Impact of accurate representation of Land Use/Land Cover over the National Capital Region (NCR) Delhi in simulating Monsoon Weather

Jerin Benny Chalakkal*, Manju Mohan

Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, New Delhi, India

Introduction

The LULC plays a crucial role in meteorological models because they determine the crustal properties that interfere with the exchange of energy, moisture, and momentum between the land surface and the atmosphere. This study attempts to assess the impact of legitimate present-state LULC based on ISRO Resourcesat 1 (2003) and Resourcesat 2 (2011) satellites onboard Advanced Wide Field Sensor (AWiFS) in the mesoscale model for simulating monsoon weather over NCR Delhi. The newly implemented AWiFS LULC precisely distinguishes the default MODIS classification used in the model framework.

Study Region: NCR Delhi

National Capital Region (NCR) - Delhi, the second biggest urban settlement globally, reported an almost ~20-fold increase in urban and built-up areas in past decades. NCR urbanisation during the past few decades caused a corresponding increase up to 3–5 and 2–4 K in values of LST and T2m, respectively, while a decrease in the magnitude of surface winds up to 2 ms^{-1} was noted. The geographical location is associated with a complex terrain with the Aravalli Northern Ridges towards the southwest and is enclosed by the Indo-Gangetic Plain (IGP) which has a decisive role in defining the local dynamics of the regional monsoon weather systems.

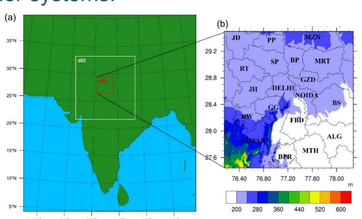

Figure 1: (a) Shows three nested domains (d1-25 km, d2-5 km, and d3-1 km resolution) used for model simulation and (b) shows the topography map (height in meters) for d3.

Data and Methodology

The current study investigates the impact of AWiFS LULC data representing a relatively recent LU distribution (2015-16) in the Weather Research and Forecasting (WRF) model framework in simulating short-term monsoon weather over the NCR- Delhi and sensitivity test for the impact of new LU dataset with model default MODIS-LULC from the 2010s.

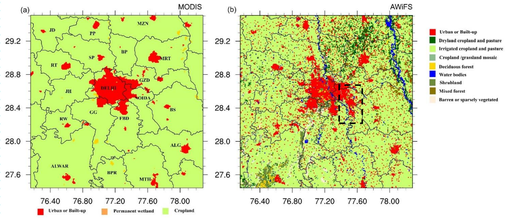

Figure 2: Two urban scenarios, i.e., Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover data representing LU from the 2010s default in WRF framework and Indian Space Research Organization (ISRO) AWiFS data representing a relatively recent LU distribution (2015-16).

Results

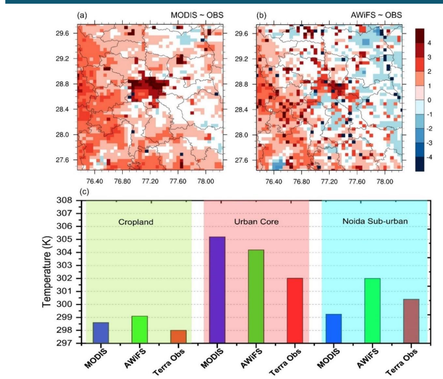

Figure 3. The difference between the model simulated (from domain d2, 5 km resolution) skin temperature (TSK) and Terra observed Land Surface temperature (LST) is shown in (a) MODIS ~ Observation, (b) AWiFS ~ Observation. The intercomparison of surface temperatures from model simulations and observation over the cropland over ALG, urban core zone over NCT, and Noida sub-urban is shown in (c)

Impact on critical near-surface variables

The near-surface atmosphere is the immediate layer over the surface that directly responds, and their influence can be clearly seen in the ambient atmosphere temperature (T2m) distribution.

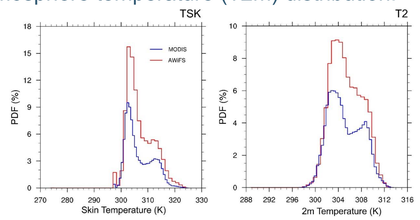

Figure 4. Probability density function (PDFs) for surface temperature (T2m) and skin temperature

Spatio-temporal resolution of AWiFS gives particulars of each sub-urban to the micro-urban sectors in detail. It is important to note that MODIS course resolution (about 1 km) prevented it from capturing intermediate vegetative or non-urban patches (which are smaller than grid size) inside the main urban zone. As a result, this model has a lot of build-ups over the urban core zone. At the same time, the AWiFS finer resolution (56 m) may take these fixes into account in their current state.

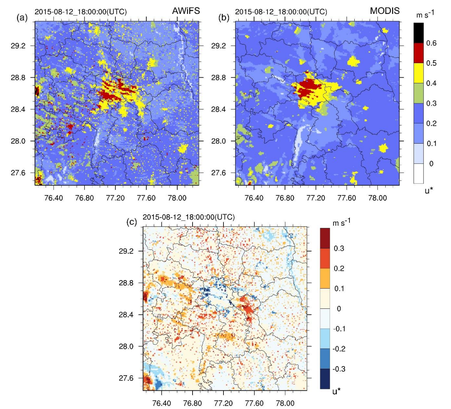

Figure 5. (a-b) distribution for surface friction velocity and its difference in (c).

Impact on Planetary Boundary Layer (PBL)

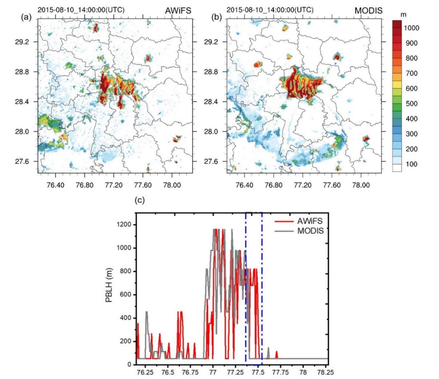

Figure 6. Planetary boundary layer height (PBLH) from AWiFS and MODIS for evening (14:00 UTC) hours and (c) shows the constant longitudinal variation of PBLH. The Blue dashed box represents the Noida sub-urban of NCR, Delhi.

Impact on convective paraments

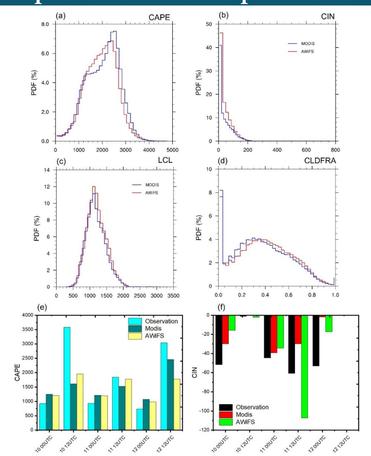

Figure 7. PDFs distribution for (a) Convective available potential energy (CAPE), (b) Convective inhibition (CIN), (c) Lifting Condensation Level (LCL), (d) Cloud Fraction (CLDFRA) for AWiFS and MODIS based simulations. The intercomparison of CAPE and CIN with the radiosonde observed from New Delhi soundings for respective days are shown in e-f.

Impact on Urban Signatures

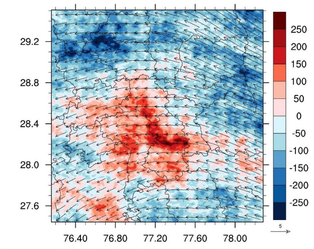

Figure 8. The spatial distribution of the difference of Convective available potential energy (CAPE), AWiFS ~ MODIS.

Chalakkal and Mohan (2022) reported the urban-monsoon linkage on rainfall modification over the study region. This study further noted a UHI of upto 3.5 °C during the monsoon and the evolution of rainfall islands over the urban centre, upwind and downwind, as a signal of monsoon-rainfall modification due to NCR urbanisation.

Conclusions

- Outside the metropolitan core region, numerous sub-urban settlements are caught in the true sense in the AWiFS and given the improved representation of NCR urban LU.
- The impact of the omission of the Noida sub-urban in MODIS LU is notable in PBL.
- Convective paraments and precipitation have a strong correlation, and the AWiFS simulation considerably improved CAPE, CIN, LCL and CLDFRA.
- Further, it indicates a higher magnitude (>200 Jkg^{-1} in difference) of CAPE is simulated over Faridabad, likely an urban-induced downwind effect due to the accurate representation of the Noida sub-urban in AWiFS.

Reference : **Chalakkal, J. B.**, & Mohan, M. (2022). Is the Monsoon climatology observed over the National Capital Region, Delhi indicative of an Urban-Monsoon linkage on rainfall modification? *Urban Climate*, *46*, 101289.

*E-mail addresses: cjerinb@gmail.com; Jerin.B.Chalakkal@cas.iitd.ac.in

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