ECMWF background errors on L-band brightness temperatures over the SMOSREX field experiment

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ECMWF background errors on L-band brightness temperatures over the SMOSREX field experiment. Convergence between CMEM and LMEB models

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1 Introduction

SMOS Brightness Temperatures (TB) will be used at the European Centre for Medium-Range Weather Forecasts (ECMWF) to analyse soil moisture through the Surface Data Assimilation System (SDAS). This is expected to improve the accuracy of initial conditions of the Numerical Weather Prediction (NWP) model.
The Community Microwave Emission Model (CMEM) has been developed at ECMWF for forward modelling of low frequency passive microwave emission (from 1 GHz to 20 GHz) of the surface [6, 2].

2 CMEM model

- Land surface emission model for Numerical Weather Prediction (NWP) application
- To be used as the forward operator computing TOA Brightness Temperature in the operational data assimilation scheme
  ⇒ NWP model interface
- Conceptually based on:
  - LMEB (L-Band Emission of the Biosphere) [8]
  - LSMEM (Land Surface Microwave Emission Model [3]
- Specifically designed for L-band microwave emission for SMOS
- Also applicable for a large range of Frequency: 1 GHz to 20 GHz
  ⇒ Suitable at higher frequency for RTTOV

CMEM Modular Model:

- Soil dielectric mixing model
  (Wang & Schmugge Dobson Mironov)
- Effective temperature model
  (Choudhurry Wigneron Holmes)
- Soil roughness model
  (None = Smooth Choudhurry Wegmüller Wigneron a or b or c)
- Smooth surface emissivity model
  (Fresnel Wilheit)
- Vegetation opacity model
  (None Kirdyashev Wegmüller Wigneron)
- Atmospheric radiative transfer model
  (None Pellarin Liebe Ulaby)

CMEM Equivalent to LMEB when options in blue are chosen

3 CMEM-LMEB convergence

CMEM in the LMEB configuration (blue options above) and LMEB models must be convergent for any surface type.

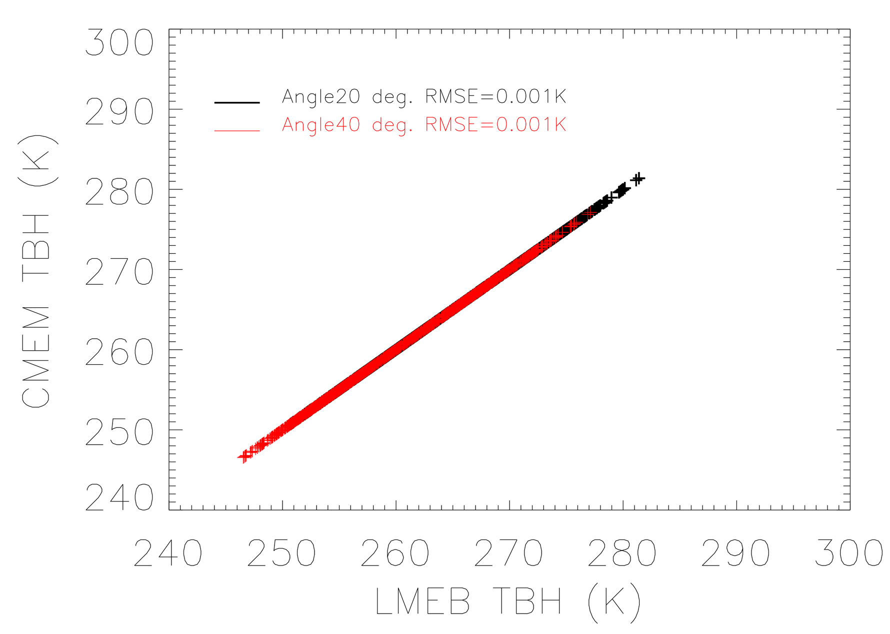
- Comparison for each tile between CMEM and LMEB.
- Aim: ensure that, when appropriate set of options is chosen, CMEM is in agreement with LMEB and SMOS retrieval algorithm.
- Model: CMEM and LMEB last Fortran 90 version from CNRM (convergent with Matlab LMEB of INRA-Bordeaux).
- Forcing: ECMWF operational product for soil moisture and atmospheric conditions on the SMOSREX pixel for 2004

Convergence tested over 9 types of surface: bare soil, water, c3 grass, c4 grass, c3 crops, c4 crops, deciduous forest, coniferous forest, tropical forest.

Convergence study has required an update of CMEM model for its τ-ω module for vegetation, and its Wigneron's parametrization module for soil roughness: account for vegetation dependency of vegetation and roughness parameters Nrh, Nrv, Hr, tth, ttv, ωh, ωv, τ_{nadir}, addition of an interception reservoir....

CMEM updated, ⇒ RMS difference between the models is very small (in the range of 0.01K to 0.001K) at any incidence angle for any vegetation type. The residual difference, still larger that computer accuracy, is due to input parameters and physical constant that are not truncated at the same number of decimal in the two models.

CMEM-LMEB convergence over forest:



CMEM is shown to be convergent to LMEB for corresponding choice of parametrization. ⇒ CMEM is able to be used in LMEB mode.

4 ECMWF First guess error on simulated L-band TB

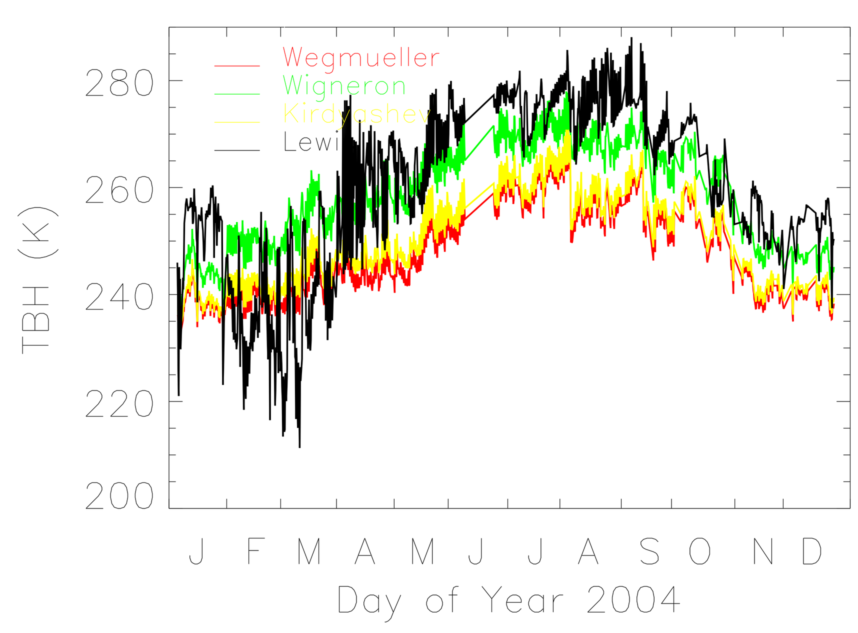
- Operational ECMWF conditions for 2004-2005, with TESSEL land surface model at T799 (25km) coupled to CMEM L-band forward operator on the SMOSREX (Surface Monitoring of Soil Reservoir Experiment) Pixel.
- ECOCLIMAP vegetation LAI
- First guess background error, as will be computed in the operational SMOS assimilation chaine.

SMOSREX [1]:

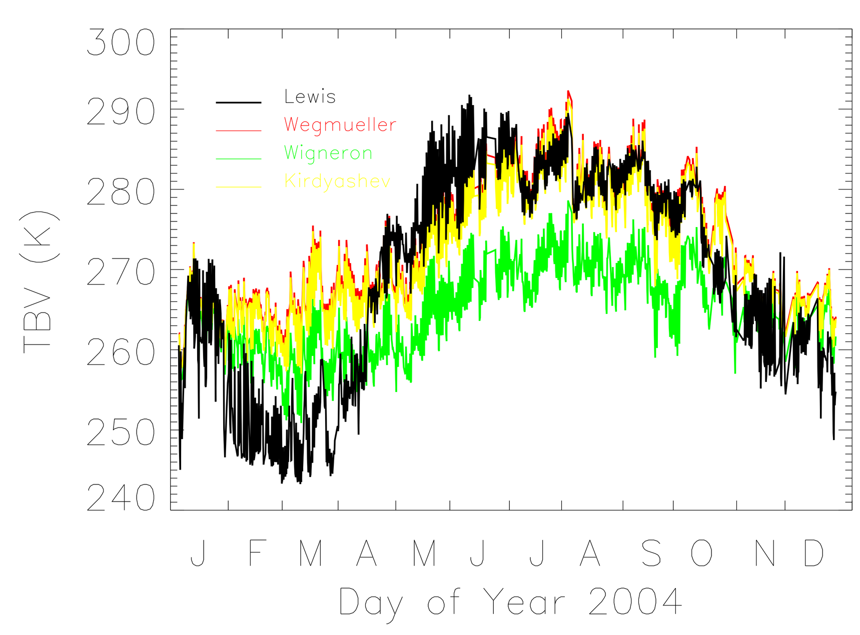
- Continuous data set of L-Band TBH and TBV for 2003-2008 (Lewis Data), with multi-angular scanning at 5 incidence angles: 20°, 30°, 40°, 50°, 60° every 3 hours
- Several studies for MW modelling and SMOS retrieval algorithm improvement: Effect of rainfall interception on L-band emission [7]; Soil roughness modelling [4]; Effective temperature parametrization [5]

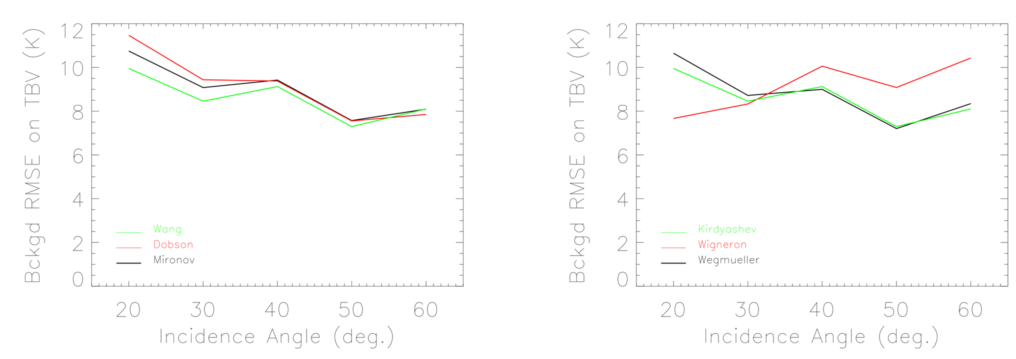
Temporal collocation of first guess TB and Lewis data at each incidence angle.
ECMWF First guess error is quantified for:
- Different modelling configurations of soil dielectric mixing model (Wang, Dobson, Mironov) and vegetation models (Wegmüller, Wigneron, Kirdyashev).
- Different observing configuration: 2 polarisations, 5 angles
For each configuration Background error is evaluated over the year 2004 against SMOSREX LEWIS TB (Bias, Correlation, RMSE, Efficiency).

Comparison between ECMWF and LEWIS TBH at 30°



Comparison between ECMWF and LEWIS TBV at 60°





Model	20°	30°	40°	50°	60°
Wegmüller	-9.1 / 10.6	-4.13 / 8.7	0.4 / 9.0	0.4 / 7.2	3.8 / 8.3
Wigneron	-5.0 / 7.7	-1.3 / 8.3	1.0 / 10.1	-2.6 / 9.1	-4.3 / 10.4
Kirdyashev	-8.3 / 10.0	-3.4 / 8.5	0.9 / 9.1	0.5 / 7.3	3.1 / 8.1

ECMWF background errors (bias / RMSE) over SMOSREX pixel with different vegetation model used in the forward operator (with Wang and Schmugge model used for dielectric constant).

Model	20°	30°	40°	50°	60°
Mironov	-9.1 / 10.7	-4.1 / 9.1	0.1 / 9.4	-0.3 / 7.6	2.6 / 8.1
Dobson	-10.0 / 11.5	-5.1 / 9.4	-0.7 / 9.4	-1.0 / 7.6	-1.9 / 7.9
Wang&Schmugge	-8.3 / 10.0	-3.4 / 8.5	0.9 / 9.1	0.5 / 7.3	3.1 / 8.1

ECMWF background errors (bias / RMSE) over SMOSREX pixel with different dielectric model used in the forward operator (with Kirdyashev model used for vegetation opacity).

- Best dielectric model at almost any incidence angle (except 60°) and for any indicator: Wang and Schmugge model.
- Best observing configuration strongly related to the vegetation model: 20° with Wigneron's model; 50° with Kirdyashev's model.
- Sensitivity of first guess error to vegetation model much larger than that to dielectric model
- Larger errors at horizontal polarisation (not shown) than at vertical polarisation.
  Errors due to:
  - ECMWF soil moisture error (overestimated in the model) - scaling difference between LEWIS measurements and ECMWF operational products - uncertainties in forward modelling.

New version of TESSEL (HTESSEL, Balsamo et al., 2007) is expected to reduce ECMWF soil moisture error and background temperature error.

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