Plans for Coupled Atmosphere-Ocean Data Assimilation in GOAPP

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Outline

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Introduction to MSC Data assimilation

Numerical models play a key role in the production of MSC forecasts.

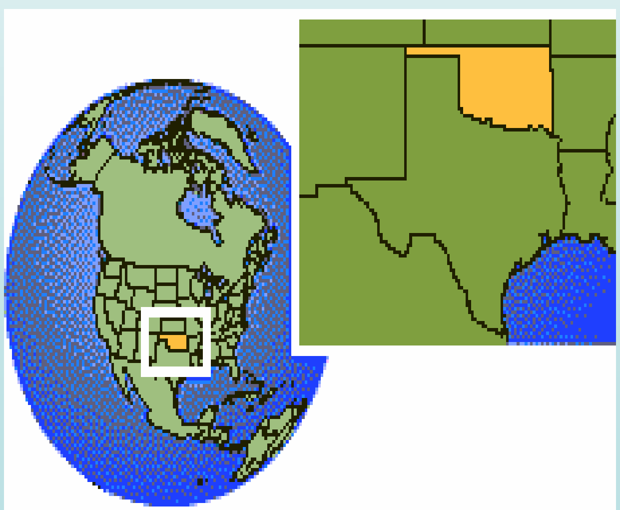
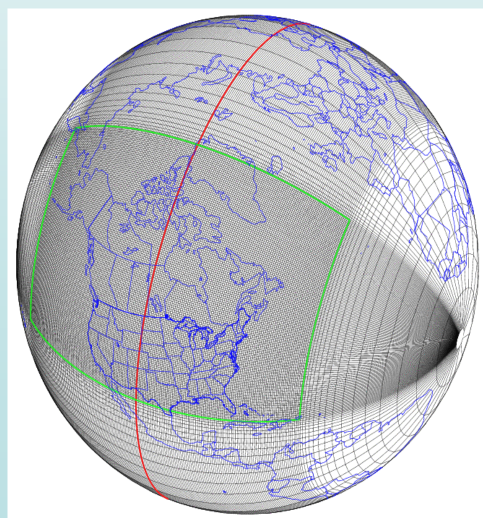
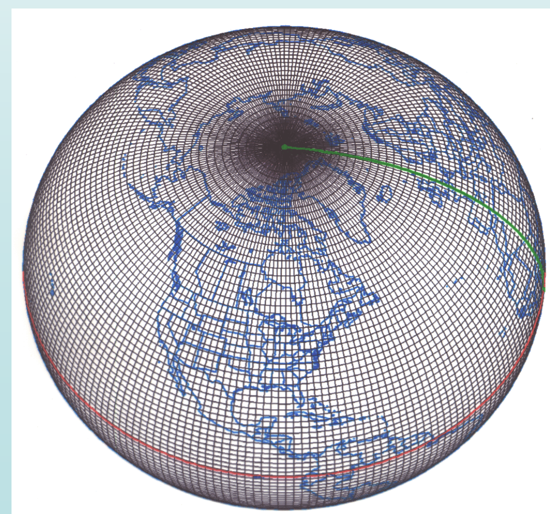
Accuracy depends on quality of numerical models, data, and the assimilation system that produces initial analyses from which forecasts run.

To start, models need initial values of variables (e.g., pressure, temperature, velocity, humidity) on the model 3D global grid.

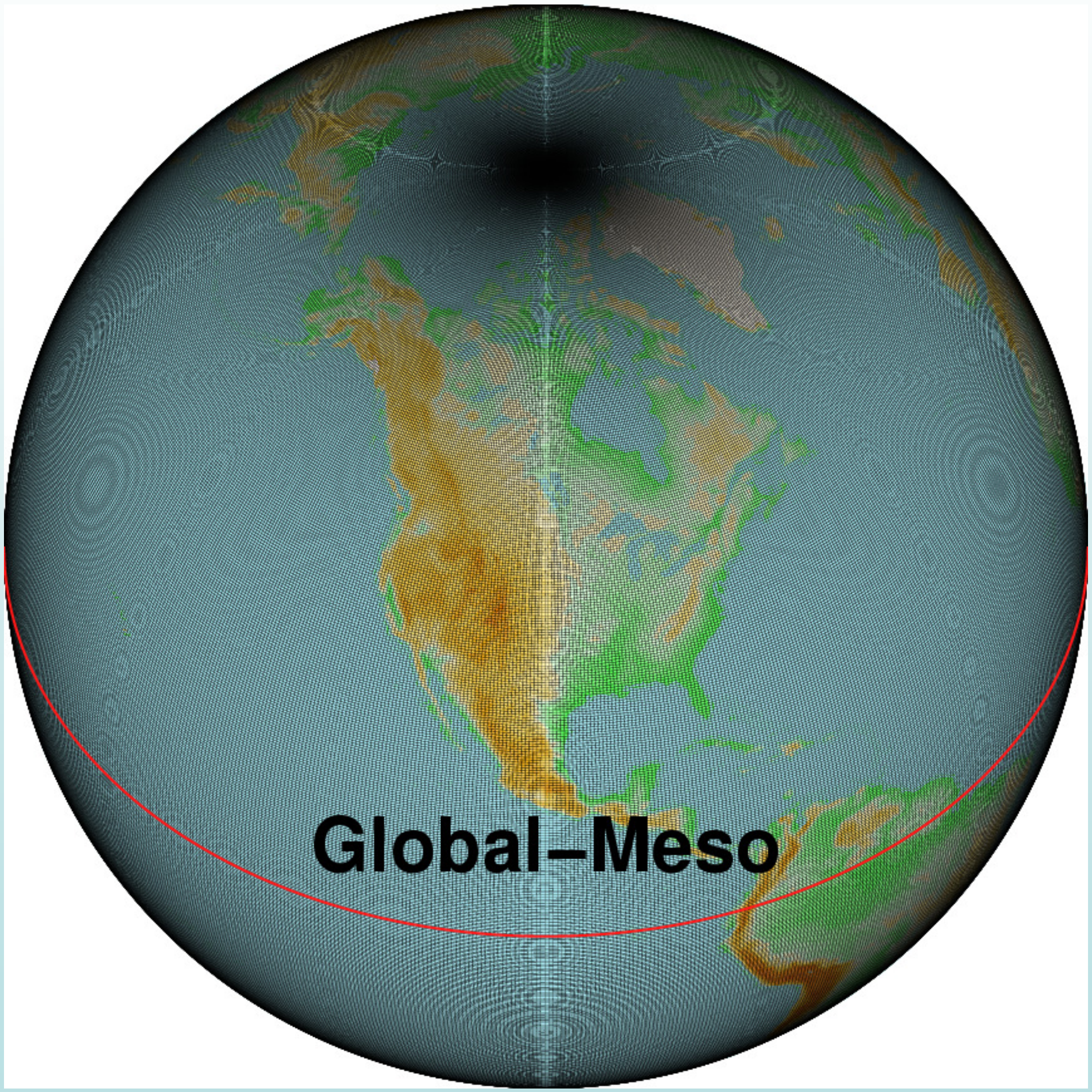
Data assimilation produces a best estimate of initial values by combining past information, carried forward in time by the model, with new observations using statistical techniques.

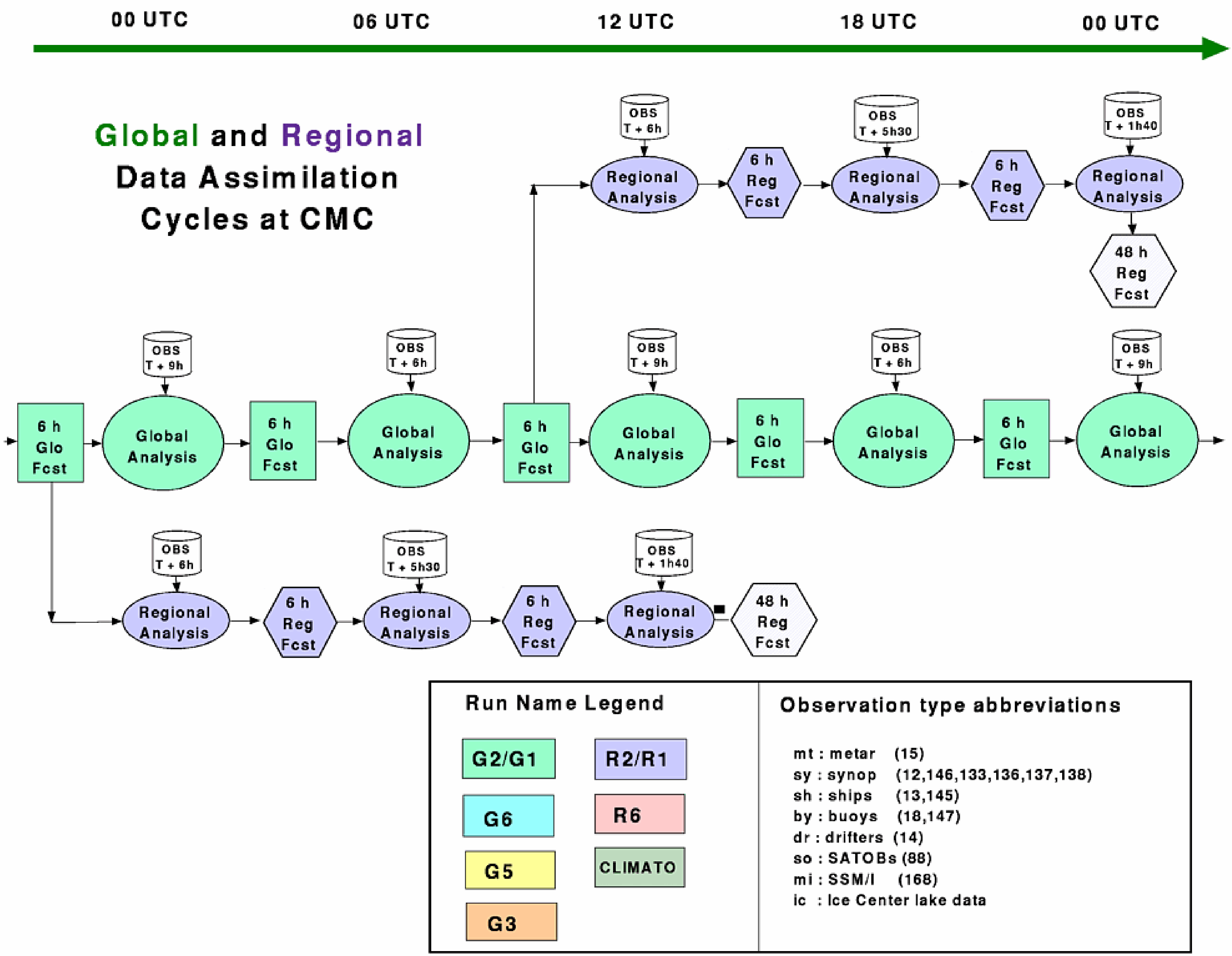
MSC's Data Assimilation and Prediction Infrastructure

- Global Environmental Multiscale Model (GEM)
- MSC operational forecast model, with development and operations based mostly in Dorval QC, running at Canadian Meteorological Centre (CMC)
- Multiple grid configuration (rotated/stretched lat-lon grid)

35 km Global GEM





00 UTC
06 UTC
12 UTC
18 UTC
00 UTC
Global and Regional
Data Assimilation
Cycles at CMC
OBS T + 6h
Regional Analysis
6 h Reg Fcst
OBS T + 5h30
Regional Analysis
6 h Reg Fcst
OBS T + 1h40
Regional Analysis
48 h Reg Fcst
6 h Glo Fcst
OBS T + 9h
Global Analysis
6 h Glo Fcst
OBS T + 6h
Global Analysis
6 h Glo Fcst
OBS T + 9h
Global Analysis
6 h Glo Fcst
OBS T + 6h
Global Analysis
6 h Glo Fcst
OBS T + 9h
Global Analysis
OBS T + 6h
Regional Analysis
6 h Reg Fcst
OBS T + 5h30
Regional Analysis
6 h Reg Fcst
OBS T + 1h40
Regional Analysis
48 h Reg Fcst
Run Name Legend
G2/G1
R2/R1
G6
R6
G5
CLIMATO
G3
Observation type abbreviations
mt : metar (15)
sy : synop (12,146,133,136,137,138)
sh : ships (13,145)
by : buoys (18,147)
dr : drifters (14)
so : SATOBs (88)
mi : SSM/I (168)
ic : Ice Center lake data

Statistical estimation: univariate case

X_b = forecast
(or background field)

y = observation

X_a = analysis

and X_t = true state

$\varepsilon_b = (\mathbf{X}_b - \mathbf{X}_t)$: **forecast error**

$\varepsilon_o = (\mathbf{y} - \mathbf{X}_t)$: observation error

$\varepsilon_a = (\mathbf{X}_a - \mathbf{X}_t)$: analysis error

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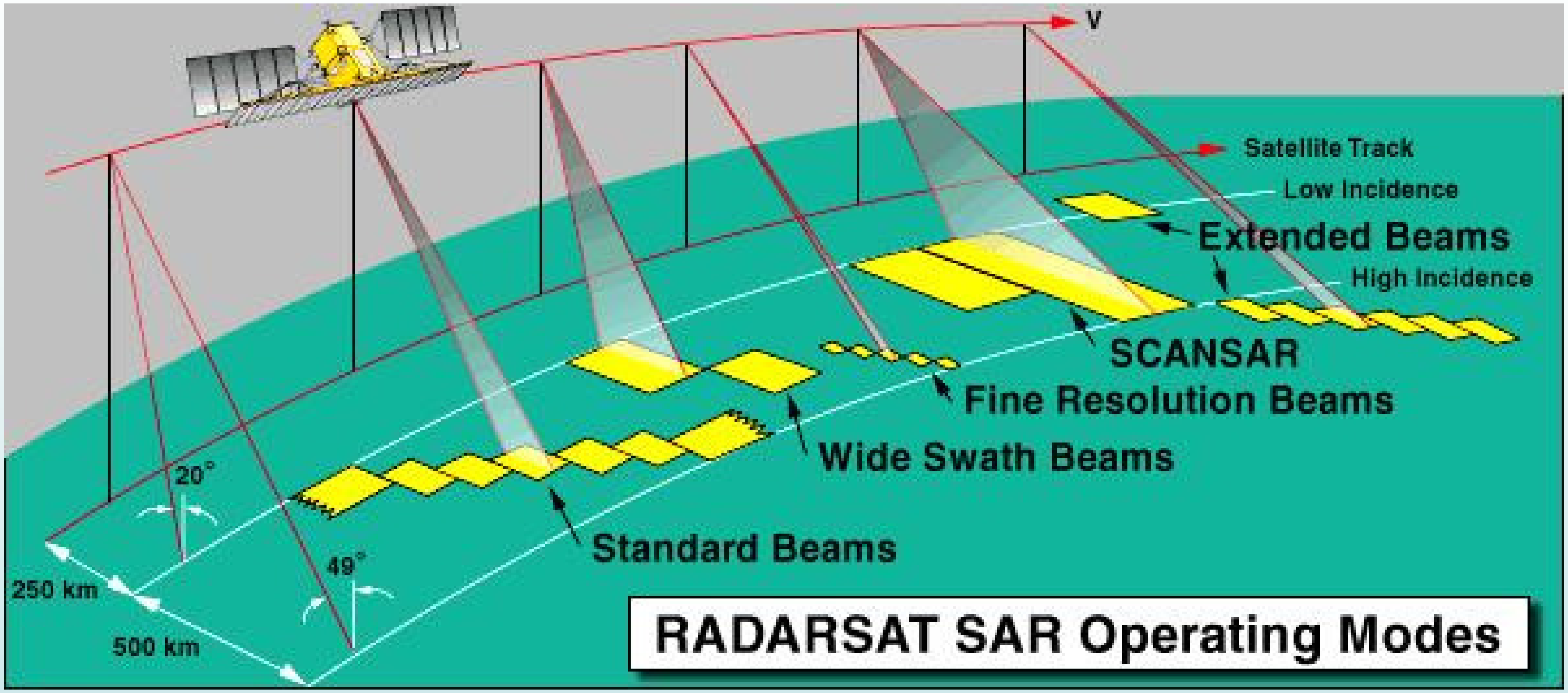
Analysis $\mathbf{X}_a = (1-\lambda)\mathbf{X}_b + \lambda\mathbf{y}$

$$\lambda = \frac{\sigma_b^2}{\sigma_b^2 + \sigma_o^2}$$

Surface Wind Validation using Radarsat

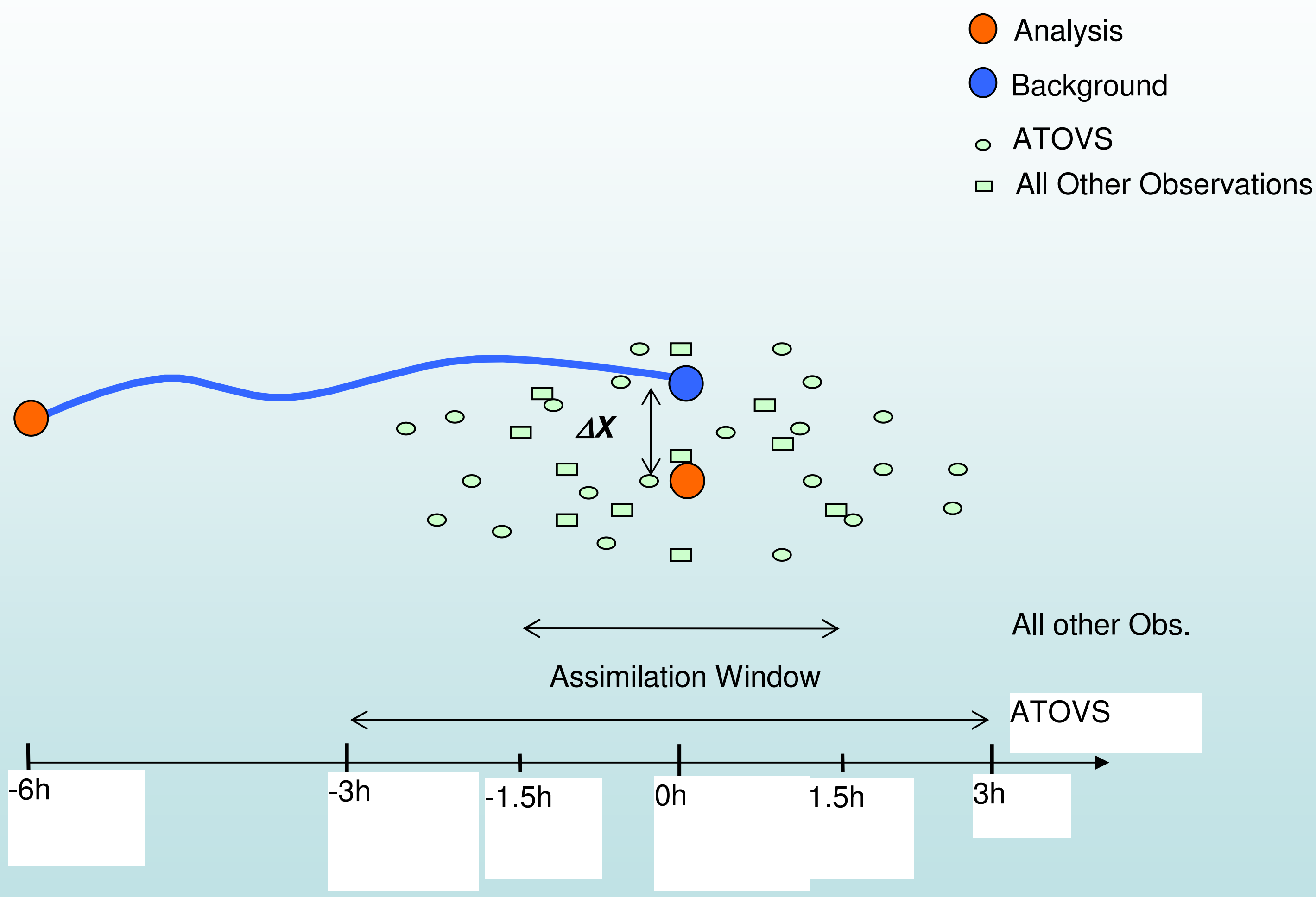
(Rick Danielson, Michael Dowd, Hal Ritchie)



Minimize the difference between our best guess fields versus GEM winds (x^b) and Radarsat obs (y)

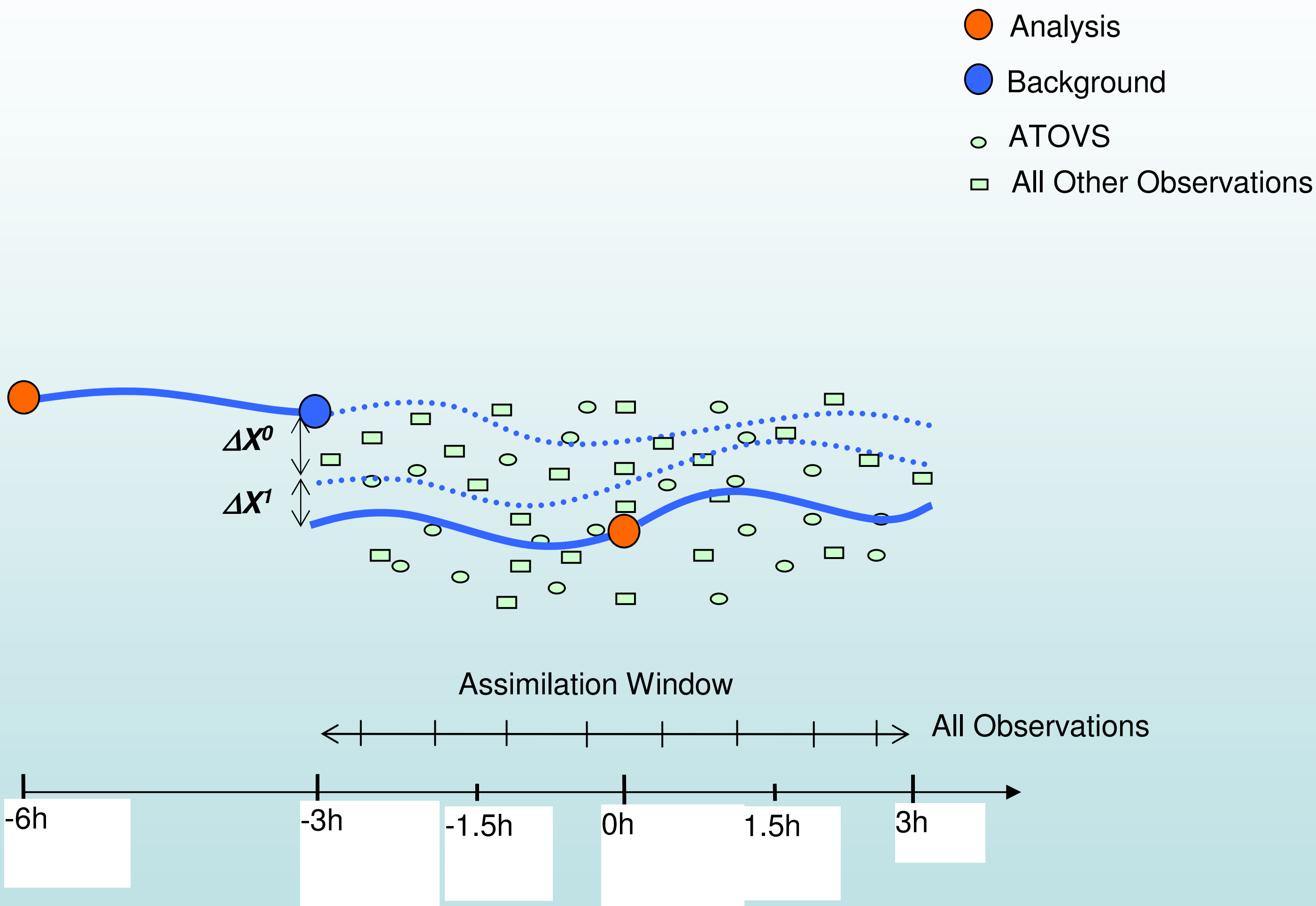
$$J(x) = \frac{1}{2}[\mathbf{x} - \mathbf{x}^b]^T \mathbf{B}^{-1}[\mathbf{x} - \mathbf{x}^b] + \frac{1}{2}[H(\mathbf{x}) - \mathbf{y}]^T \mathbf{R}^{-1}[H(\mathbf{x}) - \mathbf{y}]$$

3D-Var

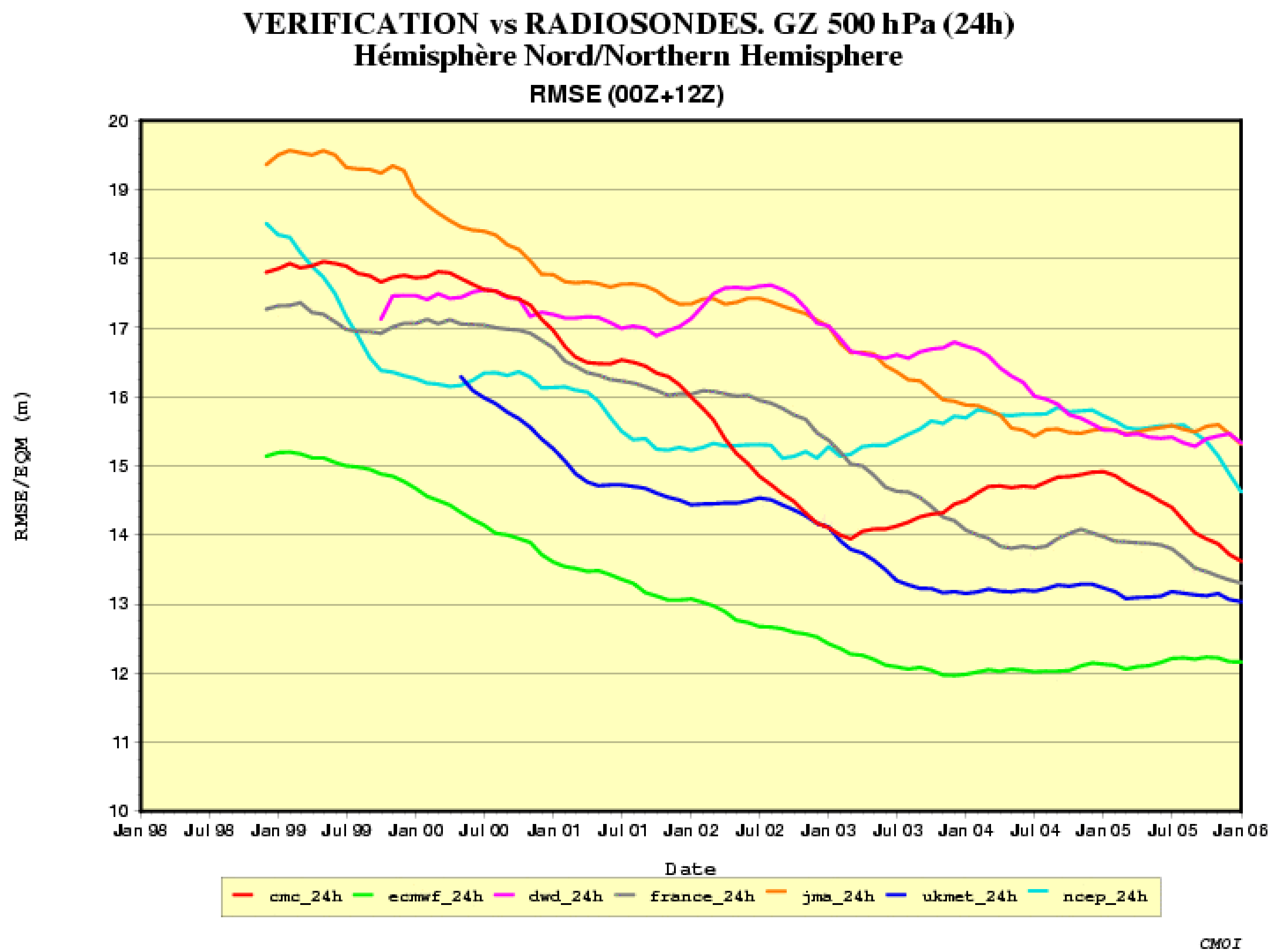


Analysis
Background
ATOVS
All Other Observations
ΔX
All other Obs.
Assimilation Window
ATOVS
-6h
-3h
-1.5h
0h
1.5h
3h

4D-Var


Analysis
Background
ATOVS
All Other Observations
ΔX⁰
ΔX¹
Assimilation Window
All Observations
-6h
-3h
-1.5h
0h
1.5h
3h

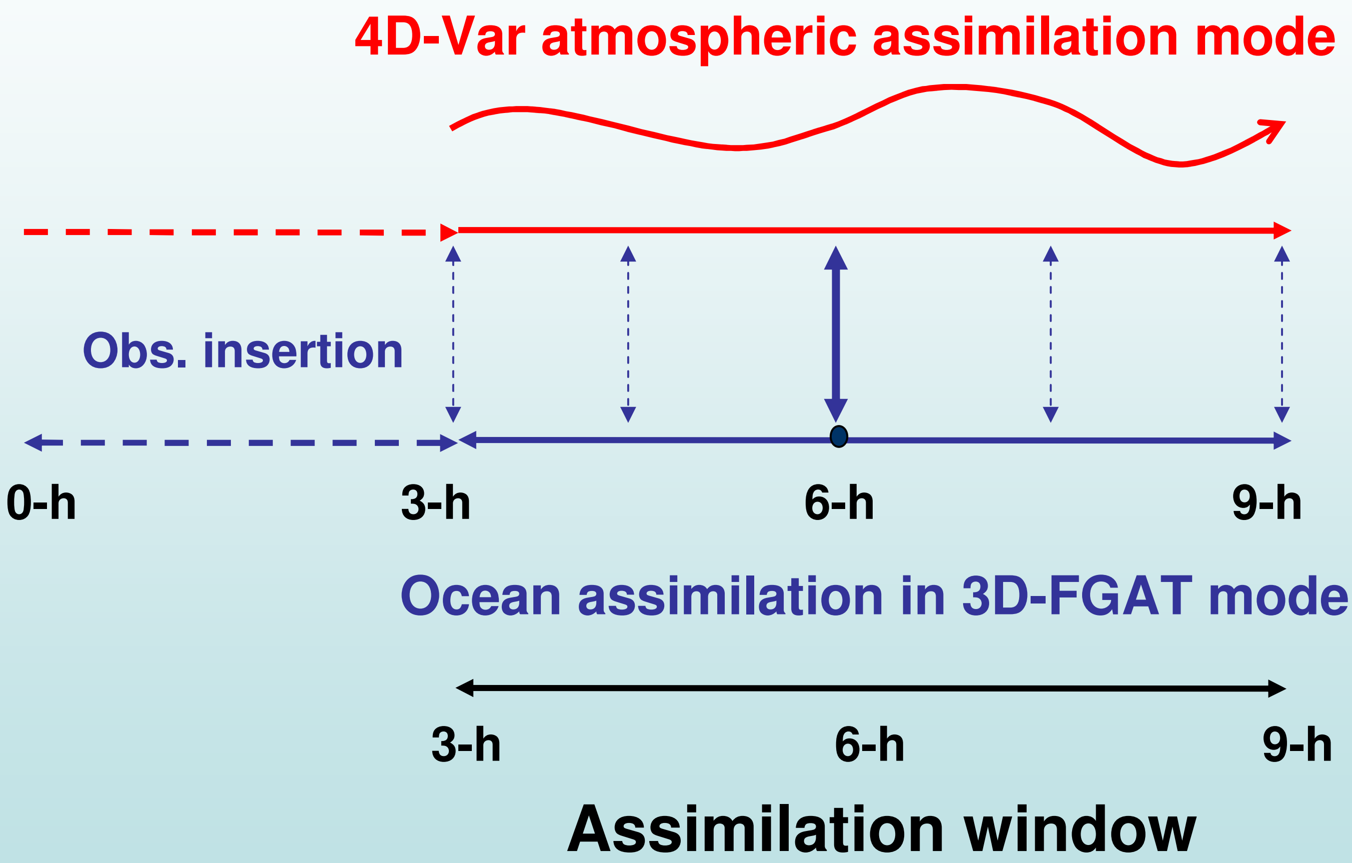
4D-Var impact (Mar. 15 2005)



Development of a coupled atmosphere-ocean data assimilation system

- Assimilation of different lengths
  - Atmospheric 4D-Var uses a 6-h window
  - Oceanic analysis over a 7-day period (typically)
- Coupled model will run with a 6-h assimilation window
  - Oceanic assimilation will benefit of having a shorter assimilation because
    - Analysis will be closer to the obseration time
    - Smaller analysis increments which tend (usually to reduce spin-up problems)
- The background state will be produced with the fully coupled model
  - Coupling will come in through the model integration over the length of the assimilation cycle (months to years)

Schematic of a coupled atmosphere-ocean data assimilation scheme



First objectives

- Develop and test the assimilation for the coupled GEM-OPA system
  - Monitoring of observations to detect if biases are developing
  - Diagnosis of the analysis increments is also a good indicator if biases are emerging
- First assessment of the coupled background error covariances
  - Variability of free coupled-model integration could provide a first estimate of these interactions
  - Results from the assimilation system could be used as a next step to reevaluate these couplings.

I.2.1 Independent Assimilation into Coupled Models - Objectives

- Initially improve A & O forecasts when driven "off-line" by analyses from uncoupled DA cycles of the other component (benchmark for later coupling)
- Further improve A & O forecasts when component models are coupled during background forecasts, not analysis step
- Provide coupled A-O fields from coupled A-O hindcasts for subperiods of 1993-2005, to be used in project I.2.2.

Schedule & Milestones

- Years 1-2: Perform atmosphere-only DA and forecasts for periods during ocean-only forecast being done in I.1.4 (ocean reanalysis & forecasting); establish atmospheric verification metrics; compare with I.1.4 (uses NCEP forcing); establish ocean verification metrics
- Years 3-4: Redo analyses & forecassts using independent DA; compare with previous results; perform initial coupled DA hindcasts for sub-periods of 1993-2005; examine how sensitivity to observations is affected by marine boundary layer parameterizations

I.2.2 Exploratory Studies on Joint Assimilation into Coupled Models

- Objective: examine A-O cross-correlation functions during analysis step, i.e. joint A-O DA
- Years 1-2: Evaluate A-O cross correlations based on long CGCM run from II.1.1 (tropical modes), set up & evaluate simplified coupled A-O GEM-OPA system, perform control simulation for twin experiment
- Years 3-4: Use “NMC method” to determine cross-correlation functions; perform joint DA & evaluate impacts; examine predictability as a function of variable, time-scale, season & region cf outputs from I.2.1

Current status

- Discussion in progress with short-listed PDF candidates for I.2.1 at UQAM
- For I.2.2, a 250-year control run based on the most recent version of CGCM3 (T63, no flux adjustment, new ocean physics) is underway and should be completed soon.   Merryfield is working with CCCma's AGCM group to reduce biases in CGCM4. A long CGCM4 control run will be undertaken when that work has reached a suitable stage.
- Merryfield and GOAPP RA W.-S. Lee have begun developing software tools for evaluating cross correlations in the CGCM.
- PDF Faez Bakalian to start at Dal asap after July 1, 2007 for I.2.2