

Genesis of tropical cyclone Madi (2013): Appraisal of recent understanding

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A presentation
by
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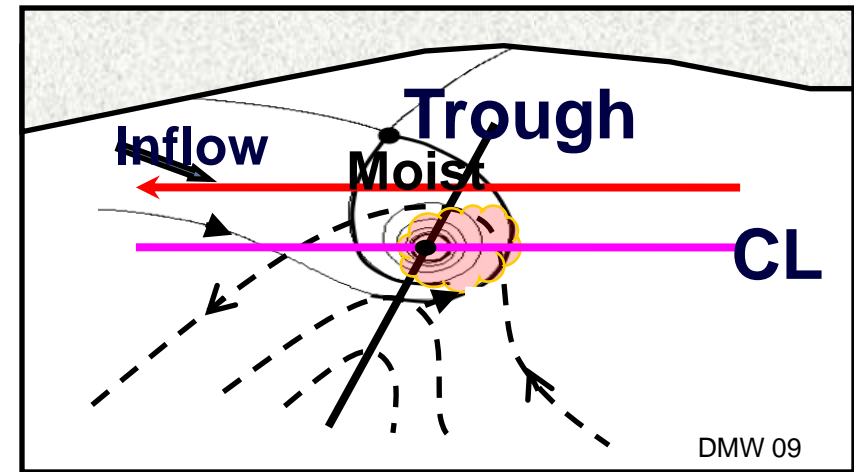
Scientific problem

“The pathway by which cumulus convection organizes to form a large scale tropical cyclone vortex is an unsolved problem in dynamic and tropical meteorology”

-Hendricks et al. (2004)

Dunkerton et al., 2009

- Marsupial paradigm (H1-H3)
 - H1- Roll up of vorticity/ wave breaking
 - H2- Pouch region
 - H3- Meso-scale vortices

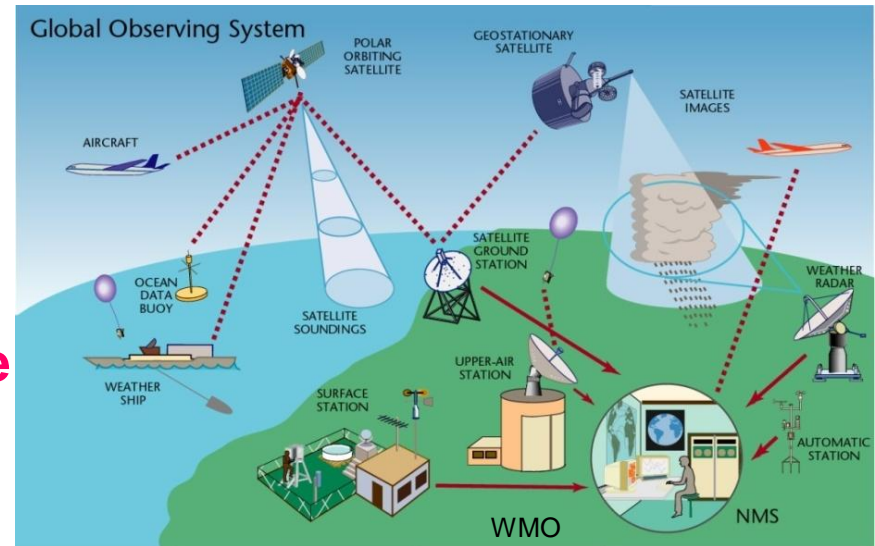


Objectives:

- To test the applicability of marsupial paradigm over NIO
- Understand the pathway of genesis of Madi (2013)

Data and methodology

- ✿ **IMD best track dataset**
- ✿ **NOAA/AOML TCHP images**
- ✿ **MSG satellite images**
- ✿ **ERA interim reanalysis**
- ✿ **NCEP ADP upper air and surface observations**
- ✿ **Satellite Radiances**



Satellite Sensors

Satellite Platform

AMSU A

NOAA 15,16,18, EOS Aqua and METOP-2

AMSU B

NOAA-15, 16, 17

AIRS

NOAA-18, and METOP -2

MHS

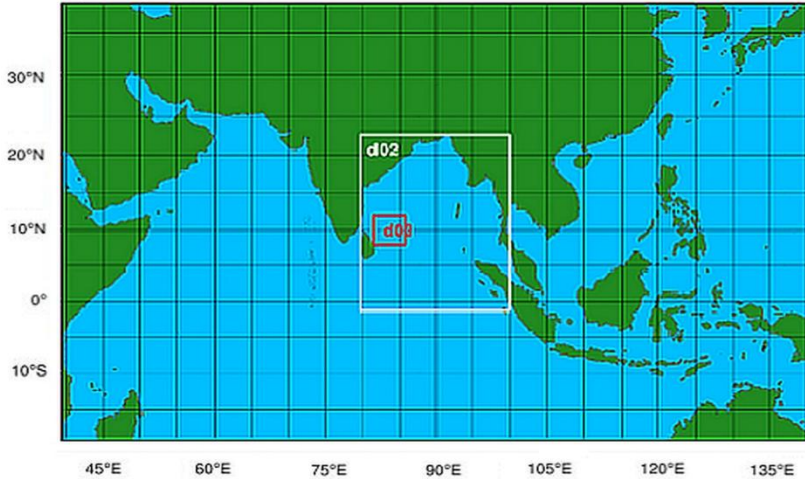
EOS Aqua

High resolution analysis is created using 3Dvar assimilation

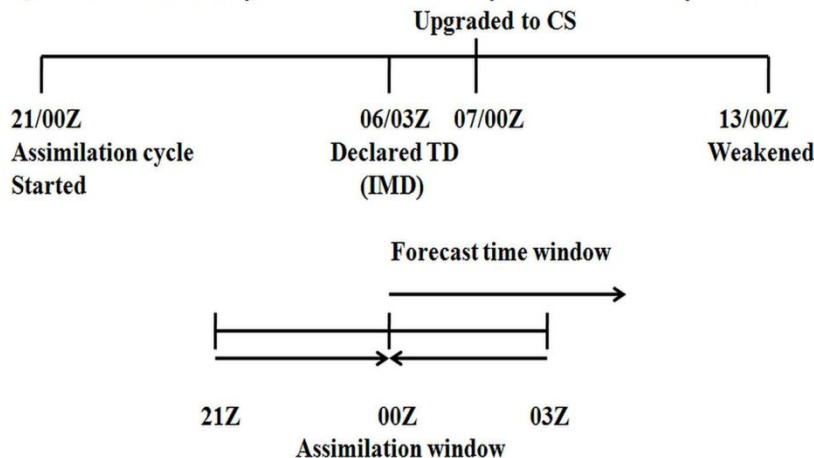
Experimental design

Weather Research and Forecasting - WRF (Version 3.6.1) & WRFDA

(a) Computational domain



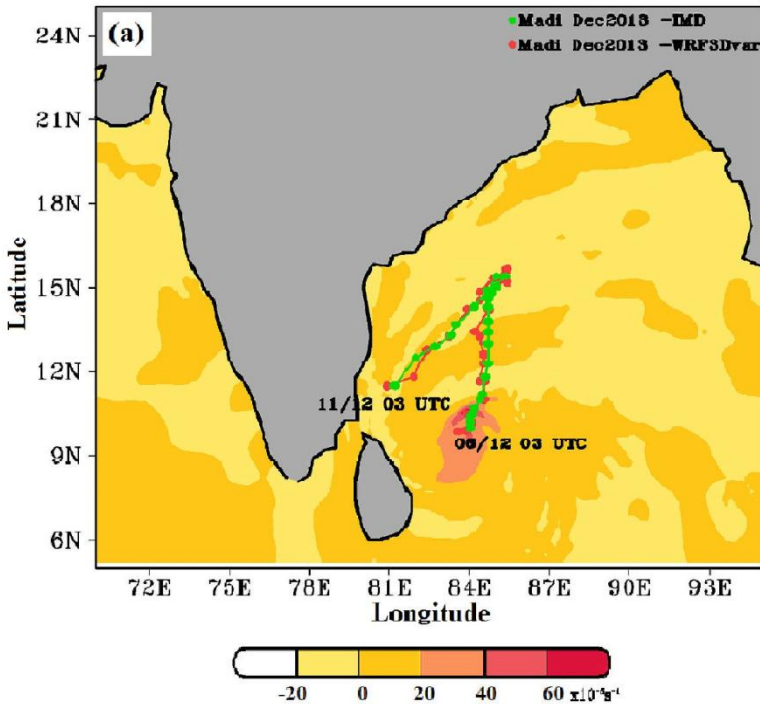
(b) Data assimilation cycle and timeline of key events of Madi cyclone



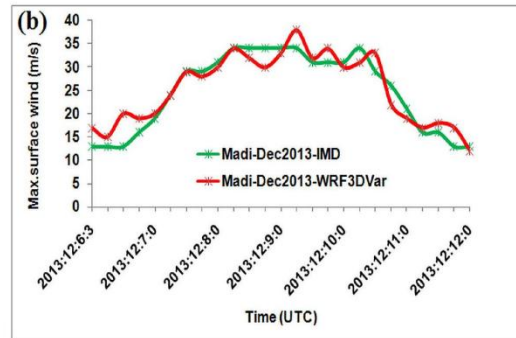
Details	Configuration
Dynamical core	ARW, compressible, Non-hydrostatic
Horizontal grid distance	18km(Domain 1), 6km (Domain 2)
Vertical levels	64
Model top	100 hPa
Initial and boundary conditions	GFS analysis (0.5 x 0.5), 6 hourly
Time step	30 s
Microphysics	Thompson
Long wave radiation	RRTM
Short wave radiation	Dudhia scheme
Surface layer	Monin Obukhov similarity theory
Land surface	Noah Land surface
PBL	Mellor Yemada Janjic
Cumulus	Kain-Fritch scheme

Simulation verification

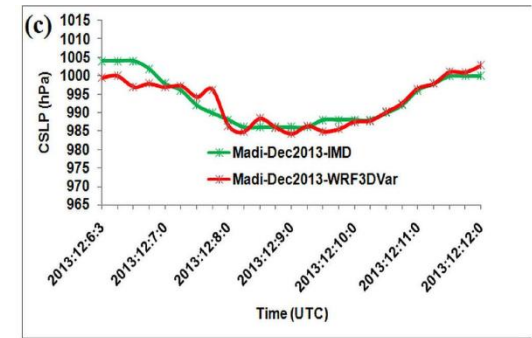
Track



Wind speed



CSLP



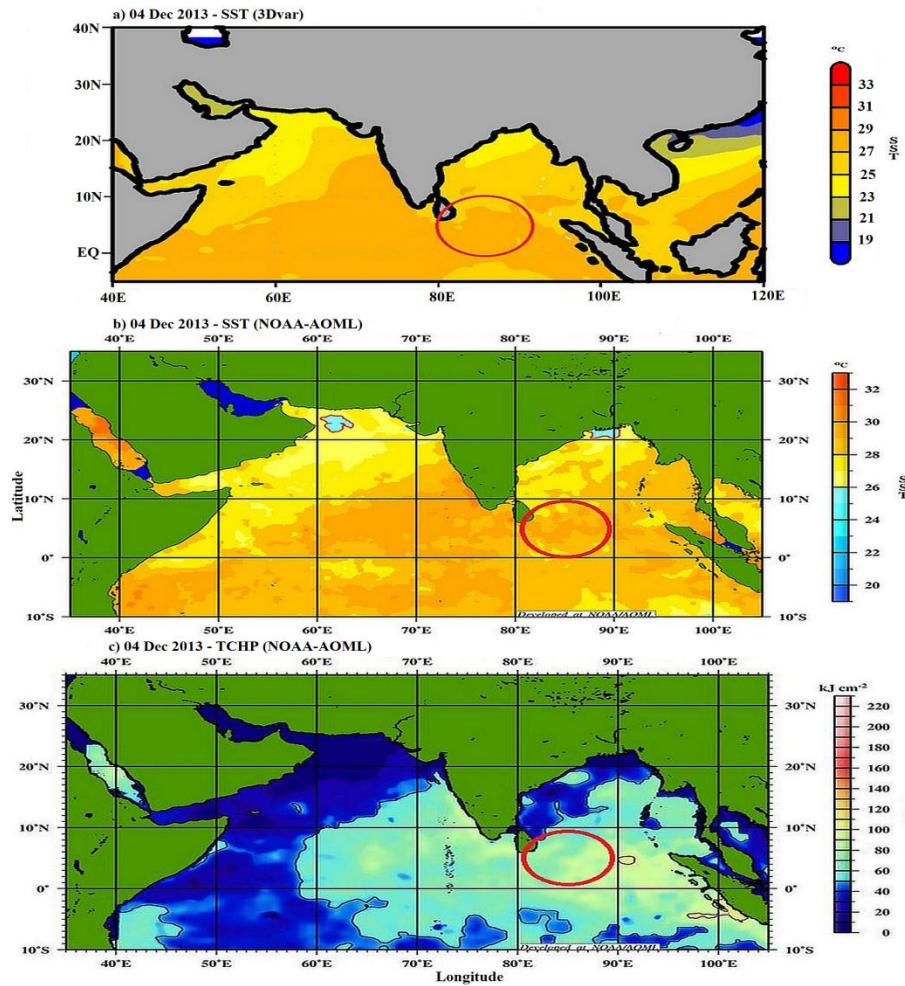
IMD in green and 3Dvar analysis in red

- Formed on Dec 6 and dissipated on Dec 13
- Category 1 on Dec 8; 986 hPa and 65 kt
- Unique track with near northerly movement

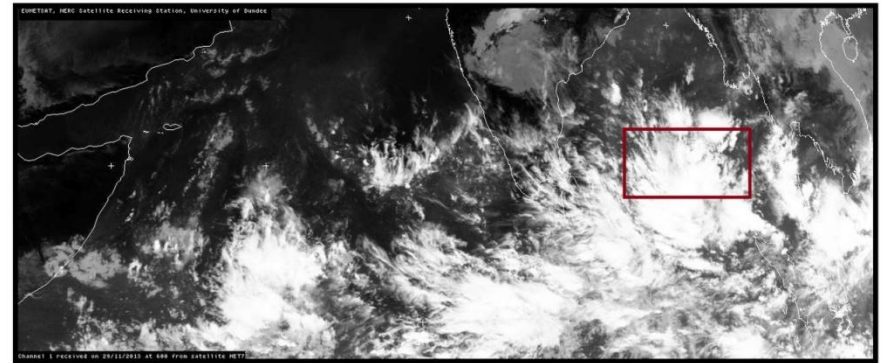
3Dvar analysis shows matching track and the recurvature of Madi cyclone also well simulated.

Large scale conditions

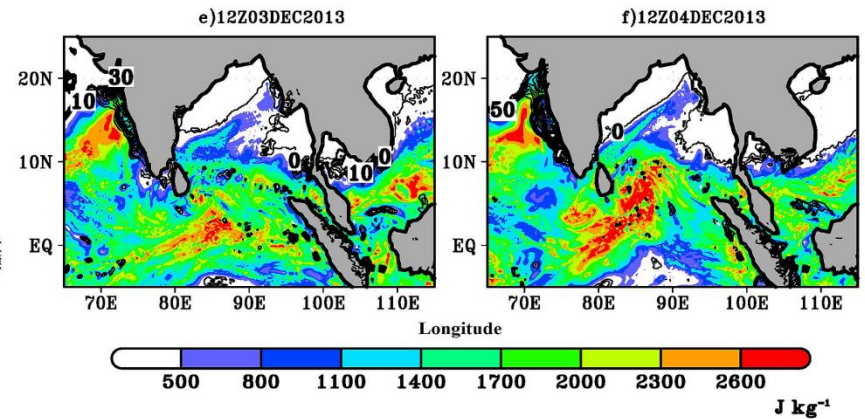
SST and TCHP



MSG satellite image



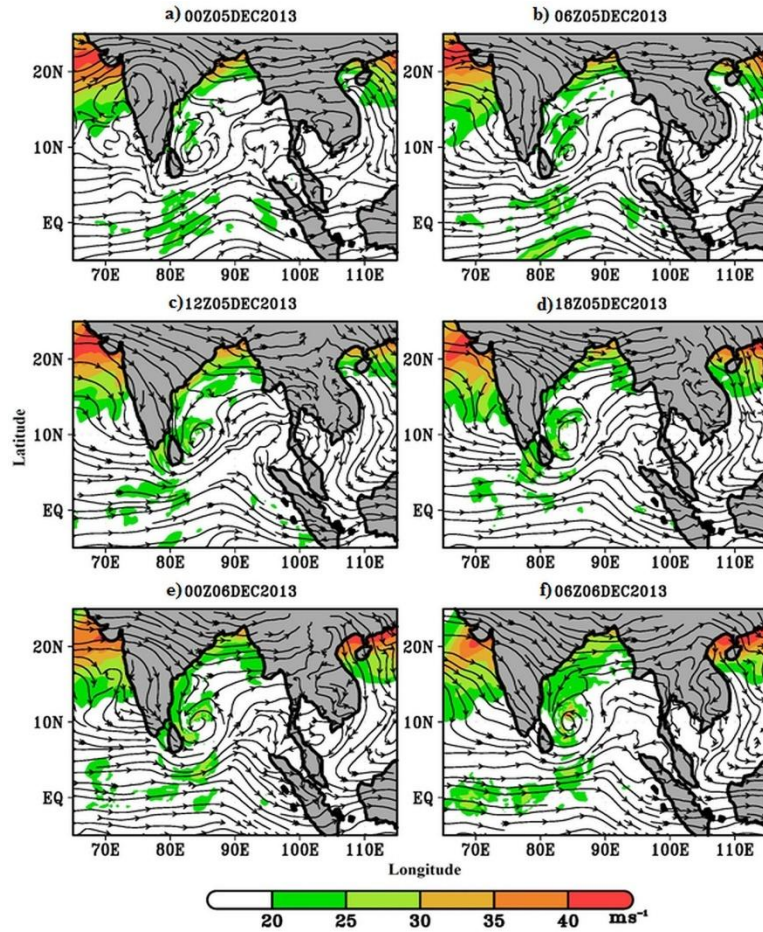
CAPE & CINE



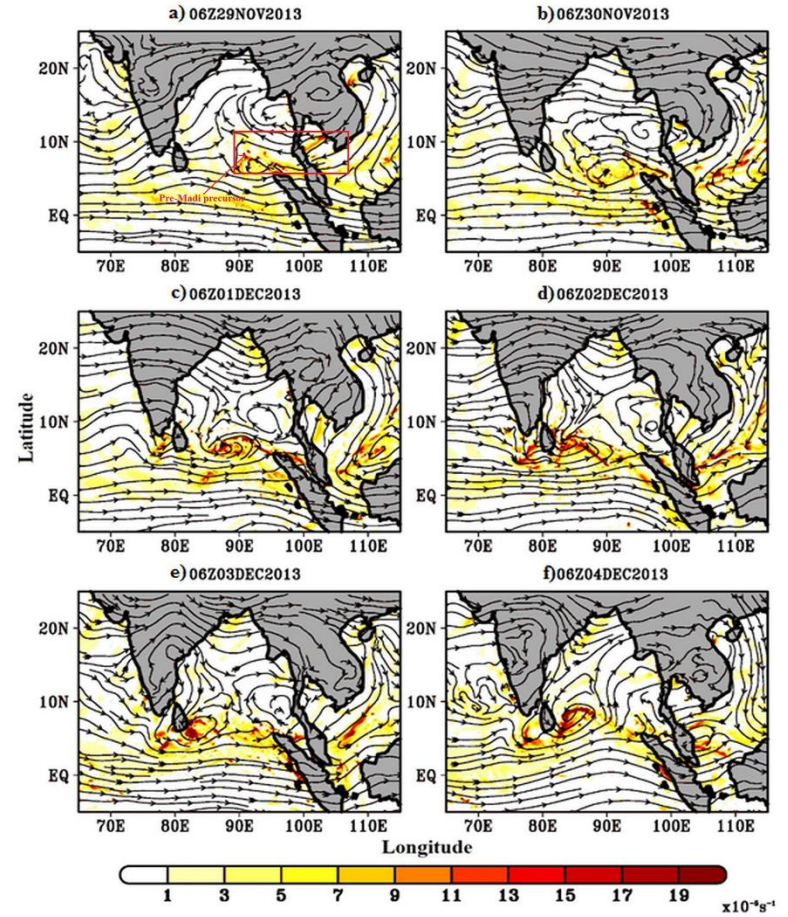
04Dec2013, Warm water SST > 26.5°C, TCHP > 100KJcm⁻², CAPE > 2500 Jkg⁻¹

Large scale conditions

Deep layer shear



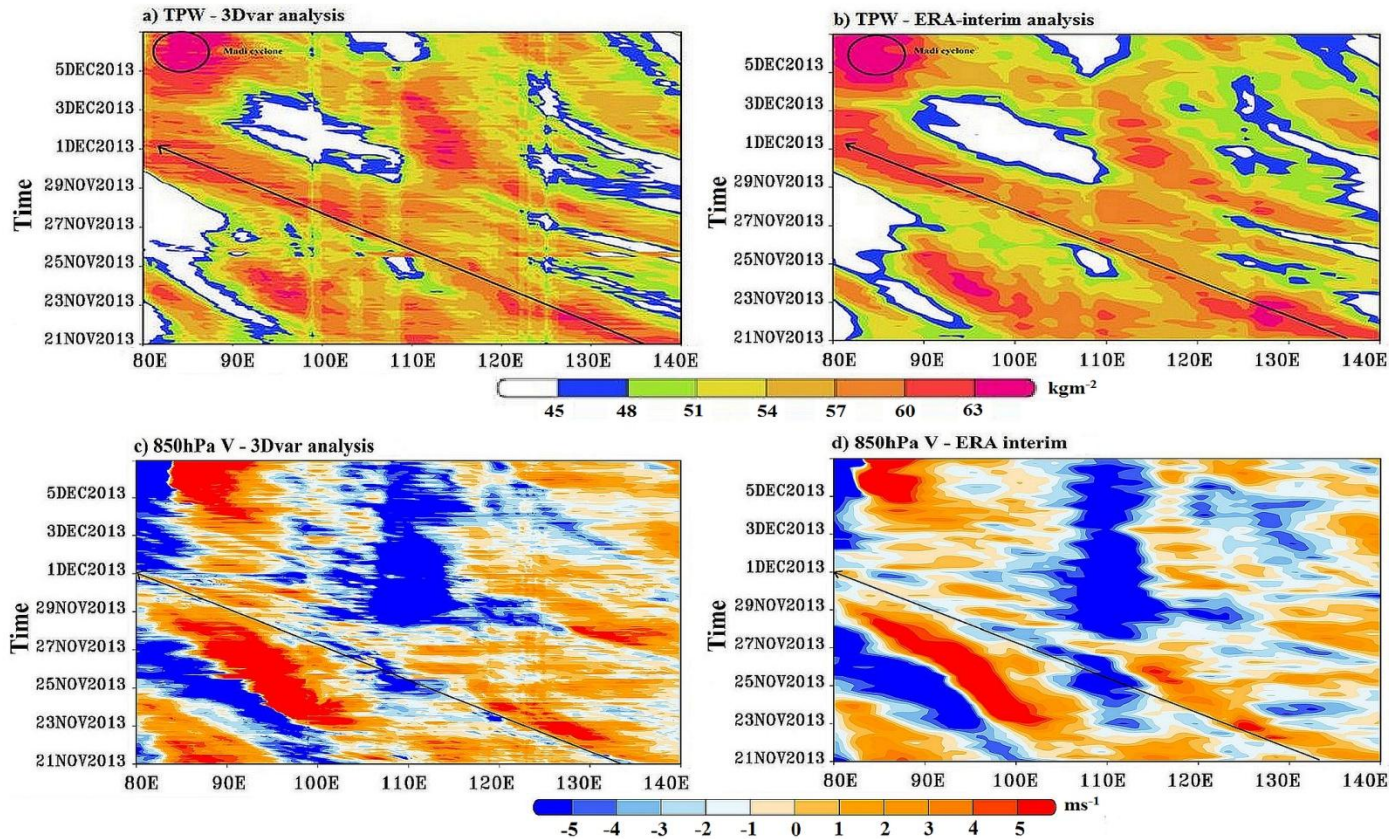
850hPa vorticity



Favorable conditions for genesis

Genesis sequence of Madi (2013) – H1

Tracking parent disturbance

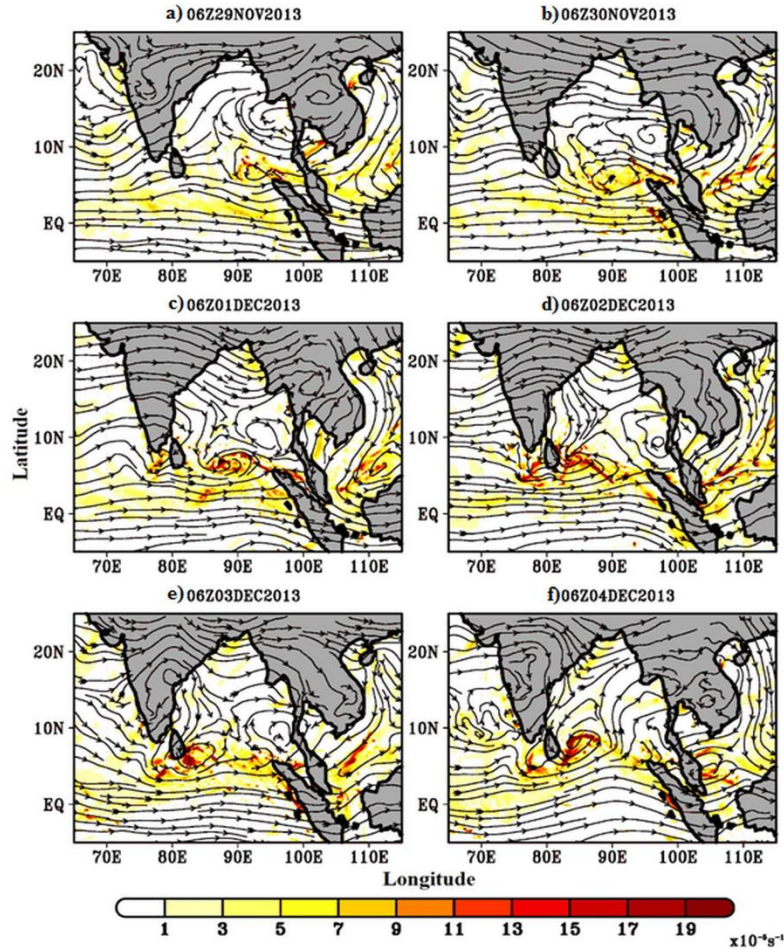


Tropical cyclone Madi's precursor disturbance originated from a westward moving disturbance and it is tracked for 15 days prior to TD declaration.

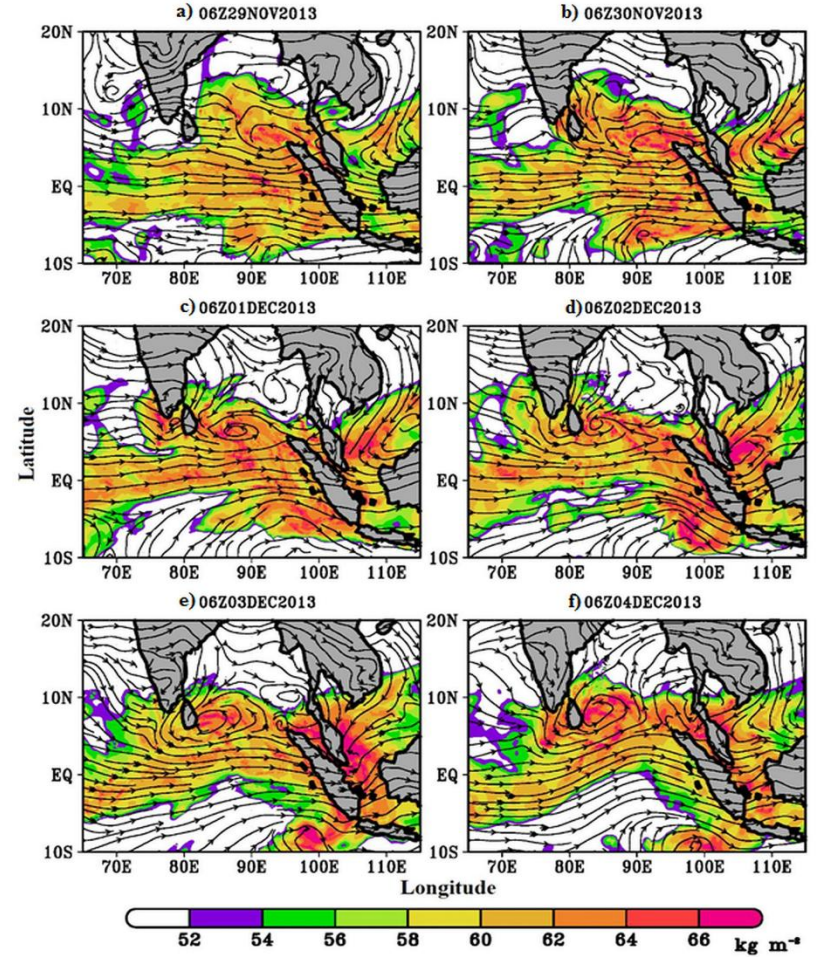
Phase speed of propagation is -7.2 ms^{-1}

Pouch formation – H2

850hPa vorticity



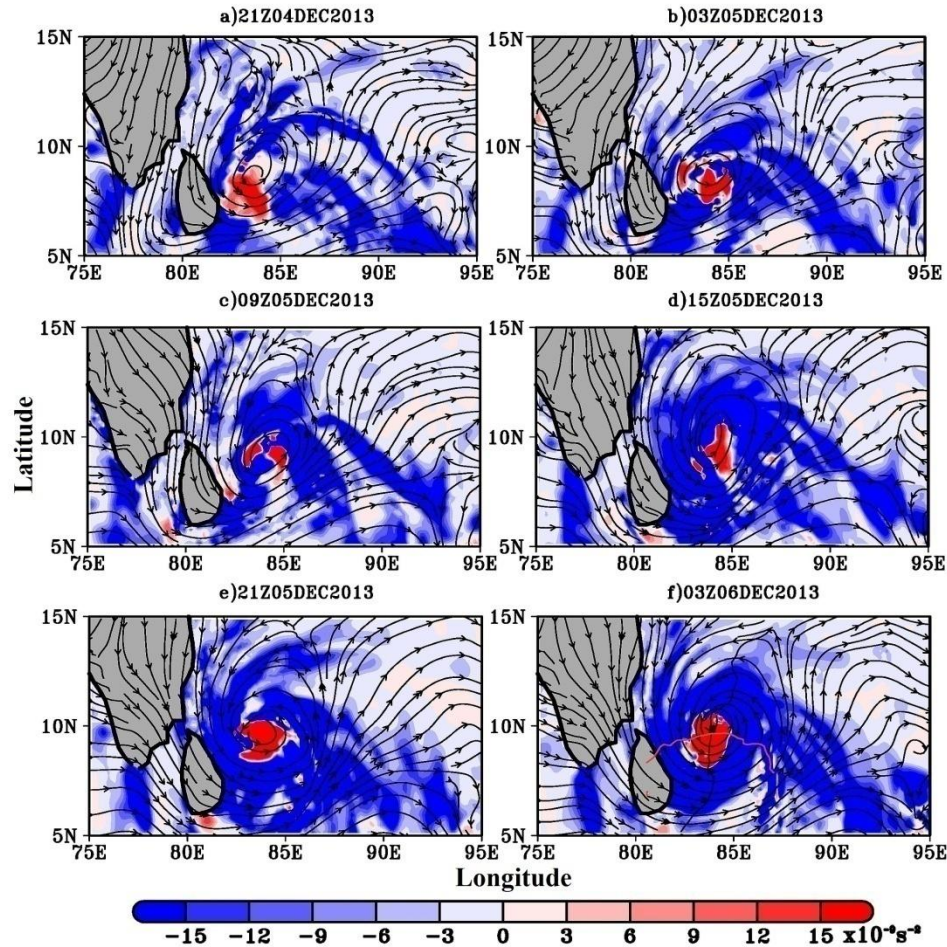
TPW



Pouch is identified as a region of enhanced moisture

Pouch formation – H2

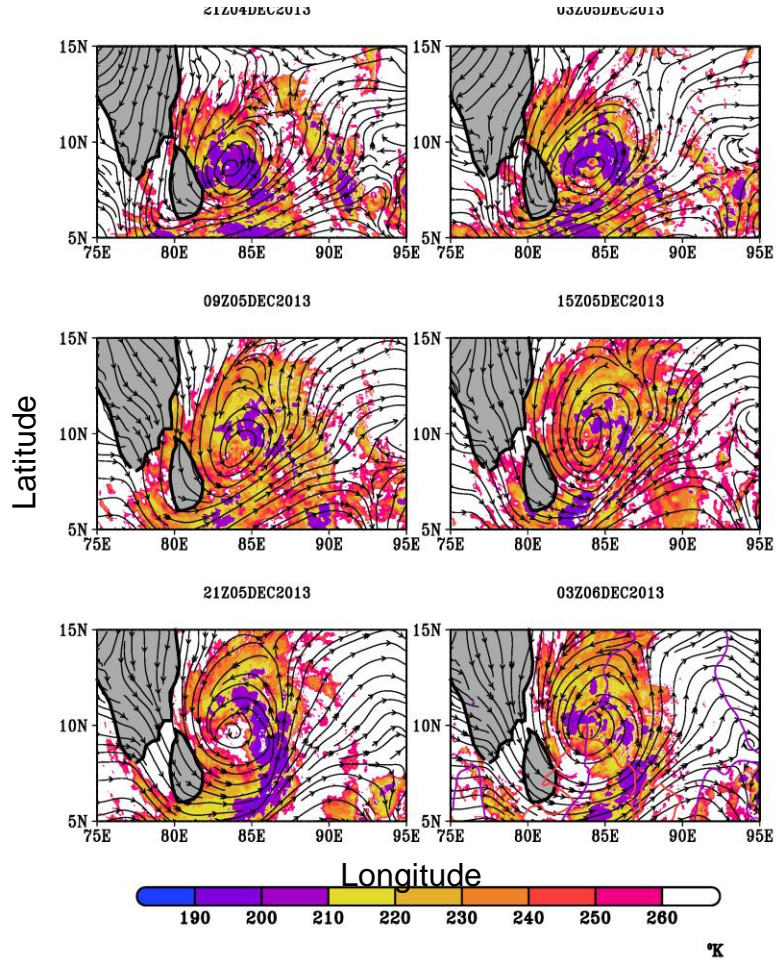
OW parameter



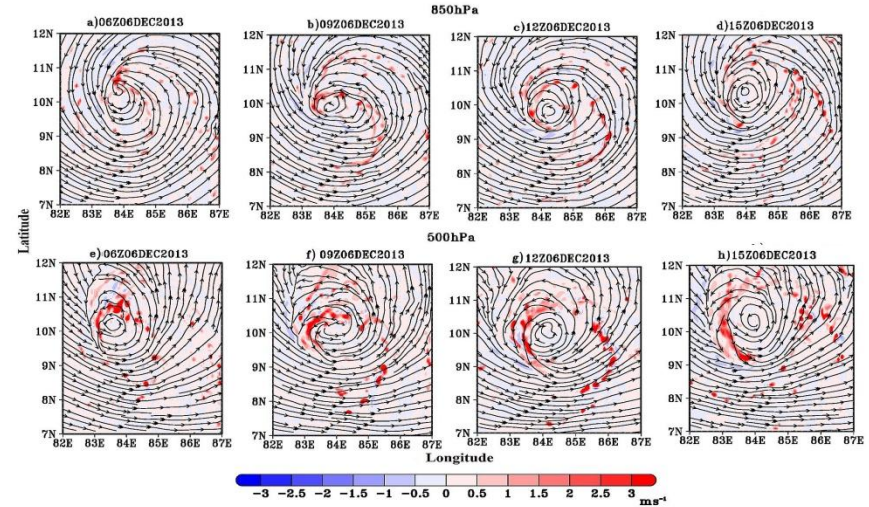
Madi forms in a rotation dominant region

Intensification of convection – H3

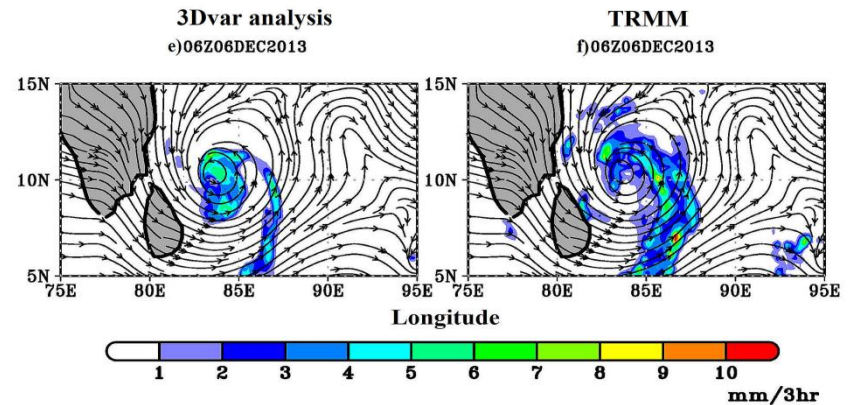
IRBT



Vertical velocity



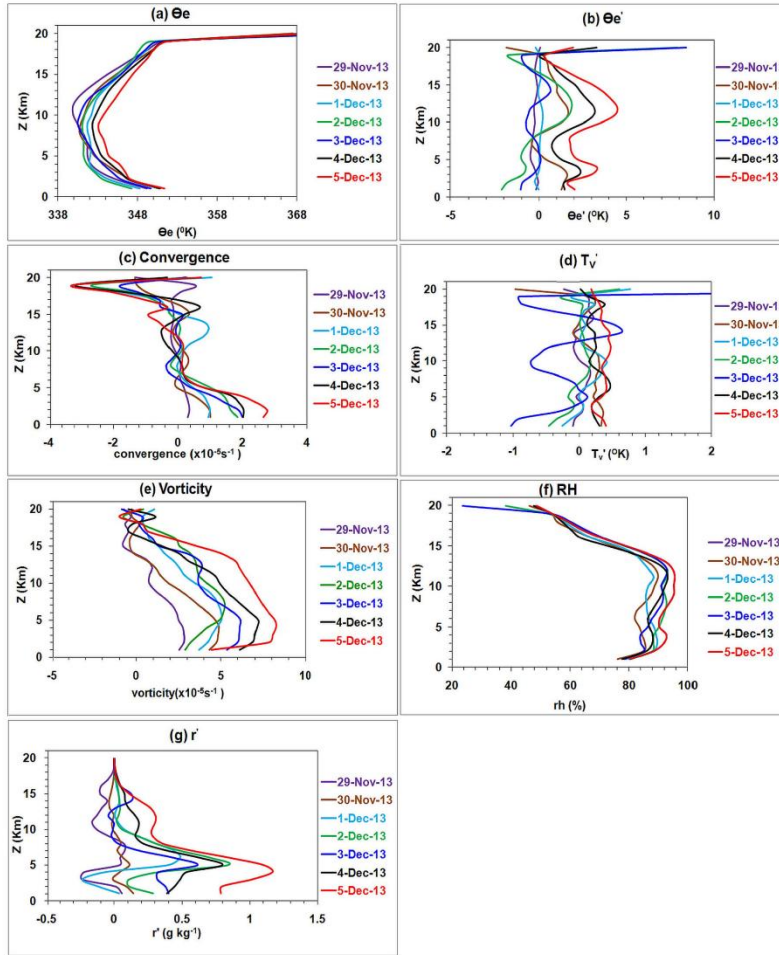
Rain rate



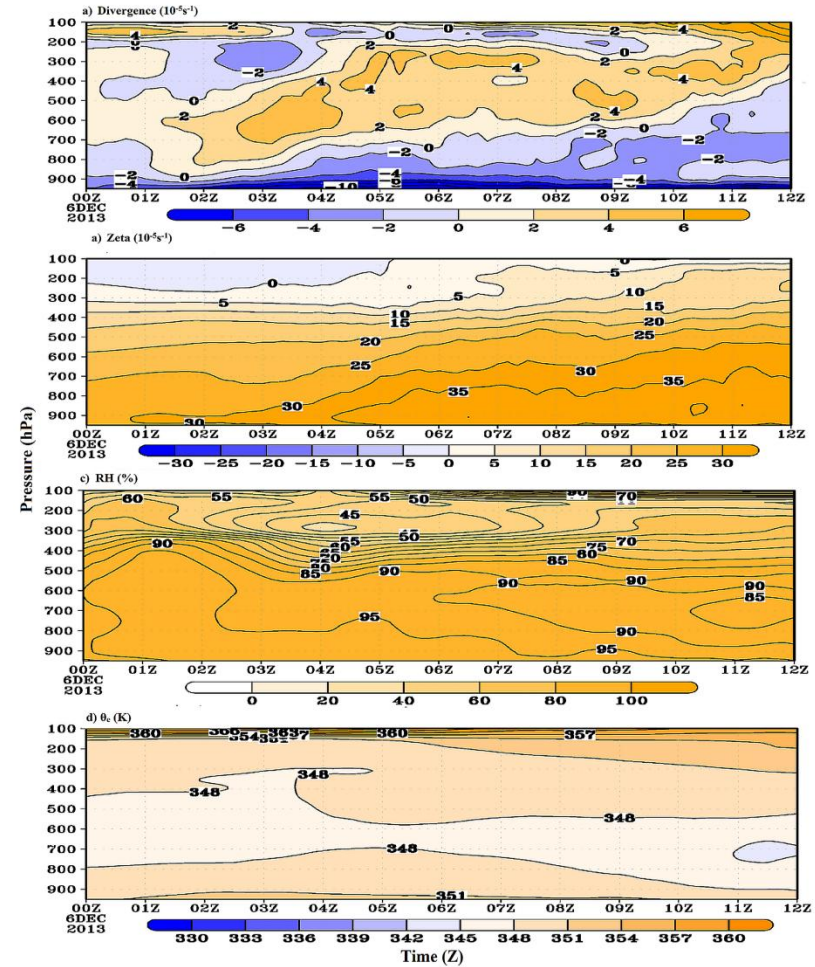
Proto-vortex is intensified by convective activity (H3)

Pathway of genesis of Madi (2013)

Profiles



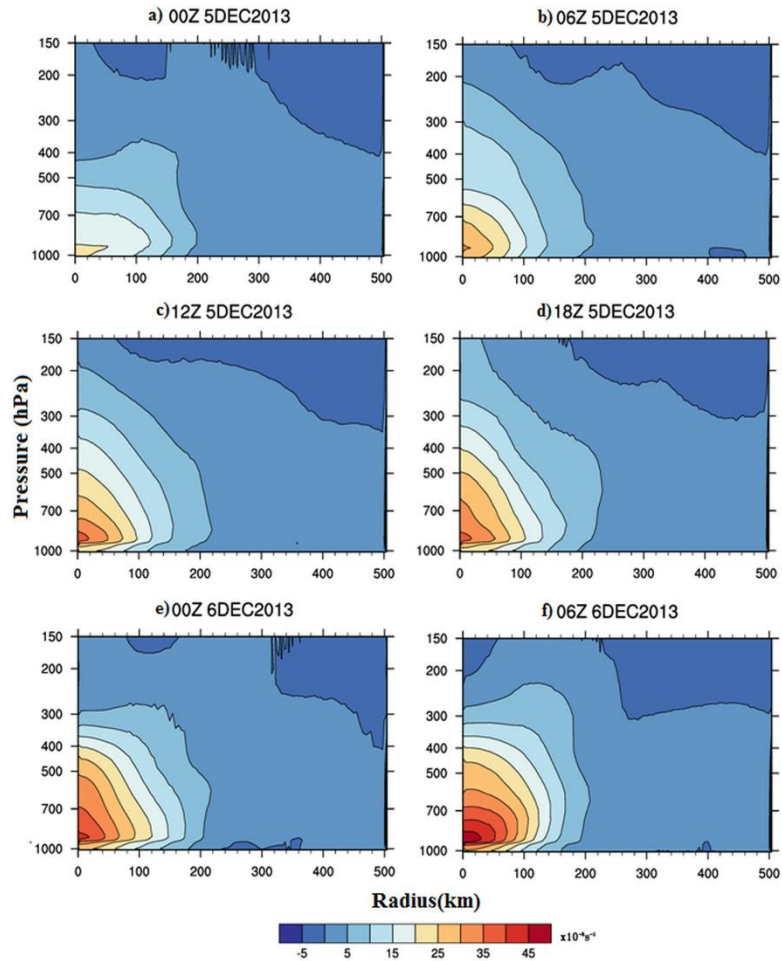
Hovmoller



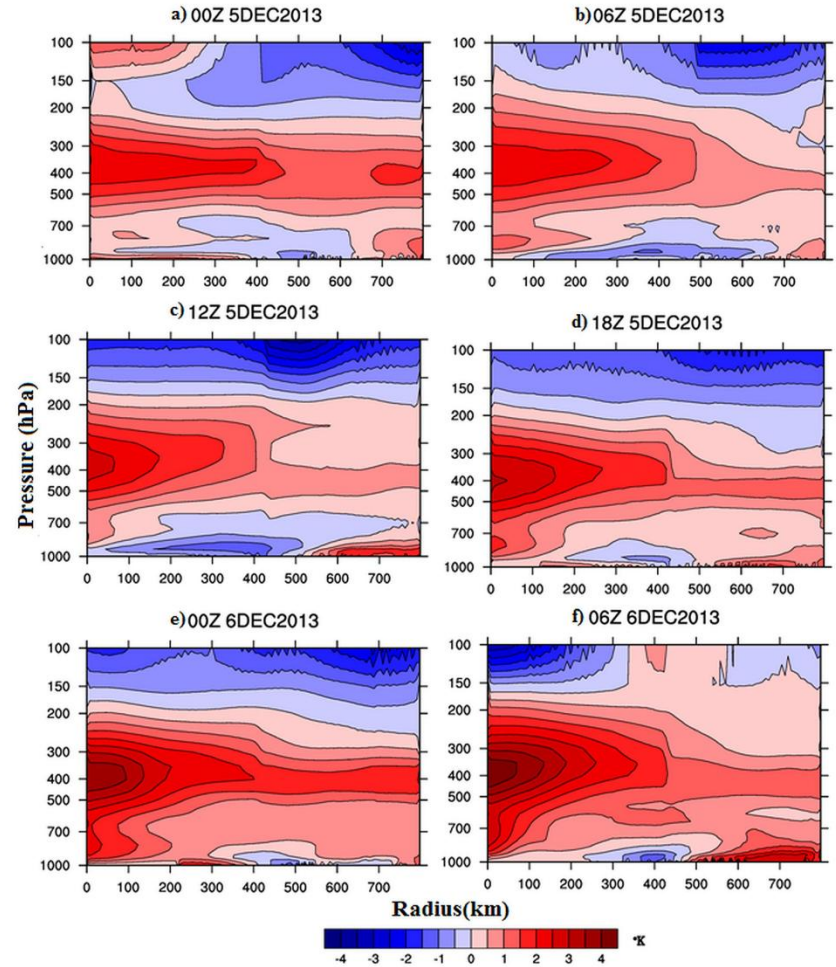
Closely follows the bottom-up pathway

Pathway of genesis of Madi (2013)

Vorticity



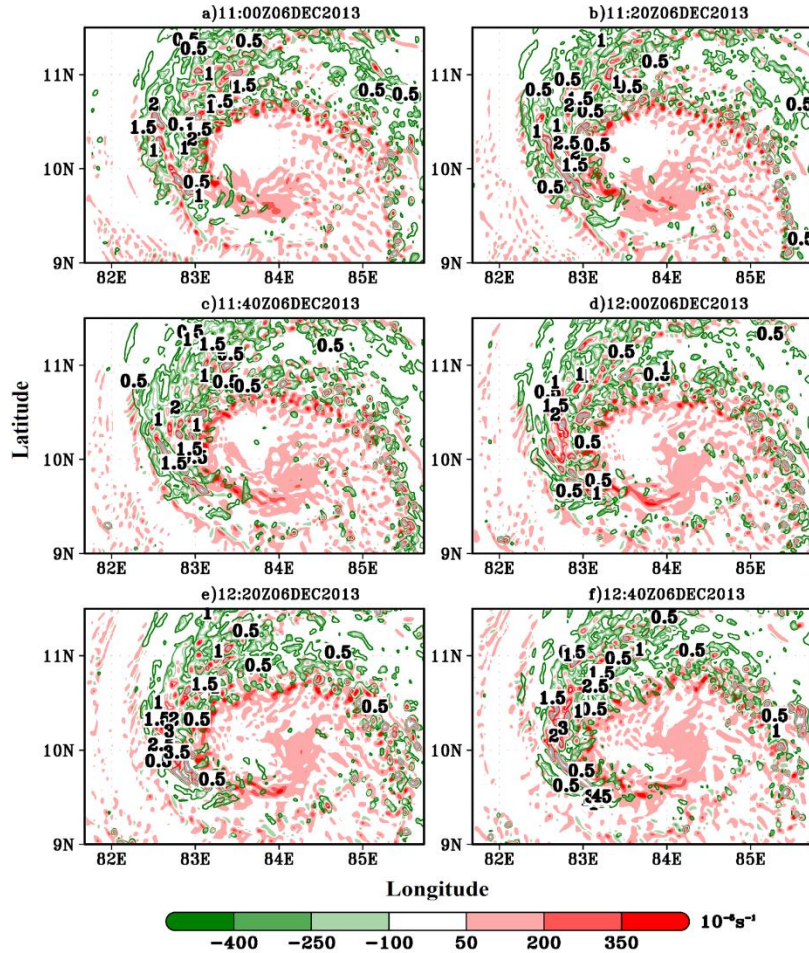
Warm core



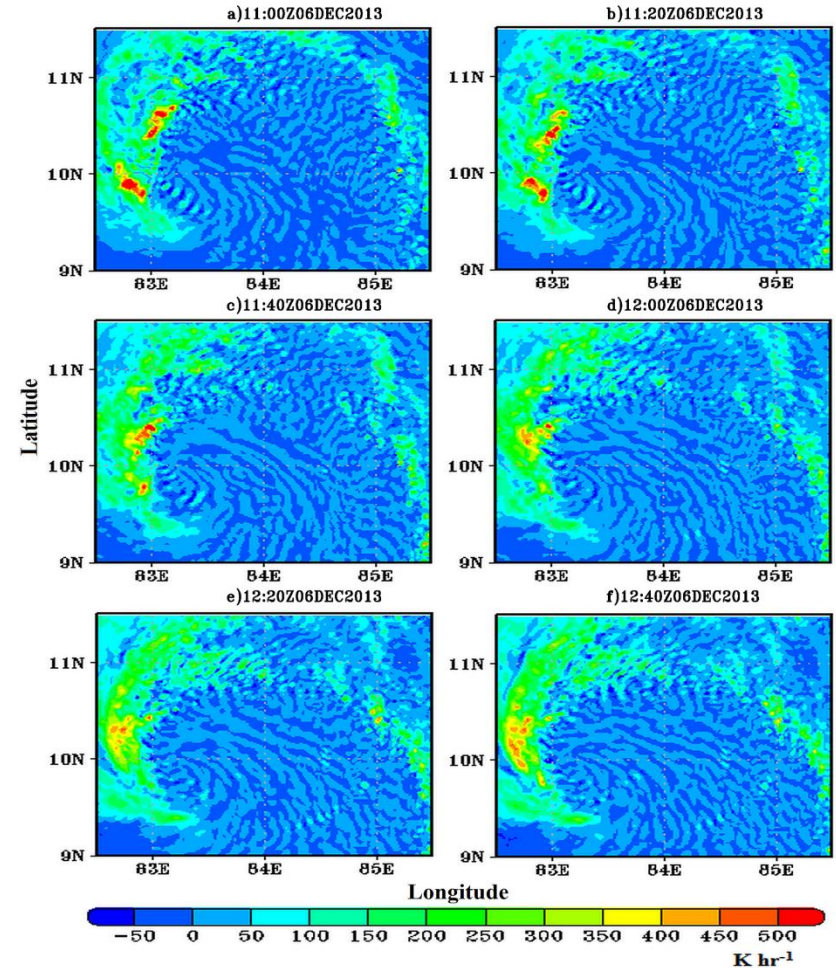
Closely follows the bottom-up pathway

Role of VHTs on genesis of Madi (2013)

Absolute vorticity



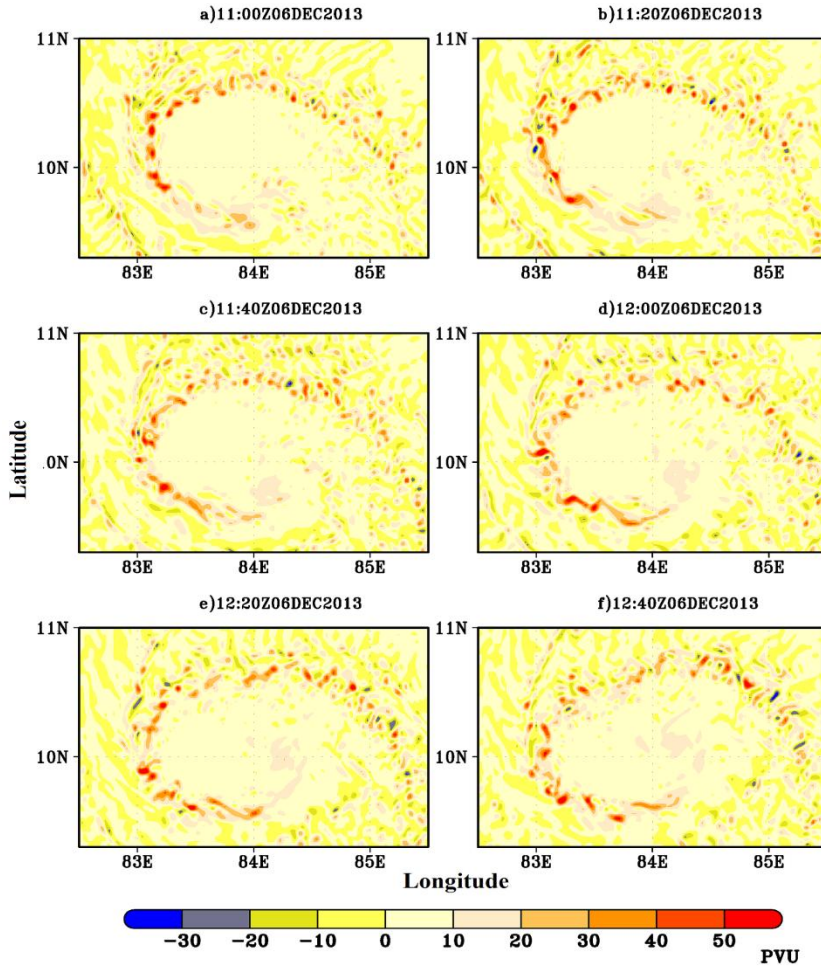
Diabatic heating



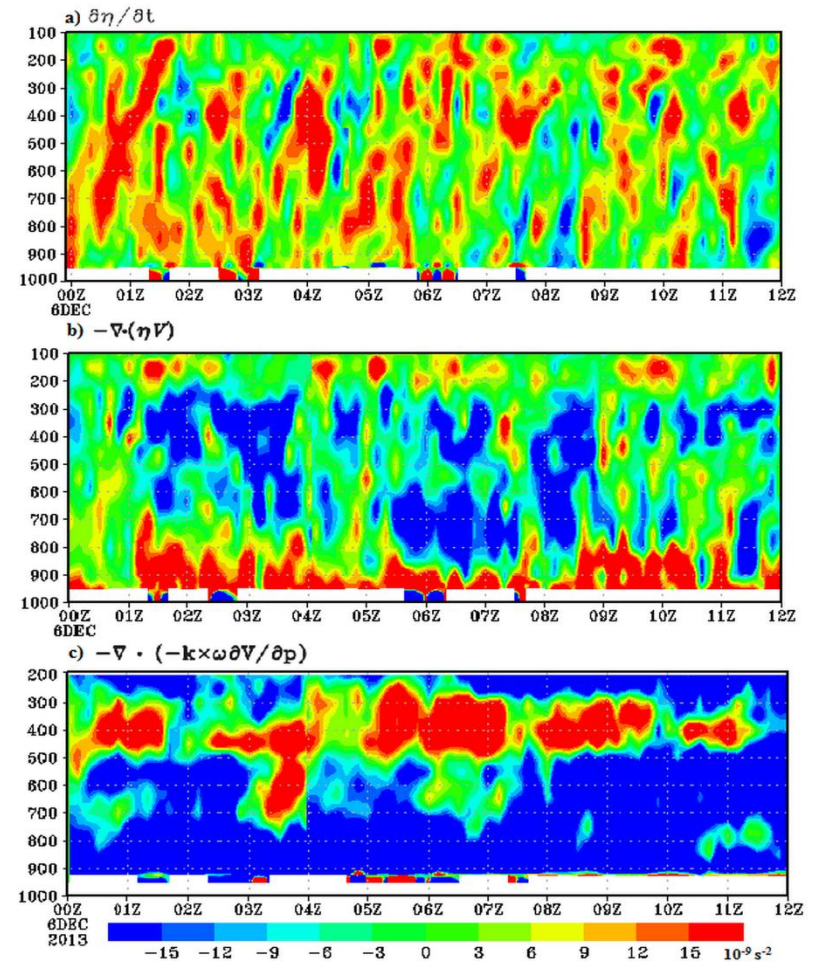
Diabatic vortex merger in the genesis environment

Role of VHTs on genesis of Madi (2013)

Potential vorticity



Vorticity budget



$$\frac{\partial \eta}{\partial t} = -\nabla \cdot u \eta - \hat{k} \cdot \nabla \times \omega \frac{\partial V}{\partial p} + \hat{k} \cdot \nabla \times F$$

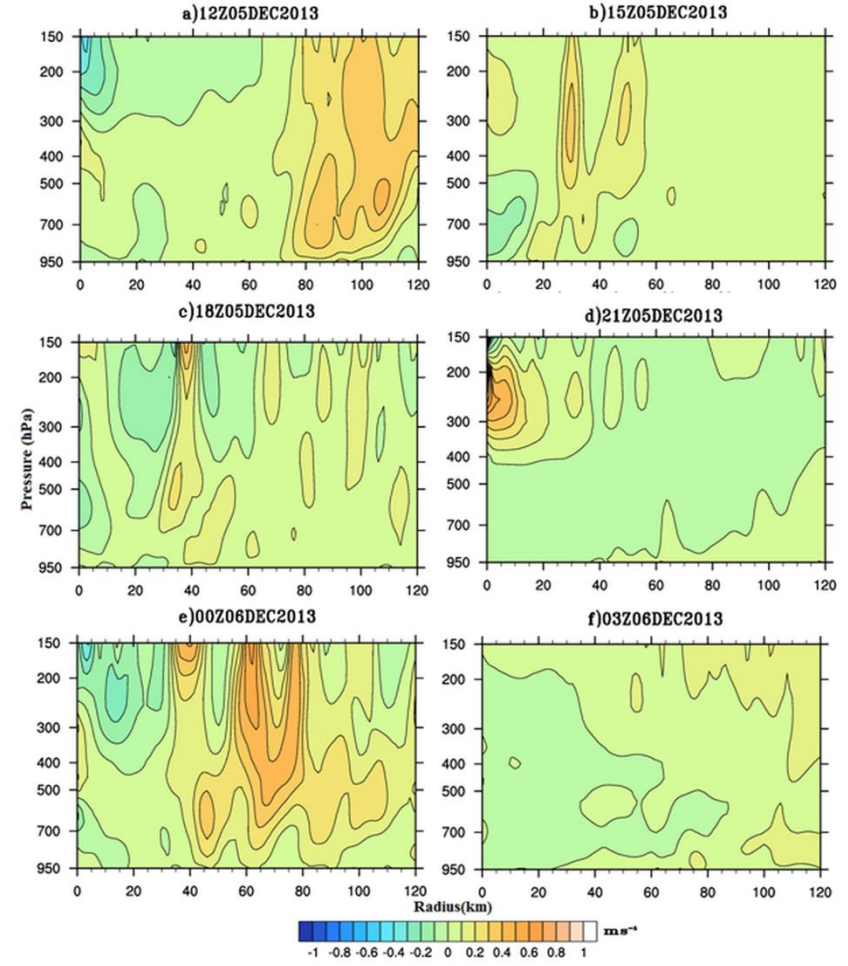
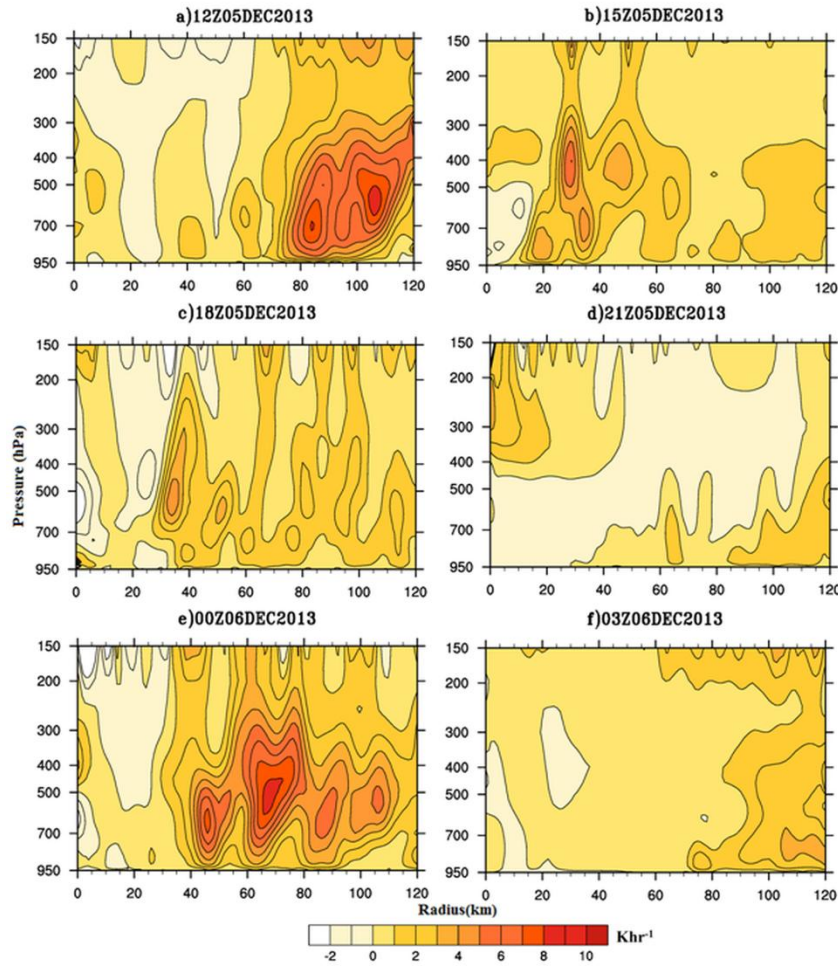
$$\eta = \xi + f$$

$$\omega = \frac{Dp}{Dt}$$

Role of VHTs on genesis of Madi (2013)

Diabatic heating

Vertical velocity



Diabatic heating rate is dominated by the latent heating in the convective updrafts

Conclusions

- ✿ The paper presents the comprehensive analysis of the genesis sequence of a very severe cyclonic storm Madi over the BoB region to examine the applicability of recent concepts and theories of cyclogenesis.
- ✿ For this purpose, we have generated high resolution analysis using meso-scale model WRF and available data sets viz. satellite data and in-situ weather observations, using 3DVAR data assimilation technique.
- ✿ Additional data sets used include ERA-interim reanalysis, IRBT observations, MSG and TRMM 3B42 rainfall observations.
- ✿ The parent disturbance responsible for genesis of tropical cyclone Madi is tracked from fifteen days prior to the period of genesis in the developed high resolution analysis.
- ✿ The closed cyclonic circulation protects the Madi precursor from all kinds of deformations and acts as a “pouch region” associated with the parent disturbance.

Conclusions

- ✿ Large scale priming of environment agrees with the hypotheses of the marsupial theory of tropical cyclogenesis.
- ✿ Our results indicate that, development of warm core inside the pouch region is continuous process about two days prior to actual time of cyclogenesis.
- ✿ The diabatic heating more than 10 K h^{-1} and collocated increase in the vertical velocity more than 0.5 ms^{-1} is evident in the genesis environment of Madi cyclone.
- ✿ These convective vortices tilts and converges under the influence of the low level absolute vorticity to form the low level cyclonic circulation leading to the genesis of tropical cyclone Madi.
- ✿ Our investigation suggests that the bottom-up mechanism was operational for the genesis of tropical cyclone Madi.

Rajasree et al., 2016, JGR

Thank you...