A thermodynamical study of dry air intrusion activity over India during dry phases of summer monsoon in CMIP6 models

Rahul Singh and S. Sandeep

Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, New Delhi 110016, India

Email: Rahul.Singh@cas.iitd.ac.in

Introduction

It is known that the dry air intrusion from the Middle East is occurring over the Indian region during summer monsoon season. This dry air intrusion is especially associated with the long dry spells of July and August. **Singh and Sandeep (2022, *Clim Dyn*)** showed the existence of a huge reservoir of moist deficit air over the northern Arabian Sea at 850-hPa using observational datasets. In addition to this, it has been argued that low level jet undergo weakening and broadening prior to monsoon break phase in feedback to an increased barotropic instability. Here, we present a systematic analysis of dry air intrusion over India by analyzing the monsoon seasons during 2000 – 2009 in CMIP6 models for historical experiments. In order to investigate the thermodynamic effects of dry air intrusion activity during dry phases of the Indian Summer Monsoon (ISM), isentropic analysis is performed on climate models simulations of Coupled Model Intercomparison Project Phase 6 (CMIP6). Here, we analyse the specific humidity and wind fields at 316 K isentropic level. The negative specific humidity anomalies of multi models average (MMA) signifies the pattern of dry air advection which shows that a large fraction of the moisture deficit is being transported to the continental India from the northern Arabian Sea, and only a small contribution comes from West Asia. The lead-lag composites of anomalies of wind vectors and relative vorticity of MMA at 316 K isentrope clearly show a weakening of the monsoon circulation associated with the break conditions. The anomalous anti-cyclonic circulation pattern propagates westwards from the Bay of Bengal which is a well-known feature of the monsoon break spells.

Data and Methods

The data used in this study are obtained from CMIP6 historical experiment i.e., one ensemble per model (r1i1p1f1). The moisture deficit (q_d) is calculated as $q_d = q_s - q$ where q_s is the saturation specific humidity and q is the specific humidity.

Moisture deficit transport is defined as the product of q_d and zonal wind (u). The moisture deficit transport is vertically integrated from 950–300 hPa, mathematically represented as $\int_{p_s}^{p} q_d u \, dp$; and averaged over 20°N–30°N at 70°E (Fig. 1).

The daily standardized anomalies of zonal vertically integrated moisture deficit transport averaged over 20°N–30°N at 70°E are computed to get the dry air intrusion index (DAI). Further, break events are calculated following the methods as suggested by Rajeevan et al., (2010) over the core monsoon zone 15°N −25°N, 75°E −85°E.

The daily climatology is computed using data for 2000–2009 from CMIP6 historical experiments. DAI is used compute the episodes of dry air intrusion over northern India during July and August. A dry air intrusion episode is defined as DAI>0 for atleast three consecutive days. If DAI≤0 throughout a monsoon break phase, then such break spells are considered as free of dry air intrusion. The dry air intrusion events during 2000–2009 period have been estimated in this way. Here, we transform the isobaric specific humidity and wind fields from model's outputs to ϑ=316 K isentrope to understand the thermodynamical aspect of ISM.

Results

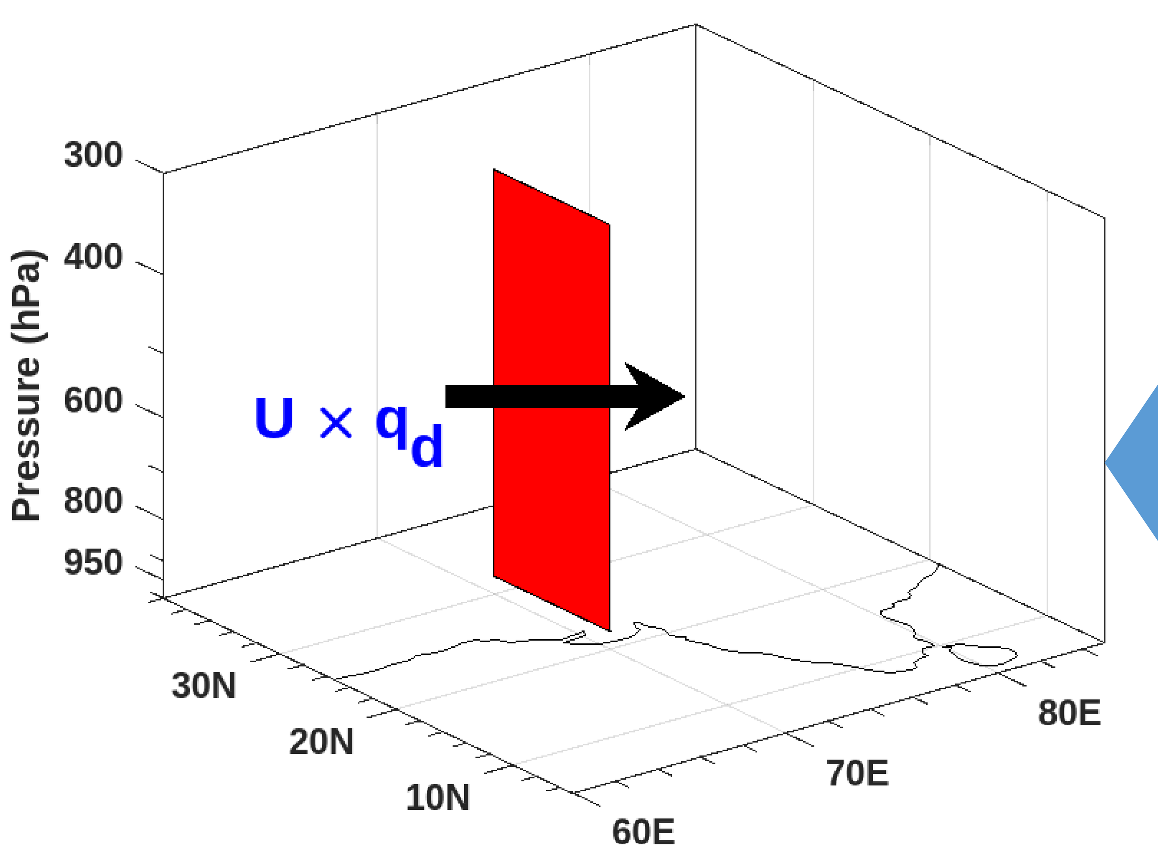


Fig. 1: Schematic of the calculation of DAI. It is computed by standardizing the daily vertically integrated anomalies of zonal moisture deficit transport from 950 hPa to 300 hPa averaged over 20°N–30°N at 70°E.

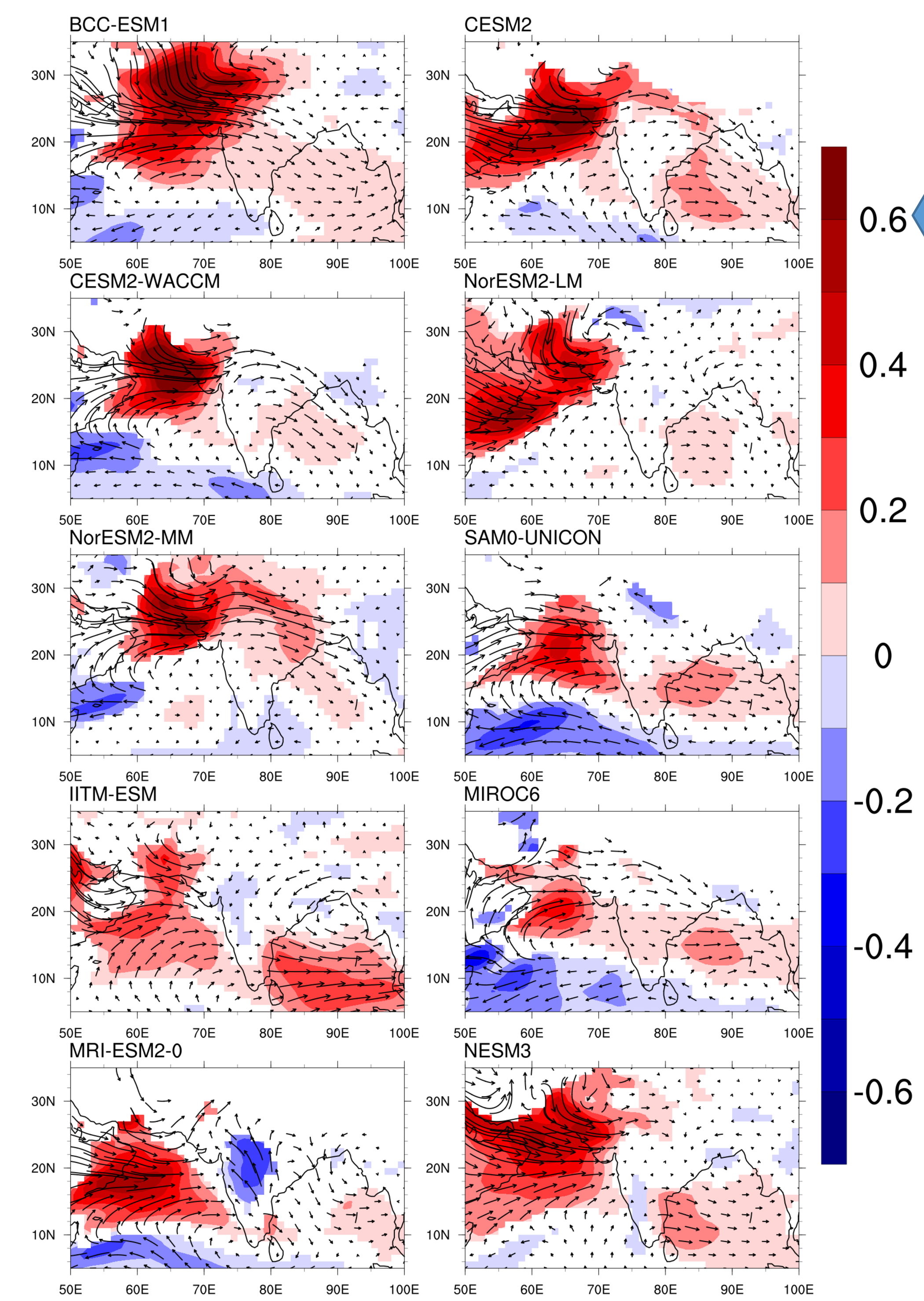


Fig. 2. Regression of saturation deficit transport vectors ($\mathbf{Vq_d}$) on PC2 of daily zonal wind anomalies at 850-hPa for ten better performing CMIP6 models. The shading shows statistically significant (p <0.05) regression coefficients of magnitude of saturation deficit transport on PC2. Statistical significance is estimated using a two-tailed *t*-test. The calculation is done for July-August period during 2000-2009.

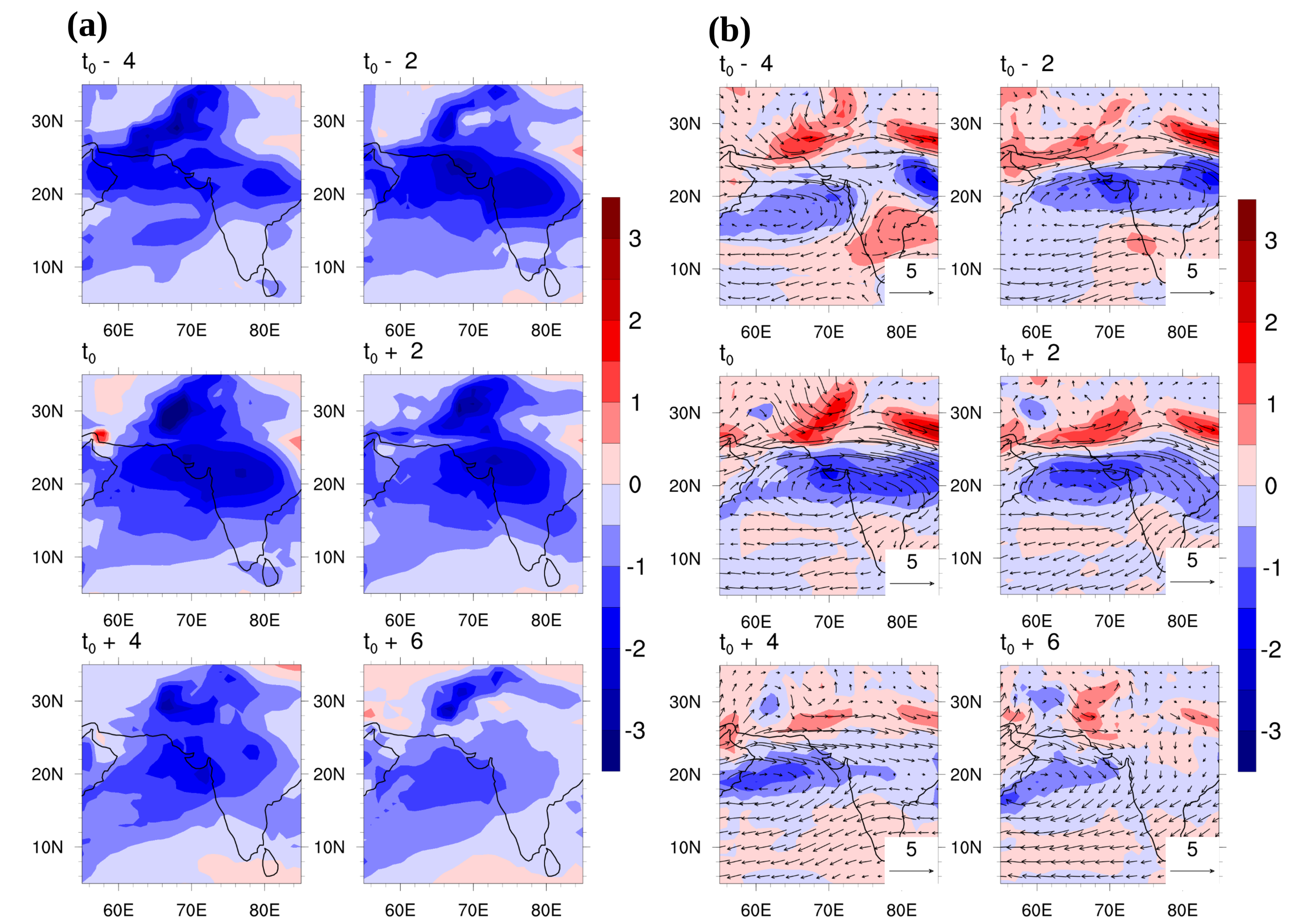


Fig. 3. Lead-lag composites of daily anomalies of **(a)** specific humidity (g kg^{-1}), **(b)** wind vectors (ms^{-1}) and relative vorticity (shading; x 10^{-5}s^{-1}) at 316K isentropic level for all dry air intrusion events in July–August during 2000-2009 for ensemble mean of ten better performing CMIP6. t_0 corresponds to the day of maximum of dry air intrusion.

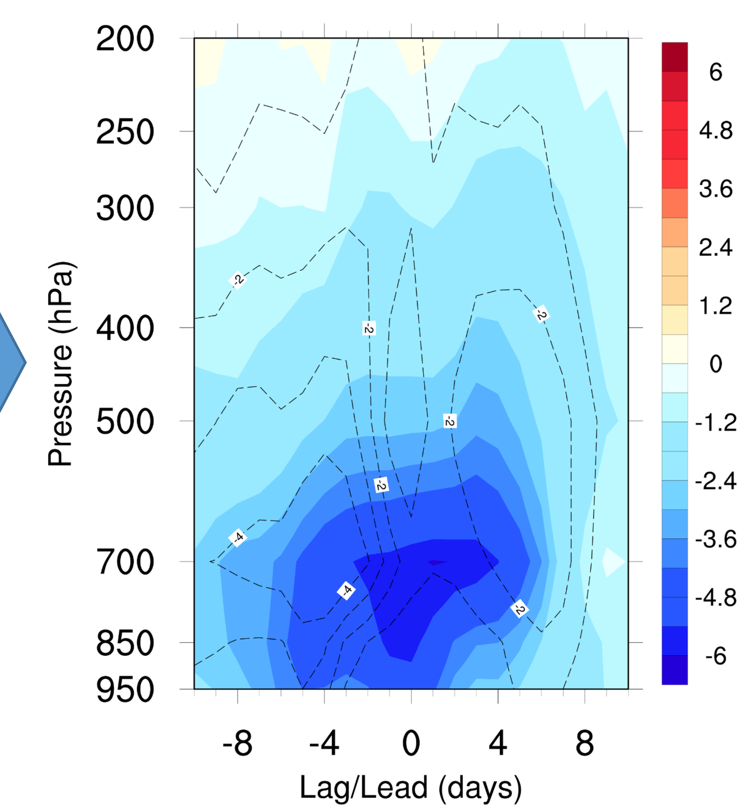
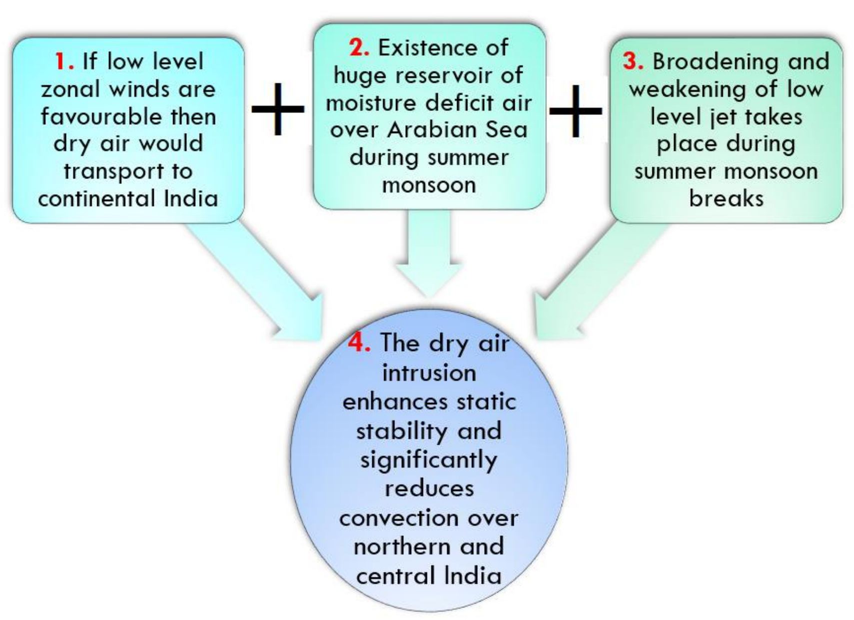


Fig. 4. Composites of time evolution of vertical structure of equivalent potential temperature anomalies (K) averaged over northwestern India (65°E–75°E, 20°N–30°N) for dry air intrusion events (shading) and for monsoon breaks without dry air intrusion (contour) for ensemble mean of ten better performing CMIP6 models. Lag 0 corresponds to the day of maximum of dry air intrusion. In the case of nointrusion composite, lag 0 corresponds to the median of the monsoon break period. The calculation is done for July-August period during 2000-2009.

Fig. 5: The graphical representation of the dynamics of dry air intrusion over India during summer monsoon breaks. If the condition (1, 2 and 3) all are found to be in coincidence then it results into 4.



Reference

Singh, R., Sandeep, S. Dynamics of dry air intrusion over India during summer monsoon breaks. *Clim Dyn* 59, 1649–1664 (2022). https://doi.org/10.1007/s00382-021-06060-9

Conclusions

1. Global climate models have a better skill in simulating the dry processes of monsoon than wet processes.
2. Low level jet acts as a primary carrier in transporting dry air from the northern Arabian Sea to continental India.

Contact: Rahul.Singh@cas.iitd.ac.in