ASCAT Soil Moisture Assimilation in NCUM Regional NWP System

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Abstract

Surface-atmosphere interaction processes are represented by land surface models in the NWP systems. Hence, it is important to initialize the land surface variables in the NWP system. Soil moisture is an important variable controlling the partitioning of moisture and energy fluxes at the surface. Surface fluxes play a major role in the hydrological budget during Indian summer monsoon season. An Extended Kalman Filter based regional soil moisture data assimilation system has been developed to improve the soil moisture initial condition in the coupled land-atmosphere regional model of NCUM (NCUM-R) with JULES land surface model. The soil moisture assimilation system uses screen-level temperature and humidity information as well as satellite measured soil moisture estimates from ASCAT instrument on board MetOp-A and B satellites. In this study an Observing System Experiment was carried out to assess the impact of ASCAT soil moisture observations on the NCUM-R forecast. A depression case over coastal Odisha during 15th August to 17th August 2018 has been studied and the results of the study are presented.

1 Introduction

Soil moisture (SM) is an essential climate variable which plays an important role in the northwardly progression of Indian summer monsoon (ISM) isochrones [1]. At a regional scale particularly during ISM regime, SM modulates the fluxes of energy, water and carbon between the land surface and atmosphere especially the progression of monsoon low pressure systems. In the NCUM NWP system, the JULES land surface model mimics the physics associated the land surface process during ISM. JULES land surface model with a thin topsoil layer, consistent with the remotely sensed satellite SM observations are required to generate true state of SM analysis. The Extended Kalman filter (EKF) based land data assimilation system [2], [3] at NCMRWF assimilates near-surface SM and land surface temperature observations retrieved from Advanced SCATterometer (ASCAT) and INSAT-3D, respectively into NCUM global system. Similarly it is required to obtain true state of lower boundary condition in the regional NCUM regional analysis-forecast system (NCUM-R), as SM plays an important role in partioning of latent and sensible heat fluxes to the atmosphere through which it affects the planetary boundary layer and atmospheric convection.

2 ASCAT soil moisture assimilation at NCMRWF

The National Centre for Medium Range Weather Forecasting (NCMRWF) regional data assimilation team installed, developed and tested the capability to assimilate ASCAT SM data in the high resolution (4 km) regional NCUM 4DVAR modeling system (NCUM-R; Domain size: 62^0E–107^0E and 6^0S–42^0N; No. of points: 1200 × 1200; Vertical level: 80; Version of UM: PS40) using the Surface Processing system (SURF). The NCUM-R forecasting model and 4DVAR assimilation systems are running at the NCMRWF on the Cray XC40 Mihir HPC.

In the EKF land data assimilation system the Jacobian of the non-linear observation operator is computed using offline forecast runs (here 3 hr forecast) of JULES model (through finite difference of the forecast). The atmospheric forcing data for the off-line JULES land surface model run with the data assimilation system (precipitation, surface long wave and short wave radiation, air temperature, surface temperature and humidity, wind speed and surface pressure) are obtained from the regional NCUM-R short range forecast. There are 5 new programs/apps introduced in the regional soil moisture data assimilation scheme to implement the Extended Kalman filter technique to develop regional SM analysis:

(a) *Regional var_anal_screen:* this program generates the analysis increment for screen level temperature and humidity over Indian NCUM-R region

(b) *Regional surf_ascat_ekf:* this program gets the ASCAT observations, by reading the BUFR format file, and interpolates them to the Indian NCUM-R model grid.

(c) *Regional Surf_um2jules:* the program generates the NCUM-R model output files and creates initial and driving data ready for JULESv5.1. This is the first step to estimate the Kalman gain H operator.

(d) *Regional Surf_Jules:* with this program the JULESv5.1 is installed and it runs in standalone mode. This is the second step to estimate the Kalman gain H operator.

(e) *Regional Surf_ekf:* this program reads the output from previous JULES model output of the previous tasks and performs the EKF based land data assimilation tasks to produce the re-gridded SM over Indian region. The atmospheric screen analysis is generated from screen observations (SYNOP data).

The ASCAT surface volumetric SM values that have passed the quality control checks are gridded onto the regional NCUM grid. No thinning is performed; instead super-obing is used.

3 Forecast experiments with ASCAT Soil Moisture analysis

The NCUM regional analysis-forecast system (with assimilation of ASCAT SM in LDAS) is run for the following period (15th August to 17th August 2018) to study the impact of ASCAT SM data assimilation on near surface meteorological variable forecast (Observing system experiment), to study a monsoon depression case over coastal Odisha.

Table 1: Details of Control and ASCAT DA - runs.

S.No.	Experiment Name	Surface Observations data used	Time period of DA Runs
1.	CTL	SYNOP	06UTC, 12th August to 06UTC, 14th August 2018 (Cold start for each day)
2.	ASCAT	SYNOP and ASCAT soil moisture	

Two numerical experiments i.e CNTL (without assimilation of SM) and ASCAT (with assimilation of satellite SM) are conducted as shown in Table 1 to test the potential of assimilation satellite SM in the state-of-the art NCUM-R land data assimilation system. With these analysis generated, three day NCUM-R forecast runs are given to simulate the monsoon depression over Coastal Odisha during 15th August to 17th August 2018 .

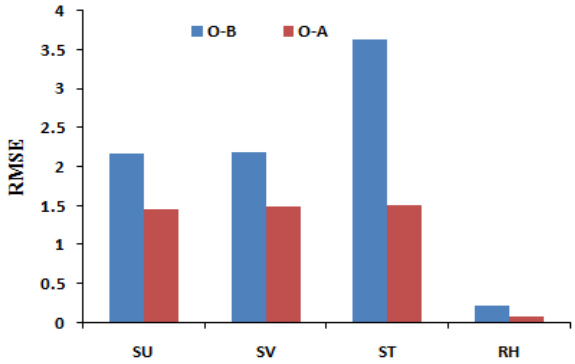

Figure 1: Mean RMSE of O-B and O-A of surface zonal wind (SU), surface meridional wind (SV), surface temperature (ST) and near-surface humidity. (RH) .

Figure 1 clearly shows that the analysis fields of zonal, meridonial wind, surface temperature and surface humidity are better matching to the observations than the background after assimilation of ASCAT SM.

The difference plot (Fig-2d) shows that SM observations (Figure 2a) are assimilated properly in the ASCAT experiment (Figure 2c) SM analysis.

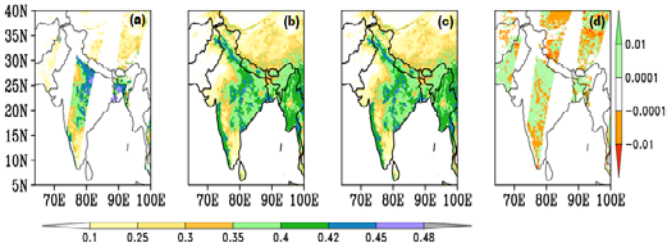

Figure 2: Soil moisture (SM; m^3/m^3) from EUMETCAST (ASCAT) and both experiments valid at 06 UTC of 14th August 2018.

The SM values are increased (decreased) over Maharashtra and west Uttar Pradesh (southern Karnataka region) regions in ASCAT experiment after assimilation of the SM. It is clearly depicted that the SM values are modified, wherever the satellite SM observations are available. The model simulated pattern of 2m-temperature (Figure not shown) are well simulated in both experiments throughout the forecast hours, however, the correlation coefficient (CC) and root mean square error (RMSE) are significantly improved in the ASCAT experiment as compared to the CTL experiment.

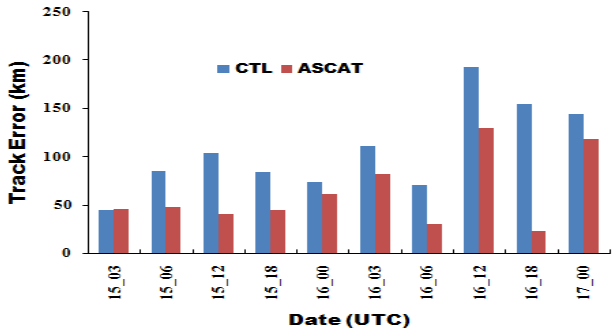

Figure 3: Track errors of monsoon depression over coastal Odisha during 15th - 17th August, 2018 based on initial condition 06 UTC of 14th August 2018.

Figure 3 shows that the track errors of the monsoon depression reduce by 50km (approx.) due to ASCAT SM assimilation. The preliminary results indicate the positive impact of assimilation of ASCAT SM in the analysis and forecast. Further advances in Land DA ongoing at NCMRWF.

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References

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