THE ECMWF SURFACE ANALYSIS:
USE OF ACTIVE AND PASSIVE MICROWAVE DATA FOR SOIL MOISTURE ANALYSIS

P. de Rosnay, G. Balsamo, M. Drusch, K. Scipal, J. Muñoz Sabater

ECMWF, Shinfield Park, RG2 9AX, Reading, UK

1. INTRODUCTION

This paper presents the European Centre for Medium-Range Weather Forecasts (ECMWF) soil moisture (SM) analysis system and its recent developments which enables the assimilation of active and passive microwave data. The current operational SM analysis used in the Integrated Forecast System (IFS), is based on an Optimal Interpolation (OI) scheme using proxy observations (2 m air temperature and relative humidity). The new SM analysis scheme is based on a point-wise Extended-Kalman Filter (EKF) for the global land surface [1]. It will be operationally implemented for Numerical Weather Prediction (NWP) in 2009. The EKF system is presented and operational issues are addressed. The new EKF surface analysis system opens a range of further development possibilities, exploiting new satellite surface data and products, for initialization of the land surface in NWP. Results of active microwave data assimilation are presented, using ASCAT (Advanced SCATTerometer) [2]. Developments for passive microwave data assimilation are also presented in the context of the preparation of SMOS (Soil Moisture and Ocean Salinity) [3].

2. EKF IMPLEMENTATION

In order to optimally combine conventional observations with satellite measurements, an advanced surface data assimilation system has been implemented in the IFS. The core of the system is a simplified EKF, which is based on minimization of a cost function as in variational methods under a linear approximation. In addition the EKF accounts for the evolution of error covariances in time. The simulated SM in the top three layers is improved by minimizing the cost function optimally combining the information from model forecast of and observed parameters (T_{2m}, RH_{2m}, and/or satellite derived SM and/or brightness temperatures), and the observation vector $\mathbf{y}$. The solution for the analyzed state vector $\mathbf{x}$ at time t is:

$$\mathbf{x_a}^t = \mathbf{x_b}^t + \mathbf{K}\left(\mathbf{y}^t - \mathbf{H}\mathbf{x}_\mathbf{b}^\mathbf{t}\right) \tag{1}$$

with $\mathbf{H}$ the Jacobian of the observation operator and $\mathbf{K}$ the gain matrix. Subscripts a and b refer to the analysis and model background respectively. In the simplified approach used here, $\mathbf{H}$ is computed by finite difference, assuming a quasi-linear problem close to the background state. The Jacobians computation represents the main cost driver of the EKF system. For operational implementation a semi-coupled approach has been proposed to compute the Jacobians at a reduced cost [4]. It is implemented and presented here. Based on these developments, the EKF surface analysis will be implemented operationally at ECMWF end of 2009. In order to evaluate the new surface analysis scheme we set up two data assimilation experiments using the OI and the EKF surface analysis respectively. Both experiments use the screen-level parameters to correct the SM prognostic variables. In both experiments the observation errors are set to $\sigma_T = 2K$, $\sigma_{RH} = 10\%$. For the two experiments the background error covariance matrix $\mathbf{B}$ is set constant with $\sigma_B = 0.01m^3m^{-3}$. Figure 1 illustrates the gain matrix coefficients obtained for the OI and the EKF.

3. ACTIVE AND PASSIVE MICROWAVE

In parallel to the EKF development and implementation, our investigation has been focused on the development and validation of observation operators for both active and passive microwave soil moisture and brightness temperature data. The observation operators are of highest importance to account for satellite data in the EKF soil moisture analysis.

Active microwave scatterometer observations contain valuable information about surface soil moisture. Results of ASCAT soil moisture data assimilation in the IFS are presented.

Passive microwave remote sensing is also a very promising approach for the global monitoring of surface soil moisture. C-band

AMSR-E and L-band SMOS brightness temperatures data will be monitored and assimilated in ECMWF's global NWP system to quantify the impact of this new observation type on the forecast quality. To this end the Community Microwave Emission Model (CMEM) has been developed at ECMWF as the forward operator for low-frequency passive microwave brightness temperatures at 1 to 20 GHz [5, 6]. CMEM has been calibrated and validated based on different observation systems (Skylab, SMOSREX, AMSR-E) deployed at different times and locations capturing processes at various scales. Key parameterizations have been identified and passive microwave bias correction has been investigated (Muñoz Sabater et al., IGARSS 2009). By implementing CMEM in the IFS we will enable monitoring of SMOS observations from shortly after its launch. SMOS data monitoring and assimilation implementation is presented.

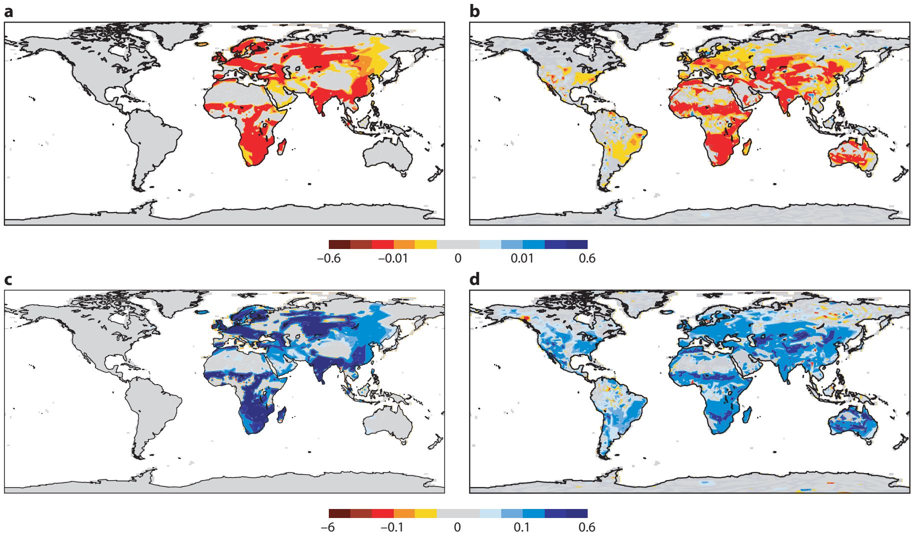

Fig. 1. Gain matrix coefficients for the OI (left) and for the EKF (right) surface analyses, using screen level parameters. They represent the soil moisture increment with respect to the 2m air temperature in innovation (top, in m^3m^{-3}/K) and the soil moisture increment with respect to the 2m air humidity innovation (bottom, in m^3m^{-3}).

4. REFERENCES

[1] M. Drusch, K. Scipal, P. de Rosnay, G. Balsamo, E. Andersson, P. Bougeault, and P. Viterbo, "Towards a Kalman filter based soil moisture analysis system for the operational ECMWF Integrated Forecast System," *Geophy. Res. Letters*, 2008, submitted.

[2] K. Scipal, M. Drusch, and W. Wagner, "Assimilation of a ers scatterometer derived soil moisture index in the ecmwf numerical weather prediction system," *Advances in Water Resources*, 2008, doi: 10.1016/j.advwatres.2008.04.013.

[3] Y. H. Kerr, P. Waldteufel, J.-P. Wigneron, J.-M. Martinuzzi, J. Font, and M. Berger, "Soil moisture retrieval from space: The soil moisture and ocean salinity (smos) mission," *IEEE Trans. Geosc. Remote Sens.*, vol. 39 (8), pp. 1729–1735, 2001.

[4] G. Balsamo, J.-F. Mahfouf, S. Bélair, and G. Deblonde, "A land data assimilation system for soil moisture and temperature: An information content study," *J. Hydrometeo*, vol. 8, pp. 1225–1242, 2007, doi: 10.1175/2007JHM819.1.

[5] M. Drusch, T. Holmes, P. de Rosnay, and G. Balsamo, "Comparing ERA-40 based L-band brightness temperatures with Skylab observations: A calibration / validation study using the Community Microwave Emission Model," *J. Hydrometeo*, 2008, in press, doi: 10.1175/2008JHM964.1.

[6] P. de Rosnay, M. Drusch, A. Boone, G. Balsamo, B. Decharme, P. Harris, Y. Kerr, T. Pellarin, J. Polcher, and J.-P. Wigneron, "Microwave Land Surface modelling evaluation against AMSR-E data over West Africa. The AMMA Land Surface Model Intercomparison Experiment coupled to the Community Microwave Emission Model (ALMIP-MEM)," *J. Geophys. Res*, 2008, in revision.