NUMERICAL MODELING OF URBAN HEAT ISLAND EFFECT OVER CHENNAI METROPOLITAN REGION USING WRF MESOSCALE MODEL – SENSITIVITY STUDIES WITH LAND SURFACE PHYSICS

PRESENTED BY

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OBJECTIVES:

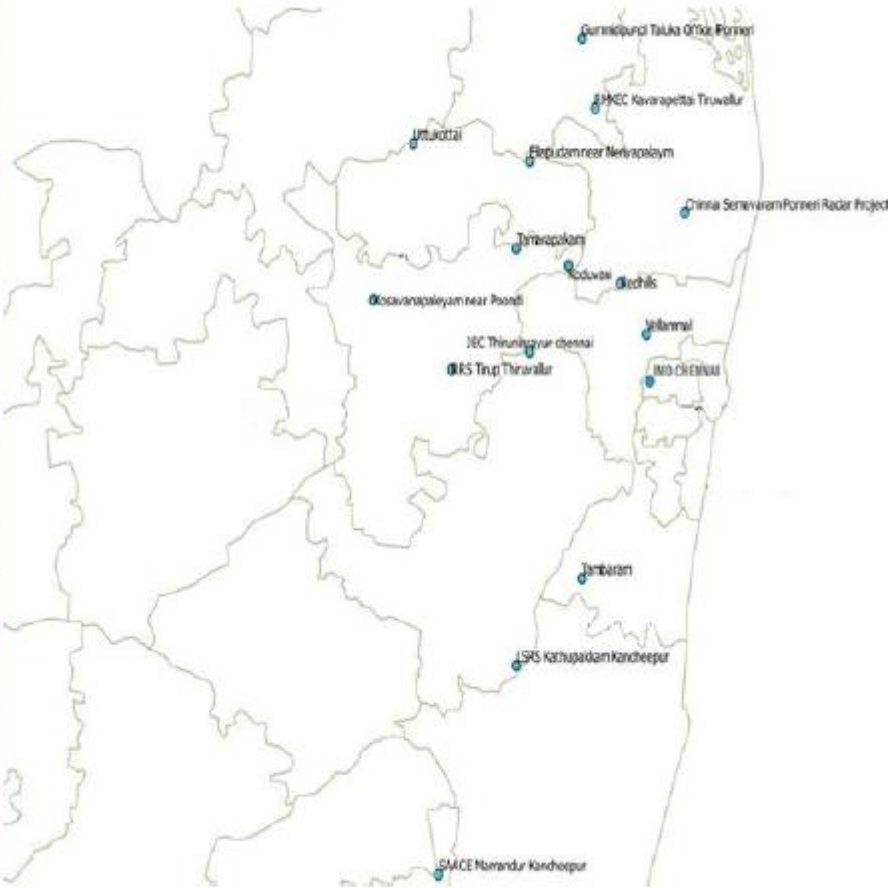
❖The main aim of the study is to investigate the UHI effect on Chennai metropolitan region along with its surrounding areas, simulating with advanced numerical mesoscale atmospheric model, using two LULC data sets i.e. USGS (2003) and NRSC (latest).

❖Sensitivity study is simulated for identifying the better land surface physics scheme between Noah and 5-layer thermal diffusion.

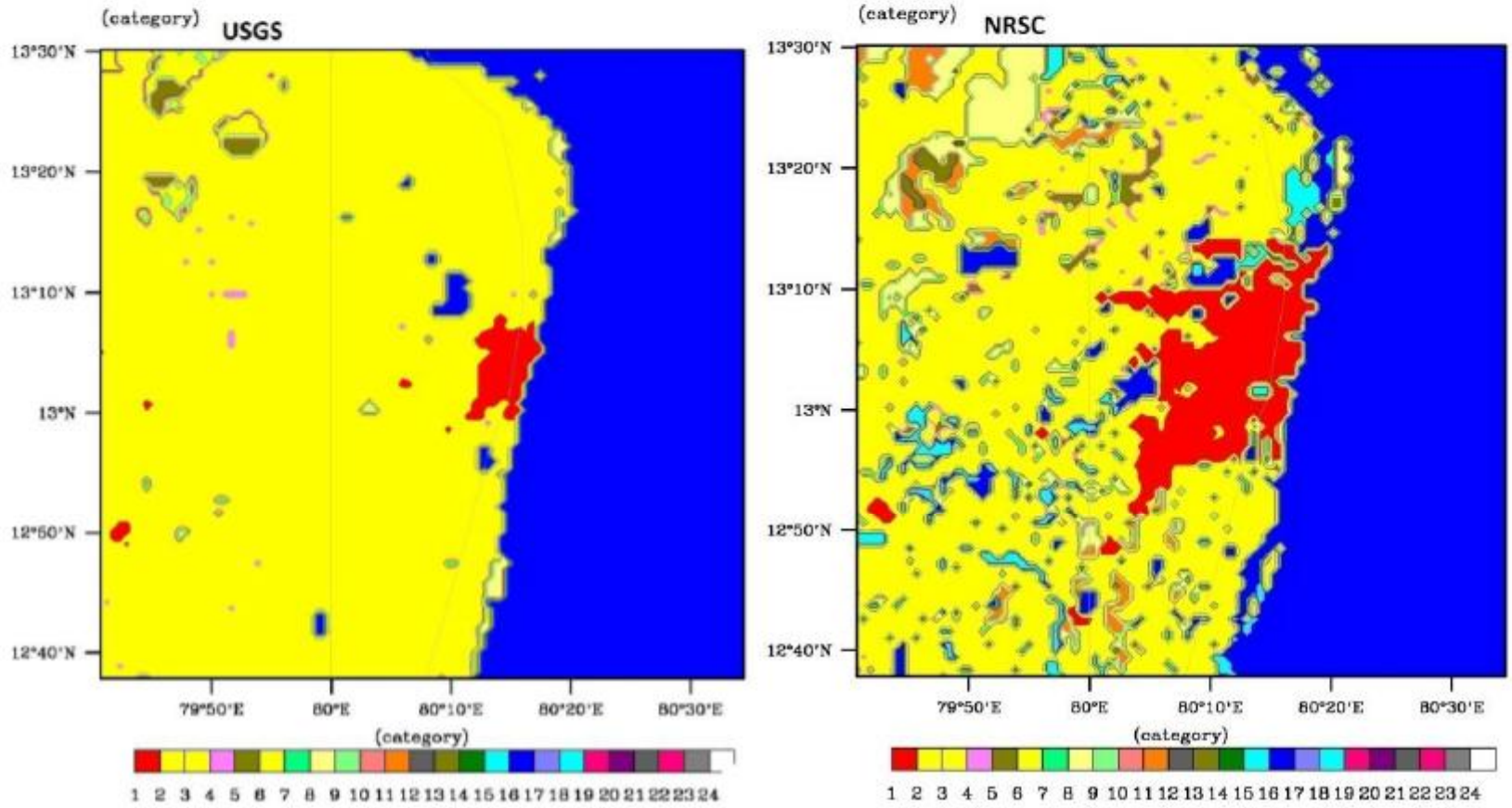
DATA AND METHODOLOGY

Weather Station details and locations

Station no.	Station name	Latitude	Longitude	Category
S1	IMD CHENNAI	13.1	80.2	URBAN
S2	VELLAMMAL	13.15	80.2	URBAN
S3	REDHILLS	13.2	80.1666666	URBAN
S4	KODUVALLI	13.2166666	80.1	SUB-URBAN
S5	GUMMIDIPUNDI PONNERI	13.4333333	80.1166666	SUB-URBAN
S6	JEC THIRUNINRAVUR	13.133333	80.05	SUB-URBAN
S7	CHINNA SEMAVARAM PONNERI	13.2666666	80.25	SUB-URBAN
S8	ELLAPUDAM	13.3166666	80.05	SUB-URBAN
S9	RMKEC KAVARAPETTAI TIRUVALLUR	13.3666666	80.1333333	SUB-URBAN
S10	TAMBARAM	12.9166666	80.1166666	SUB-URBAN
S11	RRS,TIRUP THIRUVALLUR	13.1166666	79.98	SUB-URBAN
S12	KOSAVANAPALEYAM NEAR POONDI	13.1833333	79.85	SUB-URBAN
S13	TAMARAPAKAM	13.2333333	80.0333333	SUB-URBAN
S14	SAACE MAMANDUR	12.6333333	79.9333333	RURAL
S15	UTTUKOTTAI	13.3333333	79.9	RURAL
S16	LSRS-KATHUPAKKAM KANCHEEPUR	12.8333333	80.0333333	RURAL

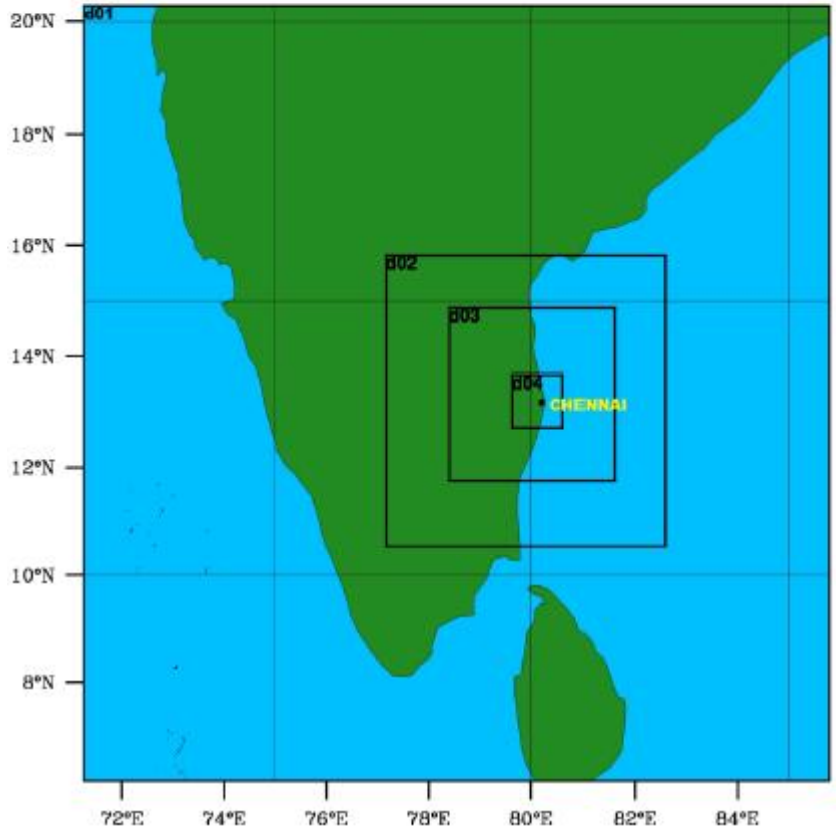


Land Use and Land Cover



Categories: 1."Urban and Built-Up Land", 2."Dryland Cropland and Pasture",3."Irrigated Cropland and Pasture", 4."Mixed Dryland/Irrigated Cropland", 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".

Model domain and configuration



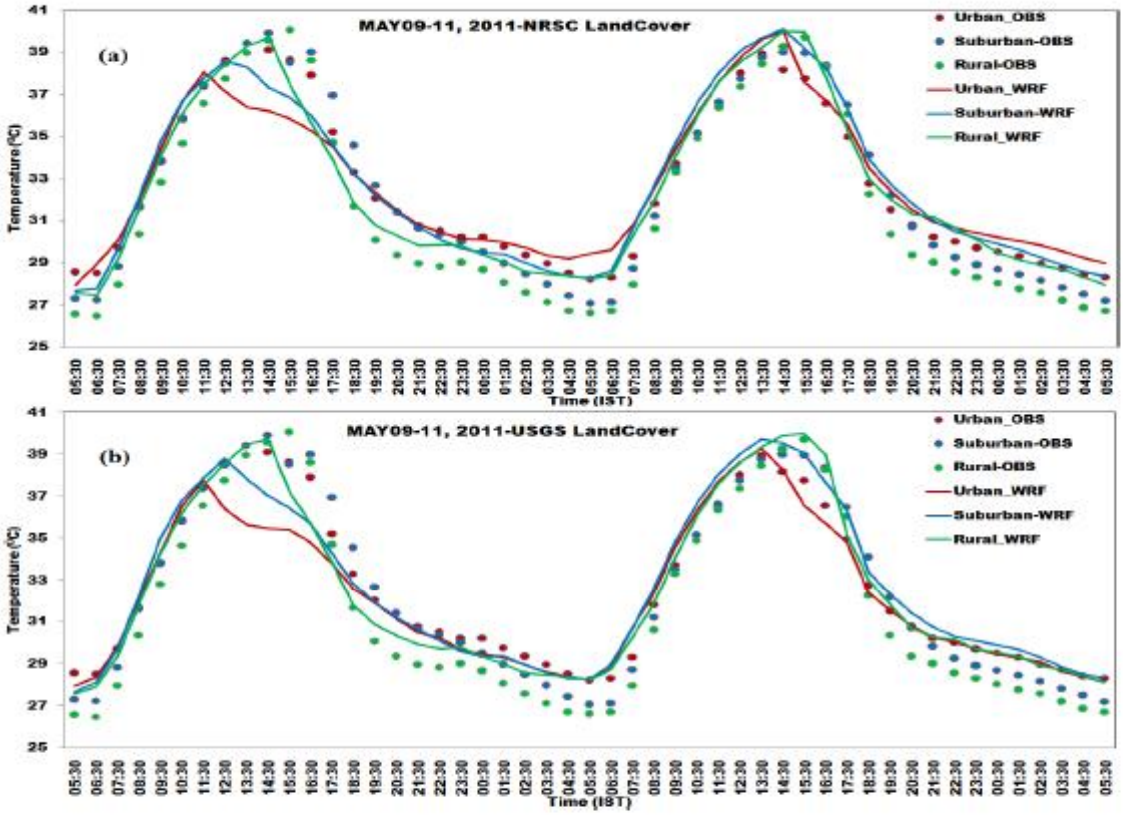
Dynamics	Eulerain Mass Dynamical core			
Domain Configuration				
	Domain1	Domain2	Domain3	Domain4
Domains	6.15502°N–20.0477°N 71.2486°E–85.5514°E	10.4648°N–15.6676°N 77.3314°E–82.6744°E	11.648°N–14.5831°N 78.6192°E–81.6332°E	12.6302°N–13.5021°N 79.6787°E-80.5738°E
Horizontal grid dimension	60 x 60 grids	67 x 67 grids	112 x 112 grids	100 x 100 grids
Vertical grid levels	50	50	50	50
Physics				
Longwave radiation	RRTM schemes			
Shortwave radiation	Dudhia scheme			
Surface layer	MM5 similarity			
Map projection	Mercator			
Land surface physics	Noah Land Surface Model, 5-layer thermal diffusion			
PBL type	YSU- Nonlocal scheme			
Microphysics	WSM 6-class graupel scheme			
Horizontal resolution	27 km, 9 km, 3 km, 1 km			

Simulations are conducted for two synoptic conditions,

a.) Summer -- stating at 00 UTC 2011 May 09 and ending at 00 UTC 2011 May 11;

b.) Winter -- stating at 00 UTC 2011 January 18 and ending at 00 UTC 2011 January 20.

Time series plot and Statistics table representing for two different LULC

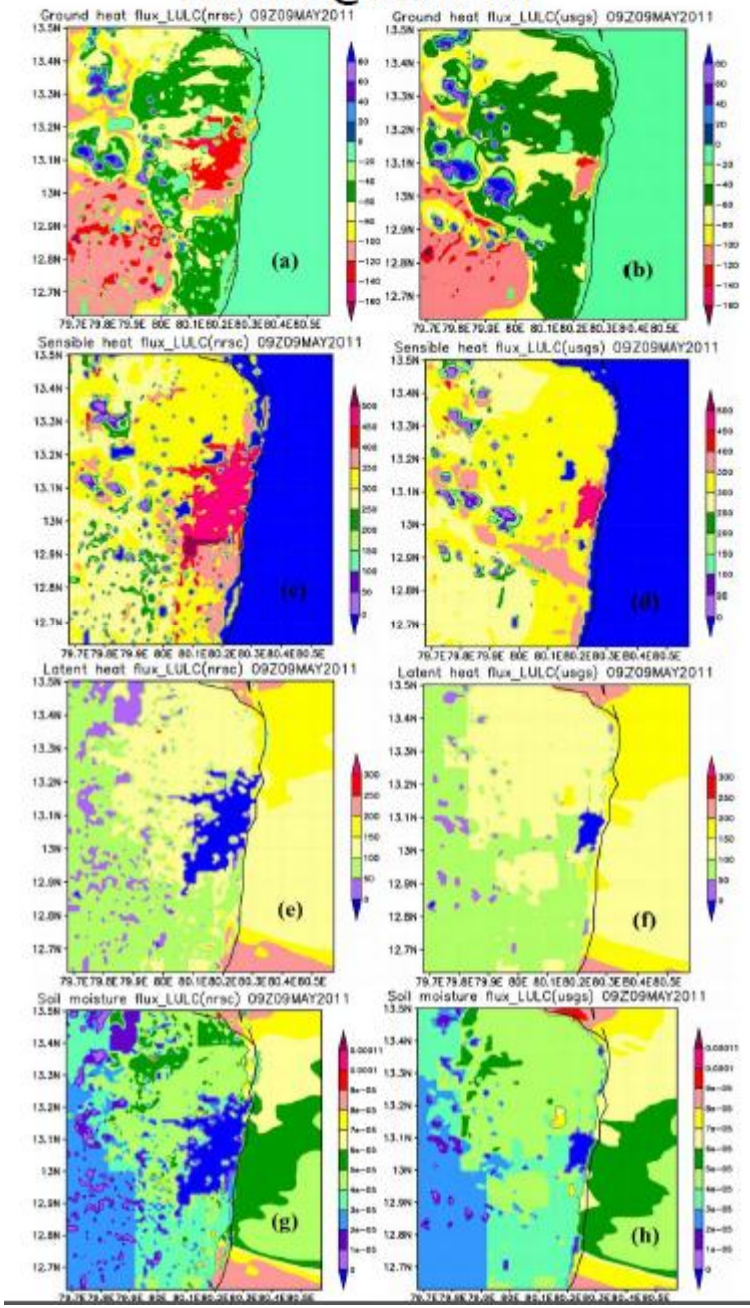


Groups of stations

Urban—IMD Chennai, Vellamal
Sub-urban—Koduvalli, Tambaram, Kavarapettai Tiruvallur, Chinna Semavaram Ponneri, Thiruninravur, Kosavanapaleyam near Poondi, RRS Tirup Thiruvallur
Rural—Mamandur Kancheepur, Kathupakkam Kancheepur

Statistical Parameters	2011 MAY 9-11 --- Groups of Stations					
	NRSC			USGS		
	Urban	sub-urban	Rural	Urban	sub-urban	Rural
CC or r	0.98	0.98	0.98	0.97	0.97	0.98
MBIAS	0.23	0.39	0.89	-0.32	0.30	0.90
RMSE	1.10	1.15	1.34	1.16	1.23	1.32

FLUXES @14:30 IST



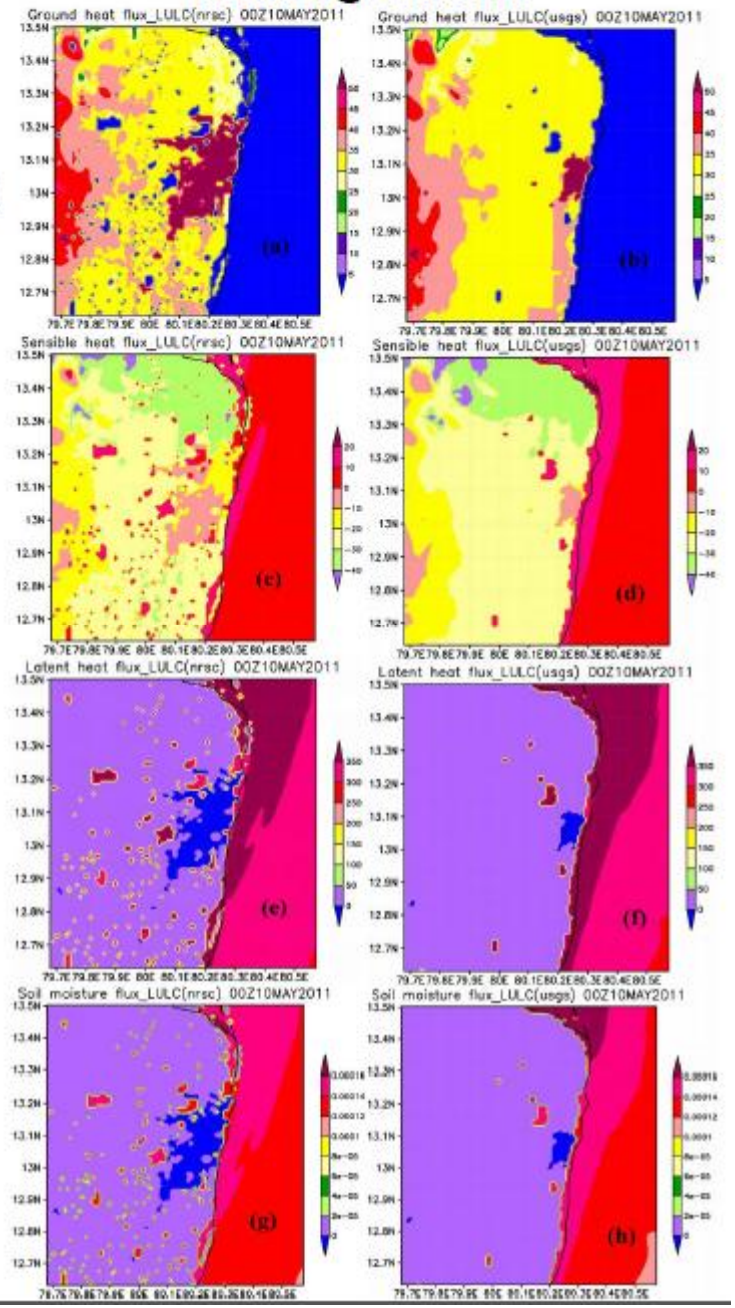
GROUND HEAT FLUX

SENSIBLE HEAT FLUX

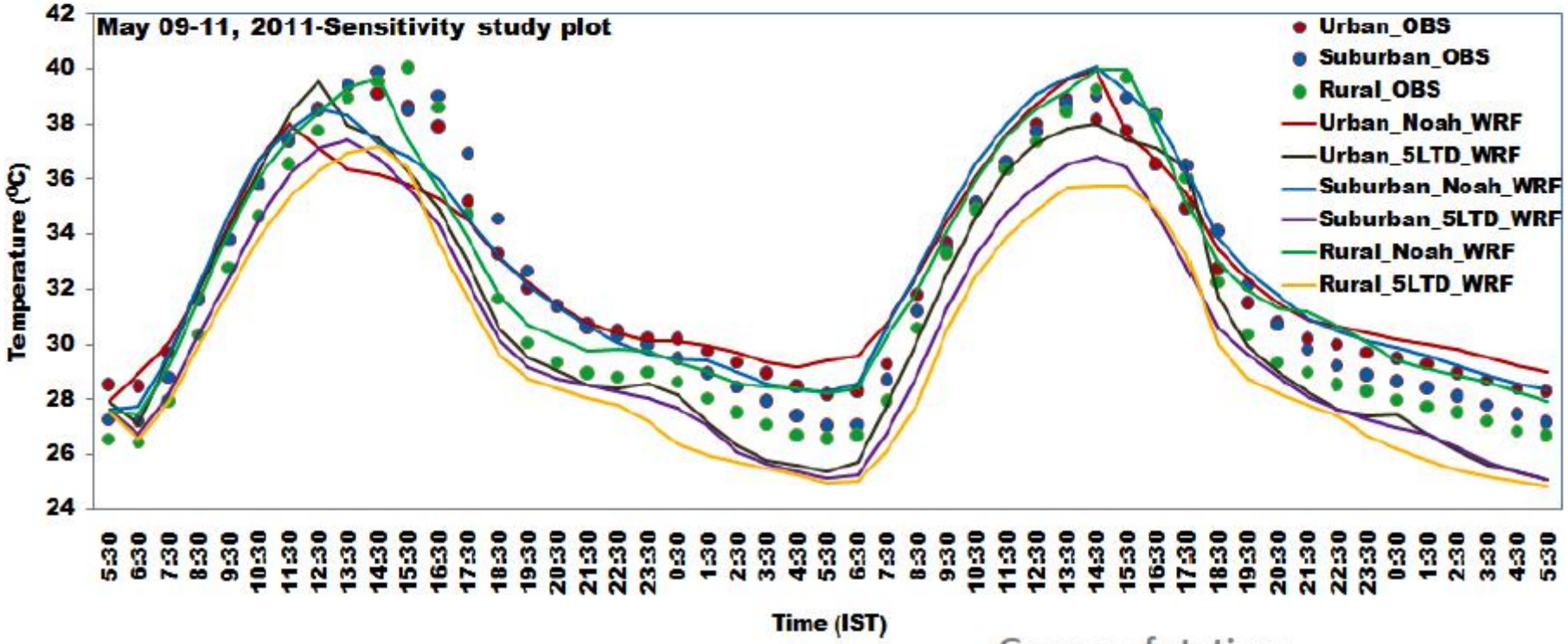
LATENT HEAT FLUX

SOIL MOISTURE FLUX

FLUXES@ 5:30 IST



Sensitivity time series temperature plot & Statistics



Statistical parameters	2011 MAY 9-11 --- Groups of Stations					
	Noah_NRSC			5-Layer Thermal Diffusion_NRSC		
	Urban	sub-urban	rural	Urban	sub-urban	Rural
CC or r	0.98	0.98	0.98	0.97	0.98	0.98
MBIAS	0.23	0.39	0.89	-1.51	-2.15	-1.85
RMSE	1.10	1.15	1.34	1.97	2.35	2.12

Groups of stations

Urban—IMD Chennai, Vellamal
Sub-urban—Koduvalli, Tambaram, Kavarapettai Tiruvallur, Chinna Semavaram Ponneri, Thiruninravur, Kosavanapaleyam near Poondi, RRS Tirup Thiruvallur
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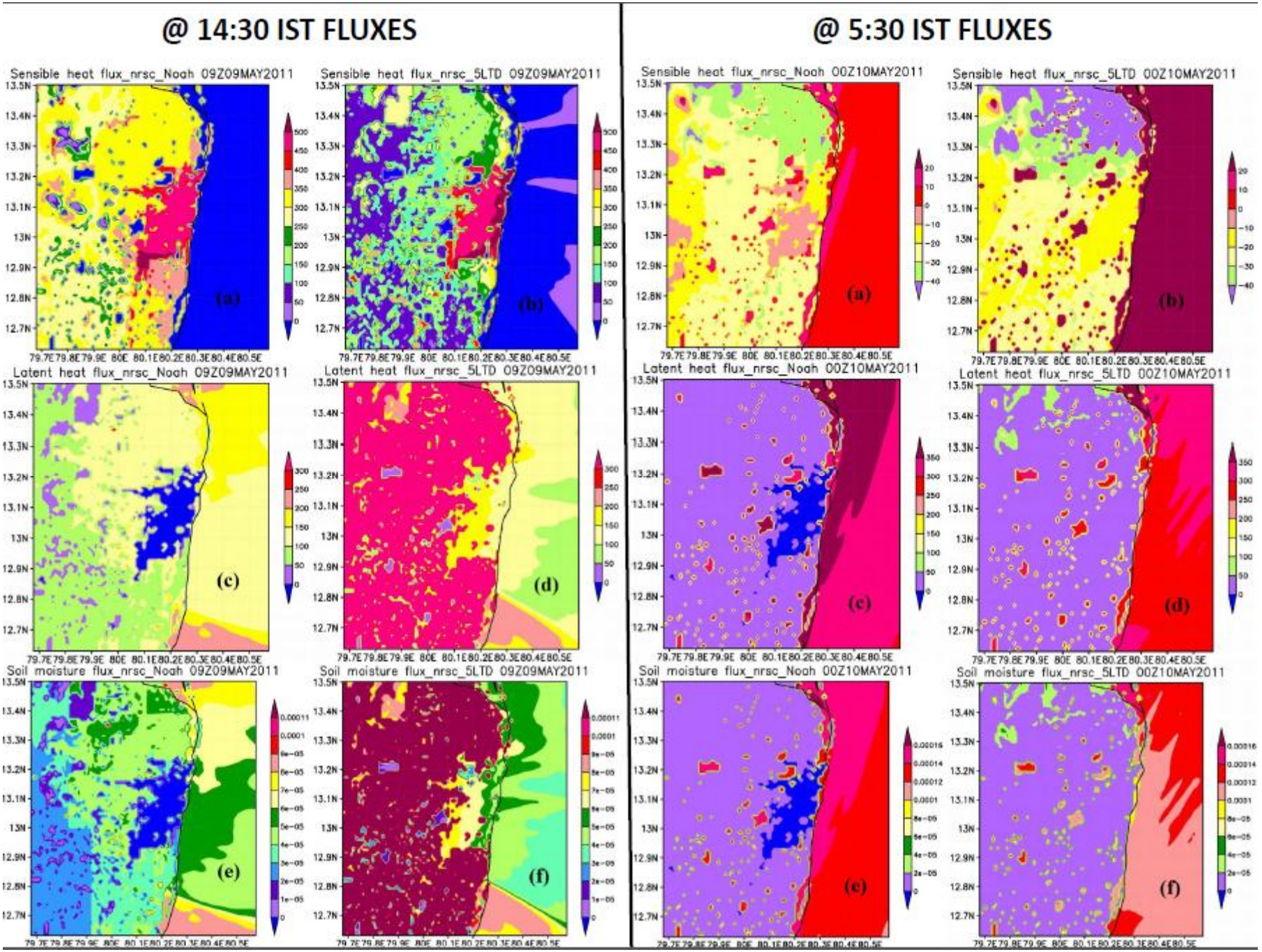
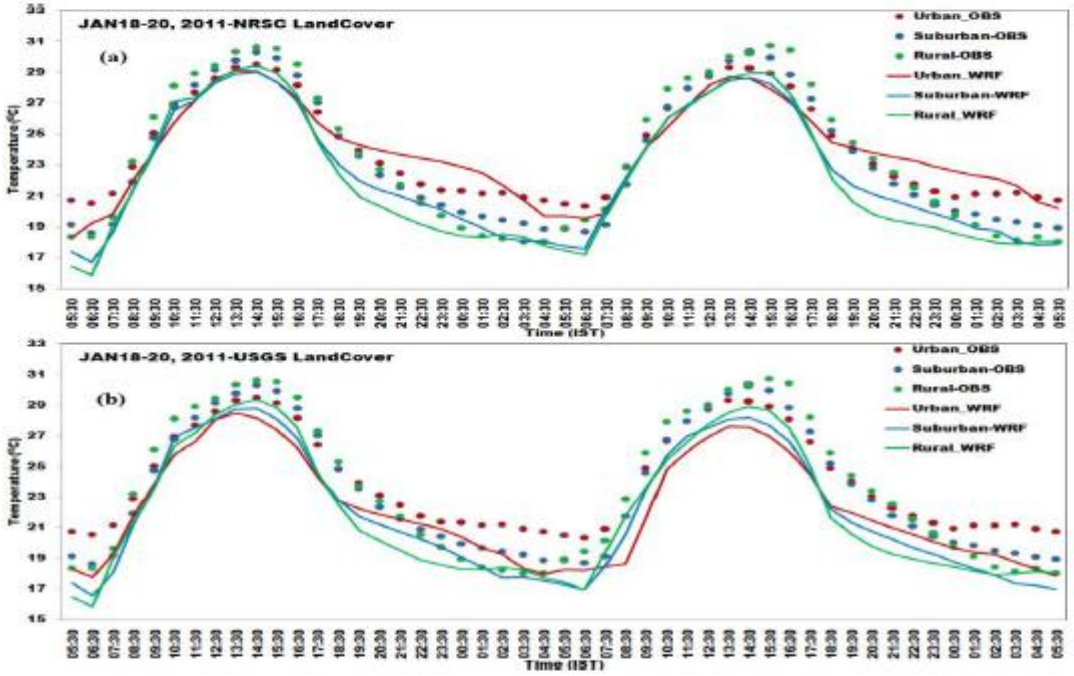

@ 14:30 IST FLUXES
@ 5:30 IST FLUXES
Sensible heat flux_nrsc_Noah 09Z09MAY2011
Sensible heat flux_nrsc_5LTD 09Z09MAY2011
Sensible heat flux_nrsc_Noah 00Z10MAY2011
Sensible heat flux_nrsc_5LTD 00Z10MAY2011
Latent heat flux_nrsc_Noah 09Z09MAY2011
Latent heat flux_nrsc_5LTD 09Z09MAY2011
Latent heat flux_nrsc_Noah 00Z10MAY2011
Latent heat flux_nrsc_5LTD 00Z10MAY2011
Soil moisture flux_nrsc_Noah 09Z09MAY2011
Soil moisture flux_nrsc_5LTD 09Z09MAY2011
Soil moisture flux_nrsc_Noah 00Z10MAY2011
Soil moisture flux_nrsc_5LTD 00Z10MAY2011
(a)
(b)
(c)
(d)
(e)
(f)

Time series plot and Statistics table representing for two different LULC

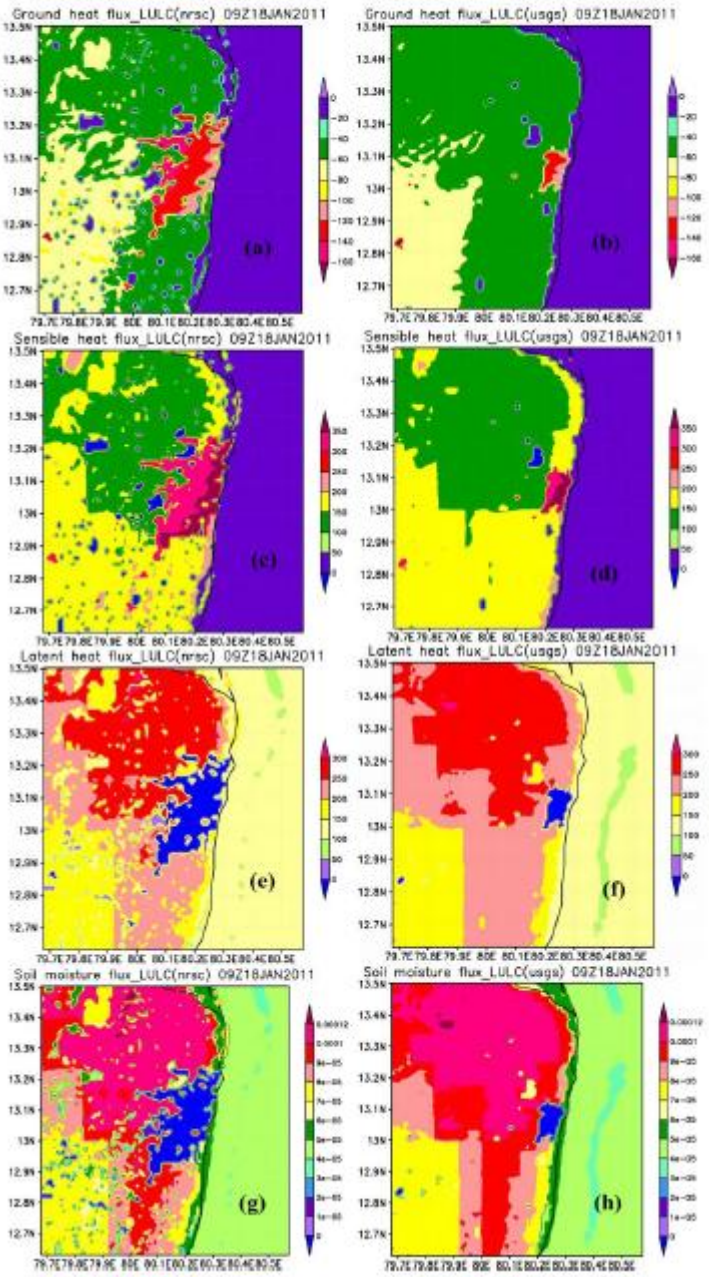


Statistical Parameters	2011 January 19-20 --- Groups of Stations					
	NRSC			USGS		
	urban	sub-urban	Rural	Urban	sub-urban	Rural
CC or r	0.97	0.99	0.98	0.98	0.99	0.97
MBIAS	-0.13	-1.07	-1.57	-1.81	-1.48	-1.71
RMSE	1.03	1.26	1.89	1.95	1.60	2.02

Groups of stations

Urban—IMD Chennai, Vellamal, Redhills
Sub-urban—Koduvalli, Tambaram, Ellapudam near Neriyapalaym, Gummidipundi Taluka Office Ponneri, Tamarapakam, Thiruninravur, Kosavanapaleyam near Poondi
Rural--Uttukottai

FLUXES @14:30 IST



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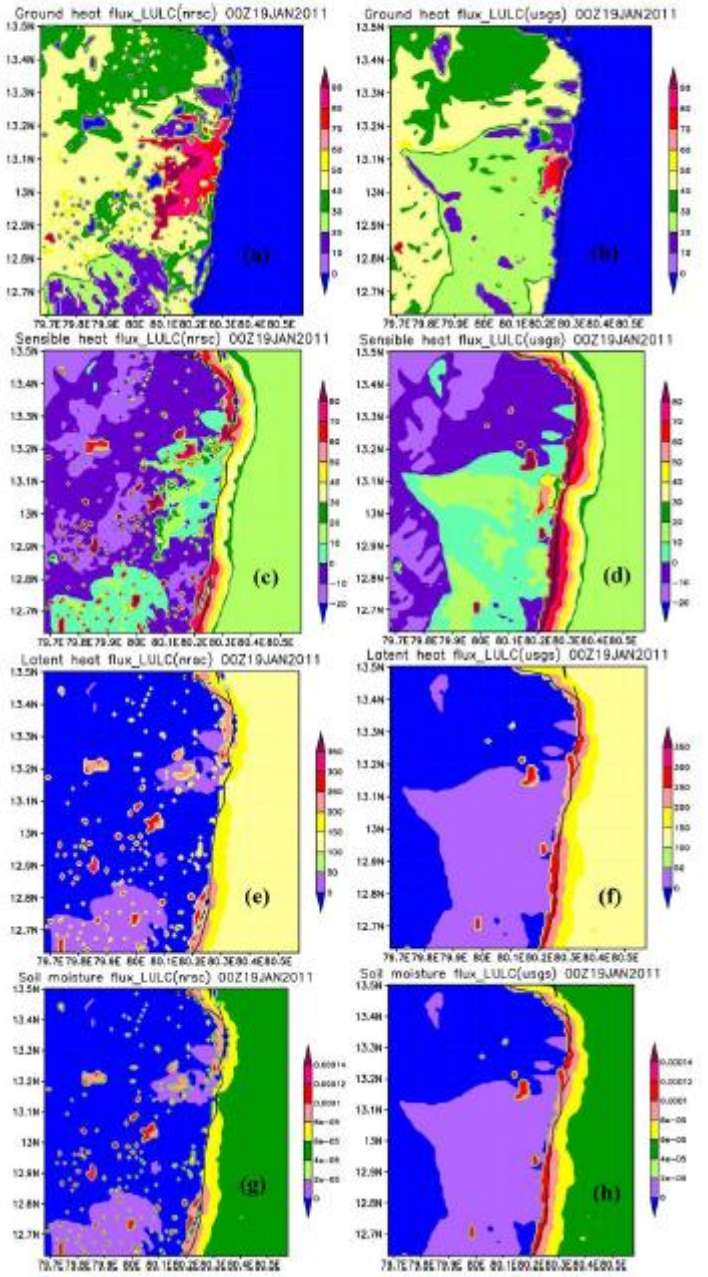
SENSIBLE HEAT FLUX

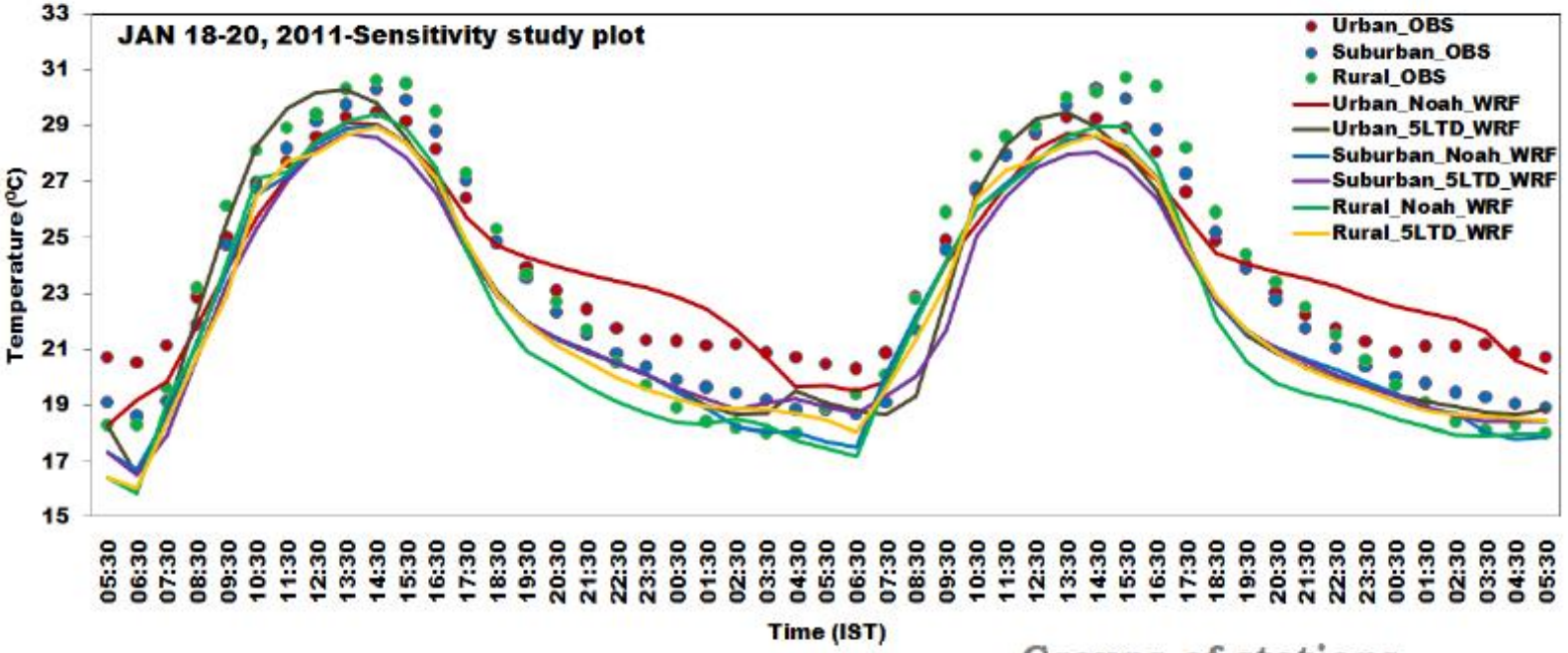
LATENT HEAT FLUX

SOIL MOISTURE FLUX

FLUXES @5:30 IST



Sensitivity time series temperature plot & Statistics table



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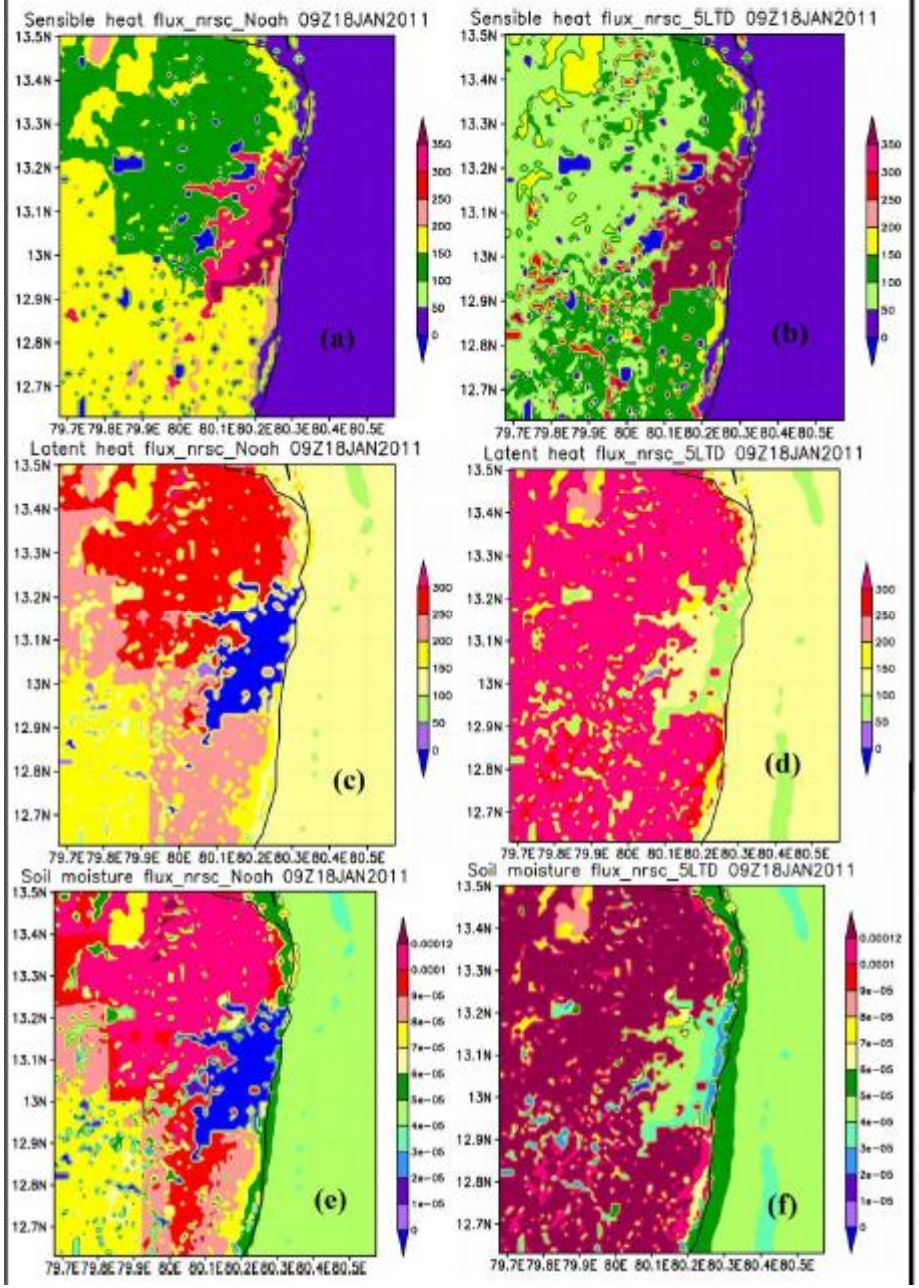

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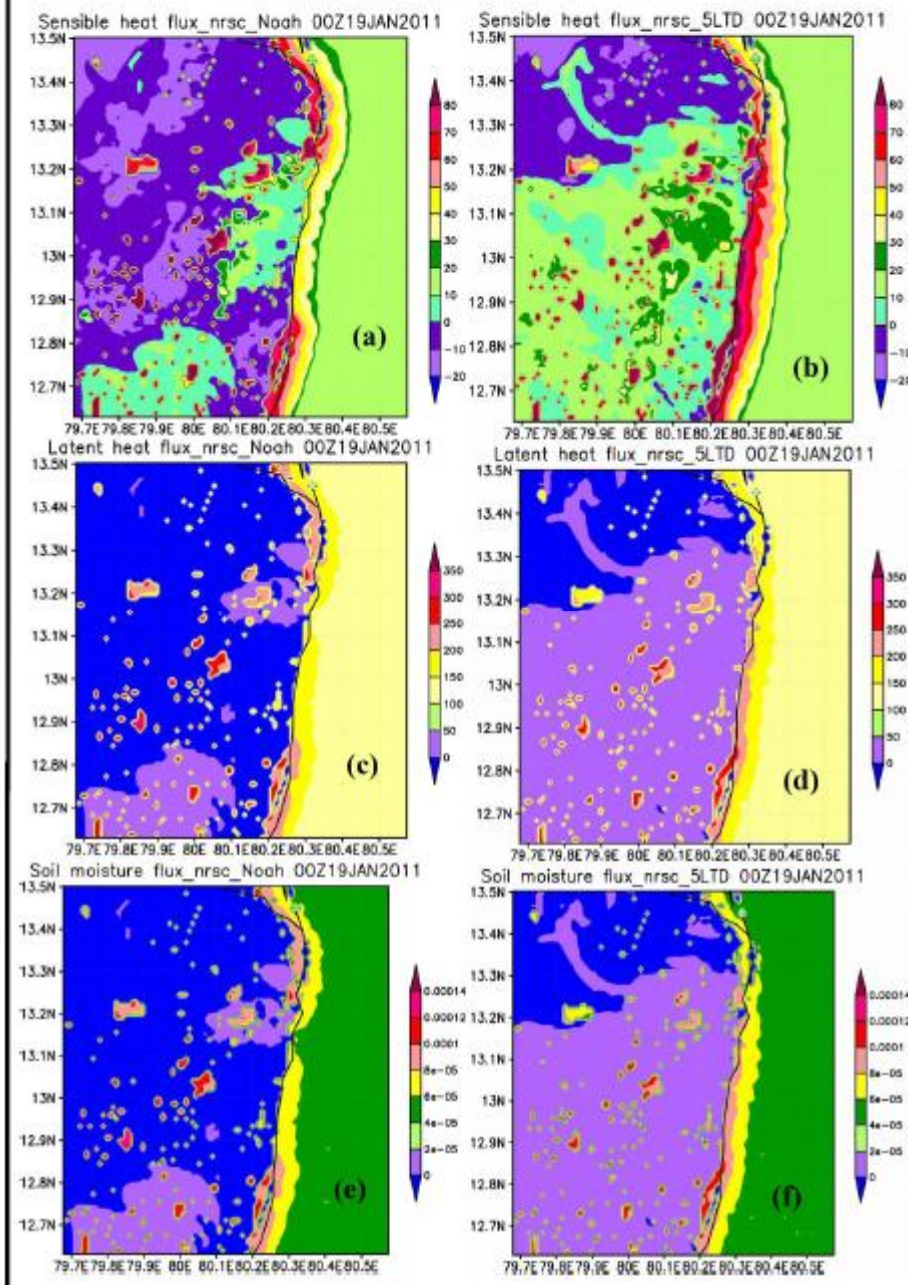

CONCLUSIONS

❖ The simulations performed with the Indian Remote Sensing Satellite (IRS) derived land cover data base of NRSC corresponding to the recent years better represented the urban heat island effect in terms of larger nocturnal air temperatures, surface energy fluxes, skin temperature over the urban areas compared to the rural areas.

❖ A sensitivity study conducting using two different land surface physics parameterizations showed that the Noah scheme simulates better results than the 5-layer soil thermal diffusion scheme.

❖ The statistics have also proved that Noah is the best compared to 5-layer thermal diffusion scheme.

❖ The simulations indicate increased intensity of UHI in the winter (January) compared to the summer (May) with maximum intensity of 5^0C and 2^0C respectively. The main factors which influence the intensity of UHI are densely build up areas, lack of vegetation, material thermal properties and anthropogenic activities.

❖ The study is helpful for planning urban ecosystem.