

Prediction of Heavy Precipitation in the Himalayan Region

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National Centre for Medium Range Weather Forecasting,
Ministry of Earth Sciences

NCMRWF is a Centre of Excellence in Numerical Modelling and Data Assimilation

Mission of the Centre

To continuously develop advanced numerical weather prediction systems, with increased reliability and accuracy over India and neighbouring regions

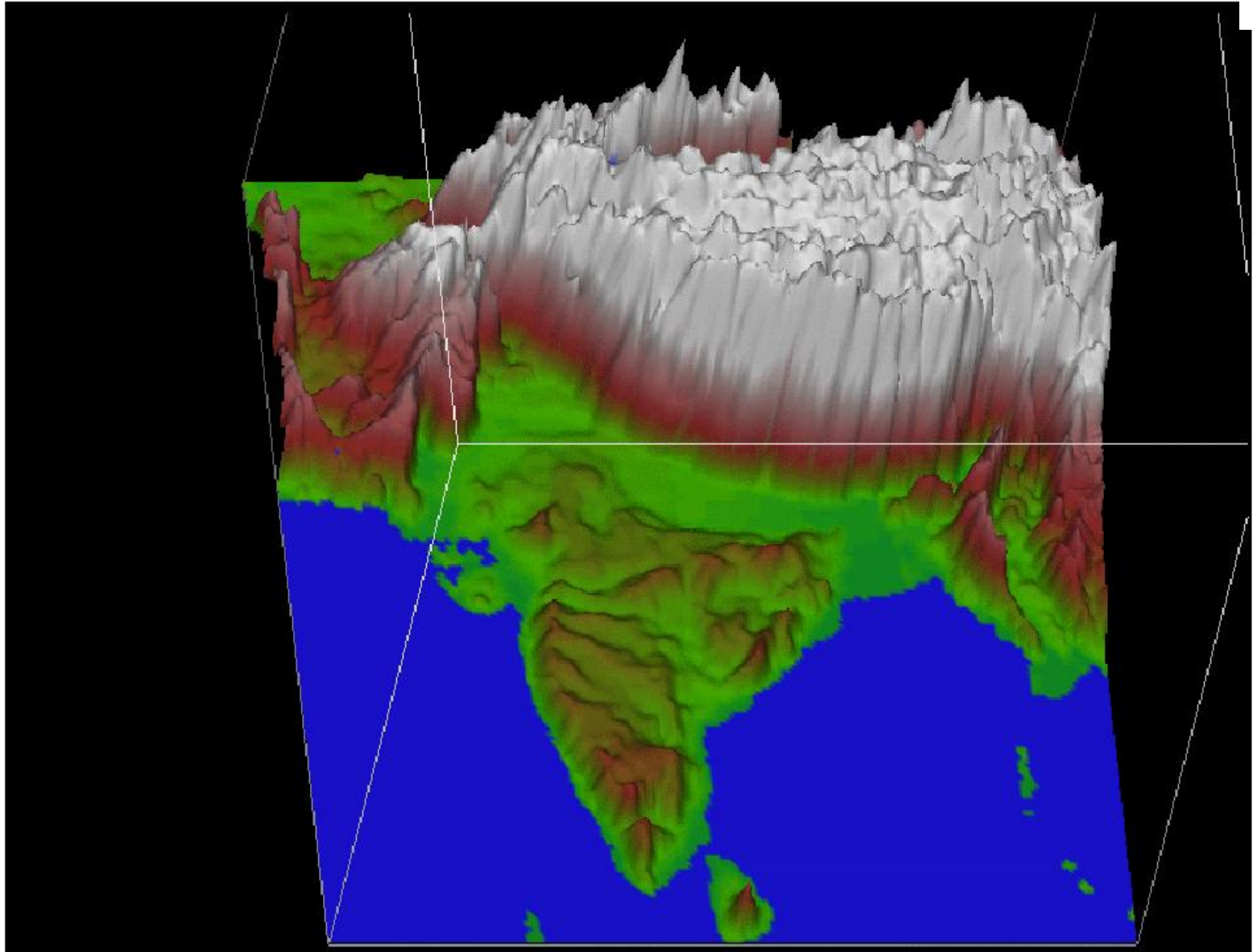
Major Mandates of NCMRWF

- Development and improvement of weather prediction models for IMD to underpin their forecasting capability
- Development of Data Assimilation (DA) systems for both Global Forecast System (GFS) & Unified Model (UM)
- Development of a Seamless prediction system based on UM

Outline

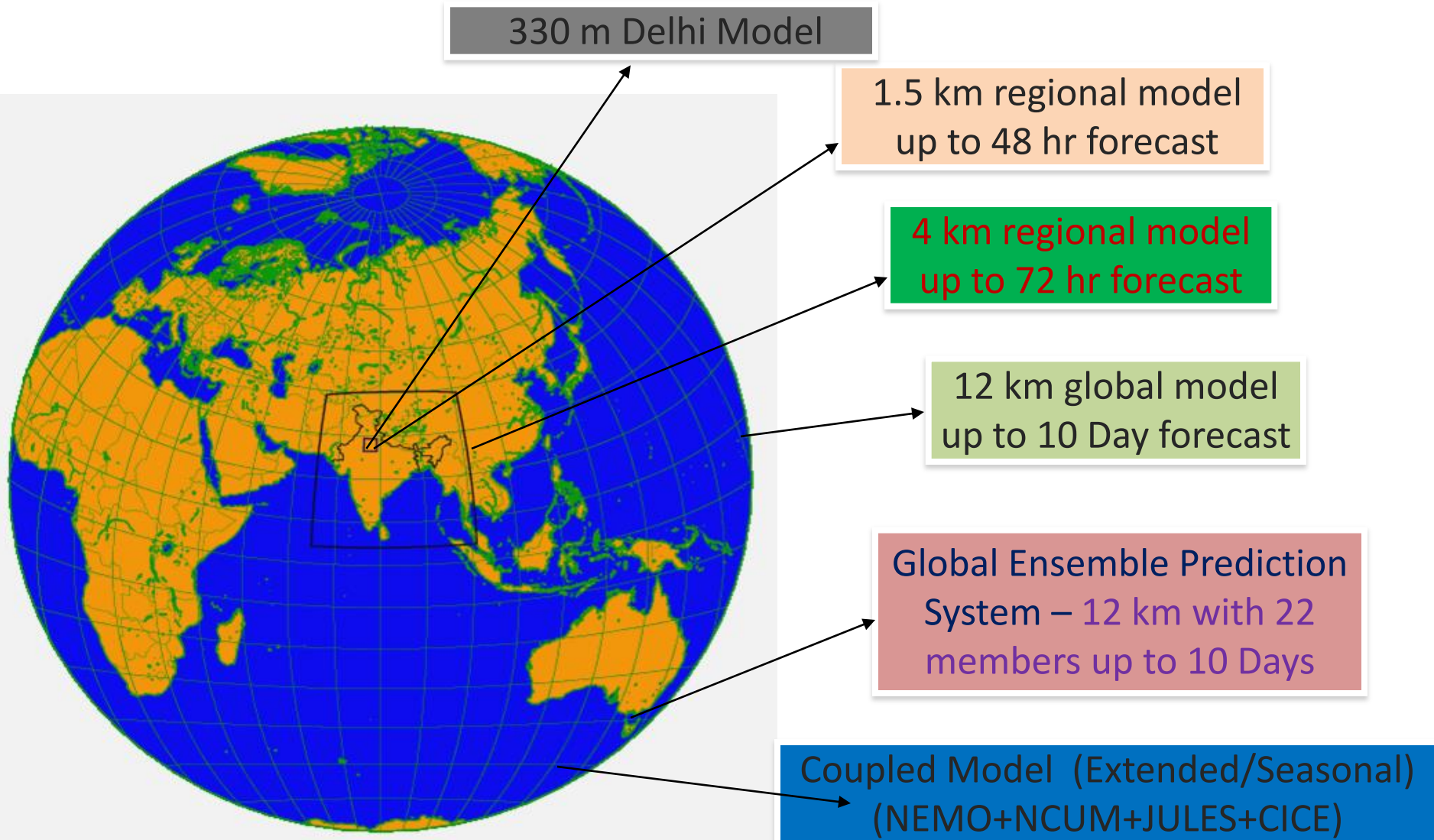
- A look at Himalayan Orography –its complexity
- Issues in handling Himalayan orography in models
- Synoptic Features in Summer & Winter over Himalayas
- Results from Global/Regional models for some recent heavy Precipitation events

Topography



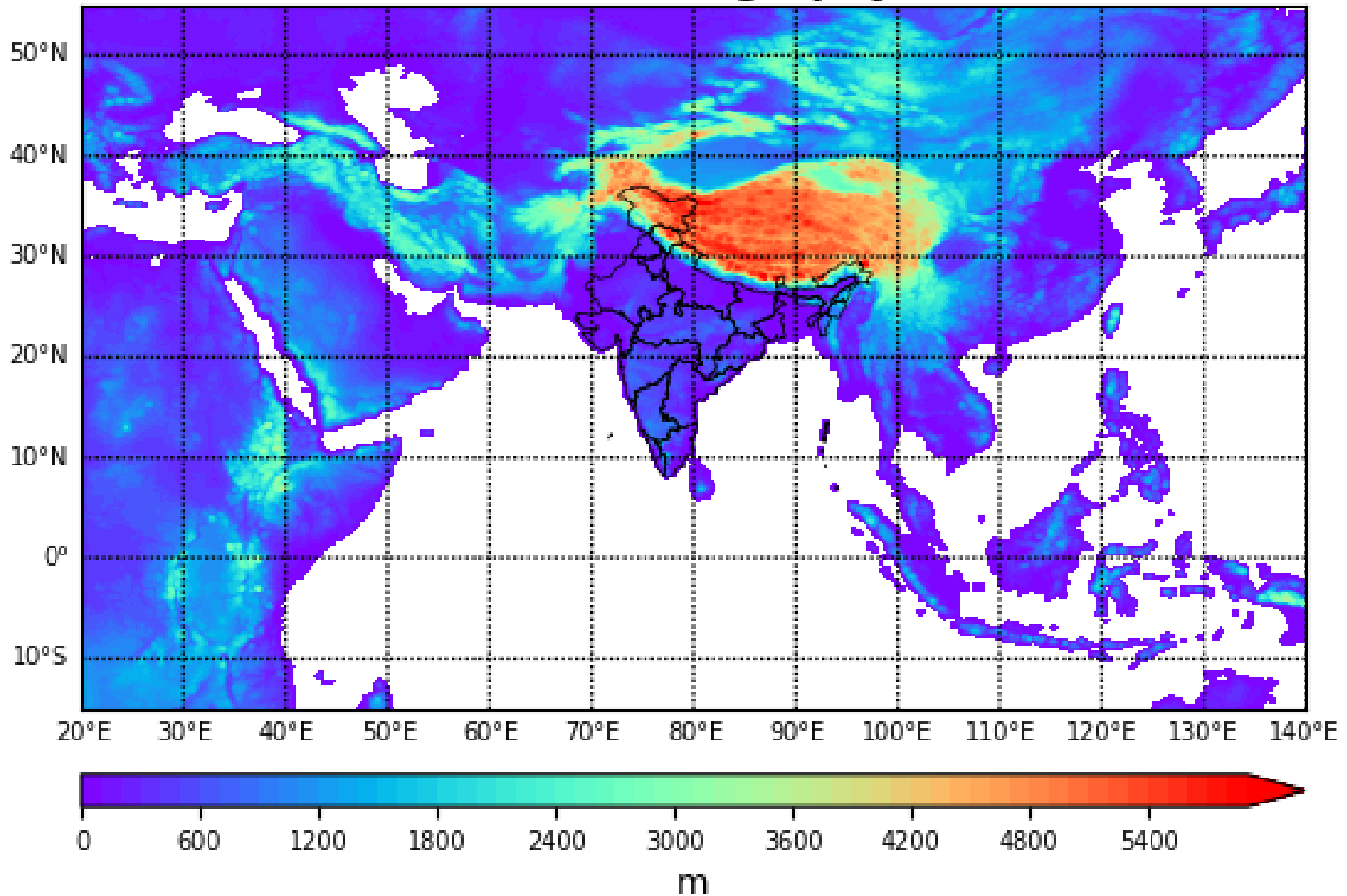
Unified Model at NCMRWF (NCUM)

Same Model for Global/Regional/Mesoscale – Seamless Model



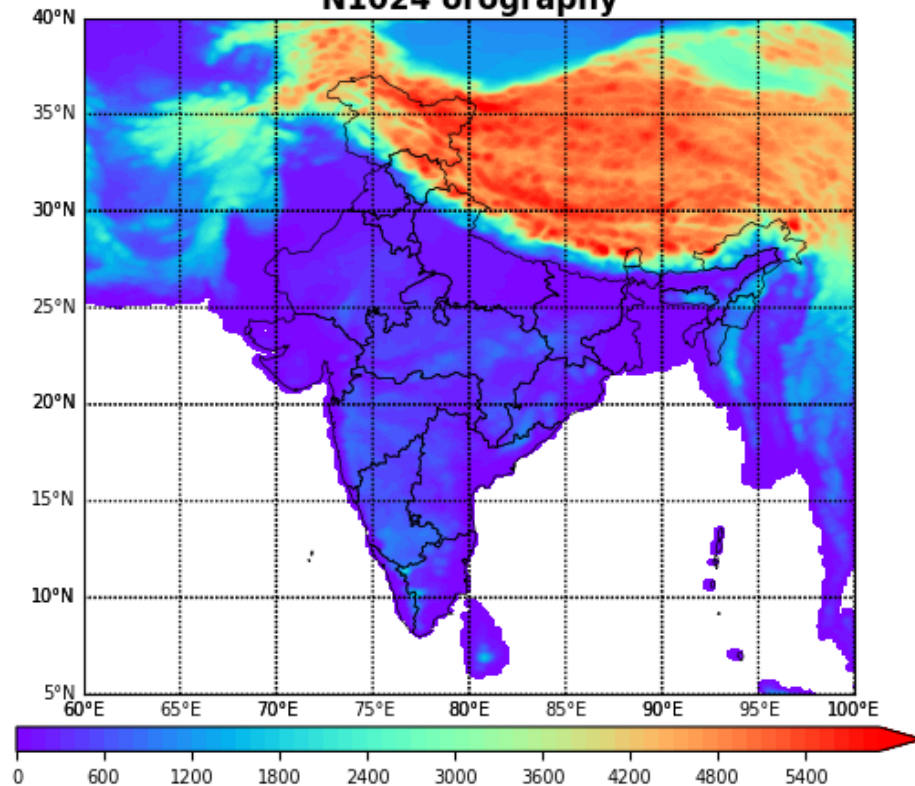
12-km Global Model Orography

N1024 orography

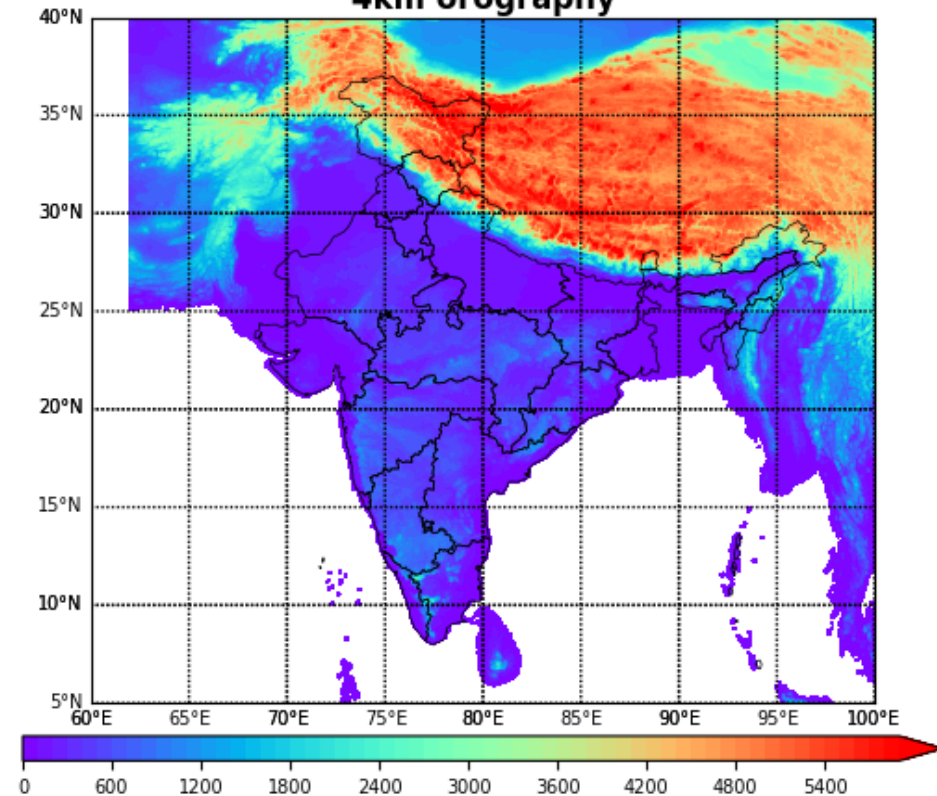


12-km v/s 4-km Orography

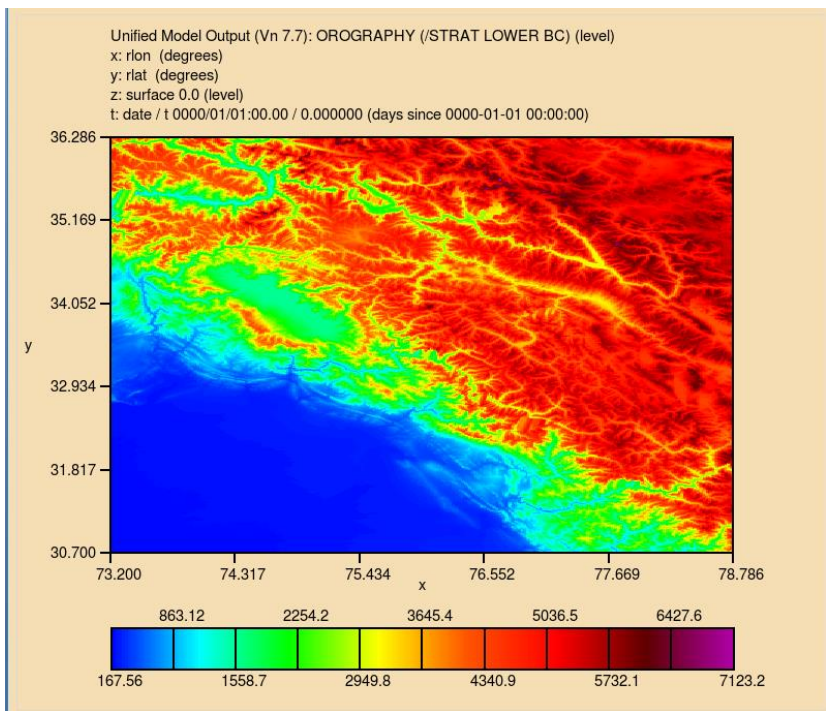
N1024 orography



4km orography



Issues in handling Himalayan orography in high resolution Regional models

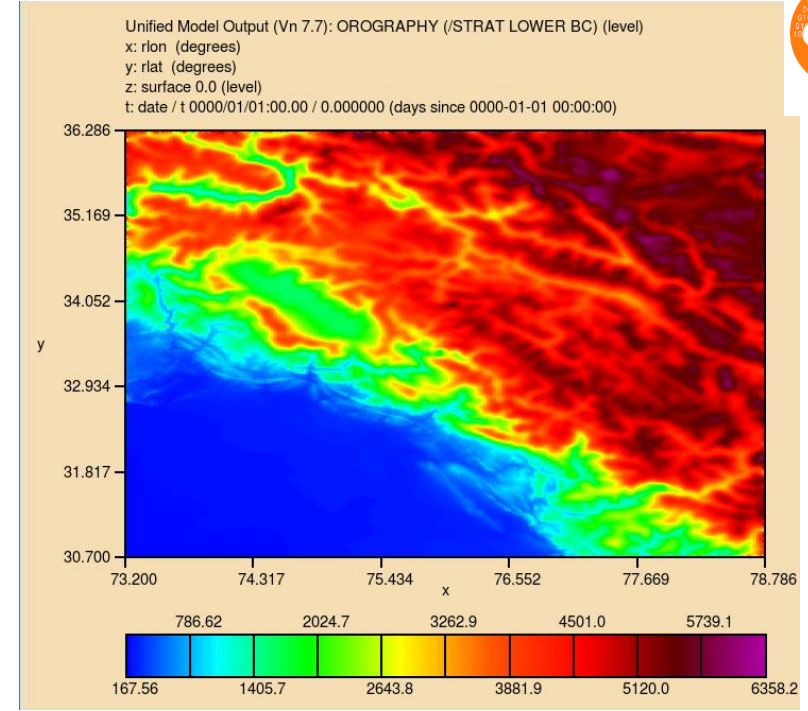


Unfiltered orography

Model aborts



- There are model failures in the first few time steps of a run, with excessive near surface winds over steep slopes of Himalayas.
- Models are unable to handle very steep orographic gradients



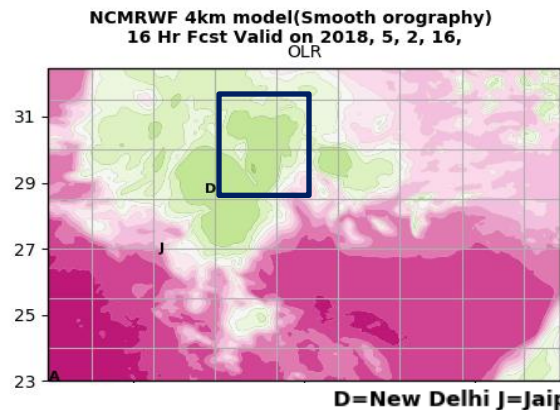
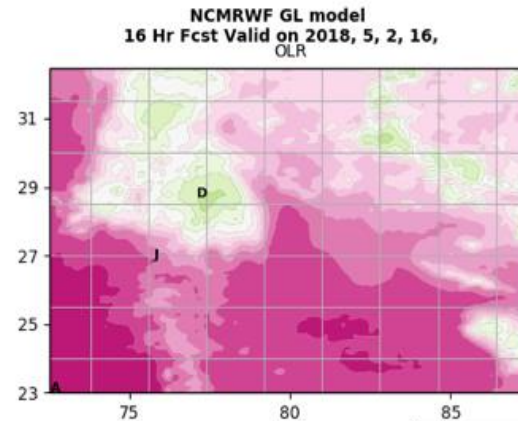
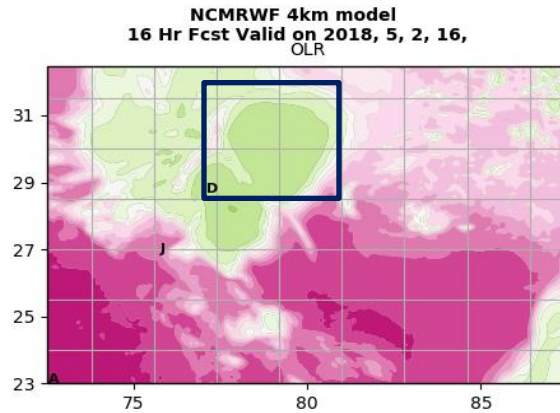
Smoothed orography



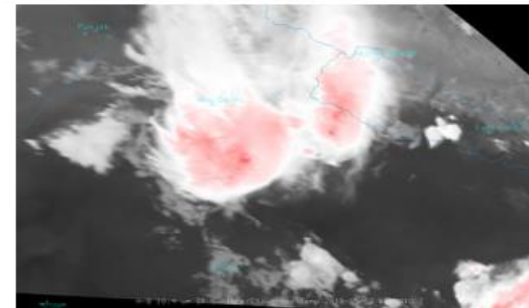
1-2-1 filtering method

- =Each sweep of this smoothing is initially only applied at points >1500m ASL.
- =The 3rd to last sweep applies the smoothing at points >1000m ASL.
- =The penultimate sweep applies the smoothing at points >500m ASL.
- =The final sweep applies the 1-2-1 smoothing at all points.

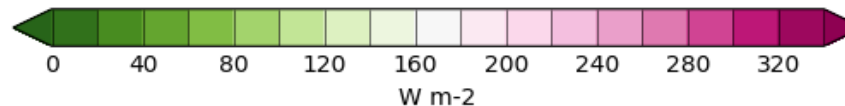
Impact of highly smoothed orography on MCS Prediction



Himawari CTT



D=New Delhi J=Jaipur A=Ahmedabad



Mesoscale
Convective
Systems

Optmisation of orography smoothing :

- ❑ Too less a smoothing lead to frequent model aborts while higher smoothing may lead to reduced skill in prediction of MCS (linked with reduced orographic lifting of air parcel)
- ❑ Coarse resolution orography in Global models often could lead to poor skill in prediction of MCS especially those triggered by orographic lifting.

Favourable Synoptic Conditions

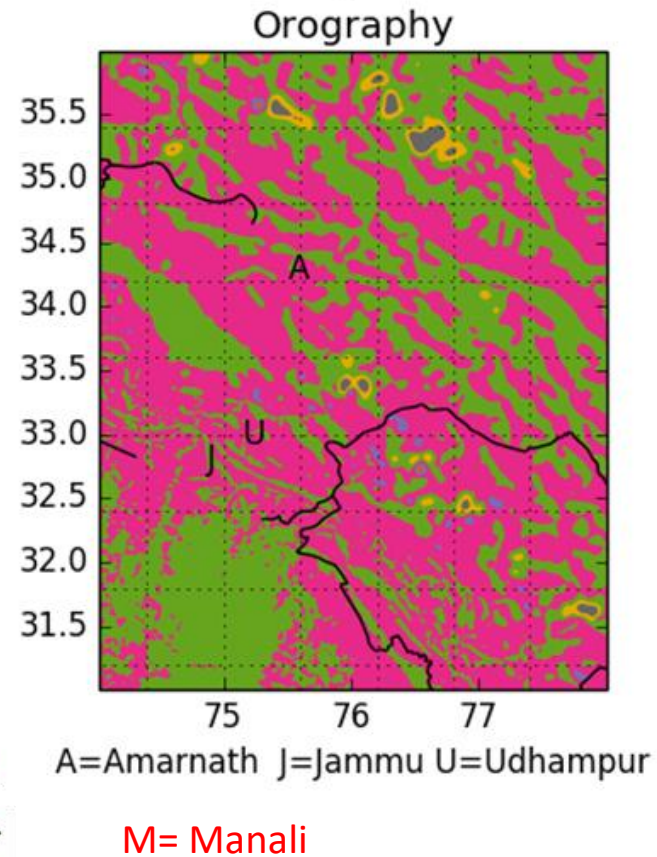
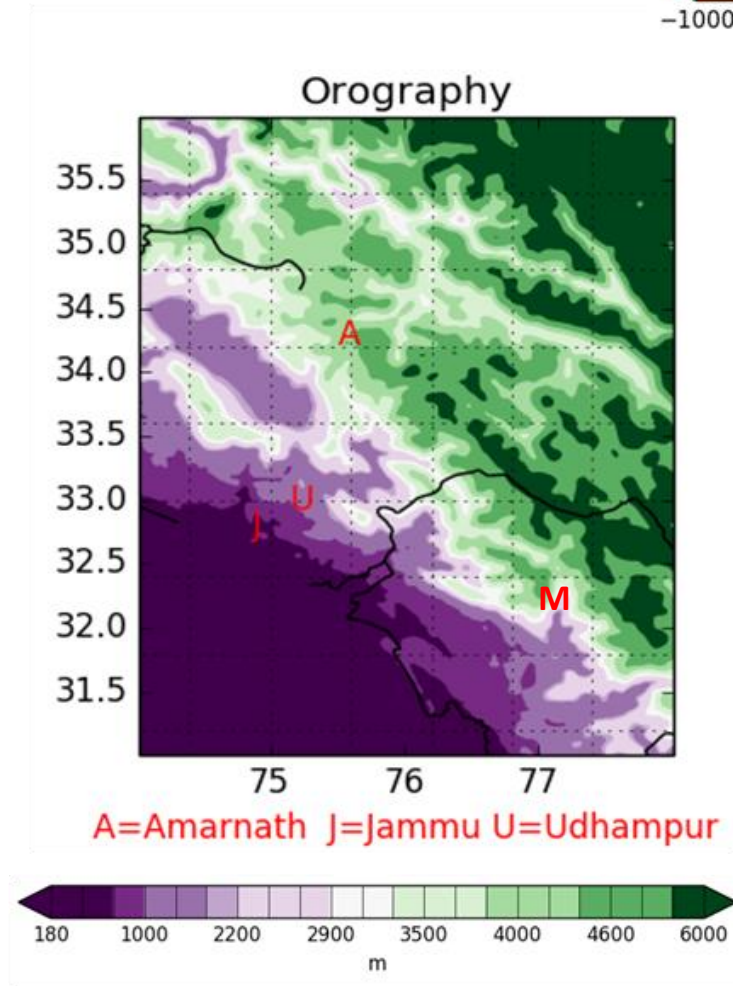
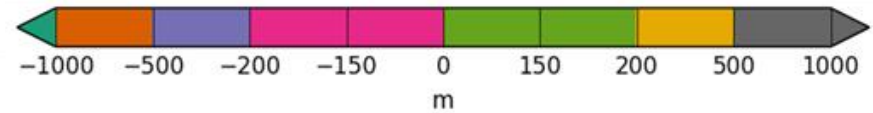
- Interaction of mid-latitude westerlies with monsoon easterlies leads to very heavy rainfall in the Himalayan region
- Movement of mid-latitude westerly troughs and induced lows – *Western Disturbance*

Shri Amarnathji Yatra model Predictions/Verifications

1.5 km Model

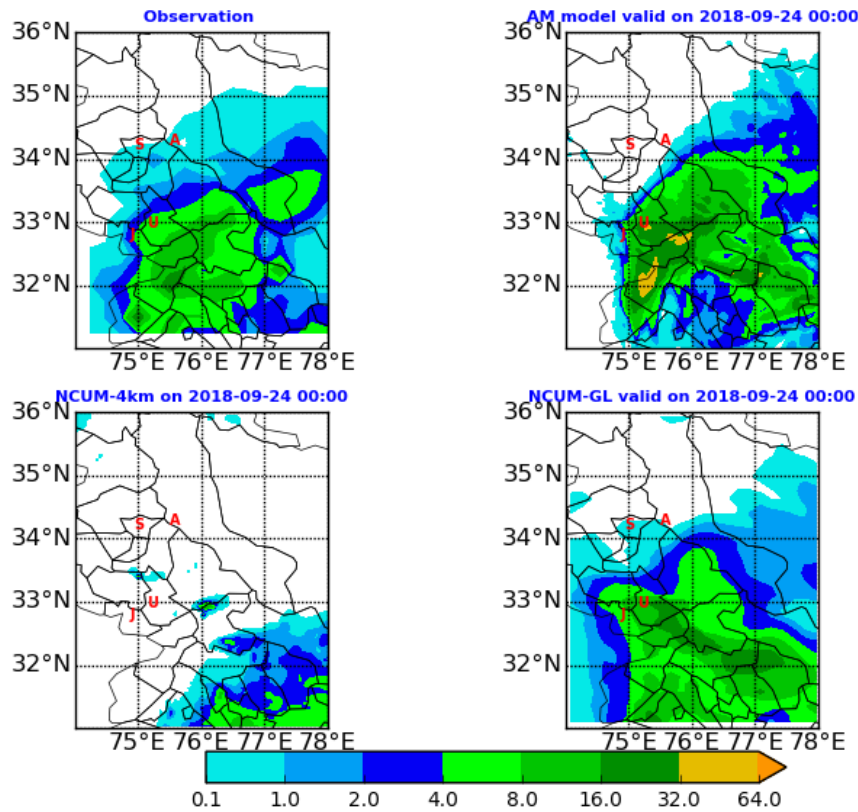
73.2-78.7 E & 30.7-36.3 N

(Case study: Manali flood)



Orography generated from CartoSat DEM (left panel). CartoSat minus SRTM DEM for Shri-AmarNathji-Yatra domain (right panel). Altitude of Amarnath is above 6000 m.

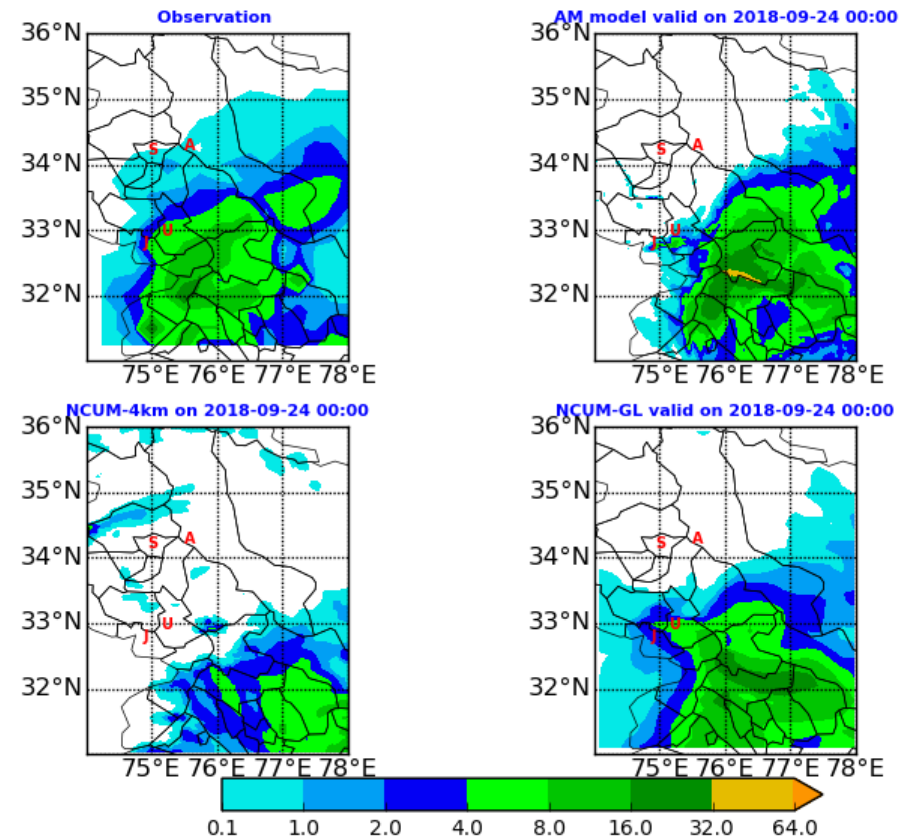
NCUM model Accum Precip(cm) Forecast based on IC 20180922 00UTC



Amarnath Yatra model shows maximum total precipitation

Day-1 verification

NCUM model Accum Precip(cm) Forecast based on IC 20180923 00UTC

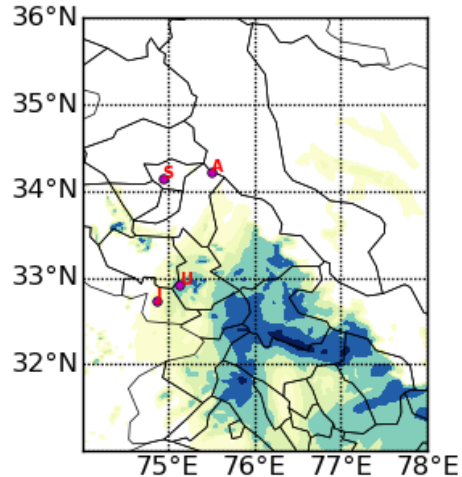


Flood image of Manali (32.23°N, 77.18°E (24-Sep-2018))

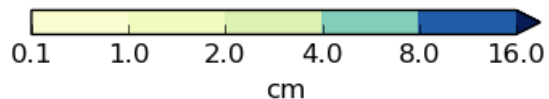




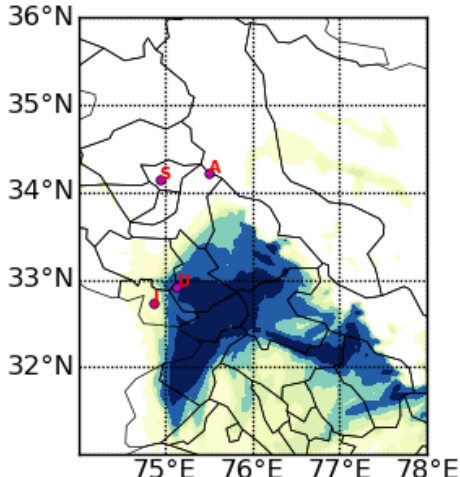
NCMRWF AY Model
24 Hr Fcst of Rain Valid on 2018-09-23 00:00



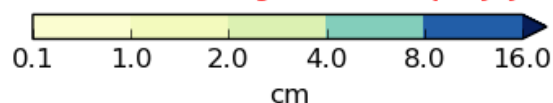
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NCMRWF AY Model
48 Hr Fcst of Rain Valid on 2018-09-24 00:00

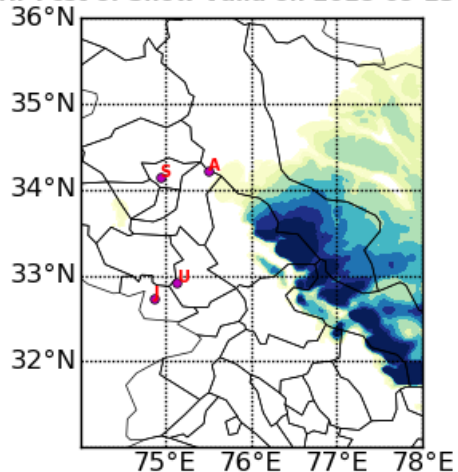


A=Amarnath S=Srinagar U=Udhampur J=Jammu

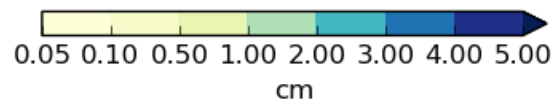


Predicted Rainfall
IC: 00 UTC 22 Sept 2018

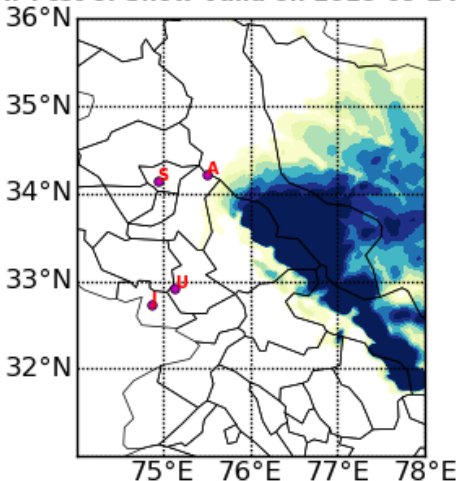
NCMRWF AY Model
24 Hr Fcst of Snow Valid on 2018-09-23 00:00



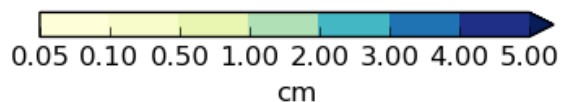
A=Amarnath S=Srinagar U=Udhampur J=Jammu



NCMRWF AY Model
48 Hr Fcst of Snow Valid on 2018-09-24 00:00

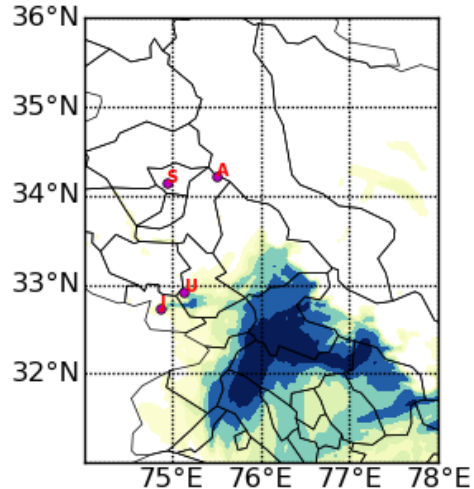


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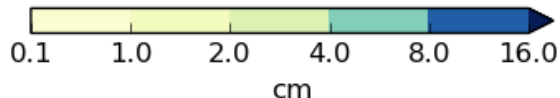


Predicted Snowfall
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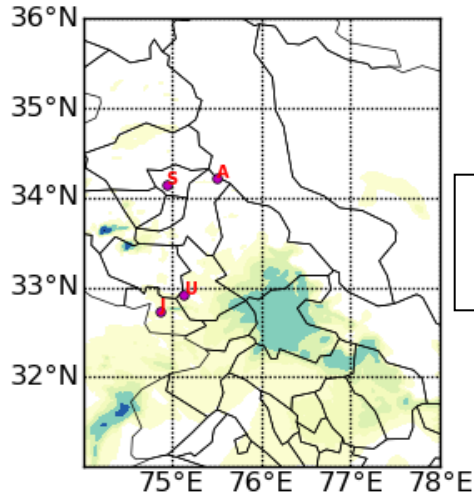
NCMRWF AY Model
24 Hr Fcst of Rain Valid on 2018-09-24 00:00



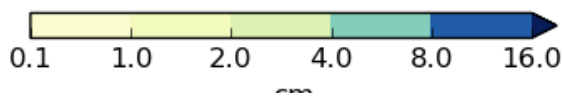
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NCMRWF AY Model
48 Hr Fcst of Rain Valid on 2018-09-25 00:00



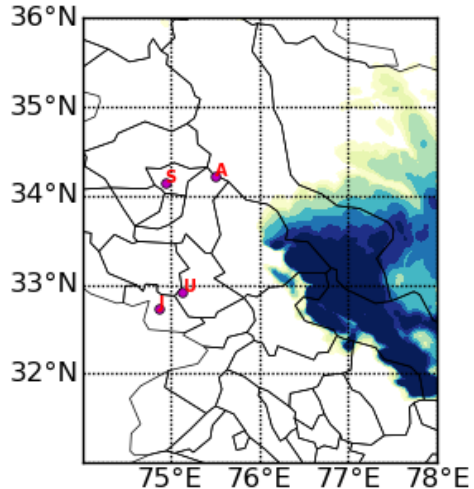
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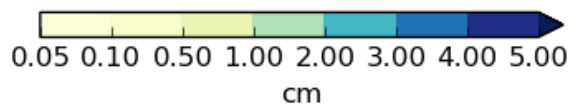
Predicted Rainfall
IC: 00 UTC 23 Sept 2018

**Model is capable in
predicting both heavy
rainfall and snowfall 48
hour ahead**

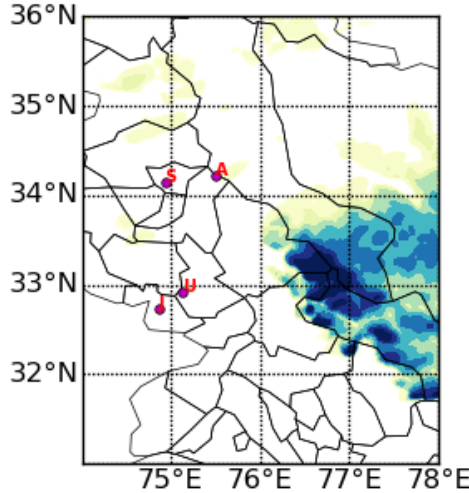
NCMRWF AY Model
24 Hr Fcst of Snow Valid on 2018-09-24 00:00



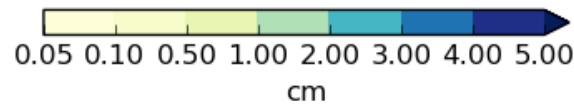
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NCMRWF AY Model
48 Hr Fcst of Snow Valid on 2018-09-25 00:00

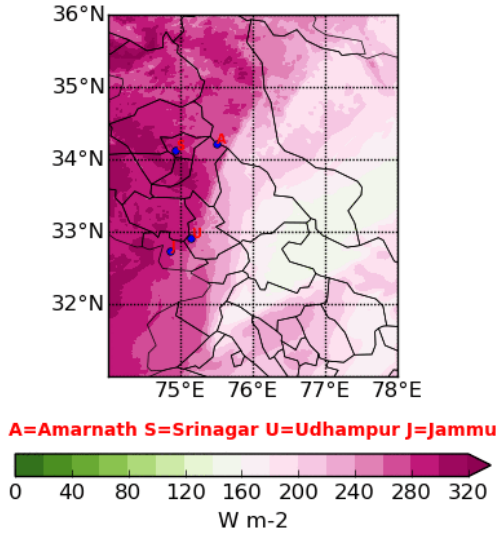


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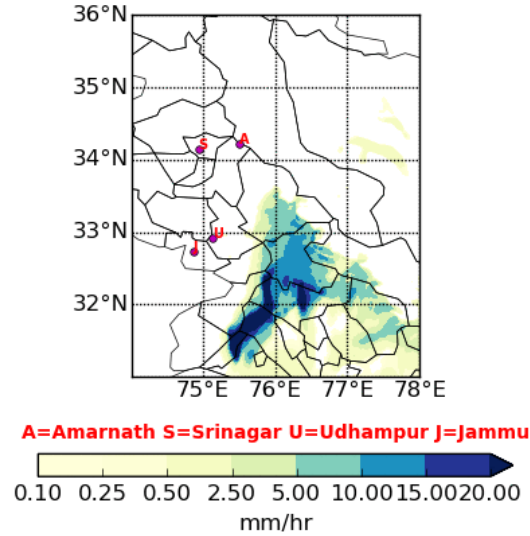


Predicted Snowfall
IC: 00 UTC 23 Sept 2018

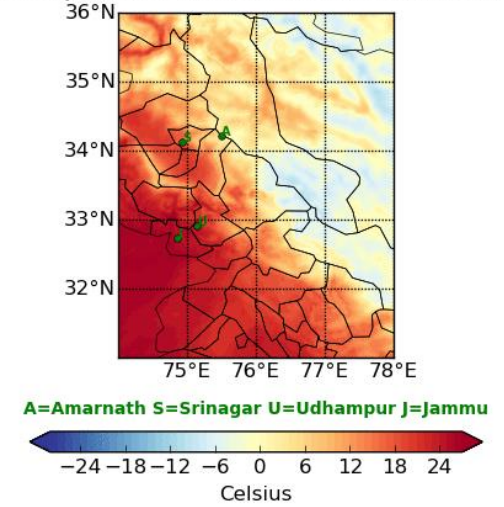
NCMRWF AY Model
5 Hr OLR Fcst Valid on 2018-09-23 05UTC



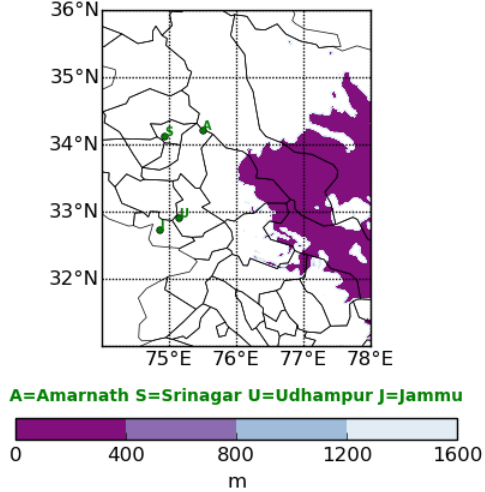
NCMRWF AY Model
5 Hr Rain amount Fcst Valid on 2018-09-23 05:00UTC



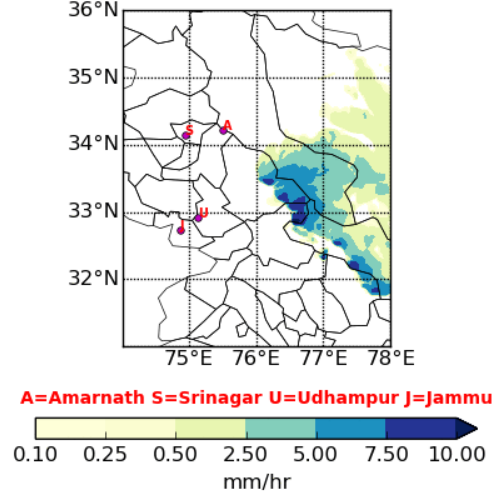
NCMRWF AY Model
5 Hr Temperature(1.5m) Fcst Valid on 2018-09-23 05UTC



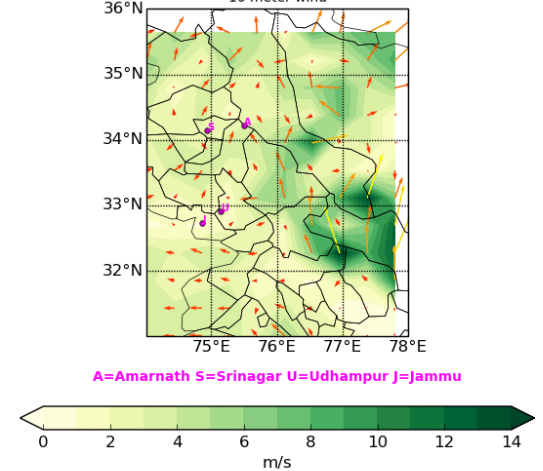
NCMRWF AY Model
5 Hr Visibility Fcst Valid on 2018-09-23 05UTC

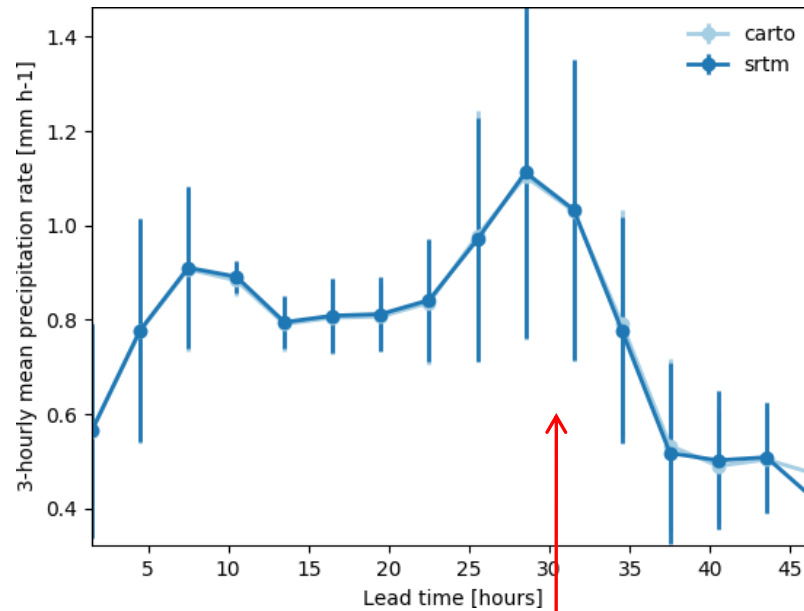


NCMRWF AY Model
5 Hr Snow amount Fcst Valid on 2018-09-23 05:00UTC

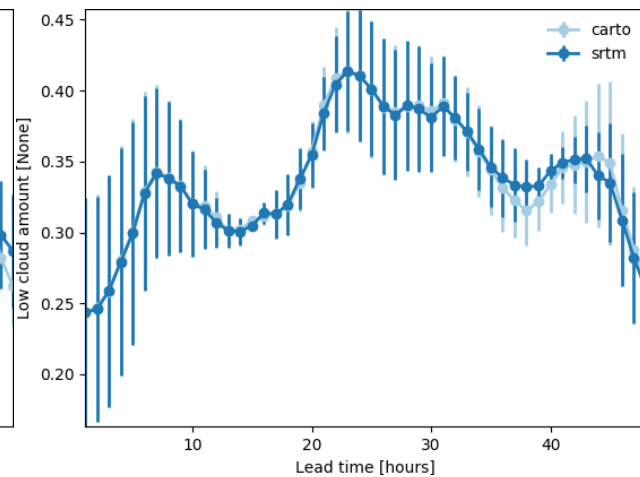
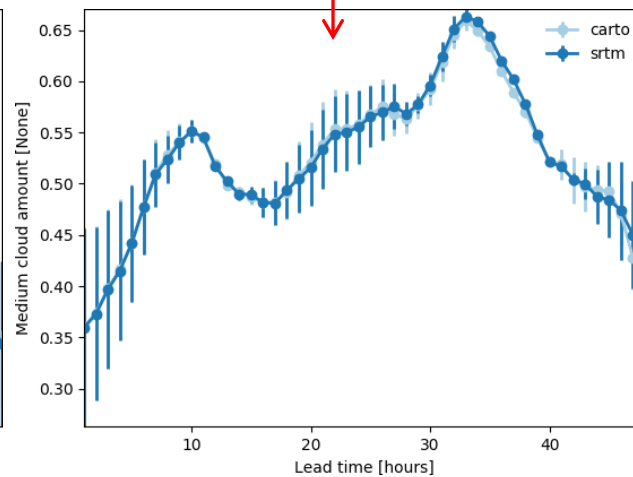
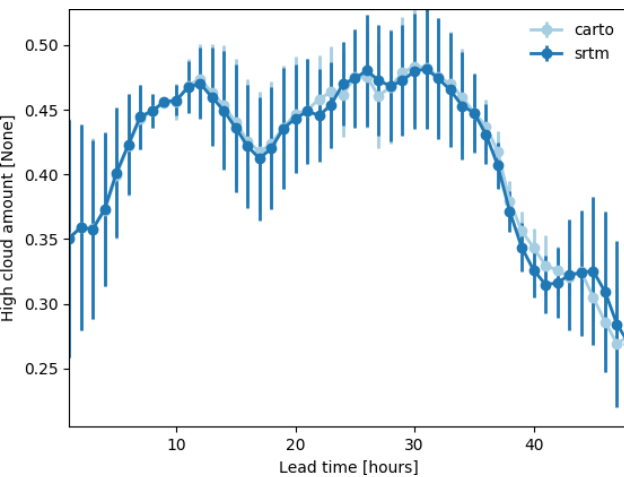


NCMRWF AY Model
5 Hr Fcst Valid on 2018-09-23 05UTC
 10 meter wind





Mid-level clouds gives Higher cloud fraction and pattern of correlation with mean precipitation over Model domain



Some of the early studies involving mountain induced heavy rains at NCMRWF

Simulation of a Himalayan cloudburst event

SOMESHWAR DAS^{1,*}, RAGHAVENDRA ASHRIT¹ and M W MONCRIEFF²

¹National Center for Medium Range Weather Forecasting, Noida 201 307, India.

²National Center for Atmospheric Research, Boulder CO 80301, USA.

*e-mail: somesh@ncmrwf.gov.in

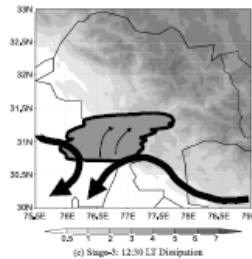
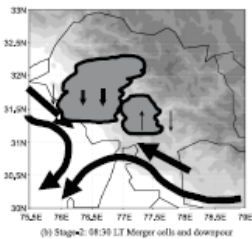
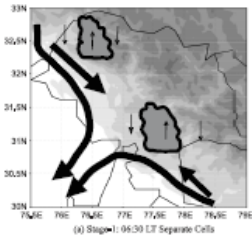



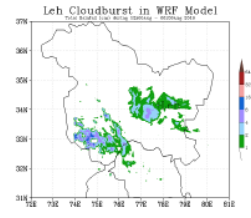
Figure 15. Conceptual model of a cloudburst (a) separate cells, (b) merger of cells and downpour and (c) dissipation.


NMRF/RR/10/2010

RESEARCH REPORT

Investigating the Leh 'Cloudburst'

Raghavendra Ashrit



October 2010

This is an internal report from NCMRWF
Permission should be obtained from NCMRWF to quote from this report.

National Centre for Medium Range Weather Forecasting
 Ministry of Earth Sciences
 A-50, Sector 62, NOIDA – 201307, INDIA

Weather and Climate Extremes 4 (2014) 22–34



Contents lists available at [ScienceDirect](http://www.sciencedirect.com)

Weather and Climate Extremes

journal homepage: www.elsevier.com/locate/wace



Forecasting the heavy rainfall during Himalayan flooding—June 2013

Anumeha Dube*, Raghavendra Ashrit, Amit Ashish, Kuldeep Sharma, G.R. Iyengar, E.N. Rajagopal, Swati Basu

National Centre for Medium Range Weather Forecasting (NCMRWF), Earth System Science Organisation (ESSO), Ministry of Earth Sciences, A-50, Industrial Area, Phase-II, Sector 62, Noida, Uttar Pradesh 201309, India

Uttarkhand Floods

- From 13 to 17 June **2013**, the Indian state of **Uttarakhand** and adjoining areas received **heavy rainfall**, about 375% more than the normal **rainfall** during a monsoon.



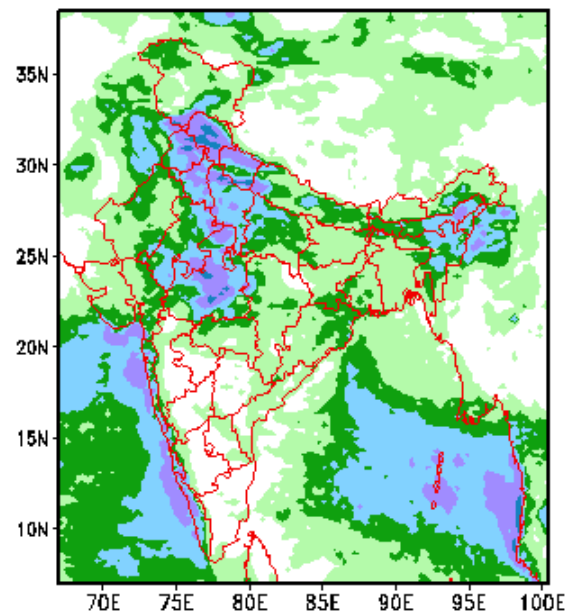
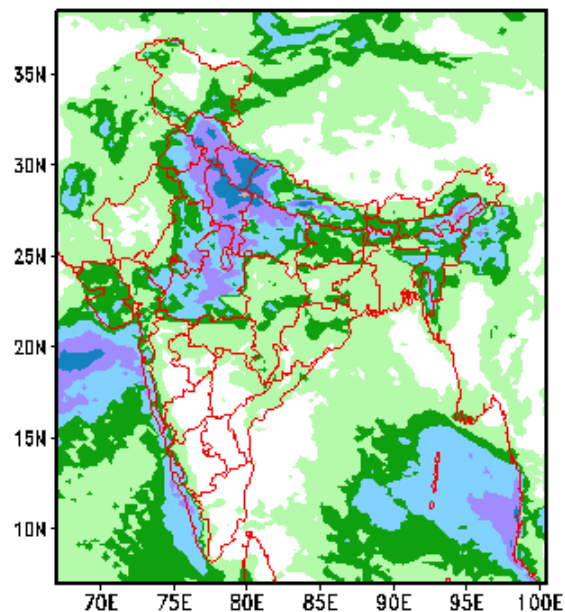
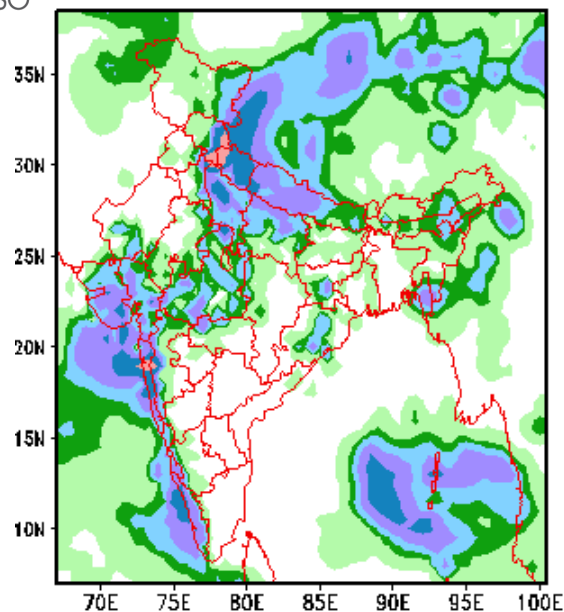
- Verification of Forecasts for 17th and 18th June 2013
 - _NCUM and UKMO
 - ×Rainfall and Circulation

- 17th June 2013: Western Uttarakhand & Himachal
- 18th June 2013 : Eastern Uttarakhand
- Synoptic Meteorological events of significance
 - Western Disturbance and the trough associated with it moving west to east over North India 17-19th June 2013
 - Well marked low pressure area located over NE Rajasthan and Haryana 17-19th June 2013.

(a) IMD OBS

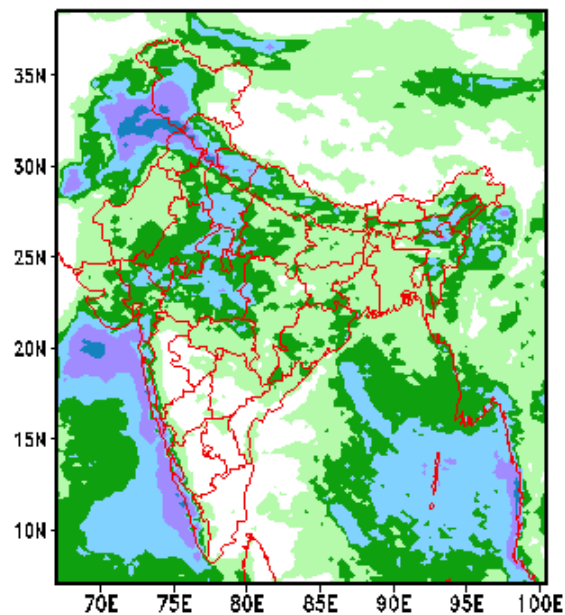
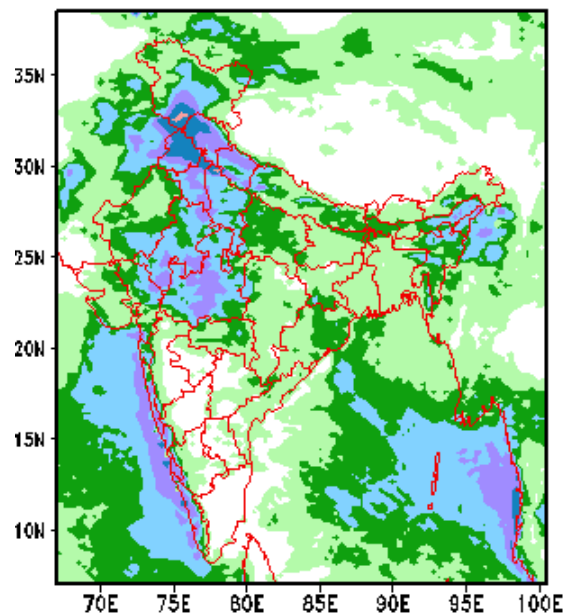
(b) DAY-1

(c) DAY-3



(d) DAY-5

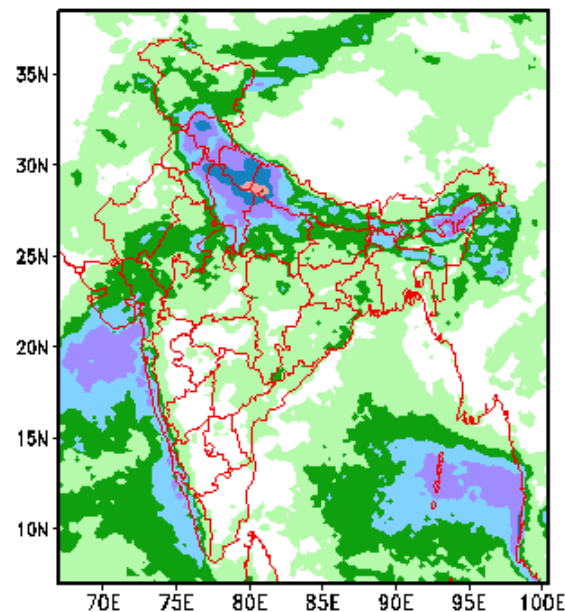
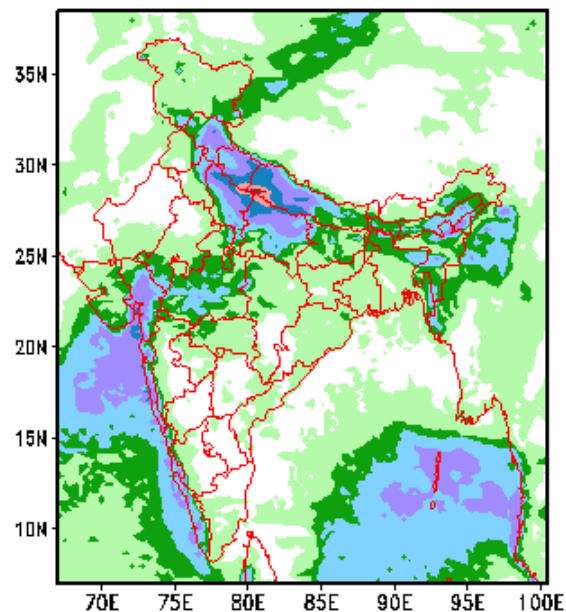
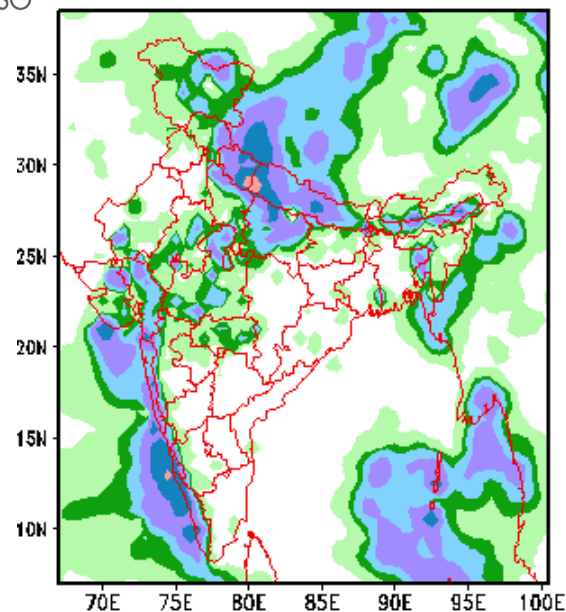
(e) DAY-7



(a) IMD OBS

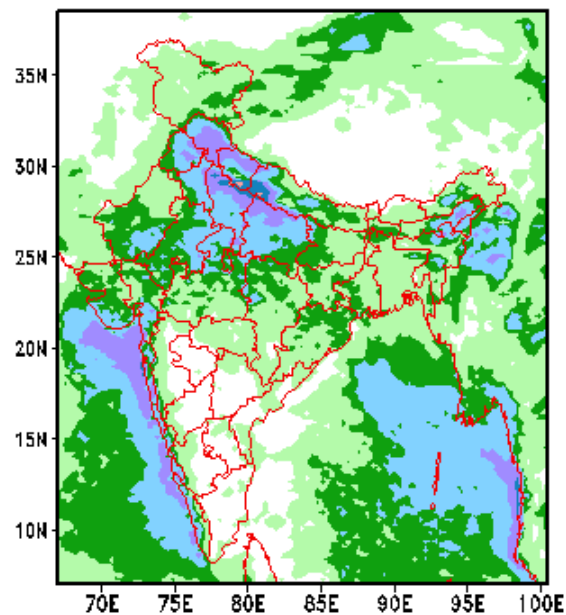
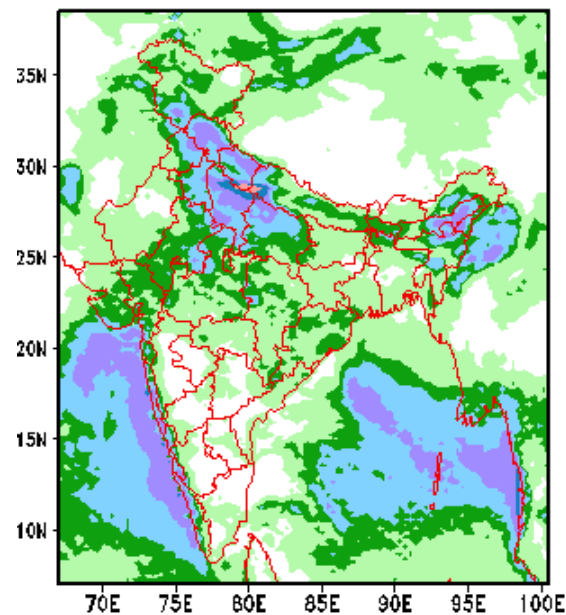
(b) DAY-1

(c) DAY-3

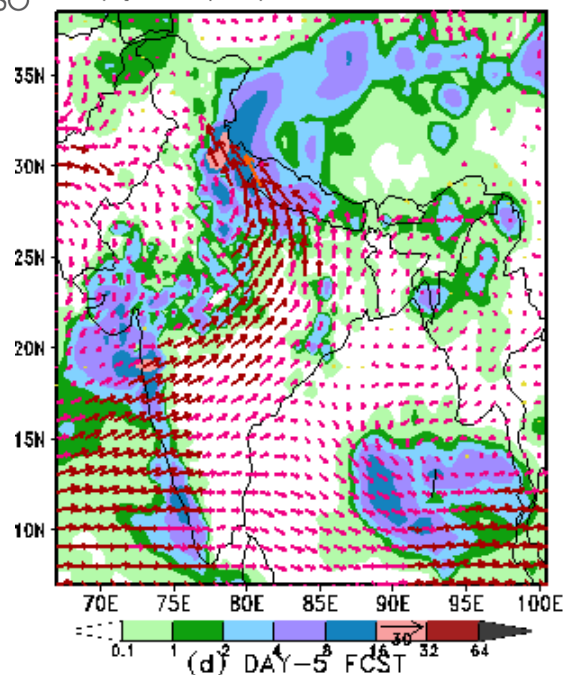


(d) DAY-5

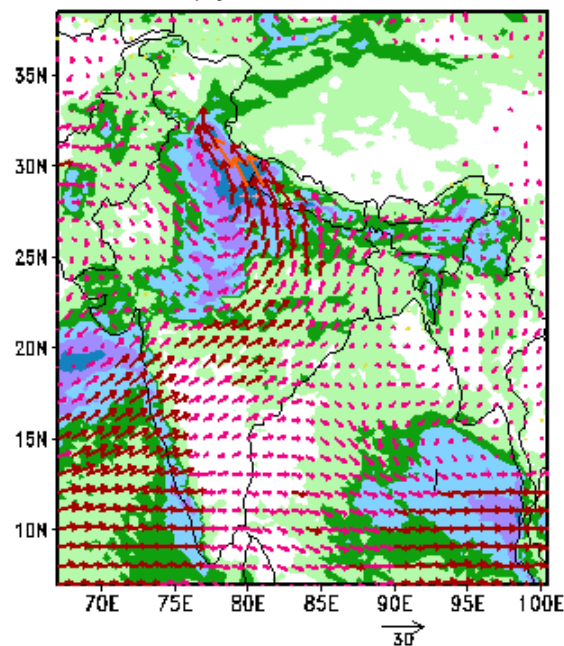
(e) DAY-7



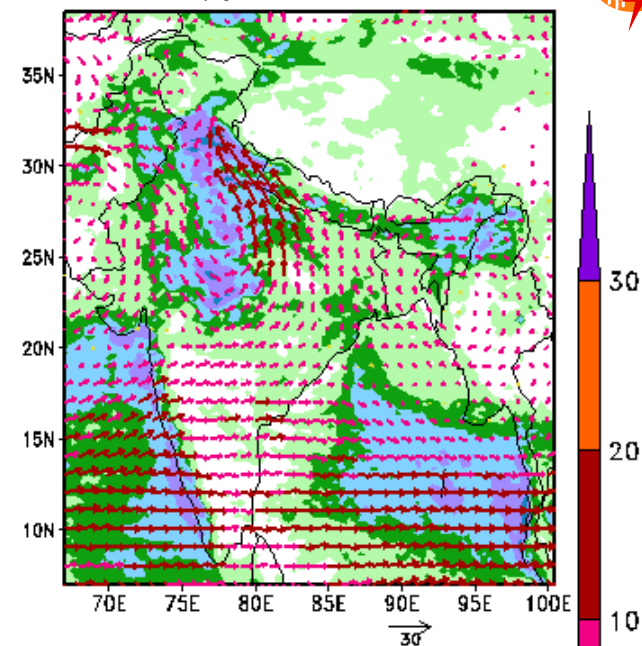
(a) OBS(IMD) RF & ANA WIND



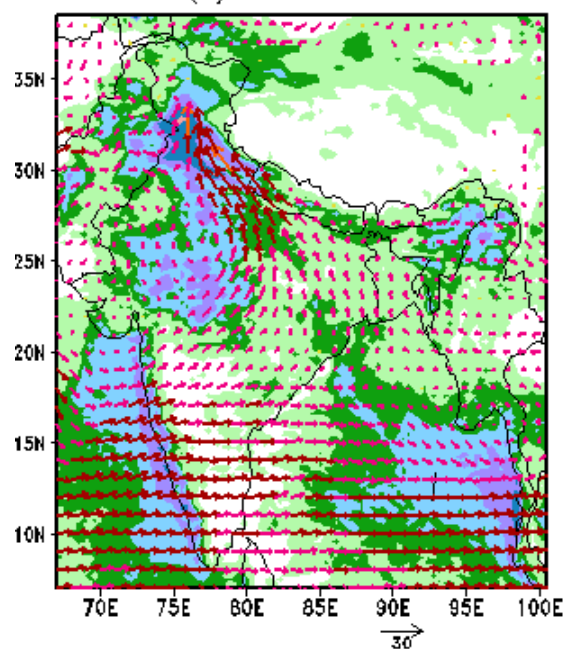
(b) DAY-1 FCST



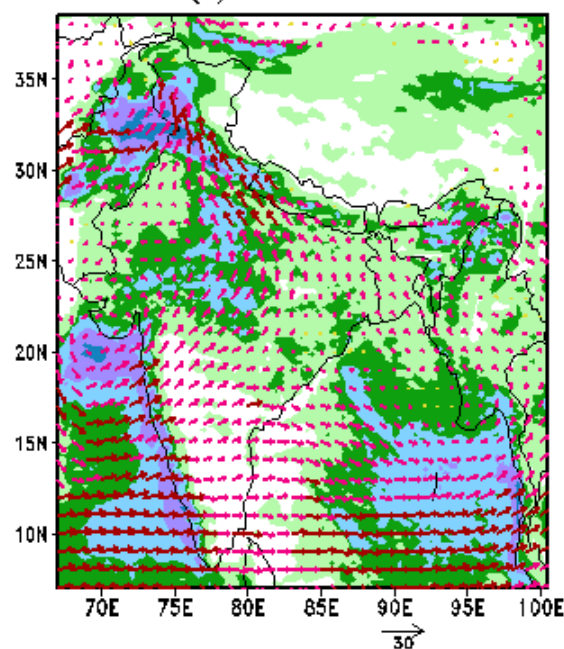
(c) DAY-3 FCST



(d) DAY-5 FCST

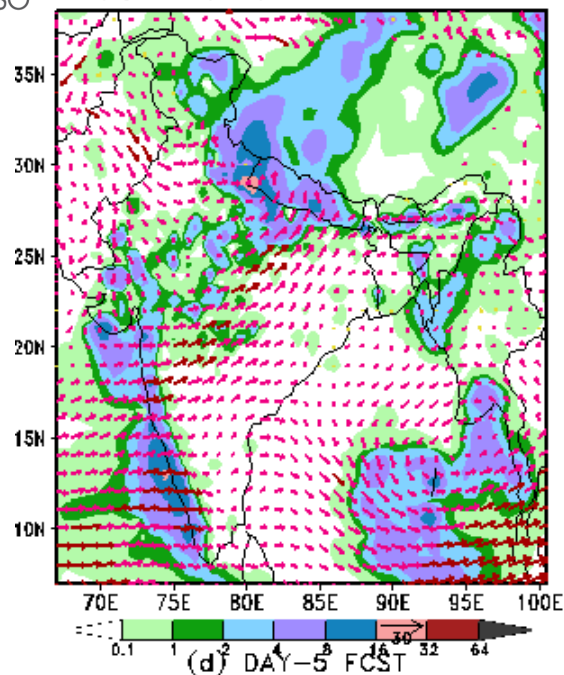


(e) DAY-7 FCST

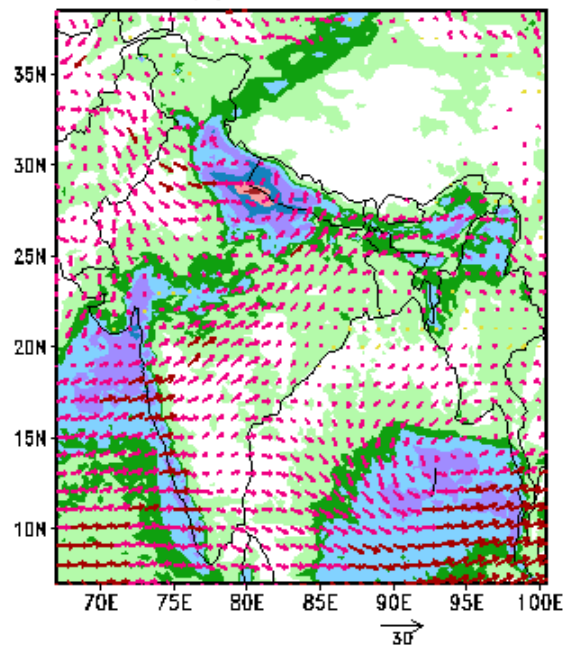


Forecasts valid for 17th June is much to the north-west of observed event.

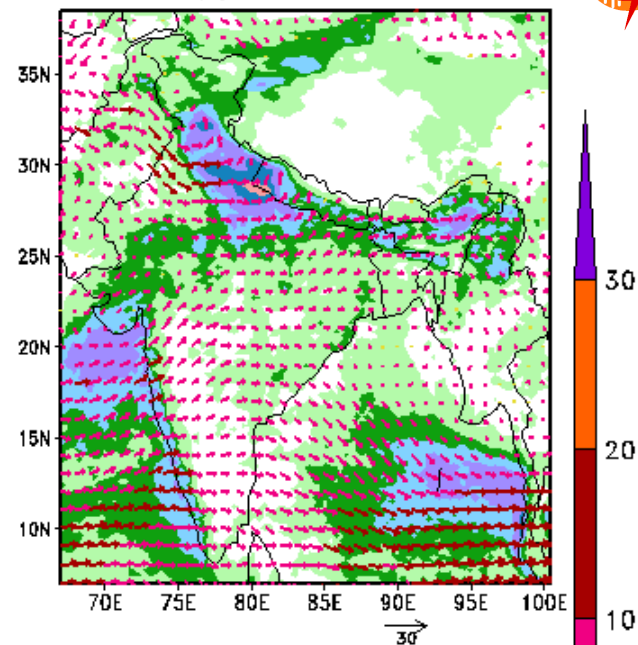
(a) OBS(IMD) RF & ANA WIND



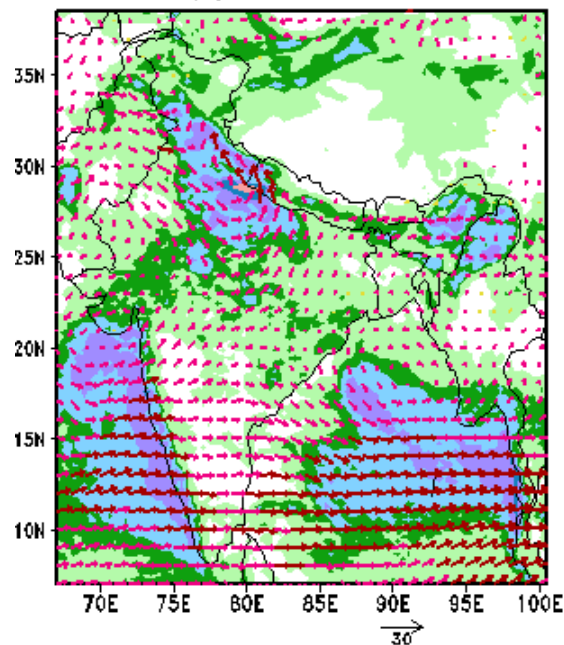
(b) DAY-1 FCST



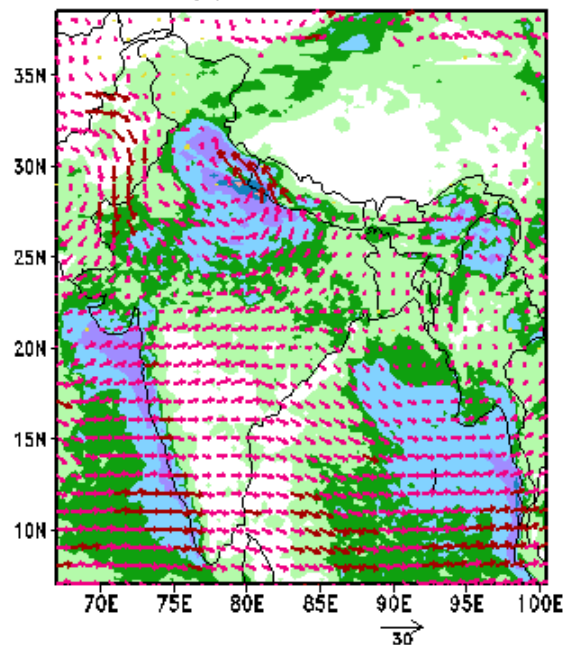
(c) DAY-3 FCST



(d) DAY-5 FCST



(e) DAY-7 FCST



Forecasts valid for 18th June seems to be accurate in amount and location

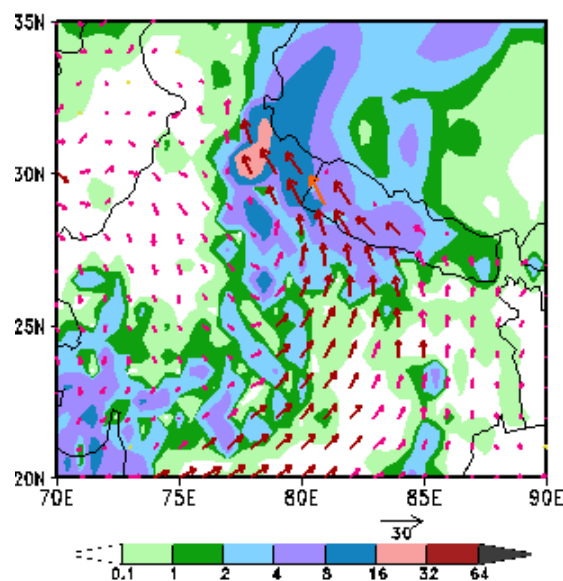
Forecasts over the Uttarakhand Region NCUM v/s UKMO - Global

- ⌣ Cyclonic circulation weakened over NE Rajasthan and Haryana on 17-19th June 2013
- ⌣ UKMO Forecasts predict the position and intensity more accurately
- ⌣ Accurate rainfall amount and location in the UKMO forecasts especially valid for 18th June 2013 could be attributed to forecast moderate intensity of the low pressure system and correct positioning of the same. (Shown in next few slides)

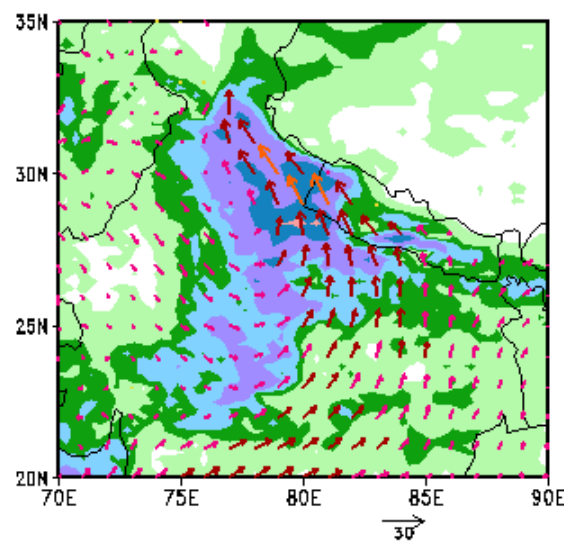
(a) OBS(IND) RF & ANA WIND

(b) DAY-1 FCST

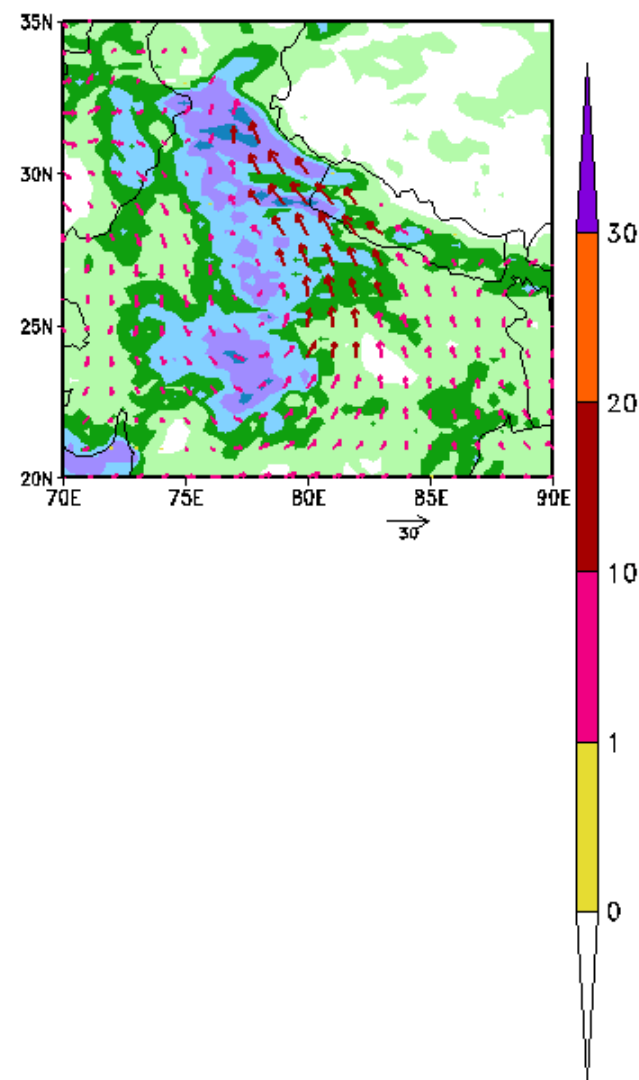
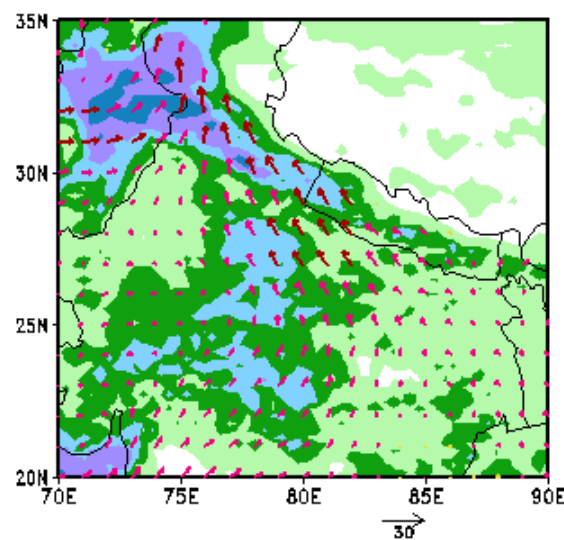
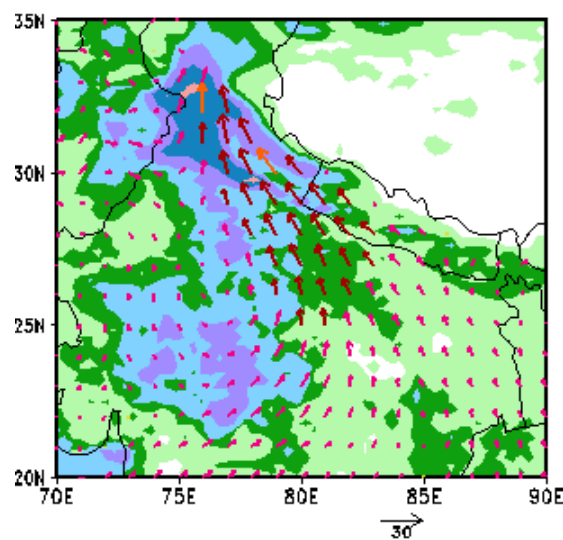
(c) DAY-3 FCST



(d) DAY-5 FCST



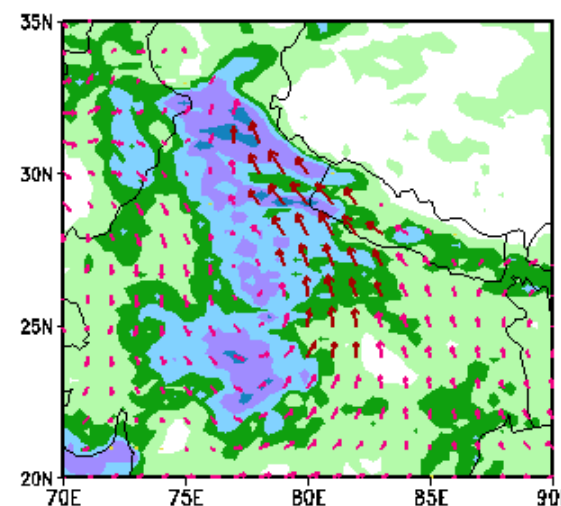
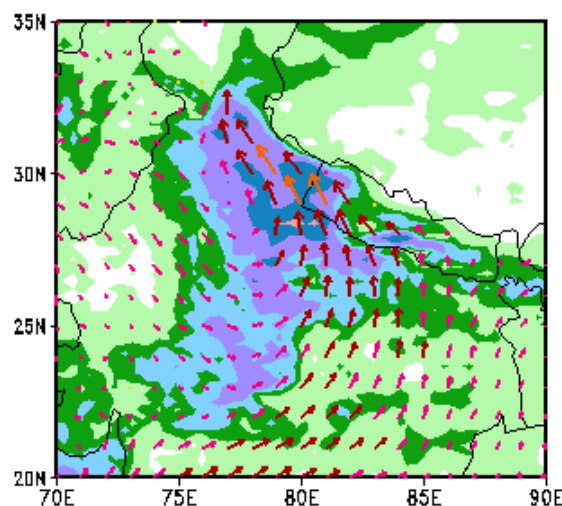
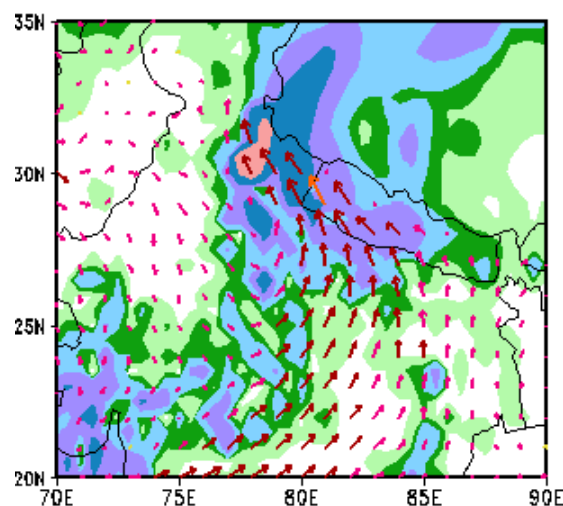
(e) DAY-7 FCST



(a) OBS(IMD) RF & ANA WIND

(b) DAY-1 FCST

(c) DAY-3 FCST

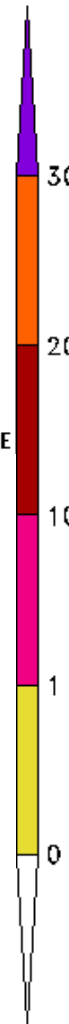
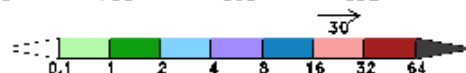
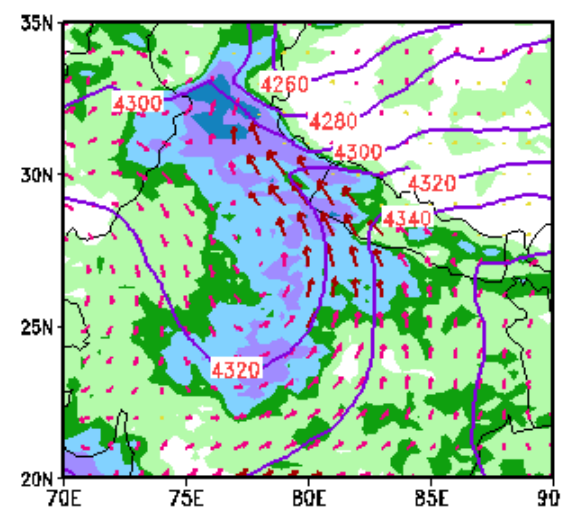
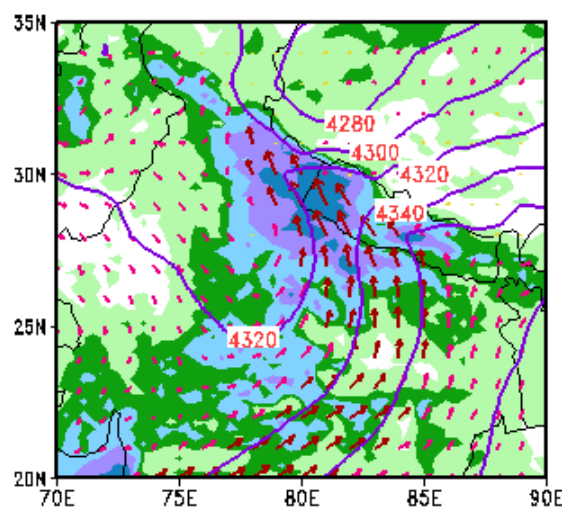
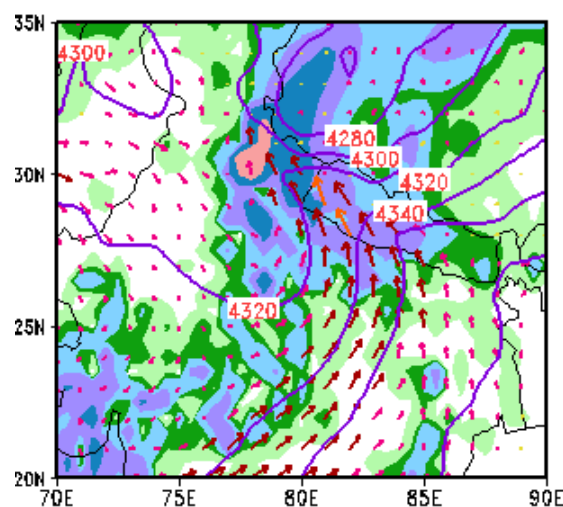


UKMO: RAINFALL WIND & GEOP HT (600 hPa) VALID FOR 17jun2013

(a) OBS(IMD) RF & ANA WIND

(b) DAY-1 FCST

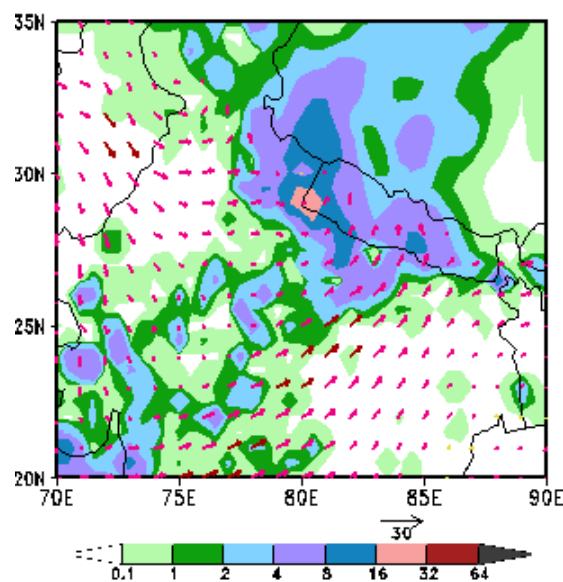
(c) DAY-3 FCST



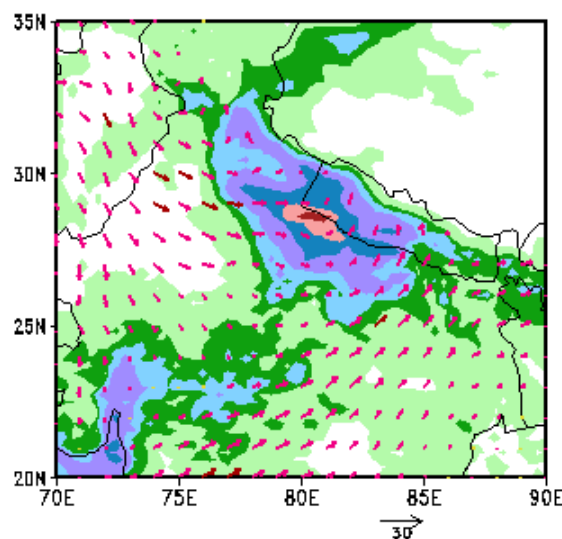
(a) OBS(IMD) RF & ANA WIND

(b) DAY-1 FCST

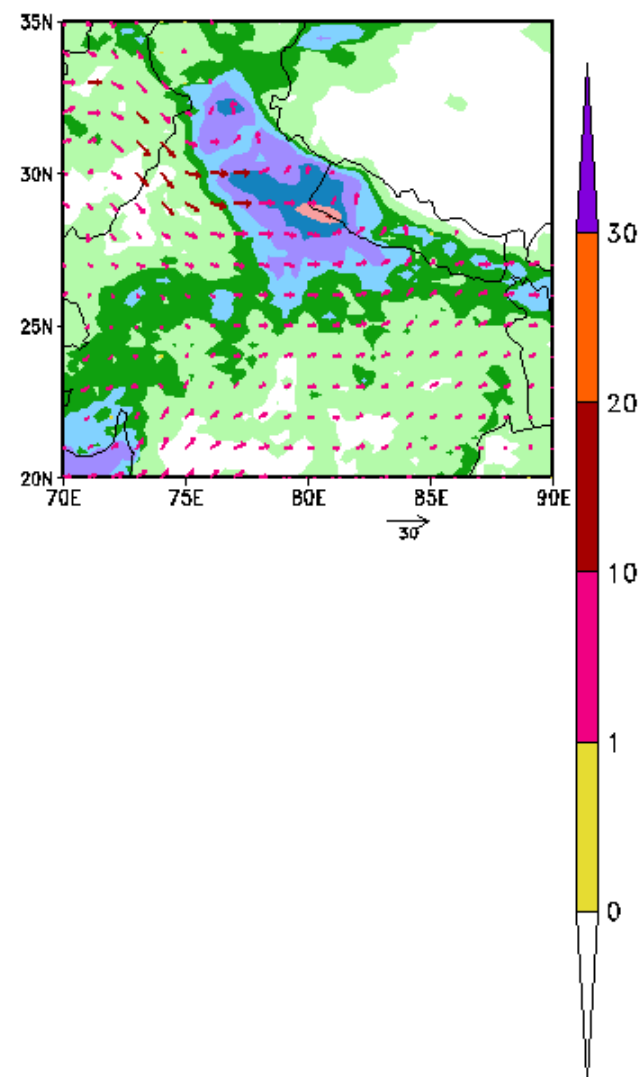
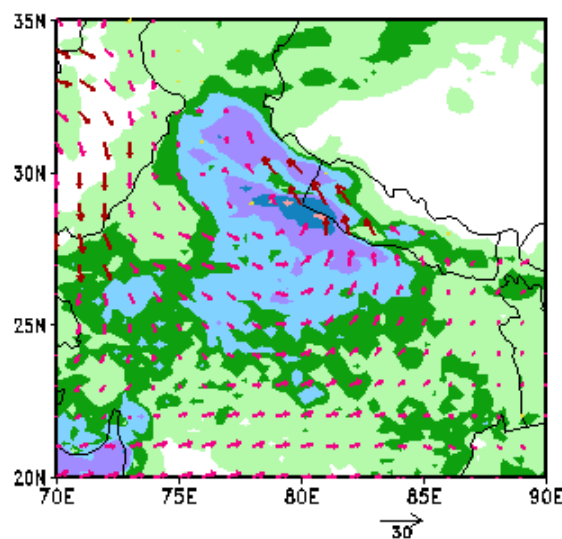
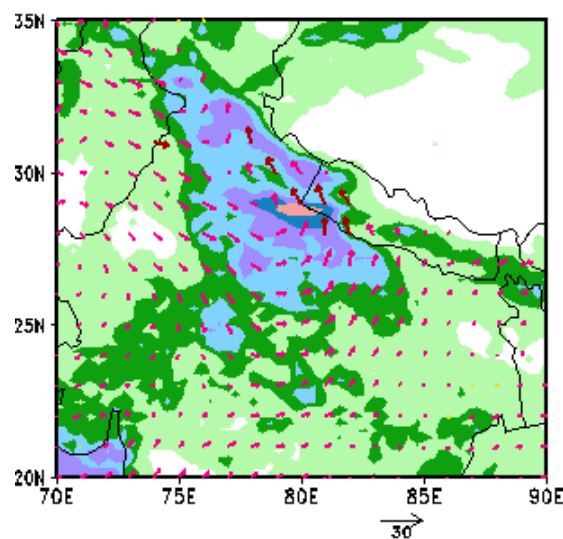
(c) DAY-3 FCST



(d) DAY-5 FCST



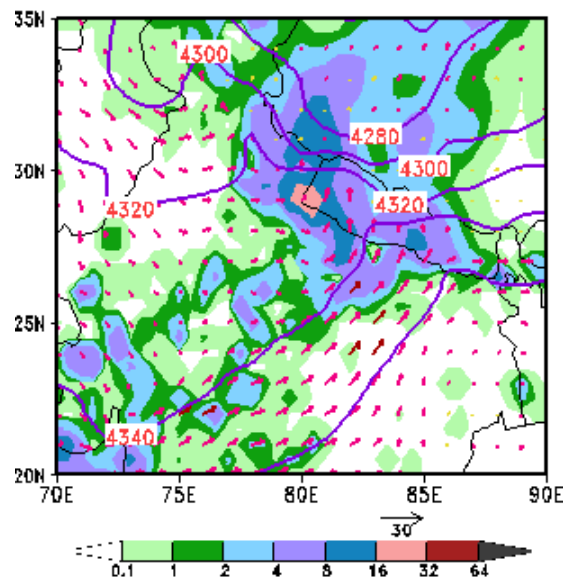
(e) DAY-7 FCST



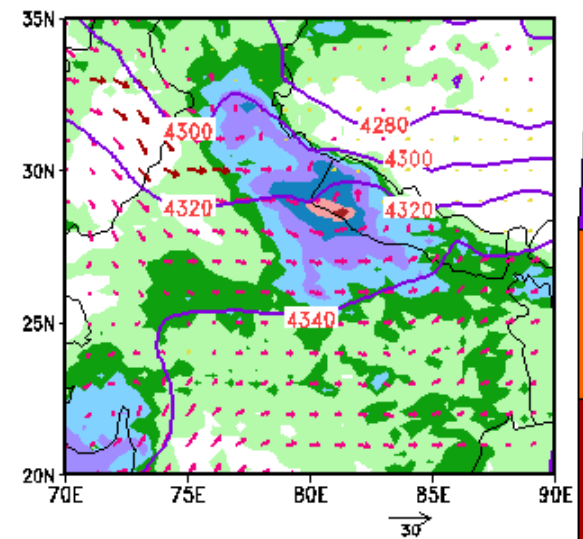
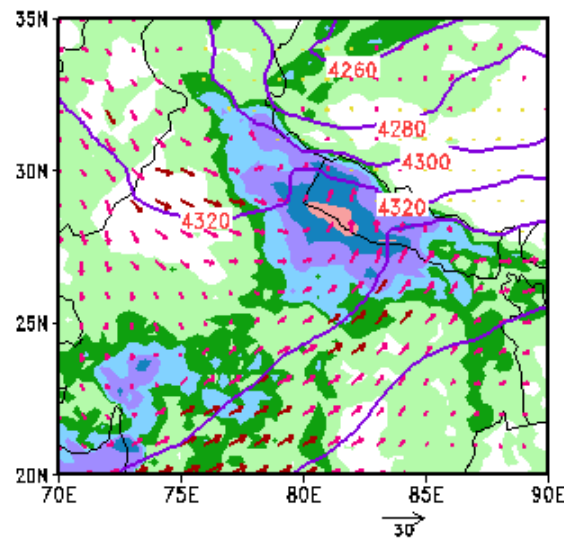
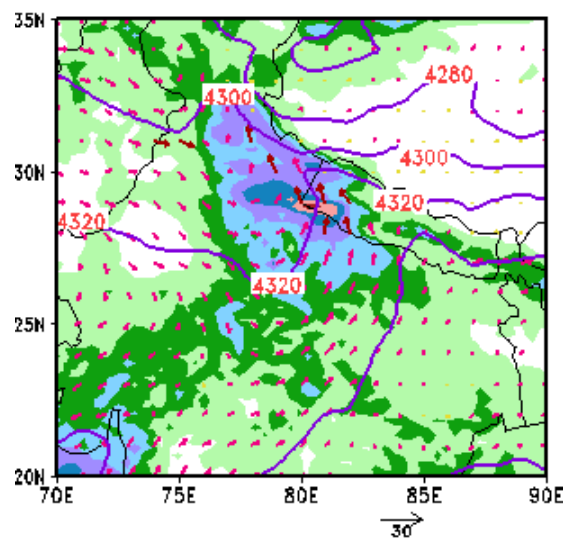
(a) OBS(IND) RF & ANA WIND

(b) DAY-1 FCST

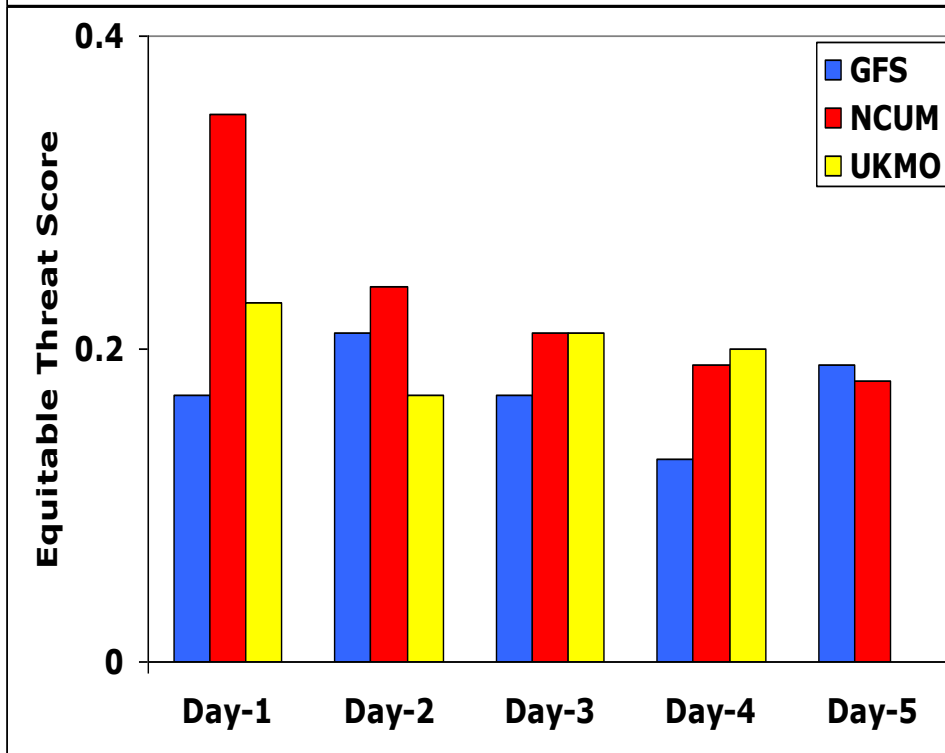
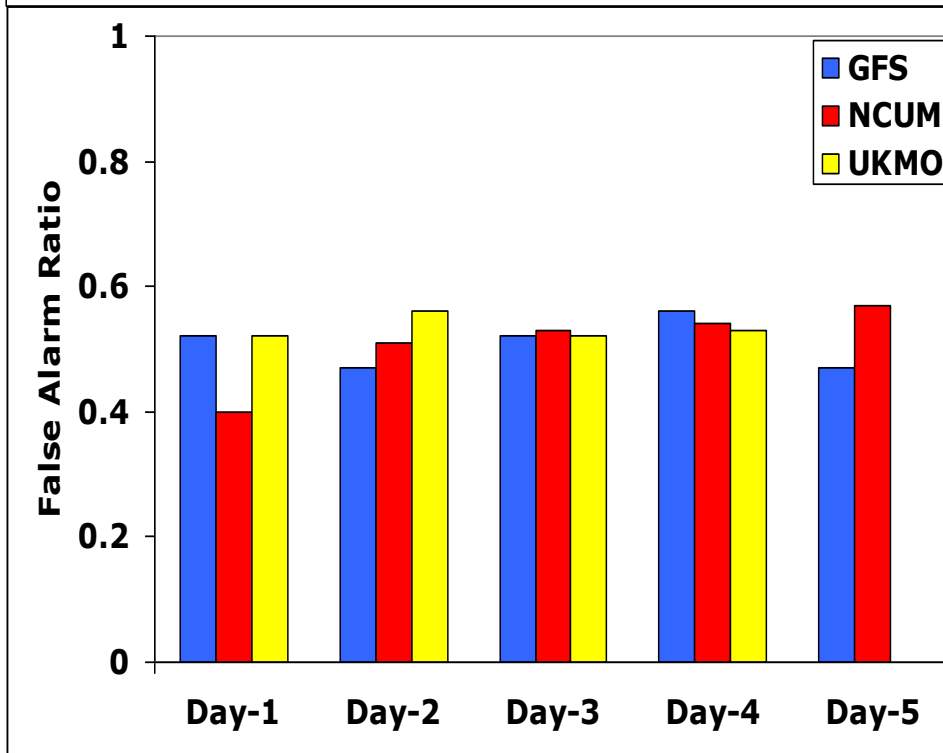
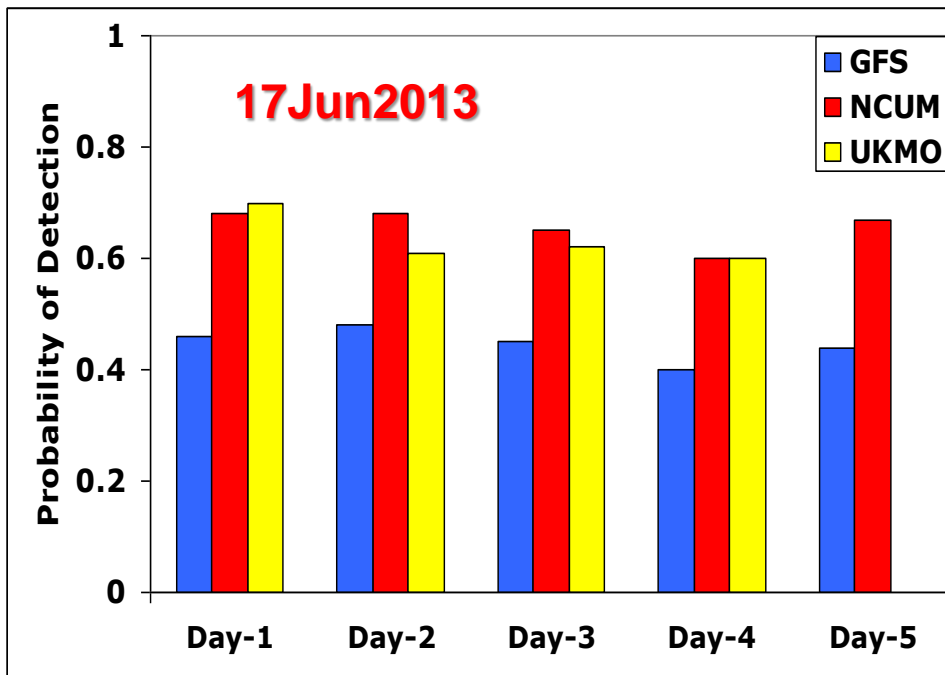
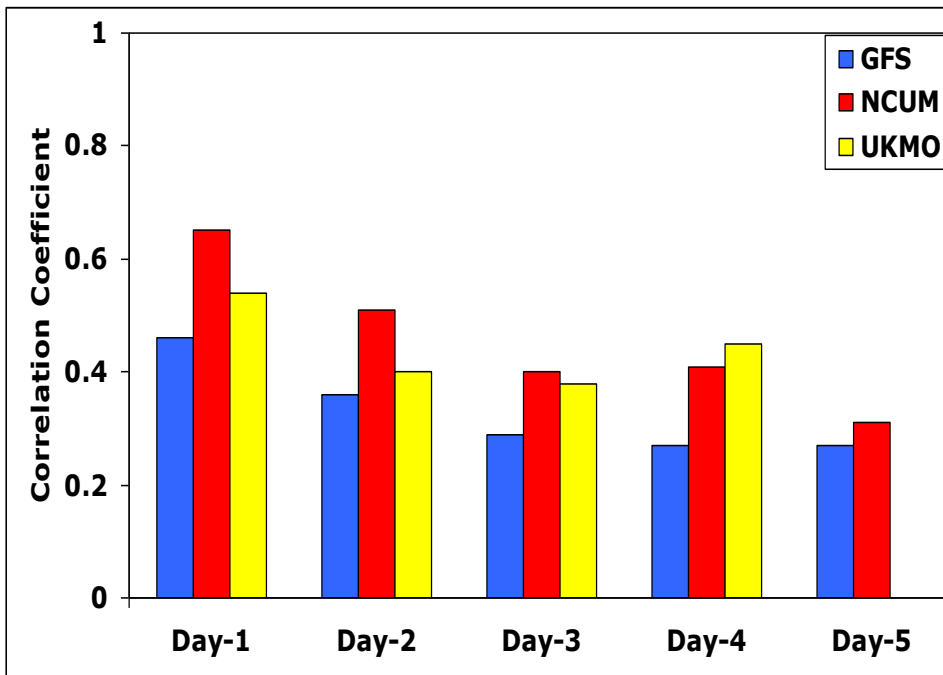
(c) DAY-3 FCST

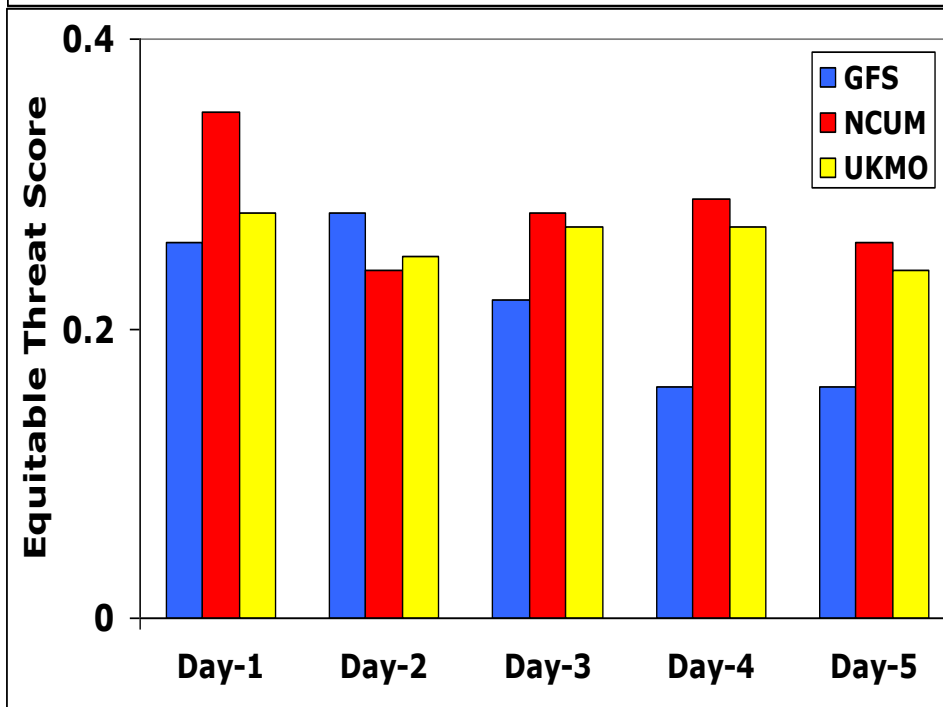
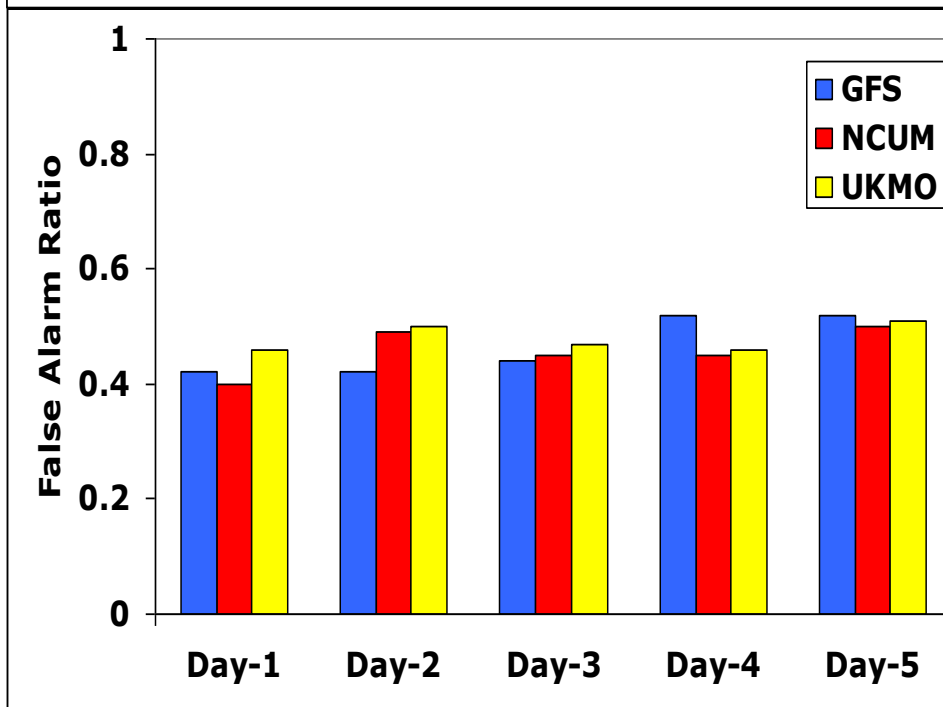
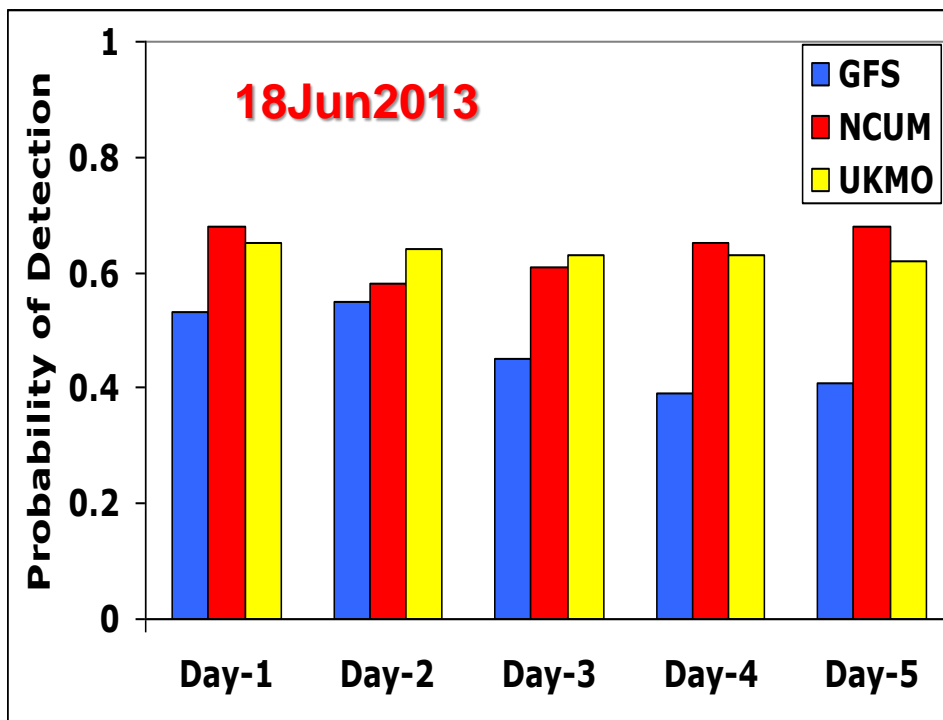
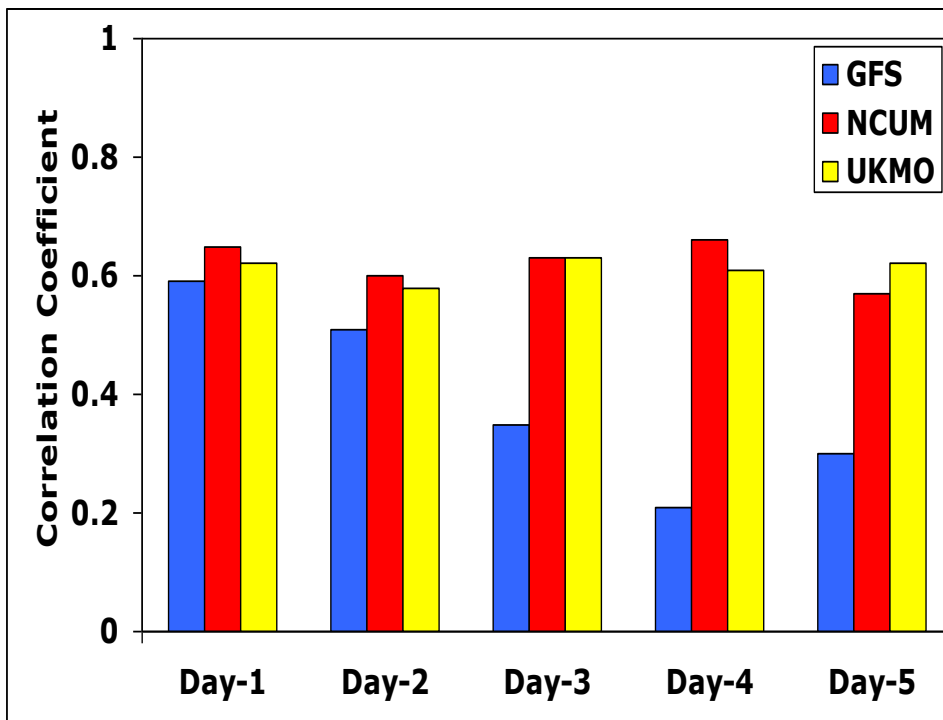


(d) DAY-5 FCST

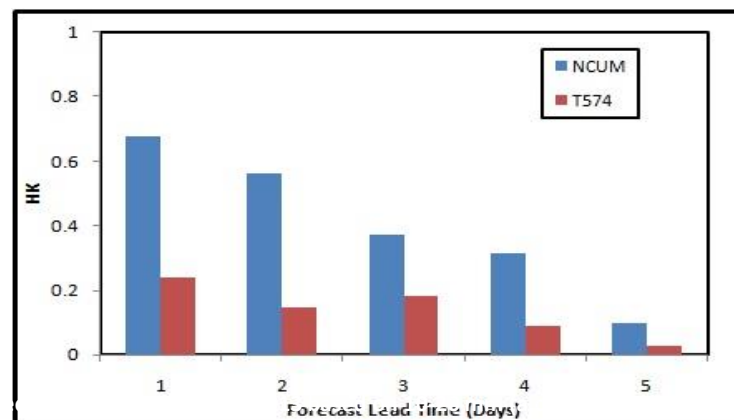
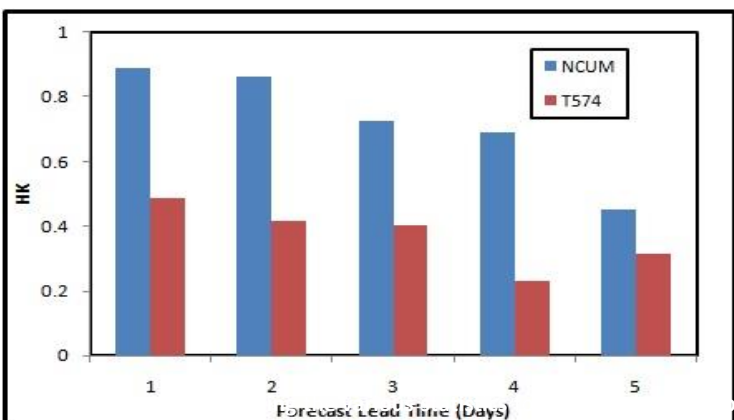
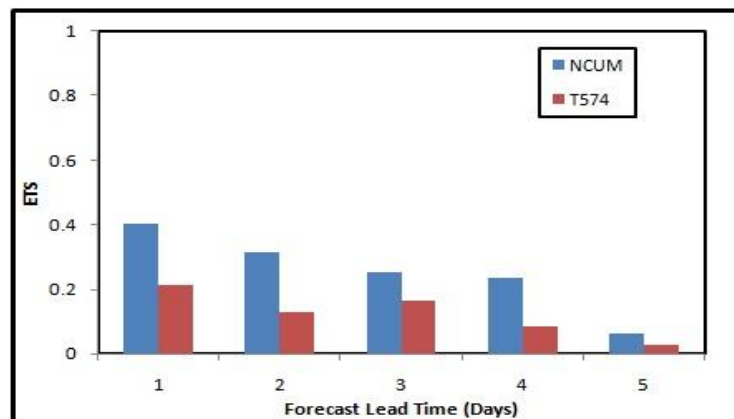
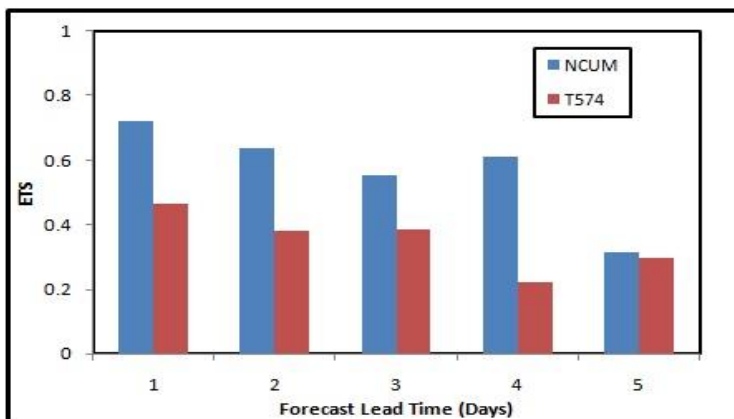
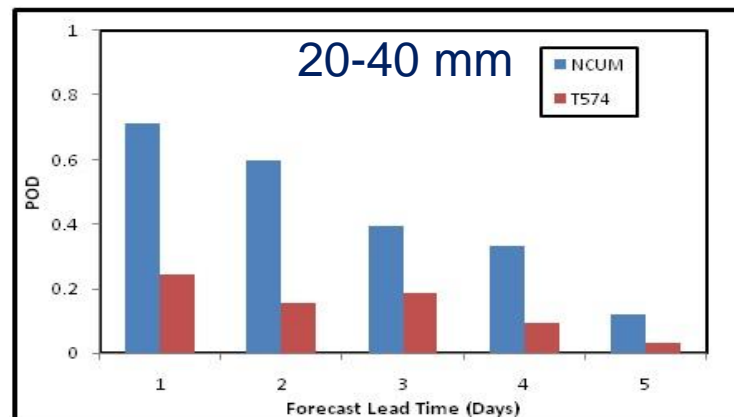
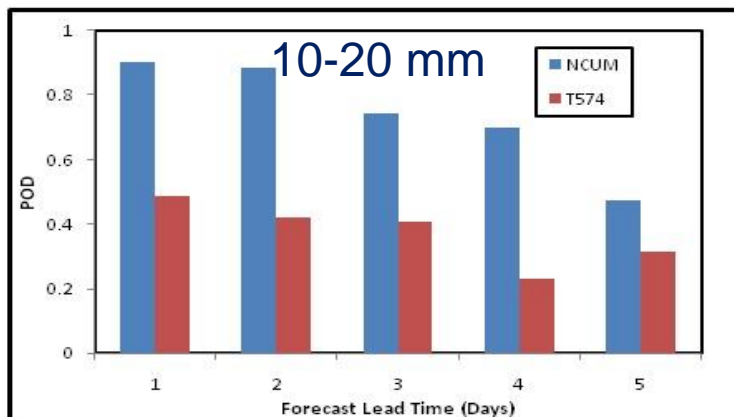


UKMO predict the position and intensity more accurately

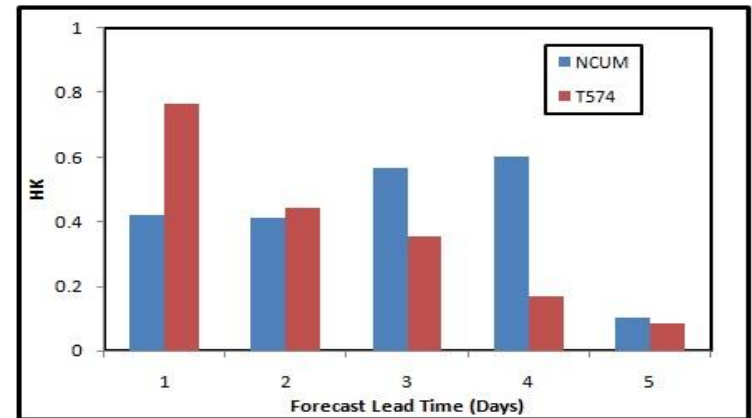
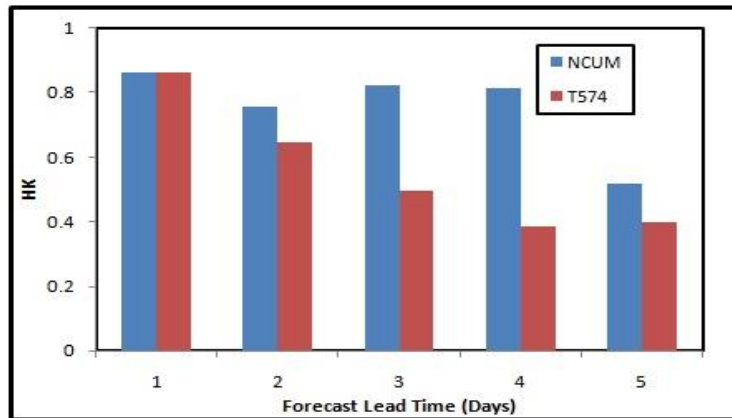
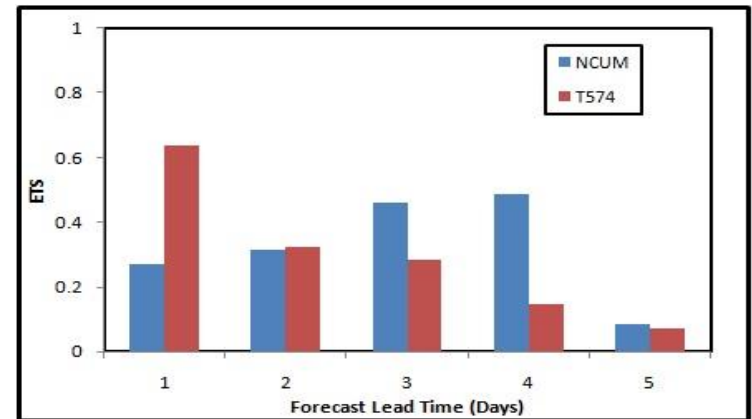
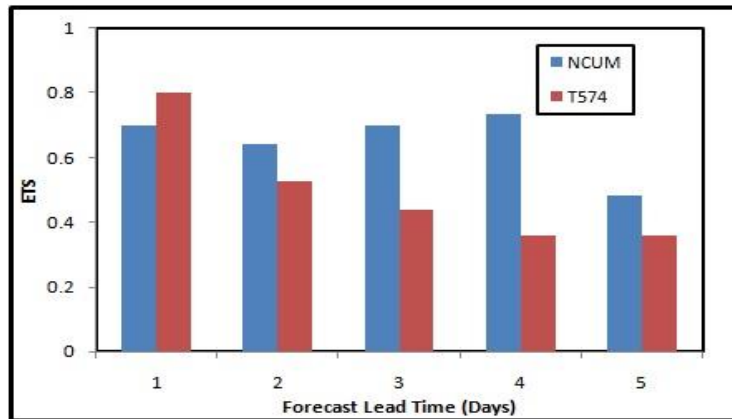
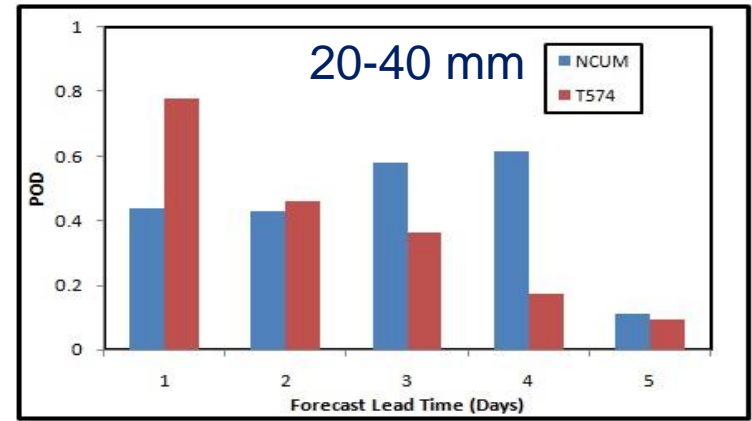
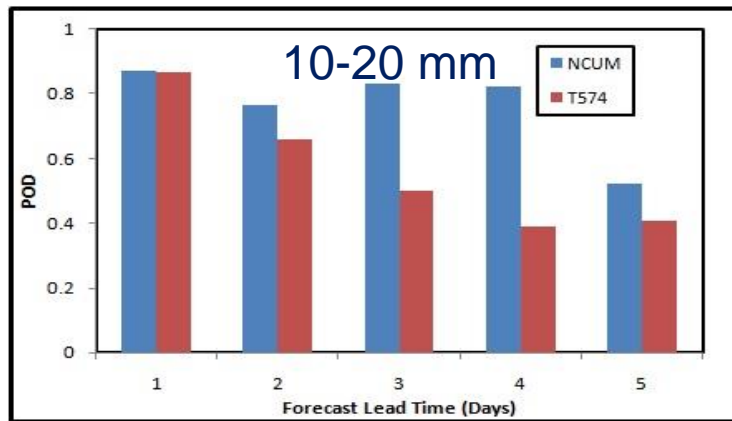




Bar graphs showing the various statistics for T574 and NCUM for Day 1 to Day 5 forecasts valid for 17th June 2013 based on 10-20 mm and 20-40 mm rainfall thresholds.



Bar graphs showing the various statistics for T574 and NCUM for Day 1 to Day 5 forecasts valid for 18th June 2013 based on 10-20 mm and 20-40 mm rainfall thresholds.



Conclusions

- 1) Representation of Himalayan Orography realistically in models is a challenge
- 2) The rainfall event associated with the flooding in Uttarakhand is captured in the models-
 - ☐ Day-1 through Day-5 in UKMO and NCUM for both 17th and 18th June 2013
- 3) The circulation associated with the flooding in Uttarakhand is captured in the models-
 - ☐ Day-1 through Day-5 in UKMO and NCUM for both 17th and 18th June 2013.
The flow is consistently dominated by the WD trough and interaction with the low over North India
- 4) High resolution (1.5 km) model predictions are encouraging. Model initialization is crucial



Thank You