ECMWF
Land Surface Data Assimilation System activities

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Land surface data assimilation

1999	2004	2010/2011

OI screen level analysis

Douville et al. (2000)

Mahfouf et al. (2000)

Soil moisture 1D OI analysis based on Temperature and relative humidity analysis

Revised snow analysis

Drusch et al. (2004)

Cressman snow depth analysis using SYNOP data improved by using NOAA / NSEDIS Snow cover extend data (24km)

Optimum Interpolation (OI) snow analysis

Pre-processing NESDIS data

High resolution NESDIS data (4km)

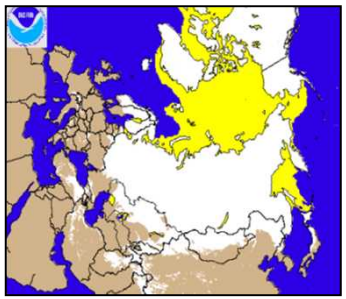
SEKF Soil Moisture analysis

Simplified Extended Kalman Filter

Drusch et al. GRL (2009)

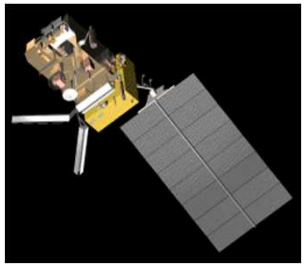
de Rosnay et al. (2011)

SYNOP Data



NOAA/NESDIS IMS

Use of satellite data



METOP-ASCAT

de Rosnay et al., 2011

SMOS

Sabater et al., 2011

Validation activities

Albergel et al. 2011

Outline

- **Snow analysis (Optimum Interpolation)**
- Soil Moisture analysis
  - Simplified Extended Kalman Filter analysis
  - Use of ASCAT data (active microwave)
  - Use of SMOS data (passive microwave):Joaquín Muñoz Sabater
  - Validation activities: Clément Albergel

ECMWF Surface analysis projects web pages:
http://www.ecmwf.int/research/ESA_projects/SMOS/index.html
http://www.ecmwf.int/research/EUMETSAT_projects/SAF/HSAF/

Snow Analysis

Snow Quantities:

- Snow depth SD (m)
- Snow water equivalent SWE (m) – ie mass per m^2
- Snow Density ρ_s, between 100 and 400 kg/m3

$$SWE = \frac{SD \times \rho_S}{1000} \quad [\mathrm{m}]$$

Background variable used in the snow analysis:

- Snow depth S^b

  computed from forecast SWE and density
  (Dutra et al., J Hydromet. 2009)

Observation types:

- Conventional data: **SYNOP snow depth** (S^O)
- Satellite: **Snow cover extent** (NOAA/NESDIS)

NOAA/NESDIS Snow extent data

Interactive Multisensor Snow and Ice Mapping System

- Time sequenced imagery from geostationary satellites
- AVHRR,
- SSM/I
- Station data

Northern Hemisphere product

- Daily
- Polar stereographic projection

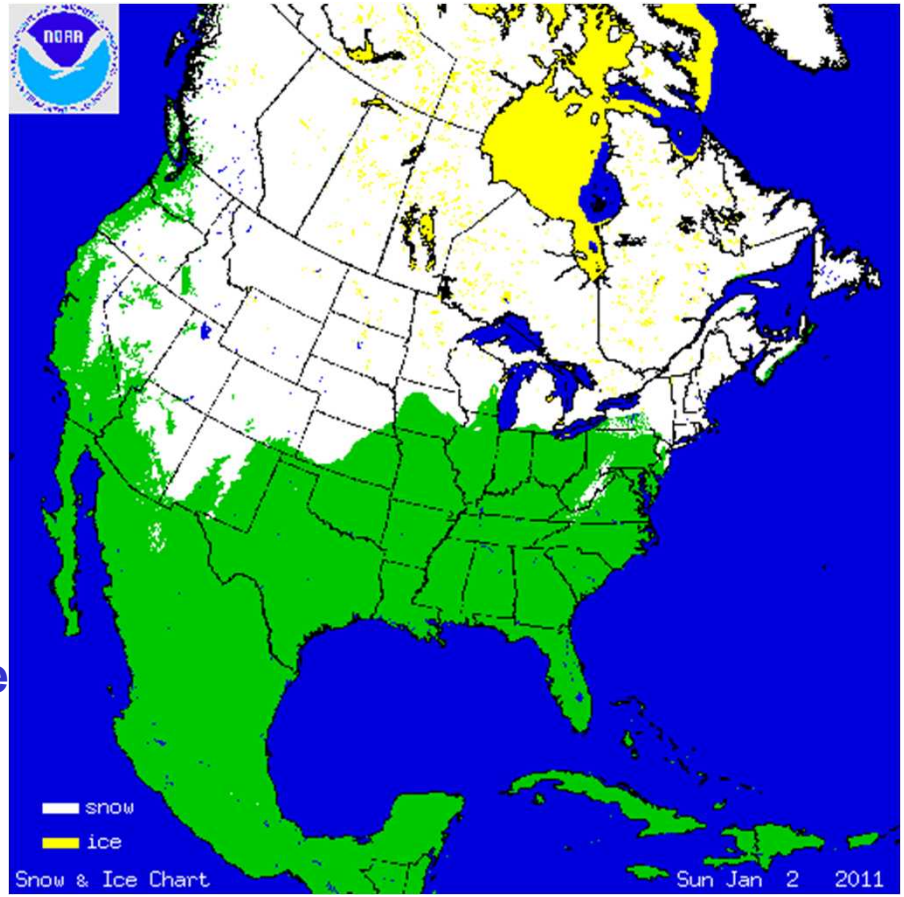
Resolution

- 24 km product (1024 × 1024)
- 4 km product (6044 x 6044)

Information content: Snow/Snow free

Format:

- 24km product in Grib
- 4 km product in Ascii



More information at: http://nsidc.org/data/g02156.html

Snow analysis recent improvements

- 1987-2010: Cressman Interpolation (1959) ; use of SYNOP

- 2004: Introduction of the use of NOAA/NESDIS data (resol. 24km)

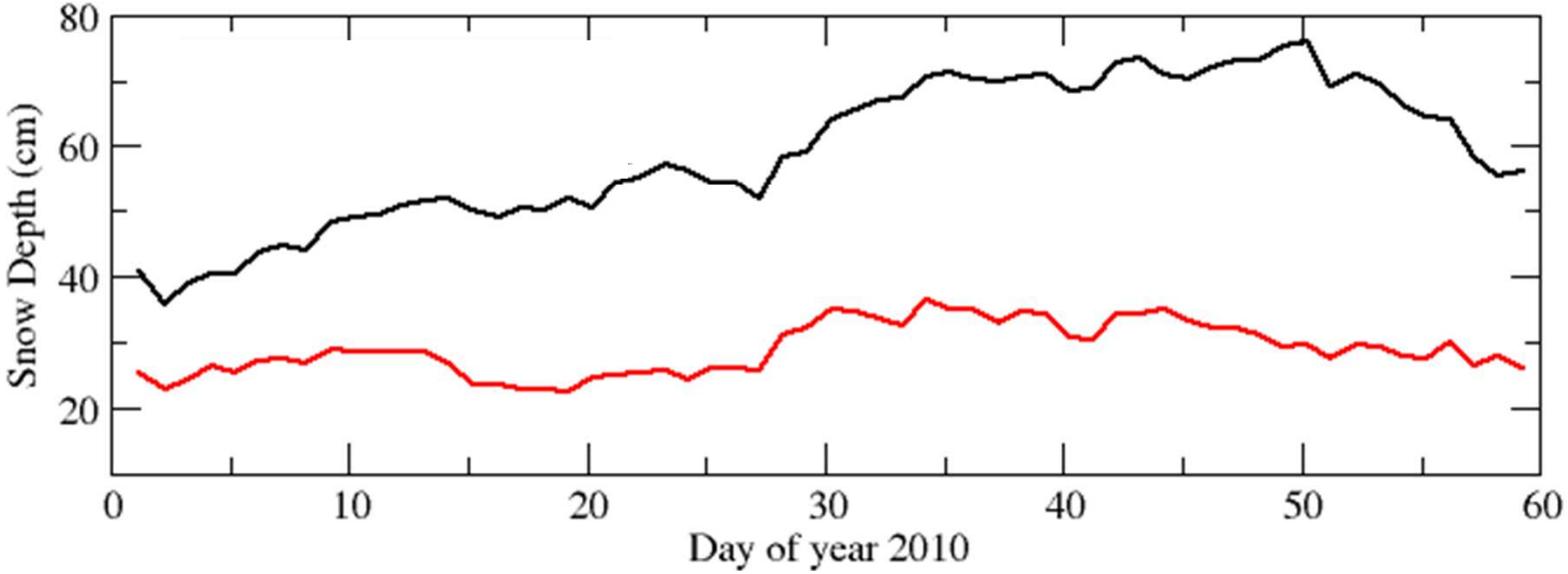
- 2010: revised snow analysis:

- **OI:** Optimum Interpolation Snow analysis, using weighting functions of Brasnett, J. Appl. Meteo. (1999). OI snow depth analysis (used at ECMWF, CMC, JMA) makes a better use of the model background than Cressman (used at DWD and still used at ECMWF in ERA-Interim).
- **NESDIS:** NOAA/NESDIS 4km ASCII snow cover product (substituting the 24 km GRIB product). The new NESDIS product is of better quality with better coverage in coastal areas.
- **QC:** Introduction of blacklist file and rejection statistics. Also allows easier identification of stations related to MS queries.

Comparison against SYNOP data

Old analysis (Cressman and NESDIS 24km)
New analysis (OI and NESDIS 4km)

RMSD between analysis and observations

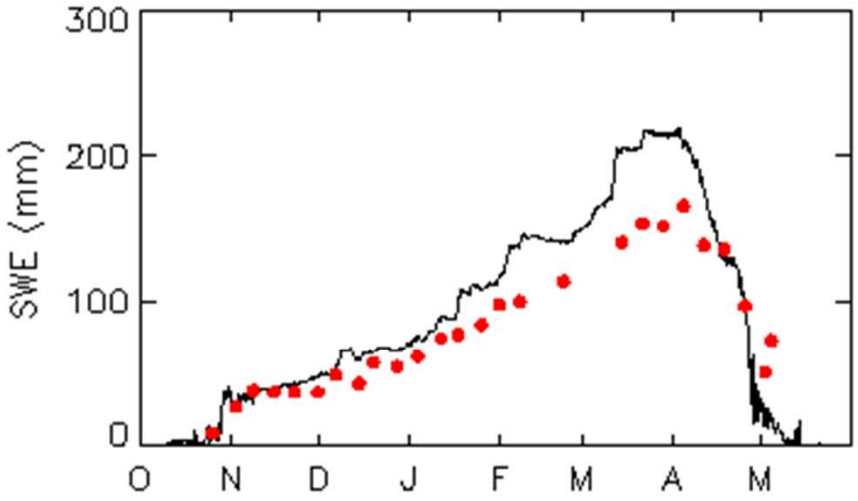


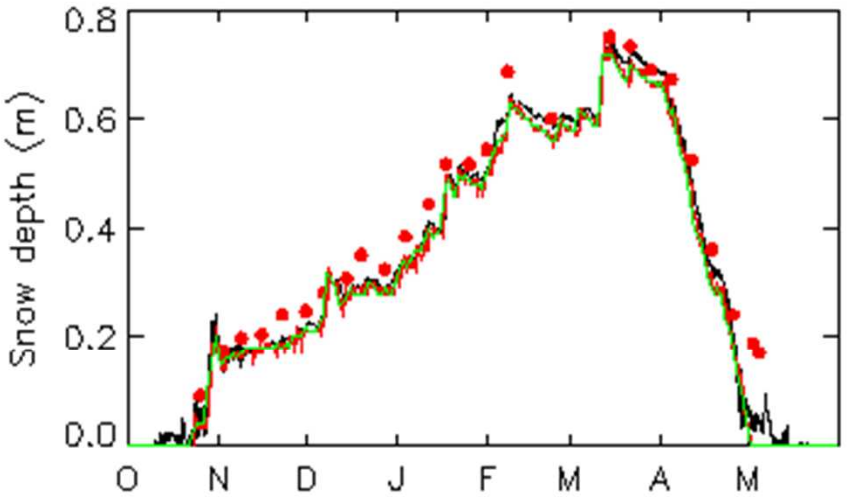
de Rosnay, Balsamo and Isaksen, IGARSS 2011

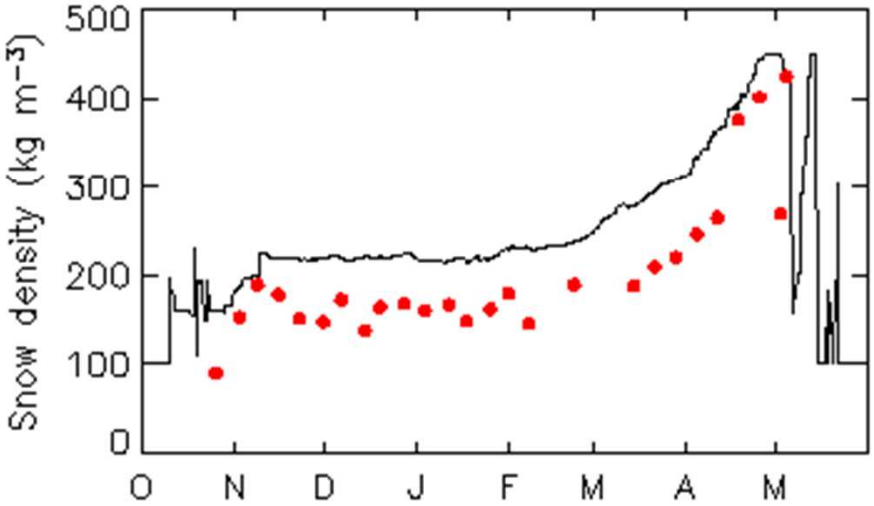
→ Much reduced analysis errors with the new snow analysis than with the old one

Independent validation

Sodankyla, Finland (67.368N, 26.633E) **Winter 2010-2011**







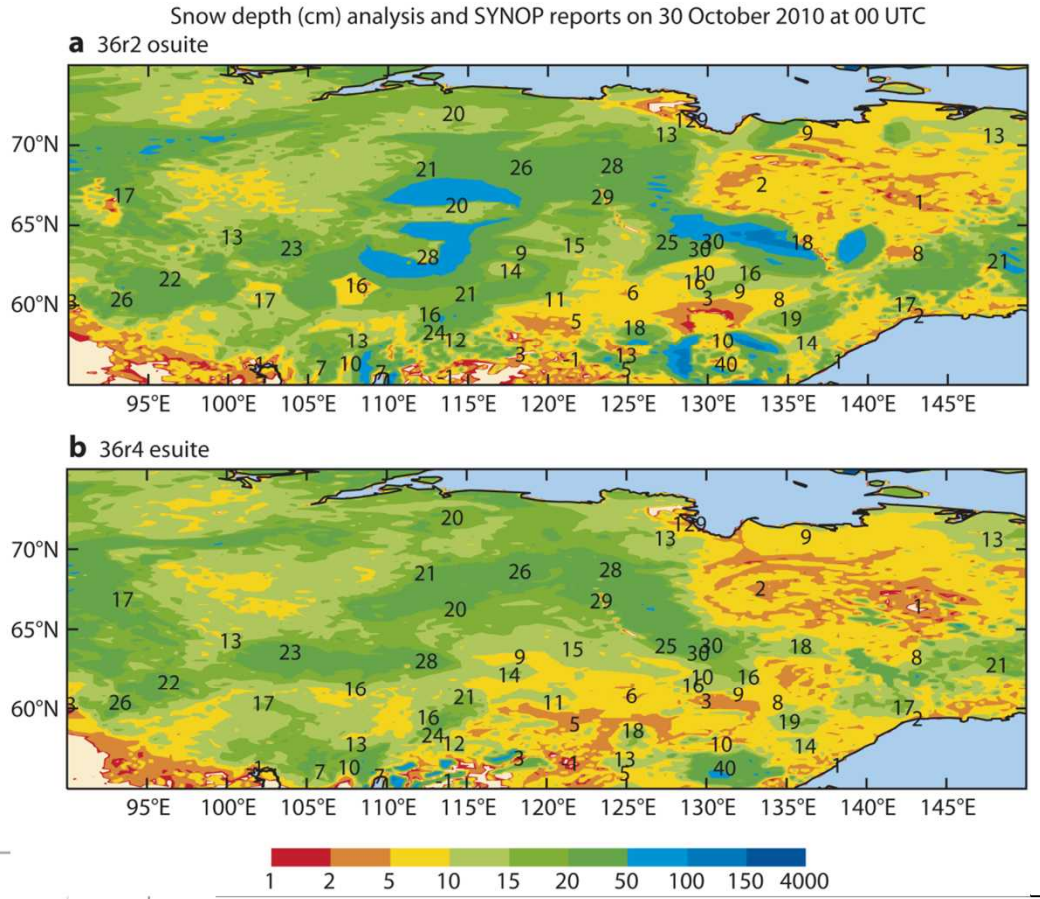
ECMWF deterministic analysis
SYNOP snow depths
FMI-ARC snow pit
and ultrasonic depth gauge

Figures produced by
R. Essery, Univ Edinburgh)

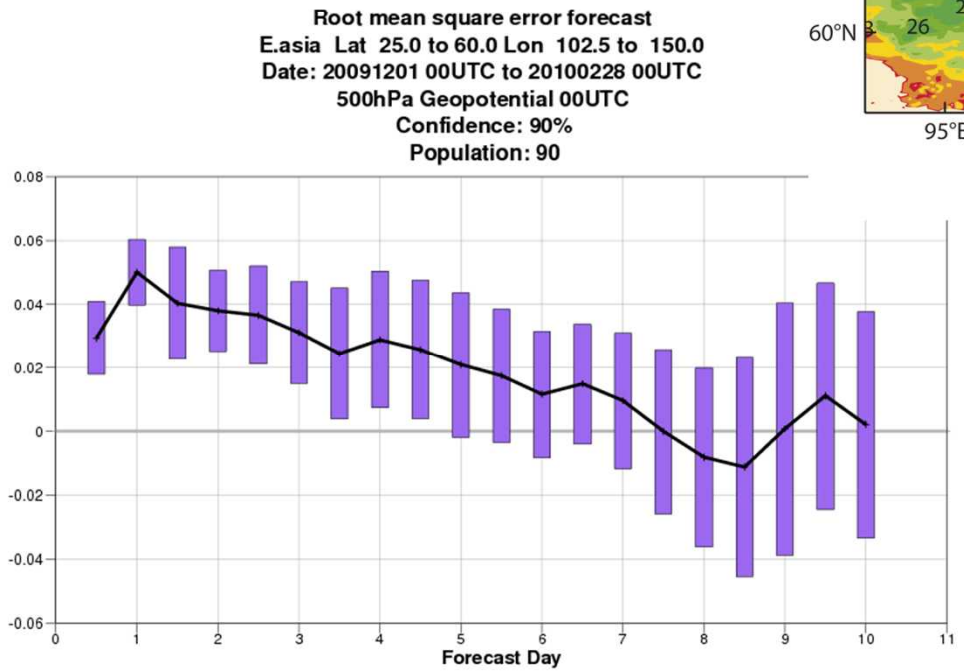
New snow Analysis in Operations

Old: Cressman
NESDIS 24km

New: OI
NESDIS 4km



FC impact (East Asia):



- OI has longer tails than Cressman and considers more observations.

- Model/observation information optimally weighted by an error statistics.

- Snow analysis
- **Soil Moisture analysis**
  - **Simplified Extended Kalman Filter analysis**
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Why an EKF soil moisture analysis ?

- Dynamical estimates of the Jacobian Matrix that quantify accurately the physical relationship between observations (eg T2m, Rh2m) and soil moisture
- Flexible to account for the land surface model H-TESSEL evolution
- Makes it possible to combine different sources of information
- Possible to investigate the use of new generation of satellite data:
    - SM active microwave (C-band ERS, MetOp/ASCAT, L-band SMAP)
    - SM passive microwave (L-band SMOS, SMAP)

SYNOP

ASCAT

SMOS

EKF soil moisture analysis

For each grid point, Analysed soil moisture state vector $\boldsymbol{\theta}_a$:

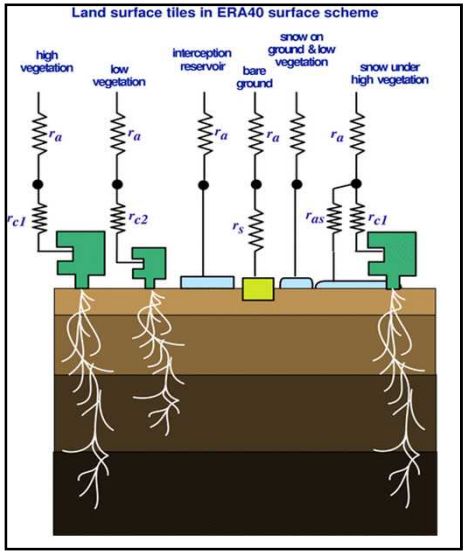
$$\boldsymbol{\theta}_a = \boldsymbol{\theta}_b + \boldsymbol{K}\,(\boldsymbol{y} - \mathcal{H}[\boldsymbol{\theta}_b])$$

$\boldsymbol{\theta}$ background soil moisture state vector,
$\mathcal{H}$ non linear observation operator
$\boldsymbol{y}$ observation vector
$\boldsymbol{K}$ Kalman gain matrix, fn of
H (linearsation of $\mathcal{H}$), **B** and **R** (covariance matrices of background and observation errors).

Observations:

- Used in operations:
  Conventional observations (T2m, RH2m)
- Used in Research:
  Satellite data related to soil moisture (e.g. ASCAT product, SMOS Brightness temperature).

EKF corrects the trajectory of the Land Surface Model

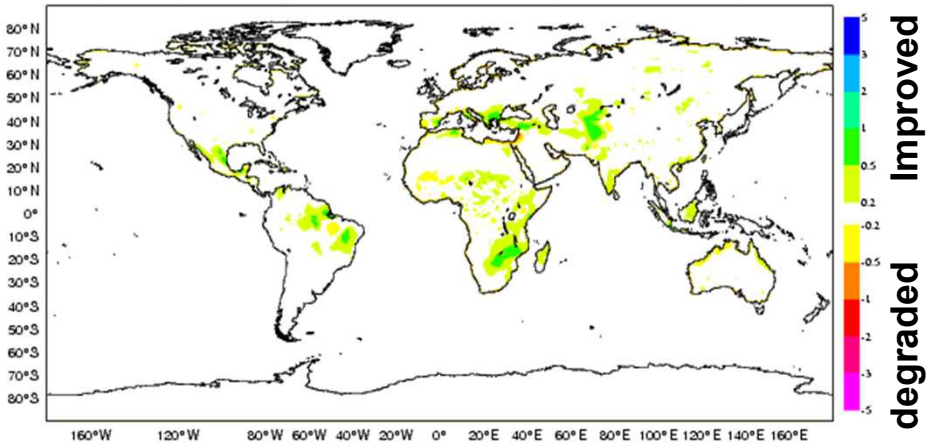


H-TESSEL (Balsamo et al., 2009, 2011)

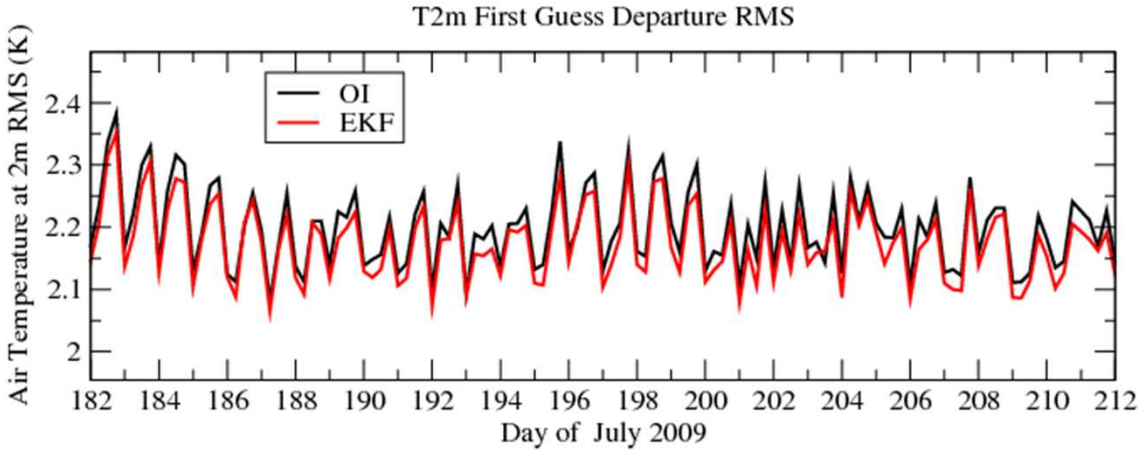
Impact on 2-meter Temperature

- EKF consistently improves SM & T2m
- EKF implemented in 2010 in operations
- Makes it possible to assimilate satellite data to analyse soil moisture

T2m error (OI-SEKF)
→ EKF improves T2m

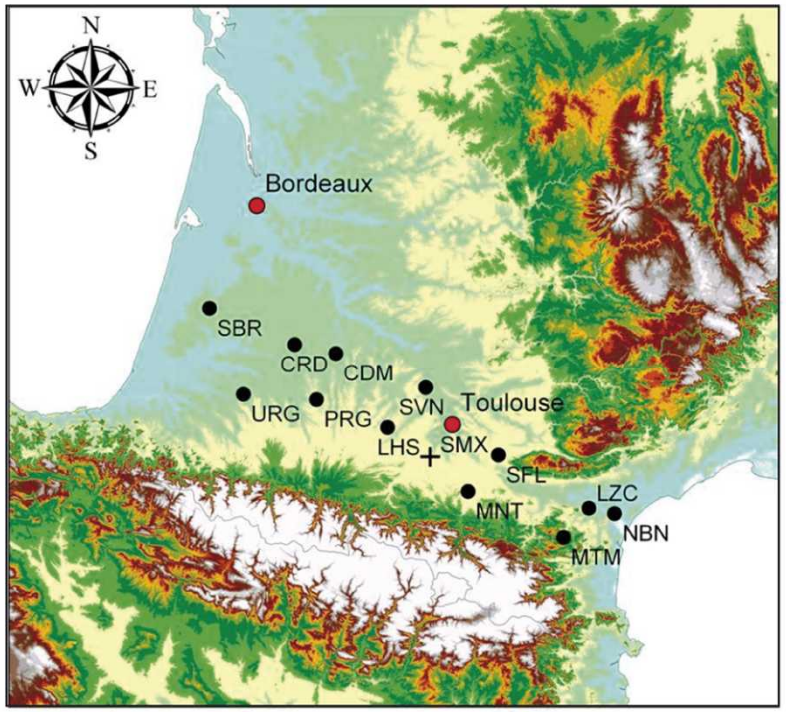


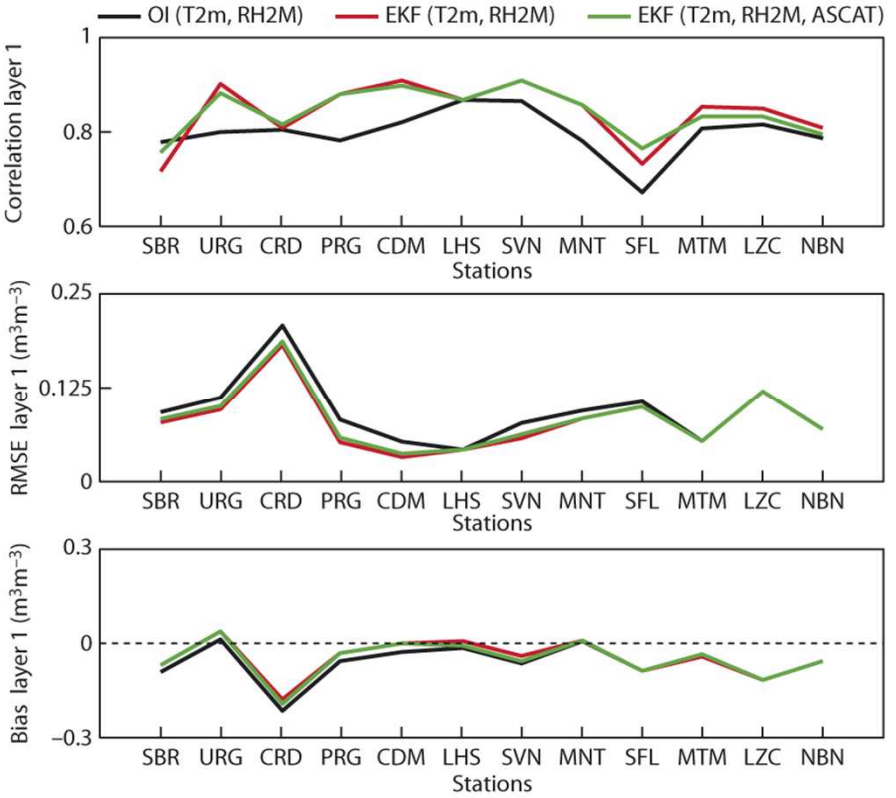
Global mean RMS (against SYNOP)



ECMWF Soil Moisture Analysis verification

Verification of ECMWF SM over the SMOSMANIA Network





→ **SEKF soil moisture improves soil moisture compared to the 1D OI**
→ **Also improves T2m**

Used in operations since November 2010

(de Rosnay et al., 2011)

- Snow analysis
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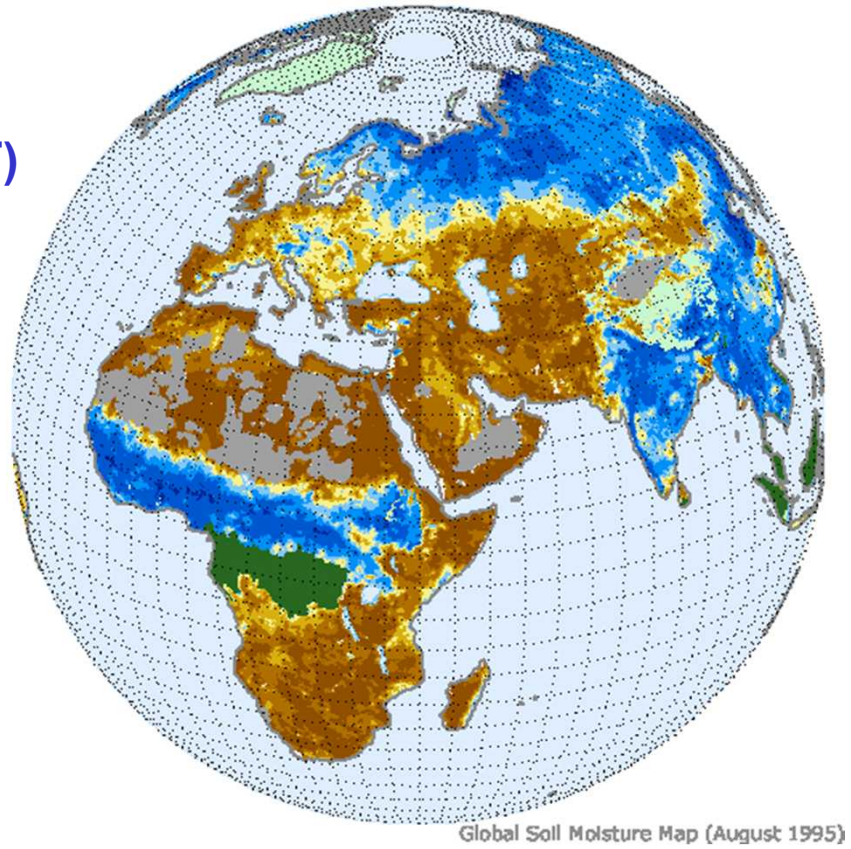
Use of Active microwave data: ASCAT

Advanced Scatterometer on MetOP (launched in 2006)

Active microwave instruments operating at C-band (5.6GHz)

Surface soil moisture index (ws) based on the TUWien retrieval scheme (Wagner et al. 1999)

ASCAT operational SM product (EUMETSAT)

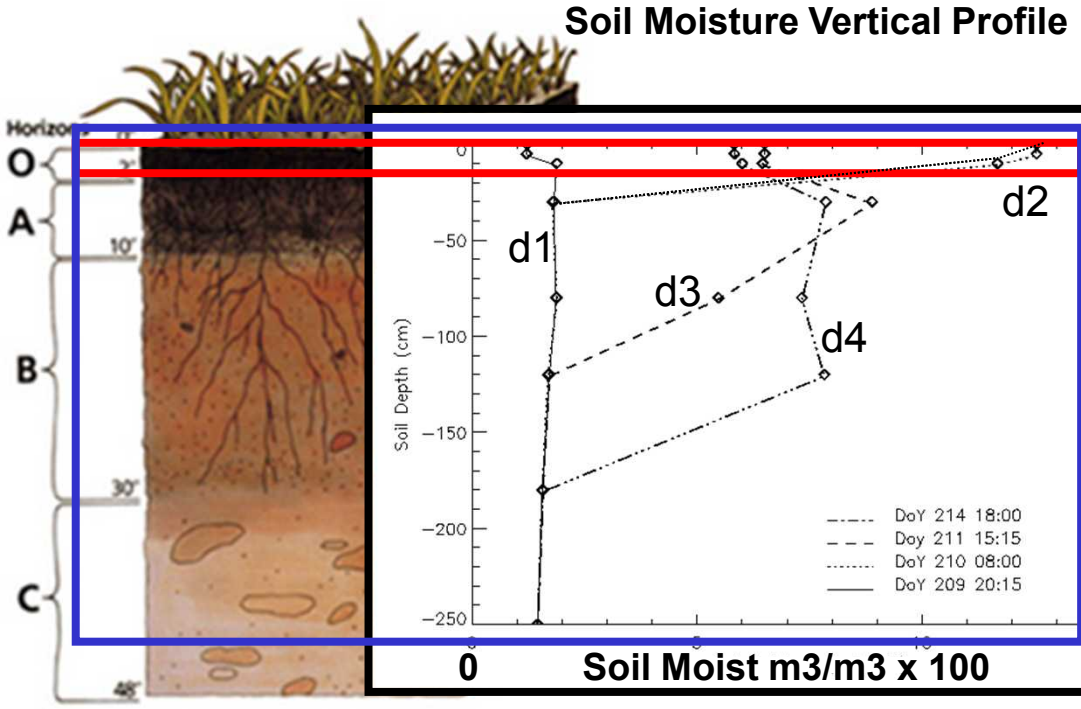


ASCAT Root Zone Soil Moisture Retrieval

Surface Soil Moisture
Top soil moisture measured: 0-2cm ASCAT, 0-5cm SMOS

Root Zone SM Profile
Variable of interest for Soil-Plant-Atm interaction, Climate, NWP and hydrological applications

Root Zone SM Profile:
Accurate retrieval requires to account for physical processes



→ ECMWF contribution to the EUMETSAT H-SAF
Root zone retrieval based on ASCAT data assimilation

http://www.ecmwf.int/research/EUMETSAT_projects/SAF/HSAF/

de Rosnay et al., res. Memo. 2011

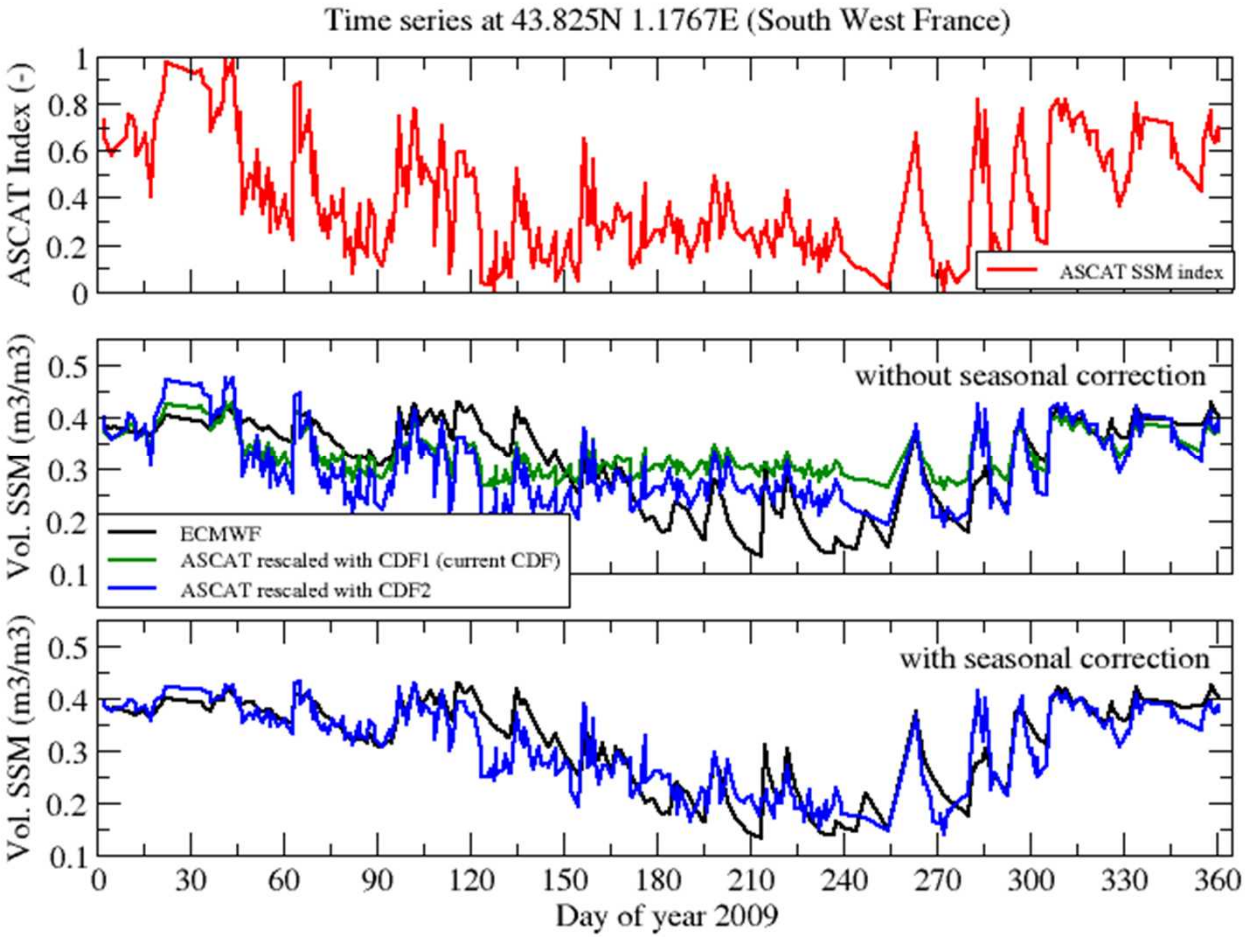
ASCAT Bias correction

ASCAT data

ECMWF SM

ASCAT bias corrected

ASCAT bias corrected (with seasonal correction)



Bias correction: crucial component of the data assimilation system
Used at ECMWF for - Operational ASCAT soil moisture monitoring
- ASCAT Soil Moisture data assimilation

ASCAT SM data assimilation

ASCAT (surface swath) → SM-DAS (Root Zone profile global)
2008- 2010 … NRT in 2012

ECMWF Atmospheric conditions

SYNOP
T2m RH2m

ASCAT
Surface SM
Bias corrected

EKF
Soil Moisture
Analysis

SM-DAS-2:
Soil Moisture
Profile

4 layers:
0-7cm
7-28 cm
28-100 cm
100-289cm

H-SAF CDOP: SM-DAS-2 Production chain

Quality Control → use data when:
- **Incidence angle: cell number € [11,26]**
- **Topographic complexity ≤ 20**
- **Wetland Fraction ≤ 15**
- **Noise level ≤ 8**

For Surface conditions:
- **Surface is snow free**
- **Soil not frozen**

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