Evaluation of remotely sensed and modelled soil moisture products using global ground-based in situ observations

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Context of the study: H-SAF Visiting Scientist program (June-December 2011)

→ Collaboration ECMWF, CESBIO, IPF Vienna

Part-1: Evaluation against ground data (Albergel et al.)

Part-2: Global map comparison (Gruhier et al.) (ongoing)

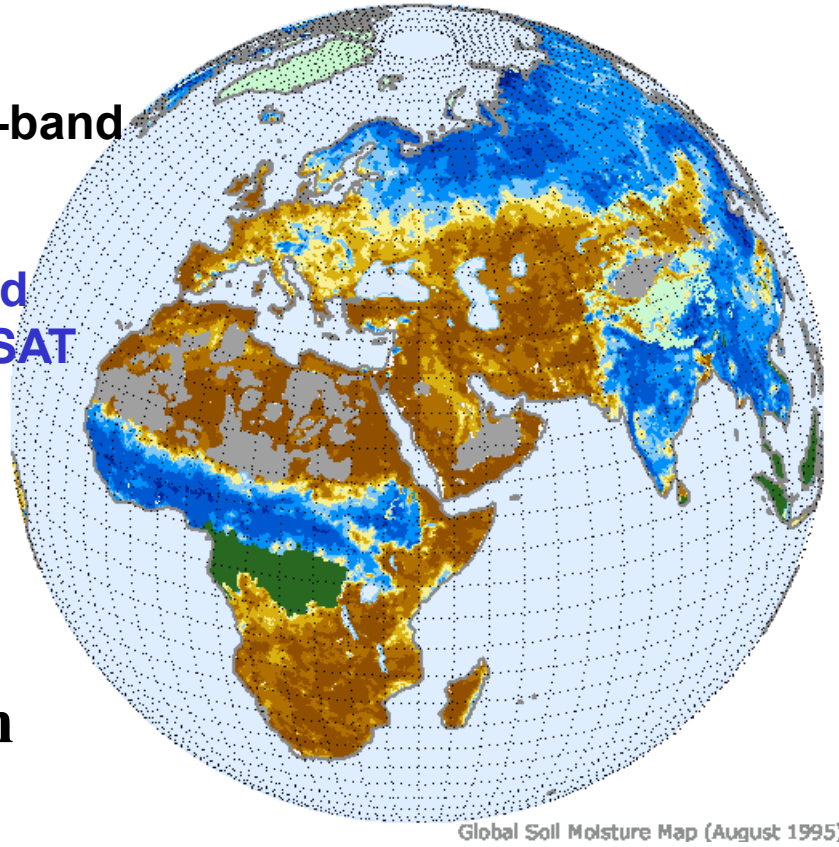
Evaluation of soil moisture : ASCAT

Advanced Scatterometer on MetOP (launched in 2006)

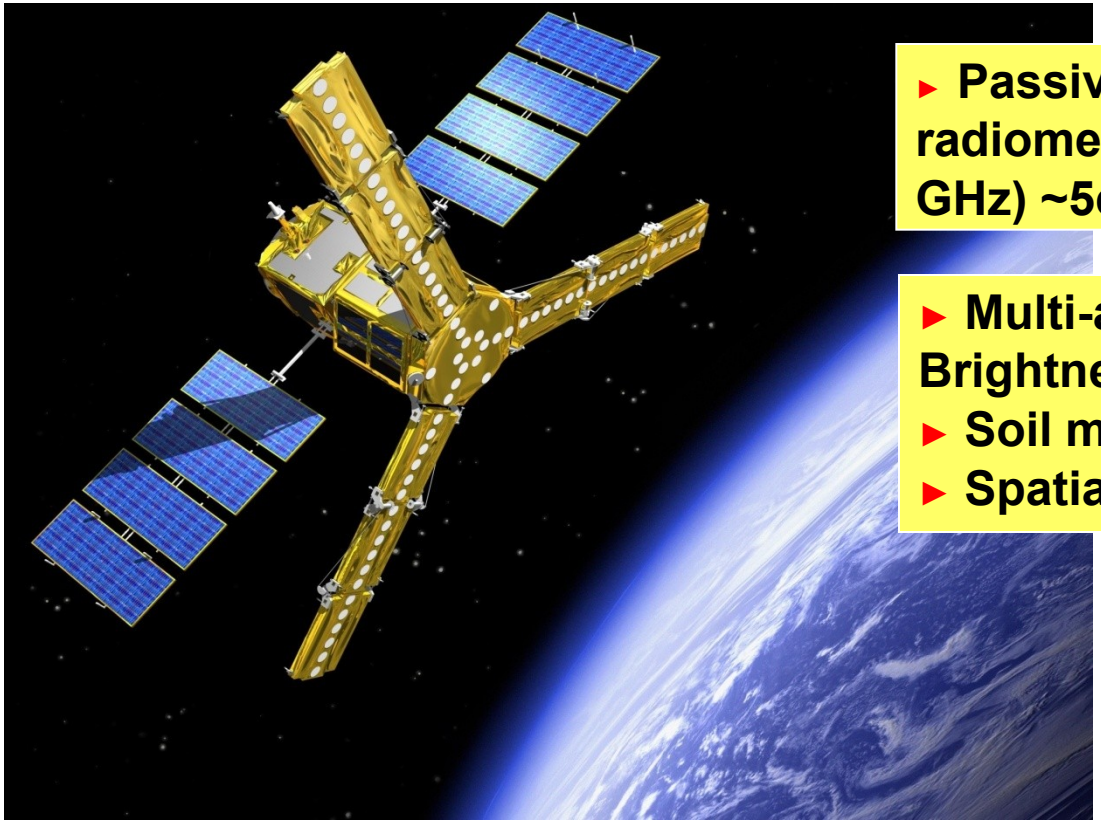
Active microwave instruments operating at C-band (5.6GHz) ~0.5-2 cm

ASCAT operational SM product : NRT data and disseminated to NWP community via EUMETSAT

~25 km



Evaluation of soil moisture : SMOS

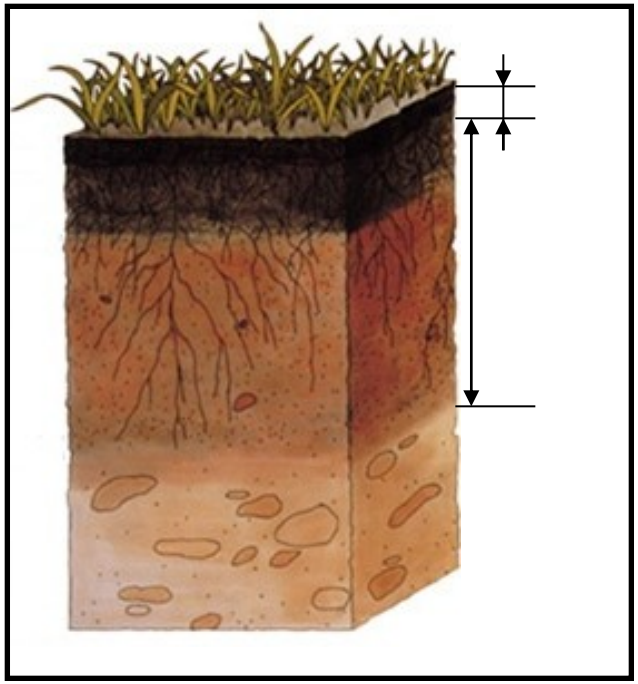


- Passive microwave interferometric radiometer operating at L-band (1.4 GHz) ~5cm (Kerr et al., 2010)
- Multi-angular measurements of Brightness Temperature
- Soil moisture accuracy: 4%
- Spatial resolution: ~40 km

In this study : level 2 product, i.e. SSM, produces at CESBIO

Soil moisture from remote sensing

- Remote Sensing : Provides quantitative information about the water content of a shallow near surface layer (e.g. ASCAT, SMOS)
- Main variable of interest for applications such as meteorological modelling and hydrological studies is the root-zone soil moisture



➔ Accurate retrieval requires to account for physical processes

SM-DAS-2 : Root zone retrieval based on Data Assimilation

ASCAT SM data assimilation : SM-DAS-2

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

ECMWF Atmospheric conditions

SYNOP
T2m RH2m

SM-OBS:
ASCAT
Surface SM

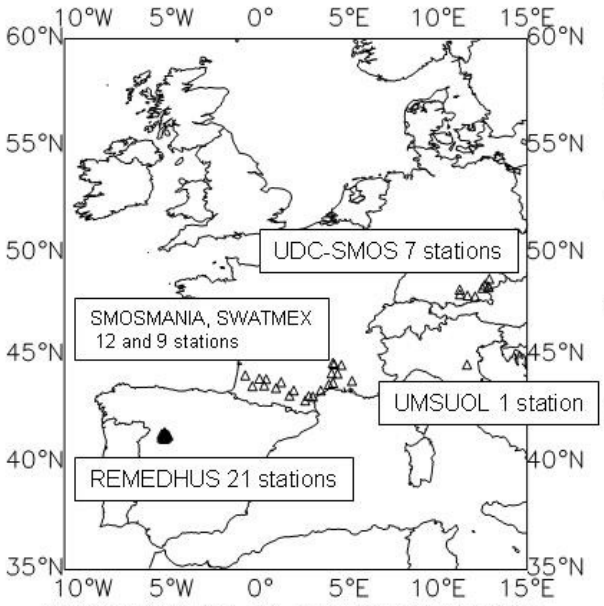
EKF
Soil Moisture
Analysis

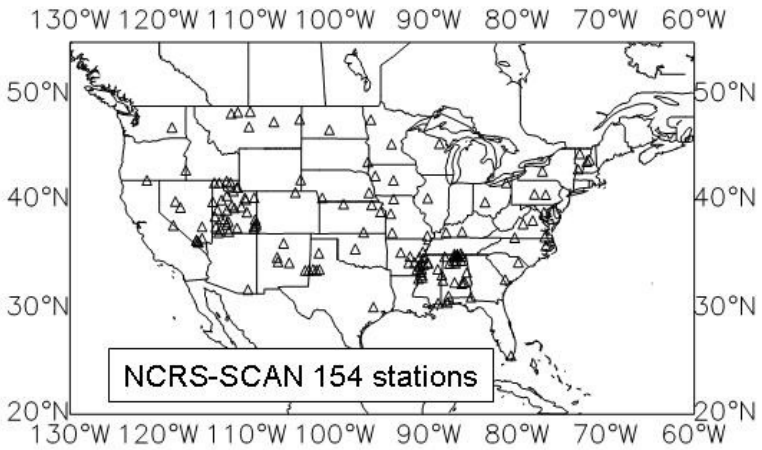
SM-DAS-2:
Soil Moisture
Profile

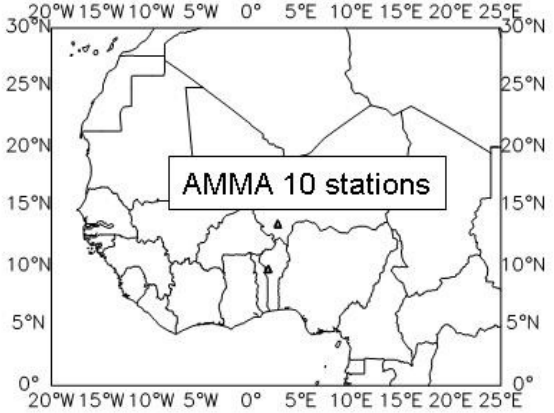
4 layers : 0-7cm, 7-28 cm, 28-100 cm & 100-289cm

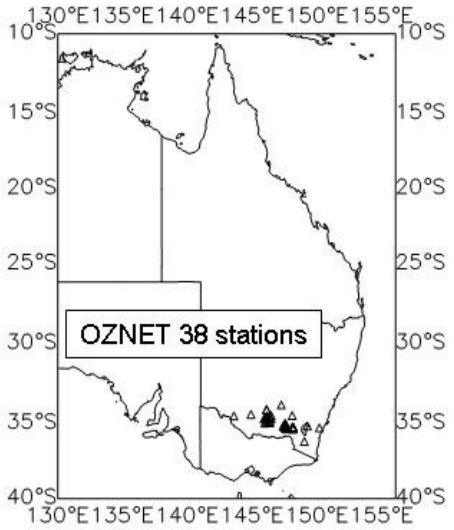
consistent 2008- 2010 … NRT in 2012

In situ SSM : 252 stations available in 2010







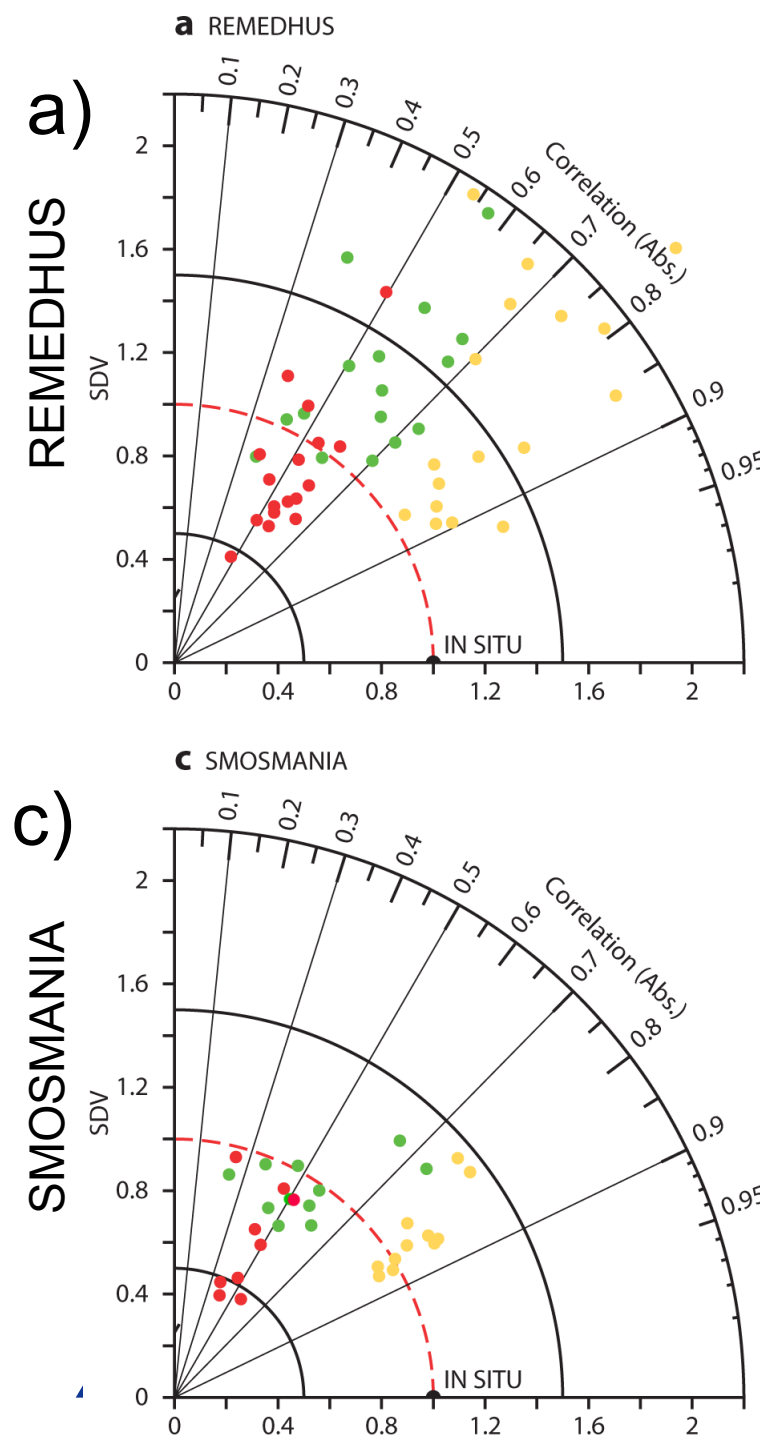


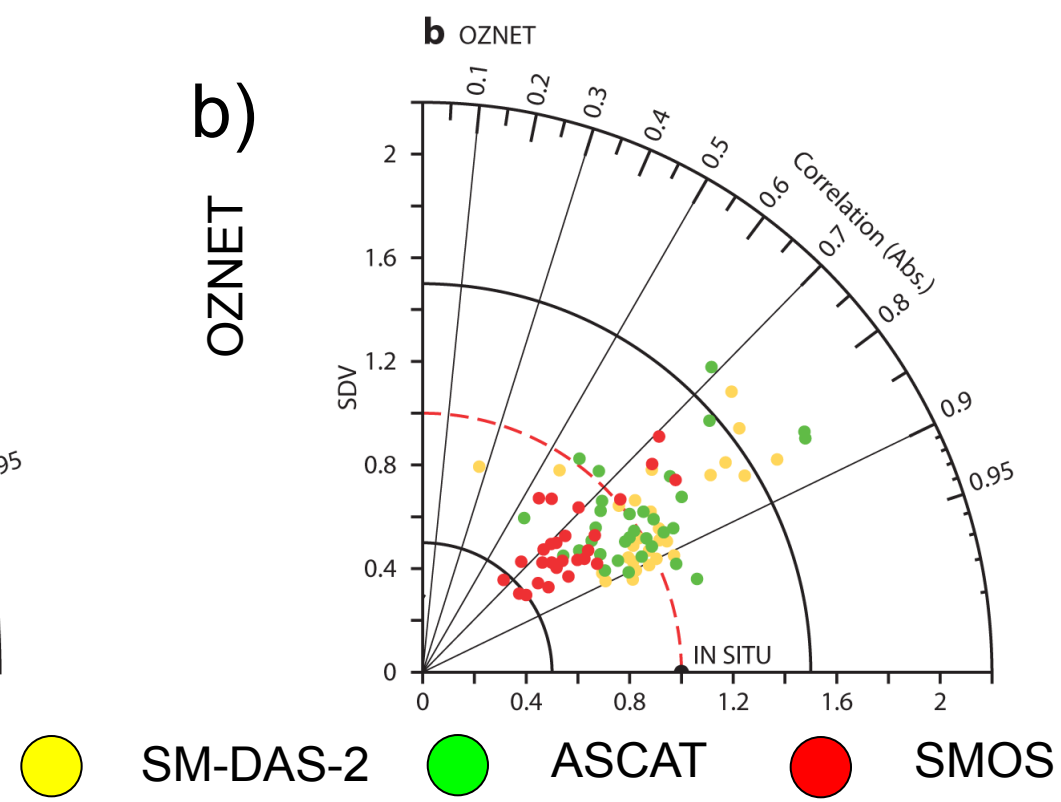
Data Preparation

- 2010 times series of SMOS, ASCAT, ECMWF SM-DAS-2 and in situ SSM
- 3 products and in situ data : SSM in different units (m^3m^{-3}, [-])

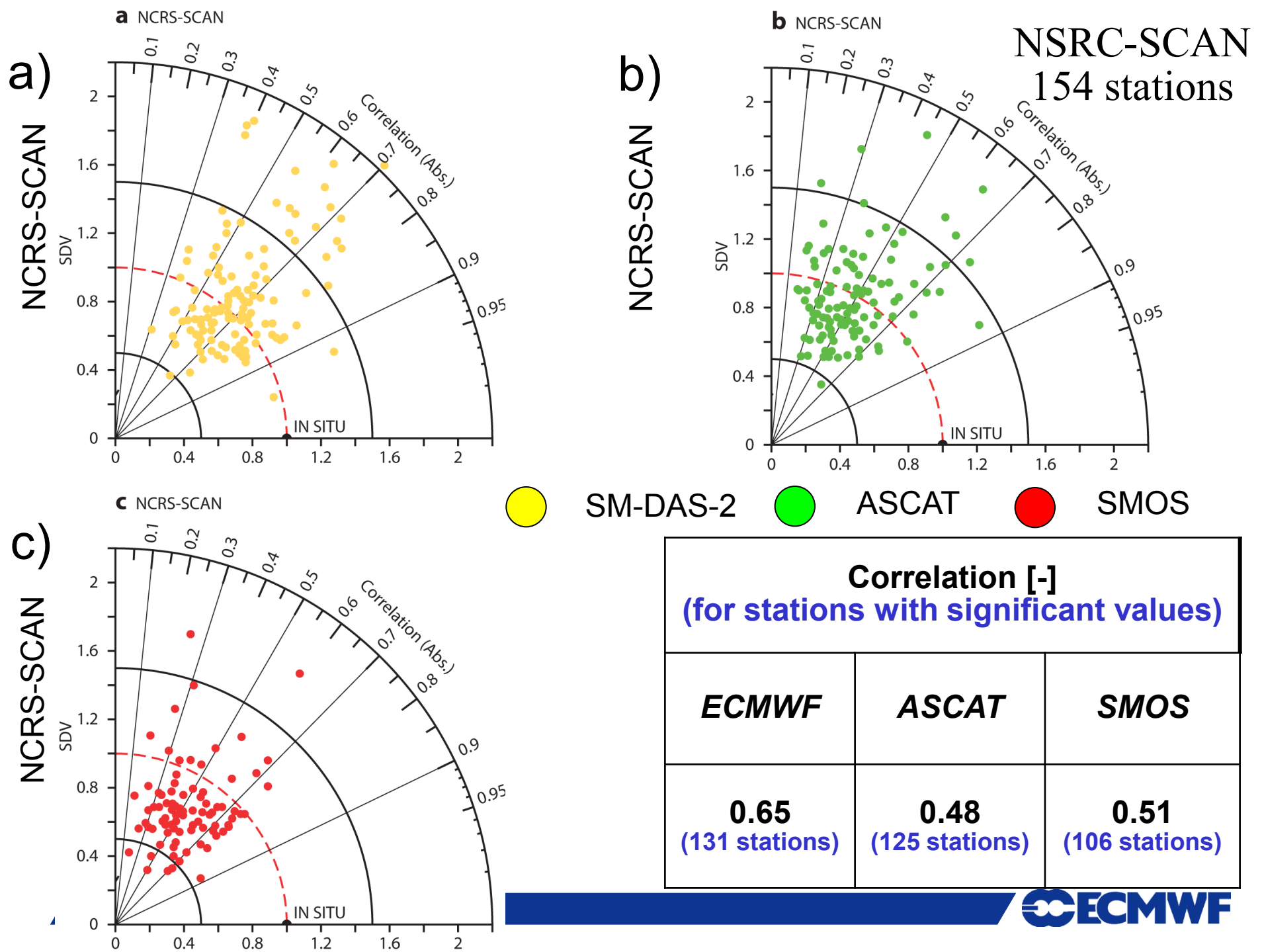
  ➔ Fair comparison between : each product is normalized using its own min and max of the time series
- Metrics used : RMSD, R, Bias (significant level of R, p-value<0.05)

(R is of particular interest for NWP applications , Koster et al. 2009)



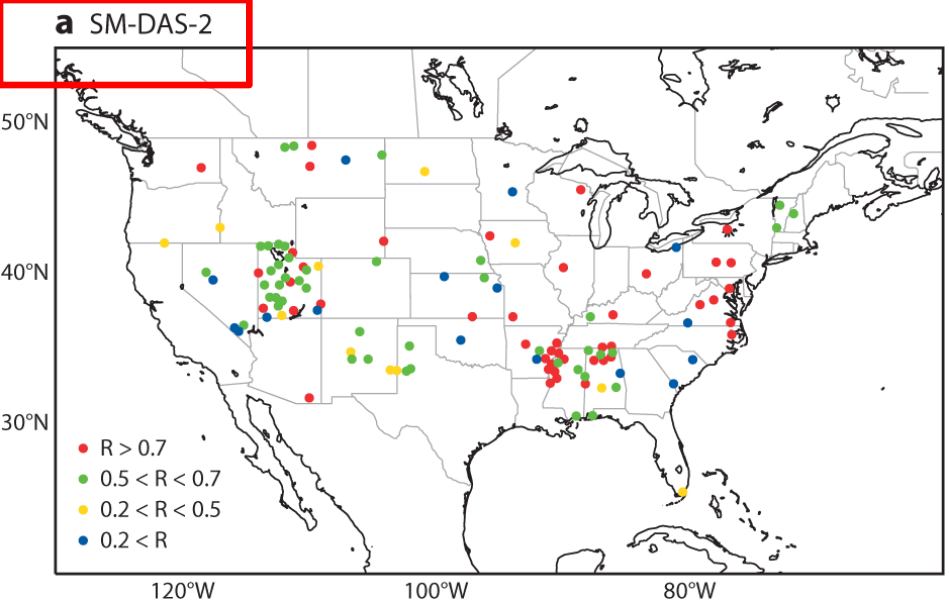


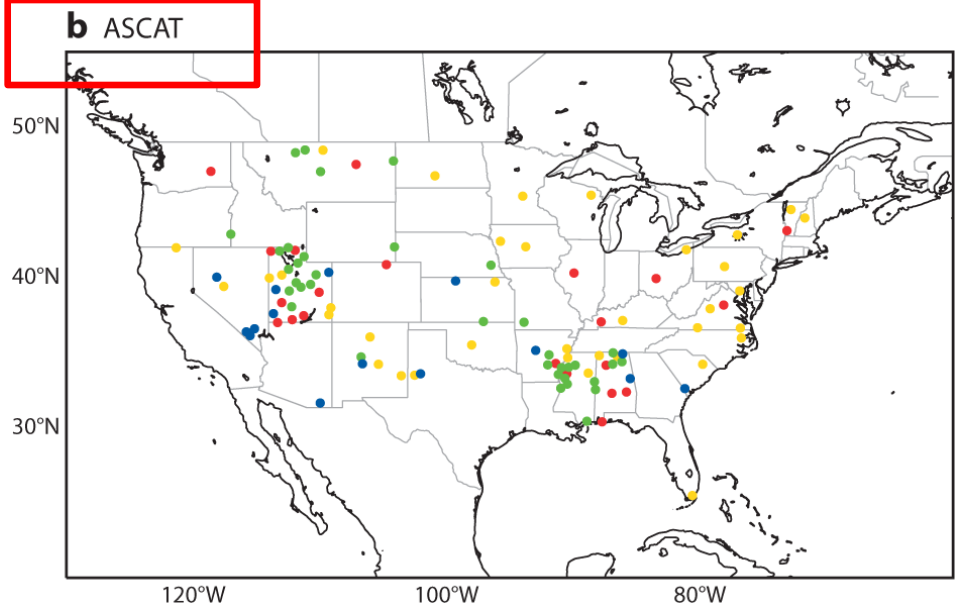
Network	Mean Correlation [-] (for stations with significant values)		
	ECMWF	*ASCAT*	*SMOS*
REMEDHUS (nb stations)	0.79 (17)	0.57 (17)	0.52 (17)
OZNET (nb stations)	0.82 (36)	0.80 (34)	0.74 (30)
SMOSMANIA (nb stations)	0.83 (11)	0.52 (11)	0.44 (10)



Correlation [-] (for stations with significant values)		
ECMWF	***ASCAT***	***SMOS***
0.65 (131 stations)	**0.48** (125 stations)	**0.51** (106 stations)

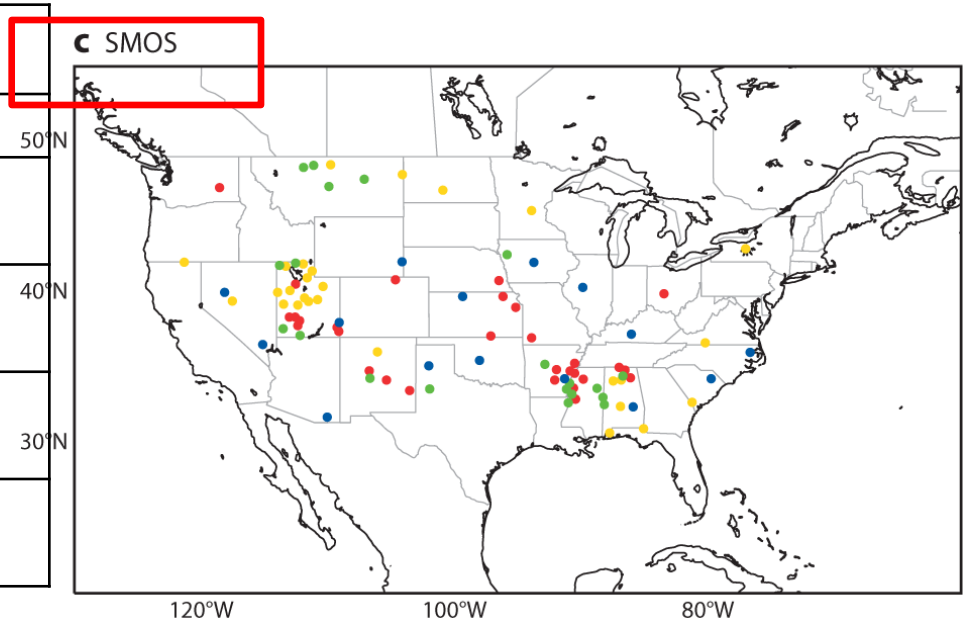
ECMWF



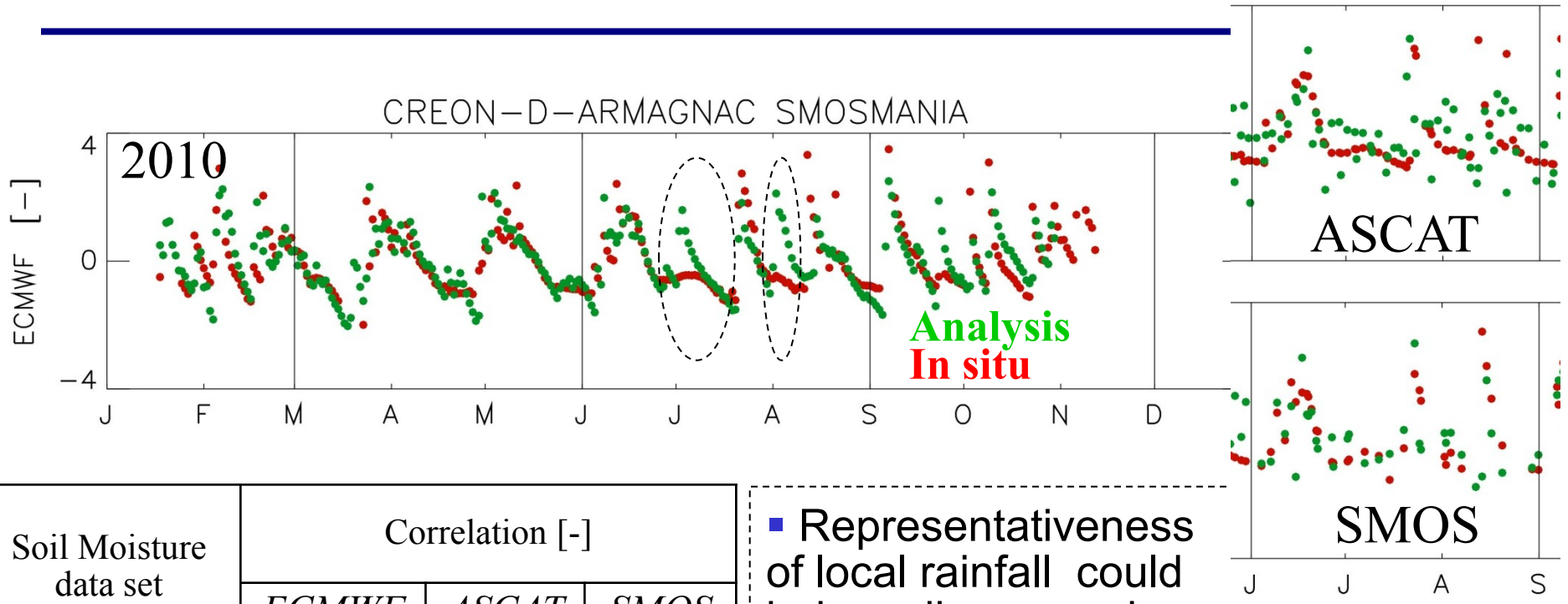


Distribution (%) of correlation values

Correlation	NCRS-SCAN		
	ECMWF	*ASCAT*	*SMOS*
Inadequate R<0.2	2	7	3
Poor 0.2<R<0.5	14	47	48
Fair 0.5<R<0.7	50	39	32
Good R>0.7	34	7	17
	100%	100 %	100%



Comparison of the Anomaly time-series



Soil Moisture data set	Correlation [-]		
	ECMWF	*ASCAT*	*SMOS*
Winter	0.70	0.71	0.55
Spring	0.65	0.56	0.51
Summer	0.53	0.46	0.46
Autumn	0.62	0.50	0.45

- Representativeness of local rainfall could induce discrepancies when compared to coarse resolution products
- Assimilation of rain-gauge rainfall accumulation is an ongoing activity

Global evaluation

- Good performances of the three products to capture surface soil moisture annual cycle as well as short term variability
- Results particularly encouraging over the Oznet network
  - does not seem to be affected by RFI
  - dense vegetation canopies ➔ reduced sensitivity to soil moisture
  - land use is predominantly agricultural ➔significant fraction of bare soil and/or of dry vegetation

Normalized Product (nb stations with significant R)	ECMWF (219)	ASCAT (208)	SMOS (180)
Correlation	0.70	0.53	0.54
Bias (index) (In Situ - Product)	- 0.05	- 0.07	0.12
RMSD (index)	0.235	0.255	0.243

Towards a root zone soil moisture product

- ECMWF SSM, good correlations, high biases and RMSD
- Spatial variability of in situ SSM very high and differences in soil properties could imply difference in the mean and the variance on SSM

➔ The true information content of modelled SSM not relies in their absolute magnitudes but in their time variation, i.e. the time-integrated impact of antecedent meteorological forcing

Good level of correlation of ECMWF SSM is supportive of the development of a root zone soil moisture index

Summary

- **ASCAT and SMOS product :**
  - similar performances in terms of correlation
  - particularly good scores in Australia, western Africa
- **SMOS in better agreement with NCRS-SCAN than ASCAT**
- **SM-DAS-2 product best performances (R, Bias, RMSD)**
- **Albergel et al., submitted to RSE, 2011**

  (Also ECMWF Tech Memo, No652 :

  http://www.ecmwf.int/publications/library/do/references/list/14)

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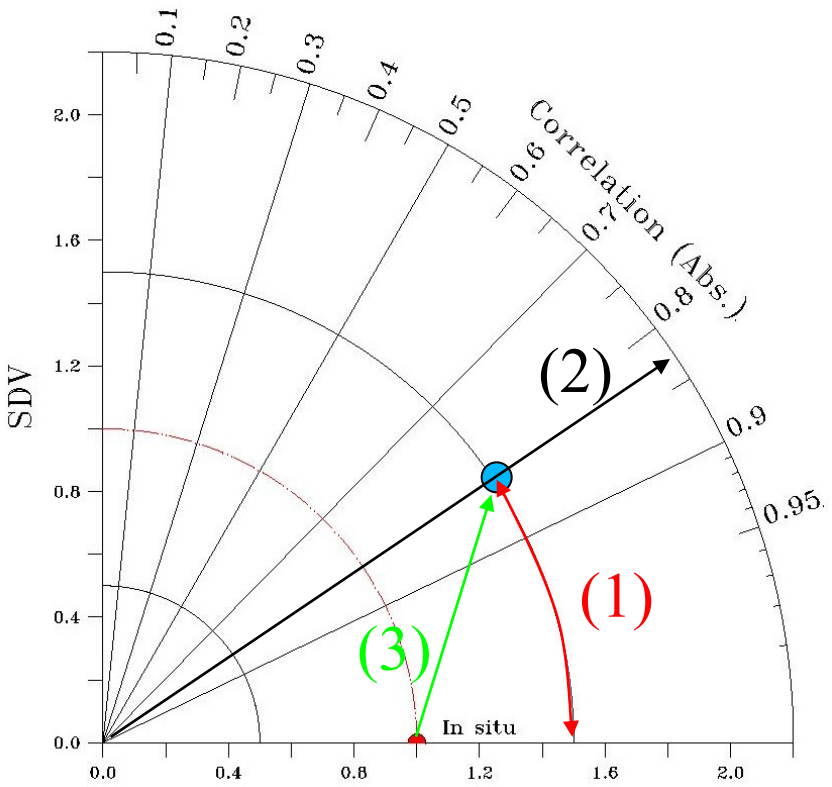
Taylor Diagram



- SDV is displayed as a radial distance (1)
- R as an angle in the polar plot (2)
- E is the distance to the 'In situ' point (3)

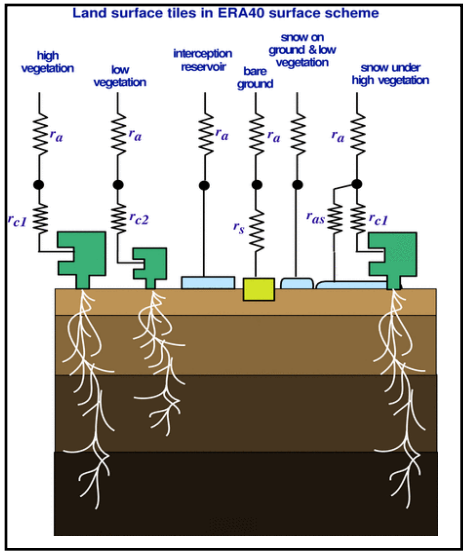
Statistical comparison

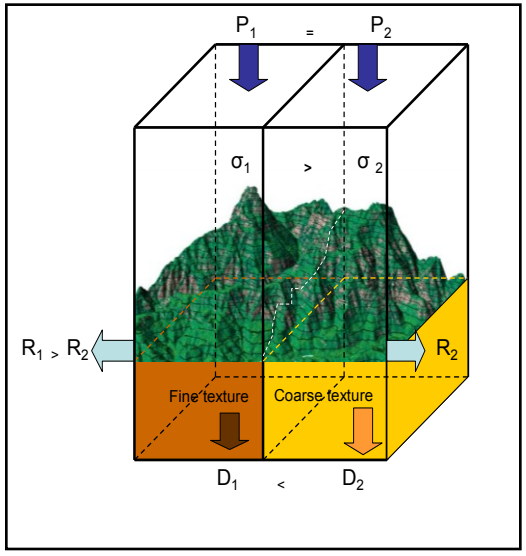
- ‘Classic’ scores: R, bias, RMSD
- Normalised standard deviation $SDV = \sigma_{analyse} / \sigma_{in\ situ}$
- Centred RMSD normalised by in situ standard deviation $E^2 = \left(rmsd^2 - Bias^2\right) / \sigma^2_{in\ situ}$
- R, SDV and E are usually represented on Taylor diagram

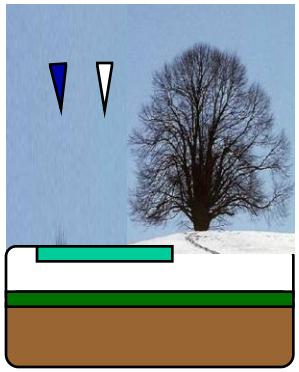
(Taylor, 2001)

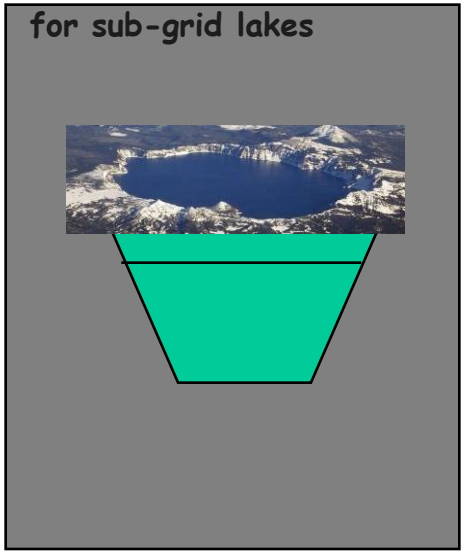
Land surface model evolution

2000/06	2007/11	2009/03	2009/09	2010/2011
TESSEL Van den Hurk et al. (2000) Viterbo and Beljaars (1995) Viterbo et al (1999) Up to 8 tiles (binary Land-Sea mask) GLCC veg. (BATS-like) ERA-40 and ERA-I scheme	**Hydrology-TESSEL** Balsamo et al. (2009) van den Hurk and Viterbo (2003) Global Soil Texture (FAO) New hydraulic properties Variable Infiltration capacity & surface runoff revision	**NEW SNOW** Dutra et al. (2010) Revised snow density Liquid water reservoir Revision of Albedo and sub-grid snow cover		**NEW LAI** Boussetta et al. (2010) **BARE GROUND EVAPORATION** **FLAKE** Mironov et al (2010), Dutra et al. (2010), Balsamo et al. (2010) Extra tile (9) to account for sub-grid lakes









Land surface data assimilation evolution

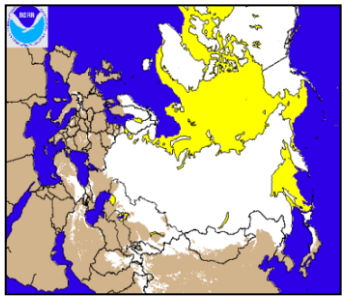
1999/07	2004/03	2008/09	2010/2011

OI screen level analysis

Douville et al. (2000)
Mahfouf et al. (2000)
Soil moisture 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

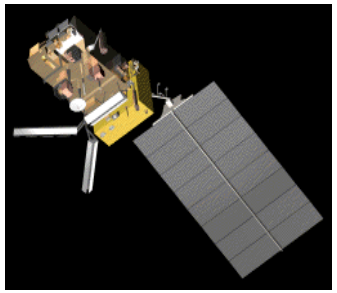


Structure Surface Analysis

OI snow analysis and high resolution NESDIS data (4km)

SEKF Soil Moisture analysis
Simplified Extended Kalman Filter
Drusch et al. (2009), de Rosnay et al. (2011)

METOP-ASCAT



SMOS

- SEKF (Simplified Extended Kalman Filter) surface analysis
- Use of active microwave data (ASCAT soil moisture product)
- Use of passive microwave SMOS data (Brightness Temperature product)
- New snow analysis and use of NOAA/NESDIS 4km snow cover product