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

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSU A</td>
<td>NOAA 15,16,18, EOS Aqua and METOP-2</td>
</tr>
<tr>
<td>AMSU B</td>
<td>NOAA-15, 16, 17</td>
</tr>
<tr>
<td>AIRS</td>
<td>NOAA-18, and METOP -2</td>
</tr>
<tr>
<td>MHS</td>
<td>EOS Aqua</td>
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</tbody>
</table>

High resolution analysis is created using 3Dvar assimilation
## Experimental design

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

**Diagram:**
- **Computational domain:**
  - 21/00Z Assimilation cycle started
  - 06/03Z Declared TD (IMD)
  - 07/00Z Weakened
  - 13/00Z Upgraded to CS

**Timeline of key events:**
- 21/00Z Assimilation cycle
- 06/03Z Declared TD
- 07/00Z Weakened
- Forecast time window
- 21Z
- 00Z
- 03Z

**Experimental design:**
- **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-Fritsch scheme

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

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

IMD in green and 3Dvar analysis in red

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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

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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 is identified as a region of enhanced moisture

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

Proto-vortex is intensified by convective activity (H3)

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Pathway of genesis of Madi (2013)

Profiles

Hovmoller

Closely follows the bottom-up pathway
Pathway of genesis of Madi (2013)

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

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Role of VHTs on genesis of Madi (2013)

Potential vorticity

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

\[
\eta = \zeta + f
\]

\[
\omega = \frac{Dp}{Dt}
\]
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...