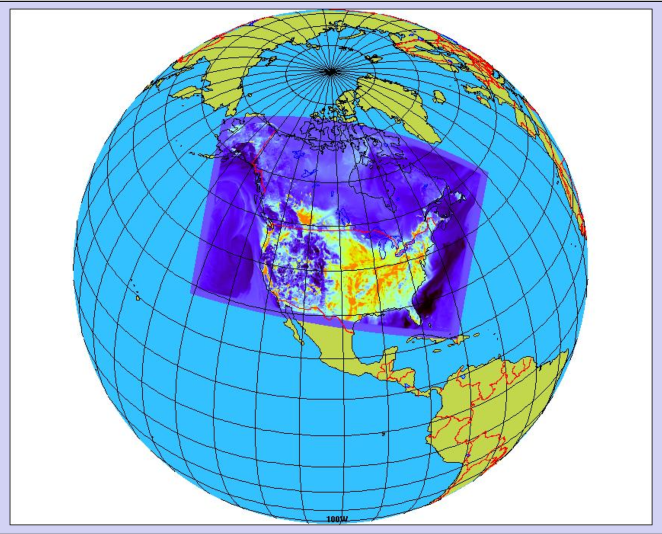

Extending Canadian Operational Air Quality Forecasts from 48 hours to 72 hours Using the Regional Air Quality Deterministic Prediction System (RAQDPS)

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Abstract

Since November 2009, the Regional Air Quality (AQ) Deterministic Prediction System (RAQDPS) has been used by Environment and Climate Change Canada to deliver 48-hours Air Quality (AQ) forecasts to Canadians. The current system is run twice a day at 00 and 12 UTC for 48 hours over a continental-scale domain with 10-km horizontal grid spacing. In recent years, there has been growing interest in extending the regional AQ forecasts beyond 48 hours, spurred by the desire of decision makers to inform at-risk populations as soon as possible, particularly when air pollution events are expected, thus enabling them to take appropriate measures to protect their health. In this presentation, a performance evaluation of extended RAQDPS forecasts out to 72 hours will be shown. Model forecasts of O_3, $PM_{2.5}$ and NO_2 will be compared against hourly observations available from the U.S. and Canadian real-time monitoring networks. Potential impacts of 72-hour forecasts on current ECCC operational AQ products and services will also be discussed.

1) RAQDPS meteorological & AQ forecast errors out to 72 hours

An experimental setup to run the RAQDPS out to 72 hours over North America has been tested for the period 2016-10-17 to 2016-12-12. This section shows how the RAQDPS model errors for meteorology and chemistry grow with the length of the integration period. The RAQDPS forecast meteorological fields are verified against radiosonde measurements at 1000 hPa for geopotential height, temperature, and winds (Fig. 1a). The chemistry fields of the RAQDPS at ground level are compared against Canadian and U.S. near-real-time hourly AQ measurements for O_3, $PM_{2.5}$, & NO_2 (Figs. 1b, 1c, 1d).

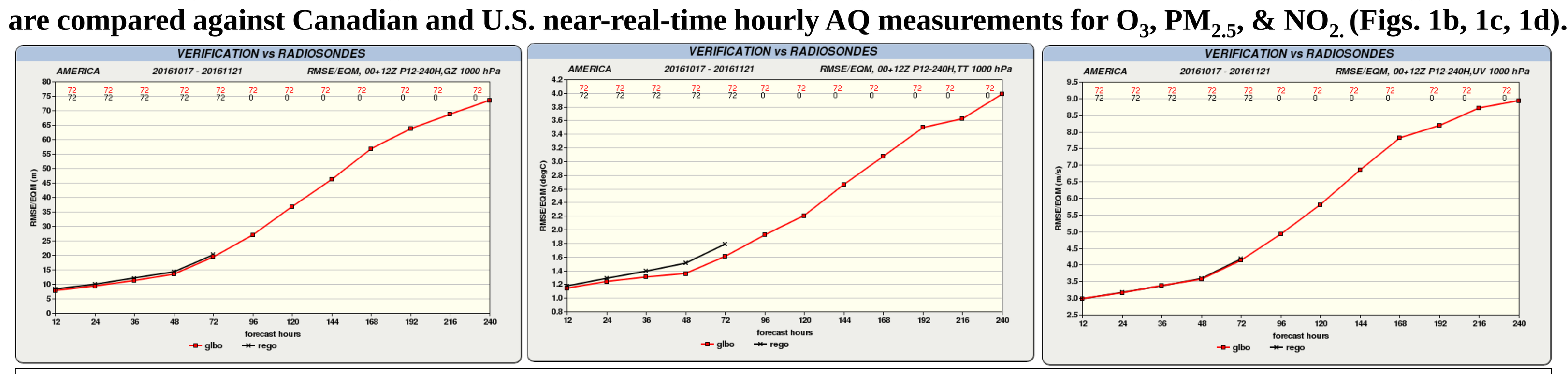


Fig. 1a) Meteorology: Verification of the RAQDPS meteorological forecasts out to 72 hours (00 UTC and 12 UTC runs combined) against radiosonde measurements at 1000 mb (black curve). RMSE scores are shown for Geopotential height (GZ), Temperature (TT), and Winds (UV), respectively, and averaged over a series of 12-hour time intervals for the period 2016-10-17 to 2016-12-12. Verification for the Global Deterministic Prediction System (GDPS) is also shown out to 240 hours (red curve).

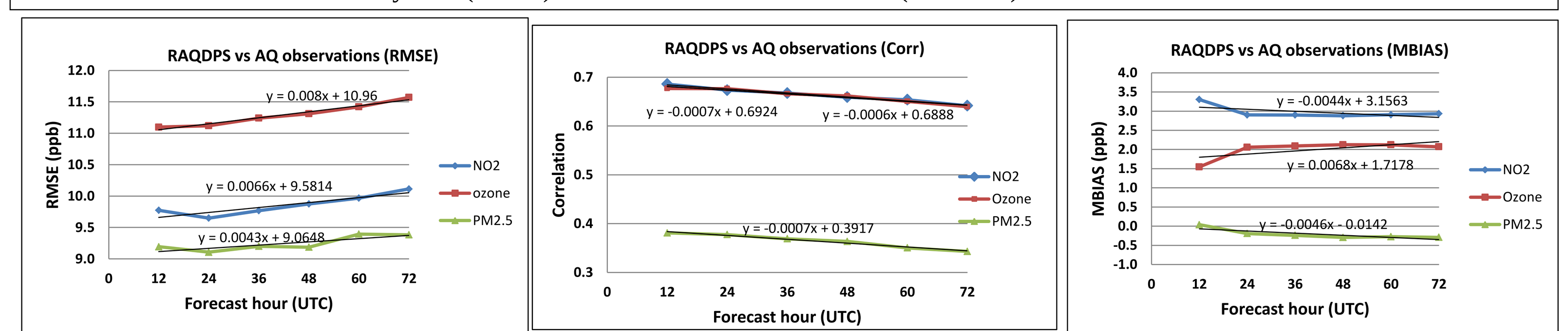


Fig. 1b) Chemistry: Verification of the RAQDPS chemistry forecasts out to 72 hours (00 UTC and 12 UTC runs combined) against Canadian and U.S. surface monitoring networks using near-real-time hourly AQ measurements. RMSE, Correlation (r), and MBIAS are shown for O_3, $PM_{2.5}$, and NO_2 averaged over a series of 12-hour time intervals for the period 2016-10-17 to 2016-12-12.

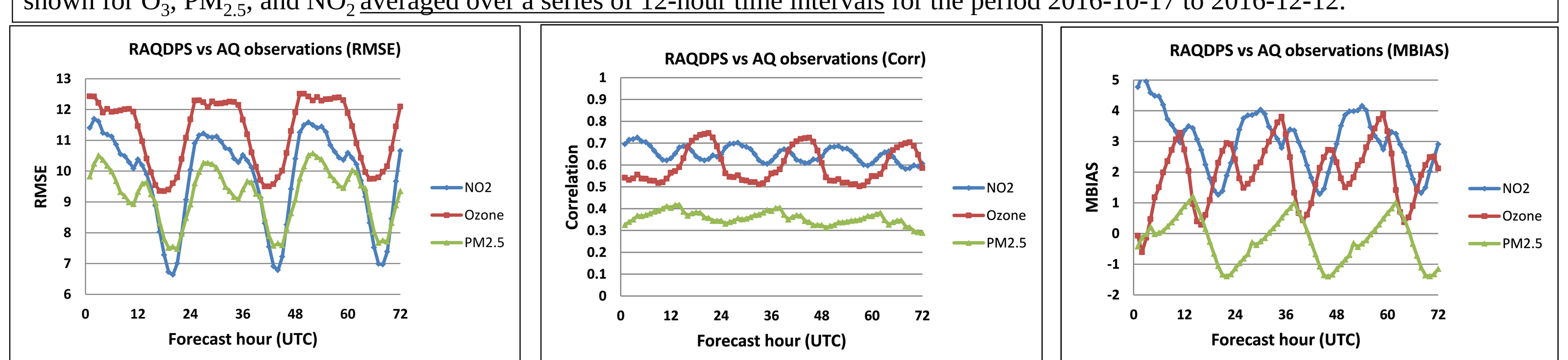


Fig. 1c) Chemistry diurnal cycle: Verification of the hourly RAQDPS chemistry forecasts (00 UTC runs only) against Canadian and U.S. surface monitoring networks using near-real-time hourly AQ measurements. RMSE, Correlation (r), and MBIAS are shown for O_3, $PM_{2.5}$, & NO_2 for the period 2016-10-17 to 2016-12-12.

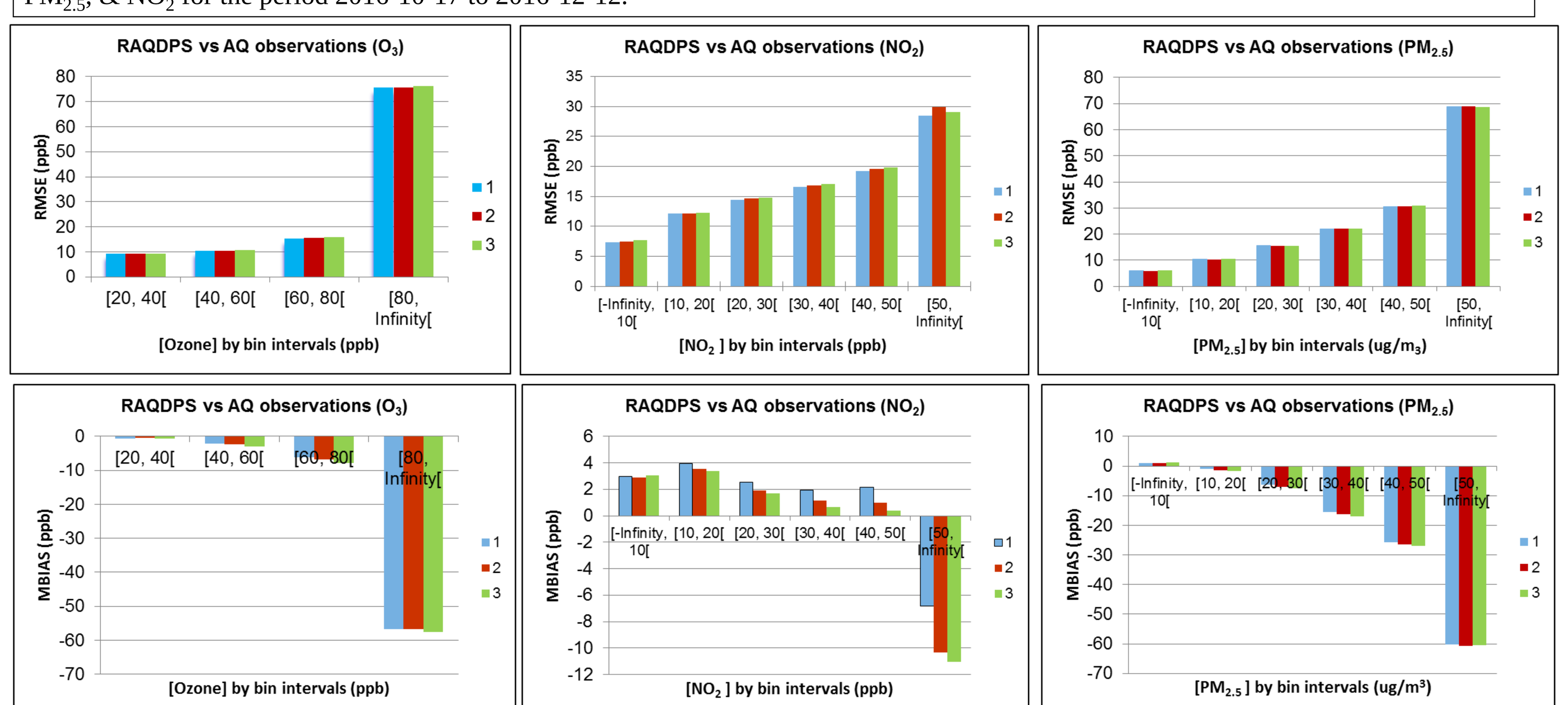


Fig. 1d) Chemistry by bin intervals: Verification of the hourly RAQDPS chemistry forecasts by observed bin interval concentrations for O_3, $PM_{2.5}$, & NO_2 (00 UTC and 12 UTC runs combined) for day 1 (blue), day 2 (red), and day 3 (green) against Canadian and U.S. surface monitoring networks using near-real-time hourly AQ measurements. RMSE and MBIAS are shown for O_3, NO_2, and $PM_{2.5}$ for the period 2016-10-17 to 2016-12-12. Number of AQ observations used: 5.4 million for $PM_{2.5}$, 6.7 million for O_3, and 2.1 million for NO_2.

	% of RMSE increase over a 72-hour period
Meteorology	
• Winds (m/s)	39%
• Temperature (C)	52%
• Geopotential height (m)	141%
Chemistry	
• NO_2 (ppb)	3%
• Ozone (ppb)	4%
• $PM_{2.5}$ (ug/m³)	2%

Summary:

- RAQDPS model errors grow with time for both meteorology and chemistry
- RAQDPS RMSE for O_3, $PM_{2.5}$ and NO_2 grow less than 5% over a 72-hour period while RMSE errors for GZ, TT, UV grow at a much faster rate (~10 times faster).
- RAQDPS RMSE values for O_3 and NO_2 are high at initial time (>10 ppb) and remain high over time because there is no chemical data assimilation. RMSE at initial time for $PM_{2.5}$ is > 9 ug/m³ (Fig 1b).
- RAQDPS model errors show a strong diurnal cycle for O_3, $PM_{2.5}$ and NO_2. Minimum RMSE occurs from 18-20 UTC while maximum RMSE occurs from 0-12 UTC.
- Chemistry forecasts for day 3 are almost as good on average as the ones for day 1 and day 2.

2) Comparison of RAQDPS chemistry for day 03 forecasts with day 01 and day 02 forecasts valid at the same time.

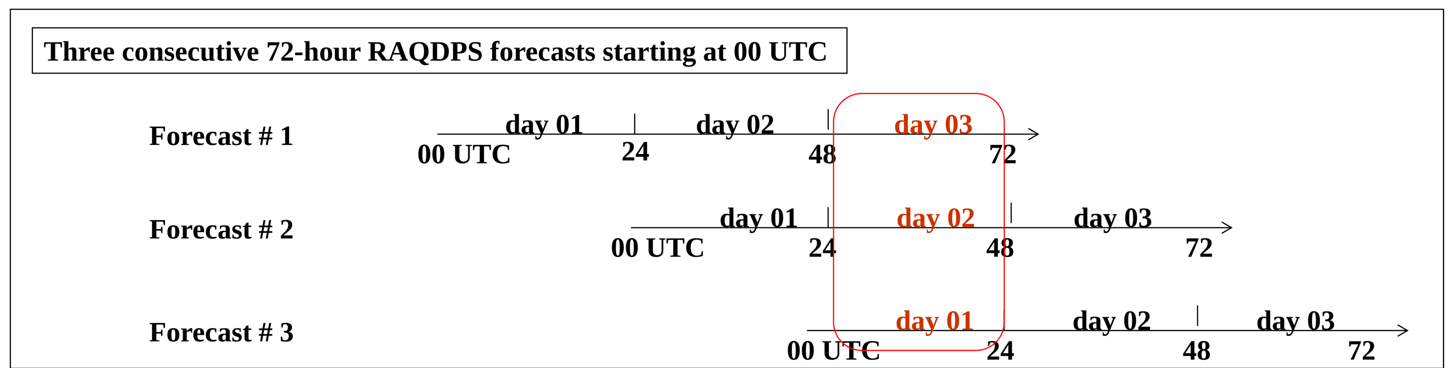


Fig 2 a) Illustration of three consecutive 72-hour RAQDPS model runs starting at 00 UTC. Forecasts for day 03 can be compared to subsequent models runs for day 02 and day 01 valid for the same time (see Figs. 2b and 2c).

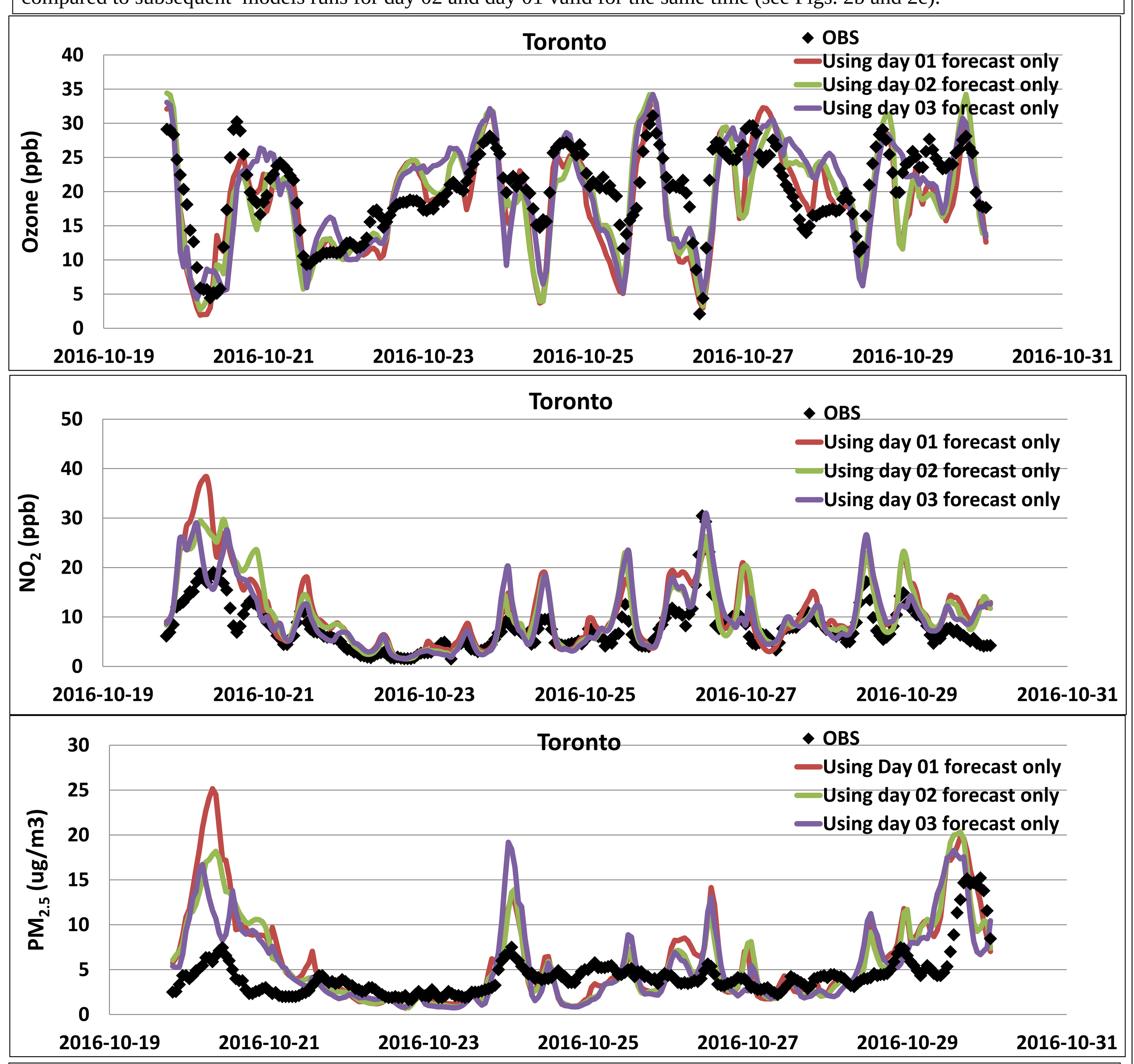


Fig 2 b) Time series for O_3, NO_2, and $PM_{2.5}$, concentrations in Toronto for the 13-day period 2016-10-19 to 2016-10-31. Near-real-time hourly AQ observations are shown (black) as well as RAQDPS forecasts using day 01 forecast only (red), day 02 forecast only (green) and day 03 forecast only (purple).

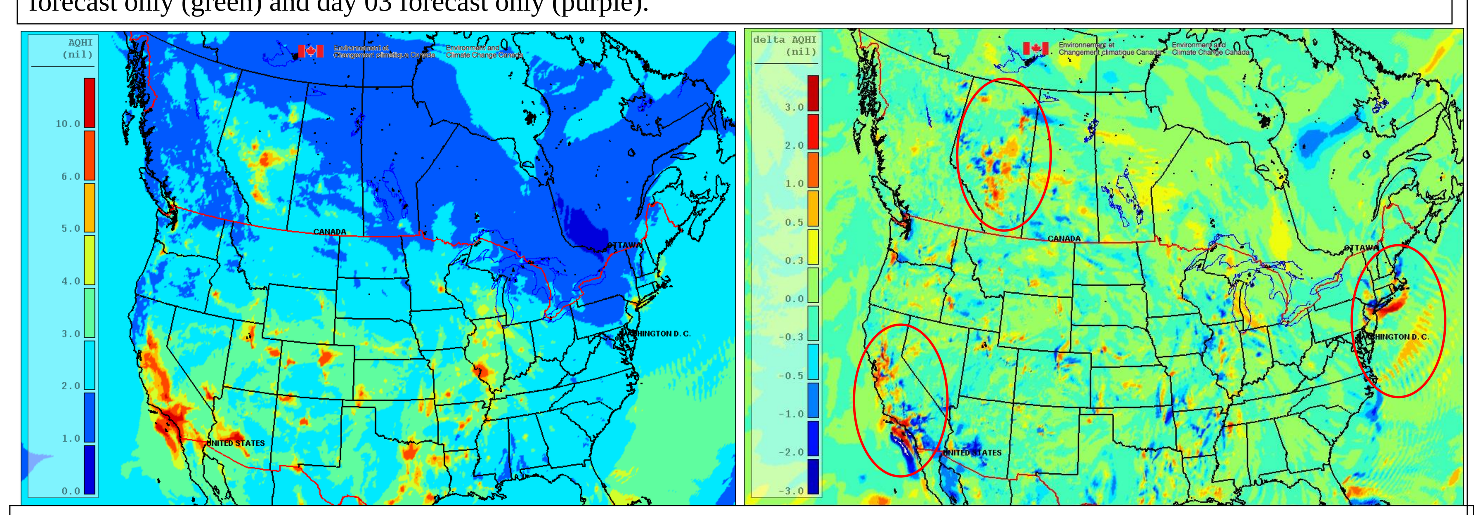


Fig 2 c) The left panel shows Air Quality Health Index (*AQHI) of the RAQDPS for day 02 valid on 20161022 calculated using daily maximum concentration for O_3, $PM_{2.5}$ and NO_2 (3-hour moving average concentrations not applied). The right panel shows the differences in *AQHI if day 03 of the previous RAQDPS forecast were used instead (also valid on 20161022).

$$*AQHI = (10/10.4)*100*[(\exp(0.000871*NO_2)-1) + (\exp(0.000537*O_3)-1) + (\exp(0.000487*PM_{2.5})-1)]$$

1	2	3	4	5	6	7	8	9	10	+

Low Risk (1-3) | Moderate Risk (4-6) | High Risk (7-10) | Very High Risk

Summary:

- Day 03 forecasts from the RAQDPS could be used as guidance by meteorologists to predict AQHI out to 72 hours in advance
- Day 01 , day 02 and day 03 forecasts from the RAQDPS valid at the same time generally show a similar behaviour when compared to AQ observations in Toronto for O_3, $PM_{2.5}$, and NO_2 (Fig. 2b)
- Changes in the RAQDPS AQHI forecasted values from one run to the next are expected to occur in areas where AQHI is already high (likely in major cities or areas of strong economic activity) (Fig. 2c)

3) Planning for 72-hour operational RAQDPS forecasts and dissemination of AQ products to clients and partners

In order to deliver a 72-hour operational AQ forecast to Canadians, several steps are required :

- **The path to success requires a good project management plan (Fig. 3a)**
- **Continuous R&D to improve the AQ forecast model (Fig. 3b)**
- **Technical skills to adapt all the modeling components of the production chain out to 72-hours (Fig. 3c)**
- **Communicate the proposed changes to partners & clients (Fig. 3d)**

This project started on October 2016 and will continue in 2017-18.

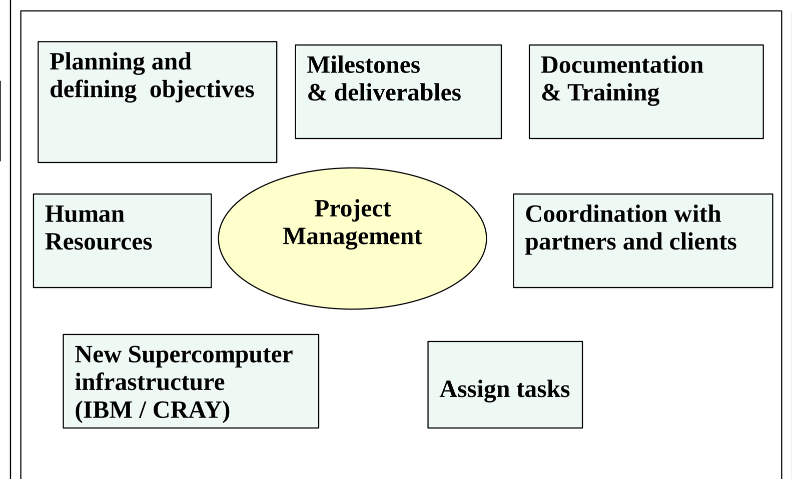


Fig 3 a) Project Management

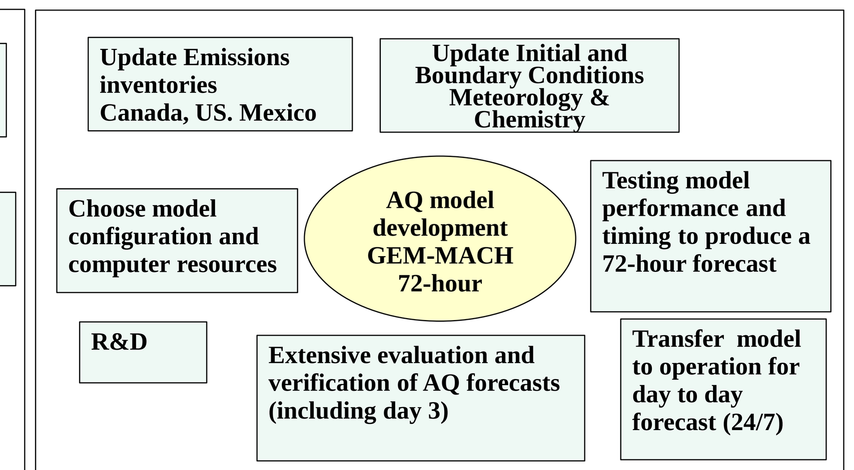


Fig 3 b) R&D for AQ model

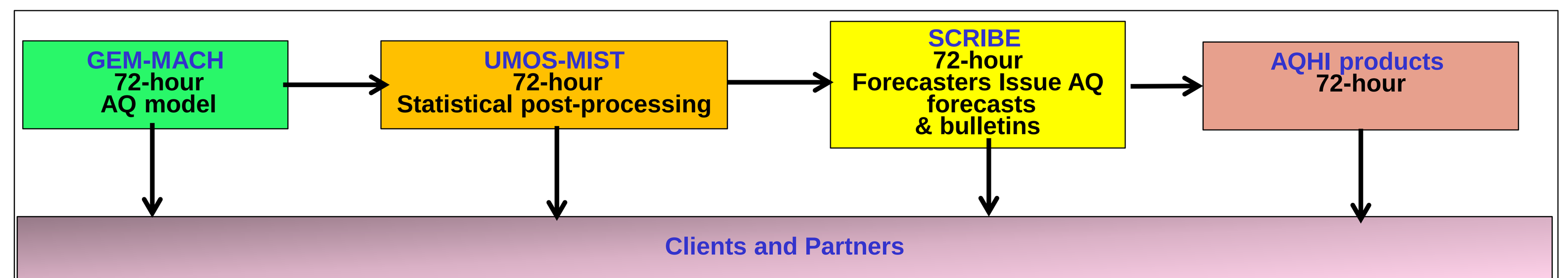
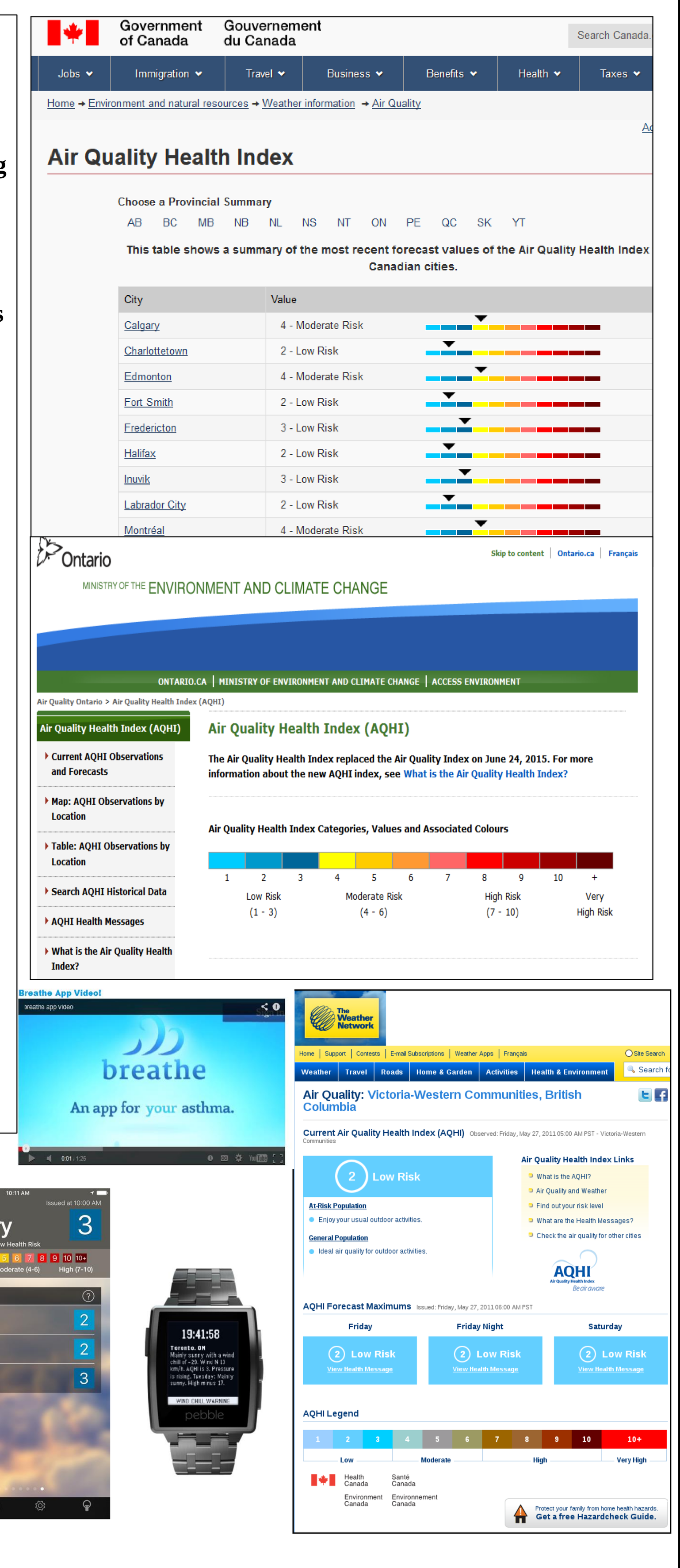


Fig 3 c) Data Flow of the AQ modelling production chain

Clients & partners: Air quality involves many jurisdictions: federal, provincial, territorial, municipal

- **Environment and Climate Change Canada (ECCC) provides a nation-wide unified set of Air Quality Modeling and forecasting products to Canadians.**
- **ECCC, Canadian provinces, and territories as well as municipalities share AQ observations measurements from monitoring networks across the country and issue AQ forecasts and special bulletins with the assistance from operational meteorologists.**
- **Health Canada is responsible for the Air Quality Health Index (AQHI) formulation and the developed standard health messaging.**
- **Natural Resources Canada provides information to ECCC for current fire activity across Canada and U.S.**
- **ECCC provides specialized AQ modeling products to decision makers e.g. Government Operation Centre (GOC).**
- **Dissemination of AQ products to the general public is done at the federal, provincial/territorial and municipal levels. It also involves Non-Governmental Organizations (NGOs) like: The Lung Association, Asthma Society of Canada, etc. The private sector delivers AQ information through medias like: Weather Network (Pelmorex), TV, radio, newspapers, etc.**
- **ECCC shares AQ modeling results, and/or sciences and technical information with international partners like: Universities, Commission for environmental cooperation (Can, U.S., Mexico) , U.S. government: States Agencies , U.S. Forest Services etc.**



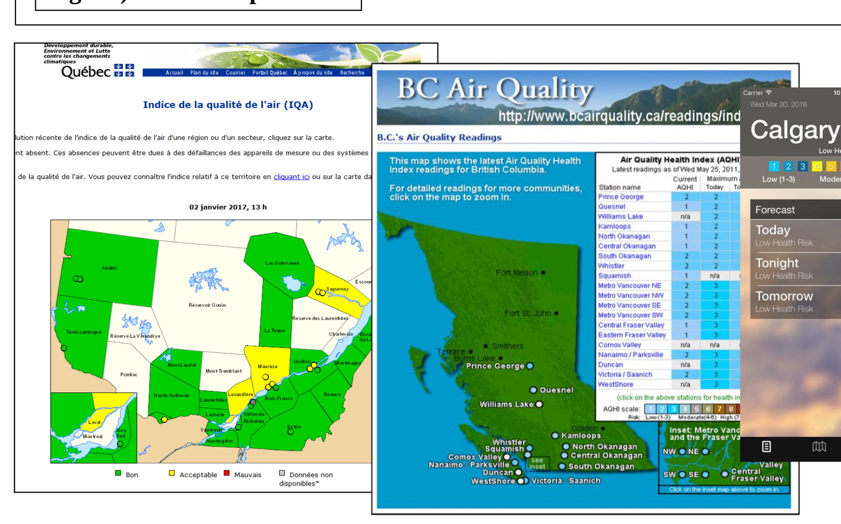


Fig 3 d) Clients & partners