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RESEARCH REPORT

EXPERIMENT ON UTILIZATION OF AWiFS LU/LC DATA IN WRF MESOSCALE MODEL

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10	Abstract (100 words)	A detailed intercomparison of the model's response to the AWiFS LULC data as against the USGS LULC data is studied using WRF model. The AWiFS 2007-2008 data appears more realistic (than USGS) since it features the recent changes in the land cover over India. The WRF model experiments using the AWiFS and USGS data show consistency in the domain averaged monthly surface fields. The mean flow in the AWiFS run is significantly altered (direction and magnitude) suggesting that the land cover changes over wide geographical region influence not only micro-meteorological features but also large scale circulation patterns up to 850 mb. The AWiFS run deduced slightly drier mean conditions with isolated locations showing strong positive changes in 2 meter water vapor . Over the Jammu & Kashmir region the impact of AWiFS data in the simulated surface parameters is alarming. The *degraded* area shows reduced rainfall while the *improved* area to its south shows enhanced rainfall. Change in 2 meter temperature rather astonishes with the zone of reduced rainfall show sharp increase in 2 meter temperature as against marginal fall over *improved* area.
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EXPERIMENT ON UTILIZATION OF AWiFS LU/LC DATA IN WRF MESO-SCALE MODEL

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Abstract

This study implements a new land use land-cover classification (LULC)data over India obtained from the Advanced Wide Field Sensor (AWiFS) aboard the Indian satellite IRS P6 in the Weather Research and Forecast (WRF) model and investigates its effects on regional near-surface atmospheric state variables as well as the planetary boundary layer over India during July 2009. A detailed intercomparison of the model's response to the AWiFS LULC data as against the USGS LULC data is also studied.

The AWiFS data over India during 2007-2008 look very much different from that of USGS generated during April 1992 to March 1993 based on the NOAA AVHRR images. The AWiFS data appears more realistic (than USGS) since it features the recent changes in the land cover over India. The WRF model experiments using the AWiFS and USGS data show consistency in the domain averaged monthly surface fields suggesting that the WRF model (and the NOAH LSM) accepts the AWiFS data.

The mean flow in the AWiFS run is significantly altered (direction and magnitude) compared to the USGS run to suggest that the land cover changes over wide geographical region influence not only micro-meteorological features but also large scale circulation patterns up to 850 mb. The AWiFS run shows reduction in 2 meter mean water vapor relative to USGS run suggesting slightly drier mean conditions with isolated locations showing strong positive changes. Over the Jammu & Kashmir region the impact of AWiFS data in the simulated surface parameters is alarming. The *degraded* area shows reduced rainfall while the *improved* area to its south shows enhanced rainfall. Change in 2 meter temperature rather astonishes with the zone of reduced rainfall show sharp increase in 2 meter temperature as against marginal fall over *improved* area.

1. Introduction:

In India about 228 mha of area, which amounts to about 69% of the geographical area, is classified as dry (arid, semi-arid and dry subhumid). About 105.5 mha of land is undergoing processes of land degradation which amounts to about 32% of geographical area. The area undergoing desertification is about 81.4 mha. These are the findings of a recent study (Ajai et al 2009) based on the satellite observations from the Advanced Wide Field Sensor (AWiFS) aboard the Indian satellite IRS P6-Resourcesat acquired during 2003, 2004 and 2005. The investigation further identifies various processes of land degradation/desertification as due to water erosion (10.21%), vegetal degradation (9.63%) and wind erosion (5.34%). Ajai et al (2009) also note that Rajasthan has the largest area (21.77%) under land degradation followed by Jammu & Kashmir (12.79%), Maharashtra (12.66%) and Gujarat (12.72%).

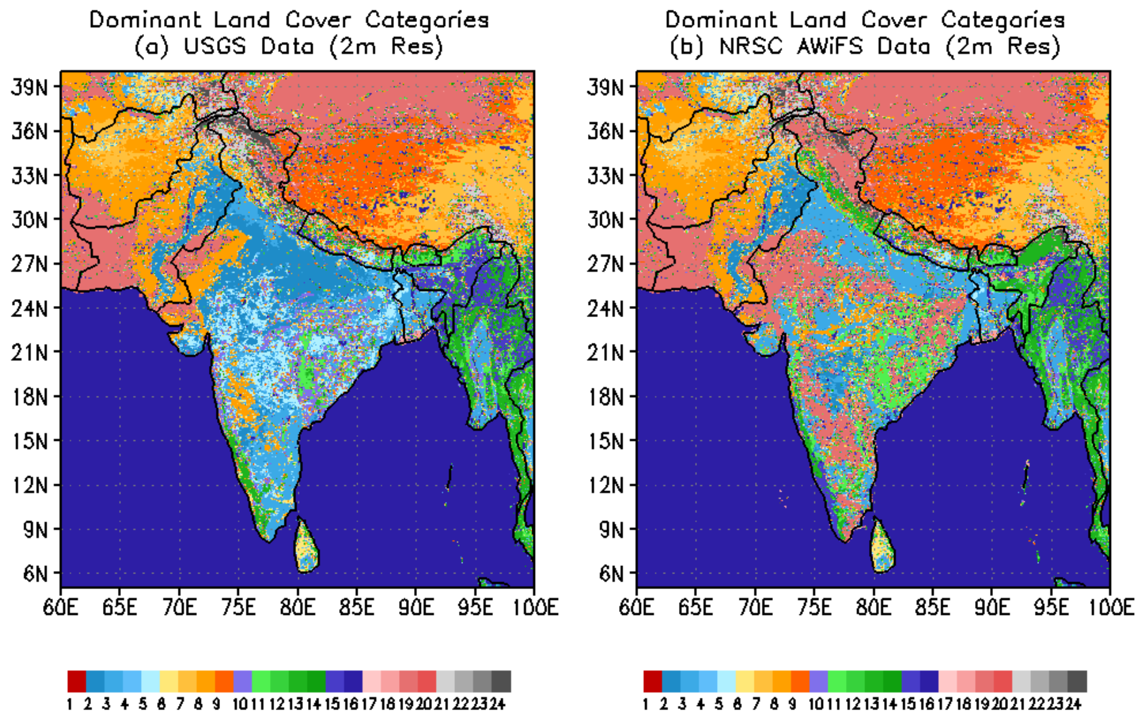
Changes in the land-cover specification or associated parameters affect the surface wind, temperature, and humidity fields, which, in turn, result in perceivable alterations in the evolving structure of the planetary boundary layer. The variations in land surface cover influence general circulation directly through the parameters of the atmospheric model or indirectly through the hydrologic coupling. Albedo, emissivity, and surface roughness are three important parameters directly influenced by the surface cover. The hypothesis by Charney (1975) suggested that the tendency to subsidence in the atmosphere and thus further inhibiting precipitation was a consequence of positive feedback produced by increased albedo over the deserts. The range of long-wave emissivity (E) is narrow for various surface covers and hence is generally considered insignificant. However, to explore the effect of vegetation changes in regional and meso-scale models leading to distinct parameter evaluation over high resolution spatial domain, transfer of long-wave radiation is important. It is rather desirable to have exact value disowning the practice of using a flat (1.0) value owing to narrow band width. The surface roughness affects the momentum transfer in the atmospheric boundary layer. Its value varies widely with the surface cover. Numerical experiments indicate that an increase in roughness length would decrease the wind speed and the surface temperature and tend to produce more rapid infilling of cyclones (Delsol, Miyakoda, and Clarke 1971).

The findings of Crawford et al. (2001) and Wetzel and Chang (1988) showed that among the five significant land surface characteristics, soil moisture, leaf area index, and fractional green vegetation cover are most important, followed by albedo and roughness length. Other sensitivity studies have explored the impact of modifying land surface characteristics and thus the surface fluxes, at regional to global scales (Dickinson and Henderson-Sellers 1988; Nobre et al. 1991; Xue 1996; Sen et al. 2004). The impact of deforestation in Amazonia and tropical Asia has been the focus of many of these studies. Such transformations typically increase surface albedo and decrease surface roughness, which result in a reduction in surface net radiation and, also, in surface latent heat flux. Pielke (2001) suggests that changes in surface fluxes affect weather and climate through impacts on atmospheric dynamics, clouds, and rainfall.

All the studies indicate that land cover properties can have profound impact on the near surface weather and accurate representation of the land surface is important for modeling the weather with precision. This study implements a new LU/LC Data from the AWiFS, in the Weather Research and Forecast (WRF) model and investigates its effects on regional near-surface and atmospheric flow variables over India during July 2009. A detailed intercomparison of the model's response to the AWiFS LU/LC data as against the USGS LU/LC data is presented here.

2. Discussion on Land Cover Data:

The spatial distribution of the dominant land cover (at 2 arc minute resolution) over India is shown in Fig.1 for the USGS and the AWiFS data used in this study.



1 Urban and Built-Up Land
2 Dryland Cropland and Pasture
3 Irrigated Cropland and Pasture
4 Mixed Dryland/Irrigated Cropland and Pasture
5 Cropland/Grassland Mosaic
6 Cropland/Woodland Mosaic
7 Grassland
8 Shrubland
9 Mixed Shrubland/Grassland
10 Savanna
11 Deciduous Broadleaf Forest
12 Deciduous Needleleaf Forest
13 Evergreen Broadleaf Forest
14 Evergreen Needleleaf Forest
15 Mixed Forest
16 Water Bodies
17 Herbaceous Wetland
18 Wooded Wetland
19 Barren or Sparsely Vegetated
20 Herbaceous Tundra
21 Wooded Tundra
22 Mixed Tundra
23 Bare Ground Tundra
24 Snow or Ice

Fig.1 Dominant Land Cover Categories

The AWiFS land use land cover data over India during 2007-2008 look very much different from that of USGS generated during April 1992 to March 1993 based on the NOAA AVHRR images. The data outside the Indian geographical boundaries is same (USGS) in both the maps. The changes are evident along Gangetic plains where irrigation practices have resulted in upgrading the classification to category 3 (in AWiFS) from 2 (in USGS). The barren land over Rajastan has spread further towards east replacing the shrubland. Increasing urbanization around the capital city of Delhi is also very clear. Over the peninsular India discernible differences are seen notably along the rain-shadow area running parallel to Western Ghats where the USGS classified shrubland has undergone degradation to barren or sparsely vegetated category in the AWiFS data. The evergreen broadleaf forest in the southern portions of Western Ghats have decreased and the savanna in the northern reaches of Western Ghats have developed into deciduous broadleaf. Another striking change is seen over the Arunachal Pradesh where the entire state is classified into evergreen broadleaf forest. Over the Eastern Ghats, more of deciduous broadleaf forest appeared. The classification over rest of the country was modified with mixed changes. The differences in percentage existence of some important categories are shown in Fig.2.

The urbanization (Fig.2A) has gone up by 1-20% in each 16 sq.km area in two patches agglomerate all over Punjab and part of Andhra Pradesh. The development of mega cities like Delhi, Hyderabad and Bangalore are clear with >80% spread around them. The irrigation practices (Fig.2B) have undergone sea-change with >80% rise along Gangetic plains starting from Punjab. Large scale development is prominent all over North India including parts of Gujarat and Madhya Pradesh. Along the east coast, a drop of 20-40% in the irrigated area is seen but for a small portion over Andhra Pradesh. The low rain regions of Andhra Pradesh and Karnataka have undergone large reduction in the irrigated area in the order of 60-80%. Along the west coast crop watering has gone up. The deciduous broadleaf forest (Fig.2C) shows healthy improvement over parts of Andhra Pradesh, Madhya Pradesh, Orissa, West Bengal, Kerala, Tamil Nadu and the North-Eastern states except over Arunachal Pradesh where the land cover status changed to the Evergreen broadleaf forest (Fig.2D) by >80%. It may be noted here that these are the areas of major rainfall activity during summer monsoon season. The southern half of Western Ghats lost 40-80% of evergreen forest where as the northern parts gained by 20-40%. The water bodies have increased all over India (Fig.2E). A hot spot of 80-100% increase over Madhya Pradesh is due to the Sardar Sarovar reservoir constructed on training the river Narmada. The other one over Gujarat is actually the coastal land eroded by the sea. The snow cover over Jammu and Kashmir (referred hereafter as J & K) region has marginally increased (Fig.2F).

The appearance of water hot spots, much improved irrigation practices and broadleaf forests over major rain zones suggests that AWiFS Lu/Lc data is much more realistic compared to age old USGS data. Implement the new AWiFS data in the NWP models is likely to improve the representation of the near surface physical processes and help in improving the prediction. This study implements the AWiFS LU/LC data in the Weather Research and Forecast (WRF) model and investigates its effects on regional near-surface and atmospheric flow variables over India during July 2009. A detailed intercomparison of the change in the model's response to the two data sets is discussed.

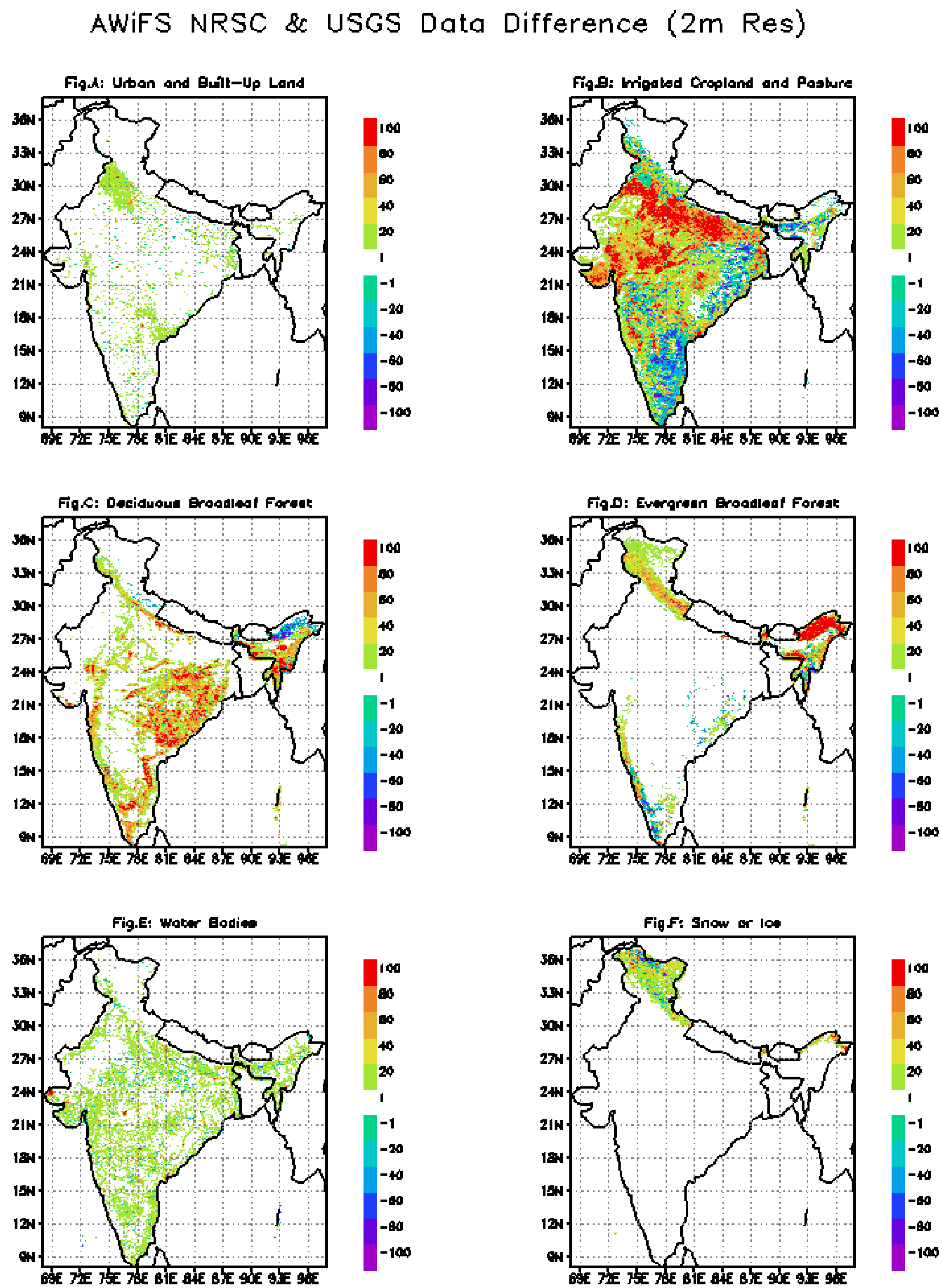


Fig 2. Percentage Difference Between AWiFS and USGS Data

3. Model Description & Experimental Design

The WRF model is a state-of-the-art, next-generation mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs (http://www.wrf-model.org). It is a nonhydrostatic model, with several available dynamic cores as well as many different choices for physical parameterizations suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometers. The dynamic cores in WRF include a fully mass- and scalar-conserving flux form mass coordinate version. The physics package includes microphysics, cumulus parameterization, planetary boundary layer (PBL), land surface models (LSM), and longwave and shortwave radiation (Skamarock et al.2006).

In this work, the microphysics and convective parameterizations used were the WRF Single-Moment 3-class (WSM3) simple Ice scheme and the Kain–Fritsch scheme respectively. Its is based on Dudhia (1989) and Hong et al (2004). The WSM3 microphysics is a simple efficient scheme with ice and snow processes suitable for mesoscale grid sizes. The WSM3 scheme predicts three categories of hydrometers: vapor, cloud water/ice, and rain/snow, which is a so-called simple-ice scheme. The Kain–Fritsch convective parameterization (Kain 2004) utilizes a simple cloud model with moist updrafts and downdrafts that includes the effects of detrainment and entrainment. The simulations are conducted with the Noah Land Surface Model (LSM) (Ek et al.,2003), which includes multi-layer soil with a single layer canopy. Typically, four soil layers (0.1, 0.3, 0.6 and 1.0 m thickness, with 2 m total soil depth) are prescribed for the description of the soil moisture/ temperature feedback. The Noah LSM also contains a simple canopy resistance scheme (Chen and Dudhia, 2001), frozen soil parameterization (Koren et al., 1999), Noah LSM prognostic soil moisture and soil temperature, and net radiation and surface heat fluxes. The LSM includes root zone, evapotranspiration, soil drainage, and runoff, taking into account vegetation categories, monthly vegetation fraction, and soil texture. The PBL parameterization used was the Yonsei University (YSU) scheme (Hong and Pan 1996). This scheme includes counter gradient terms to represent heat and moisture fluxes due to both local and non-local gradients. Atmospheric shortwave radiations is computed using the Dudhia (1989) scheme and for long wave radiation rapid radiative transfer model (RRTM) of Mlawer et al (1997) scheme is used.

The WRF model uses significant amount of geophysical data. Geographical data includes soil and LU/LC categories, terrain height, annual mean deep soil temperature, monthly vegetation fraction, monthly albedo, maximum snow albedo, and slope categories. These data are interpolated on a user-specified modeling grid through a special processor capable of handling different types of vegetation/LU/LC and soil dataset. The output generated by the processor contains grid-cell average surface elevation, fractional and dominant LU/LC, fractional vegetation, and soil type. The physical parameters (e.g., albedo, moisture availability, emissivity, surface roughness length, thermal inertia) for each vegetation/LU/LC category are defined within the LSM. While most WRF applications employ the 24-category USGS data it is flexible enough to allow incorporation of additional data sets. The surface properties such as vegetation/land use data were prescribed by the 24 land use categories with different surface albedo, moisture, emissivity, and roughness length values assigned to each category; topography was prescribed according to USGS terrain data. The WRF model was set up by using a single nest at 27 km horizontal grid spacing. The domain covers the entire Indian sub-continent as well as part of the Arabian Sea and Bay of Bengal (Fig.3).

As a preliminary simulation experiment, the model integration is carried out for the entire month of July 2009. The initial and lateral boundary conditions are obtained from the NCMRWFs' T254L64 global model. The two simulation experiments involve using the 2 arc minute USGS and AWiFS LU/LC data over India. (The two experiments are referred to as USGS and AWiFS hereafter). In the AWiFS experiment the LU/LC data within the Indian geographical boundaries corresponds to AWiFS data and over rest of the domain to the USGS data. Topography and soil types used are same for both the experiments and are from the USGS data. Both the model integration were initialized at 0000 UTC of 1st July 2009 and ended at 31st July 2009. Both the runs were carried out using persistent SST. The lateral boundary conditions were updated at six hour interval.

We used 38 vertical levels in the model with the highest resolution (20–100 m) in the boundary layer. The model top was fixed at 50 mb. The WRF model resolves the original 2 arc minute data to design resolution of 27 km, the dominant categories at grid points may likely to change. The resultant LU category data that have actually gone into the model for simulating the evolution of surface fields are shown in Fig.3. The LU/LC data grided to model resolution of 27 km did not alter the Lu/Lc spatial orientation in either data set. All major features in Lu/Lc as seen in original 2 arc minute data are retained. A very striking feature of 27 Km data is seen with urban category that is wiped out in both data sets. The largest urban area over the country, the Delhi NCR, has been re-classified to category 2 & 3.

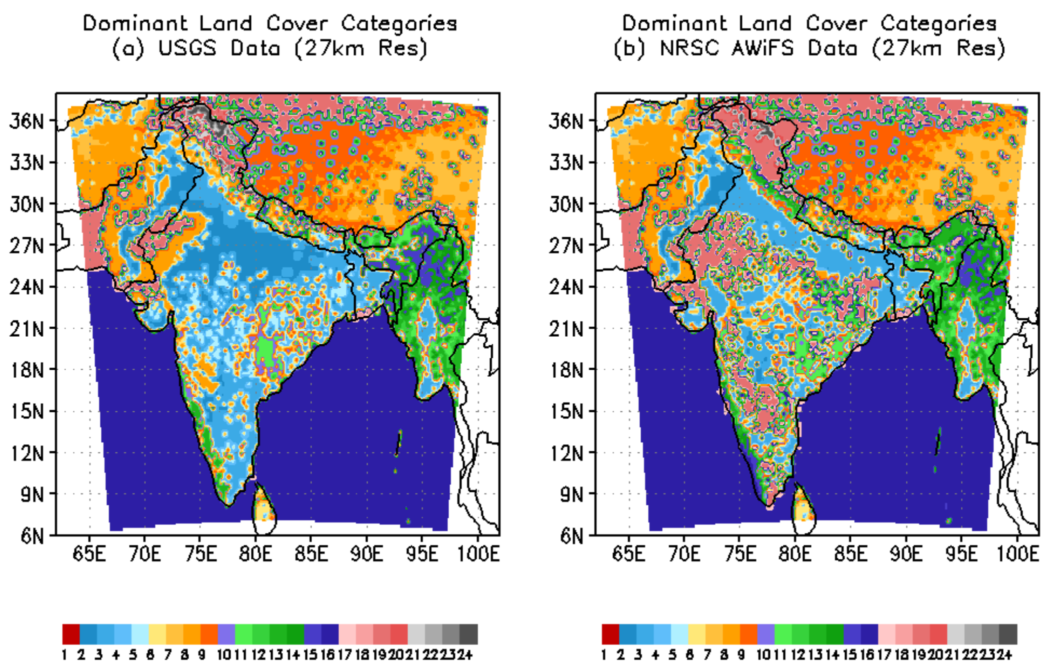


Fig 3. Dominant Land Cover Categories at Model Resolution

3. Discussion of Results

During July 2009, the synoptic activity over India was near normal. The monsoon covered entire country on 3rd July. Two low pressure areas and a deep depression formed during the month. One of the low pressure areas (13-16 July) and the deep depression (20-21 July) formed over northwest Bay of Bengal, moved west northwestwards along the monsoon trough zone and caused normal to excess rainfall along west coast and over central parts of the country.

(a) Mean July Rainfall and Circulation

The accumulated rainfall in the model simulation for July 2009 is shown in Fig.4. Both the experiments produced similar pattern (Fig.4a,b) over India and neighborhood. The rainfall maxima over the north-east Arabian Sea is not extended to the western ghats in AWiFS and a central spot was noticed just above Goa. The distribution and magnitude of observed rainfall (Fig.4d) along Western Ghats is closer to AWiFS produced pattern in view of amplified rain activity of the order of 25-50 cm around 13.3 deg N and 75.0 deg E as well. The Orissa, Maharashtra and and Madhya Pradesh regions experienced cyclonic activity during July 2009. The spatial distribution of rainfall looks more or less same in both experiments but the magnitude at the rain centre of the storm is significantly amplified in case of AWiFS (Fig.4c). As for the location of storm induced rain zone, AWiFS is no better compared to USGS. It implies that AWiFS LU/LC data, in general, influences the monsoon flow by direction and magnitude but its impact in driving cyclonic systems is uncertain.

The 850 hPa wind field simulated by the two experiments for July 2009 is shown in Fig.5. The USGS and AWiFS data sets produced typical monsoon flow pattern with westerlies across western ghats and re-curved wind over head Bay of Bengal forming the monsoon trough along ganges (Fig.5a,b). The flow pattern looks similar in both the cases, but their magnitude was significantly different (Fig.5c) in small regional pockets with the order varying between -2.5 to +2.5 m/s. The plot focused on Orissa and Madhya Pradesh (Fig.5d) shows that the AWiFS simulated enhanced convergence with 1.5 m/s rise in the magnitude of wind over comparatively high rainfall activity associated with the low pressure system.

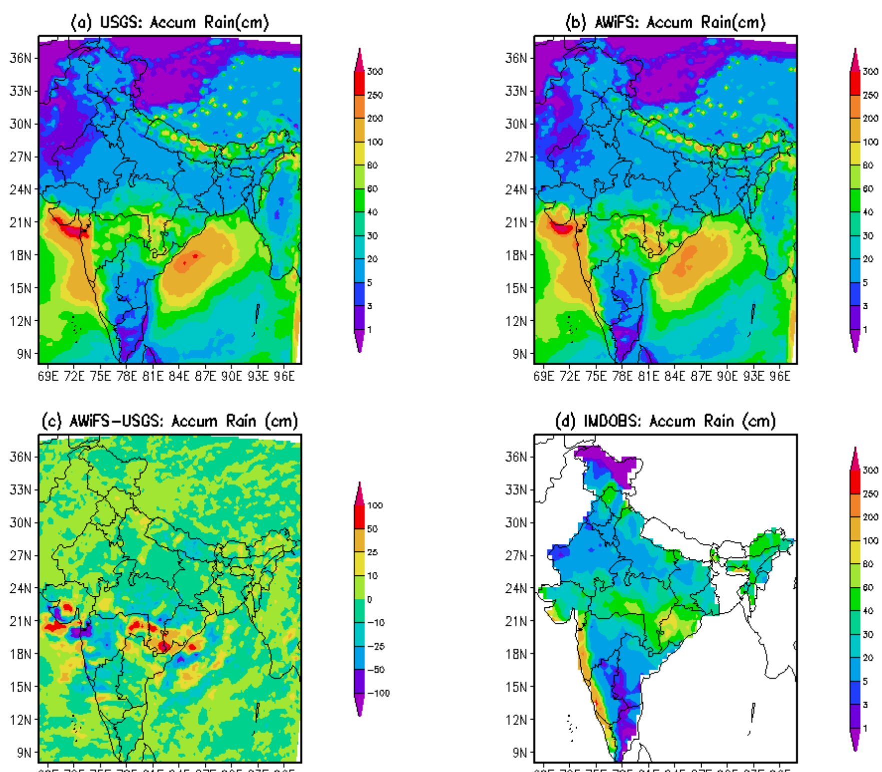


Fig 4. Spatial Distribution of Accumulated Rainfall for July 2009

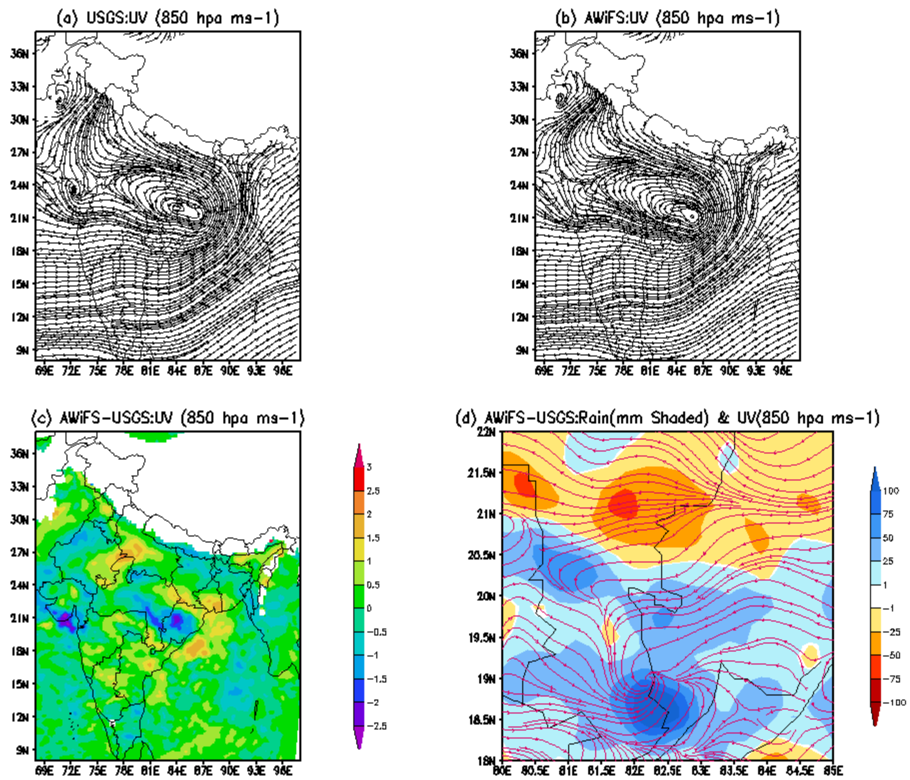


Fig 5. Distribution of Average Wind during July 2009

(b) Land Surface Parameters

The average (July 2009) spatial distribution of some of the important land surface parameters in both the experiments are shown in Fig.6 and their differences (model's response) are shown in Fig.7. The roughness length (Fig.6a,b) in the AWiFS is significantly altered over the eastern ghats over peninsula and the adjoining areas. This feature is also prominent over Himachal Pradesh and neighboring parts of Uttar Pradesh (Fig.6a,b). Over a large area covering parts of UP, Bihar, Madhya Pradesh, Rajasthan the roughness length has changed from about 0.1 (USGS) to 0.05 (AWiFS) meters. The difference plot (Fig.7a) shows the impact of AWiFS prominently over Orissa and adjoining states. Over the rest of country the increase in roughness length were of the order of 0.1-0.4 meters in general (Fig.7a). The hilly regions of J & K experienced reduction in the roughness length. In the USGS run, the surface albedo (Fig.6c) is in the range of 0.15 to 0.2 all over the country except the northwestern desert regions (0.2 to .25) and the northern J & K where the values exceed 0.45. The AWiFS run features the albedo values in the range of 0.15-0.2 spreading from NW desert region towards east and southern peninsula (Fig.6d). The two panels in Fig.6c,d indicate increased desertification or dryness in the AWiFS run. The increase in the albedo is in the range of 0.05 to 0.15 (Fig.7b) over the peninsula, western, central and eastern India. Over the J & K region a remarkable change is seen in the albedo with changes ranging from -0.25 to +0.3. Such remarkable changes in the albedo over J & K region are likely to have immense impact on the regional climatology which will be discussed in detail in section next section. The surface emissivity also features more or less similar pattern as that of albedo in both the experiments (Fig.6e,f). However, the emissivity has decreased by 0.02 to 0.04 W m^{-2} over barren fields of Rajastan and spread towards peninsular India. Over the central India and irrigated northern plains, the emissivity values are 0.02 W m^{-2} higher in AWiFS (Fig.7c). Over J & K the reduction in the emissivity is about 0.02 W m^{-2}. The latent heat spatial distribution looks similar in both experiments but for small areal change over peninsular India (Fig.6g,h). However, their difference shows interesting meso-scale features (Fig.7d) and remarkable increase in AWiFS run, at isolated locations with increase in latent heat by over 100 W m^{-2}. Over the Bay of Bengal, the vaporization has increased in AWiFS run by about 25 W m^{-2} along the east coast. Over the Arabian Sea, the latent heat shows increase in the AWiFS run along the west coast of the Kerala and Karnataka (~ +25 W m^{-2}) and decrease along the coast of Maharashtra and Gujarat (~ -25 W m^{-2}). It may be recalled that these two areas experienced rise and reduction in the wind speed respectively (Fig.5c). The water vapor mixing ratio at 2 meter height (Q2) in the two experiments appear more or less same in Fig6i,j. However, the difference plot (Fig7e) suggests a prominent reduction in the AWiFS run over Uttar Pradesh increase over Himachal Pradesh. Over rest of the country, the response is mixture of low order fall and rise ranging between -0.2 to +0.3 with isolated locations of very sharp rise in the AWiFS runs. Similar to Q2, the mean surface temperature in the two experiments (Fig6k,l) suggests no remarkable impact of the AWiFS run. However, the difference plot (Fig7f) suggests that all over India barring J & K varied from -2 to +2 degrees. The specific spatial pattern was not in tandem with other surface fields (Fig.7f). The cool climate of J & K responded with huge changes and thus are discussed in separate section..

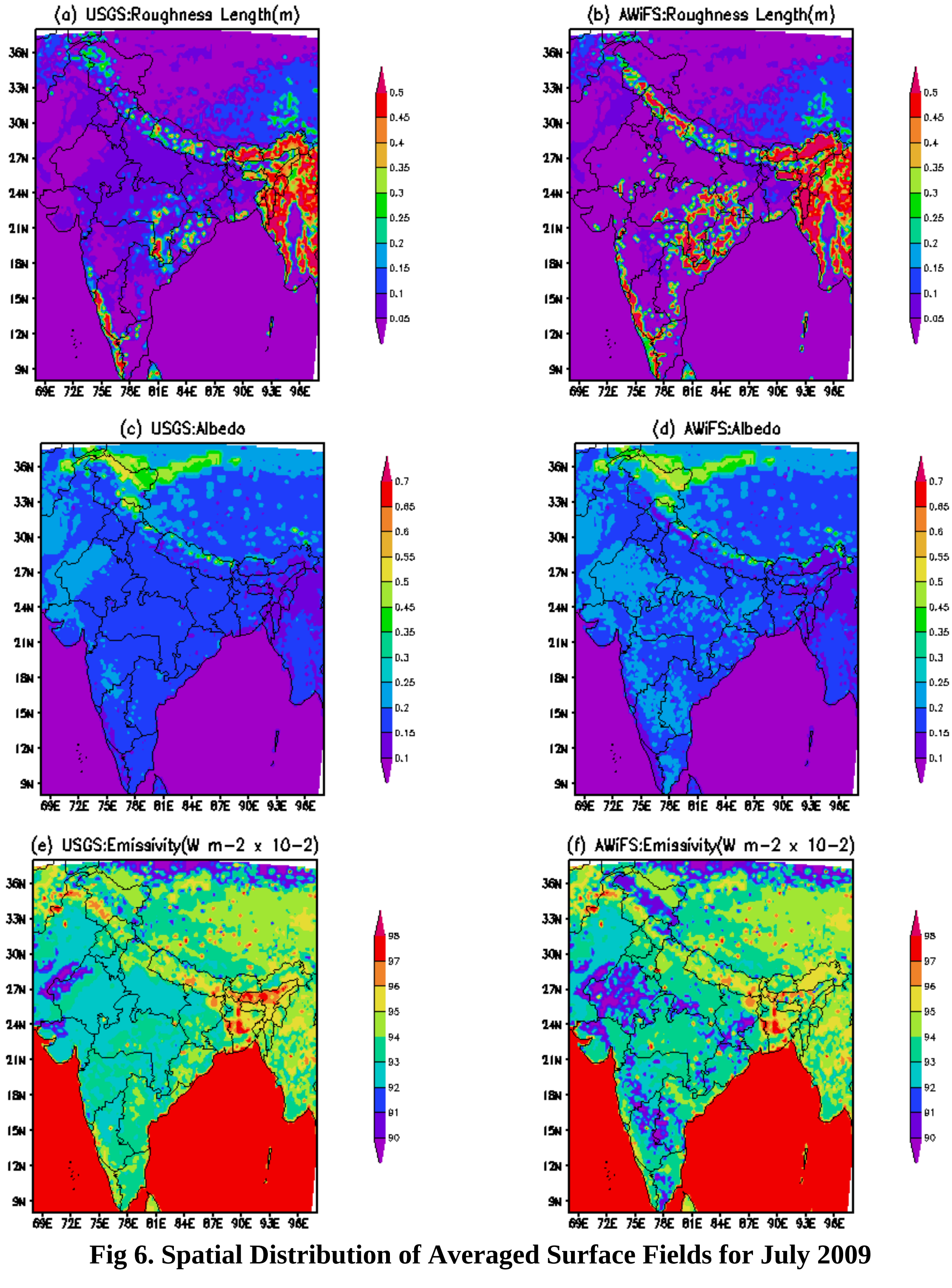


Fig 6. Spatial Distribution of Averaged Surface Fields for July 2009

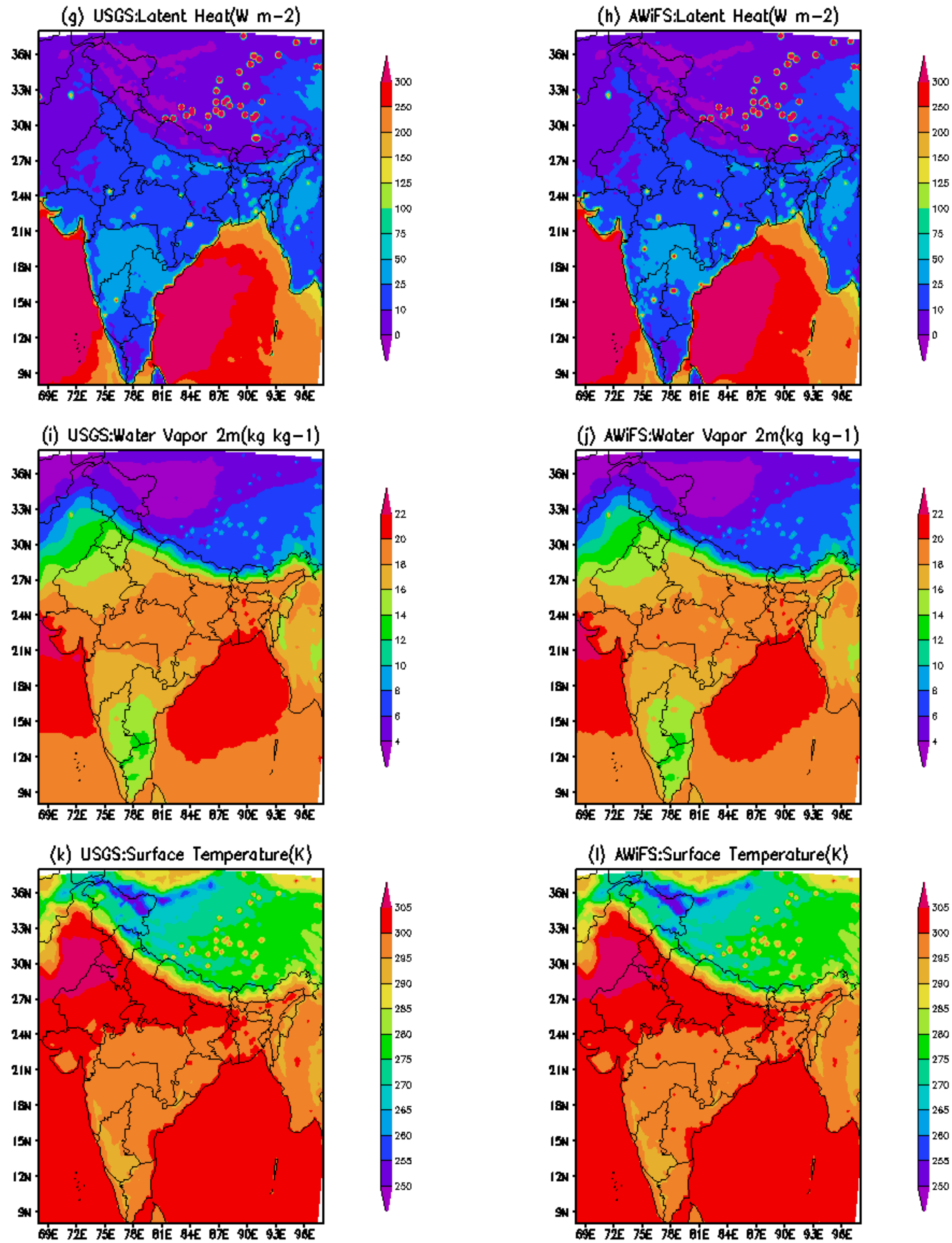


Fig 6. ***continued***

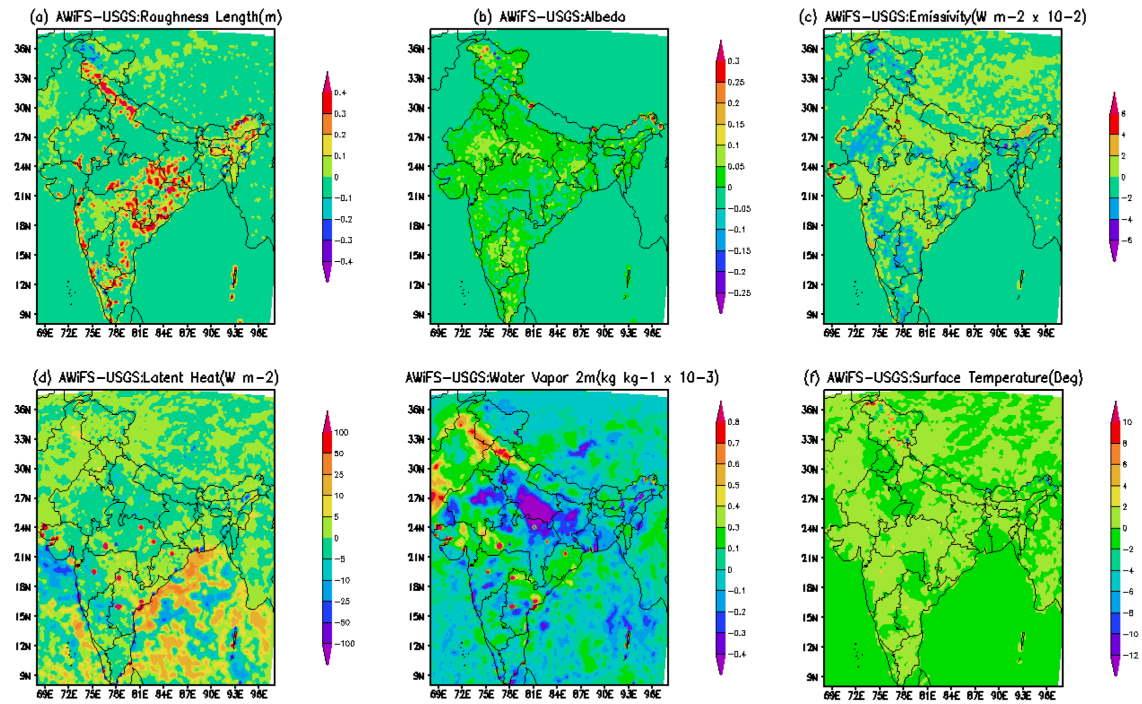


Fig 7. Difference in Spatial Distribution of Surface Fields for July 2009

(c) Impact over J & K Region:

The landuse index used in the model at 27 km resolution is shown over J & K region for the USGS and AWiFS runs (Fig.8a,b). The snow & ice extent (cat 24) in the northern part of the region is reduced in the AWiFS data compared to the USGS. Similarly a large part of J & K having deciduous broadleaf forest (cat 11) in the USGS data are changed to barren or sparsely vegetated (cat 19) areas in the AWiFS data. This *degraded* region is shown by *blue curve* in Fig.8b. On the other hand, to the south of this region, the area with grassland (cat 6), shrub land (cat 7) in USGS has changed into evergreen broadleaf forest (cat 13) and evergreen needleleaf forest (cat 14). This *improved* region is shown by *green curve*.

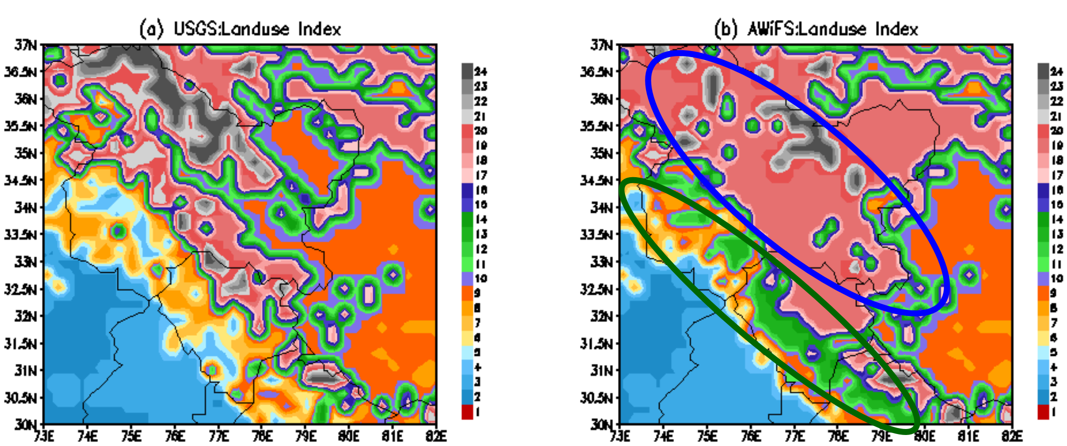


Fig 8. Landuse Index over J & K

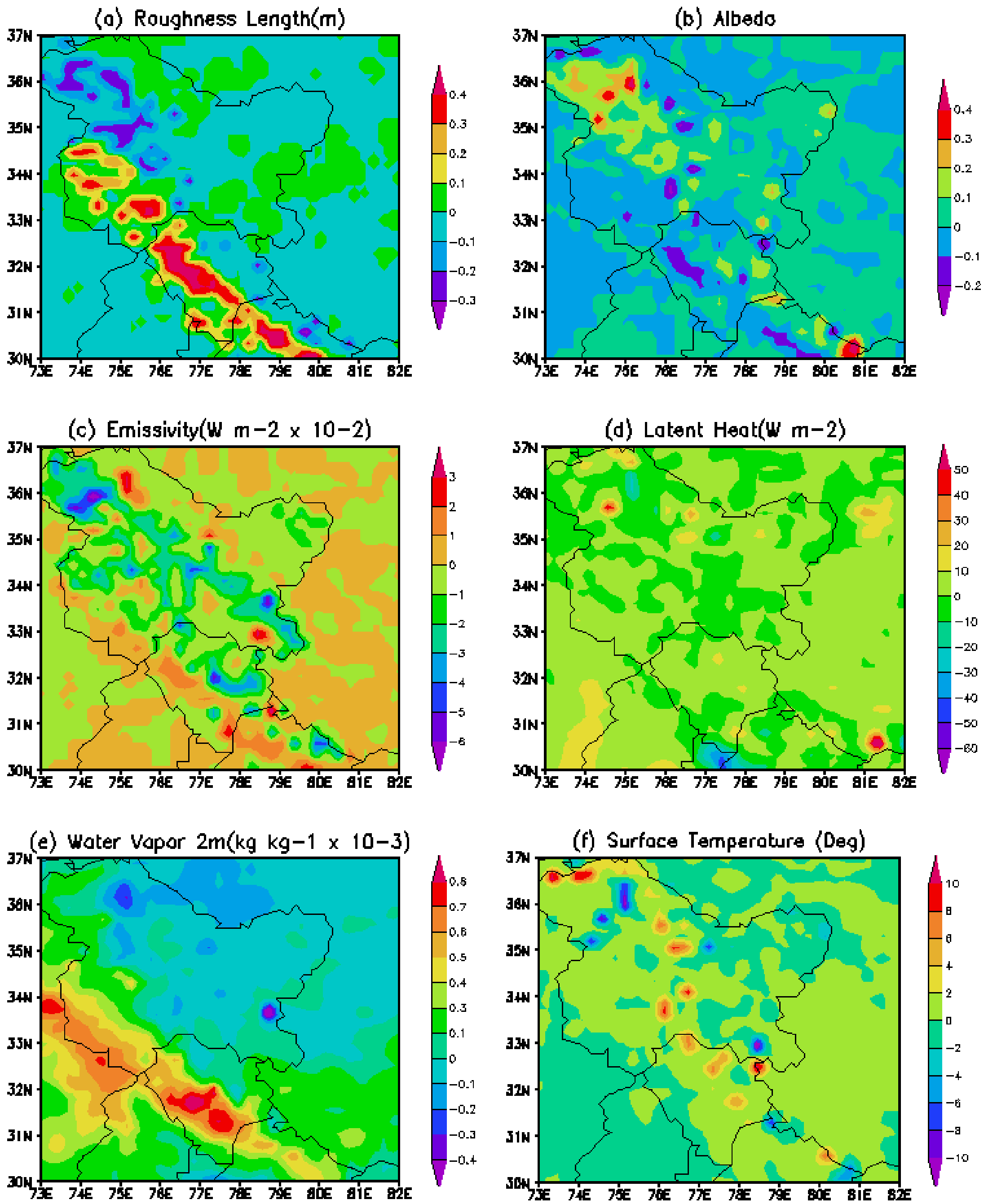


Fig 9. Difference in Surface Parameter Simulations

The impact of *degraded* (and *improved*) land cover (AWiFS run) is discussed in terms of changes in mean roughness length, albedo, emissivity, latent heat flux, Q2 and surface temperature (Fig.9a-f). The roughness length (Fig.9a) over the *degraded* area has decreased in the AWiFS run by about 0.3 meters. The *improved* area to its south including parts of J & K and Himachal Paedesh features an increase in roughness length by maximum of 0.4 meters (Fig.9a). The change in the albedo is positive (negative) over *degraded* (*improved*) pockets of the domain (Fig.9b). The surface emissivity (Fig.9c) all over the region has decreased in the AWiFS run with a maximum range of 0.04 to 0.06 W m^{-2} indicating accumulation of ground heat as result of reduced long wave radiation. The change in the latent heat flux varied between -10 to +10 W m^{-2} with isolated locations showing large increase (>30 W m^{-2}) and decrease (<-30 W m^{-2}) (Fig.9d). The impact of these changes in the AWiFS runs is reflected in the mean water vapor and surface temperature. The mean water vapor at 2 meters height is decreased over the *degraded* region (by -0.0002 to -0.0004 Kg/Kg) and increased over the *improved* areas to the south (Fig.9e) (by 0.0002 to 0.0008 Kg/Kg). The change in mean surface temperature is interesting (Fig.9f) and seems different in response compared to other surface parameters discussed. The AWiFS run shows a 2 deg rise in a north-west south-east oriented patch over the *degraded* area. There are numerous spots with temperature increase (and decrease) of the order of 4-10 deg.

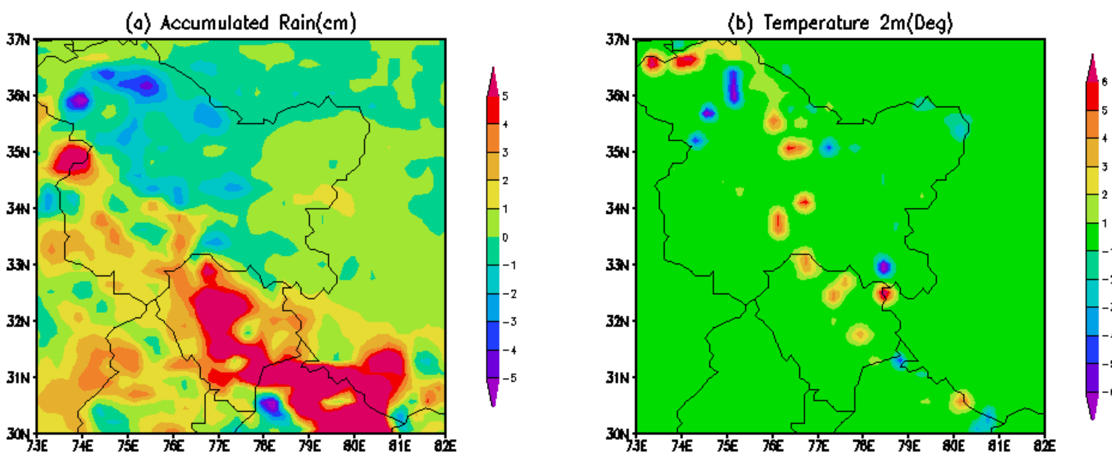


Fig 10. Difference Between AWiFS and USGS Simulations

The changes in the surface parameters of great interest – the rainfall and ambient temperature - are shown in Fig.10. The *degraded* area shows reduced rainfall while the *improved* area to its south shows enhanced rainfall. The reduction in the accumulated rainfall over the *degraded* area shows a maximum of 4-5 cm, while over the Himachal Pradesh, enhancement in the accumulated rainfall shows a peak value of 5 cm. Change in 2 meter temperature is shown in Fig.10b. It is rather astonishing to see that the mean 2 meter temperature in the zone of enhanced rainfall shows just a marginal decrease (Fig.10b) as against locations of sharp increase (maximum of 6 degrees at many places along the north-west south-east corridor) over *degraded* area in which major, consistent, changes in various surface parameters are evident.

(d) Temporal Evolution:

Temporal evolution of all India averaged surface fields is shown in Fig.11. The time series show similar temporal response in both the experiments. The magnitudes of these parameters averaged for the model domain and averaged over the time of the model integration slightly differed from each other (Table.1). The rainfall, soil moisture and canopy water show marginal decrease in the AWiFS run. The dryness in the AWiFS run is reflected in increased surface temperature by 0.03 degree.

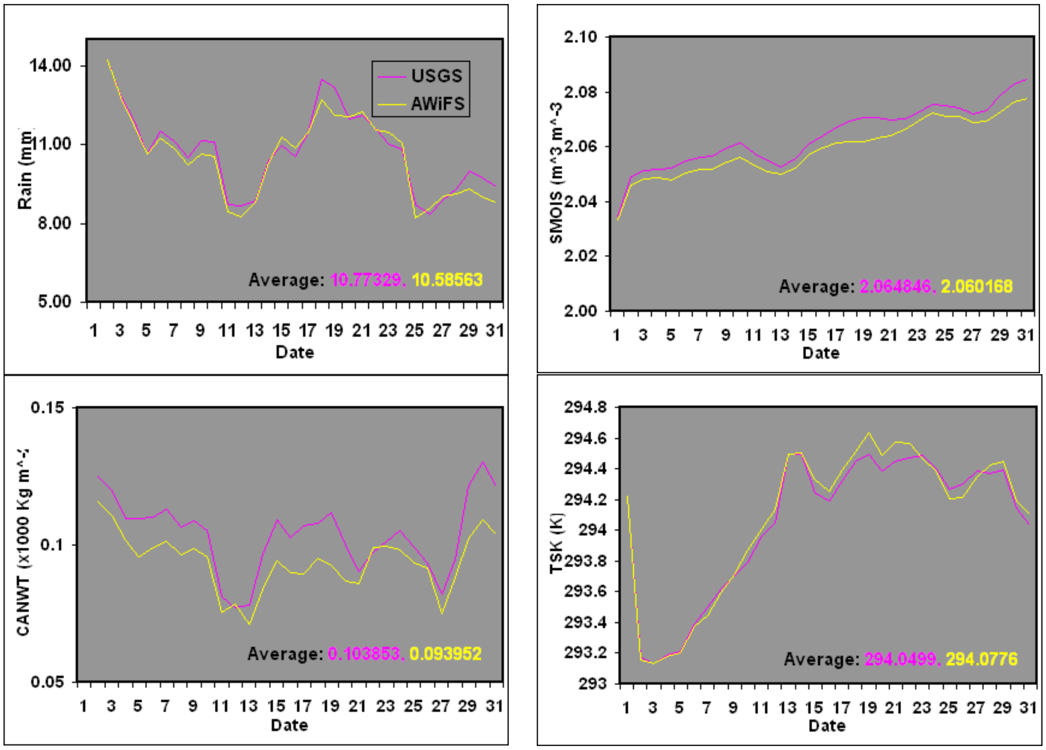


Fig 11. Temporal Evolution of Surface Fields for July 2009

Table 1. Domain Averaged Surface Fields for July 2009

Parameter	USGS	AWiFS	AWiFS-USGS
Rain (mm)	10.77329	10.58563	-0.18766
Soil Moisture (m^3 m^{-3})	2.064846	2.060168	-0.00468
Canopy Water (kg m^{-3} x 1000)	0.103853	0.093952	-0.00990
Surface Tempeature (K)	294.0499	294.0776	0.027667

4. Conclusions:

The following conclusions can be derived from this preliminary study:

1) The 2007-2008 AWiFS 2 arc minute LU/LC data appears more realistic (than USGS) since it features recent changes in the landuse over India such as rapid urbanization, changes in forest cover, changes in agricultural practices, construction of new water reservoirs and large scale irrigation projects.

2) The consistency in the domain averaged monthly surface fields simulated by AWiFS compared to USGS suggests that the WRF model (and the NOAH LSM) accepts the AWiFS data without suffering any shock emanating from the data and model inconsistencies.

3) The altered mean monsoon flow (both direction and magnitude) in the AWiFS run compared to the USGS run suggests that the land cover changes over wide geographical region influence not only micro-meteorological features but also large scale circulation patterns up to 850 mb.

4) The AWiFS run shows reduction in the mean water vapor at 2 meters relative to USGS run suggesting slightly drier mean conditions over India. However, isolated locations showing strong positive changes are significantly higher.

5) The AWiFS run features enhanced rainfall over hilly Himachal Pradesh in the north and the eastern ghats over peninsula which also feature increased roughness length. This suggests that the low level moisture convergence bear a direct relation to the roughness length.

6) The reduction in rainfall despite increased water vapor in the AWiFS run is a striking feature over Rajastan's extended barren fields and the regions bordering Andhra Pradesh and Karnataka. The albedo has increased over these regions obviously due to *degraded* Lu/Lc status.

7) The scenario in the simulated surface parameters owing to recent Lu/Lc status is alarming over J & K region. The *degraded* area shows reduced rainfall while the *improved* area to its south shows enhanced rainfall. The resultant change in 2 meter temperature is rather astonishing. The zones of enhanced rainfall show marginal decrease in 2 meter temperature while the *degraded* area exhibits sharp rise.

The conclusions listed above are to be considered preliminary since they are based on one month long simulation using single initialization. A much longer simulation extending beyond couple of seasons is necessary to completely account for land-atmosphere feedbacks. The Lu/Lc data used in the initialization sans important features like extended urbanization due to filtering on regridding the original 2 arc minute resolution data. The loss of the urban category around Delhi NCR region is clearly visible and such deprivation deters the accuracy of localized simulation features. The meso-scale modeling being specific for addressing localized weather phenomena, it is essential to further carry simulations at as high a resolution as possible without compromising on local Lu/Lc features exhibited by original data.

A comparison of USGS and AWiFS data suggests that although the barren fields over Rajasthan are extended, the loss of Lu/Lc status is marginal whereas over J & K the degradation is huge with deciduous broadleaf forest prior to 2007-2008 reducing to barren lands. The loss of forest may be due to varied ecological / human activity; however forests sustain strong and even continued drought conditions and are not expected to vanish. The current simulation exhibiting alarming rise in temperature over J & K suggests that huge Lu/Lc degradation seriously influence the environment. It appears that degradation over wide area matters a lot since forest loss in small pocket over south Western Ghats did not produce as much rise in temperature as over J & K. It is heartening to note that the neighboring states of Hamachal Pradesh and north Uttar Pradesh have become richer in land cover with the growth of broadleaf forest in parts. It is interesting that over these *improved* Lu/Lc areas, the rainfall and temperature status have improved only marginally implying that maintenance / preservation of forest cover result stable climate conditions whereas forest destruction would have alarming affects on the environment. Sustained land reclamation measures need be taken over wide corridor rather than local in order to produce fruitful results in environment protection.

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