A prototype of the Canadian Land Data Assimilation System and its application to soil moisture analysis.

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Abstract

The Canadian Land Data Assimilation System (CaLDAS) combines land surface modelling capabilities with optimal estimation data assimilation techniques to provide a reliable land surface analysis as initial condition in weather and climate prediction at the Meteorological Service of Canada (MSC). A first application of CaLDAS focused on soil moisture since it can strongly affect atmospheric low level temperature and humidity via the partitioning of latent and sensible heat fluxes at the surface. The assimilation of different sources of data is investigated for the production of a daily soil moisture analysis, with the aid of Observing System Simulated Experiments (OSSEs). In the CaLDAS OSSEs we consider the assimilation of ground-based observations (SYNOP temperature and humidity), current available satellite observations (AQUA and GOES satellites), and observations provided in the future (by SMOS and Hydros satellites). A prototype of CaLDAS is described and perspectives of implementation at MSC are briefly discussed.

The land surface modelling

The parameterization schemes in CaLDAS can be separated into three main components: (1) the land surface scheme (ISBA, Noilhan and Planton, 1989, Noilhan and Mahfouf, 1996) which simulates the evolution of the land surface state, (2) the atmospheric driver which provides the necessary forcing at the surface (i.e. precipitation, radiation, etc.), and (3) the observation operator (i.e. a radiative transfer model) which simulates a given observable (i.e. a brightness temperature) informative on the variable to be initialized (i.e. soil moisture). The first two components of the system are part of the operational code at MSC, while the observation operator has been implemented for both infrared and microwave frequencies. A microwave radiative transfer model (LSMEM, Drusch et al. 2001) is used to simulate land microwave emission, while for infra-red a uniform emissivity approximation is used to calculate a surface skin temperature in clear-sky conditions. In the so-called "off-line" implementation of CaLDAS, the atmospheric forcing is provided to the MEC model, a simplified version of GEM (Côté et al., 1998) where only the land surface and the atmospheric surface boundary layer (Delage, 1997) parameterizations are activated. In the "atmospheric coupled" mode the GEM model itself is used to provide the sensitivities to soil moisture, and it accounts for the components (1) and (2) previously listed.

The data assimilation scheme

The data assimilation scheme for the land surface follows the formulation of Mahfouf (1991) generalized to different observations in Balsamo et al. (2004). A daily soil moisture analysis is performed using a simplified variational scheme where the observation operator is estimated from finite differences. The assimilation system considers a set of indirect observations which are informative on soil moisture and available in a 24-hour time-window. A linear estimate of the observation operator is calculated as sensitivity of the generic observable Y to the initial perturbation of soil moisture $(\Delta Y(t=t_i)/\Delta W_p(t=t_0))$, according to the perturbation method described in Balsamo et al. (2004,b) for the following observations: the microwave brightness temperatures at L-band (1.4 GHz), $T_{b,H}(L)$ and $T_{b,V}(L)$ (horizontal and vertical polarizations) and C-band (6.9 GHz), $T_{b,H}(C)$ and $T_{b,V}(C)$, the clear-sky infra-red skin temperature $T_s(IR)$, and the screen-level temperature T_{2m} and humidity Q_{2m}. A simulation of satellites overpasses according to the specified orbital parameters allows to account for a realistic temporal and spatial availability of the observations.

Results over North America

A set of Observing System Simulated Experiments is performed over North America in order to assess the impact of the different observations types. The two implementations of CaLDAS (MEC "off-line" and

GEM "atmospheric coupled") are applied over a case study selected for the 5th July 2004. A complete set of simulated observations are assimilated to correct a prescribed initial soil moisture error. In Figure 1 is shown the gain matrix element used to assimilate microwave L-band observations (at 12 UTC) as observed in the future by Hydros satellite (Entekhabi et al., 2004). The main structures of the gain

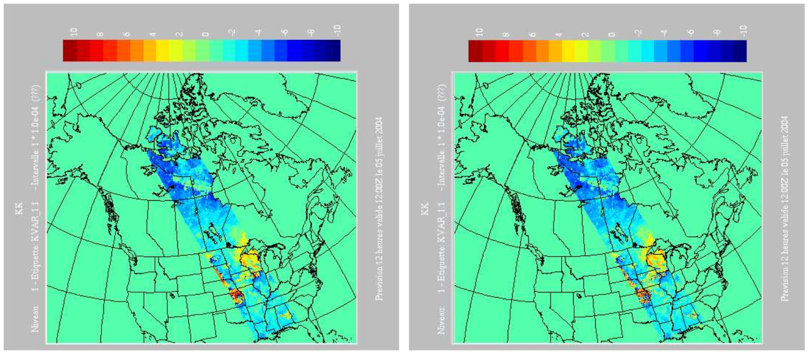

Figure 1: Gain matrix element $(\Delta T_b^H(L)/\Delta W_p[K \cdot m^3 m^{-3}])$ for Hydros L-band simulated observation on the 5th July 2004 at 12 UTC: Off-line (*left*) vs. atmospheric coupled (*right*) estimates.

matrix element for assimilating the L-band brightness temperature are preserved and comparable in both implementations. An objective validation of this equivalence for each observation source considered is obtained applying the information content diagnostics (Cardinali et al., 2004), which confirms a similar observation "weight" given by the analysis as shown in Figure 2.

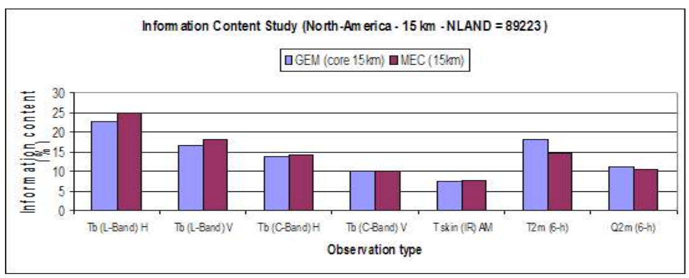

Figure 2: Information content study over CaLDAS North American domain: GEM (*left*) vs. MEC (*right*).

Conclusions and Perspectives

A first prototype of the CaLDAS system is being tested for the analysis of soil moisture via the simplified variational assimilation of different observations types. The equivalence of "off-line" and "atmospheric coupled" approaches introduces the possibility to use a separate land surface modelling system, while preserving the consistency with the operational land surface state. The off-line setup of CaLDAS has a considerable advantage of a drastically reduced computational cost, allowing for the investigation of a more complex data assimilation scheme (i.e. Ensemble Kalman Filter), land surface scheme (i.e. multi-layer/multi-budget schemes) and the extension of the analysis to other relevant land surface variables (i.e. snow and vegetation). A first implementation of the system will consider, in the near future, the available screen-level observations both at synoptic and asynoptic hours.

References

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