Impact of South Asian pollutants on rainfall and the UTLS in chemistry climate model simulations

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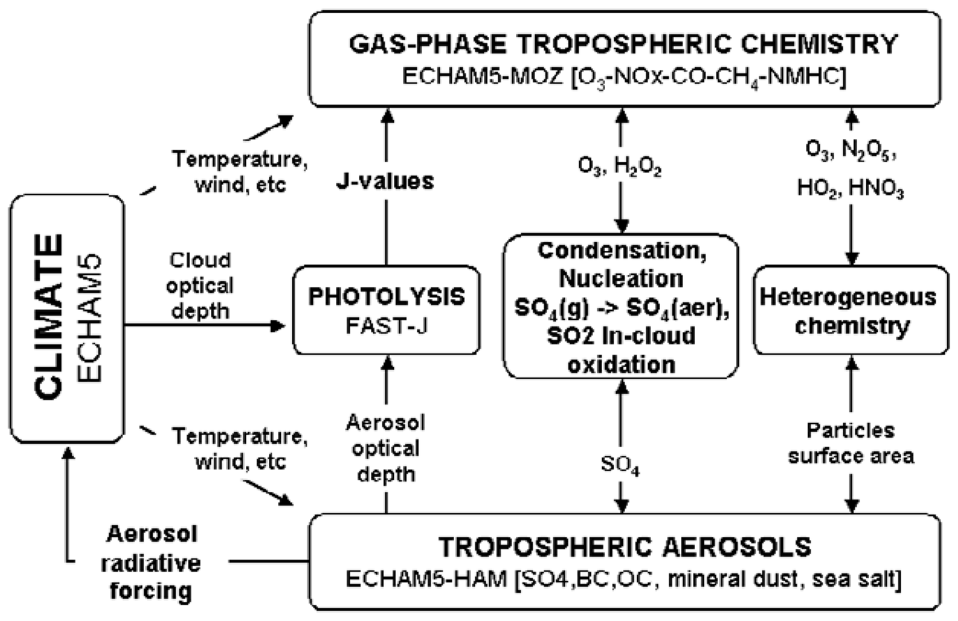
Schematic of the aerosol-chemistry-climate model ECHAM6-HAMMOZ



The model comprises (1) the general circulation model ECHAM6, (2) the tropospheric chemistry module, MOZ, and (3) the Hamburg Aerosol Model (HAM).

The modules ECHAM, HAM, and MOZ are fully interactive.

Levels: T63 47 hybrid σ-p levels

Resolutions: $1.875^{o} \times 1.875^{o}$

- The HAM module takes into account the major aerosol compounds, namely sulfate, BC, OC, sea salt, and mineral dust.
- It represents aerosols as internal and external mixtures with four soluble and three insoluble modes.
- The chemical scheme used in the tropospheric chemistry module, MOZ, is identical to the MOZART-2 model.
- It includes 63 tracers and 168 reactions to represent Ox–NOx–hydrocarbon chemistry.

Tropospheric warming over the North Indian Ocean caused by the South Asian anthropogenic aerosols

Suvarna Fadnavis et al., *Atmospheric Chemistry and Physics, 2022, doi:10.5194/acp-2021-969*

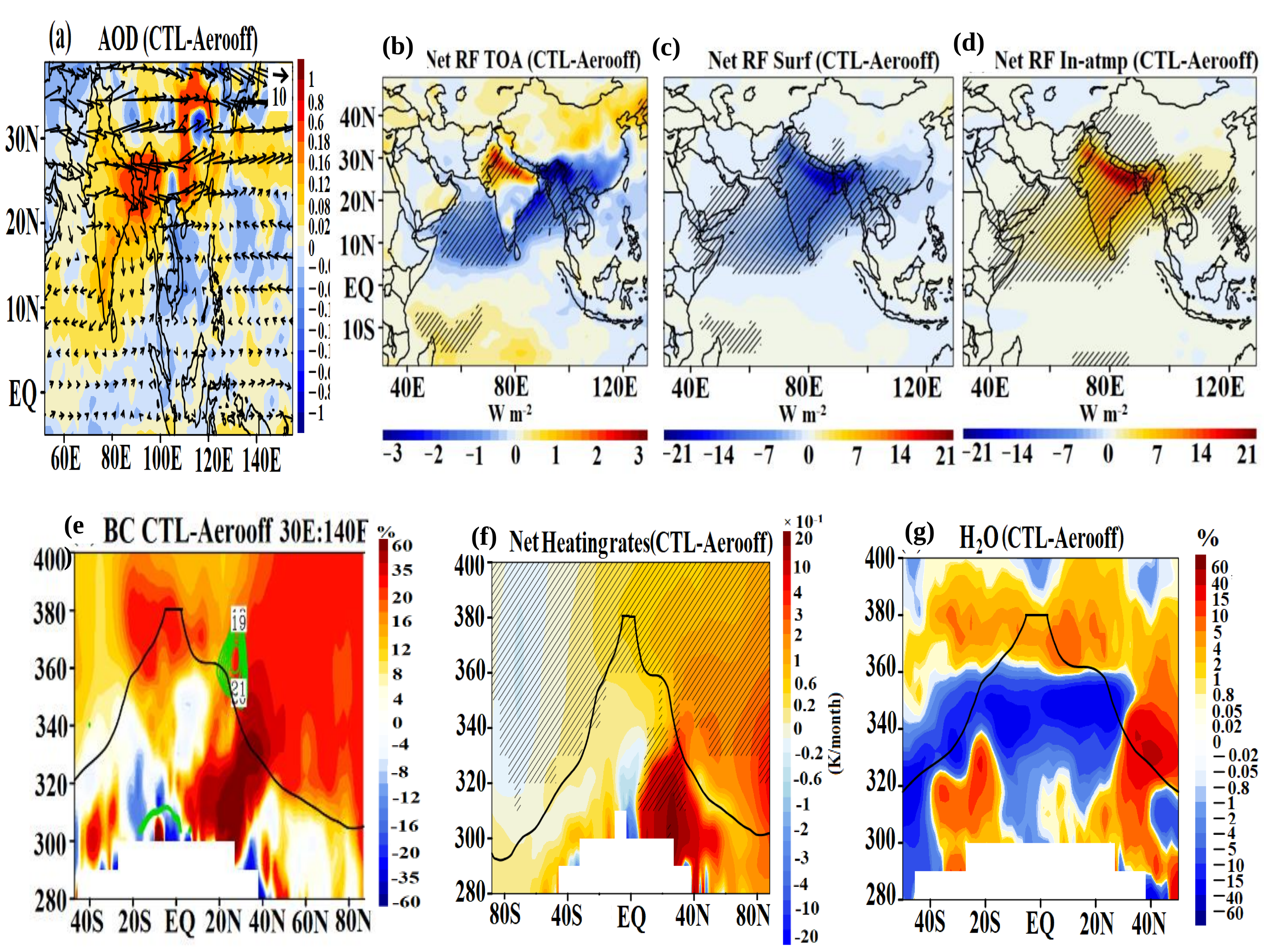


Fig: Spatial distribution of (a) AOD anomalies averaged for spring, (b) RF at TOA, (c) RF at the surface, (d) RF at in-atmosphere, (e) Meridional cross-section over Indian Ocean-western Pacific (averaged 30° E – 140° E) of anomalies (%) of BC, (f) same as (b) but for heating rate, (g) same as (b) but for water vapor.

ECHAM6-HAMMOZ model simulations for the period 2001–2016:

- (1) CTL (2) All anthropogenic BC, OC, and sulfate aerosols switch off over South Asia (aerooff), (3) Only BC aerosols switched off (BCoff), (4) only OC aerosols switched off (OCoff), (5) only sulfate aerosols switched (Suloff).
- There is an enhancement in AOD by 0.08 – 0.8 over South Asia due to South Asian anthropogenic aerosols.
- The aerosol changes cause a reduction in RF at TOA by -1 to -3 W m^{-2} and surface by -7 to -21 W m^{-2}, and an increase in In-atmosphere RF by -14 W m^{-2}.
- The South Asian aerosols are transported to the Southern hemisphere.
- South Asian aerosols are also transported into UTLS and the Arctic enhances heating by 0.6 to 20 K/month.
- Atmospheric heating cause an increase in water vapor by 10% in the UTLS.
- Enhancement of stratospheric water has implications on stratospheric ozone loss and climate change.

The impact of COVID-19 lockdown measures on the Indian summer monsoon

Fadnavis, Sabin, Rap, Müller, Kubin and Heinold, *Environ. Res. Lett., 2021, doi:10.1088/1748-9326/ac109c,*

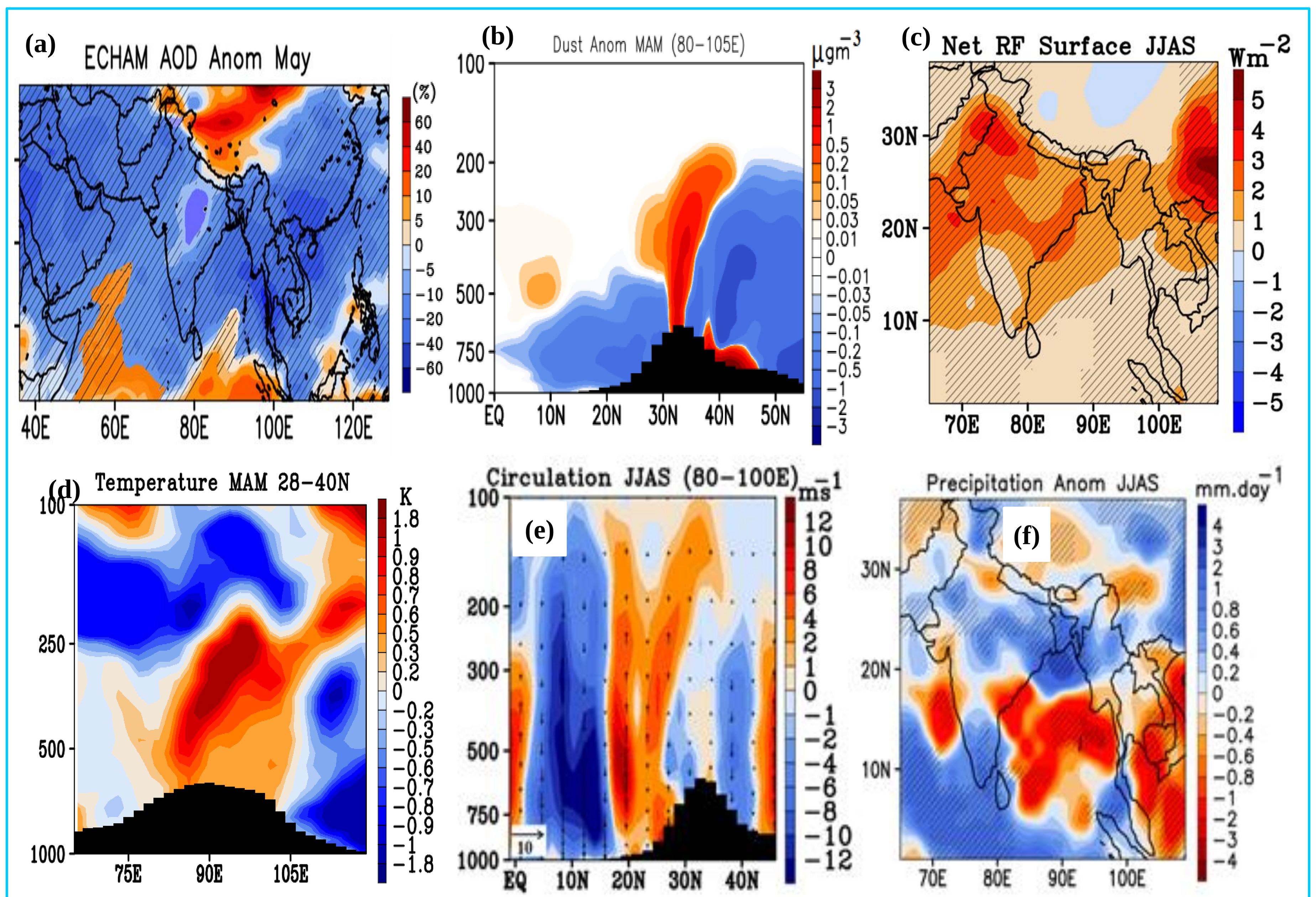


Fig: (a) Aerosol Optical Depth (AOD) at 550 nm (%), (b) Dust anomalies, (c) seasonal mean net radiative forcing at the surface, (d) Latitude-pressure section of anomalies in temperature, (e) Latitude-pressure section of anomalies in vertical velocities, (f) distribution of anomalies in rainfall averaged for the monsoon season (mm day-1).

Anthropogenic aerosols and gaseous emissions are scaled as per Google and Apple mobility data during COVID-19 lockdown period April-May 2020 in the ECHAM6-HAMMOZ model.

- Our simulations show that lockdown measures caused a reduction of aerosol pollution over the Asian region by ~40%,
- Increase in regional surface solar radiation by up to 4 Wm^{-2} and tropospheric shortwave heating rates by 0.0003 – 0.004 $K.day^{-1}$ over India. This effect is compounded by accumulated dust over the TP region.
- This warming resulted in an accelerated moisture inflow and strengthened the monsoon Hadley circulation and precipitation by 20%.

Abrupt emission reduction during COVID-19 intensified the spring 2020 rainfall over India

Asutosh, Fadnavis, Chavan, Sabin and Rolf, *Frontiers in Environmental Science, doi: 10.3389/fenvs.2022.911363, 2022*

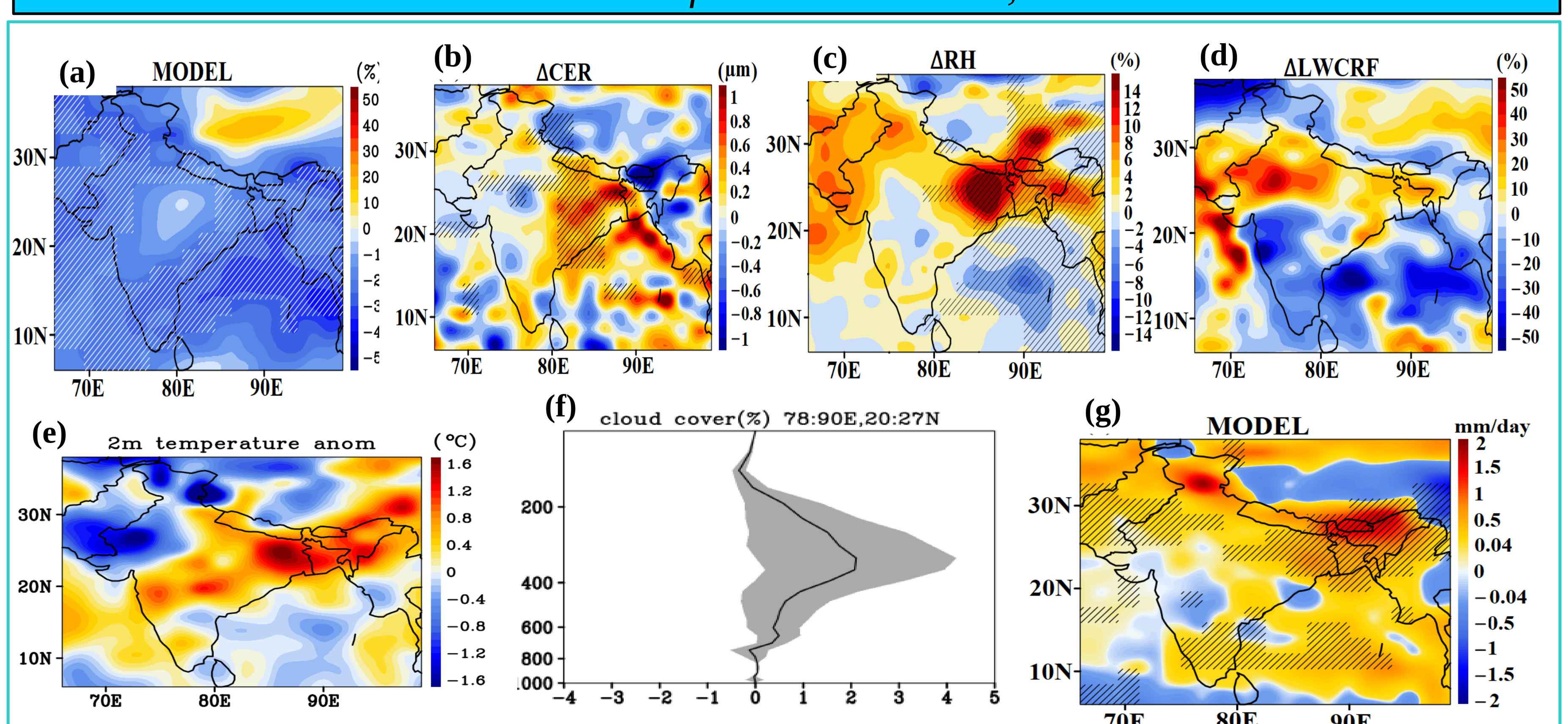


Fig: (a) Percentage change in aerosol optical depth (AOD) averaged for the lockdown period from ECHAM6-HAMMOZ simulated AOD anomalies. (b) Cloud Effective Radius (ΔCER, μm), (c) relative humidity (averaged for 1000-500 hPa, %), (d) Longwave Cloud Radiative Forcing (Δ LWCRF, %), (e) 2m air temperature (ΔT2m, °C), (f) cloud cover (%), (g) anomalies in rainfall (mm day^{-1}).

We report that the reduction in anthropogenic emissions during the COVID-19 lockdown period has enhanced precipitation by 5–25% over India. It is due to changes in cloud microphysical properties: (1) an enhancement in cloud cover, a reduction in aerosol-induced cloud invigoration and dynamical changes, (2) an increase in cloud cover associated with a reduction in cloud base height, (3) an increase in the effective radius of cloud particles led to an increase in cloud water content, (4) an anomalous northward moisture transport over the Indian landmass.