Environnement Canada Environment Canada

Canada

Air Quality Forecast at the Meteorological Service of Canada: What's up in 2014

NOAA's AQ Forecaster Focus Group Workshop, 2014

Mike Howe, Didier Davignon

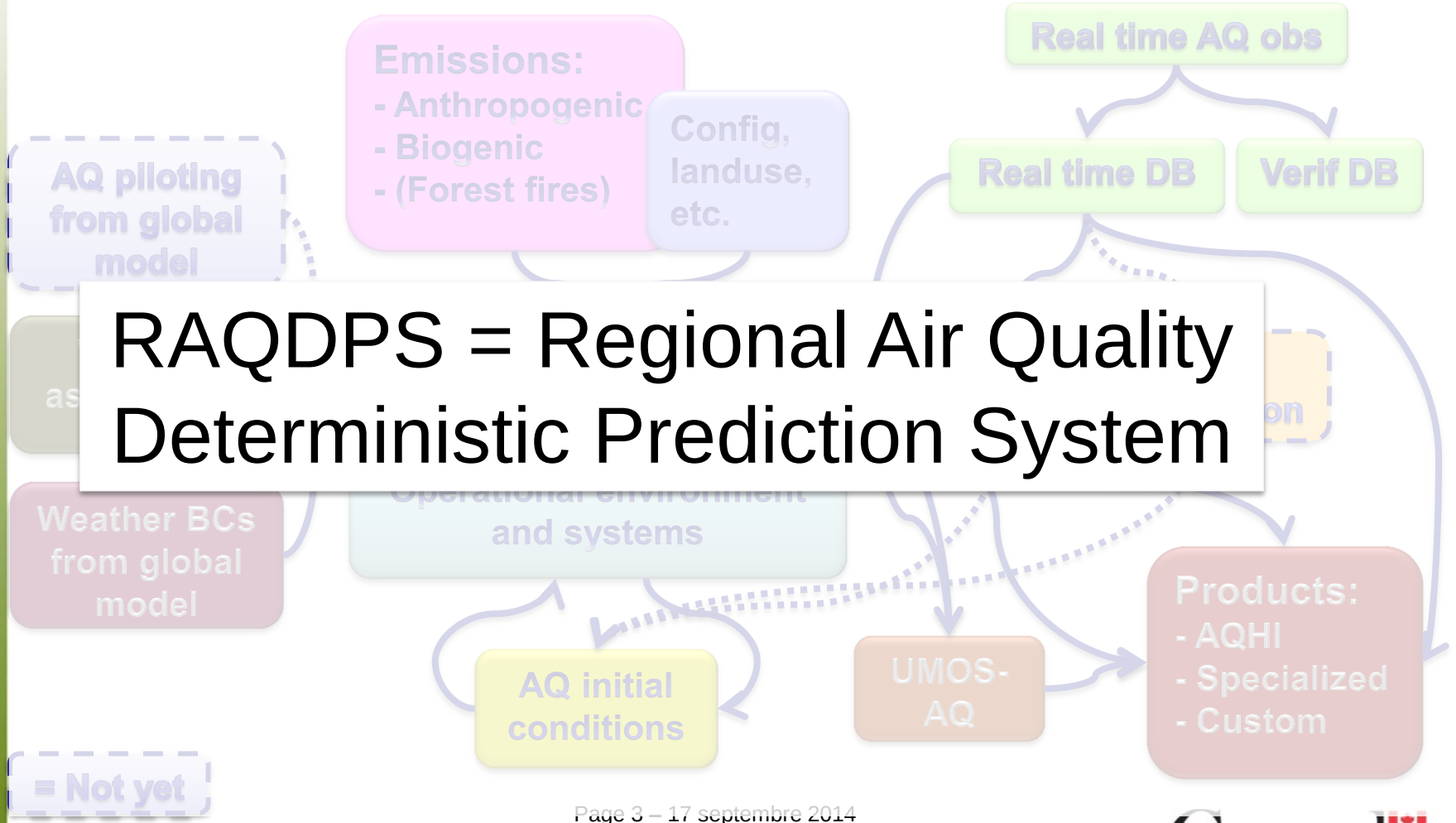
MSC-WEPS-NPO

2014-09-09

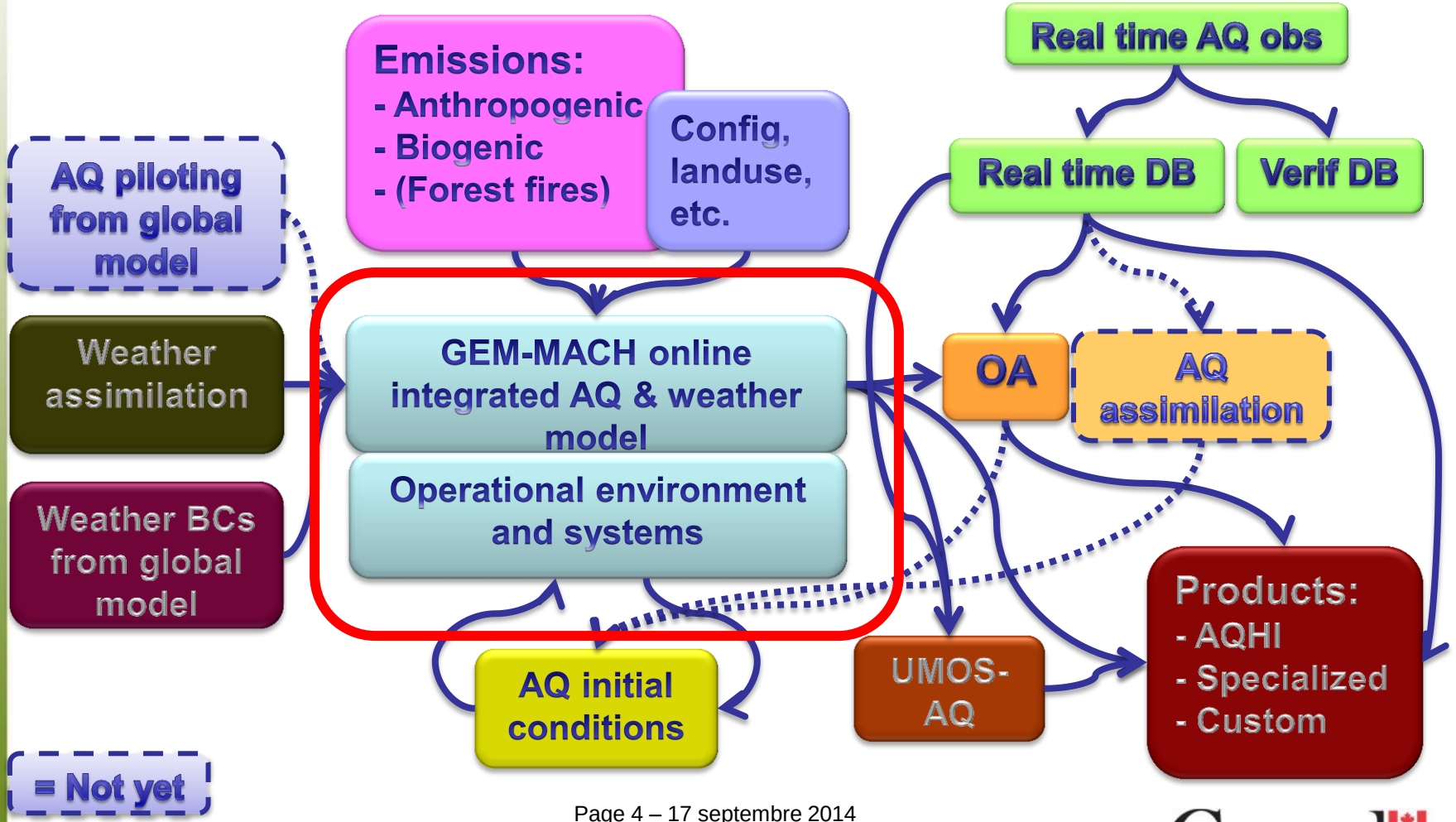
Summary

- The Canadian Air Quality Modelling System
  - Overview & status
  - Evaluation
  - In development
- New initiatives
  - PanAm games 2015
  - AQHI map

RAQDPS: components

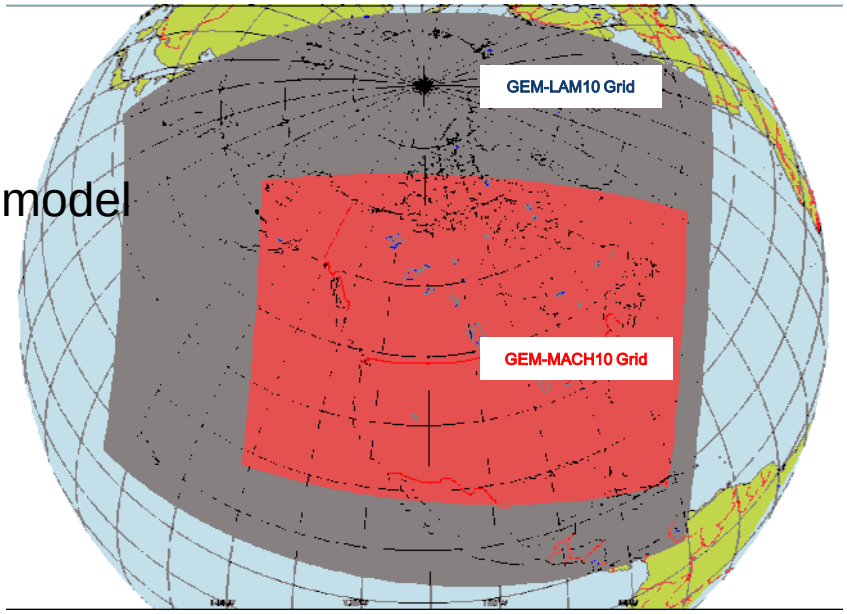


RAQDPS: GEM-MACH



GEM-MACH, operational version (v1.5.1)

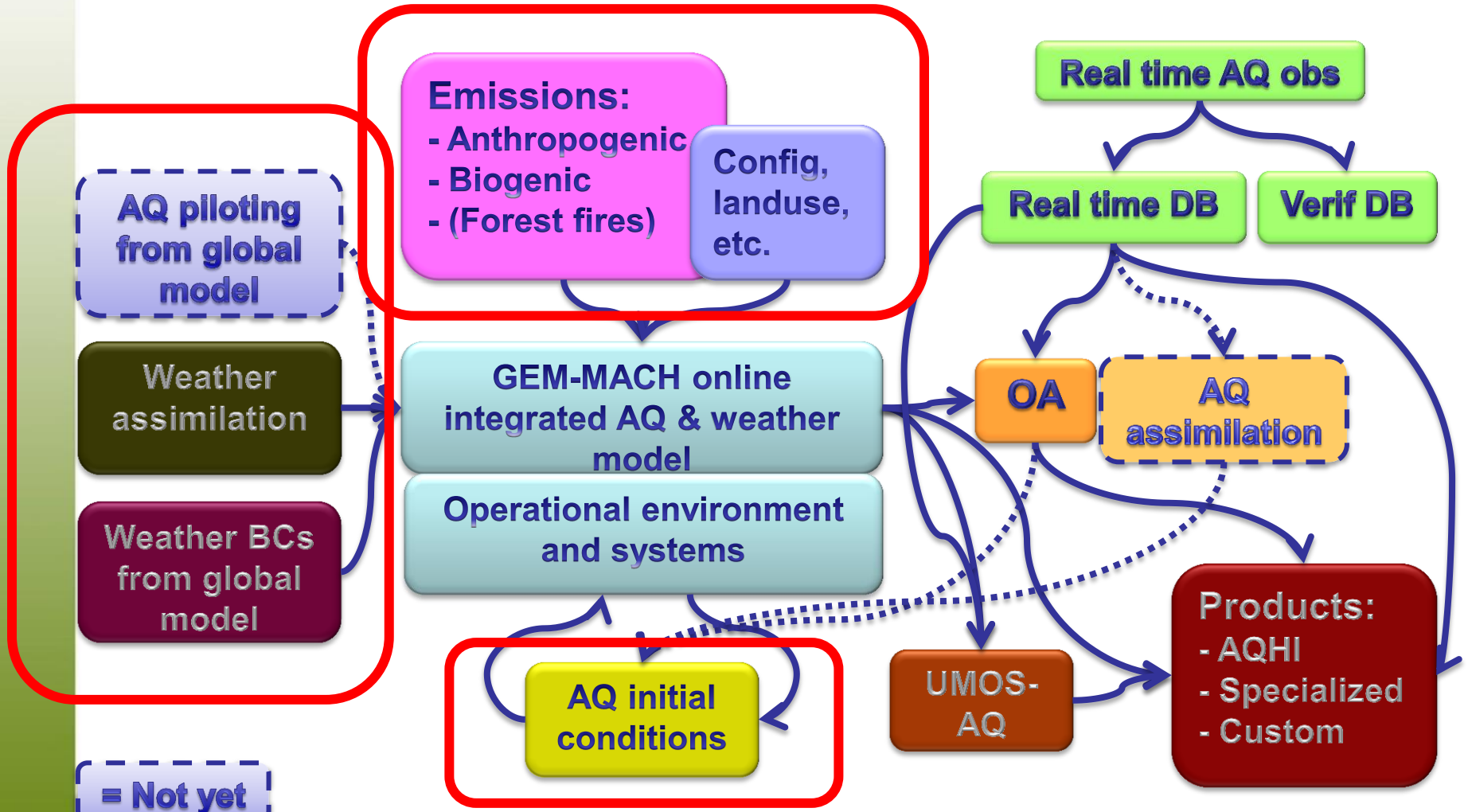
- Regional system with a domain covering North America
- Subdomain of the regional weather model
- Inherits assimilated weather
- 10 km horizontal grid spacing
- 80 vertical levels with lid at 0.1 hPa
- runs twice daily (00z, 12z)
- 5 minutes time step for weather (and tracer advection)
- 15 minutes time step for solving chemistry
- One-way coupling (meteorology affects chemistry)
- 2-bin sectional representation of PM size distribution (i.e., 0-2.5 µm and 2.5-10 µm) with 8 chemical PM components



Next: GEM-MACH v2

- Based on latest weather model GEM v4 (major update).
  - New vertical coordinate (hybrid in *log*-hydrostatic-pressure)
  - New vertical discretization (Charney-Phillips staggering) lowest layer depth is now 40-m;
  - Physics spin-up capability;
  - Piloting of LAM at the lid; global Yin-Yang grid;
  - Native vertical diffusion scheme possible for chemical tracers & new TKE scheme.
- Improvements to chemistry modules (on-going)
  - Correcting problems with emissions, dry deposition
  - Improved mass conservation
  - Improved below-cloud scavenging
  - Testing alternate chemistry SAPRC-07

RAQDPS: Emissions & input



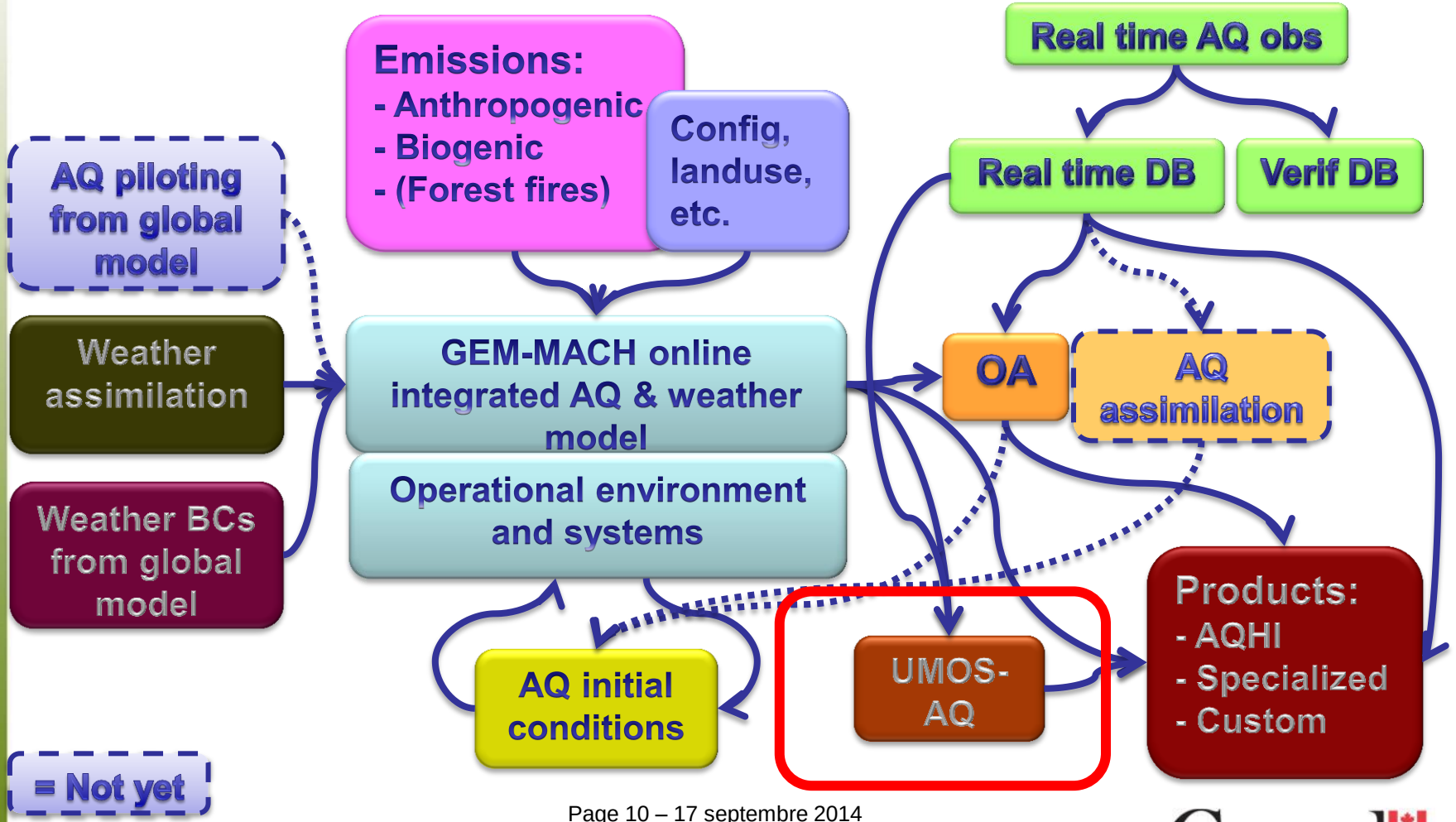
Emissions

- Processing emission inventories with SMOKE
  - Canada 2006, ***to be updated to 2010***
  - USA EPA 2005 v4.2 projected to 2012
  - Processing area sources, point sources, mobile sources
    - More than 10 000 major points, processed individually in the model
  - Provide hourly speciated profiles for a typical weak, each month
- Biogenic emissions
  - Four emission factors: NO, isoprene, monoterpenes & other VOCs
  - Using BEIS system with BELD3 vegetation database (231 categories), + Canadian National Forest Inventory
  - Adjust emissions rates online according to meteorology
    - Solar radiation, cloud cover, 10m temperature

Boundary conditions

- Using previous 12h forecast as initial AQ conditions
- Using the operational weather analysis as initial weather conditions
- Weather piloting from the operational weather runs (which is on a larger domain)
- AQ piloting: using a climatology at the boundaries
  - Vary according to month of the year
- Under evaluation for 2015:
  - Initial conditions from surface analysis
- In development for GEM-MACH v2:
  - Piloting from global GEM and GEM-MACH

RAQDPS: statistical model



Statistical model: UMOS-AQ

- Post-processing applied to GEM-MACH raw model output
- Corrects model bias (at point locations) through multi-variate linear regression approach
  - Applied to meteorological variables since 2000
  - Adapted for air quality variables (O_3, NO_2, $PM_{2.5}$) in 2010
  - Predictors:
    - Meteorological and chemical variables from GEM-MACH
    - Persistence (observations at 00Z or 12Z, depending on model run)
  - Equations are recalculated four times a month
  - Has two seasons (summer/winter) with a transitional period of approximately six weeks

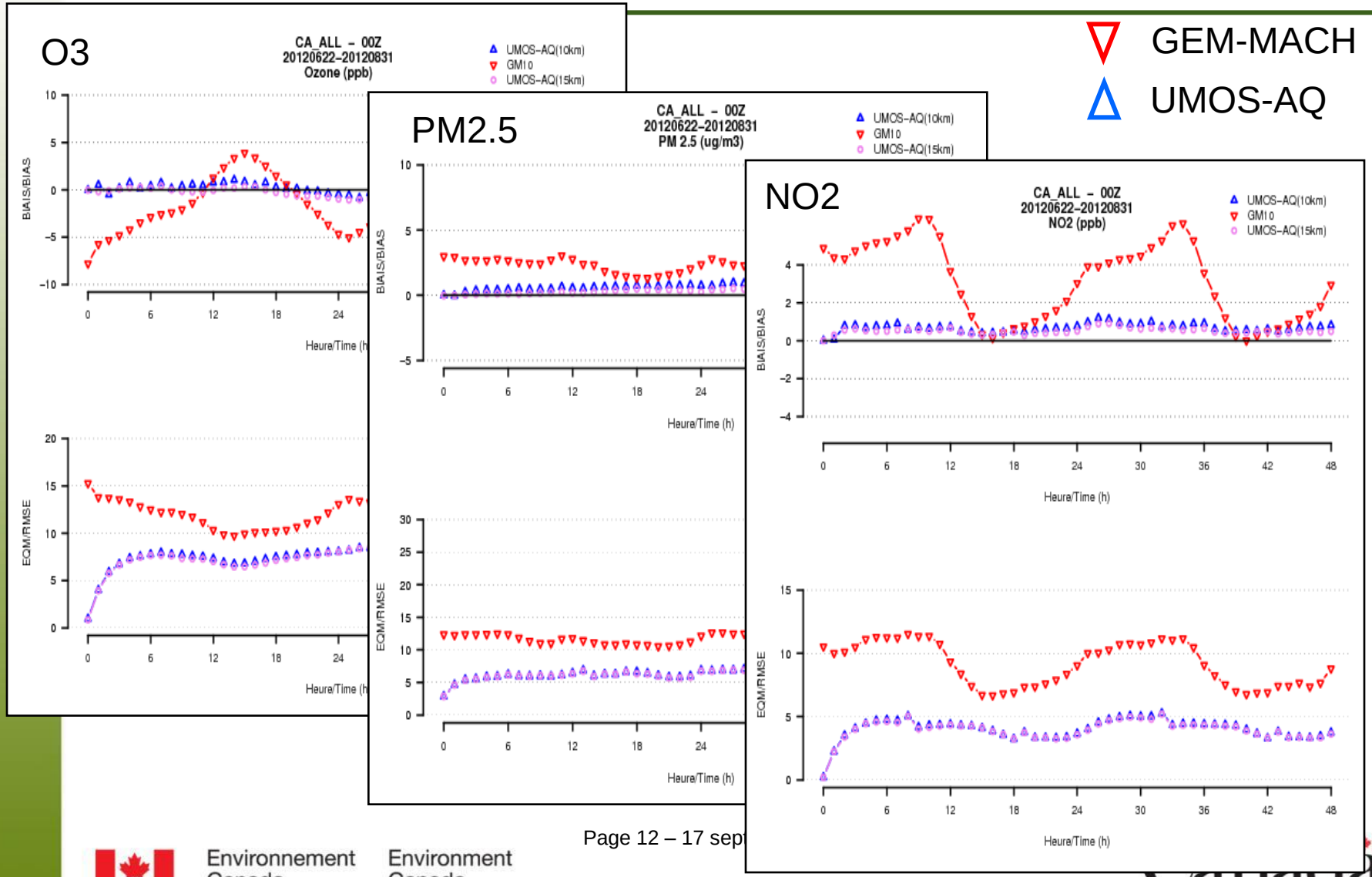
GEM-MACH/UMOS Performance

BIAS

RMSE

GEM-MACH

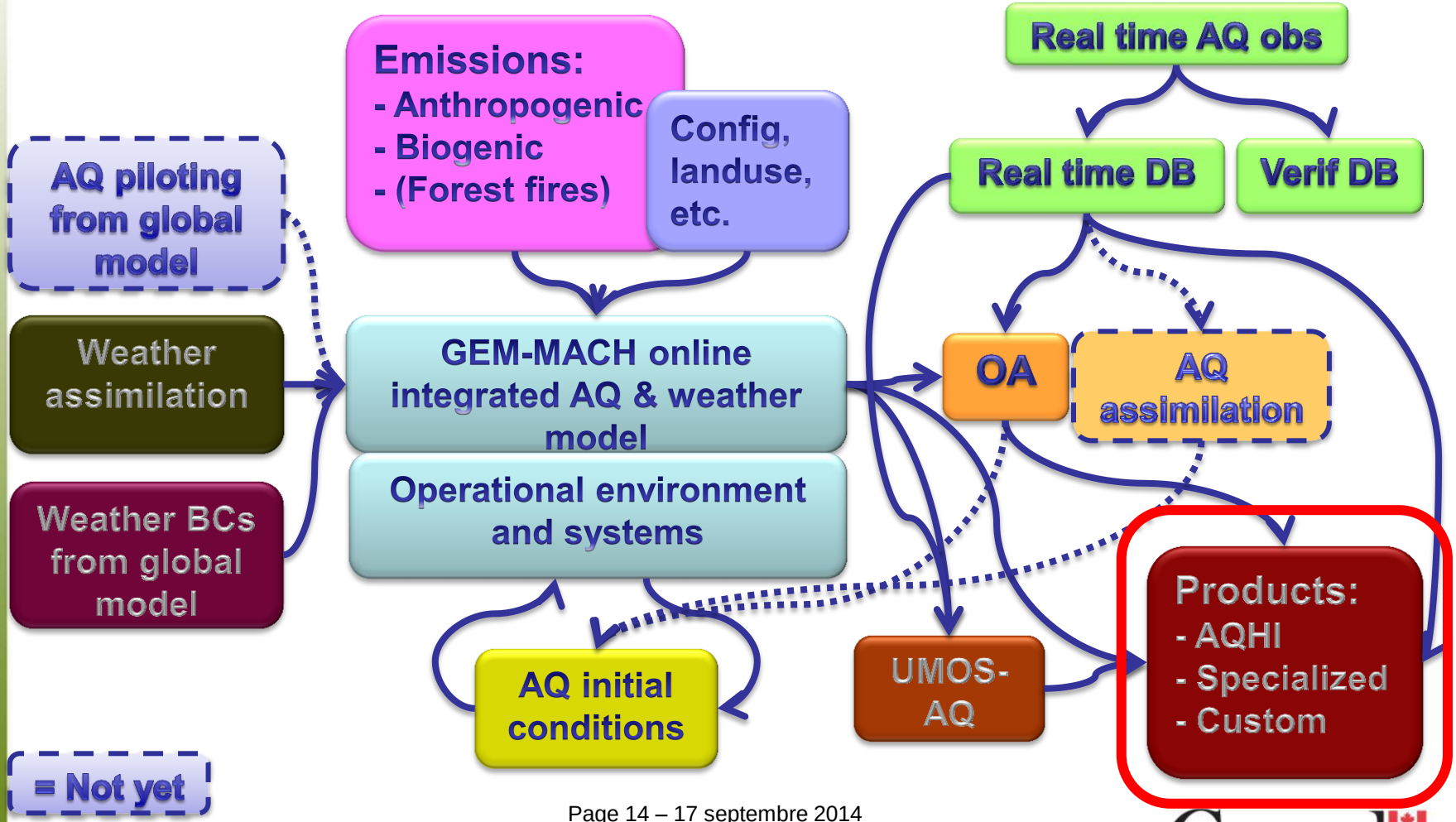
UMOS-AQ



Statistical model: developments

- XM Tool project
  - Develop and evaluate new non-linear tools for post-processing of air quality forecasts of O_3, NO_2, and $PM_{2.5}$
  - Improve guidance for air quality **episodes**.
  - Improve **timing** of air quality episodes.
  - Improve overall model forecast skill.

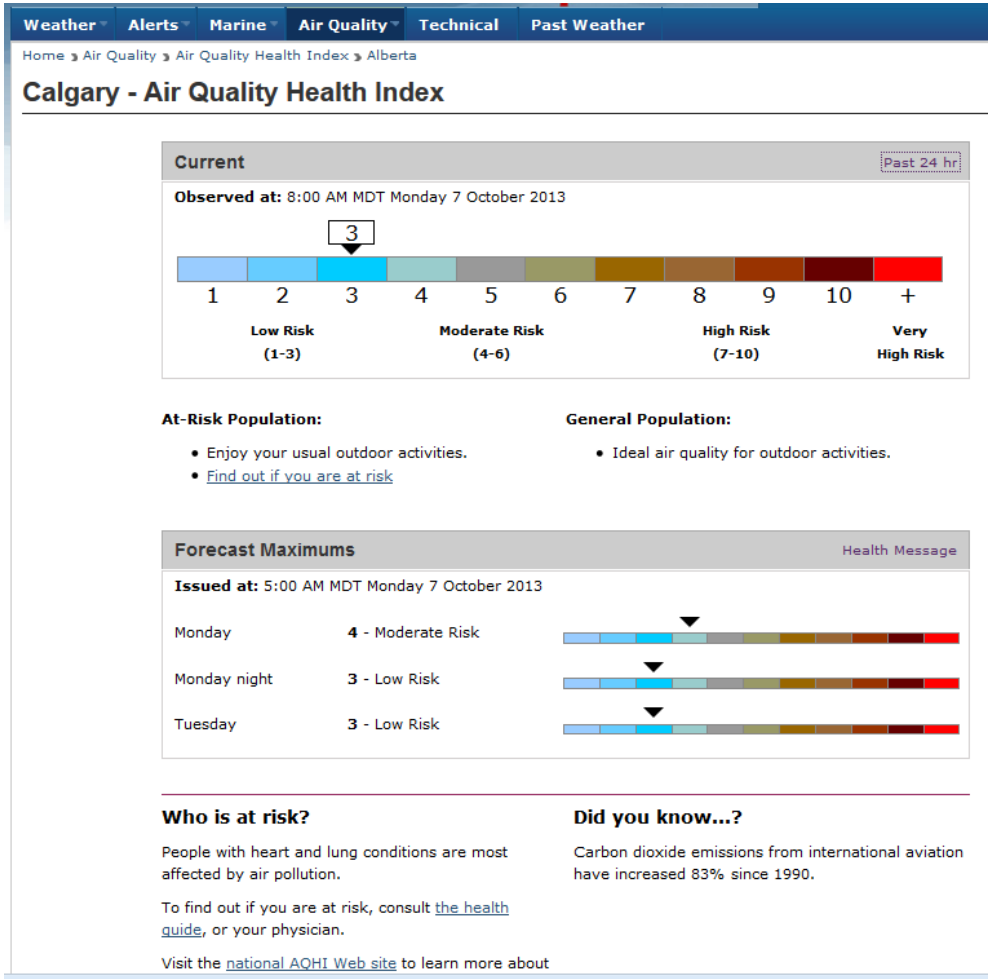
RAQDPS: products



Products: Air Quality Health Index

Used for public forecast
- Multi-pollutant index
- Triggers warnings

$$AQHI_{2.5} = \frac{10}{10.4} * \left[100 * \left(\left(e^{0.000871 * NO_2} - 1\right) + \left(e^{0.000537 * O_3} - 1\right) + \left(e^{0.000487 * PM\,2.5} - 1\right)\right)\right]$$



Products: forecasters tools

- Air quality forecast is prepared by site.
- Forecasters examine time series of
  - Recent observations
  - Hourly forecasted for the 3 AQHI pollutant (O_3, $PM_{2.5}$, NO_2), with a 3h running average
    - From UMOS-AQ
  - Resulting AQHI
- Additional products are made available to forecasters
  - Internal website with all monitoring sites observations & forecasts
    - Plus output from parallel runs (when available)
  - Allow investigation of special situations

AQHI Forecaster Resource Site

Section des Applications en Modélisation de la Qualité de l'Air (SAMQA)
Air Quality Modeling Applications Section (AQMAS)

AQHI Resources > Ontario 2013-10-25 12 UTC

In case of problems, call Netops Français

Forecast Report

Select month

- Brampton (FALIF)
  - Brampton (60428)
- Burlington (FAMXK)
  - Burlington (63001)
- Hamilton (FEVNS)
  - Hamilton Downtown (60512)
  - Hamilton Mountain (60513)
- Kingston (FEVJR)
  - Kingston Lake Ontario Park (60303)
- London (FCAEN)
  - London (60904)
- Mississauga (FEAKO)
  - Mississauga (60434)
- Newmarket (FDGED)
  - Newmarket (65101)
- Oakville (FCGKZ)
  - Oakville (61603)
- Oshawa (FDMOP)
  - Oshawa (61702)
- Ottawa (FEVNT) & Gatineau (EGLTT)
  - Hull (Ile) (50204)
  - Ottawa Central (60106)
  - Ottawa Downtown (60104)
- Peterborough (FDGEJ)
  - Peterborough (61104)
- Sault Ste. Marie (FDZCP)
  - Sault Ste Marie (60709)
- Toronto (FEUZB)
  - Toronto Downtown (60424)
  - Toronto East (60410)
  - Toronto North (60421)
  - Toronto West (60430)
- Windsor (FDEGT)
  - Windsor Downtown (60204)
  - Windsor West (60211)
- Unassociated stations
  - Algoma (64101)

Active Notices

Subject	Valid From	Valid To
Now available / maintenant disponible!! FireWork-GEMMACH	2013-06-12 15:40:30	2013-10-31 23:59:59

Notice Archive

Surface Field Maps

GEM-MACH

- NO2
- O3
- PM10
- PM2.5
- AQHI2.5
- AQHI10

Objective Analysis

- O3
- PM2.5

Observation Maps

AQHI	Hourly
Ontario	Ontario
Toronto	Toronto

Tools

- 24-hour observation summaries
- Monitoring of incoming air quality observations (Not operational)
- Troubleshooting Guide: Procedures for SPCs

AQHI observation availability for the last 6 months

Site / Month	2013-05	2013-06	2013-07	2013-08	2013-09	2013-10
Brampton	97%	99%	96%	87%	97%	92%
Burlington	97%	97%	93%	95%	95%	98%
Hamilton	97%	99%	97%	97%	99%	99%
Kingston	97%	99%	94%	92%	92%	98%
London	97%	99%	97%	96%	99%	96%
Mississauga	97%	98%	93%	96%	99%	98%
Newmarket	96%	97%	96%	97%	99%	99%
Oakville	96%	99%	93%	97%	99%	97%
Oshawa	97%	99%	95%	97%	99%	99%
Ottawa & Gatineau	99%	99%	99%	99%	100%	100%
Peterborough	97%	98%	96%	97%	99%	99%
Sault Ste. Marie	97%	99%	96%	97%	99%	99%
Toronto	97%	99%	97%	97%	99%	99%
Windsor	97%	99%	97%	99%	99%	99%

The target for minimum availability of the AQHI at any site is at least 85%

Good availability >= 95%

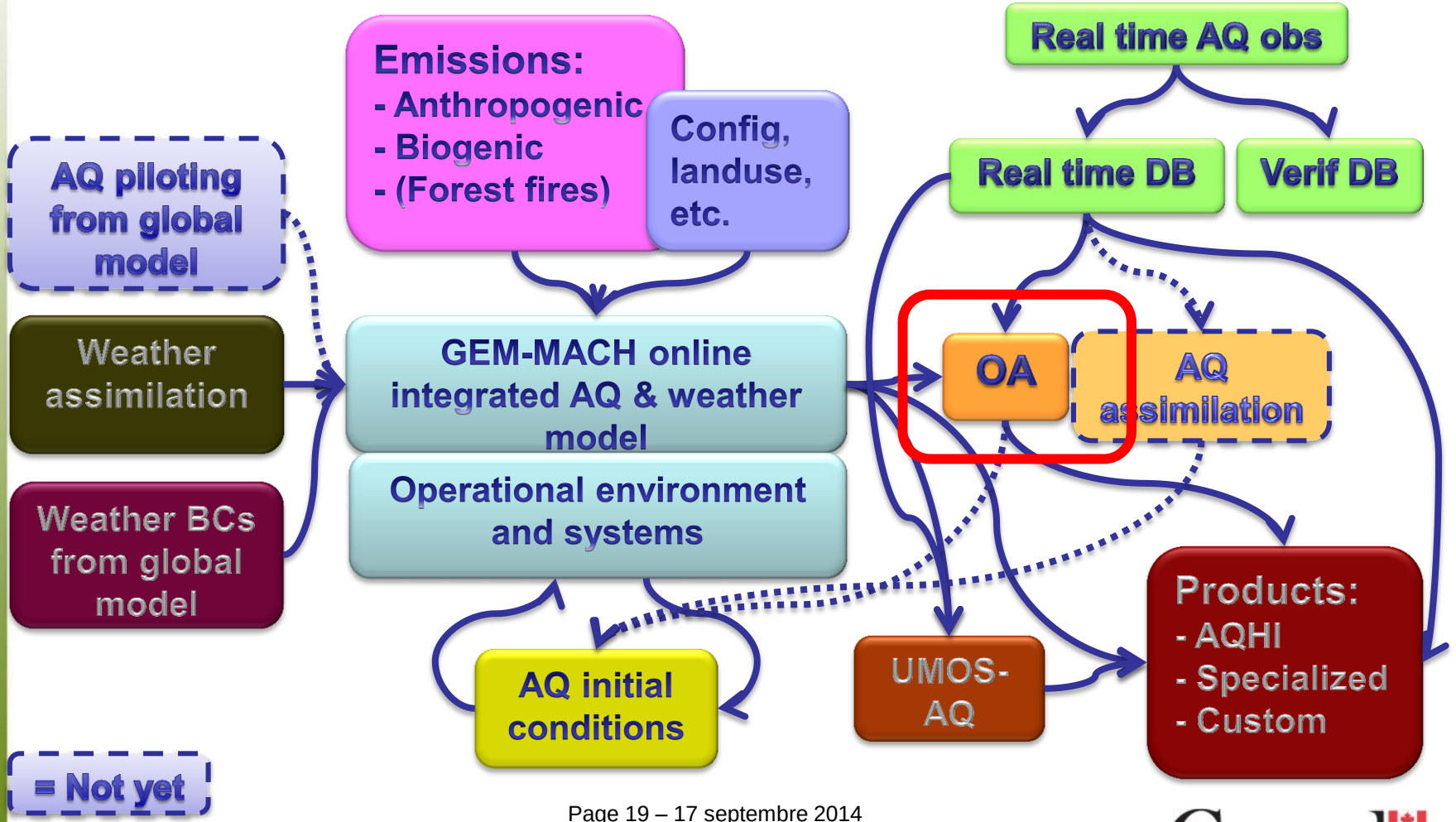
Poor 85% <= availability < 95%

Insufficient availability < 85%

Other products

- Maps of model output for ozone, $PM_{2.5}$ at the surface, 50m and 500m are published on our public website.
  - Raw model output to be used with care
- Hourly objective analysis for O_3, $PM_{2.5}$ (not public yet)
- Internal website with AQHI including the impact of forest fires
- Animations of forest fire forecasted plumes over North-America

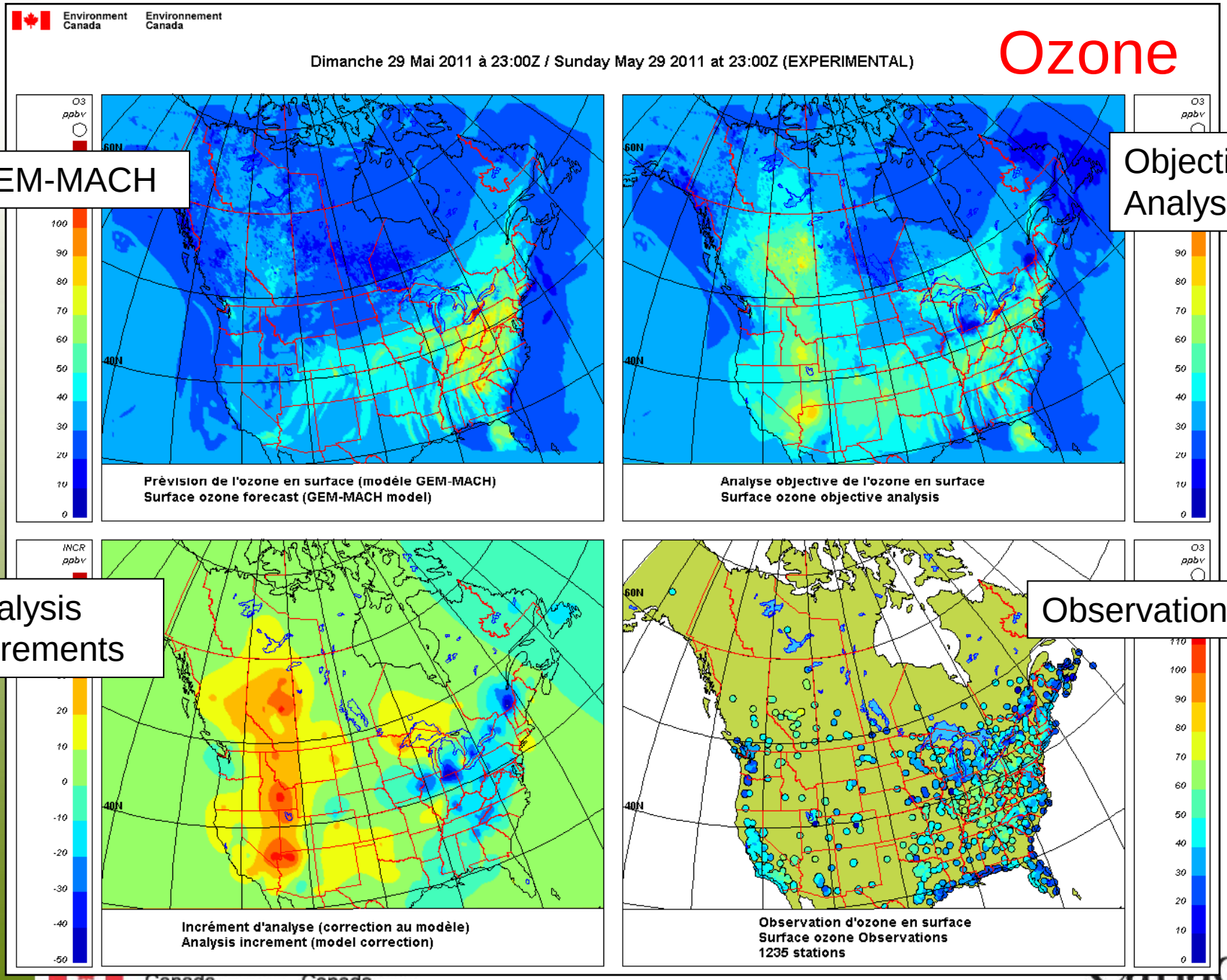
RAQDPS: objective analysis



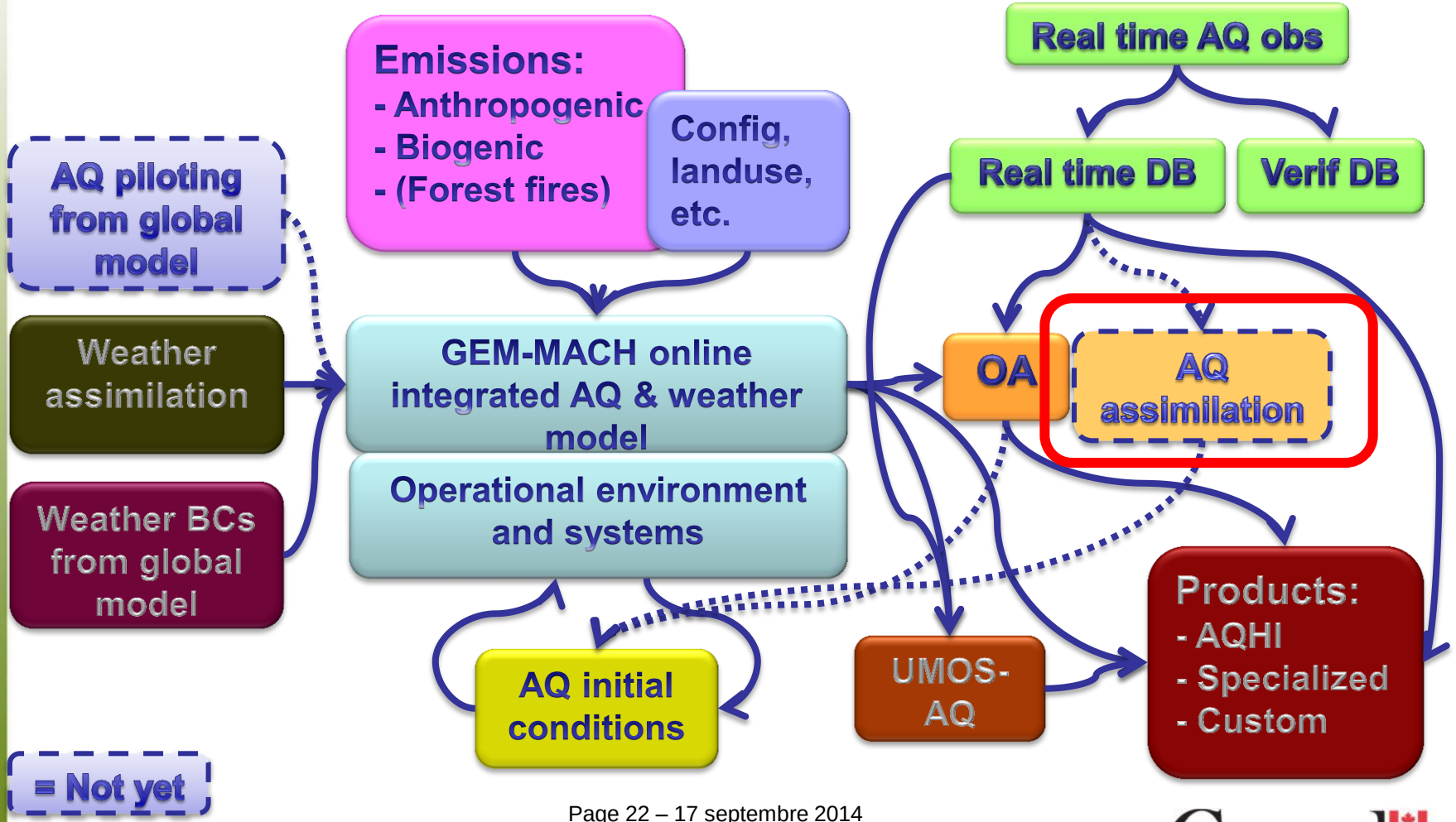
OA: Objective Analysis for Surface Pollutants

- Operational as of February 2013
- Blends model forecasts with surface observations from Canadian regional networks and the U.S. EPA/AIRNow observation network
  - Using an optimal interpolation approach
  - Knowledge of the errors of model and observation data is applied to weight each input accordingly
- Products available hourly (2x = early and late analyses):
  - O_3 and $PM_{2.5}$ **(NO_2 to be added in 2015)**
  - **For 2015: AQHI maps** derived from individual analyses for O_3, $PM_{2.5}$, and NO_2
- Analyses are not yet used to initialize GEM-MACH
  - Tests have been made, applying a correlation factor to spread information at the surface into the vertical dimension
  - Promising results, especially for PM (gain goes beyond 48h)

Ozone


Environment Canada
Environnement Canada
Dimanche 29 Mai 2011 à 23:00Z / Sunday May 29 2011 at 23:00Z (EXPERIMENTAL)
GEM-MACH
Objective Analysis
Analysis Increments
Observations
O3 ppbv
INCR ppbv
60N
40N
Prévision de l'ozone en surface (modèle GEM-MACH)
Surface ozone forecast (GEM-MACH model)
Analyse objective de l'ozone en surface
Surface ozone objective analysis
Incrément d'analyse (correction au modèle)
Analysis increment (model correction)
Observation d'ozone en surface
Surface ozone Observations
1235 stations

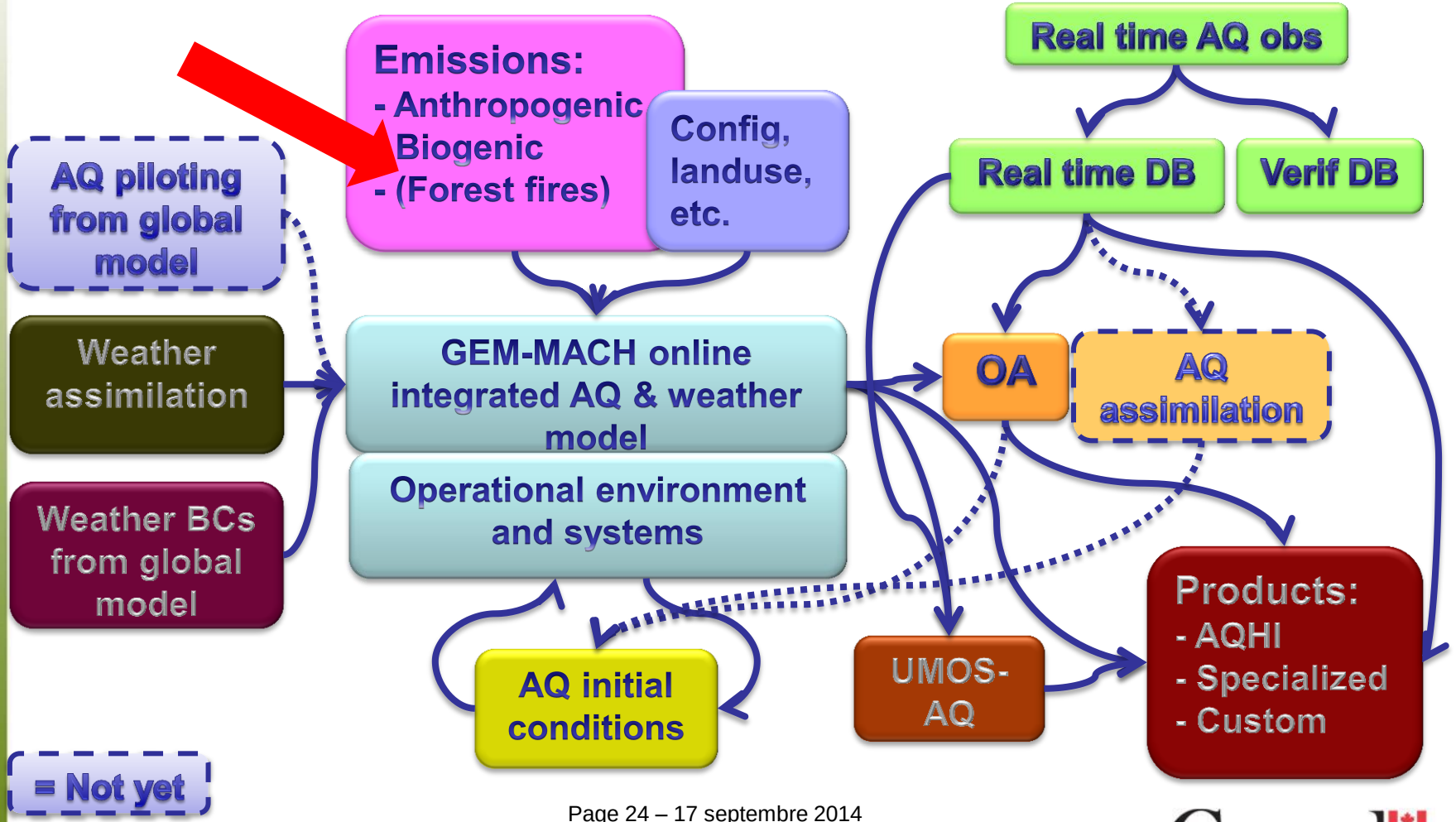
RAQDPS: towards AQ assimilation



Towards AQ assimilation

- Long-term plan is to develop an En-Var chemical data assimilation system
- Interim plan: use surface objective analysis
  - Analyses are not yet used to initialize GEM-MACH
  - Tests have been made, applying a correlation factor to spread information at the surface into the vertical dimension
  - Promising results, especially for PM (gain goes beyond 48h)

RAQDPS: Forest Fires



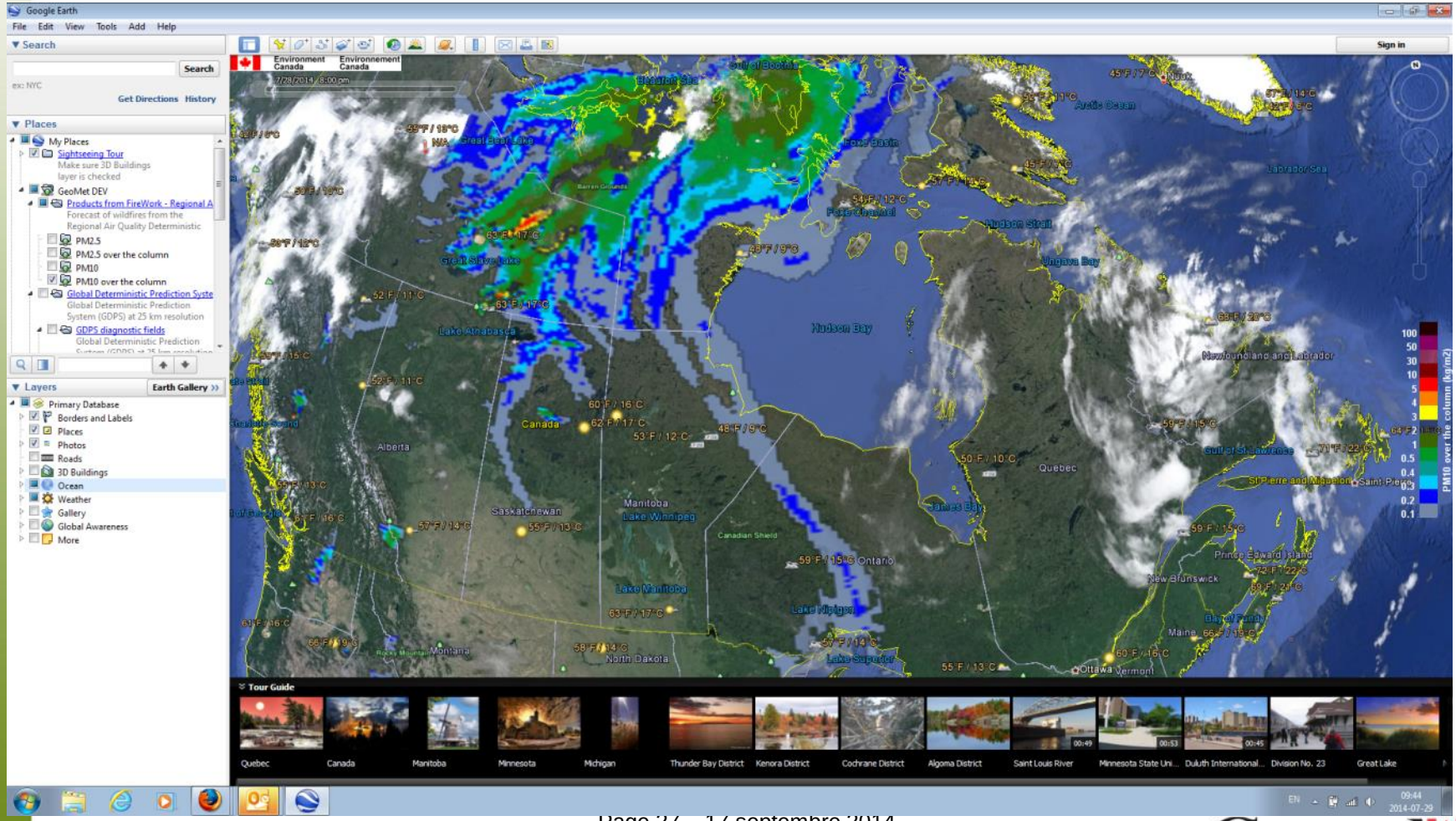
Forest Fire modelling

- Now possible thanks to:
  - Near real-time hotspot data available for all of North-America
  - Partners from the Canadian & US Forest Services provide fire activity and characteristics in near real-time (NRCan)
  - BlueSky initiative provides tools to compute emissions from the above data
- Large interest from emergency management partners
- Mostly developed with the objective of improving the air quality forecast
  - Run as a parallel product

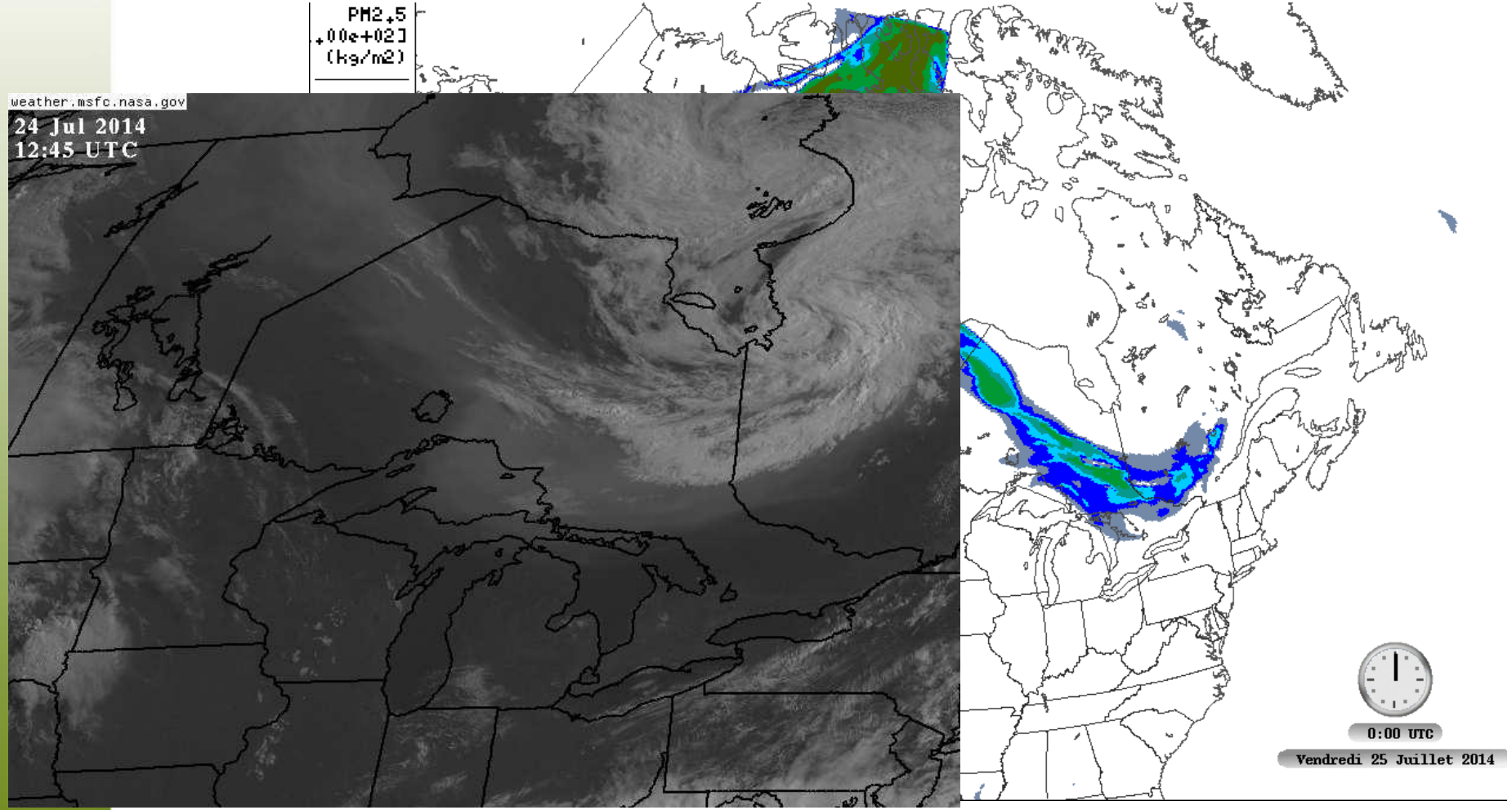
Current Firework Modelling strategy

- The experimental set-up uses the same configuration of the operational 10 km GEM-MACH to execute a separate run that takes into accound fire emissions.
- Run in parallel with forest fire emissions:
  - Run twice a day
  - Inclusion of “old smoke” from the previous run
- Products
  - $PM_{2.5}$ Maps and animations based on the difference between Firework and the operational run to isolate plumes
  - Alternate AQHI with Firework
- Next year (2015): implement Freitas plume-rise scheme

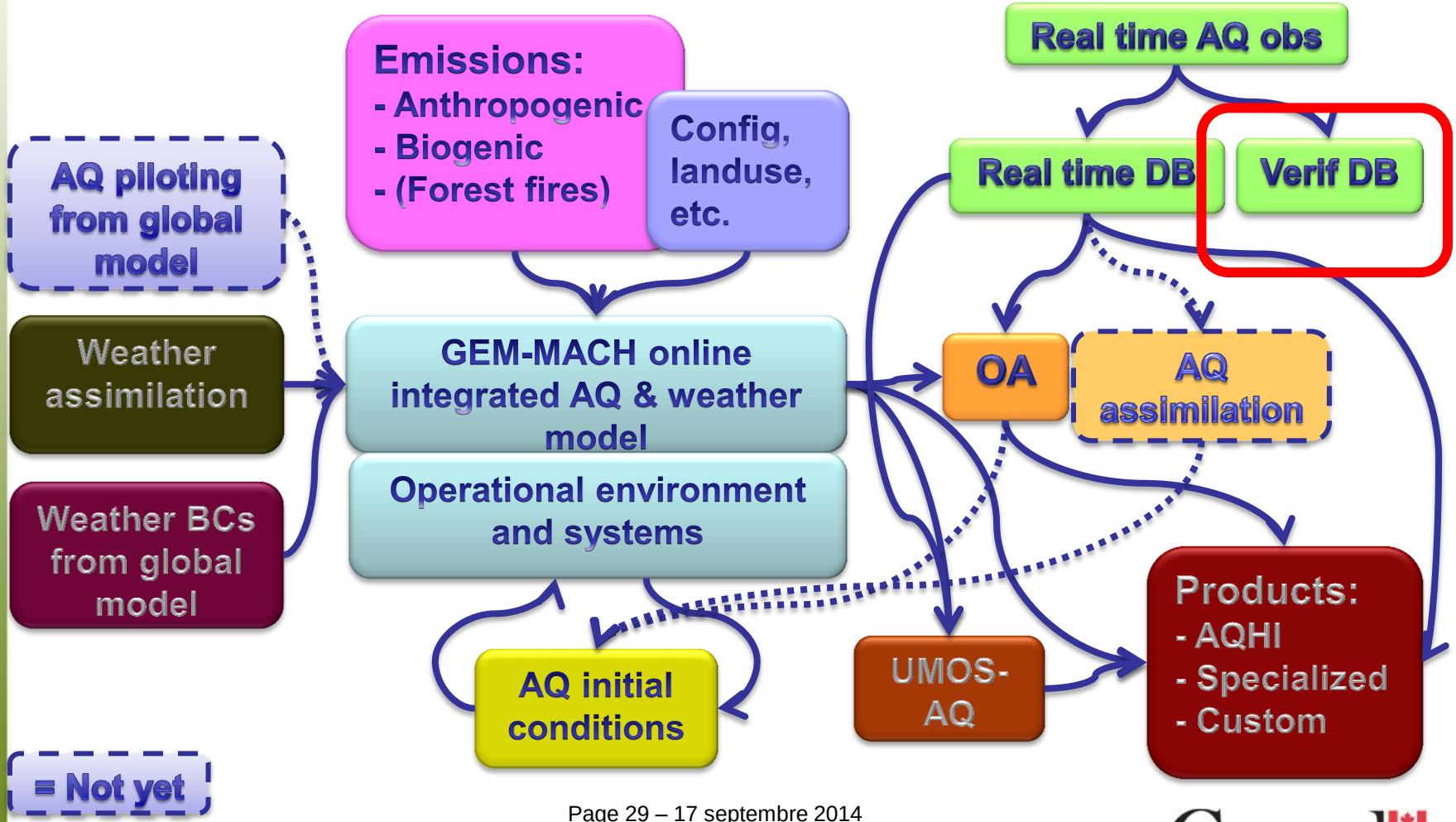
Publishing FireWork layers as WMS/KML



Long-range impact of Fires (July 25-26)

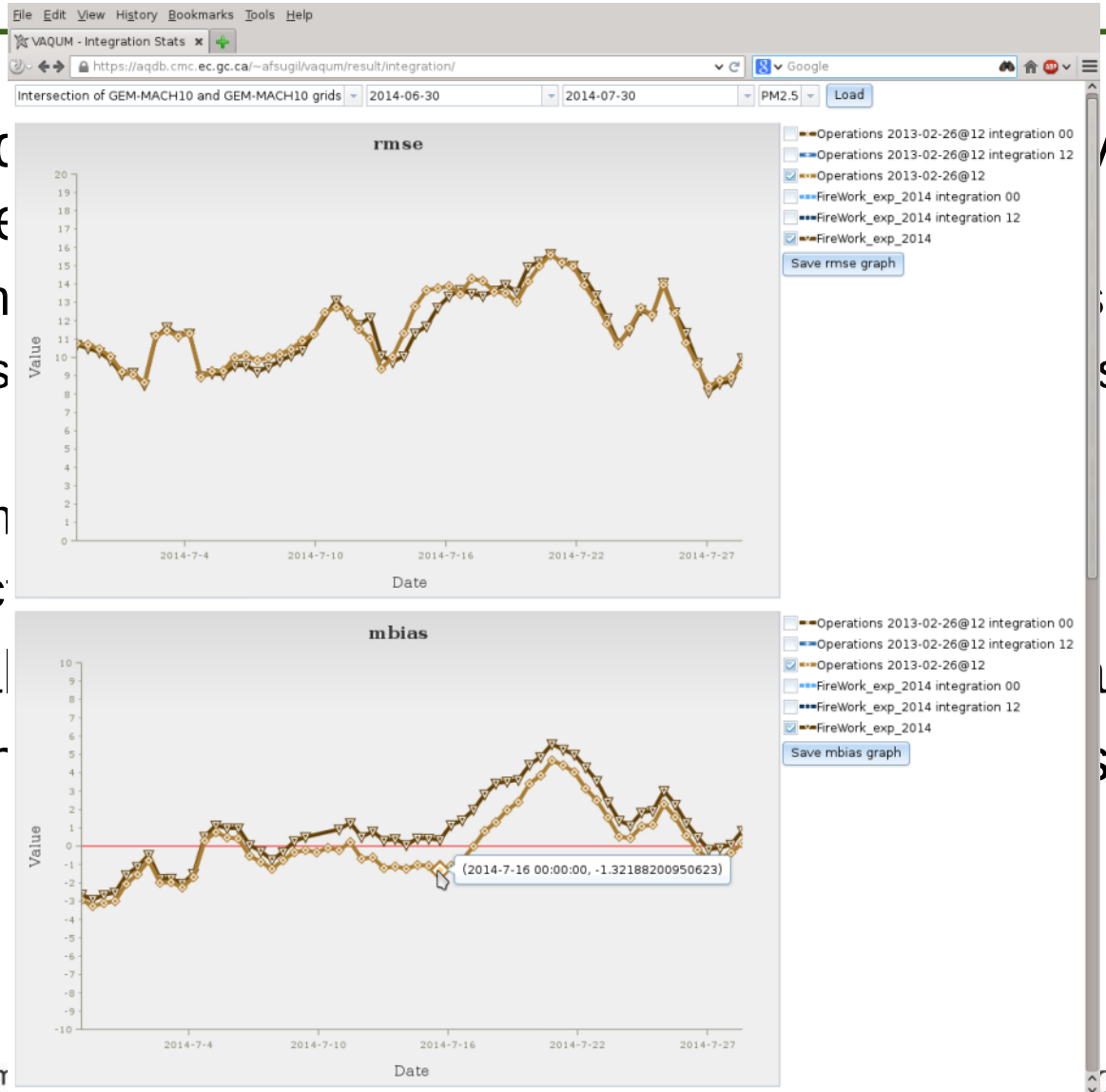


RAQDPS: verification



VAQUM: Verification for Air Quality Models

- Designed
  - Can in
  - Allows
  - About
  - Maxim
  - Collec
- Essentia
- Monitorir



Sample model perfomance: summer 2014

Summer 2014															
BOOTSTRAPPING		Full Domain		Canada		Western Canada		Eastern Canada		USA		Western USA		Eastern USA	
Pollutant	Statistique	OPS	FireWork	OPS	FireWork	OPS	FireWork	OPS	FireWork	OPS	FireWork	OPS	FireWork	OPS	FireWork
NO_2	MB			0.66	0.74	-0.12	0.00	1.38	1.43						
	R			0.52	0.51	0.50	0.50	0.54	0.53						
	URMSE			6.51	6.61	6.01	6.17	6.86	6.92						
O_3	MB	2.87	3.70	2.07	3.74	1.82	4.97	2.21	3.06	3.06	3.73	-4.53	-3.65	5.78	6.37
	R	0.66	0.66	0.64	0.61	0.59	0.52	0.67	0.67	0.65	0.66	0.68	0.67	0.69	0.69
	URMSE	13.04	13.20	10.46	11.49	10.96	13.44	10.17	10.19	13.47	13.50	13.26	13.64	12.46	12.42
$PM_{2.5}$	MB	0.34	1.54	-2.03	-0.07	-5.24	-1.39	0.56	0.99	1.15	2.08	-2.66	-0.71	3.40	3.74
	R	**0.27**	**0.34**	**0.17**	**0.37**	**0.07**	**0.39**	**0.38**	**0.40**	**0.31**	**0.33**	**0.20**	**0.26**	0.32	0.32
	URMSE	11.60	12.87	12.10	11.98	13.55	13.92	10.07	10.03	11.31	13.13	8.05	13.84	12.31	12.39

Légende		ALL Scores	CAN (E,W)	USA (E,W)	ALL Scores	CAN (E,W)	USA (E,W)
OPS G-M better		27	8	5	**53%**	**44%**	**42%**
FireWork better		14	4	5	**27%**	**22%**	**42%**
Non-significant		10	6	2	20%	33%	17%
Unavailable							
	Total	51	18	12			

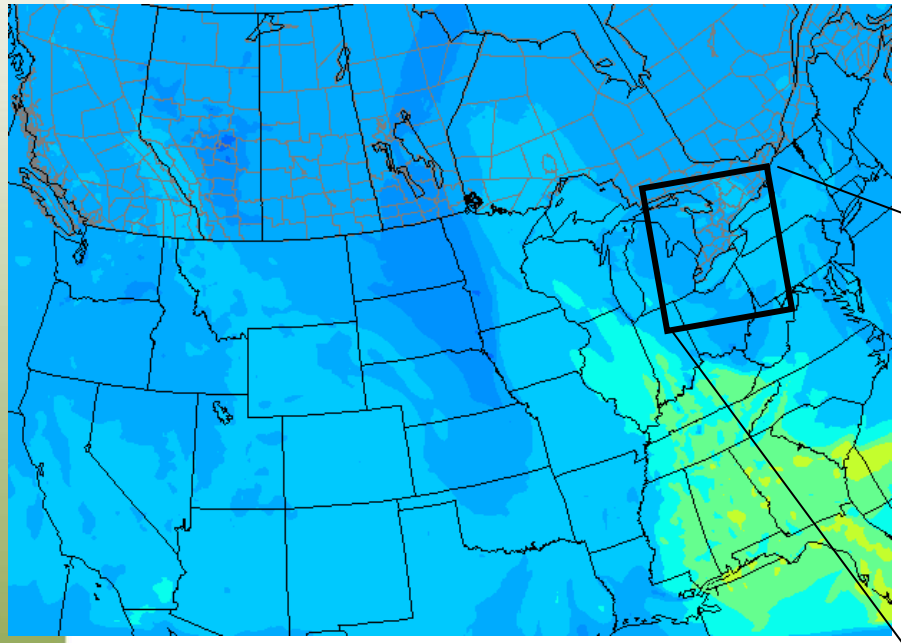
- General model behaviour in summer:
  - Too much ozone & pm in the East
  - Not enough in the West (though FireWorks corrects PM)
  - FireWork helps with PM correlations where fires occur

Other initiatives

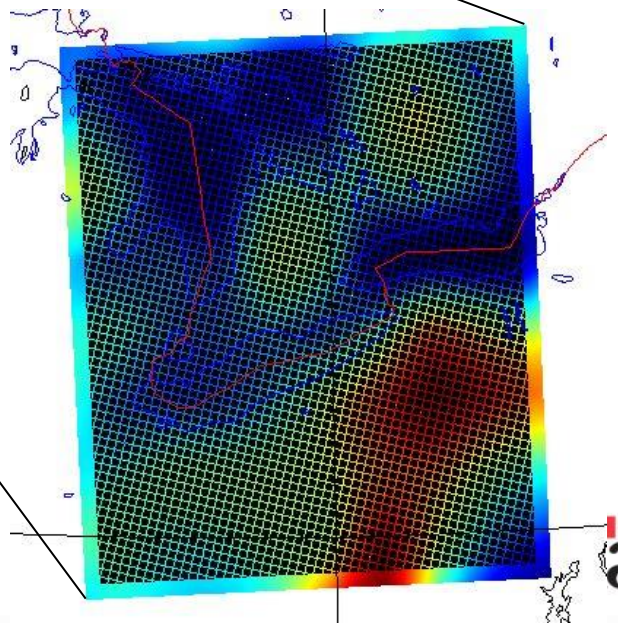
- PanAm games 2015, Toronto
- AQHI by district

Air Quality Modeling for Pan Am

Nested GEM-MACH v2 at 2.5-km, 250x300



- High Resolution Domain
- Includes Detroit/Windsor, Cleveland, Buffalo, Pittsburgh
- Includes 3 Great Lakes to capture lake breeze effect
- Met will be driven by operational 2.5-km GEMv4



- **24-hr forecast, initiated once a day**
- **Real-time predictions of AQHI at air quality stations**

Objectives of the Air Quality (AQ) Science Showcase

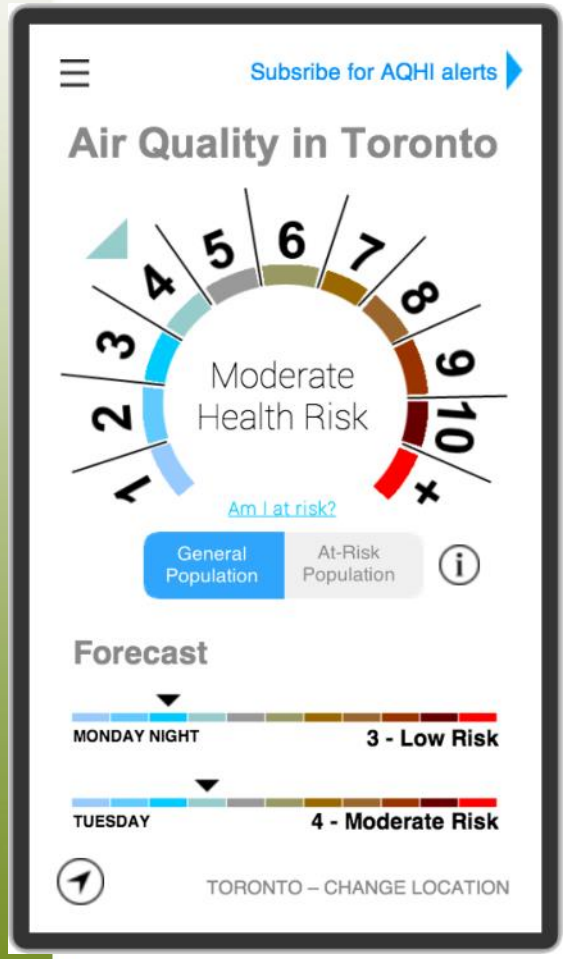
- To develop an integrated environmental model to address scientific questions related to urbanization:
  - To study the feedbacks between aerosol and weather in an urban environment
  - To perform an aerosol source apportionment study at the UofT rooftop comparing both receptor and emission models, assess decadal changes in emission-based models and observations.
  - To improve urban spatial surrogate maps for allocating on-road mobile emissions and food cooking emissions
  - To develop and validate a high resolution objective analysis
- To align projects to a common domain and time period to foster collaboration within EC and with our partners
- To accelerate the development of a high resolution operational AQ prediction system for urban cities across Canada

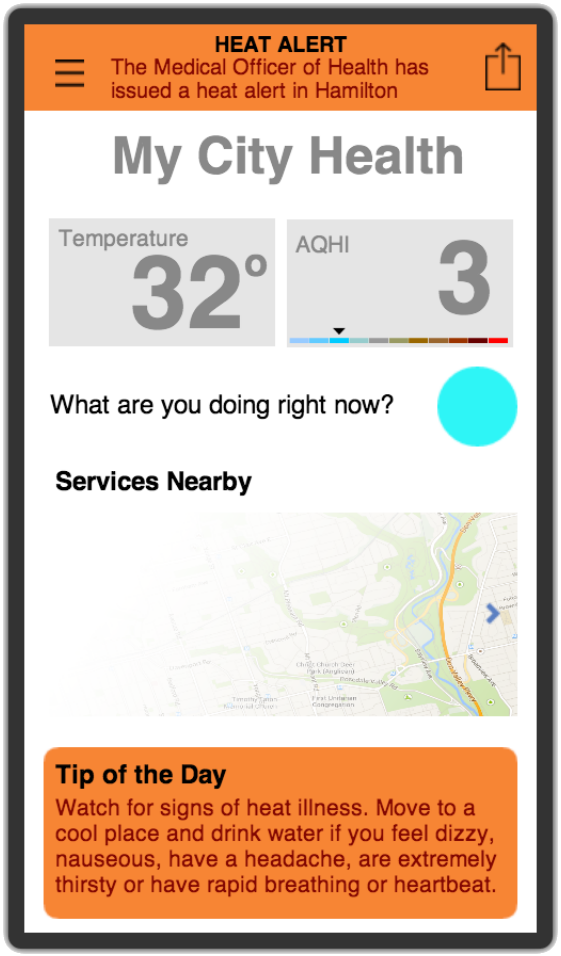
Source: Craig Stroud, EC-ASTD

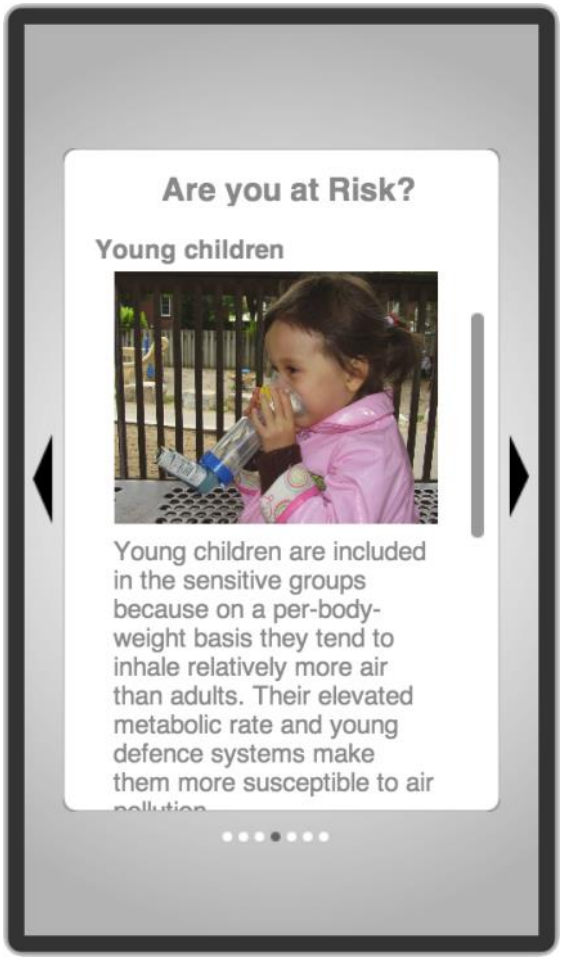
AQHI Enhancement for Pan Am Games 2015

- Raise visibility of individual AQHI locations in the (6 in Toronto and 2 in Hamilton)
- Hourly forecasts at individual locations for Day 1
- Continue to use community value with Weather Network and other media
- Integration of warnings into public health GIS risk-management tools
- Integration of AQHI products in mobile apps

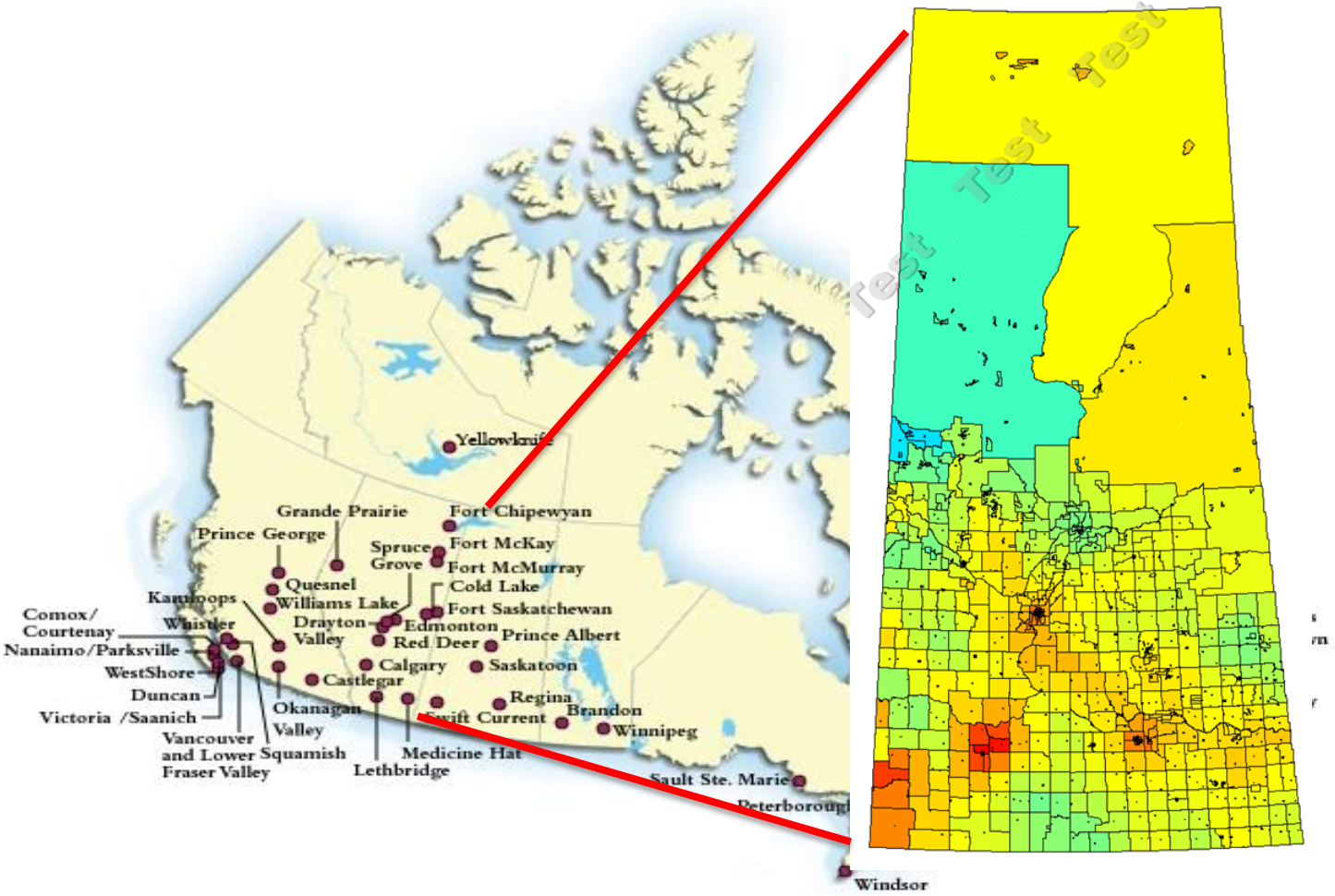
Heat and Health







Providing AQHI as a map

- 

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Thank you!

Didier Davignon

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