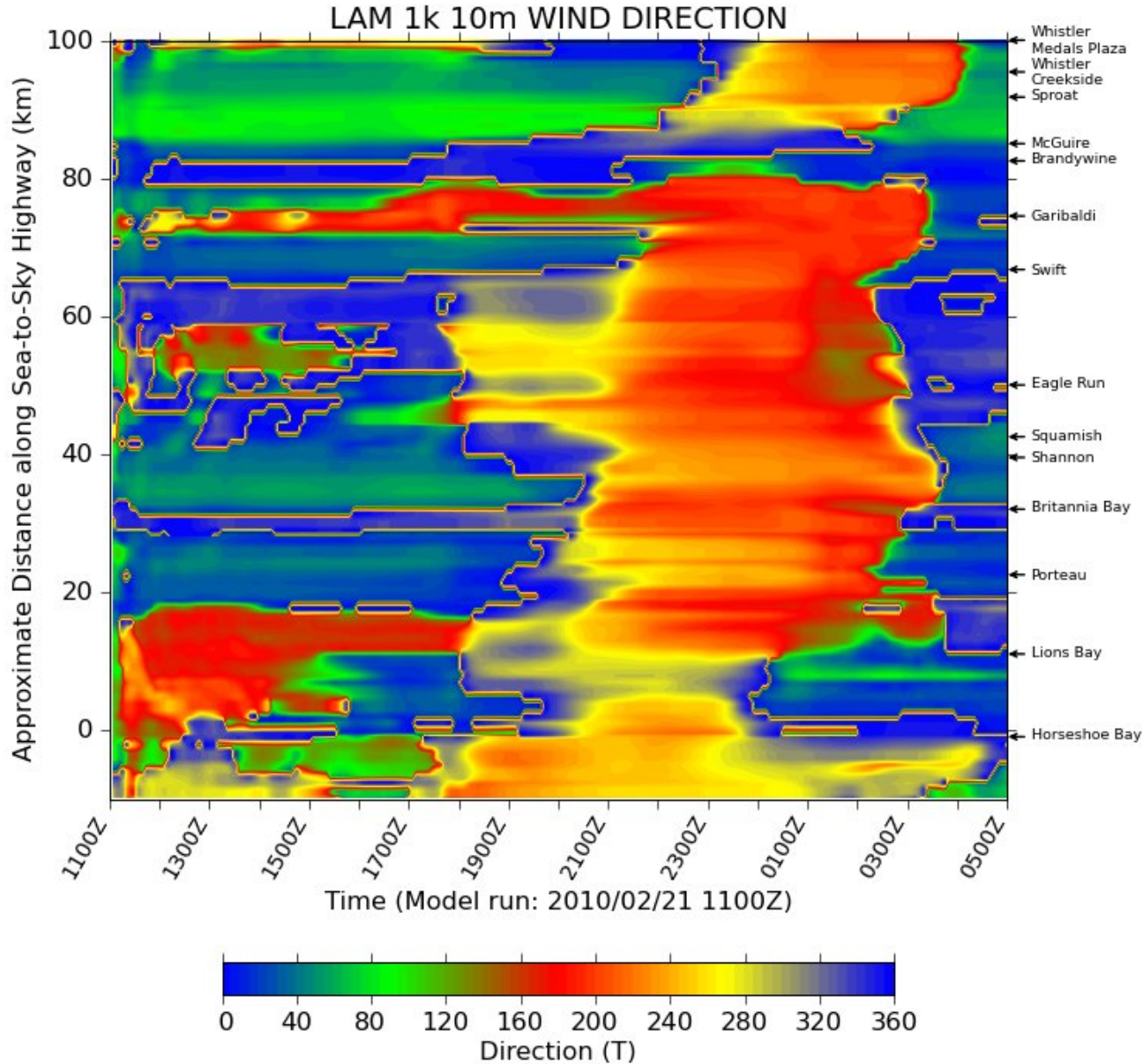2m-temperature [°C] base: 20091125 0600 + 03h (valid: 20091125 0900)
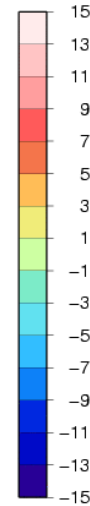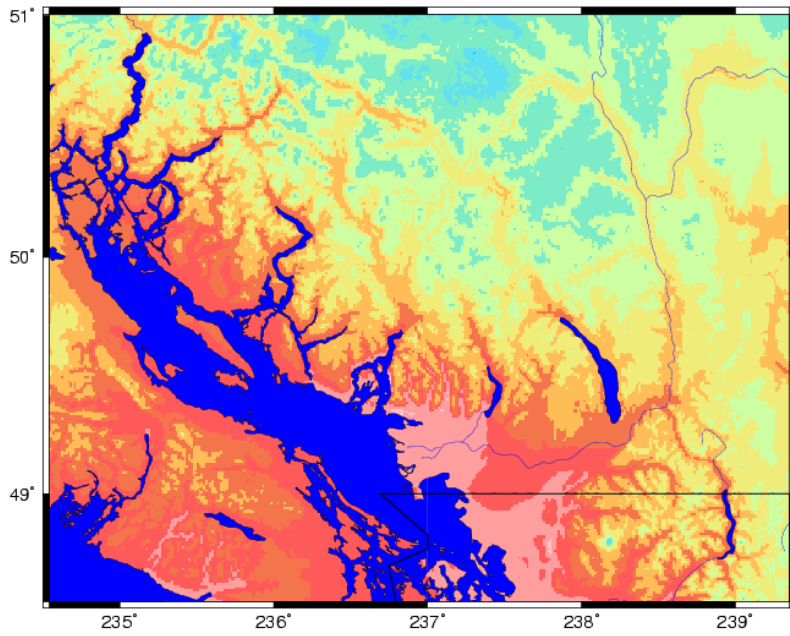
INCA (Integrated Nowcasting through Comprehensive Analysis) developed at the Austrian national weather service

Products were available in real time for forecaster use and evaluation
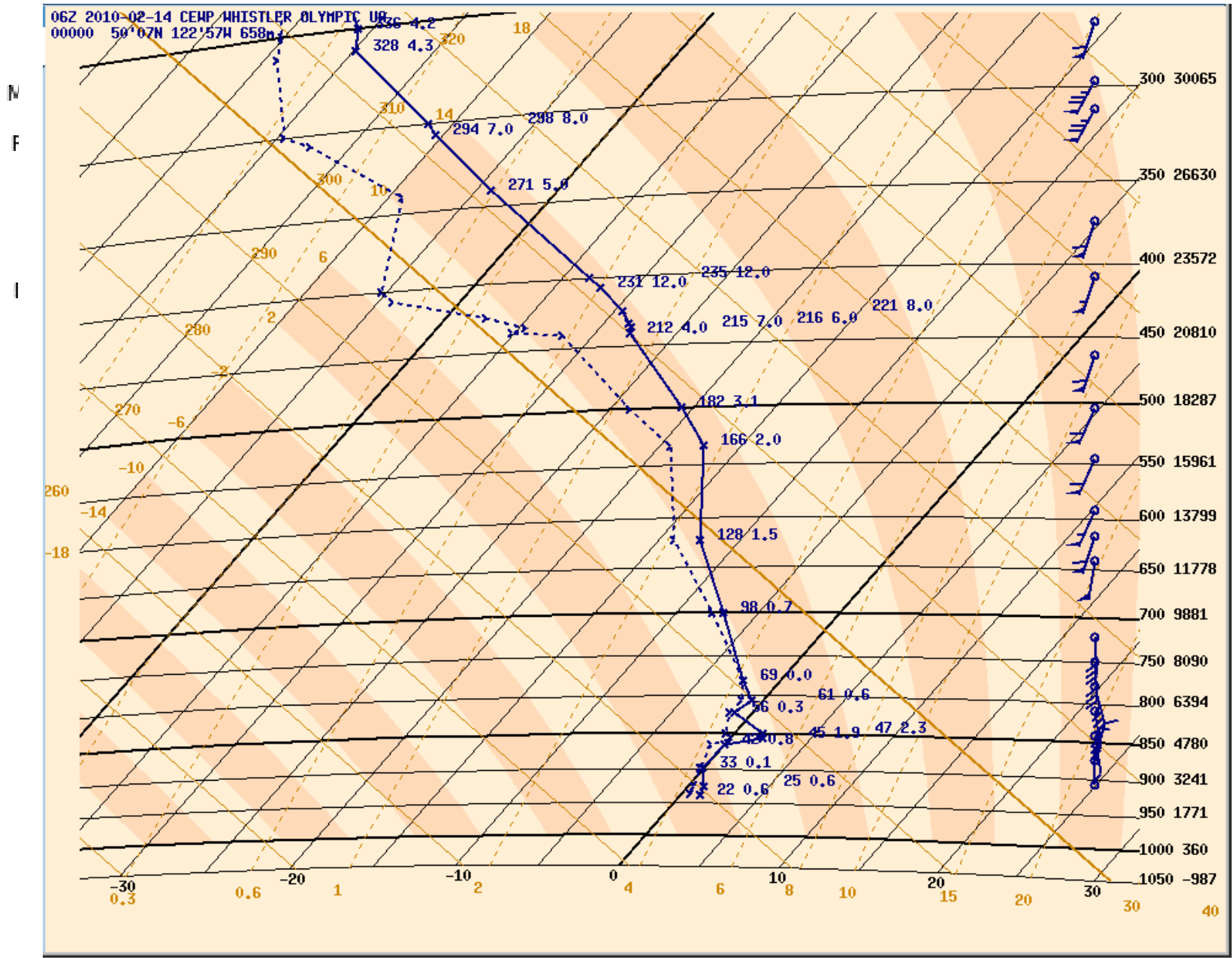
Snowfall line [m] base: 20091125 0600 + 03h (valid: 20091125 0900)
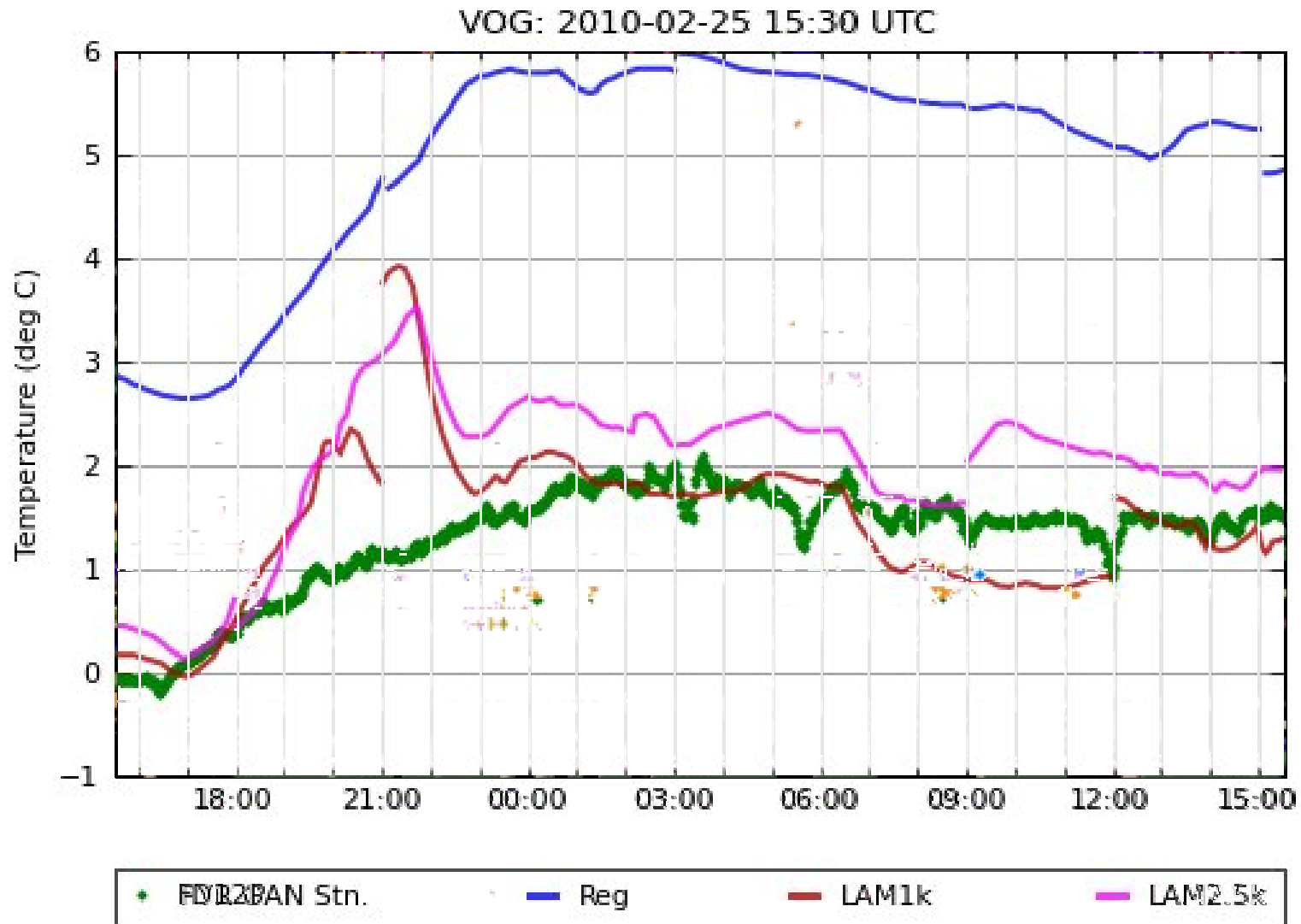
LAM 1k 10m WIND DIRECTION
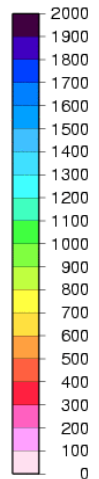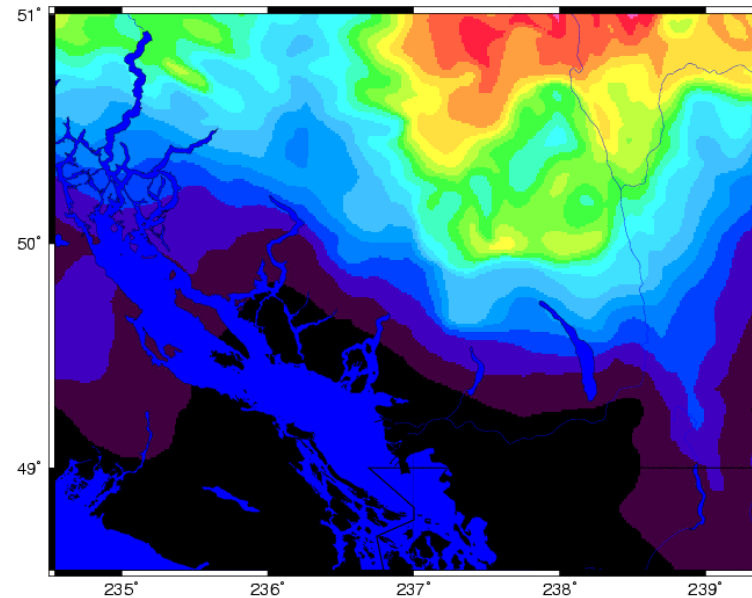
GEM LAM for points along Sea to Sky Highway showing flow reversal with day time heating. Note 23 Z is 15 Local Time.

Freestyle Skiing Ladies Aerials Final
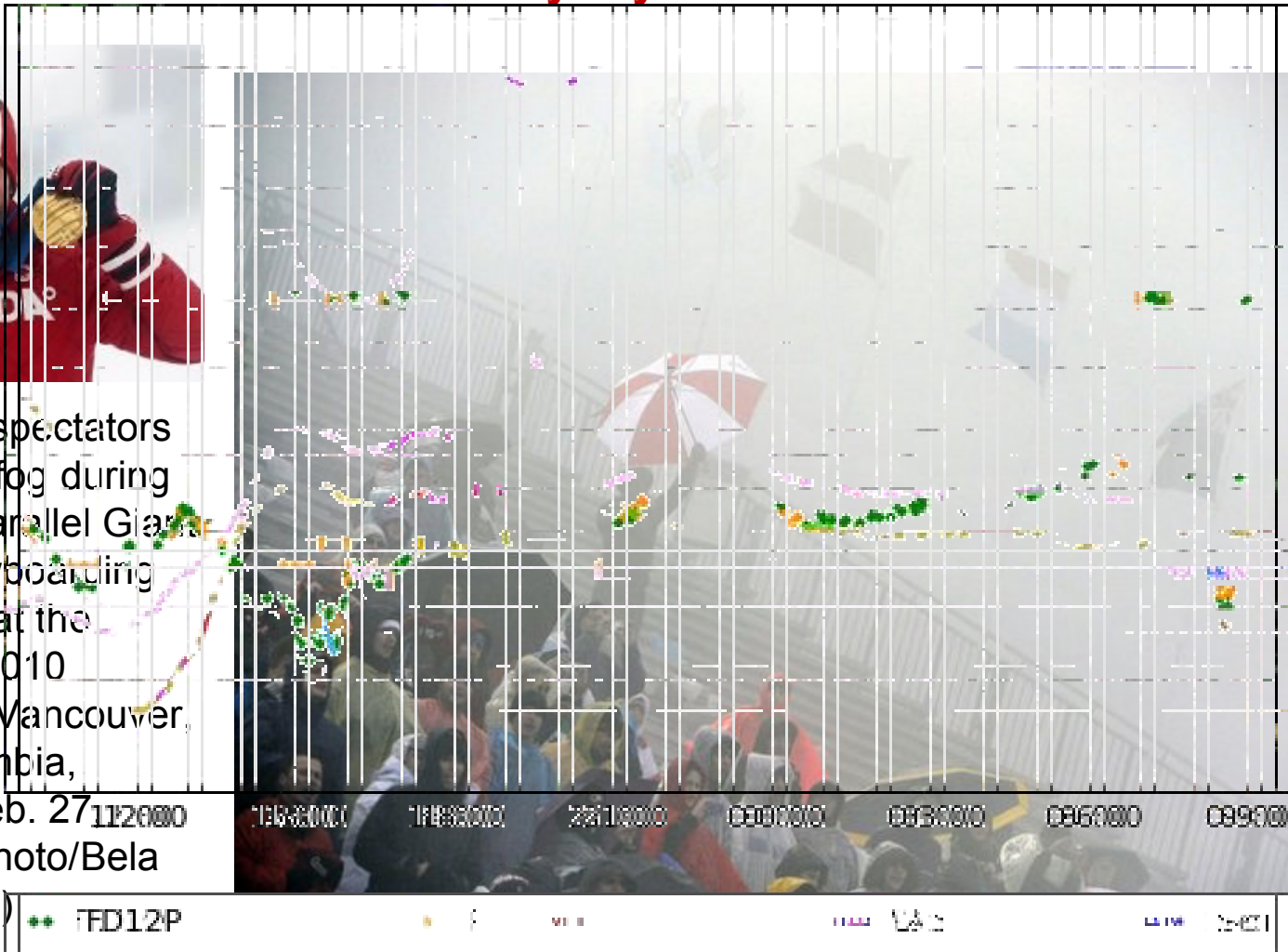
VOG: 2010-02-25 15:30 UTC

Snowboard Men's Parallel Giant Slalom Final
February 27, 2010
Gold Medal to Jassey Jay Anderson of Canada

Snowboard spectators stand in the fog during the men's Parallel Giant Slalom snowboarding competition at the Vancouver 2010 Olympics in Vancouver, British Columbia, Saturday, Feb. 27 2010. (AP Photo/Bela Szandelszky)

Products During Olympics

SNOW-V10 : Science of Nowcasting Winter Weather for Vancouver 2010

ABOMLAM1KM	ABOMREG	CMA	INTW	LAM1K	LAM2.5K	REG	WDTUSL	WSDDM	ZAMGINCA	ZAMGINCARR

PEK	RND	VOA	VOB	VOC	VOD	VOE	VOG	VOI	VOL	VON	VOT	VOW	VOX	VOZ	VWB	WGP	WSK	WWA	YVR

LAM1K VOG Forecast   download csv   model descriptions   back to snow-v10 »

run time (UTC)	valid time (UTC)	Clouds	Temp. °C	Dew Pt.	RH (%)	Wind (°/kts)			Visibility (km)			Ceiling (km)			Precip. Type	Frozen/Solid		Rain		Frozen Liquid Equiv.		All Precip. Liquid Equiv.	
						dir	speed	max	inst.	min	max	inst.	min	max		Rate (cm/h)	Accum. (cm)	Rate (mm/h)	Accum. (mm)	Rate (mm/h)	Accum. (mm)	Rate (mm/h)	Accum. (mm)
20Z 2010-02-25 03:15:00		10/10	1.7		99	172	3.1	8.5	Inf	Inf	Inf	Inf	Inf	Inf		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20Z 2010-02-25 03:30:00		10/10	1.7		100	172	3.2	8.7	Inf	Inf	Inf	0.90	0.90	1.28		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20Z 2010-02-25 03:45:00		10/10	1.7		100	179	3.5	11.8	0.27	0.27	Inf	0.02	0.02	0.90		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20Z 2010-02-25 04:00:00		10/10	1.8		100	181	3.7	12.6	0.22	0.21	0.27	0.02	0.02	0.02		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20Z 2010-02-25 04:15:00		10/10	1.8		100	182	4.3	13.8	0.18	0.18	0.22	0.02	0.02	0.02		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20Z 2010-02-25 04:30:00		10/10	1.8		100	180	4.4	14.0	0.14	0.14	0.18	0.02	0.02	0.02	Drizzle	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
20Z 2010-02-25 04:45:00		10/10	1.9		100	181	4.7	14.6	0.13	0.13	0.14	0.02	0.02	0.02		0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00
20Z 2010-02-25 05:00:00		10/10	1.9		100	184	5.1	15.8	0.13	0.13	0.13	0.02	0.02	0.02	Rain	0.07	0.00	0.52	0.10	0.24	0.00	0.76	0.10
20Z 2010-02-25 06:00:00		10/10	1.8		100	194	5.6	18.7	0.14	0.13	0.14	0.02	0.02	0.02	Rain	0.30	0.00	1.95	1.00	1.04	0.50	3.00	1.70
20Z 2010-02-25 07:00:00		10/10	1.3		100	211	4.5	18.3	0.13	0.13	0.15	0.02	0.02	0.02	Rain/drizzle & snow	0.86	0.00	1.55	2.40	1.55	2.00	3.13	4.40
20Z 2010-02-25 08:00:00		10/10	1.1		100	213	3.7	10.8	0.14	0.13	0.14	0.02	0.02	0.02	Rain	0.11	0.00	1.71	1.10	0.53	0.70	2.24	1.80
20Z 2010-02-25 09:00:00		10/10	0.9		100	208	2.1	9.9	0.16	0.14	0.16	0.02	0.02	0.02	Rain	0.02	0.00	0.14	0.80	0.04	0.60	0.18	1.50
20Z 2010-02-25 10:00:00		10/10	0.8		100	207	2.1	6.8	0.18	0.16	0.18	0.02	0.02	0.02		0.00	0.00	0.01	0.10	0.00	0.00	0.01	0.10
20Z 2010-02-25 11:00:00		10/10	0.8		100	183	2.0	2.1	0.23	0.18	6.66	0.02	0.02	2.29		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20Z 2010-02-25 12:00:00		10/10	0.9		100	190	3.2	9.2	0.20	0.19	0.23	0.02	0.02	0.02		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20Z 2010-02-25 13:00:00		9/10	1.0		100	170	2.6	9.1	0.16	0.15	0.20	0.02	0.02	0.02	Drizzle	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
20Z 2010-02-25 14:00:00		10/10	0.9		100	159	3.8	9.3	0.14	0.14	0.17	0.02	0.02	0.02	Drizzle	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00

- A SNOW-V10 web site was created with many of the products (time series for sites, remote sensing products, area displays, soundings (gondola and others), and a very successful Blog.

Verification
Data Details: Model Points

- Closest model points to the airports are selected
- Verification data set uses data from the most current model run with the exception of GEM Regional where a 3 hour spin up time is removed
- Note that the selected CYVR RUC point falls under the model water mask

	Model Run Times	Model Resolution		Location	
		Horizontal	Temporal	CYYZ	CYVR
Actual Location	-	-	-	43.68, -79.63	49.19, -123.19
GEM Regional	0,6,12,18 Z	15 km	7.5 min	43.65, -79.68	49.22, -123.16
GEM LAM East	12 Z	2.5 km	5 min	43.67, -79.63	-
GEM LAM Olympic	9,21 Z up to Dec 9 6,15Z afterwards	2.5 km	1 min	-	49.18, -123.19
GEM LAM Olympic 1K	11,23 Z up to Dec 9 11,20 Z afterwards	1 km	30 sec	-	49.18, -123.17
RUC	Every hour	13 km	1 hour	43.66, -79.70	49.19, -123.21

Data Details: Variables

Variable	Instrument		Model Variable Name				
	CYYZ	CYVR	REG	LAM EAST	LAM OLY	LAM 1K	RUC
Temperature (2m)	Campbell HMP45C212	Campbell HMP45C212	TJ	TJ	TJ	TJ	TMP @ 2m
Relative Humidity (2m)	Campbell HMP45C212	Campbell HMP45C212	HR	HR	HR	HR	RH @ 2m
Wind Speed (10m)	Ultrasonic WS425	78D	UU/VV	UU/VV	UU/VV	UU/VV	UGRD/VGRD @ 10m
Wind Direction (10m)	Ultrasonic WS425	78D	UU/VV	UU/VV	UU/VV	UU/VV	UGRD/VGRD @ 10m
Maximum Wind Speed (Gust) (10m)	Ultrasonic WS425	78D	FB calc	FB calc	FB calc	WGE	GUST @ sfc
Cross-Wind (10m)	Ultrasonic WS425 *	78D *	Calc *	Calc *	Calc *	Calc *	Calc *
Visibility	FD12P	FD12P	FB calc	FB calc	VIS	VIS	VIS @ sfc
Ceiling	CT25K	CL31	NU	N/A	H_CB	H_CB	DIST 0-CBL
Precipitation Rate	FD12P	FD12P	RC+RR	RC+RR	RC+RR	RT	PRATE @ sfc
Precipitation							

* Cross-winds specific to each runway configuration are calculated using wind information (speed, direction, max wind) from the designated wind sensor or model output

Data Details: Data Reduction

- Period covered is December 1, 2009 to March 31, 2010
- Model and instrument data are reduced to 10 min time intervals by:
  - Using the last instantaneous value for all REG variables
  - Linearly interpolating RUC data to 10 min (although hourly RUC data are compared in this work)
  - For LAMs and instrument data:
    - Using the average during last 10 min for temp, RH, wind speed, max wind, cross-winds
    - Using the minimum value during last 10 min for visibility and ceiling
    - Using the maximum value during last 10 min for precip rate
    - Using the most frequently occurring precip type in the last 10 min
- Only the RUC 6h forecast is compared in this work
- Observational persistence data are generated using 10 min reduced instrument data
- Climate data are generated using 30 years (1980-2009) of hourly observations at CYYZ and CYVR. One "climate" value was produced per hour using 30 points by:
  - Using the average value for temp, RH, wind speed
  - Using the median value for wind direction, ceiling, visibility

Continuous Variable Error Analysis

- Basic mean absolute (MAE) and mean (ME) errors are tabulated for a subset of variables
- Errors include all forecast lead times and times of day
- Provides a very average picture; model performance during significant events are washed out with long periods of uninteresting weather

<p style="text-align:center; color:red">Toronto Pearson Airport CYYZ</p>

Variable	CYYZ MAE					CYYZ ME			
	REG	LAM	RUC	CLI		REG	LAM	RUC	CLI
Temperature	1.7	2.3	1.9	3.9	deg C	-1.2	-1.4	-1.5	-1.2
Relative Humidity	10.5	9.0	12.3	11.0	%	8.6	4.9	11.8	4.5
Wind Speed	1.6	1.2	1.4	1.8	m/s	-1.4	-0.2	-0.7	-0.4
Wind Direction	19.4	20.6	23.7	75.4	deg	5.6	5.1	3.1	-29.6
Max Wind Speed	2.3	2.4	1.7	N/A	m/s	1.4	1.7	-0.2	N/A
Cross-Wind Rwy 1	2.8	2.9	2.4	N/A	m/s	0.0	0.1	-0.6	N/A
Cross-Wind Rwy 2	2.8	2.9	2.4	N/A	m/s	0.0	0.1	-0.6	N/A
Cross-Wind Rwy 3	2.6	2.7	2.3	N/A	m/s	0.2	0.5	-1.0	N/A

Continuous Variables - cont'd

Vancouver International Airport CYVR

Variable	CYVR MAE						CYVR ME				
	REG	LAM	RUC	CLI	LAM1K		REG	LAM	RUC	CLI	LAM1K
Temperature	1.4	1.1	1.7	2.7	1.4	deg C	-1.2	-0.5	0.8	-1.0	-1.0
Relative Humidity	8.0	7.7	10.5	9.2	7.1	%	2.7	-1.9	-4.3	-1.4	1.1
Wind Speed	1.4	1.4	2.6	1.7	1.3	m/s	-0.8	0.3	1.9	-0.2	-0.3
Wind Direction	40.8	42.4	48.4	55.5	42.6	deg	-8.1	1.9	16.5	8.3	-0.5
Max Wind Speed	2.0	2.8	3.1	N/A	1.9	m/s	0.4	1.8	2.1	N/A	-1.4
Cross-Wind Rwy 1	1.8	1.9	1.9	N/A	1.8	m/s	0.6	0.9	0.9	N/A	0.9
Cross-Wind Rwy 2	2.0	2.4	2.7	N/A	2.3	m/s	0.9	1.4	1.3	N/A	1.2

- RUC6h wind directions and cross-winds at CYVR have been corrected (Aug 26, 2010)
- Wind direction errors using the Climate data set are large and somewhat misleading (discussed later)

Time history of wind speeds at CYYZ during the period of winter assessment

REG underestimates wind speed
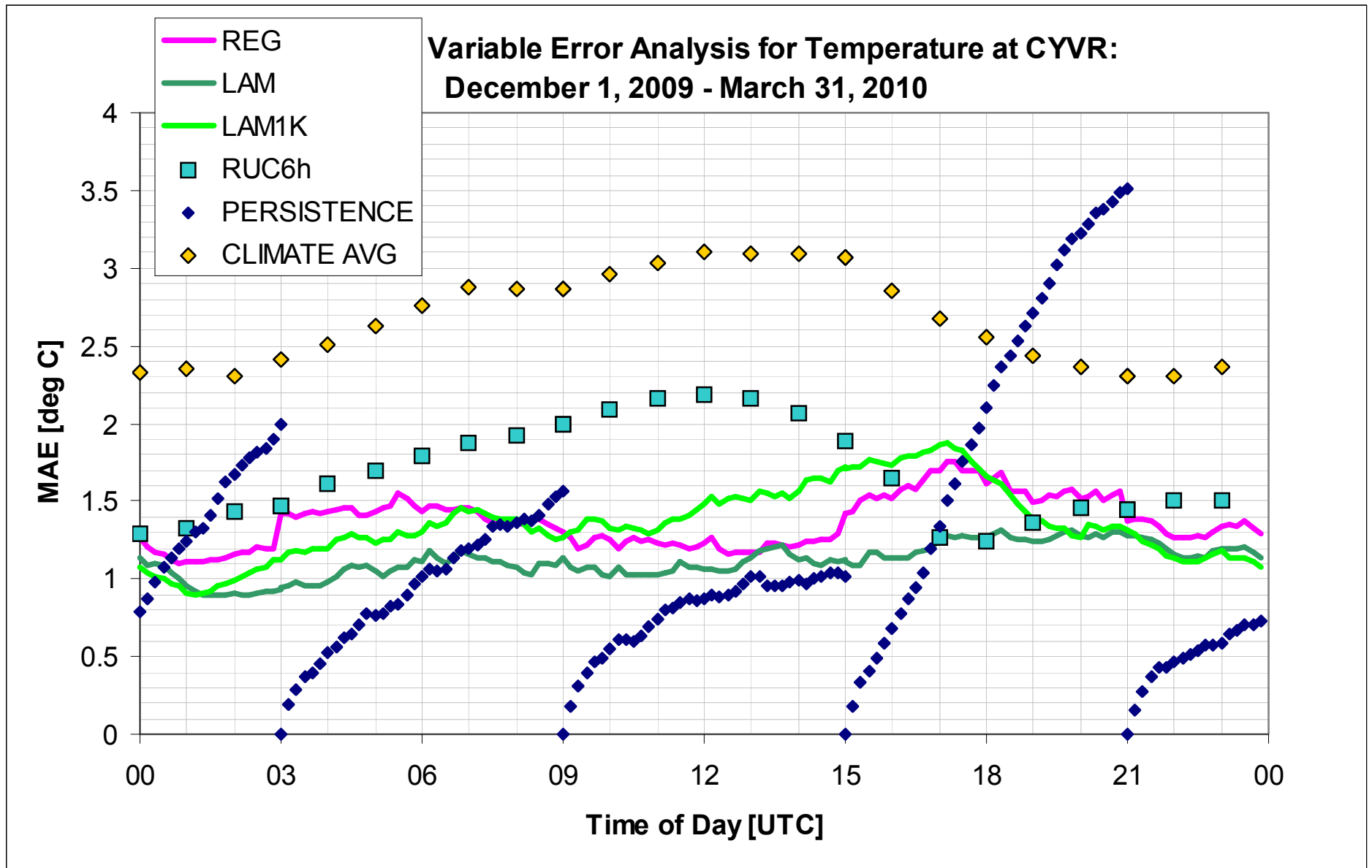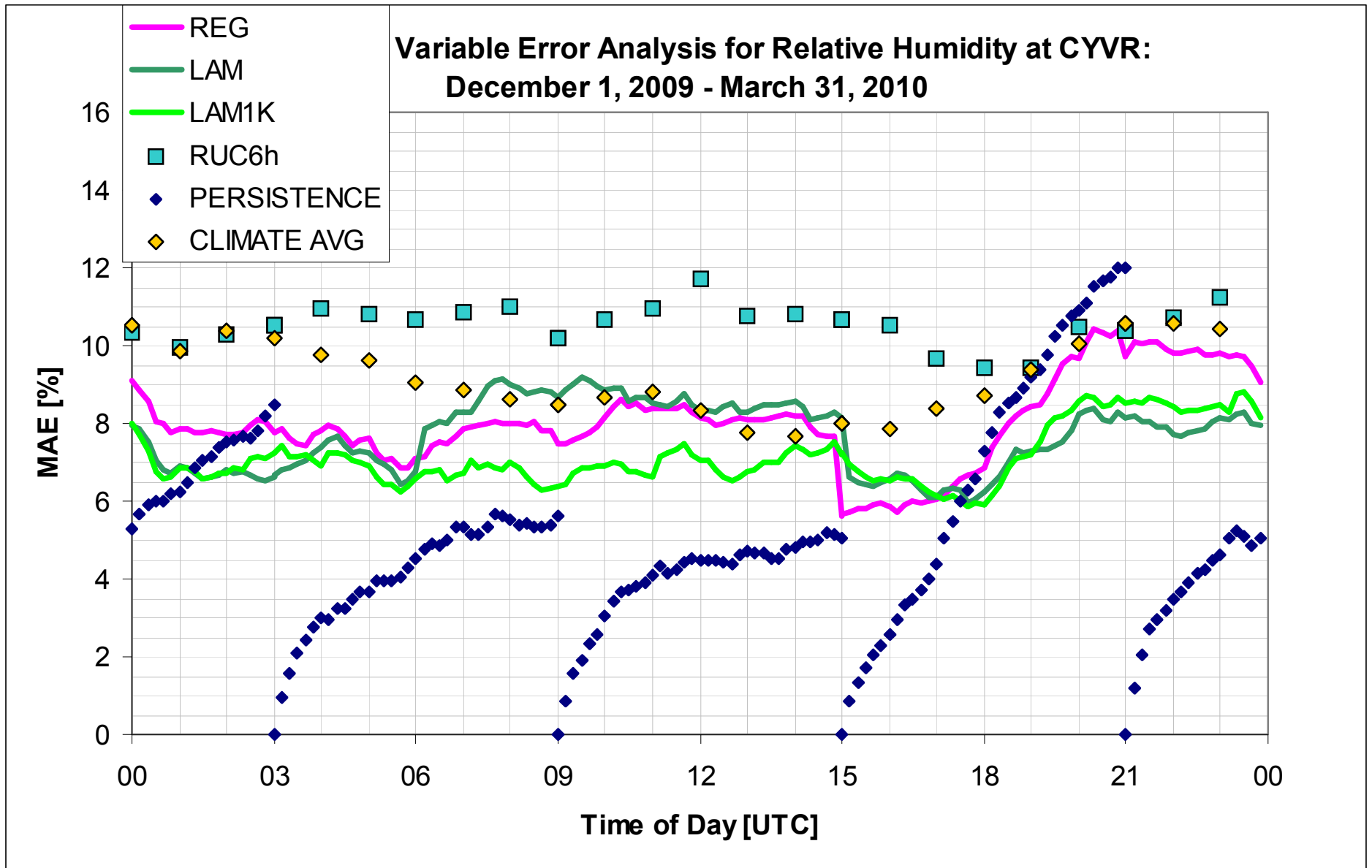

CYYZ: Wind Speed December 1 2009 - April 1 2010
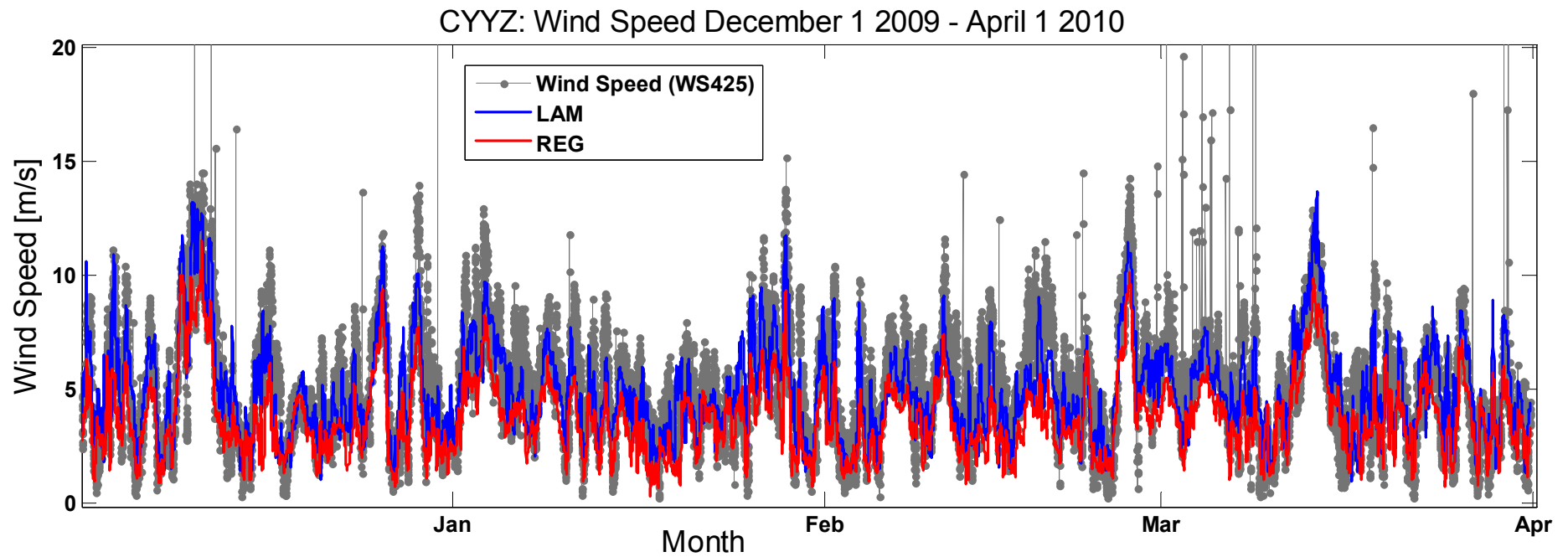
Continuous Variables: Time of Day

- MAE and ME can also be calculated at different times of the day (TOD)

- It can expose diurnal trends and differences relating to model spin up

- Only ~120 values (1 per day for 4 months) go into the mean error calculations

- Errors can be compared with observational persistence curves at specific times of the day (3, 9, 15, 21 Z presented here)
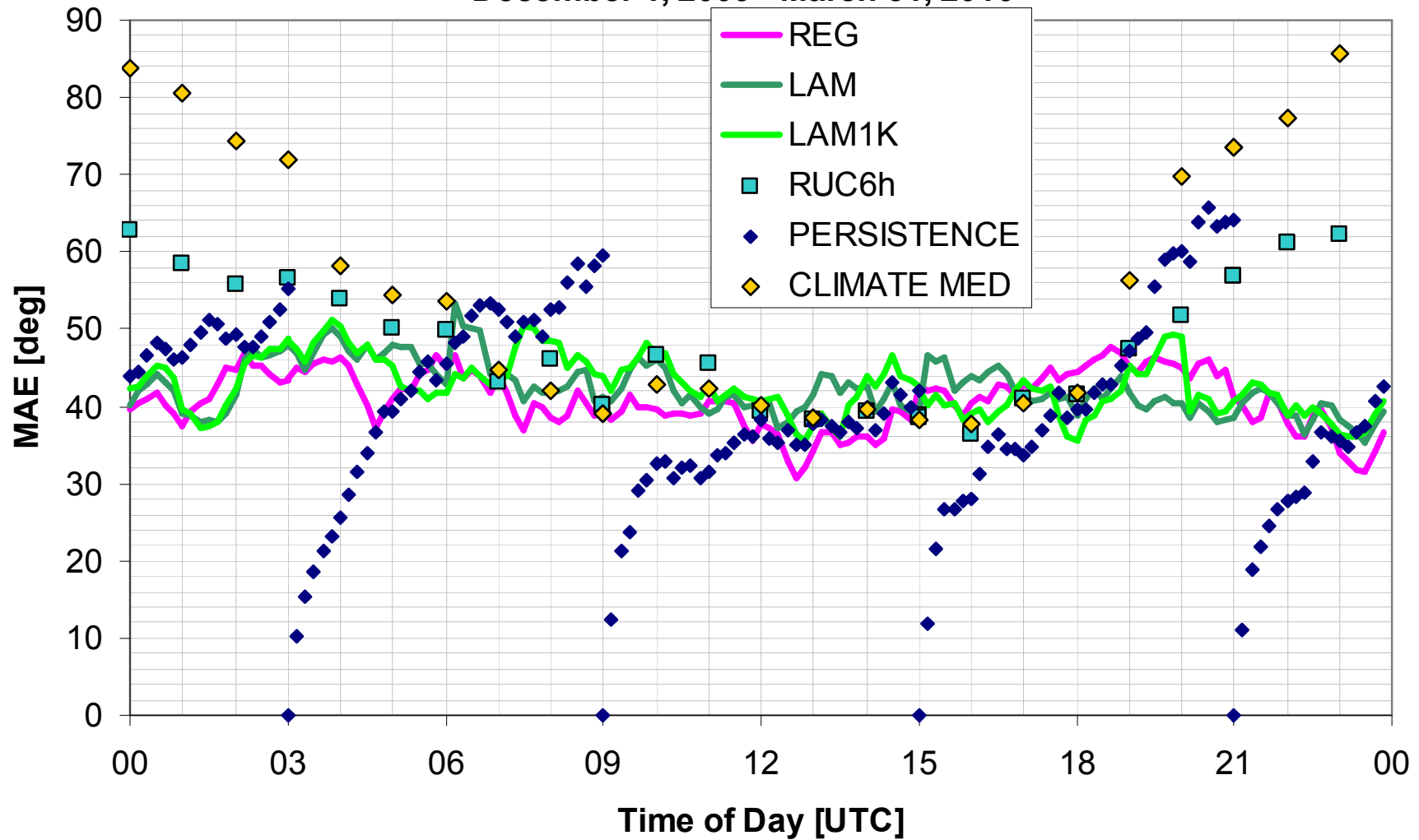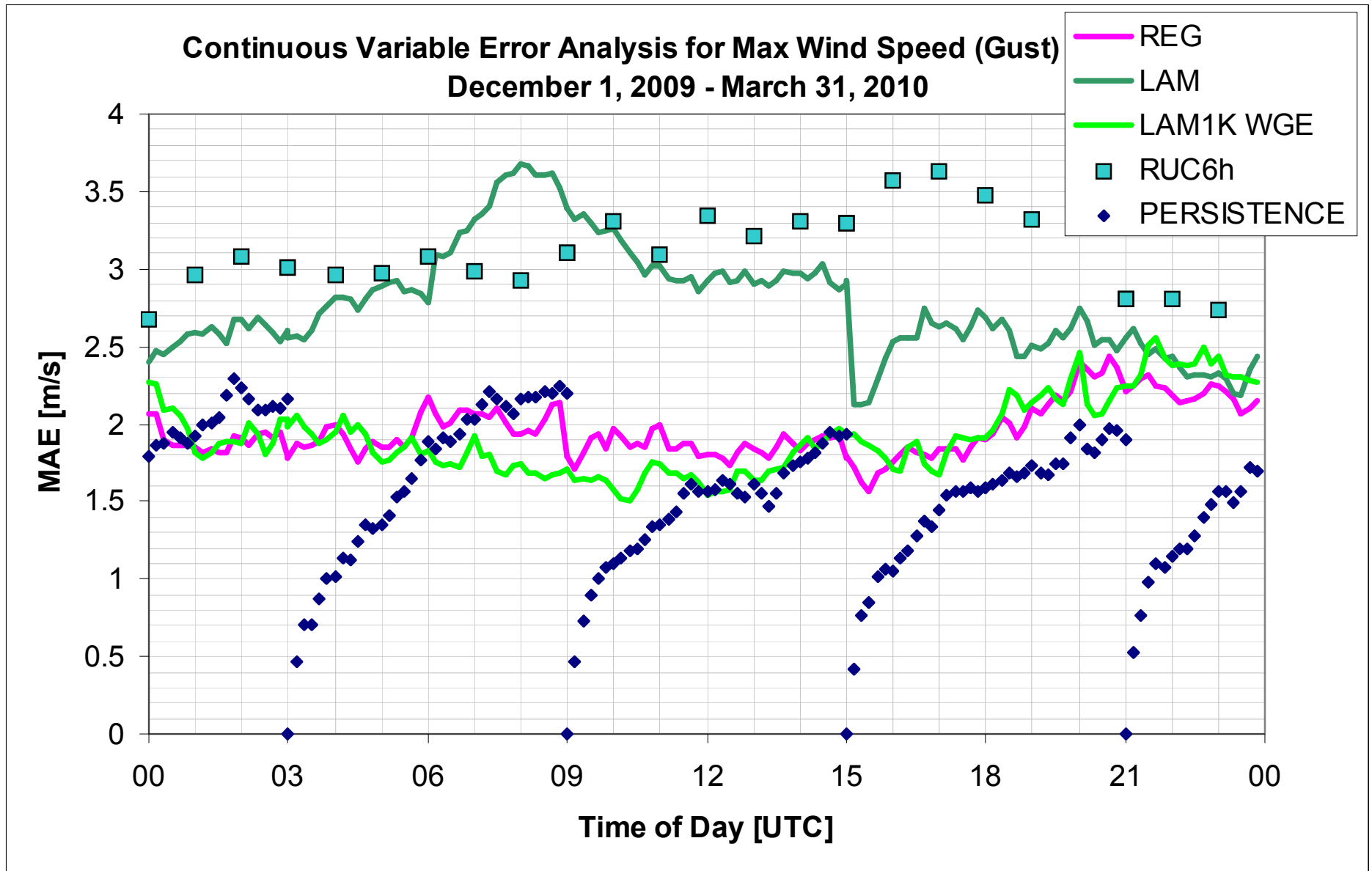
Time of Day: Temperature

Variable Error Analysis for Temperature at CYVR: December 1, 2009 - March 31, 2010

Legend:
- REG
- LAM
- LAM1K
- RUC6h
- PERSISTENCE
- CLIMATE AVG

Y-axis: MAE [deg C]

X-axis: Time of Day [UTC]

Time of Day: Relative Humidity

Variable Error Analysis for Relative Humidity at CYVR:
December 1, 2009 - March 31, 2010

Legend:
- REG
- LAM
- LAM1K
- RUC6h
- PERSISTENCE
- CLIMATE AVG

Y-axis: MAE [%]
X-axis: Time of Day [UTC]

Time of Day: Wind Direction

Continuous Variable Error Analysis for Wind Direction at CYVR:
December 1, 2009 - March 31, 2010

Time of Day: Wind Gust

Continuous Variable Error Analysis for Max Wind Speed (Gust)
December 1, 2009 - March 31, 2010

Legend:
- REG
- LAM
- LAM1K WGE
- RUC6h
- PERSISTENCE

Y-axis: MAE [m/s]
X-axis: Time of Day [UTC]

Categorical Error Analysis

Variable	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6	Category 7	Category 8
Winds	< 5 kts	5 ≤ w < 10 kts	10 ≤ w < 15 kts	15 ≤ w < 20 kts	20 ≤ w < 25 kts	w ≥ 25 kts	-	-
Wind Direction	d ≥ 339 & d < 24º (N)	24 ≤ d < 69º (NE)	69 ≤ d < 114º (E)	114 ≤ d < 159º (SE)	159 ≤ d < 204º (S)	204 ≤ d < 249º (SW)	249 ≤ d < 294º (W)	294 ≤ d < 339º (NW)
Visibility	v < 1/4 SM	1/4 ≤ v < 1/2 SM	1/2 ≤ v < 3 SM	3 ≤ v < 6 SM	v ≥ 6 SM	-	-	-
Ceiling	c < 150 ft	150 ≤ c < 400 ft	400 ≤ c < 1000 ft	1000 ≤ c < 2500 ft	2500 ≤ c < 10000 ft	c ≥ 10000 ft	-	-
Precip Rate	r = 0 mm/hr (None)	0 < r ≤ 0.2 mm/hr (Trace)	0.2 < r ≤ 2.5 mm/hr (Light)	2.5 < r ≤ 7.5 mm/hr (Moderate)	r > 7.5 mm/hr (Heavy)	-	-	-
Precip Type	No Precip	Liquid	Freezing	Frozen	Mixed (w/Liquid)	Unknown	-	-

End User Requirements

Threshold Matrix for Downhill, Slalom and Giant Slalom (from Chis Doyle)

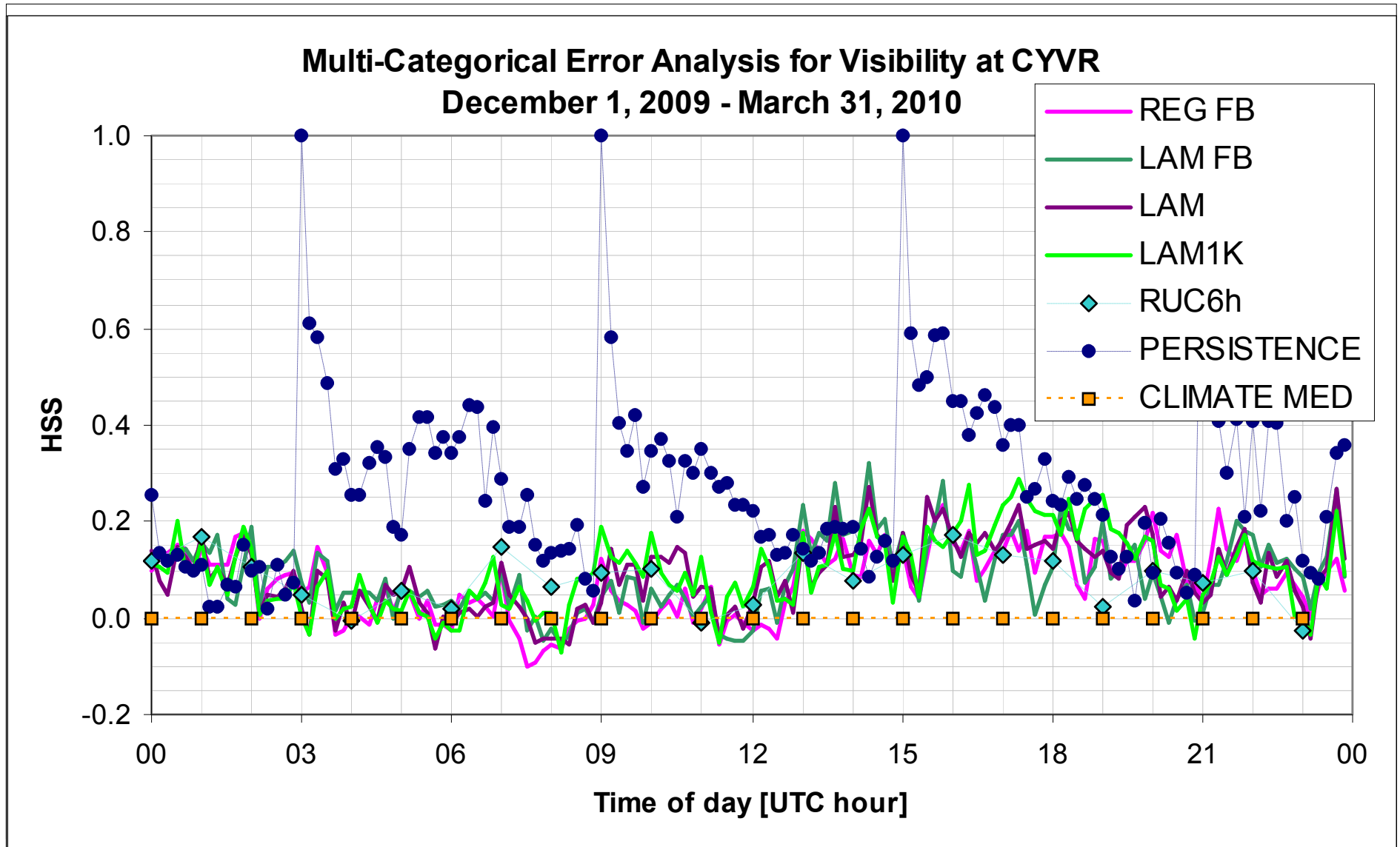|	New Snow (24 hours)	Wind	Visibility	Rain
Critical Decision point	**> 30 cm**	**Constant above 17 m/s or gusts > 17 m/s**	**< 200 m on the entire course. Lower Thresholds for GS…course dependant but ~ 100m for GS**	**15mm in 6 hours or less**
Significant decision point	**➢15 cm and < 30 cm** **>10 cm and < 30 cm Paralympics)**	**Constant 11 m/s to 17 m/s <**	**200 m on portions of the course**	**Mixed precipitation**
Factor to consider	**> 5 cm** **> 2 cm within 6h of an event**	**Gusts above 14 m/s but < 17 m/s>**	**>200m but <500m on whole or part of the course**	

Heidke Skill Score: Multi-Categories

Using:

$j \longrightarrow$

$i \downarrow$

Observed category

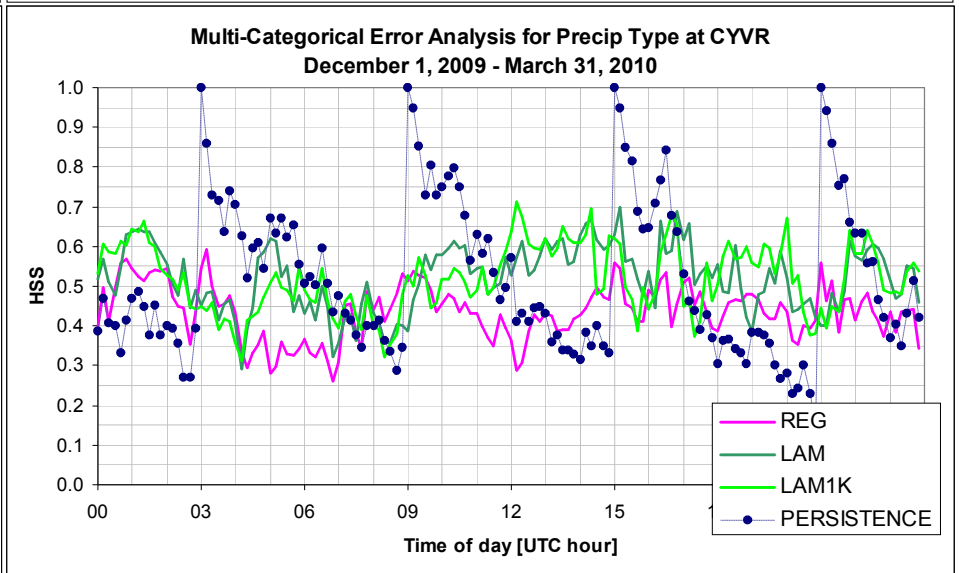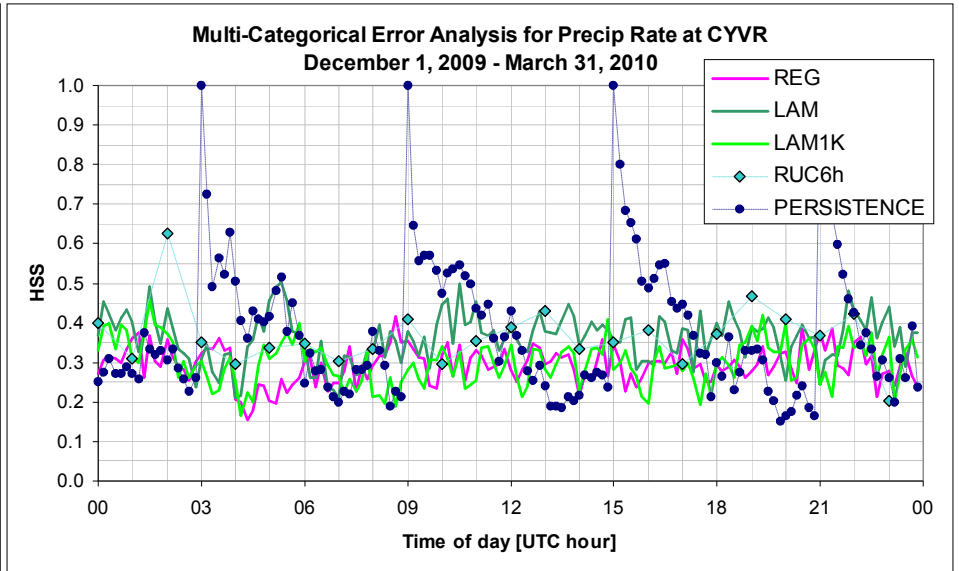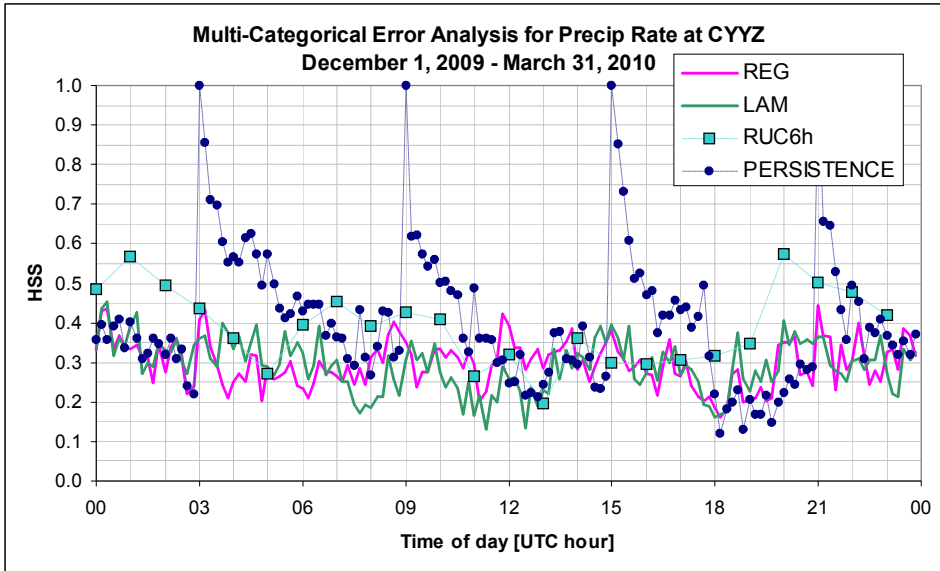| Forecast Category		1	2	3	. . . . .	K	total
	1						$N(F_1)$
	2						$N(F_2)$
	3						$N(F_3)$
	. . . .						
	K						$N(F_k)$
	total	$N(O_1)$	$N(O_2)$	$N(O_3)$		$N(O_k)$	N

Calculate:

$$HSS = \frac{\frac{1}{N}\sum_{i=1}^{K} n(F_i,O_i) - \frac{1}{N^2}\sum_{i=1}^{K} N(F_i)N(O_i)}{1 - \frac{1}{N^2}\sum_{i=1}^{K} N(F_i)N(O_i)}$$

Categorical TOD: Ceiling & Visibility

Multi-Categorical Error Analysis for Visibility at CYVR
December 1, 2009 - March 31, 2010

Categorical TOD: Precip Rate & Type
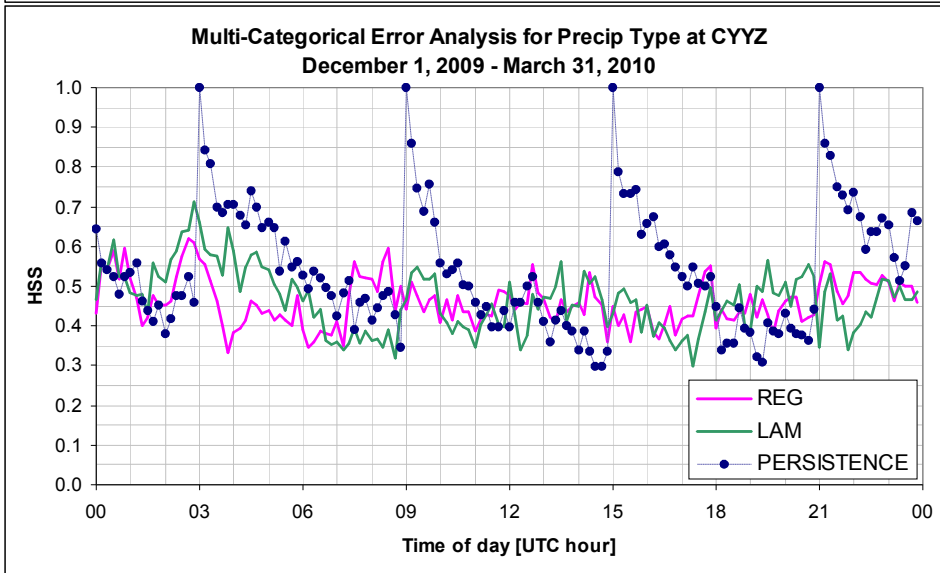
2 hour Persistence, Ceiling, YVR

Cloud Base (ft)	< 150	150-<400	400-<1000	1000-<2500	2500-<10000	≥ 10000
< 150	0	15	1	0	4	15
150-<400	10	185	91	20	19	15
400-<1000	6	86	330	236	159	56
1000-<2500	0	35	256	1429	734	115
2500-<10000	12	4	128	727	5249	976
≥ 10000	7	15	56	160	938	4994

Observation

GEM REG Model All Times of Day Combined, YVR

Observation

Cloud Base (ft)	< 150	150-<400	400-<1000	1000-<2500	2500-<10000	≥ 10000
< 150	0	0	9	1	3	22
150-<400	17	0	169	39	3	112
400-<1000	138	0	508	130	50	36
1000-<2500	102	0	769	935	602	164
2500-<10000	147	0	1314	917	4228	514
≥ 10000	28	0	652	152	1146	4209

GEM LAM Model All Times of Day Combined, YYZ

| Visibility (BI)	< ¼ SM	¼ ≤ v < ½ SM	½ ≤ v <3 SM	3≤ v < 6 SM	V ≥ 6 SM
< ¼ SM	3/5	6/19	25/34	20/17	45/24
¼ ≤ v < ½ SM	0/2	4/14	20/19	7/5	12/3
½ ≤ v <3 SM	20/66	50/94	370/492	326/357	631/388
3≤ v < 6 SM	7/42	29/61	266/393	270/363	1225/948
V ≥ 6 SM	0/11	12/12	335/680	849/1291	12880/12082

Observation (row axis label)

Analysis redone by looking for the minimum model value in +/- 60 minutes of the observed time. HSS score does not improve.

Comparison by Location – RH
6 hour forcast for INTW and OBSP

MAE from all sites - Relative Humidity

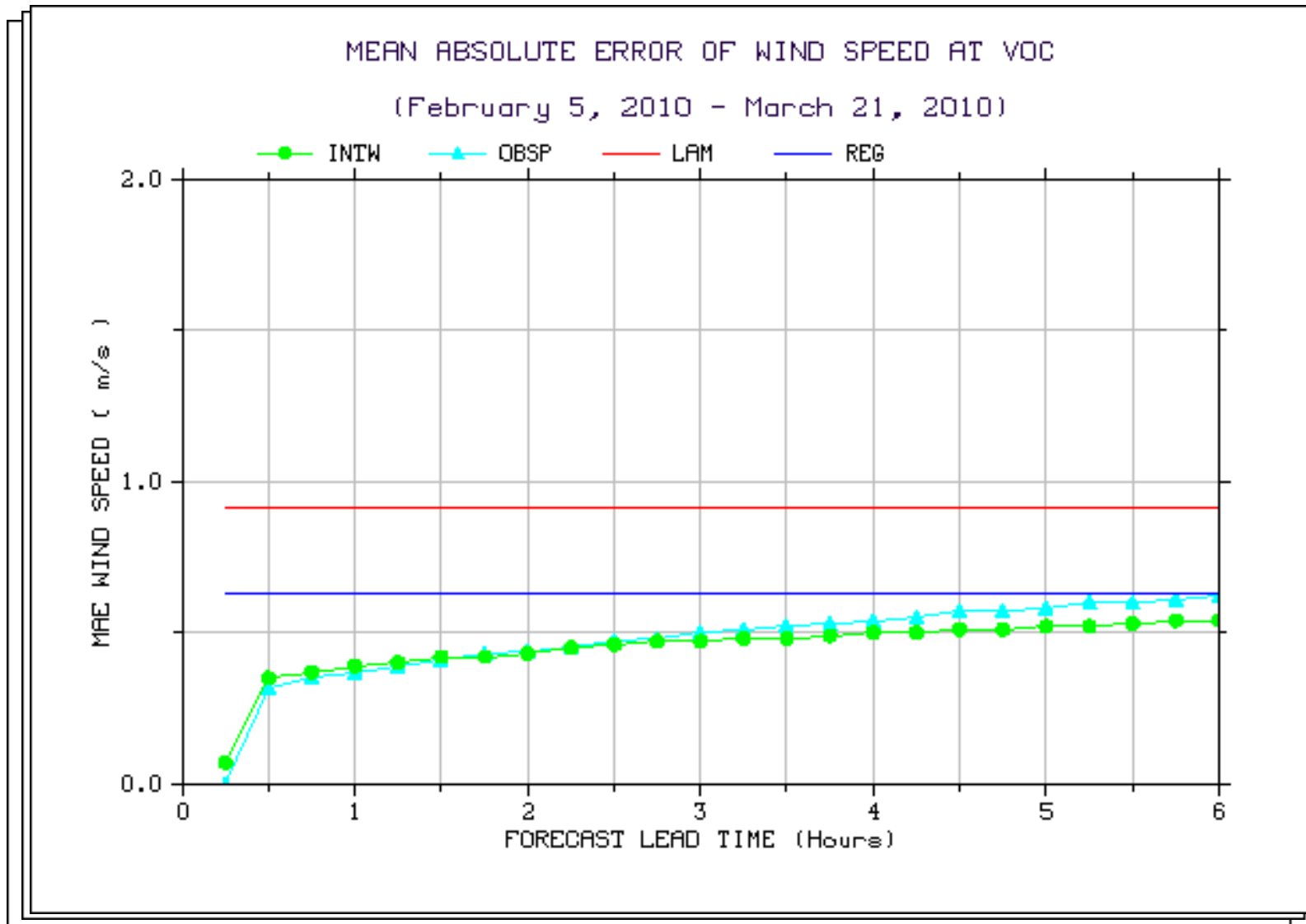| Site	Altitude	LAM	REG	INTW	OBSP
Vancouver (YVR)	2	6.81	8.14	5.30	5.73
Whistler Creekside (VOB)	933	8.63	11.70	5.15	5.33
Timing Flats (VOT)	805	36.24	33.96	8.02	5.95
Whistler Mt. Mid Lvl. (VOL)	1320	8.39	14.43	5.96	4.40
West Vancouver (WWA)	168	10.33	11.14	7.14	6.87
Squamish Airport (WSK)	52.1	11.34	9.88	6.16	6.98
Cypress Bowl North (VOE)	953	6.45	8.89	4.87	4.94
Callaghan (VOX)	860	11.53	8.37	6.17	6.96
Callaghan Ski Jump (VOW)	936	9.50	12.04	5.61	5.41
Callaghan Valley (VOD)	884	12.47	8.43	6.94	7.62
Nesters (VOC)	651.5	9.82	7.65	6.16	7.25
Blackcomb (VOI)	937	8.57	10.34	5.49	6.61
Cypress Bowl (VOG)	885.5	7.47	9.85	5.50	6.20
Whistler (VOA)	1640	15.98	10.63	6.72	7.81

MAE by Forecast Lead Time - RH
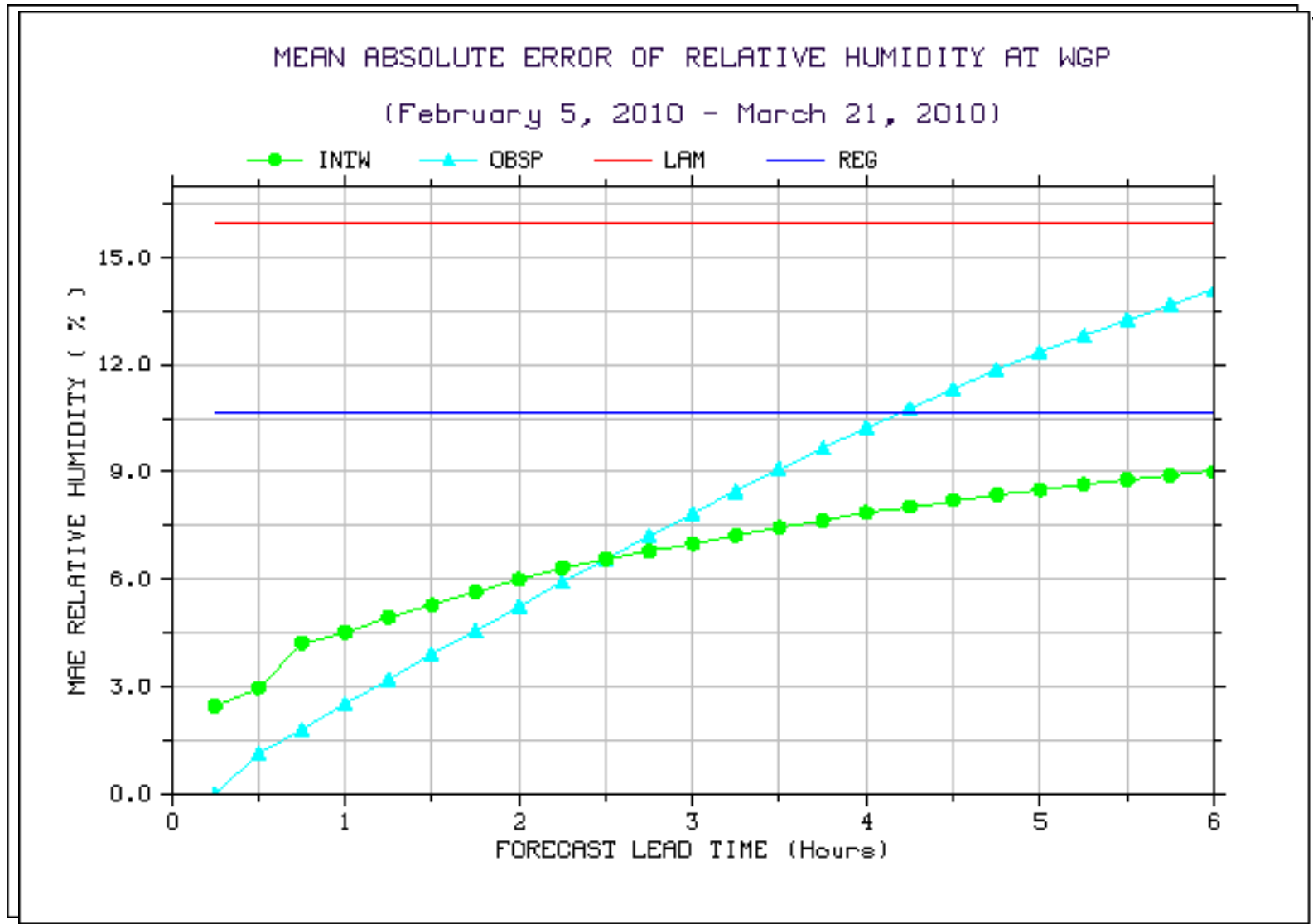
Comparison by Location – WINDSPD
# 6 hour forcast for INTW and OBSP

MAE from all sites - Wind Speed

Site	Altitude	LAM	REG	INTW	OBSP
Vancouver (YVR)	2	1.40	1.76	1.27	1.41
Whistler Creek Side (VOB)	933	0.81	0.56	0.34	0.33
Timing Flats (VOT)	805	0.95	0.54	0.40	0.40
Whistler Mt. Mid Lvl. (VOL)	1320	0.72	0.71	0.60	0.62
West Vancouver (WWA)	168	0.69	0.83	0.62	0.67
Squamish Airport (WSK)	52.1	0.83	0.76	0.61	0.68
Cypress Bowl North (VOE)	953	0.81	0.64	0.50	0.52
Callaghan SJ Bottom (VOX)	860	1.02	0.75	0.38	0.39
Callaghan Ski Jump (VOW)	936	0.80	0.59	0.44	0.46
Callaghan Valley (VOD)	884	0.77	0.54	0.43	0.47
Nesters (VOC)	651.5	0.91	0.63	0.45	0.48
Blackcomb (VOI)	937	0.61	0.47	0.44	0.45
Cypress Bowl (VOG)	885.5	0.85	0.77	0.69	0.72

MAE by Forecast Lead Time - WINDSPD

ALL OF CATEGORIES FOR WIND GUST AT CYYZ
(December 1, 2009 - March 31, 2010)

ALL OF CATEGORIES FOR PRECIPITATION RATE AT CYYZ
(December 1, 2009 - March 31, 2010)

HSS Score for INTW, OBS, GEM REG, GEM LAM and RUC using Multi-Categories for Wind Gust and Precipitation at YYZ
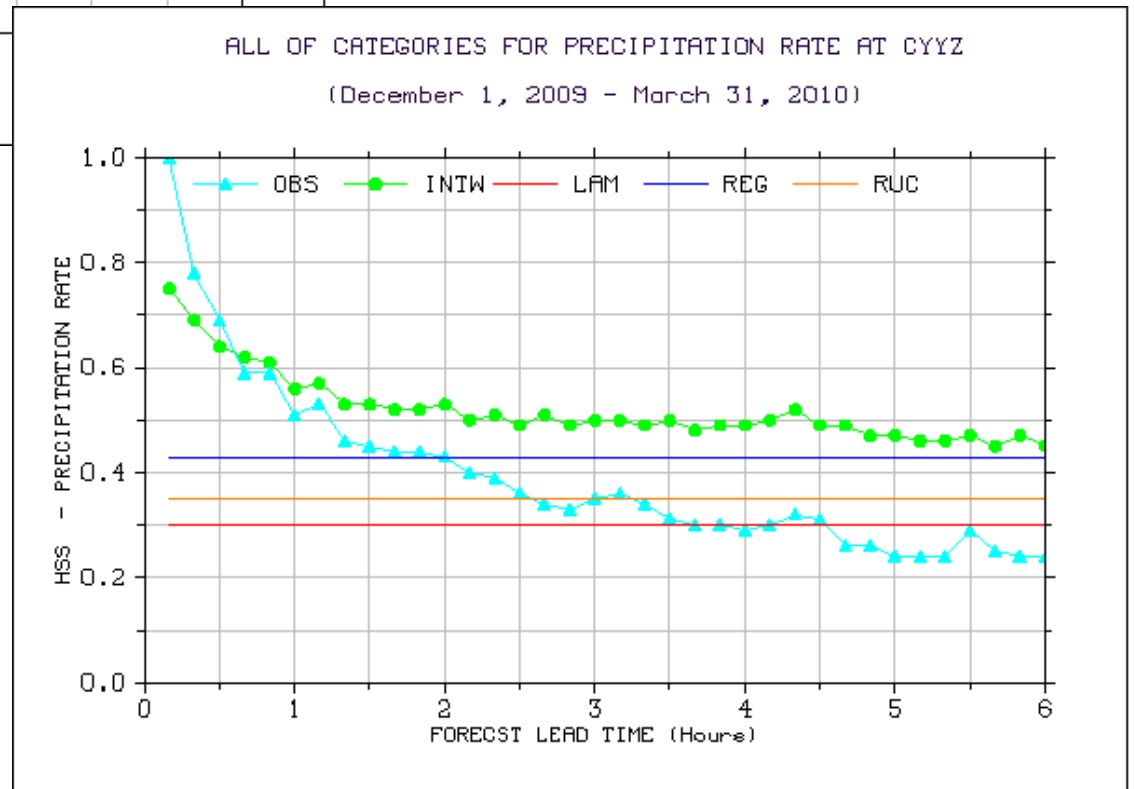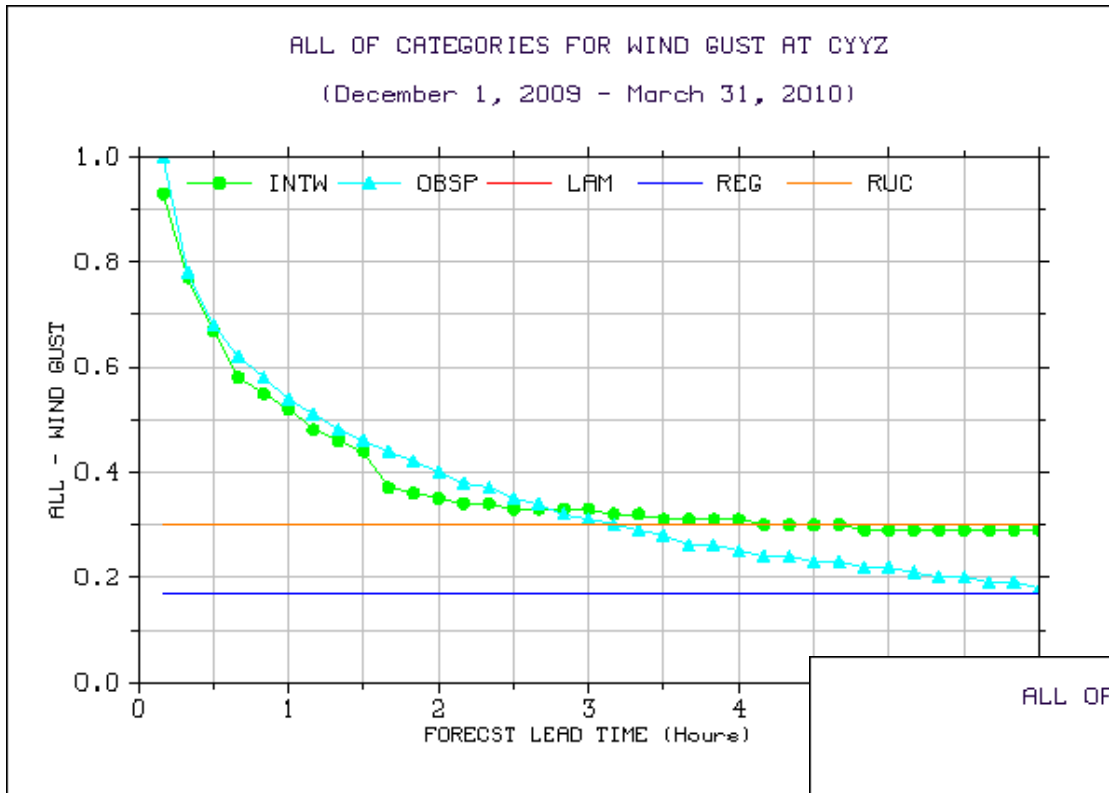
Model Issues

- Model minimum temperatures for cloud free nights are too cold. (Impacts frost forecasts, Precip type)
- RH predictions are poor, barely beating climatology. (Impacts visibility forecasts)
- Visibility forecasts are poor from statistical point of view. (also require snow and rain rates)
- Cloud base forecasts, although showing some skill, could easily be improved with better model resolution in boundary layer.
- Model graupel not observed and not well defined.
- Model has a bias against high wind speeds.
- Extreme wind shear events missed.
- Overall statistical scores do not show complete story. Need emphasis on high impact events.

Summary

- CAN-Now and SNOW-V10 have made progress in forecasting "non traditional" variables like ceiling, visibility (RVR), wind gusts, etc.

- The CAN-Now system is beginning to gain acceptance.

- Nowcast schemes like INTW are showing skill.

- There is value in presenting real-time obs and several models to forecasters doing Nowcasting.

- High resolution measurements are necessary for developing improved nowcast schemes and for verification of mesoscale model output.

- The models are not yet good enough to issue standalone nowcasts. Significant errors exist of high impact events that require forecaster intervention.

Images at noon at Top of Men's Downhill. Nov 1/09 -April 20/10