Synoptic Variations of West Asian Dust Associated With Indian Summer Monsoon Precipitation

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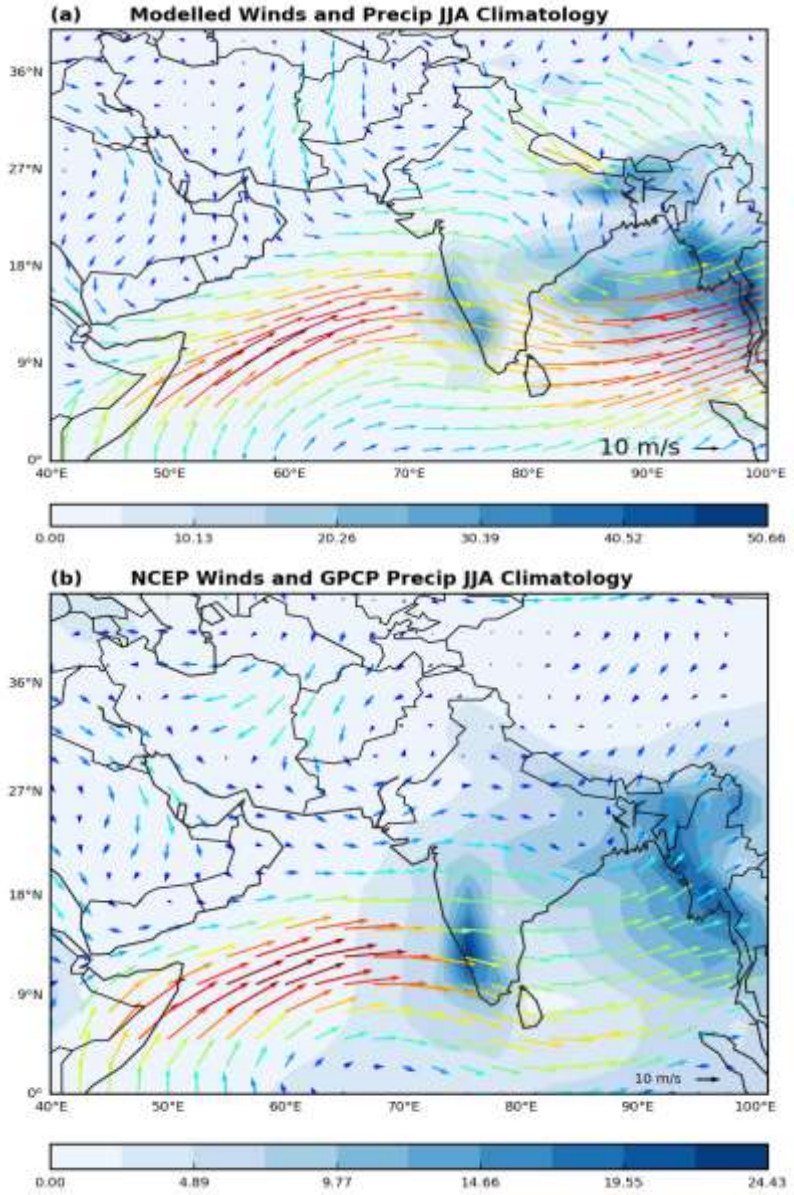
Indian Summer Monsoon (ISM)

- Most important weather phenomena in the country
- Prime driver of agricultural economy - source of 80% of annual rainfall in the country
- Catastrophic historical record of ISM anomalies (flash floods and prolonged droughts).
- Complex with high spatio-temporal variability → intricate atmosphere, ocean and land interactions.
- Growing recognition of impact of aerosols in modulation of monsoon system.



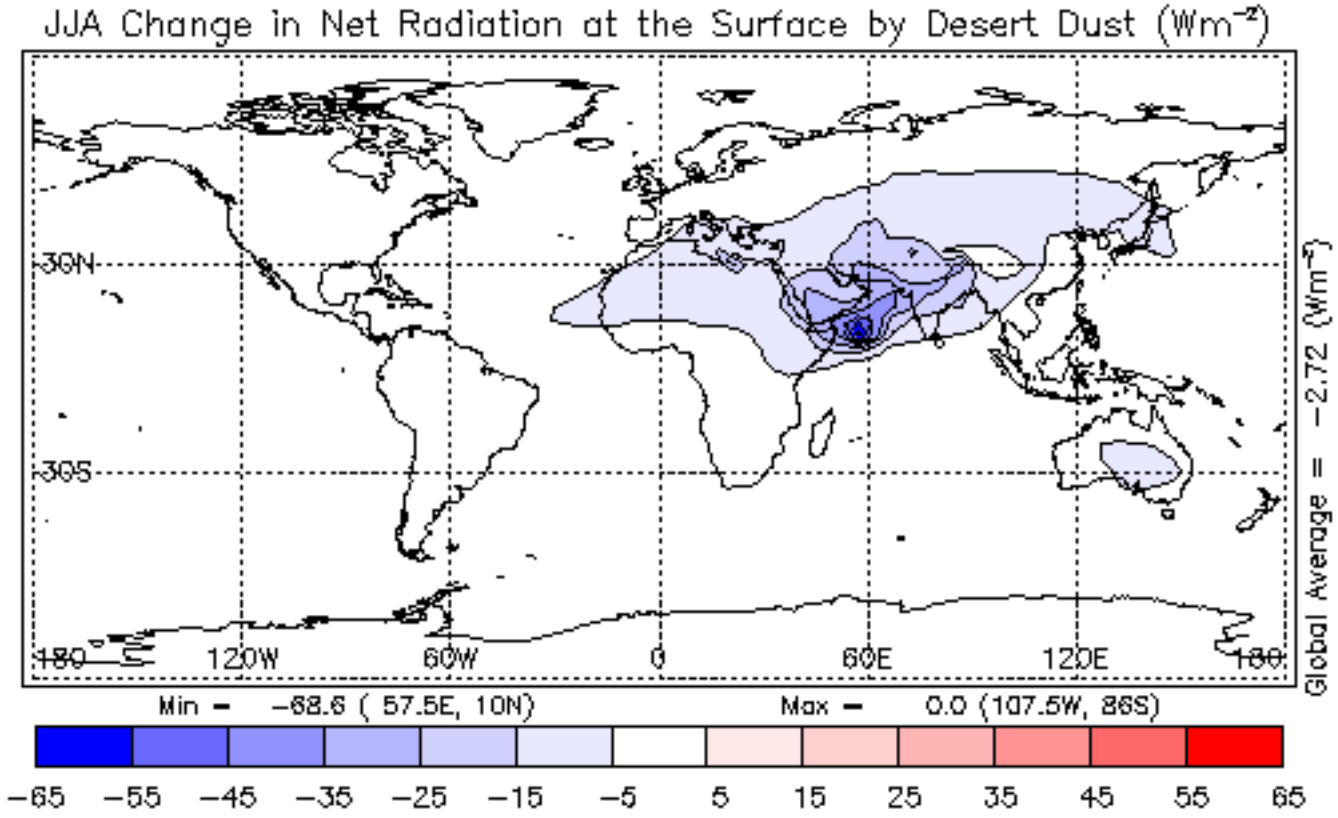
(Sharma and Miller, 2017)

Mineral Dust Aerosol in the Atmosphere

Perturbation of
'Radiative Flux'

Direct Radiative Effect
(Absorption and Scattering)

Indirect Effect
(CCN)



(*Miller and Tegen,* 1998)

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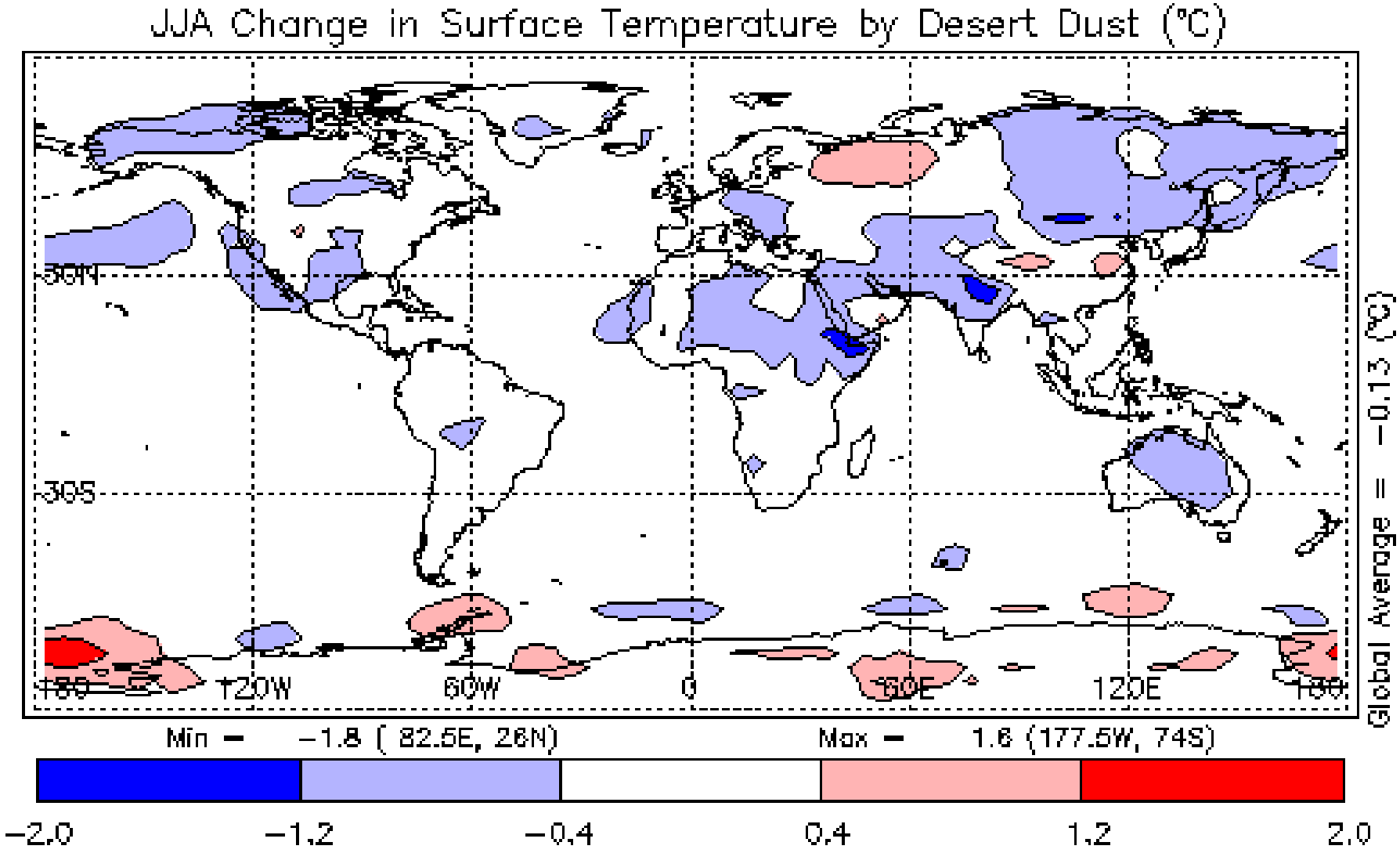


(*Miller and Tegen*, 1998)

Mineral Dust Aerosol in the Atmosphere

Perturbation of 'Radiative Flux'

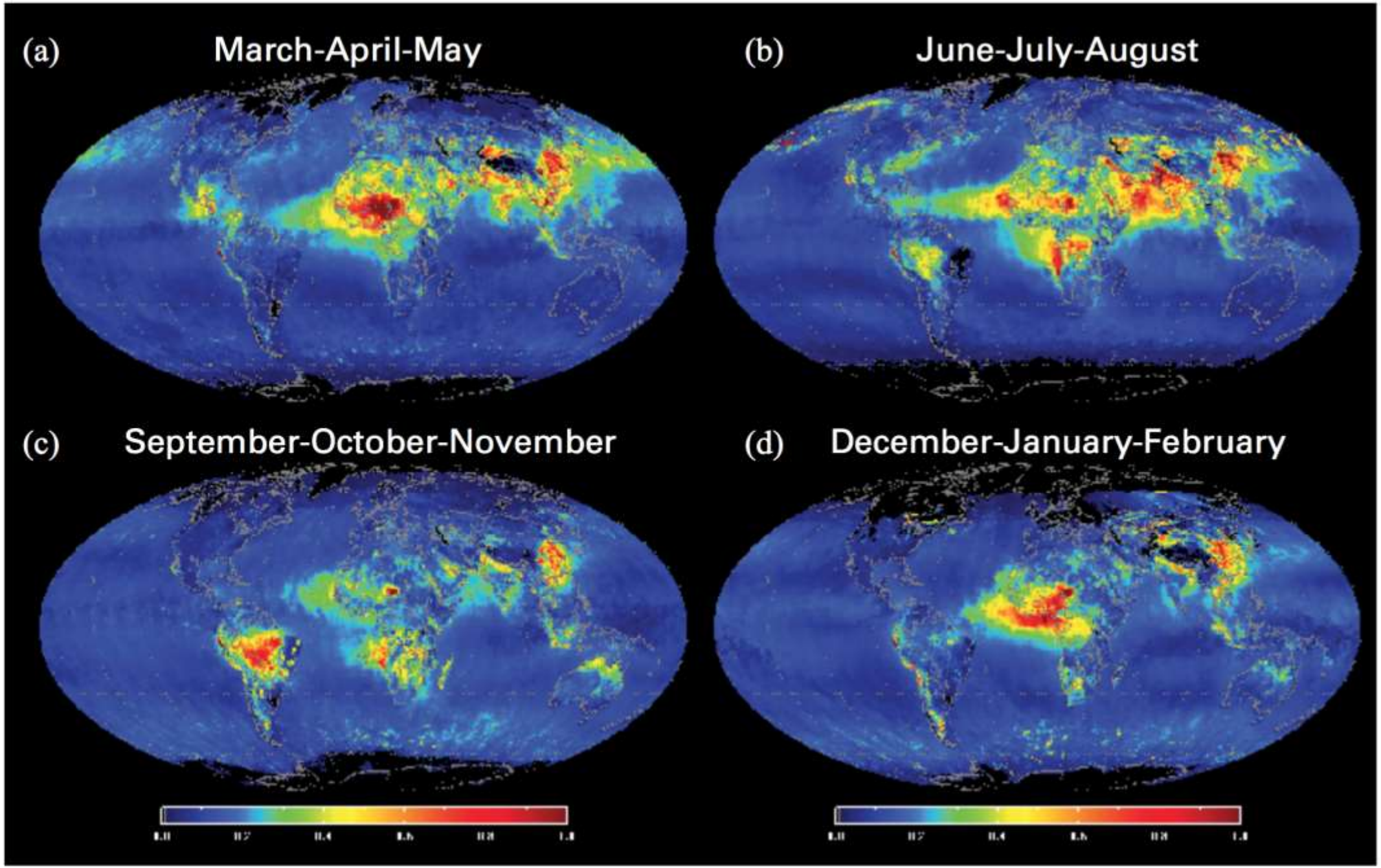
- Direct Radiative Effect (Absorption and Scattering)
- Indirect Effect (CCN)

Alteration of Transport Pathways Energy and Moisture

→ Thousands of kilometer beyond the dust layer (*Miller and Tegen,* 1998)

'Aerosol Hotspots'

→ Northern Iran (Sistan Region), Mesopotamia, North West Africa, Thar Desert) and the Arabian Sea



(*Lau et al.*, 2009)

Mineral Dust Aerosol in the Atmosphere

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- Direct Radiative Effect (Absorption and Scattering)
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Feedback Mechanism

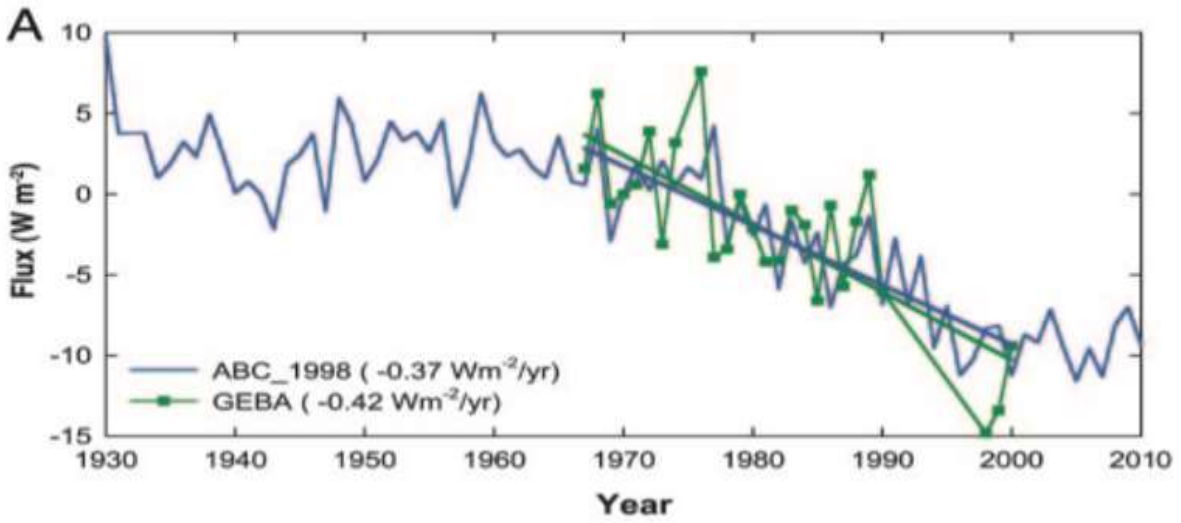
→ 'Aerosol Hotspots'
(Northern Iran (Sistan Region),
North West Africa, Thar Desert)

Modulation of Monsoon

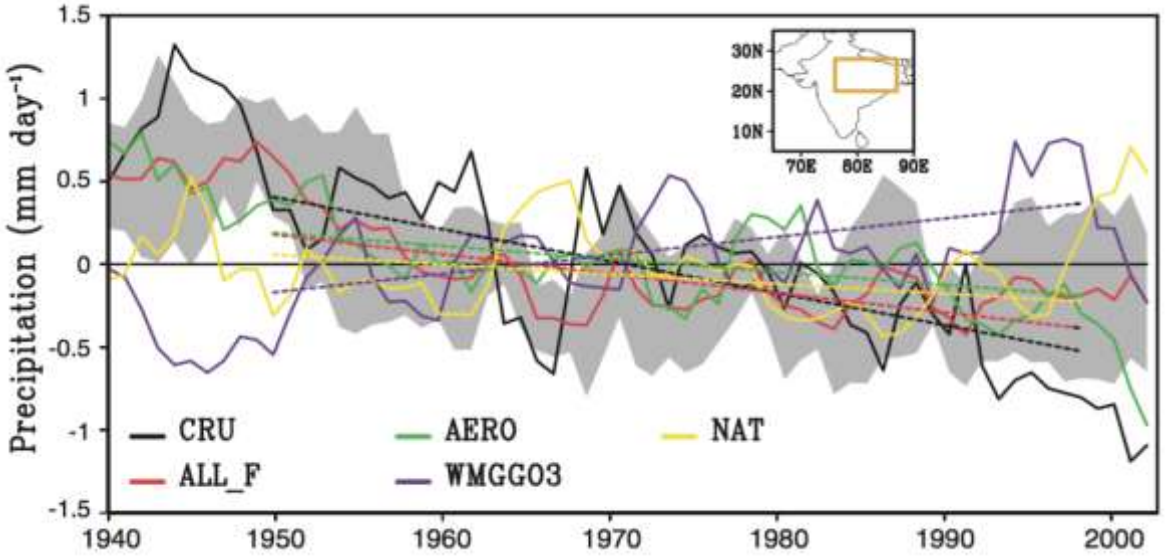
Mechanisms of Monsoon Modulation

Solar Dimming Effect (*Ramanathan et al.*, 2005)

- Reduction in Surface Solar Radiation (DRE)
- Regional maxima over north India
- Weak NS temperature gradient → weak ISM



(*Ramanathan et al.*, 2005)

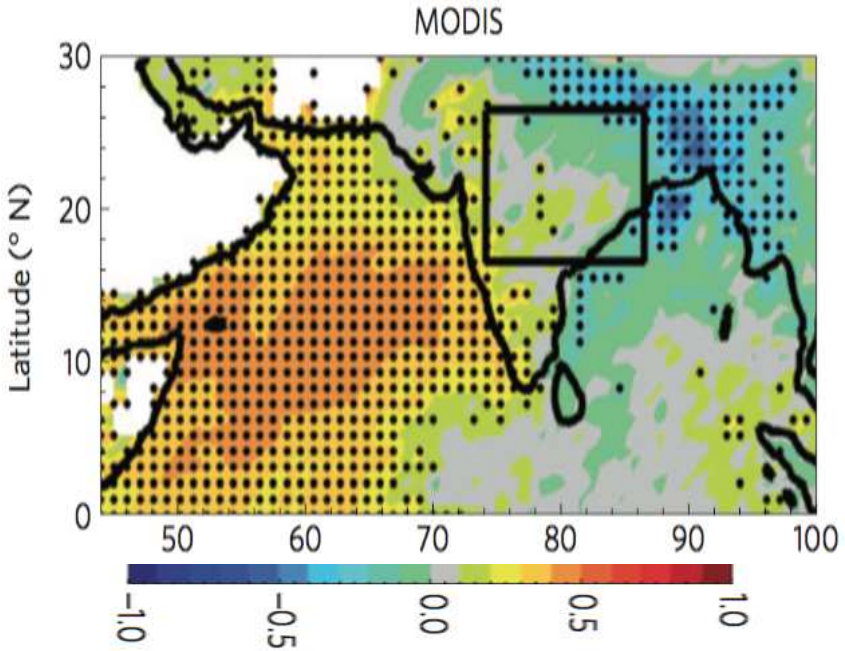


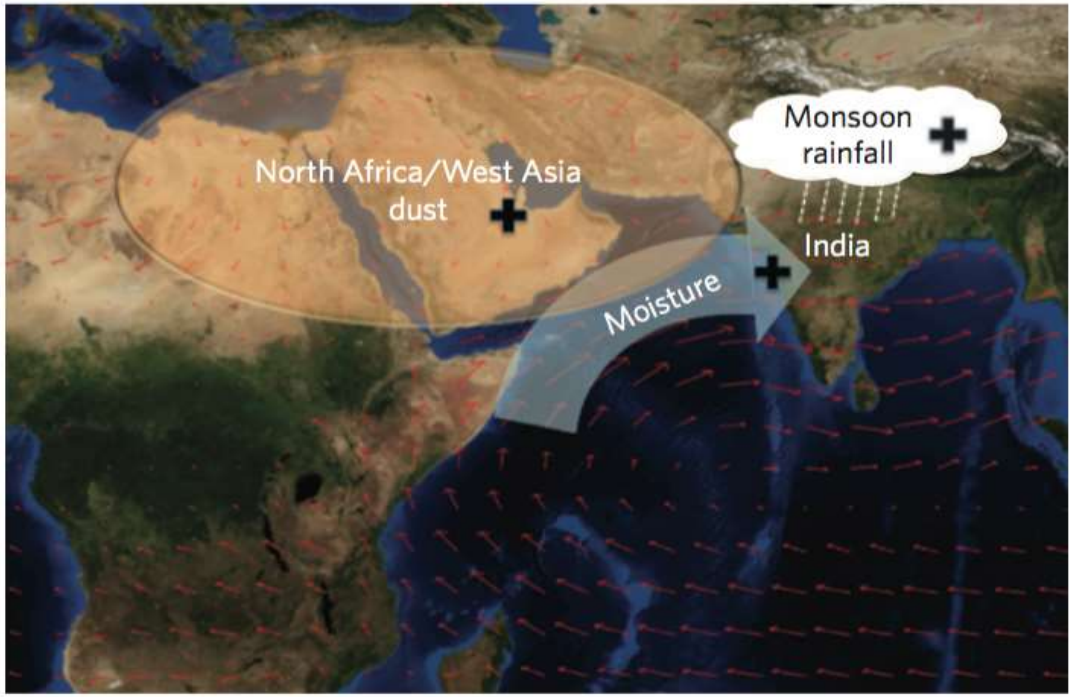
(*Bollasina et al.*, 2011)

Mechanisms of Monsoon Modulation

Recent Observations (*Vinoj et al.*, 2014)

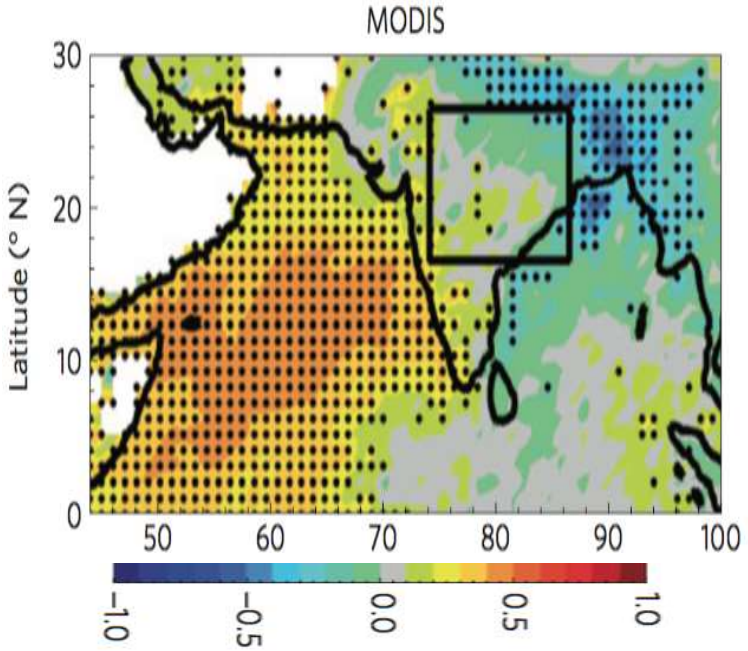
- Enhanced dust emissions over the Arabia → increased rainfall from 2000 – 09
- Regional response on weekly timescales





(*Vinoj et al.*, 2014)

Dust – Monsoon Link on Weekly Timescale



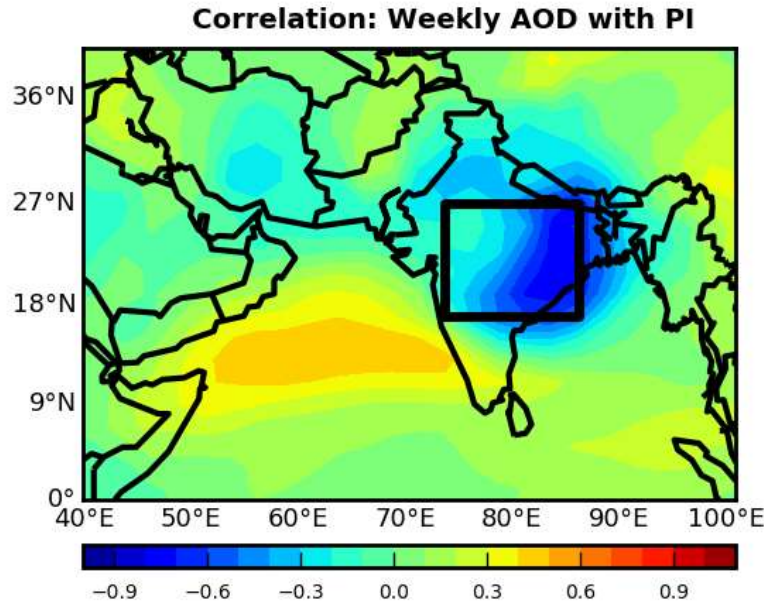
(*Vinoj et al.*, 2014)

Model Result:

- Reproduction of weekly dust monsoon correlation using the same Precipitation Index (PI)

However:

- Dust aerosols have no radiative effect in this model



(Sharma and Miller, 2017)

Radiative forcing by mineral dust aerosol is not responsible for monsoon modulation on weekly (synoptic) timescales.

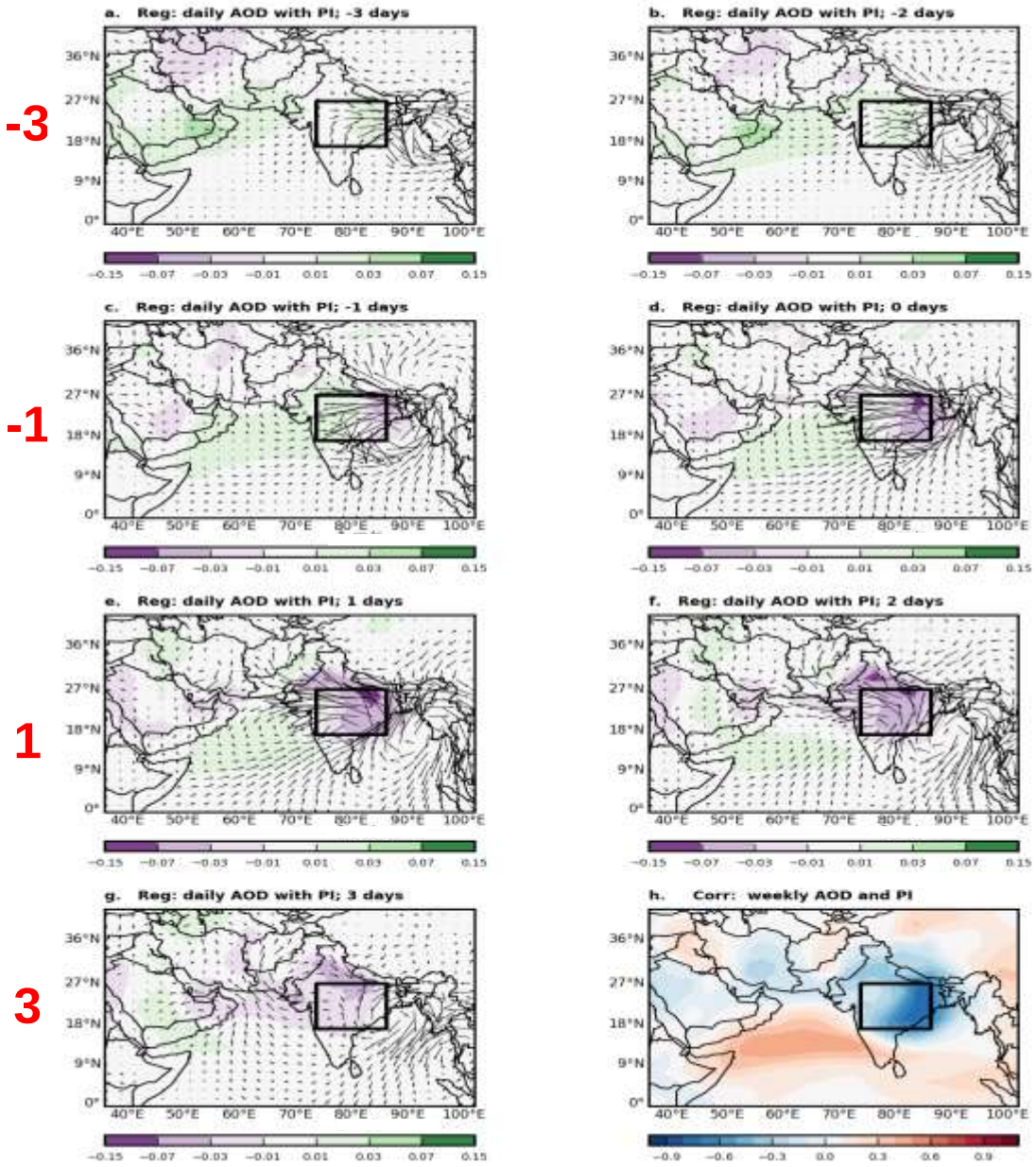
Monsoon circulation is responsible for triggering higher dust emissions on weekly (synoptic) timescales.

Hypothesis: Role of Monsoon Circulation on Dust Aerosols

Regression of daily AOD with PI

- Dust transport across the Arabian Sea on daily timescales.
- Negative lag = AOD leads precipitation
  Positive lags = Precipitation leads AOD
- Role of boundary layer winds in dust entrainment towards India.
- Subsequent strengthening and weakening along with the westward drift of the cyclonic vortex over the Bay of Bengal as observed by *Gadgil* (2003).
- As the cyclone moves westward, the dust plume gets drawn from the Arabian Peninsula to the Arabian Sea – inflow towards the cyclonic vortex.

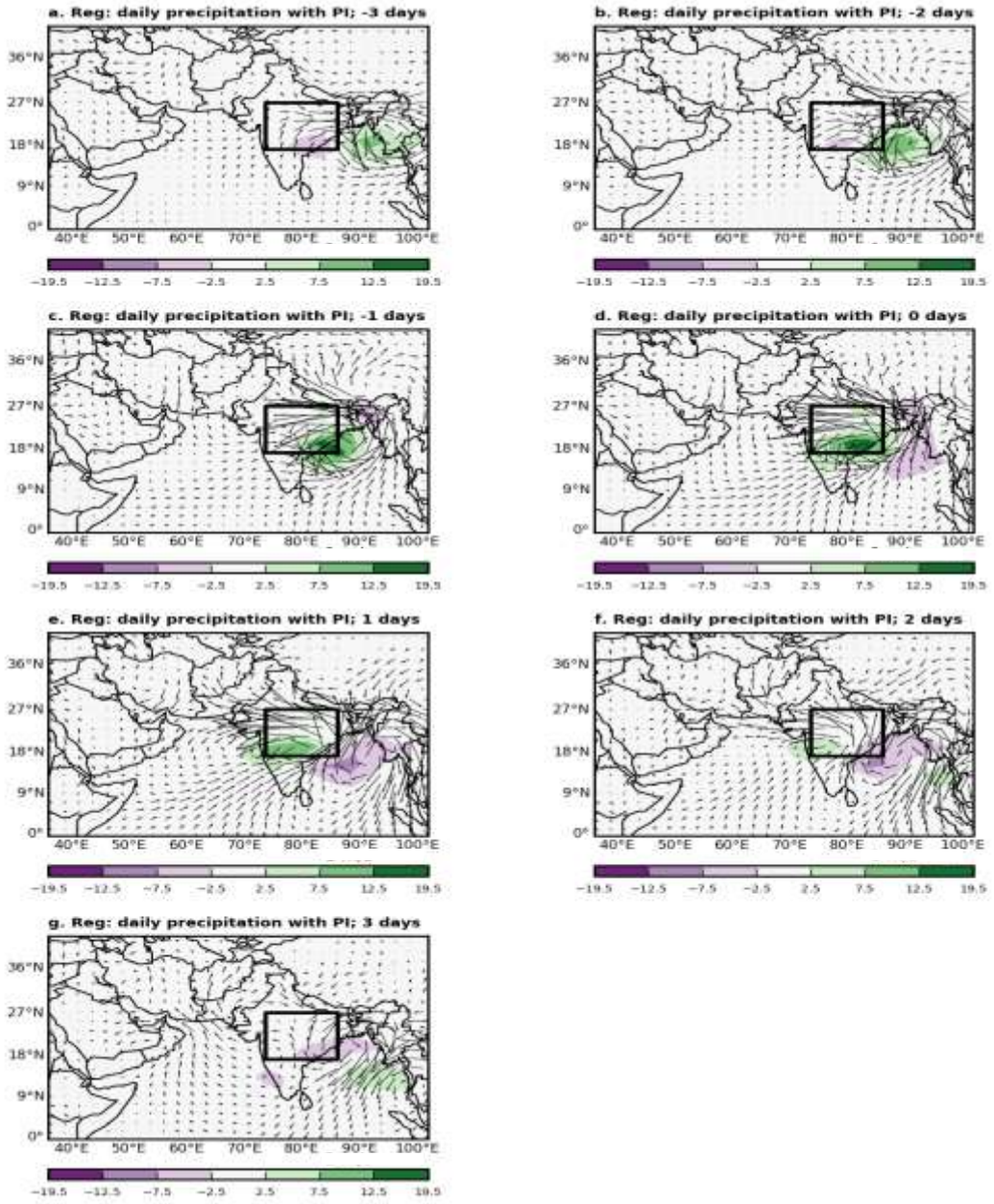
Importance of ‘Monsoon Circulation’



Regression of daily Precipitation with PI

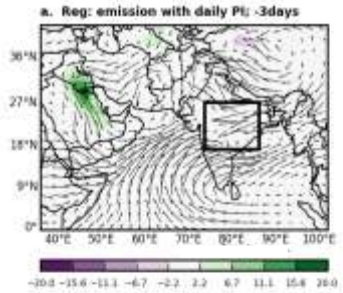
- Regression of daily precipitation over the region with precipitation index over central India with an overlay of boundary layer winds.

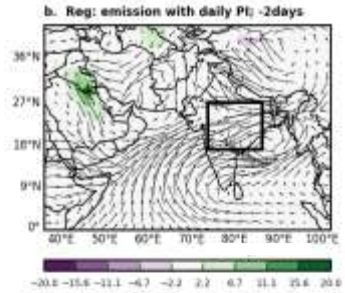
- The model captures westward movement of the cyclonic vortex along with an increase in the precipitation intensity.

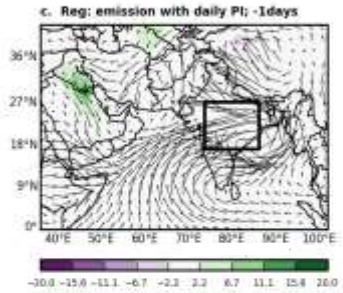


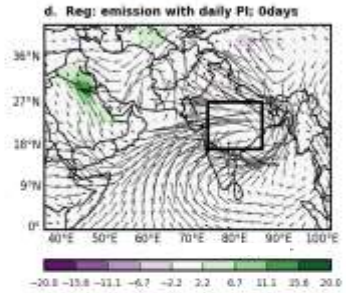
Sub - daily Regression Analysis of Dust Emissions and Surface Wind Speed

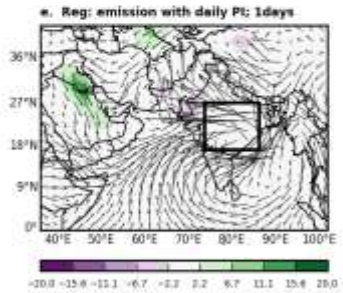
Dust Emission

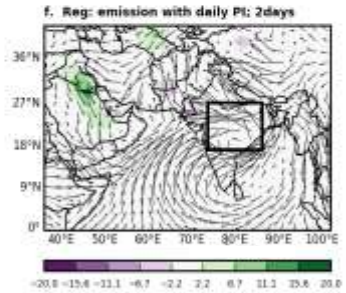


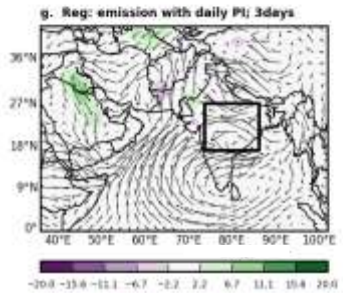




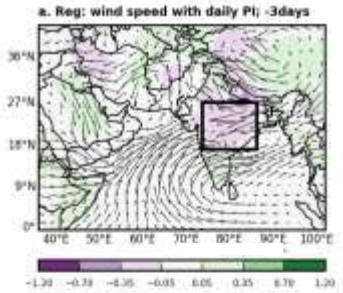


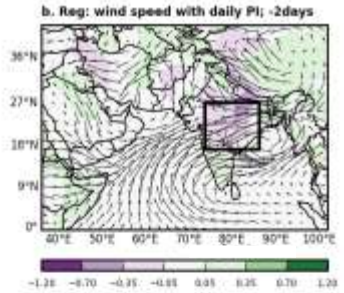


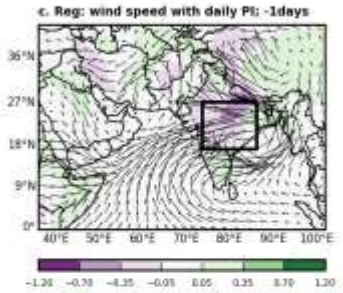


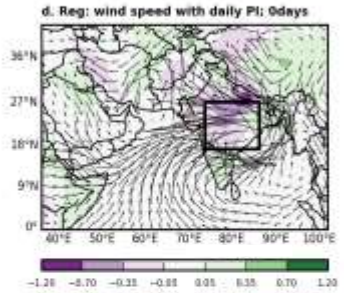


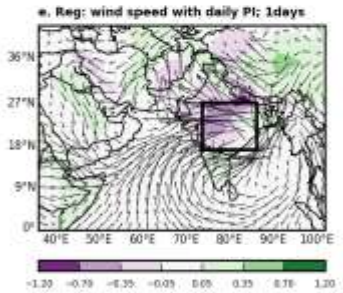
Surface Wind Speed

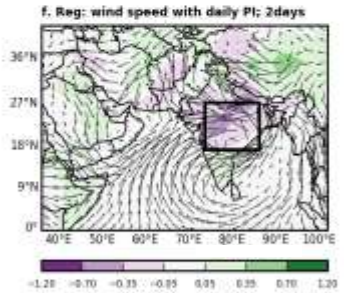


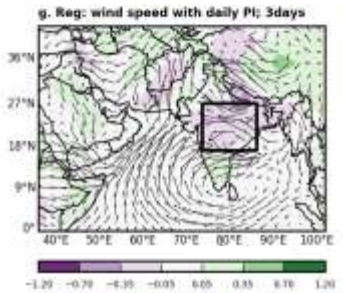






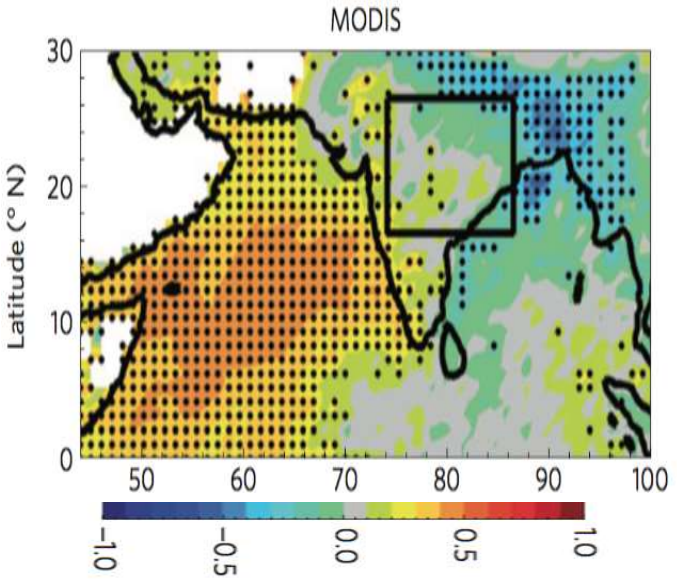




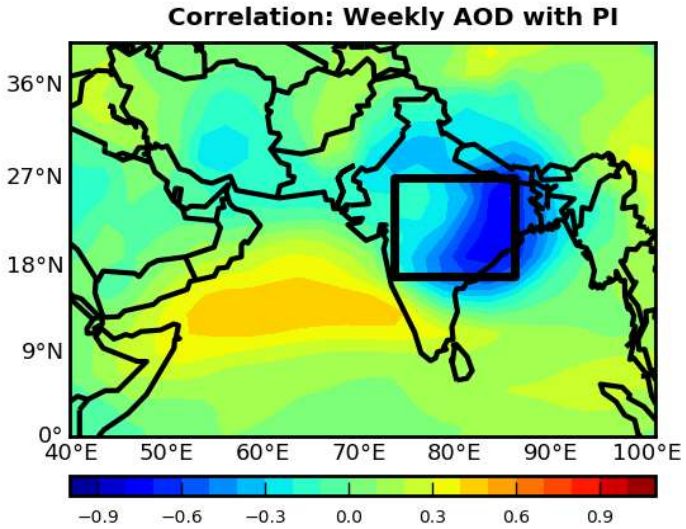


- Regression of emission with wind speed at 0600 – 0900 UTC (roughly 10.30 am – 1.30 pm local solar time) with normalized daily PI.
- The cyclonic vortex that brings rain to India increases wind speed over the Euphrates and Tigris Basin/ Mesopotamia leads to higher dust emissions.

Evidence:
The increased activity of dust leading to a precipitation maxima can be attributed to monsoon circulation



(*Vinoj et al.*, 2014)



(Sharma and Miller, 2017)

Conclusions

- There exists a correlation between AOD and monsoon precipitation over central India on weekly timescales (*Vinoj et al.*, 2014).
- The correlation can be reproduced in a model without the radiative effects of dust aerosols.
- Rainfall over central India is associated with Shamal winds and dust emissions over Mesopotamia.
- Monsoon circulation transports dust from Arabian Peninsula over the Arabian Sea.

Thank You!