Advances in Land Data Assimilation at Environment Canada

ECMWF/GLASS Workshop, November 2009

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Environment Canada

COLLABORATORS / CONTRIBUTORS

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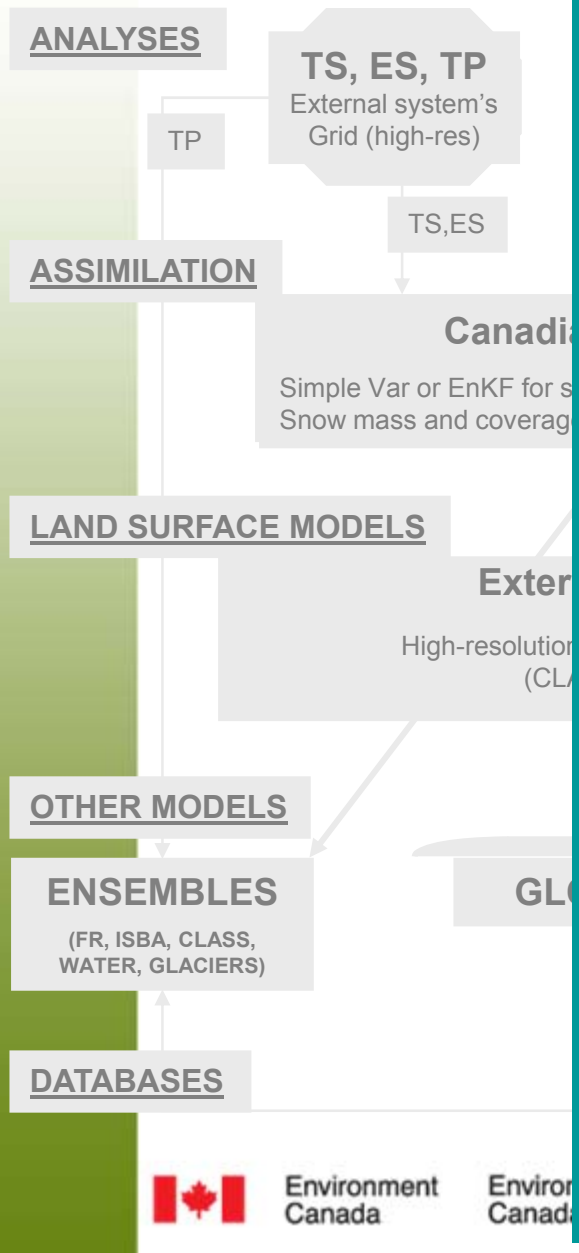
- ***Bernard Bilodeau (MRD)***
- ***Marco Carrera (MRD)***
- ***Douglas Chan (CRD)***
- ***Chris Derksen (CRD)***
- ***Sylvie Leroyer (MRD)***
- ***Michel Roch (MRD)***
- ***Sheena Solomon (MRD)***
- ***Linying Tong (CMC)***
- ***Libo Wang (CRD)***

MRD = Meteorological Research Division
CRD = Climate Research Division
CMC = Canadian Meteorological Centre

LAND DATA ASSIMILATION at ENVIRONMENT CANADA
NEW EMPHASIS

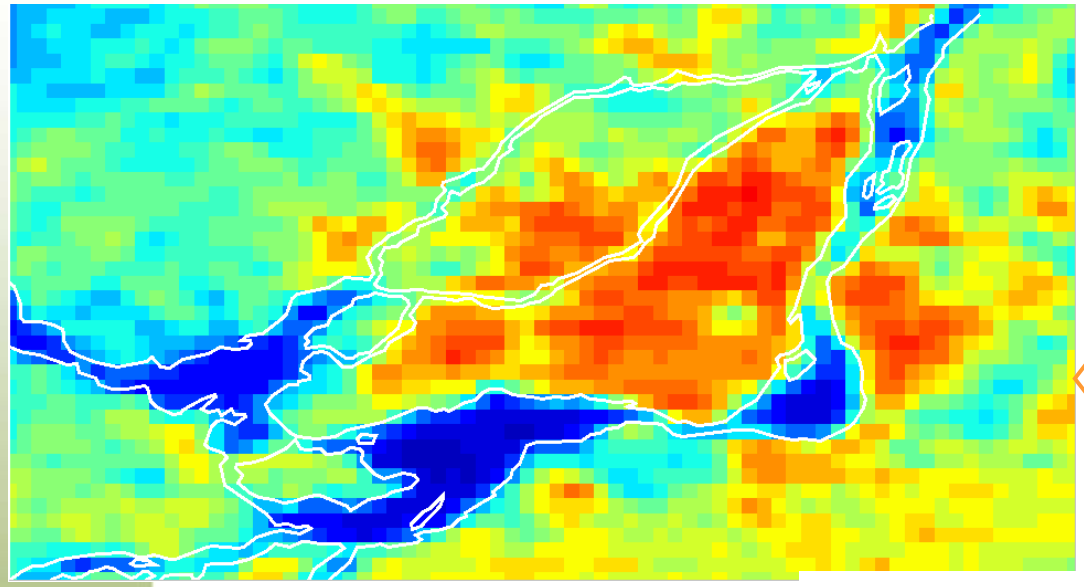


- ***New approach for land data assimilation based on offline surface modeling ...***
- ***... and on more sophisticated methods for land surface data assimilation***
- ***with emphasis on assimilation of space-based remote sensing data (for soil moisture, terrestrial snow, and vegetation)***
- ***Single system for all NWP systems (deterministic and ensemble-based) + hydrology models***
- ***Better coupling with atmospheric assimilation and prediction systems (Global 4DVAR, Global and Regional EnKF, as well as Global and Regional EPS)***
- ***High-resolution land surface modeling (based on high-resolution information for orography, land use / land cover)***

CURRENT RESEARCH THEMES (for the assimilation component)

- ***First guess: High-resolution land surface modeling***
- ***Modeling of first guess uncertainty***
- ***Optimizing the use of screen-level observations (analyses) in land data assimilation***
- ***Simple variational (or EKF) vs EnKF (and vs Hybrid?)***
- ***Assimilation of snow (fractional coverage and SWE) based on space-based remote sensing***
- ***Vegetation characteristics from ecosystem modeling (first guess only at this time + previous work with MODIS)***
- ***Impact of surface processes on NWP prediction (special emphasis on medium range)***

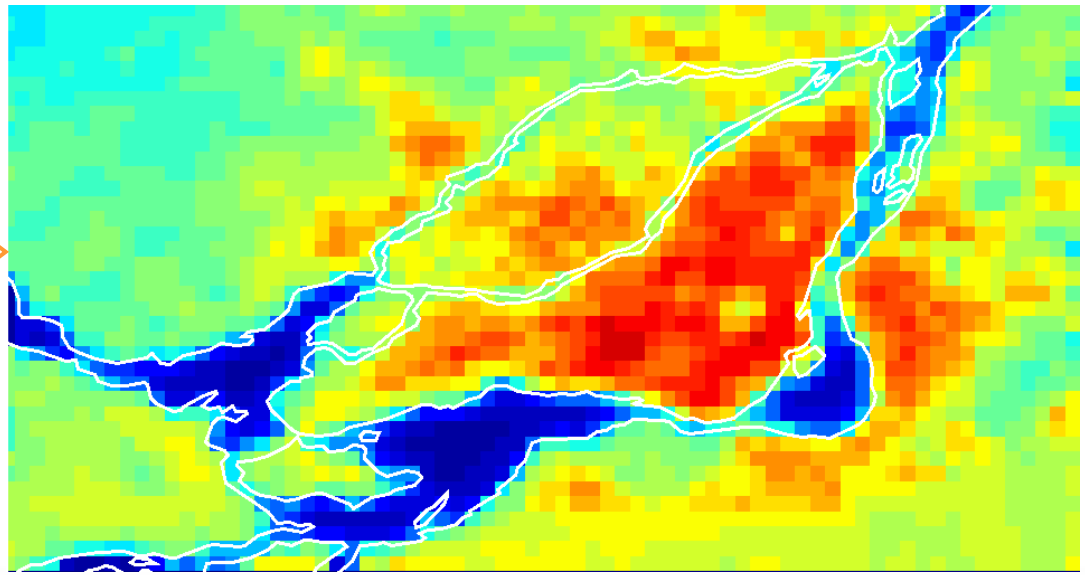
HIGH-RESOLUTION (OFFLINE) LAND SURFACE MODELING
URBAN METEOROLOGY (Leroyer et al.)



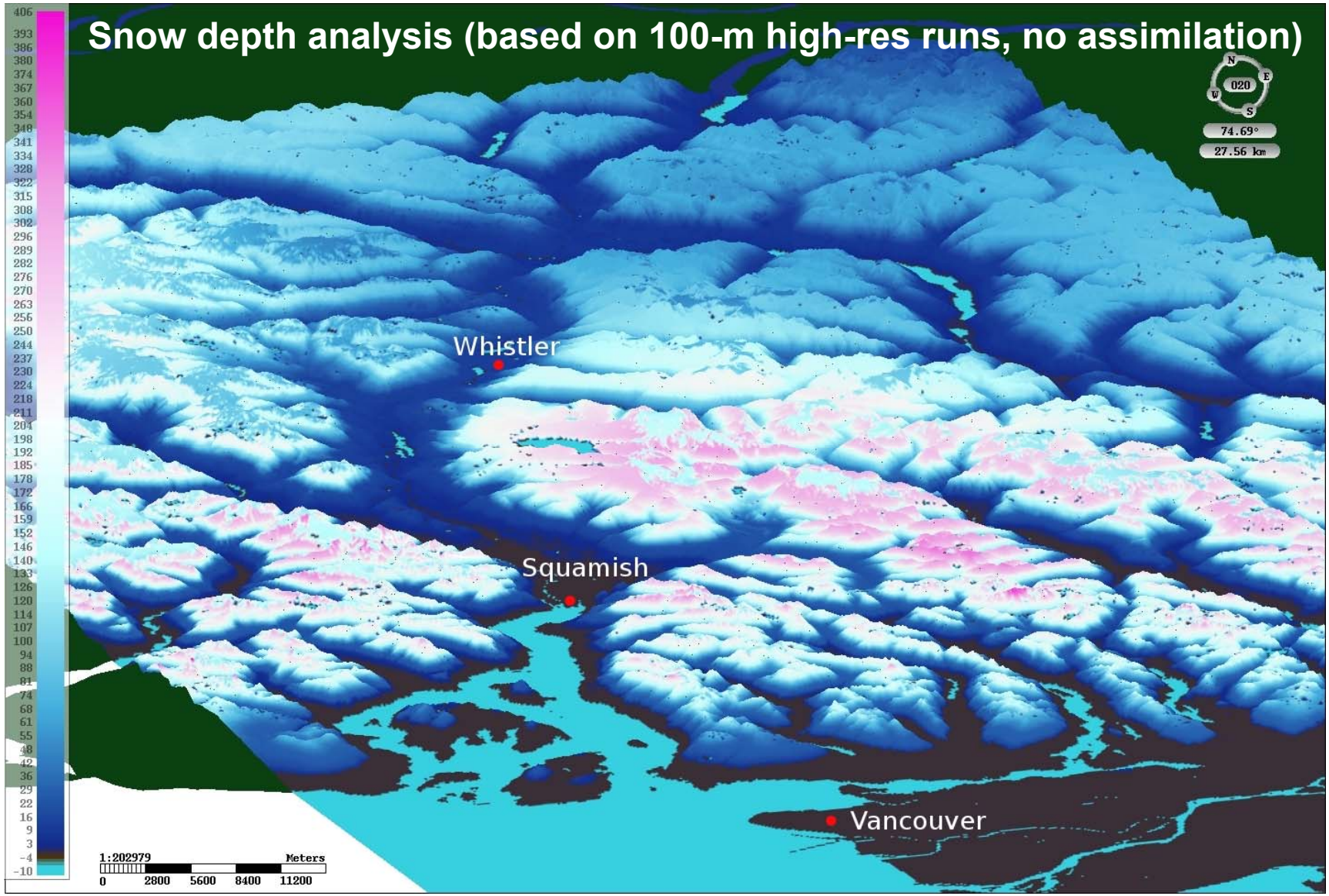
Radiative Surface Temperature (C)
July 6th 2008 (10:54 LST)

MODIS MOD11A1 product
Resolution: 1km
(exactly 928 m)
- Atmospheric effects corrected
- Satellite View Angle : 15

Urban off-line modeling system
Assimilation of soil water content every day
Resolution: 928 m
→ upscaling

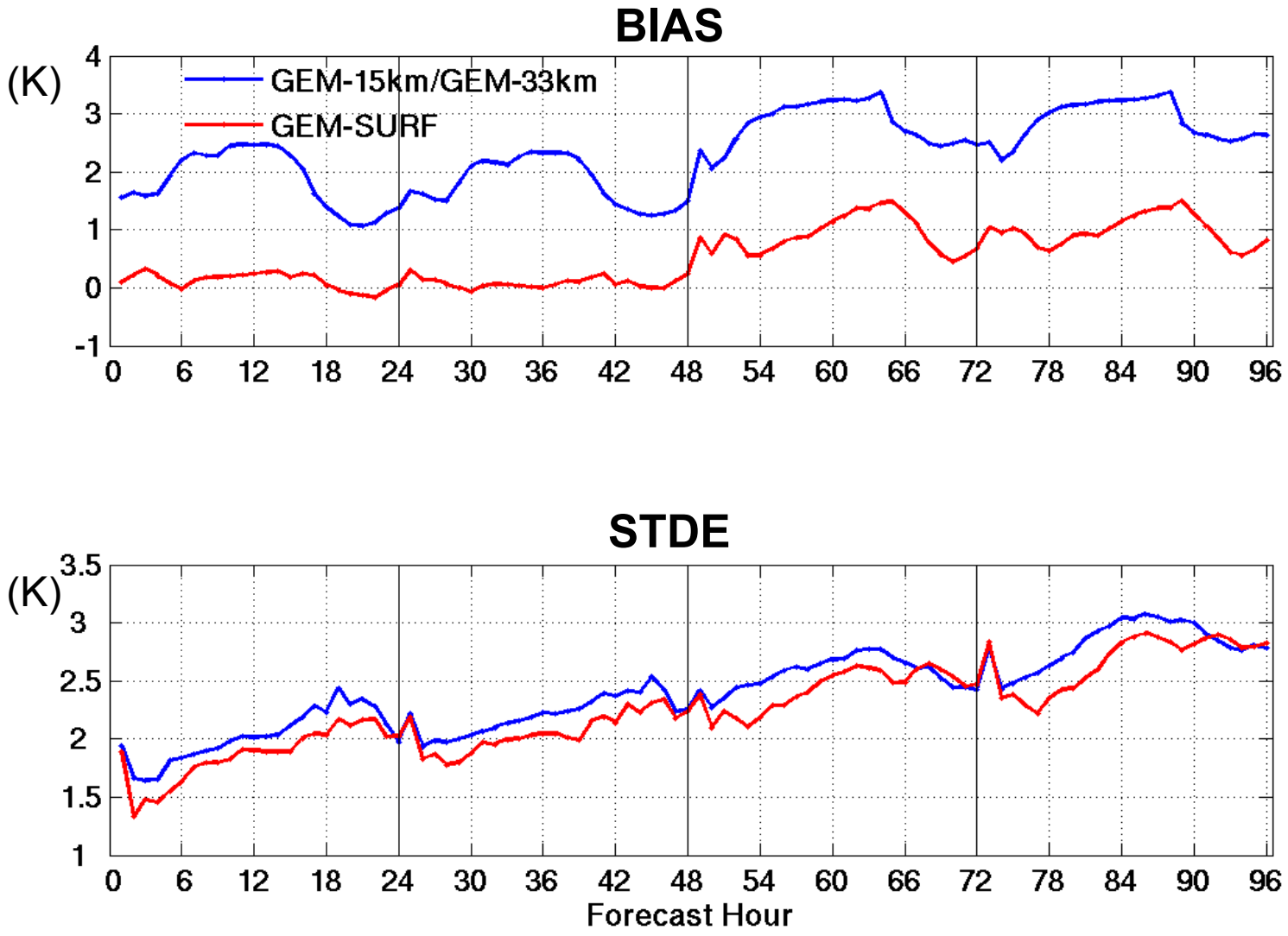


HIGH-RESOLUTION (OFFLINE) LAND SURFACE MODELING VANCOUVER 2010 OLYMPIC GAMES (Bernier et al.)



HIGH-RESOLUTION (OFFLINE) LAND SURFACE MODELING VANCOUVER 2010 OLYMPIC GAMES (Bernier et al.)

Screen-level air temperature – 1 January to 31 December 2008



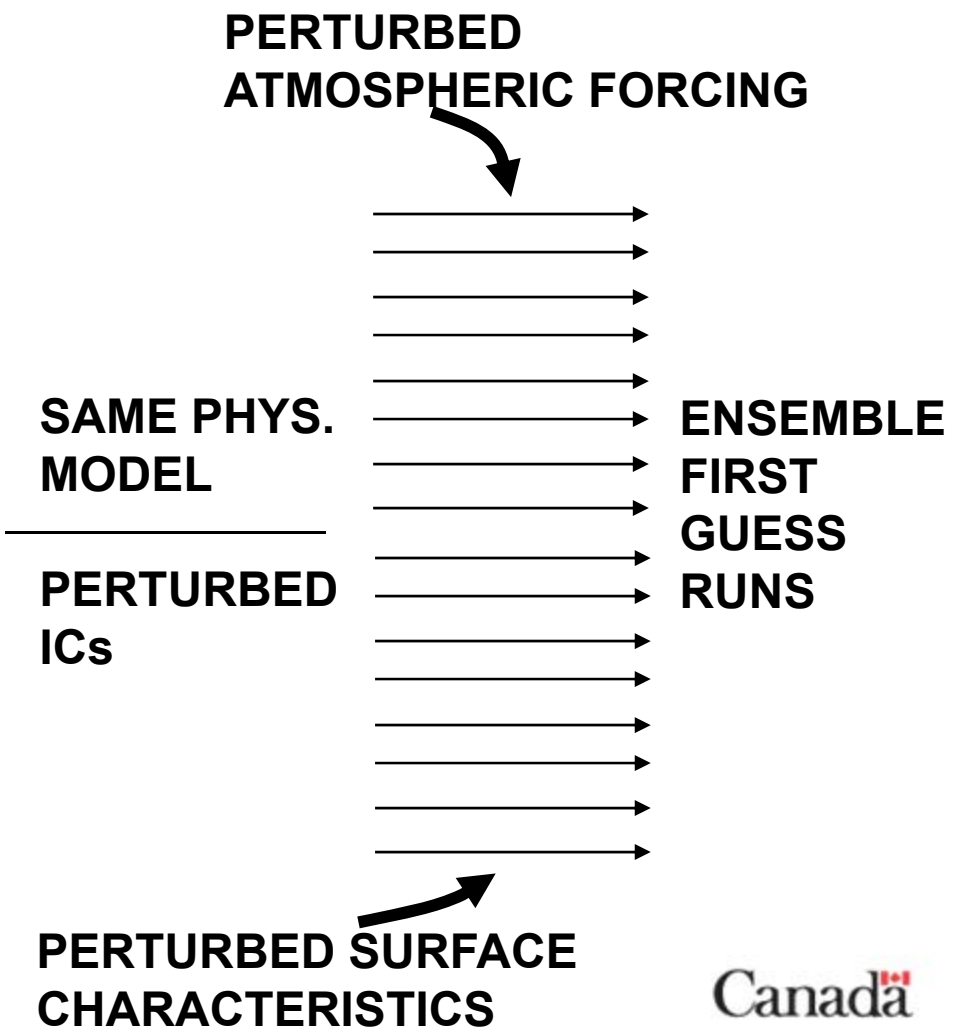
MODELING of FIRST GUESS UNCERTAINTY (EnKF)

Analysis equation

$$\mathbf{x}^a = \mathbf{x}^b + \mathbf{B}\mathbf{H}^T \left[\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R}\right]^{-1} \left[\mathbf{y} - H\left(\mathbf{x}^b\right)\right]$$

CONTRIBUTORS for B

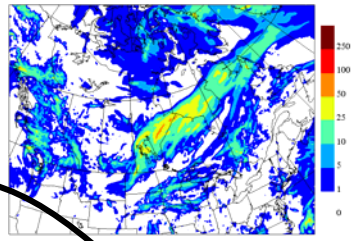
- **Initial conditions**
  - *Soil moisture*
  - *Surface temperature*
  - *Snow conditions*
- **Land surface characteristics (ancillary data)**
  - *Vegetation characteristics (fraction coverage, LAI)*
  - *Soil texture*
  - *Albedo*
  - *Emissivity*
  - *orography*
- **Atmospheric forcing**
  - *U, V, T, q, SW↓, LW ↓, precipitation*
- **Land surface modeling**



Canada

UNCERTAINTY RELATED TO ATMOSPHERIC FORCING (EnKF) (Carrera, Bilodeau)

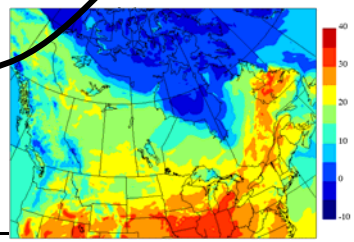
Perturbed precipitation observations (surface + radar)



CaPA

Ensemble of precipitation analyses

REPS or perturbed outputs from REG-15



Ensemble of forcing for radiation, air temperature and humidity, and surface pressure

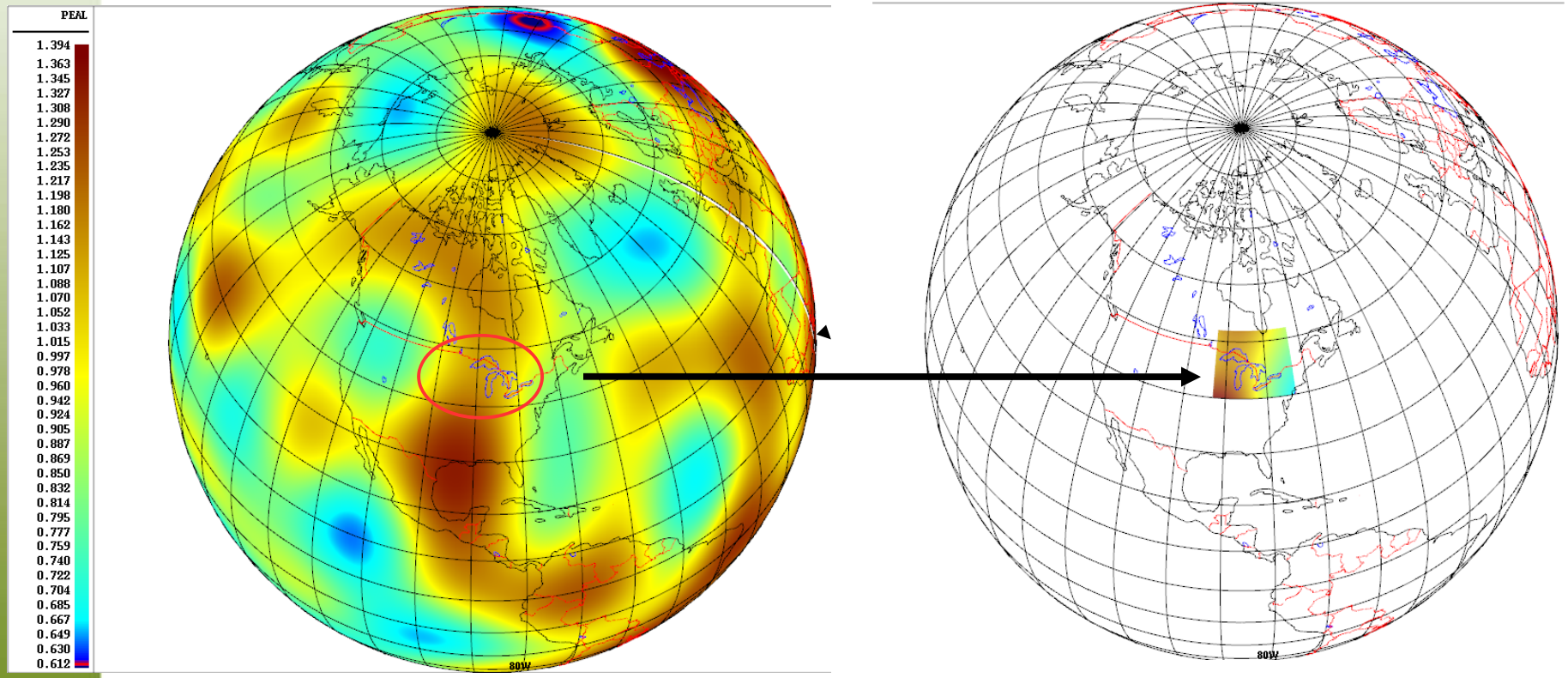
DOWNSCALING

EXTERNAL LAND SURFACE MODEL

UNCERTAINTY RELATED TO LAND SURFACE CHARACTERISTICS (Solomon, Charron)

Spatially and temporally coherent perturbations for albedo, LAI, Fveg, and roughness length), based on spherical harmonics with coefficients obtained Markov chains

$$\psi(\lambda,\varphi,t) = \mu + \sum^{Lmax} a_{lm}(t) Y_{lm}(\lambda,\varphi)$$



Perturbation of albedo generated in the sphere and interpolated over the region of interest

ANCILLARY SURFACE DATA

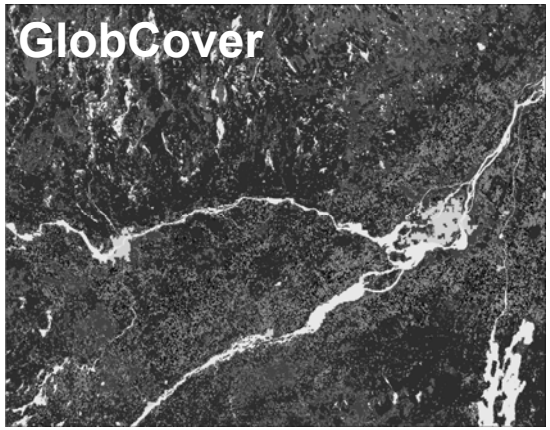
Orography
- USGS-GTOPO30 (~900m)
- SRTM-DEM (~90m)
- CDED1 (~20m)

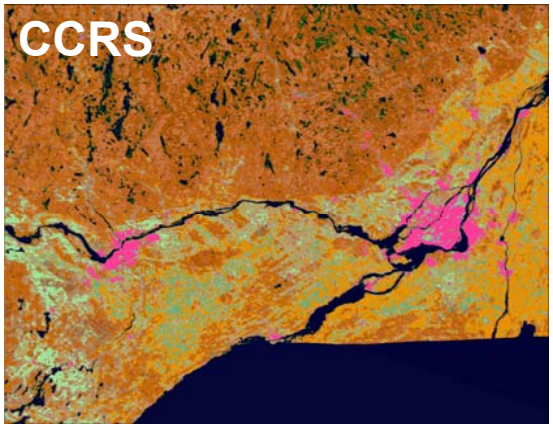
Land use / land cover
- USGS-GLCC (~1km)
- NTDB (~20m)
- EOSD (~25m)
- CCRS-2005 (~300m)
- GlobCover-2005 (~300m)
- Circa-2000 (~30m)

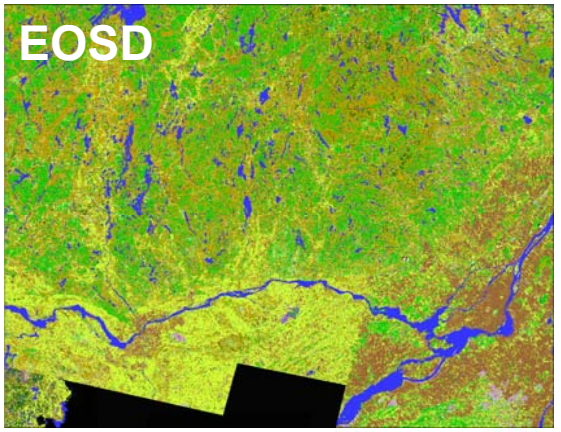
Soil texture
- FAO (~8km)
- STATSGO (~1km)
- AAFC-SLC
- Harmonized World Soil Db

Land / water fractions
- CanVec (~20 m)
- USGS-GLCC (~1km)
- GlobCover (~ 300 m)

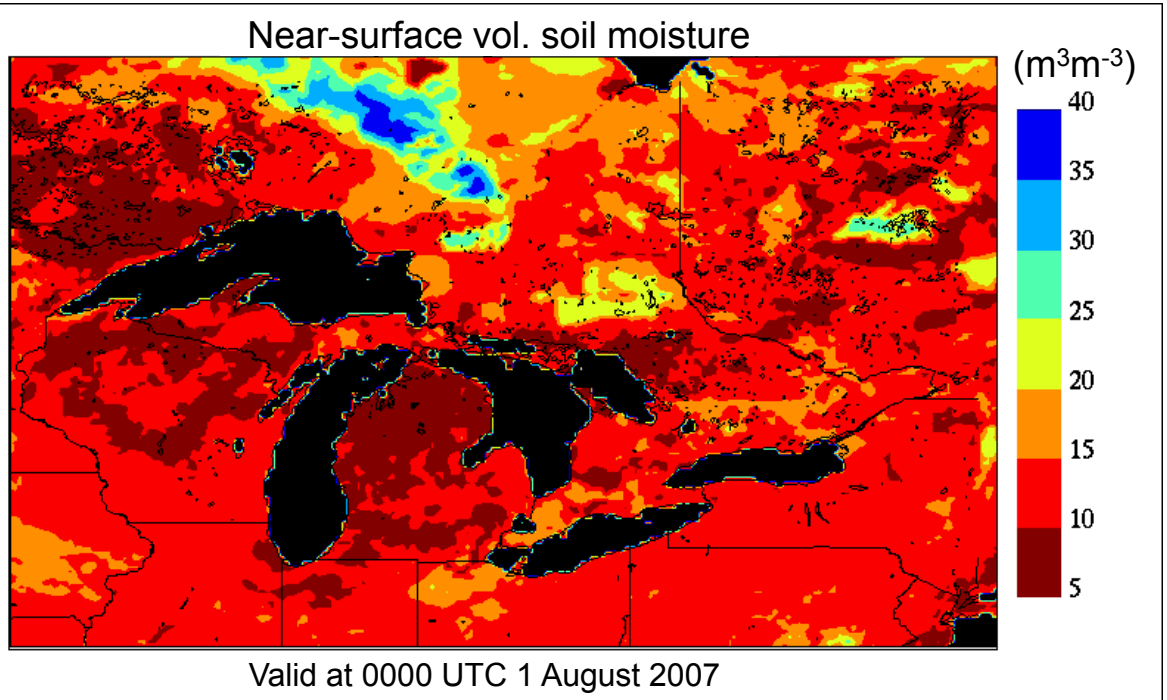
Other databases for **urban** environment







IDEALIZED EXPERIMENTAL SET-UP (Bilodeau, Carrera)



From 1 July to 1 August 2007

Great Lakes region

10-km grid, 200 x 120 points

"Truth" based on open loop with soil moisture initialised at field capacity

Synthetic obs generated using CMEM (T_{BH} and T_{BV}) and surface layer stability functions (screen-level temperature and relative humitity)

Soil moisture on 1 July set at wilting point (beginning of cycles)

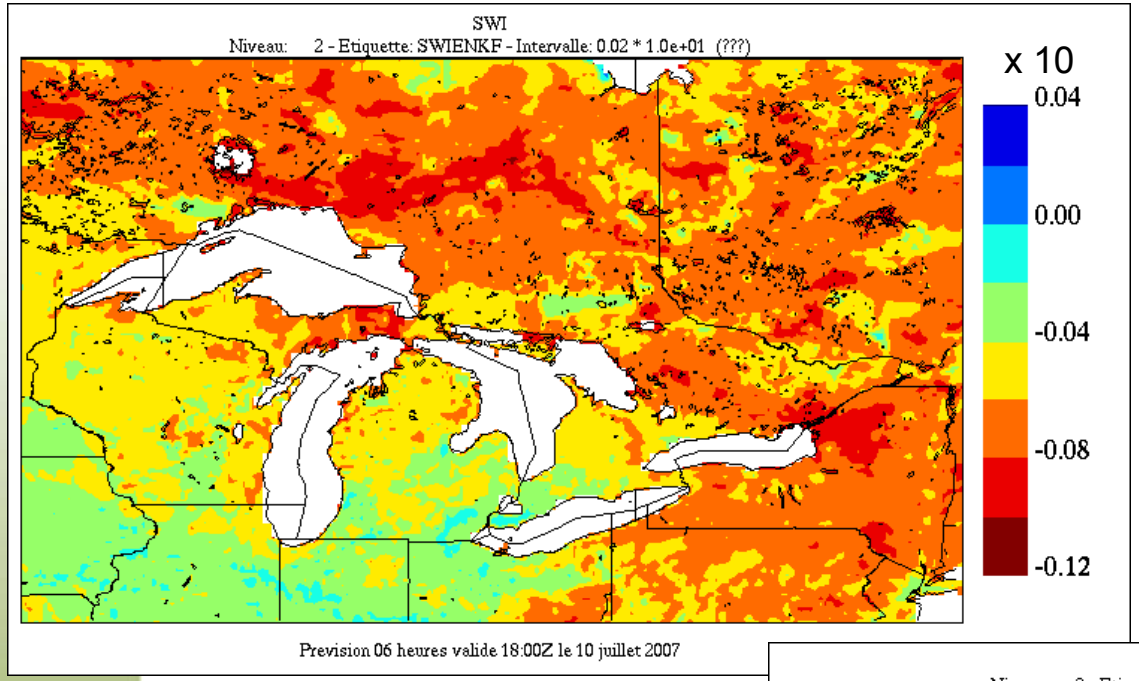
Assimilation with EnKF (Supervisor Monitor Scheduler - SMS)

10 members, same forcing and same surface conditions as "truth"

Exp_1: L-Band Brightness temperatures (T_{BH} and T_{BV} every 6h)

Exp_2: Screen-level observations (T_{2m} and RH_{2m} every 6h)

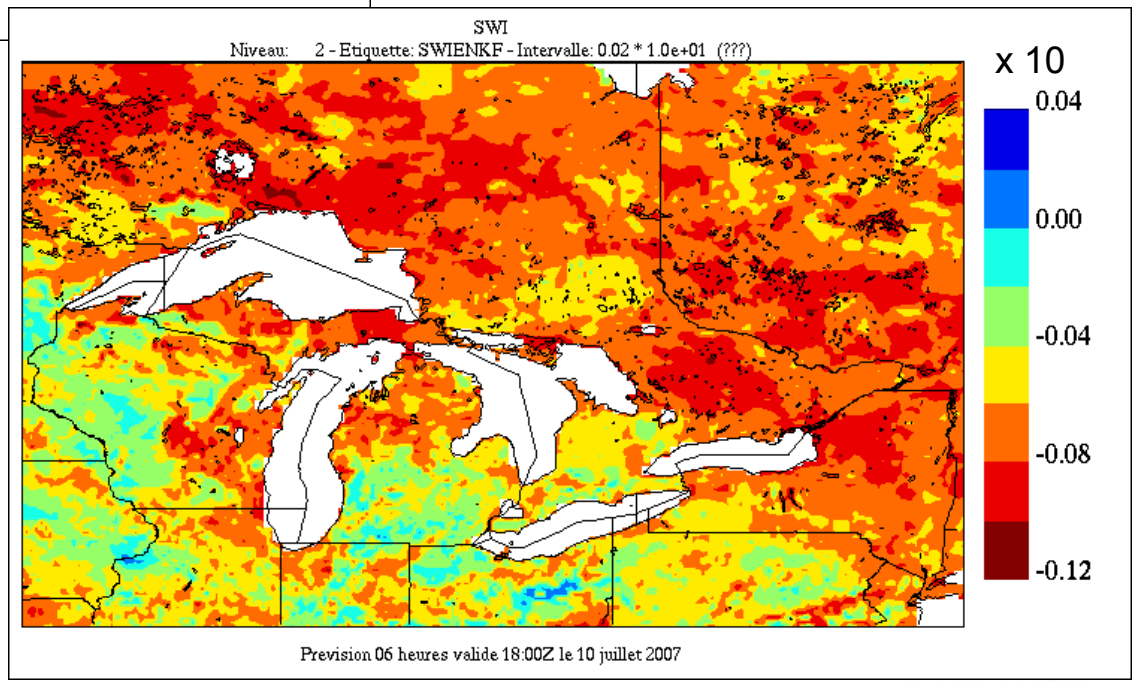
CONVERGENCE of ROOT-ZONE SOIL MOISTURE (After 10 days)



$$\frac{w_2 - w_{2\_Truth}}{w_{fc} - w_{wilt}}$$

Assimilation of synthetic L-Band brightness temperatures

Assimilation of synthetic screen-level air temperature and relative humidity



Valid 10 July 2007

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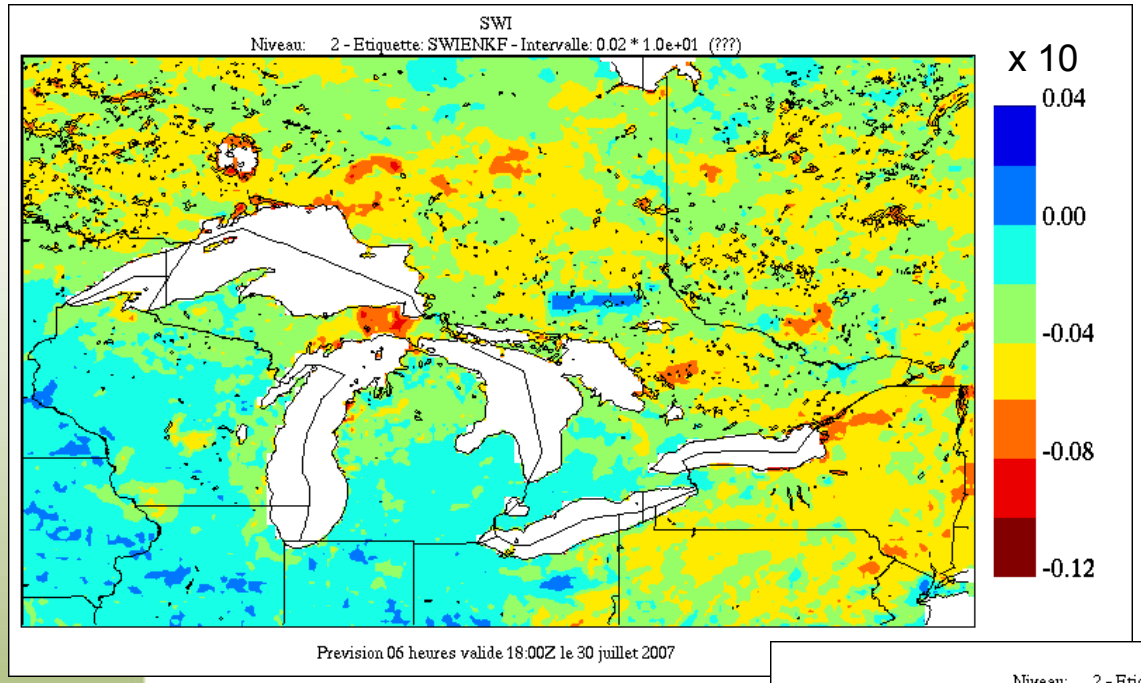
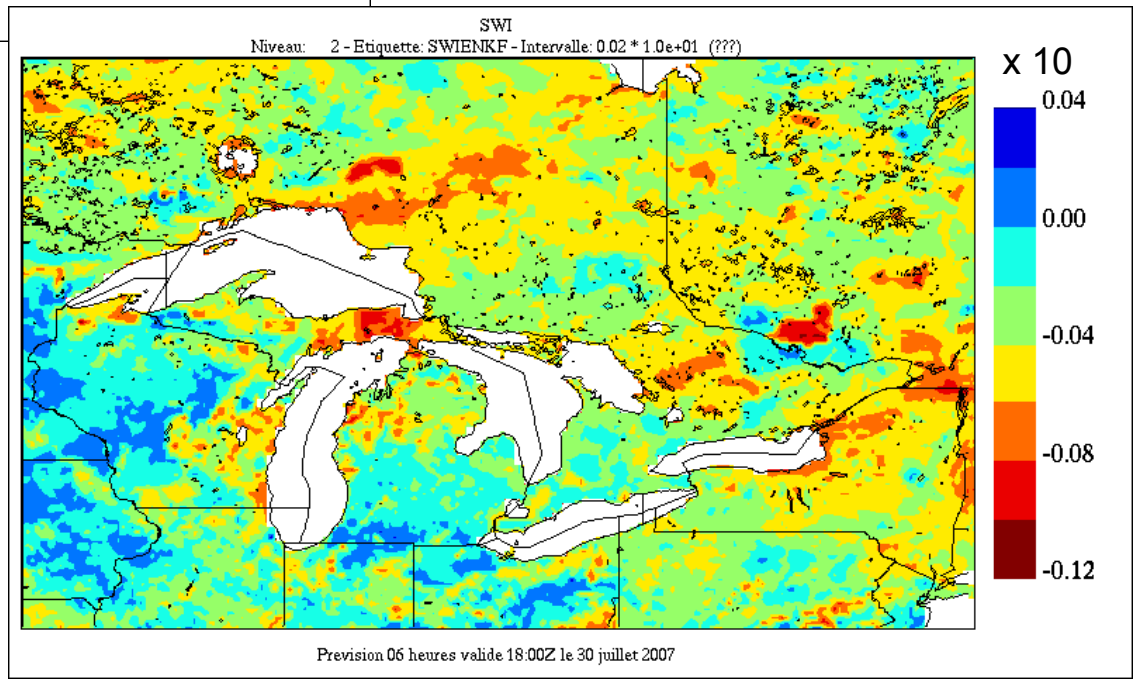
CONVERGENCE of ROOT-ZONE SOIL MOISTURE (After 30 days)



$$\frac{w_2 - w_{2\_Truth}}{w_{fc} - w_{wilt}}$$

Assimilation of synthetic brightness temperatures

Assimilation of synthetic screen-level air temperature and relative humidity



Valid 30 July 2007

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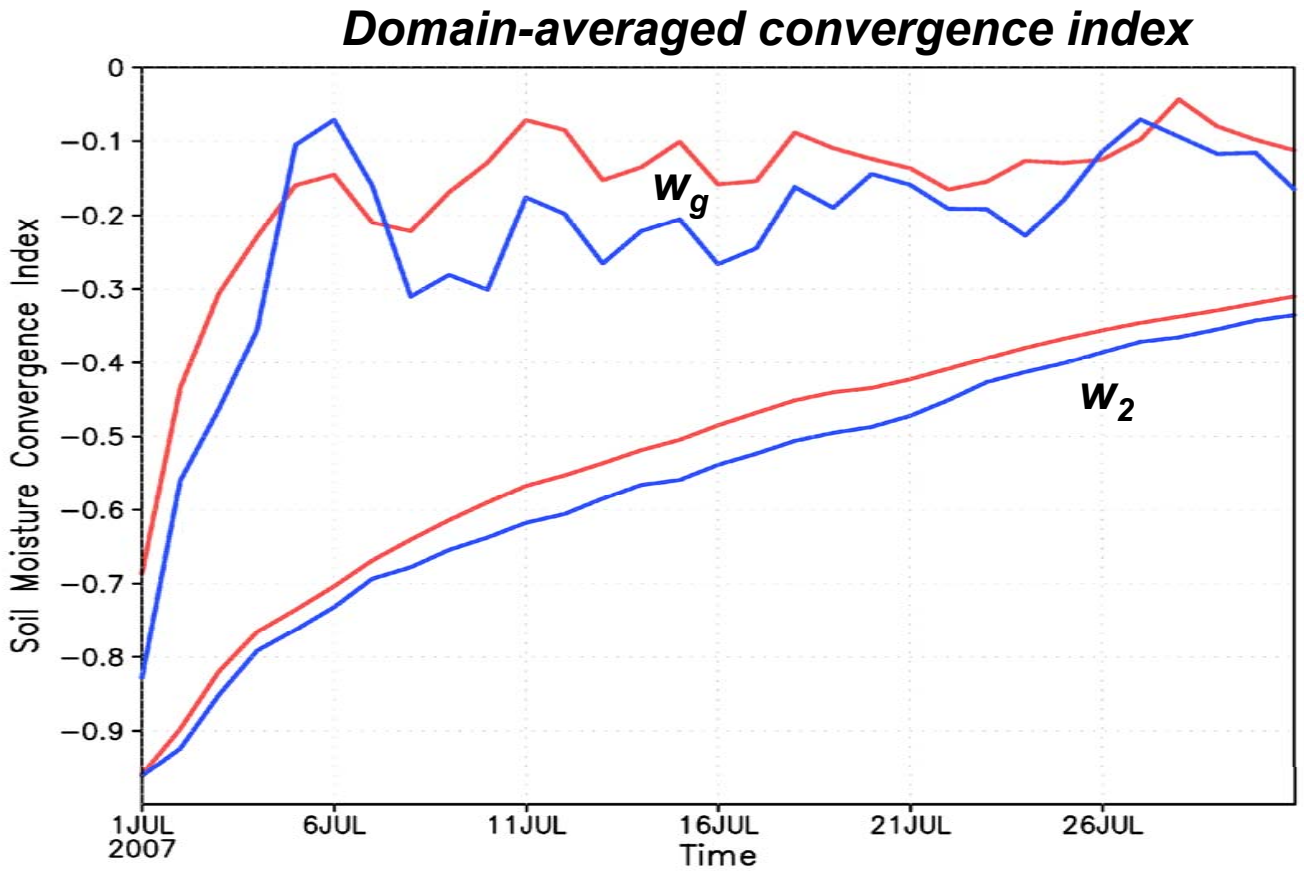
DOMAIN-AVERAGED CONVERGENCE of SOIL MOISTURE

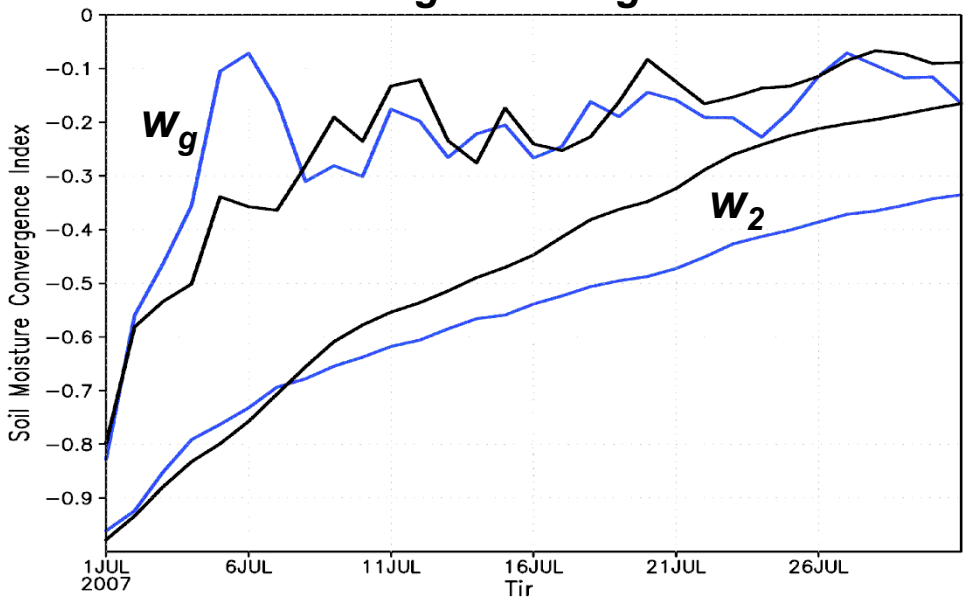


Screen-level

L-Band brightness temperatures

OTHER EXPERIMENTS (Simple VAR and JOINT ASSIMILATION)

Domain-average convergence index



Screen-level data

Simple VAR

EnKF

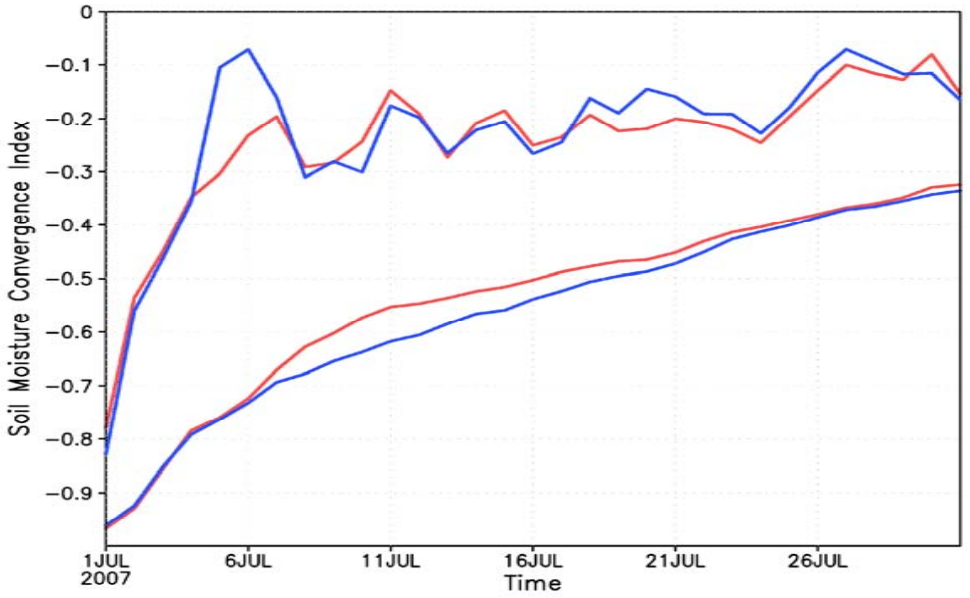
EnKF

$(TT, HR)_{2m}$

$T_{Bv,h}+(TT, HR)_{2m}$

** TB data every 3 days*

Domain-average convergence index



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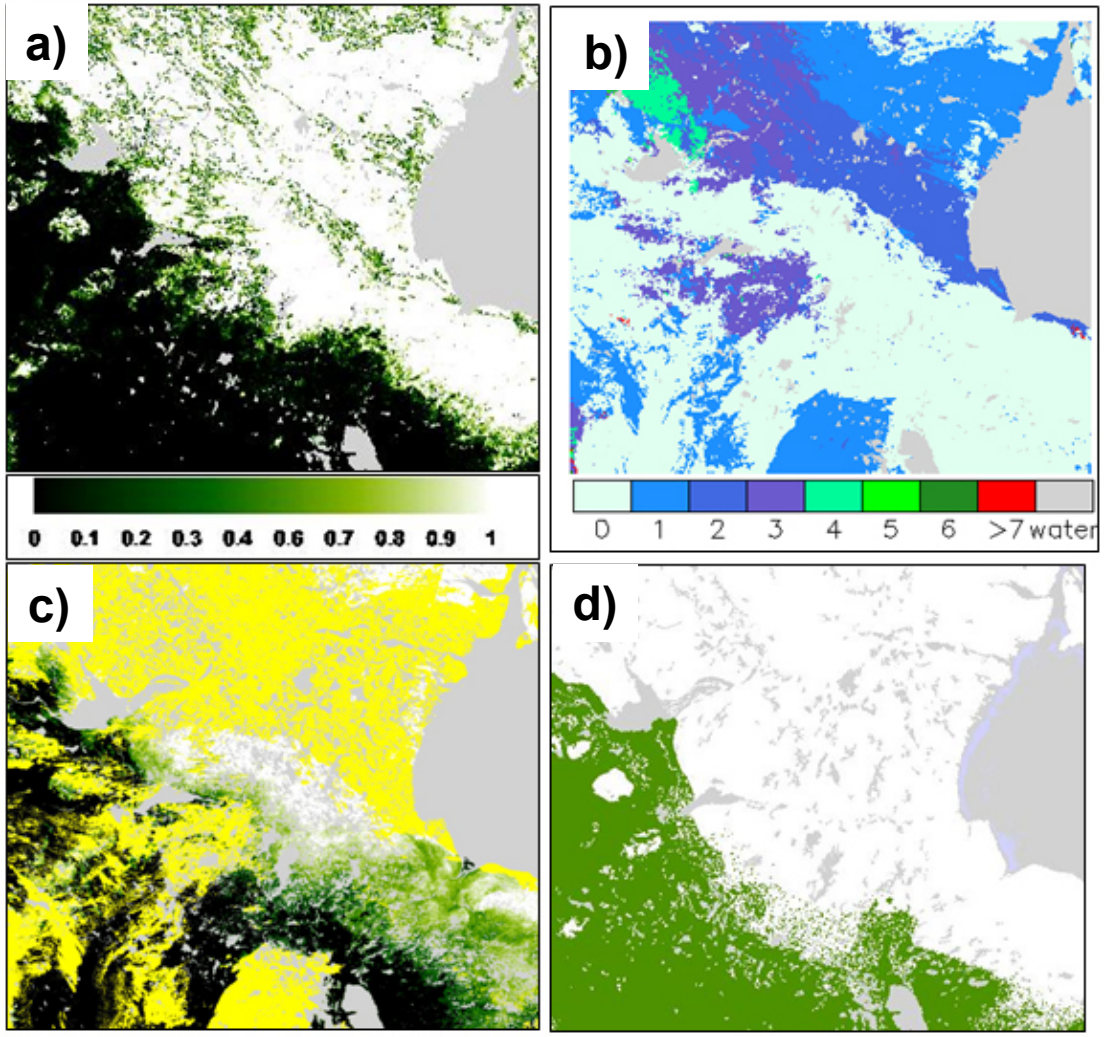
REMOTE-SENSING PRODUCTS for SNOW ASSIMILATION
FRACTIONAL SNOW COVERAGE AREA (Wang, Derksen)



(Valid on 26 April 2007)

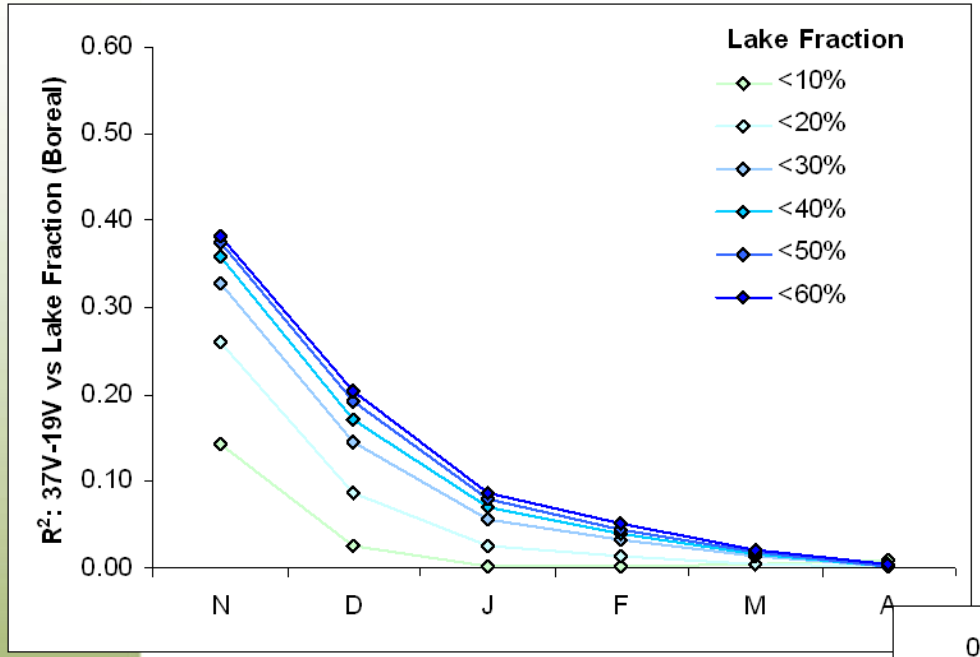
a) MODIS Cloud Gap Filled fractional snow coverage area (5 km)

b) MODIS Cloud Gap Filled persistence map (days since clear view of ground)

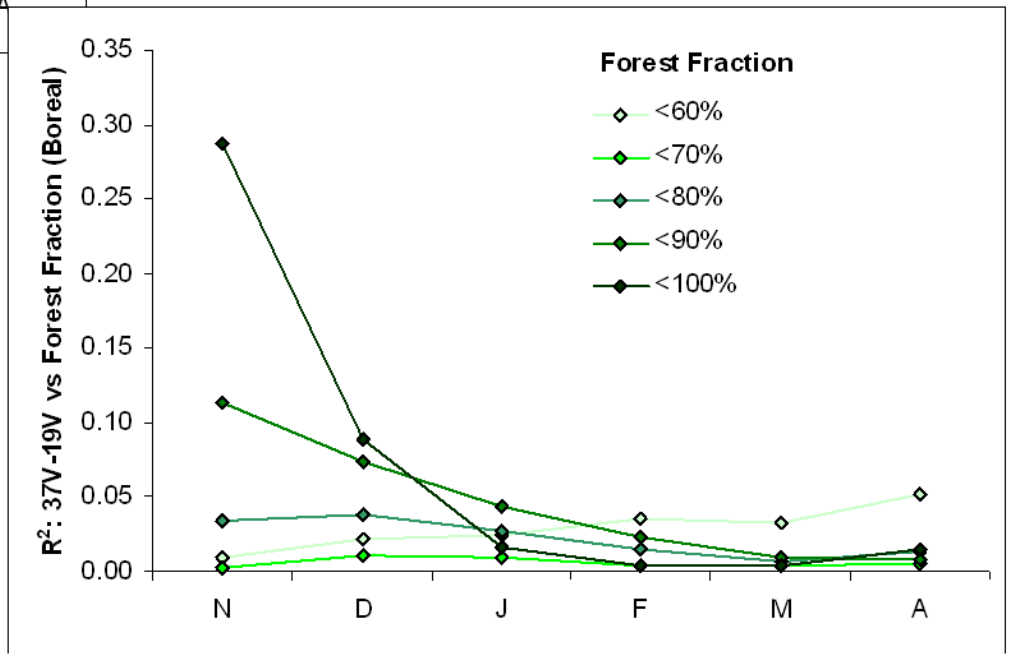
c) Fractional snow coverage area estimated using EC's implementation of the EUMETSAT algorithm (yellow=clouds) (1 km)

d) NOAA IMS binary snow/no-snow map (4 km)

REMOTE-SENSING PRODUCTS for SNOW ASSIMILATION
SNOW WATER EQUIVALENT (Derksen, Wang)



Example statistical uncertainty results for passive microwave SWE retrievals based on the variance explained in brightness temperatures due to grid cell (a) lake and (b) forest fractions



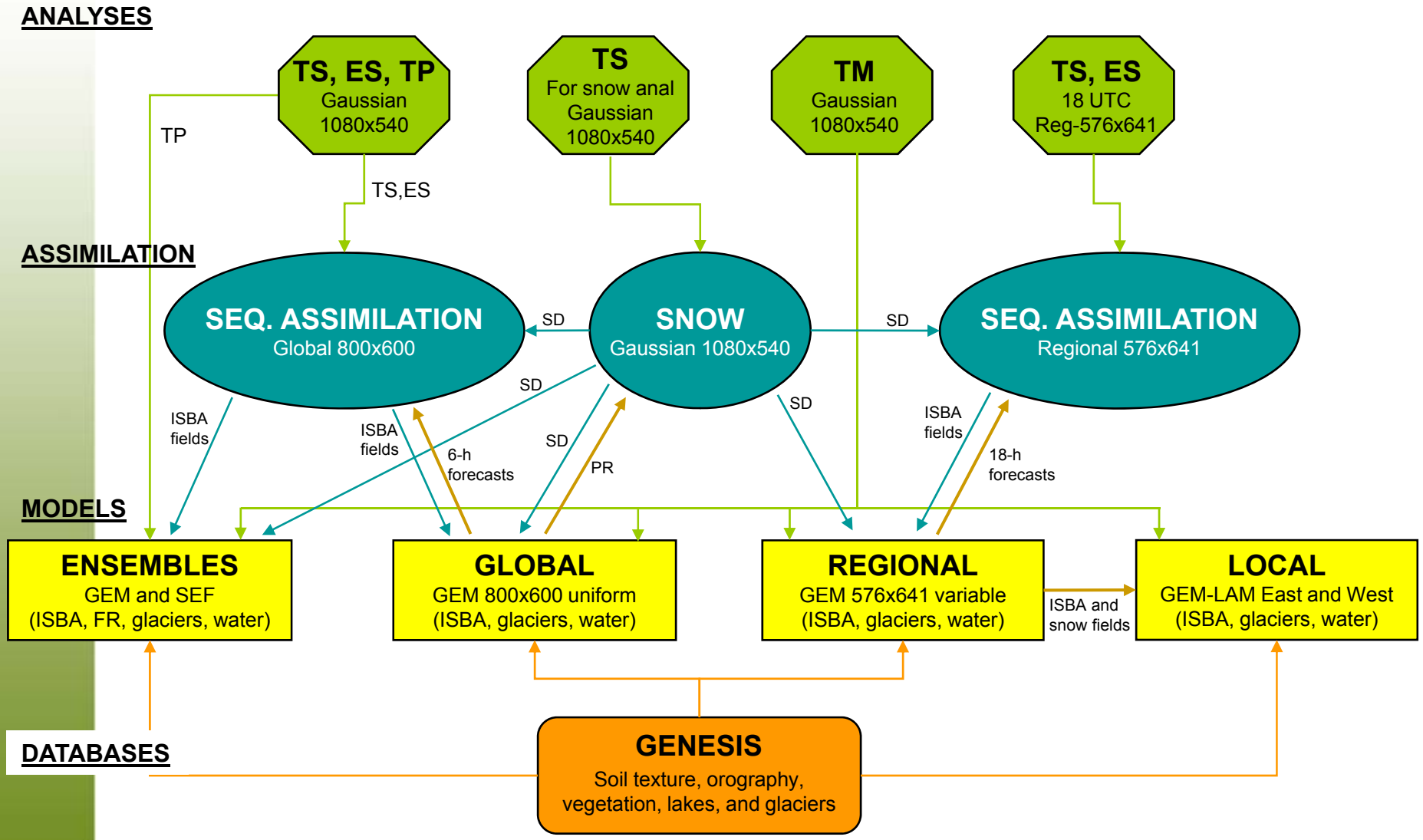
UPCOMING RESEARCH THEMES (for the assimilation component)

- ***Modeling of innovations uncertainty*** **(R)**
- ***Incremental assimilation***
- ***Coupling with REPS and GEPS***
- ***Impact on hydrology***
- ***Evolution of land surface model (Canadian multi-budget version of ISBA, or CLASS)***

FIRST VERSION of CaLDAS to be SYSTEMATICALLY TESTED for OPERATIONAL IMPLEMENTATION at CMC will be READY in 2010 – EXPECTED IMPLEMENTATION in 2011

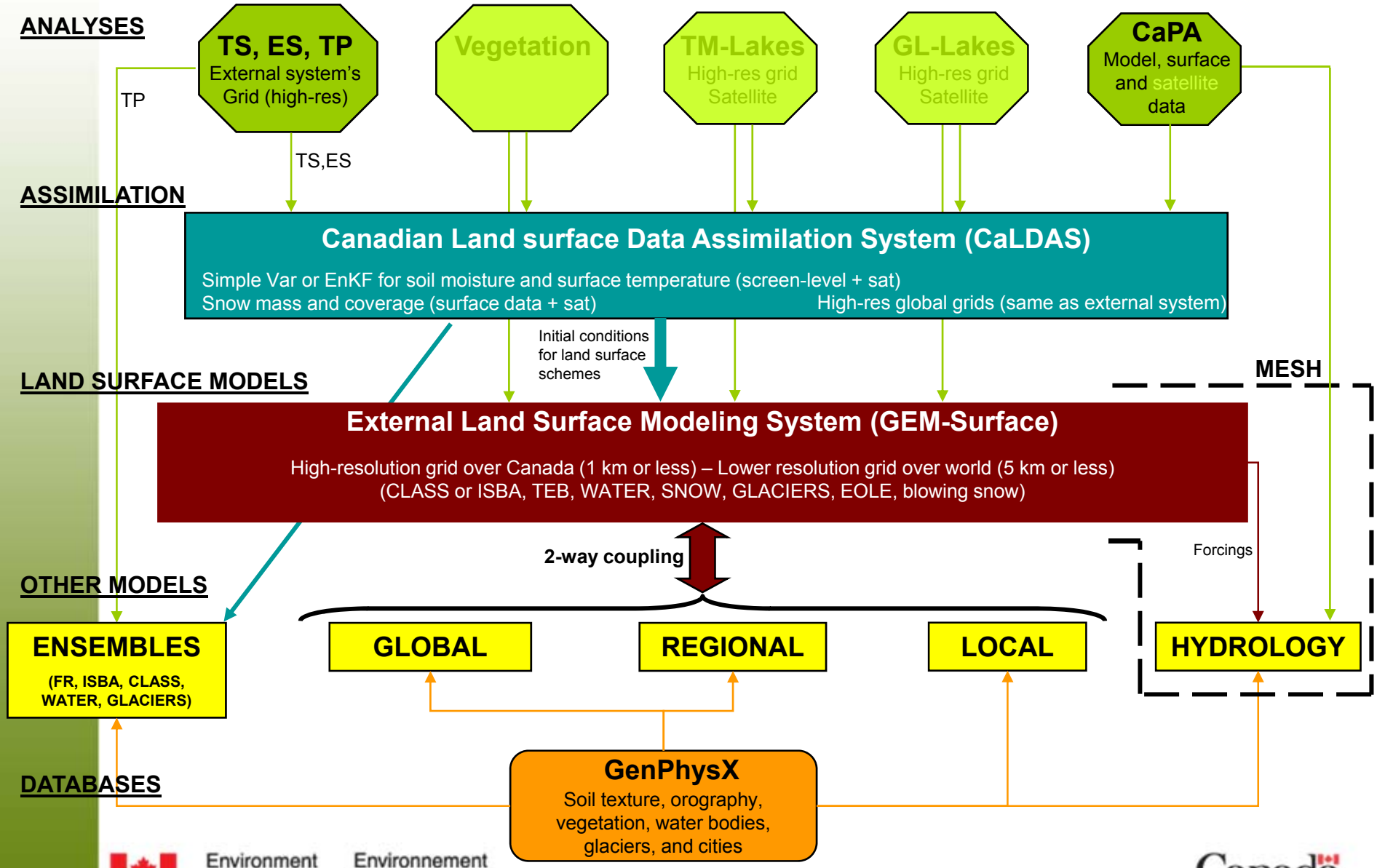
Thank you all for your attention

LAND DATA ASSIMILATION at ENVIRONMENT CANADA
CURRENT SITUATION

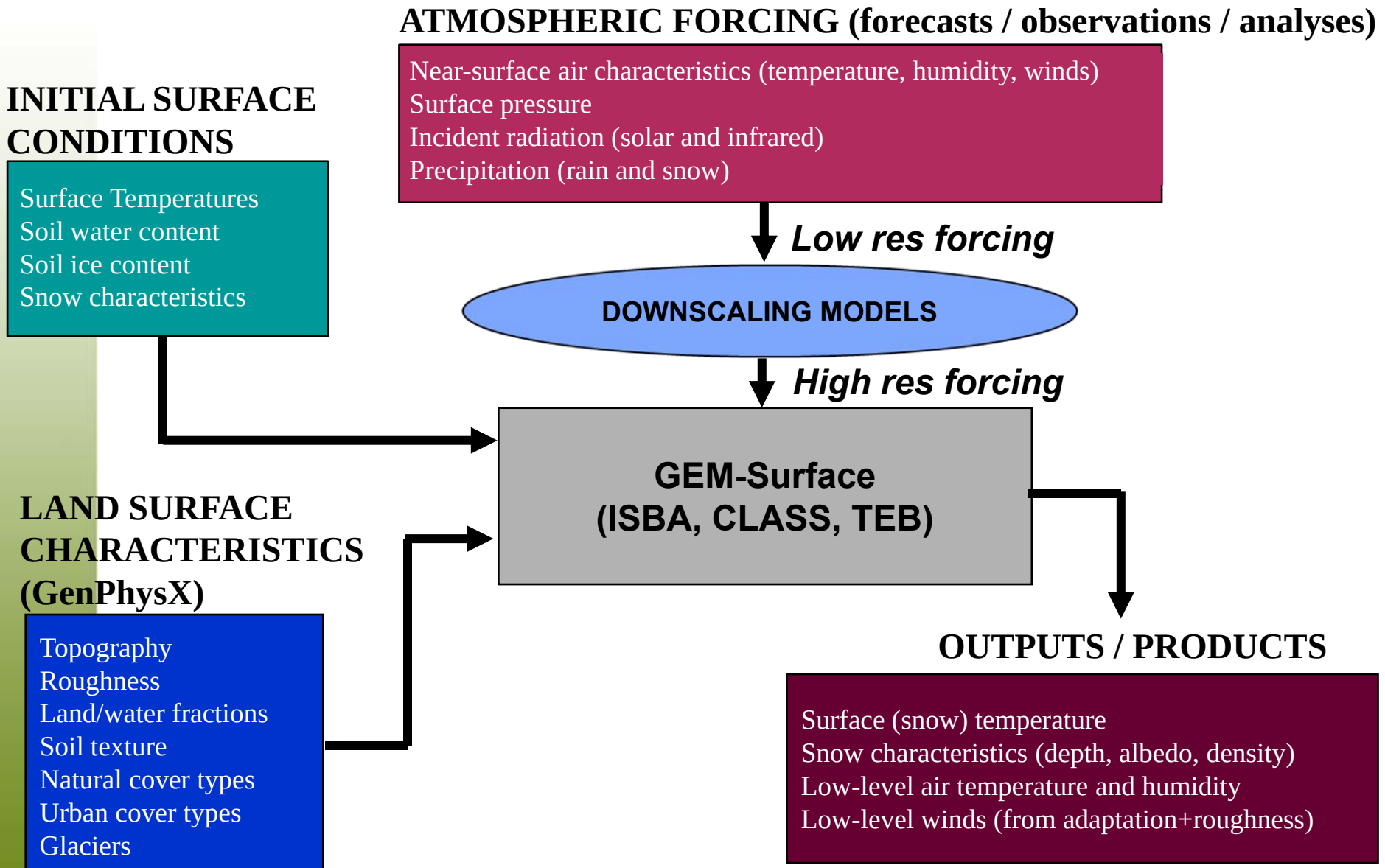


ISBA fields: Tsurf(1,2), Wsoil(1,2), wice, snow albedo, snow density, wsliq, wlveg

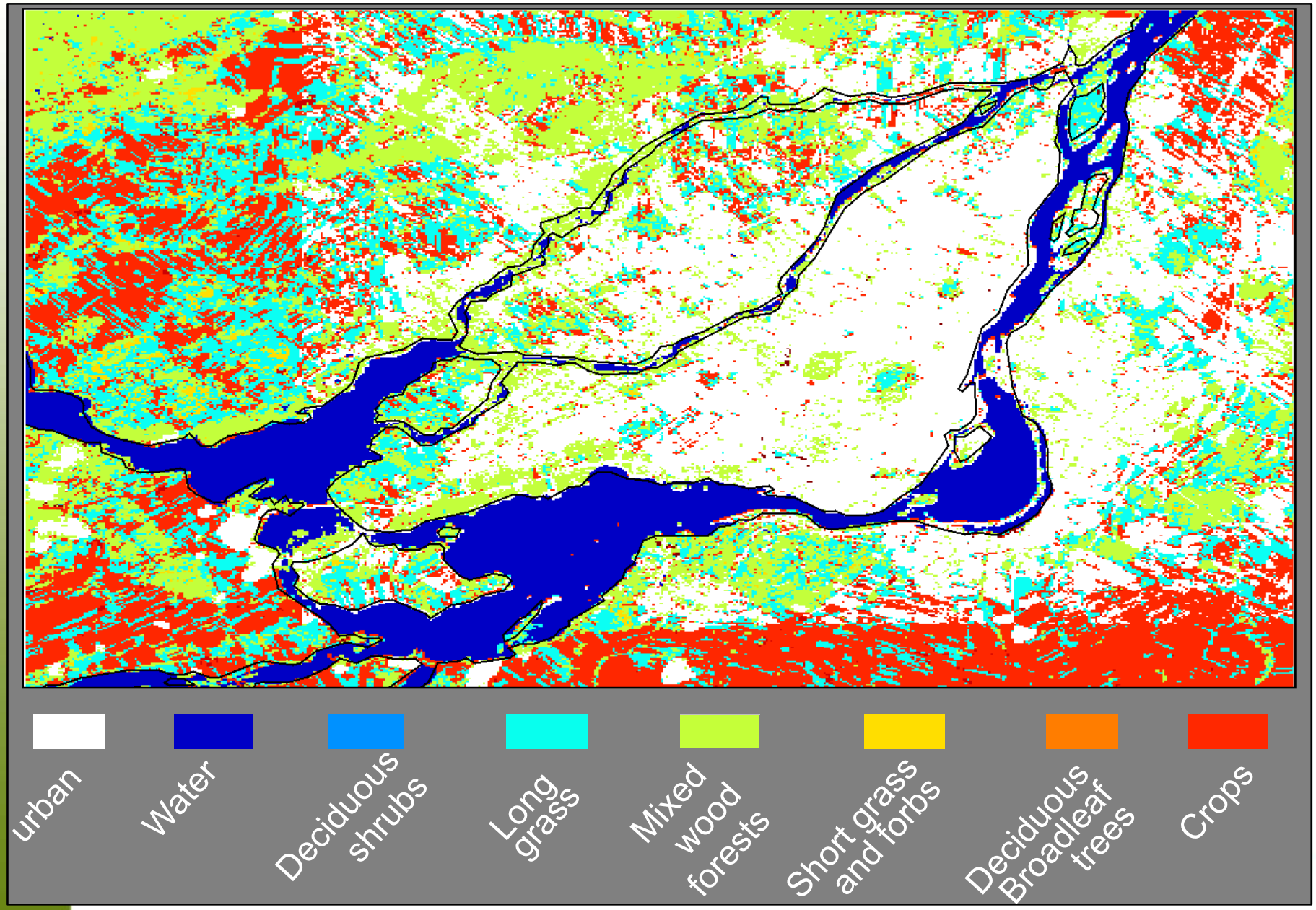
LAND DATA ASSIMILATION at ENVIRONMENT CANADA
In DEVELOPMENT



HIGH-RESOLUTION OFFLINE LAND SURFACE MODELING

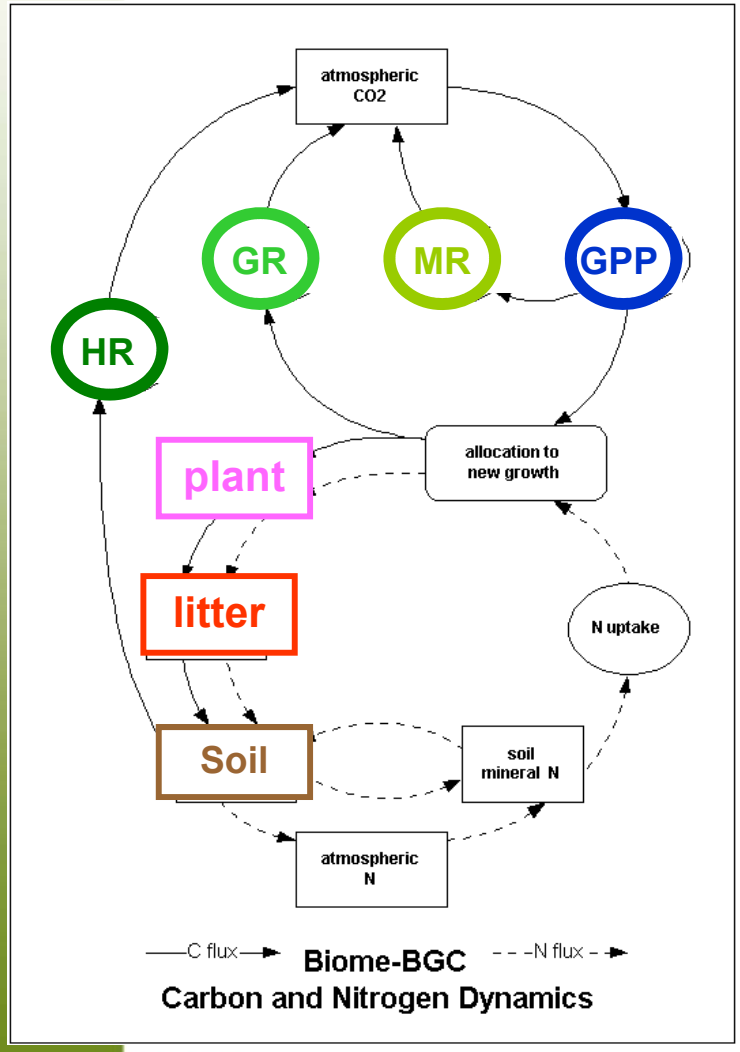


HIGH-RESOLUTION (OFFLINE) LAND SURFACE MODELING URBAN METEOROLOGY (Leroyer et al.)



VEGETATION CHARACTERISTICS from ECOSYSTEMS MODELING (Chan, ..., Belair)

Biome-BGC



ATMOSPHERIC FORCING from MSC NWP PRODUCTS

Biome-BGC integration

Land use / Land cover databases

"Analyses" of Leaf Area Index

C flux

N flux

Photosynthesis (**GPP**)

Maintenance **R**espiration

Growth **R**espiration

Heterotrophic **R**espiration

SYSTEMS to be TESTED for OPERATIONAL IMPLEMENTATION at CMC

Improved surface modeling in GEM (inline)

READY for PRE-IMPLEMENTATION TESTS in 2010

POSSIBLE IMPLEMENTATION in 2011

First version of CaLDAS

FIRST CONFIGURATION in 2010

POSSIBLE IMPLEMENTATION in 2011

First version of high-resolution offline land surface system

PRE-IMPLEMENTATION SHOULD START in 2010

POSSIBLE IMPLEMENTATION in 2012