

Future Changes in Land-Atmosphere Feedback over India

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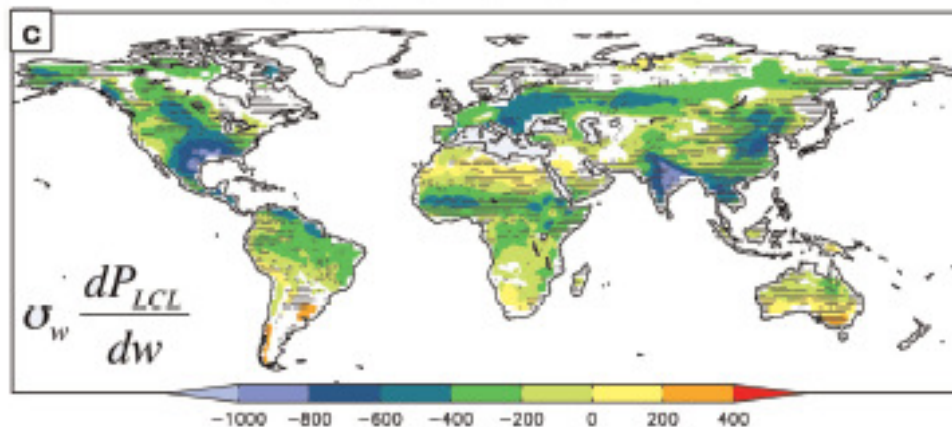
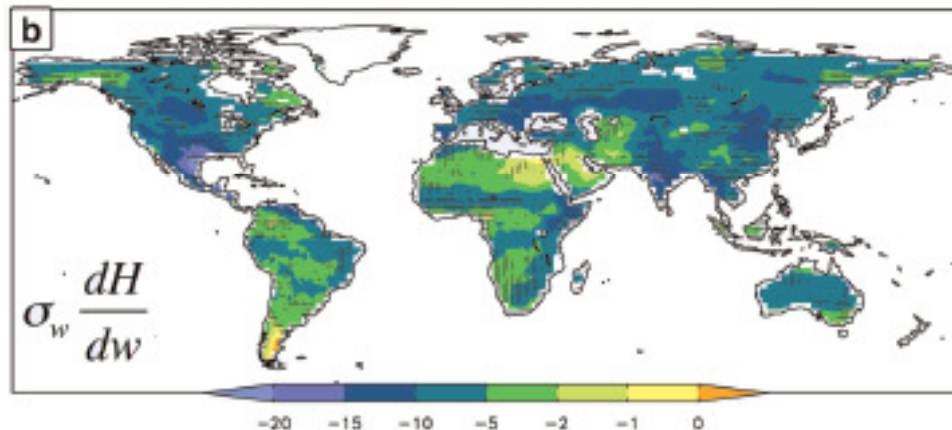
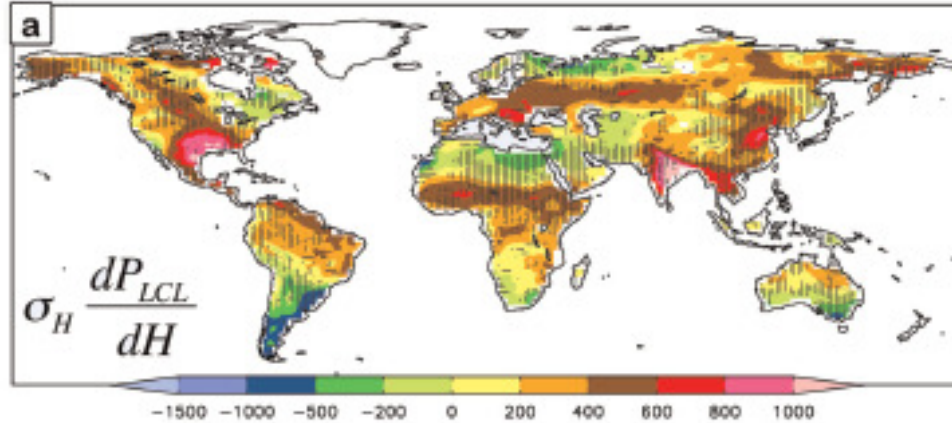
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INDIA





- Soil moisture affects the partitioning of net radiation between sensible and latent heat flux to the atmosphere
- The feedback from land to atmosphere can occur through two land-atmosphere coupling pathways:
 - *Water cycle* - changes in evapotranspiration and its variability influence atmospheric humidity, stability, cloud formation, and precipitation (e.g., Koster et al. 2006 and others)
 - *Energy cycle* - Surface sensible heat flux drives growth of the boundary layer, enabling the formation of clouds by mixing moist air upward to the height where temperature and pressure allow condensation to occur (e.g., Betts et al. 1996 and others)
- The Coupled Model Intercomparison Project Phase 5 (CMIP5) model simulations project increases in land-atmosphere feedback through water cycle and energy cycle (Dirmeyer et al. 2013, 2014)
- This study examines the thermally driven land-atmosphere coupling pathway through the energy cycle in the high resolution downscaled regional climate change projections available from CORDEX South Asia

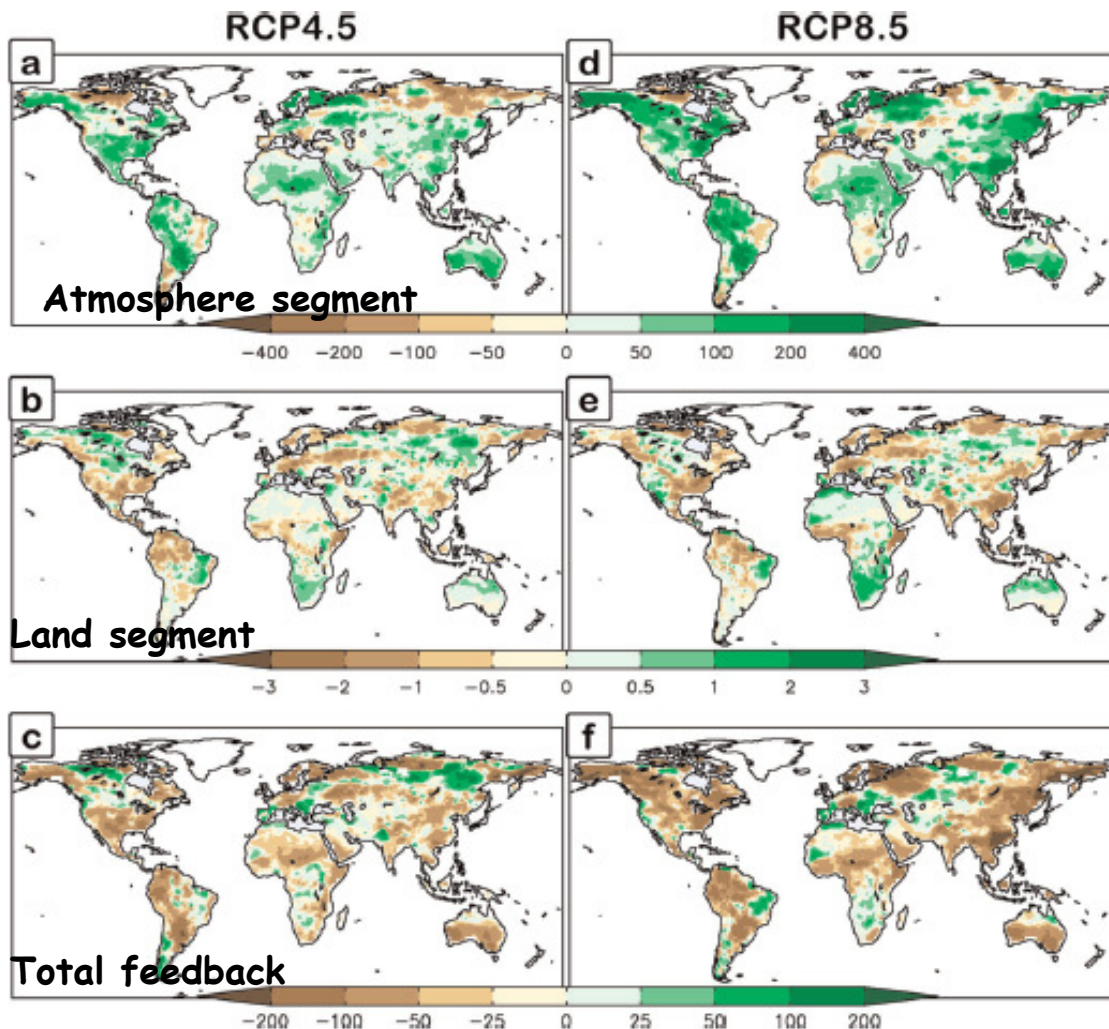
Thermal Land Surface Controls on the Atmosphere Dirmeyer et al. 2014, GRL



- Multi-model mean of 10 CMIP5 AOGCMs during JJA (1916-2005)
- **Atmosphere segment:** Sensitivity of the height of LCL above ground in pressure co-ordinates (P_{LCL}) to sensible heat flux (H)
 - These differentials are estimated as the slope of the linear regression through the detrended monthly values for the selected years of simulation estimated separately for each month of the year
- **Land segment:** Sensitivity of H to surface soil moisture (w)
- **Total feedback path**
 - Striping indicates where at least 8 models concur on an increase (vertical) or decrease (horizontal) in RCP8.5

Intensified land surface control on boundary layer growth in a changing climate

Dirmeyer et al. 2014, GRL



- Land-atmosphere feedback goes from soil moisture to sensible heat to PBL growth
- This feedback pathway is likely to strengthen in a warming climate
- Sensitivity to land use change and climate extremes may amplify in the future

Land-Atmosphere coupling plays a critical role in influencing the South Asian monsoon climate variability



A study on the role of land-atmosphere coupling on the south Asian monsoon climate variability using a regional climate model

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Theor Appl Climatol (2017) 127:949–964

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- Sensitivity study using WRF (45 km) by replacing the soil moisture evolution at each time step with its climatology (2000-2011) taken from the control run
- Soil moisture makes a significant contribution to monsoon (large-scale) rainfall variability over the monsoon region
- Soil moisture is found more strongly coupled to sensible heat flux over most of the monsoon region
- The coupling of the soil moisture to temperature and rainfall over central India is operated mainly through sensible heat flux
- The monsoon trough region, northwest region, and southeast India exhibit a strong coupling of soil moisture and boundary layer height.

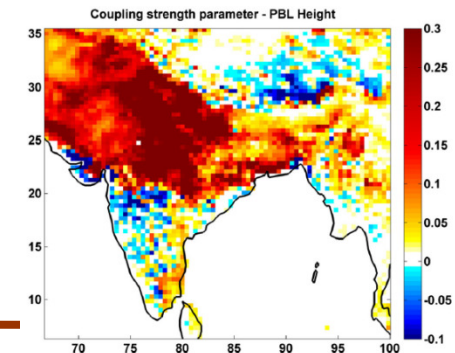
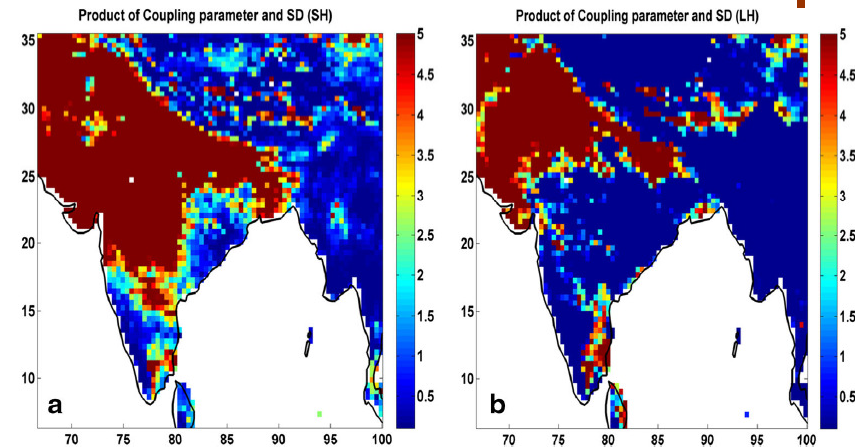
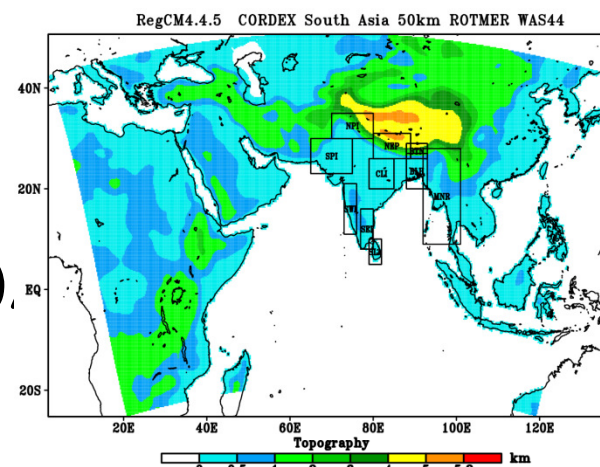


Fig. 15 The product of coupling strength parameter for planetary boundary layer height

CORDEX South Asia Experiments with IITM-RegCM4 50km

- RCM: ICTP RegCM4.4.5 + CLM4.5
- CMIP5 Downscaling of
Historical(56y;1950-2005),
RCP4.5(94y;2006-2099),
RCP8.5(94y;2006-2099)
- Driven with 6 CMIP5 AOGCMs: GFDL-ESM2M, CNRM-CM5,
CSIRO-Mk3.6, MPI-ESM-LR,
IPSL-CM5A-LR & CanESM2
- IITM-RegCM4 outputs are published on CCCR-IITM
ESGF data node after quality assurance as per
CORDEX archival specifications.

http://cccr.tropmet.res.in/home/cordexsa_datasets.jsp



ESGF Data Node @ CCCR-IITM
http://cccr.tropmet.res.in/home/esgf_node.jsp



Changes in Downscaled Regional Climate Projections from CORDEX South Asia



Precipitation

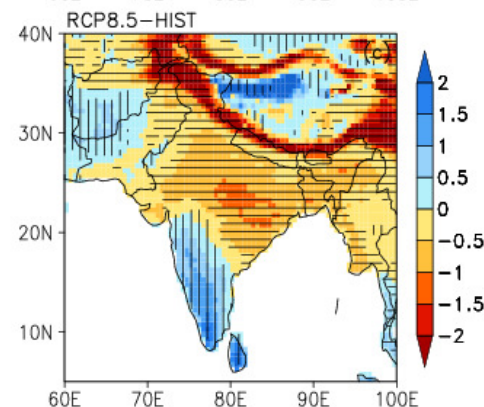
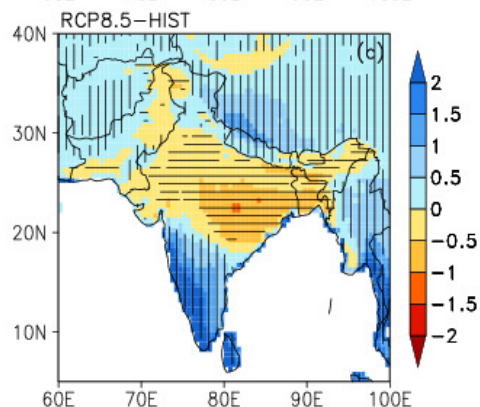
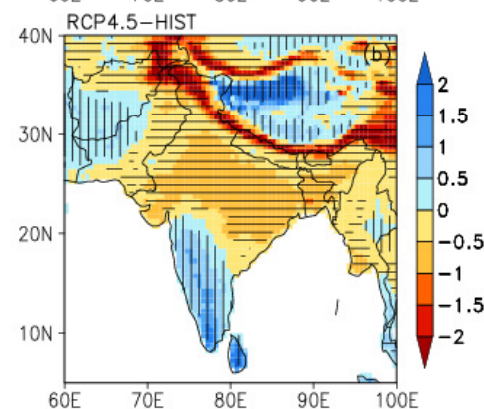
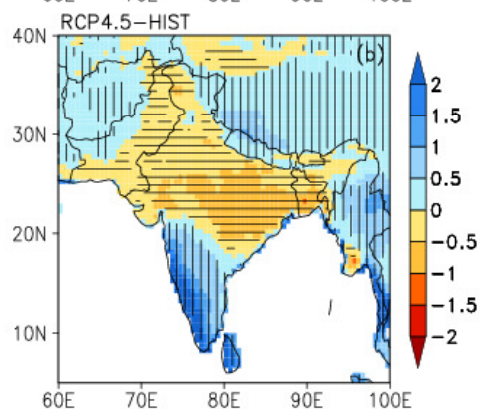
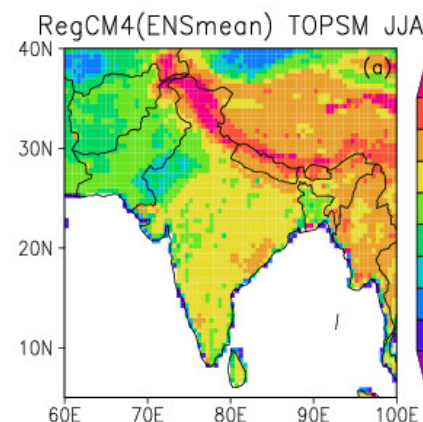
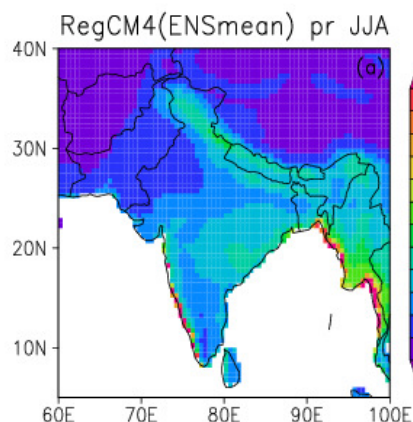
Surface Soil Moisture

**Historical
(1951-2005)**

**Projected
Change
(2006-2099)**

RCP 4.5

RCP 8.5

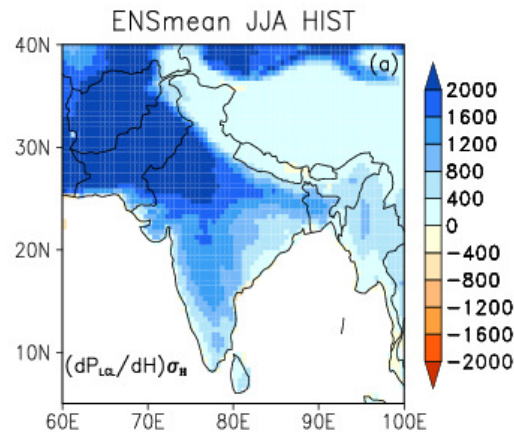


- Ensemble mean of 6 regional climate projections downscaled with IITM-RegCM4 RCM

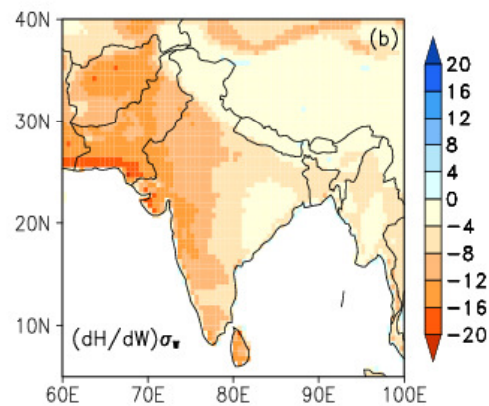
- Striping indicates where at least 4 realizations concur on an increase (vertical) or decrease (horizontal) in RCPs.



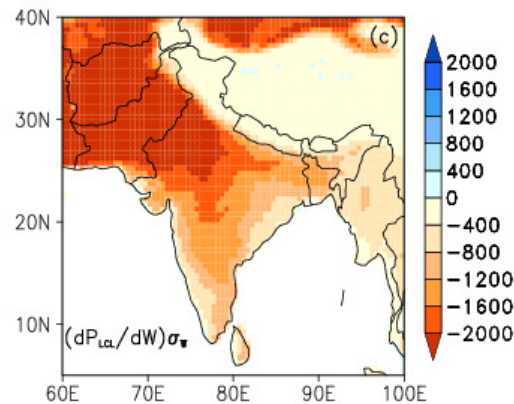
Thermal Land Surface Controls on the Atmosphere during Summer Monsoon Season



- Ensemble mean of 6 regional climate projections downscaled with IITM-RegCM4 RCM
- **Atmosphere segment:** Sensitivity of the height of LCL above ground in pressure co-ordinates (P_{LCL}) to sensible heat flux (H)



- **Land segment:**
Sensitivity of H to surface soil moisture (w)

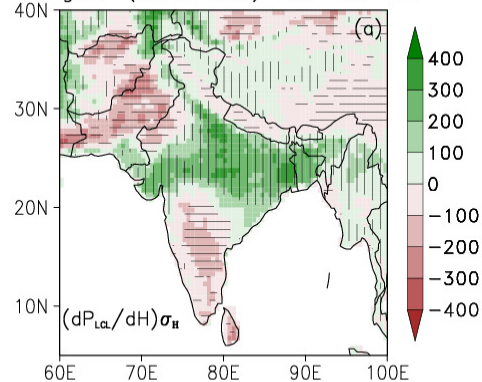


- **Total feedback path**

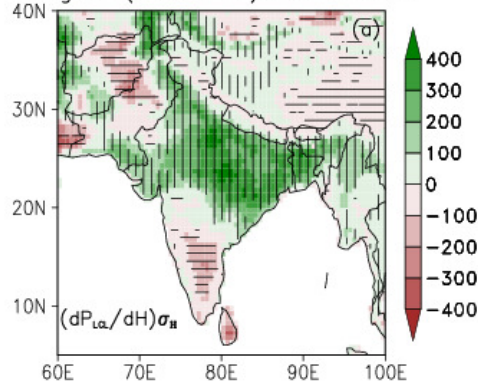
Intensified land surface control on boundary layer growth in a changing climate



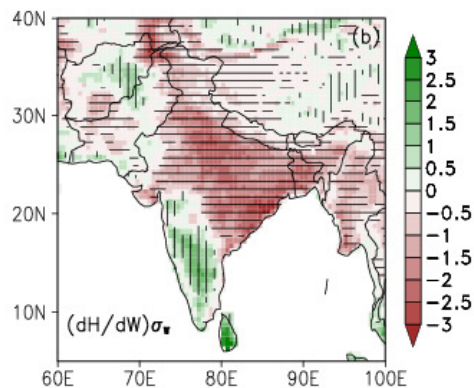
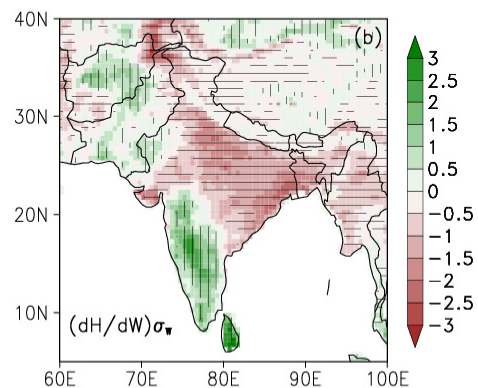
RegCM4(ENSmean) JJA RCP4.5



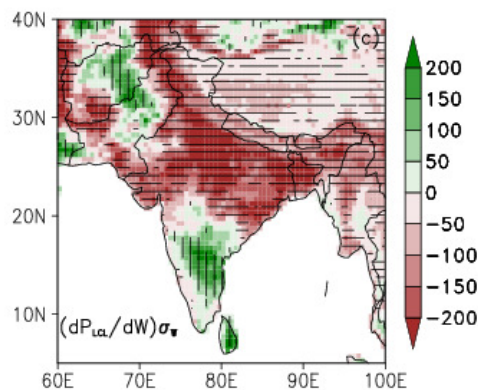
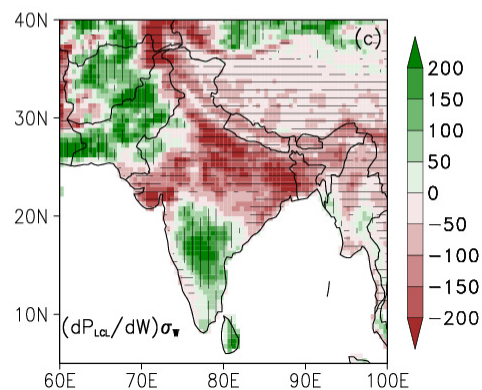
RegCM4(ENSmean) JJA RCP8.5



Atmosphere segment



Land segment



Total feedback

- Striping indicates where at least 4 realizations concur on an increase (vertical) or decrease (horizontal) in RCPs.



Summary

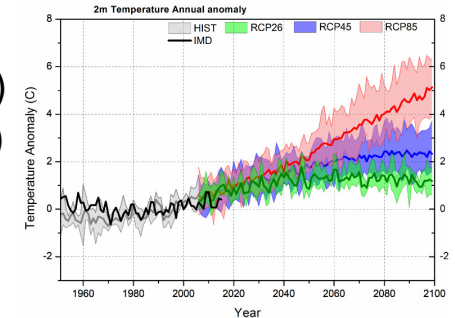
- Regional climate projections downscaled with IITM-RegCM4 RCM for historical and future climate scenarios are examined for changes in the energy cycle component of land surface feedback on the atmosphere
- Land-atmosphere feedback links from soil moisture to sensible heat flux to growth of the atmospheric boundary layer
- Projected changes indicate increased sensitivity in both of these segments of the feedback pathway over the monsoon trough region
- With increased sensitivity, the summer soil moisture variations could have more impact on regional climate than they do today

Latest updates



- Summary of 17 CORDEX South Asia 0.44° datasets available on ESGF (~20 TB)

- IITM-RegCM4: Hist (6); RCP8.5 (6); RCP4.5 (6)
 - SMHI-RCA4 : Hist (10); RCP8.5 (10); RCP4.5 (10); RCP2.6 (5)
 - CSC-REMO2009: Hist (1); RCP8.5 (1); RCP4.5 (1); RCP2.6 (1)
- http://cccr.tropmet.res.in/home/cordexsa_datasets.jsp



- Future climate change projections over India assessed using CORDEX South Asia RCM outputs
 - Available at <http://cccr.tropmet.res.in/home/reports.jsp>
- The new information available from CORDEX South Asia are found useful for contributing to the Hindu Kush Himalayan Monitoring and Assessment Programme (HIMAP; <http://www.icimod.org/himap>)
 - Sanjay et al. (2017), *Advances in Climate Change Research*, doi: 10.1016/j.accr.2017.08.003

Future Plans

- Apply bias-correction to the CORDEX South Asia RCM outputs and publish on CCCR-IITM ESGF data node as CORDEX-Adjusted datasets
- CCCR-IITM is developing a global high resolution (27km) atmospheric version of the IITM Earth System Model for future downscaling activities



Thanks for your attention

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Thank You

- JMBSC, MRI, JMA
- CCCR-IITM, MoES, GoI