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Extended Kalman Filter based Land Data Assimilation System for Soil Moisture Analysis at NCMRWF

Abhishek Lodh, John. P. George and E.N. Rajagopal

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National Centre for Medium Range Weather Forecasting
Ministry of Earth Sciences, Government of India
A-50, Sector-62, NOIDA-201309, INDIA

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10	Abstract	An Extended Kalman Filter (EKF) based land data assimilation system of UK Met Office (UKMO) is used at NCMRWF for global soil moisture assimilation. Since the spatial and temporal variability of soil moisture is high and the availability of in-situ observations is limited, soil moisture information from satellites is crucial for soil moisture analysis, even though satellite measurements have lot of limitations (e.g., It represents only thin soil layer and have vegetation/terrain dependency). The advantage of EKF based system includes improved propagation of surface soil moisture information available from satellite to the deeper layers effectively. In this report the details of the soil moisture assimilation using the EKF system at NCMRWF and the results from sensitivity experiment conducted using NRSC/ISRO LuLc are presented.
11	Security classification	Unrestricted
12	Distribution	General
13	Key Words	Land Data Assimilation, Extended Kalman Filter, Soil Moisture

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Abstract

Land surface variables such as soil moisture play a major role in the exchange of moisture and heat between the land surface and the atmosphere. Assimilation of land surface variables aims at constraining errors of the numerical weather prediction by providing the improved initial surface conditions. An Extended Kalman Filter (EKF) based land data assimilation system of UK Met Office (UKMO) is used at NCMRWF for global soil moisture assimilation. Since the spatial and temporal variability of soil moisture is high and the availability of in-situ observations is limited, soil moisture information from satellites is crucial for soil moisture analysis, even though satellite measurements have lot of limitations (e.g., it can provide an estimate of the moisture only of the thin surface soil layer and have vegetation/terrain dependency). The advantage of EKF based system includes improved propagation of surface soil moisture information available from satellite to the deeper layers effectively. Additionally, the EKF based land data assimilation system is highly flexible and, in principle, any model land variable can be assimilated (such as soil moisture, soil temperature, snow amount and vegetation properties [such as LAI]) by this system. However, this report presents only the details of the soil moisture assimilation using the EKF system at NCMRWF and also the results of the sensitivity experiments conducted with NRSC/ISRO land use land cover (LuLc).

1. Introduction

Land surface influence the atmosphere mainly through the exchange of water and energy. In numerical weather prediction (NWP), several studies have shown that land surface processes can affect significantly the skill of short and medium range weather forecasts and has the potential of enhancing the seasonal predictability (Douville et al., 1998, 2000; Hess, 2001; Drusch and Viterbo, 2007). Hence, better initialization of land surface variables (one of the surface boundary conditions) such as soil moisture in numerical weather prediction (NWP) models improves the forecasts, especially the surface variables and hydrological cycle (Dharssi et al., 2011, De et al., 2011).

Atmospheric initialization is an old problem with many decades of use of various data assimilation techniques, including ensemble methods. However, data assimilation for land surface variables (e.g., soil moisture) are relatively new, and a variety of methods have been proposed in the recent past. Initially, the techniques used by leading NWP centres in the world (e.g., ECMWF, Meteo-France, German Weather service) for soil moisture assimilation includes optimal interpolation (OI) based soil moisture analysis scheme (Giard and Bazile, 2000, Drusch and Viterbo, 2007) and soil moisture nudging scheme (Mahfouf et al., 2000). However, most of the leading NWP centres have moved to more advanced techniques in the recent past (e.g., ECMWF's Extended Kalman Filter based assimilation system, De et al., 2011).

UK Met Office (UKMO) started the soil moisture assimilation with simple nudging scheme which makes use of screen level analysis of temperature and humidity and later included satellite (ASCAT soil wetness from MetOp satellite) soil moisture observations (Dharssi et al., 2011). UKMO currently uses an Extended Kalman Filter (EKF) based Land Data Assimilation system for soil moisture analysis (Dharssi et al., 2015). Recently National Centre for Medium Range Weather Forecasting (NCMRWF) adapted this scheme for soil moisture assimilation. There are various advantages of this scheme which includes penetration of surface observations (available from satellites) to deeper layers effectively. The EKF system is highly flexible and, in principle, any land variable can be assimilated (such as soil moisture, soil temperature, snow amount and vegetation properties [such as LAI]) in this system. However, this report presents only the details of the soil moisture assimilation using the EKF system.

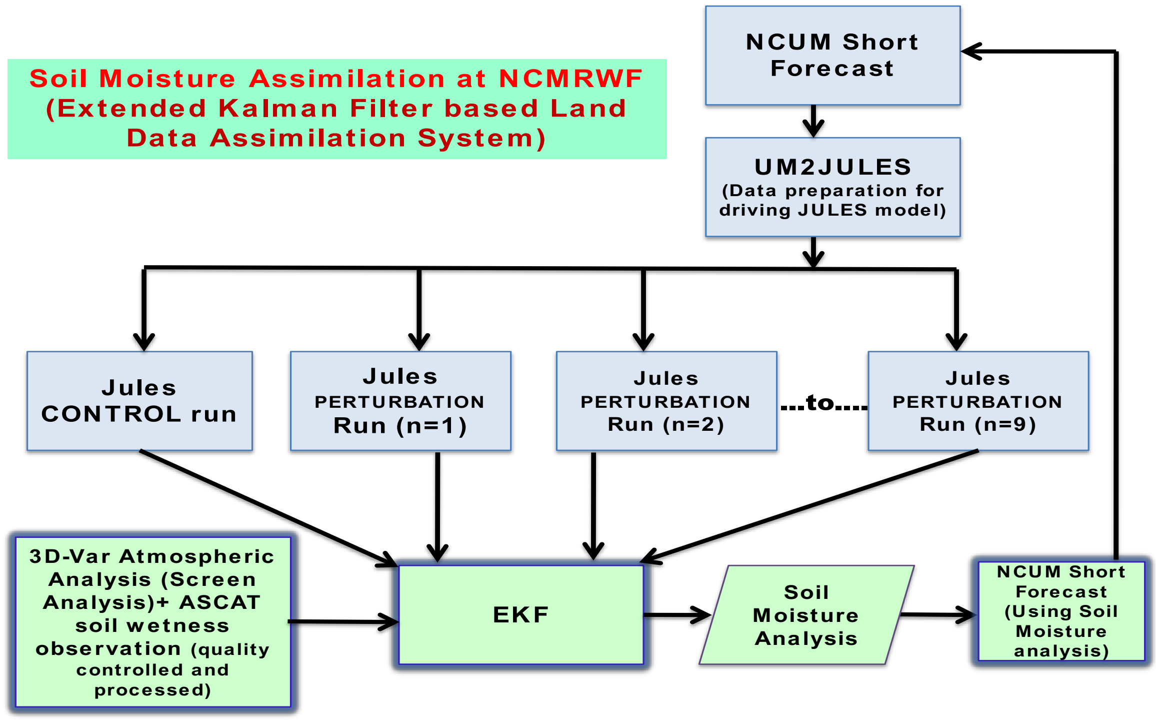

Figure 1: Schematic of Extended Kalman Filter (EKF) based Land Data Assimilation system used for soil moisture assimilation at NCMRWF

2. Significance of EKF based Assimilation system

Some of the important aspects of the EKF land data assimilation system implemented at NCMRWF are described below:

- Extended Kalman Filter (EKF) based land data assimilation (DA) system implemented at NCMRWF uses JULES (the Joint UK Land Environment Simulator) land surface model. JULES land surface model has evolved from the UKMO Surface Exchange Scheme (MOSES). JULES has a tiled model of sub-grid heterogeneity with separate surface temperatures, short-wave and long-wave radiative fluxes, sensible and latent heat fluxes, ground heat fluxes, canopy moisture contents, snow masses and snow melt rates computed for each surface type in a grid-box (JULES model details are available at https://jules.jchmr.org/). Nine surface types used in JULES model includes five plant types (broadleaf trees, needle-leaf trees, temperate grass [C3] , tropical grass [C4] and Shrubs) and four non-vegetation types (urban, inland water, bare soil and land-ice).
- The EKF land DA system is flexible and in principle can analyze any land surface

variable. The present EKF system can produce analysis of soil moisture & soil temperature at four soil layers (JULES land surface scheme has four layers of soil with 10, 25, 65 and 200 cm thickness) and skin temperature. However, presently soil moisture observations are only assimilated.

- A key component of the EKF system is the calculation of the Jacobians of the observation operator which describe the link between the observations and the land surface model variables. The Jacobians are estimated using finite difference by performing simulations of land surface model (JULES model) with perturbed initial conditions (Dharssi et al., 2012, 2015). The EKF land data assimilation system implemented at NCMRWF uses off-line JULES for the perturbation forecasts. The number of perturbed forecasts depends on number of model variables to be analysed. For analysis of land surface temperature, soil moisture and temperature on four soil levels require ten perturbed forecasts, including the control forecast. At NCMRWF currently ten perturbed (9 perturbed + 1 control) runs are being generated and shortly, land surface temperature observations will be assimilated in this system. The length of a perturbed forecast is typically few hours long (covering the assimilation window) but can be as short as one time-step, depending on the observations assimilated.

3. Components of EKF based System for soil moisture assimilation

NCMRWF uses Unified Model (NCUM) for operational global and regional numerical weather prediction. Ten day forecasts are produced routinely using the NCUM model. Surface conditions over land viz., soil moisture analysis is a major input to the NCUM model. State-of-art surface field processing (SURF) program modules of UKMO is used at NCMRWF for the preparation of surface analysis. The different modules of the EKF based Soil Moisture Analysis Scheme are described below. Some of the scientific and technical details of the EKF based land data assimilation system and its components are also described in following sub-sections.

3.1 NCUM Atmospheric Forcings for JULES

Horizontal resolution of the global NCUM is 17 km in horizontal (N768) with 70 levels in the vertical reaching up to the height of 80 km above the earth surface. The model has JULES land surface scheme. The soil is discretized into four layers of 10, 25, 65 and 200 cm thickness (from top to bottom, top layer close the surface is 10 cm). A summary of the Global N768L70 model is given in Table 1. Ten day global forecasts are produced routinely using the NCMRWF Unified Model (NCUM) based on 00 UTC initial conditions. Soil moisture analysis generated by the EKF system at every 6 hourly (00, 06, 12 and 18 UTC) are used to initialize the short forecast (same global model) used in the data assimilation cycle (00, 06, 12 and 18 UTC). Atmospheric forcing (driving data) for the JULES land surface model is produced during the short forecast (precipitation, surface LW and SW radiation, air temperature and humidity, wind speed and surface pressure) of NCUM global model.

Table 1: Summary of the Unified Model at NCMRWF for Global NWP

Unified Model Version	8.5 (UM8.5)
Dynamical core	ENDGame (Even Newer Dynamics for General Atmospheric Modelling of the Environment)
Horizontal Resolution	~ 17 km in mid-latitudes
Grid	1536 x 1152
Model levels	70, lid ~80 km height
Forecast length (based on 00 UTC)	240 hrs
Time step	7.5 minutes
Radiation Time Step	1 hour

3.2 Generation of NCUM Atmospheric Forcings in JULES input format (UM2JULES)

This task of the land data assimilation system prepares the short-forecast (within the data assimilation window) output of NCUM atmospheric model in the desired format for the JULES stand alone model (for stand-alone simulation) at each grid point (land) over entire globe (i.e., this task extracts the JULES driving data from NCUM forecast files and write it out in a format that JULES can understand).

3.3 JULES Land Surface Model Offline Run (Perturbation runs)

Jacobians (which provide the key link between the observation space and model space within the EKF) are computed from offline simulations of JULES land surface model with forcing (driving data) from the NCUM short forecast. We run one unperturbed (control) run of the land surface model and one perturbed run per control variable (in the current implementation the control variables are soil moisture on 4 soil levels, 1 skin temp and 4 level soil temperature which requires 9 perturbed runs). The length of perturbation and control runs are set to 3 hours in the current implementation to reduce the computing time of the simulations. In an attempt to reduce the amount of computing time used for the JULES forecast over all grid points over globe (for producing Jacobians), an option to split the model domain into a pre-determined number of equal-sized partitions has been adopted. Currently we are splitting the global domain into four equally sized partitions.

3.4 Extended Kalman Filter

Following Ide et al. (1997), the analysed soil moisture state vector X_a at time t_i for each grid point can be written as:

$$X_a(t_i) = X_b(t_i) + K_i\,[y_o(t_i) - h_i(x_b)]$$

Here, y_o the observation vector for screen (soil temperature and soil moisture) errors. The subscripts *a*, *b*, *o* stands for analysis, background and observations.

$$K_i = BH_i^T\,(H_iBH_i^T + R)^{-1}$$

K_i is Kalman gain matrix at time t_i, H_i is the Jacobian (linearisation) of the non-linear observation operator h_i and is defined using $h_i\,(x + x') \approx h_i\,(x) + H_i x'$ where x' is a small perturbation to the model state x. The elements of H_i are estimated using finite difference by individually perturbing each component of x by a small amount x'. A given element of H_i is calculated using

$$H_{ki} = \frac{h_{ki}(x + x_i') - h_{ki}(x)}{x'_i}$$

Where h_k (x) is a short model (JULES) forecast (control) of "observation output type" *k*. h_k (x+x') is a perturbation forecast starting from perturbed initial conditions x_b + x'. The number of perturbed forecasts required increases with the number of model variables to be analyses and the number of soil layers. The data assimilation problem is kept manageable in this implementation of EKF by assuming that the model land columns are independent of each other (one dimensional approach).

Thus summarizing, an EKF based Land data-assimilation system acts on each grid point column individually. For each grid-point analysis the following steps are required:

- An analysis vector containing the soil moisture field that we wish to analyse. A typical run might include level 1 soil moisture, level 2 soil moisture, level 3 soil moisture, level 4 soil moisture, level1 soil temperature, level 2 soil temperature, level 3 soil temperature, level 4 soil temperature, skin temperature. Hence, size of vector X (size

x) is 9.

- A vector of observations y valid at this grid-point. A typical EKF run includes Screen Error T, Screen Error Q and ASCAT gridded observation in volumetric units. Hence, number of observations (nobs) is 3.
- Observation error covariance matrix R (nobs, nobs). Observations are assumed to be uncorrelated in error (at each grid-point) and so the matrix is diagonal, constructed from the namelist observation errors.
- Background covariance matrix B (sizex, sizex). Background errors are also assumed to be uncorrelated, constructed from namelist background errors.
- Jacobian matrix or Hmatrix (nobs, sizex). Each element contains the sensitivity of the observation with respect to analysis vector and are estimated from Jules perturbation runs, compared to a control in which no perturbation is applied.

3.5 Observations used in soil moisture assimilation system

In-situ observation network is very limited and is inadequate to represent the spatial distribution of soil moisture over most parts of the world including Indian region. So for the preparation of soil moisture analysis, the only practical way is to gather the indirect observations of soil moisture (Best et al., 2007). Mahfouf (2009) has shown that screen level information of meteorological variables (SYNOP observations – Surface meteorological observation) can provide reliable information on soil moisture. The lowest level analysis increment of temperature and humidity from the atmospheric analysis is used in the soil moisture assimilation system implemented at NCMRWF. The analysis increments are produced by a “Screen 3D-Var” data assimilation system using only screen level observations in the atmospheric data assimilation system.

In recent years, significant progress has been achieved in the space based soil moisture estimation. The active sensor ASCAT (operating at 5.255 GHz) and using vertically polarized antennas on Metop-A (launched on 19 October 2006) and Metop-B (launched on 17 September 2012) provides good quality information about surface soil wetness. Hence, these ASCAT observations which provides information on soil moisture can be used in data assimilation system. ASCAT surface soil wetness observations from Metop-A and Metop-B satellites are available in near-real time through MOSDAC/ISRO (received through EUMETCast). However, the major limitation of the satellite soil moisture observations (depends on the sensor frequency) is that the soil moisture information is limited to upper few centimeters of the soil.

The steps involved in the pre-processing of satellite observations for EKF job is explained in Figure 13 of Appendix A and the list of changes done to build SURface Fields Processing platform (SURF version 30.0.1) at NCMRWF are listed in Appendix B.

More details about the setup of the EKF based land data assimilation system can be found at the links given below:

- https://code.metoffice.gov.uk/doc/surf/surf-32.0.0/doc/SUDP7.html
- https://code.metoffice.gov.uk/doc/surf/surf-32.0.0/doc/SUDP16.html
- https://code.metoffice.gov.uk/doc/surf/surf-32.0.0/doc/SUDP17.html

4. Results

4.1 Verification of Soil Moisture analysis

The global soil moisture analysis (surface layer, 0-10 cm) generated at NCMRWF using EKF based Land DA system at N512 resolution (~25 km) was compared against UKMO analysis of soil moisture N768 resolution (~17 km) at the time of implementation of the EKF system at NCMRWF (Figure 2). The correlation coefficient of the two different soil moisture analyses over whole globe is around 0.92 (for any typical day) even though there is a difference in spatial resolution of the analysis system and some difference in observations used as well as the background field. The mean and root-mean square error of NCUM and UKMO soil moisture for month of January 2015 is shown in Figure 3 and 4, respectively. In January both the analysis shows that over India, soil wetness lies between 0 to 0.1 m^3/m^3. The error of NCUM and UKMO soil moisture analyses when compared with AMSR2 satellite observations lies between ± 3% for January 2015.

For the comparison of soil wetness analysis (top layer soil moisture analysis) with observed satellite soil moisture products, it is customary to express soil moisture in volumetric units i.e. in volumetric fraction of soil water in a given soil depth. Soil wetness analysis (units: kg/m^2 or mm) is converted to volumetric soil moisture (units: m^3/m^3) using the formula: Volumetric soil moisture $= \frac{\text{Soil wetness}}{\rho_{water} \times \partial z} = 0.01 \times$ Soil wetness (for $\partial z = 100$ mm for first soil level and water density $\rho_{water} = 1000$ kg/m^3).

Figure 5 shows the mean NCUM and UKMO soil moisture for the month of July 2015. The regions of maximum soil moisture (0.4 m^3/m^3) are also the regions which receive high monsoon rainfall. Comparison of soil moisture (UKMO) analysis with *in-situ* IMD observations for station Hisar and Agra during JJAS 2013 is in shown in Figure 6. The soil moisture analysis is able to produce the highs and lows of soil moisture values from June to September 2013.

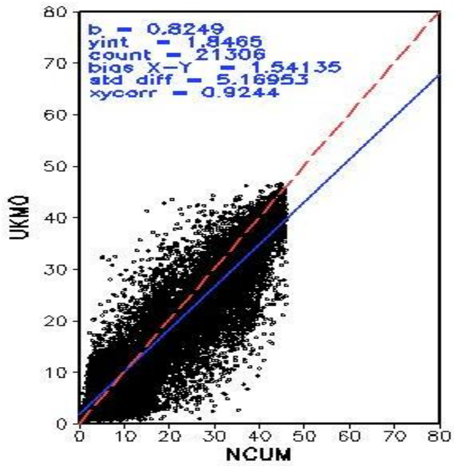

Figure 2: Comparison of Soil Moisture Analysis at first layer (kg/m^2) produced by NCMRWF at N512 and UKMO at N768 resolution for a typical day 25th November 2014

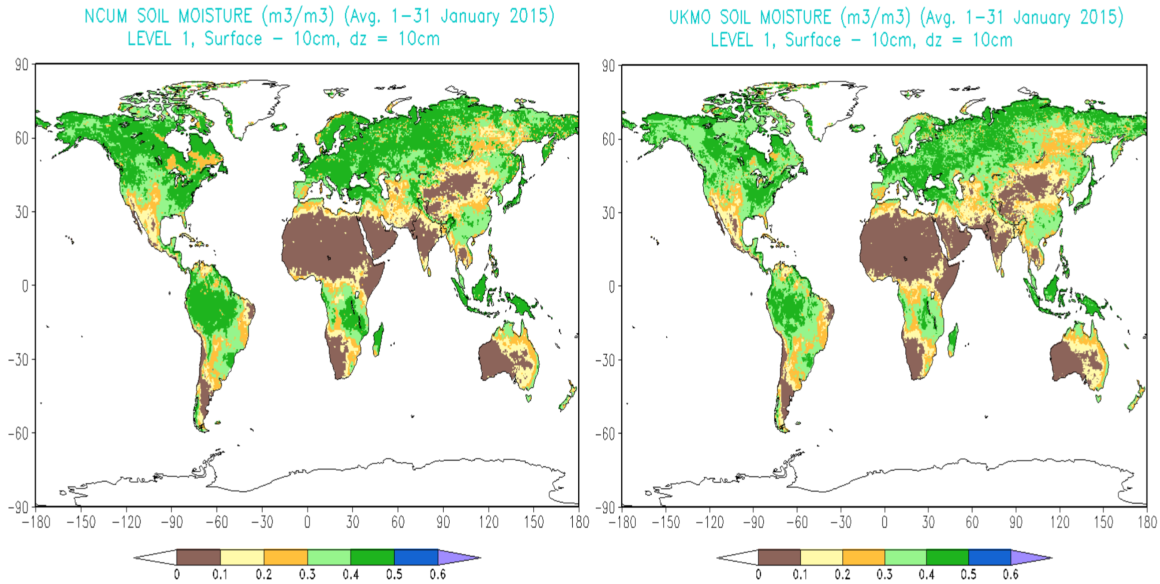

Figure 3: Comparison of the Average Soil Moisture Analysis at first layer (m^3/m^3) produced by NCMRWF at N512 and UKMO at N768 resolution for January 2015

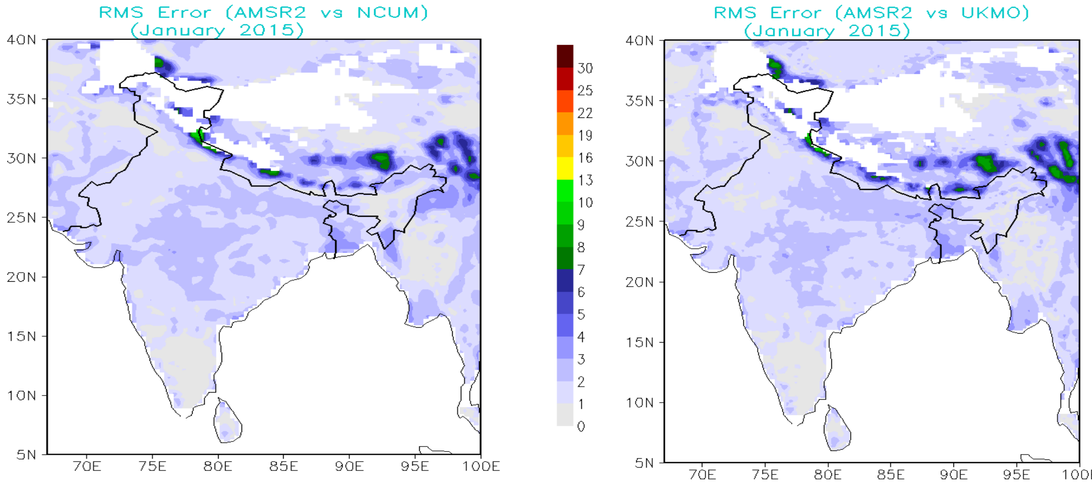

Figure 4: Root Mean Square error of Soil Moisture Analysis (m^3/m^3) at first layer produced by NCMRWF at N512 and UKMO at N768 resolution for January 2015

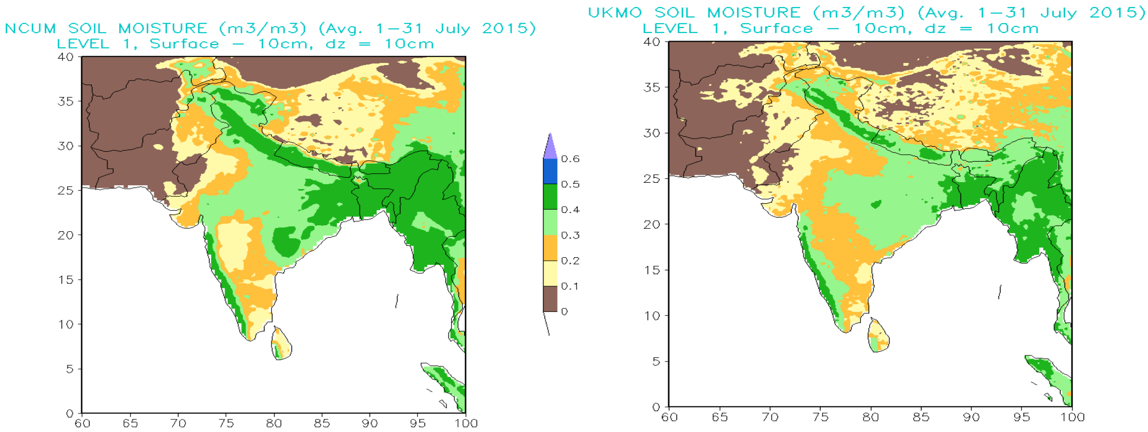

Figure 5: Comparison of Soil Moisture Analysis (over India domain) at first layer (m^3/m^3) produced by NCMRWF at N512 and UKMO at N768 resolution for July 2015

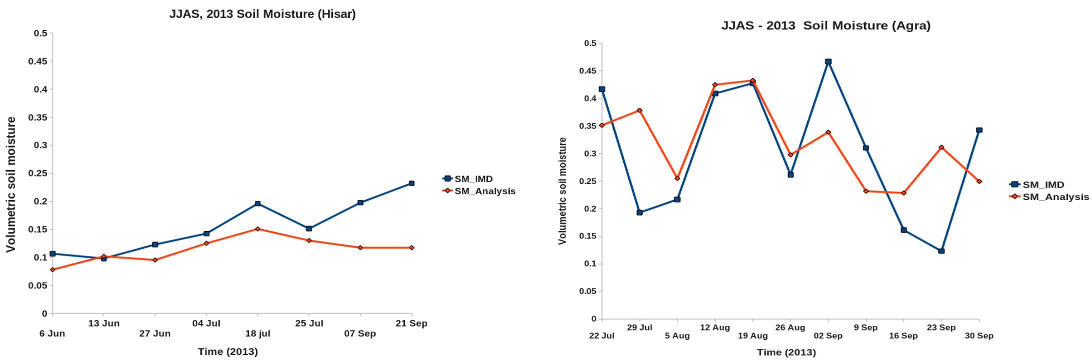

Figure 6: Comparison of Soil Moisture analysis (m^3/m^3) with IMD observations for station Hisar and Agra during JJAS 2013

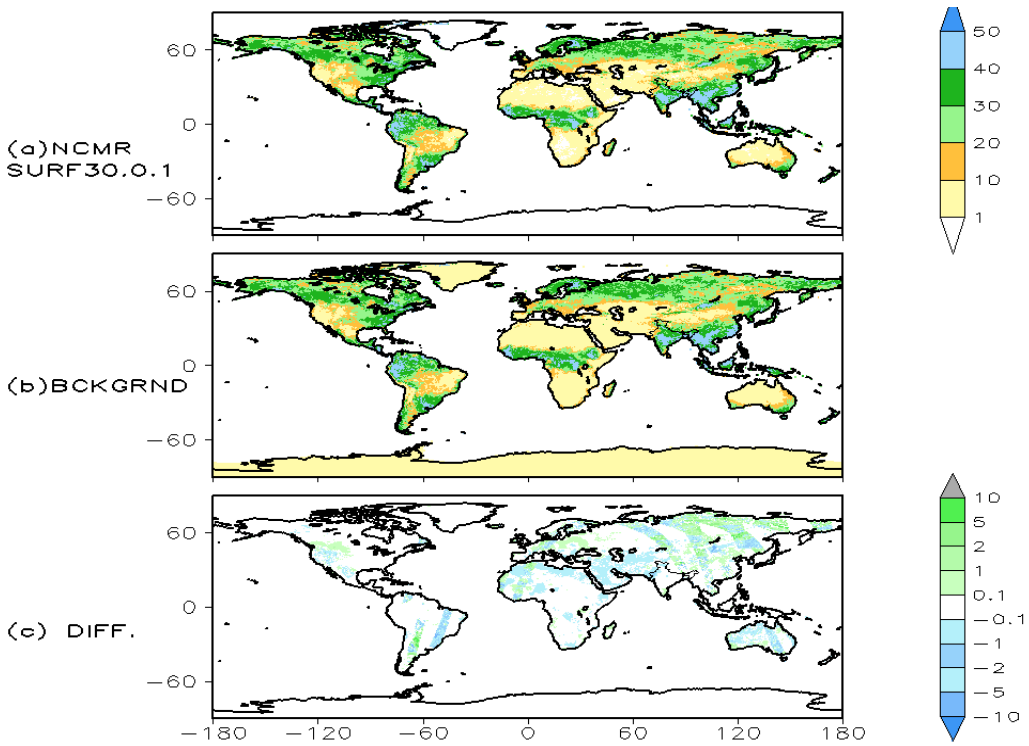

Figure 7: NCMRWF Soil Moisture Analysis (kg/m$^{2)}$ at N768 resolution and background soil moisture field for a typical day 12th August 2015, 06 UTC

The difference or increment in surface soil moisture (EKF based Land data assimilation) when compared with background soil moisture for a typical 12th August 2015, 06UTC cycle is shown in Figure 7, and it shows the importance of real-time satellite soil moisture data in the land data assimilation system.

Evolution of soil moisture (first layer) during the onset phase of monsoon 2015 from the UKMO assimilation system and the assimilation system at NCMRWF is presented in Figures 8 and 9 respectively. From these figures it is clear that NCMRWF assimilation system (NCMRWF and UKMO systems are nearly same but differ in the observation volume and the background fields) produce reasonably good analysis of soil moisture and it compares well with the UKMO soil moisture analysis.

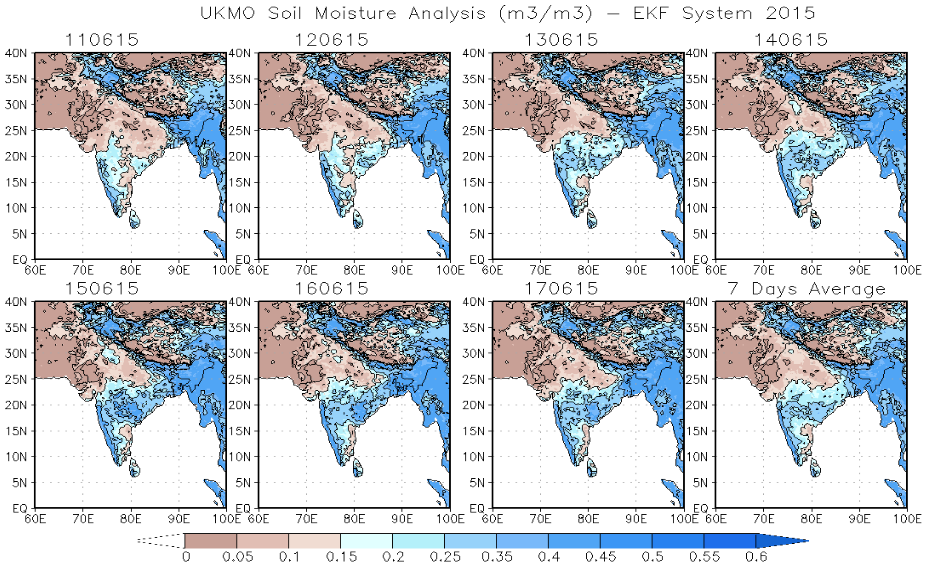

Figure 8: UK Met Office Soil Moisture analysis (m^3/m^3) during onset phase of Monsoon-2015

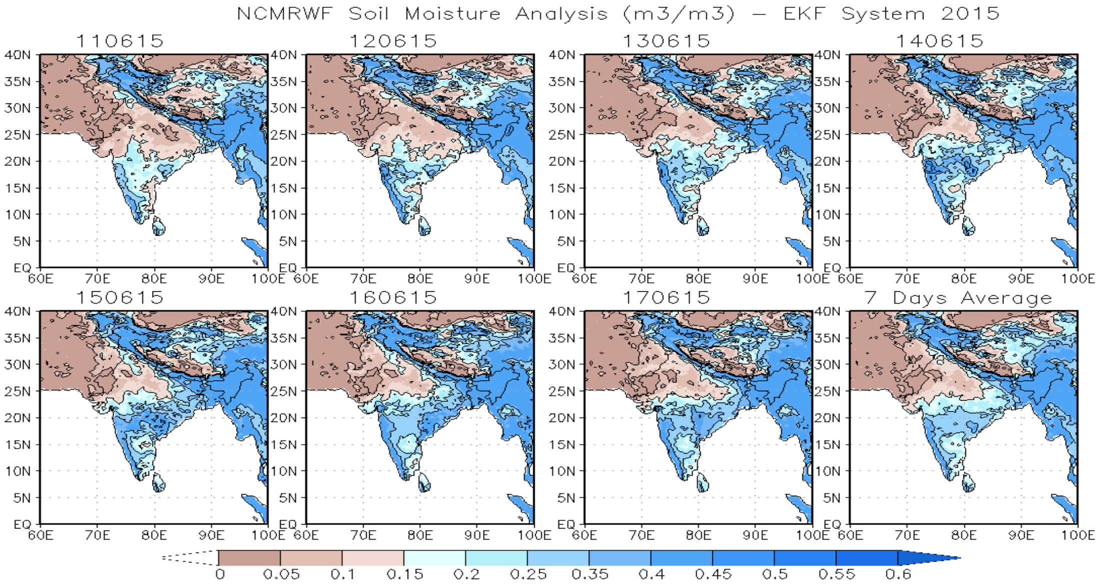

Figure 9: NCMRWF Soil Moisture analysis (m^3/m^3) during onset phase of Monsoon-2015

4.2 Comparison of analysis produced by EKF scheme with old nudging scheme

The EKF produced analysis is compared against the analysis prepared by simple nudging scheme (Best and Maisey, 2002) (both analysis use screen level analysis of temperature and humidity as well as ASCAT satellite soil moisture observations). Figure 10 reveals that in comparison with soil moisture analysis created by the nudging scheme, there is a reduction in soil moisture over Indian subcontinent in the EKF analysis, which is indicated in observations as well.

(a) (b)

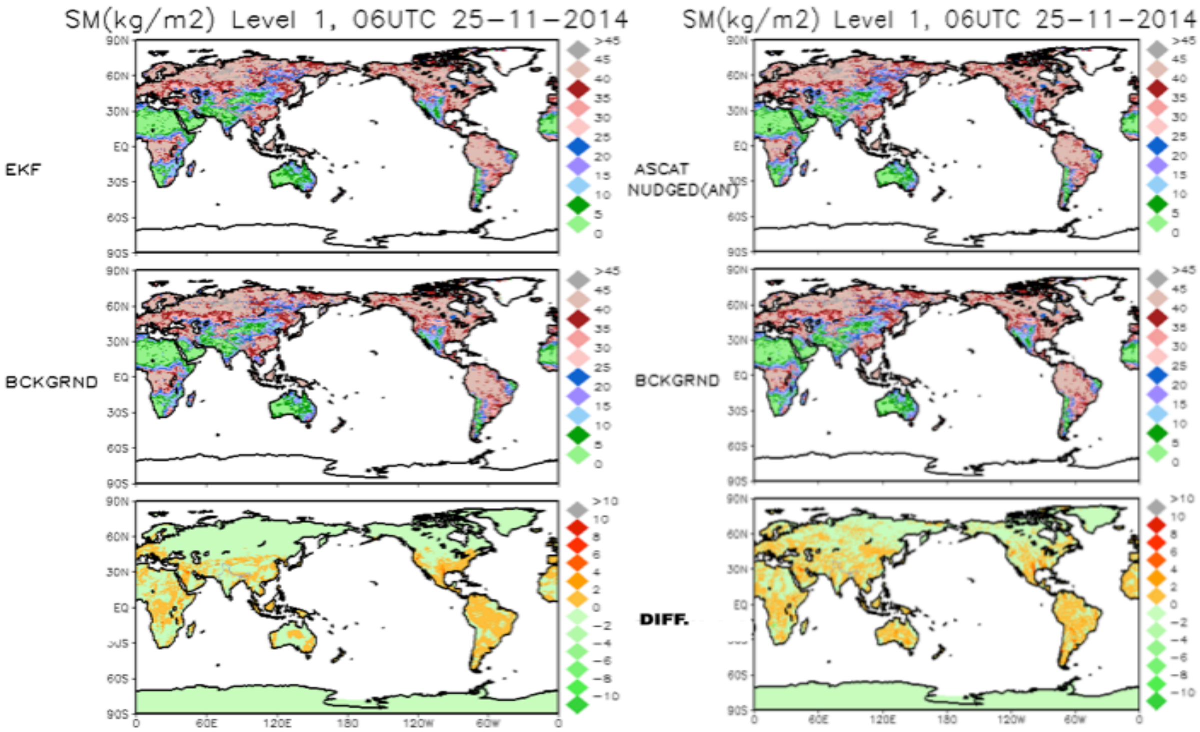

Figure 10: Soil moisture (level 1) (kg/m^2) analyses produced from (a) EKF (b) nudging scheme for 25th November 2014, 06 UTC and their difference with respective background soil moisture**.**

4.3 Impact of vegetation (land use/land cover modifications) on soil moisture analysis

The Joint UK Land Environment Simulator (JULES) model has sub-grid scale heterogeneity of land surface variables with 9 surface types. JULES originally uses comparatively old IGBP vegetation data set. A new land use/land cover dataset was generated by NRSC/ISRO for Indian region using recent satellite observations. Experiments are carried out with the new NRSC/ISRO dataset in JULES model instead of IGBP data to study the impact of the new land use/land cover (LuLc)data set (ISRO /NRSC) on soil moisture assimilation. Results show marginal impact in EKF soil moisture assimilation in the land use/land cover change (Figures 11 and 12).

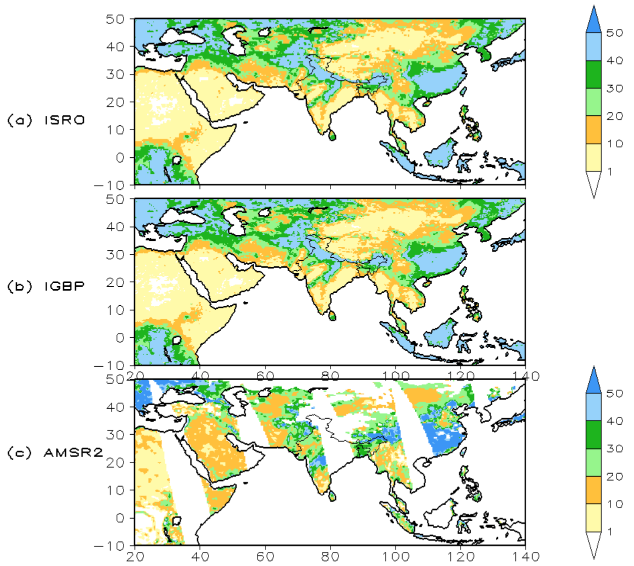

Figure 11: Soil moisture analysis (18 UTC 1st March 2015) (kg/m^2) using (a) ISRO LuLc (b) IGBP LuLc (c) AMSR2 satellite observations

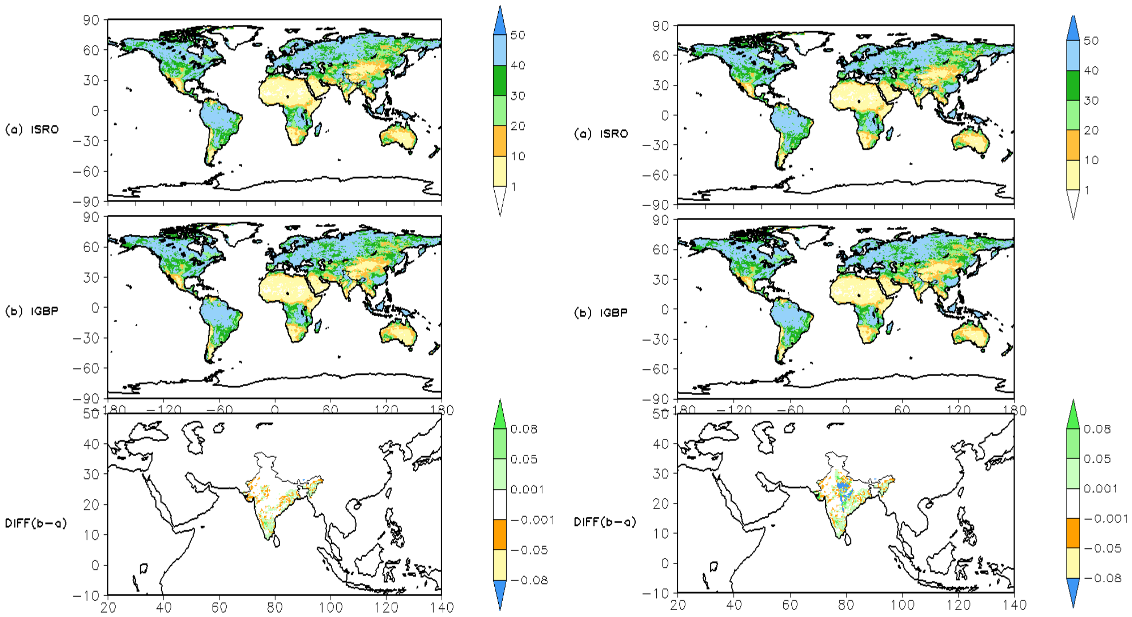

Figure 12: Difference in soil moisture analysis (ISRO – IGBP) (kg/m^2) (a) EKF without ASCAT obs. & (c) is EKF with ASCAT observations

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Appendix A: Scientific Overview of ASCAT - Nudging scheme

Nudging scheme (Best and Maisey, 2002) was included in SURF system to correct soil moisture from low-level analysis increments of specific humidity and skin temperature. If the model soil moisture is not allowed to evolve freely, it results in severe forecast errors due to unrealistic drying in the model. The problem is most acute in highly evaporative regions where hot and sunny weather persists, especially in tropics. In these circumstances, the model tends to over-evaporate resulting in a steady drying of the soil. There are insufficient direct measurements of soil moisture available to make any analysis scheme feasible and therefore errors in the forecasting of screen temperature and humidity are used as a proxy for errors in the soil moisture.
(Source : *Balsamo et al*., 2007: http://collaboration.cmc.ec.gc.ca/science/rpn/publications/pdf/CaLDAS_revised_final_11_04_07.pdf)

For a dry model bias, where the atmospheric analysis tries to compensate the lower troposphere by moistening, water will also be added in the soil, providing a stabilizing feedback between the land surface and the atmosphere. Therefore, soil moisture nudging scheme makes use of screen-level observations of temperature and humidity. The scheme operates on the principle that model errors in soil moisture lead to model errors in near surface temperature and humidity. Therefore, model errors in screen-level temperature and humidity can be used to diagnose model errors in soil moisture. Knowing the atmospheric analysis increment of specific humidity, at the lowest model level, the correction of soil moisture applied in the root-zone is assumed to be proportional to it:

$$S_a - S_b = C_v D \Delta t (q_a - q_b)$$

where $\Delta t = 6$ hours. The relaxation coefficient D is constant in space and time and corresponds to a specific humidity analysis increment ($q_a - q_b$). The vegetation fraction in the above formula guarantees that the scheme is not active over deserts (since bare soil evaporation is not controlled by soil moisture in the root-zone). No increments are produced in the presence of snow, and the field capacity and permanent wilting point thresholds limit the analysed soil moisture θ_a. θ_b is background soil moisture. The main justification to do ASCAT – Nudging scheme is to study the impact of ASCAT data assimilation on soil moisture products and to investigate further possibility to combine conventional observations and satellite data for the soil moisture analysis.

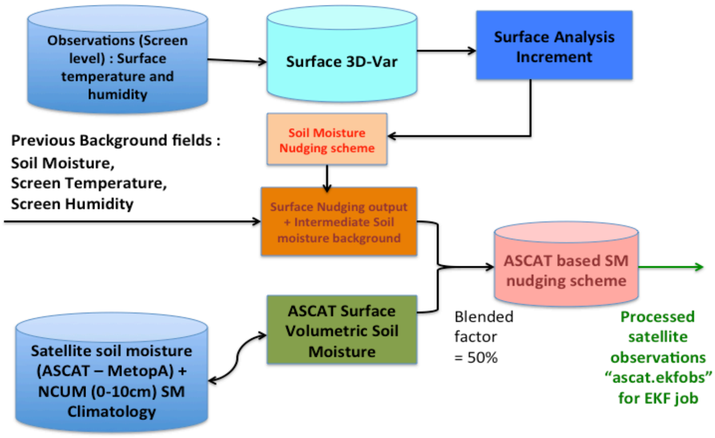

Figure 13: Schematic of ASCAT –nudging soil moisture assimilation system at NCMRWF

The ASCAT job by setting "PRODUCEEKFOBS" to TRUE in the namelist (ASCAT_Control.nl) file is basically a data-preprocessor job to obtain the real time satellite soil moisture data after quality control. ASCAT bufr data is produced in gridded format for use in the SURF30.0.1 ASCAT-EKF program. The observation error associated with each ASCAT observation for the EKF is set to 0.05 m^3/m^3.

Appendix B: List of Changes done to build *Su*rface Fields Processing platform (SURF version 30) at NCMRWF

The State-of-art surface field processing suite, SURF30.0.1 of UKMO is installed at NCMRWF for the preparation of analysis of varying surface conditions such as SST, Sea Ice, Snow and Soil moisture at the model resolution. All the versions of SURF are built and can be found on Bhaskara HPC at /gpfs2/home/umprod/NCUM/PS34/

The configuration files defining the build options for SURF system can be found in Bhaskara HPC at the location "/gpfs2/home/umprod/NCUM/PS34/SURF30.0.1/BuildDir/surf30.0.1". The configuration file used to build the SURF30.0.1 is "fcm-make-scs.cfg". Within this "cfg" file the user has to define the target mirror. It is build using "FCM make". While building SURF30 at operational level the target mirror is named "surf30.0.1".

The structure of a sample "fcm-make-scs.cfg" file is given below:

```
steps                                  = extract mirror
mirror.prop{config-file.steps}         = preprocess build
mirror.target                          = surf30.0.1
##
extract.location[ops]              = $HERE/../OPS/work/OPS
extract.location[gcom]             = $HERE/../GCOM/work/GCOM
extract.location[ops_external]     = $HERE/../OPS_EXTERNAL/work/OPS_EXTERNAL
extract. location[um]              = $HERE/../UM/work/UM
extract. location[gen]             = $HERE/../GEN/work/GEN
extract.location[surf]             = $HERE/../SURF/work/SURF/trunk
extract.location[jules]            = $HERE/../JULES/work/JULES
##
$projects                      = gcom surf ops_external um ops drhook jules gen
include = $HERE/opt.cfg
include = $HERE/i686-ifort.cfg
include = $HERE/core.cfg
include = $HERE/dep.cfg
include = $HERE/build.cfg
```

The other important configuration file is "i686-ifort.cfg". Selection of the configuration files depends on the type of the operating system the user is working on. The C-compiler used is "icc -ip -w -O3" and the FORTRAN compiler used is "mpiifort". The netCDF version used to build SURF30 is "netcdf-4.3.3.1" and this version can be found in Bhaskara HPC at "/gpfs1/home/Libs/INTEL/NETCDF4/netcdf-4.3.3.1"

The SURF30.0.1 can be compiled with

```
fcm make –f fcm-make-scs.cfg
```

In order to build the SURF30.0.1 executables, one has to shift to the directory

/gpfs2/home/umprod/NCUM/PS34/SURF30.0.1/BuildDir/surf30

The surf30.0.1 executables can be build with

fcm make –f fcm-make.cfg

The SURF30.0.1 executables build now can be found at the location:

/gpfs2/home/umprod/NCUM/PS34/SURF30.0.1/BuildDir/surf30.0.1/build/bin

Code changes required in SURF30.0.1 for ASCAT observational data pre-processing

This is done at N768 resolution to produce "ascat.ekfobs" for EKF input. The code changes required for ASCAT- SURF30.0.1 build executables to read external bufrfiles are:

1) Set LenRep to 96K in **Surf_ASCAT_BUFRExtract.f90** found at

/gpfs2/home/umprod/NCUM/PS34/SURF30.0.1/BuildDir/surf30.0.1/extract/surf/src/code/
Surf_ASCATsoilWetness

2) Set LENREP = 198304 in files **get1bmsg.f & countbmsg.f** found at:

/gpfs2/home/umprod/NCUM/PS34/SURF30.0.1/BuildDir/surf30.0.1/extract/ops_external/code/MetDB_BUFR_RETRIEVAL/lib/source

```
INTEGER, PARAMETER :: LenRep=198304
  PARAMETER (LENREP   = 198304)
```

3) Set "MaxNumBUFRfiles" parameter in the program **SurfMod_ASCAT_Constants.f90** to 1000.

INTEGER, PARAMETER :: maxNumBUFRfiles = 1000

This program "**SurfMod_ASCAT_Constants.f90**" can be found at :
/gpfs2/home/umprod/NCUM/PS34/SURF30.0.1/BuildDir/surf30.0.1/extract/surf/src/code/Surf_ASCATsoilWetness

4) Modify the meteorological database parameters in file **mdbbd.f** at the "ops_external" location:

/gpfs2/home/umprod/NCUM/PS34/SURF30.0.1/BuildDir/surf30.0.1/extract/ops_external/code/MetDB_BUFR_RETRIEVAL/lib/source

```
PARAMETER (MAX_MDBBD_CREQ = 15000)
PARAMETER (MDATA         = 880000)
PARAMETER (MDES          = 4000)
PARAMETER (MEXT          = 360)
```

MDATA, MDES and MEXT refers to maximum size of the array values, max number of descriptors and size of IEXTRA array values, respectively. The above changes are required at NCMRWF as we receive the BURF files from MOSDAC, unlike at UK-Met Office there is a METDB server. The bufr files are externally provided to the system. Hence, the "input size" and "maximum number of BUFR" files within the SURF30 codes at NCMRWF were increased.

Procedure to run ASCAT Nudging and EKF job

To run an ASCAT Nudging job, first we have to declare the list of environment variables required to run a SURF-ASCAT job. The environment variables needed to set up a ASCAT-Soil Moisture Nudging job are:

a) SURF_GSWP2_CLIM_IN: UM level 1 soil moisture climatology (qrascat.gswp2.clim).

   This file can be found at Bhaskara HPC server, at the location:
   /gpfs1/home/moum/UM/UM_Input/ancil/atmosphere/n768e/qrascat.gswp.clim

b) SURF_ASCAT_CDF_IN: Parameter file for CDF matching file (qrascat.cdf).

   This file can be found at BHASKARA at the location:
   /gpfs1/home/moum/UM/UM_Input/ancil/atmosphere/n768e/qrascat.cdf

c) SURF_ASCAT_UMFIELDS: Fieldsfile from short forecast job. Sample file is available at the location:

   /gpfs3/home/umprod/PS34/DA/SFCST/$CYCLE_TIME/$CYCLE/glu.ppsmc

d) SURF_ASCAT_SOILANCIL: UM soil parameters file. This file can be found at:

   /gpfs1/home/moum/UM/UM_Input/ancil/atmosphere/n768e/qrparm.soil

e) SURF_ASCAT_VEGANCIL: UM vegetation fractions file. This file can be found at:

   /gpfs1/home/moum/UM/UM_Input/ancil/atmosphere/n768e/qrparm.veg.frac

While performing the ASCAT-Nudging observation processing job for METOPA observations, UM SURF_ASCAT_SMC_IN and SURF_ASCAT_UMFIELDS files are same.

In the directory where the SURF30.0.1 executables are kept (/gpfs2/home/umprod/NCUM/PS34/SURF30.0.1/BuildDir/surf30.0.1/build/bin), We have to use the following submit command to execute the ASCAT-nudging job

bsub <SurfScr_ASCAT_768_glu (filename)

The environment variables required for running the EKF job are:

1) SURF_EKF_CONTROLDIR: exports the directory containing control files for the EKF and JULES job.

2) SURF_EKF_JULESJINDIR exports the input template file (Template_Jules3.0.jin) necessary for Jules perturbation run.

3) SURF_JULES_OUTPUTDIR exports the directory containing files from Jules runs to form the H Matrix

4) SURF_EKFOB_DIR exports directory containing gridded ASCAT observations

5) SURF_SMNUDGE_ANALYSISINC exports directory containing screen errors (anal_inc_surf)

6) SURF_EKF_BACKGROUND exports the file containing the background fields file (ppsmc).

7) SURF_EKF_ANLFILE exports the file containing the final soil moisture analysis.

In the directory where the SURF30.0.1 executables are kept, we similarly run the EKF job by the following submit command

bsub < SurfScr_EKF_IGBP (filename).