

Analysis of Australian Monsoon lows using WRF model

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Outline

- Aim
- Introduction
- Previous studies
- Data
- Analyzed systems
- Analysis
- Questions remained
- Future work
- Questions?

Aim

- To look at some of the diagnostics of Australian Monsoon Lows / Monsoon depressions / tropical lows
- Compare the diagnostics with a tropical cyclone event
- An attempt to understand the formation of these systems.

Introduction

- Australian monsoon lows are distinct features of Australian monsoon.
- They contribute to a significant portion of north Australian rainfall
- Though they are significant weather events, only limited studies available

Introduction

- Scientific information about these systems was not well documented (like tropical cyclones)
- Limited information is available about the widespread rainfall, extended period of rainfall events and flood damage due to these system

Introduction

- Where as, several studies are available on the Indian monsoon lows /Monsoon depressions and well documented information is available for research purposes.
- For Australian Monsoon systems, McBride and Keenan 1982 found that though most of the tropical systems develop in the monsoon shear line the interaction between these systems and mid-latitude systems is highly variable on case by case .

Introduction

- Three Australian monsoon systems were analysed in the current study.
- Out of the three one reached the Tropical Cyclone intensity.
- Some of the diagnostics during the formation stage of these systems were presented.

Previous studies

McBride and Zehr (1981) studied the characteristics of developing and non-developing tropical systems in northwest pacific.

- Studied developing and non-developing tropical systems in Pacific and Atlantic basins using composite data sets made from different sources.
- Found that there is a requirement of not only for very small vertical shear near the system but also two adjoining regions of strong 200-900hPa vertical shear of opposite sign on either side of the system.

Previous studies

Davidson and Holland (1987) studied two tropical depressions that formed over inland Northern Australia and tracked to south east and found

- The structure of these lows were similar to Tropical cyclones
- At low levels, strengthening easterlies and increase in horizontal wind shear across the trough
- Increase in monsoon westerlies followed by the increase in cloud formation
- At upper levels strengthening trough and subtropical jet

Previous studies

Reinhard M Hell and Roger K Smith (1998)

studied a tropical depression over northwest coast of Australia

- The tropical depression formed in the monsoon trough over northwest coast of Australia and drifted southwest along the west coast of Australia.
- The broad scale flow and convective organization was similar to Indian monsoon depression
- Associated with strong low-level convergence (below 950hPa) by weaker divergence above (up to 300hPa)
- Stronger divergence in the upper troposphere (between 250 and 100hPa)

Previous studies

Smith et al (2015) studied the formation of three tropical systems during January 2013

- Out of the three lows that formed in the monsoon trough two reached the tropical cyclone intensity.
- Found that strong vertical shear and drying of the middle troposphere contributed to the non-intensification of one of the three tropical systems.
- The formation of tropical lows over land are not fundamentally different from the lows that form over the sea.

Previous studies

Tang et al (2016) studied the spin-up of a tropical low over land during Australian monsoon.

- Did some numerical studies of spin-up of two tropical lows over land during Australian monsoon.
- Found that the suppressing of the effect of rainfall on the moisture availability in the model has little effect on the evolution of the low.

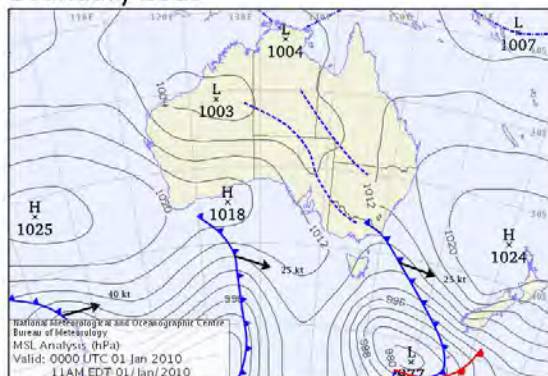
Data

- NCEP FNL (National Centre for Environmental Prediction Final) operational Global Analysis data is used for the analysis.
- The data are on 1 degree by 1 degree grids prepared operationally every six hours.
- The analysis is available at various pressure levels from surface to 10hPa.
- GRIB1 or GRIB2 format binary data were downloaded for the period
- GrADS (Grid Analysis and Display System) software was used to prepare the graphs.

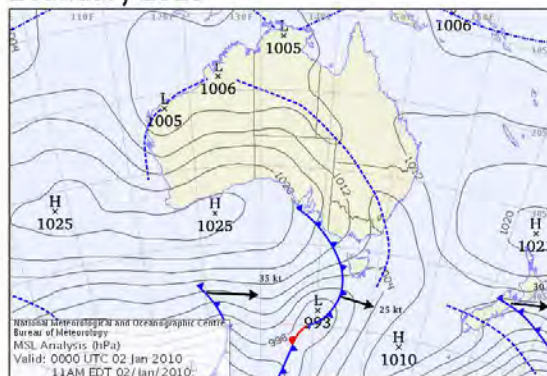
Systems analysed – L2010

Daily mean sea level pressure analyses

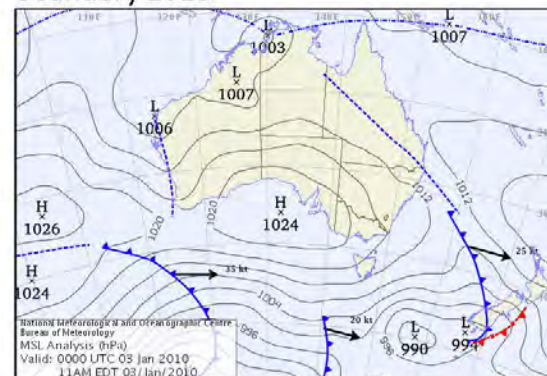
1 January 2010



2 January 2010



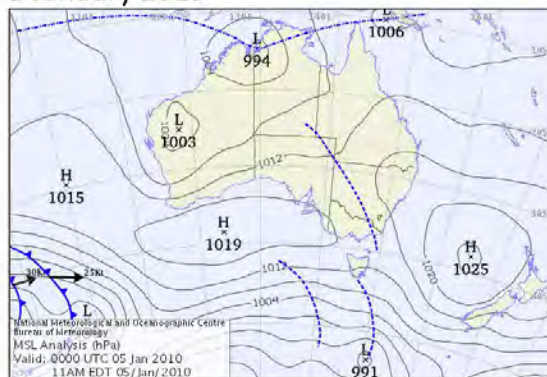
3 January 2010



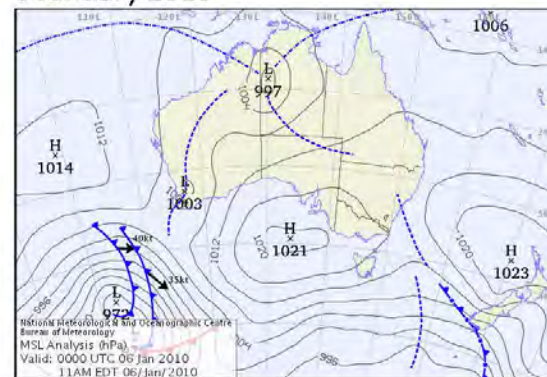
4 January 2010



5 January 2010



6 January 2010

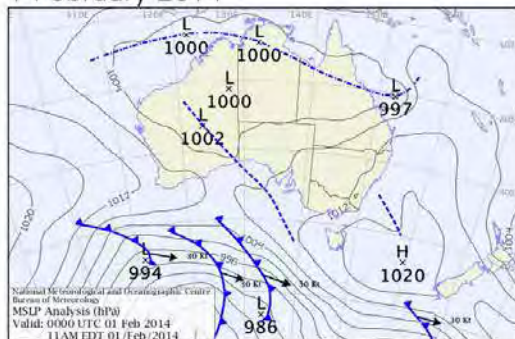


Systems analysed – L2010

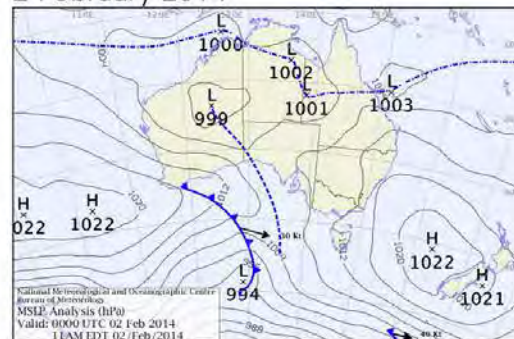
- A tropical low (L2010) formed over the northern Australia on 1 January 2010.
- The system drifted southwest along the north coast and caused flash flooding in the area with widespread rainfall, up to 400mm daily rainfall events at some locations.

Systems analysed – L2014

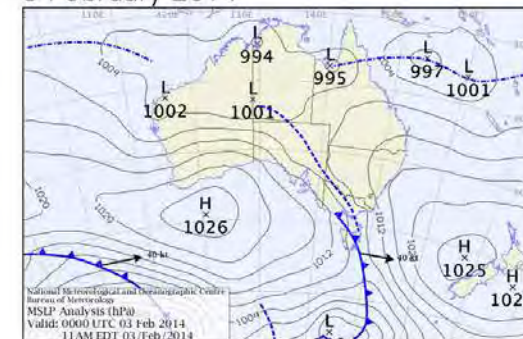
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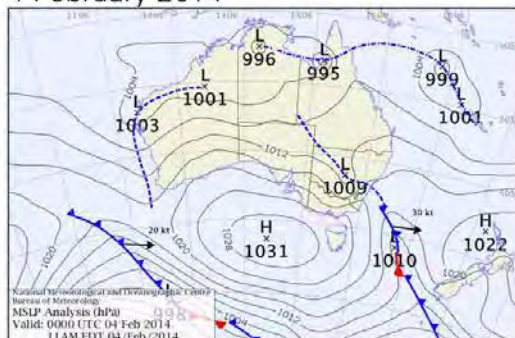
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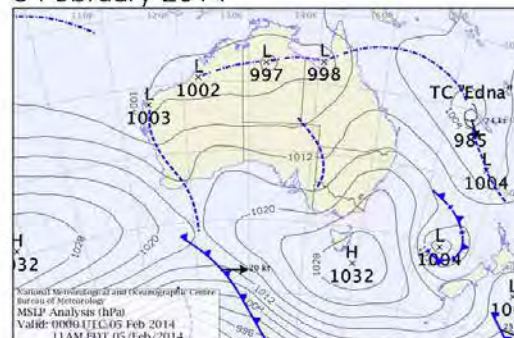
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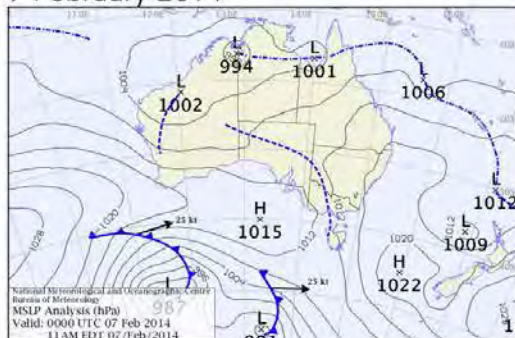
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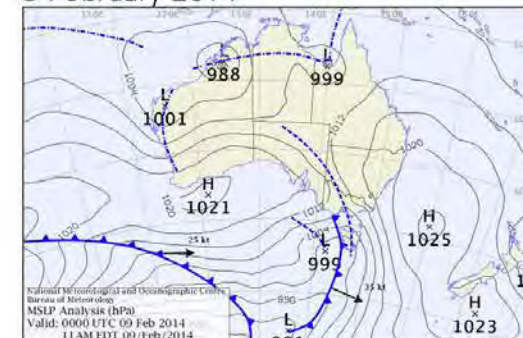
7 February 2014



8 February 2014



9 February 2014

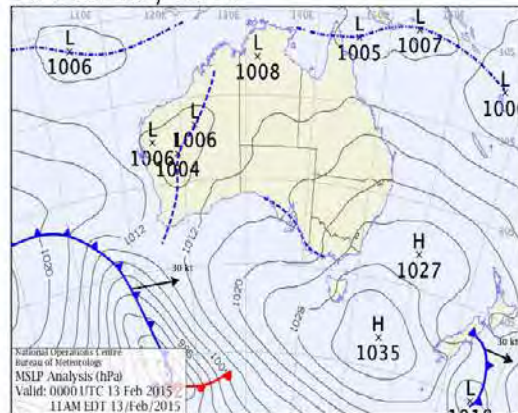


Systems analysed – L2014

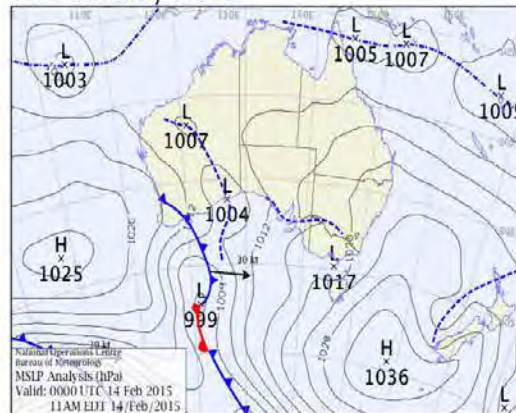
- A low pressure system formed on 1 February 2014 (L2014) within a broad area of monsoon trough that persisted between Equator and 5 degree South.
- This low pressure system drifted over to northwest coast of Australia and remained quasi-stationary until 8 Feb.
- The system caused widespread rainfall over northern Australia with individual daily rainfalls up to 400mm at some stations.

Systems analysed – TC2015

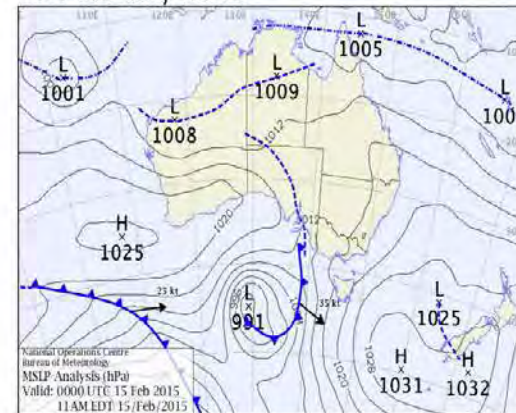
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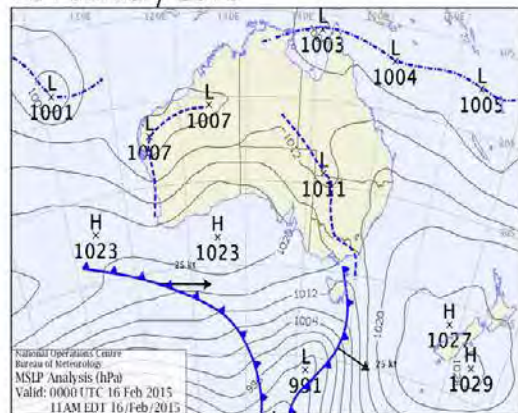
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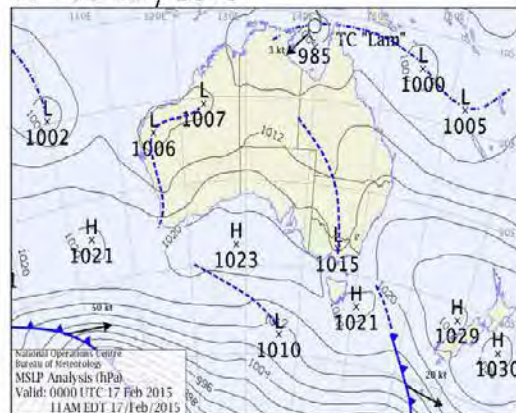
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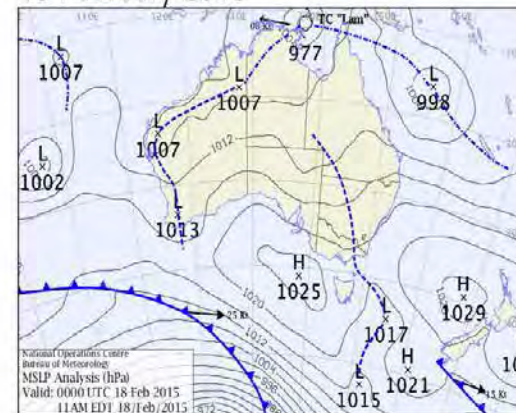
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17 February 2015



18 February 2015

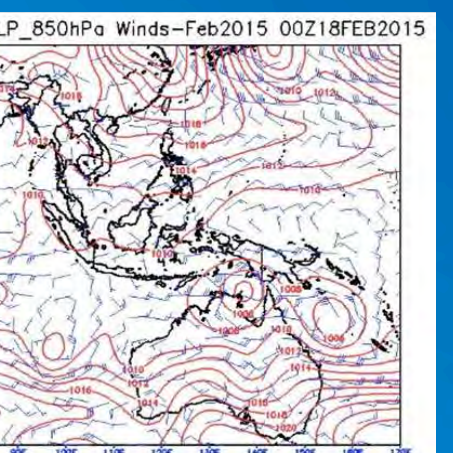
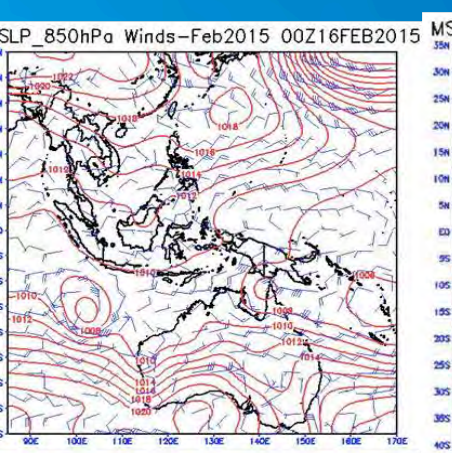
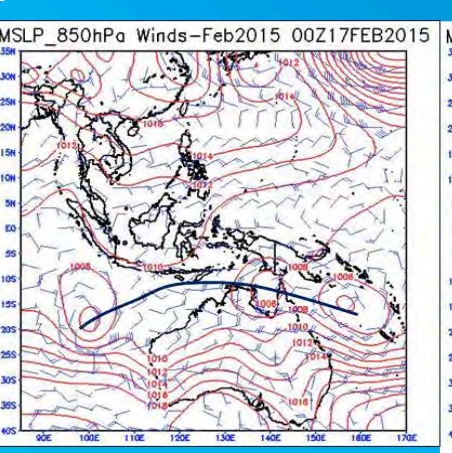
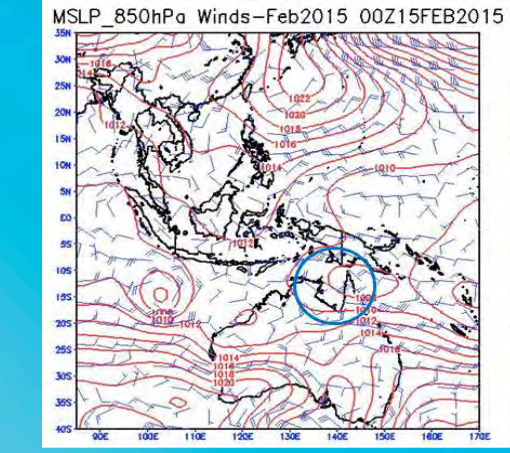
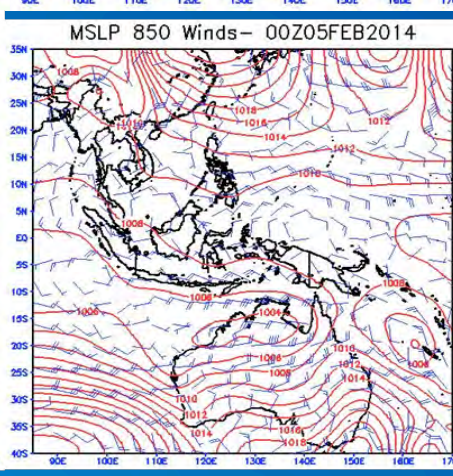
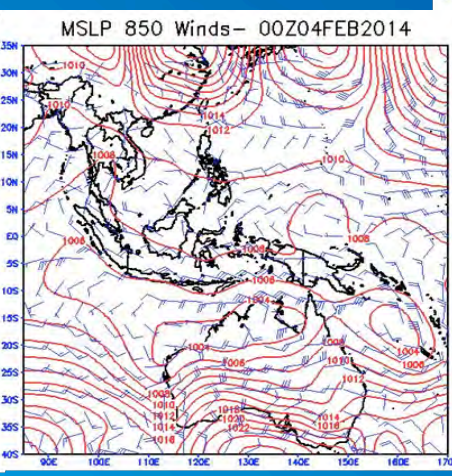
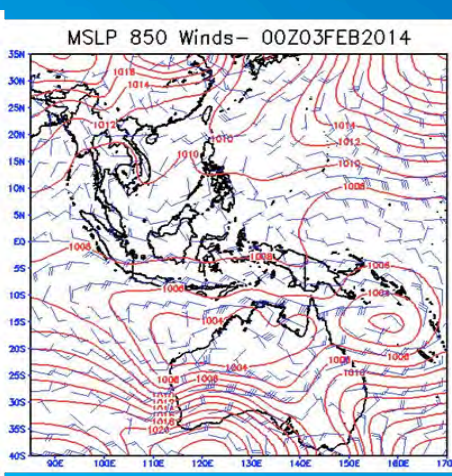
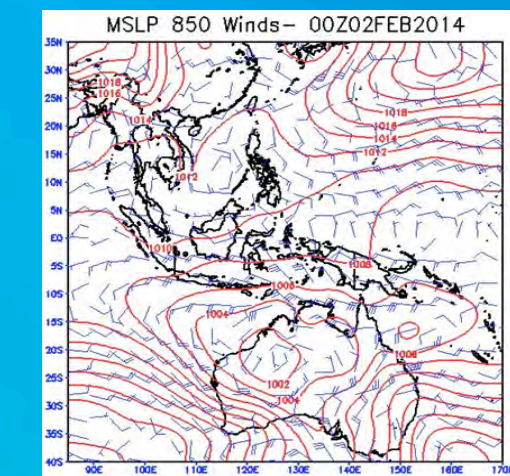
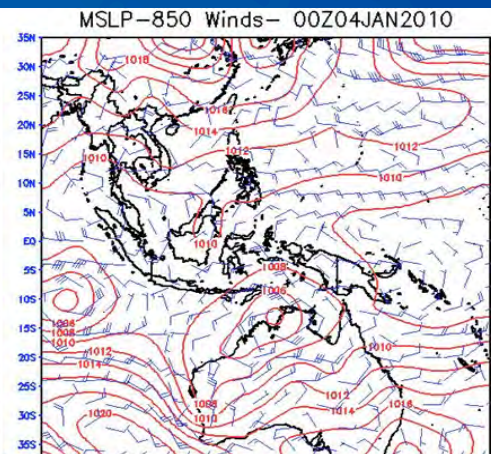
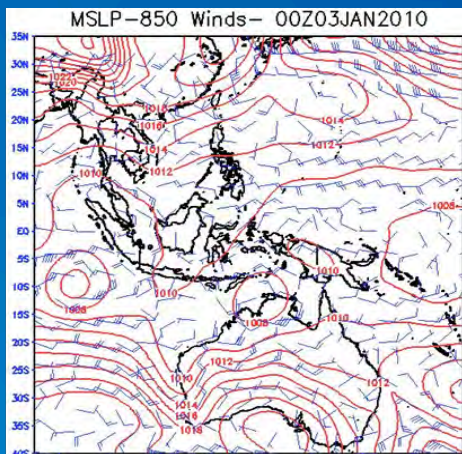
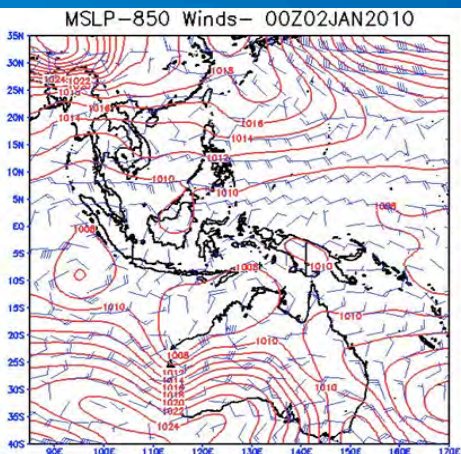
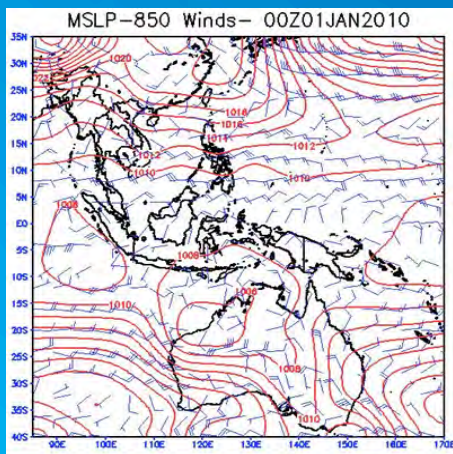


Systems analysed – TC2015

- A low formed on 12 February 2015 over the Coral Sea within the active monsoon trough (TC2015).
- It moved west into the Gulf of Carpentaria and further intensified as tropical cyclone Lam on the 18 Feb.
- The system dissipated on 20 Feb over land.
- It produced widespread heavy rainfall and flooding over northern Australia.

The following parameters were presented

- Mean sea level pressure and 850 wind fields
- Wind field at 200hPa level
- Vertical wind profile
- Relative humidity profile
- Zonal wind shear
- Meridional wind shear
- Divergence field



Mean sea level pressure & 850hPa wind

- L2010 weaker cross equatorial flow
- L2014 Initially tropical air was feeding into the system but later dominated by the dry southerlies.
- TC2015 Well established monsoon trough with good cross equatorial flow throughout.

Jan 2010



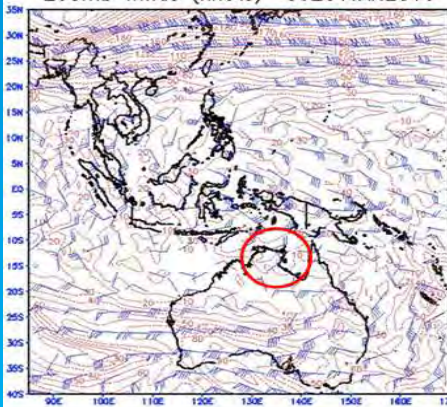
Feb 2014



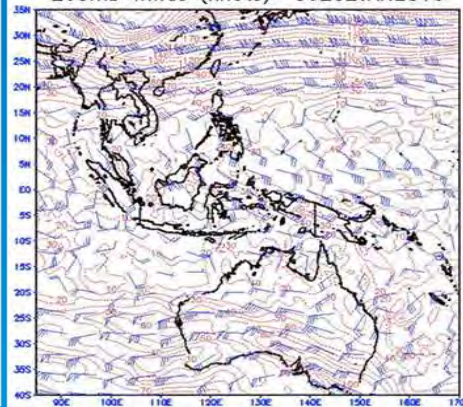
Feb 2015



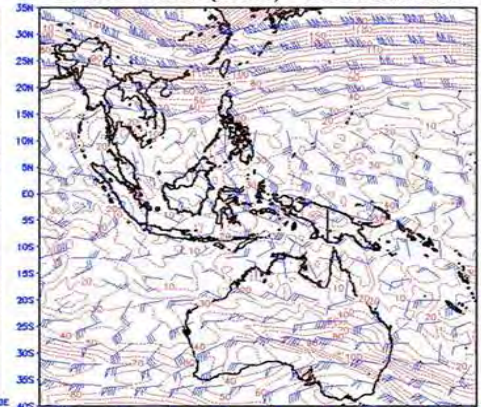
200mb Winds (knots) 00Z01JAN2010



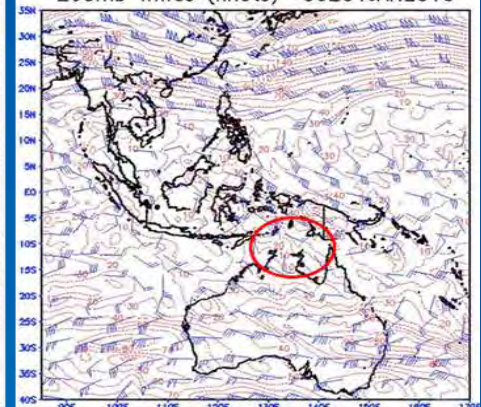
200mb Winds (knots) 00Z02JAN2010



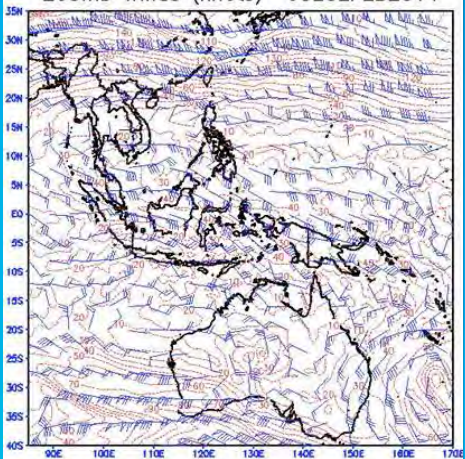
200mb Winds (knots) 00Z03JAN2010



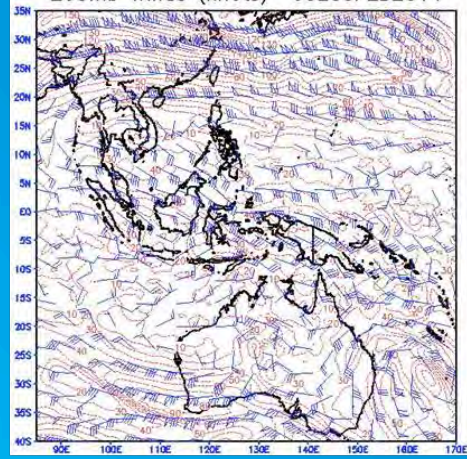
200mb Winds (knots) 00Z04JAN2010



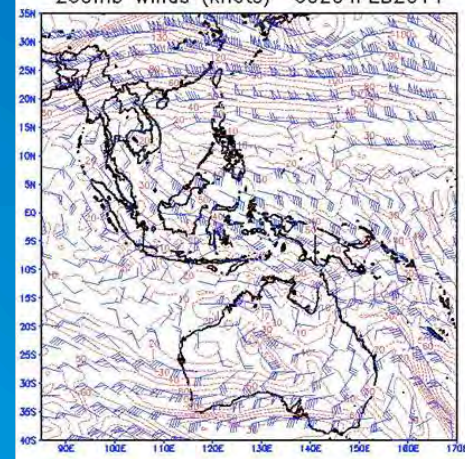
200mb Winds (knots) 00Z02FEB2014



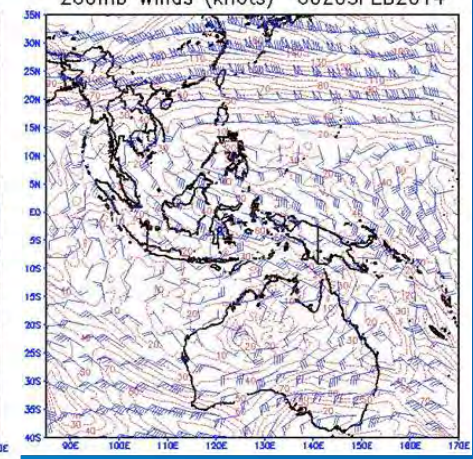
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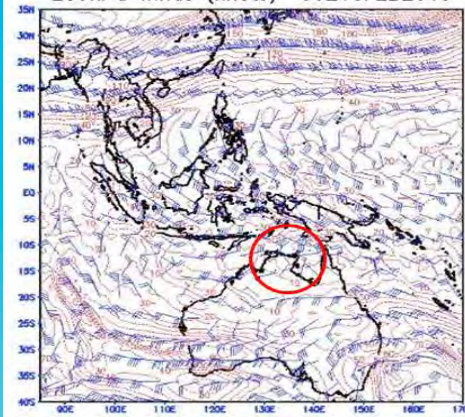
200mb Winds (knots) 00Z04FEB2014



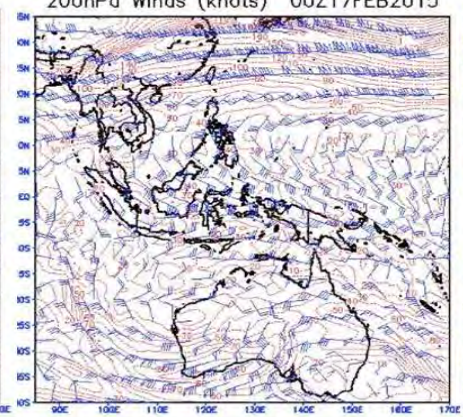
200mb Winds (knots) 00Z05FEB2014



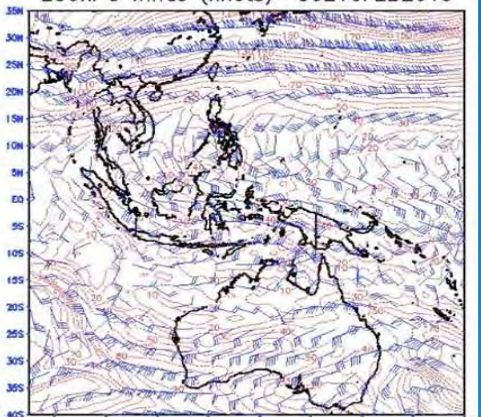
200hPa Winds (knots) 00Z15FEB2015



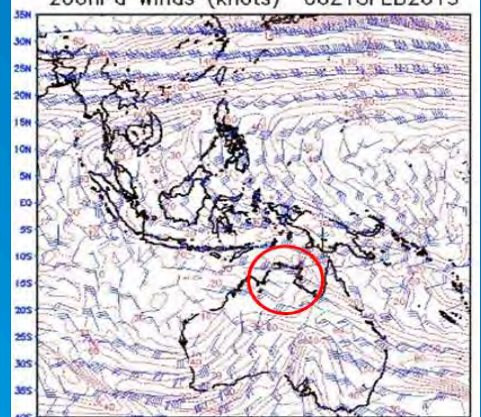
200hPa Winds (knots) 00Z17FEB2015



200hPa Winds (knots) 00Z16FEB2015

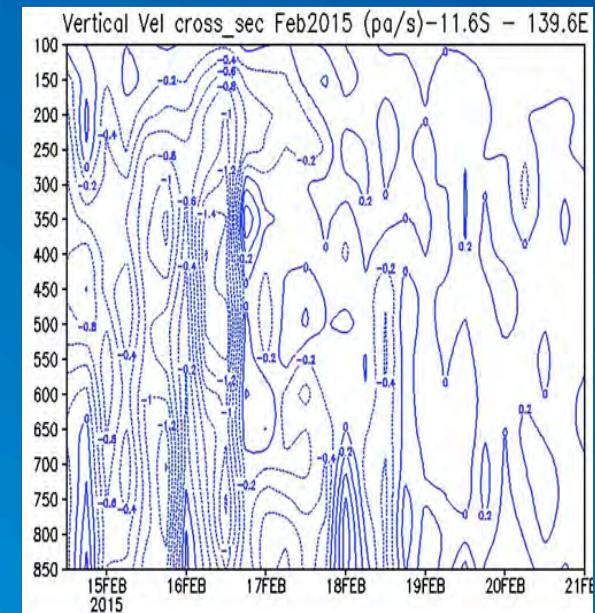


200hPa Winds (knots) 00Z18FEB2015



200hPa Wind

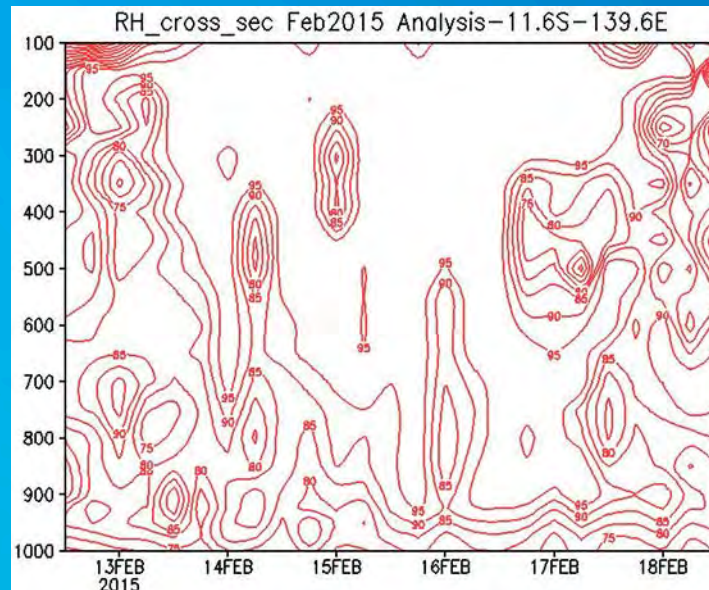
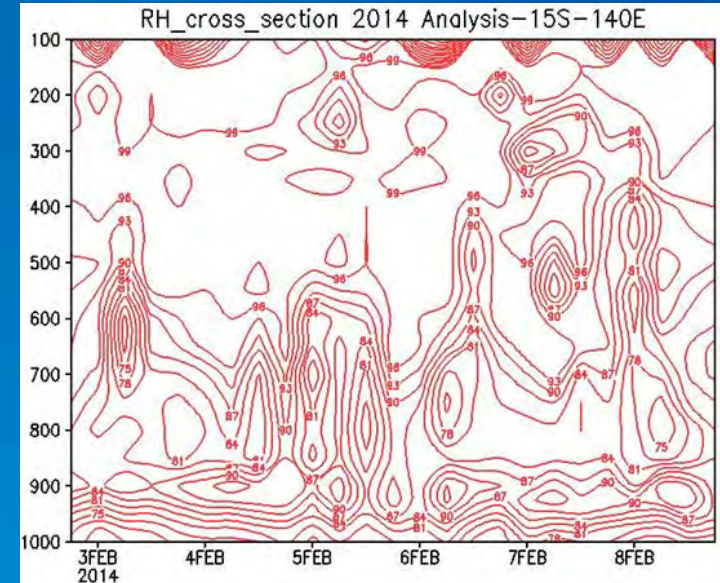
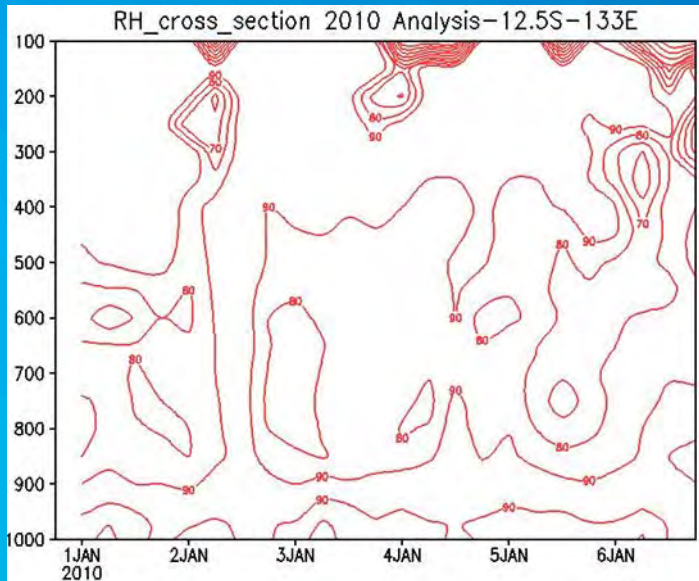
- L2010 weak upper level divergence due to eastward shift of upper level trough
- L2014 weak upper level divergence due to southward shift of upper level trough
- TC2015 Persistent upper level trough over the region throughout the period



Vertical velocity profile

- For L2010 and L2014 the upward motion was stronger at the beginning and became weak later.
- TC 2015 strong upward motion remained throughout the period.

Relative humidity profile

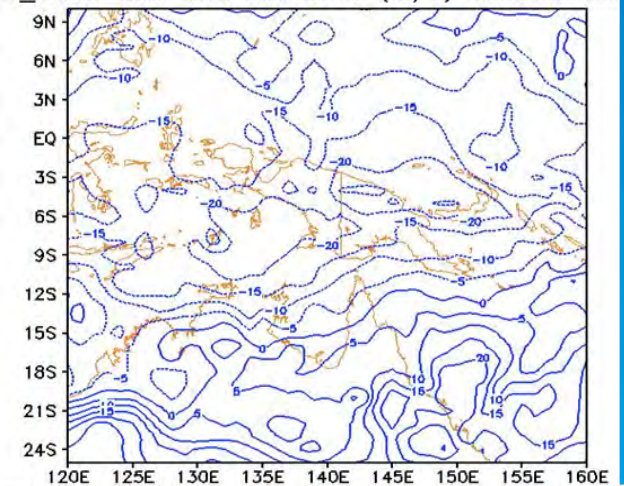


Relative humidity profile

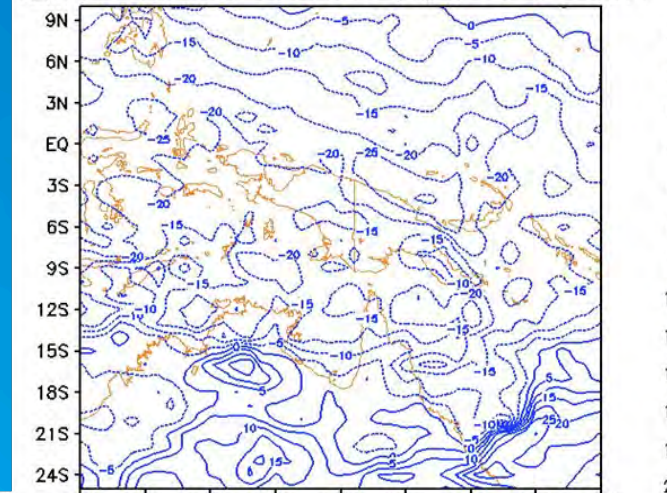
- L2010 Relative Humidity (RH) distribution remain more or less uniform throughout the vertical column and during entire period of the system. Levels close to surface remained more moist.
- L2014 and TC2015 RH distribution was variable in the vertical column and well as during evaluation of the system.
- For L2014 and TC2015, levels close to surface and middle and upper levels remained dryer than L2010
- However, middle level dryness continued during second half period for L2014.

Zonal wind shear

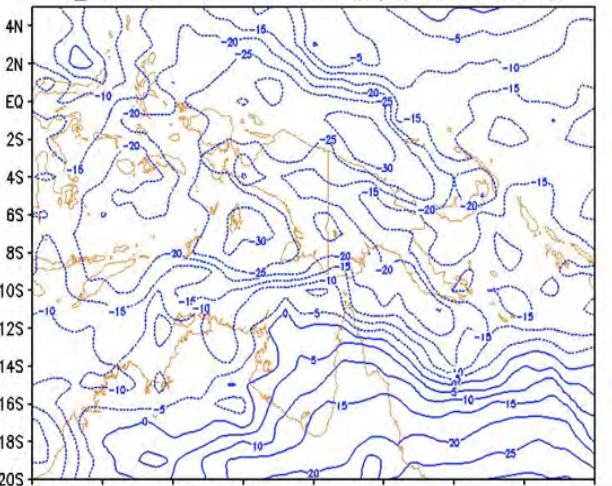
U_Shear 200-900 Jan 2010 (m/s) 00Z01JAN20



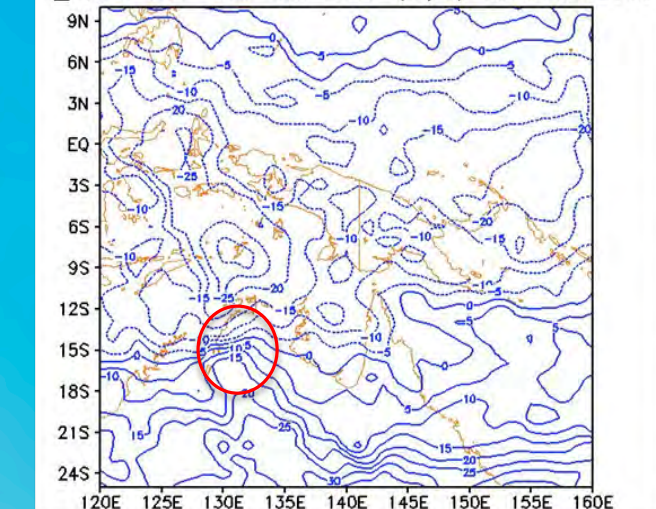
U_Shear 200-900 Feb 2014 (m/s) 00Z01FEB2014



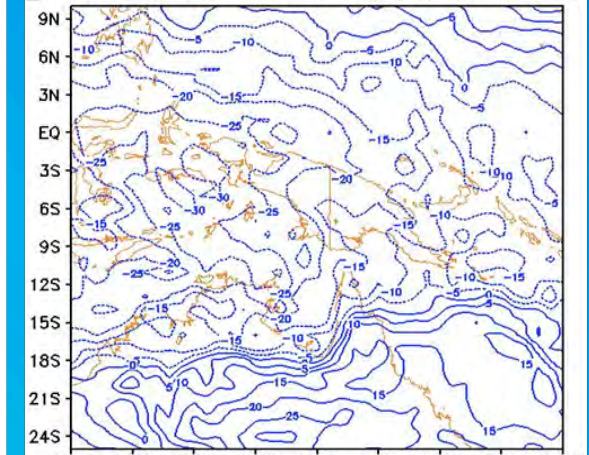
U_Shear 200-900 Feb 2015 (m/s) 00Z15FEB2015



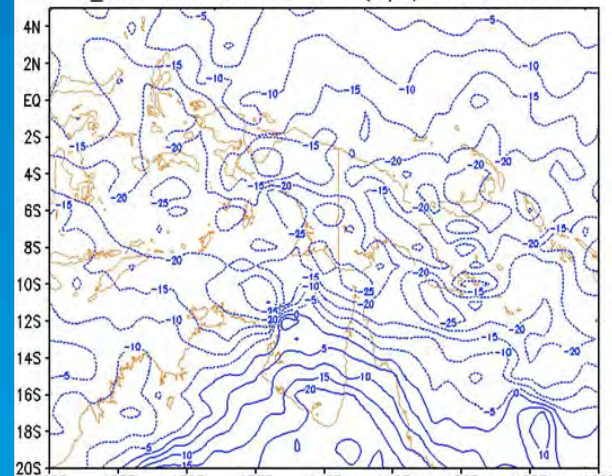
U_Shear 200-900 Jan 2010 (m/s) 00Z05JAN2010



Shear 200-900 Feb 2014 (m/s) 00Z05FEB20



U_Shear 200-900 Feb 2015 (m/s) 00Z18FEB2015

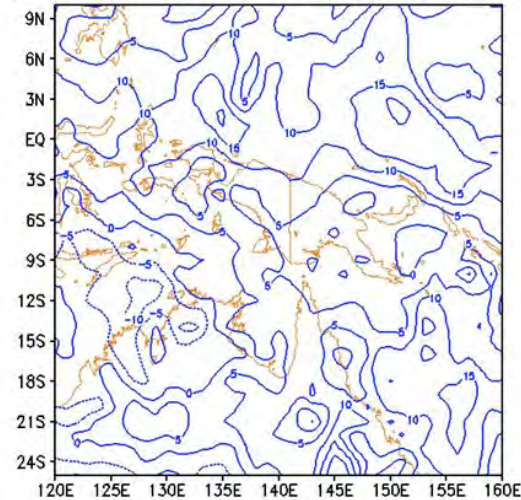


Zonal wind shear

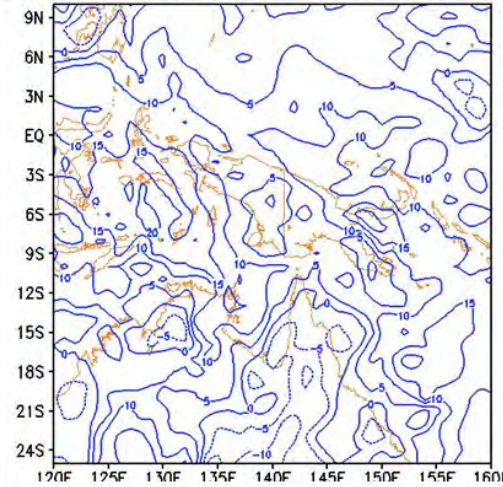
- Zonal wind shear between 200 and 900hPa over the domain became tight near the center for all three systems.
- For L2010 between latitude 9S and 15S shear changed from -20m/s and -10m/s on 1 Jan to -25m/s and 15m/s on the 5 Jan in the same latitude band.
- Similar type of tightening observed for L2014 and TC2015.

Meridional wind shear

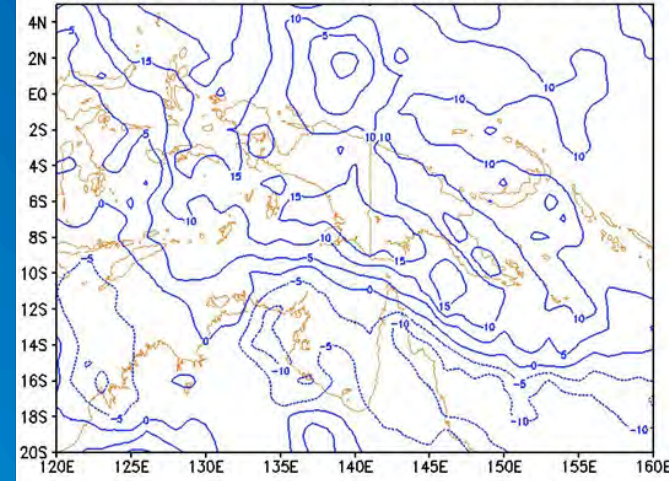
V_Shear 200-900 Jan 2010 (m/s) 00Z01JAN2010



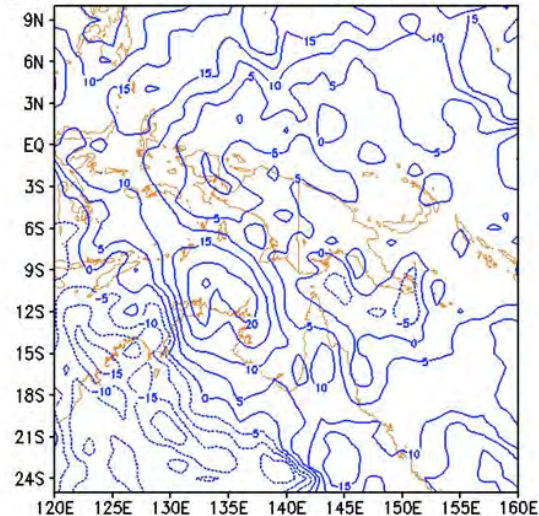
V_Shear 200-900 Feb 2014 (m/s) 00Z01FEB2014



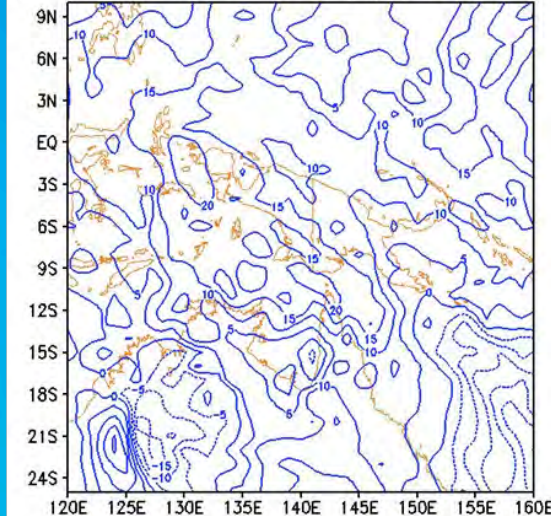
V_Shear 200-900 Feb 2015 (m/s) 00Z15FEB2015



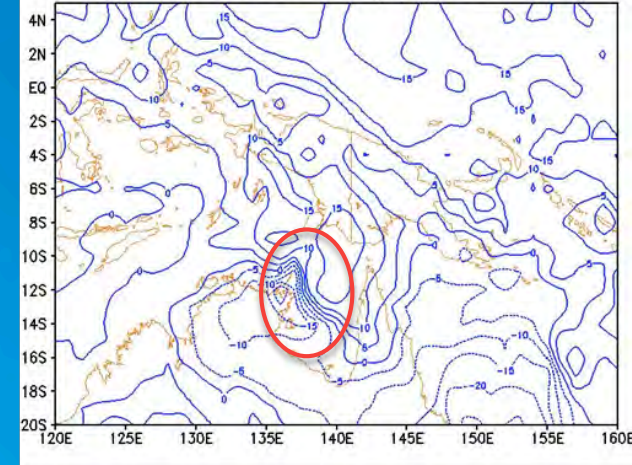
V_Shear 200-900 Jan 2010 (m/s) 00Z05JAN2010



V_Shear 200-900 Feb 2014 (m/s) 00Z05FEB2014



V_Shear 200-900 Feb 2015 (m/s) 00Z18FEB2015

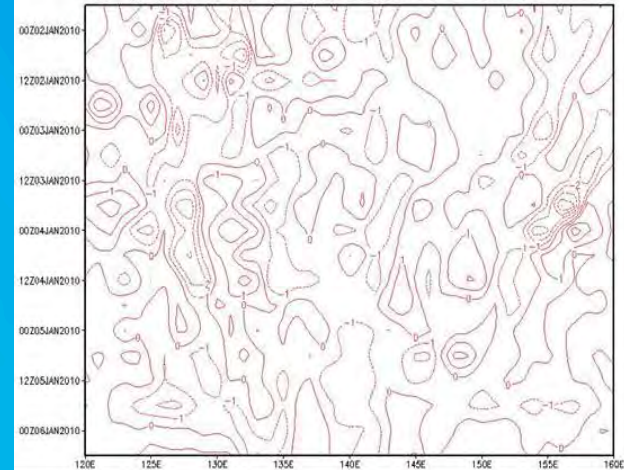


Meridional wind shear

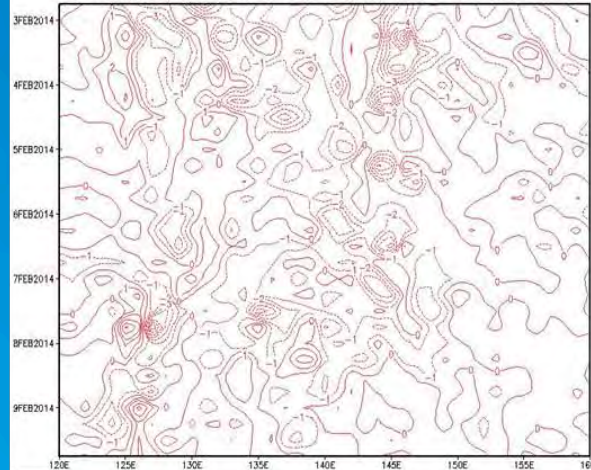
- Meridional wind shear became stronger in L2010 being increase of northerlies to the west and increase of southerlies to the east of the system
- For L2014 no significant change in meridional winds but strengthening of southerlies happened to the north and east of the system
- Considerable strengthening of northerlies to the west and southerlies to the east of the system took place during TC2015

Divergence field

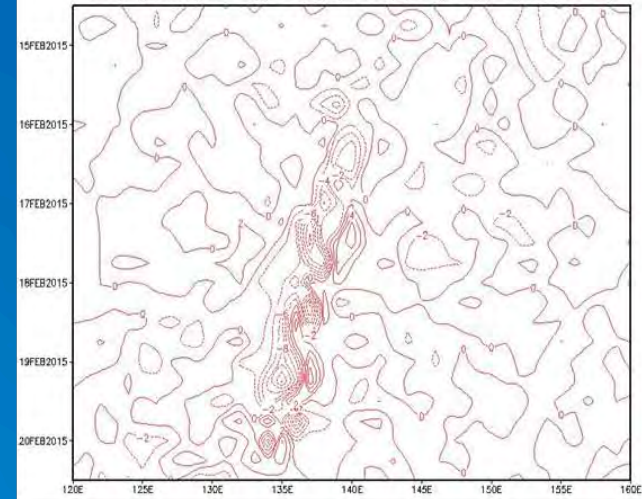
Divergence($\times 10^{-5}$) Long_cross_Jan2010-850hPa-12.5S



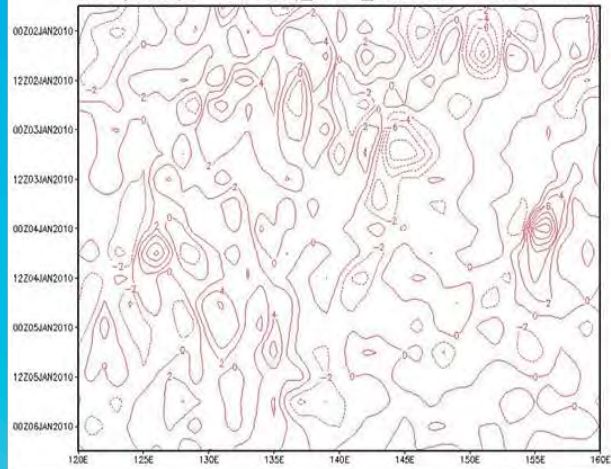
Divergence($\times 10^{-5}$) Long_cross_2014-850hPa-15S



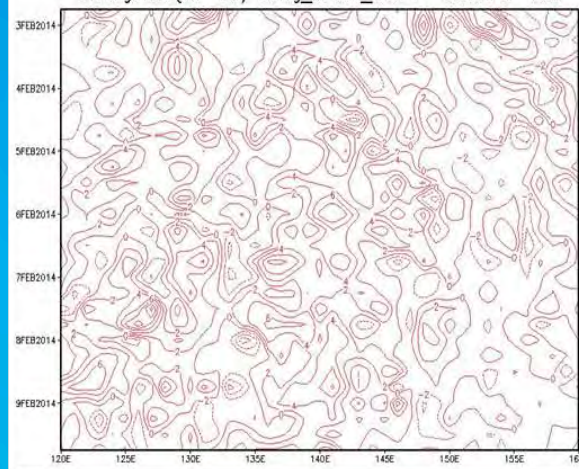
Divergence($\times 10^{-5}$) Long_cross_2015-850hPa-11.6S



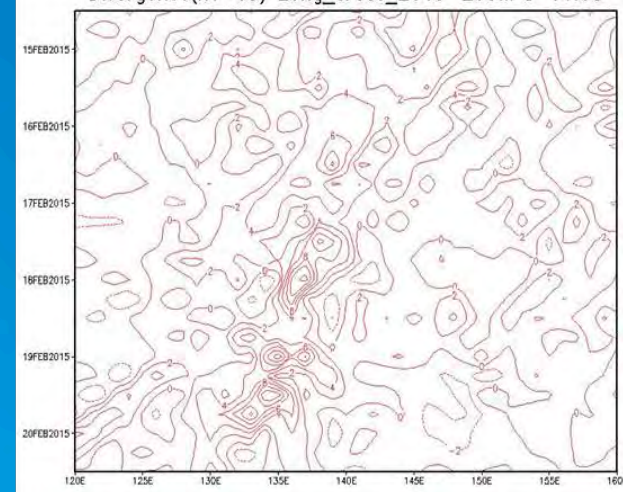
Divergence($\times 10^{-5}$) Long_cross_Jan2010-200hPa-12.5S



Divergence($\times 10^{-5}$) Long_cross_2014-200hPa-15S



Divergence($\times 10^{-5}$) Long_cross_2015-200hPa-11.6S



Divergence field

- For L2010, a broad area of low level convergence with no sign of significant change with time and a weak area of divergence with strong convergence to the east and west of the system persisted at upper levels (200hPa)
- Persistent areas of low level convergence and upper level divergence prevailed during L2014
- Intensifying low level convergence and upper level divergence persisted throughout for TC2015.

The questions

- As we noted some of the above characteristics were different for each system.
- It appears that each system has different ways of interaction with general circulation and regional variables during formation and mature stages.

Further studies

Further studies are required to understand features such as, What is the role of general circulation i.e.,

- *Heat low over Australian continent*
- *Strength and position of extra tropical ridge over Australia*
- *Cross equatorial flow*
- *Upper level jet*
- *Links with large scale futures such as MJO and ENSO*

Further studies

Dynamical factors such as

- *CISK mechanism*
- *Cyclonic vorticity*
- *Vertical and horizontal shear
at various levels*

Future work

- Analyze and document the monsoon lows over northern Australia
- Use WRF model (at JCU) to understand the influences of various large and regional scale circulation features in formation and intensification of these systems.
- Aim for better prediction and monitoring of these important weather systems of Australia.

References

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Thank you

Any Questions ?