Towards the assimilation of soil moisture in the **COMET** Ensemble Data Assimilation System

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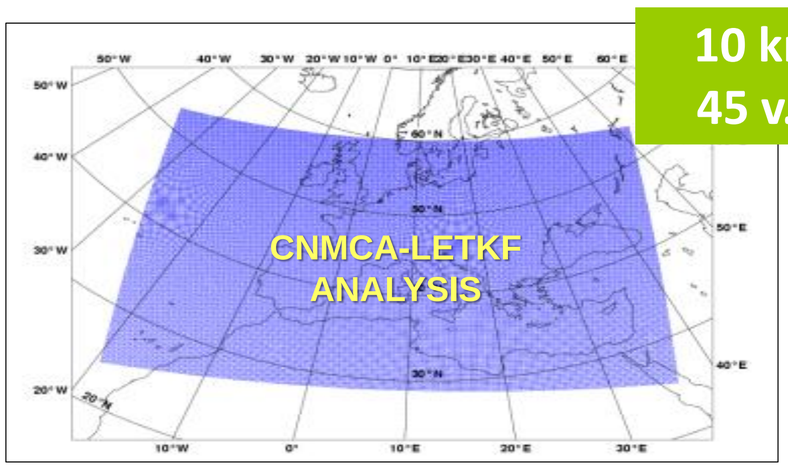
Operational COMET Ensemble Data Assimilation System

CNMCA – LETKF (*Bonavita, Torrisi and Marcucci, Q.J.R.M.S.,2008,2010)*

- ***OPERATIONAL SINCE 1 JUNE 2011*** *CNMCA/COMET is the first meteorological centre which uses operationally a pure EnKF DA to initialize a deterministic NWP model*
- ***LETKF Formulation*** *(Hunt et al,2007)*



CNMCA-LETKF Analysis Members

- 6-hourly assimilation cycle
- 40 ensemble members + deterministic run with 0.09° (~10Km) grid spacing (COSMO model), 45 hybrid z-sigma vertical levels (top at ~27km)
- (T,u,v,pseudoRH,ps) set of control variables
- Observations: using RAOB (also 4D), PILOT, SYNOP, SHIP, BUOY, Wind Profilers, AMDAR-ACAR-AIREP, MSG3-MET7 AMV, MetopA-B scatt. winds, NOAA/MetopA-B AMSUA/MHS and NPP ATMS radiances + LandSAF snowmask.
- "Relaxation-to-Prior Spread" Multiplicative Inflaction according to Whitaker et al (2010)

an. pert. $\mathbf{x}_a' = \mathbf{x}_a' \sqrt{\alpha \frac{\sigma_b^2 - \sigma_a^2}{\sigma_a^2} + 1}$ α = 0.95, σ^2 = variance

- Additive noise from EPS
- Lateral Boundary Condition from deterministic IFS perturbed with ECMWF-EPS
- Climatological Perturbed SST
- Adaptive selection radius using a fixed number of effective observations (sum of obs weights)

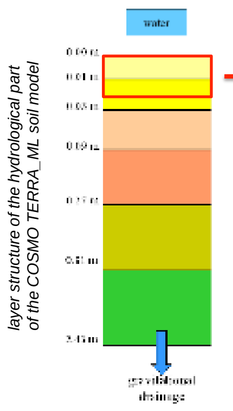
DeterministicAnalysis
computed using the standard LETKF-Kalman gain and the deterministic short-range forecast

SOIL MOISTURE ASSIMILATION : PRE-PROCESSING OF ASCAT HSAF SOIL MOISTURE DATA

Transformed SOIL MOISTURE

- HSAF ASCAT derived Soil Moisture: **degree of saturation** (%) in the first 2 cm
- COSMO TERRA_ML model soil moisture: **liquid water content** (m H2O) in the various model layers

COSMO TERRA_ML
8 different soil types: ice, rock, sand, sandy loam, loam ,loamy clay, clay, peat



layer structure of the hydrological part of the COSMO TERRA_ML soil model

To compare observed and model values the model values are transformed (to have quantities independent from the thickness of the layers) in **volumetric water content** (m^3/m^3) and then interpolated in the first 2 cm

+

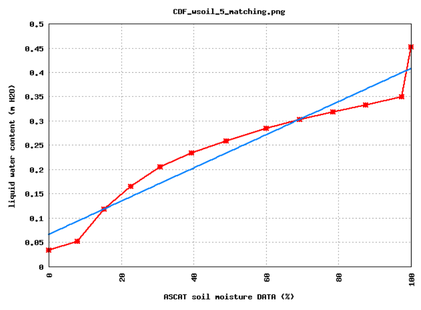
NEED TO RESCALE THE SATELLITE OBS TO THE MODEL VALUES

- **Normalization methods**
- **CDF matching method**

CDF matching

To scale the ASCAT derived soil moisture to the model climatology so that the cumulative distribution functions (CDF) of satellite and model soil moisture match.

choice of the soil type to assign to an ASCAT observation : nearest grid-point or the most probable among the 9-nearest ones
CDF matching performed for each soil type separately (8 different soil types) in COSMO TERRA)
Piece wise sample CDF for ASCAT and model sm data, using 13 percentiles
Linear regression analysis of ASCAT data plotted against model data: "total regression analysis" or "local regression analysis"

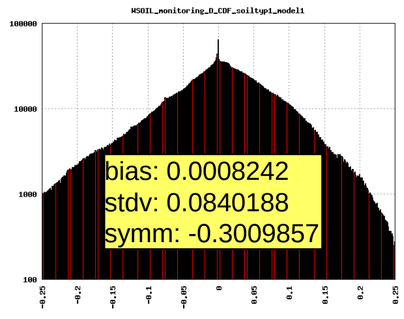


CDF matching: **local regression analysis**
global regression analysis

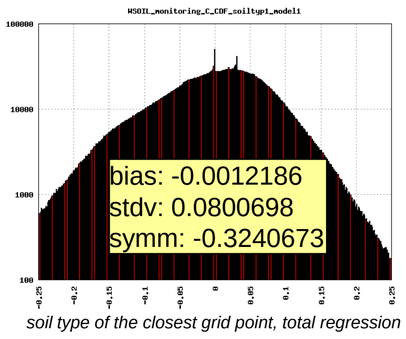
$$\omega_{obs} = max\left(0, a + b\frac{\theta_{obs}}{100}\right)$$

b slope, a intercept

OBS INCREMENTS STATISTICS (january 2015 - january 2016)



soil type of the closest grid point, local regression



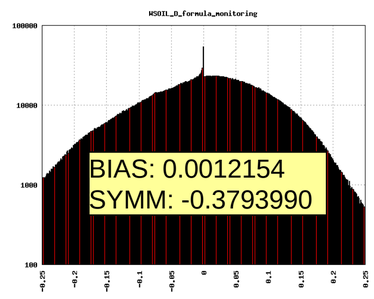
soil type of the closest grid point, total regression

Normalization methods

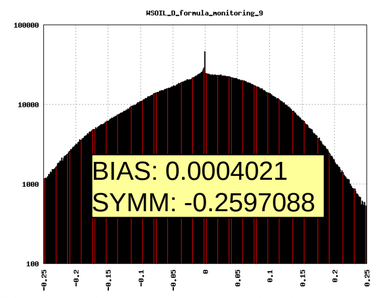
$$\omega_{obs} = \omega_{ADP} + \frac{\theta_{obs}}{100}(\omega_{PV} - \omega_{ADP})$$

Volume of voids (ω_{PV}): maximum possible volume of water that the soil can hold
Field capacity (ω_{FC}): amount of soil moisture held in the soil after excess water has drained away and the rate of downward movement has decreased.
Wilting point (ω_{PWP}): the minimal amount of water the plant requires not to wilt
Air Dryness point (ω_{ADP}): minimum possible amount of water that can remain in the soil

OBS INCREMENTS STATISTICS (january 2015 - january 2016)



soil type of the grid point closest to the obs



soil type most probable among the 9 grid points closest to the obs

DATA QUALITY CONTROL

ASCAT data is rejected where:
- *snow:* the analysed snow amount is greater than 0.05 kg/m^2
- *frost:* the 2m Temperature analysis is below 275.15 K
- *wetlands:* the inundation and wetland amount has a value greater than 15%
- *mountains:* the topographic complexity has a value greater than 20%
- *ASCAT estimated error:* the error in the ASCAT surface soil wetness is estimated to be greater than 7% (Met Office) or 8% (ECMWF). This check rejects ASCAT data from regions with dense vegetation and sand dunes.

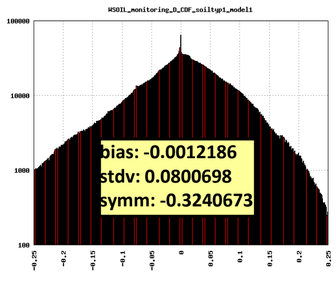
The soil moisture's obs increments are **highly non gaussian**, too concentrated around the value 0 (in dry and saturated condition)

To avoid discarding good quality observations, a control variable for the soil moisture whose increments have a gaussian behavior could be obtained, so to apply the quality control to this control variable

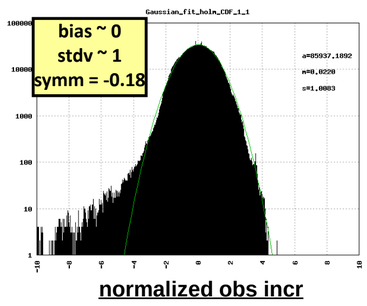
METHOD PROPOSED by HOLM (2001)

- Find a variable φ whose forecast difference $\delta\varphi$ follows a gaussian conditional error distribution $P(\delta\varphi|\phi)$ as a function of some variable ϕ ;
- Determine the bias ($b(\phi)$) and standard deviation ($\sigma(\phi)$) of the forecast differences as a function of ϕ, with the bias preferably negligible;
- Normalize forecast differences by the bias and standard deviation $\tilde{\delta\varphi} = \frac{\delta\varphi - b(\Phi)}{\sigma(\Phi)}; \quad (1)$
- Change the control variable according to equation **(1)**.

OBS INCREMENTS (CDF technique)
(january 2015 - january 2016)



not normalized obs incr



normalized obs incr

CURRENT AND FUTURE DEVELOPMENTS

1. **Use of derived soil moisture increments in the KENDA-LETKF code, to improve the analysis of atmospheric variables in the lowest levels**
2. **Development of a suitable soil moisture analysis**
3. **retuning of observation increments at higher resolution (2.8 km)**