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# Forecasting Size Changes in Tropical Cyclones

## *Size forecasting: the poor cousin?*

VLAB 18 July 2017

## Defining TC Size/ Structure

## Why is it so important?

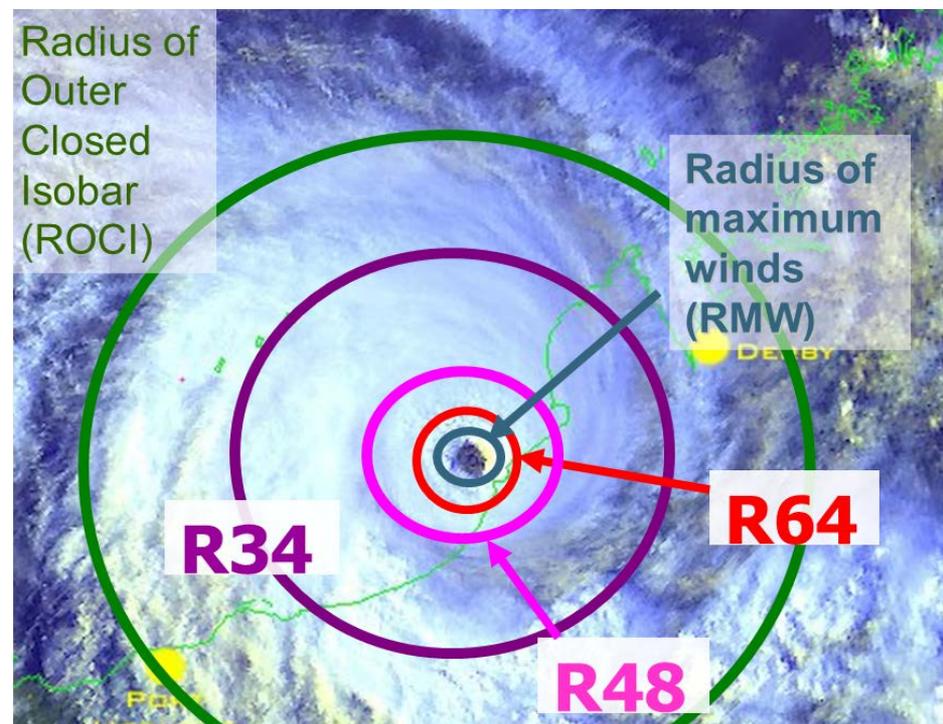
## Conceptual models

## Factors affecting size changes

## The Forecast process

## Objective guidance: inc. NWP

Joe Courtney



Should you use these resources please acknowledge the Australian Bureau of Meteorology Training Centre. In addition, you need to retain acknowledgement in the PowerPoint slides of EUMETSAT, the Japan Meteorological Agency, the Bureau of Meteorology and any other sources of information.



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# Size Forecasting: Why?

## Why?

determine warning area;

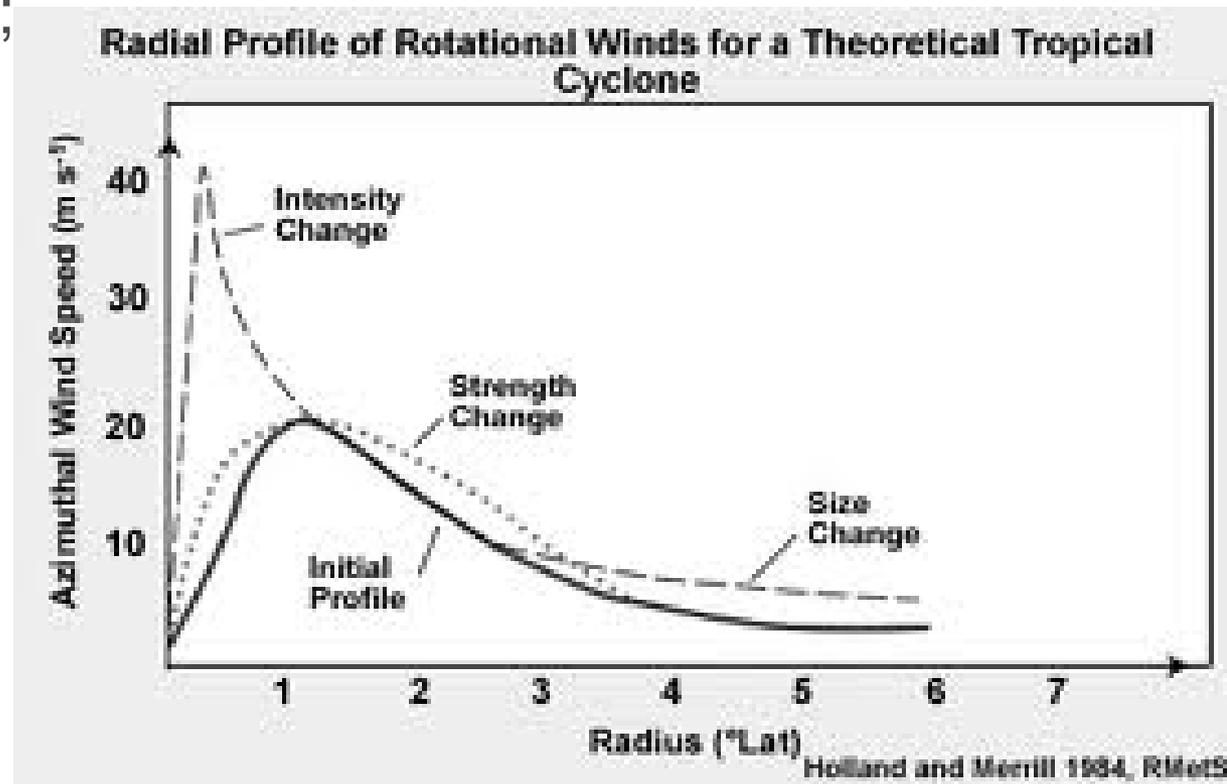
Onset and duration of  
wind threat;

storm tide forecasting;

wave forecasting;

intensity changes

Rainfall?



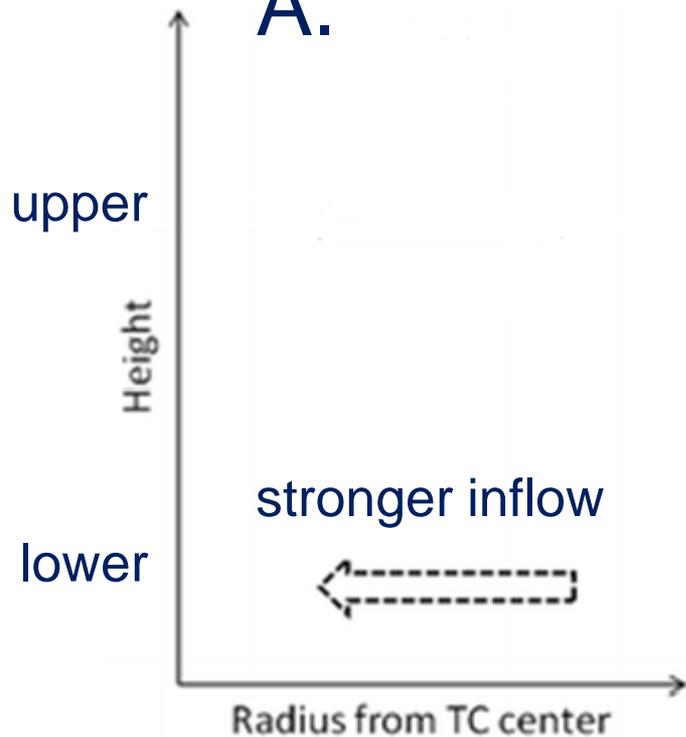


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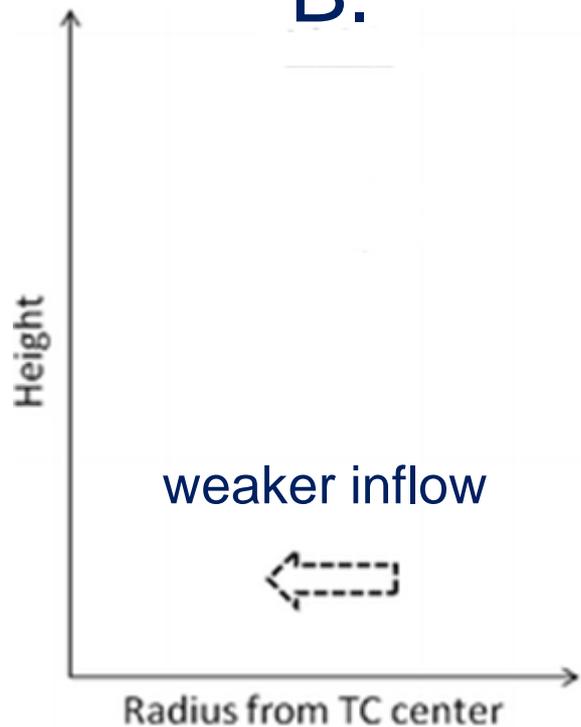
# Size Changes: conceptual models

Which of these would cause an increase in size (gale radius) ?

A.



B.



C. No difference

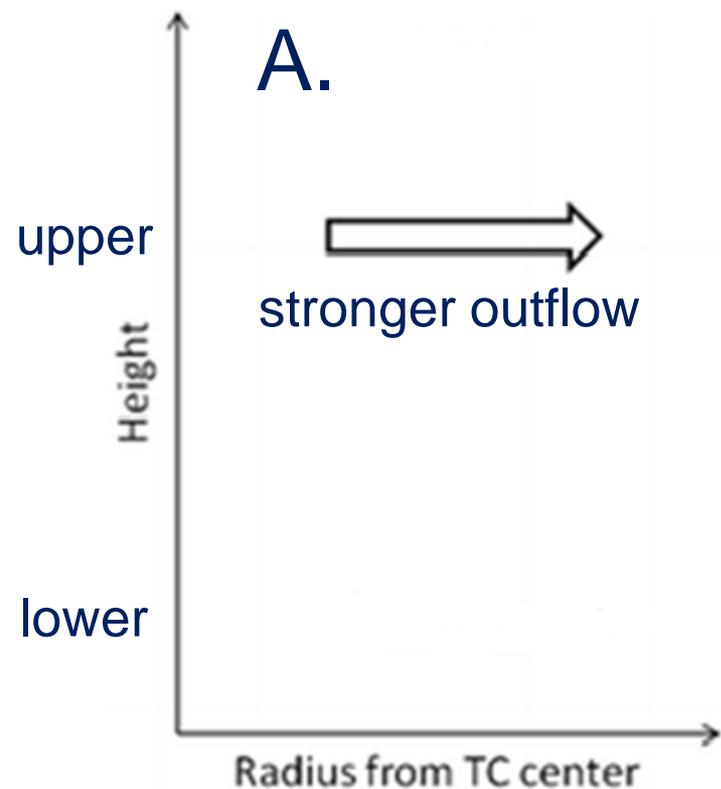


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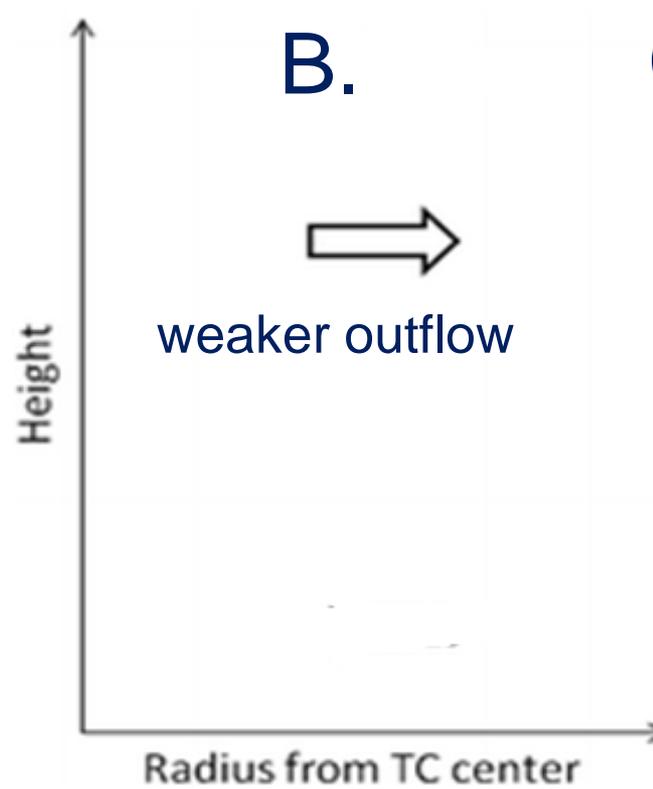
# Size Changes: conceptual models

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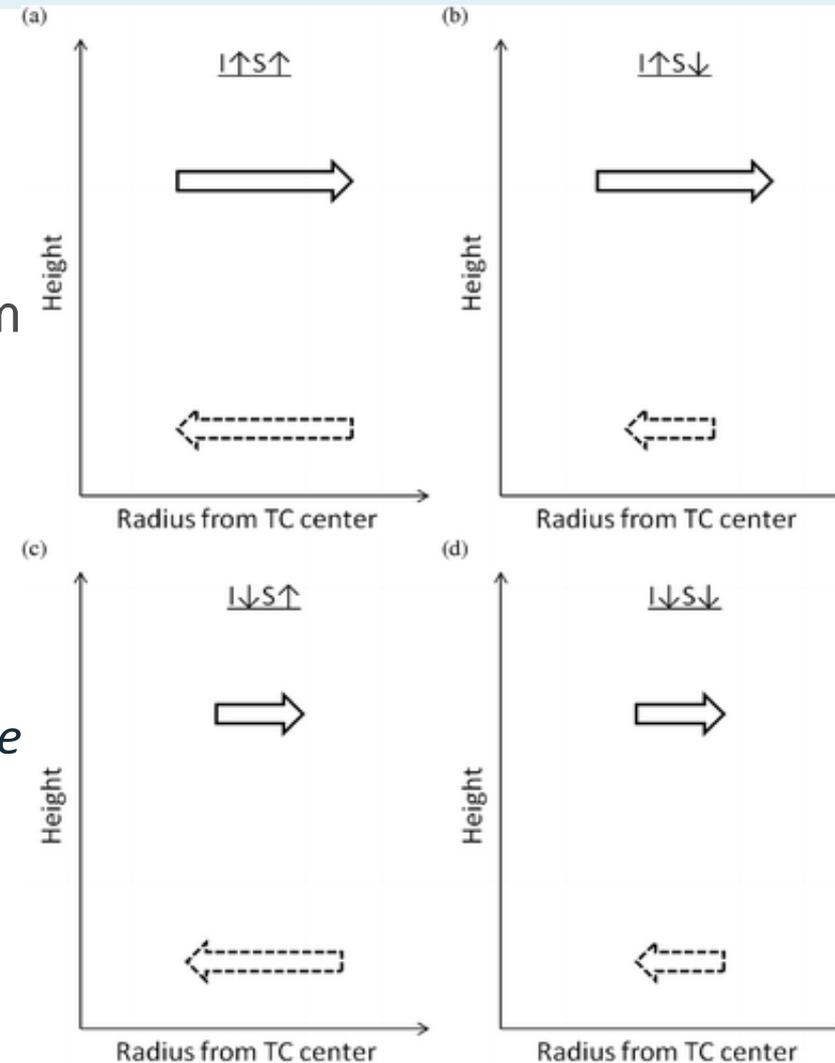


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# Size Changes: conceptual models

**intensity** change is positively related to the change in **upper-level** angular momentum export

**size** change is positively proportional to the change in the **lower-level** angular momentum import related to the change in synoptic flow patterns near the TC



Chan&Chan 2013 <http://journals.ametsoc.org/doi/full/10.1175/MWR-D-12-00204.1>

Fig 17 Angular momentum transports for intensity (I) and Size (S) changes at upper and lower levels.

*'The initial vortex size is found to be crucial in the evolution of TC size' and*

*'influenced by outer-wind circulation'*

Chan and Chan, 2015

<http://onlinelibrary.wiley.com/doi/10.1002/qj.2292/full>



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# Size changes: conceptual model

## Simple size model through life cycle

Stage 1. *Initial*: gales first appear, asymmetric

Stage 2. *Consolidation*: becomes more symmetric and expands as convection and circulation becomes established;

Stage 3 *Intensification*: minimal change

Stage 4 *Weakening*: becomes more asymmetric and eventual decay

Note: Ignoring land and significant variations in synoptic forcing, wind shear, dry-air in low-mid levels.



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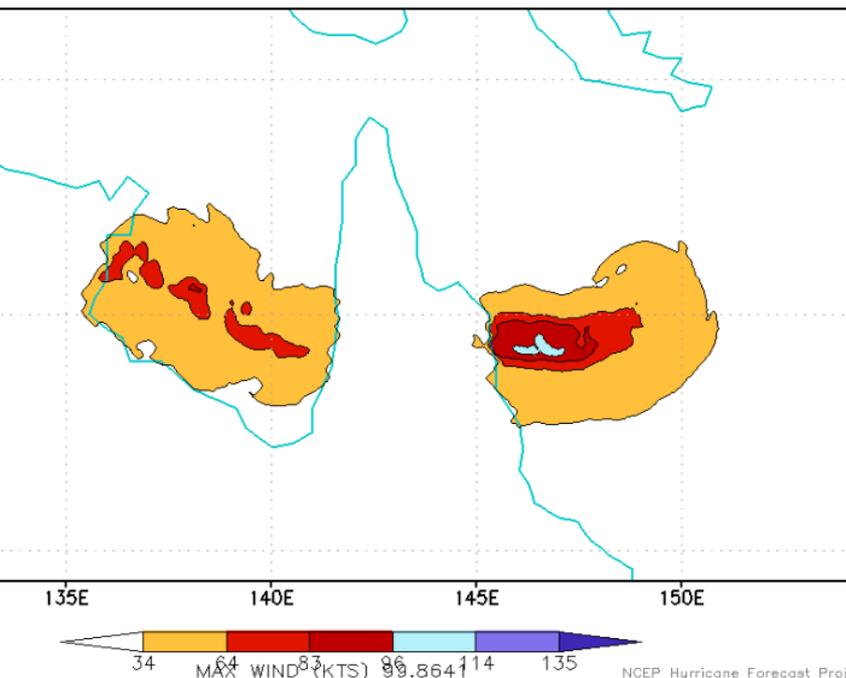
# Factors affecting Size changes: land

## Land strongly attenuates wind flow especially for hilly and heavily forested areas and weakens intensity

INIT 2015031800 Z for 126 h FCST VALID 2015032306 Z

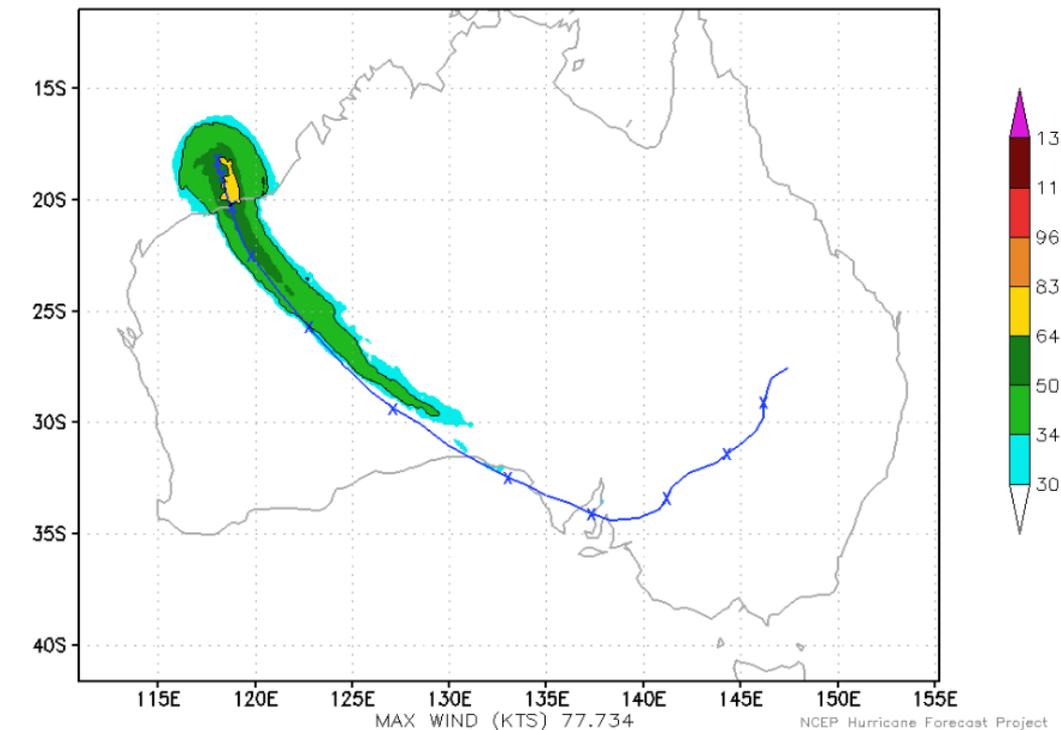
HWRP 10M MAX WIND(KTS) NATHAN18P

INIT POS (14.10 LAT, -149.20 LON) FINAL POS (14.00 LAT, -135.10 LON)X=12 h POS



HWRP 10M MAX WIND(KTS) STAN09S

START POS (-18.20 LAT, 118.10 LON) FINAL POS (-27.60 LAT, 147.40 LON)X=12 h POS



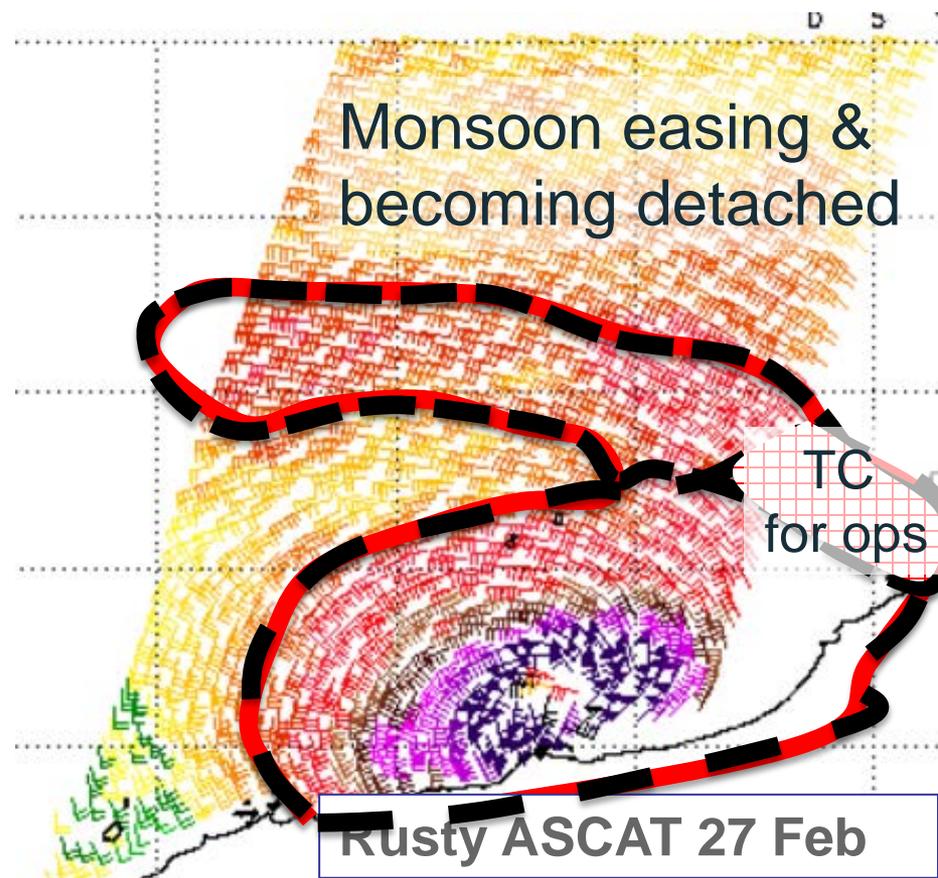
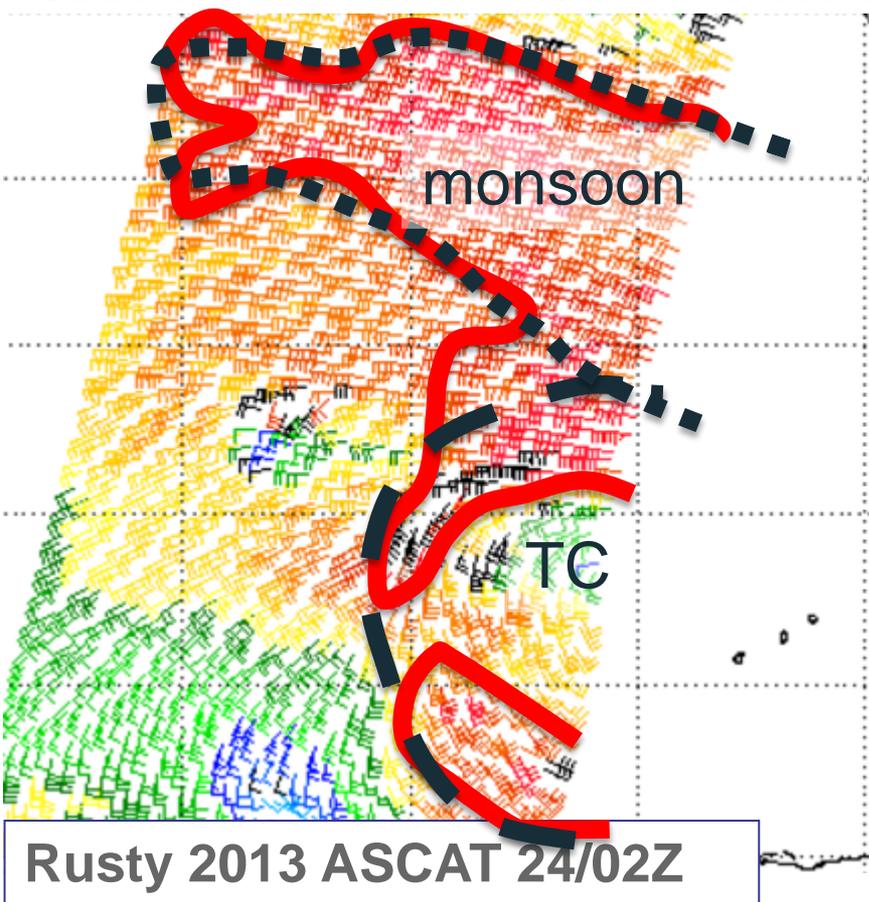


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# Factors affecting Size changes: synoptic systems a. Monsoon flow

strong monsoon can cause broad gale region on northern side

Issue: TC wind field Vs environmental flow?



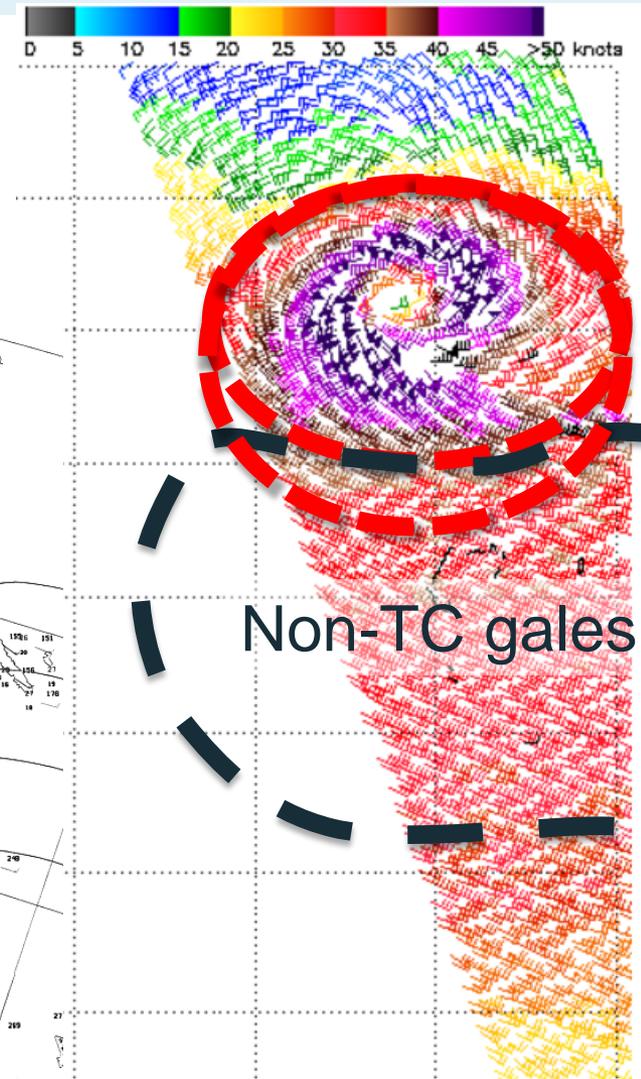
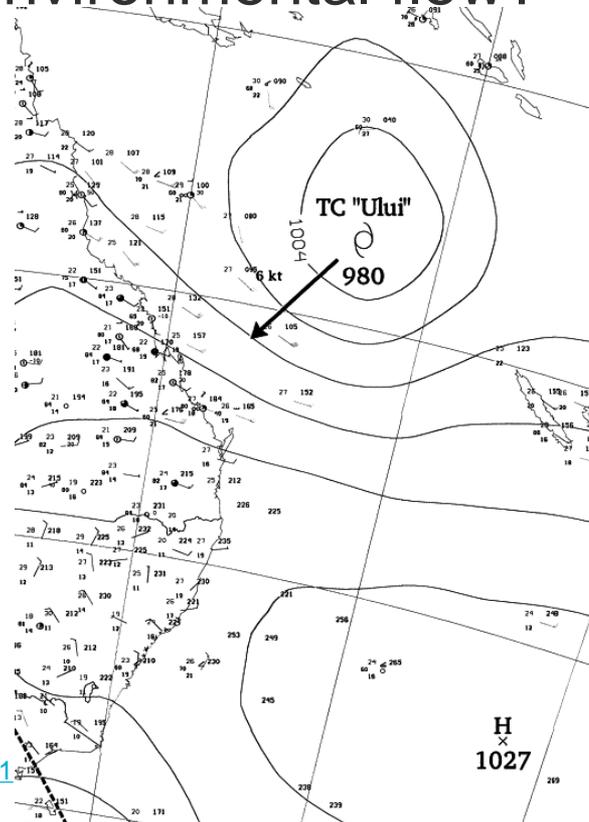


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# Factors affecting Size changes: synoptic systems b. Sub-tropical Ridge

A strong ridge can expand gale extent on southern side esp Coral Sea

Issue: TC wind field Vs environmental flow?  
Drier than monsoon flow



Non-TC gales

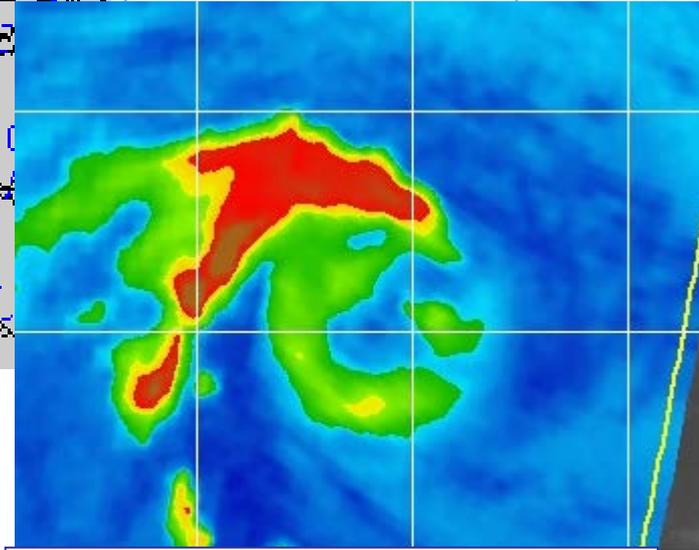
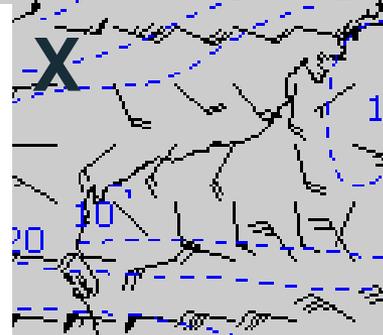
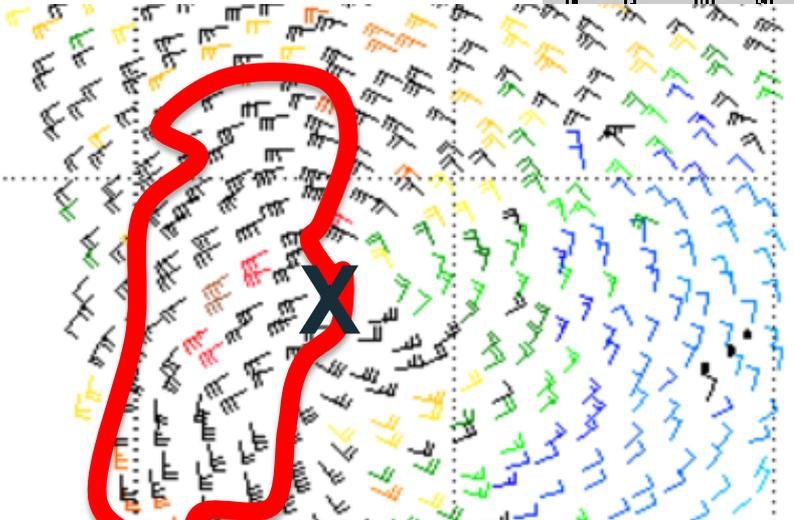
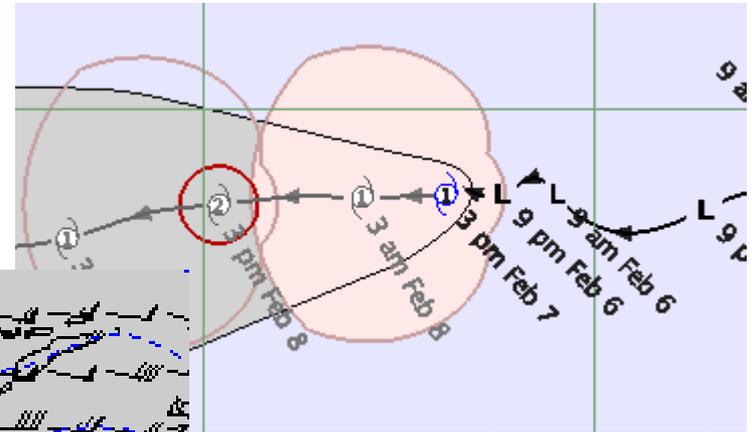
Environmental RH and Size  
Hill and Lackmann, 2009

<http://journals.ametsoc.org/doi/full/10.1175/2009MWR2679.1>

# Factors affecting Size changes: convection from wind shear and dry air

## Case study: Freddy 2009

Shear inhibited development  
Gales mostly western side  
Related to convective and RH pattern



QSCAT 2229Z 6 Feb (NOAA)

SSM/I 2219Z 7 Feb (NRL)

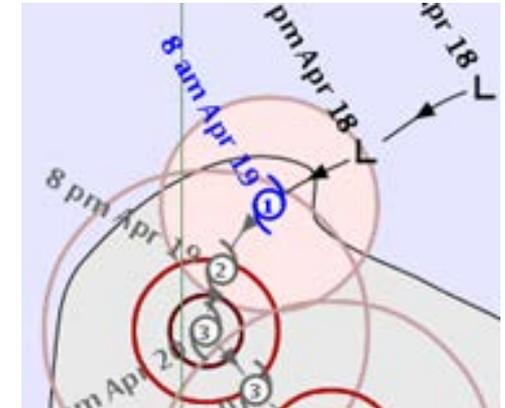
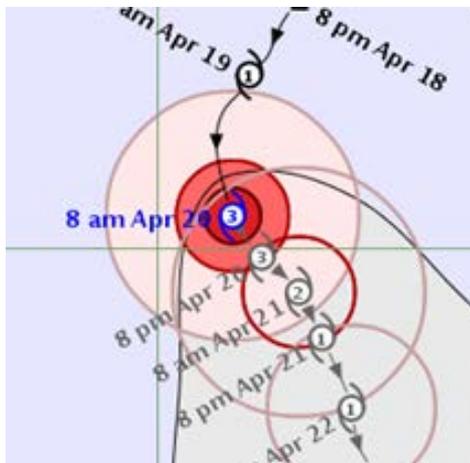


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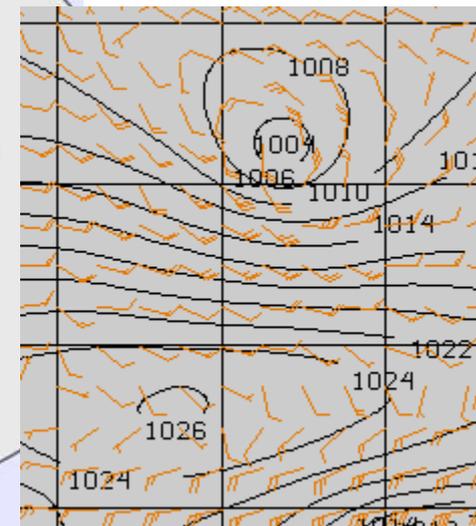
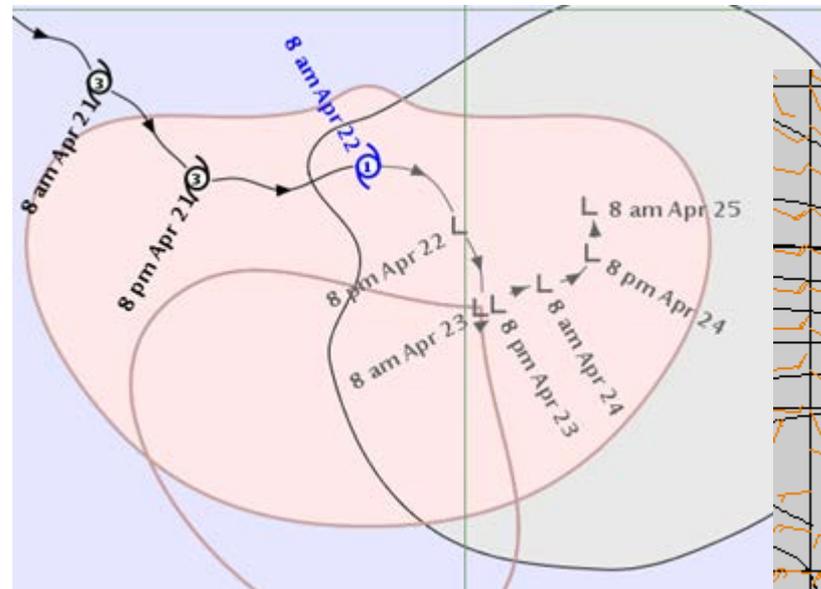
# Do TCs expand during intensification? Contract during weakening?

## Case study: Jack 2014

1. Early characteristics: symmetric gales
2. Peak intensity remain similar size



3. weakening; synoptic forcing with STR to south



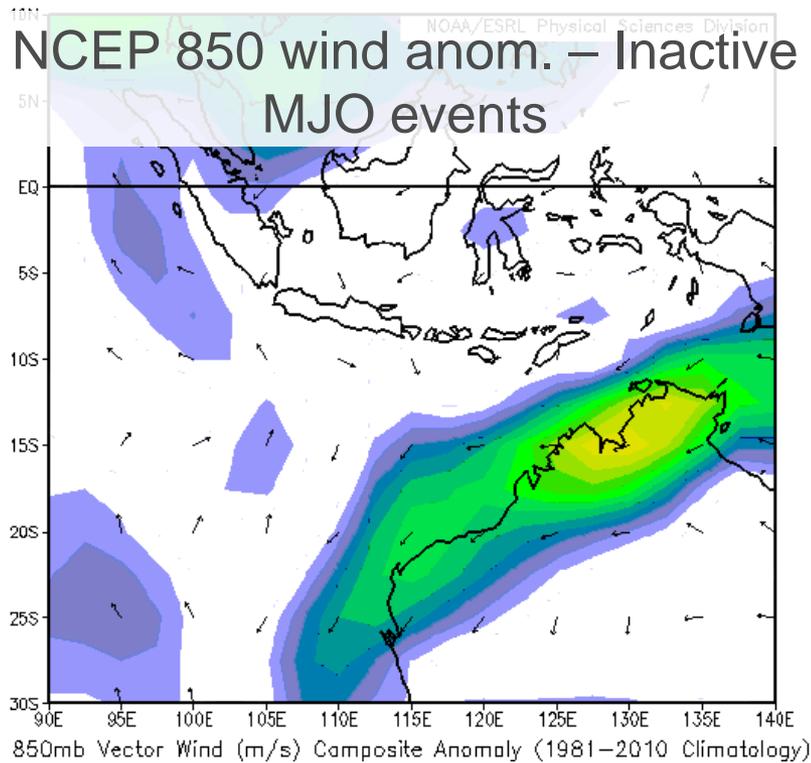


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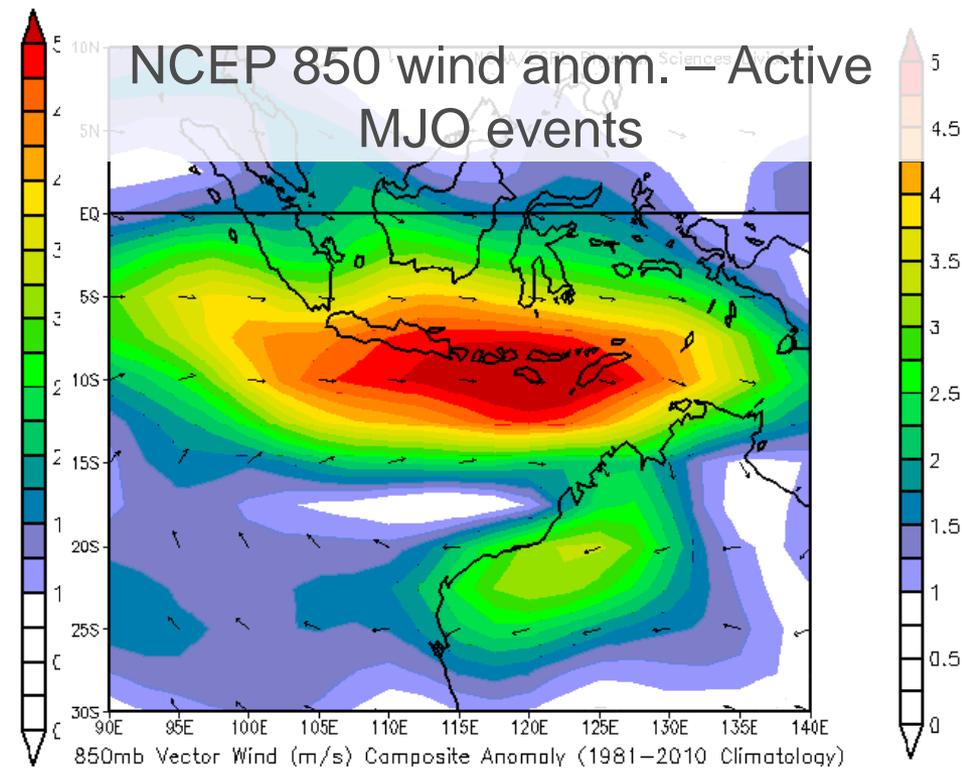
# Small Vs Large TCs

Smaller TCs form during weaker monsoon and drier environments (inactive MJO)

Larger TCs during enhanced monsoon and moist environment (active MJO)



typical formation gale radius – 74km



typical formation gale radius – 100km

Credit: Grant Elliott

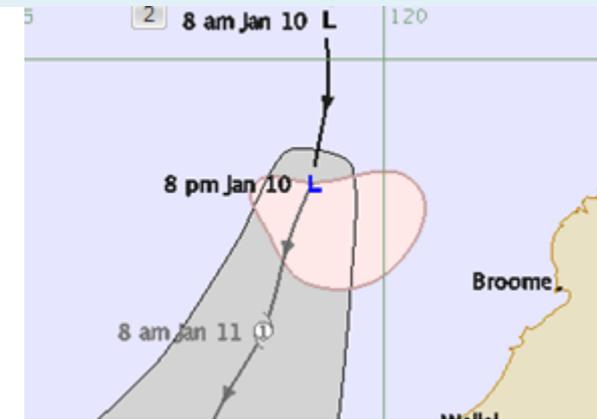
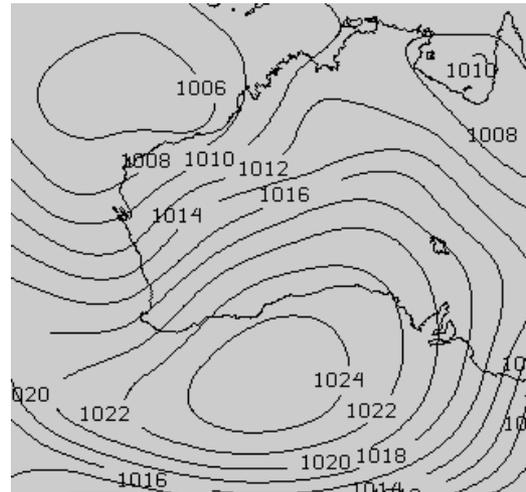
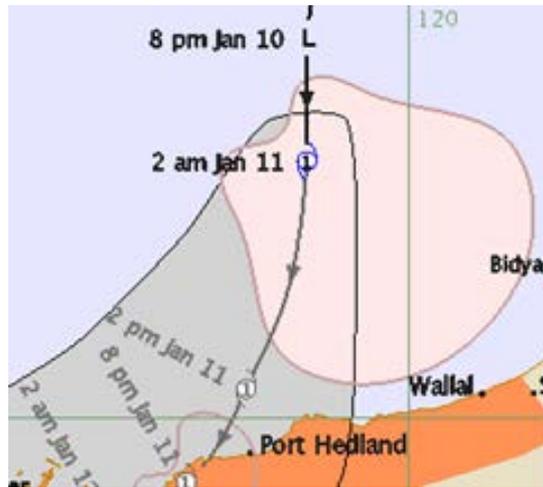


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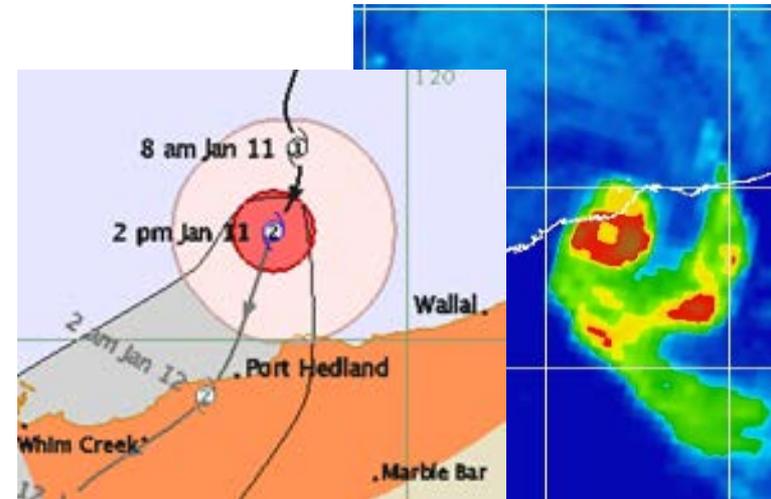
# Small TC Case study: Heidi 2012

## easterly forcing and drier outer circulation

1. Initial characteristics: small area gales
2. Extension to SE with ridge to southeast



3. Intensification: becoming symmetric  
Contraction and closer to land  
Very small RMW at landfall <10km

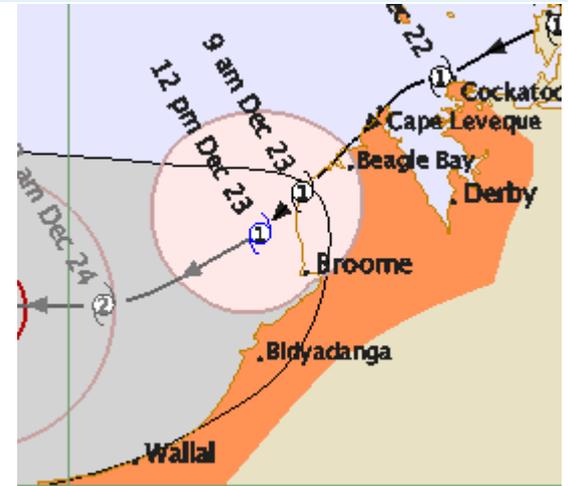
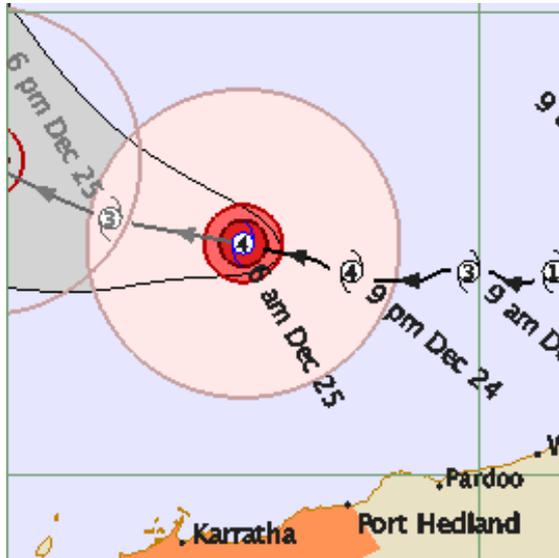




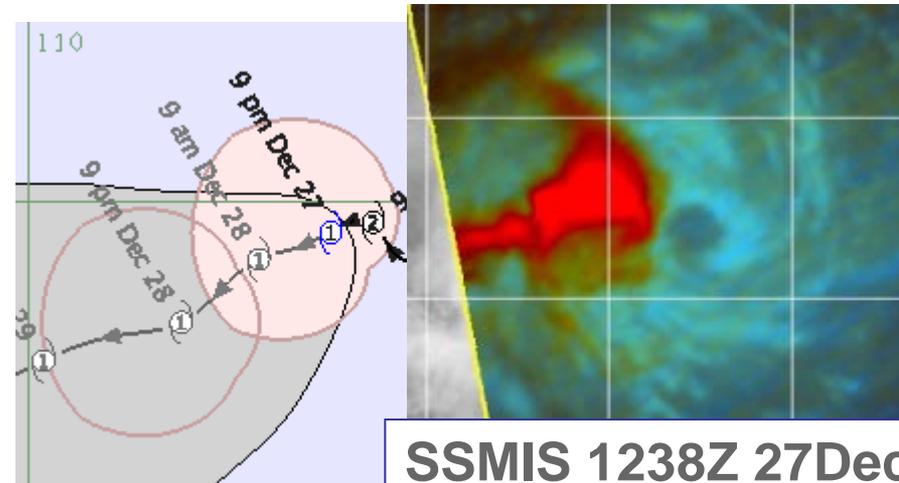
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# Case study: Billy Dec 2008

1. Developing off the coast; gales restricted by land; gales 35-70nm



2. Expansion with intensification over open water; 100nm



3. Asymmetry with increased (E'ly) wind shear; 30-80nm



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# Do TCs expand as they move towards the mid-latitudes?

YES

NO

MAYBE

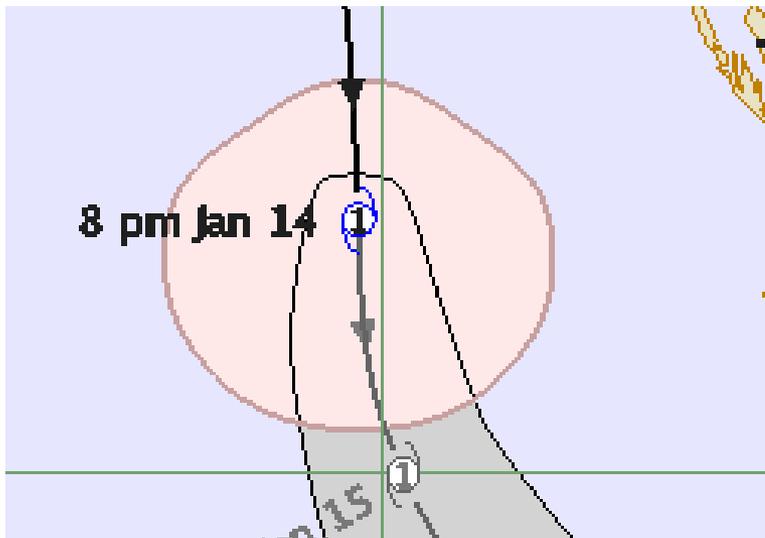


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# Do TCs expand as they move towards the mid-latitudes?

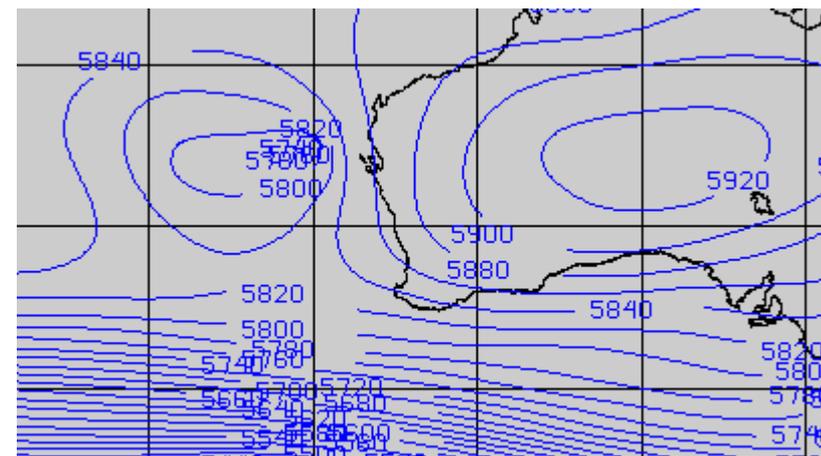
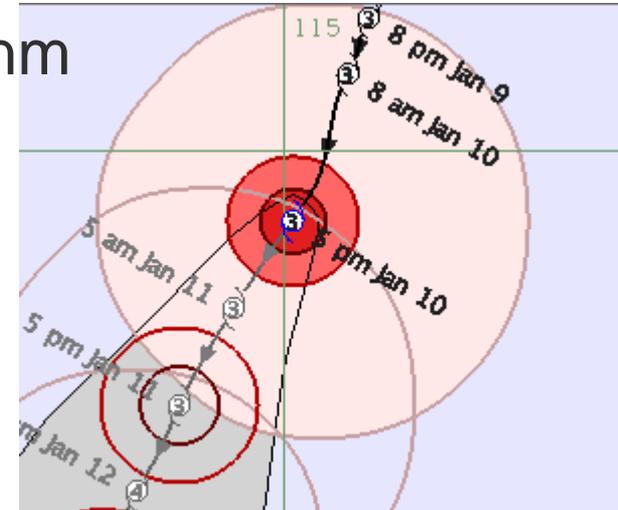
## a. Narelle 2014

- 10 Jan, Symmetric cat 3 at 16S: 150-180nm
- Remains mostly symmetric at 28S  
80-120nm



**NO gale expansion**

- Weak mid-latitude westerlies



EC 500hPa heights



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# Do TCs expand as they move towards the mid-latitudes?

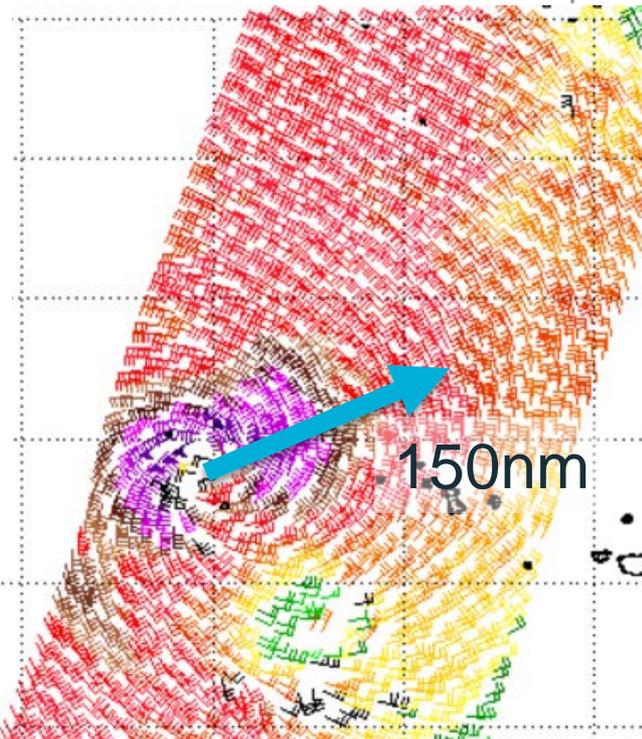
## b. Oli (2010 South Pacific)

1. 3 Feb Large system @ 16S  
(monsoon enhanced)

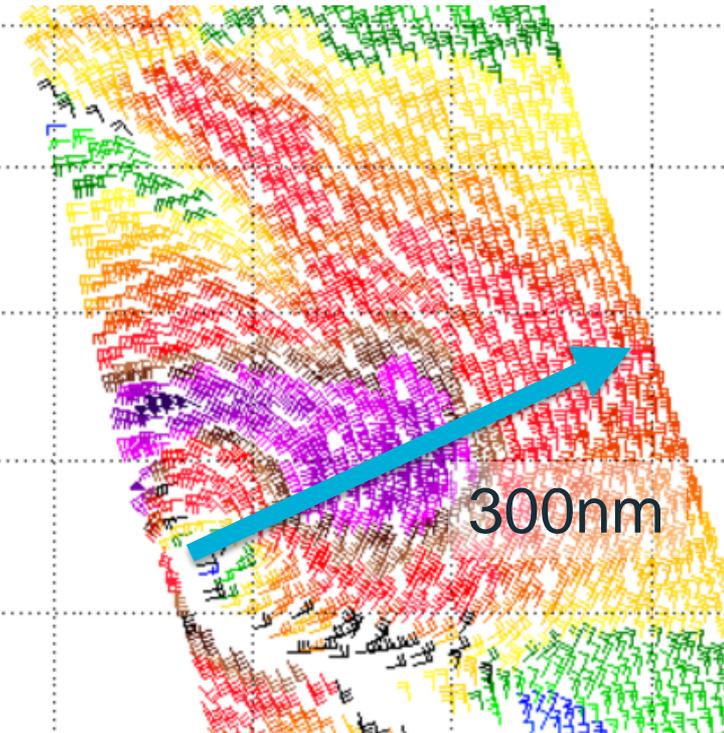
2. 7 Feb Accelerates to SE  
to 33S

OLI

70° 165° 160° 155° 150° 145° 140° 135° 130° 125° 120° 115°



ASCAT winds 19Z 3 Feb



ASCAT winds 06Z 7 Feb

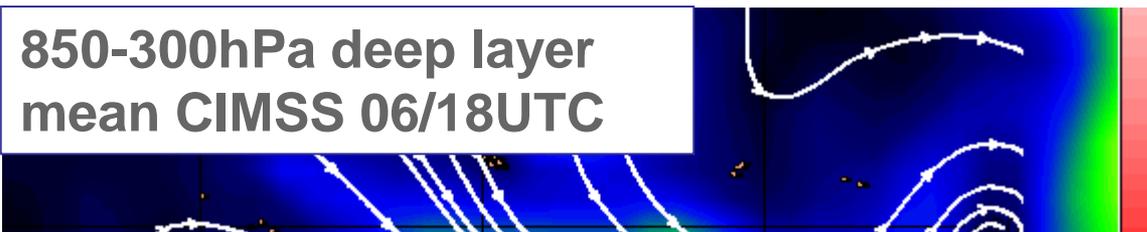


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# Do TCs expand as they move towards the mid-latitudes? YES

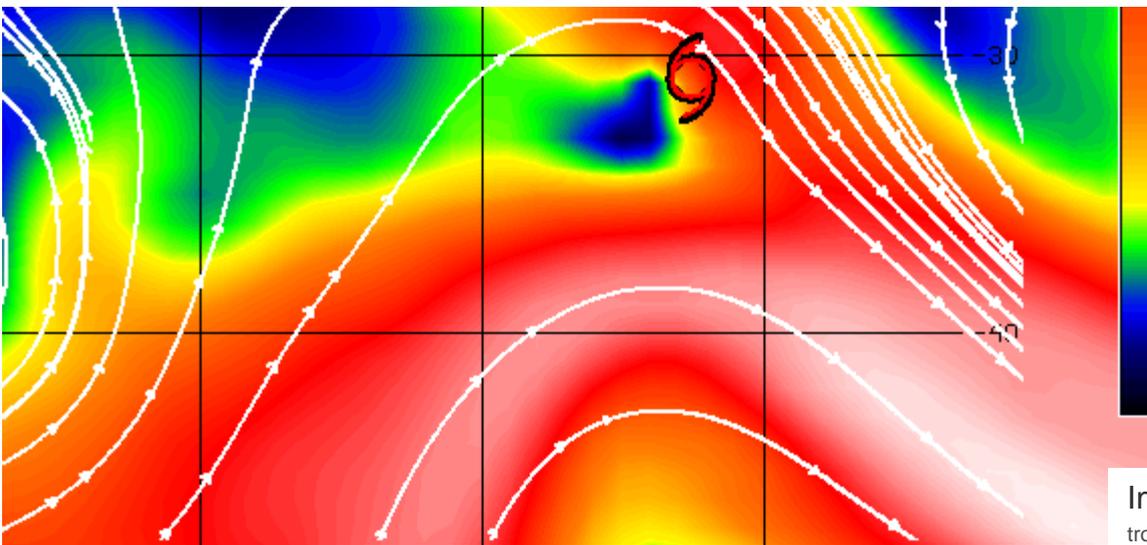
## b. Oli (2010 South Pacific)

850-300hPa deep layer  
mean CIMSS 06/18UTC



Gale expansion from  
acceleration from  
Mid-latitude trough

**Gale expansion (in some quadrants) & acceleration  
– significant case for wave enhancement**



Other case is ETT  
Also associated with  
interaction with mid-  
latitude trough

Image: CIMSS

tropic.ssec.wisc.edu/archive/data/SEPacific/20100206/300to850mbDeepLayer  
MeanLarge/20100206.18.SEPacific.300to850mbDeepLayerMeanLarge.png

LAYER (FOR TC MSLP RANGE: 950-969 HPA) 1800 UTC 06FEB10



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# Do TCs expand as they move towards the mid-latitudes?

Answer: Sometimes

**YES** when interacting with mid-latitude trough

**NO** in absence of trough

**Will become asymmetric**

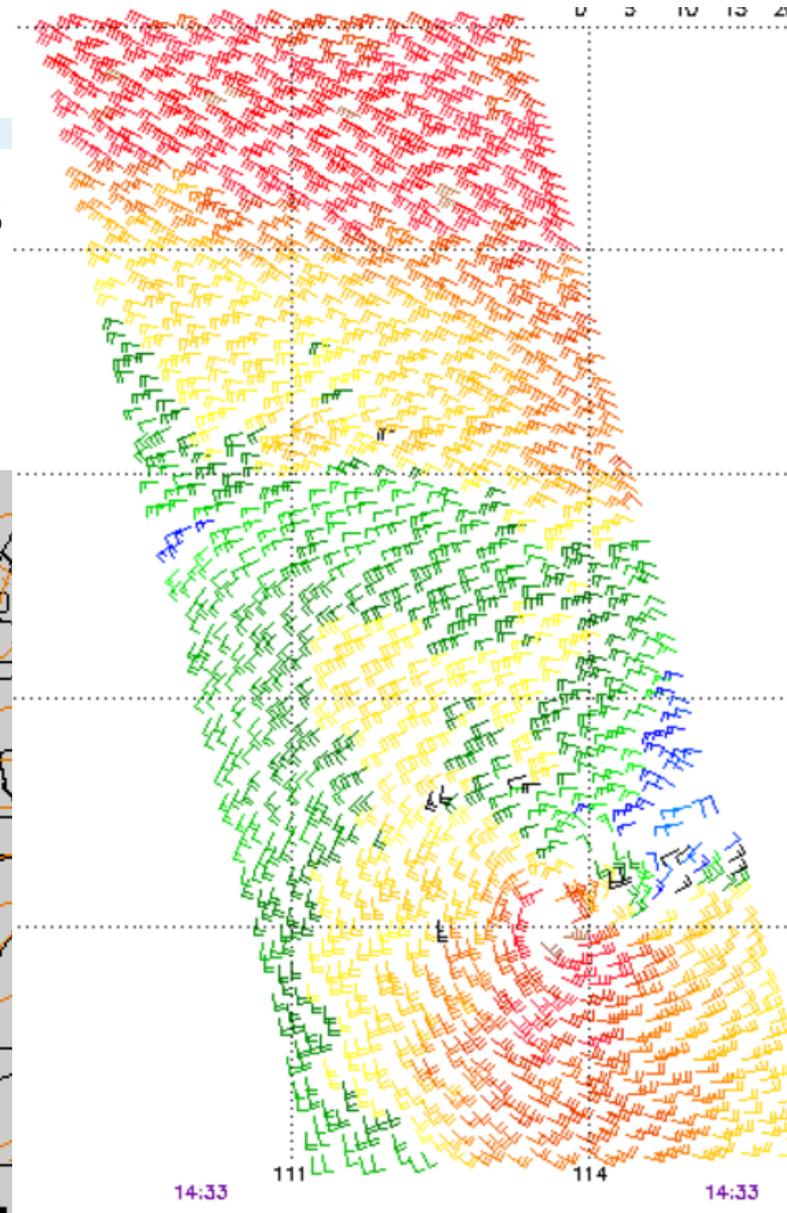
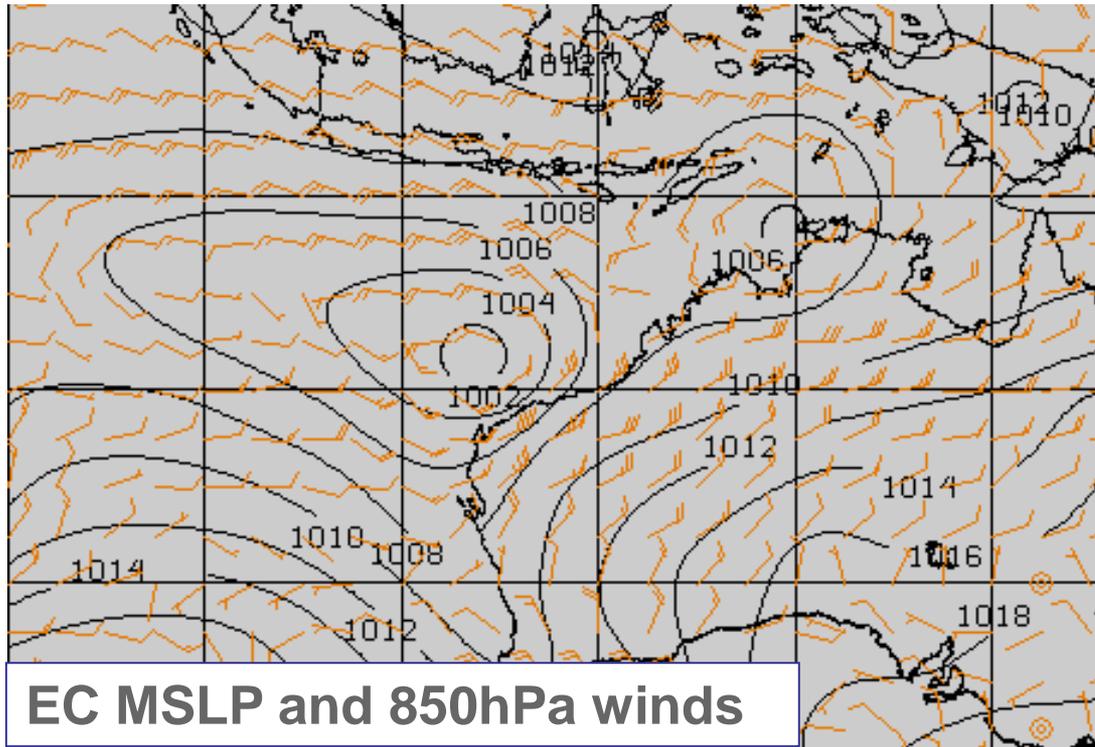


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# Case study: Lua 2012

## 1. 13/06Z named

Initial characteristics: Strong easterlies removed from strong monsoon





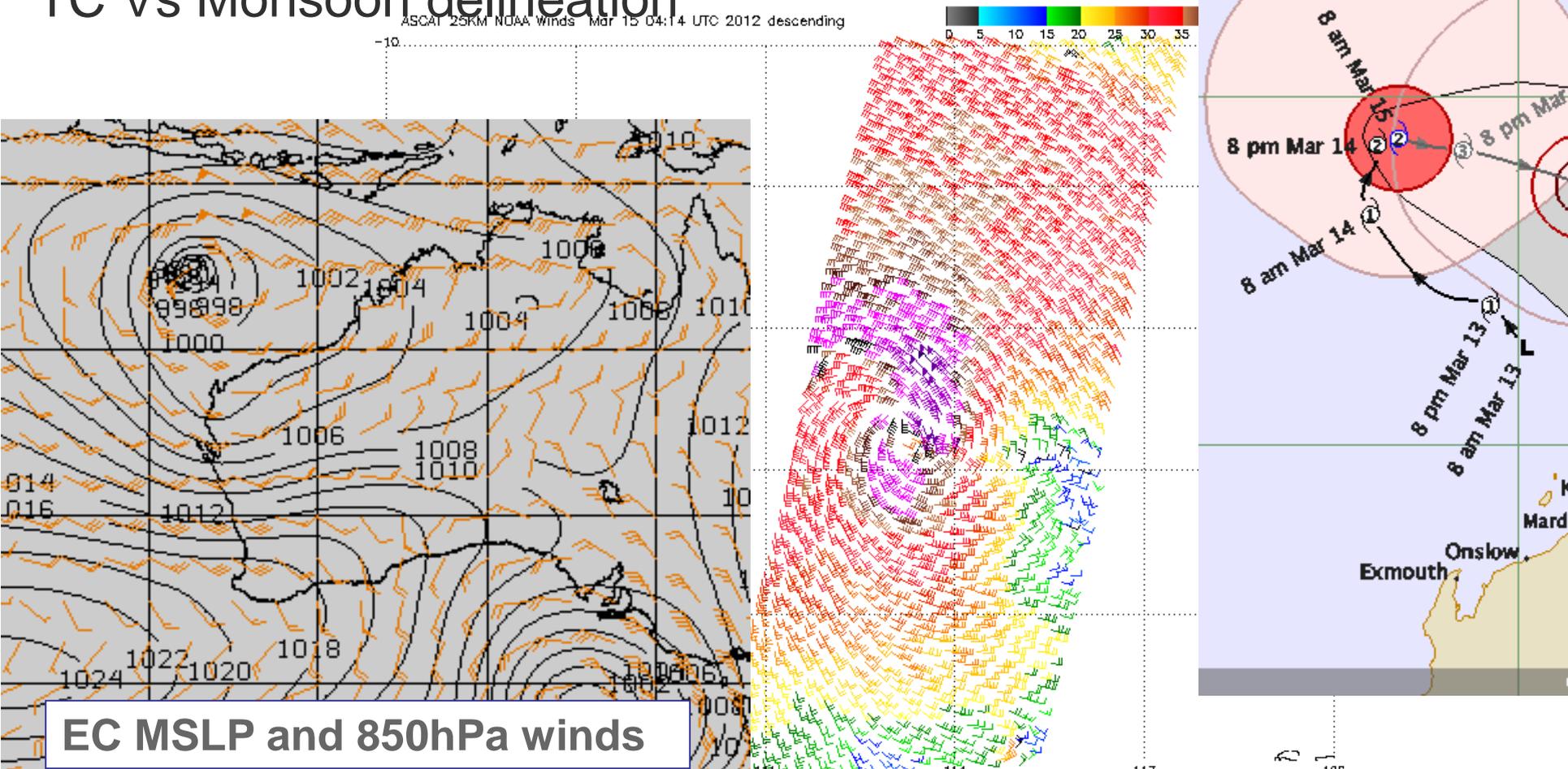
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# Case study: Lua 2012

## 2. 15/00UTC cat 2

expansion in northern half from monsoon

TC Vs Monsoon delineation





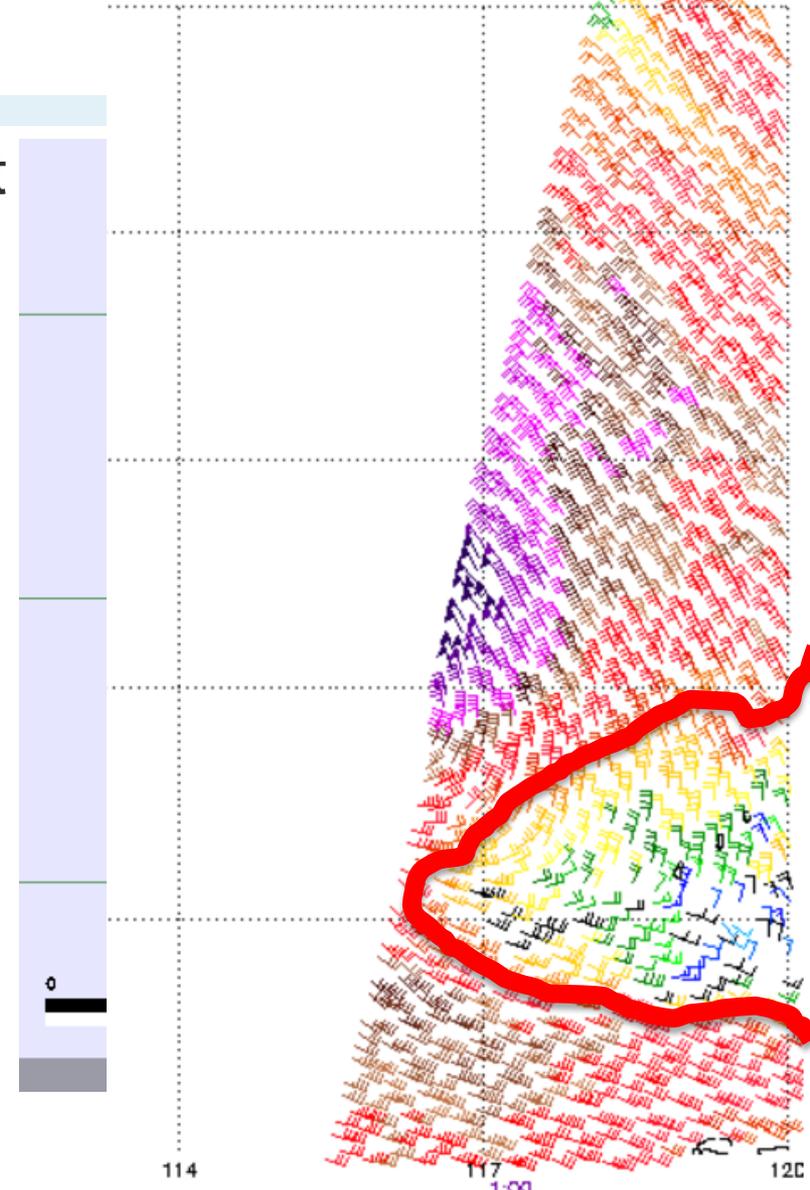
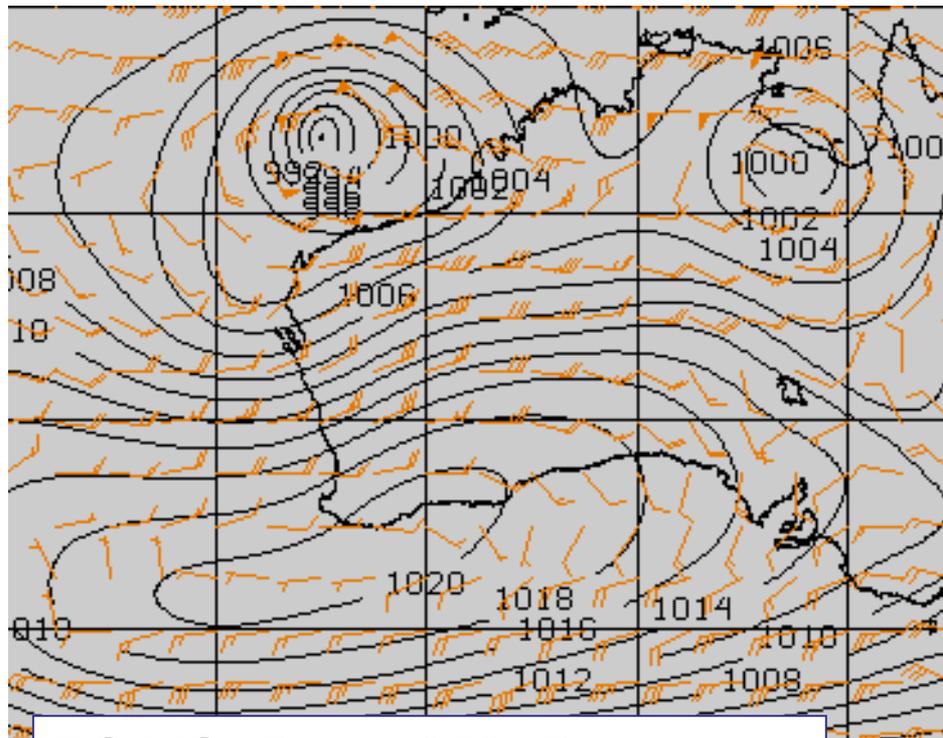
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# Case study: Lua 2012

## 3. 16/03UTC cont 2



southern expansion STR development  
TC field Vs synoptic?  
– operational decision



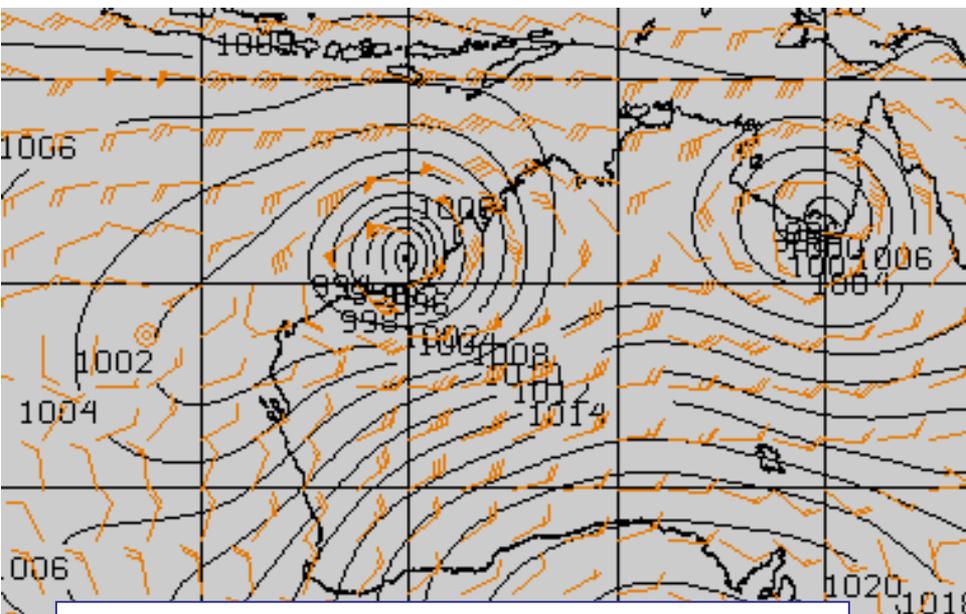


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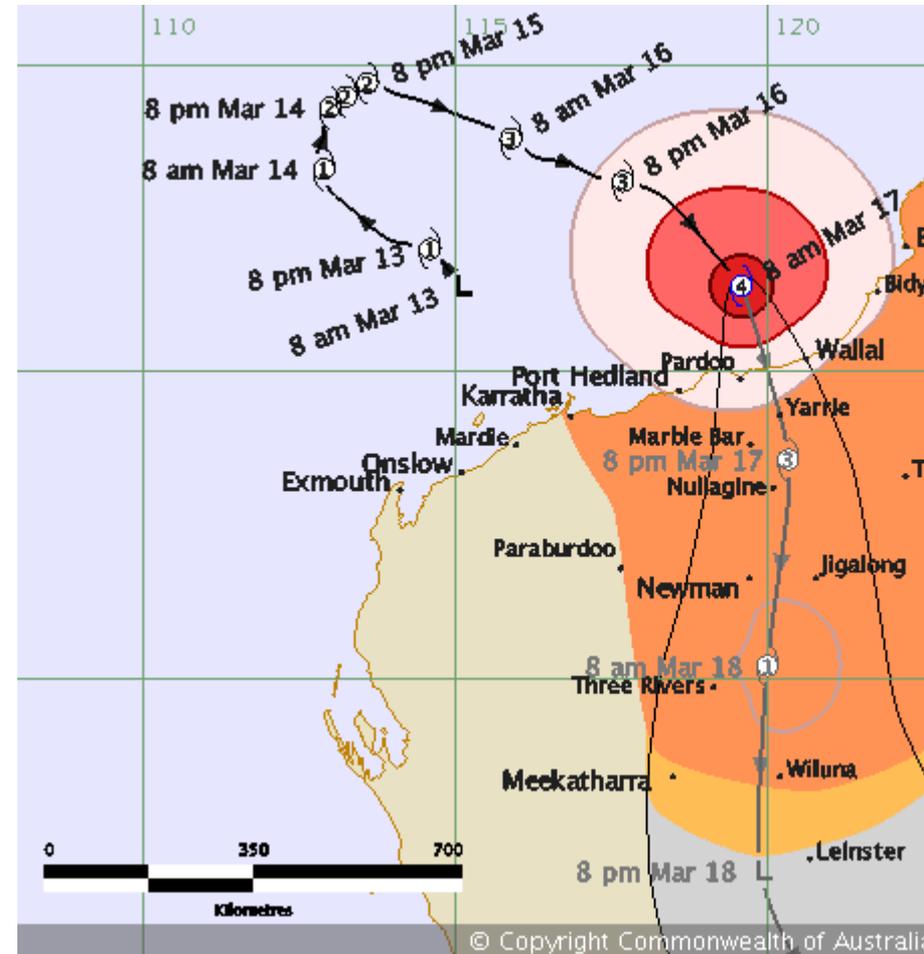
# Case study: Lua 2012

## 4. 17/00UTC Cat 4 Land influence

Contraction - land to south;  
Starting to become disconnected  
with monsoon to north



EC MSLP and 850hPa winds



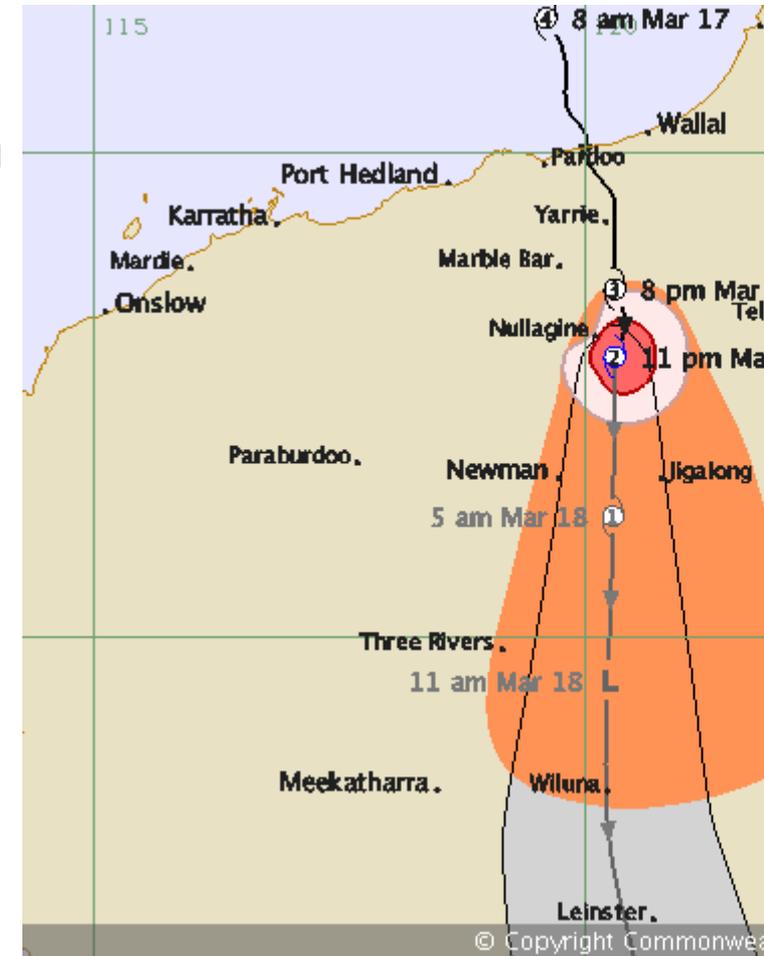
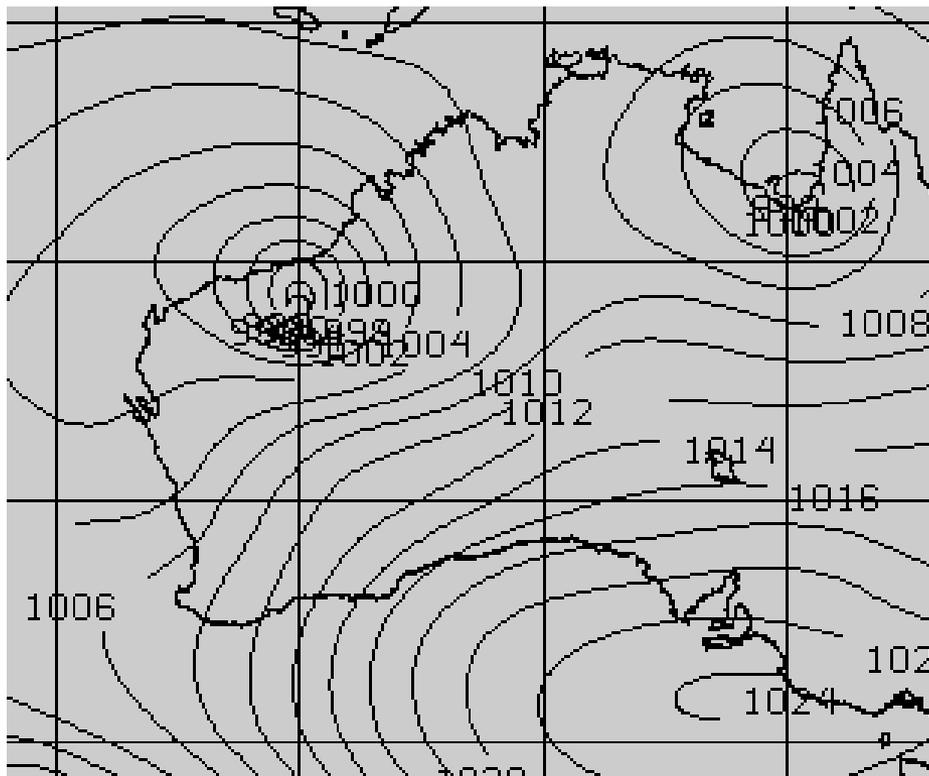


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# Case study: Lua 2012

## 5. 17/15UTC land

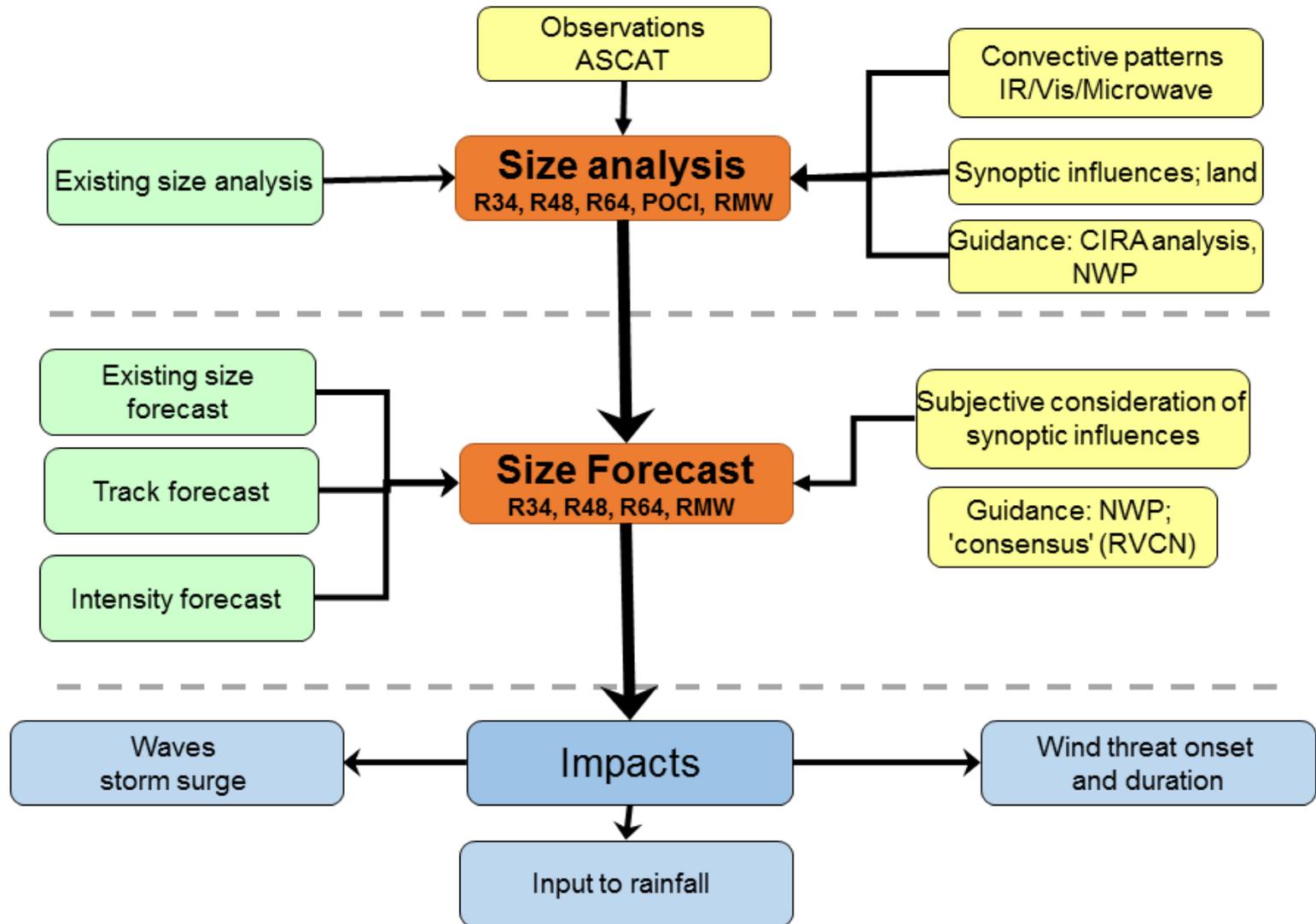
Contraction during weakening over land  
Asymmetry from translation speed 16 kn  
and strong STR;





# Size Changes: Forecast process

## TC Size Forecast Process Map





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# Forecast process

## 1. a good analysis

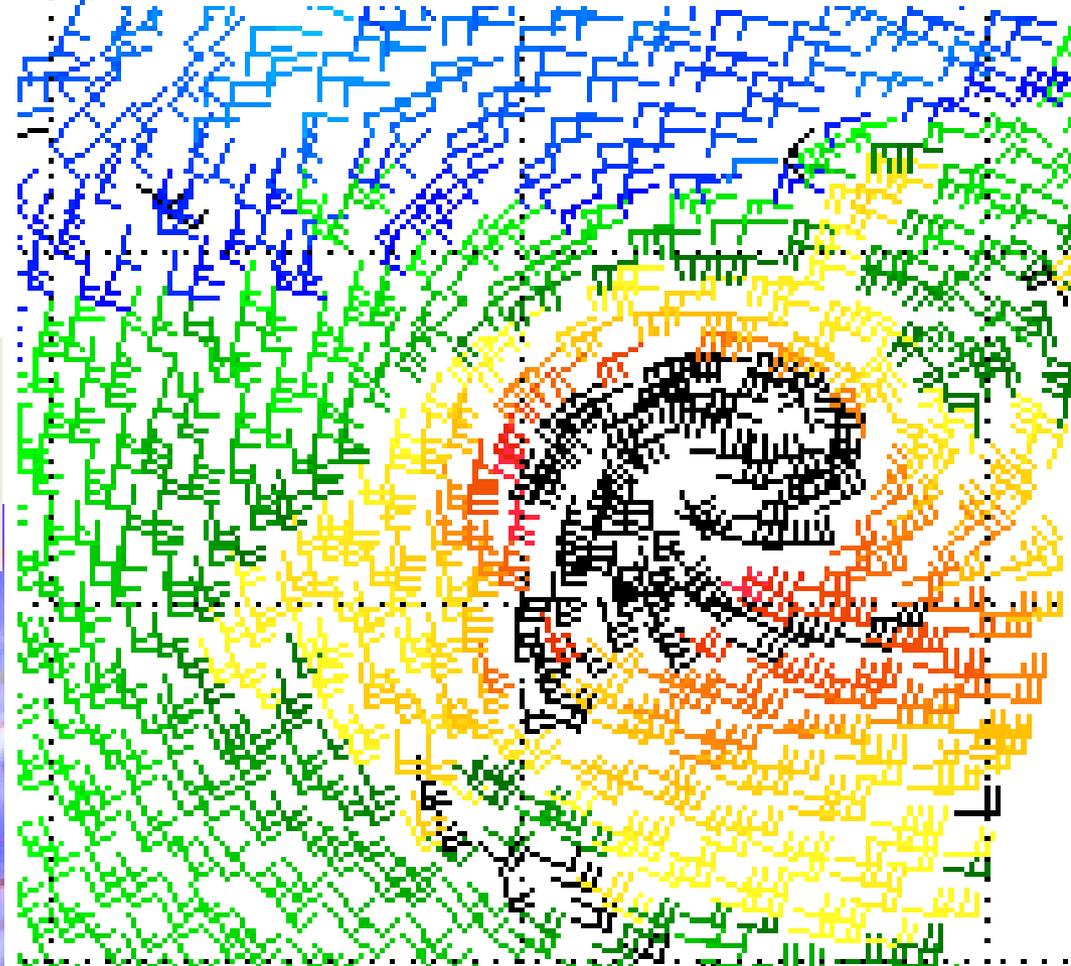
Synoptic influences (eg wind shear) :

**Obs/Scatterometry**

Satellite signatures

NWP analysis

**TASK: Draw 30kn isotach**



Tip for operations:

For EUMET ASCAT solution in use  
30.0kn as gale boundary

IR spectra -64.46 C  
(https://www.bom.gov.au)  
Location 18°24'30"S 117°00'30"E  
Wind direction 180 °  
Wind speed 36.1 kt  
Time 28.01.2018 13:17  
Geospatial



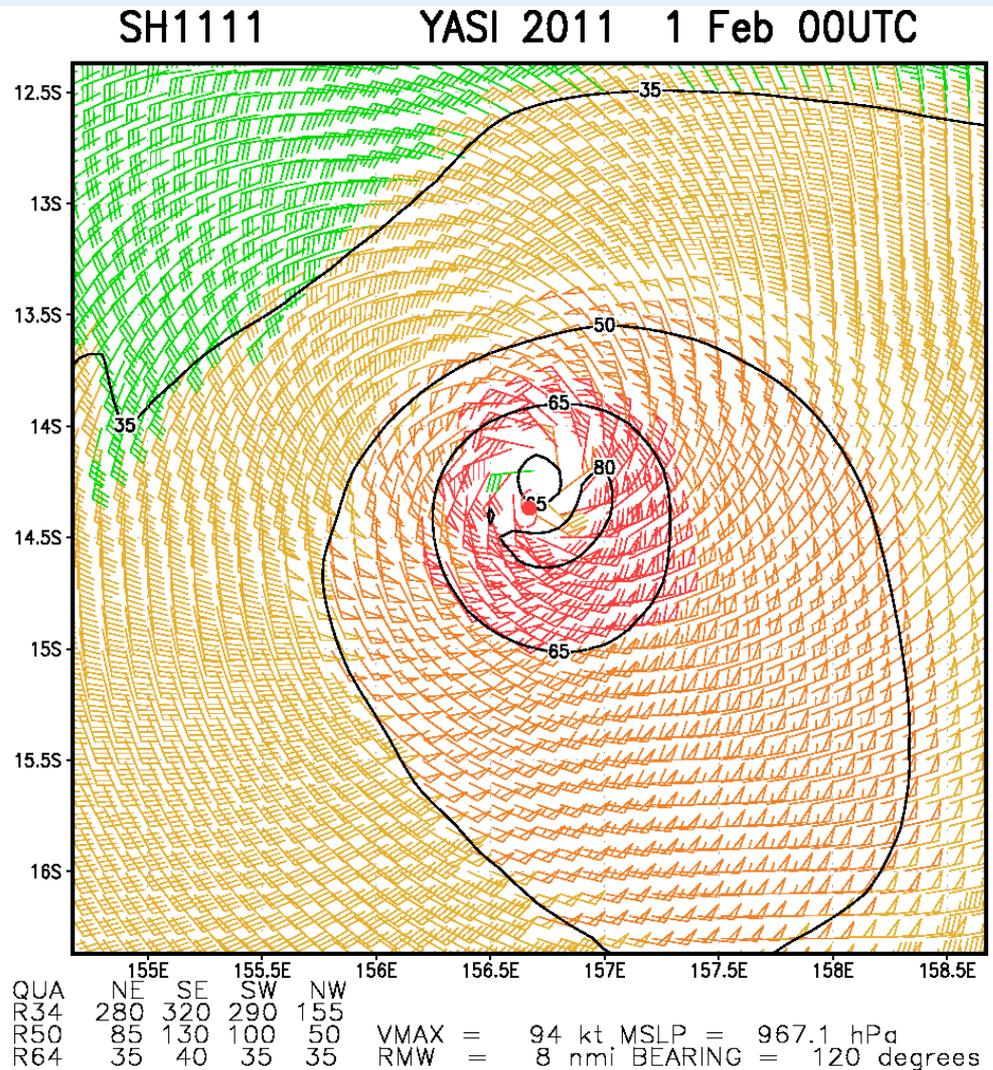
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# Size analysis: Multi-platform Wind analysis (MTCSSWA)

Combines:  
scatterometry  
IR wind algorithm  
Cloud drift winds  
AMSU derived winds

Good for relative  
asymmetries but absolute  
values best with recent  
ASCAT and obs

CIRA work available via NOAA:  
<http://www.ssd.noaa.gov/PS/TROP/mtcswa.html>





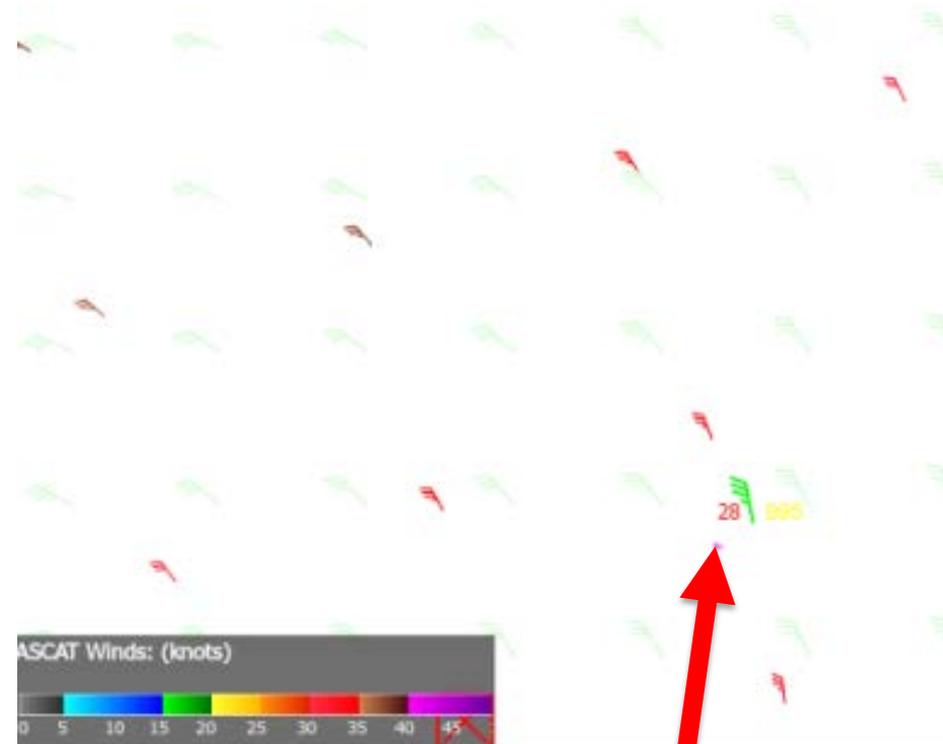
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# Forecast process

1. analysis: Verify NWP with obs/scat and Compare with policy

Overlay obs and Scat and models

*Stan*: Rowley Shoals, ASCAT and EC wind fields overlaid



Rowley Shoals obs



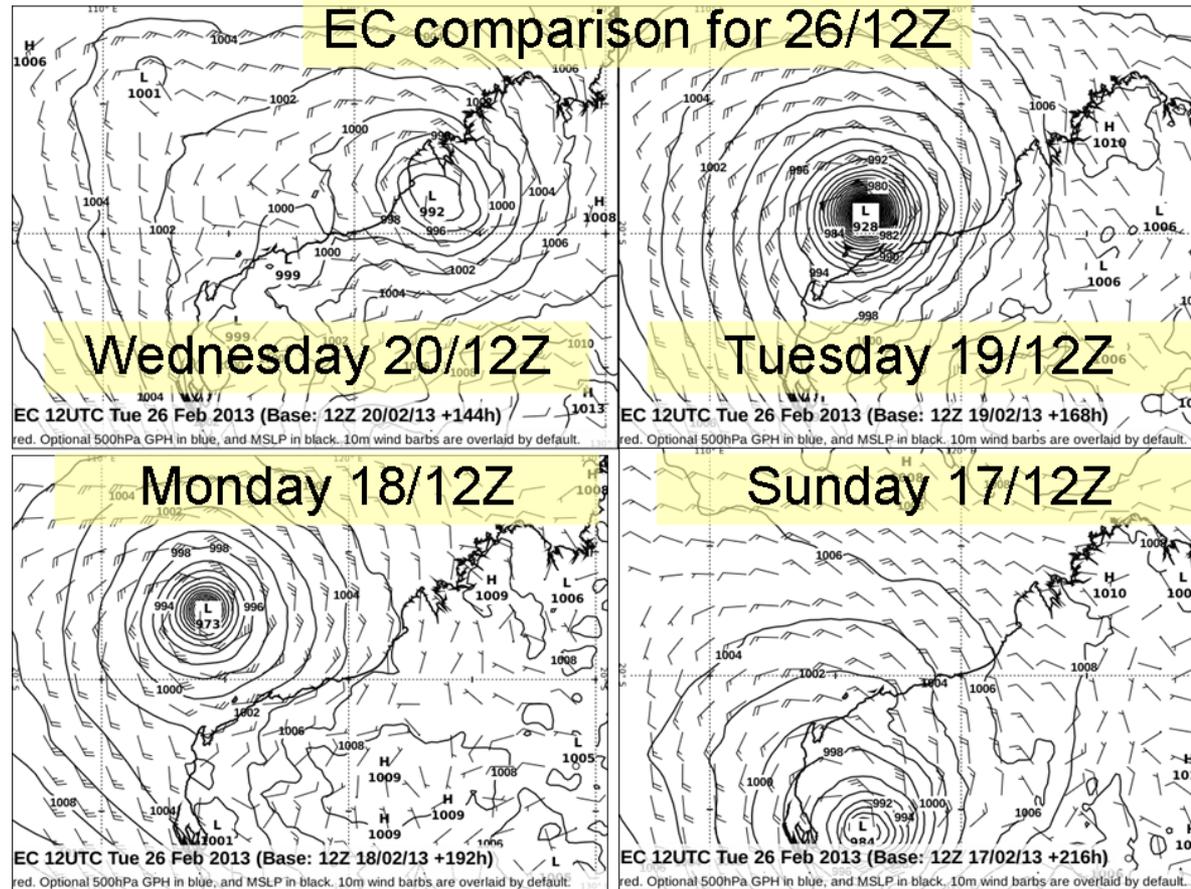
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# Forecast process

## 2. Good track and intensity forecast:

so structure forecast considered in depth after this,

BUT consideration of  
NWP can be done early;  
for R34 suggest when  
analysis is done;  
Comparison with  
existing policy  
Review if track/intensity  
changes





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# Forecast process: NWP

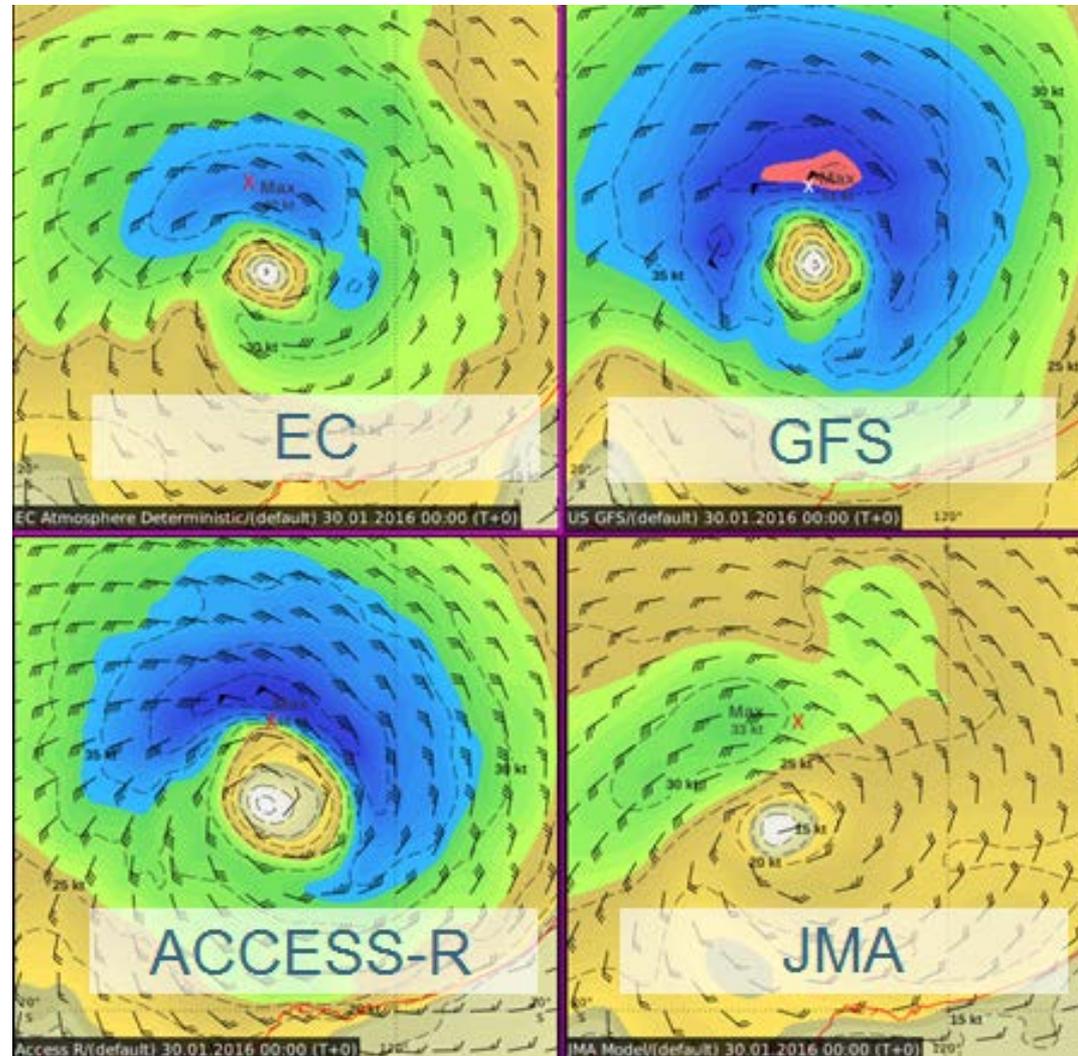
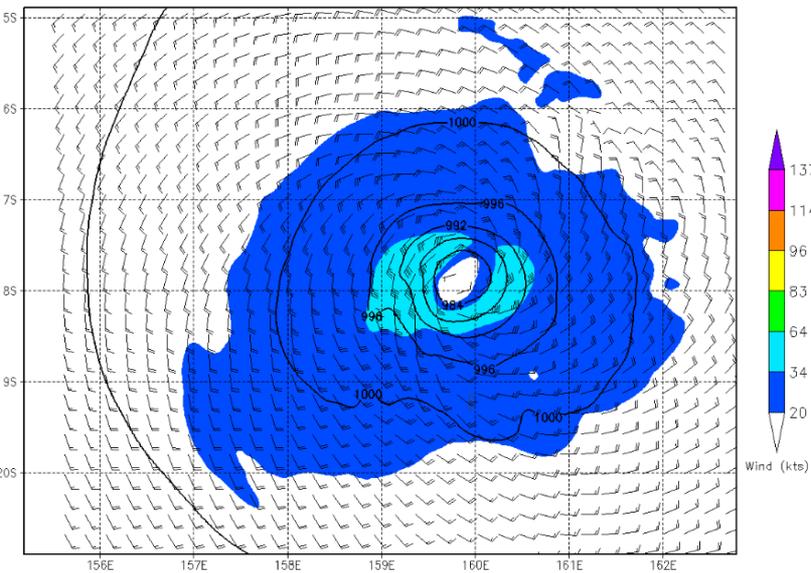
## 4. NWP: wind fields

### Comparisons

Fields Vs numeric output  
(max extent)

towards ensembles...

NCEP HWRP - TATIANA12P 2016021200 - F000





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# NWP: care using numeric output

Fields Vs numeric output – 'jumpiness'

R34 defined as the max extent of winds occurring in the quadrant

SH,	15,	2017040606,	03,	HWRP,	12,	145S,	1106E,	62,	983,	XX,	34,	NEQ,	72,	81,	65,	60,
SH,	15,	2017040606,	03,	HWRP,	18,	149S,	1108E,	79,	972,	XX,	34,	NEQ,	60,	141,	99,	62,
SH,	15,	2017040606,	03,	HWRP,	24,	154S,	1110E,	99,	962,	XX,	34,	NEQ,	66,	105,	90,	78,
SH,	15,	2017040606,	03,	HWRP,	30,	157S,	1111E,	104,	956,	XX,	34,	NEQ,	60,	93,	91,	56,
SH,	15,	2017040606,	03,	HWRP,	36,	160S,	1109E,	106,	951,	XX,	34,	NEQ,	67,	119,	94,	51,
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SH,	15,	2017040606,	03,	HWRP,	54,	169S,	1104E,	98,	969,	XX,	34,	NEQ,	67,	86,	78,	42,



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# Statistical-dynamical (from CIRA-NRL-JTWC)

JTWC track type RVCN consensus of forecast wind radii (from Atlantic data) from GFS, EC\*, GFDL\*, HWRF\* where \*bias corrected

Still use with care given concern about NWP 'jumpiness' and 'max extent'

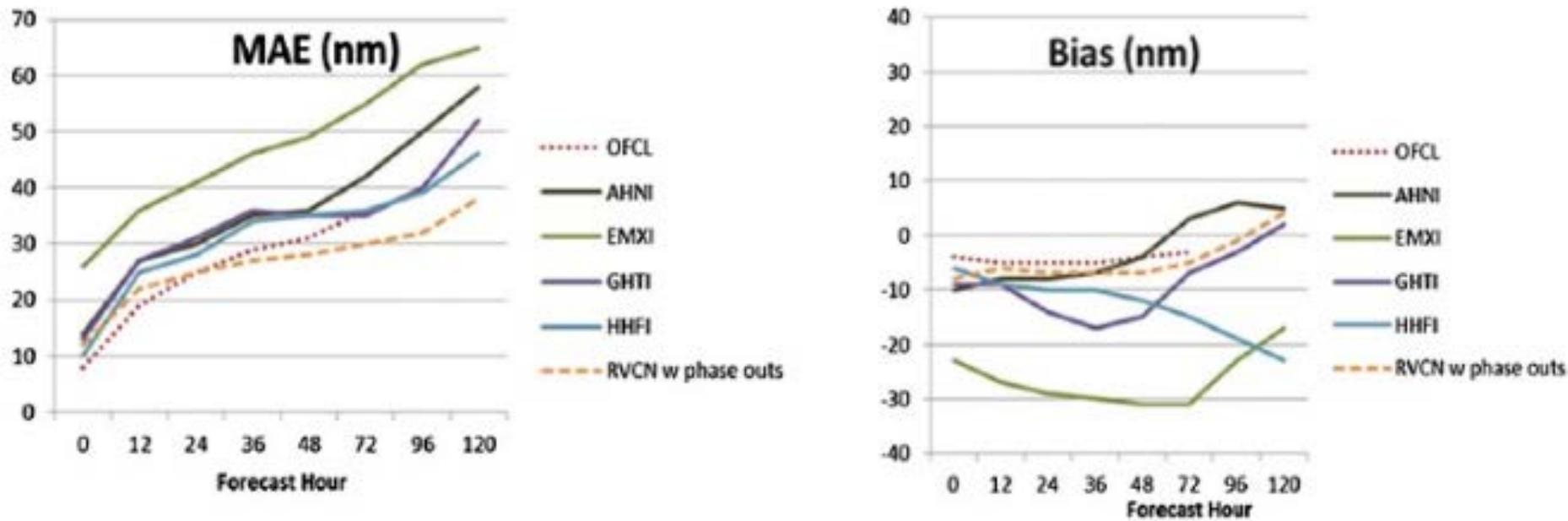


Fig 4 R34 verification for Atlantic 2012-14 from Sampson and Knaff 2015.

[https://www.academia.edu/23044064/NCEP\\_NOTES\\_A\\_Consensus\\_Forecast\\_for\\_Tropical\\_Cyclone\\_Gale\\_Wind\\_Radii](https://www.academia.edu/23044064/NCEP_NOTES_A_Consensus_Forecast_for_Tropical_Cyclone_Gale_Wind_Radii)



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# RMW variations

## Inner-core dynamics

RMW: 'contraction' 35-65kn intensity  
 Variations for stronger systems related to eyewall changes  
 Not related to gale radius  
 Microwave imagery for RMW

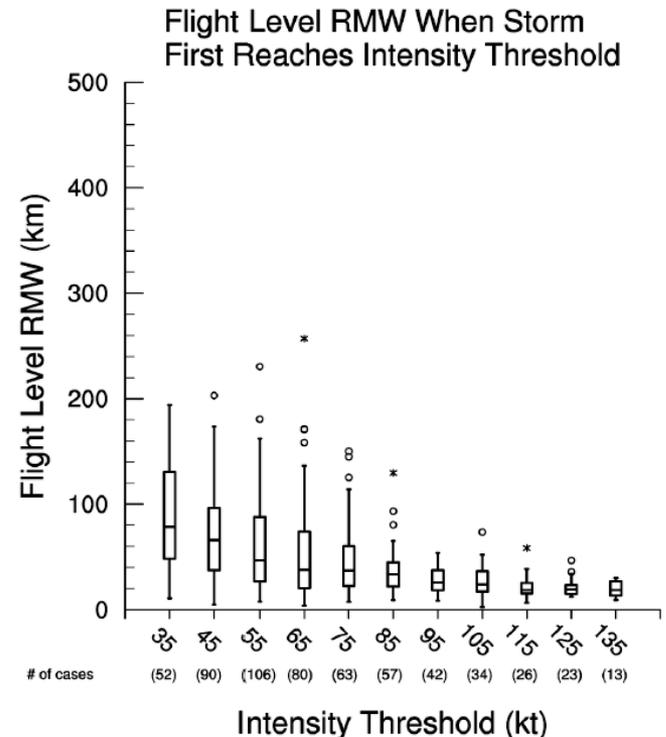
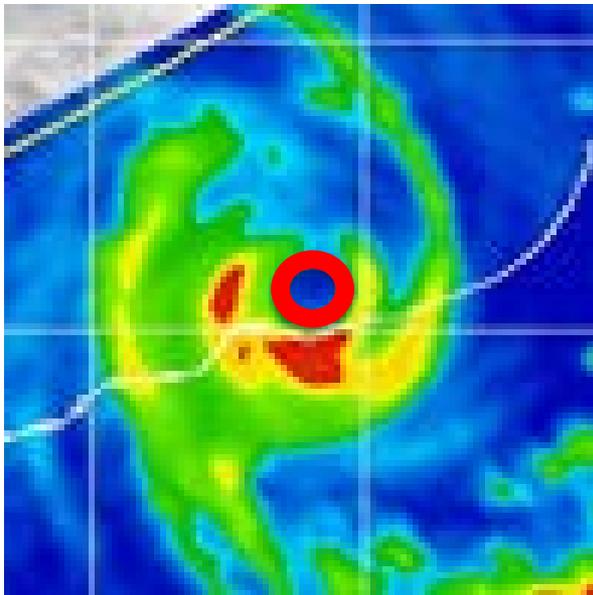


Figure 14. Box-and-whisker plot showing the observed flight level RMW at the time when each storm *first* reaches a given intensity threshold. This plot was constructed by binning the RMW values only at the time point when the interpolated Best-Track intensity of the storm first reaches the given threshold. The binning is as follows: the '35' bin contains all cases where the intensity is less than 35 kt, the '45 kt' bin contains all the cases where the intensity is  $\geq 35$  kt and  $> 45$  kt, etc.

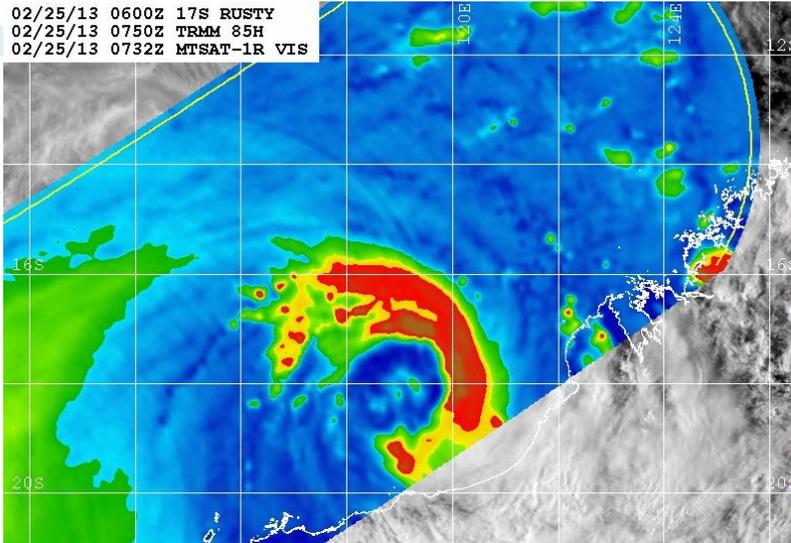


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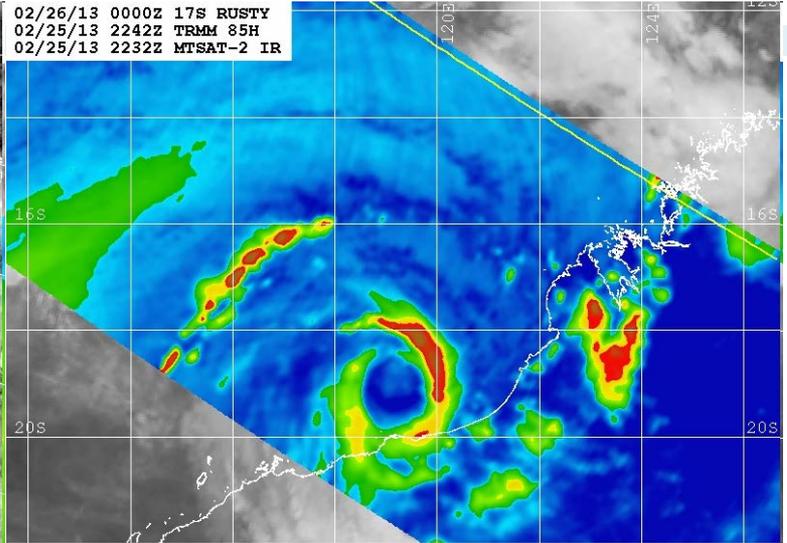
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# TC Rusty eye contraction TMI

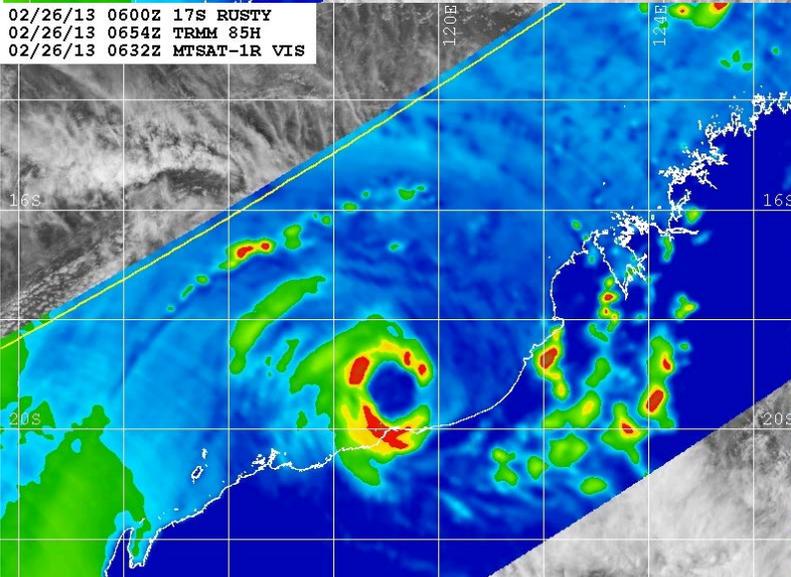
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02/25/13 0750Z TRMM 85H  
02/25/13 0732Z MTSAT-1R VIS



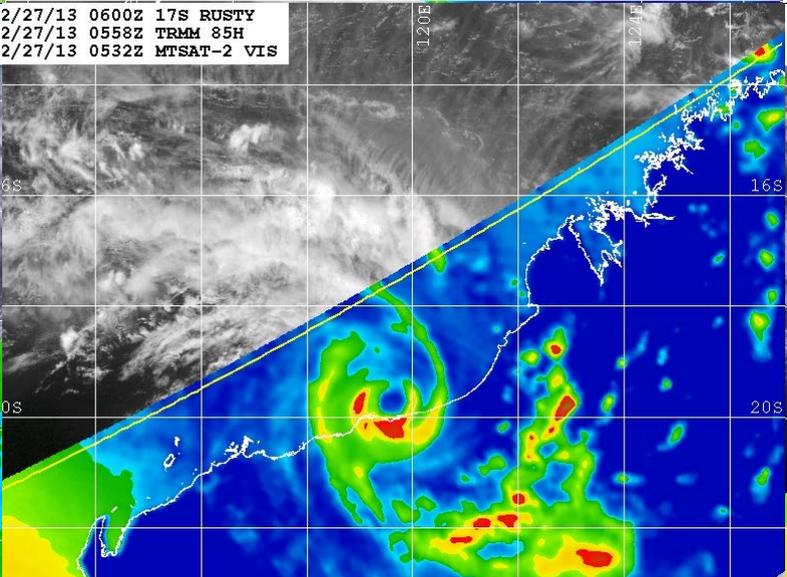
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02/25/13 2242Z TRMM 85H  
02/25/13 2232Z MTSAT-2 IR



02/26/13 0600Z 17S RUSTY  
02/26/13 0654Z TRMM 85H  
02/26/13 0632Z MTSAT-1R VIS



2/27/13 0600Z 17S RUSTY  
2/27/13 0558Z TRMM 85H  
2/27/13 0532Z MTSAT-2 VIS



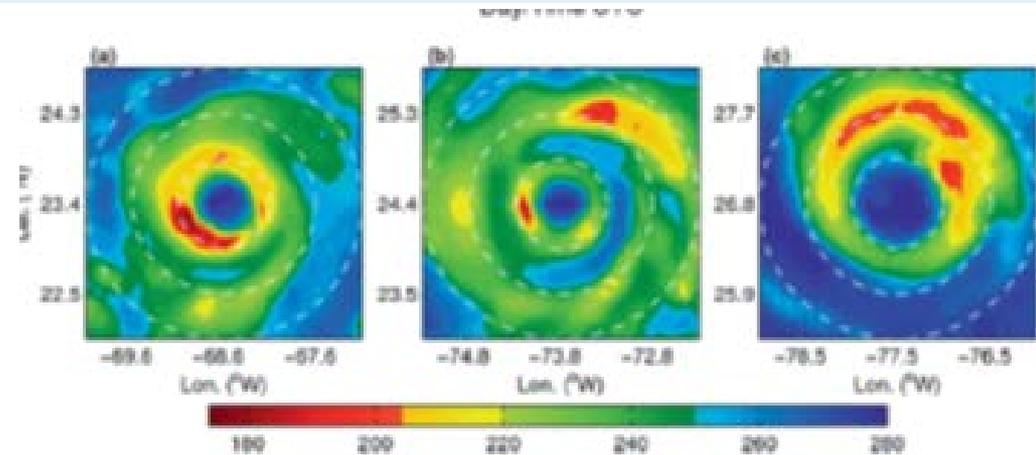


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# Structure changes: Other

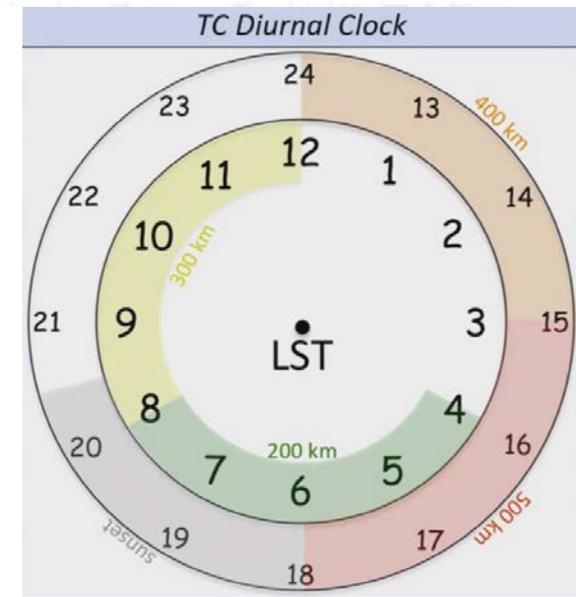
## Eyewall Replacement Cycles (ERC)

refer Kossin&Sitkowski (2009, 2012)



## Diurnal variations (Jason Dunion)

<https://ams.confex.com/ams/32Hurr/webprogram/Paper293600.html>





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## Summary

Size forecasting more independent than intensity forecasting than commonly thought; affected by

- Changes in low-level synoptic forcing e.g. monsoon
- land
- factors affecting the patterns of convection such as wind shear and RH

Process: based on good analysis and interpretation of guidance

Better ways of combining NWP and analyses is coming

# Happy Forecasting!