AIRS impact on analysis and forecast of an extreme rainfall event (Indus River Valley, Pakistan, 2010) with a global data assimilation and forecast system

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Reale, O., K. M. Lau, J. Susskind, and R. Rosenberg (2012), AIRS impact on analysis and forecast of an extreme rainfall event (Indus River Valley, Pakistan, 2010) with a global data assimilation and forecast system, J. Geophys. Res., 117, D08103, doi:10.1029/2011JD017093.

- One of the few studies studying the impact of AIRS on PRECIPITATION
- Focus on a set of catastrophic floods that affected the Indus River Valley (Pakistan) in 2010

Outline

Previous work - AIRS impact on:

- midlatitude winter dynamics
- global AIRS impacts in all seasons
- tropical cyclone Nargis (2008)
- Analyses and Forecasts of Extreme Precipitation in the tropics associated with TCs (Nargis, Helene, Wilma)

New - AIRS impact on:

- Precipitation Analysis for the 2010 floods along the Indus river (Pakistan)
- Conclusions, ongoing and future work
- Acknowledgements

Global Impact of Clear-sky Radiances versus Quality Controlled cloudy Retrievals (AIRS v5)

- Operational weather systems generally assimilate AIRS radiances from channels unaffected by clouds. This imposes a severe limitation on the horizontal distribution of the data, particularly detrimental to precipitation forecast.
- Susskind et al (2011) document the AIRS version 5 retrieval algorithm. Key elements are the use of information from partly cloudy areas and the ability *to generate case-by-case and level-by-level error estimates and use them for quality control*
- This team has been performing a very large number of experiments, comparing AIRS retrievals and radiances in all seasons, five different years, with different quality controls, looking at both global impacts and individual high-impact weather systems. AIRS v5 retrievals are particularly beneficial for precipitation forecasting.

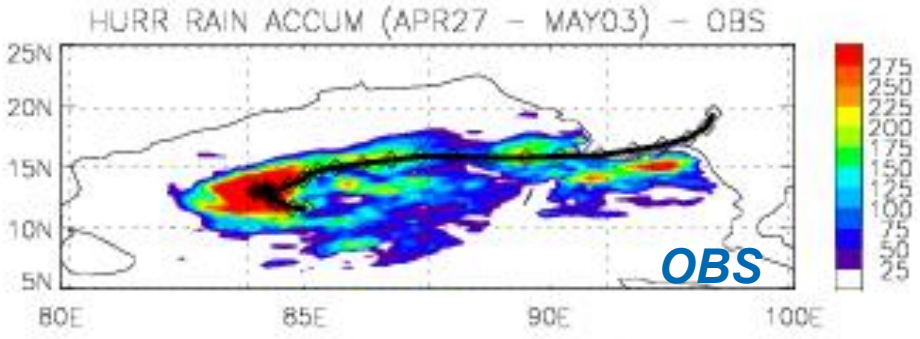
AIRS past experiments settings

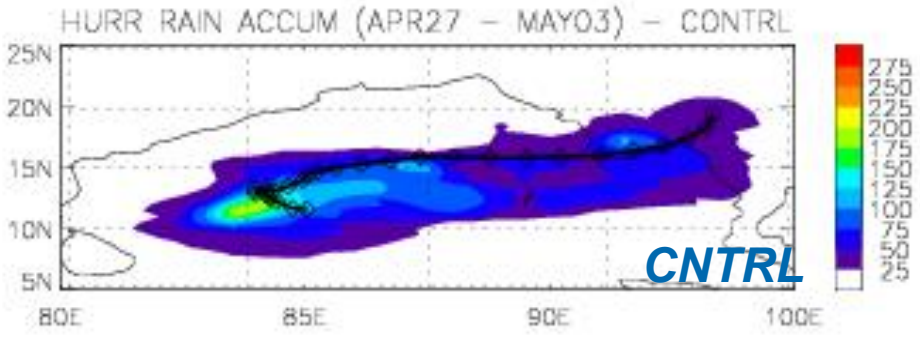
- GEOS-5 DAS: versions 2.1.2, 2.1.4 (close to MERRA)
- Periods chosen: Jan 2003 (active boreal winter); 8/10/06 to 9/15/2006 (NAMMA), 10/15/2005 to 11/15/2005 (Active TC Atlantic season), 4/15/2008 to 5/15/2008 (TC Nargis), 7/15/2010-8/31/2010 (Pakistan floods)
- Control assimilation: assimilating all conventional and satellite obs, but no AIRS-derived information
- AIRS RET: Same data as control plus AIRS version 5 retrievals added as rawinsonde temperature profiles
- AIRS RAD: AIRS clear-sky v5 radiances
- Forecasts at 0.25 or 0.5 degrees

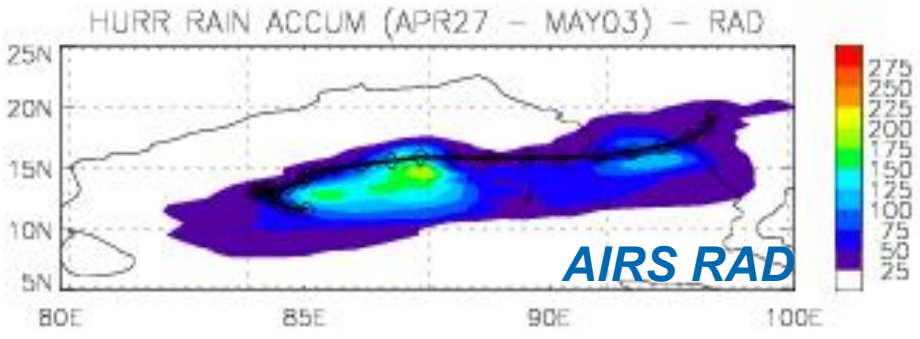
Previously published AIRS impact study on precipitation associated with tropical cyclones compares performance of AIRS clear-sky radiances against cloudy retrievals.

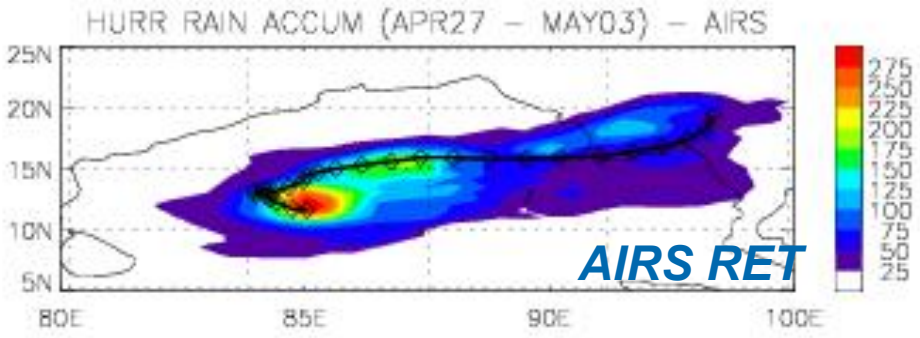
- Assimilation of AIRV v5 retrievals produces better precipitation forecast than the assimilation of clear-sky radiances
- 3 TCs selected in different seasons, Atlantic and Indian Oceans

Zhou, Y., W. K. Lau, O. Reale, R. Rosenberg, 2010: AIRS Impact on precipitation analysis and forecast of tropical cyclone in a global data assimilation and forecasting system.
Geophys. Res. Lett., **37**, L02806, doi.1029/2009GL041494









Precipitation ‘Analysis’

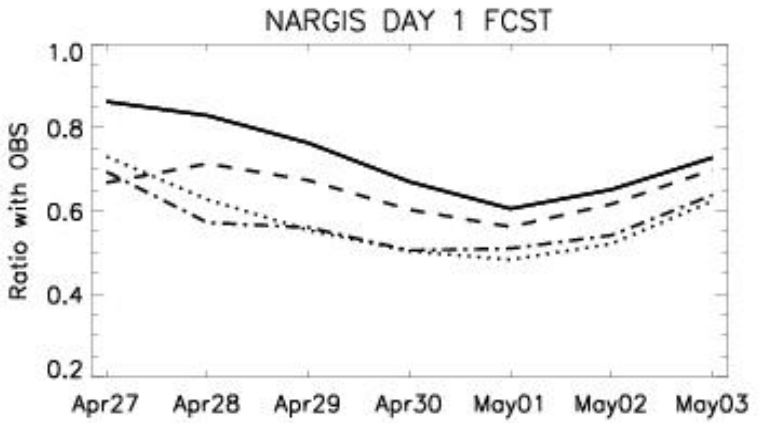
for Nargis

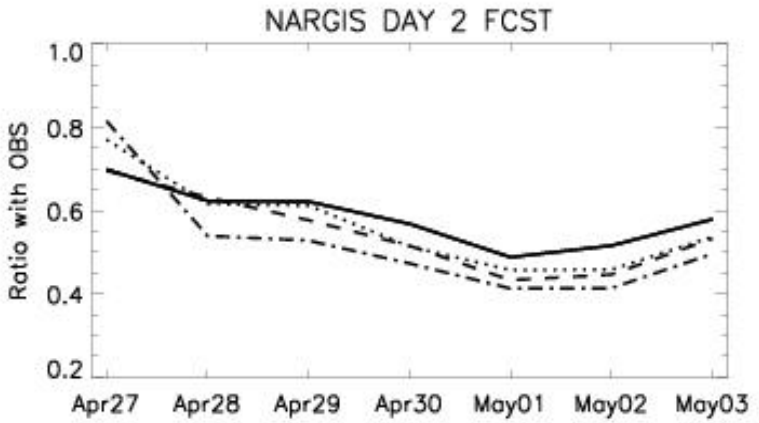
No precip data are assimilated. Precip comes from the `corrector sequence’ and is essentially a set of very short term forecasts strongly constrained by observations.

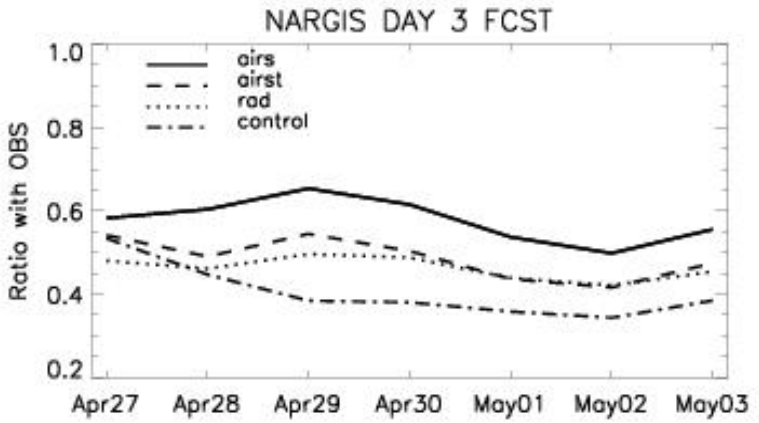
The assimilation containing AIRS retrievals –which improves Nargis structure- also produces the **best precipitation** `analysis’ and forecast.

Validation is made against SSM/I, AMSU and TMI data

Zhou, Y., W. K. Lau, O. Reale, R. Rosenberg, 2010: AIRS Impact on precipitation analysis and forecast of tropical cyclone in a global data assimilation and forecasting system. *Geophys. Res. Lett.*, **37**, L02806, doi.1029/2009GL041494







Precipitation Forecast for Nargis

Forecasts computed along track and validated with SSM/I data.

Ingestion of AIRS retrievals cause the GEOS-5 to have better skill. Improvement with respect of CNTRL caused by AIRS cloudy retrievals (tight QC) is about 20%. The impact of radiances is negligible. Overall skill is very good in the 1-day forecasts. Skill still reasonable at day 3.

Since the largest amount of casualties caused by Nargis were due to FLOODs, this result has prominent implications

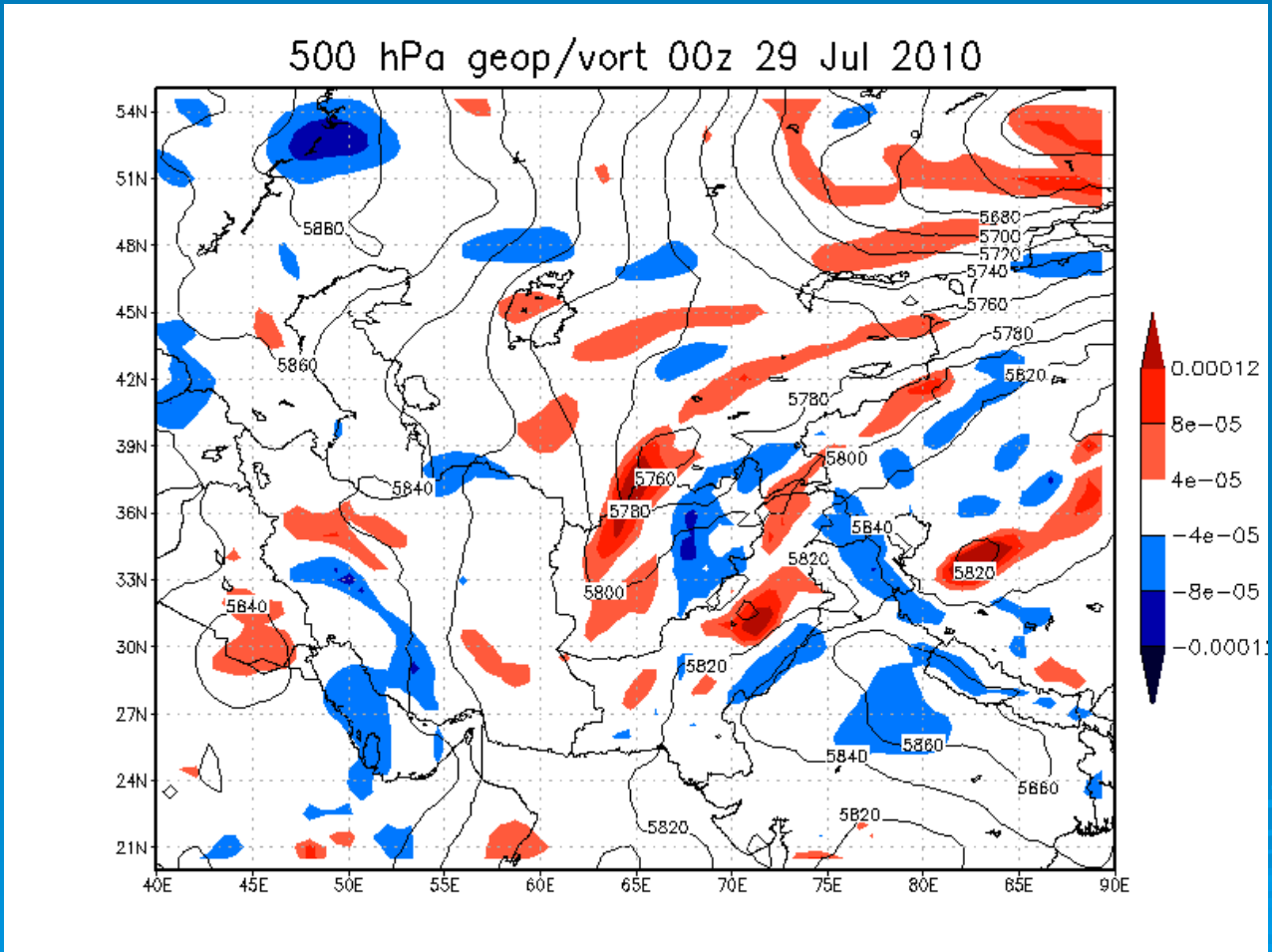
Zhou et al., (2010)

also show consistent AIRS impact on Wilma (2005), Helene (2006)

Article on: Indus River Floods (Pakistan, 2010)

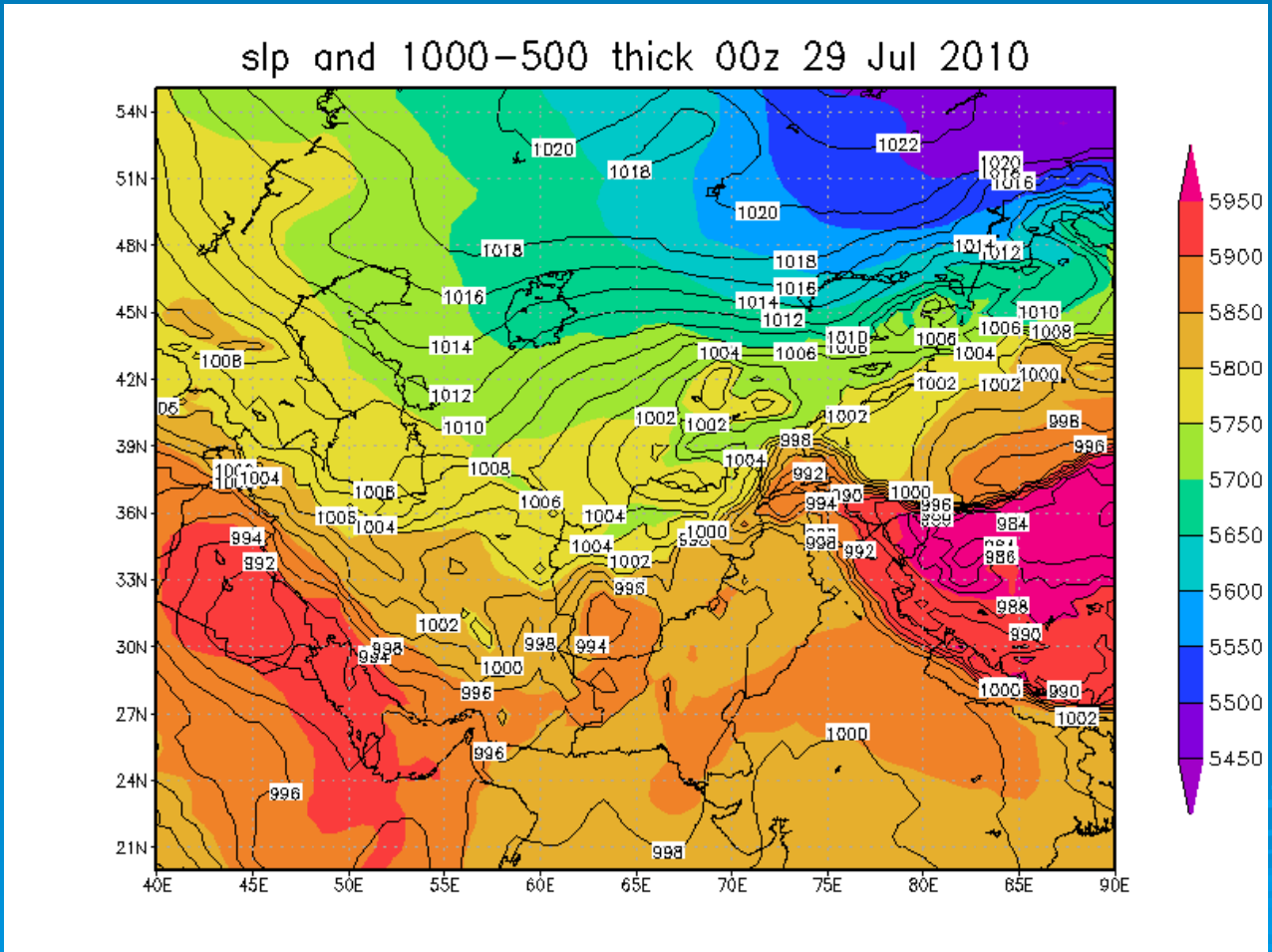
- From 200 to 400mm fell between 27 July and 31 July 2010 over several locations where the seasonal mean is on the same magnitude or less
- Most operational systems failed to predict accurate spatial distrbution of rainfall over Pakistan because of the poor representation of cloudiness distribution (Houze et al 2011)
- Accurate spatial/temporal distribution of rainfall the most important parameter to predict watershed response
- **An important precursor for flood-producing precipitation is the large-scale low-level moisture transport** (often occurring in a non-precipitating environment) **in the several days preceding the event**
- 3 sets of 48-day assimilation experiments (CNTRL, RET and RAD) and corresponding 3 sets of 43 7-day forecasts were performed.
- Precipitation analysis and forecast, and changes in the moist circulation consequent to the different assimilation strategies were assessed (Reale et al. 2012)

The peak of the 2010 Pakistan event is driven by an evident extra tropical forcing (deep mid latitude trough)



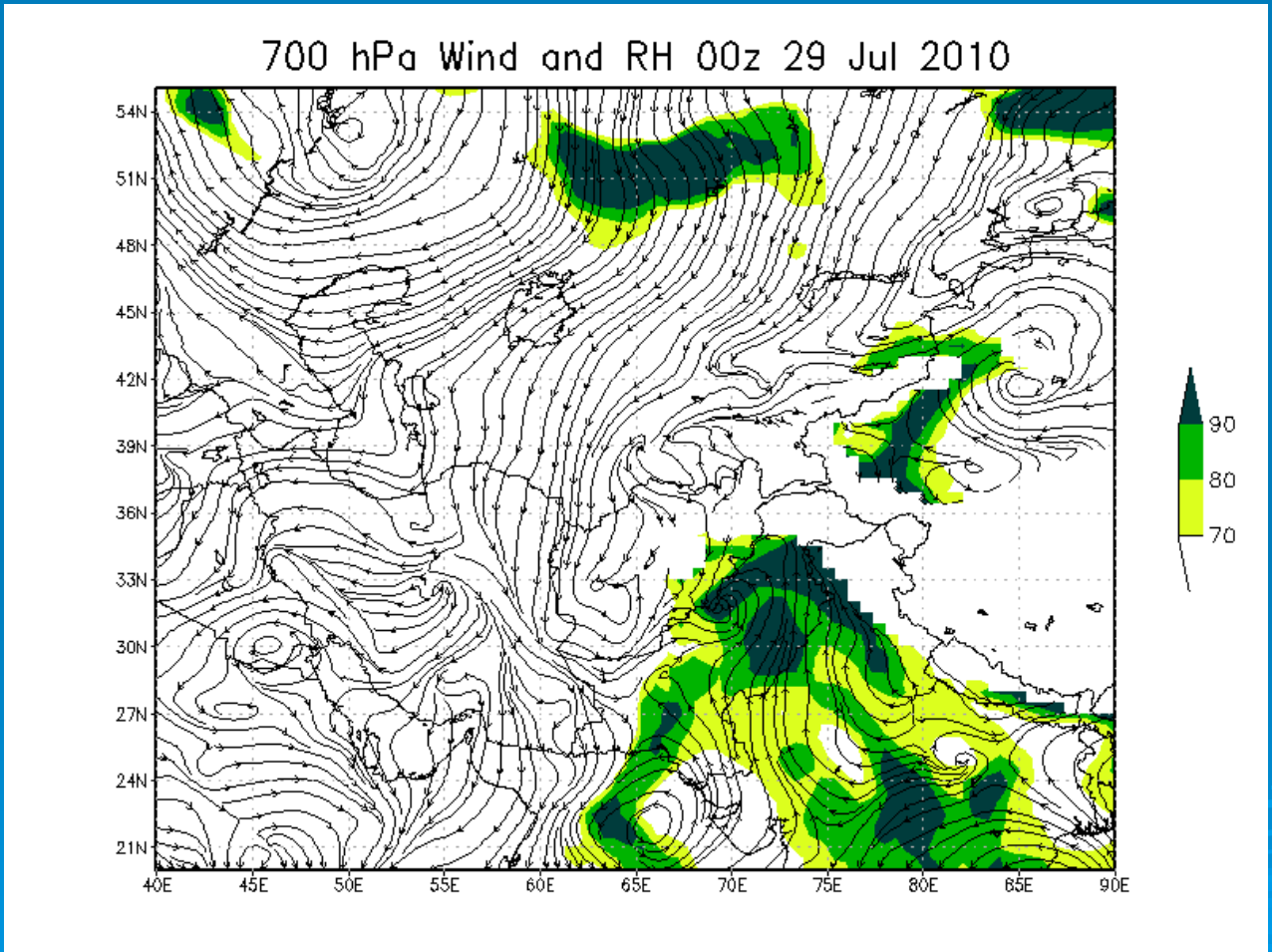
500 hPa (m, solid) and vorticity (s^-1, shaded)

The event development as partly extra tropical: intense low-level cold advection from the north



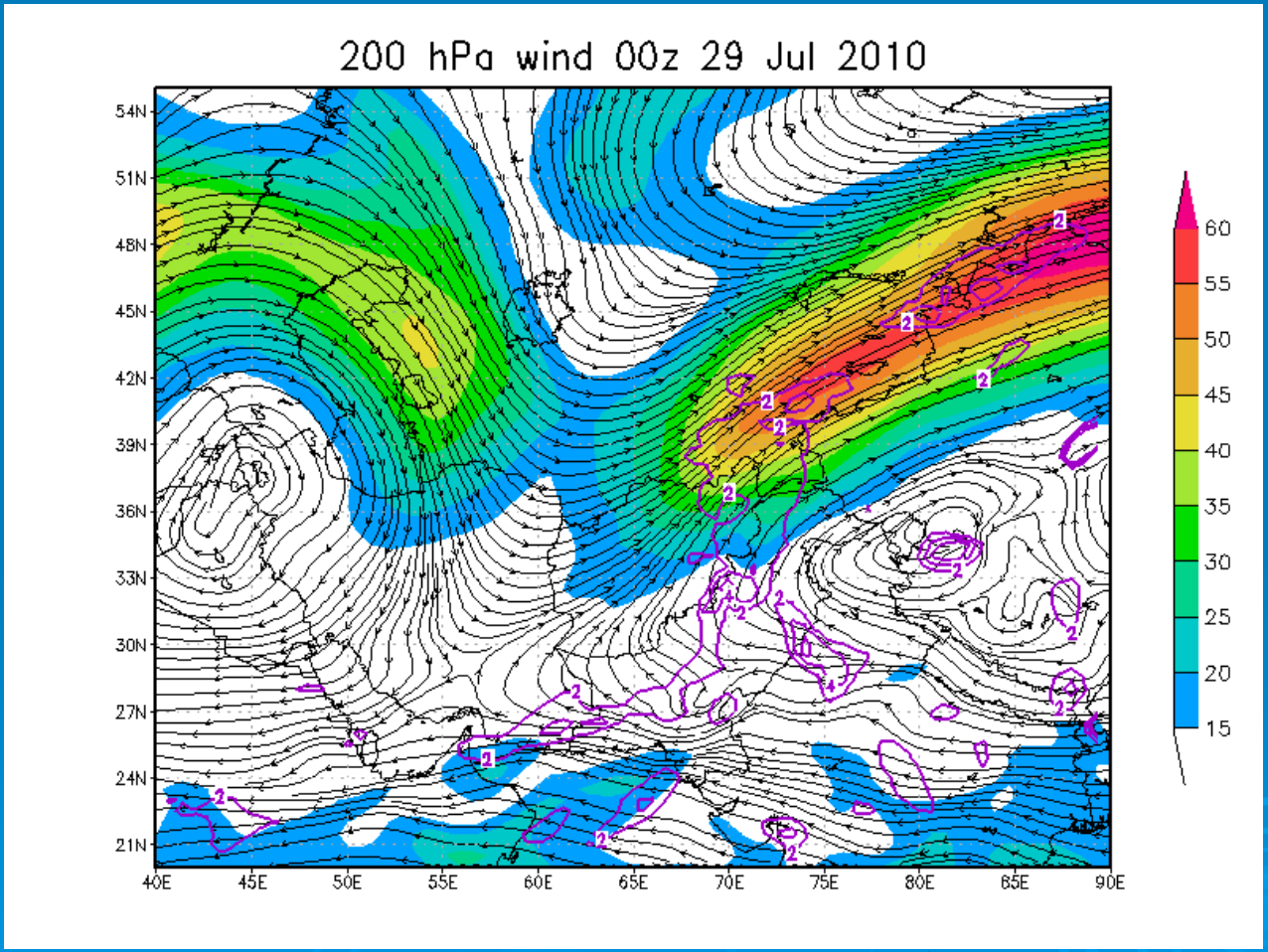
Slp (hPa, solid) and 1000 minus 500 hPa thickness (m, shaded)

Strong low-level moist advection from the south is triggered by the upper-level forcing



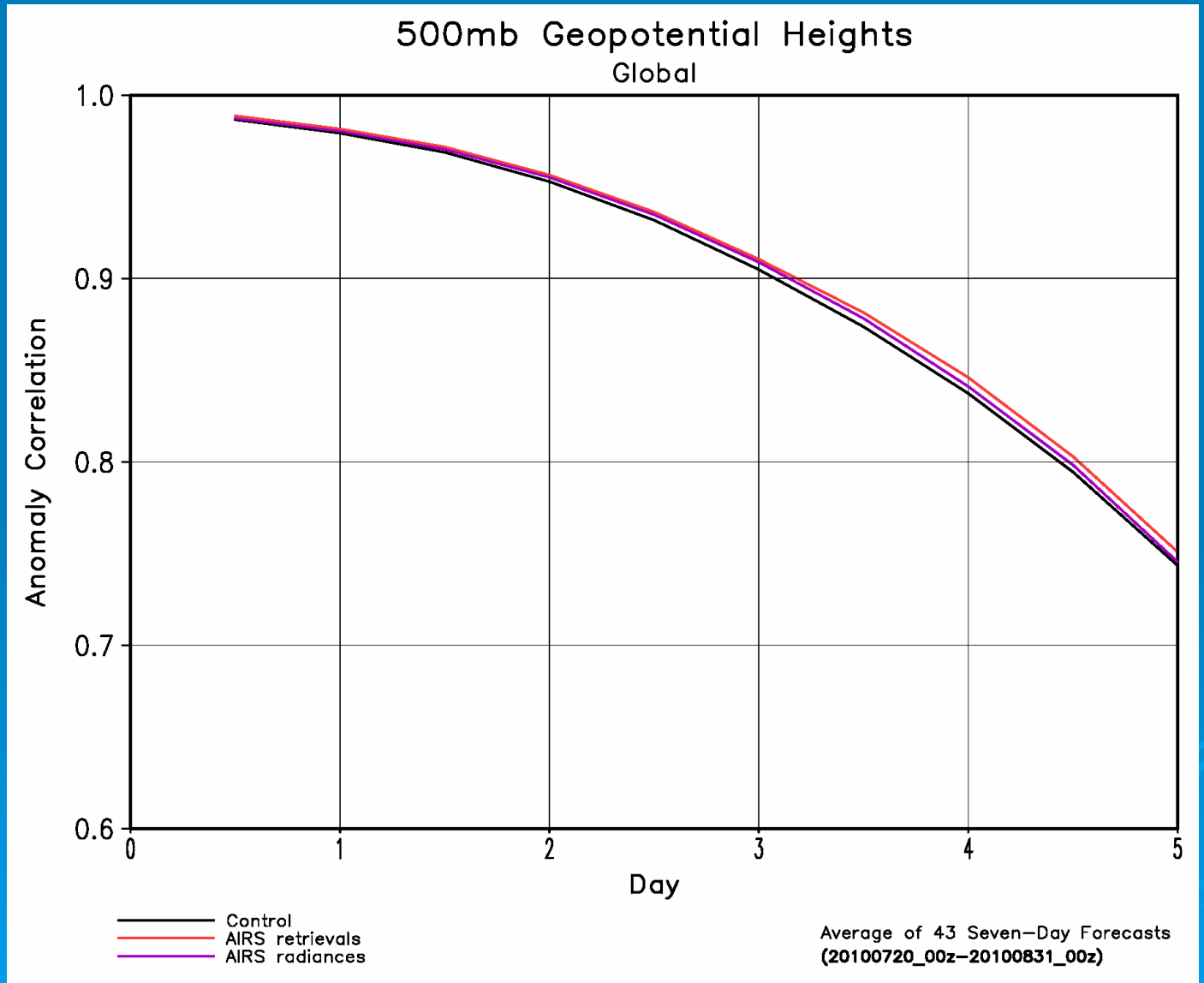
700 hPa wind and relative humidity (shaded)

Jet coupling appears to be the final mechanisms causing dramatic and sudden increase in upper-level divergence



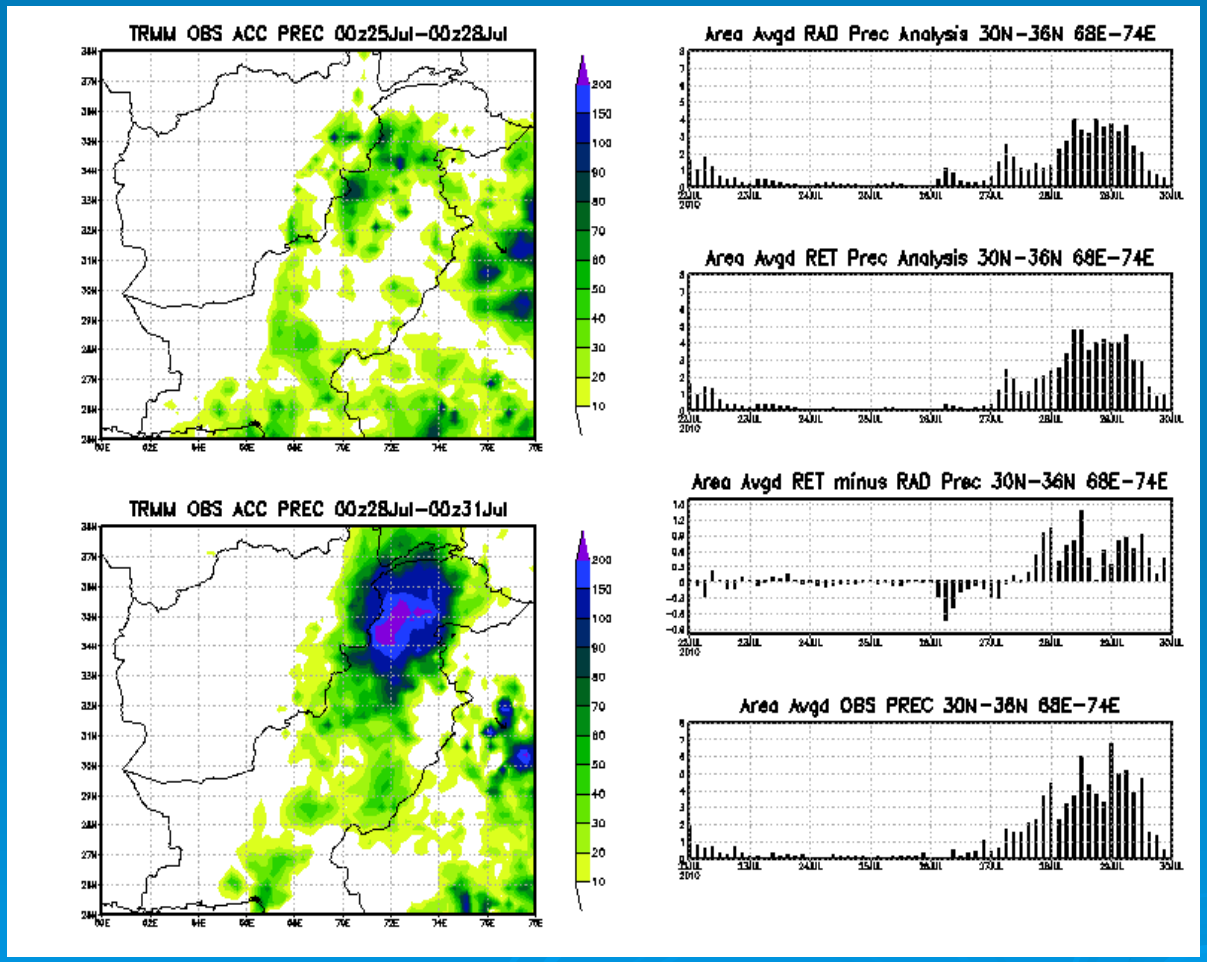
200 hPa wind (streams and shaded, m/s) and divergence (10^-5s^-1, contour)

Before investigating the peak of the precipitation event, the global skill is verified: assimilation of AIRS v5 retrievals produces better forecasts than clear sky radiances.



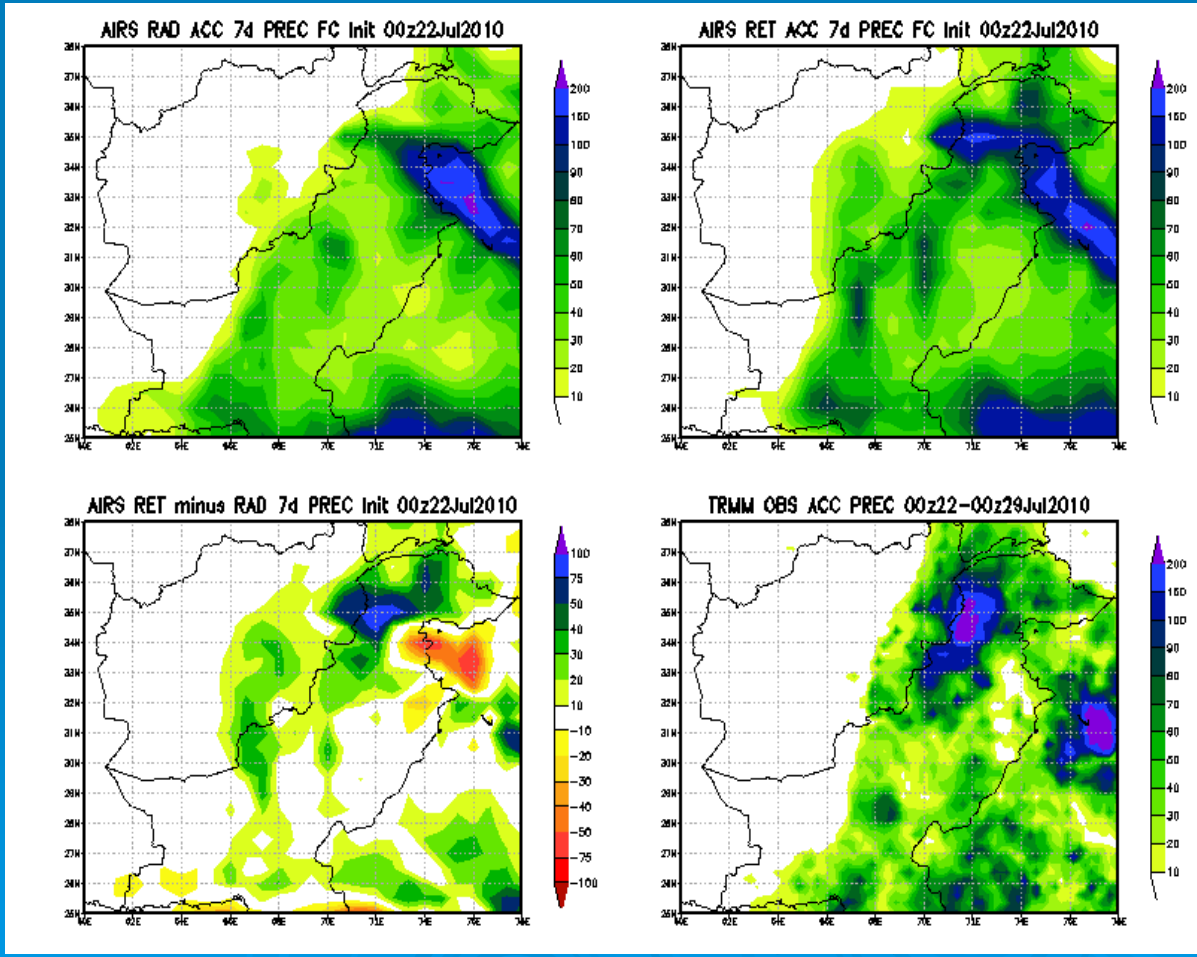
500 hPa anomaly correlation computed from 90S to 90 N

AIRS retrievals improve the area-average precipitation `analysis' with respect to AIRS radiances at its peak time

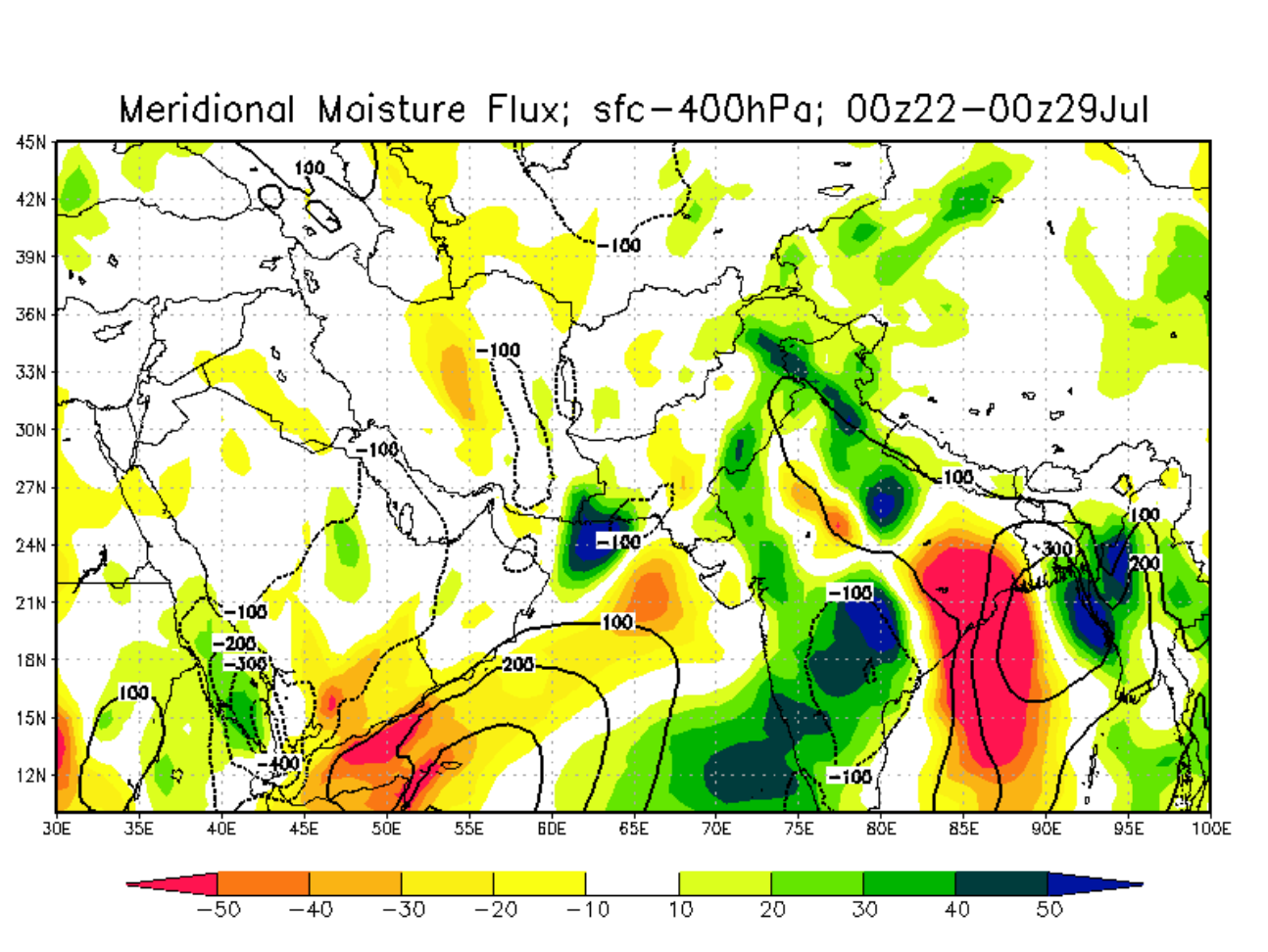


No actual precip data are assimilated.
Precip comes from the `corrector sequence'

AIRS retrievals improve the 7-day accumulated precipitation forecast with respect to AIRS radiances at the peak of the event



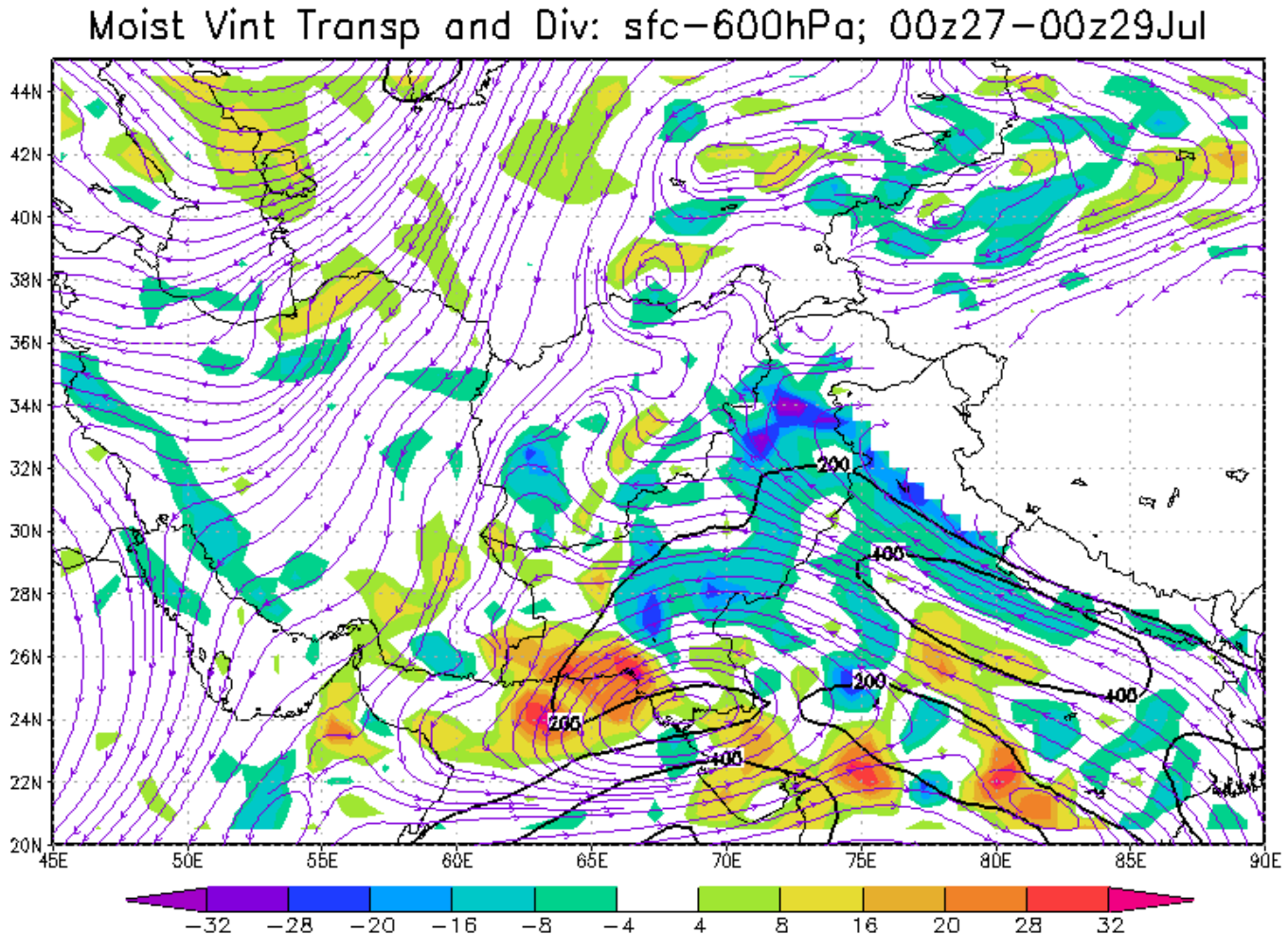
Mechanism: AIRS retrievals increases the 7-day average moisture transport with respect to AIRS radiances



Solid: 7-day avgd vertically integrated meridional moisture transport (RAD)

Shaded:
RET minus RAD departure

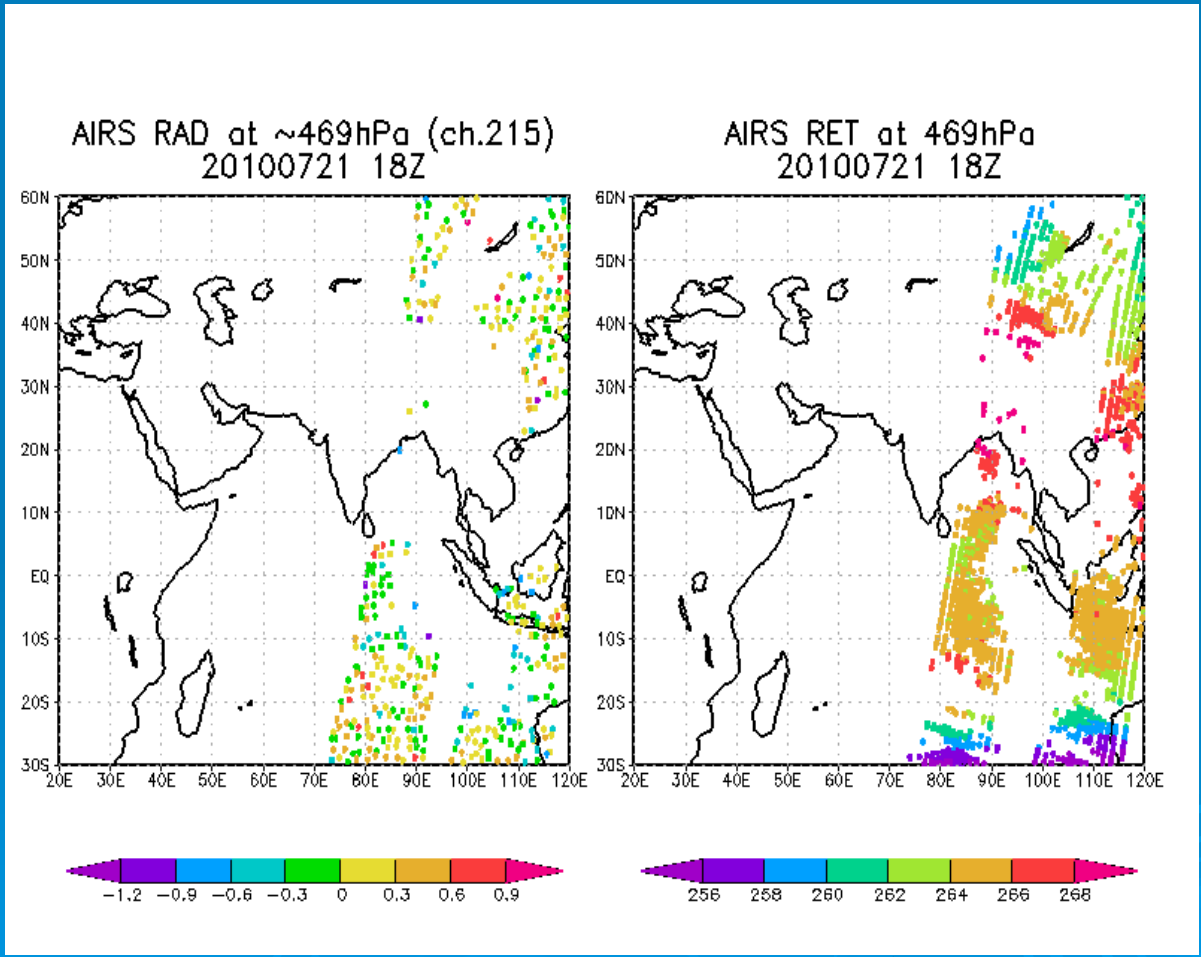
AIRS retrievals increases the 2-day average moisture concentration with respect to AIRS radiances



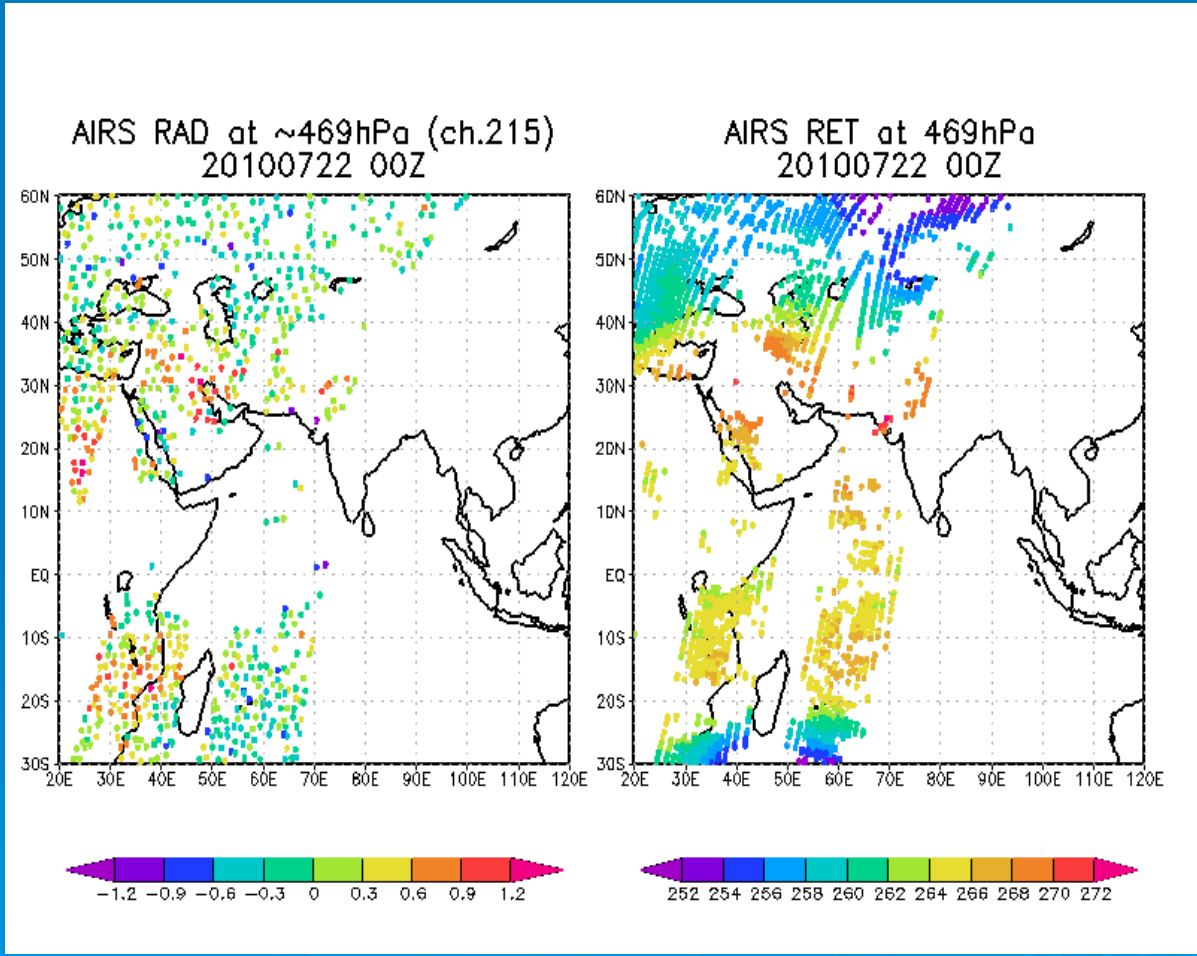
Solid: 2-day avgd vertically integrated total moisture transport

Shaded: RET minus RAD flux divergence

Difference in coverage between clear sky radiances and v5 retrievals: 18Z passes



Difference in coverage between clear sky radiances and v5 retrievals: 00z passes



Summary of the impact study on the Indus-river floods (Pakistan, 2010)

- Information provided from AIRS v5 cloudy retrievals allow an improved representation of the low- and mid-level moist atmospheric flow from the Indian Ocean, on different time scales
- Assimilation of AIRS version 5 cloudy retrievals improve the analysis of precipitation more than assimilation of AIRS clear-sky radiances
- Improved precipitation analysis arise out of an improved representation of cloudiness distribution, moisture transport and convergence.
- The analysis improvement consequent to AIRS v5 retrieval assimilation produced improved precipitation forecasts up to 7 days with respect to assimilation of AIRS clear-sky radiances
- Improved precipitation forecast could enable better hydrological forecasts
- While a rigorous comparison on the effectiveness of the radiance or retrieval methodology cannot be performed (e.g different selection of channels) it can be concluded that from the operational perspective the AIRS v5 retrievals produce better results than v5 radiances

Conclusions of 3 years of work

- Sets of data assimilation experiments without AIRS, with AIRS version 5 retrievals and with AIRS clear-sky radiances were produced for boreal winter, spring, three summers and fall conditions, for a total of about 700 days; 5- or 7-day forecasts are produced from each set of analyses, for a total of about 700 forecasts
- The overall impact on forecasts skill coming from v5 retrievals is higher than the corresponding impact of radiances in every season and every year
- Four published articles (3 GRL and1 JGR) demonstrate a superior impact of AIRS v5 retrievals in a variety of situations (global, regional, event-focused, different years and seasons)

Ongoing and future Work

- Funded research (June 2011-2014) on AIRS impact on processes affecting **Tropical Cyclone structure** in global models
- Current results show that AIRS improves the Tropical Cyclone ANALYSIS in GEOS5-DAS in terms of intensity, vertical structure, and position; impact is particularly strong on developing and transitioning tropical cyclones
- Promising results on TC intensity forecasts
- AIRS impact on Tropical Cyclones in the GEOS-5 is being studied over the Atlantic, Indian and Pacific Oceans, different years, both hemispheres
- Starting AIRS version 6 experiments soon

Acknowledgments

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- **Dr. Ramesh Kakar** *for support to* ***currently funded*** *proposal ``Using AIRS data to understand processes affecting Tropical Cyclone structure in a Global Data Assimilation and Forecasting Framework'' (PI: Dr. O. Reale)*
- **Dr. Tsengdar Lee** for generous allocations of NASA High End Computer resources
- **AIRS team** at JPL and the **Sounder Research Team** at NASA GSFC

National Aeronautics and Space Administration

AIRS-related articles published by this team

Reale, O., J. Susskind, R. Rosenberg, E. Brin, E. Liu, L. P. Riishojgaard, J. Terry, J. C. Jusem, 2008: Improving forecast skill by assimilation of quality-controlled AIRS temperature retrievals under partially cloudy conditions. Geophysical Research Letters, 35, L08809, doi: 10.1029/2007GL033002.

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