



# Pakistan Flood and Russian heat wave/wild Fires

## 2010: Teleconnection of Hydrometeorologic Extremes

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NASA/GSFC



## Pakistan Flood

- More than 500 mm of rain fell in 10 days July 25- August 5 over northern Pakistan, more than 300% of the normal July-August total
- Worst flood in 100 years; one-fifth of the country under water
- 1500 people perished, 20 million homeless, or displaced
- Tens of thousands suffered from outbreak of disease (diarrhea, gastroenteritis, cholera, malaria..)
- UN dispatch help, and \$460 million; international relief fund about 1billion
- Economic loss up to 43 billions

## Russian Heat Wave/Wild Fires

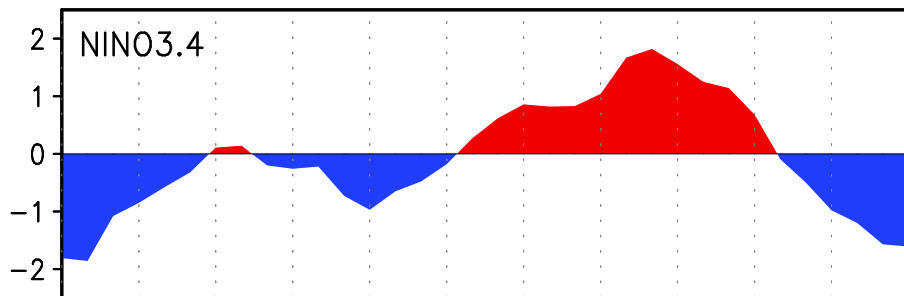


- Abnormally high temperature ( >10 C) about normal over vast regions of western Russia, western Siberia, and eastern Europe.
- New nationwide temperature record of 44C (111 F) was set in Yashkul, Kalmykia; Moscow exceeded 40C (104F)
- 7000 intense fires over over 500,000 hecta-acres (5000 km<sup>2</sup>) of forested areas
- Dense smoke blanketed entire region for weeks
- 5000 lives lost from fire and related health hazards
- Total economic loss estimated at 15 billion

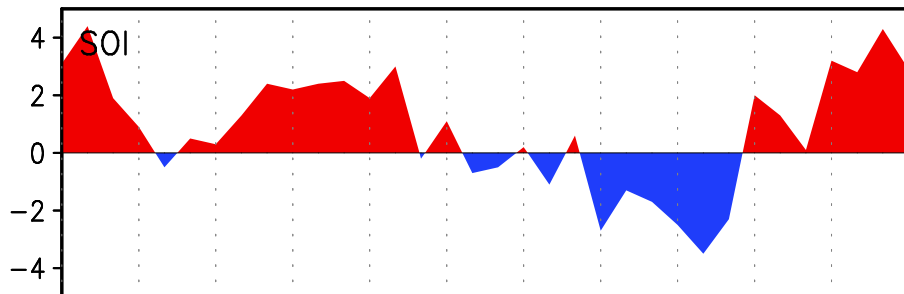


*Golden rule for  
hydrometeorological extremes events*

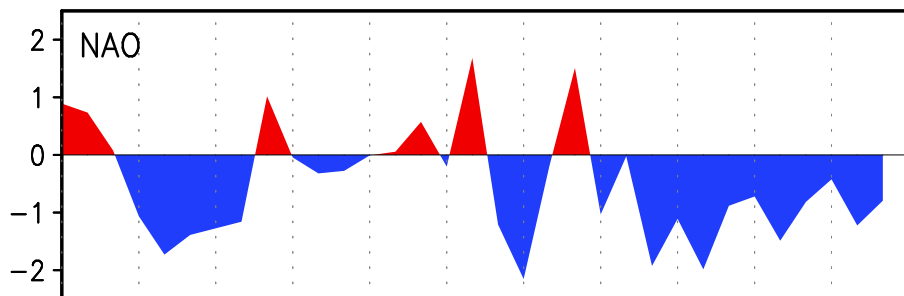
**Alignment of major controlling factors,  
and  
amplification by local feedback processes**



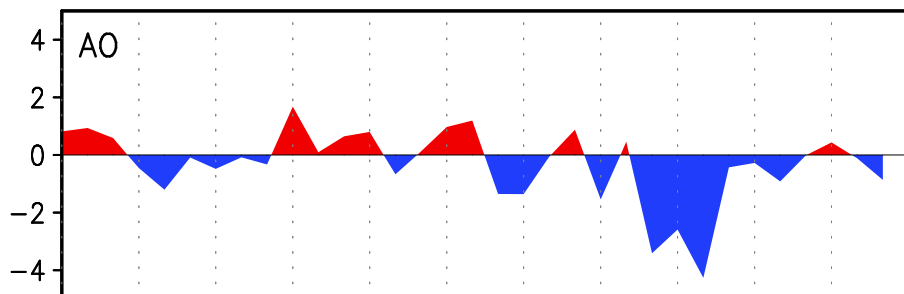
El Nino



Southern Oscillation



North Atlantic Oscillation



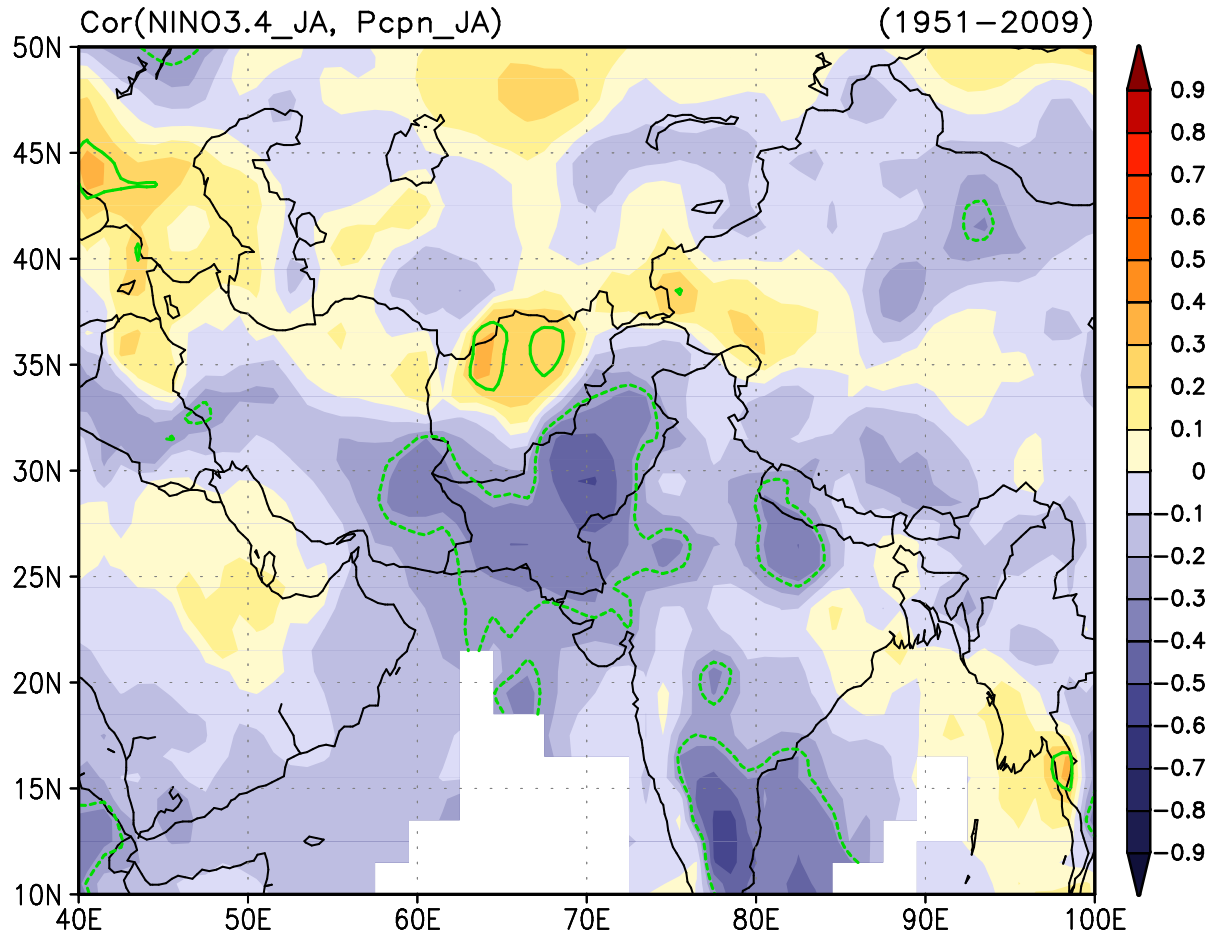
Annular Mode

JAN 2008 APR JUL OCT JAN 2009 APR JUL OCT JAN 2010 APR JUL OCT

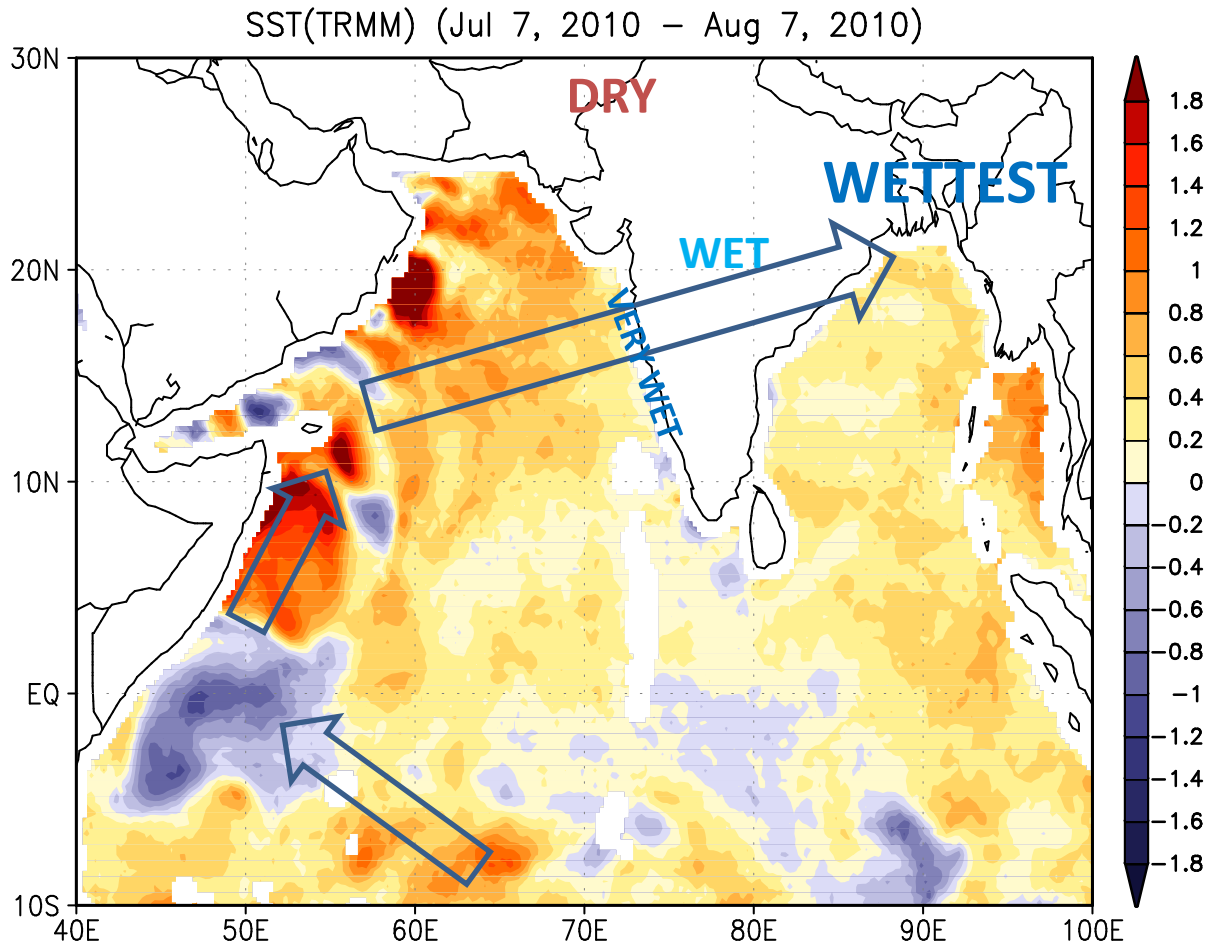




# Correlation of rainfall (July-August) with Nino-3.4 SST

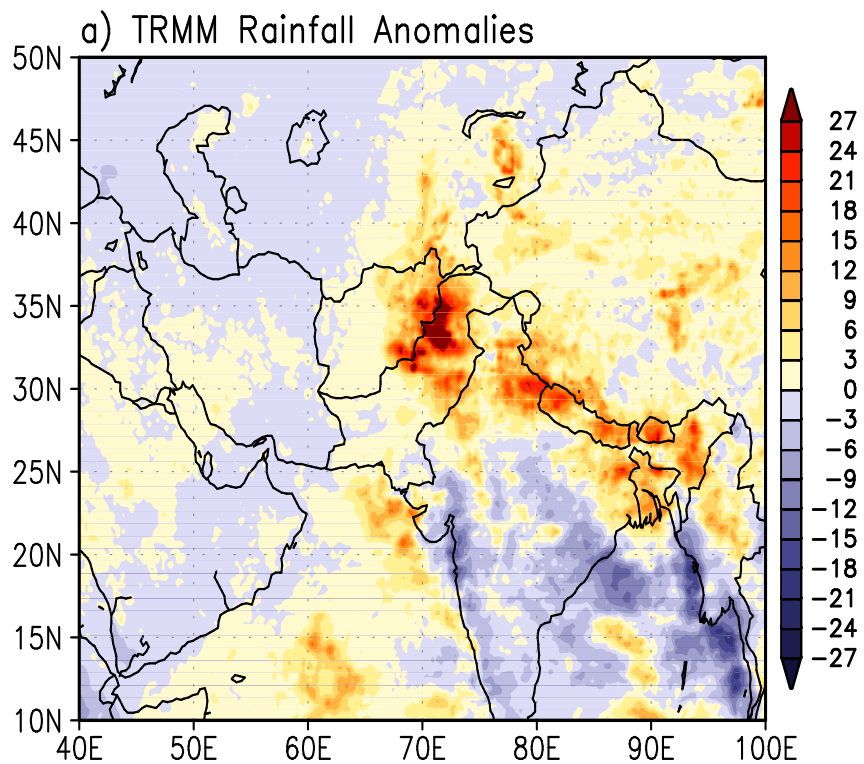


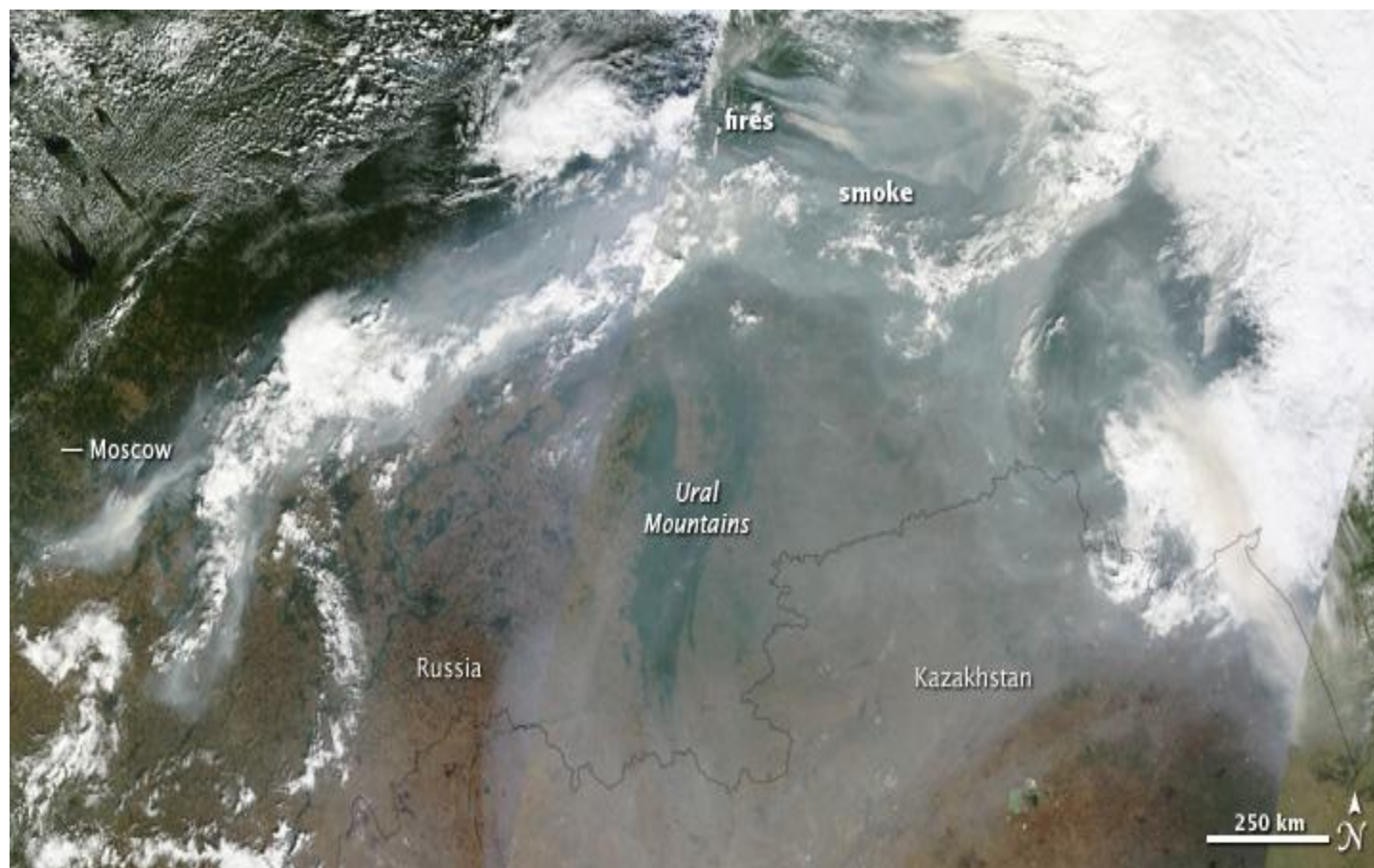
Statistically La Nina condition is favorable for enhanced rainfall over Pakistan



Arabian Sea is anomalous warm during July-August 2010, providing plentiful moisture to the Indian monsoon. Schematic indicates climatological conditions

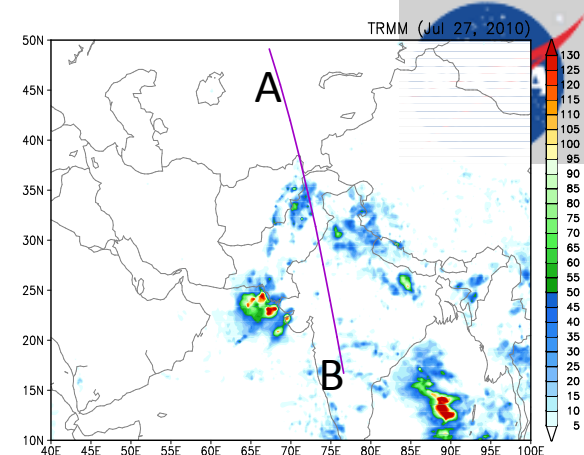
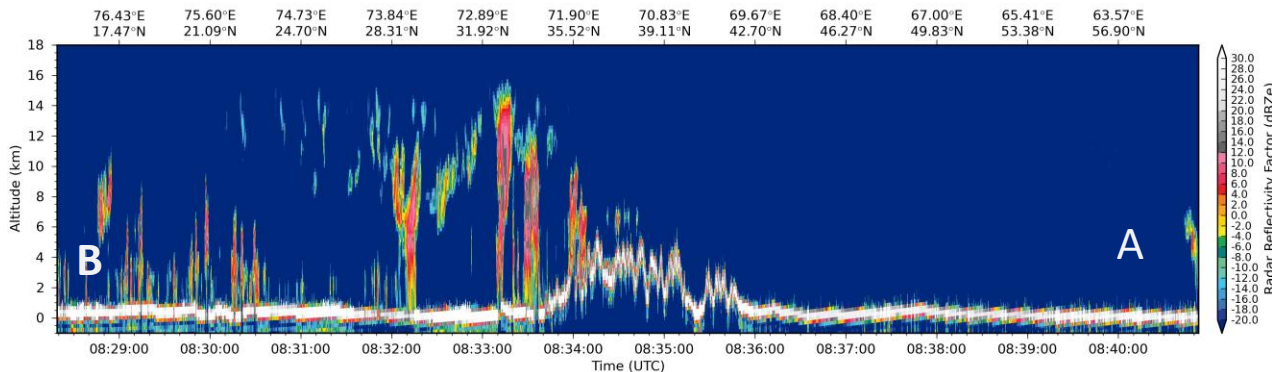
July 25 – August 8, 2010



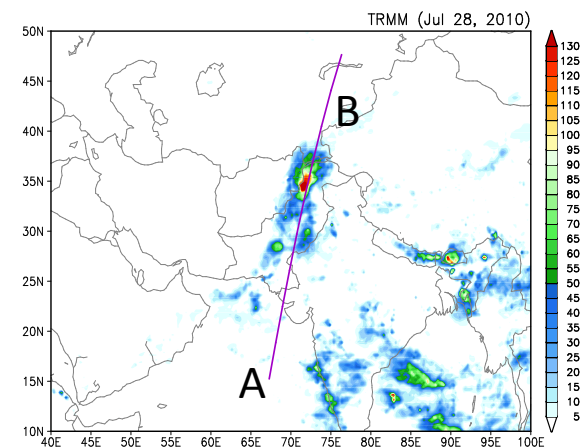
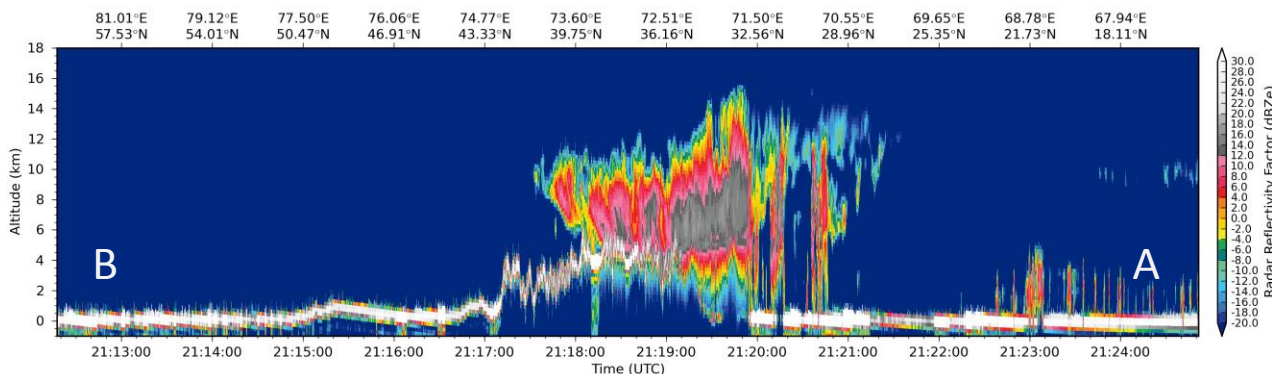




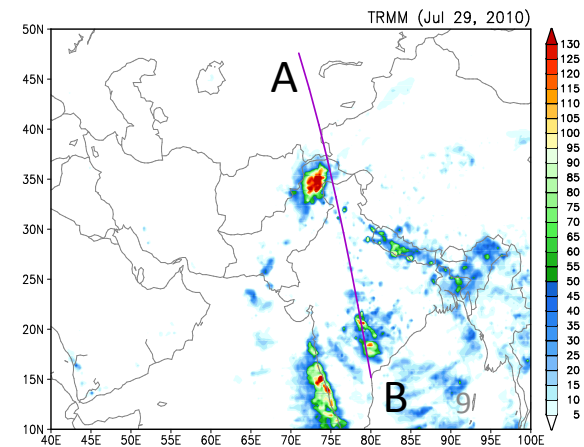
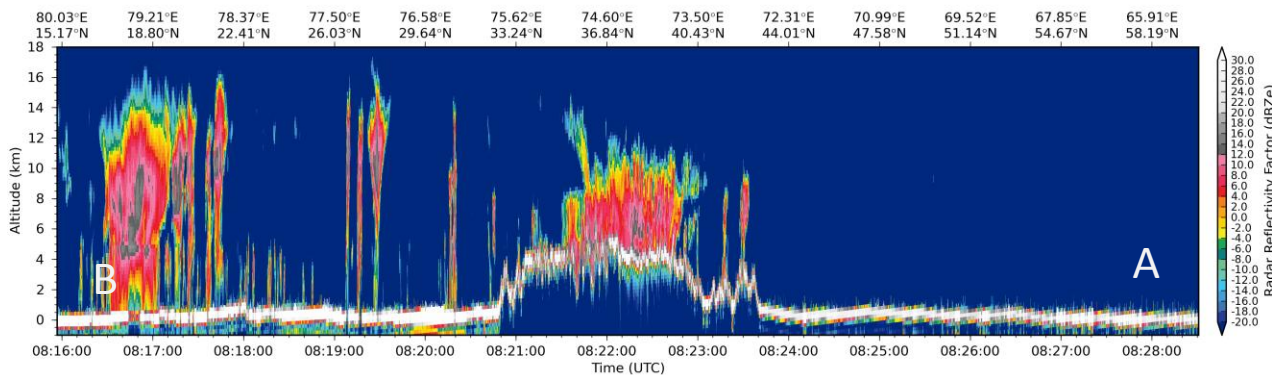
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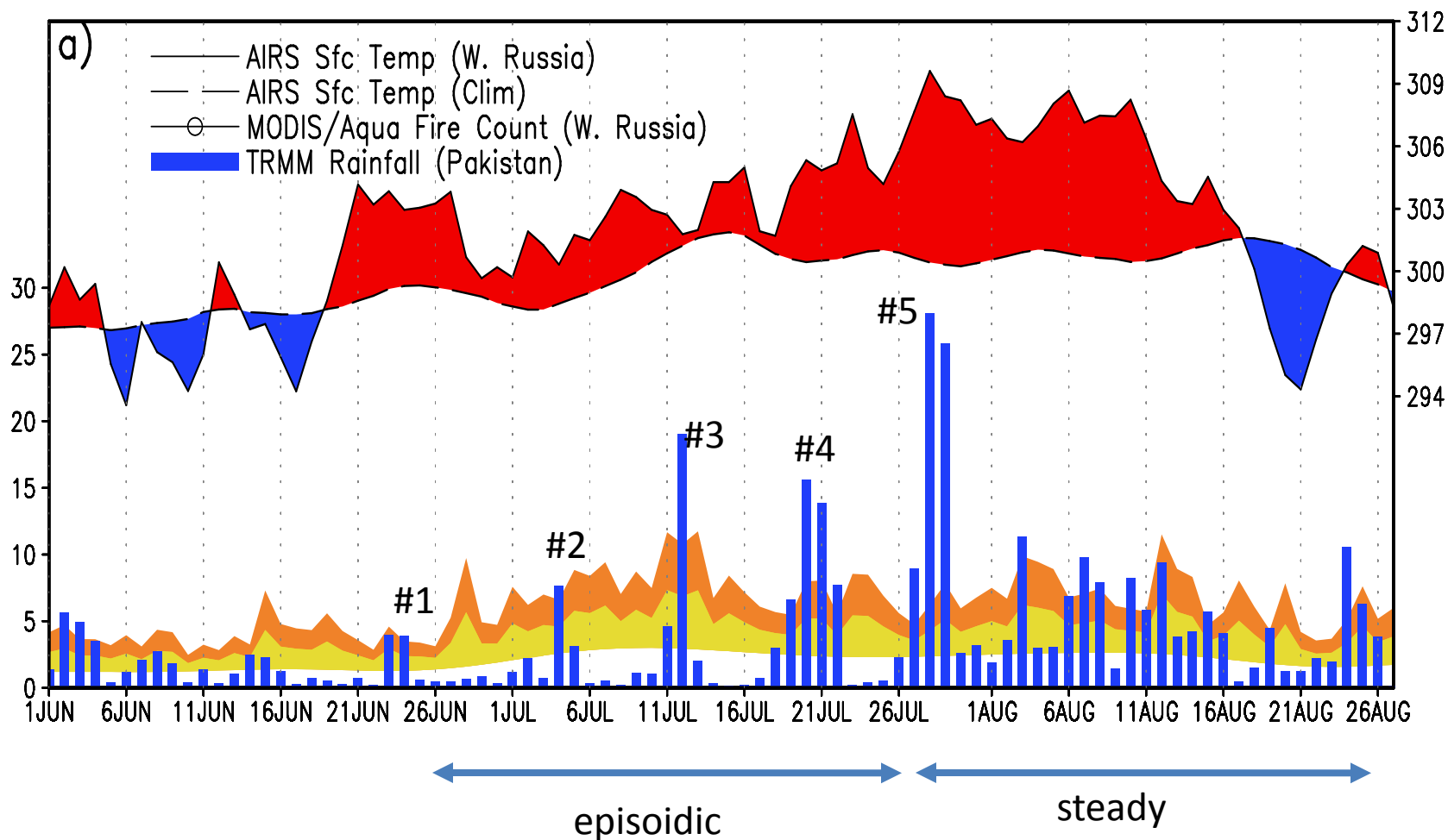
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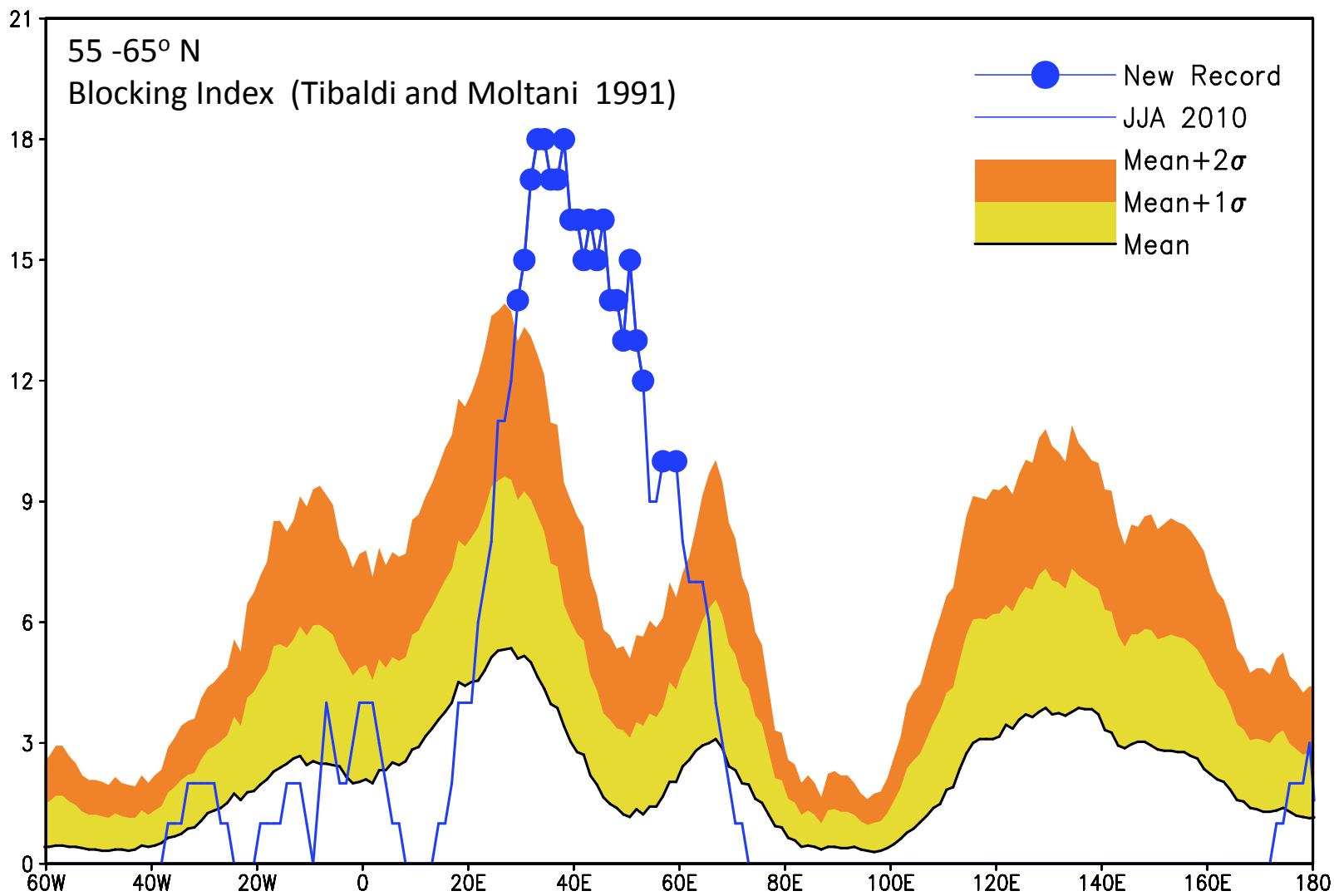


CloudSat Profile 2010-07-29T08:15:57Z/2010-07-29T08:28:30Z



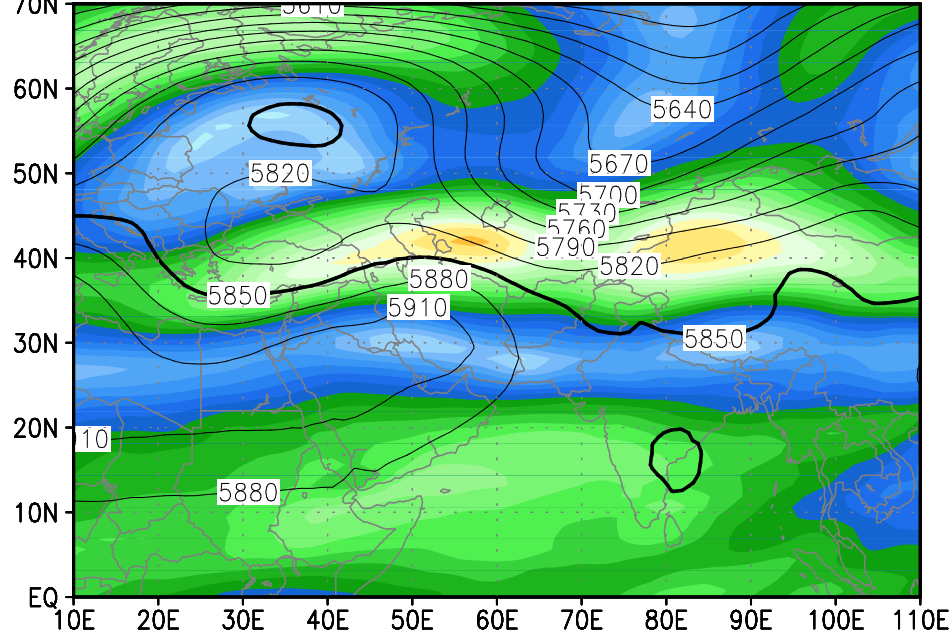




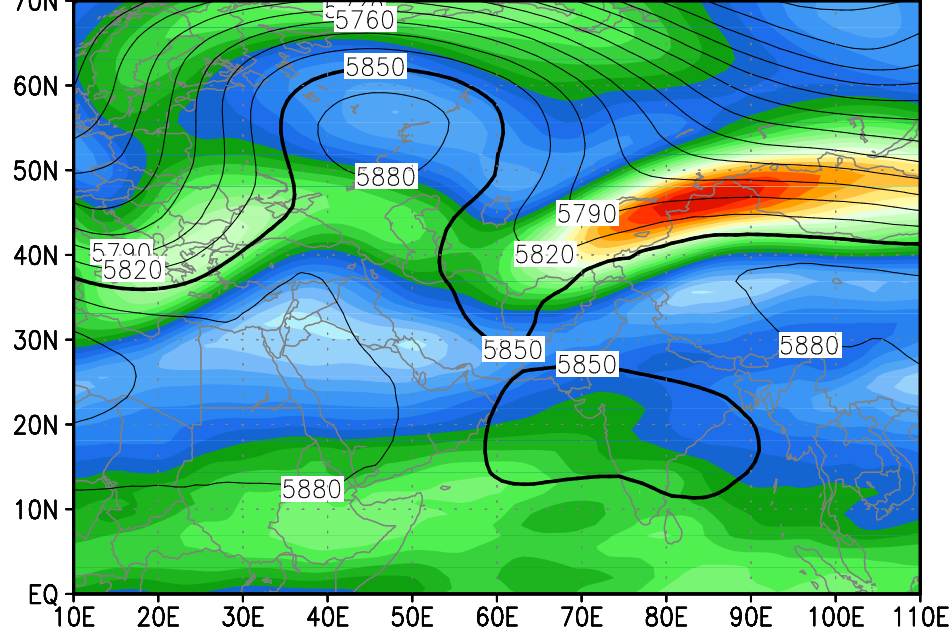


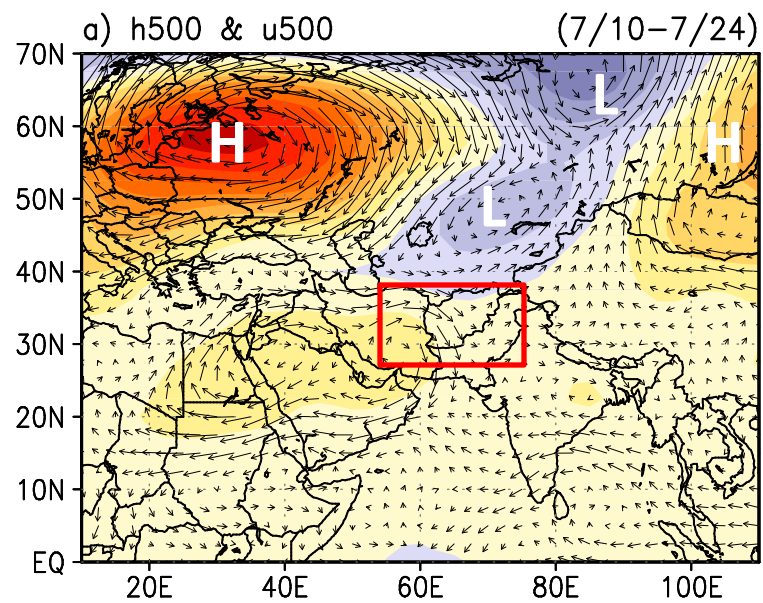


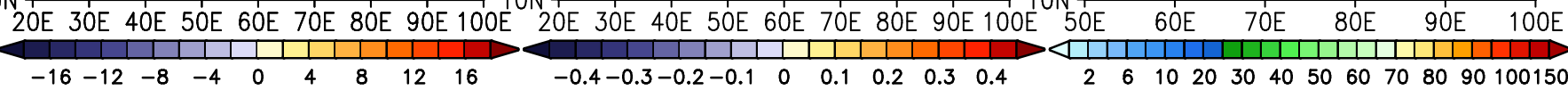
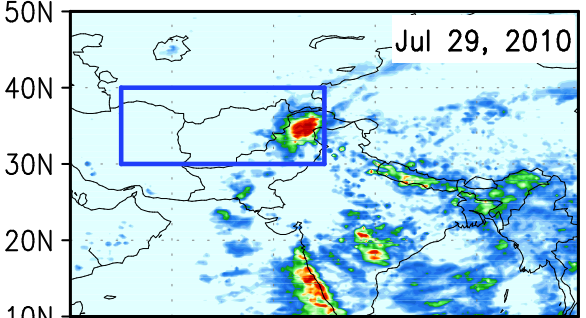
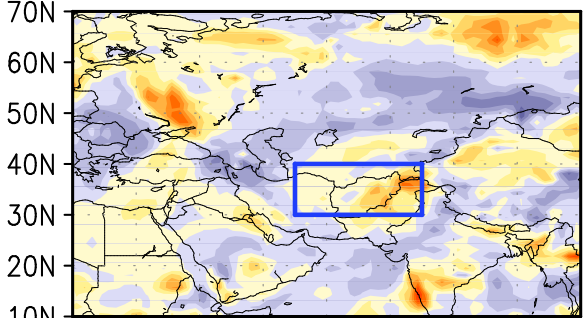
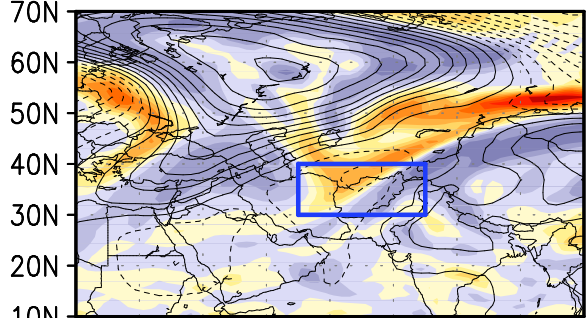
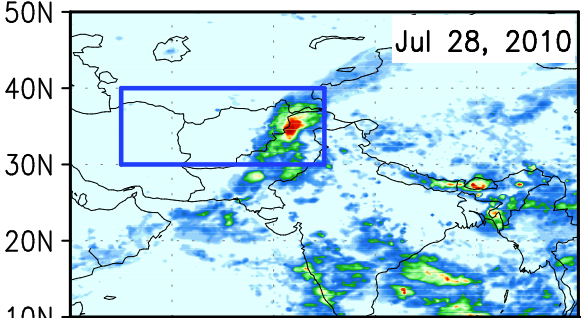
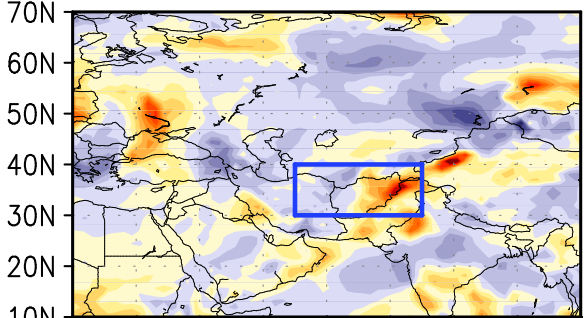
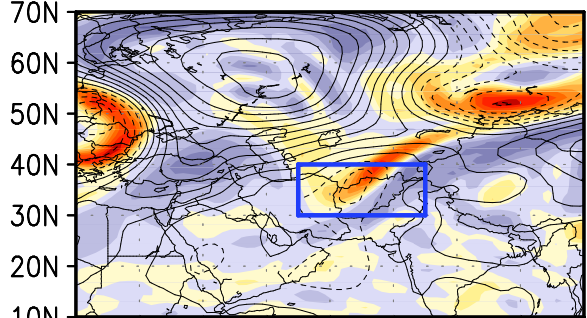
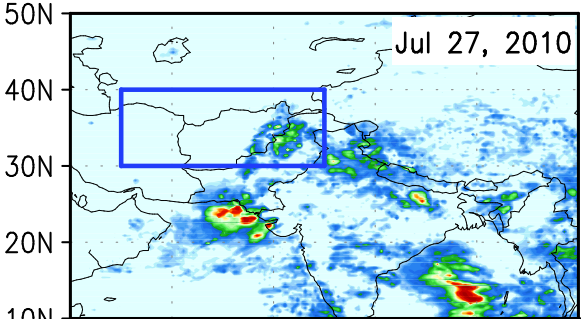
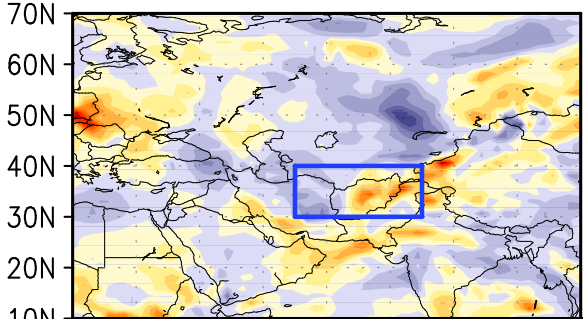
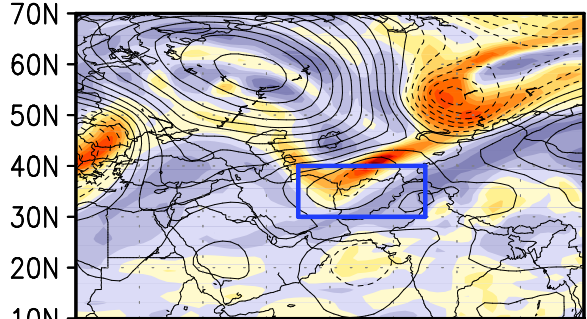
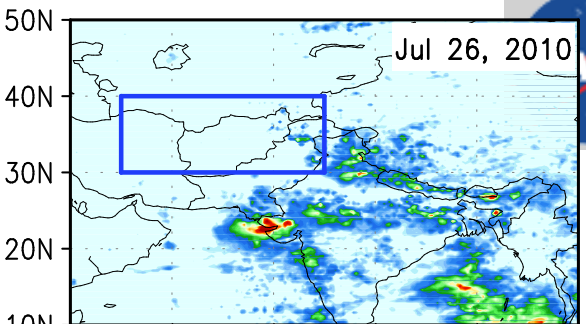
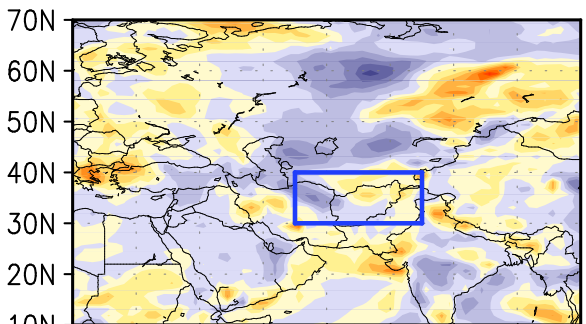
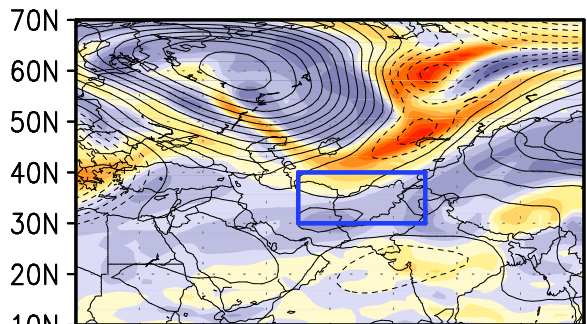
(a) (7/10–7/24/2010) H500hPa & WS200hPa



(b) (7/25–8/08/2010)

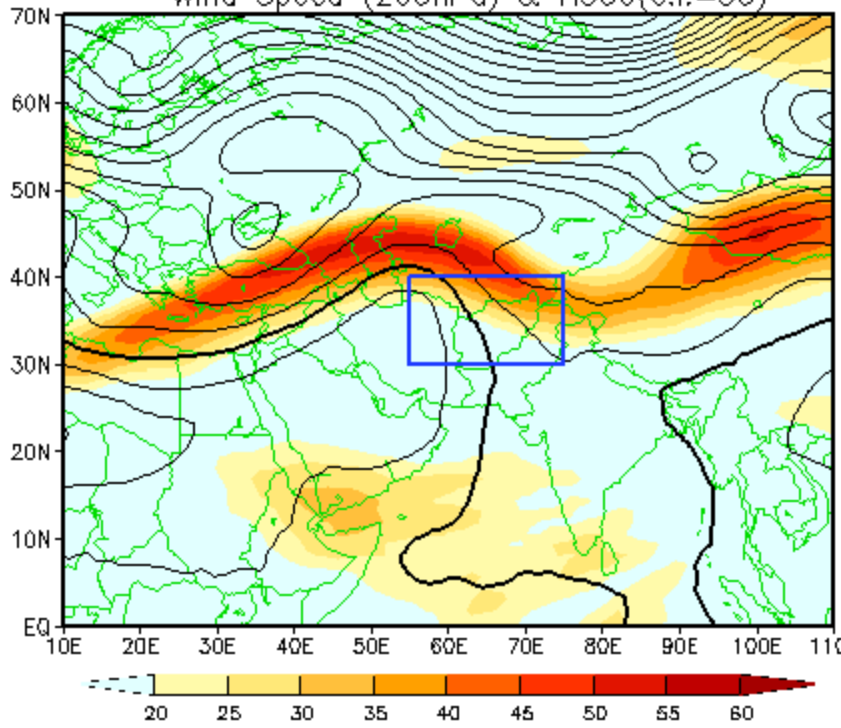




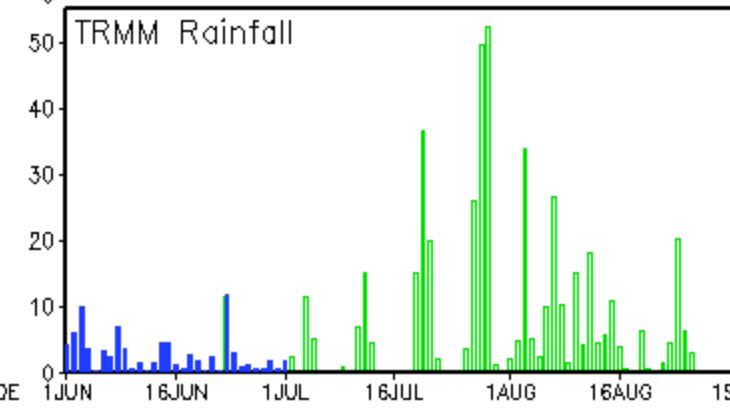
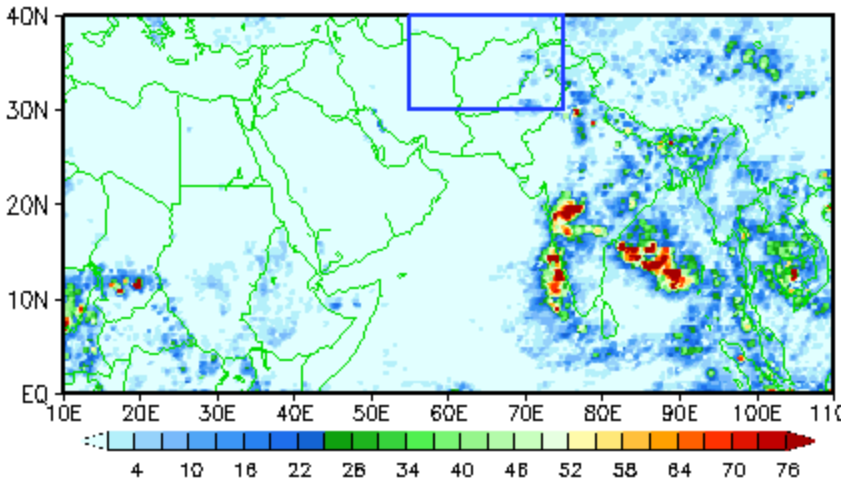
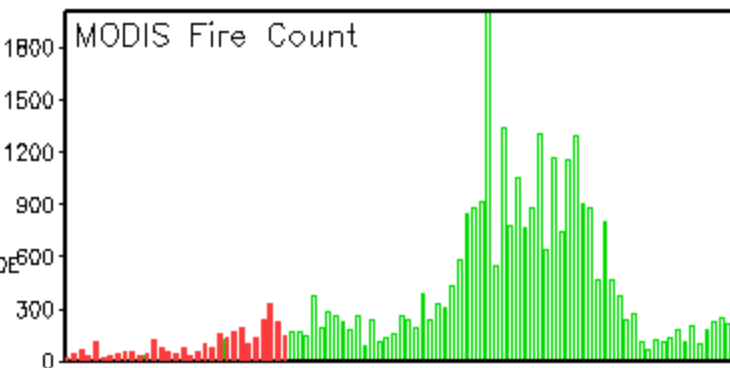
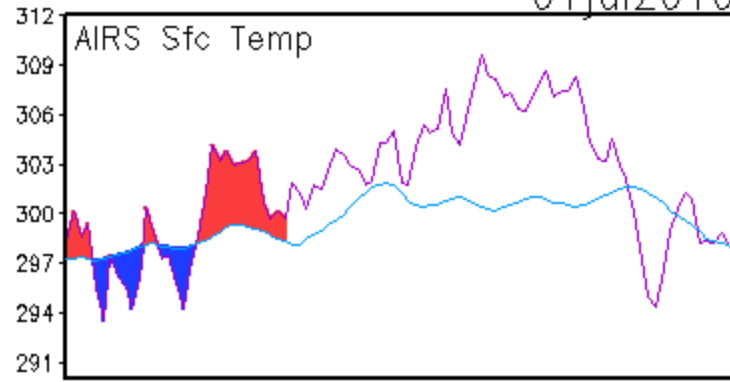


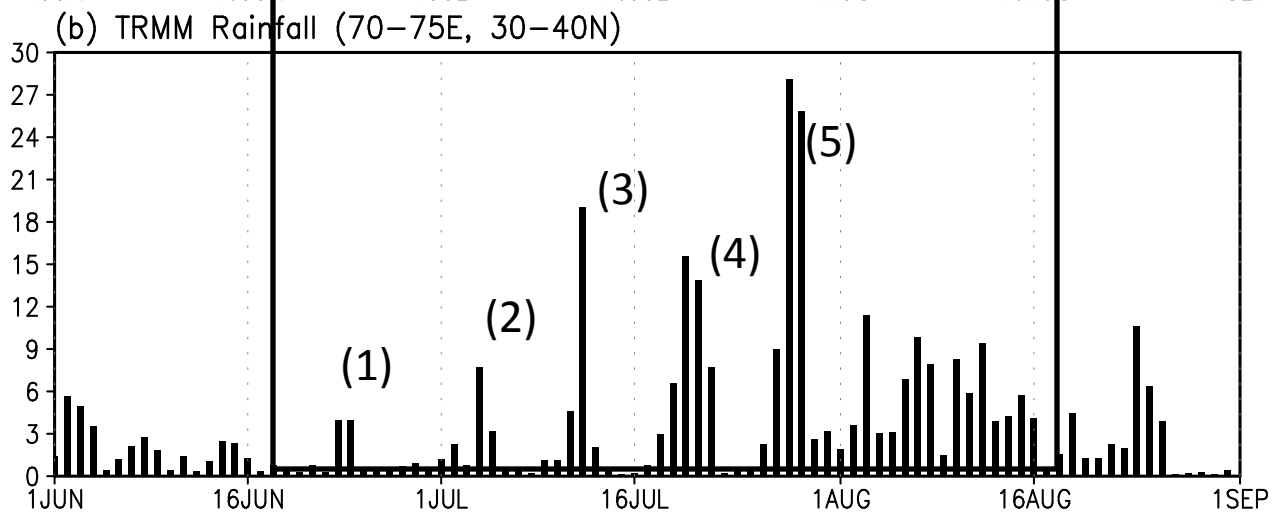
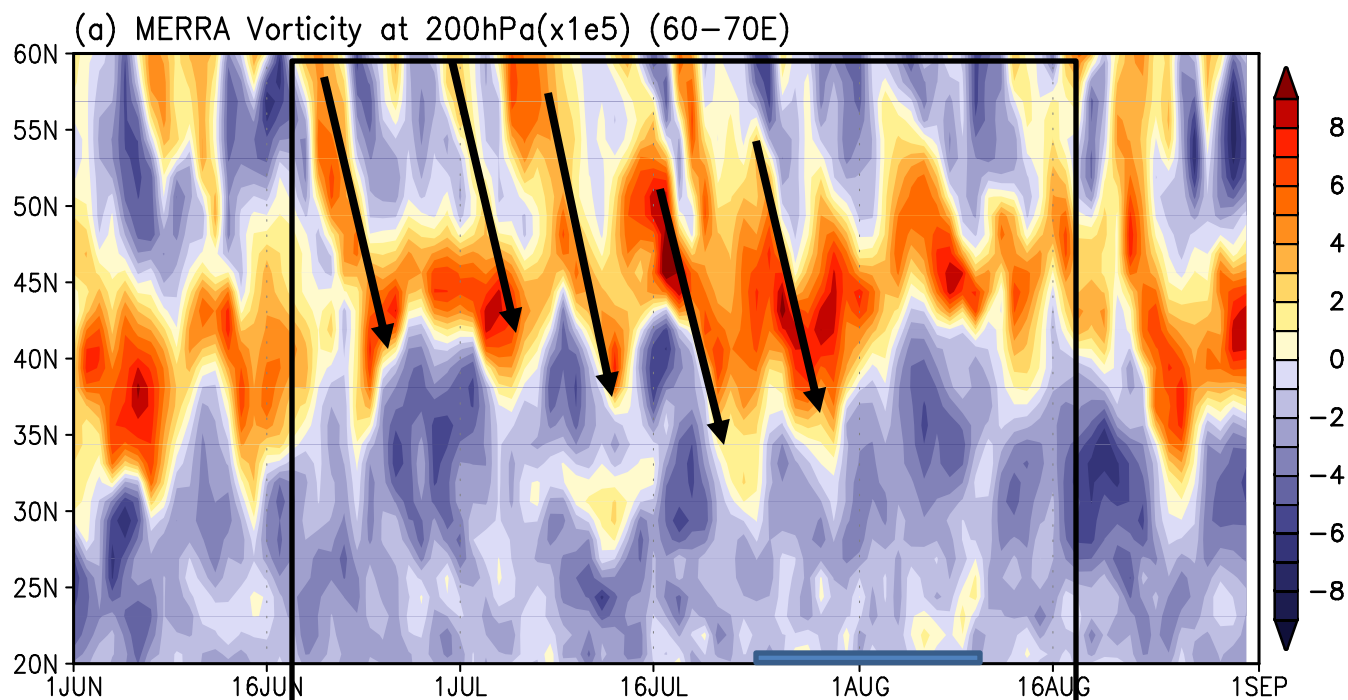


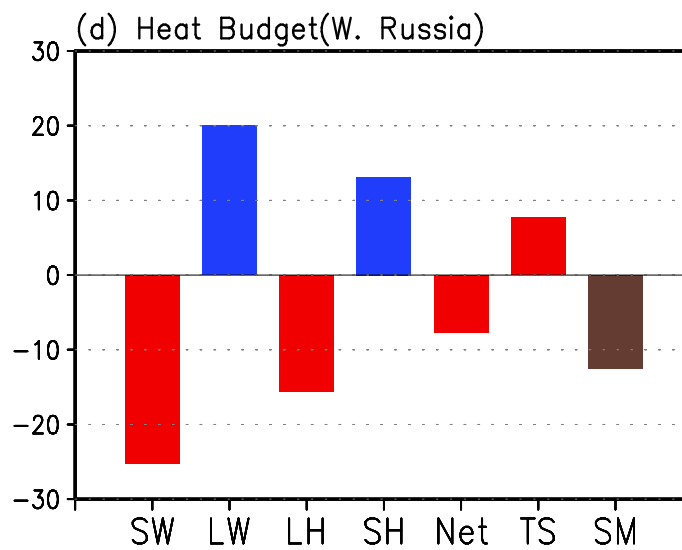
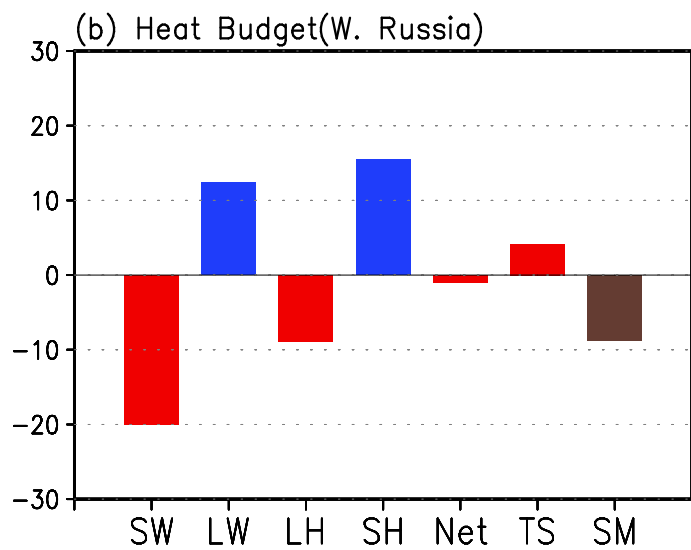
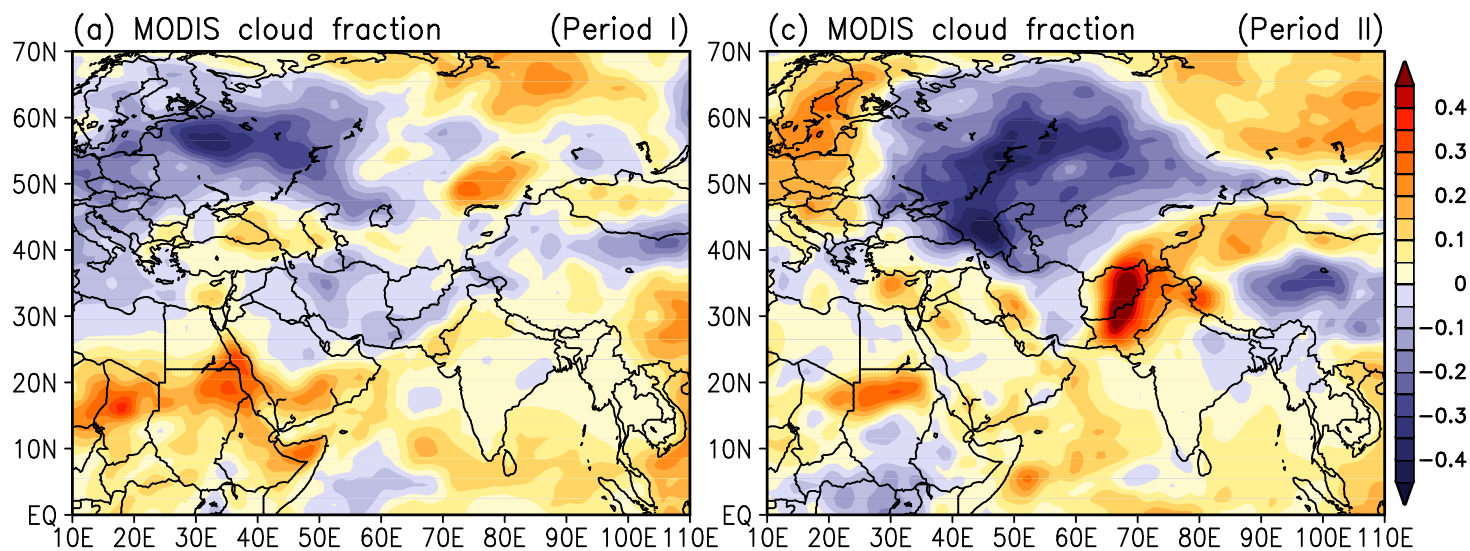
Wind Speed (200hPa) & H500(c.i.=30)



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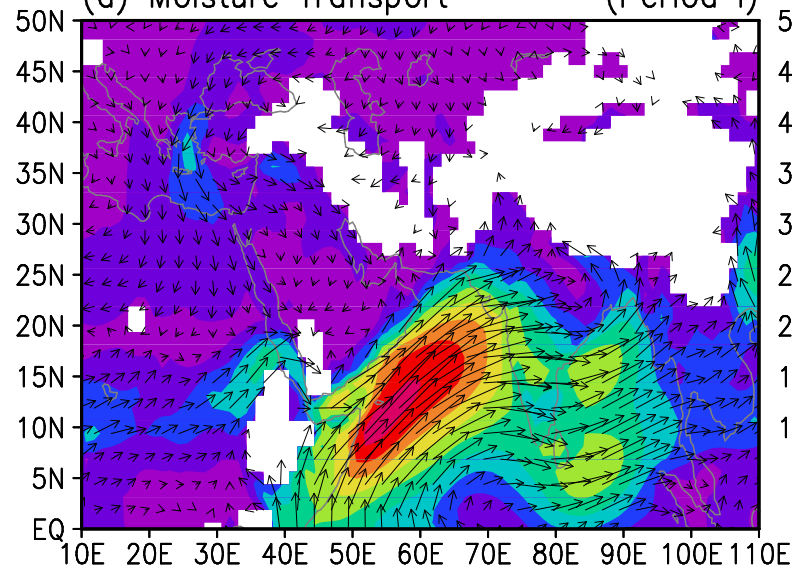




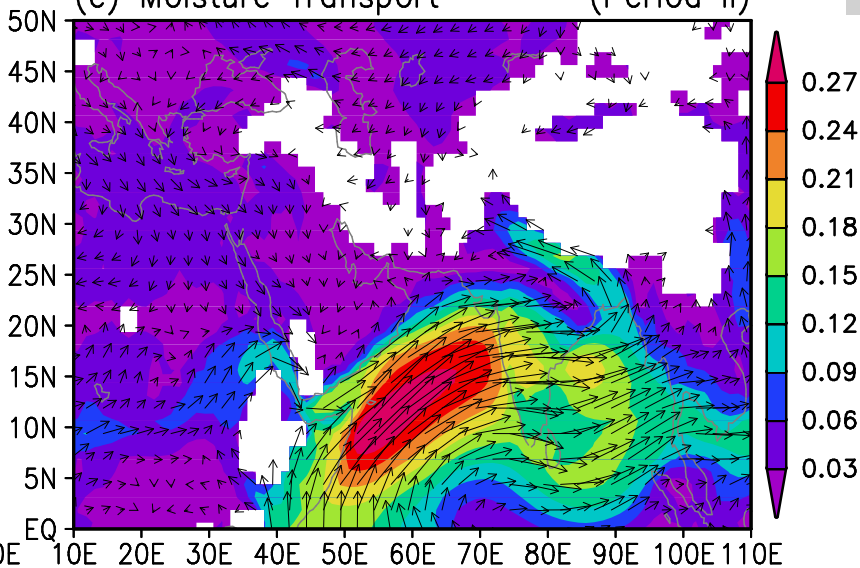




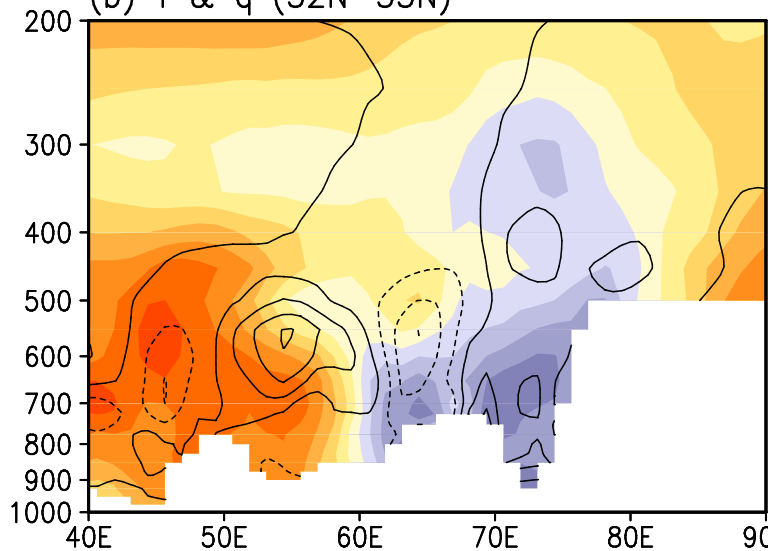
(a) Moisture Transport (Period I)



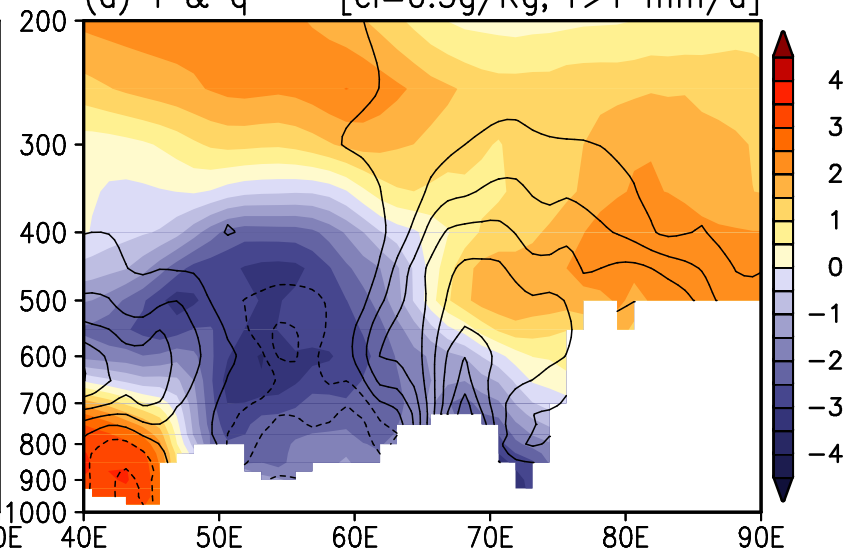
(c) Moisture Transport (Period II)



(b) T & q (32N–35N)

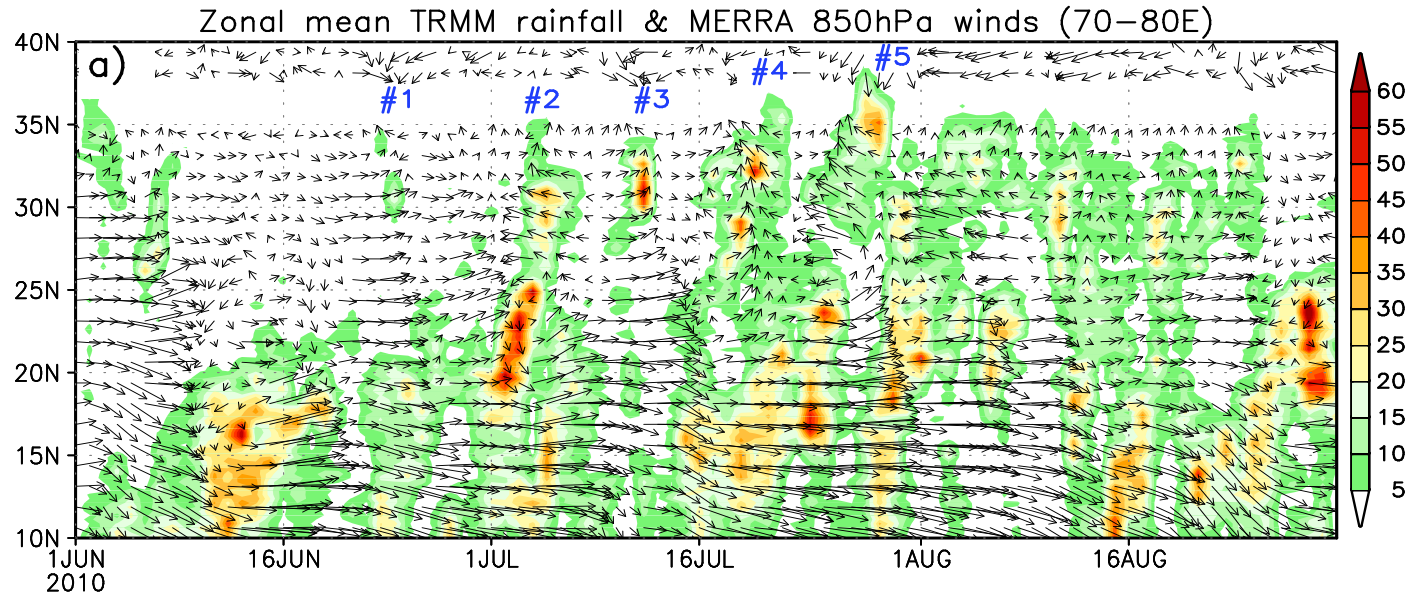


(d) T & q [ci=0.5g/Kg, r>1 mm/d]



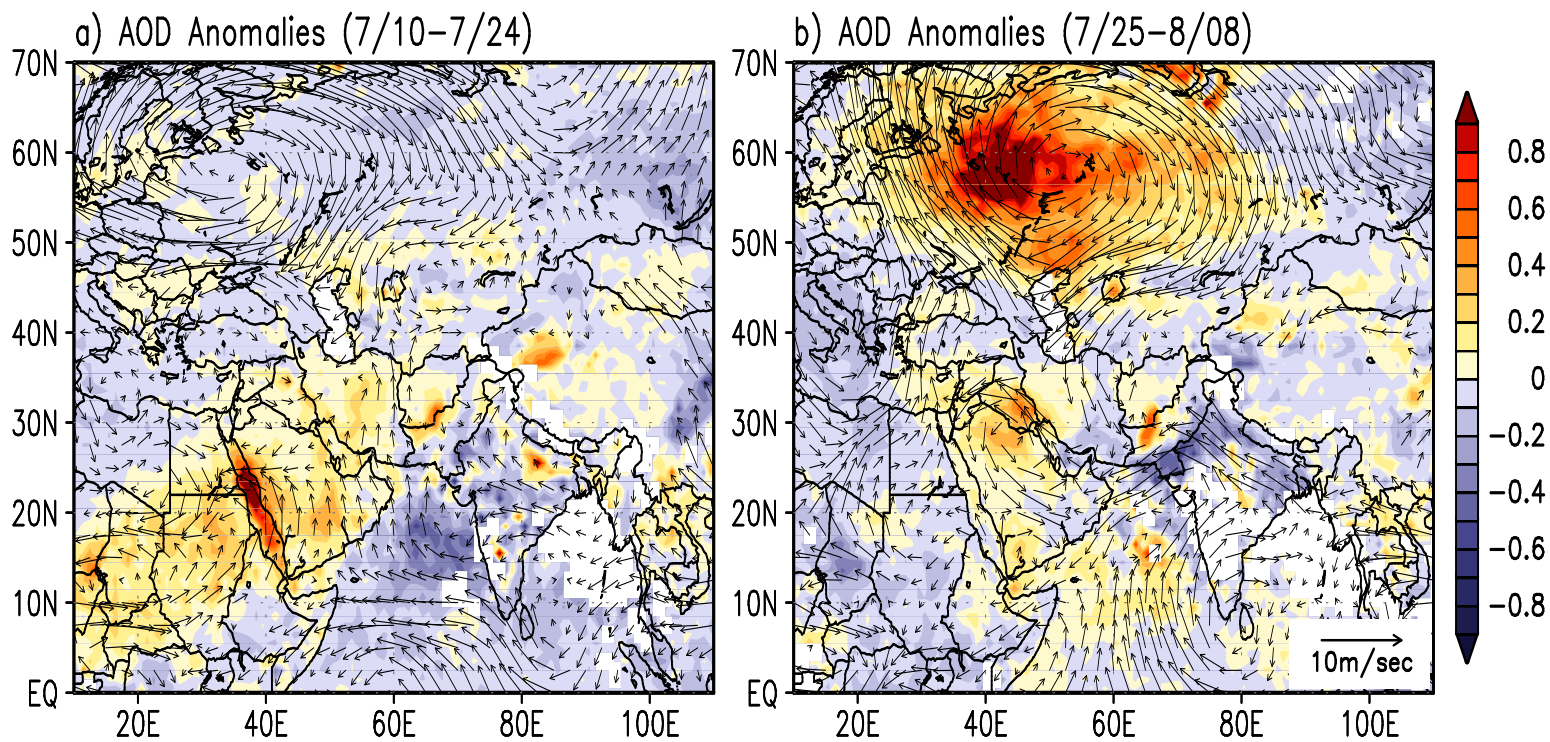


# Monsoon Intraseasonal Oscillation (MISO)

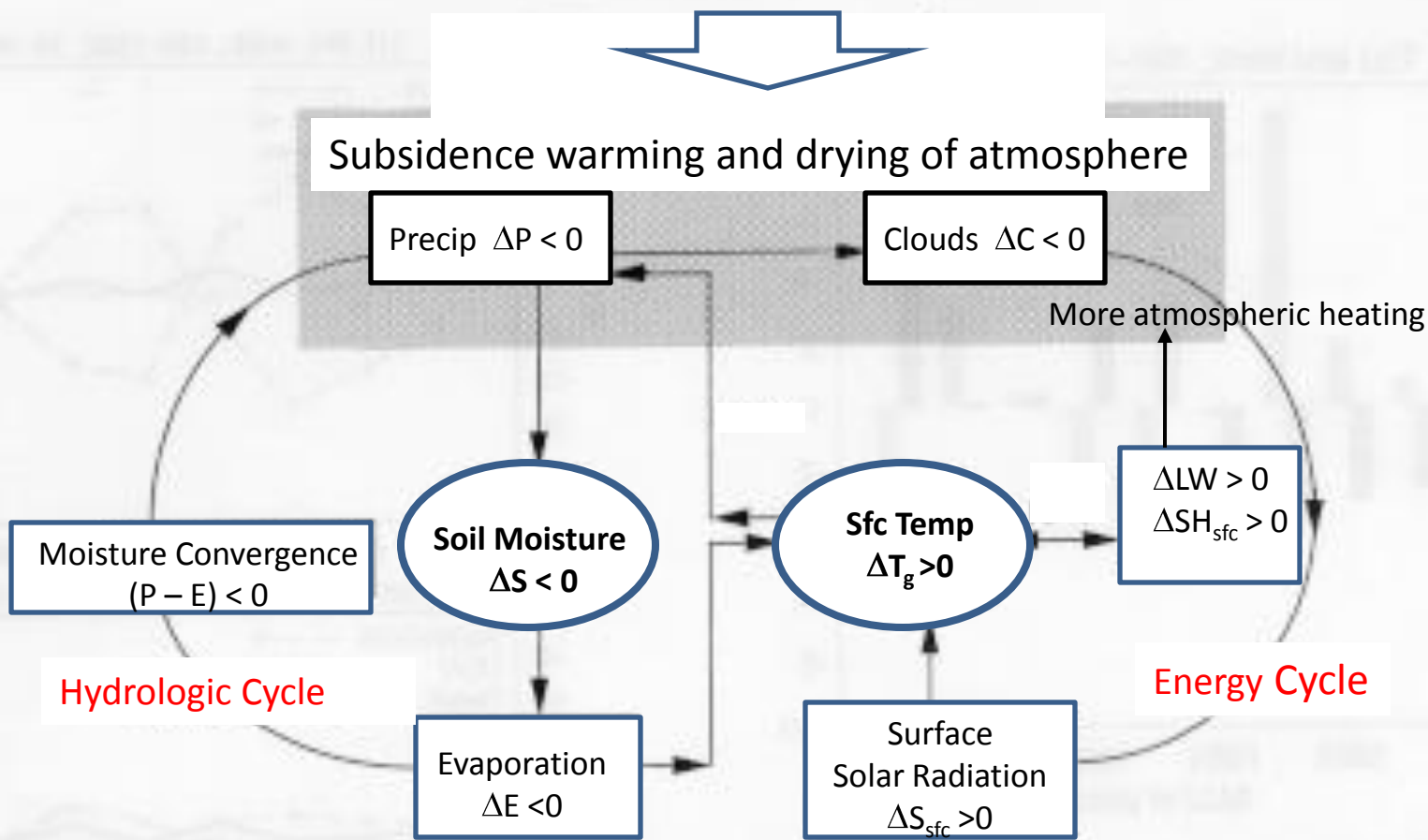




# Can fire cause flood?



# A possible scenario of positive feedback involving interaction of atmospheric blocking, land surface processes, and possibly forest fire



*A working hypothesis : Black Carbon and CO<sub>2</sub> emitted from wild fires will further heat the atmosphere, evaporate cloud droplets, increase atmospheric stability, therefore reduce even more clouds and precipitation amplifying the Russian heat wave and fires and strengthening the Rossby wave signal affecting Pakistan flood*



# Preliminary assessments

- The 2010 Russian heat wave/wild fires and Pakistan flood were teleconnected via Rossby wavetrain
- Heavy rain over Pakistan appeared to be triggered from downstream Rossby wave from large-scale blocking high over W. Russia
- The heavy rain is associated with the development of anomalous mid-tropospheric cyclones, with elevated warm core, mid-tropospheric ascent, and upper level divergence, southeast of an equatorward penetrating trough, drawing moisture from Bay of Bengal, and the Arabian Sea
- Atmosphere-land surface feedback may have prolonged and amplified the Russian heat wave/fire
- Extreme northward propagation of MISO, associated with southeasterly flow along the Himalayas foothills may have provided enhanced moisture feeding the MTC
- Warming of the Arabian Sea (La Nina) may contribute additional moisture over N. Pakistan

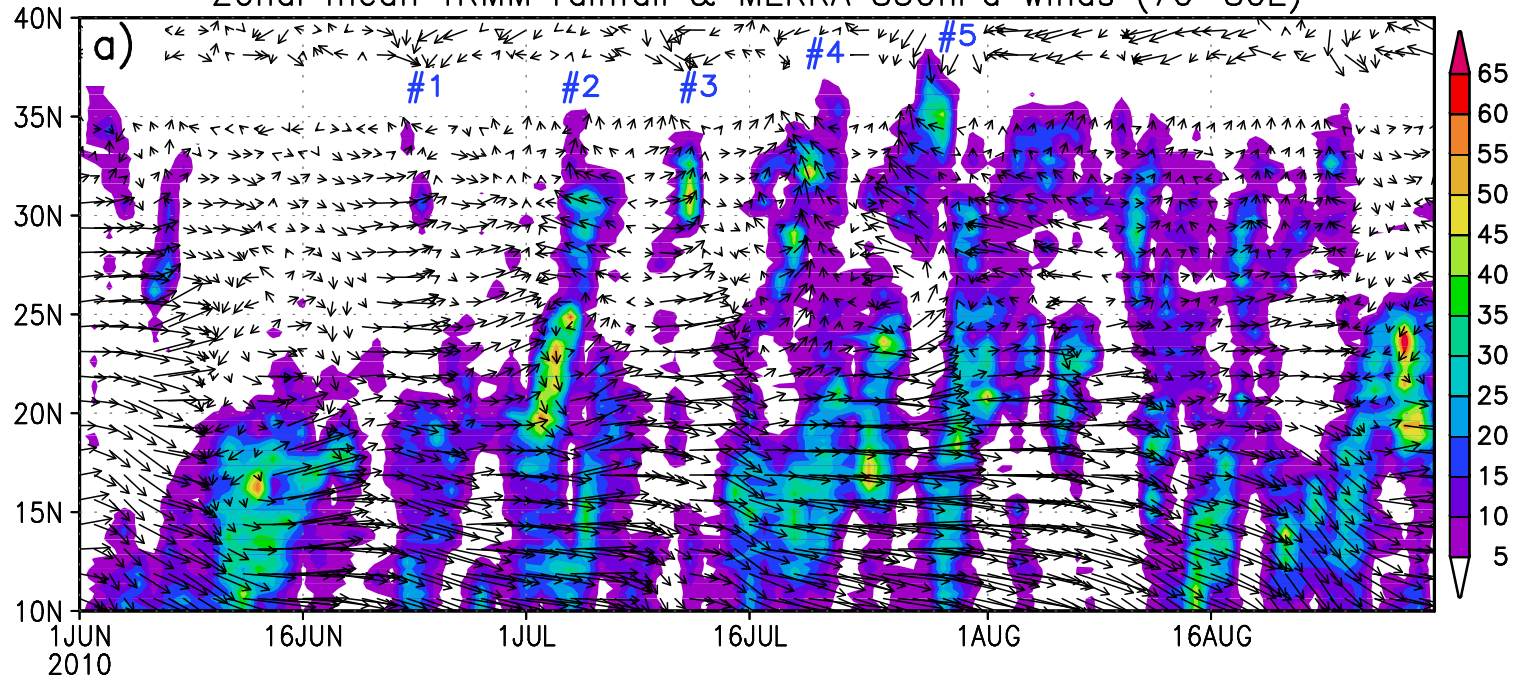
## **Many more questions, e.g.,**

- Did aerosol play a role in amplifying the heat wave, and thus enhanced the teleconnection?
- What if there were no La Nina condition, but Russian heat wave only, or the reverse (La Nina only, but no Russian heat wave) would the Pakistan flood still occur?
- Does this connection fit a long-term trend?

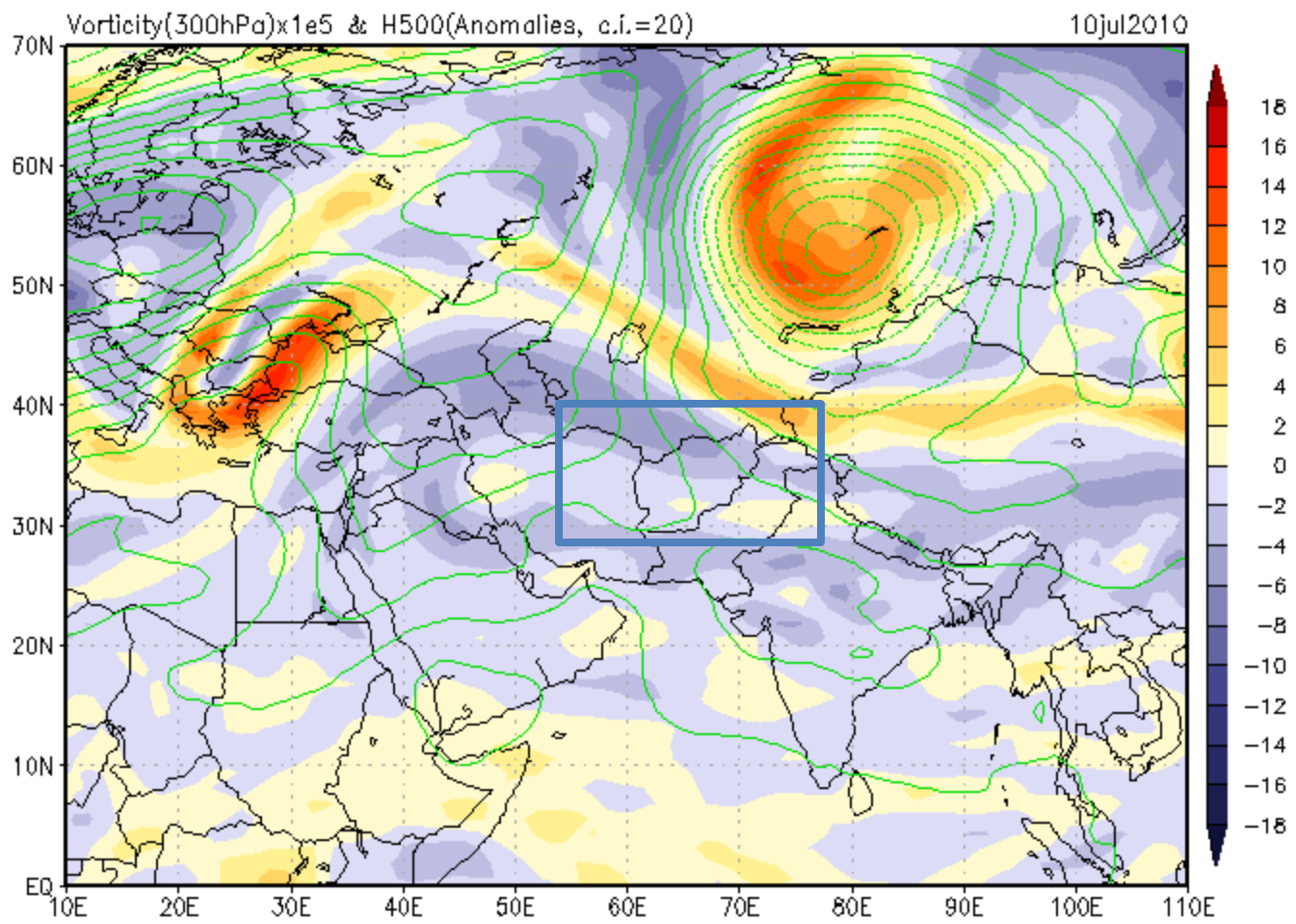


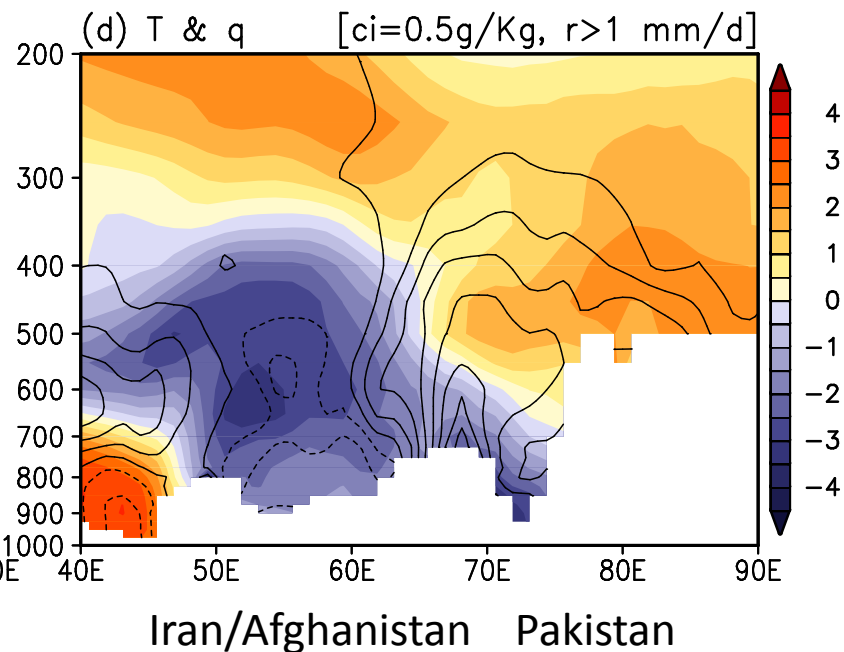
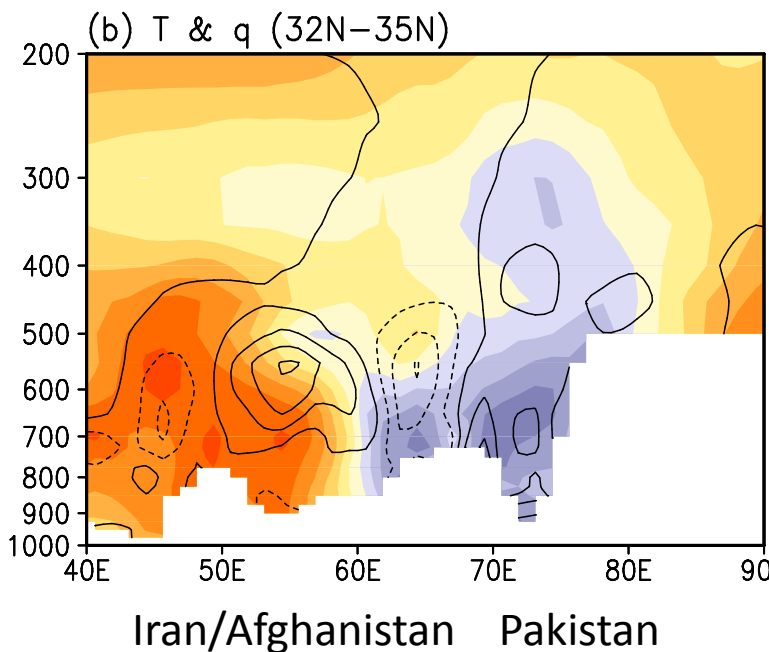
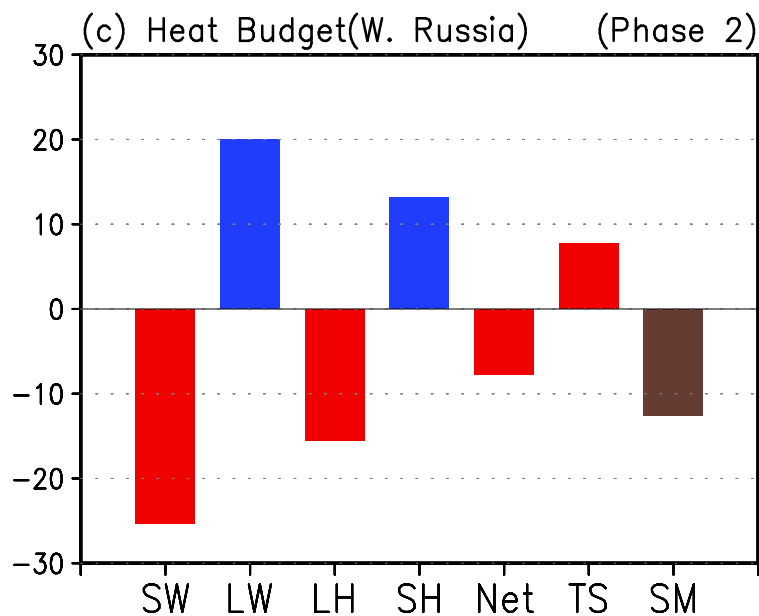
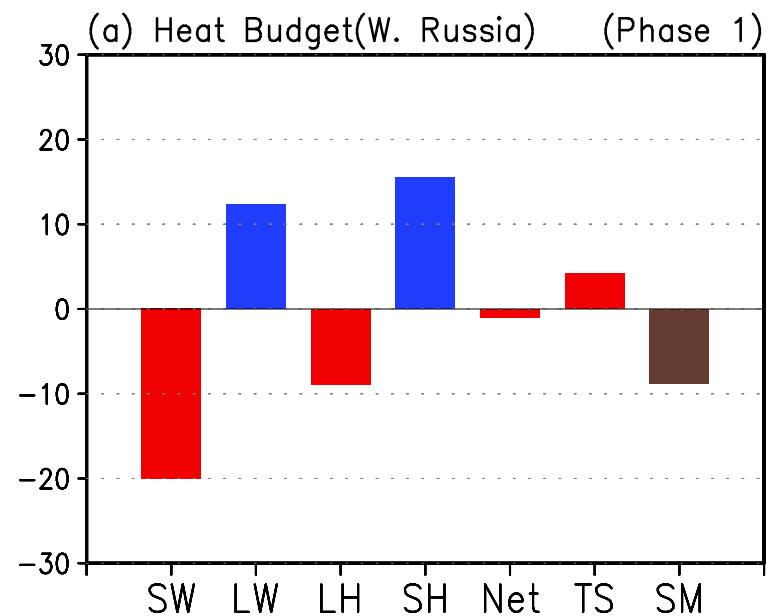
# Back Up

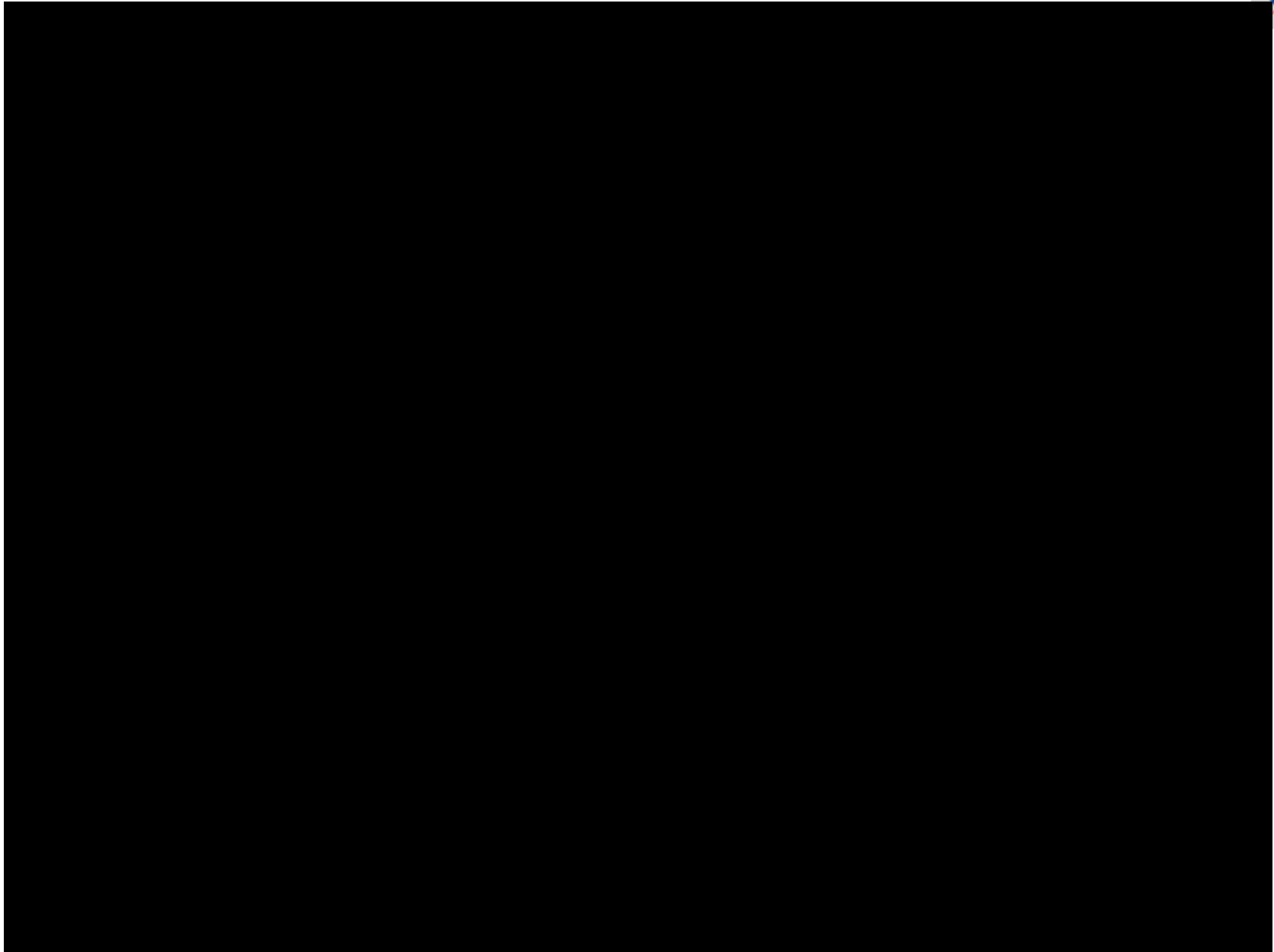
# Zonal mean TRMM rainfall & MERRA 850hPa winds (70–80E)

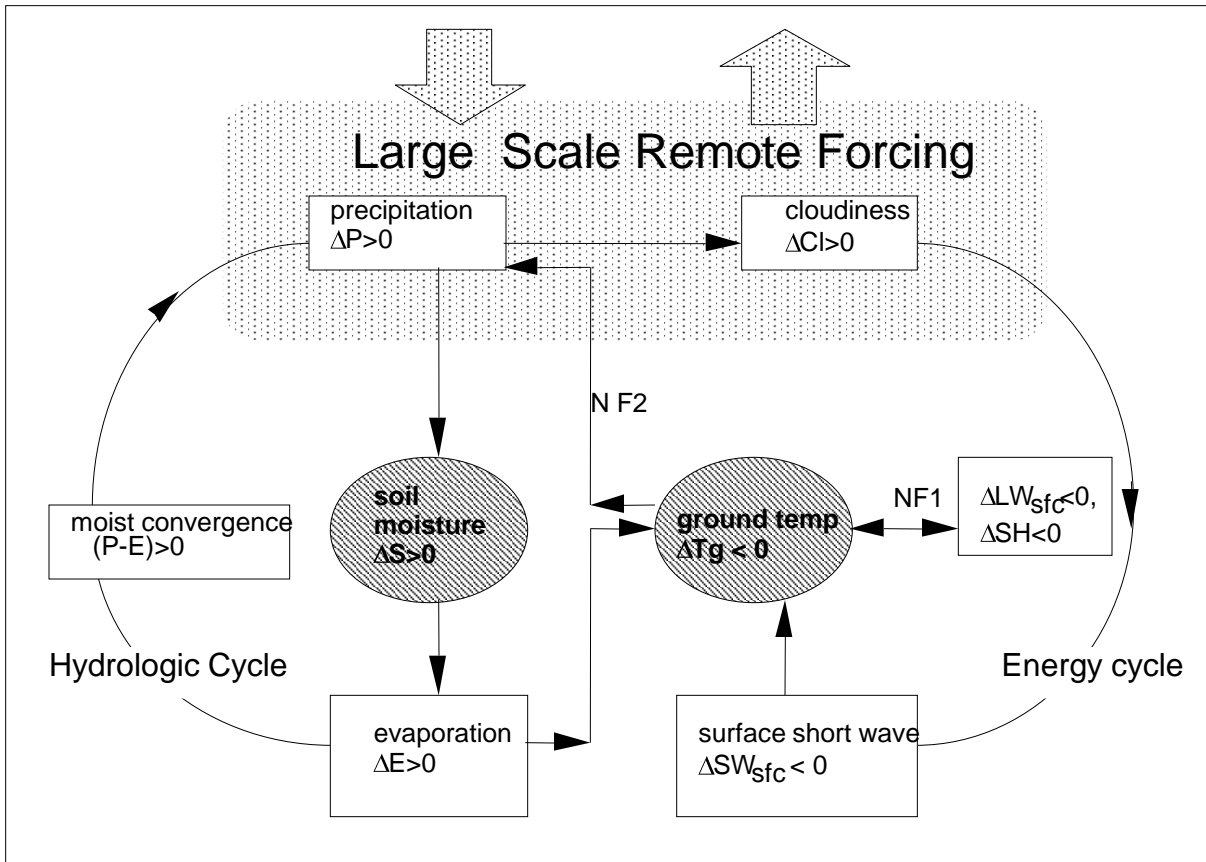


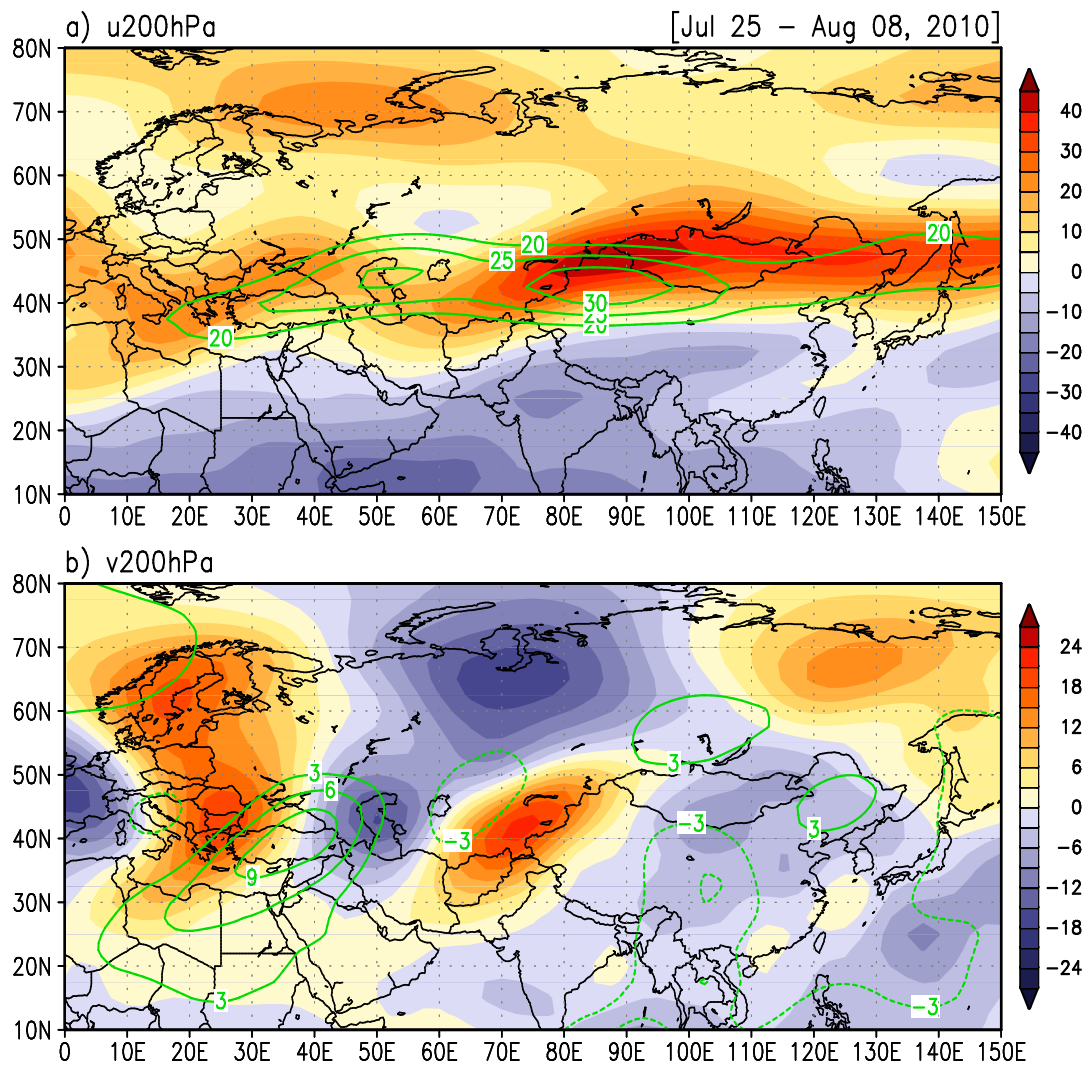






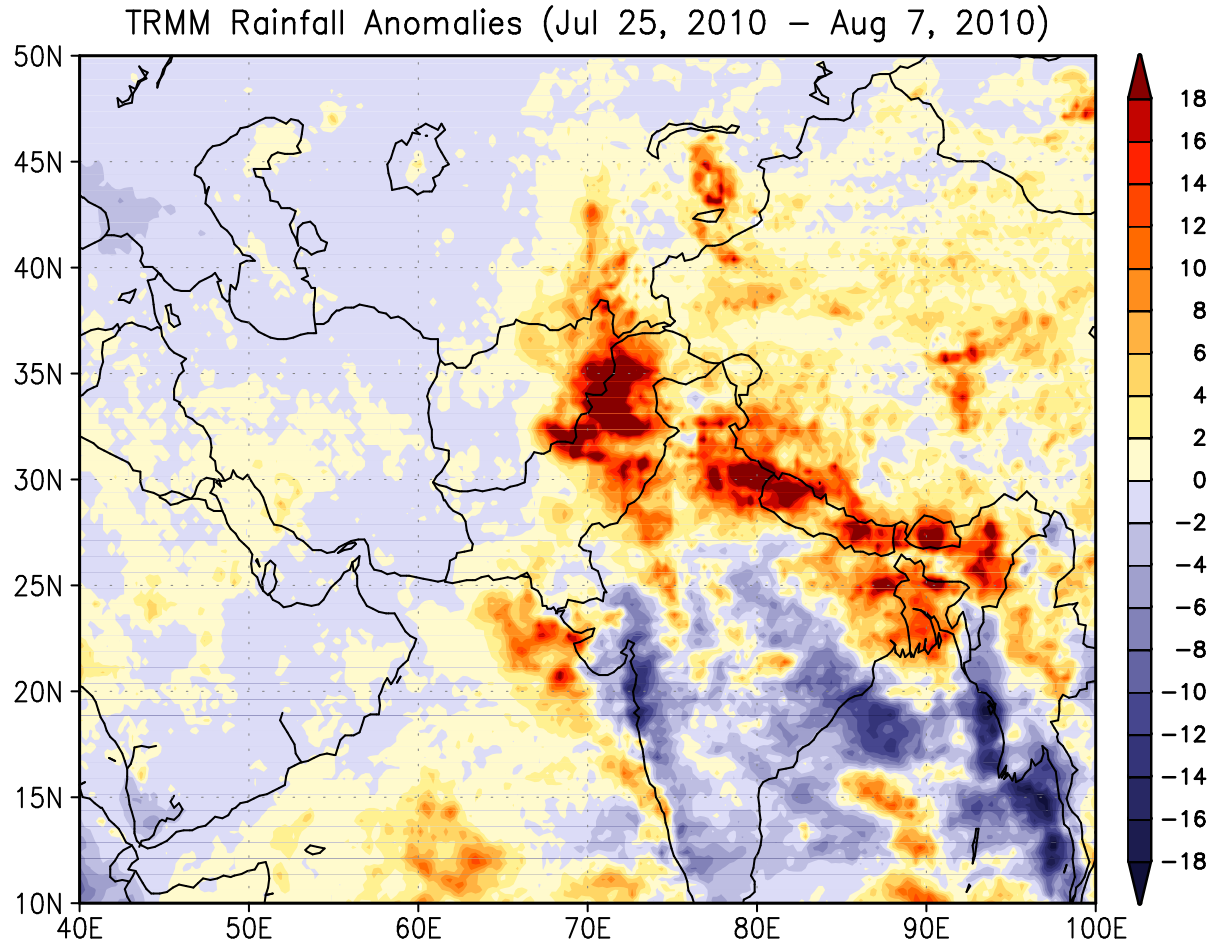




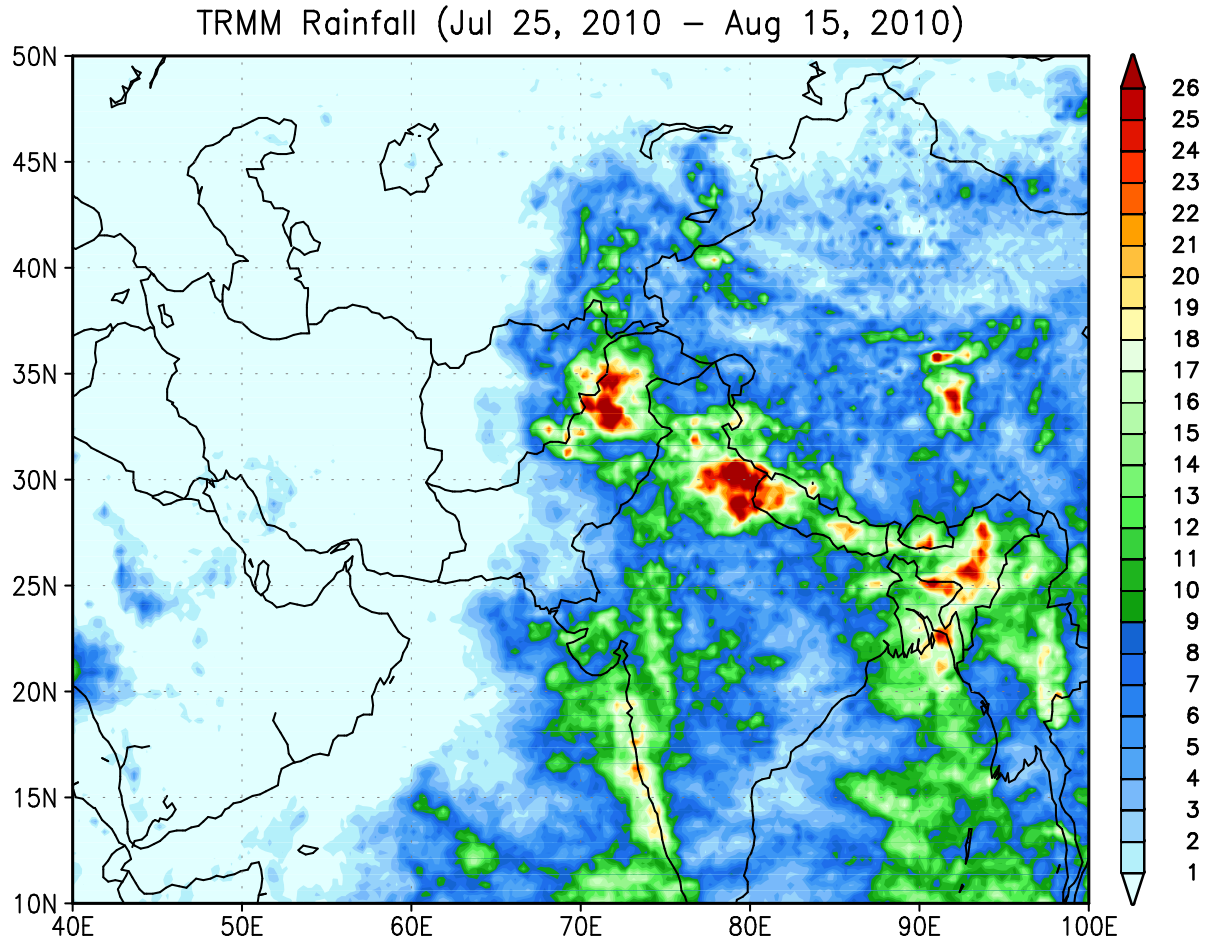


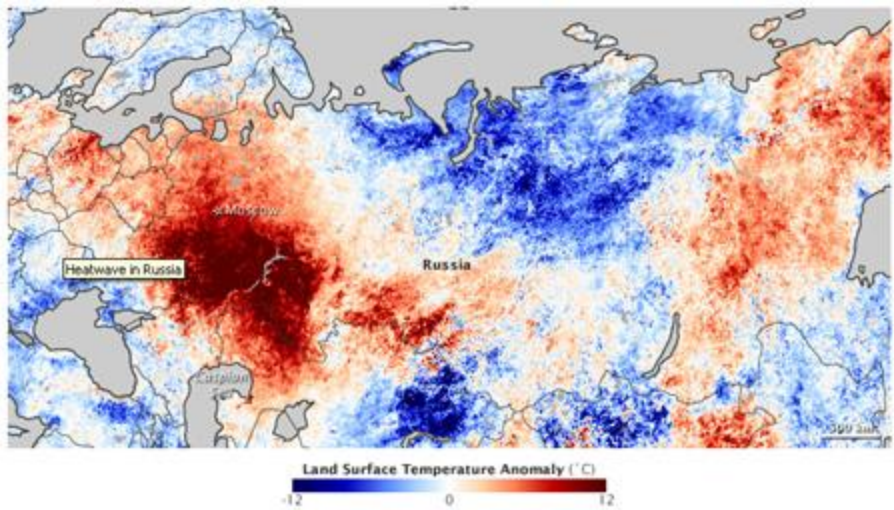


# July 25 – August 7

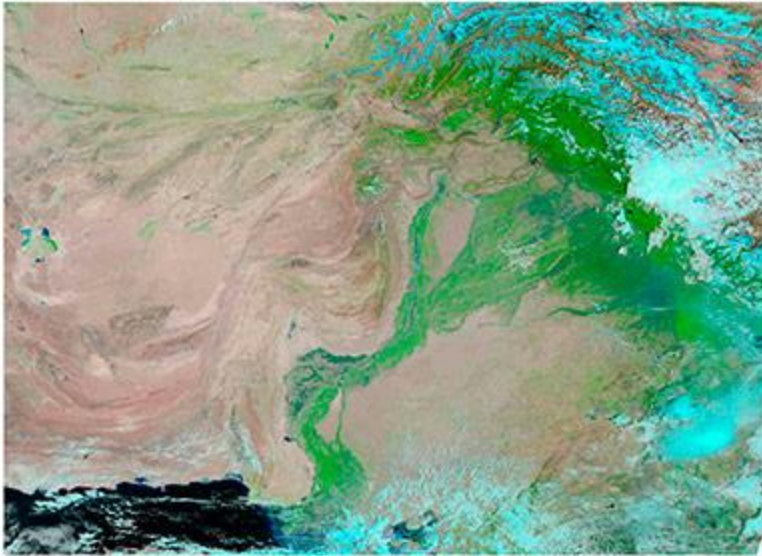


# July 25 – Aug 15

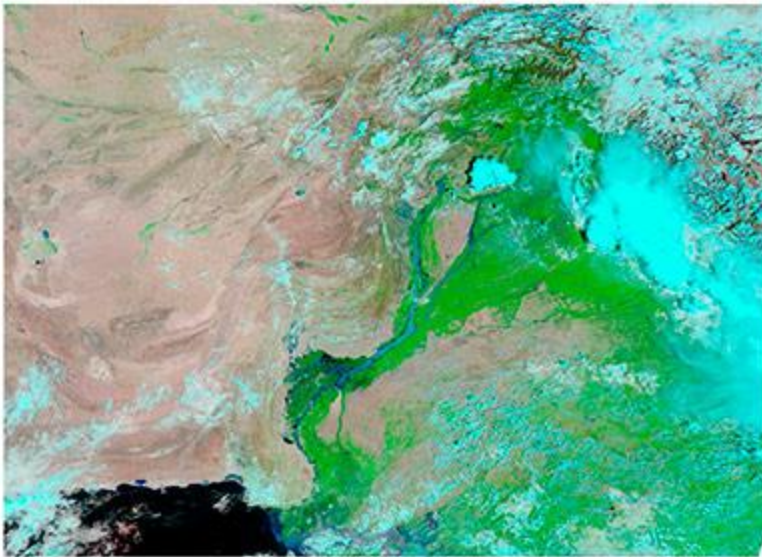








July 10, 2010



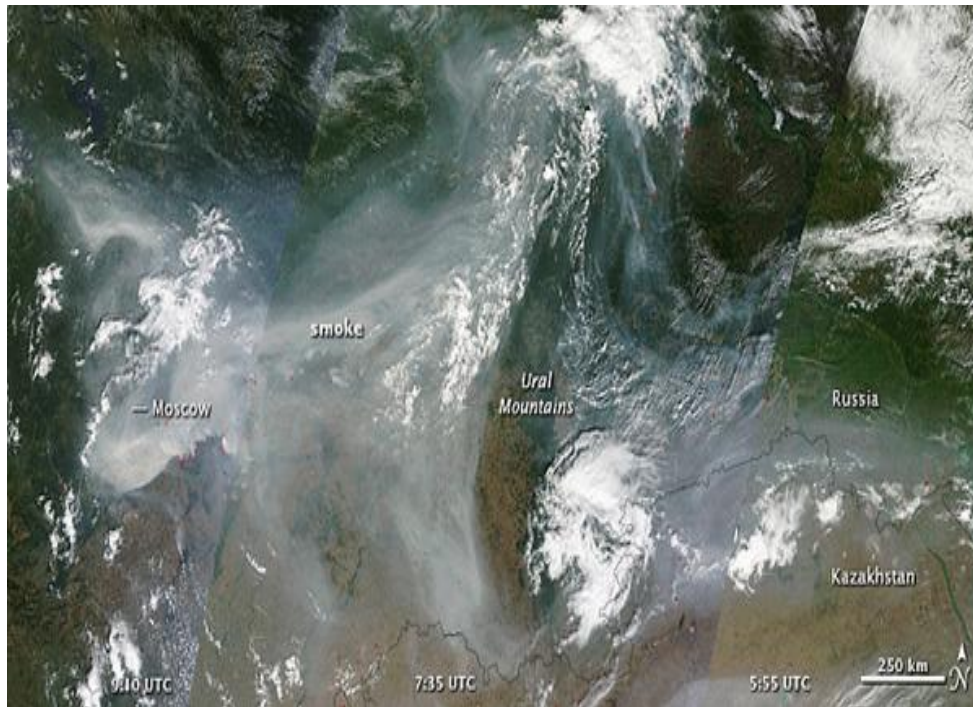
August 11, 2010



MODIS satellite images show the swollen Indus river and two of its tributaries, the Jhelum and Chenab rivers.



MODIS composite image of fire, smoke and clouds associated with Russian Heat Wave, Aug 12, 2010



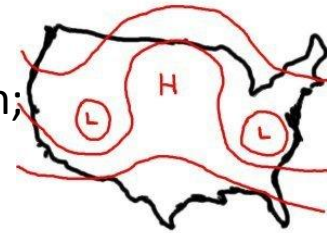




## Some useful meteorological terms:

**Blocking** : extratropical high pressure system, stable atmosphere, anti-cyclonic (clockwise) rotation, blocked westerly flow; quasi-stationary weather pattern; prevents the passage of storms; inhibits clouds and rain

Omega, block



Rex Block/  
Backward S



**Extratropical Cyclones**: baroclinic instability, strong north-south temperature gradient, low pressure system, westward tilt with height, frontal structure

**Tropical Cyclones** : low-level cyclonic rotation overlain by upper level anticyclonic outflow, amplified and sustained by latent heating, *e.g.*, hurricanes, typhoon, monsoon depression

**Mid-Tropospheric Cyclones**: A hybrid extratropical-tropical rain bearing weather system found in the subtropics, with well-defined low or “cut-off low” in mid-troposphere, westward tilt with height, sustained by strong latent heating



Cut-off low/MTC

**Atmospheric teleconnection**: Ways in which the atmosphere disperse energy from a source region over large distances ( $>10^3$  km); Rossby wavetrain, *e.g.* PNA

