Environment Canada Environnement Canada

Canada

Snow in Canada's Numerical Weather Prediction (NWP) Systems

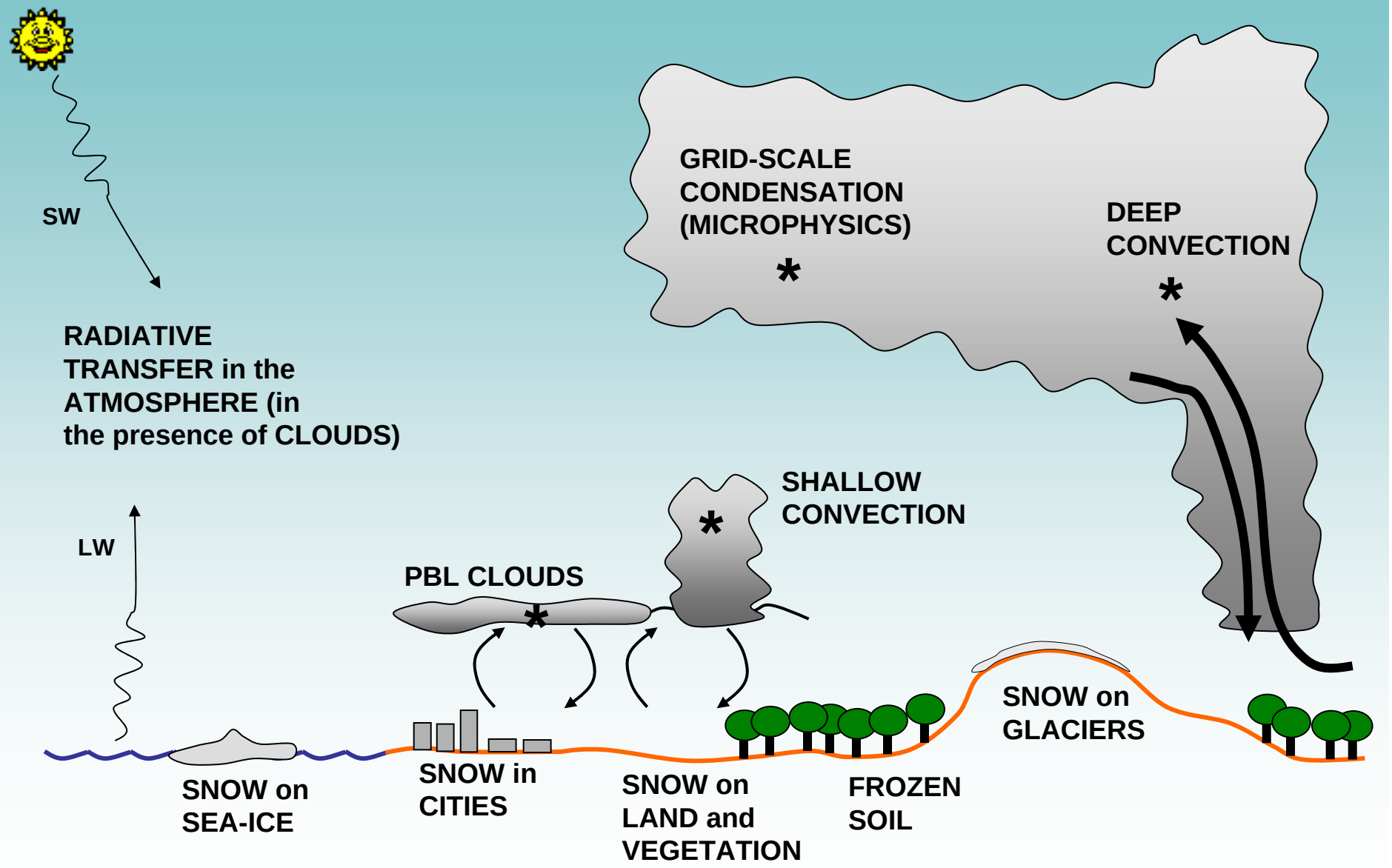
Towards a Polar Snowfall Hydrology Mission

Montreal, 26-28 June, 2007

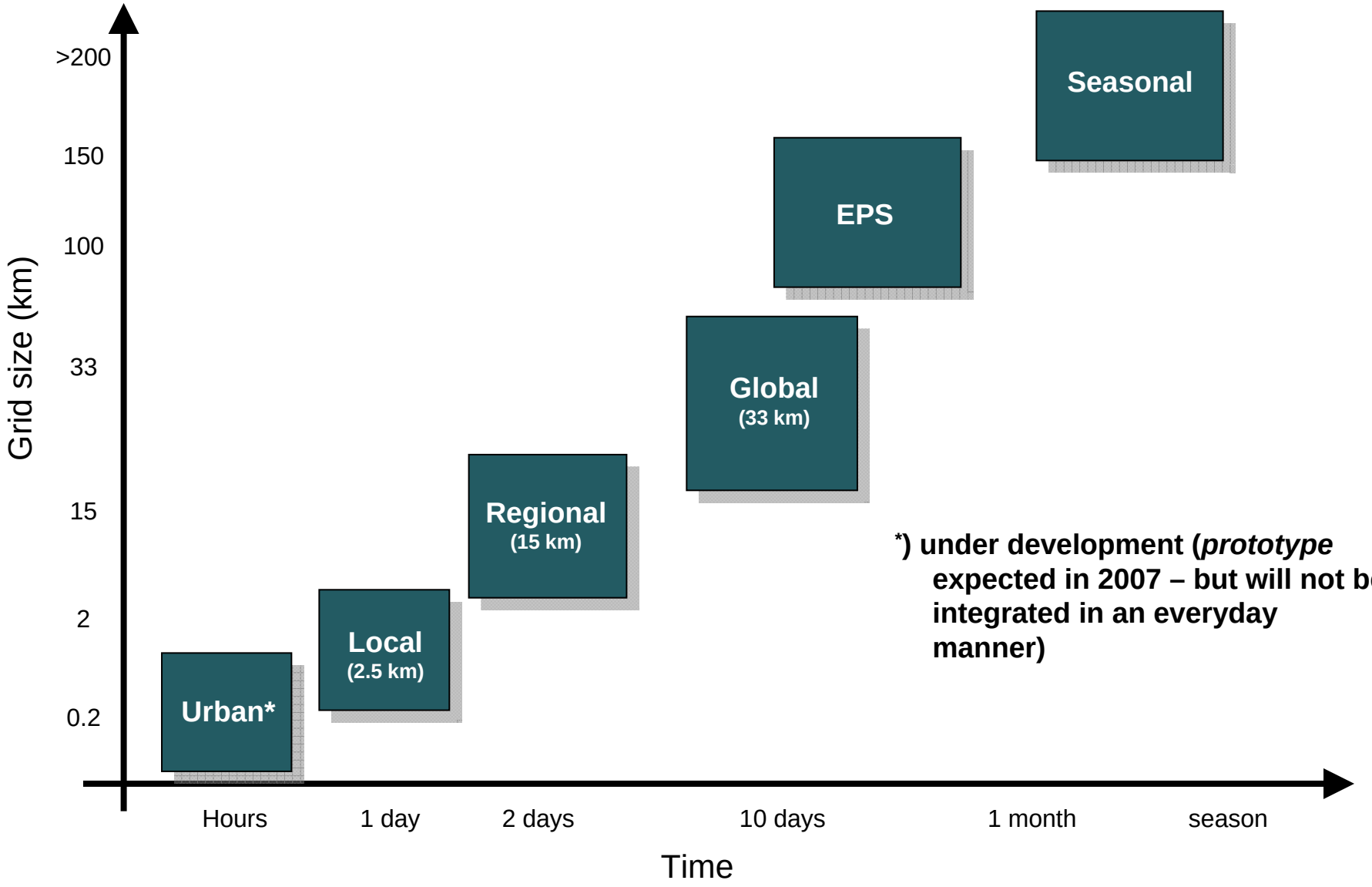
STEPHANE BELAIR

Meteorological Research Division

Snow and Ice in CMC's NWP Systems

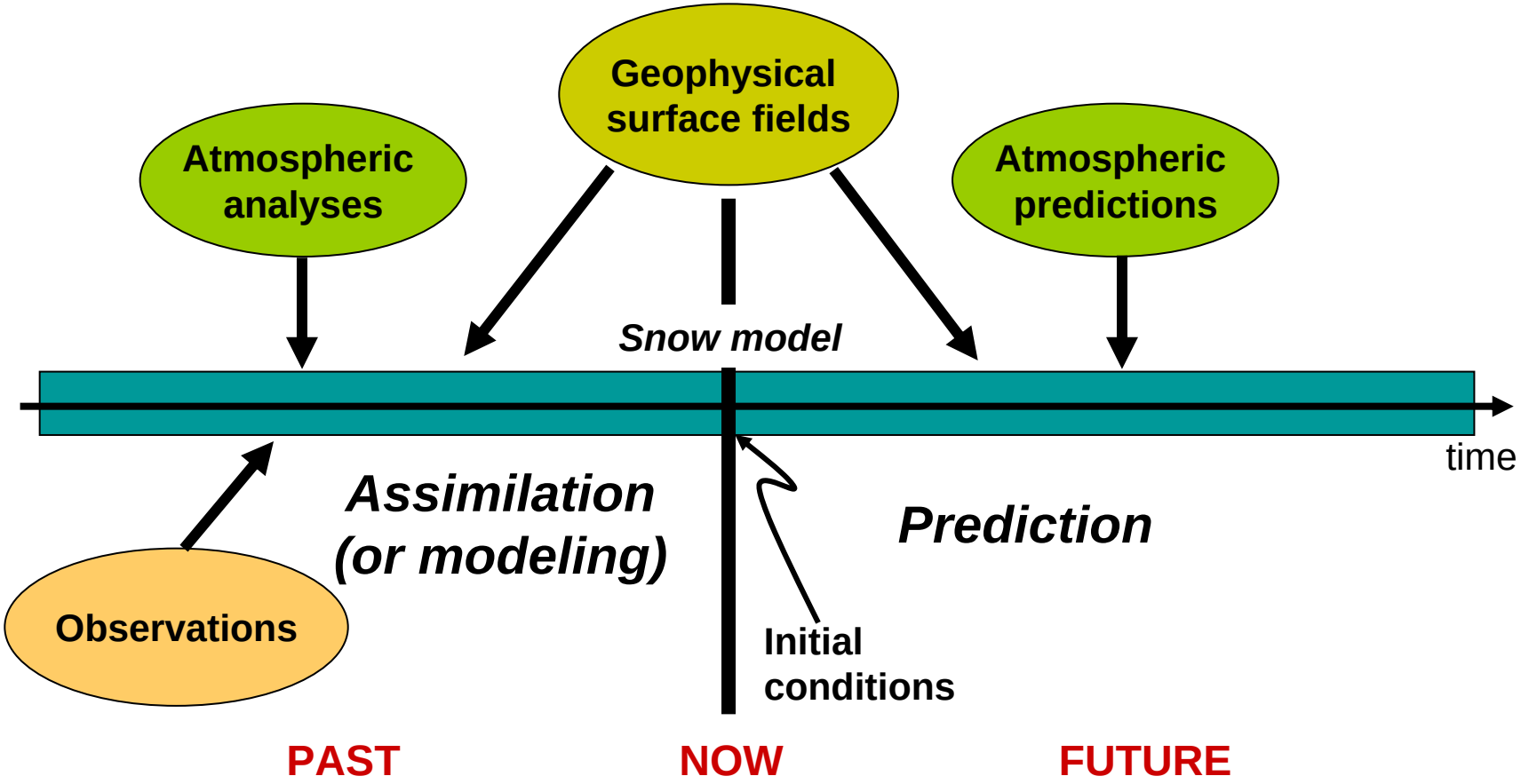


Operational Forecasting Suite at the Canadian Meteorological Centre



*) under development (*prototype* expected in 2007 – but will not be integrated in an everyday manner)

Focus Today: Prediction and Assimilation of Snow on Surface



Data Assimilation of Snow - Current

ATMOSPHERIC FORCING

- Met analyses and forecasts

T, hu, winds
Precipitation
Radiation

ANCILLARY DATA

(databases for soil texture, vegetation, water/land mask, orography, cities)

OFFLINE SNOW MODEL

SNOW OBS

- Surface stations measurements (snow depth)

Assimilation based on optimal interpolation

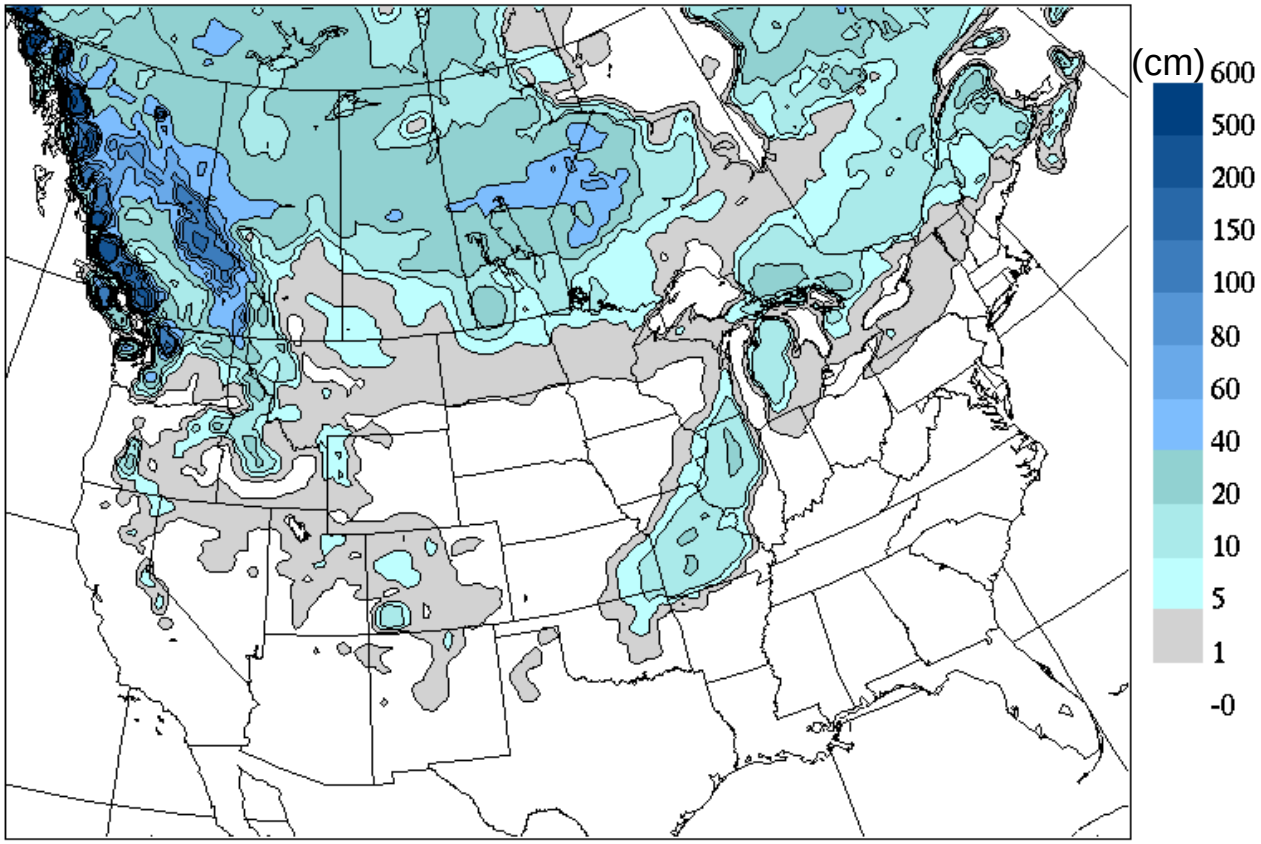
Background snow depth is given by a simple off-line snow model

Reports from SYNOP and METAR are used

(*Brasnett, Brown*)

Example of Snow Depth Analysis (I)

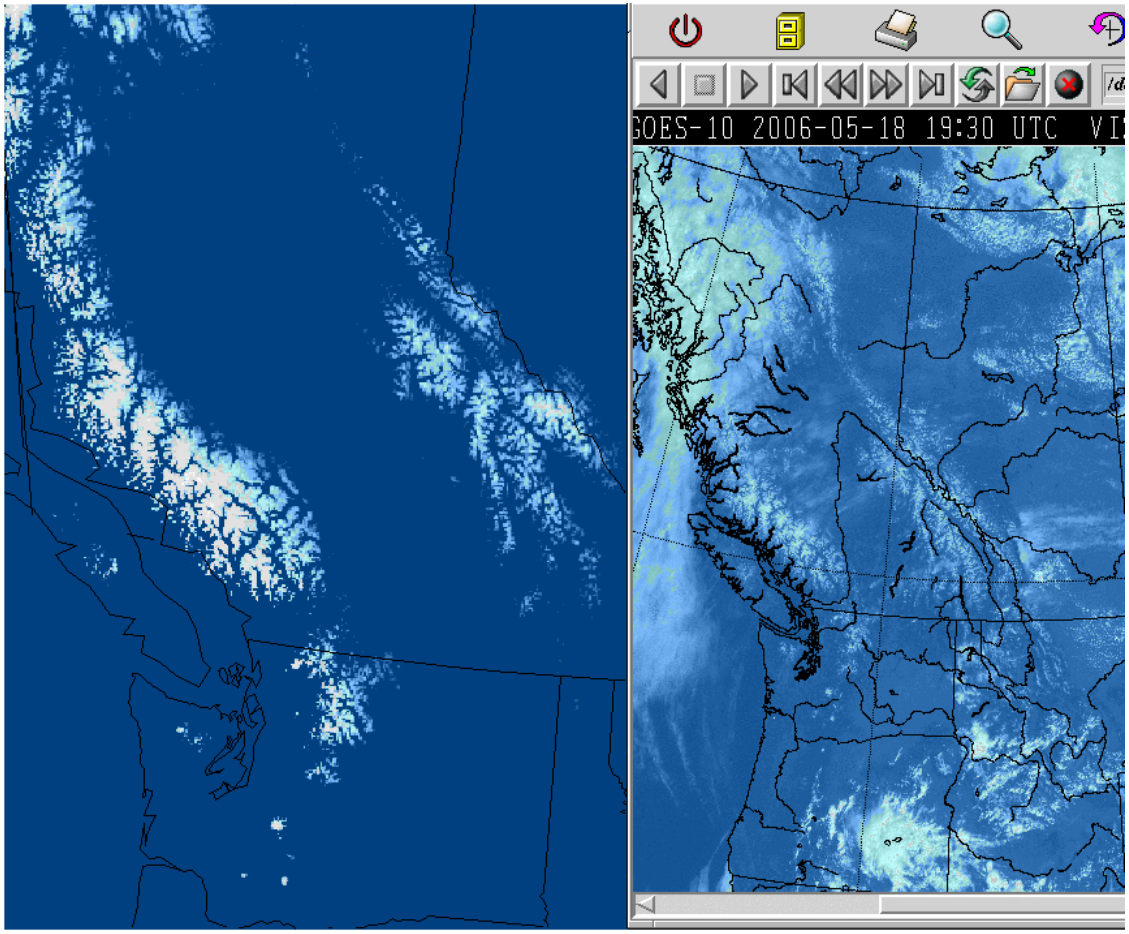
Global Analysis (33 km)



Valid 5 December 2006

Example of Snow Depth Analysis (II)

2.5-km Snow Depth Analysis **GOES**



*When done on a LAM **<u>2.5-km grid</u>**, with adaptation of temperature forcing for the high-resolution orography, the analysis is more realistic in mountainous regions*

(from Amin Erfani)

Data Assimilation of Snow – In progress

ATMOSPHERIC FORCING

T, hu, winds
Precipitation
Radiation

- Met analyses and forecasts
- **Precip analyses**
- **Adaptation (downscaling)**

ANCILLARY DATA

(databases for soil texture, vegetation, water/land mask, orography, cities)

OFFLINE SNOW MODEL

Variational or EKF strategies are examined

Background snow depth is given by a more complex off-line snow model

Precip analyses from CaPA

Space-based remote sensing data will also be used

(*Brasnett, Brown*)

SNOW OBS

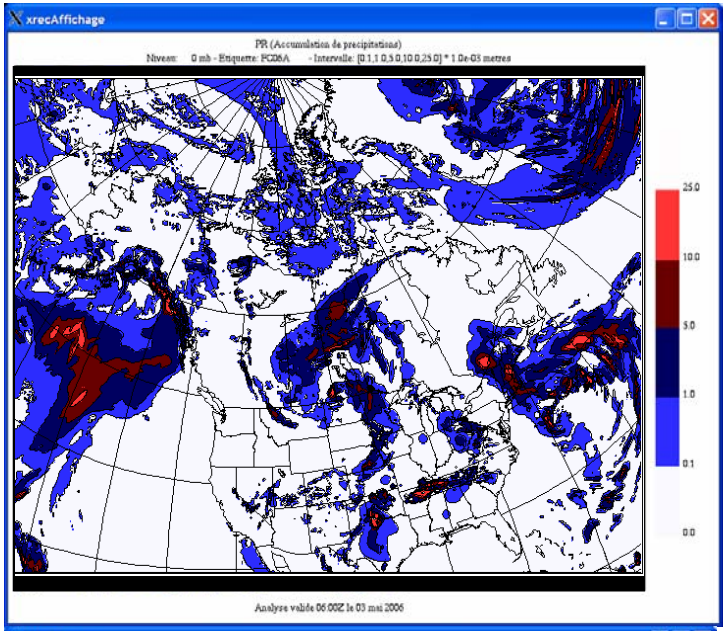
- Surface measurements (snow depth)
- **High-res visible-infrared space-based measurements for snow fractional coverage (e.g., MODIS)**
- **Lower-res microwave space-based radiometric obs for SWE (e.g., SSM/I, AMSR-E)**
- **New missions?**

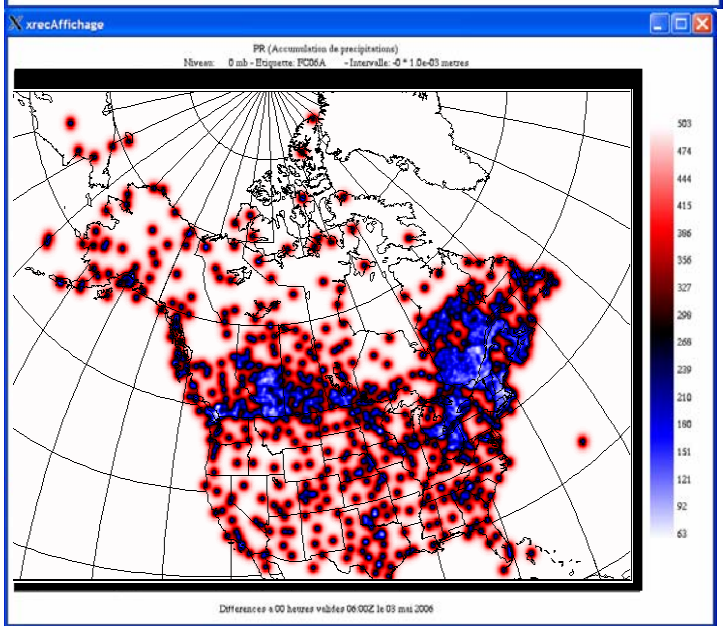
The Canadian Precipitation Analysis (CaPA)

Surface obs

Satellite obs

Model outputs





Correction of a first guess field using a weighted average following:

$$x_a^j = x_b^j + \Sigma_{i=1..N}\, w^{ij} (y_o^i - y_b^i)$$

The background (first guess) is given by our best model products

The weight matrix is given by

$$W=(B+O)^{-1}\, b$$

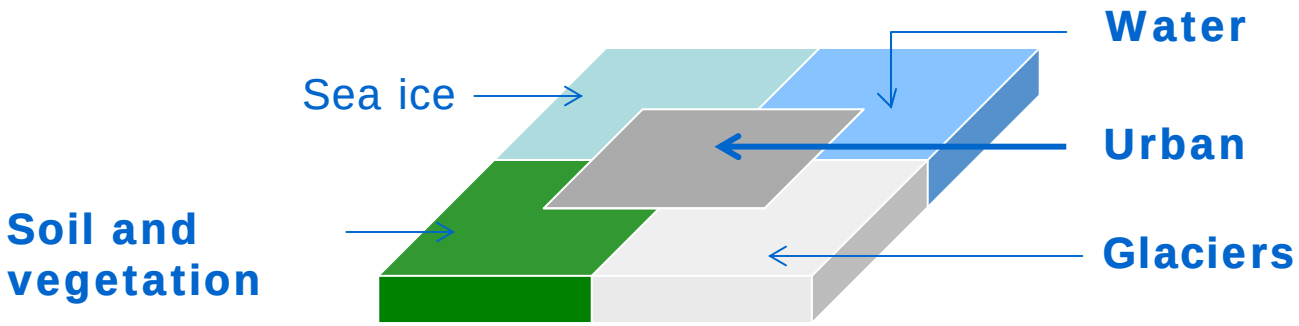
where B and O are the background and observations error covariance matrices, given by

$$B^{ij} = \sigma_b^2 \times \left(1 + \frac{r_{ij}}{L}\right) \times \exp\left(-\frac{r_{ij}}{L}\right)$$

$$O^{ij} = \sigma_o^2 \times \delta_{ij}$$

(*Fortin*, *Mahfouf, Brasnett, Gagnon*)

Snow Models in CMC's NWP Systems

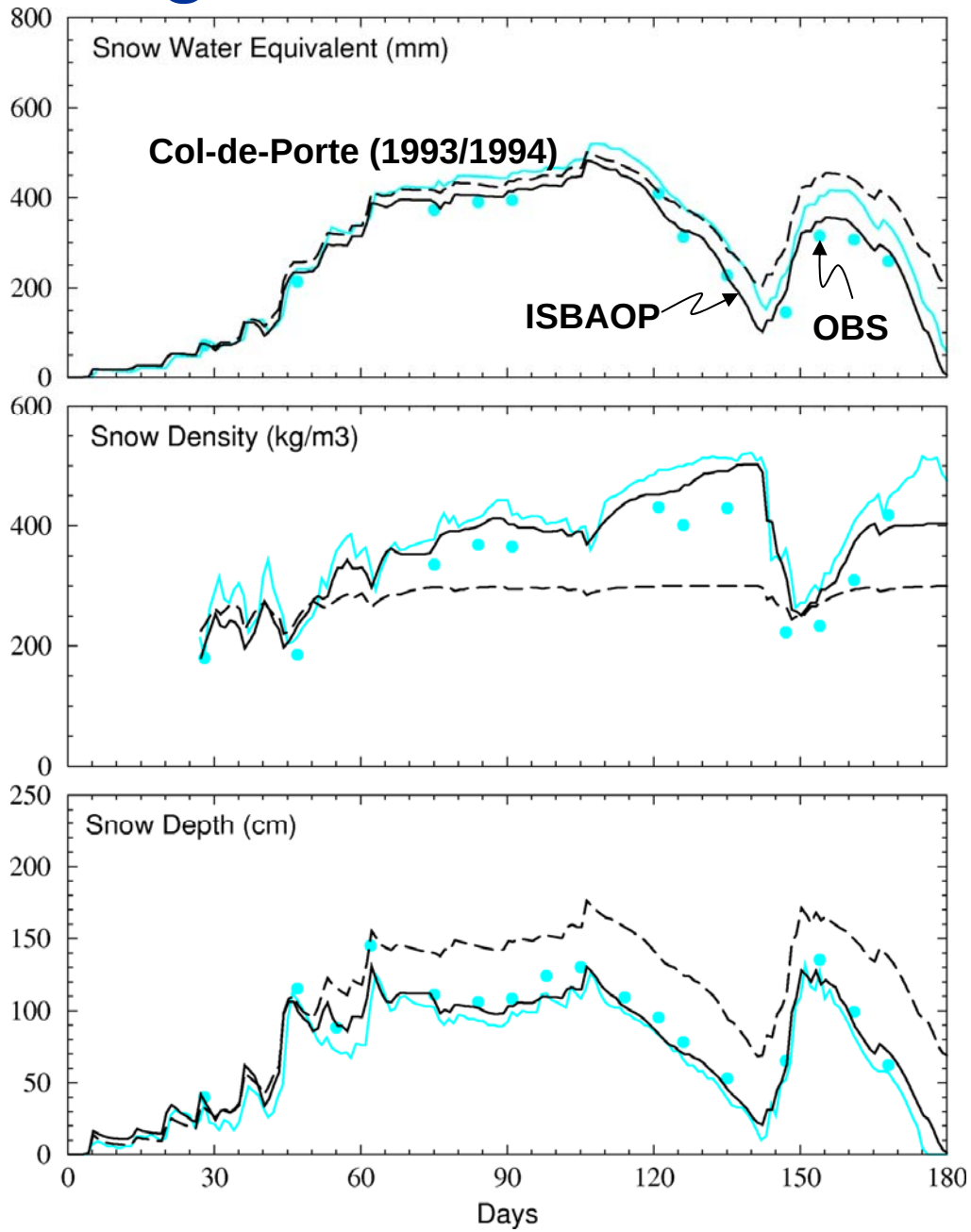


Soils and vegetation	ISBA, CLASS, Force-Restore
Water	Simple scheme with constant surface temperature (Lake model eventually?)
Urban covers	TEB
Glaciers	Force-restore scheme (with snow), module from CLASS
Sea ice	3-layer model with snow on top
Snow	**Very simple schemes over glaciers and sea ice; one layer model in ISBA, CLASS, slightly more complex in TEB**

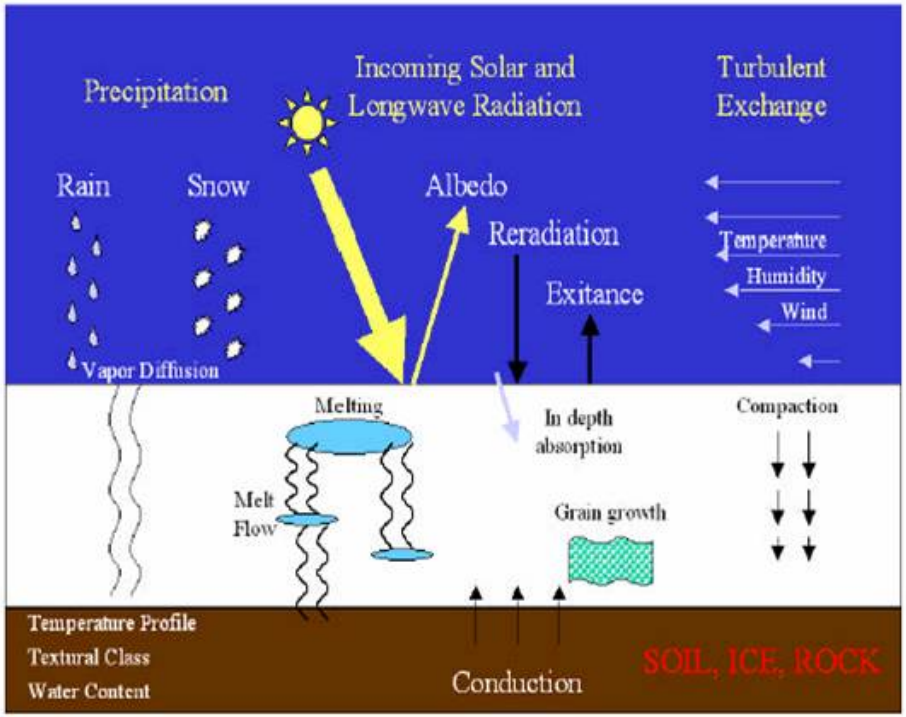
Snow Modeling in ISBA

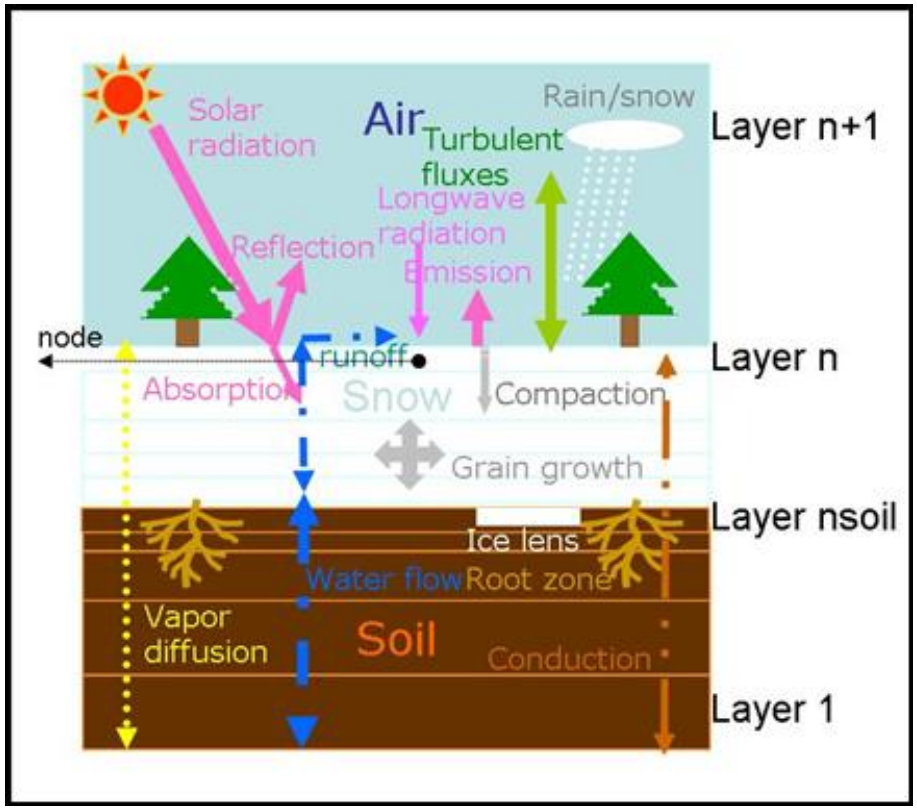
- Single layer model
- Force-restore approach for temperatures
- Water balance for snow mass
- Prognostic equations for:
  - Snow mass
  - Surface and snow pack temperatures
  - Snow density
  - Snow albedo
  - Liquid water in snowpack
- Includes:
  - Refreezing in the snow pack
  - Melting due to rain
  - Snow coverage fractions (bare soil, vegetation)

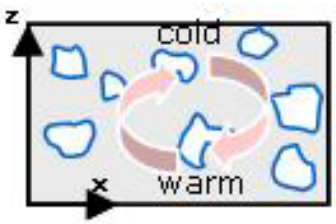
(Bélair et al., 2003)

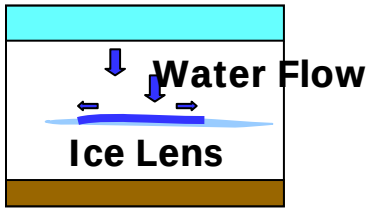


More Complex Surface Models
Example: SNTHERM (Jordan)

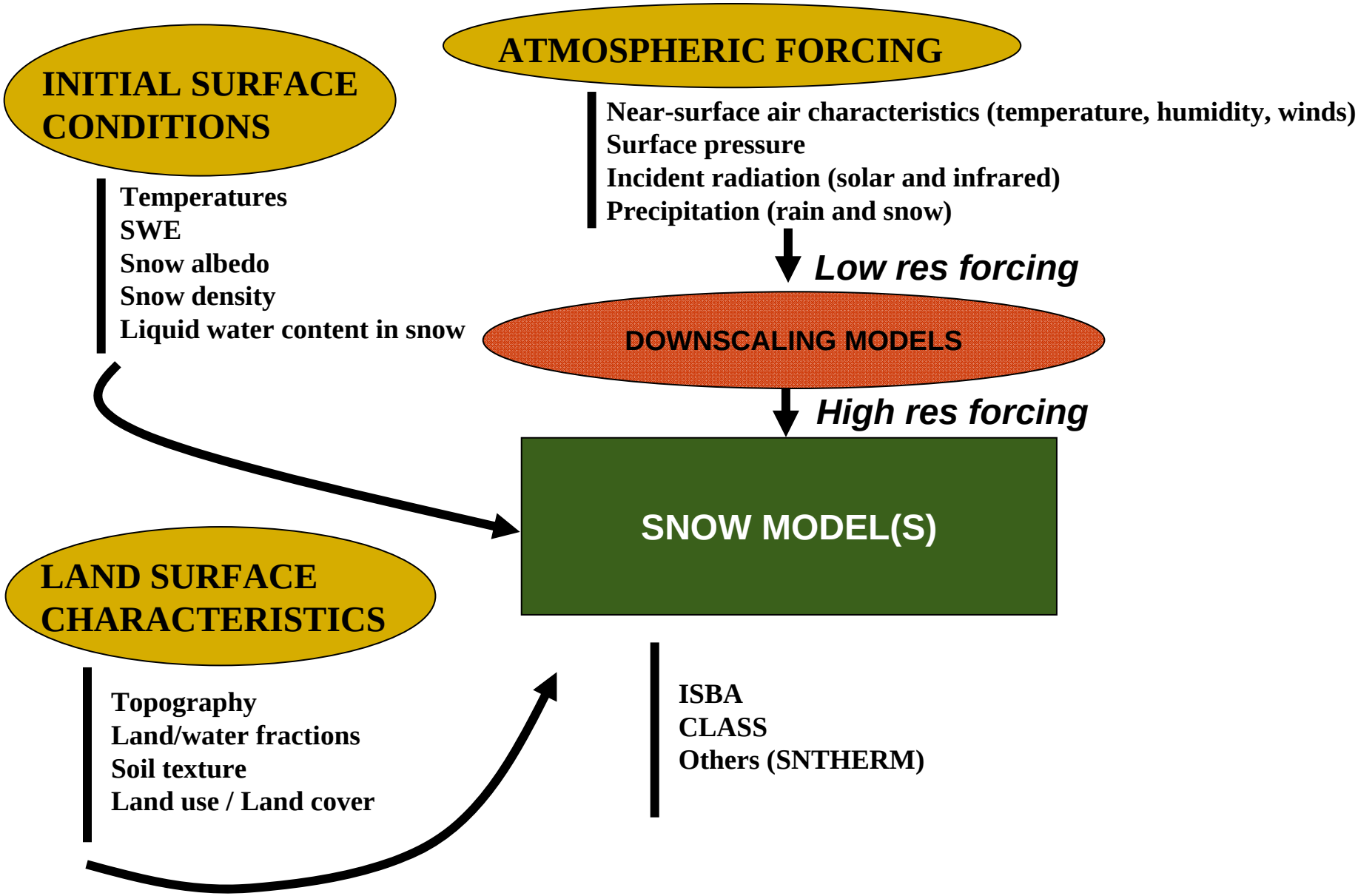




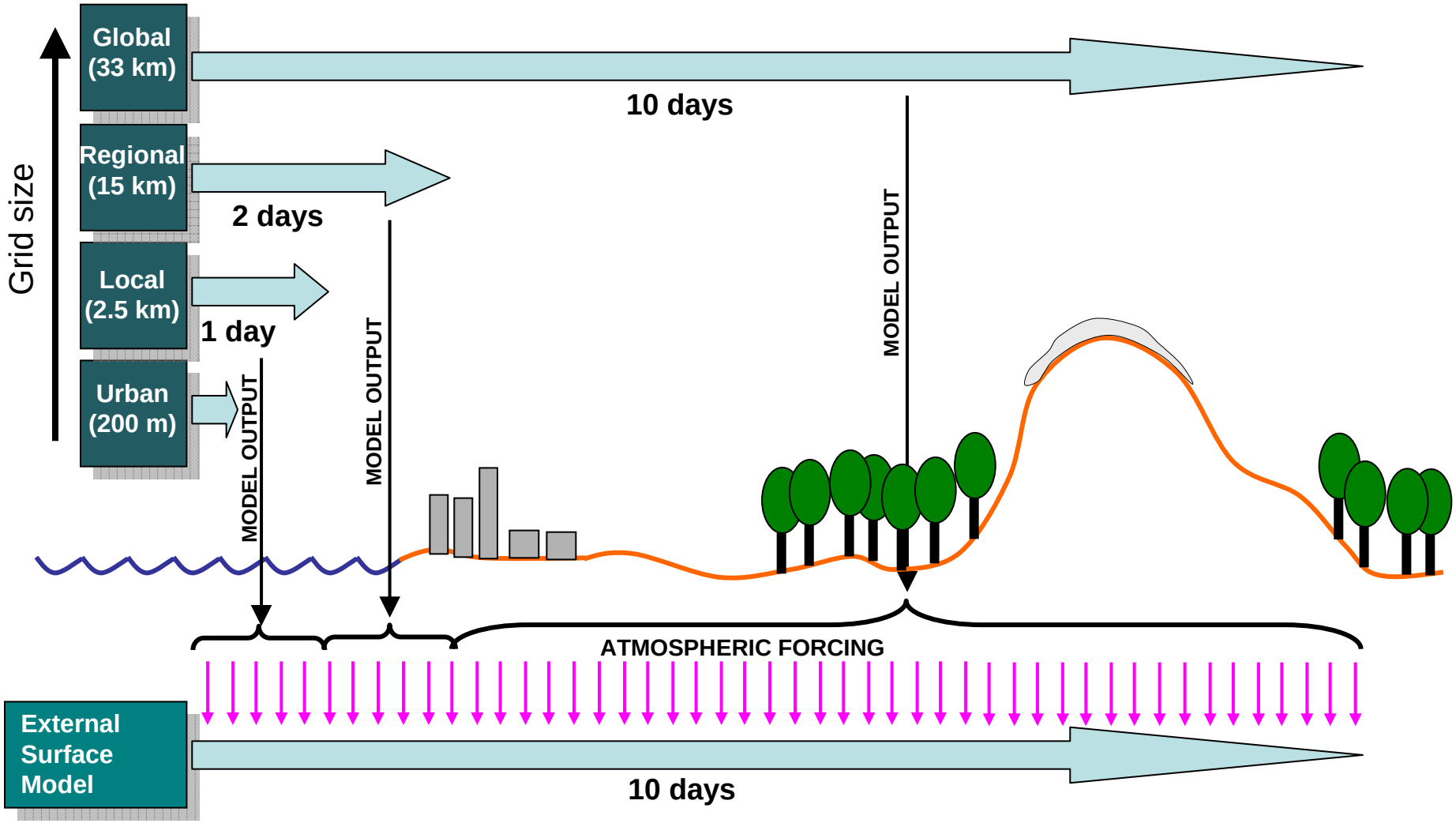




Surface Snow Prediction System



External Land Surface Systems



With horizontal resolution as high as that of surface databases (e.g., 200 m)

Cost of the external surface modeling system is *<u>much less</u>* than an integration of the full atmospheric model

Downscaling: Impact on Surface Snow

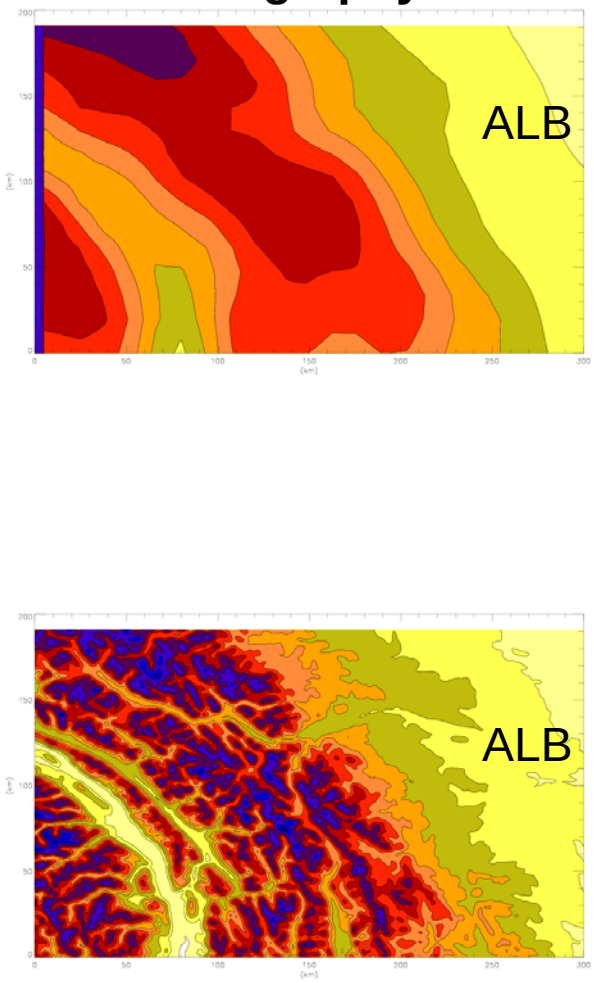
(GEM)

15 km

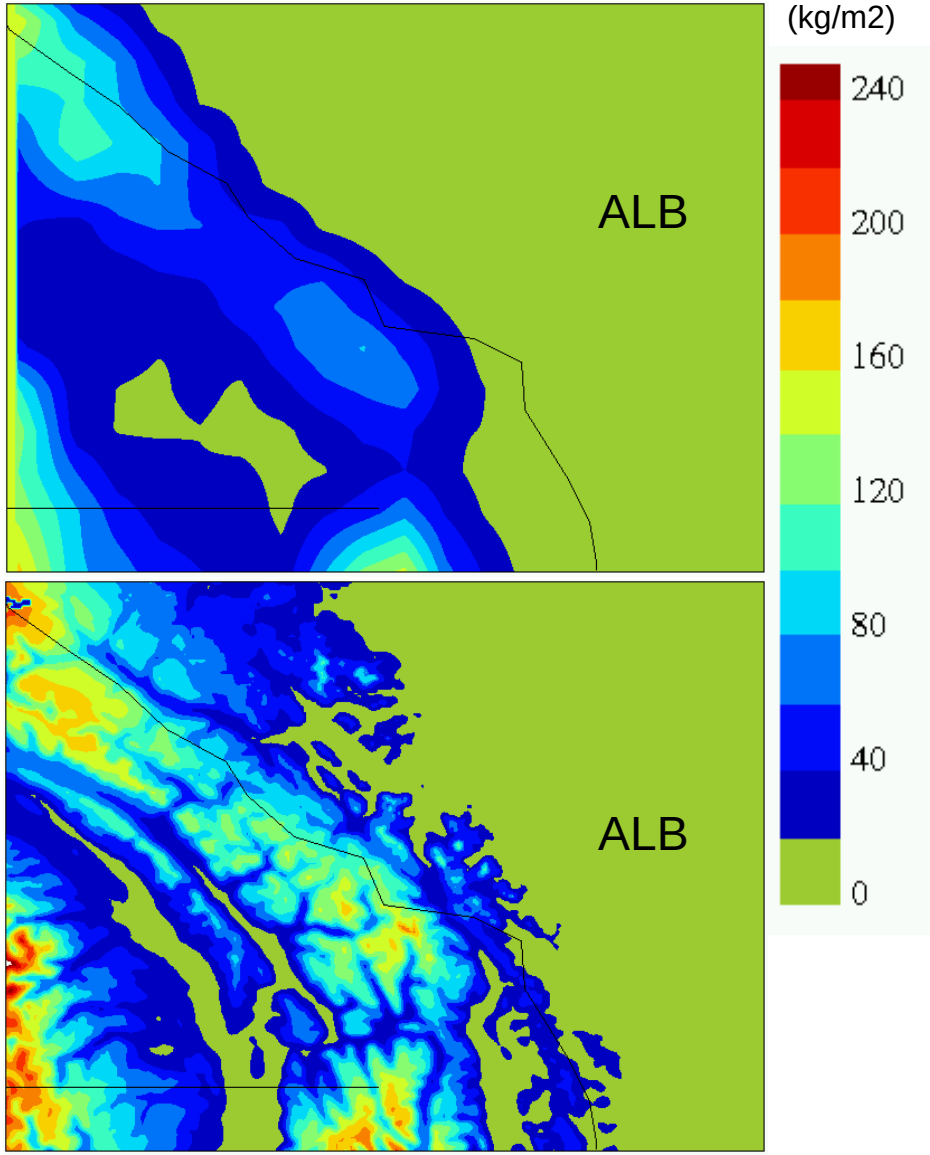
1 km

(MEC)

Orography



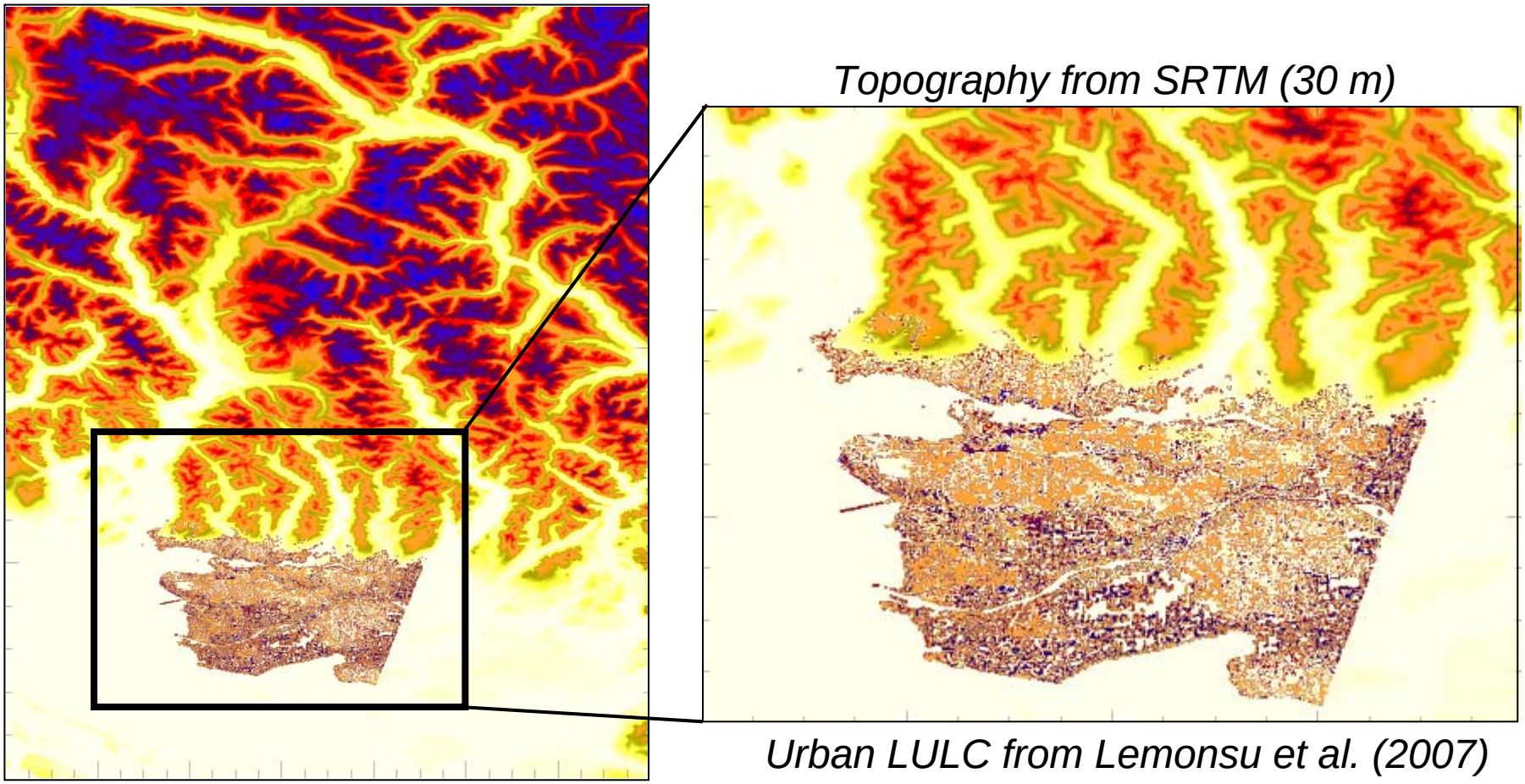
Snow Water Equivalent



(Valid 0000 UTC 1 December 2006)

Special Project for VAN 2010 Olympics

Topography and the Vancouver urban area



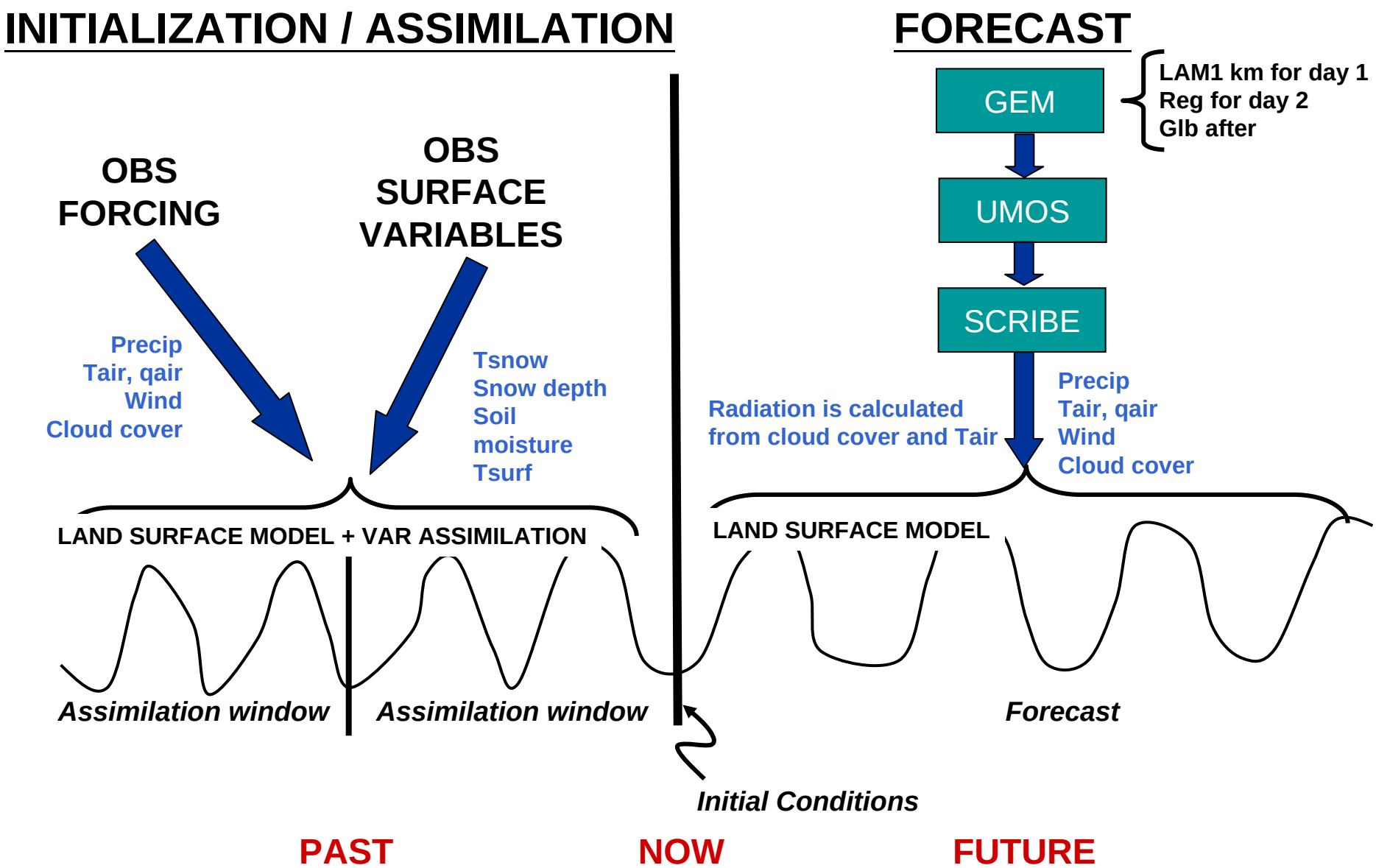
Computational grid: 1400 x 1800 (100 m)

Snow in NWP: Last Few Comments

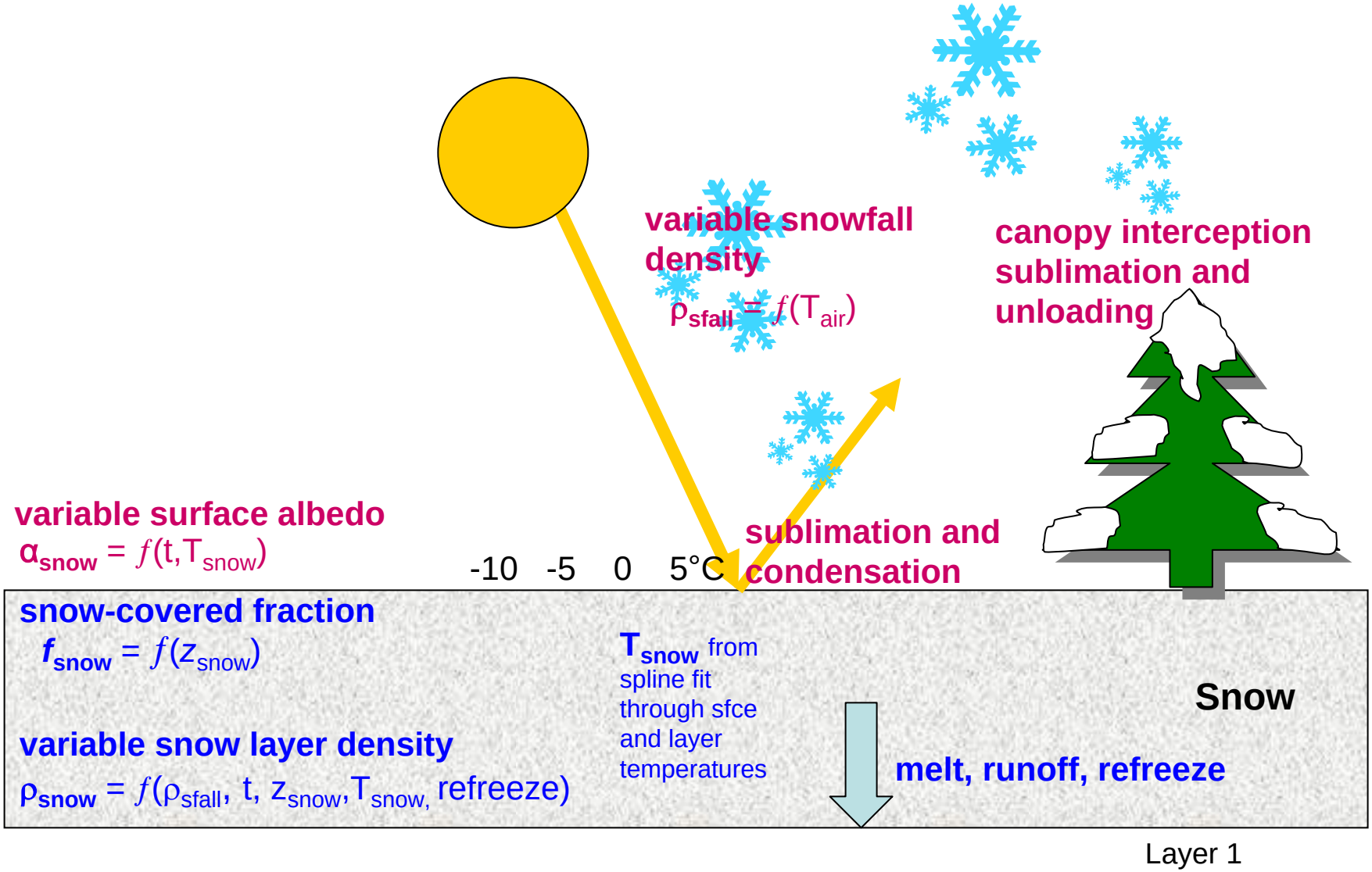
- Blowing snow is being included in the atmospheric model, but it may be difficult to include blowing snow in an external land surface system
- Verification: more is needed (including space-based remote sensing)
- Remote-sensing of snowfall could be used in precipitation analysis (not much else information in northern regions) – Important to have a good idea of the observation errors
- Remote sensing of surface snow conditions (again, need good estimate of the observation errors):
    - *Snow coverage*
    - *SWE*
    - *Snow albedo*
- Temporal resolution: would be nice to have information daily
- Spatial resolution: at least of the order of the regional model grid-size (~10-20 km)

Thank you …

Statistical Adaptation for Local Prediction



Snow Modeling in CLASS (Similar in ISBA)



(from Ross Brown)