

An aerial photograph showing a town in Pakistan that has been severely flooded. The water is a murky brown color and has inundated most of the buildings and streets. In the center of the town, a white mosque with two minarets and a red roof stands out. The surrounding area is a mix of brick and concrete buildings, some of which are partially submerged. The sky is a pale blue, and the overall scene conveys the scale of the flooding.

TRMM Insights into Recent Floods in Pakistan

**R. A. Houze, Jr.
with
K. Rasmussen, and A. Hill**

PMM Science Team Meeting, 18 March 2013

Pakistan 2010



2000 lives, extensive livestock, household, infrastructure & agricultural losses



Volume 92 Number 3 March 2011

BAMS

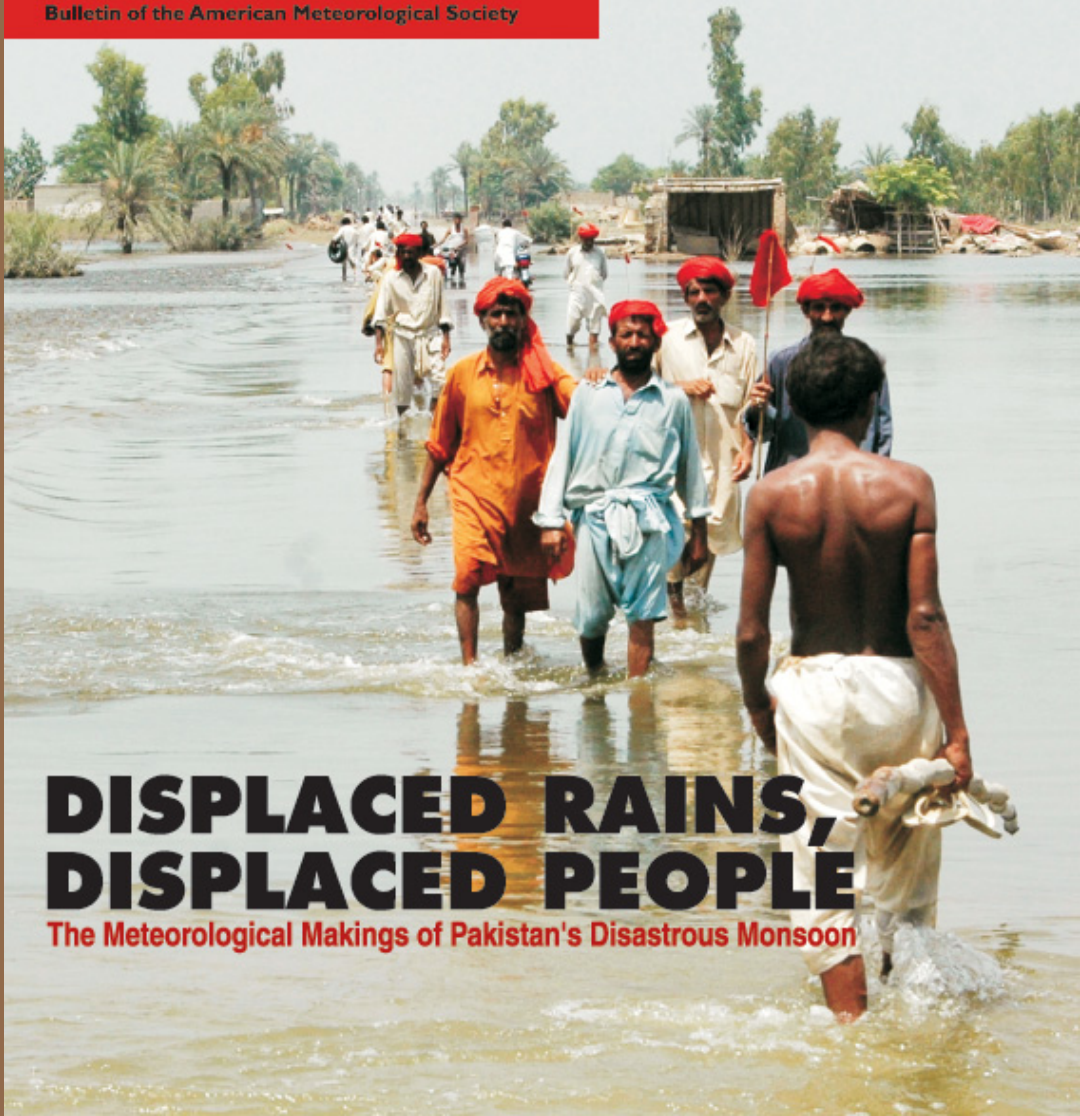
Bulletin of the American Meteorological Society

ARCTIC MIXED-PHASE CLOUDS

DISSECTING DECADAL VARIABILITY

OCEAN SURFACE WINDS DATABASE

Article on the 2010 Pakistan floods in BAMS March 2011



DISPLACED RAINS, DISPLACED PEOPLE

The Meteorological Makings of Pakistan's Disastrous Monsoon

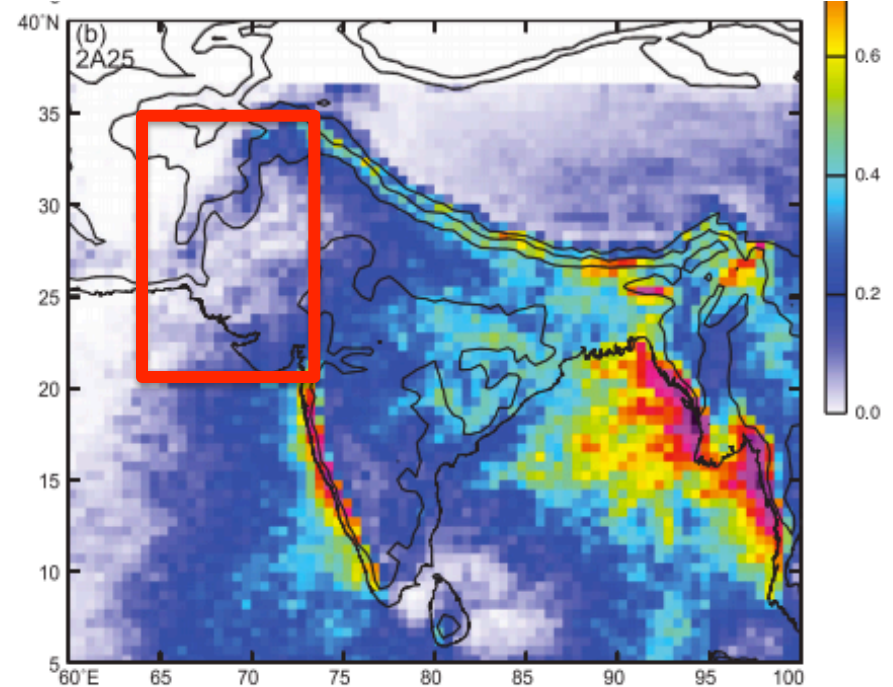
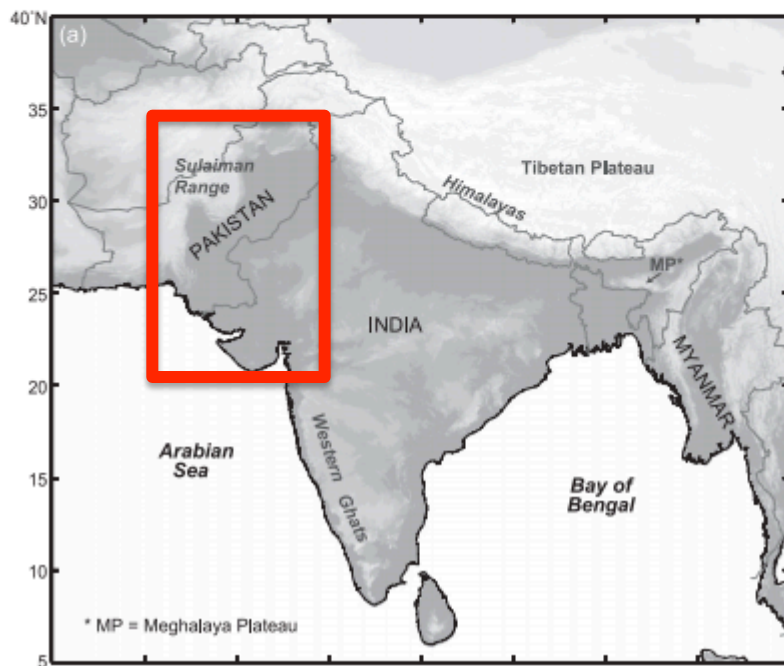
Major floods in Pakistan in last 3 years

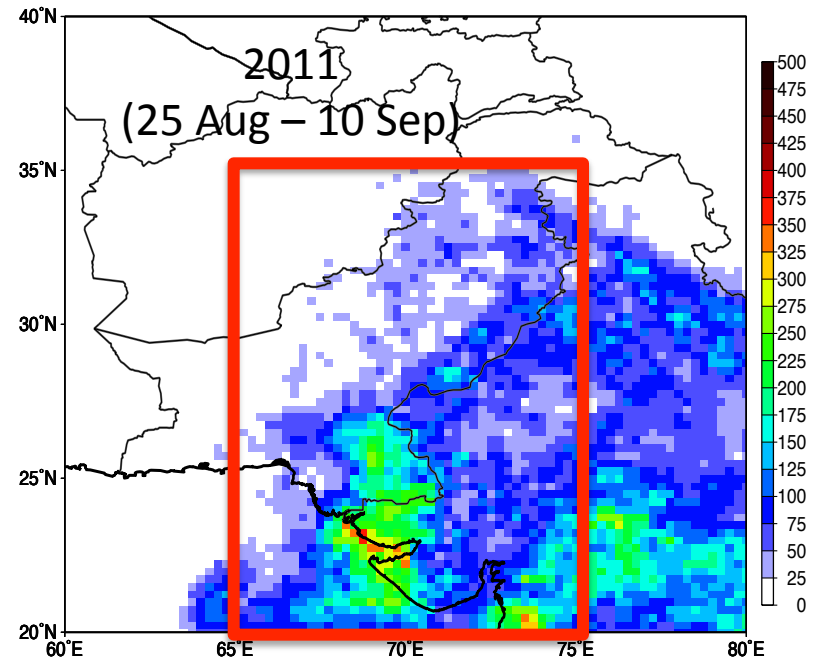
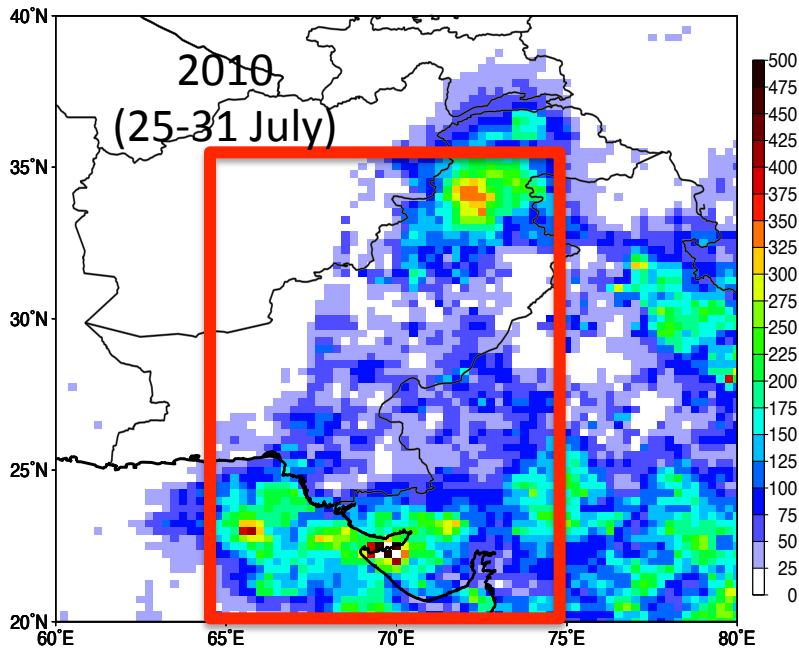
2010—Indus River, 2000+ dead, 20M+ affected

2011—Sindh region, lower Indus River, 400+ dead, 8M+ affected

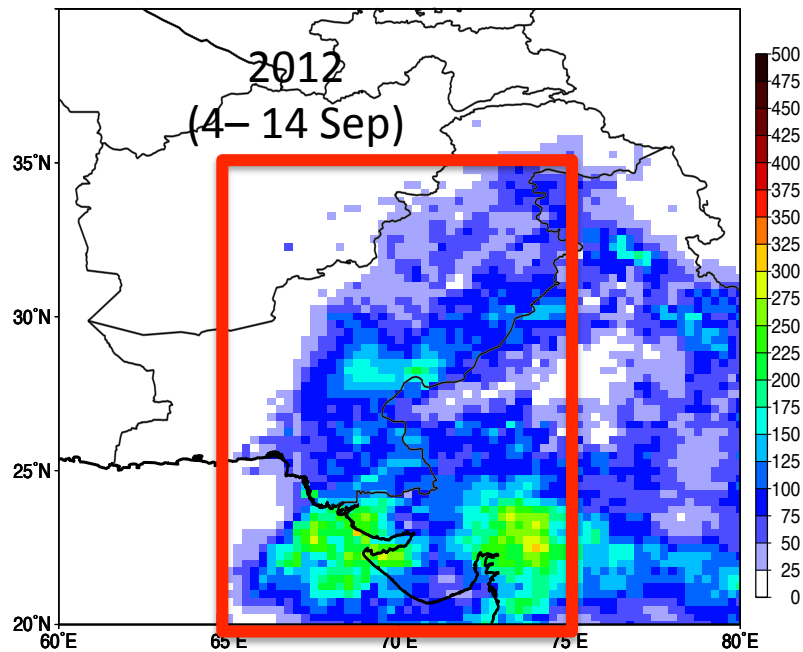
2012—Sindh region, lower Indus River, 450+ dead, 5M+ affected

Geography & Rainfall Climatology





Rainfall in
flood
episodes
mm/h



Radar Identification of Extreme Rainstorms

Identify each contiguous 3D echo object seen on radar

Convective component

Extreme characteristic

Contiguous 3D volume of convective echo > 40 dBZ

Top height > 10 km

“Deep convective core”

Stratiform component

Extreme characteristic

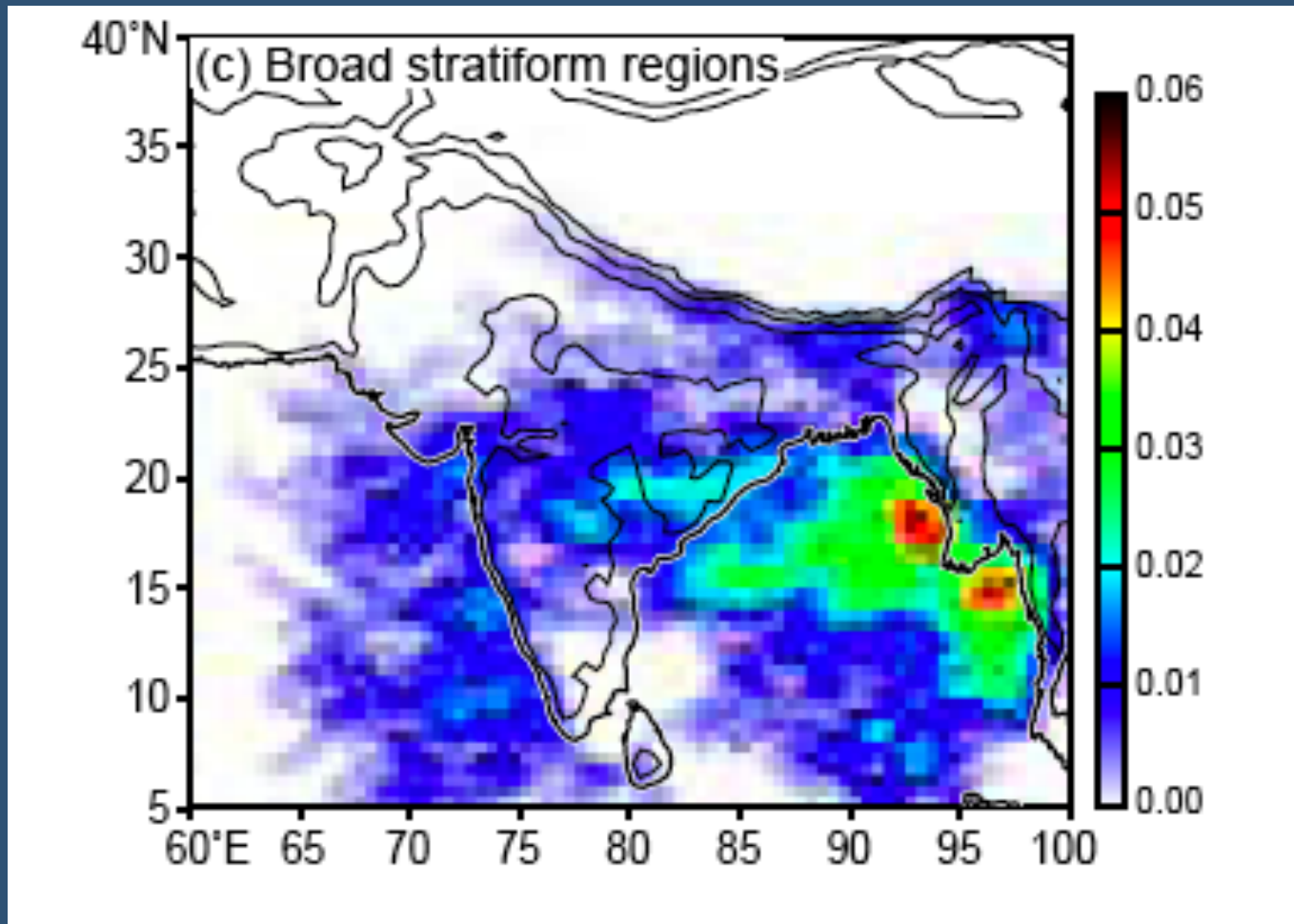
Contiguous stratiform echo with horizontal area > 50 000 km²

“Broad stratiform region”

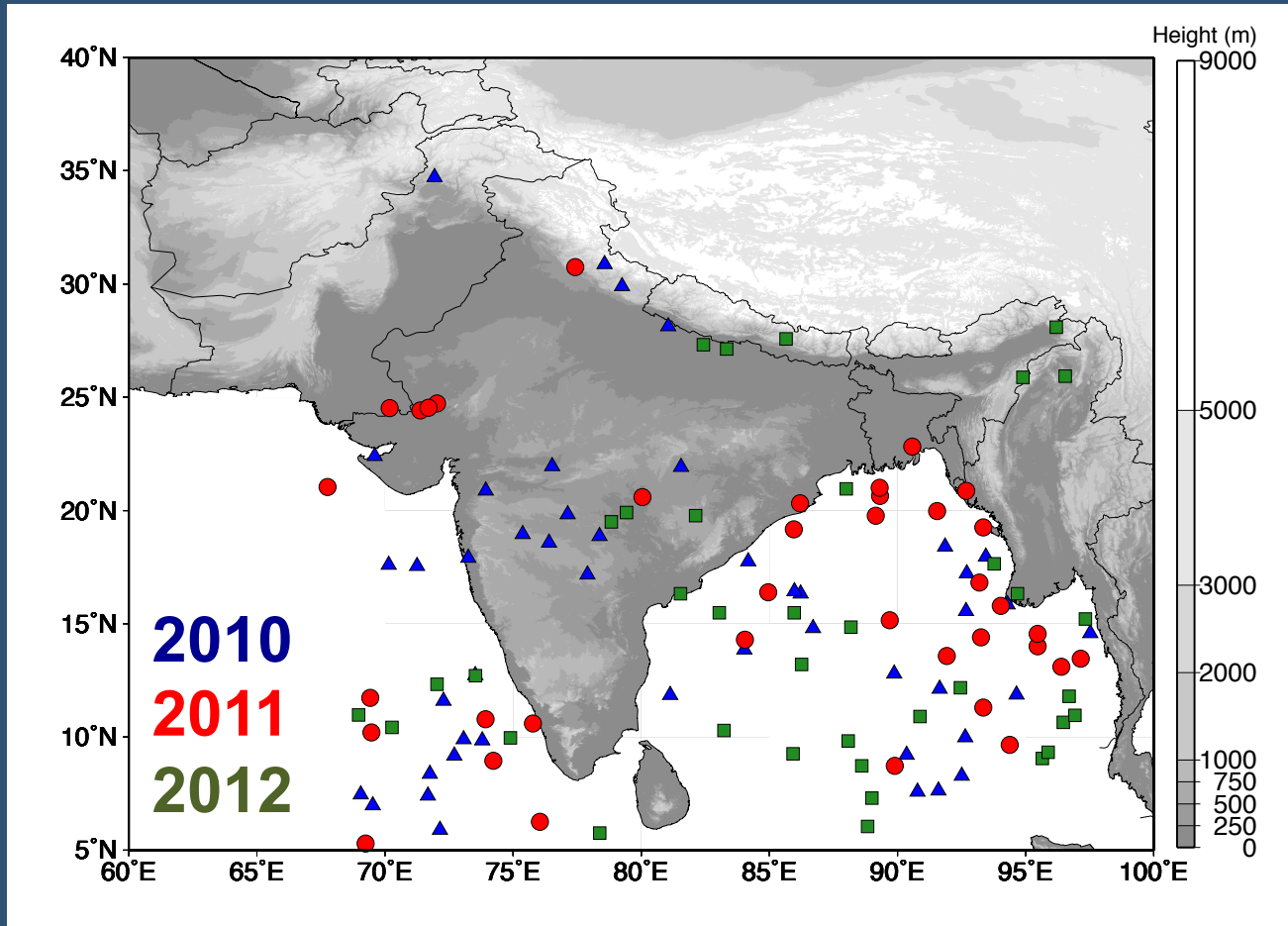
Horizontal area > 1 000 km²

“Wide convective core”

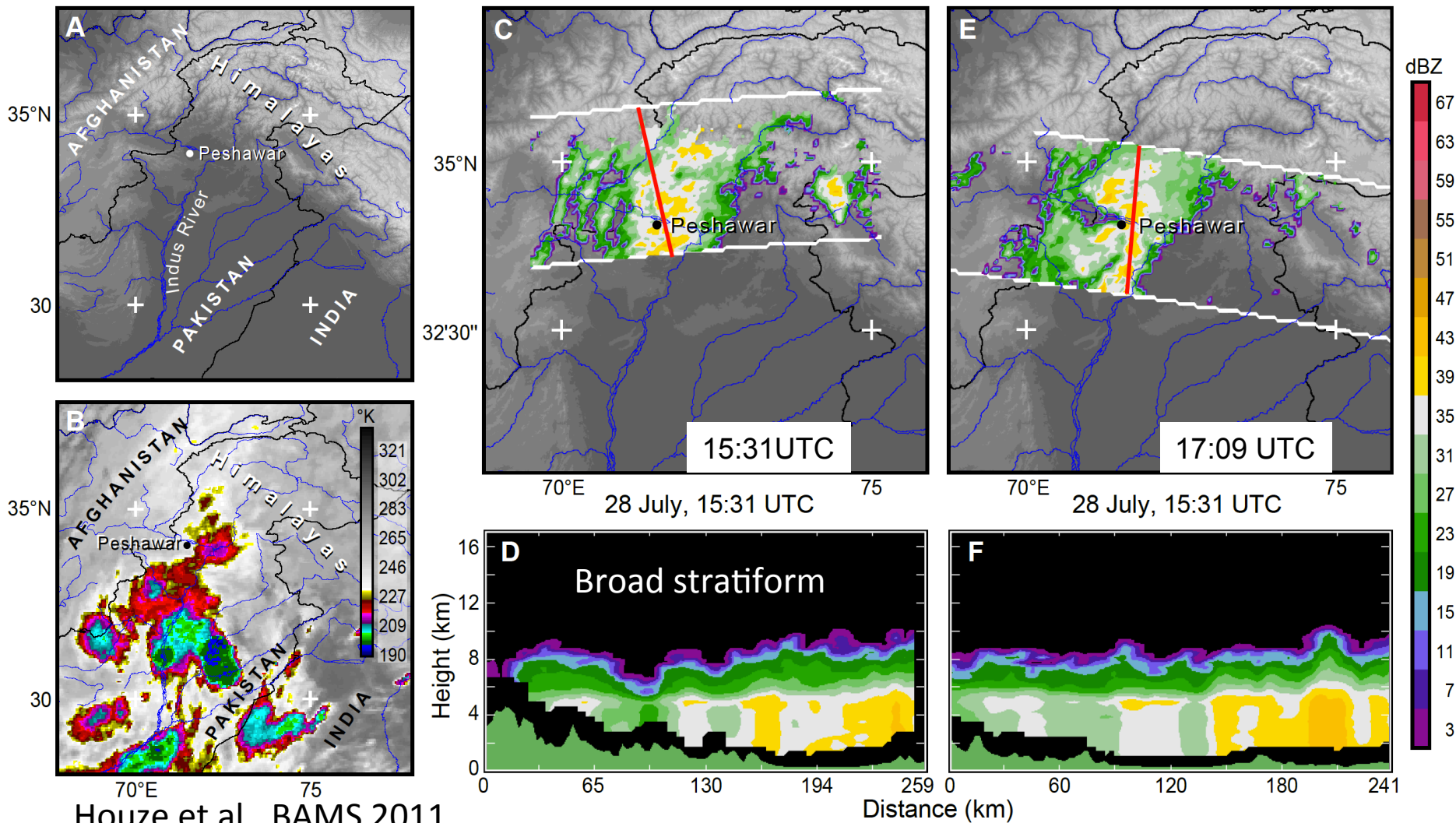
Probability of Broad Stratiform Echo based on multiyear climatology of TRMM PR data



Observations of Broad Stratiform Regions During 2010, 2011, & 2012 Flood Episodes

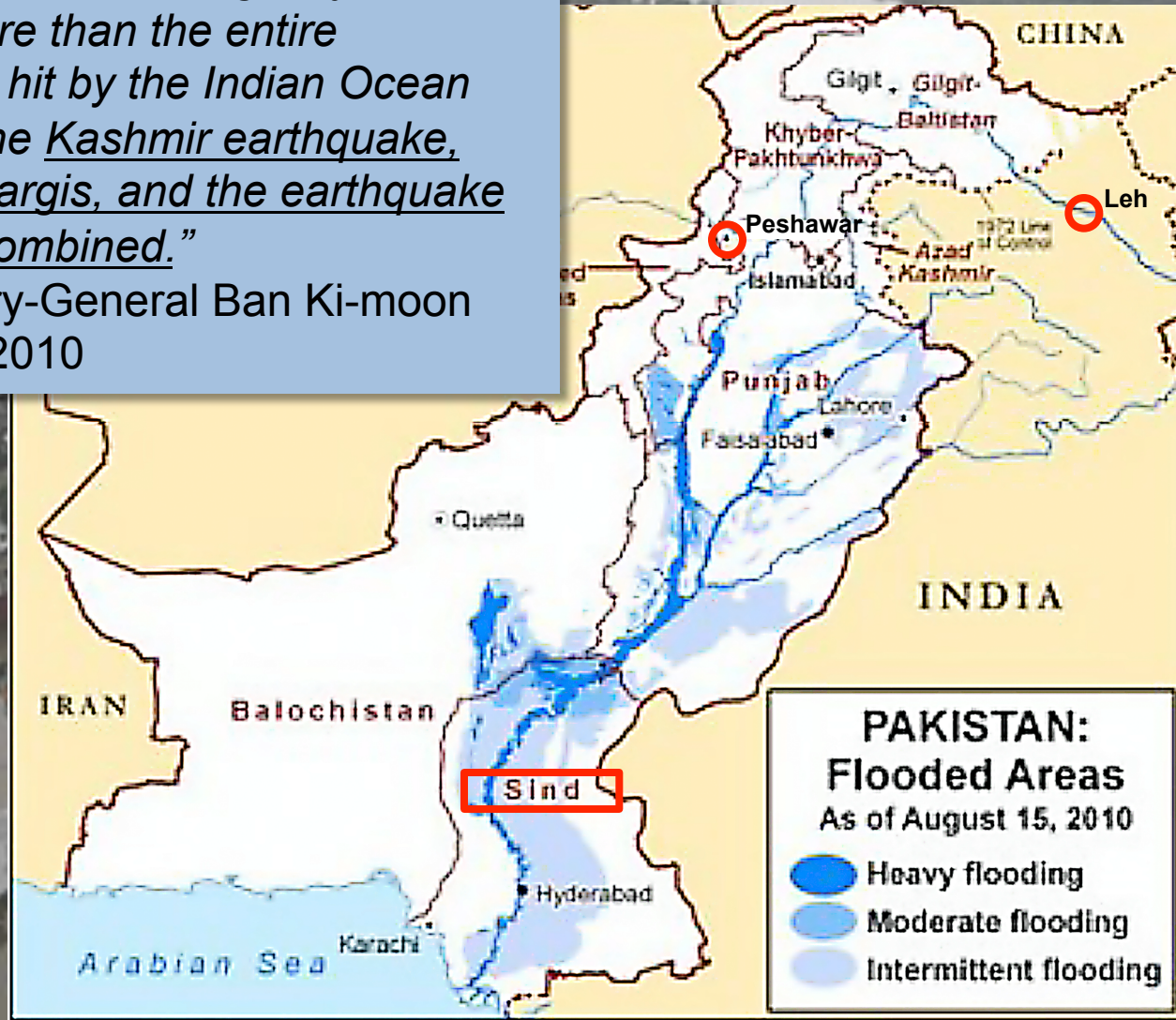


Broad stratiform precipitation over the mountains of Pakistan in 2012

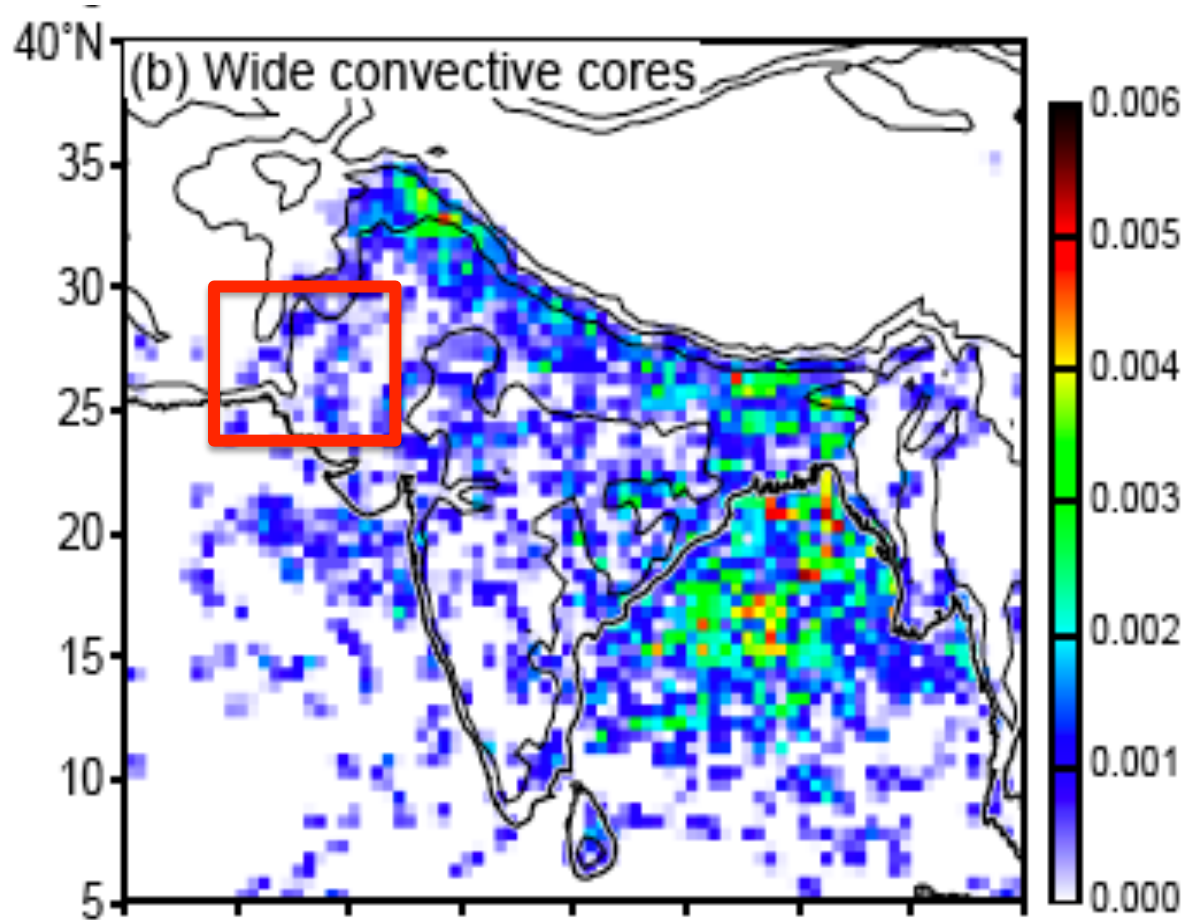


"Almost 20 million people need shelter, food and emergency care. That is more than the entire population hit by the Indian Ocean tsunami, the Kashmir earthquake, Cyclone Nargis, and the earthquake in Haiti—combined."

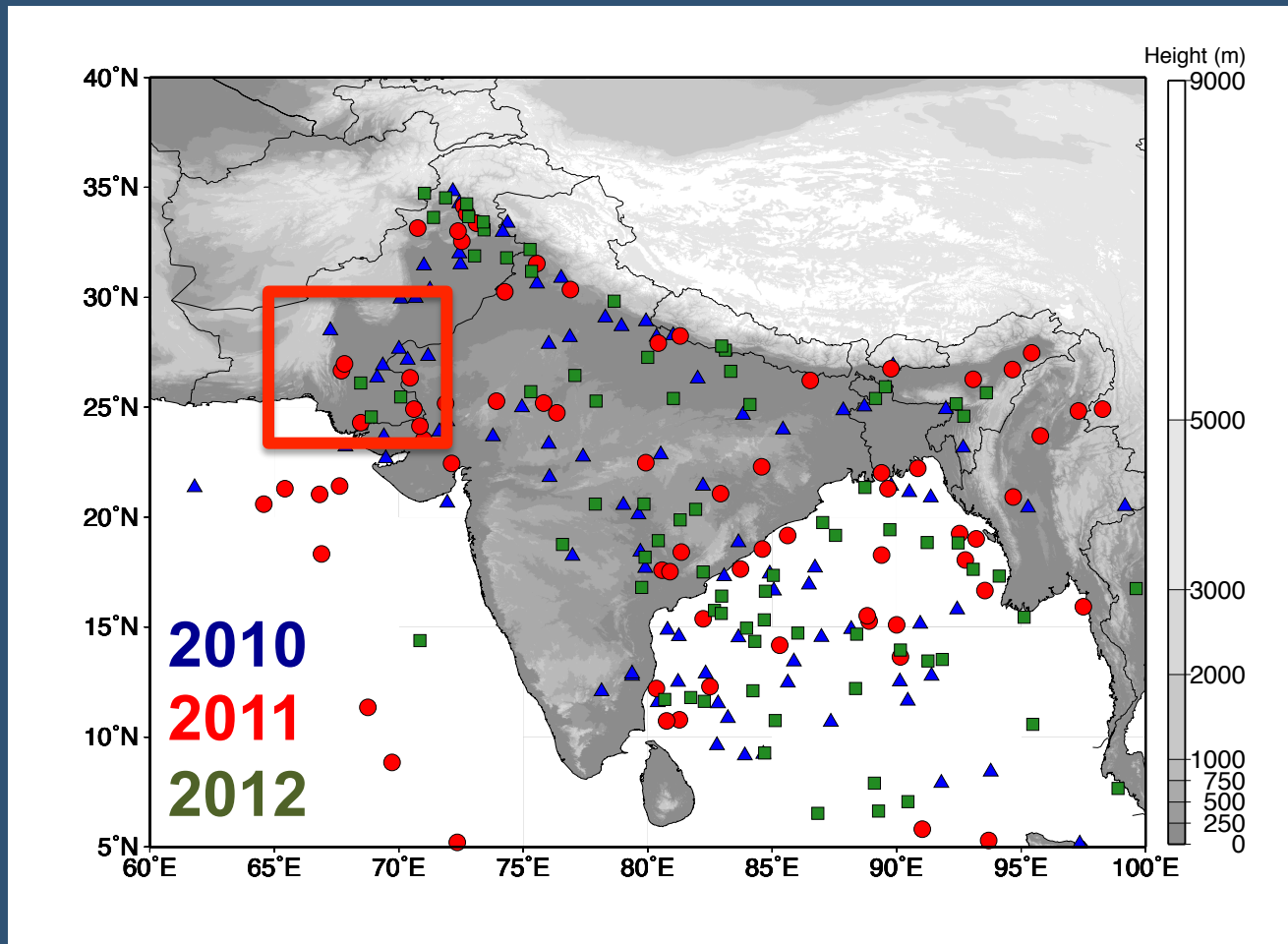
Secretary-General Ban Ki-moon
August 2010



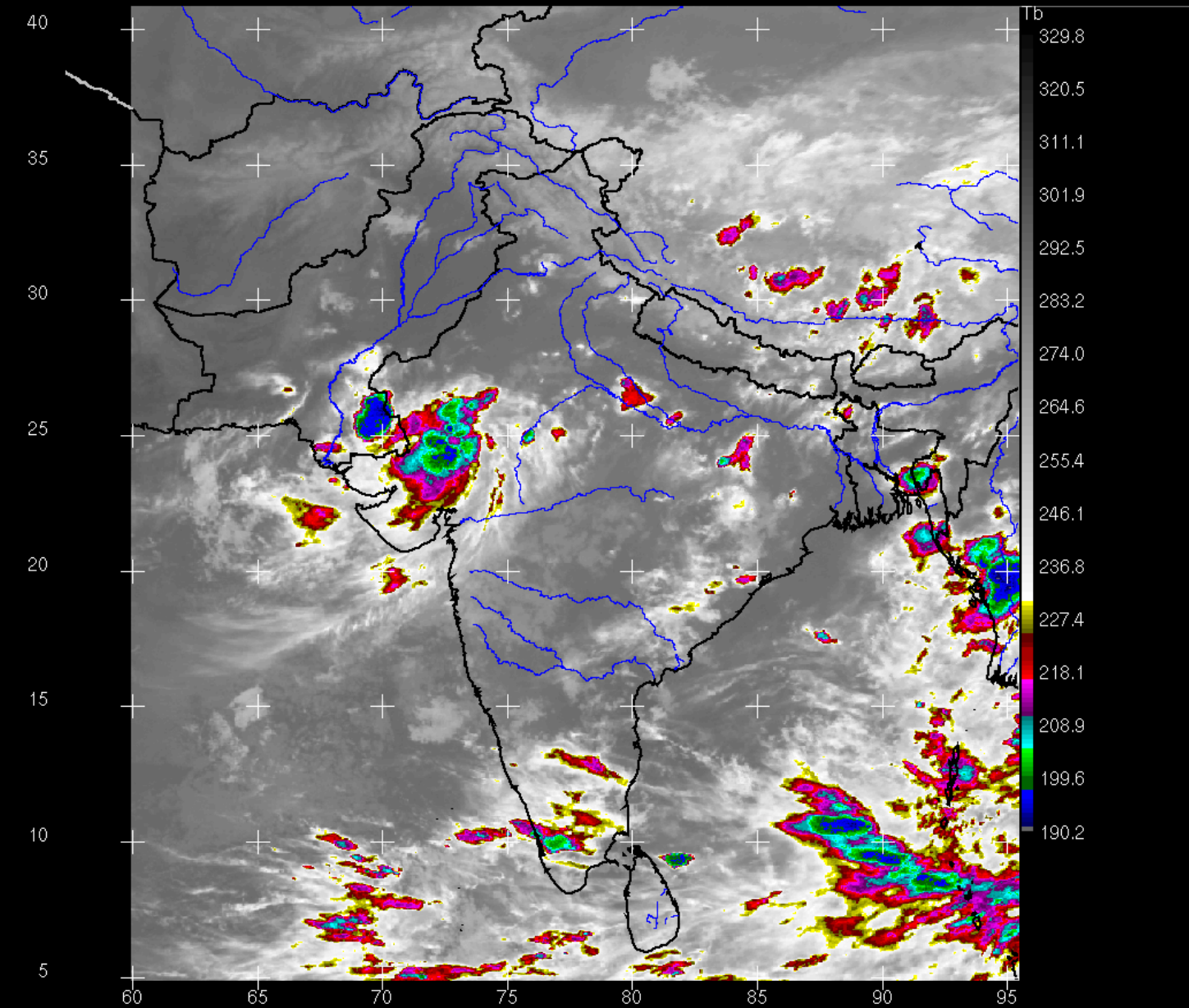
Multiyear TRMM PR Climatology of Wide Convective Echo Cores



Observations of Wide Convective Core Echoes During 2010, 2011, & 2012 Flood Episodes



11-sep-2011,16:00:00 elev_west elev plot. elev_ctr elev plot. elev_east elev plot. meteosat5_ir Tb plot. Elev_ncep1 elev contour. Elev_ncep3 elev contour.



A toolbar containing various icons for map navigation and data visualization, including a compass, a grid, and several 'TOPO' labels.

Alt: 0.00 km MSL

Examples of Storms Producing Floods

2010

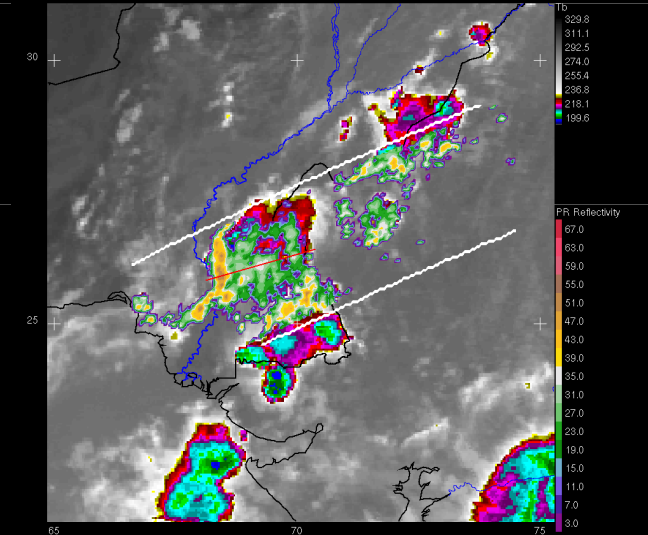
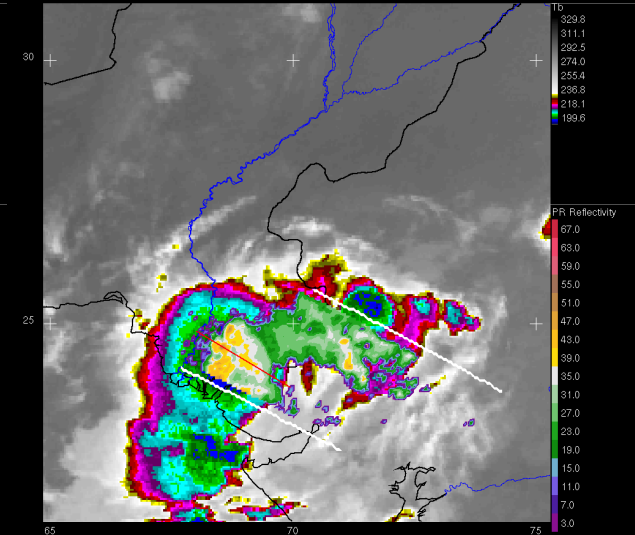
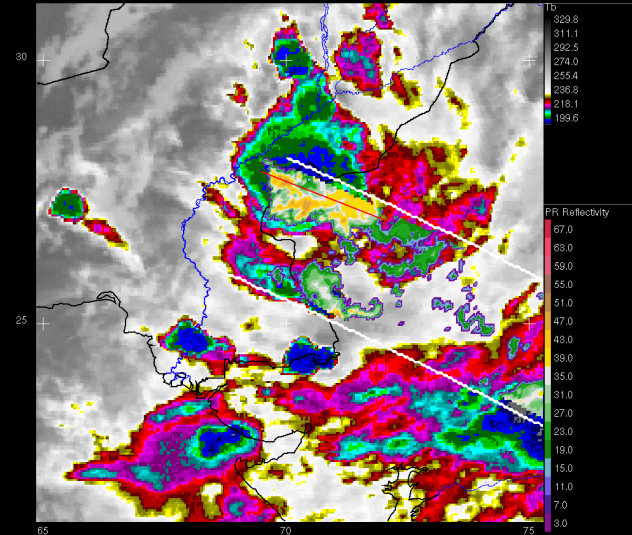
2011

2012

31-Jul-2010,17:40:00 elev_west elev plot. elev_ctr elev plot. elev_east elev plot. meteosat5_ir Tb plot. Trmm_pr_swath swath contour. Trmm_pr_swath PR Reflectivity filled contour. Elev_ncep1 elev contour. Elev_ncep3 elev contour.

12-Sep-2011,03:35:00 elev_west elev plot. elev_ctr elev plot. elev_east elev plot. meteosat5_ir Tb plot. Trmm_pr_swath swath contour. Trmm_pr_swath PR Reflectivity filled contour. Elev_ncep1 elev contour. Elev_ncep3 elev contour.

5-Sep-2012,07:16:00 elev_west elev plot. elev_ctr elev plot. elev_east elev plot. meteosat5_ir Tb plot. Trmm_pr_swath swath contour. Trmm_pr_swath PR Reflectivity filled contour. Elev_ncep1 elev contour. Elev_ncep3 elev contour.



Alt: 4.00 km MSL

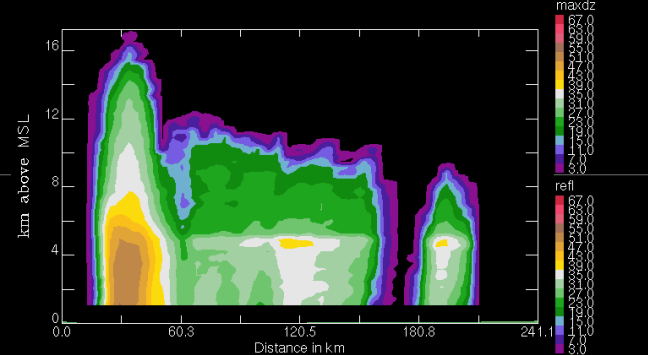
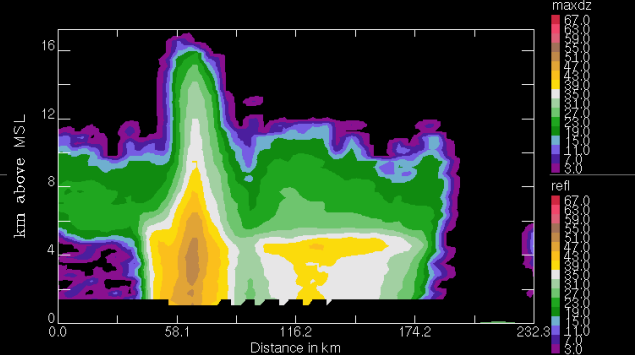
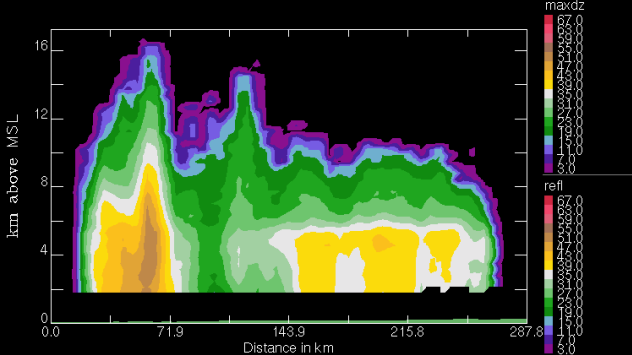
Alt: 4.00 km MSL

Alt: 4.00 km MSL

31-Jul-2010,17:40:00 Planar cross-section plot. Contour of topo using: topo_west. Contour of topo using: topo_ctr. Contour of topo using: topo_east. Contour of maxdz using: trmm_pr_swath. Contour of refl using: grnd_radar.

12-Sep-2011,03:35:00 Planar cross-section plot. Contour of topo using: topo_west. Contour of topo using: topo_ctr. Contour of topo using: topo_east. Contour of maxdz using: trmm_pr_swath. Contour of refl using: grnd_radar.

5-Sep-2012,07:16:00 Planar cross-section plot. Contour of topo using: topo_west. Contour of topo using: topo_ctr. Contour of topo using: topo_east. Contour of maxdz using: trmm_pr_swath. Contour of refl using: grnd_radar.



Alt: 4.00 km MSL

Alt: 4.00 km MSL

Alt: 4.00 km MSL

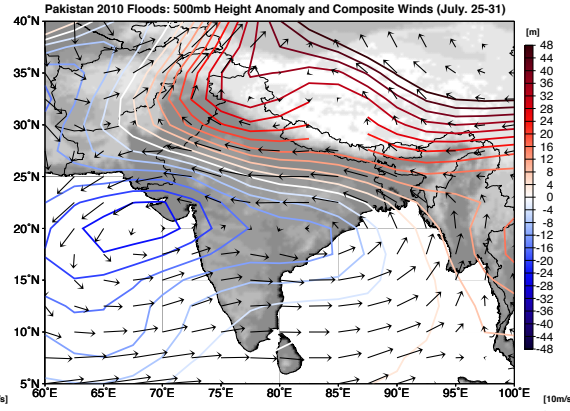
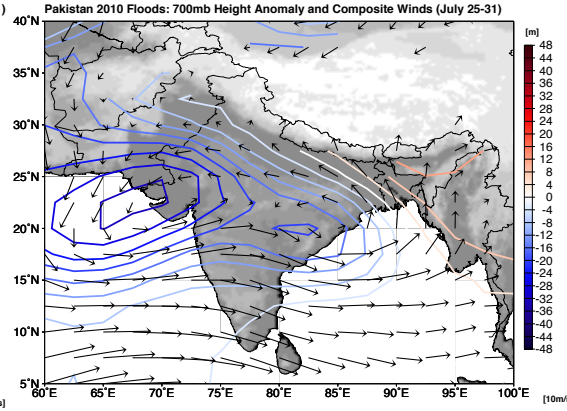
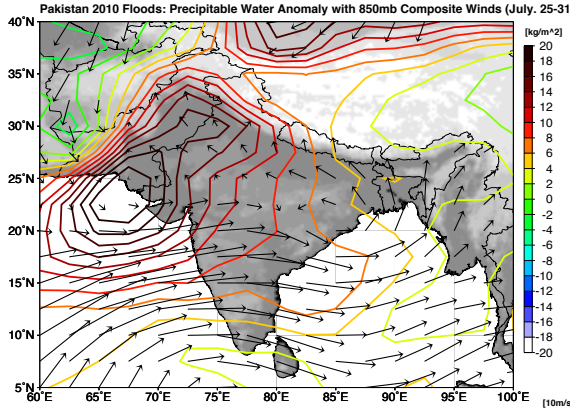
Composites for Flood Periods

850 mb PW Anomaly

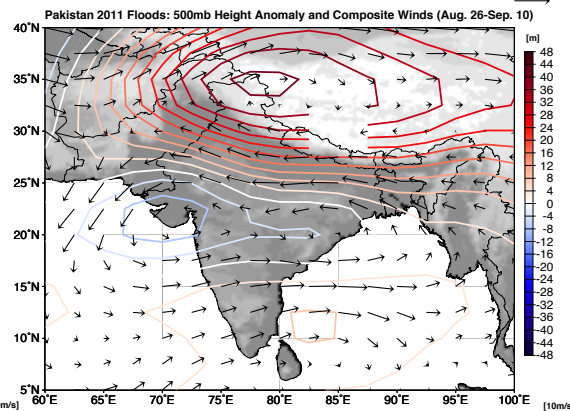
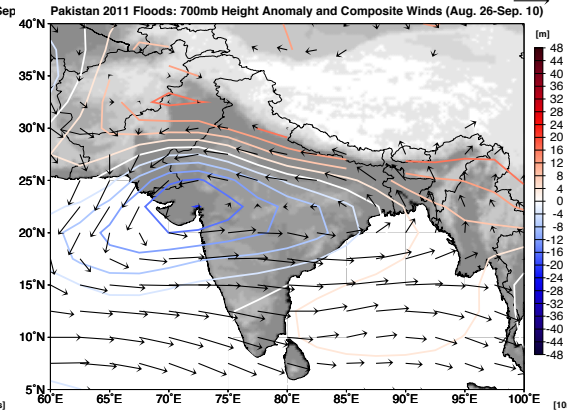
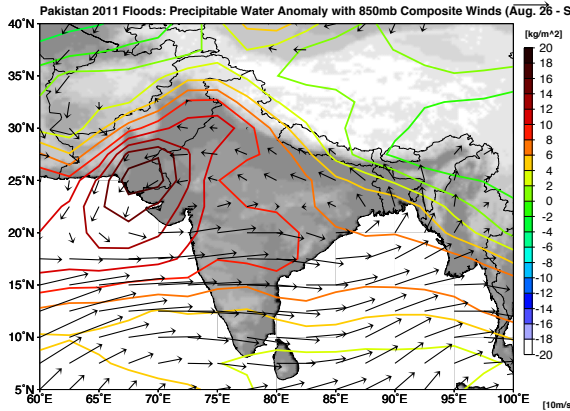
700 mb Hgt Anomaly

500 mb Hgt Anomaly

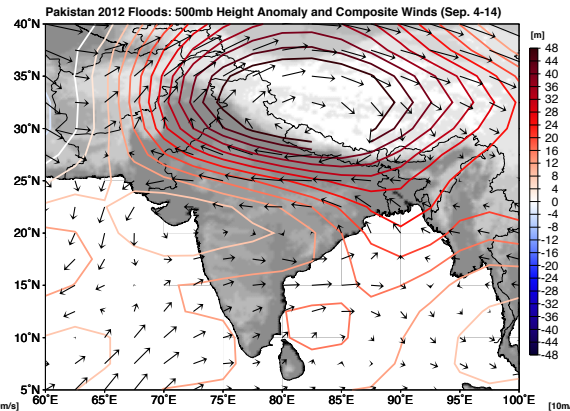
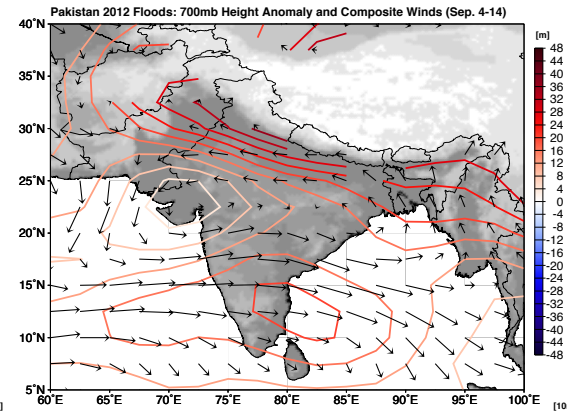
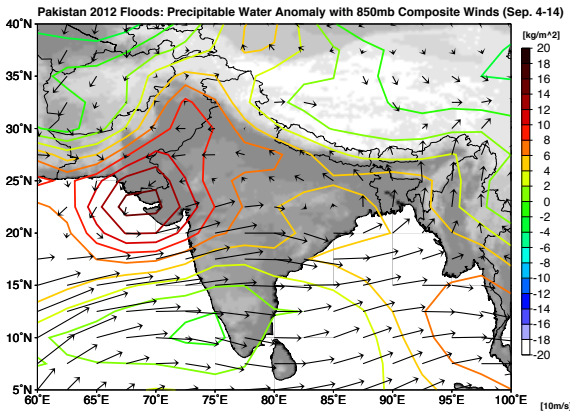
2010



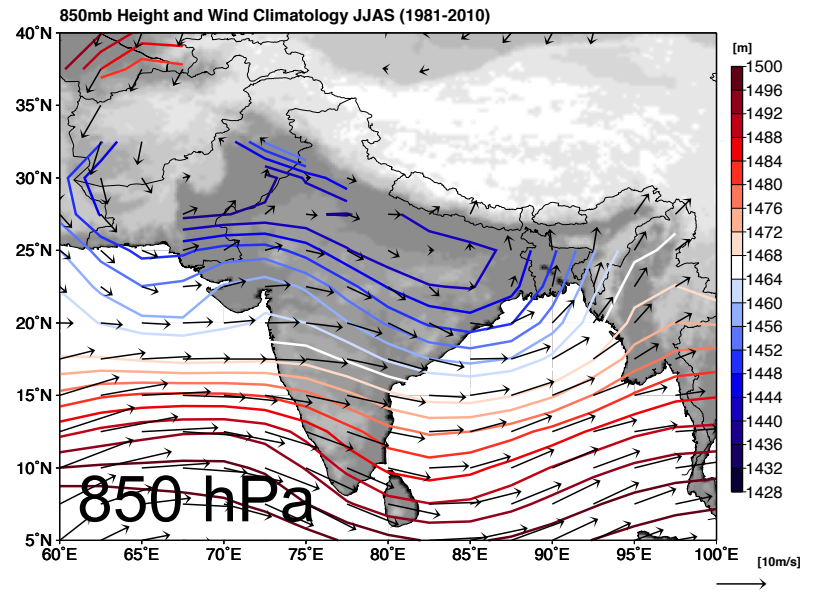
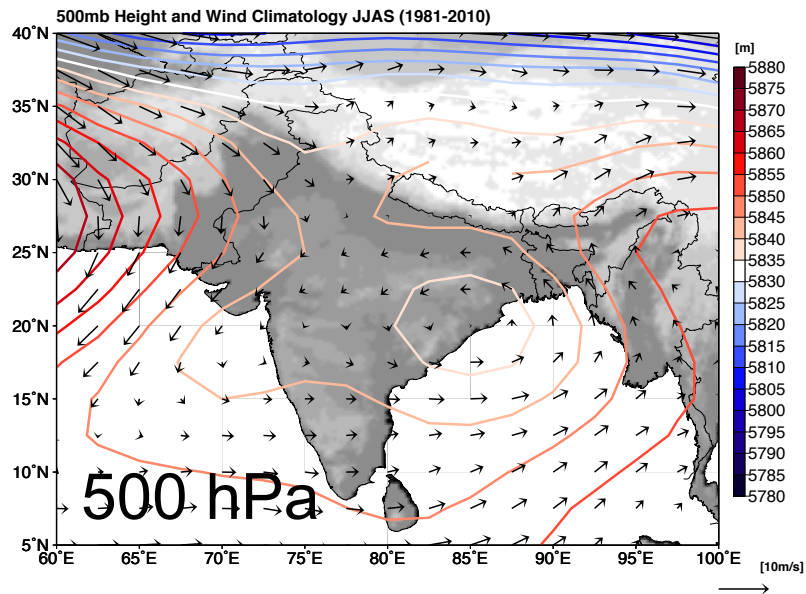
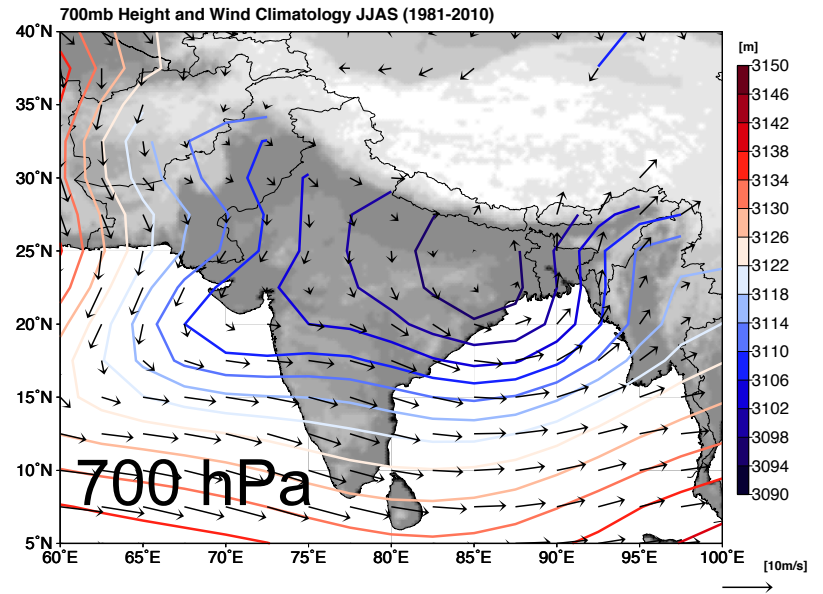
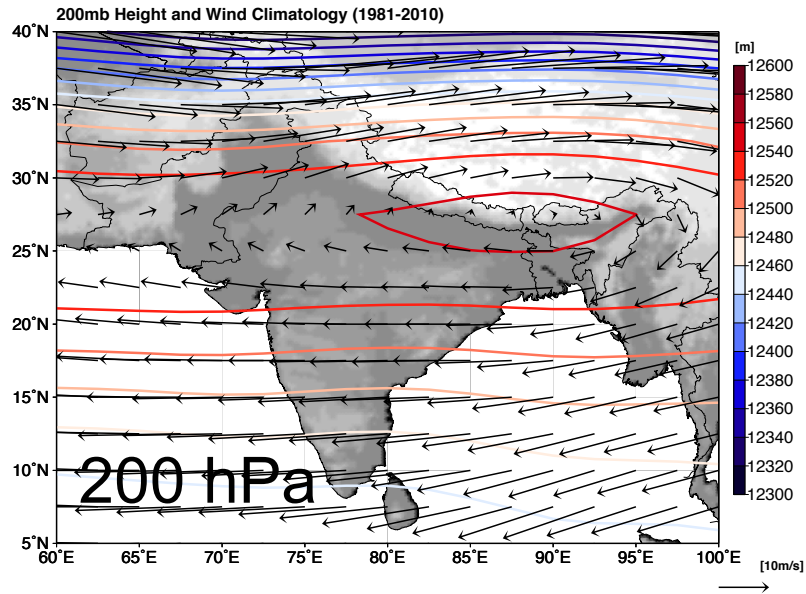
2011



2012



JJAS Climatology 1981-2010



Conclusions: TRMM Insights into Recent Floods in Pakistan

An aerial photograph of a village in Pakistan that has been severely flooded. The water is a dark, murky blue-grey color, surrounding the buildings and reflecting the sky. In the center of the village, there is a prominent white mosque with a red roof and two minarets. Other buildings are made of brick and have flat roofs. Some trees are visible, and the overall scene depicts a significant natural disaster.

- Anomalous occurrence of mesoscale organized convection with stratiform
- Associated with similar anomalous 700 and 500 hPa flow patterns in 3 consecutive years

End



**Acknowledgements: NASA Grants
NNX10AH70G, NNX11AL65H, and NNX13AG71G**

PMM Science Team Meeting, 18 March 2013

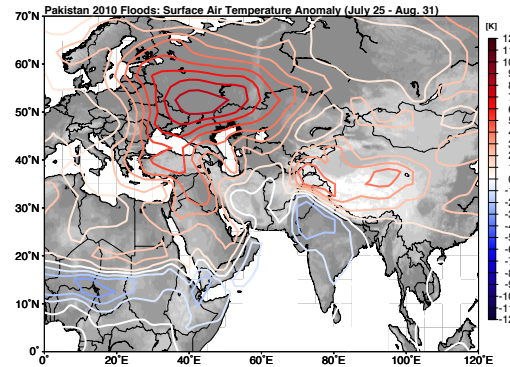
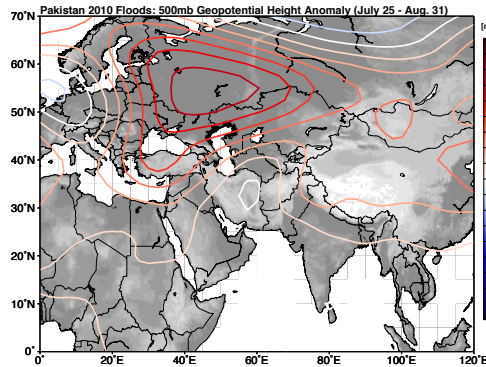
Extra slides

Blocking Pattern

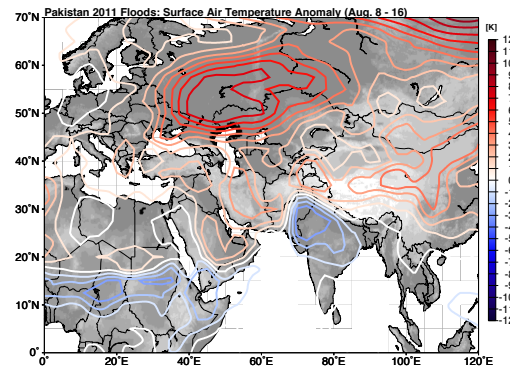
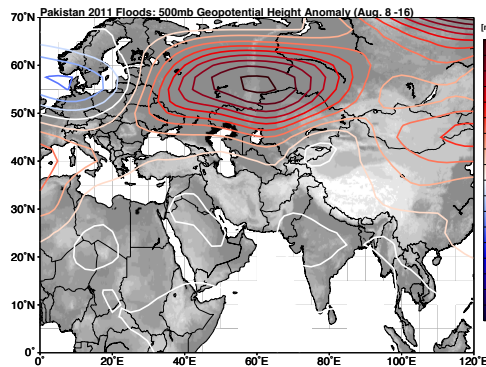
500 hgt anom

Surf. T anom

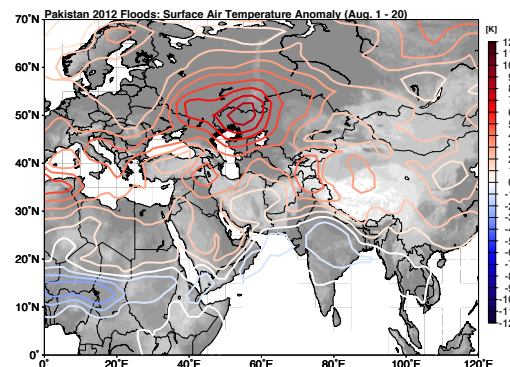
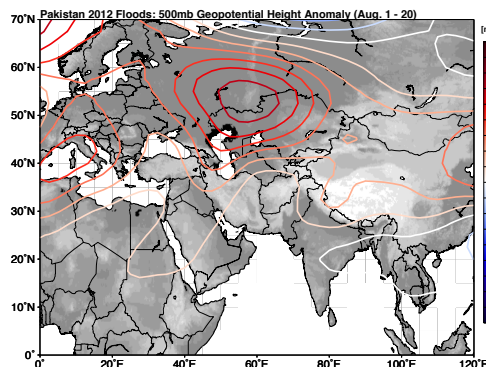
2010



2011



2012

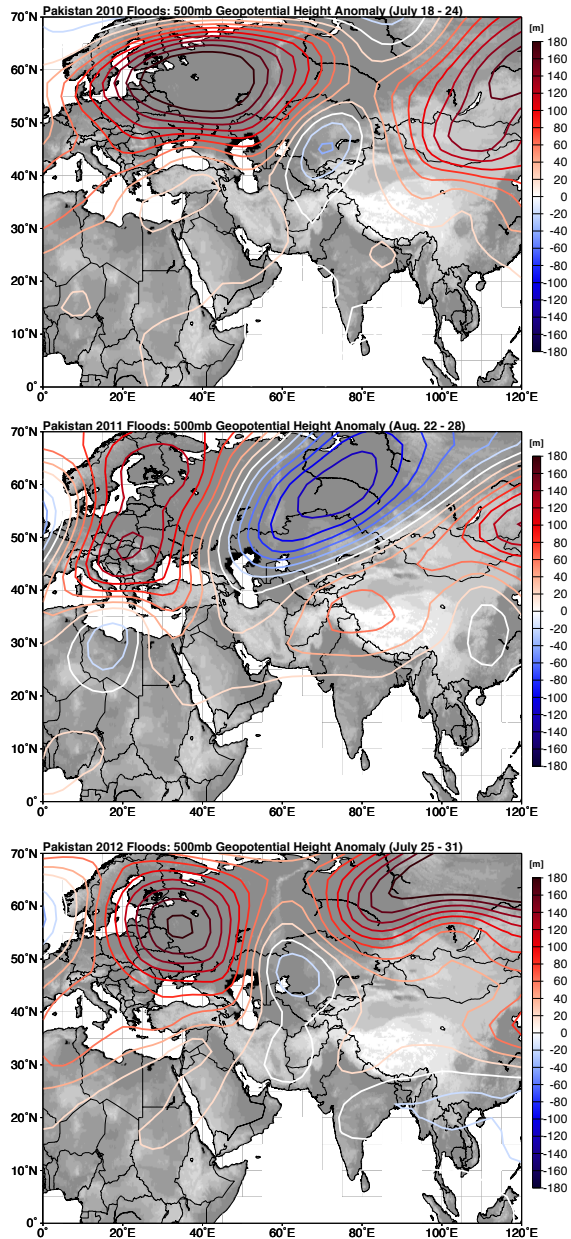


Periods vary in length but all surpass the 5 day minimum length to classify as “blocking” pattern

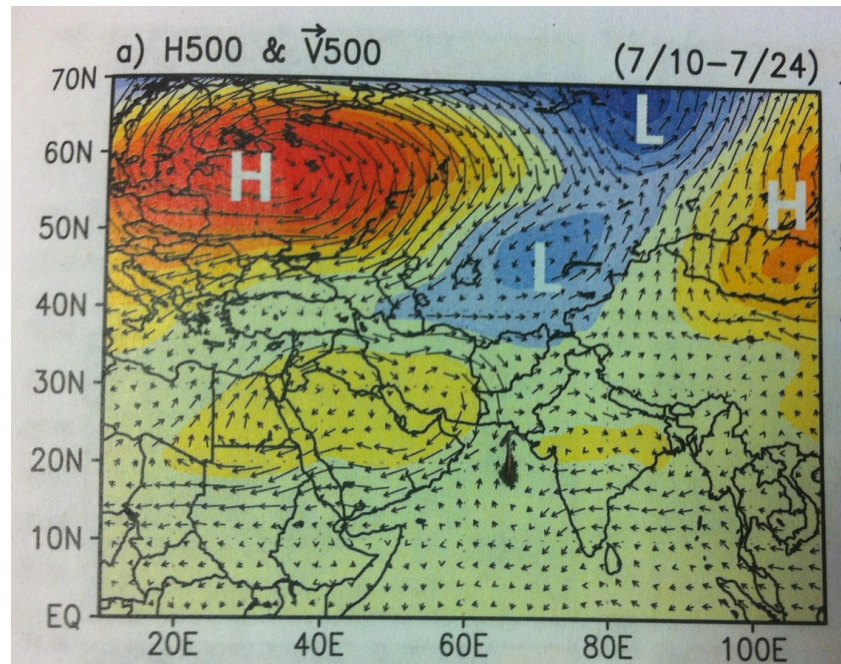
Periods:
July 25th – Aug. 31st 2010
Aug. 8-16th 2011
Aug. 1-20th 2012

Rossby Wave Train

Onset periods of significant flooding indicate this Rossby Wave Train (Lau and Kim 2012) that precede flooding events in ALL THREE YEARS
July 18-24th 2010
Aug 22-28th 2011
July 25-31st 2012



anomalies



Climatology of TRMM PR Rainfall

