The Atmospheric Circulation as a Key Mediator of Aerosol-driven Climate Impacts

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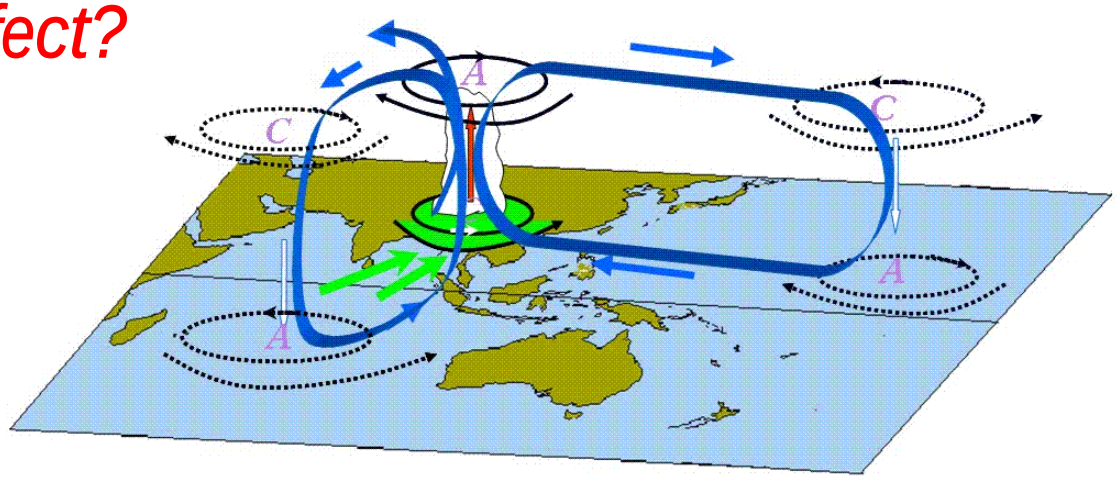
Summer Broad-Scale Circulations

Is there a downstream effect?
Why?

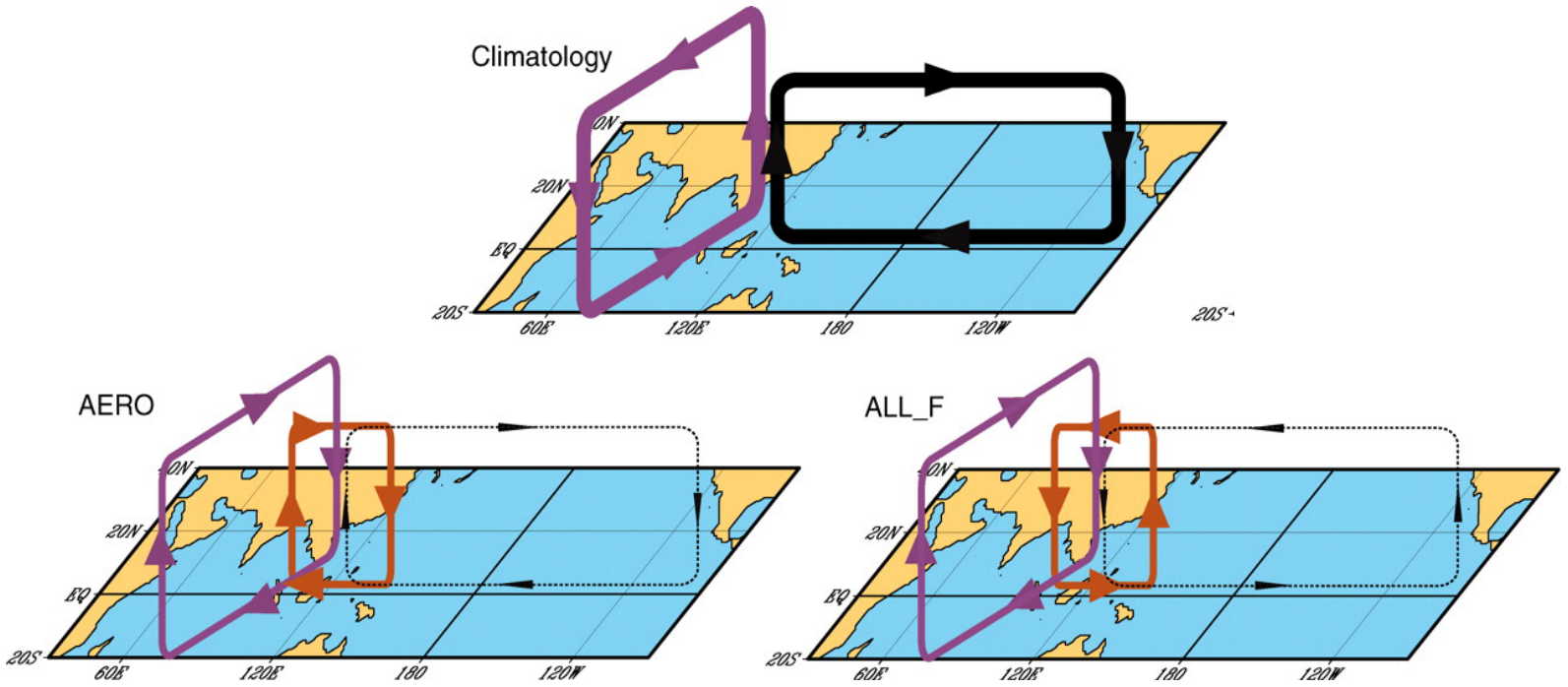


Beyond the local response ...

Aerosol increase cause a decline in summer precipitation over SA

Aerosol-precipitation-circulation interactions are poorly known. Atmospheric circulation changes may extend the aerosol impact beyond the source region.

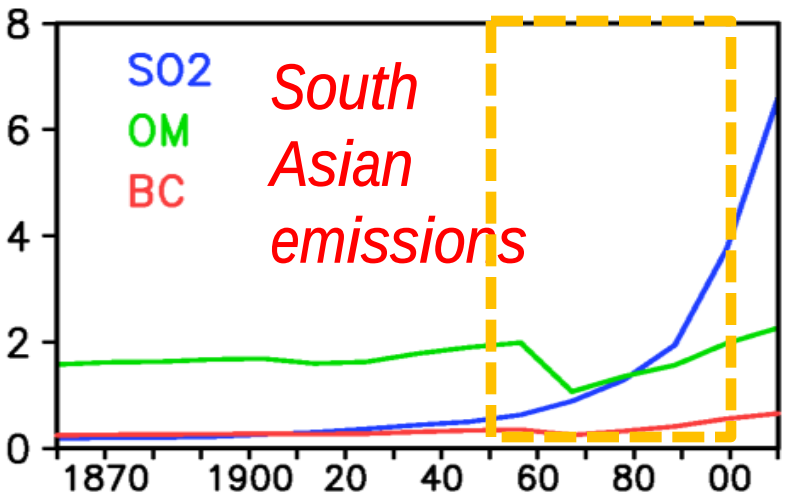
Changes in deep convection lead to strong feedbacks with the dynamics



Bollasina et al. 2011

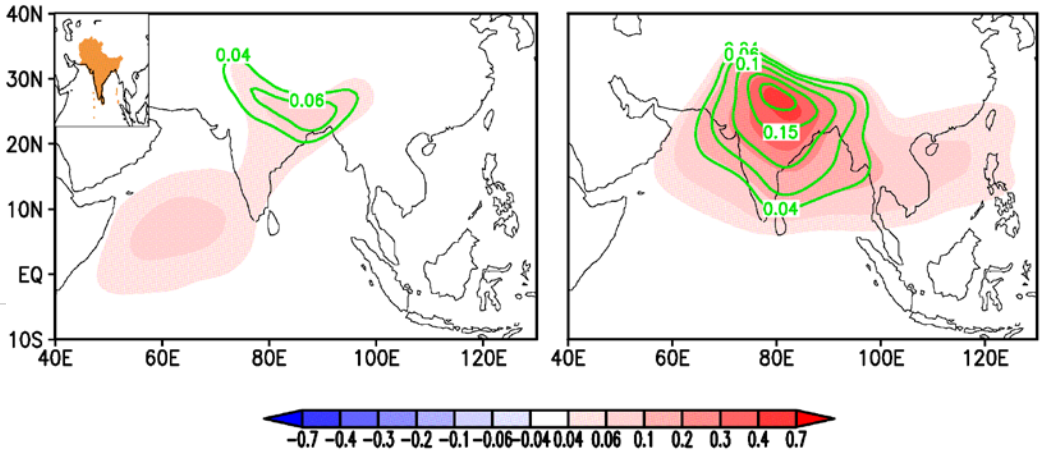
Remarkable increase in anthropogenic aerosols from 1950s

Emission increase (*x-fold*)		
	South Asia	East Asia
SO_2	10	16
BC	2	5



DJF JJAS

AOD : Total (shades) & absorbing (contours, x10)

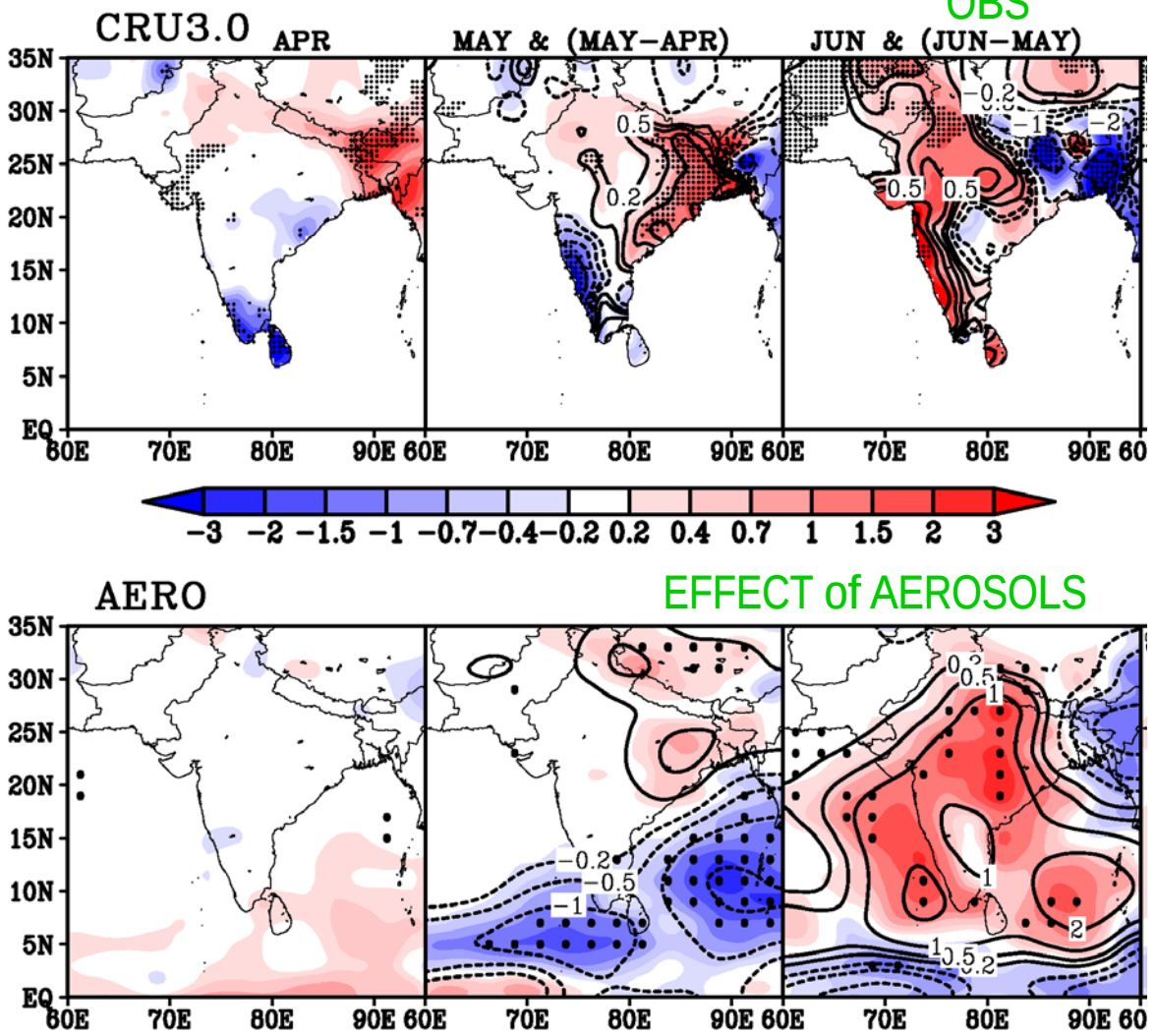


Aerosol-induced changes in the atmospheric circulation during the onset phase

Why the onset?

Precipitation trend

OBS

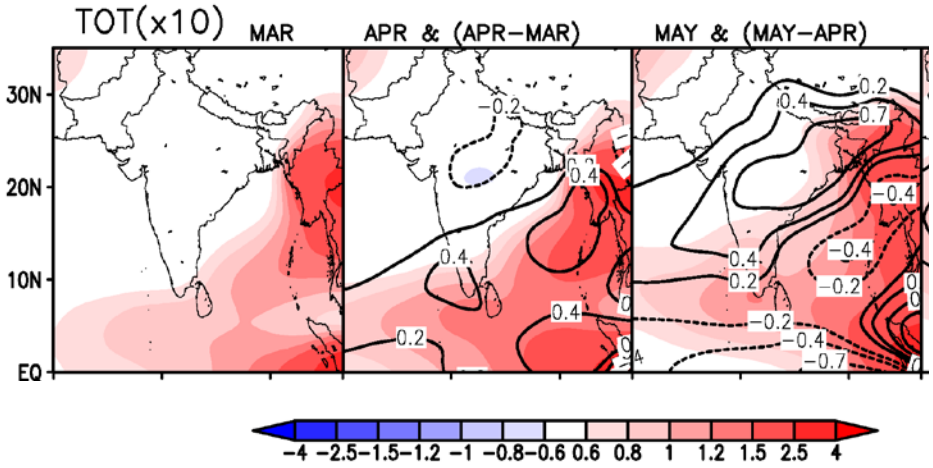


Bollasina et al. 2013

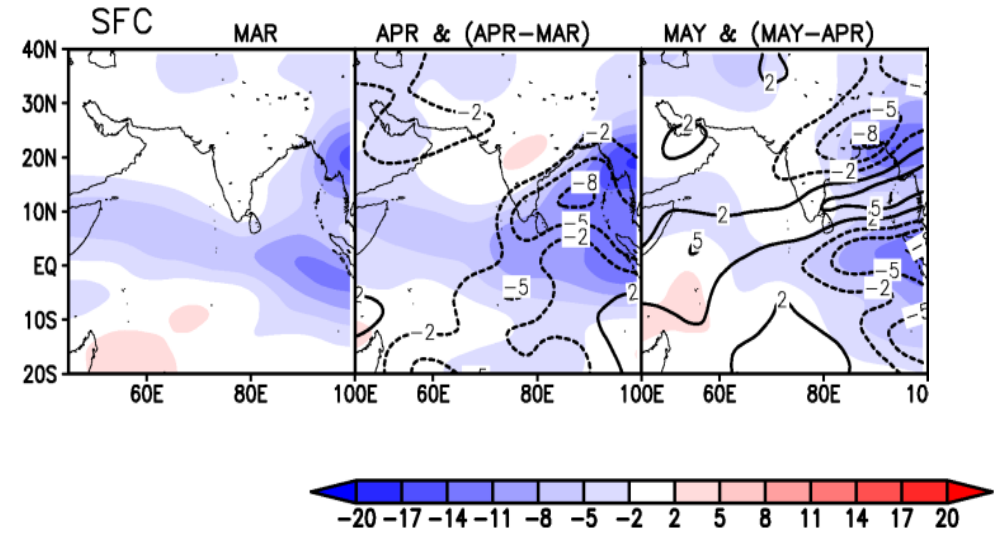
Increased aerosols lead to large regional energy deficit

ALL AEROSOLS

AOD trend

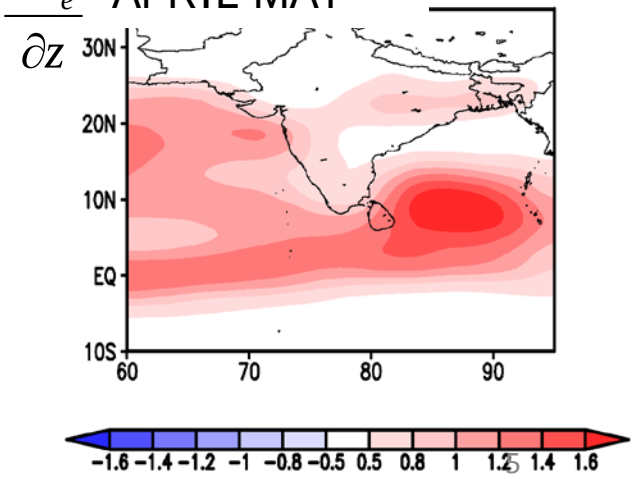


Radiative Flux Perturbation (W m^{-2} (50 y)$^{-1}$)

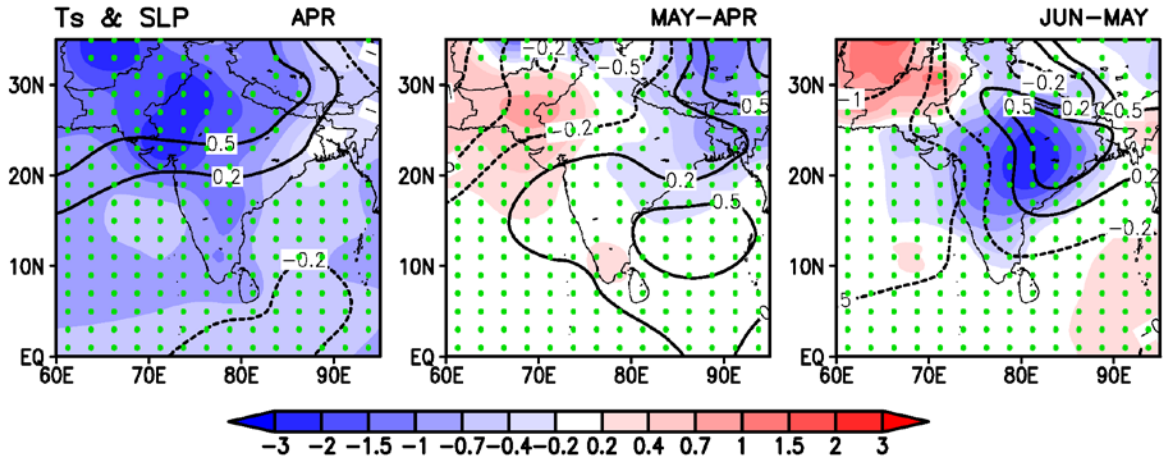


⇨ Increased atmos. stability

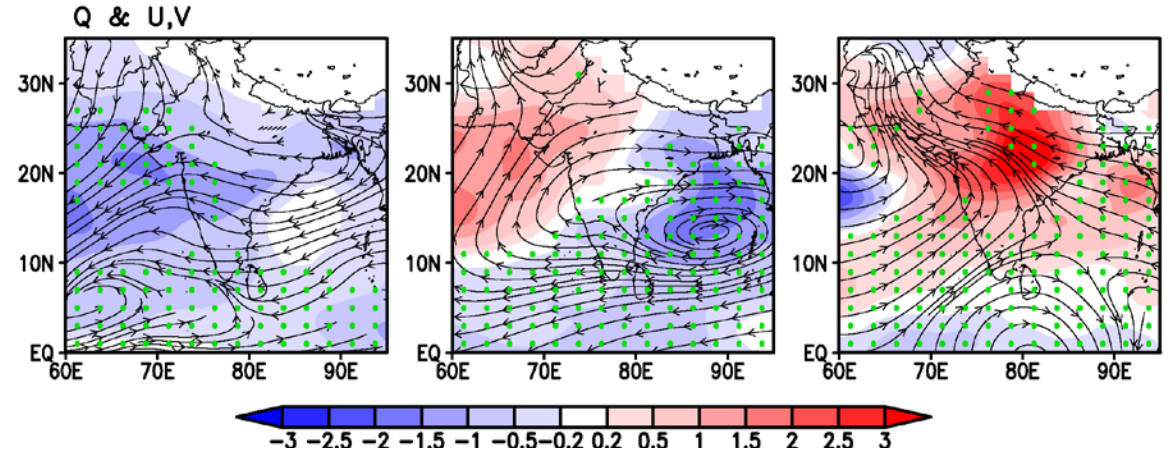
$\frac{\partial \theta_e}{\partial z}$ APRIL-MAY



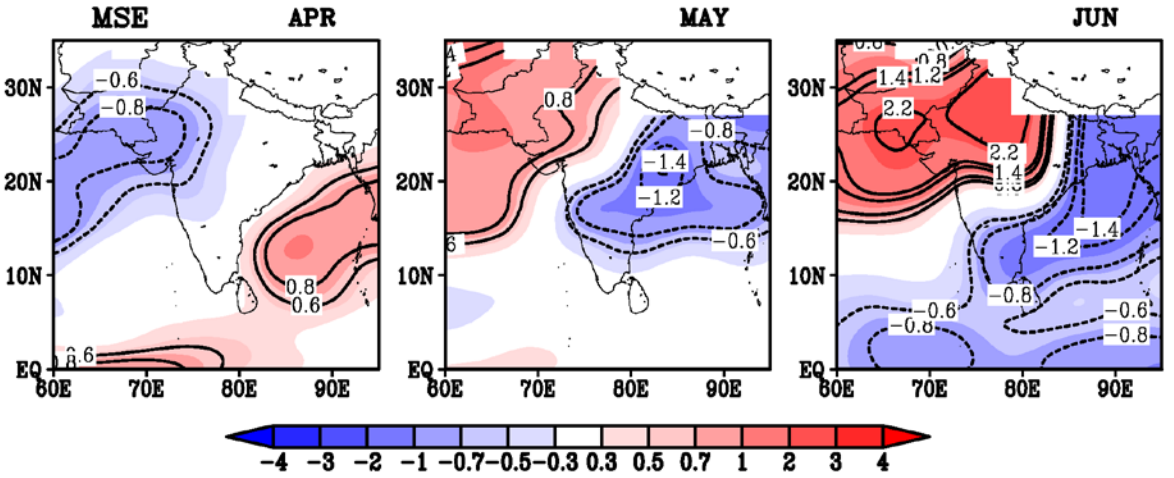
Surface Temperature &
Sea Level Pressure



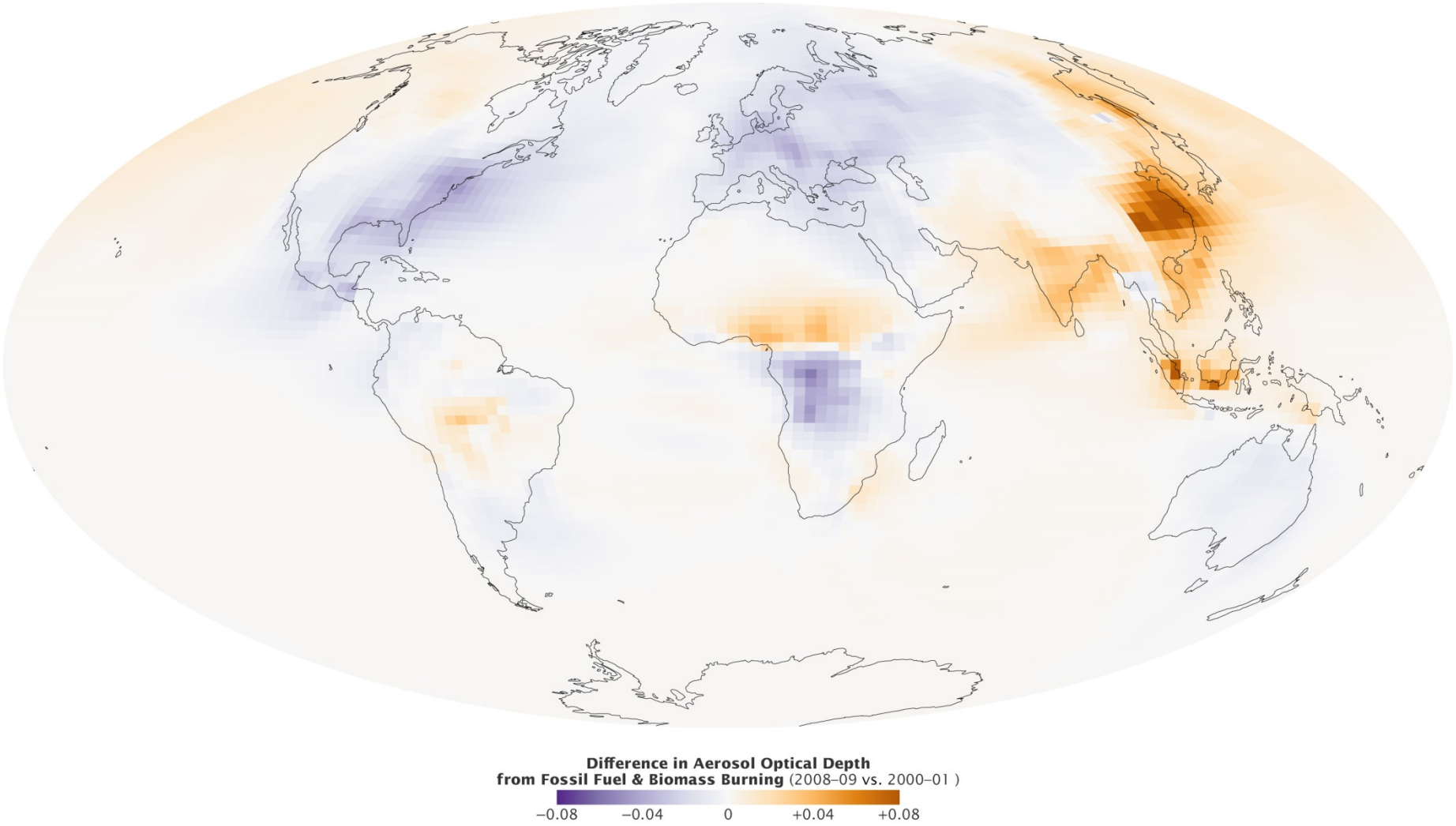
Spec.Humidity
& 850-hPa Winds



Sub-cloud Moist Static Energy

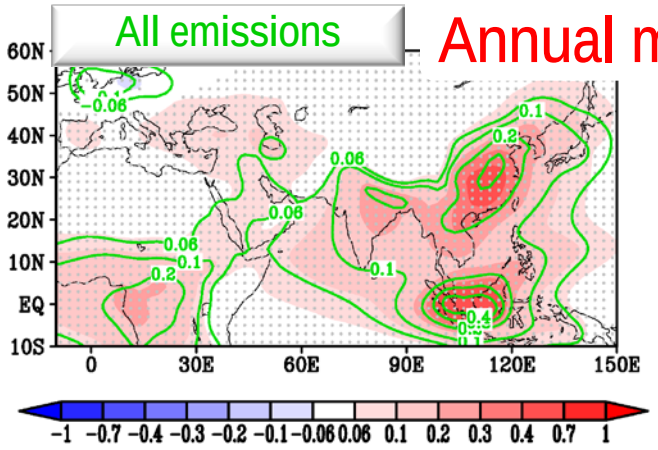


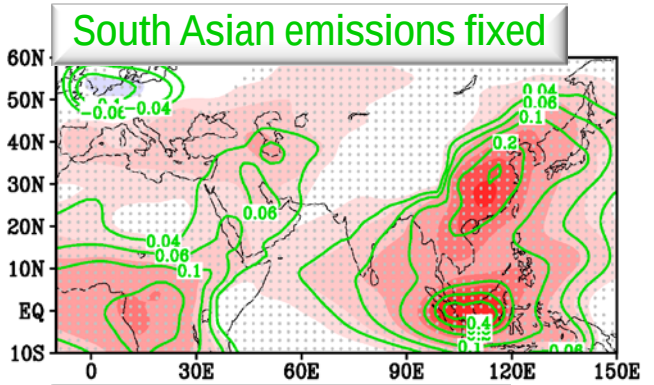
A contrasting pattern of aerosol changes

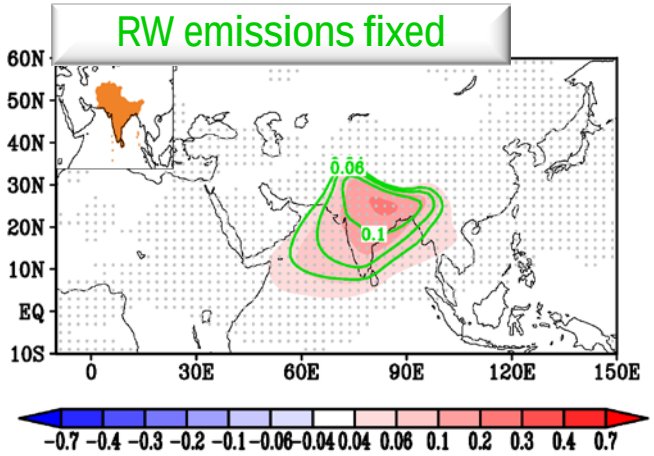


Changes in anthropogenic aerosols between 2000–01 and 2008–09 (Chin et al. 2014)

Contrasting local and remote aerosol forcing



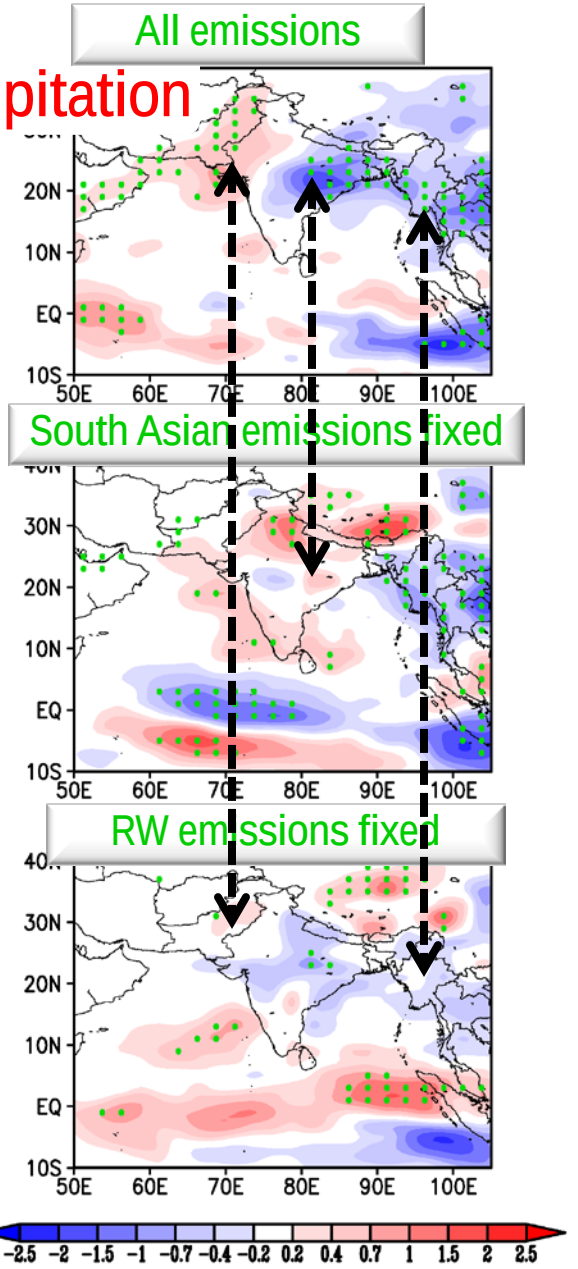




GFDL CM3
All-Forcing experiments

Core monsoon India

ALLF = -0.81
PI_SA = +0.24
PI_RW = -0.41

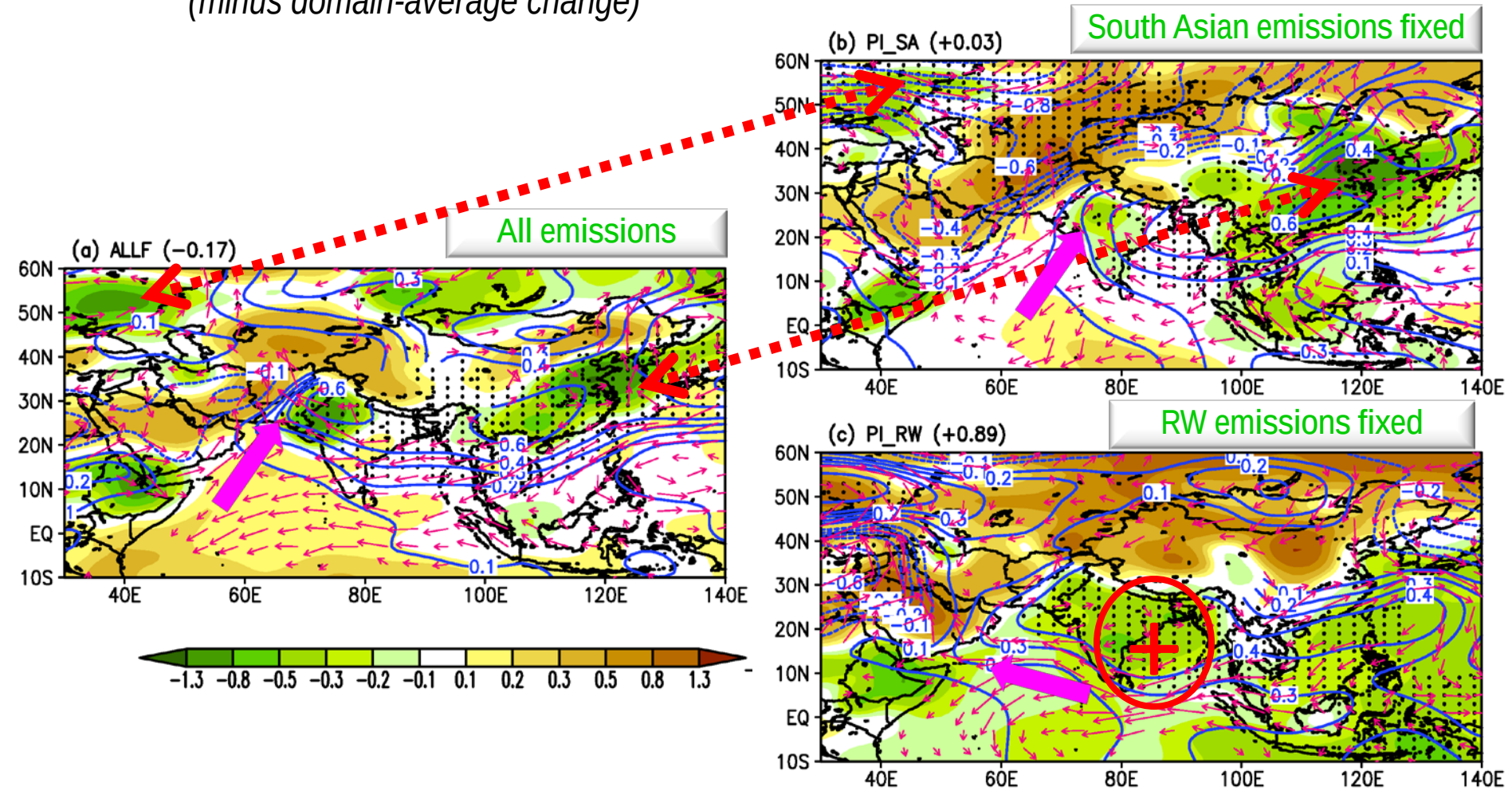


Bollasina et al. 2014

Different patterns in near-surface changes

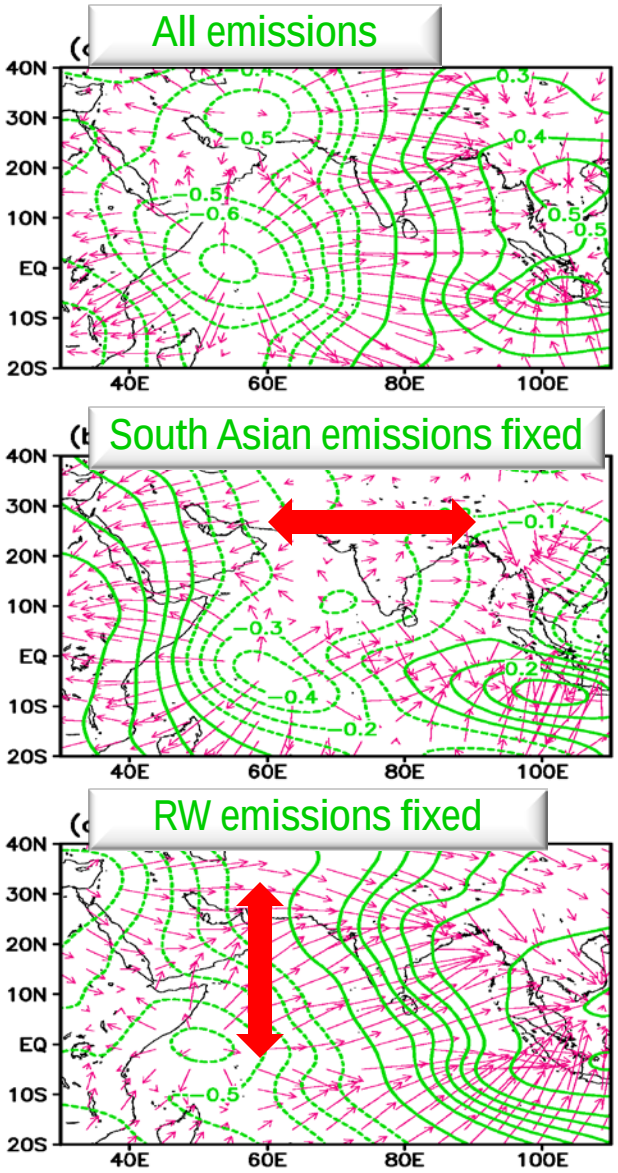
Ts (shades), SLP (contours), 850-hPa winds

(minus domain-average change)



Implications for the large-scale circuation

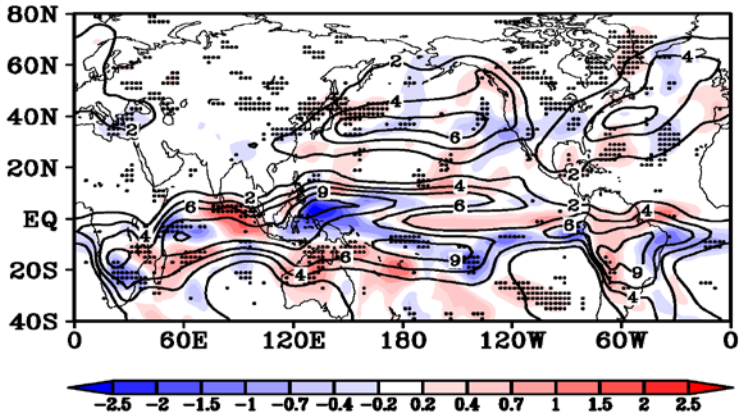
JJAS 200-hPa velocity potential & divergent circulation



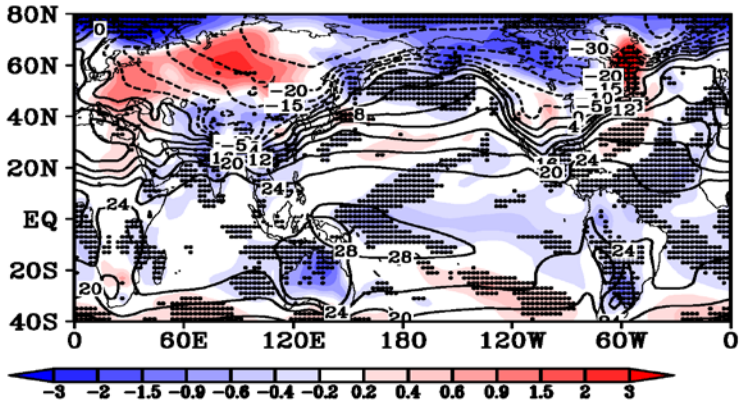
Potential large-scale impact of SA aerosols

Precipitation (mm/day)

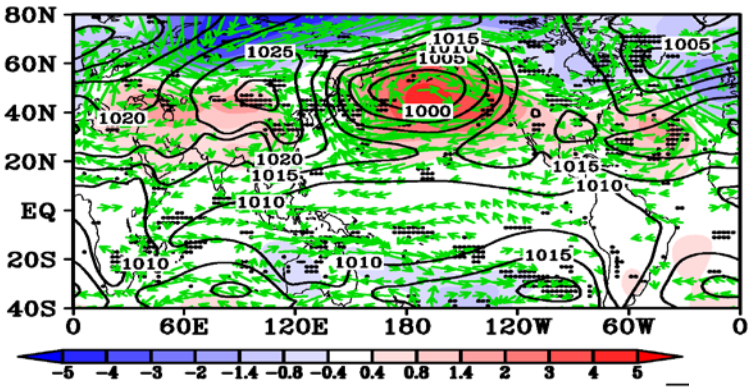
DJF



Sfc. Temperature (K)



SLP (hPa) &
850-hPa winds (m/s)



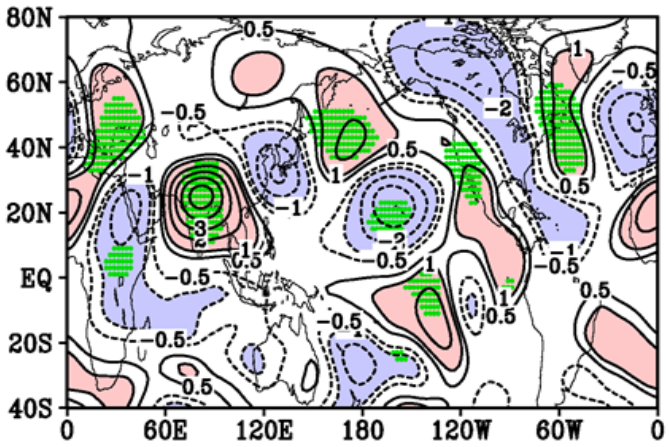
Bollasina et al. (2015)

Atmospheric circulation response

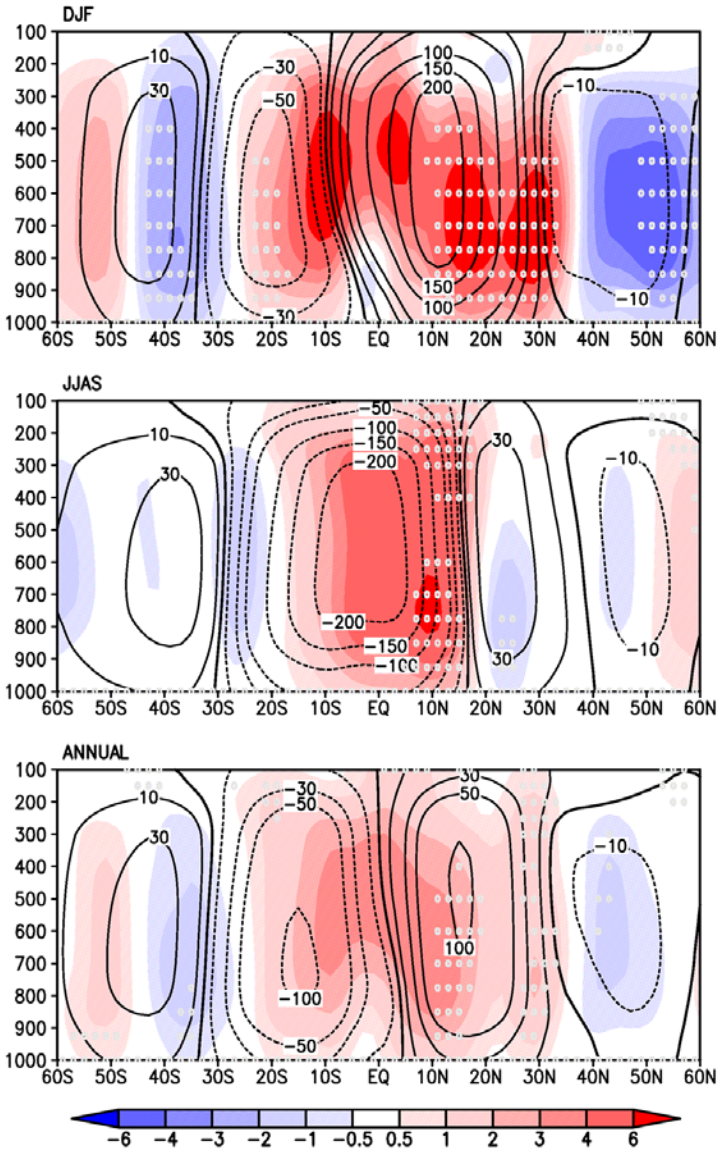
Wave-like patterns across the Northern Hemisphere

DJF

200-hPa Stat. eddy streamfunction (10^6 m^2/s)



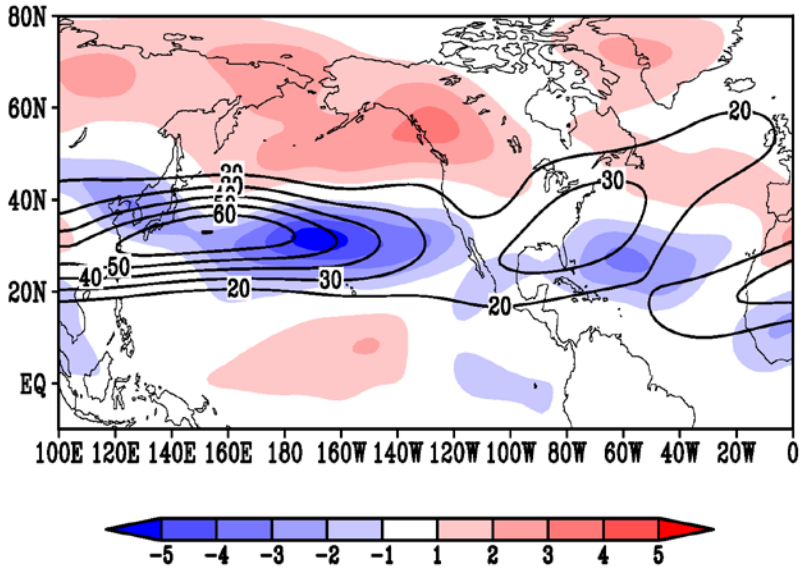
Mass meridional streamfunction (x10^9 Kg/s): 1950s values (black) and changes (shades)



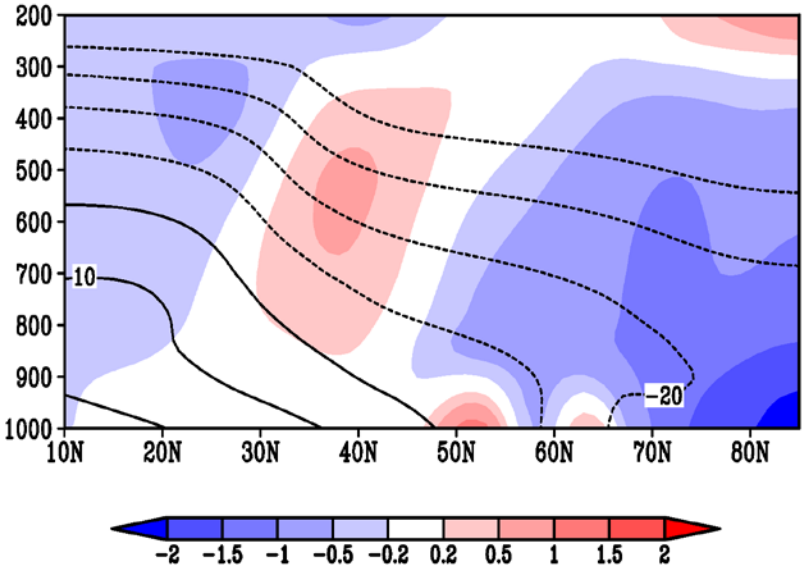
Boreal winter jet

Northward shift of the Atlantic-Pacific jet associated with changes in the tropospheric meridional temperature gradient

300-hPa zonal wind (m/s)



Temperature (K)



Concluding remarks

- **Circulation adjustments** *following* local aerosol forcing are **key players**
- Can **extend** the aerosol impact downwind (teleconnections) & lead to further +/- feedbacks
- **Complex and varied interplay** among local, regional, remote aerosols

Next step (Fall/Winter)

Contrasting Europe + North America vs. South Asia vs. East Asia in transient/time slice experiments

Key Issues

- Observations (Poor coverage and limited data)
- Scale dependency (Spatial and temporal, e.g., interannual vs. decadal, spatial heterogeneity in patterns of change)
- Characteristics (e.g., extremes vs. seasonal)
- Timing (e.g., seasonal cycle - onset vs. withdrawal)
- Upstream/downstream effects (remote effects/teleconnections)
- Challenges in simulations (overall large biases, incremental improvement in CMIP5; mean state vs. changes?)
- Forcing uncertainties (On top of GHG: Aerosols? Natural variability? Linearity? Land use?)