Impact of MODIS sounder Data Assimilation: The Maiden Snowfall over Jammu & Kashmir during December 2010.

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DBCRAS Configuration:

Direct Broadcast CIMSS (Co-operative Institute for Meteorological Satellite Studies) Regional Assimilation System

Domain Centre	**28° N, 77°E (Delhi, India)**
Horizontal Resolution	**48 km (210 x150 grids)**
Vertical Sigma levels	**38**
Topography	**2 minute USGS Global dataset**
Boundary Condition	**NCEP GFS forecast at 6- hourly interval**
Analysis	**12 hour spin-up forecast with the assimilation of MODIS cloud parameters and precipitable water and surface data**
Cloud assimilation	**Bayler et al., 2000**
Initialization	**Vertical normal mode (Bourke and McGregor, 1983)**
Model dynamics	**Semi-implicit time scheme (McGregor et al., 1978)** **Third order time filter (Raymond, 1991)** **Advective form of equations of motion (Leslie et al., 1985)** **Pseudo-non-hydrostatic and parameterized rain drag (Raymond and Aune, 1998)** **6^{th} order tangent filter replaces the horizontal diffusion (Raymond, 1988)**
Model physics **Convective Parameterization** **Cloud microphysics**	 **Modified Kuo type (Raymond and Aune, 2003)** **Explicit cloud and precipitation microphysics (Raymond, 1995) with diagnosed liquid/ice phase (Dudhia, 1989)** **Water/ice cloud sedimentation (Lee, 1992)**
Shortwave and Long wave Radiation	**Ackerman and Stephens, 1987**
Land-surface processes	**Vertical turbulent exchange (Raymond, 1999)** **5-layer soil model (Kondo et al., 1990 and Lee and Pielke, 1992)**
Model products	**Different meteorological parameters** **11 μ Infra-Red and 6.7μ Water Vapor synthetic satellite images**

Ancillary Data required

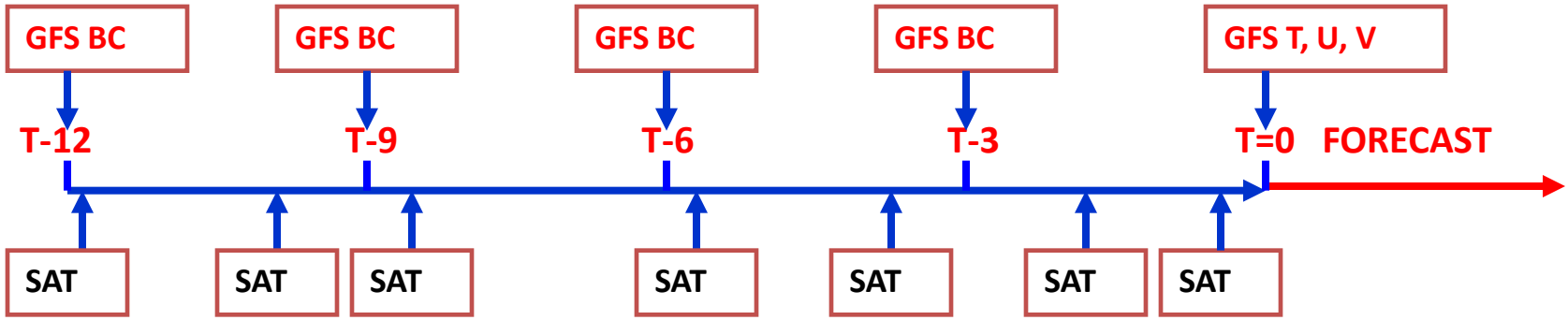
- Global NOAA 24km daily snow cover file
- **Global Surface Observations:**
- NCEP daily 0.5 degree Sea Surface temperature
- MODIS sounder data: Cloud top pressure, Effective cloud Amount (ECA) and total precipitable water
- **NCEP Global Forecast System (GFS) half-degree forecast files**

  For Spin up: Three hourly GFS files 00 through 12 hour forecast

  For Forecast: Six hourly GFS files 06 through 72 hours

***INSAT-3D sounder data: Cloud parameters and three layered precipitable water**

A 12-hour DBCRAS spin-up forecast is modified to handle the varying polar orbits of the Aqua and Terra satellites.



Analysis:

A 12-hour spin-up forecast is used to adjust water vapor and clouds. Satellite information is inserted at the mid-time of each individual satellite scan. Water vapor, cloud and precipitation mixing ratio from the 12-hour spin-up are merged with 6-hour forecast GFS winds and temperatures from the previous GFS run. The merge is conducted on 25 pressure levels from surface to 10 hPa.

First Major Snowfall over Jammu and Kashmir, December, 2010

The Northern part of India, Jammu & Kashmir experienced the first major snowfall of 2010-2011 winter on Thursday, the 30th December 2010.

Snow which began falling on Wednesday (29th December, 2010), accumulated in sizeable amounts throughout the valley and it caused considerable disruption in power and transportation.

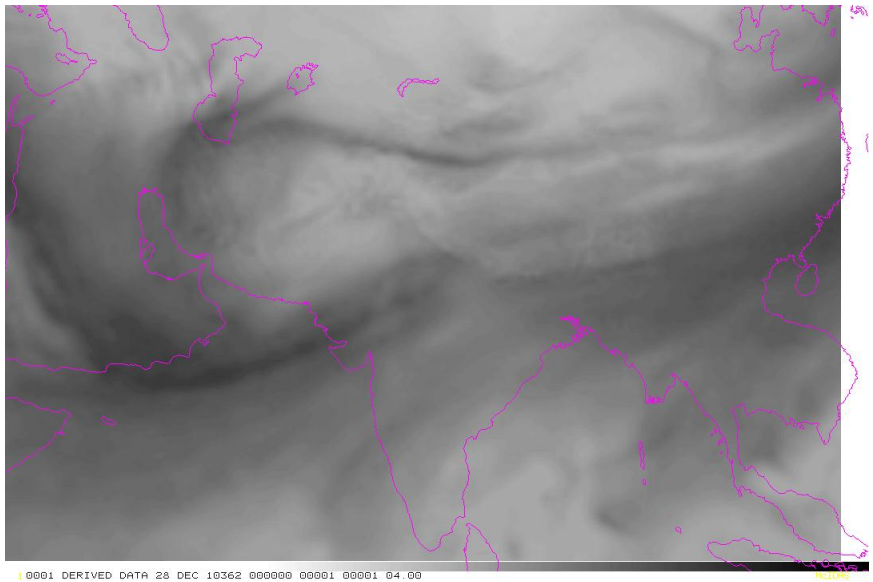
India Meteorological Department (IMD) had predicted heavy snowfall on the coming days of New Year including the New Year eve.

IMD had also given forecast of the arrival of a **Western Disturbance**, likely to hit the Himalayas and result in snowfall in the higher reaches of Himalayas including Kashmir and rainfall in the lower part of the hills.

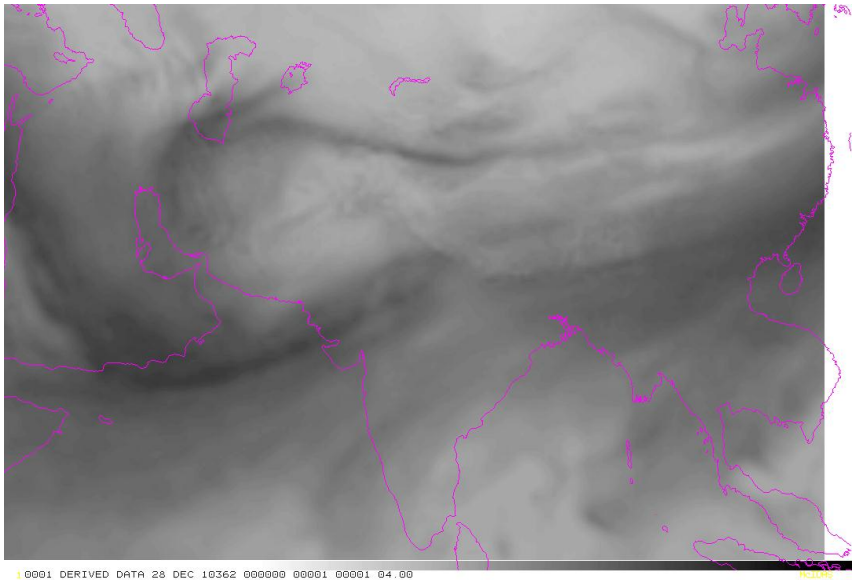
IMPACT of MODIS sounder products: Spin-up

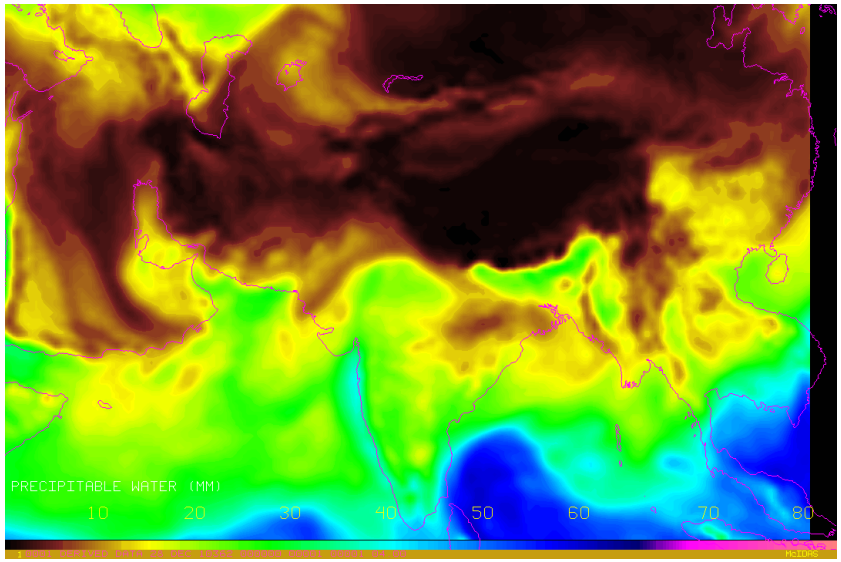
Synthetic WV images :Spin-up through 12 hours starting from 12 UTC of 28-12-2010.

With MODIS



Without MODIS



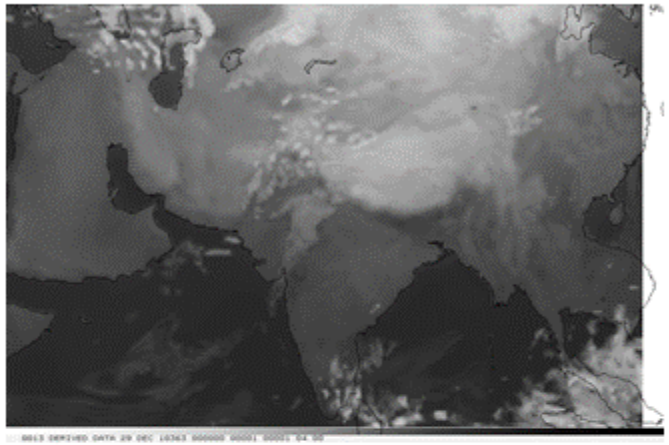


This 12 hour spin-up produces the analysis (initial condition) for the model forecast starting from 00 UTC of 29-12-2010.

IMPACT of MODIS sounder products: IR Synthetic Satellite image and Precipitable Water

Spin up valid for 29-12-2010, 00UTC

a Without MODIS



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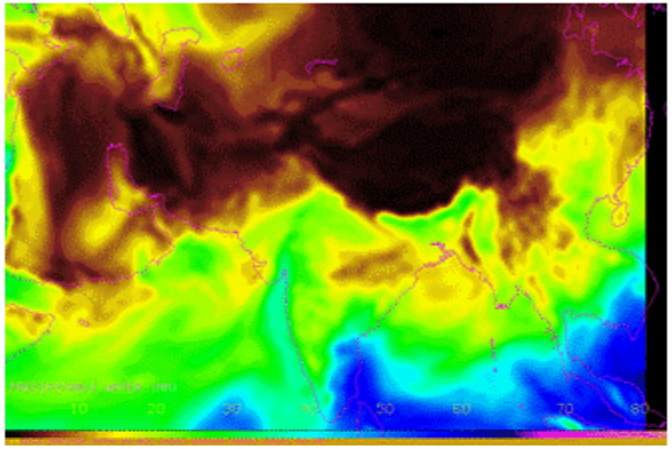
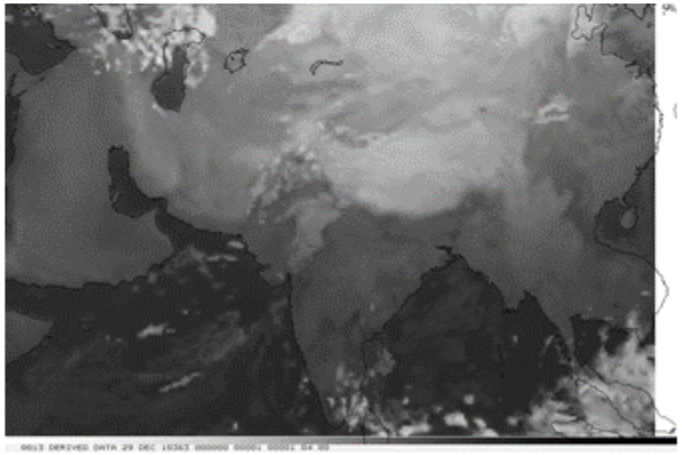


c With MODIS



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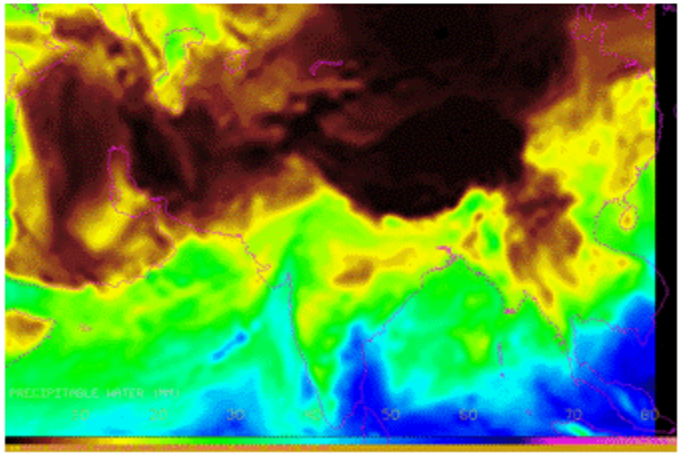

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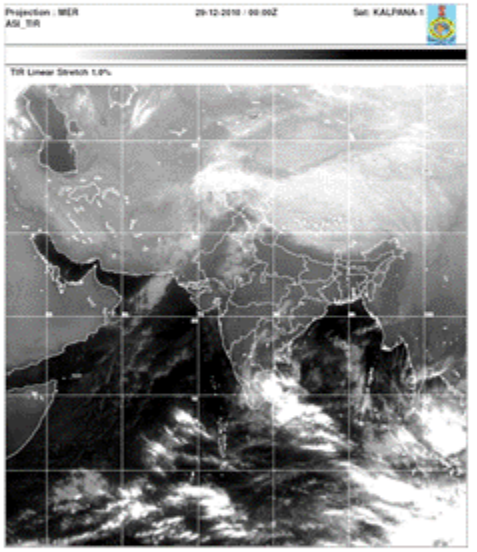
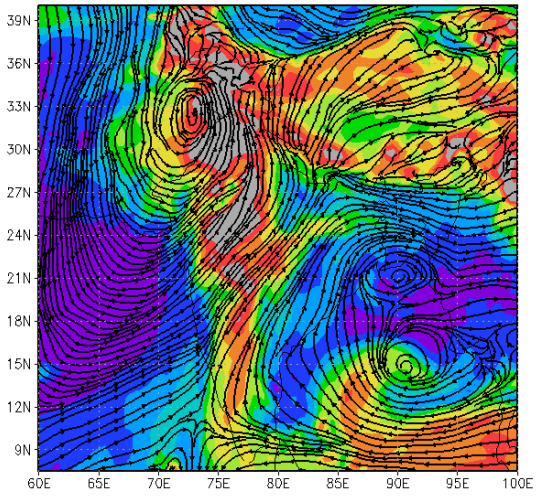


How realistically can DBCRAS reproduce the Western Disturbance Features …. (with MODIS assimilation)

LOW LEVEL MOISTURE INCURSION → DBCRAS (with MODIS Assimilation)

(a)



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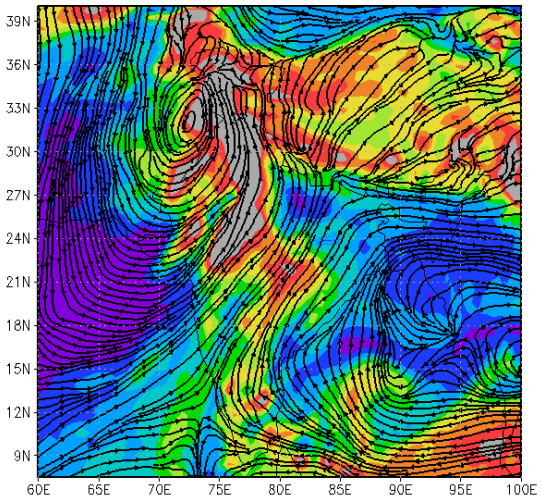

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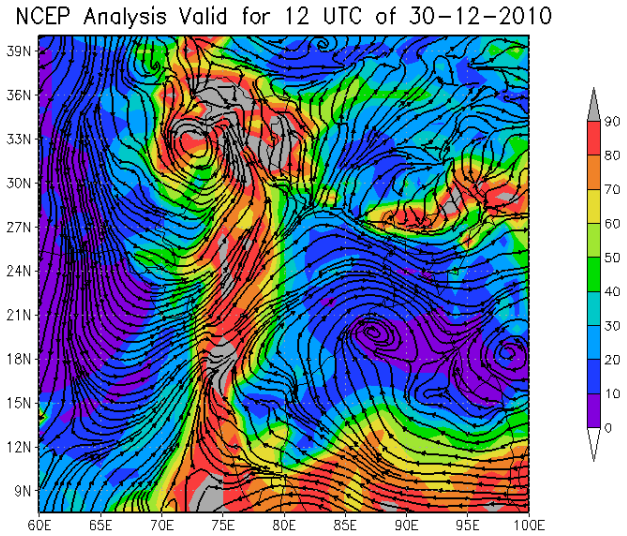
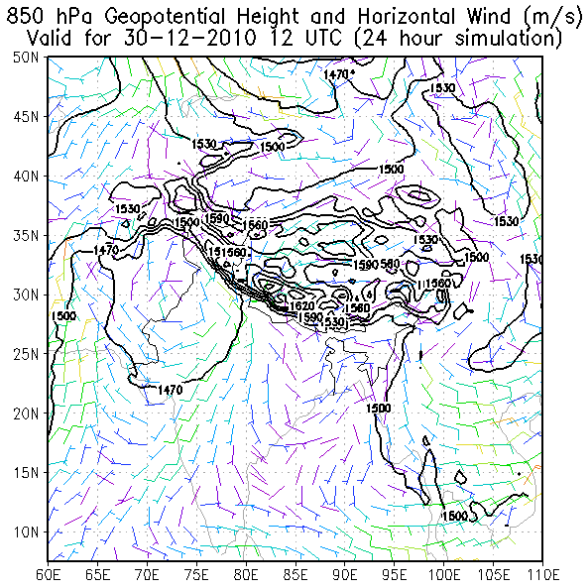
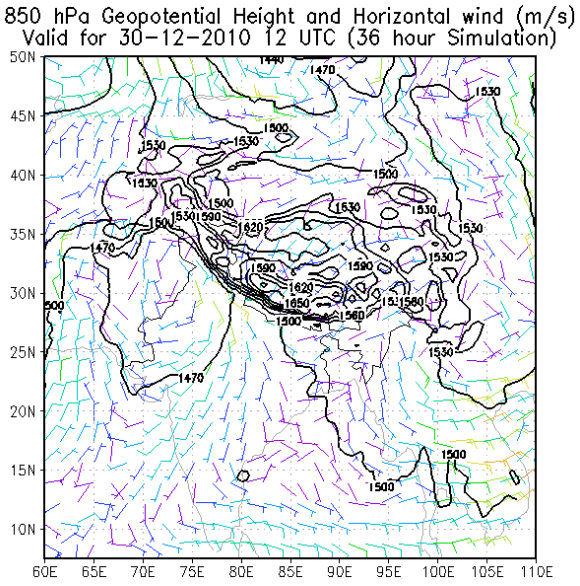
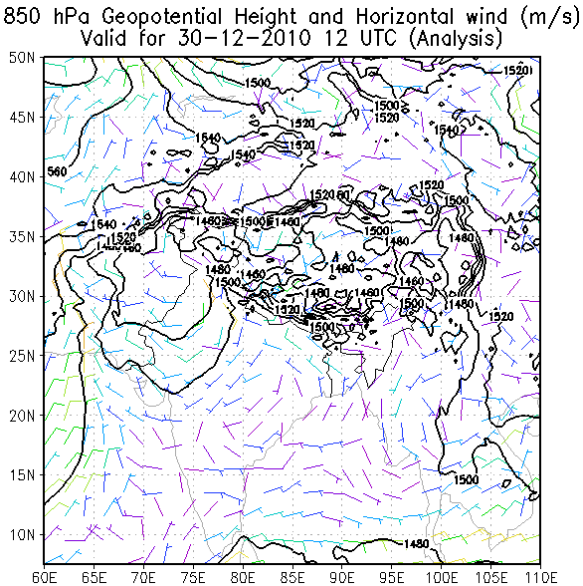


Shifting of seasonal anticyclone eastward of Bay of Bengal, and the convergence of streamlines from Arabian Sea and Bay of Bengal cause the incursion of moisture into the low pressure system formed over Pakistan and south of Jammu & Kashmir and this in turn strengthened the System.

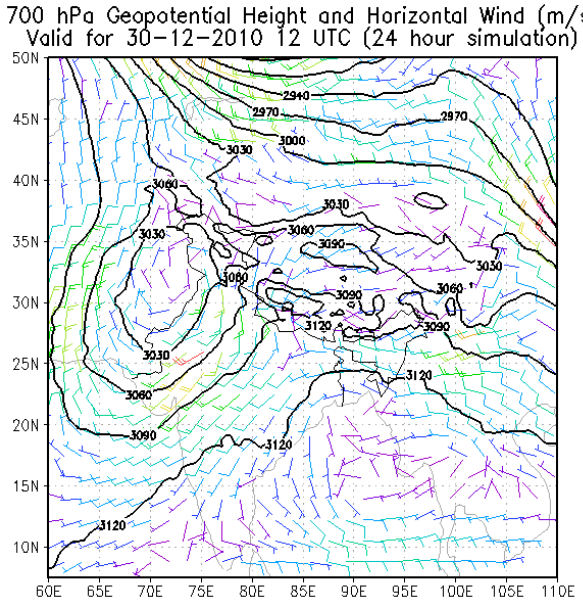
Influence of Western Disturbance → DBCRAS (with MODIS Assimilation)

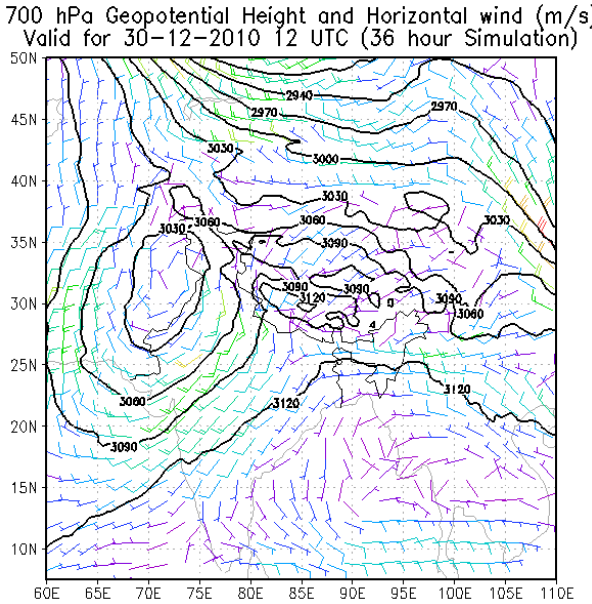


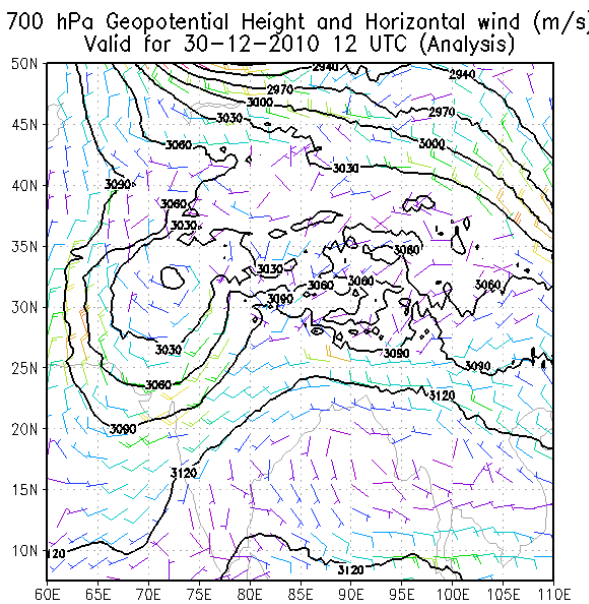




Influence of Western Disturbance (contd…)

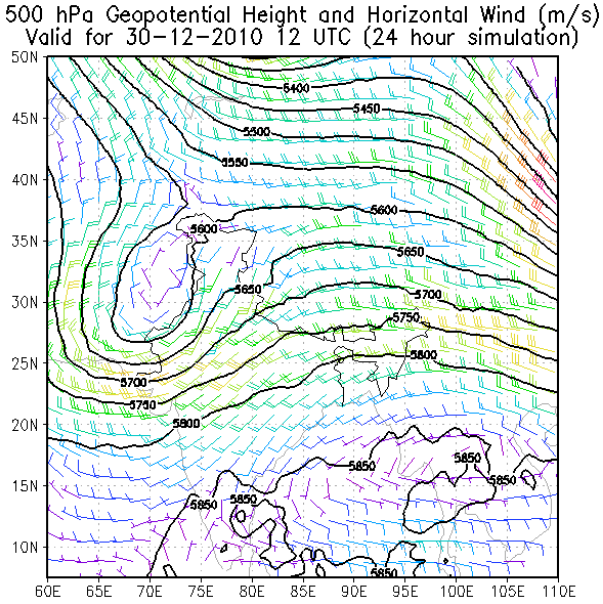


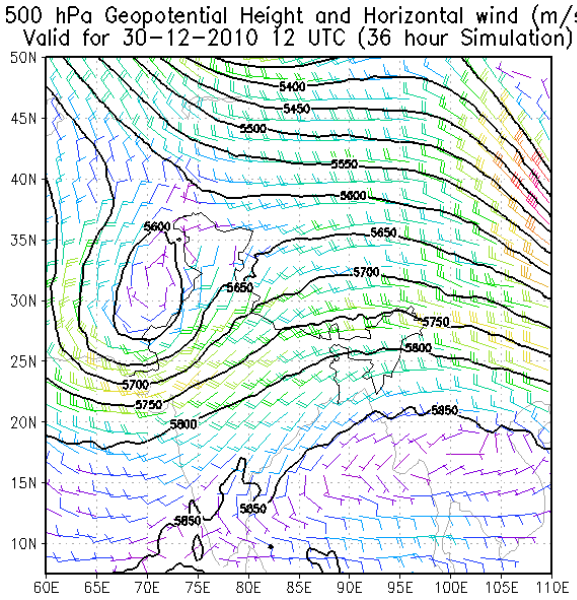


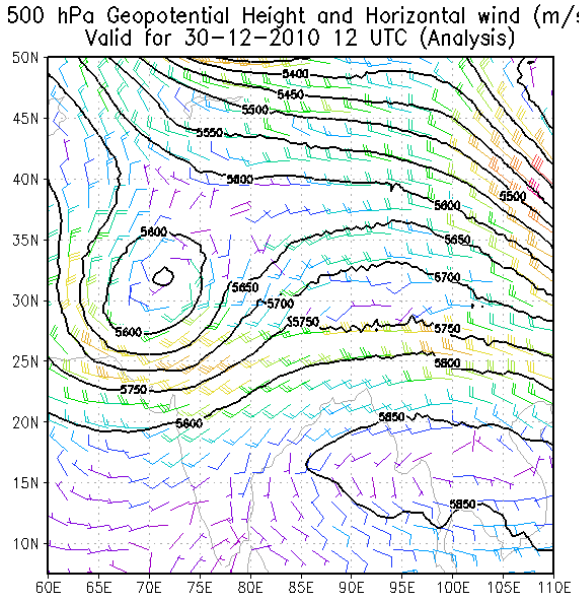


Splitting of WD into two components: Southward (towards the low pressure system) and further north away from the system

Influence of Western Disturbance (contd…)

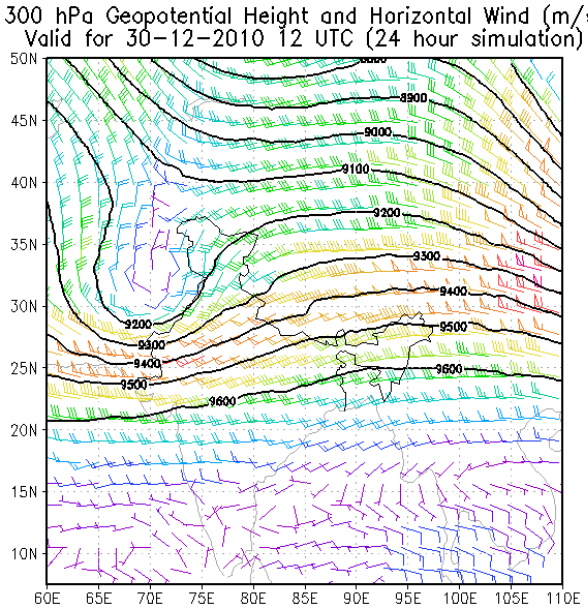


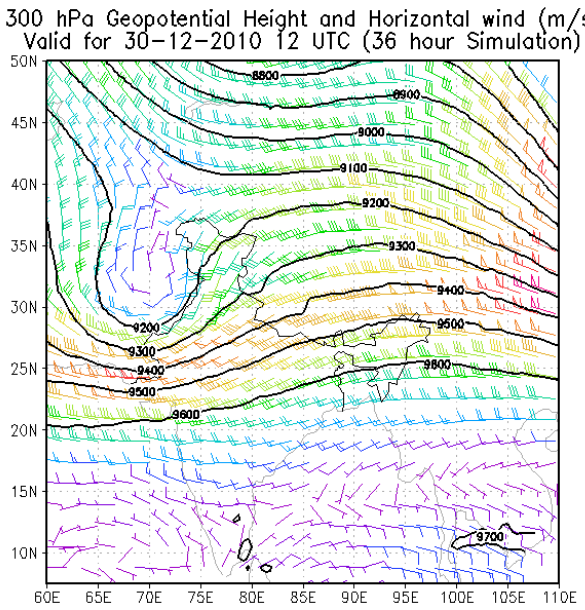


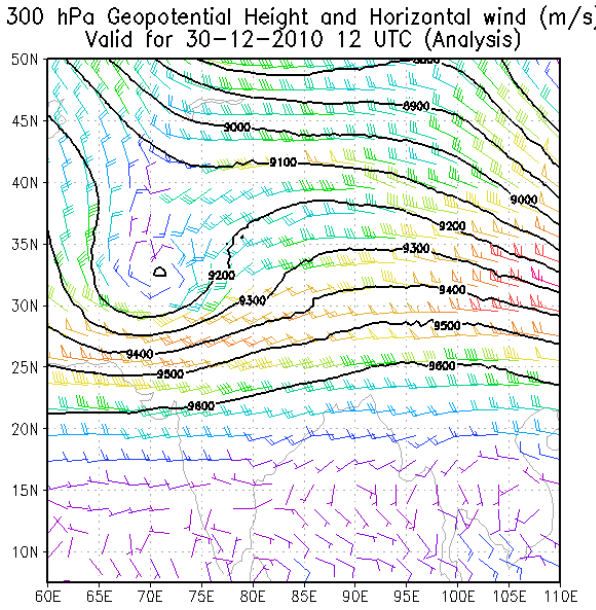


Splitting of WD into two components: Southward (towards the low pressure system) and further north away from the system, **and then the joining of two components when the system moves further east…**

Influence of Western Disturbance (contd…)

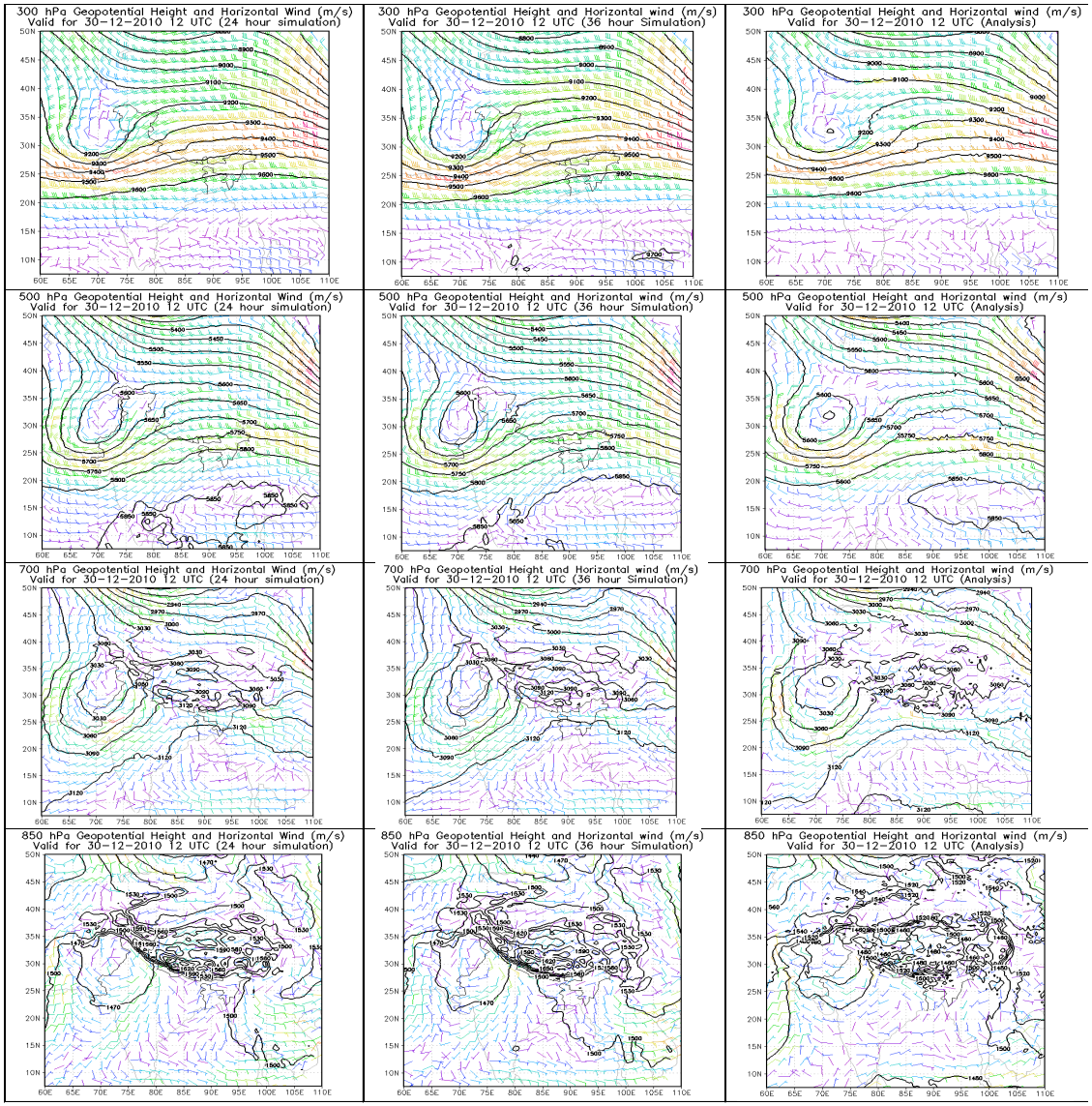






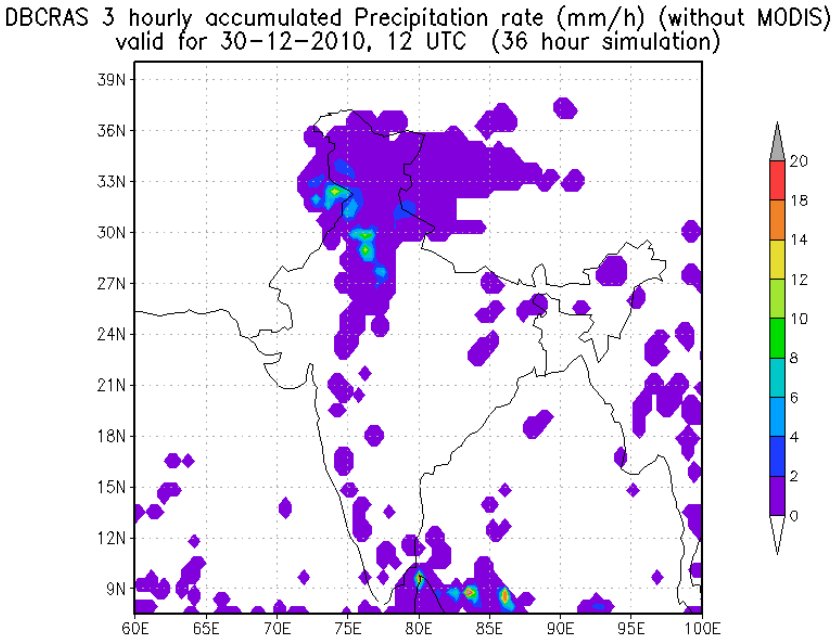
Splitting of WD into two components: Southward (towards the low pressure system) and further north away from the system, **and then the joining of two components when the system moves further east…**

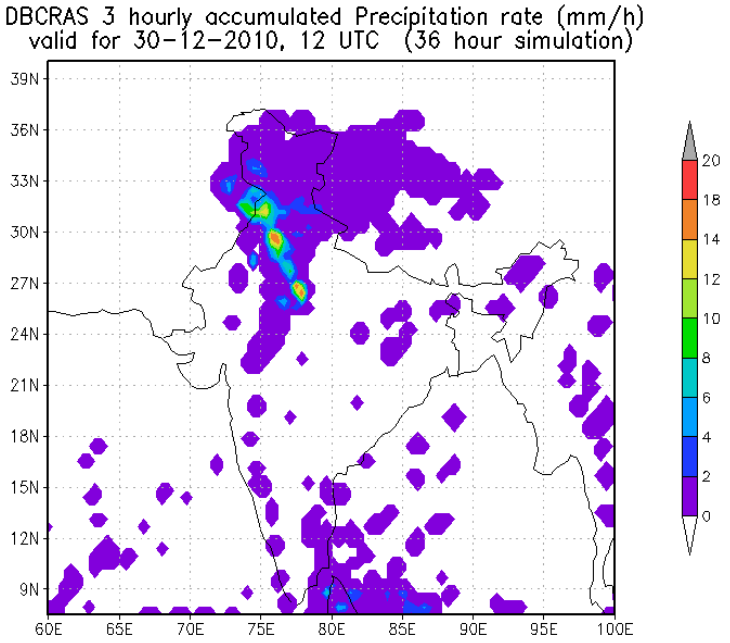
24 hour Forecast | **36 hour Forecast** | **Analysis**

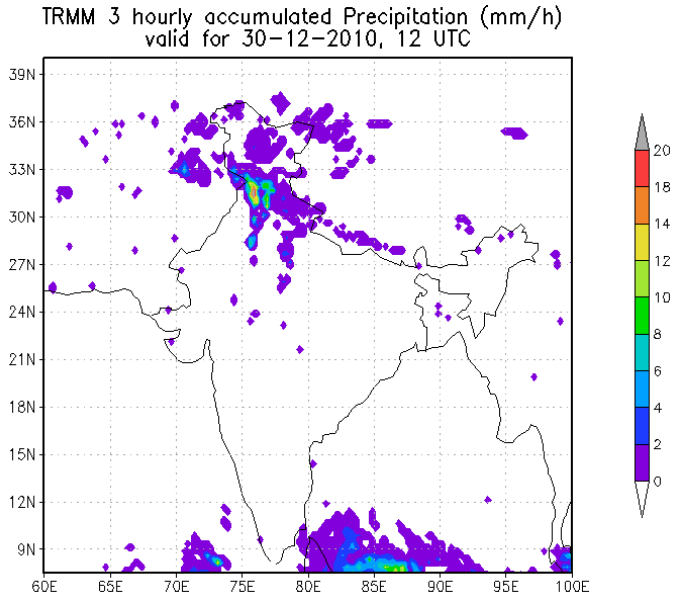


The low pressure area over Pakistan and south of Jammu & kashmir persisted in the atmosphere right from 850 to 300 hPa and the low level moisture incursion pumped enough moisture into the system which was carried along with the WD in due course of its eastward journey and its encounter with Himalaya shed the moisture .

DBCRAS Accumulated Precipitation and TRMM







Good qualitative agreement between the simulated (with MODIS) and observed precipitation

DBCRAS simulated precipitation showed more spatial extension towards south

Conclusions:

- ✓ **For the first time the DBCRAS model was tested over Indian domain with the assimilation of MODIS (Terra and Aqua) sounder products.**
- ✓ **The synthetic satellite images simulated by the model with MODIS assimilation resemble to the corresponding Kalpana images .**
- ✓ **The model was able to simulate the dynamics and physics of the Western Disturbance that caused the first snowfall in the 2010-2011 winters during the end of December 2010.**
- ✓ **Even though there is an overall agreement in the precipitation pattern simulated by the model with the TRMM observation, the model simulations showed widespread precipitation southward.**

THANK YOU