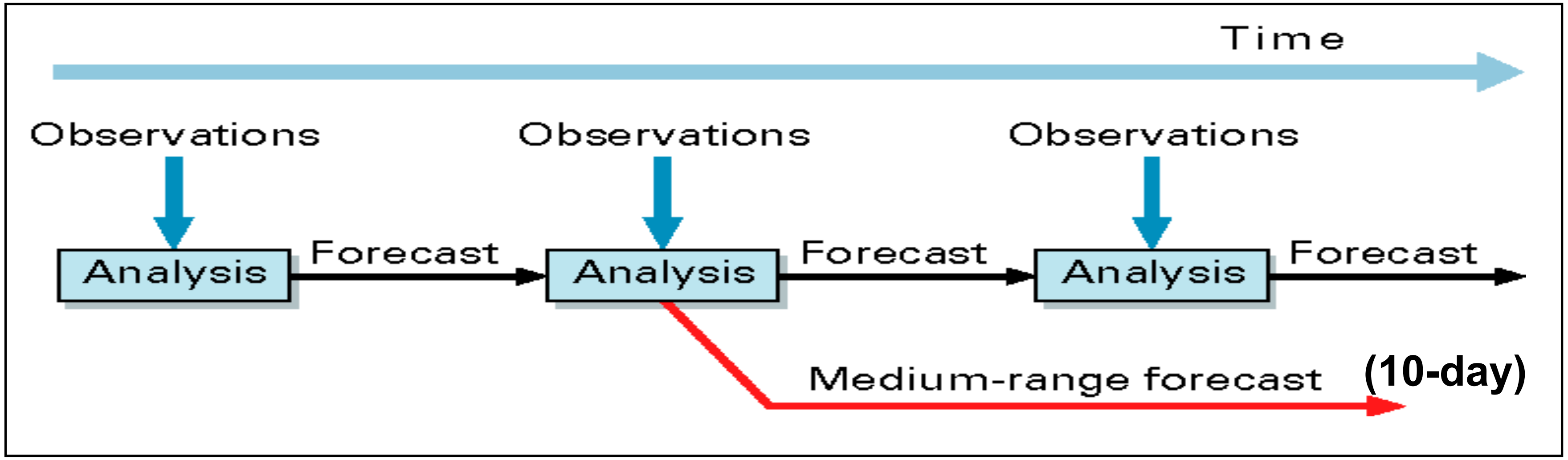
EWGLAM/SRNWP meeting, Salzburg, 1-4 October 2018

Land surface modelling and assimilation activities at ECMWF

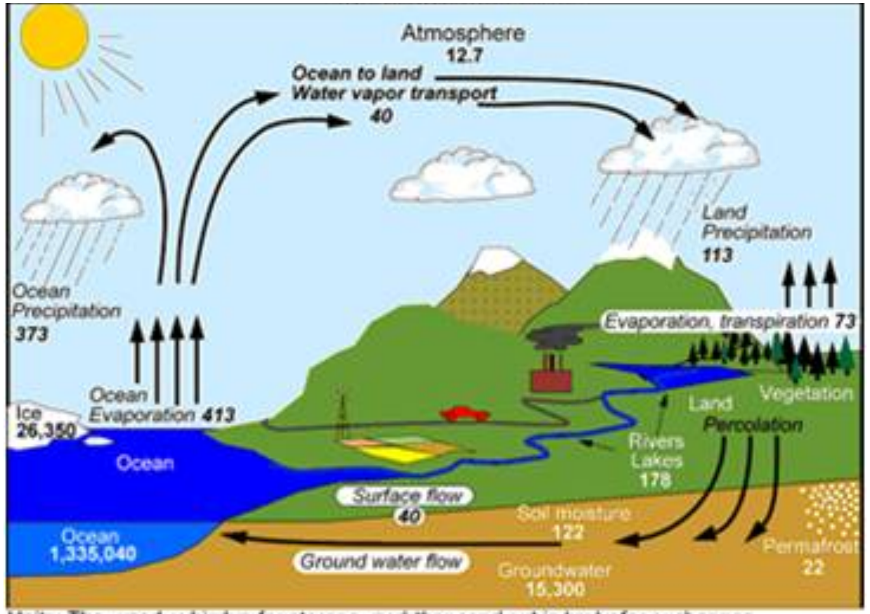
Gianpaolo Balsamo, Patricia de Rosnay

and many other colleagues

ECMWF Integrated Forecasting System (IFS)

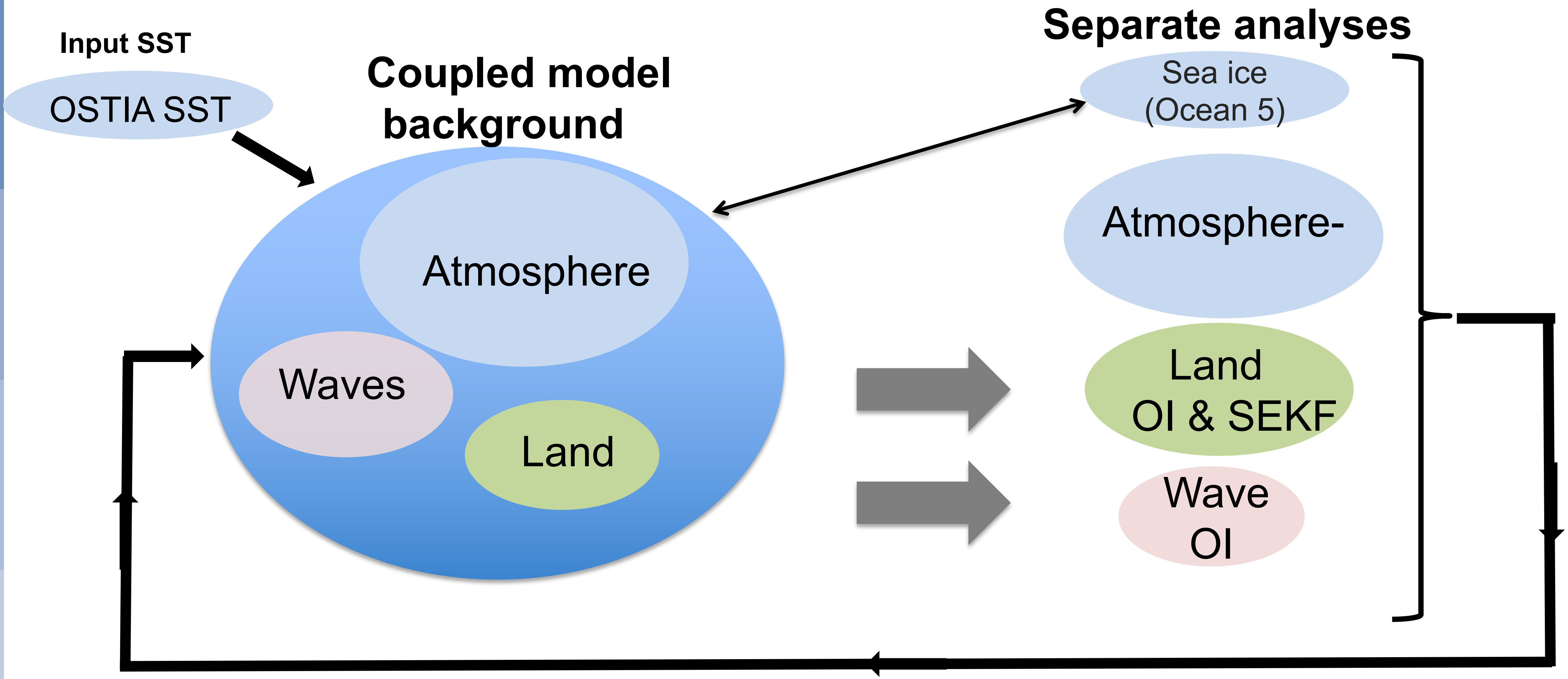


- **Coupled Forecast Model**
- **Data Assimilation: atmosphere (4D-Var), land (SEKF,OI), ocean (3D-Var)**

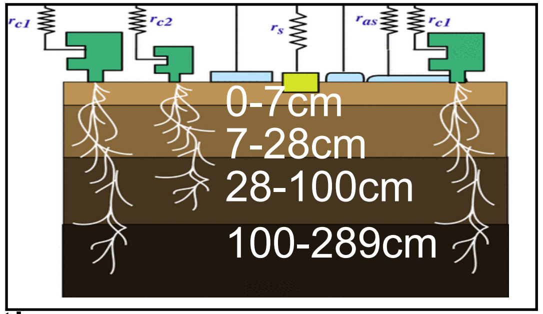


Units: Thousand cubic km for storage, and thousand cubic km/yr for exchanges

Current operational NWP system at ECMWF: weakly coupled land-atmosphere-wave and sea ice assimilation



ECMWF Soil Analysis submitted for IFS 46r1 (2019)



Ensemble Data Assimilation (EDA)

NWP Forecast
Coupled Land-Atmosphere

Land initial conditions

Jacobians

T2m, RH2m

& soil moisture

Background

Soil Analysis (SEKF)
SM1, SM2, SM3

σ_{O_T2M}= 1K $\sigma_{b\_}$= 0.01m3/m3 **σ_{SMOS_NN}= 0.02+3ε**

σ_{O_RH2M}= 4% σ_{ASCAT}= 0.05m3/m3

In situ Observations

T_2m
RH_2m

Screen level analysis (2D-OI)
T_2m RH_2m
$\sigma^{o}{}_{T2m} = 2K$ $\sigma^{o}{}_{RH2m} = 10\%$

ASCAT SM
SMOS SM

Satellite

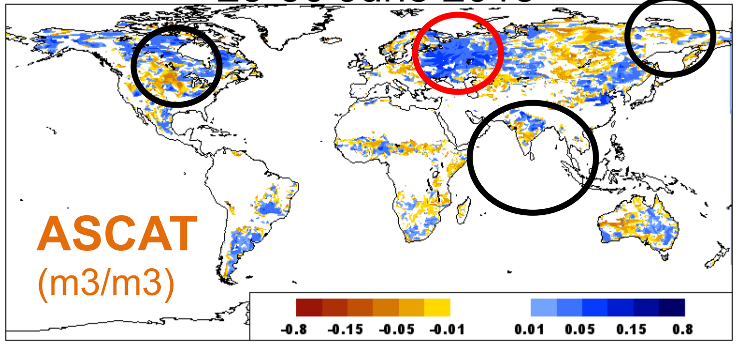
SMOS EC Neural network

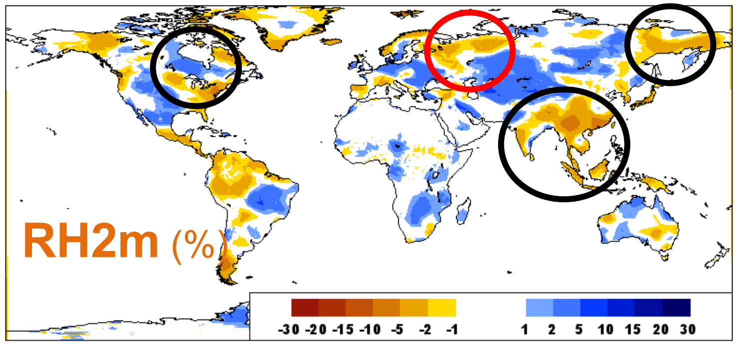
SMOS TB

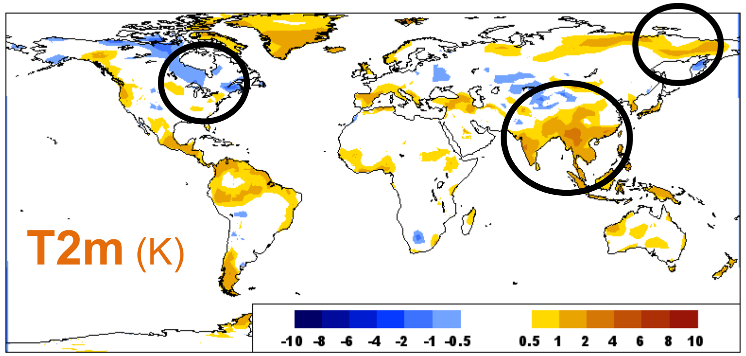
ASCAT Soil Moisture data assimilation for NWP

Innovation (Obs- model)

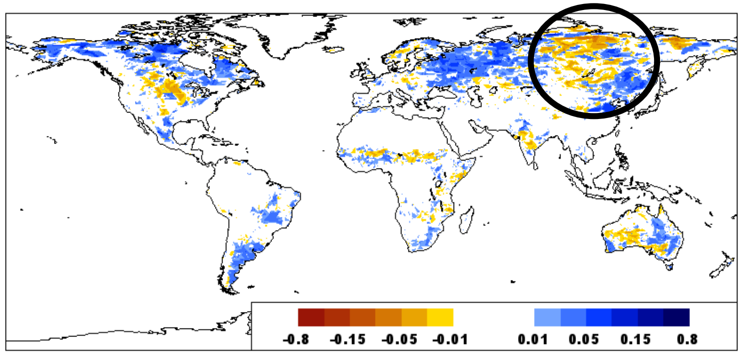
25-30 June 2013



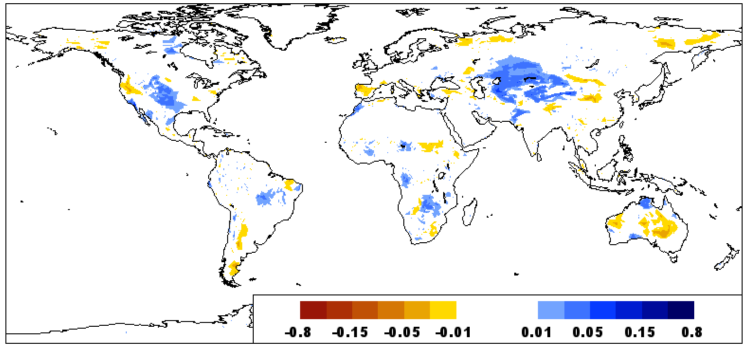




Accumulated Increments (m^3/m^3) in top soil layer (0-7cm)



Due to ASCAT



Due to SYNOP T2m and RH2m

Vertically integrated Soil Moisture increments (stDev in mm)

	SYNOP	ASCAT
Layer 1	0.68	**1.43**
Layer 2	**1.48**	0.68
Layer 3	**4.28**	0.46

ASCAT more increments at surface
SYNOP more increments at depth

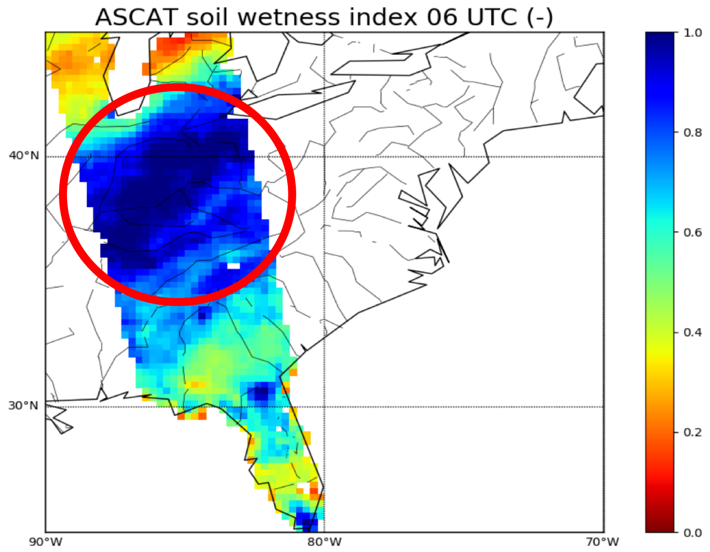
→ For 12h DA window, link obs to root zone stronger for T2m,RH2m than for surface soil moisture observations

ASCAT assimilation

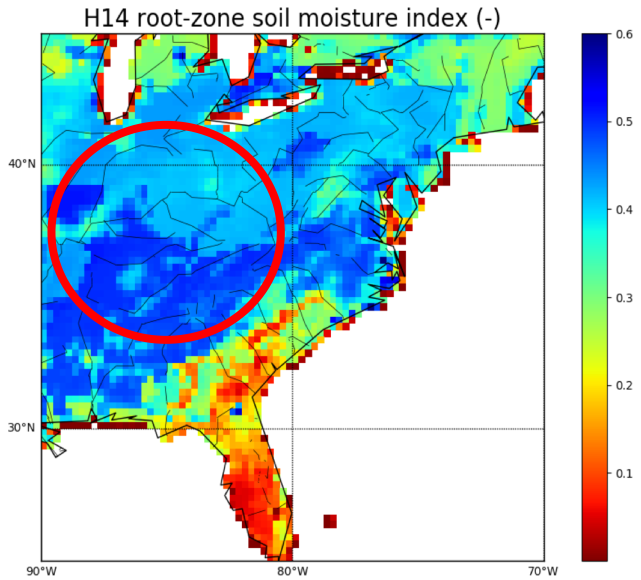
Ohio river flooding near Cincinatti, 22 February 2018

Flooding in central US February 2018

Case study that illustrates the relevance of ASCAT to monitor soil moisture in extreme conditions



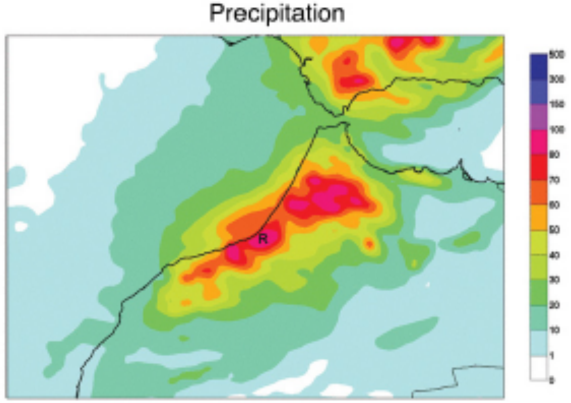
ASCAT **surface** soil wetness index



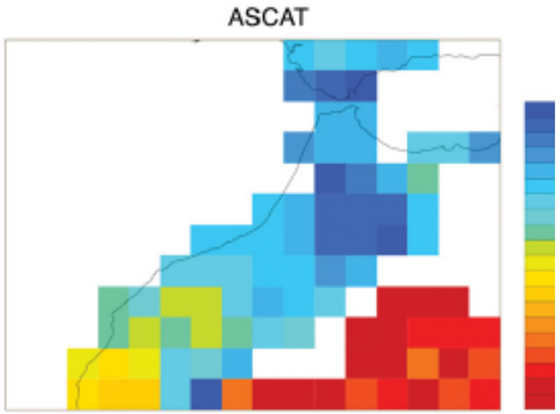
EUMETSAT H-SAF H14 **Root zone** soil moisture index
→ Captured very wet conditions also in the root zone

ASCAT assimilation

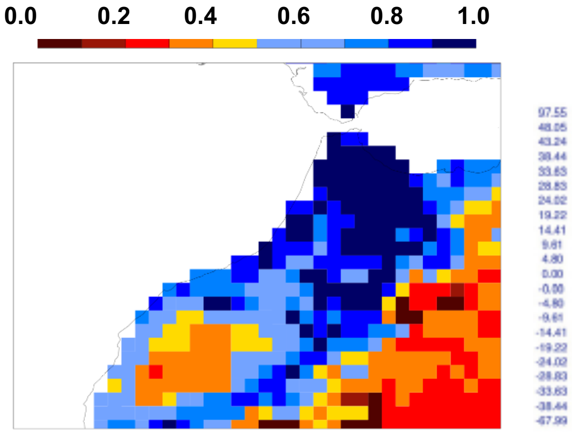
Flash flood in Morocco 23 February 2017



Case study that illustrates the relevance of ASCAT to monitor soil moisture in extreme conditions



ASCAT surface soil moisture (m^3/m^3)



H14 Root zone soil moisture index
→ Captured very saturated conditions
In the root zone

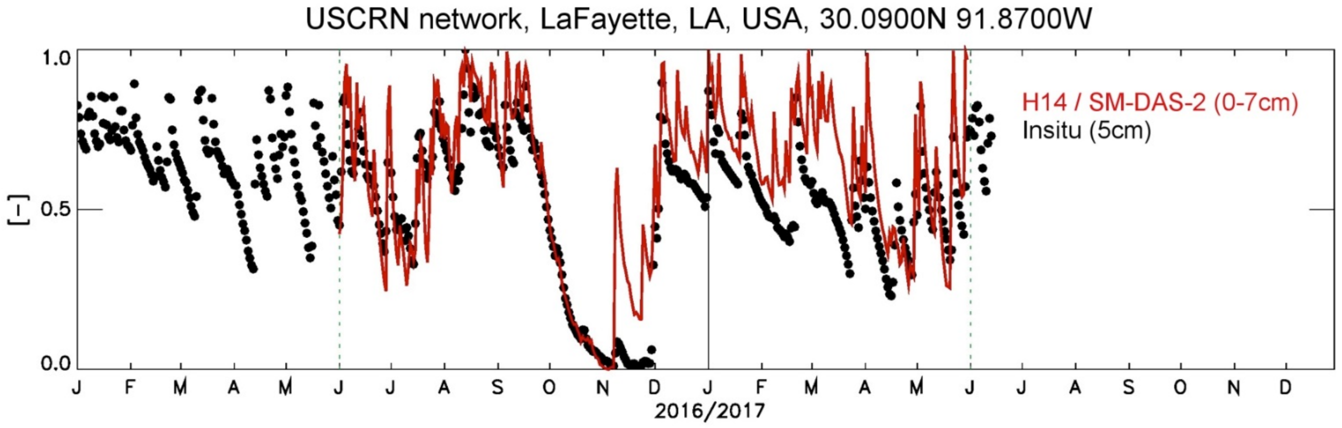
EUMETSAT H-SAF soil moisture

Scatterometer root zone soil moisture based on data assimilation

Evaluation of SM-DAS-2/H14 for 2016-2017 H-SAF OR

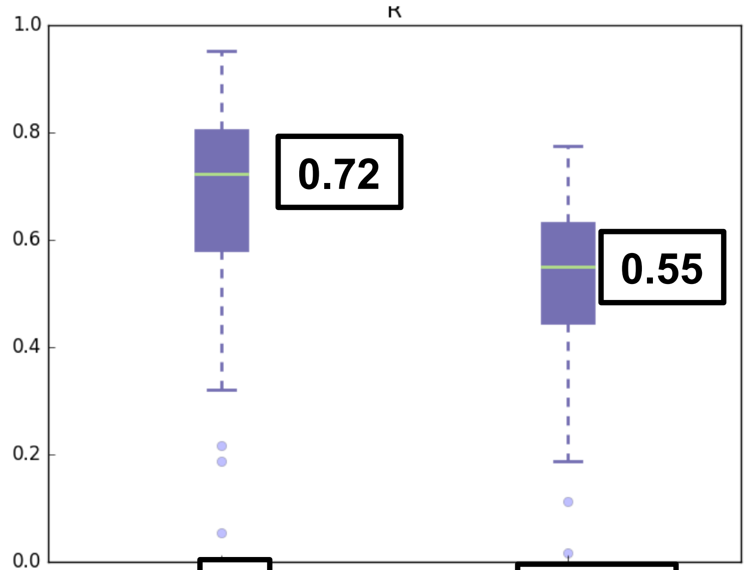
Surface and root zone liquid soil moisture content

USCRN, 102 stations used



Observation (5cm)
H14/SM-DAS-2 (0-7cm)

Accuracy requirements for product SM-DAS-2 [R]			
Unit	**Threshold**	**Target**	**Optimal**
Dimensionless	0.50	0.65	0.80



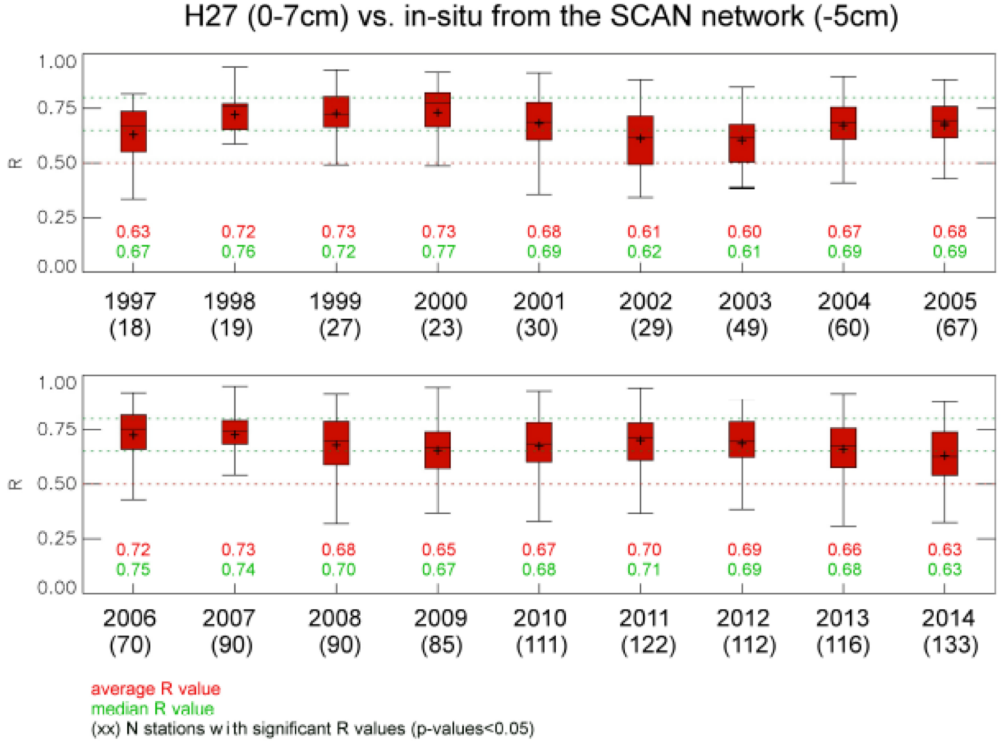
Courtesy Clément Albergel and David Fairbairn

ECMWF

EUMETSAT H-SAF soil moisture

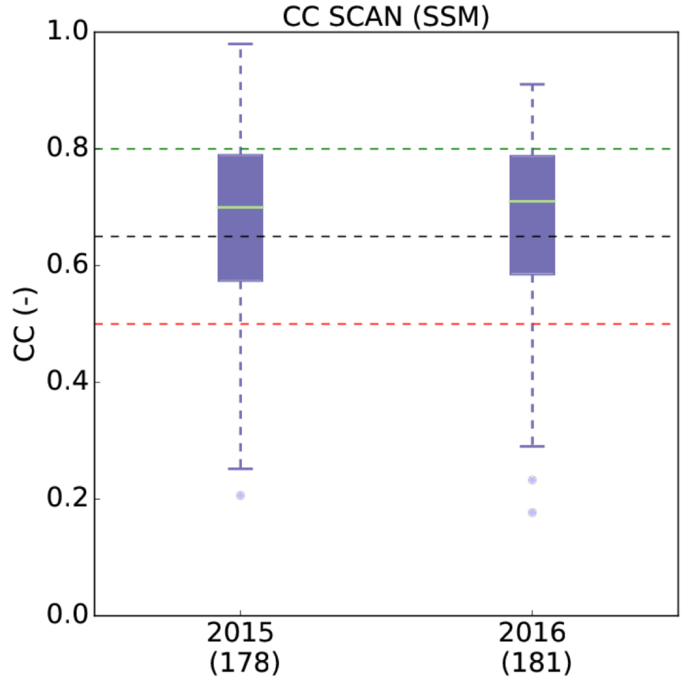
Scatterometer root zone soil moisture DR

H27 validation



Courtesy Clément Albergel and David Fairbairn

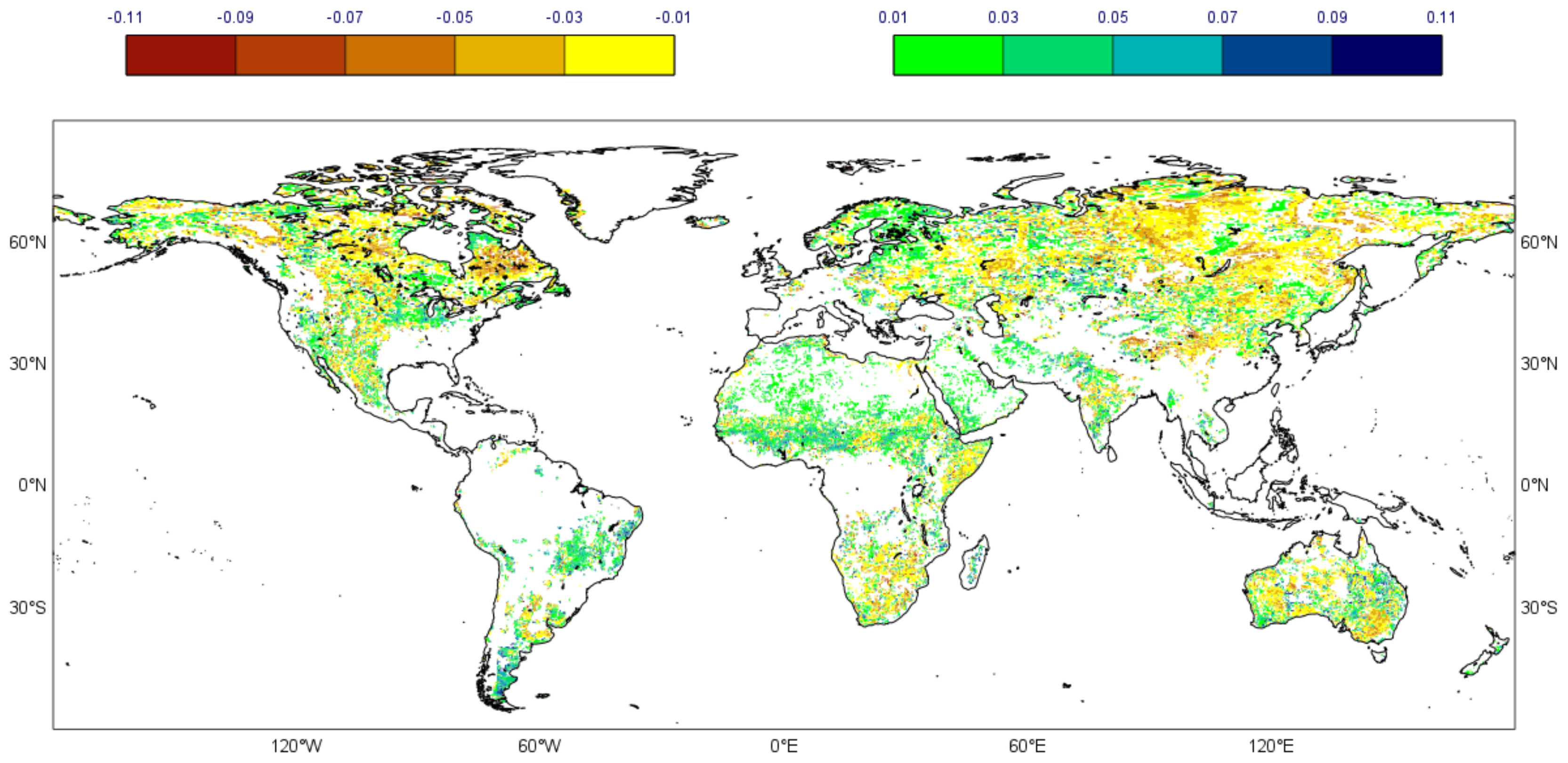
H140 (0-7cm) vs in situ from SCAN



Accuracy requirements for product SM-DAS-3 [R]			
Unit	**Threshold**	**Target**	**Optimal**
Dimensionless	0.50	0.65	0.80

ERA5 reanalysis
Scatterometer soil moisture CDR data assimilation

ERS/ASCAT innovation (O-B) in m3/m3 for assimilated soil moisture observations in ERA5 JAS 1997

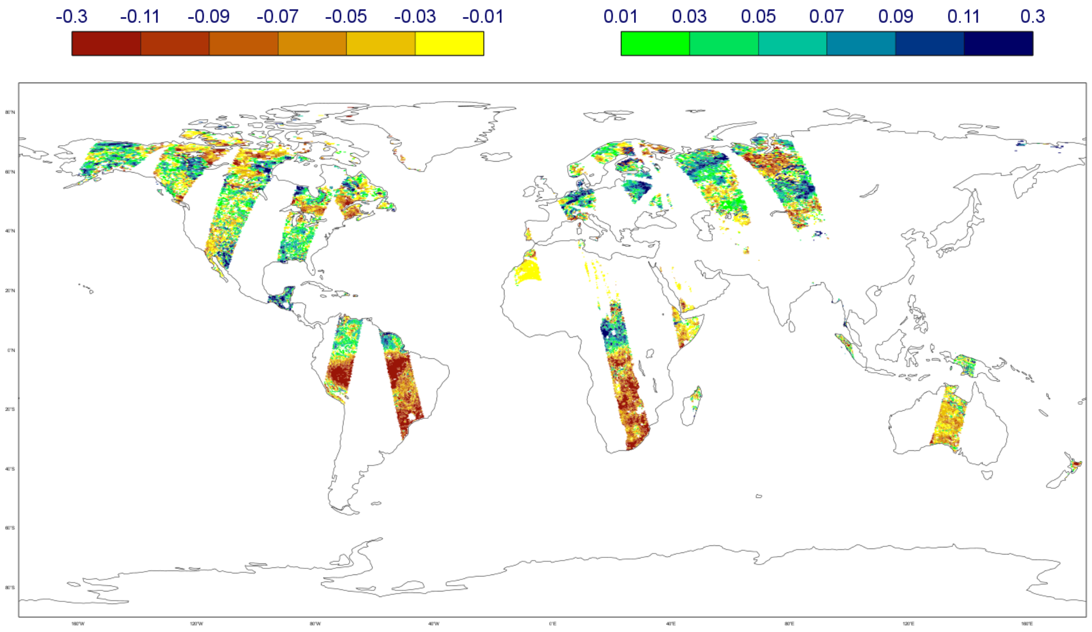


New soil analysis (under evaluation): EDA SEKF and SMOS NN DA

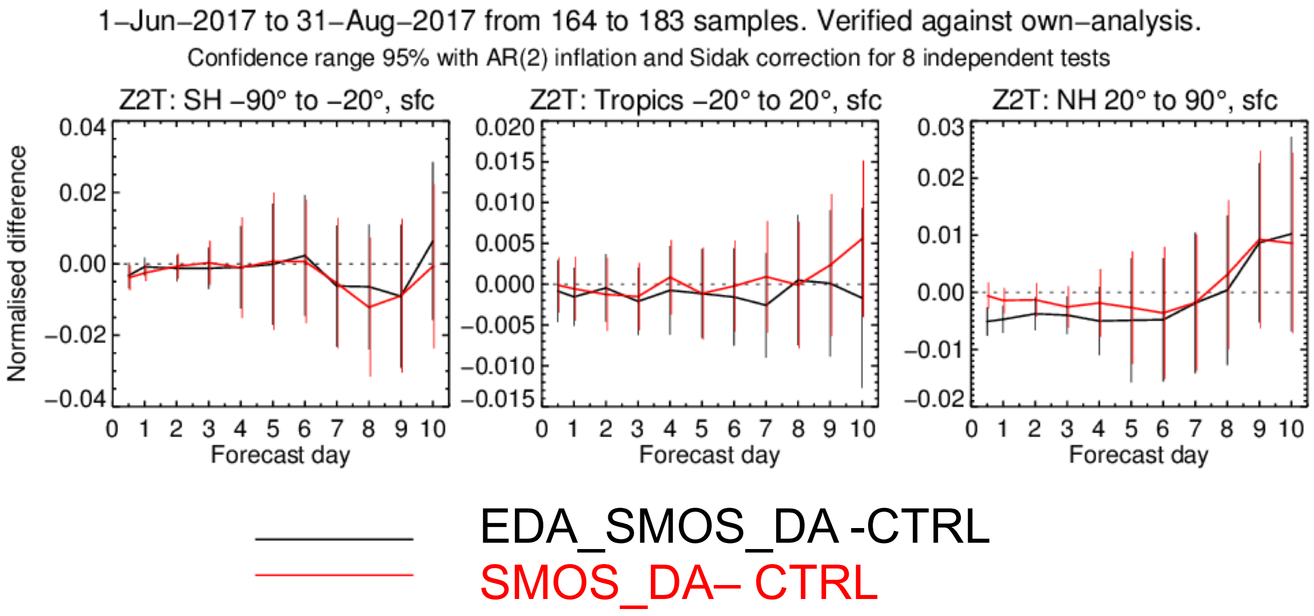
- ➢ Enhanced coupling:
- \- Use the EDA to compute the SEKF Jacobian
- ➢ SMOS neural network soil moisture assimilation
- ➢ CPU reduction from EDA SEKF, cost neutral for SMOS

Reduction of the SEKF CPU cost by a factor ~3.6

	NPES*THREADS	45r1	46r1
Tco 1279	300*9	1580	435
TCo399	54*6	815	235



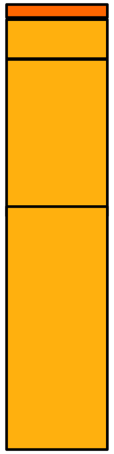
SMOS innovation (obs-model)
01 August 2017 (m3/m3)



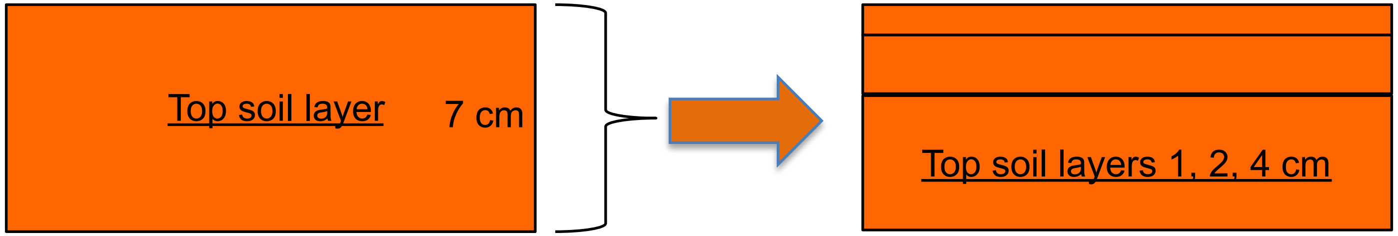
Atmospheric impact (T2m) compared to CTRL

Impact of the soil model vertical resolution: heatwaves severity

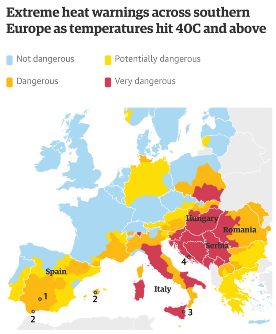
Increased vertical discretization of the soil (**up to 9 layers**) permits a better representation of heatwaves extremes

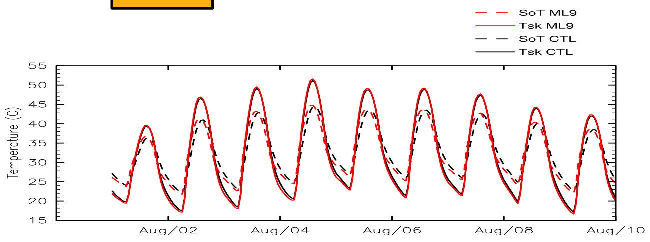


4-layers:
 # 0-7 cm
7-28 cm
28-100 cm
100-289 cm

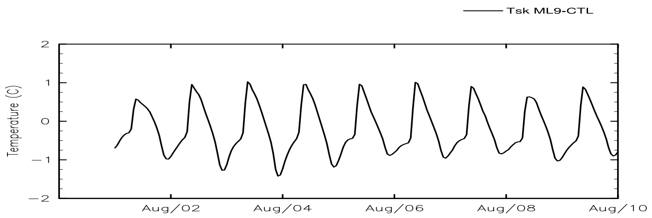


9-layers:
 # 0-1 cm
 # 1-3 cm
 # 3-7 cm
7-15 cm
15-25 cm
25-50 cm
50-100 cm
100-200 cm
200-300 cm



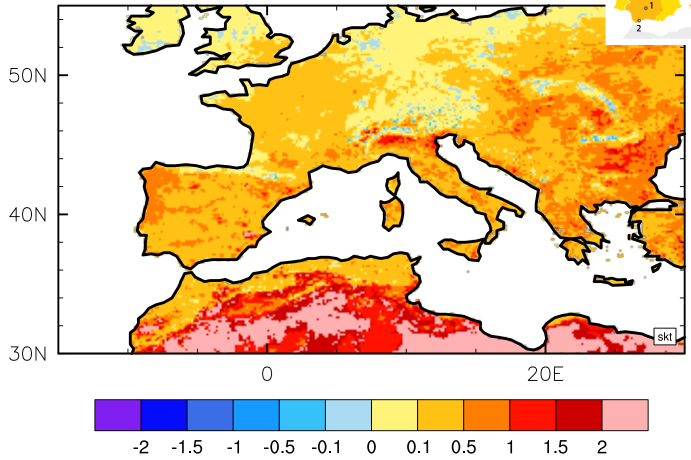


ECMWF
Land model
ML9 & ML4
(offline)



Difference
ML9-ML4
soil model
(offline)

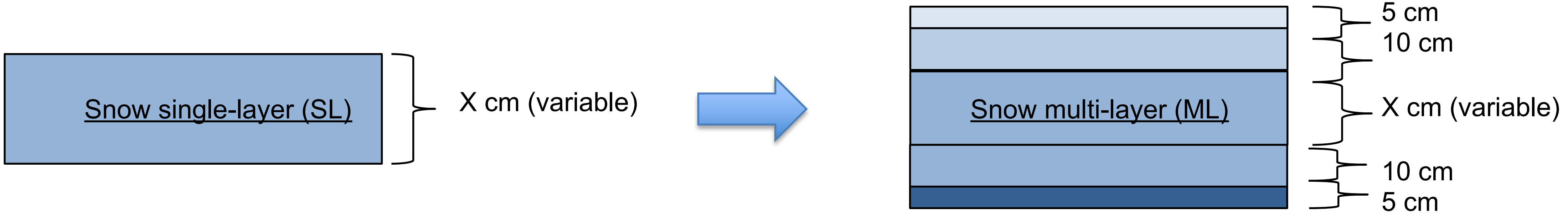
Differences in the maximum skin temperature ML9-ML4



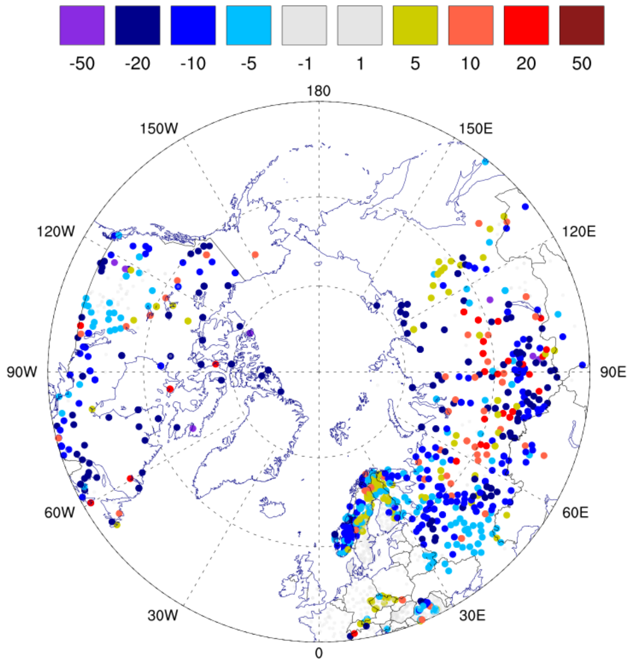
An enhanced soil vertical discretisation is increasing the amplitude of the diurnal cycle. Extremes heatwave are up to 1 K hotter. During summer 2017 the effect of an improved soil multi-layer discretisation is examined for a European heatwave, here shown for Corboba (Spain) where temperatures went above 40^{o} Celsius on the 6th of August 2017

Increased snow model vertical resolution: impact in cold regions climate

Increased vertical discretization of the snowpack (**up to 5 layers**) permits a better representation of cold spells

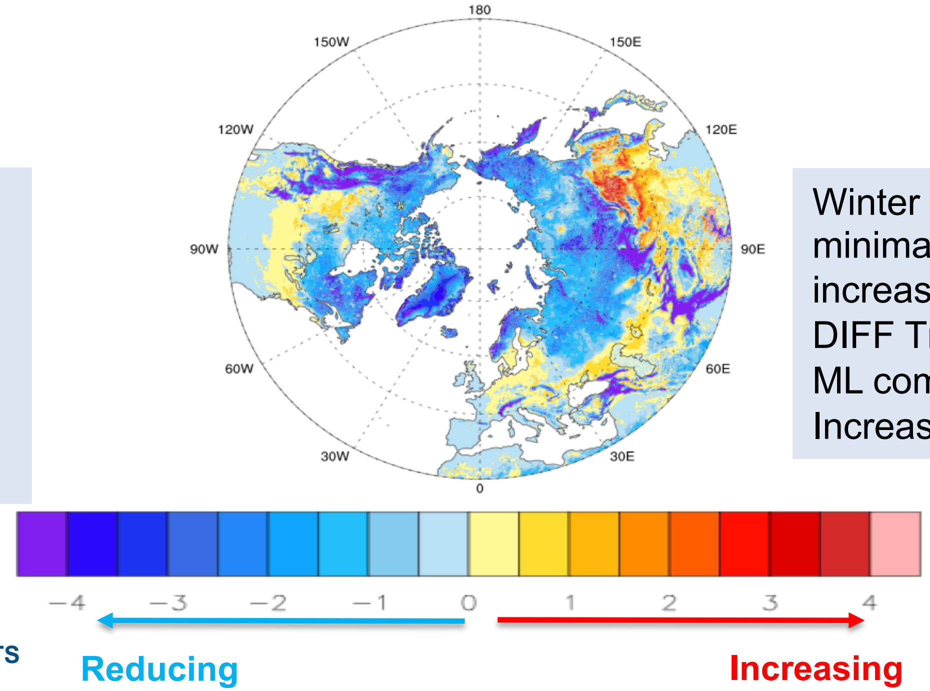


Difference ML- SL in Snow depth RMSE winter (DJF)



An improved snow depth (ML – SL) evaluated with in-situ SYNOP snow depth. RMSE of 0.19m (0.23m) in ML (SL). This is 17% RMSE error reduction in snow depth.

Difference ML - SL in T_{skin} minimum winter (DJF)



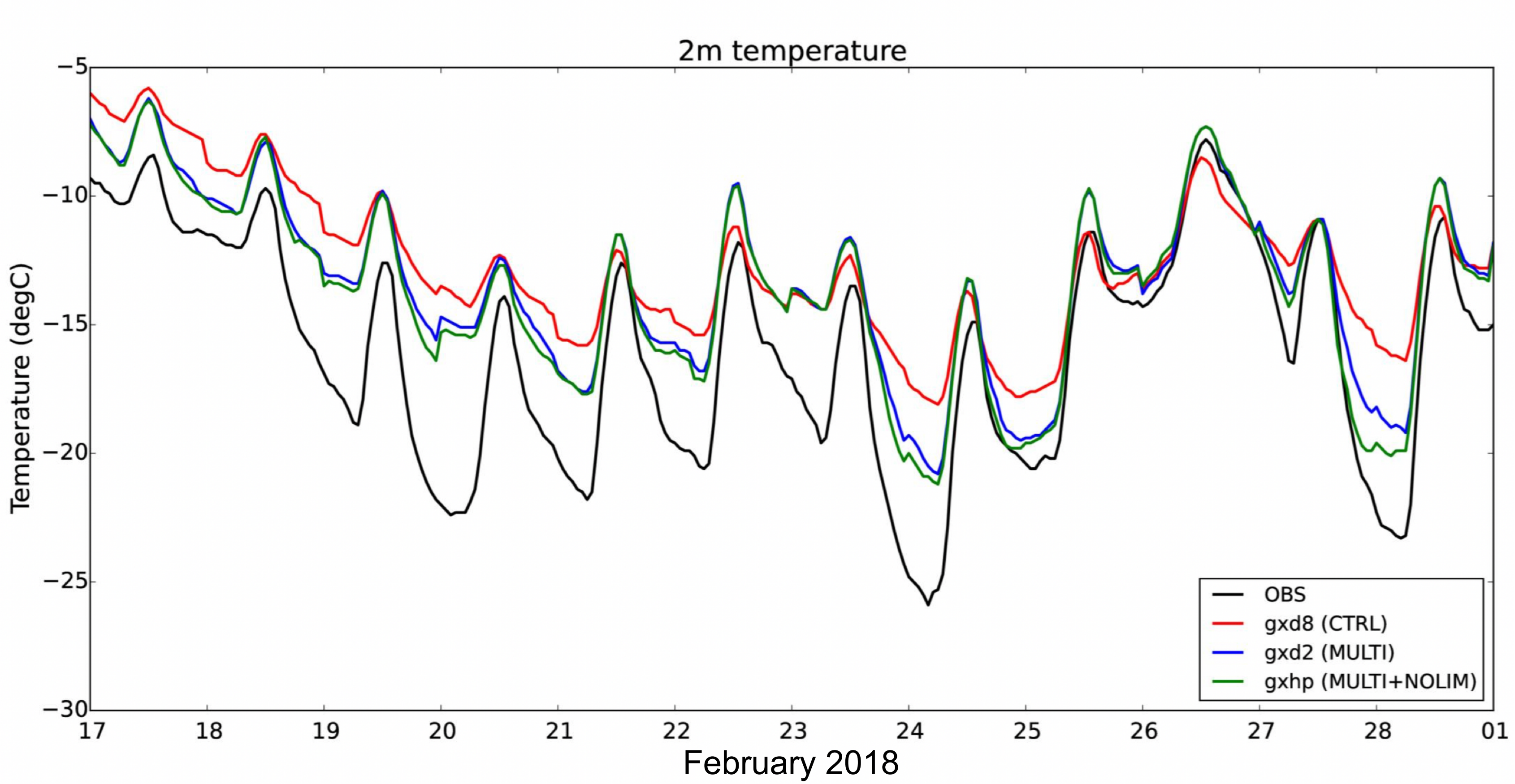
Winter reduction of the 2m minima temperatures with increasing diurnal-cycle. DIFF Tmin 2-4 K colder in ML compared to SL snow. Increased variability

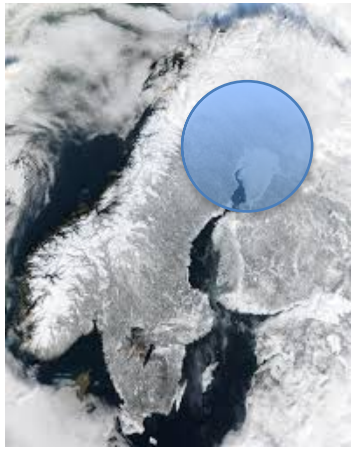
Thanks to Gabriele Arduini, Jonny Day, Linus Magnusson

Impact of snow model vertical resolution increase on near surface temperature

Increased vertical discretization of the snowpack (**up to 5 layers**) permits a better 2-m forecast: here hourly day-2 forecasts are shown for 24-hour to 47-hour ahead, concatenated to form a continuous time-series

T2m Observations, T2m forecast (current snow, SL), T2m forecast (ML)





In clear-sky the MULTI-layer snow scheme is capable to produce stronger winter inversions improving observation match.

NOLIM indicates a stability limiter safety is deactivated.

The increased variability in the diurnal cycle is beneficial for ensemble forecasting.

Thanks to Gabriele Arduini, Thomas Haiden, Irina Sandu & USURF Team

Summary

- Coupled modelling: a more seamless coupling in 45r1, all forecasts have the same land/ocean
- Coupled assimilation: land-ocean-sea-ice-atmosphere weakly coupled
- SMOS neural network SM assimilation in IFS
- Reanalyses: ERA5 use of Scatterometer series ERS/SCAT and Metop ASCAT
- Flood forecasts: benefits from overall improvements in the ECMWF IFS, including soil moisture DA
- Plans to investigate satellite soil moisture DA for extreme events NWP & flood FC
- Plans to enhance the vertical discretisation of snow/soil layers progressed (snow-ready-for-cy47)

Earth surface modelling components @ECMWF in 2018

- **NEMO3.4**

  NEMO3.4 (Nucleus for European Modelling of the Ocean)

  Madec et al. (2008)

  Mogensen et al. (2012)

  ORCA1_Z42: 1.0° x 1.0°

  ORCA025_Z75 : 0.25° x 0.25°

- **EC-WAM**

  ECMWF Wave Model

  Janssen, (2004)

  Janssen et al. (2013)

  ENS-WAM : 0.25° x 0.25°

  HRES-WAM: 0.125° x 0.125°

- **LIM2**

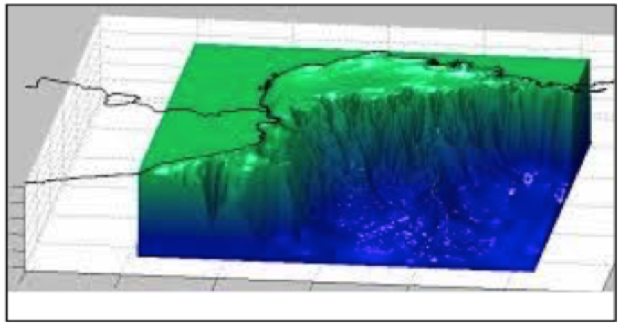
  The Louvain-la-Neuve Sea Ice Model

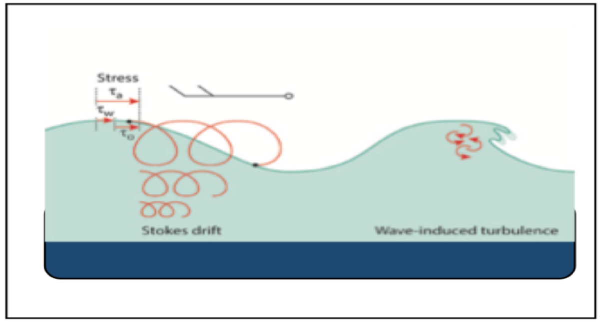
  Fichefet and Morales Maqueda (1997)

  Bouillon et al. (2009)

  Vancoppenolle et al. (2009)

  ORCA025_Z75 : 0.25° x 0.25°





- **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. (2013)

  New satellite-based

  Leaf-Area-Index

- **SOIL Evaporation**

  Balsamo et al. (2011),

  Albergel et al. (2012)

- **H_2O / E / CO_2**

  Integration of

  Carbon/Energy/Water

  Boussetta et al. 2013

  Agusti-Panareda et al. 2015

- **Lake & Coastal area**

  Mironov et al (2010),

  Dutra et al. (2010),

  Balsamo et al. (2012, 2010)

  Extra tile (9) to for sub-grid lakes and ice

  LW tiling (Dutra)

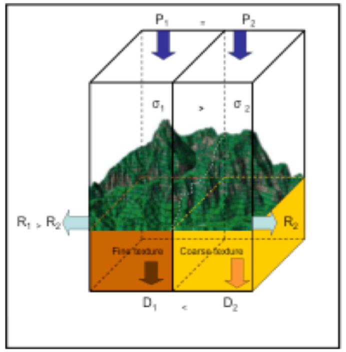
- **Enhance ML**

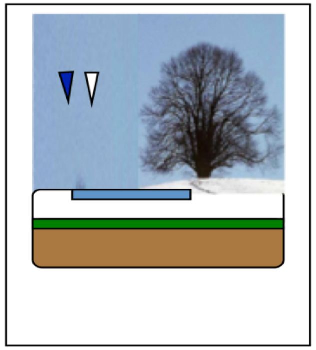
  Snow ML5

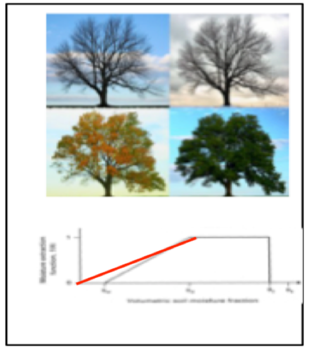
  Soil ML9

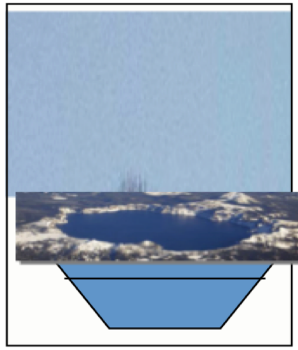
  Dutra et al. (2012, 2016)

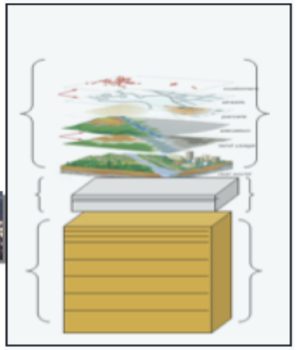
  Balsamo et al. (2016)











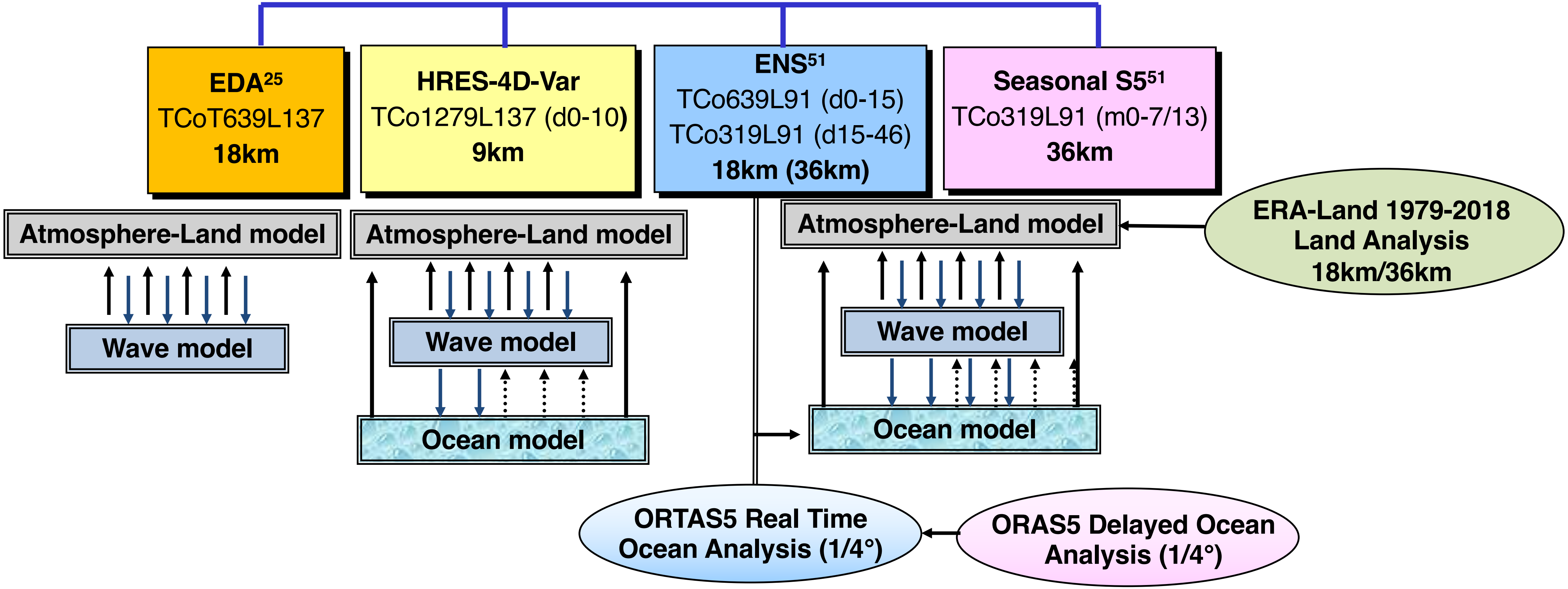
Atmos Land Resol.	**ECMWF in 2018**
80 km	ERAI
32 km	ERA5+ SEAS5+*
18 km	ENS+*
9 km	HRES+*

***Ocean** used across forecast systems and in Ocean reanalysis

(*migration completed with HRES-coupled operational from the 5th June 2018)

+Land used across forecast systems and new Climate reanalysis

Seamless surface-atmosphere coupling of Integrated Forecasting System as operational from June 5th, 2018



See Buizza et al (2018), Keeley et al (2018), Mogensen et al (2018), published in the ECMWF 2018 Summer Newsletter