ISBA and Numerical Weather Prediction (in Canada)

Stéphane Bélair

Environment and Climate Change Canada (ECCC)

A Tribute to Joel Noilhan – 21 March 2019

A Year in France, Under Joel's Supervision (1995)

<u>**The project**</u>:

Recode ISBA in the new Meso-NH atmospheric model

Evaluate performance with a case study during HAPEX-MOBILHY

One of the first papers with Meso-NH (1998)

High-Resolution Simulation of Surface and Turbulent Fluxes during HAPEX-MOBILHY

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(Manuscript received 17 April 1997, in final form 18 November 1997)

ABSTRACT

The newly developed nonhydrostatic model MESO-NH, in which the surface scheme Interactions Soil–Biosphere–Atmosphere has been incorporated, is used in this study to assess the impact of increasing the horizontal resolution from 10 km to 1 km on the simulation of surface and turbulent fluxes for the 16 June 1986 case of HAPEX-MOBILHY, a field experiment that took place in southwestern France.

Except for a slight deterioration over the cultivated areas surrounding the Landes forest (caused by an inconsistency between the soil texture fields at 10 and 1 km), the simulation of the surface fluxes of sensible and latent heat is generally improved by the increase of horizontal resolution. The contrast of the sensible heat fluxes between the Landes forest and the surrounding cultures is well captured in both 10-km and 1-km runs, but the spatial variability of these fluxes is better represented in the high-resolution results. An oasis-type effect over the larger clearings of the Landes forest is even produced by the model, as was observed.

For the 1-km simulation, the comparison of the turbulent fluxes against observations has to include both the grid-scale fluxes resulting from resolved larger eddies within the well-mixed layer, as well as subgrid-scale (i.e., parameterized) fluxes. (At 10-km resolution, all turbulent fluxes are parameterized.) The greater contributions of the grid-scale component are found over the forest, where the larger eddies are more vigorous due to stronger sensible heat fluxes at the surface. For sensible and latent heat fluxes, the grid-scale component is particularly important in the middle of the mixed layer, whereas for turbulent kinetic energy this component is greater near the bottom and top of the mixed layer. In general, the increase of horizontal resolution does not improve significantly the simulation of the turbulent fluxes. Thus, the use of such an intermediate horizontal resolution (i.e., 1 km), lying between that typically used in large-eddy simulation models (<200 m) and that of mesoscale models (>few kilometers), is questionable, even though this resolution is probably optimal for simulating surface fluxes, since it is roughly the same as the resolution of the soil and vegetation databases.

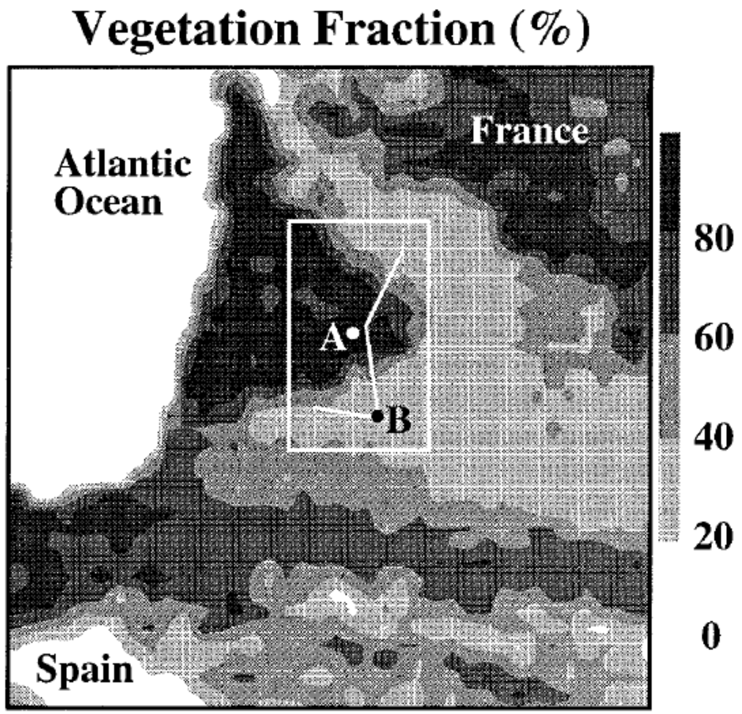


FIG. 1. Fraction of vegetation (% of coverage) over the integration domain for the 10-km simulation. The white box shows the 1-km integration domain. The path of the NCAR King Air aircraft is indicated by the thick white line. The measured and simulated fluxes over points A and B are shown in Figs. 5 and 6, and respectively.

1-km simulation with Meso-NH + ISBA of the 16 June 1986 HAPEX-MOBILHY case

Surface fluxes during HAPEX-MOBILHY

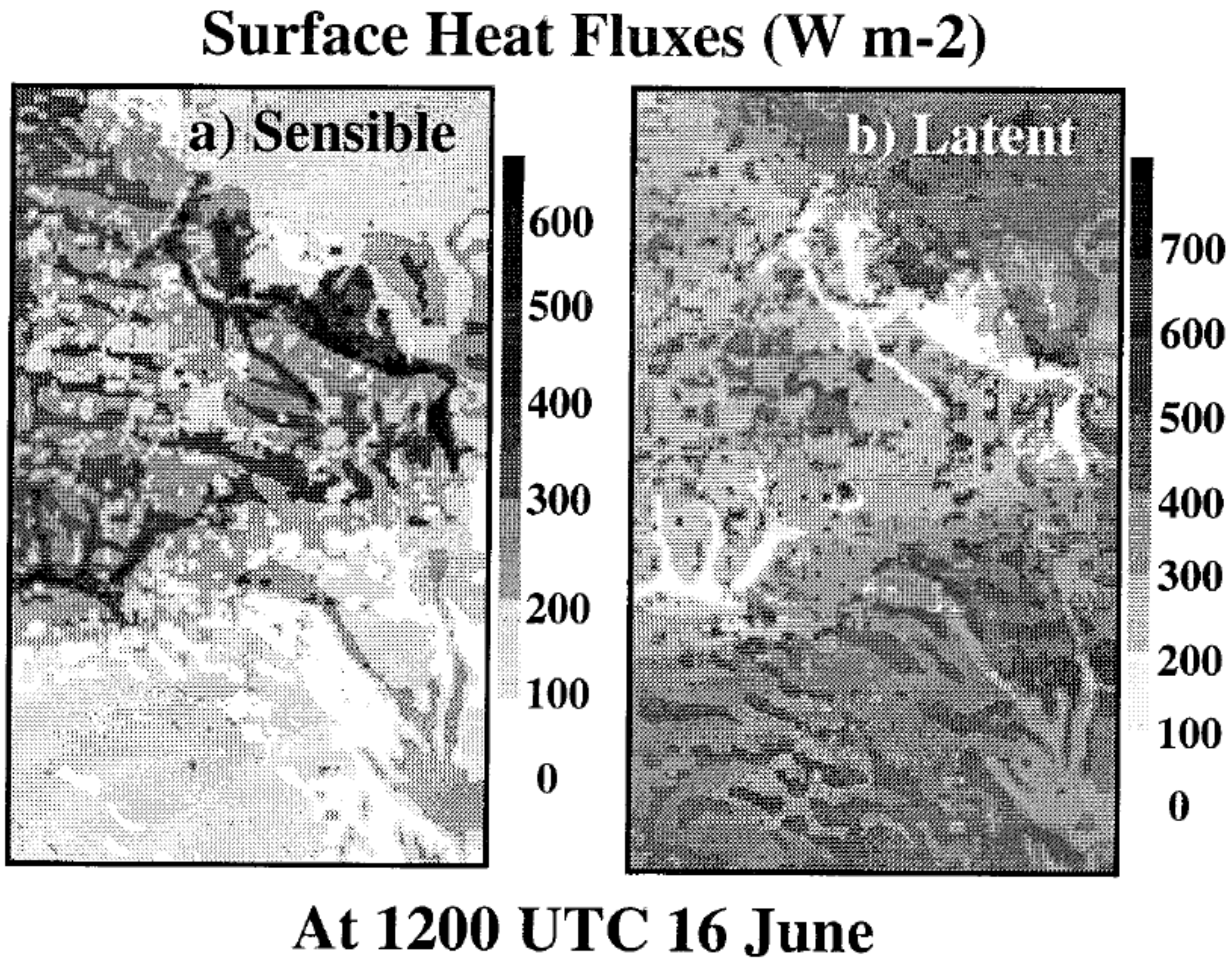
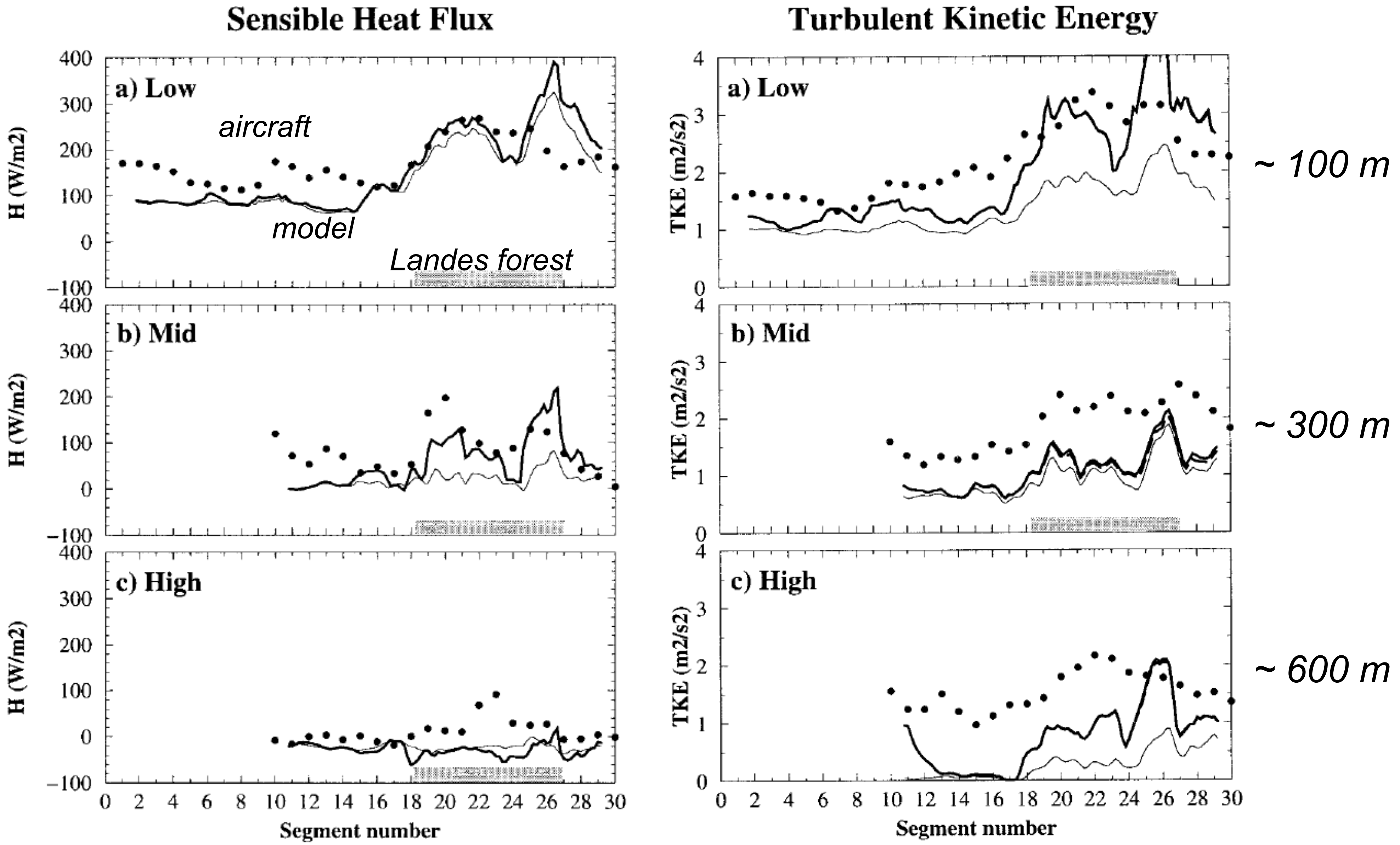


FIG. 10. Surface fluxes of (a) sensible and (b) latent heat (W m^{-2}) from 3-h 1-km integration, valid at 1200 UTC 16 June.

Simulating aircraft fluxes during HAPEX-MOBILHY



Back to Canada (1996)… ISBA vs CLASS

A simple Force-Restore scheme was then operational at EC

The Canadian Land Surface Scheme (Verseghy, 1991) was getting popular in the Canadian scientific community

… but it was difficult to implement operationnally (surface characteristics, initial conditions)

And results with ISBA were quite good

So...

Operational Implementation in EC’s Regional Short-Range NWP Model (2001)

Operational Implementation of the ISBA Land Surface Scheme in the Canadian Regional Weather Forecast Model. Part I: Warm Season Results

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(Manuscript received 12 April 2002, in final form 15 October 2002)

ABSTRACT

The summertime improvement resulting from the operational implementation of a new surface modeling and assimilation strategy into the Canadian regional weather forecasting system is described in this study. The surface processes over land are represented in this system using the Interactions between Soil–Biosphere–Atmosphere (ISBA) land surface scheme. Surface variables, including soil moisture, are initialized using a sequential assimilation technique in which model errors of low-level air temperature and relative humidity are used to determine analysis increments of surface variables.

It was found that the magnitude and nature of the analysis increments applied to the surface variables depended on the surface and meteorological conditions observed in each region. In regions characterized by weak meteorological activity (i.e., no clouds or precipitation), model errors of low-level air characteristics are more likely to be related to an incorrect representation of surface processes due to either erroneous initial conditions or inaccurate parameterizations in the land surface scheme. In other regions characterized by more frequent and more intense precipitation events, surface corrections are mainly associated with inaccurate atmospheric forcing.

Objective evaluation against observations from radiosondes and surface stations showed that the amplitude of the diurnal cycle of near-surface air temperature and humidity is larger with the new surface system, in better agreement with observations. This type of improvement was found to extend higher up in the boundary layer (up to 700 hPa) where cold and humid biases were significantly reduced by introducing the new surface system. The model precipitation was also found to be significantly influenced by the new representation of surface fluxes. The problematic increase of a positive bias in precipitation with integration time was found to be significantly reduced with the new system, due to the warmer and drier boundary layer.

Operational Implementation of the ISBA Land Surface Scheme in the Canadian Regional Weather Forecast Model. Part II: Cold Season Results

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(Manuscript received 12 April 2002, in final form 15 October 2002)

ABSTRACT

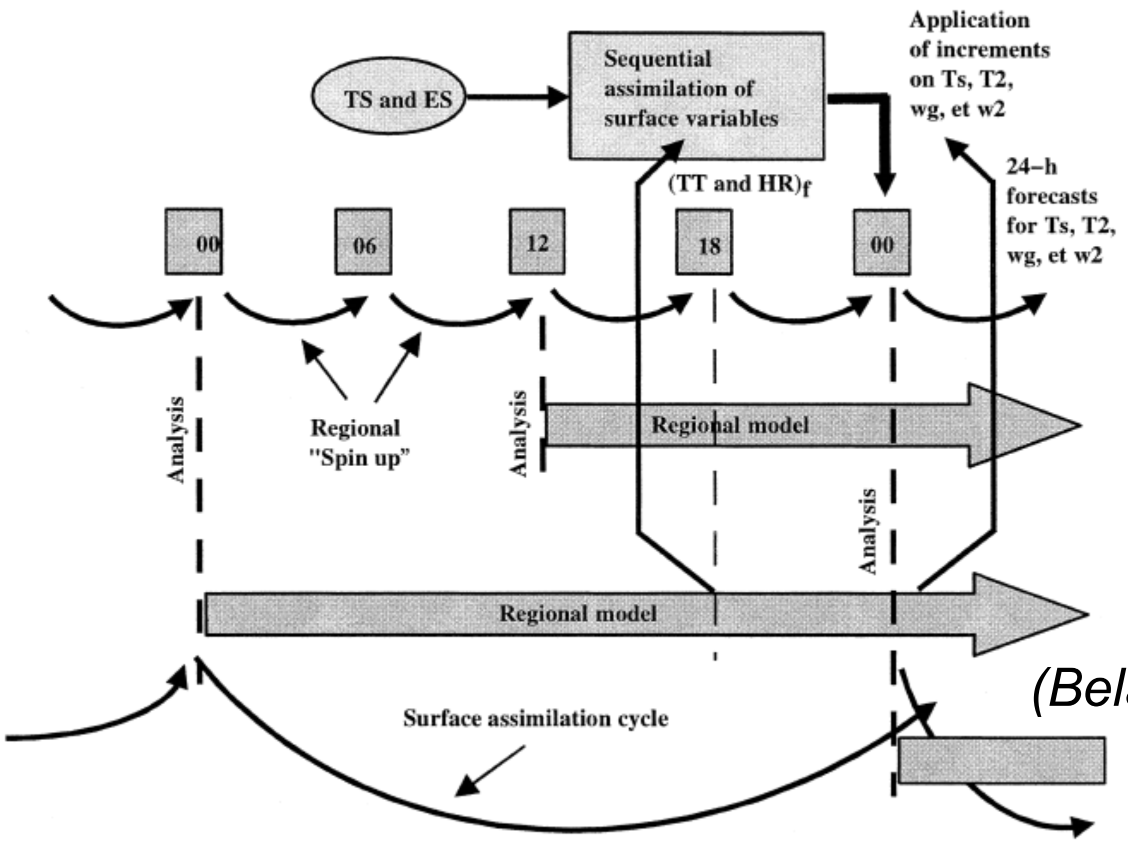
The performance of a modified version of the snow scheme included in the Interactions between Surface–Biosphere–Atmosphere (ISBA) land surface scheme, which was operationally implemented into the regional weather forecast system at the Canadian Meteorological Centre, is examined in this study. Stand-alone verification tests conducted prior to the operational implementation showed that ISBA’s new snow package was able to realistically reproduce the main characteristics of a snow cover, such as snow water equivalent and density, for five winter datasets taken at Col de Porte, France, and at Goose Bay, Newfoundland, Canada. A number of modifications to ISBA’s snow model (i.e., new liquid water reservoir in the snowpack, new formulation of snow density, and melting effect of incident rainfall on the snowpack) were found to improve the numerical representation of snow characteristics.

Objective scores for the fully interactive preimplementation tests carried out with the Canadian regional weather forecast model indicated that ISBA’s improved snow scheme only had a minor impact on the model’s ability to predict atmospheric circulation. The objective scores revealed that only a thin atmospheric layer above snow-covered surfaces was influenced by the change of land surface scheme, and that over these regions the essential behavior of the atmospheric model was not significantly altered by improvements to the treatment of snow cover. It was shown that this lack of response was most likely related to the treatment of the snow cover fraction in each atmospheric model grid tile. The estimation of snow cover fraction relied on simple formulations that were dependent on poorly known parameters, such as the fractional coverage of vegetation. Results showed that uncertainties of only 15% in vegetation fractional coverage could be responsible for uncertainties of as much as 1–1.5 K in screen-level air temperature. This indicates that some care must be exercised in the specification of vegetation and snow cover fractional coverage.

Operational Implementation in EC's Regional Short-Range NWP Model (2001)

The sequential OI analysis of soil moisture and surface temperature

(Mahfouf 1991)



(Belair et al 2003)

FIG. 2. Schematic diagram of the sequential assimilation of surface variables, TS and ES are analyses of 2-m air temperature and dew-point temperature depression, that is, $T - T_d$, whereas TT and HR are forecasts (see subscript "f") of 2-m air temperature and relative humidity.

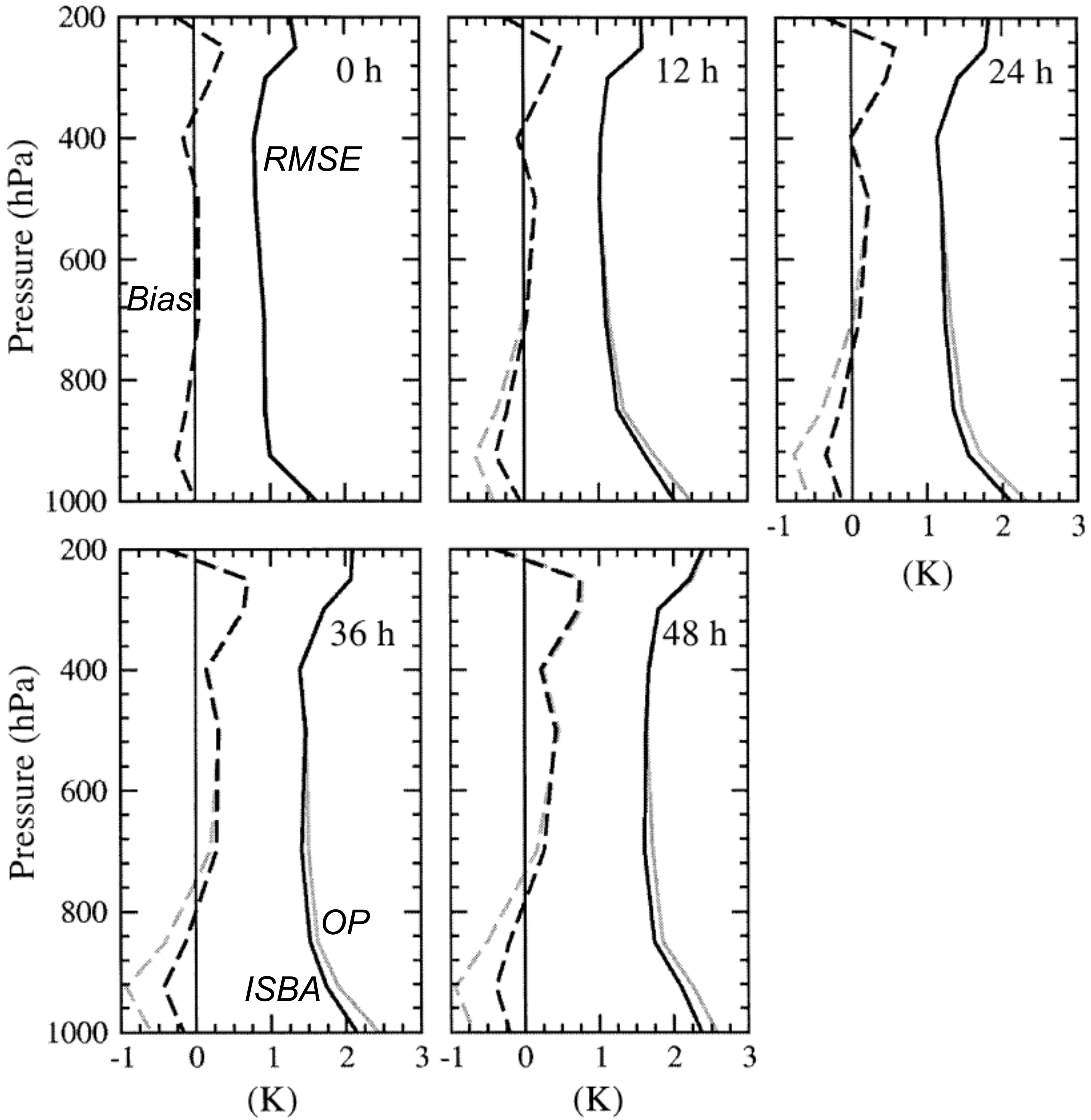
Operational Implementation in EC's Regional Short-Range NWP Model (2001)

Upper-air evaluation

Temperature

18 cases

North America



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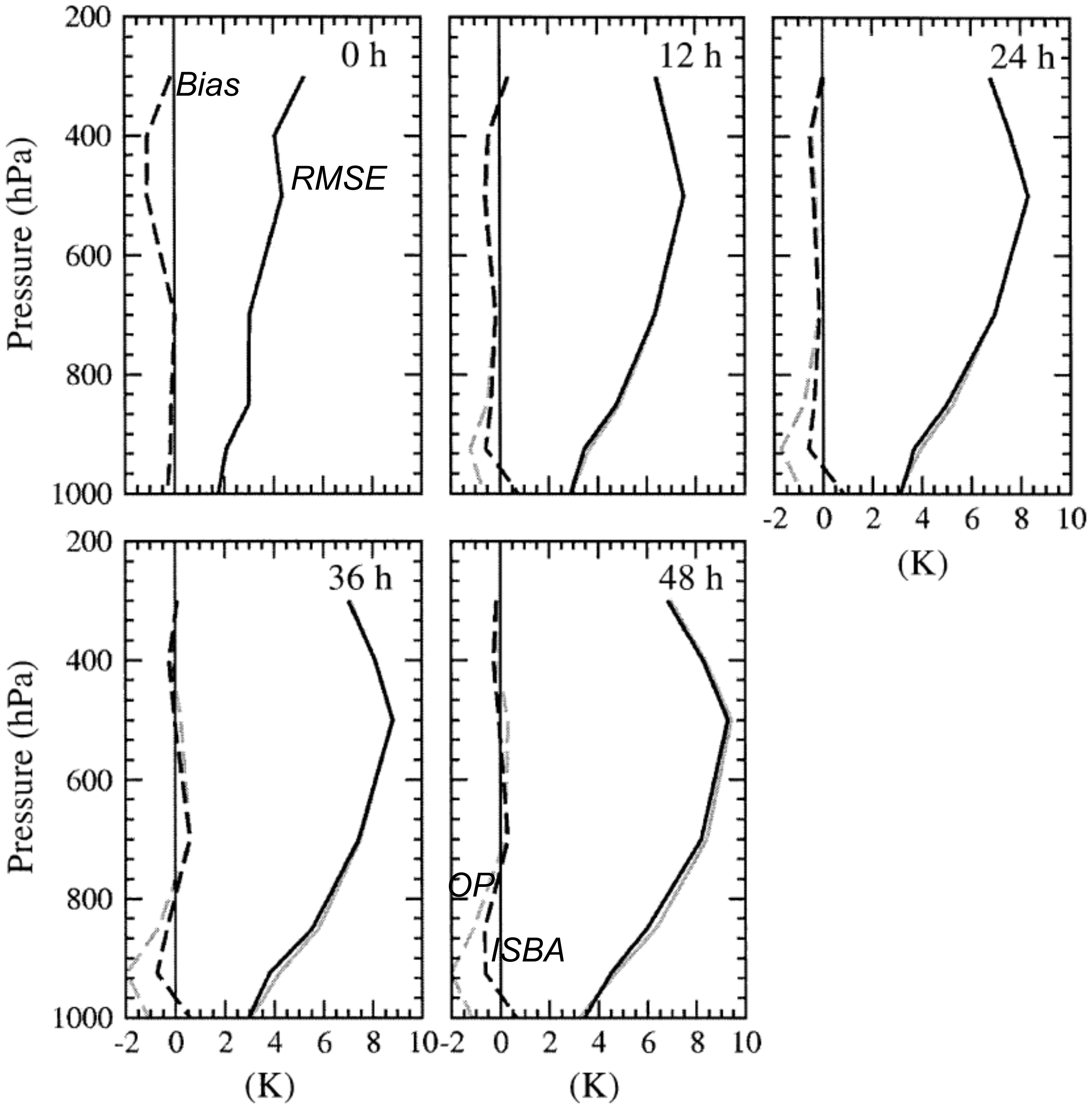
Operational Implementation in EC's Regional Short Range NWP Model (2001)

Upper-air evaluation

Dew point depression

18 cases

North America



Operational Implementation in EC's Regional Short-Range NWP Model (2001)

Objective evaluation of precipitation

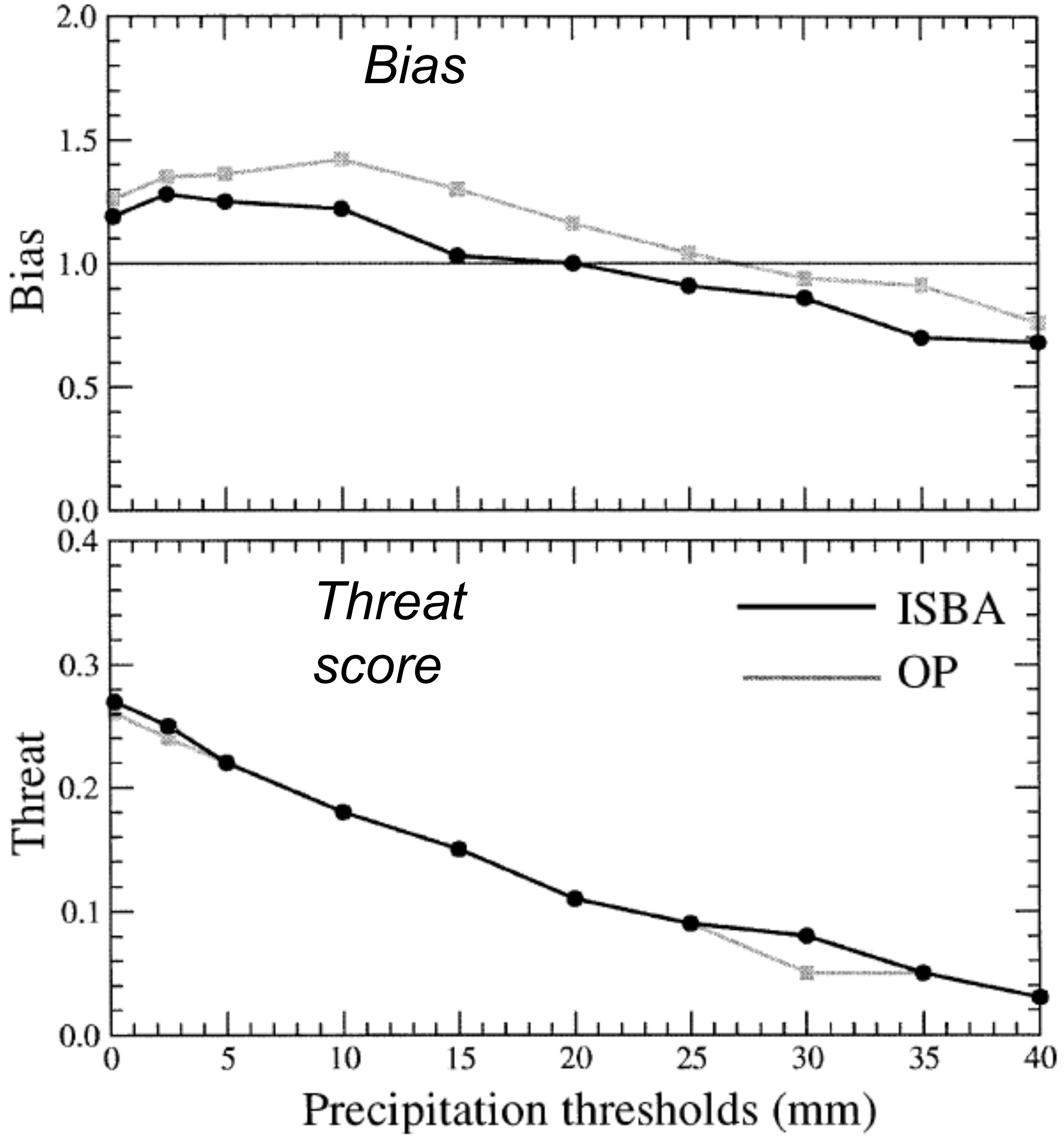
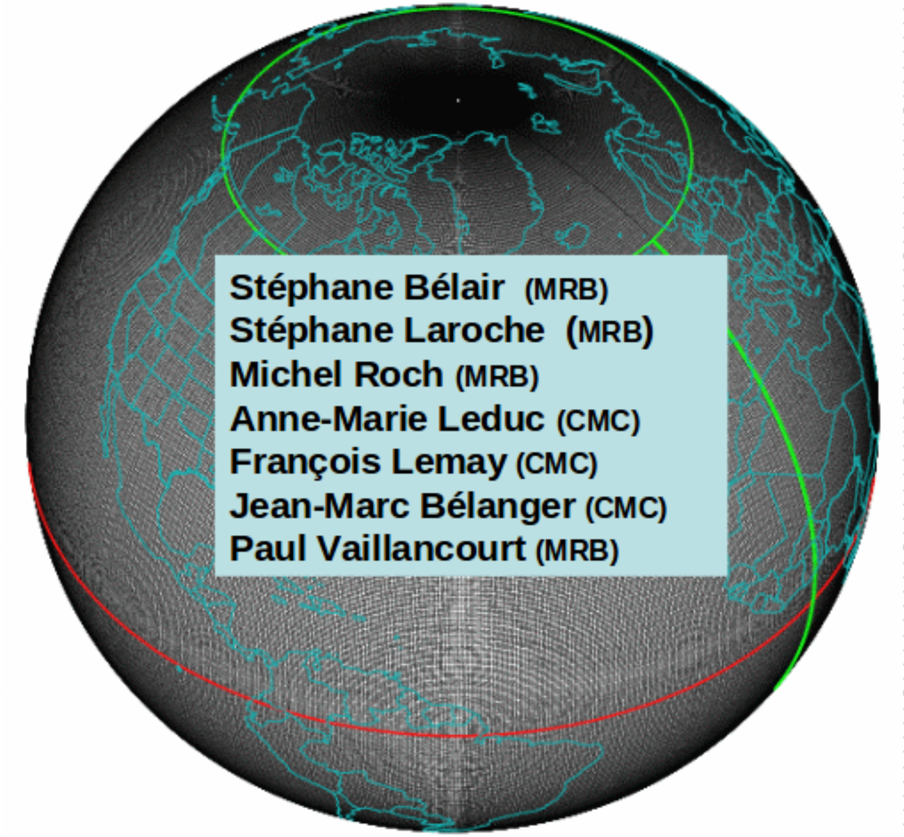


FIG. 18. Same as Fig. 17, but for 24–48-h precipitation.

Operational Implementation in EC's Global Prediction System (2006)

Global-Méso et son Impact sur la Prévision Moyenne-Échéance au Canada



Main Features of Global-Meso

- **Increased horizontal and vertical resolution**
  - *800x600x58L (33 km) compared to 400x200x28L (100 km)*
- **Numerical poles at geographic locations**
- **Representation of clouds and precipitation**
  - *Shallow convection with Kuo Transient*
  - *Deep convection with Kain-Fritsch*
  - *Modified Sundqvist scheme for grid-scale condensation*
- **Bougeault-Lacarrère for the turbulent mixing length**
- **Constant thermodynamic roughness length over water in the Tropics**
- **ISBA land surface scheme with sequential assimilation of soil moisture (based on OI)**

Environment Canada

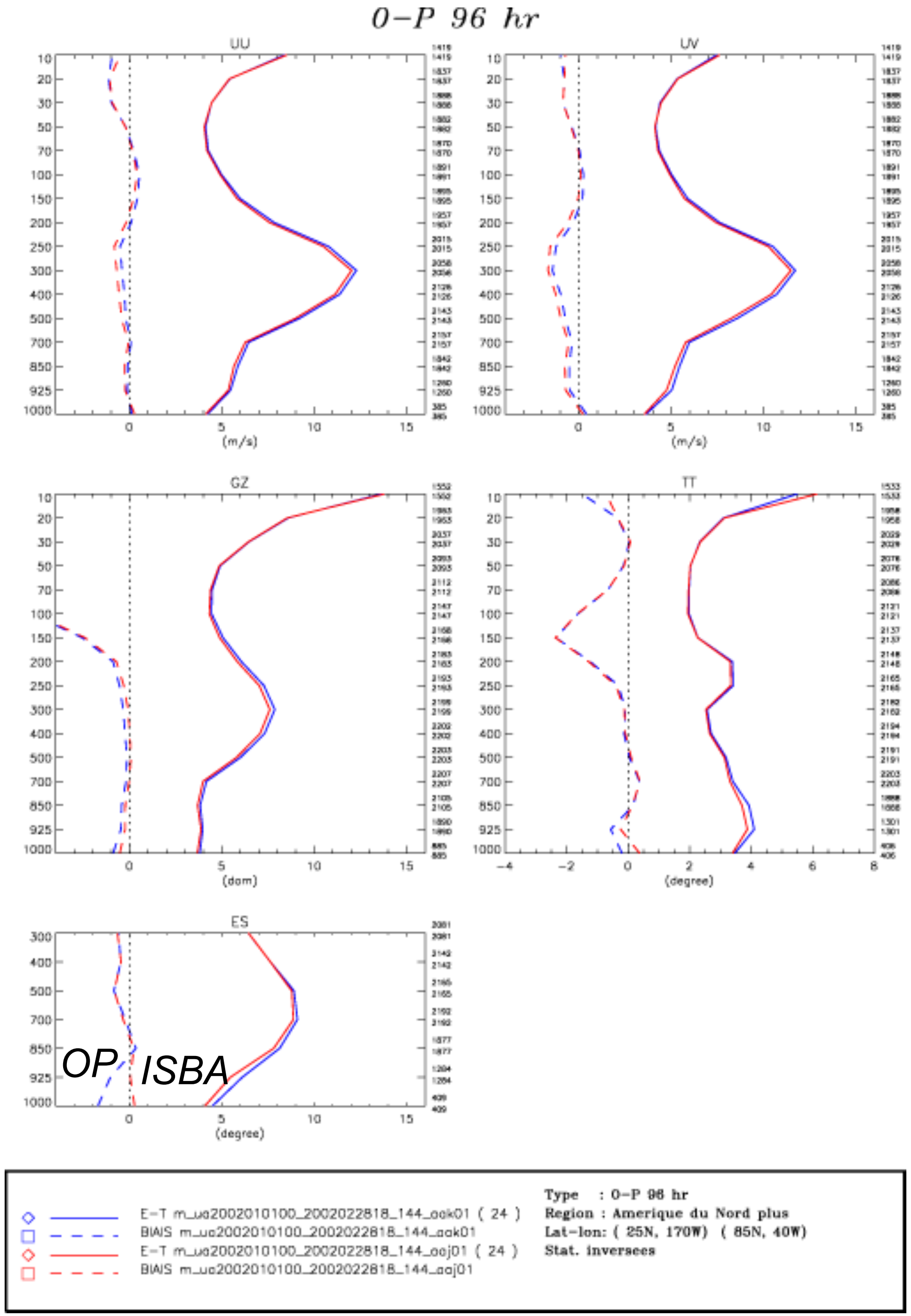
Operational Implementation in EC's Global Prediction System (2006)

Impact of ISBA + sequential OI analysis on medium-range forecasts

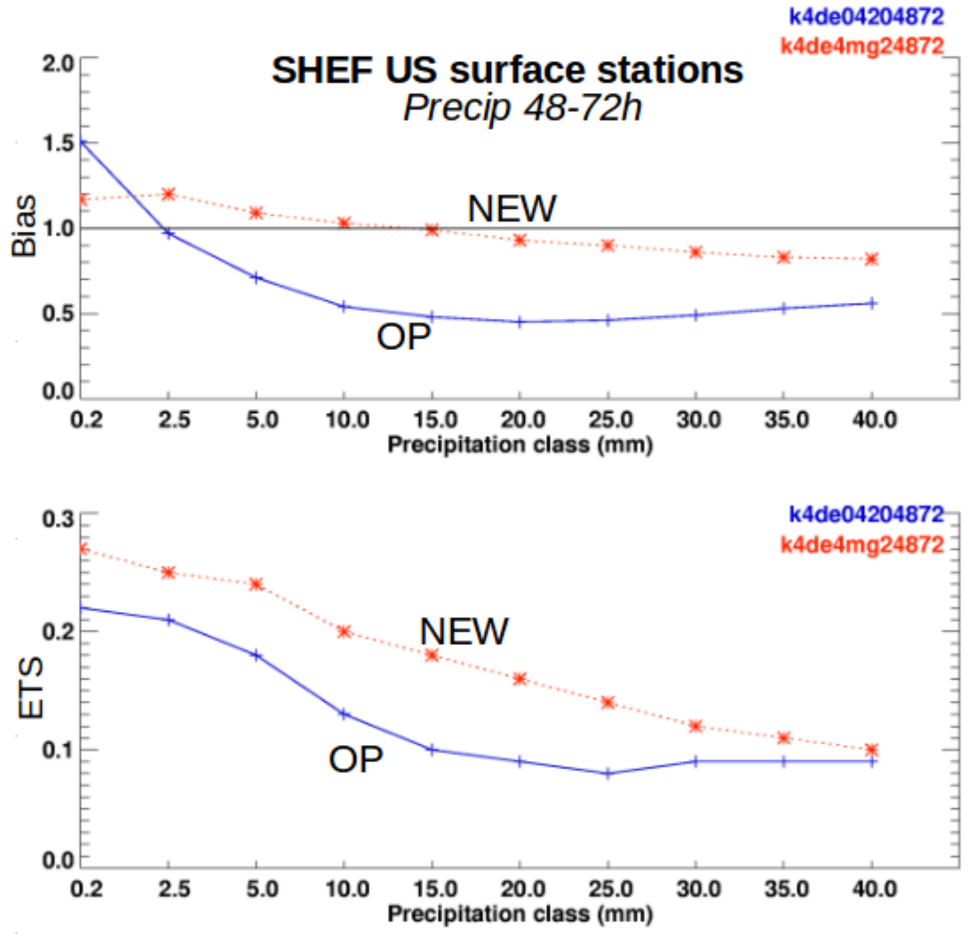
Upper-air evaluation for temperature

North America

Control in blue, ISBA in red



Operational Implementation in EC's Global Prediction System (2006)



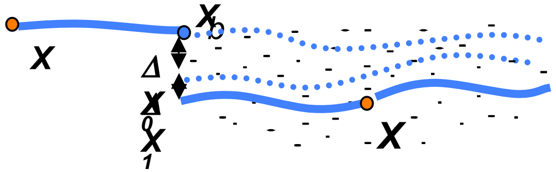
55 summer 2004 cases

Impact entire GLOBAL MESO on precipitation…

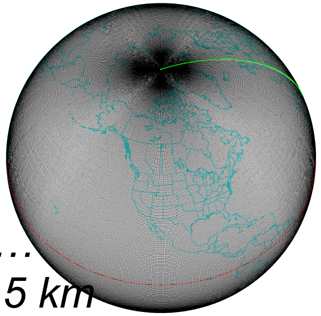
A substantial portion of the improvement comes from ISBA + sequential analysis (but could not find the results / evidence that was showing that point...)

Control in blue, GLOBA-MESO in red

ISBA now operational in all of ECCC's NWP systems



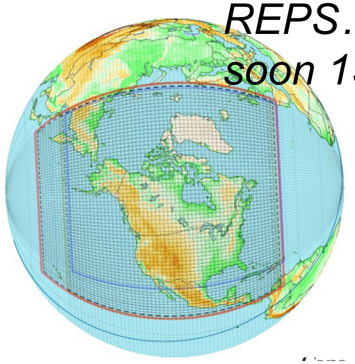
Monthly and seasonal
1 and 4 months
GEPS and
CanSIPS



GEPS
50km / 15 days
(soon 39 km)

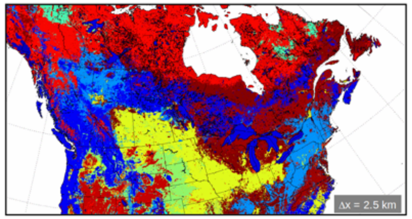
RDPS
10km / 48h

REPS… soon 15 km



GDPS
25km / 240h
(soon 15 km)

HRDPS
2.5km / 48h



"HR" = high resolution
"R" = regional
"G" = global

"D" = Deterministic
"E" = Ensemble

"PS" = Prediction System

Horizontal scale

Time scale

The SVS Scheme…

Multiple energy and water budgets (new subgrid-scale tiling)

Multi-layer model for soil moisture

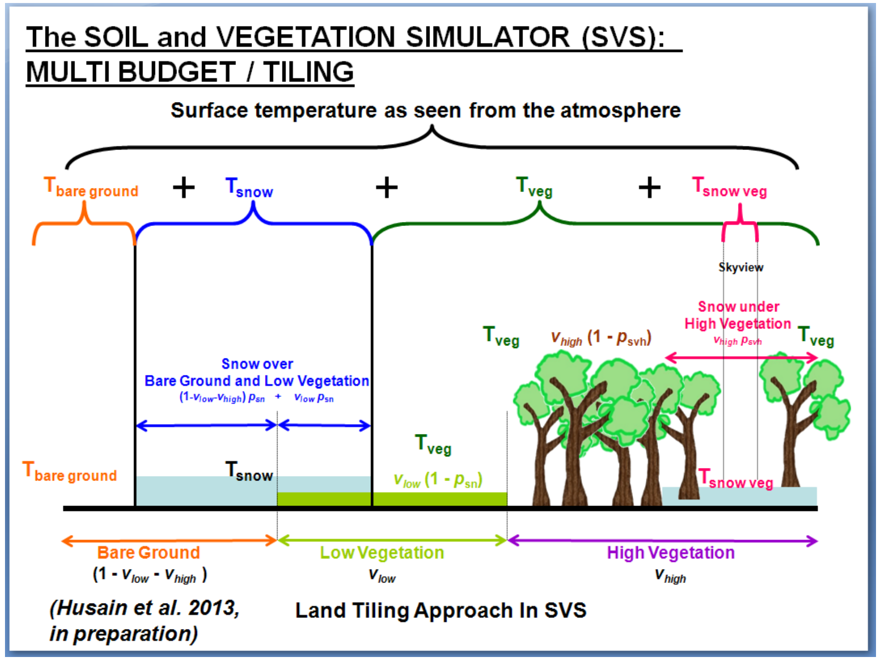
New snow pack under the vegetation

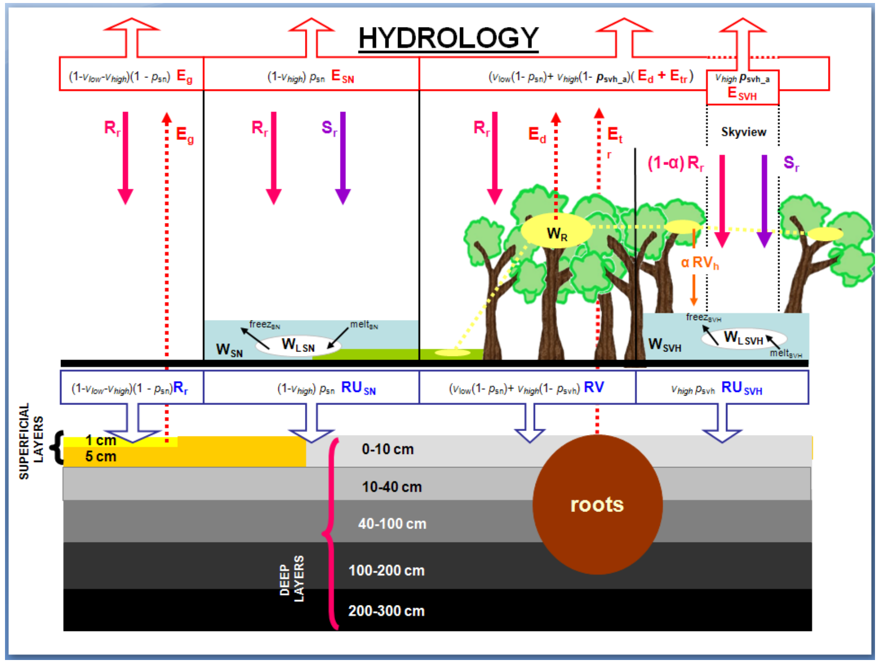
Root density function depending on vegetation type

Changes to vegetation thermal coefficient, albedo, and emissivity

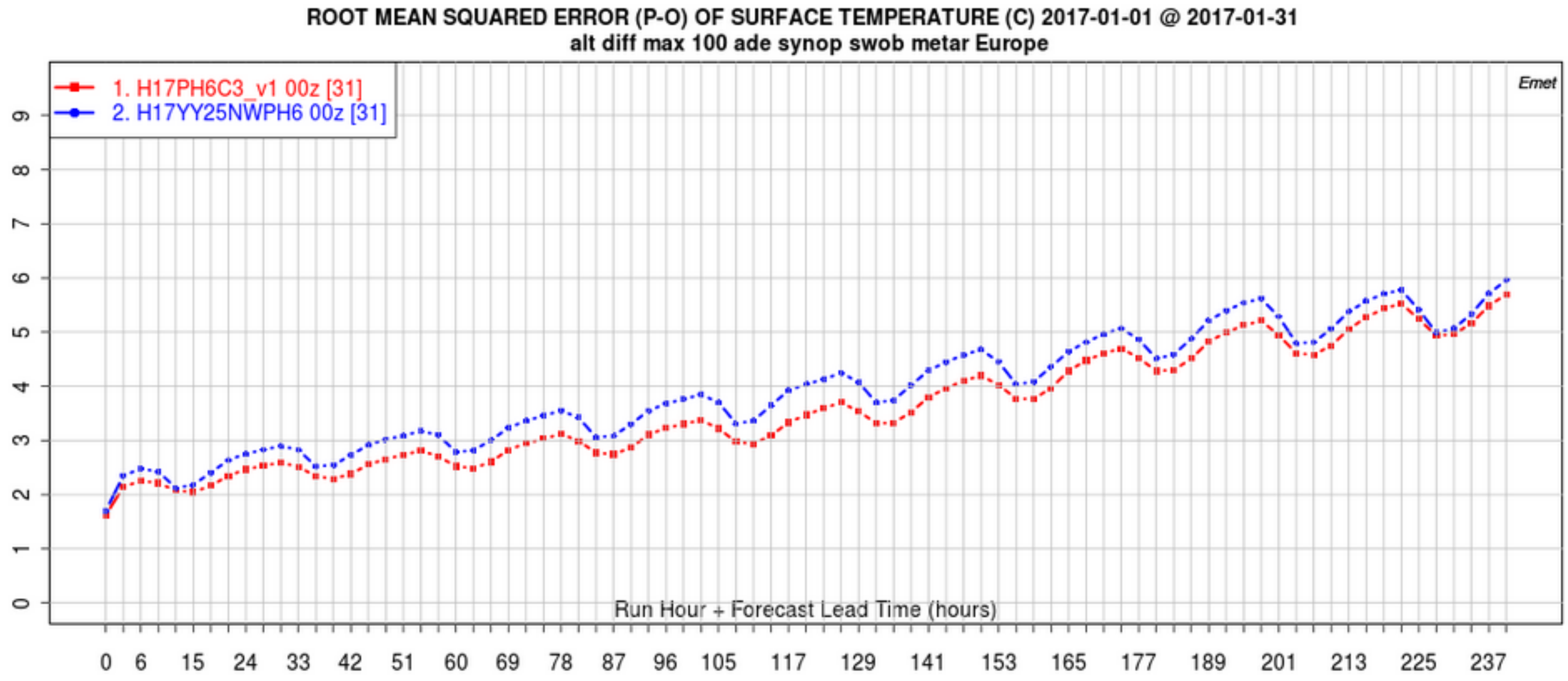
Stomatal resistance from photosynthesis scheme

Still a single canopy layer scheme





Impact of SVS, initialized by CaLDAS (screen)



RMSE for air temperature
Winter, Europe

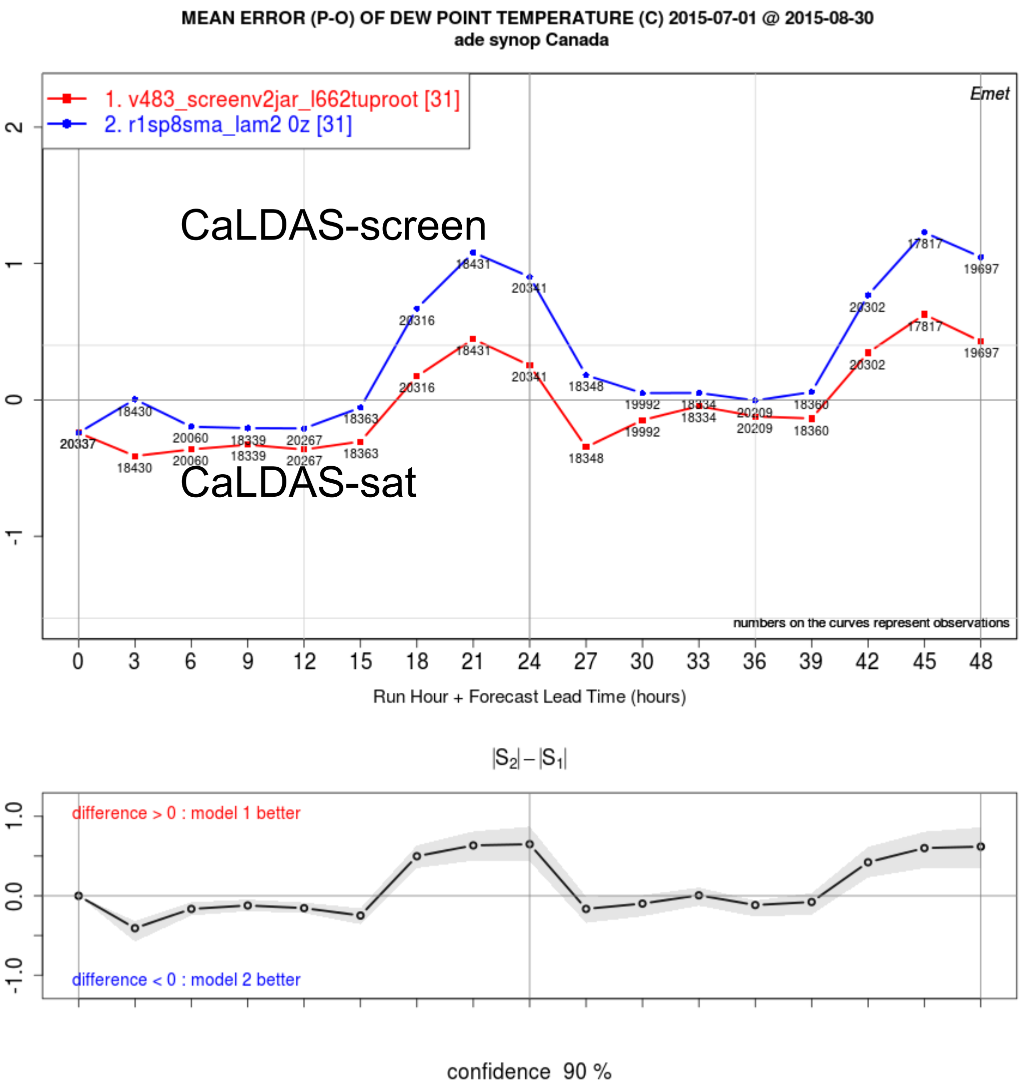
Impact of SVS, initialized by CaLDAS (sat)

BIAS

Dew point temperature

Canada

Summer



The land surface… increasingly popular...

Land data assimilation… satellite observations for soil moisture, surface temperature, ground snow, vegetation, photosynthesis…

Modelling… balance to achieve for several applications (NWP, agriculture, forests service, hydrology, and others)

Integration as part of environmental prediction suites

Coupling with atmosphere still a challenge, i.e., good surface not always equal with good atmosphere

… and many more subjects (including calibration)

My gratitude to Joel, and to everyone at Meteo-France for the long-lasting and fruitful collaborations

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A Simple Parameterization of Land Surface Processes for Meteorological Models

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(Manuscript received 19 April 1988, in final form 1 September 1988)

ABSTRACT

A parameterization of land surface processes to be included in mesoscale and large-scale meteorological models is presented. The number of parameters has been reduced as much as possible, while attempting to preserve the representation of the physics which controls the energy and water budgets. We distinguish two main classes of parameters. The spatial distribution of primary parameters, i.e., the dominant types of soil and vegetation within each grid cell, can be specified from existing global datasets. The secondary parameters, describing the physical properties of each type of soil and vegetation, can be inferred from measurements or derived from numerical experiments. A single surface temperature is used to represent the surface energy balance of the land/cover system. The soil heat flux is linearly interpolated between its value over bare ground and a value of zero for complete shielding by the vegetation. The ground surface moisture equation includes the effect of gravity and the thermo–hydric coefficients of the equations have been either calculated or calibrated using textural dependent formulations. The calibration has been made using the results of a detailed soil model forced by prescribed atmospheric mean conditions. The results show that the coefficients of the surface soil moisture equation are greatly dependent upon the textural class of the soil, as well as upon its moisture content. The new scheme has been included in a one-dimensional model which allows a complete interaction between the surface and the atmosphere. Several simulations have been performed using data collected during HAPEX-MOBILHY. These first results show the ability of the parameterization to reproduce the components of the surface energy balance over a wide variety of surface conditions.