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Forecasting Size Changes in Tropical Cyclones
Size forecasting: the poor cousin?

VLAB 18 July 2017

Defining TC Size/ Structure

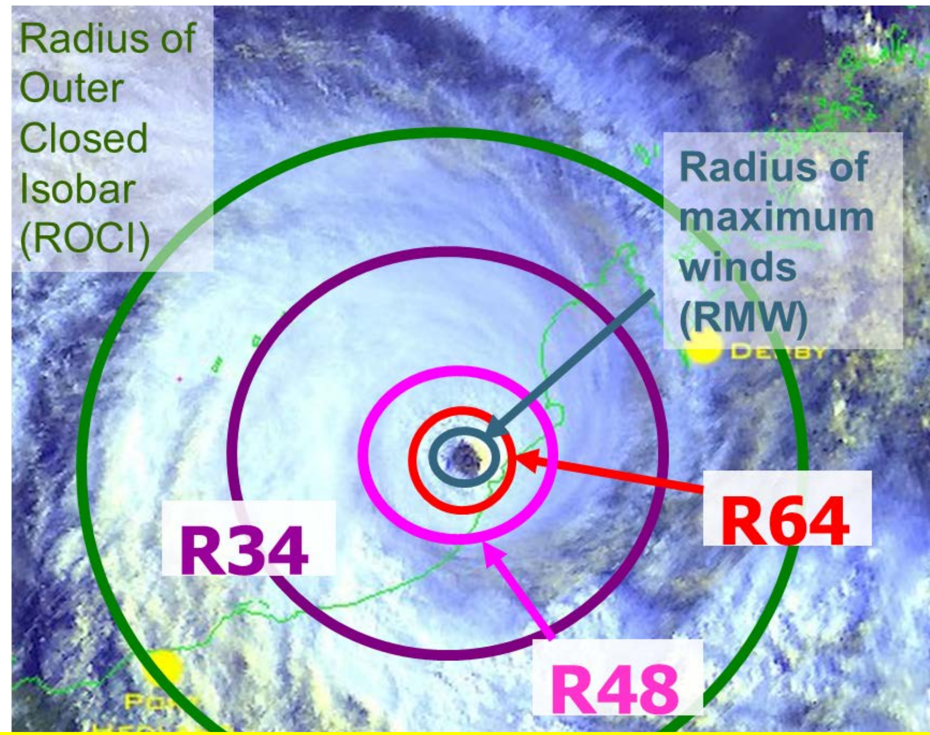
Why is it so important?

Conceptual models

Factors affecting size changes

The Forecast process

Objective guidance: inc. NWP



Joe Courtney

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Size Forecasting: Why?

Why?

determine warning area;

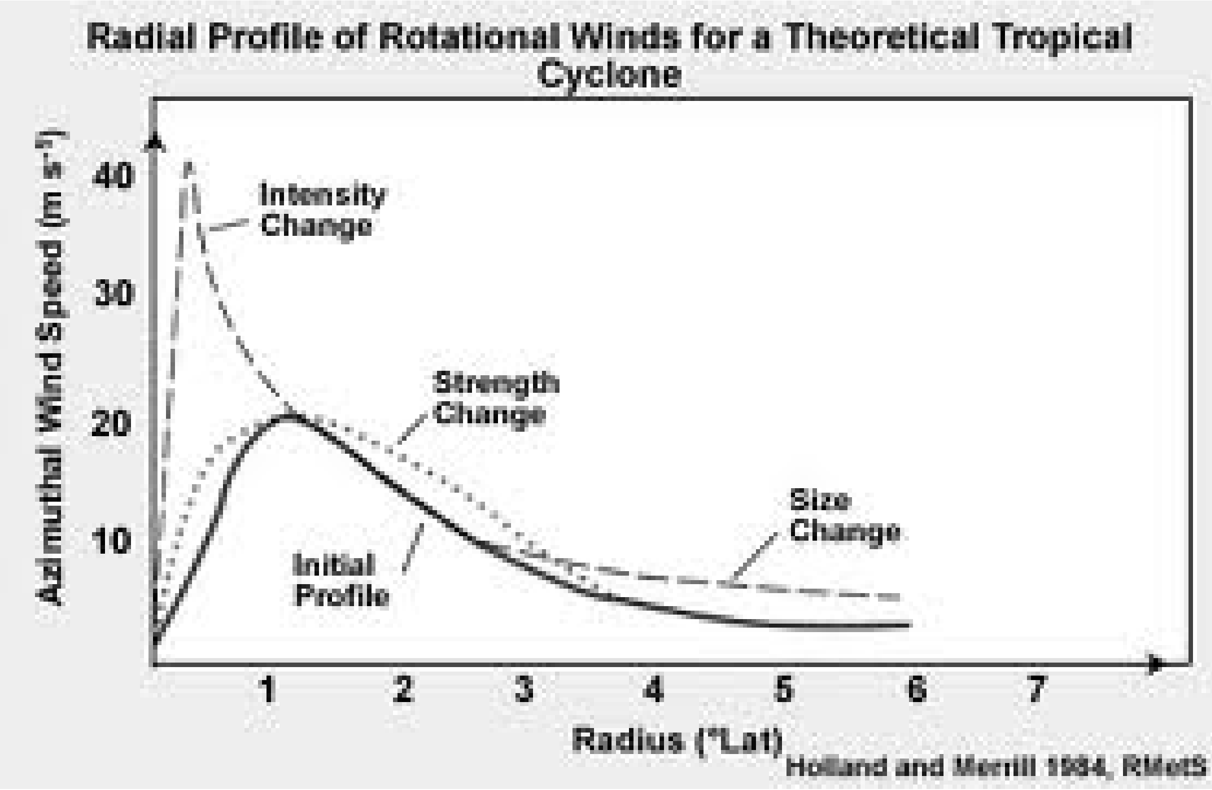
Onset and duration of wind threat;

storm tide forecasting;

wave forecasting;

intensity changes

Rainfall?



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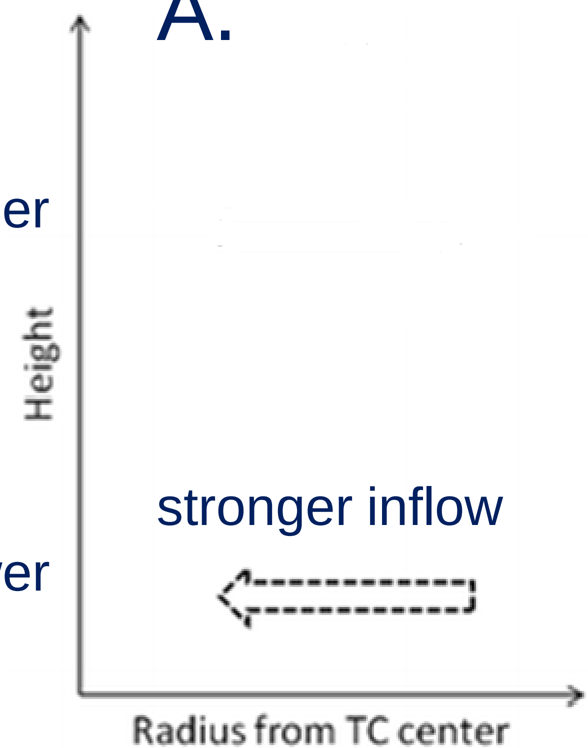
Size Changes: conceptual models

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

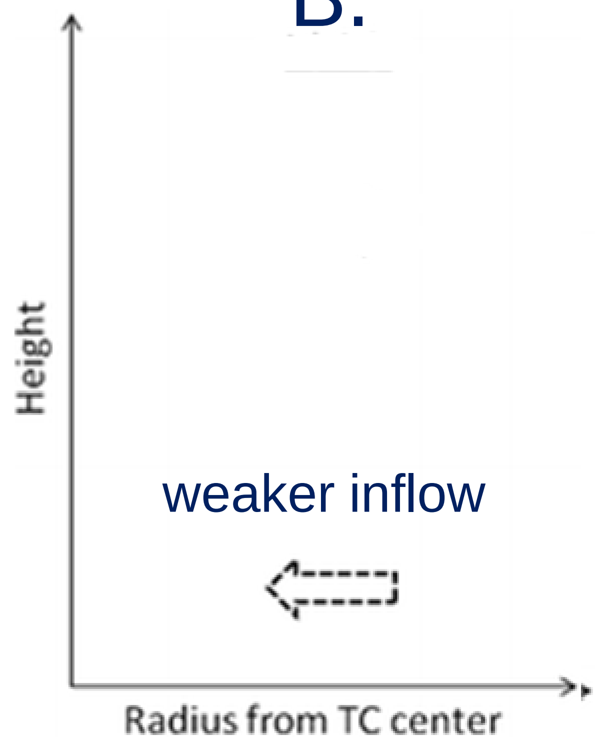
A.

upper

lower



B.



C. No difference

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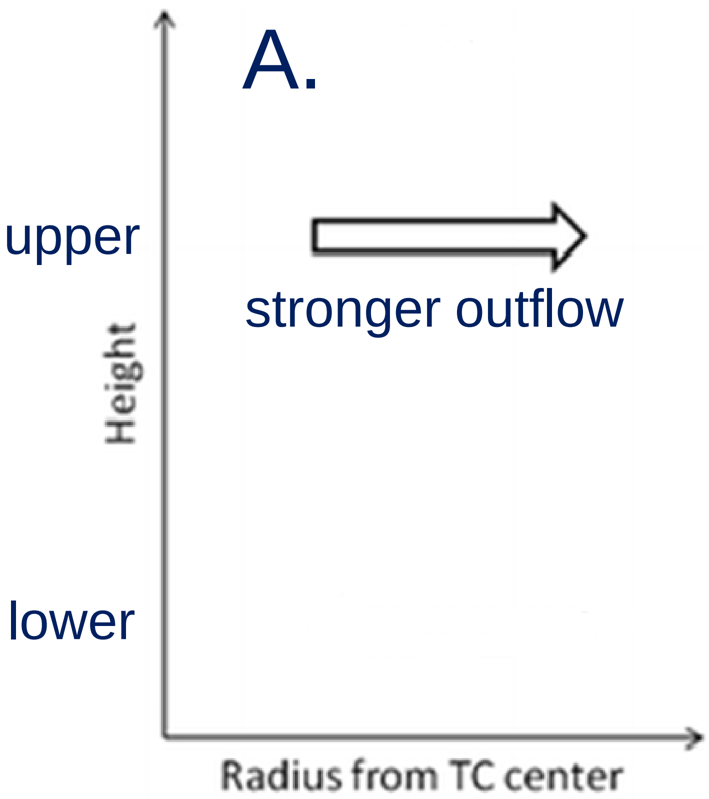
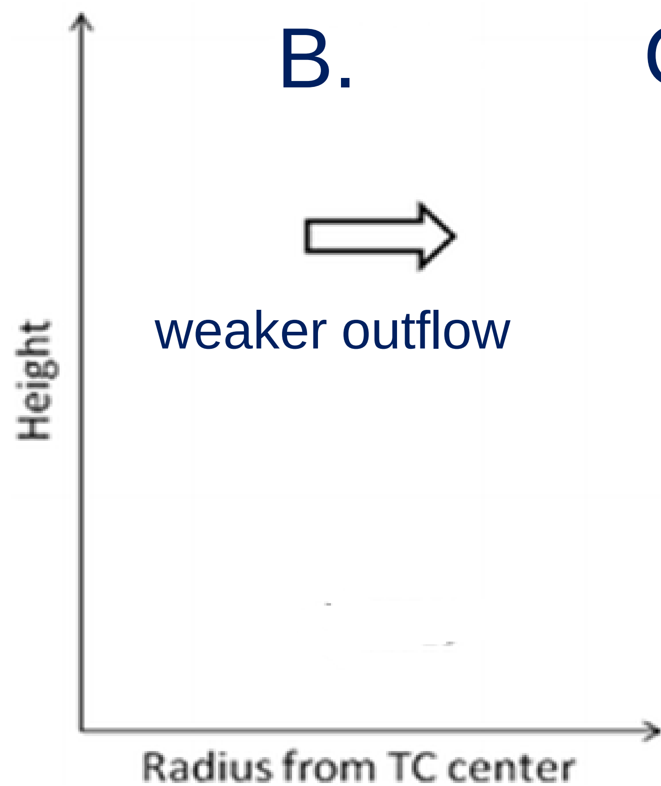
Size Changes: conceptual models

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





C. No difference

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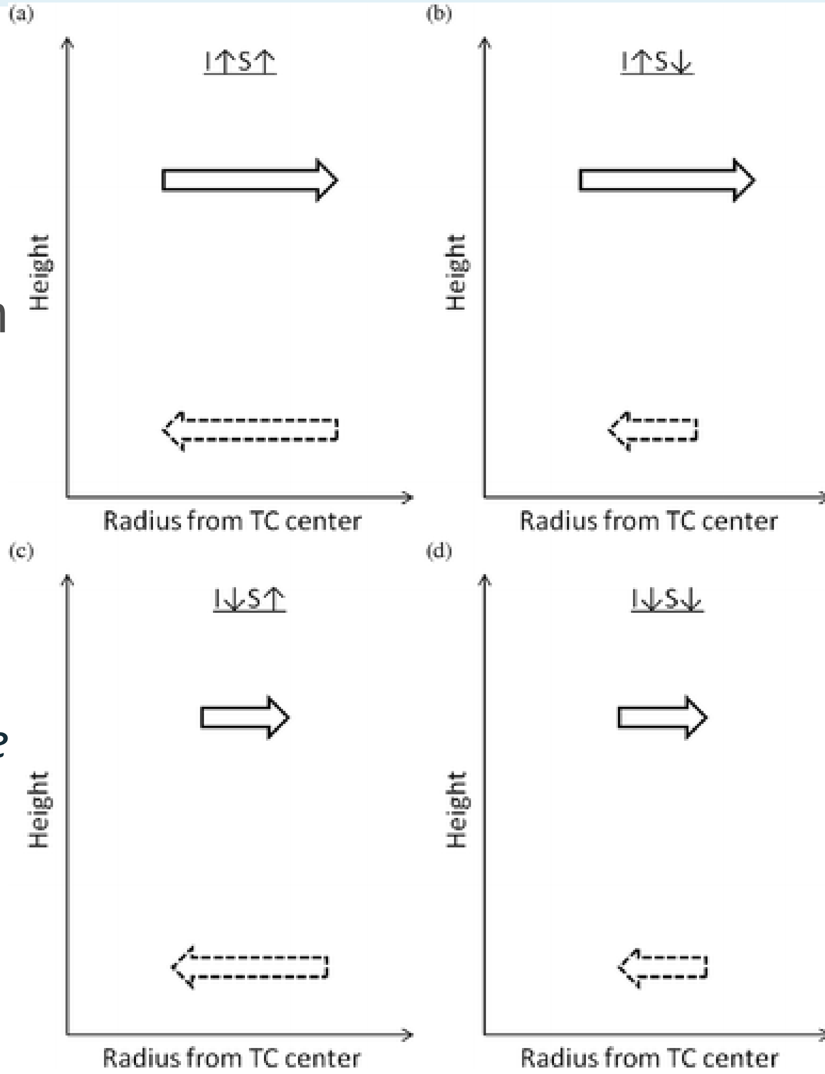
Size Changes: conceptual models

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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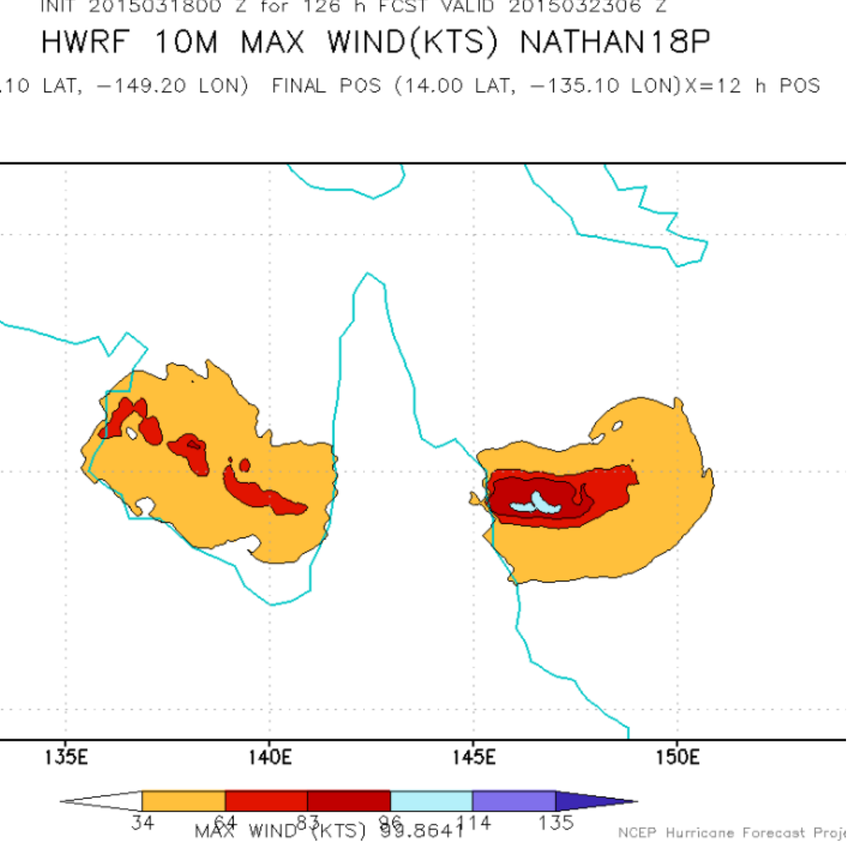
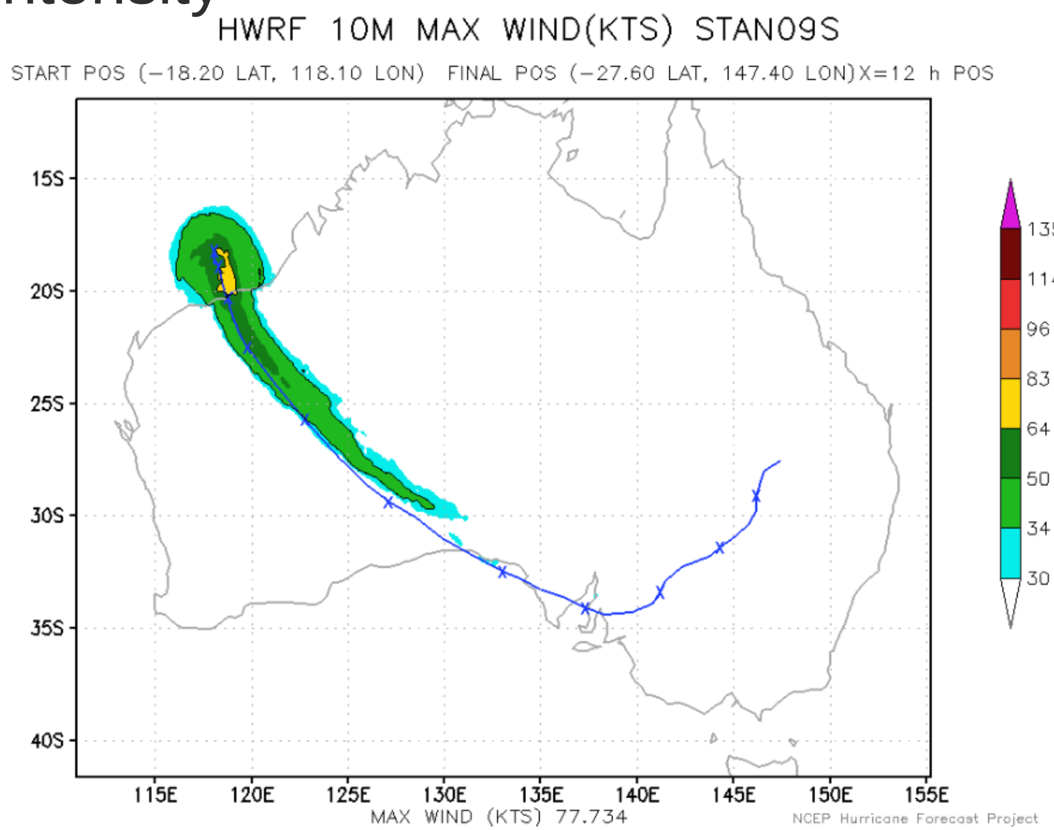
Factors affecting Size changes: land

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





HWRF http://www.emc.ncep.noaa.gov/gc_wmb/vxt/HWRF/tcall.php?selectYear=2015&selectBasin=Southern+Hemisphere&selectStorm=NATHAN18P

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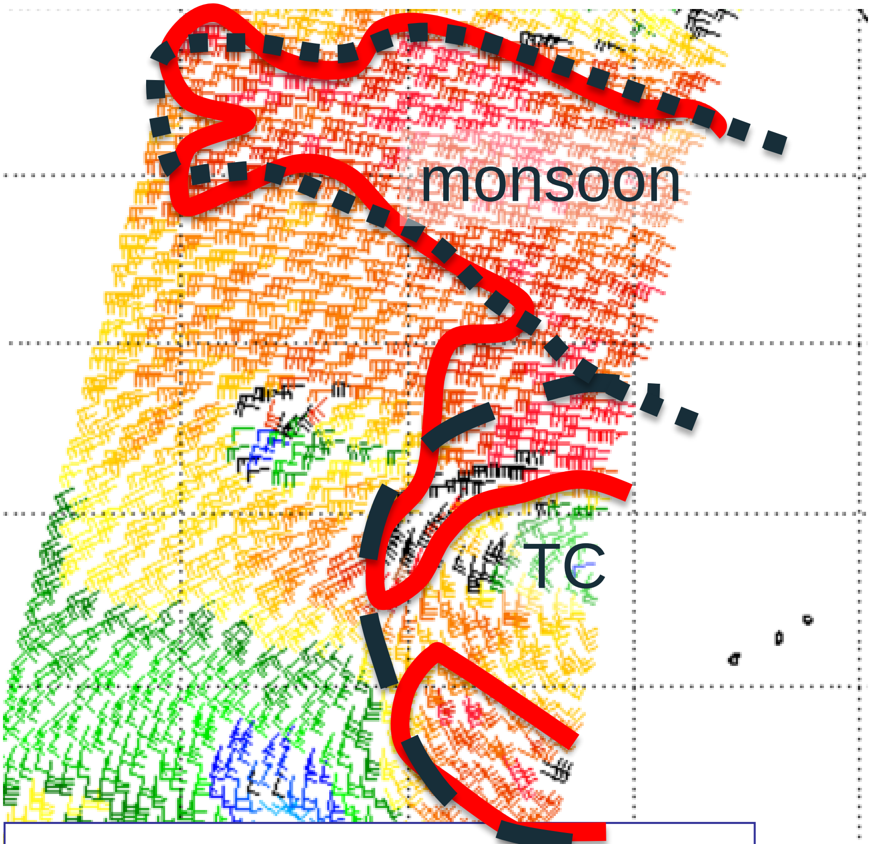
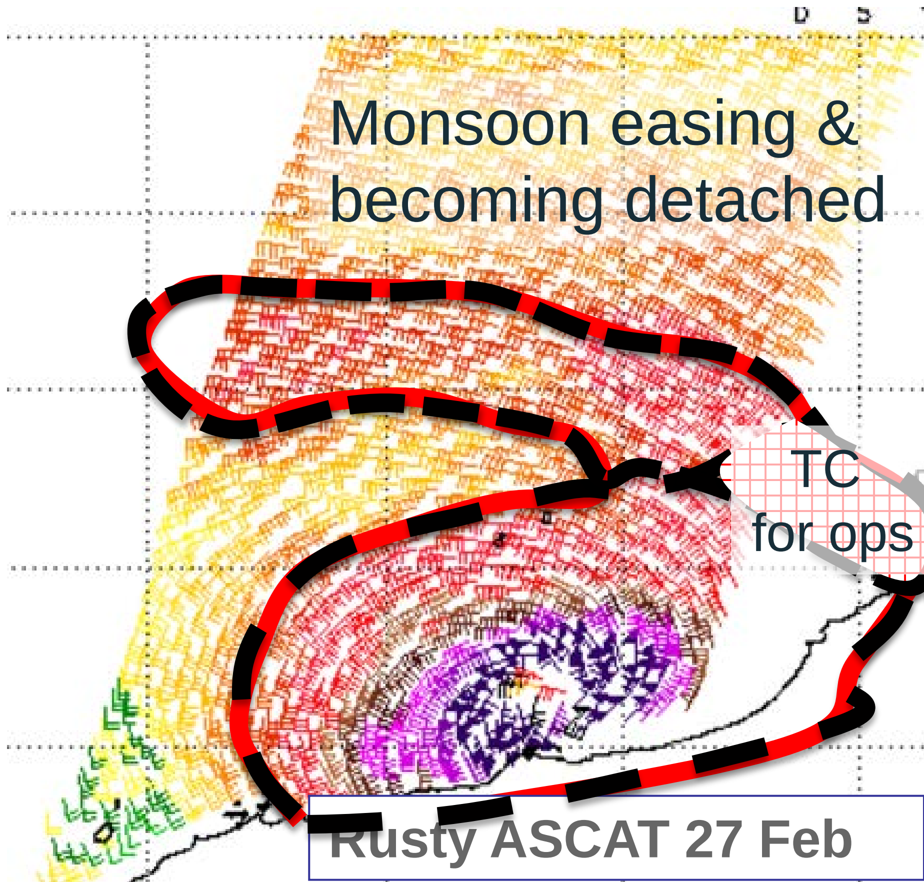
Factors affecting Size changes: synoptic systems a. Monsoon flow

strong monsoon can cause broad gale region on northern side

Issue: TC wind field Vs environmental flow?



Rusty 2013 ASCAT 24/02Z



Rusty ASCAT 27 Feb

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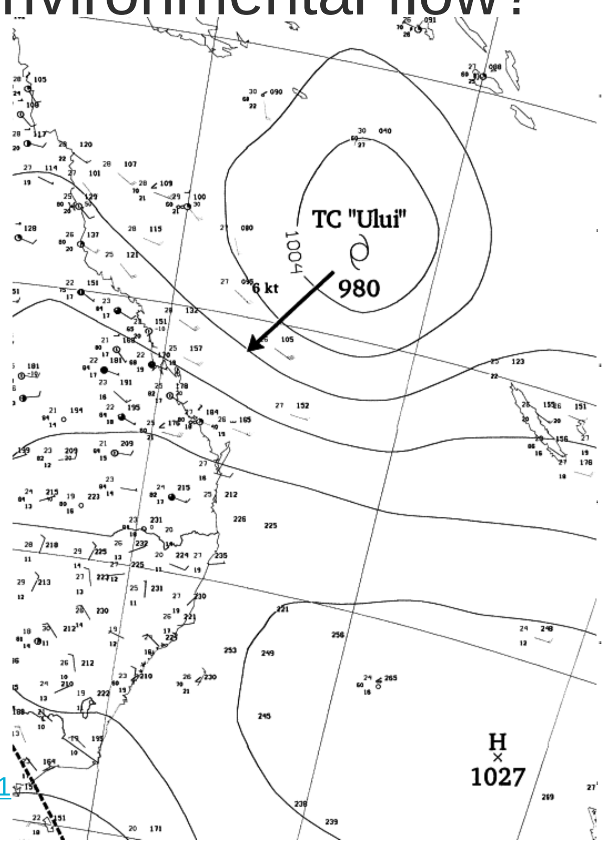
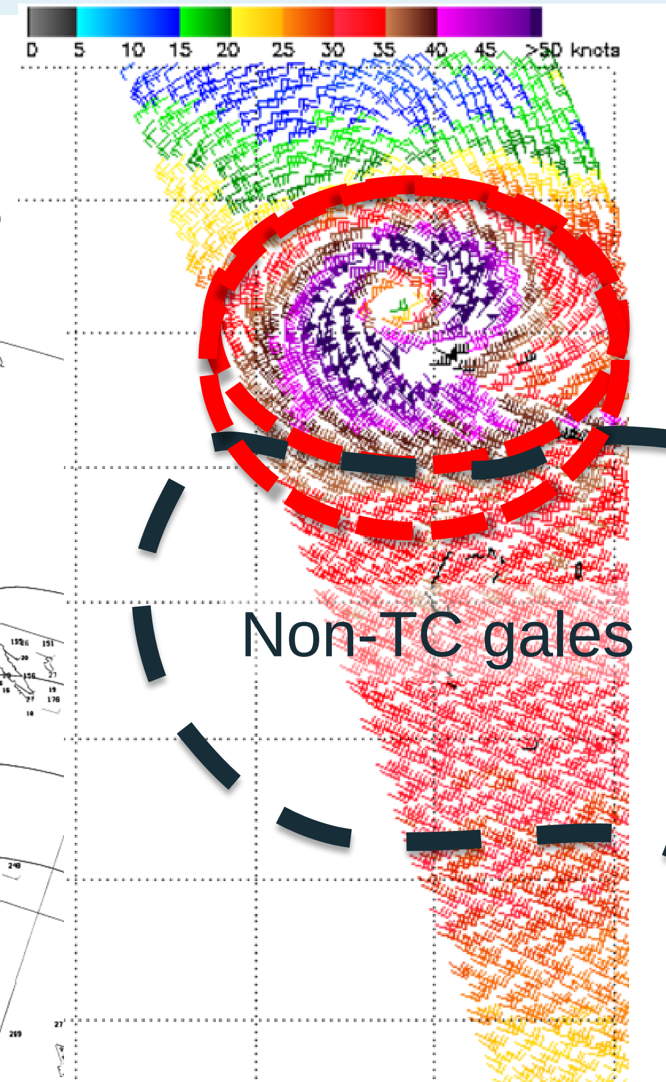
Factors affecting Size changes: synoptic systems b. Sub-tropical Ridge

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

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





Environmental RH and Size
Hill and Lackmann, 2009
http://journals.ametsoc.org/doi/full/10.1175/2009MWR2679.1

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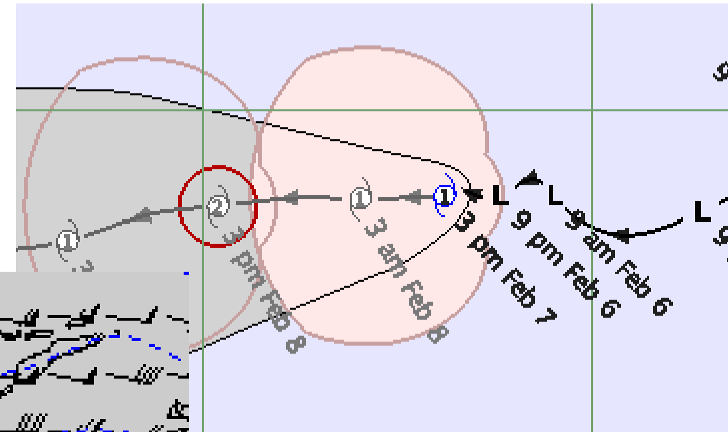
Factors affecting Size changes: convection from wind shear and dry air

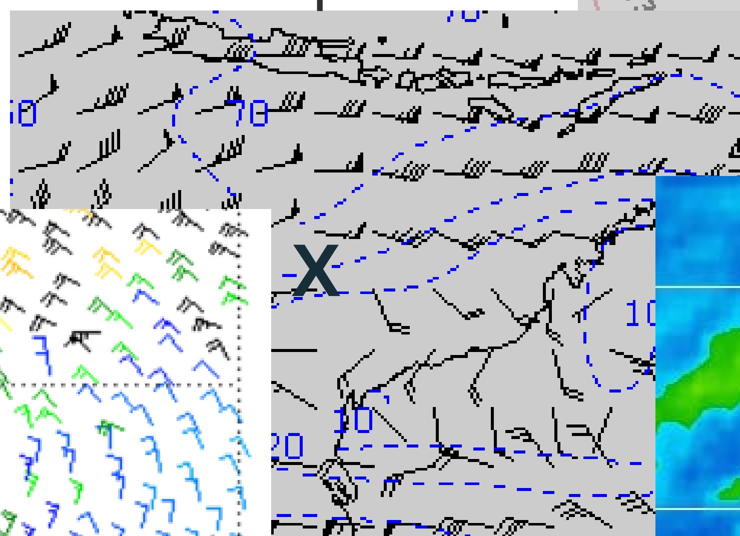
Case study: Freddy 2009

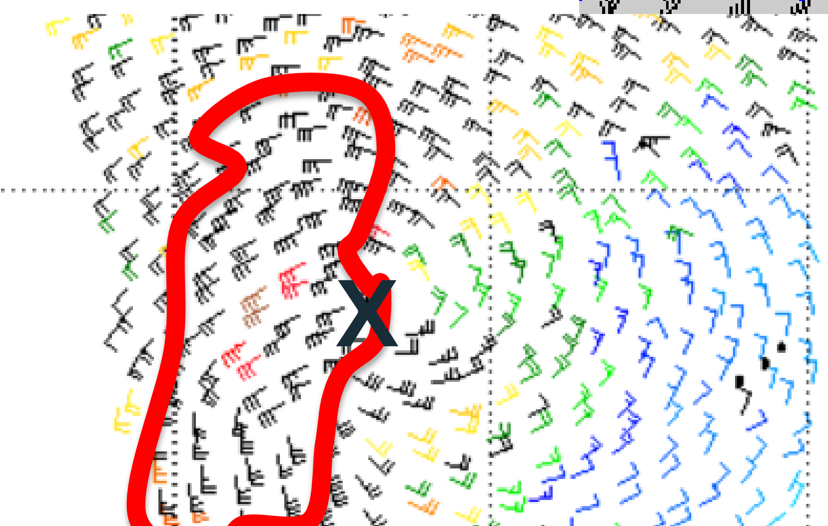
Shear inhibited development

Gales mostly western side

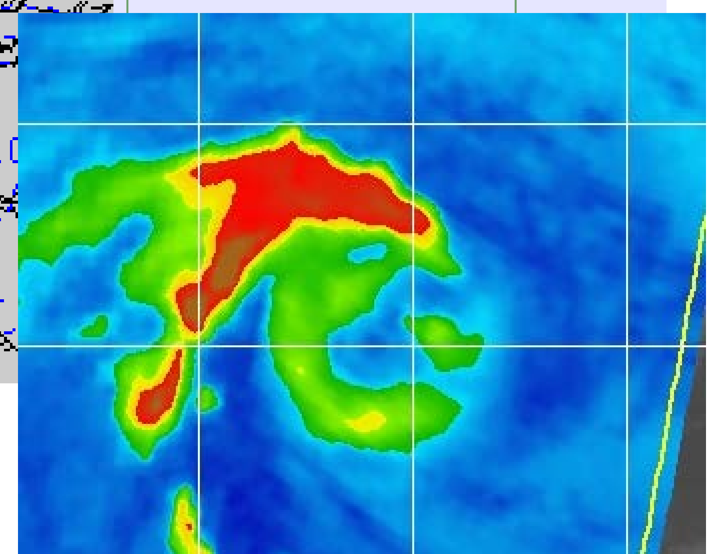
Related to convective and RH pattern







QSCAT 2229Z 6 Feb (NOAA)



SSMI 2219Z 7 Feb (NRL)

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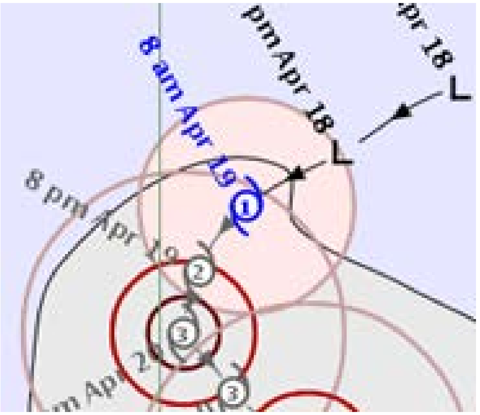
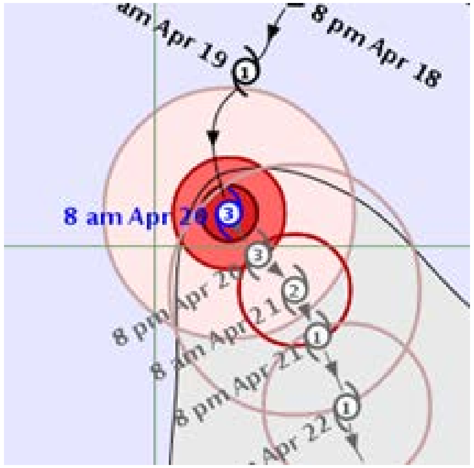
Do TCs expand during intensification? Contract during weakening?

Case study: Jack 2014

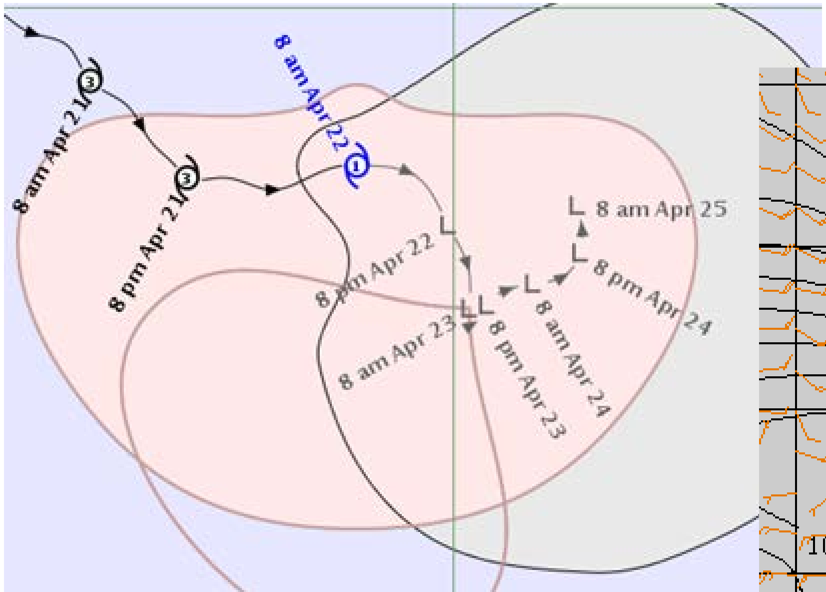
1. Early characteristics: symmetric gales

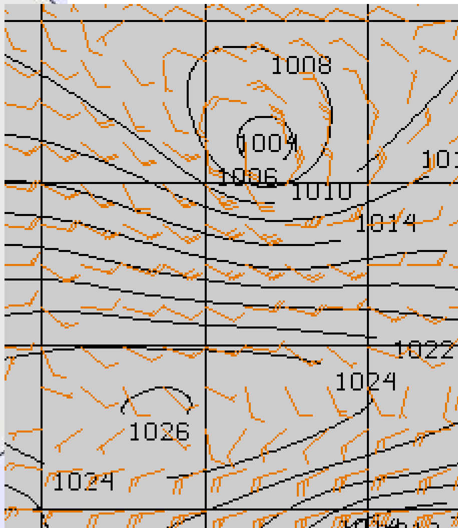


2. Peak intensity remain similar size



3. weakening; synoptic forcing with STR to south





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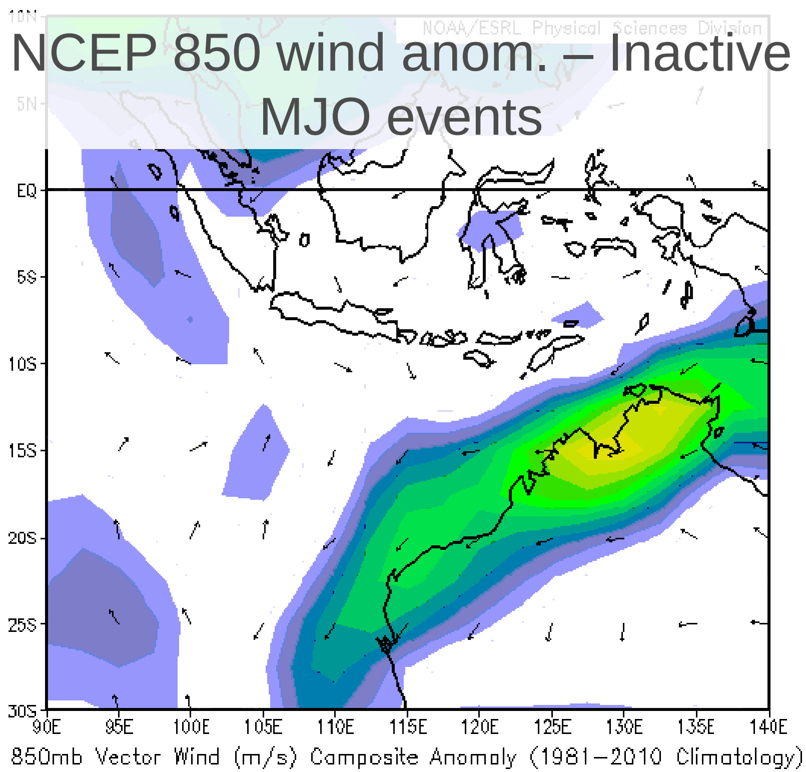
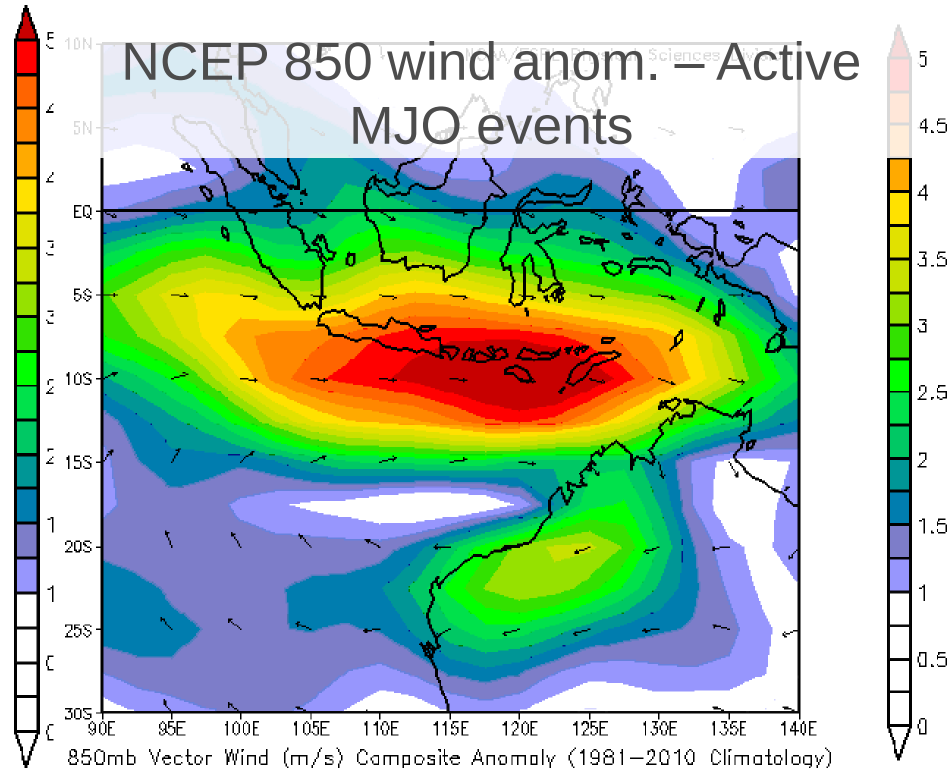
Small Vs Large TCs

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



typical formation gale radius – 74km

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



typical formation gale radius – 100km

Credit: Grant Elliott

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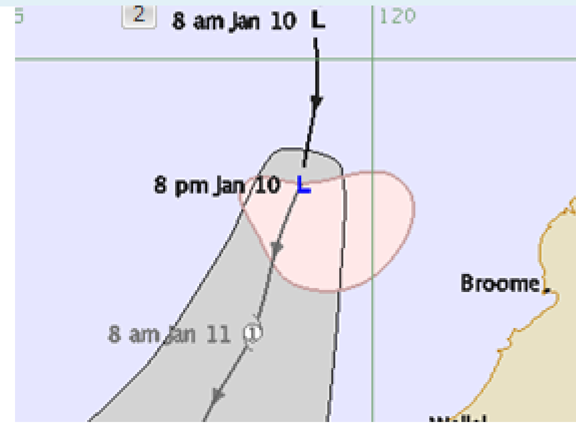
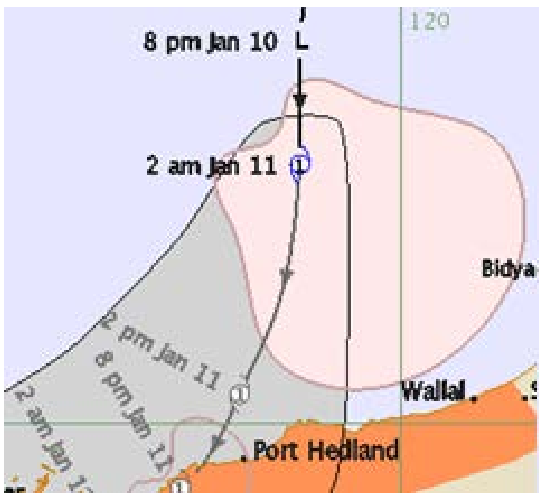
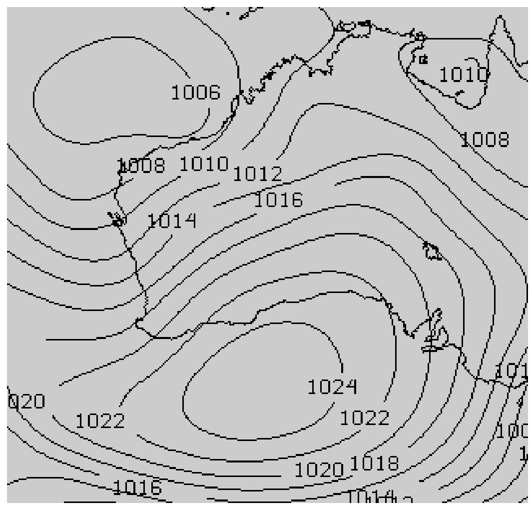
Small TC Case study: Heidi 2012 easterly forcing and drier outer circulation



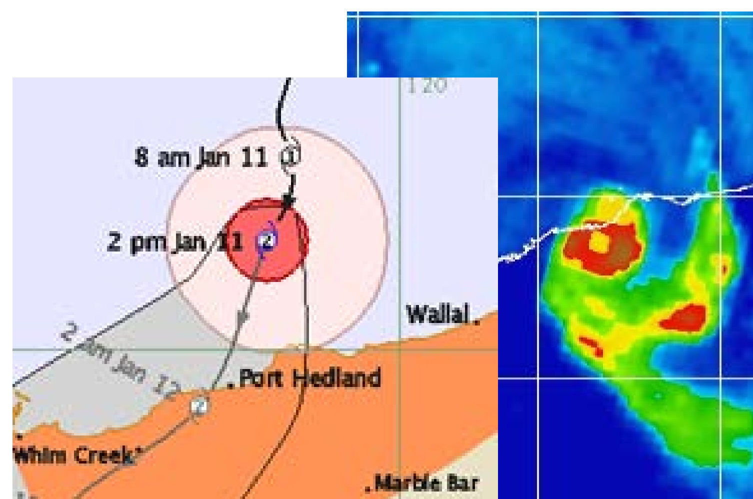
1. Initial characteristics: small area gales
2. Extension to SE with ridge to southeast





3. Intensification: becoming symmetric
Contraction and closer to land

Very small RMW at landfall <10km



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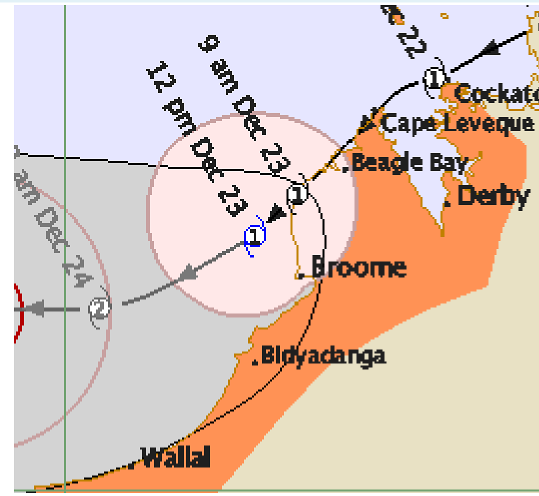
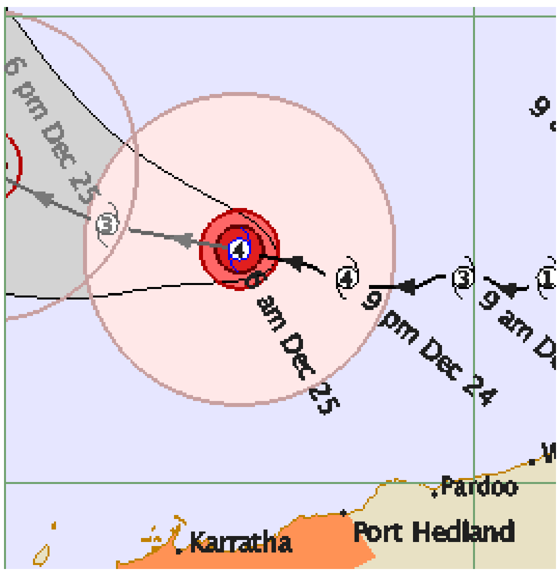
Case study: Billy Dec 2008

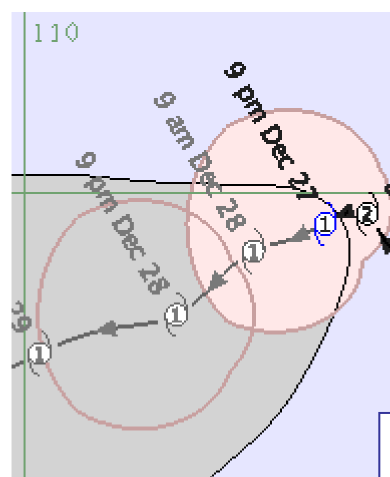
1. Developing off the coast; gales restricted by land; gales 35-70nm

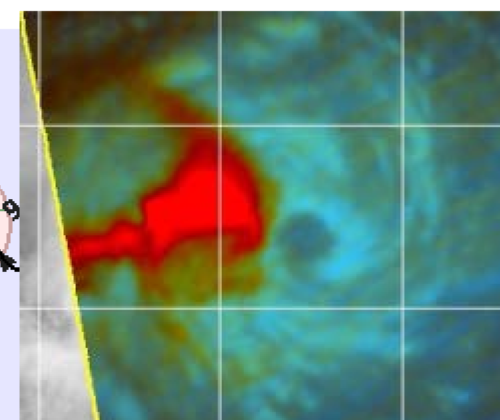




2. Expansion with intensification over open water; 100nm

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




SSMIS 1238Z 27Dec

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

YES NO MAYBE

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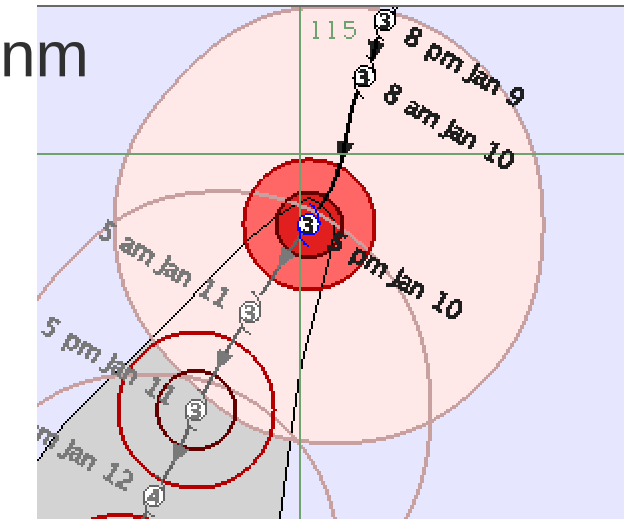
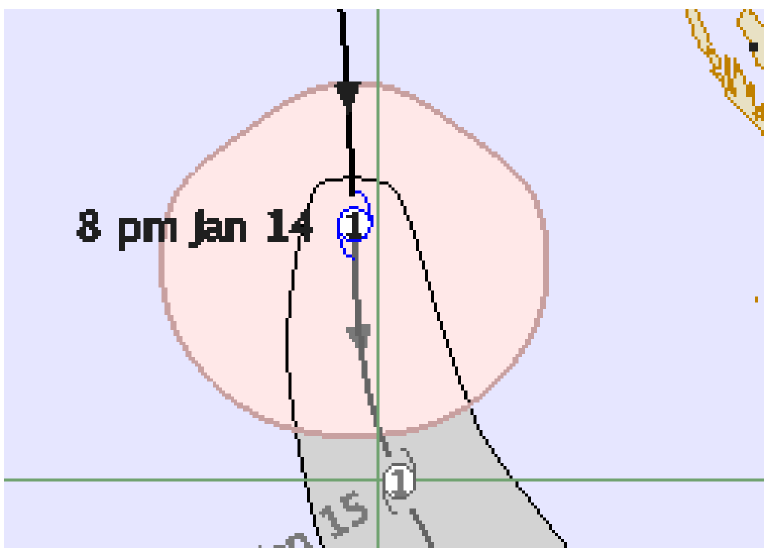
Do TCs expand as they move towards the mid-latitudes?
a. Narelle 2014

1. 10 Jan, Symmetric cat 3 at 16S: 150-180nm

2. Remains mostly symmetric at 28S

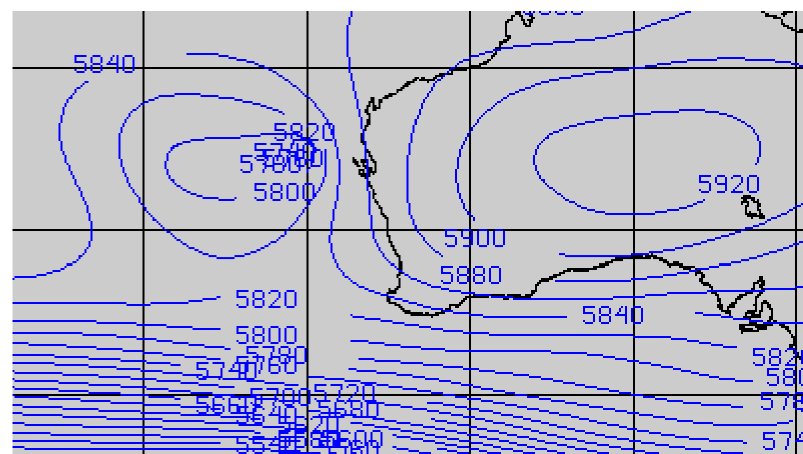
80-120nm





NO gale expansion

- Weak mid-latitude westerlies



EC 500hPa heights

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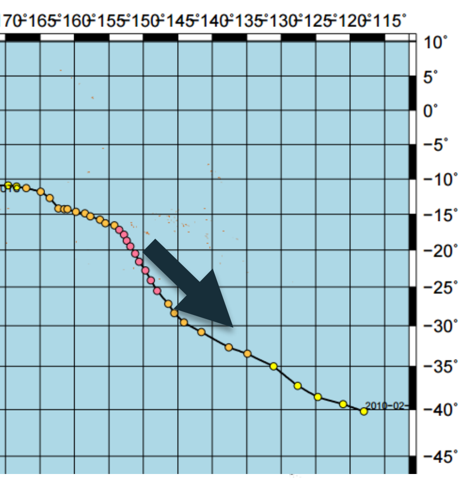
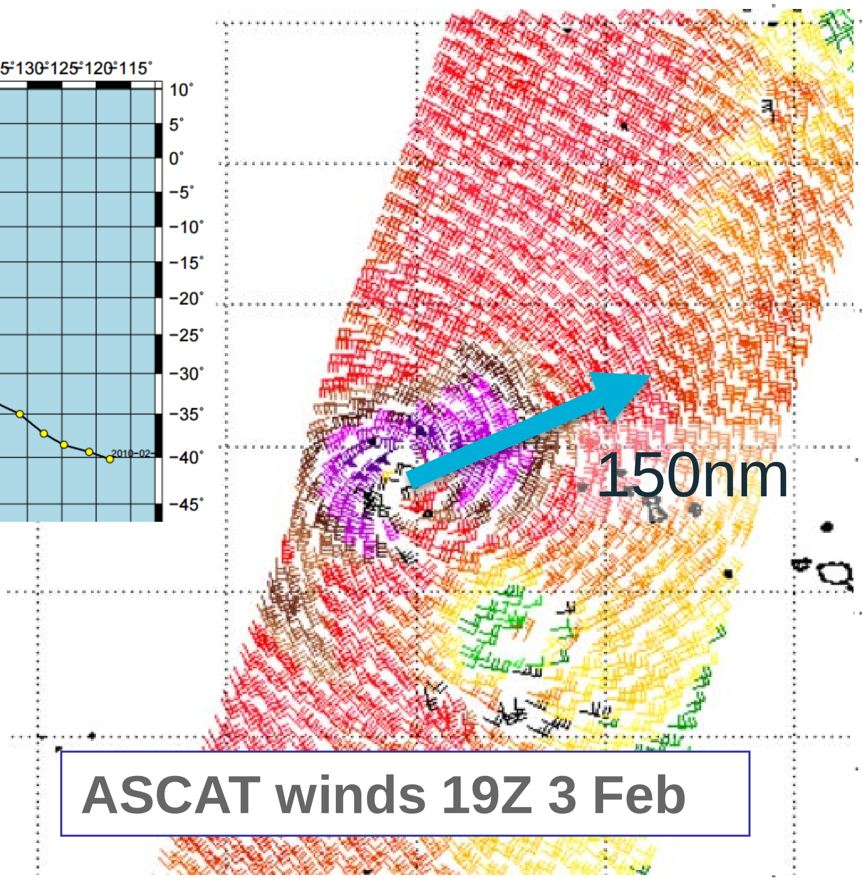
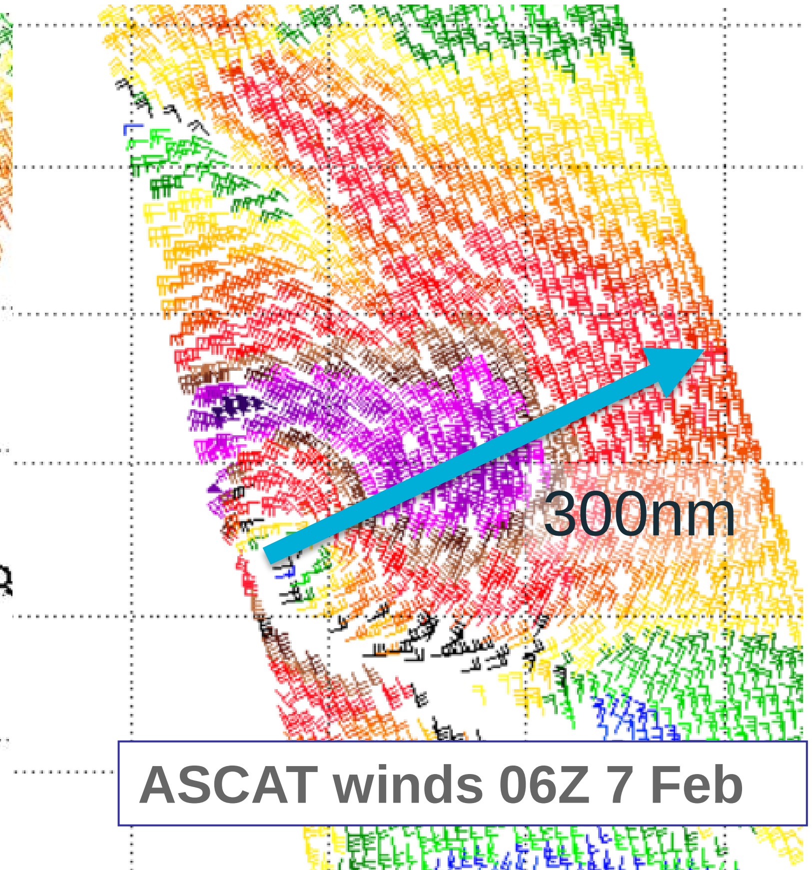
Do TCs expand as they move towards the mid-latitudes? b. Oli (2010 South Pacific)

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

2. 7 Feb Accelerates to SE to 33S







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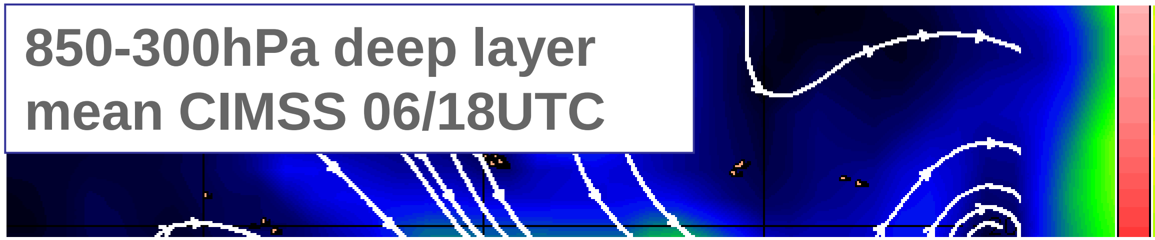
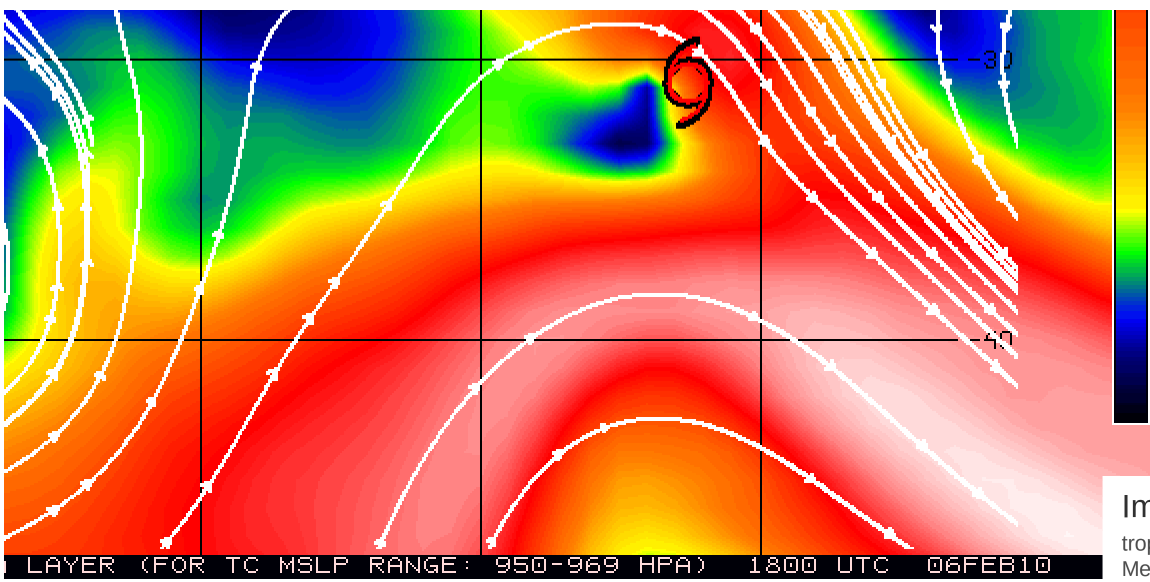
Do TCs expand as they move towards the mid-latitudes? YES
b. Oli (2010 South Pacific)

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/20100206/300to850mbDeepLayerMeanLarge/20100206.18.SEPacific.300to850mbDeepLayerMeanLarge.png

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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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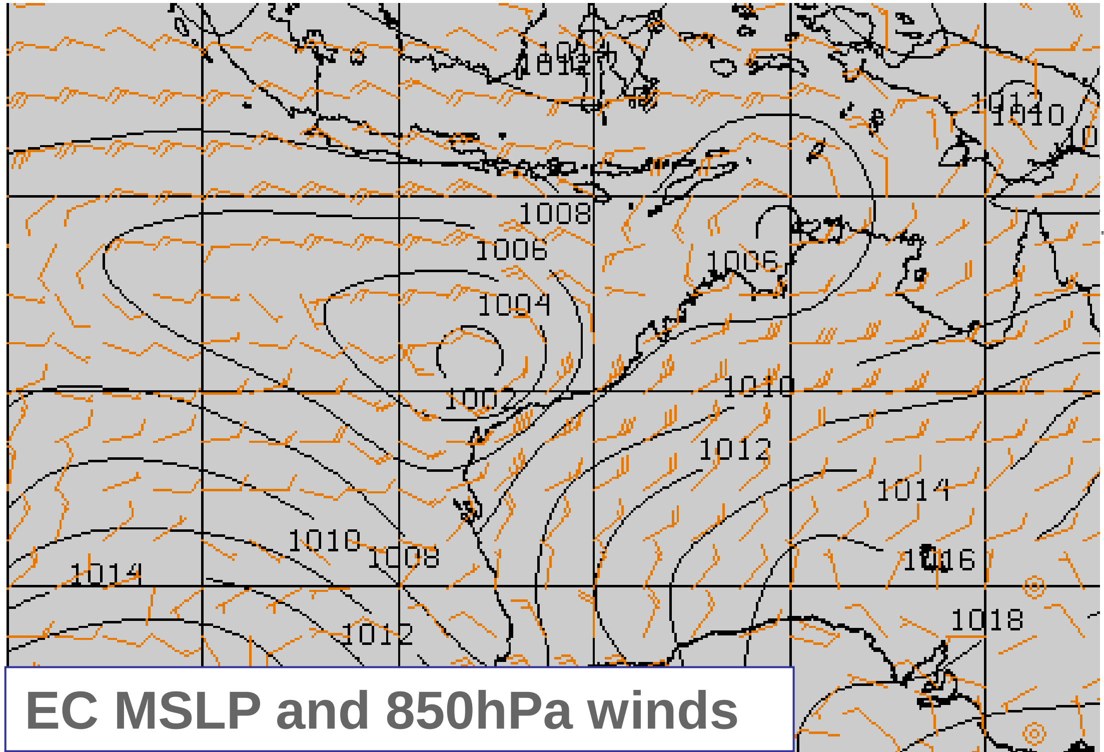
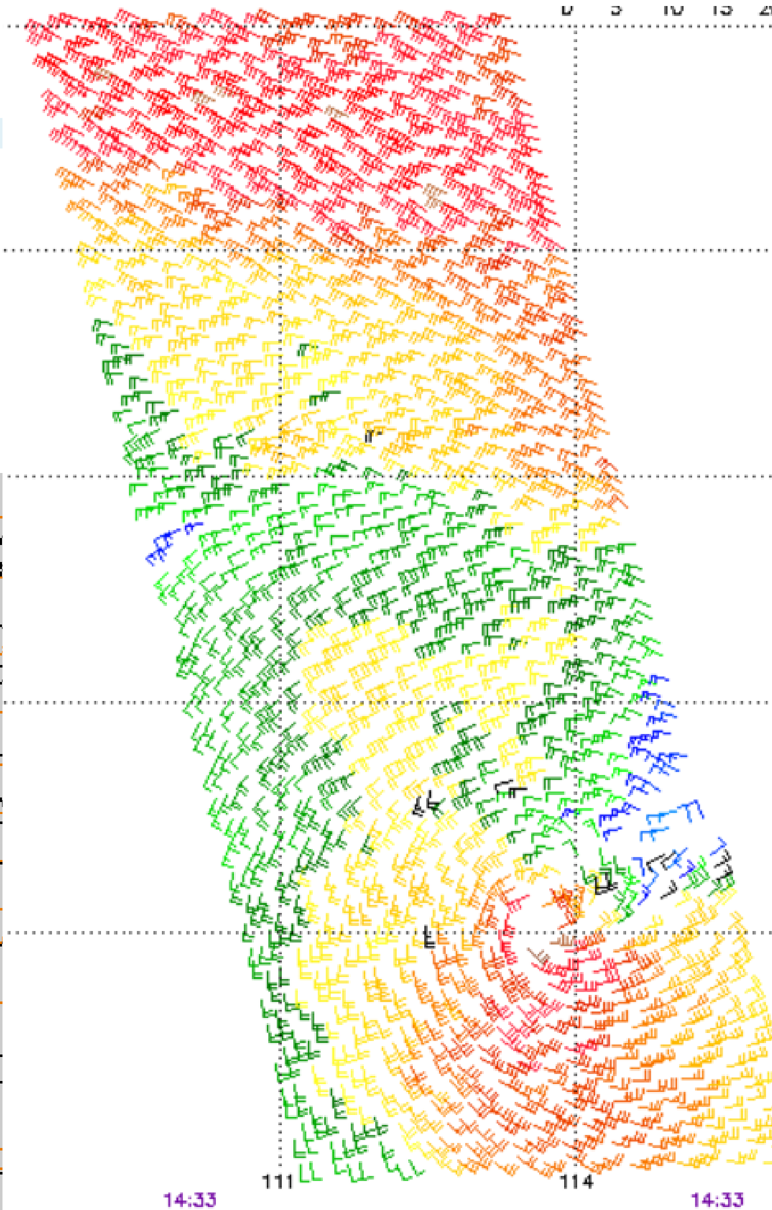
Case study: Lua 2012
1. 13/06Z named

Initial characteristics: Strong easterlies removed from strong monsoon



EC MSLP and 850hPa winds



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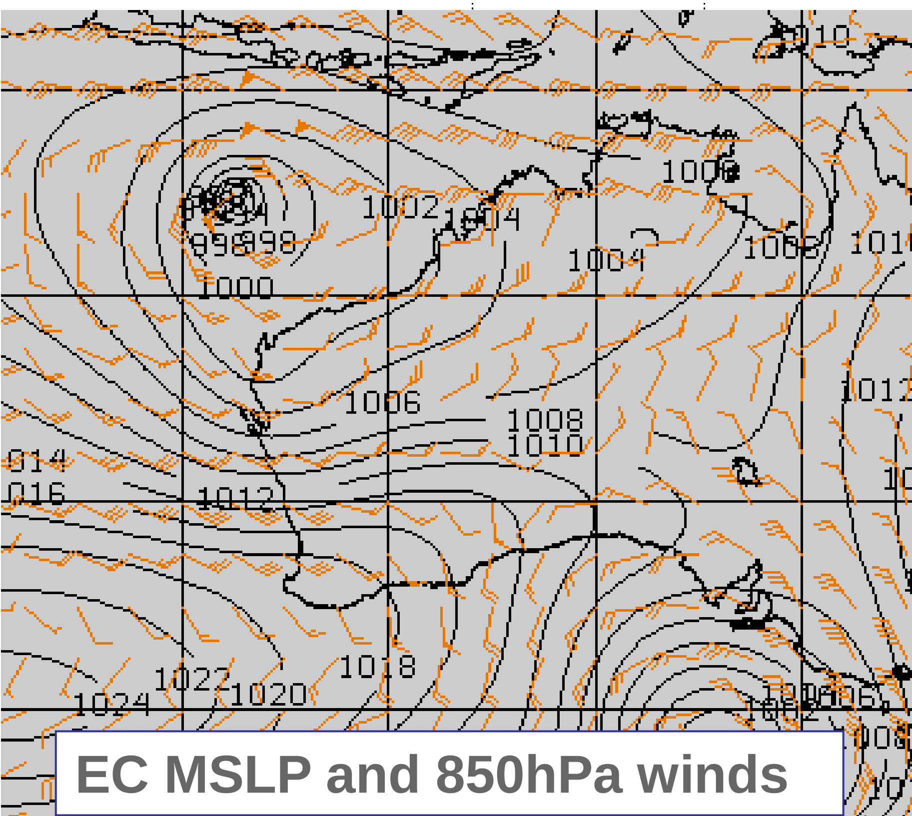
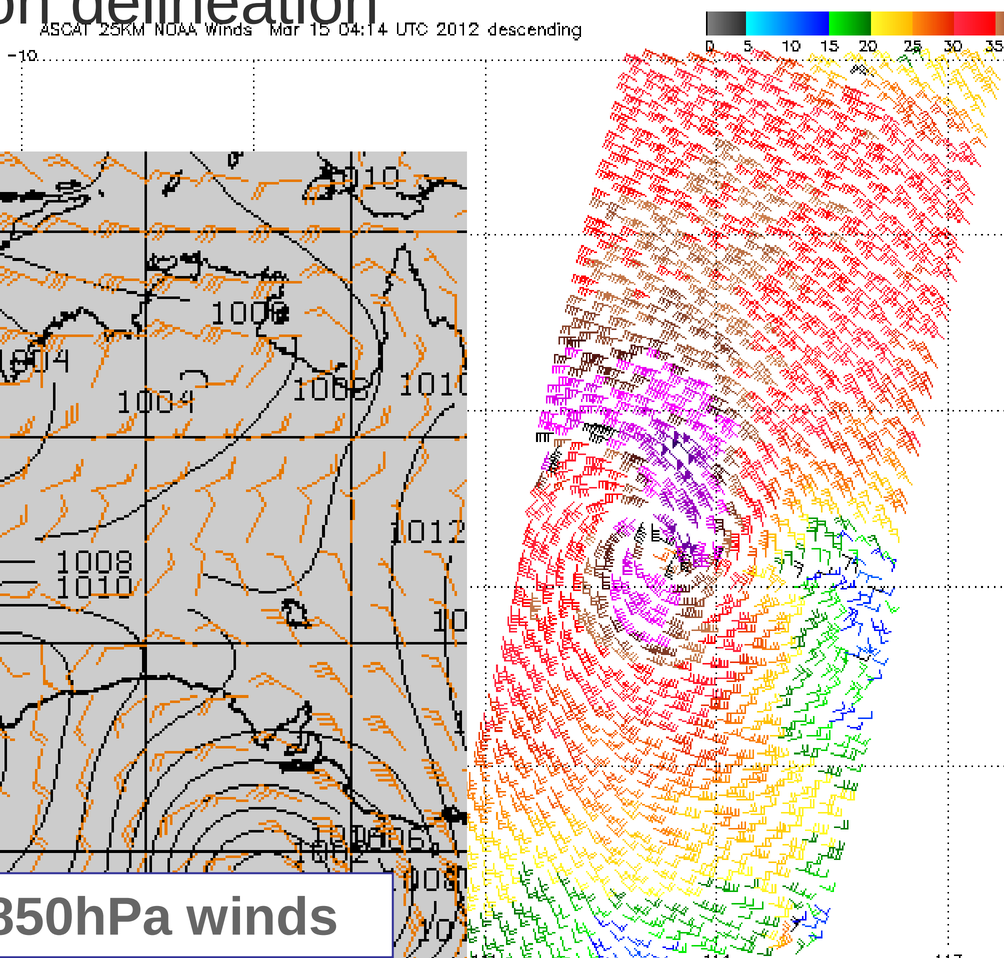
Case study: Lua 2012
2. 15/00UTC cat 2

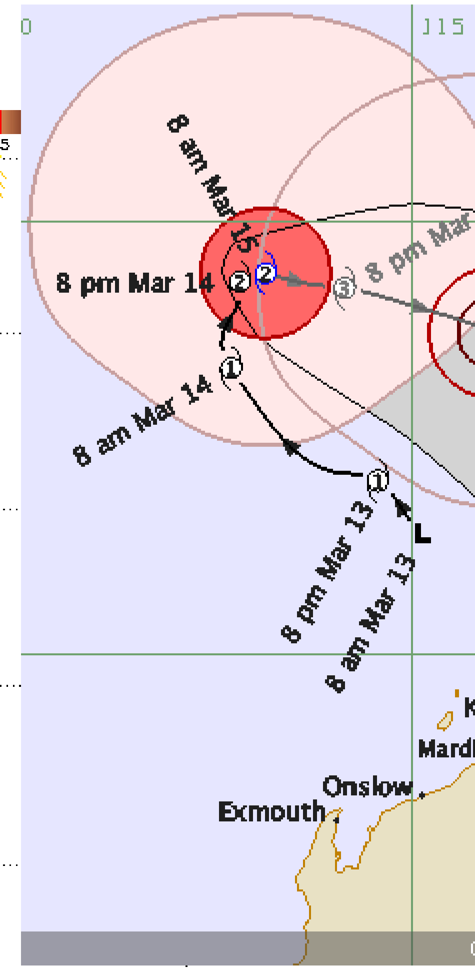
expansion in northern half from monsoon

TC Vs Monsoon delineation



EC MSLP and 850hPa winds





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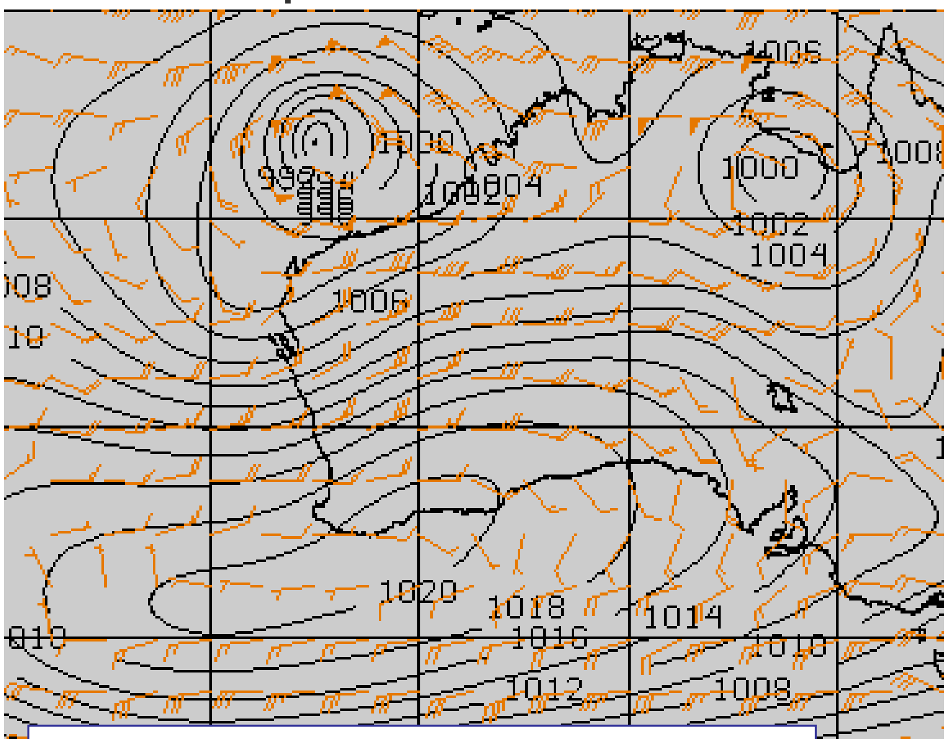
Case study: Lua 2012
3. 16/03UTC cat 2

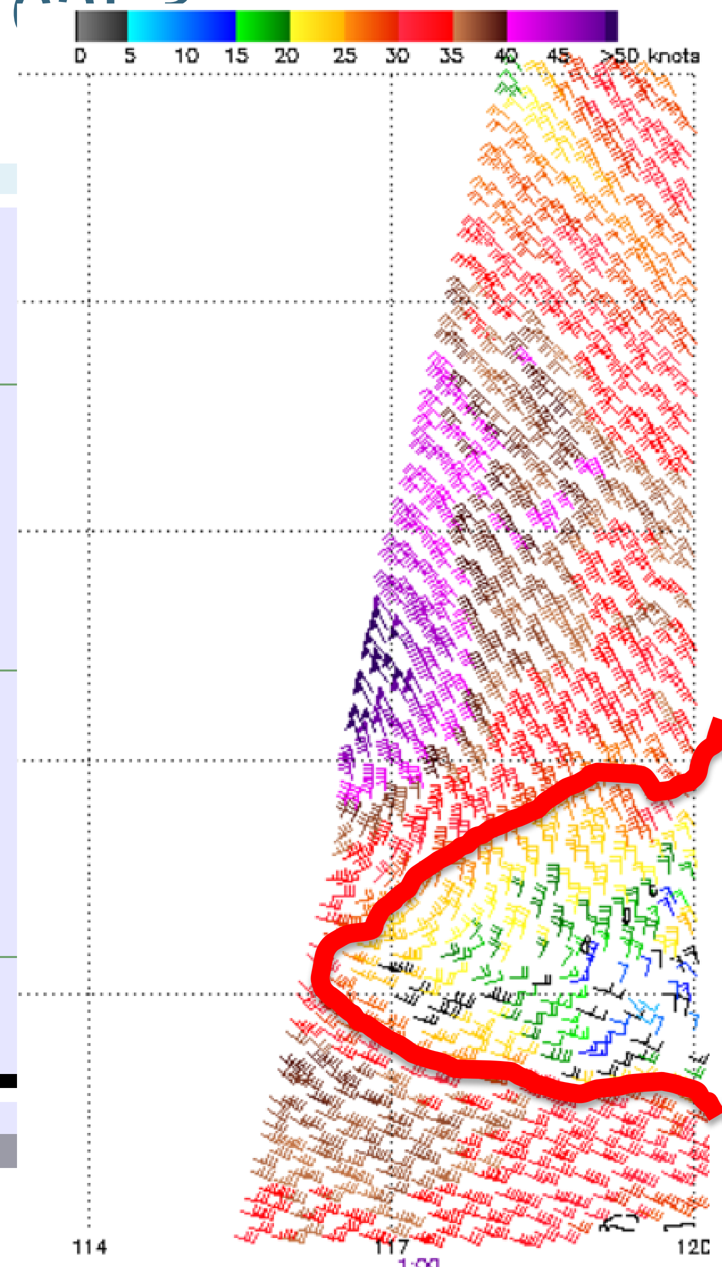
southern expansion STR development

TC field Vs synoptic?

– operational decision



EC MSLP and 850hPa winds



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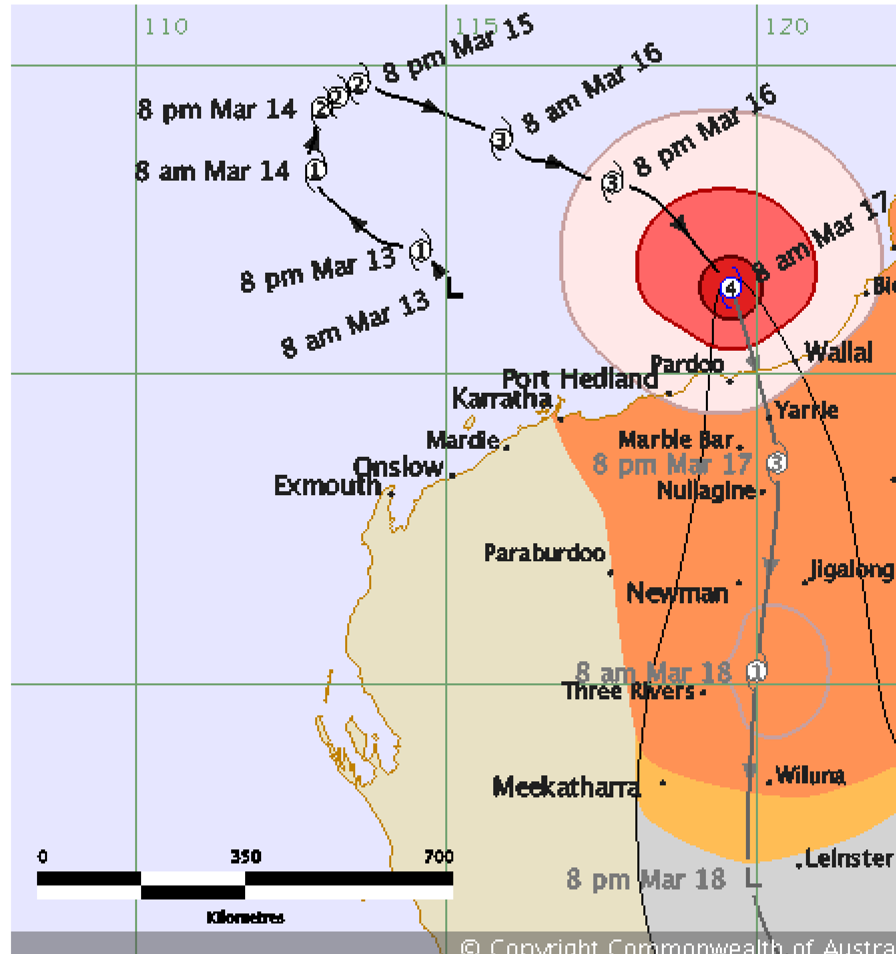
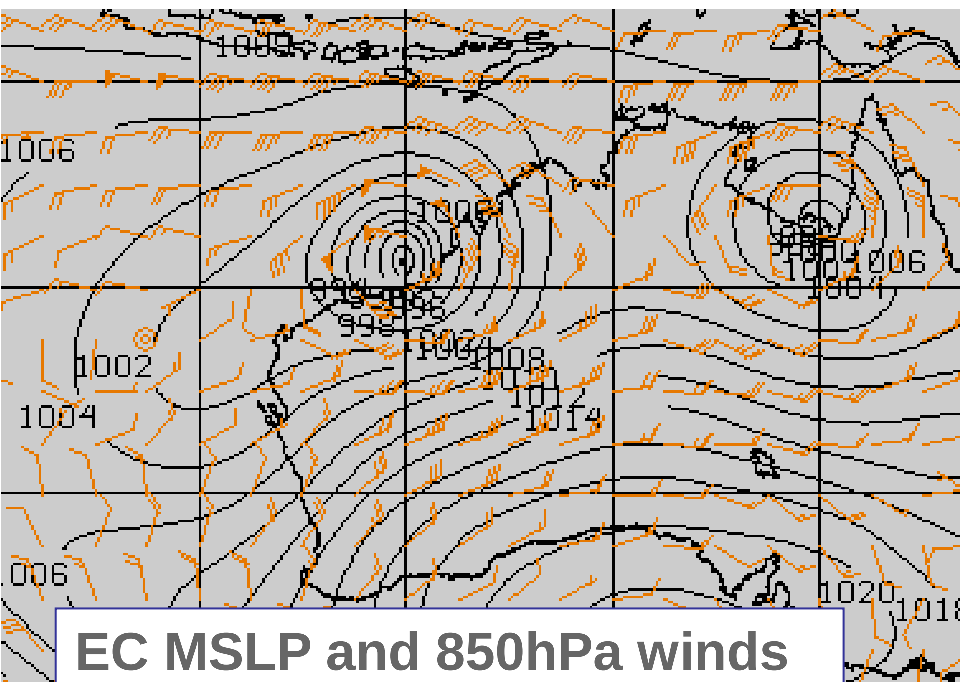
Case study: Lua 2012
4. 17/00UTC Cat 4 Land influence

Contraction - land to south;

Starting to become disconnected with monsoon to north





EC MSLP and 850hPa winds

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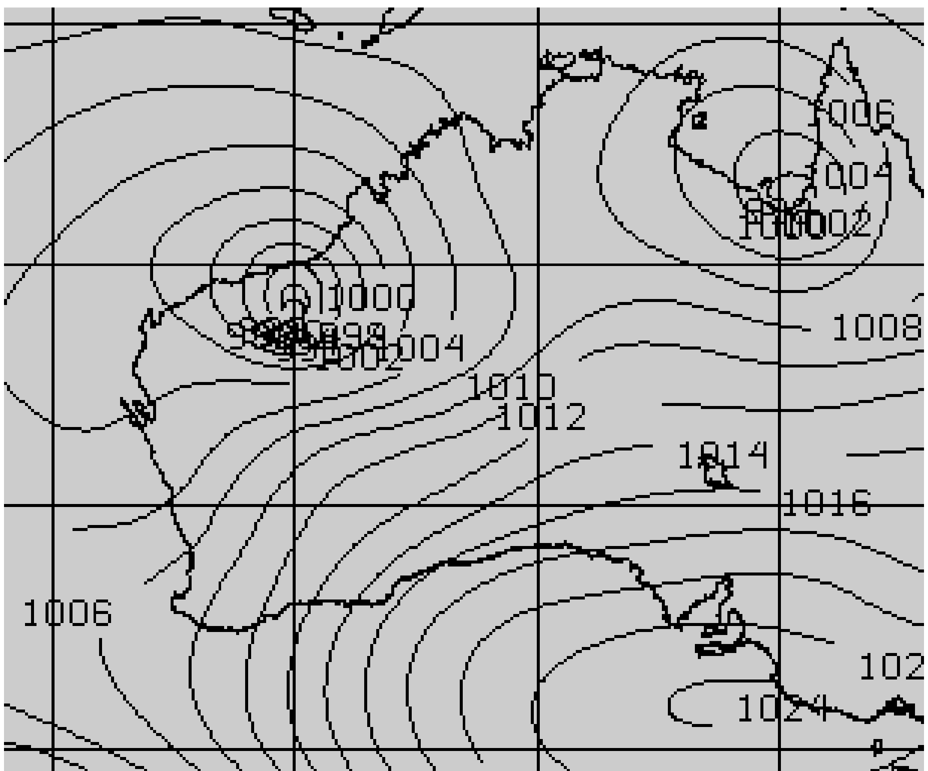
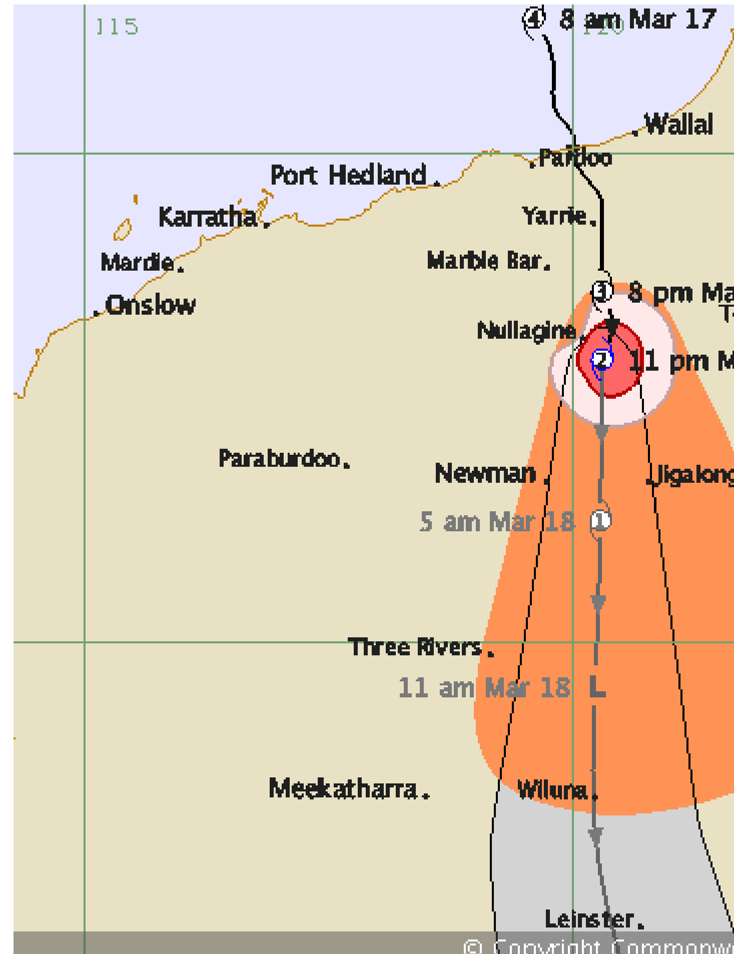
Case study: Lua 2012
5. 17/15UTC land

Contraction during weakening over land

Asymmetry from translation speed 16 kn and strong STR;





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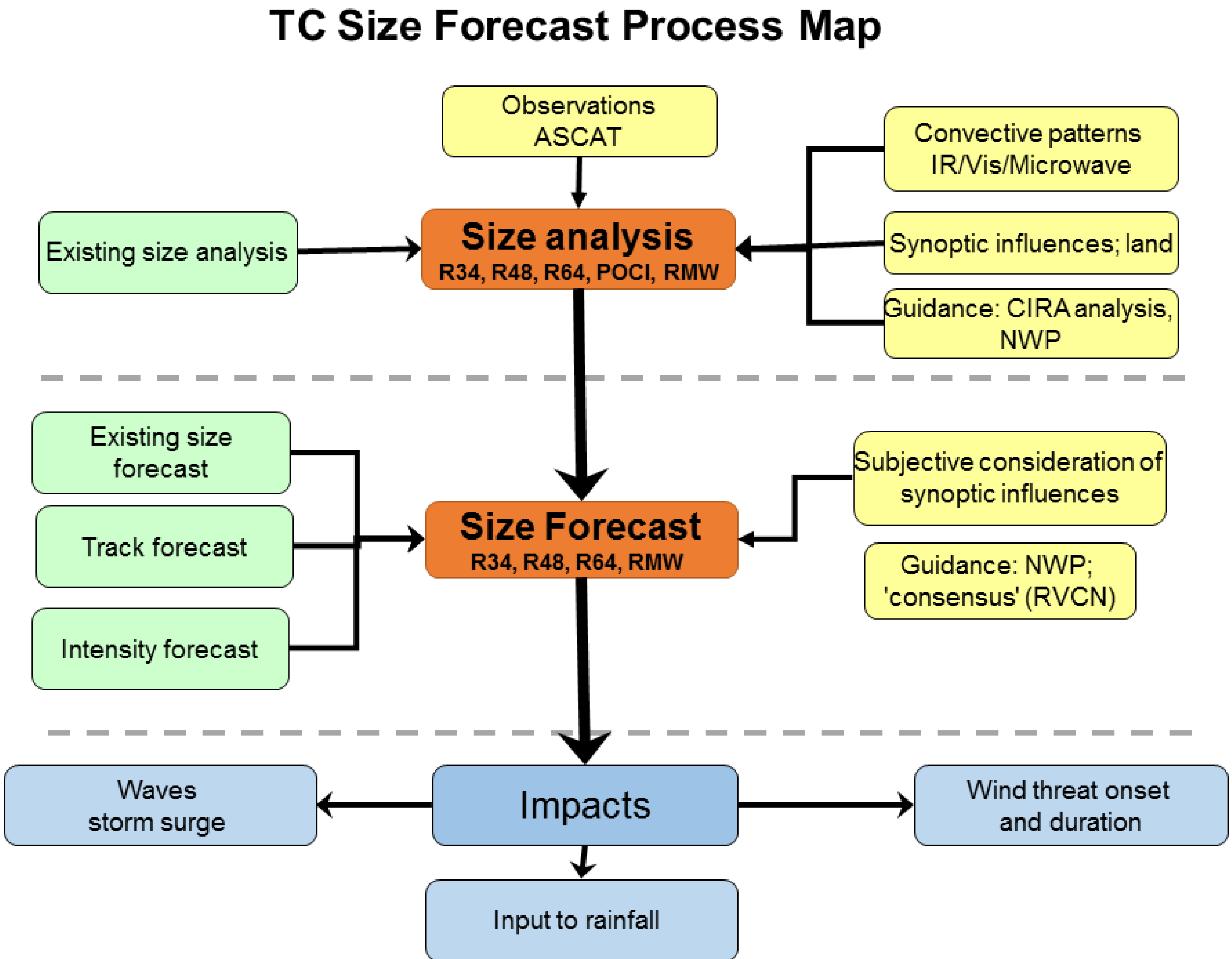
Size Changes: Forecast process



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Forecast process
1. a good analysis

Synoptic influences (eg wind shear)

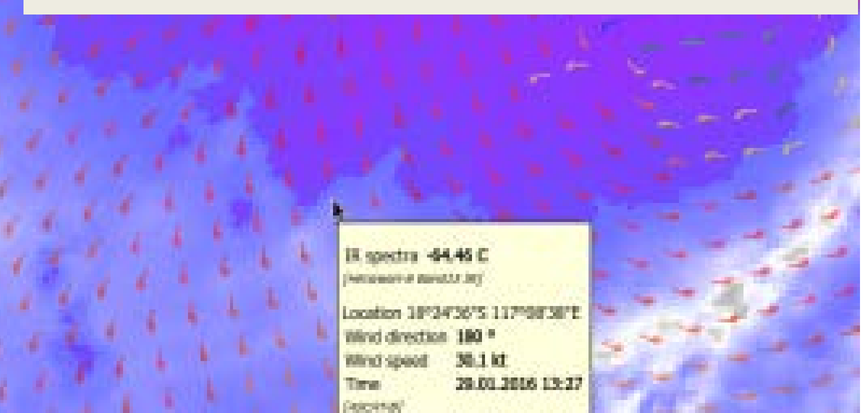
Obs/Scatterometry

Satellite signatures

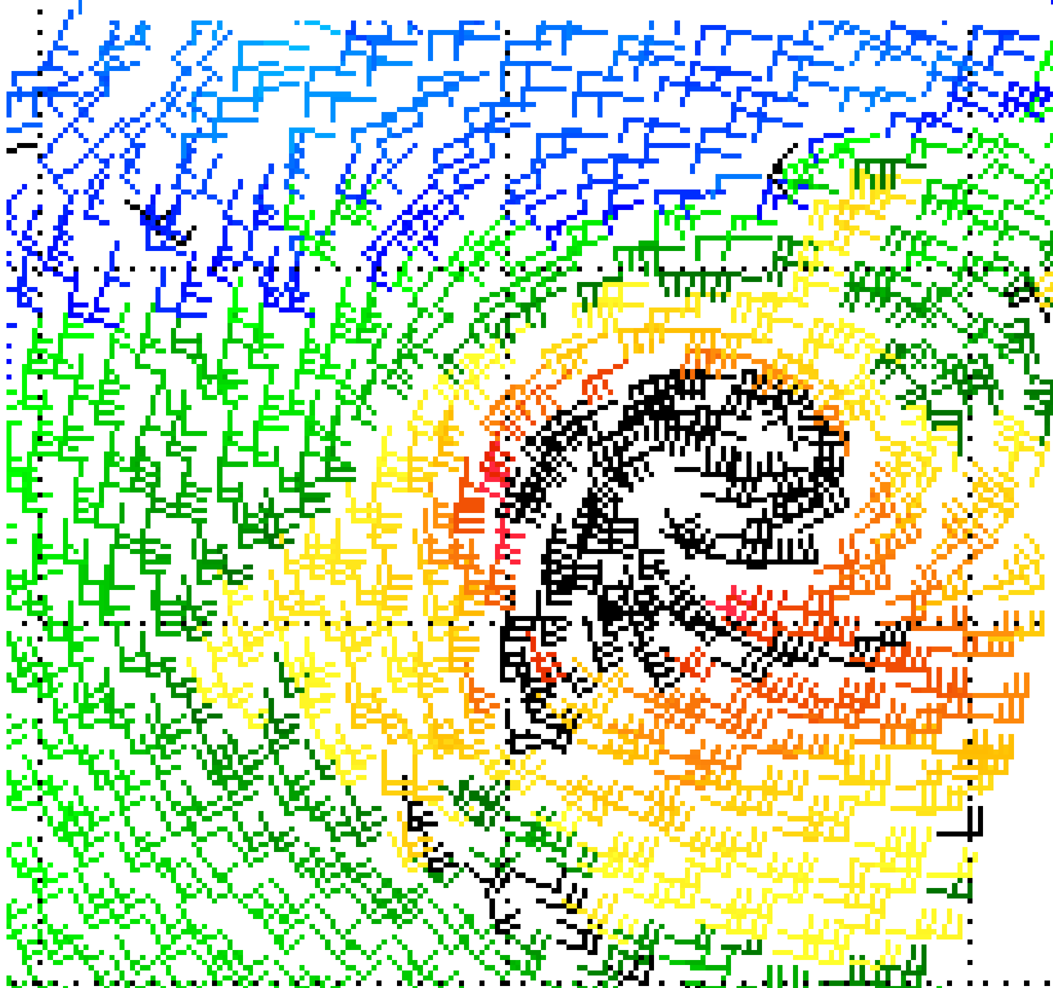
NWP analysis

Tip for operations:

For EUMET ASCAT solution in use 30.0kn as gale boundary



TASK: Draw 30kn isotach



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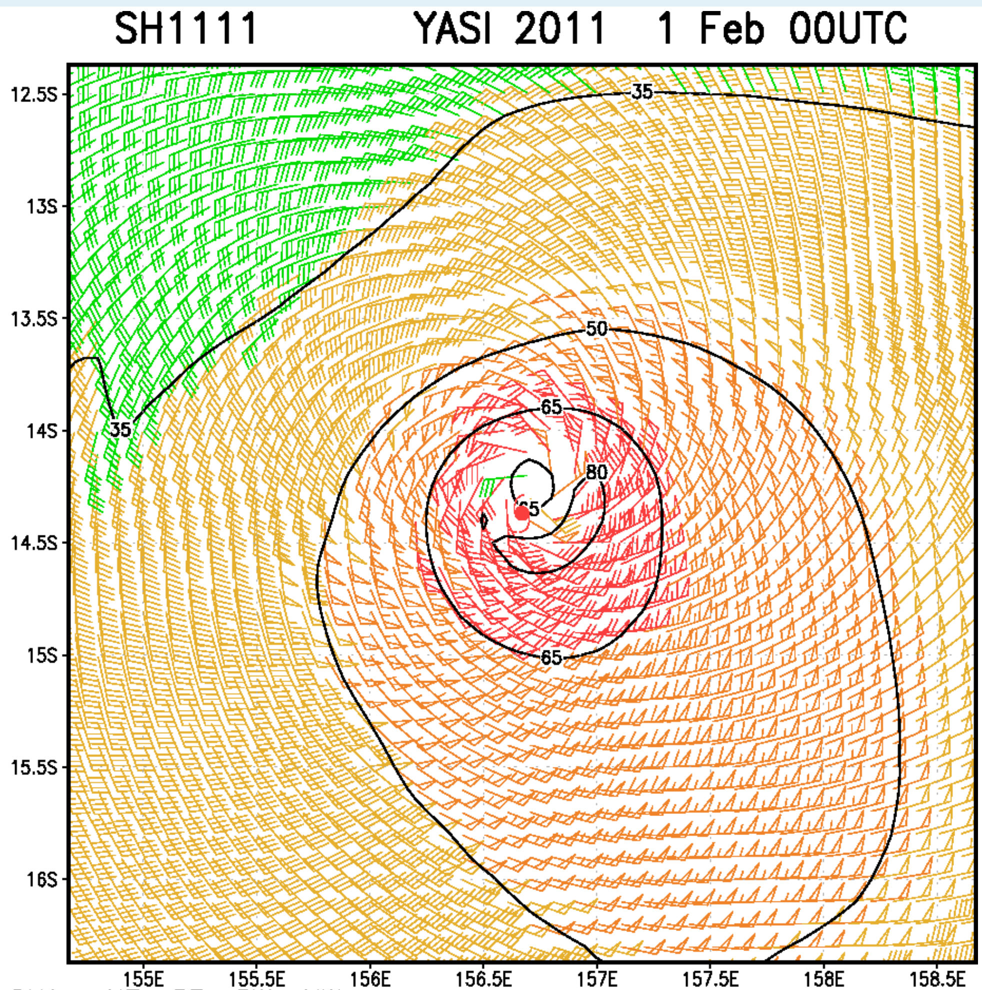
Size analysis: Multi-platform Wind analysis (MTCSWA)

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



QUA	NE	SE	SW	NW		
R34	280	320	290	155		
R50	85	130	100	50	VMAX = 94 kt	MSLP = 967.1 hPa
R64	35	40	35	35	RMW = 8 nmi	BEARING = 120 degrees

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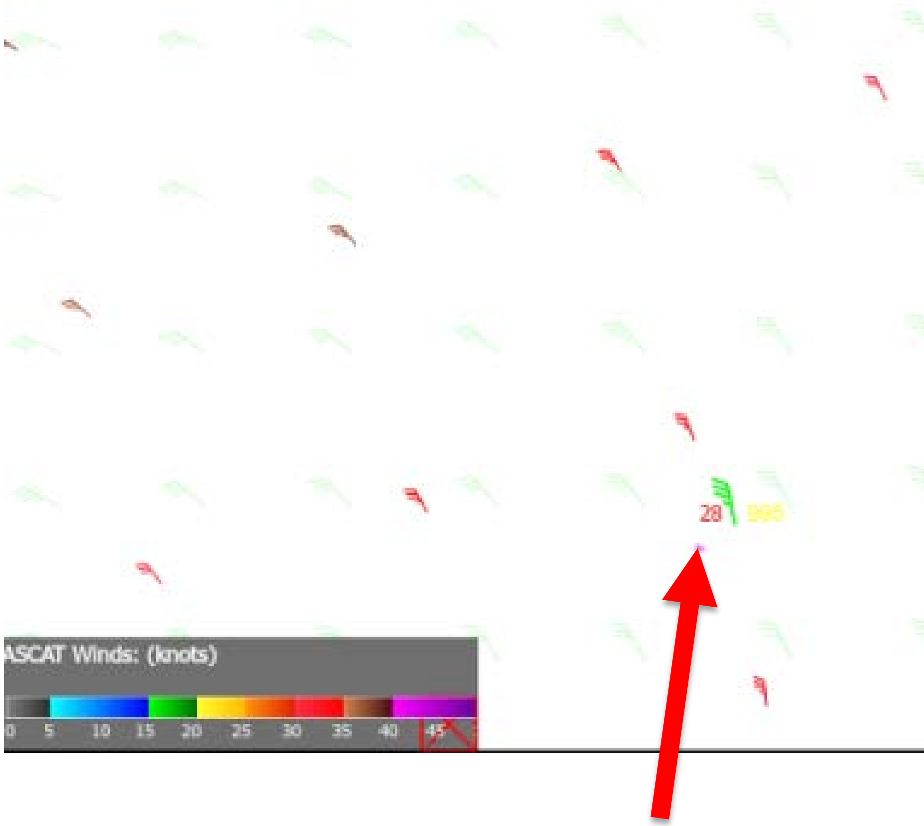
Forecast process

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

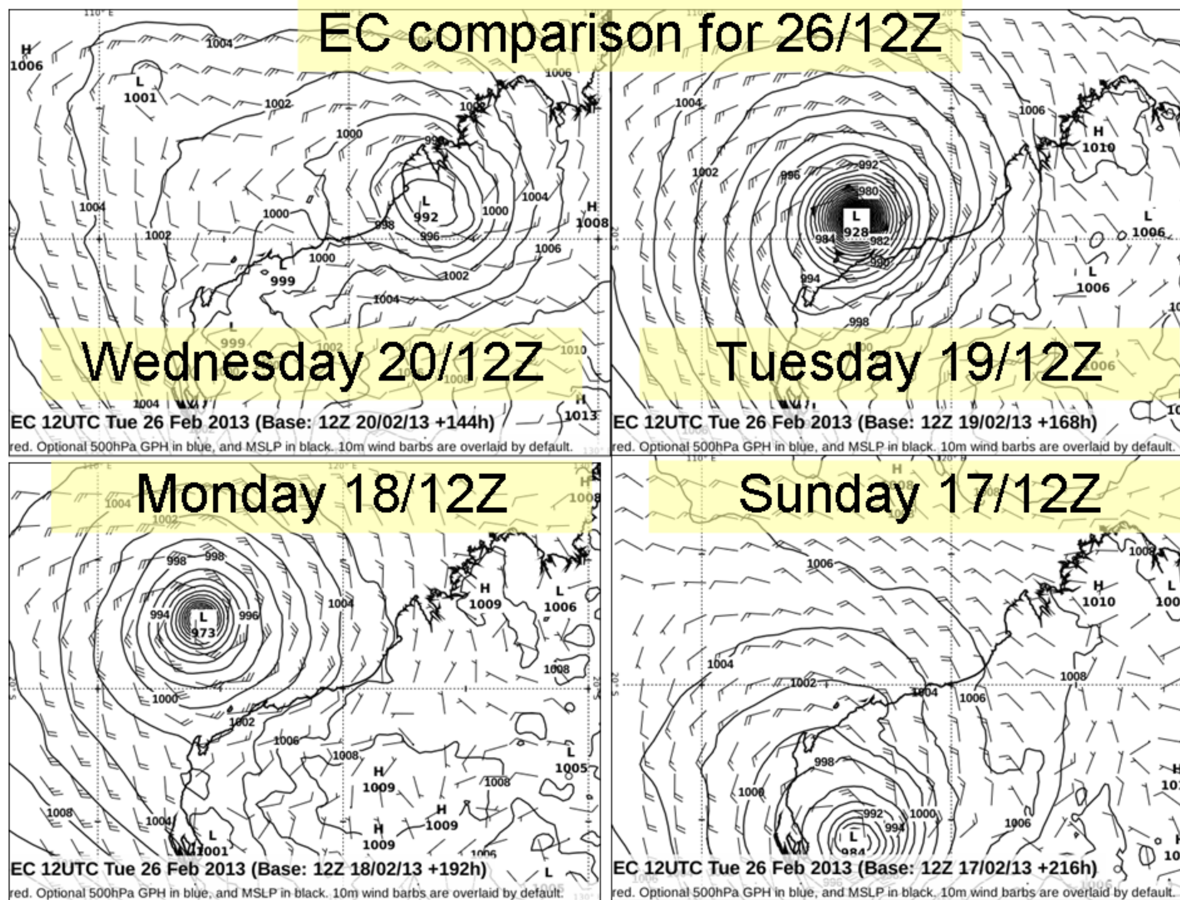
2. Good track and intensity forecast:

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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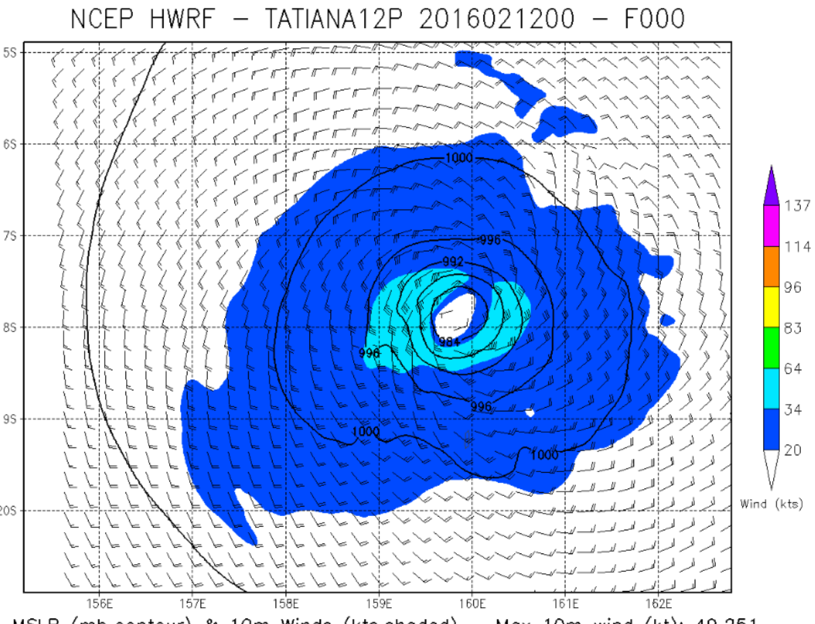
Forecast process: NWP

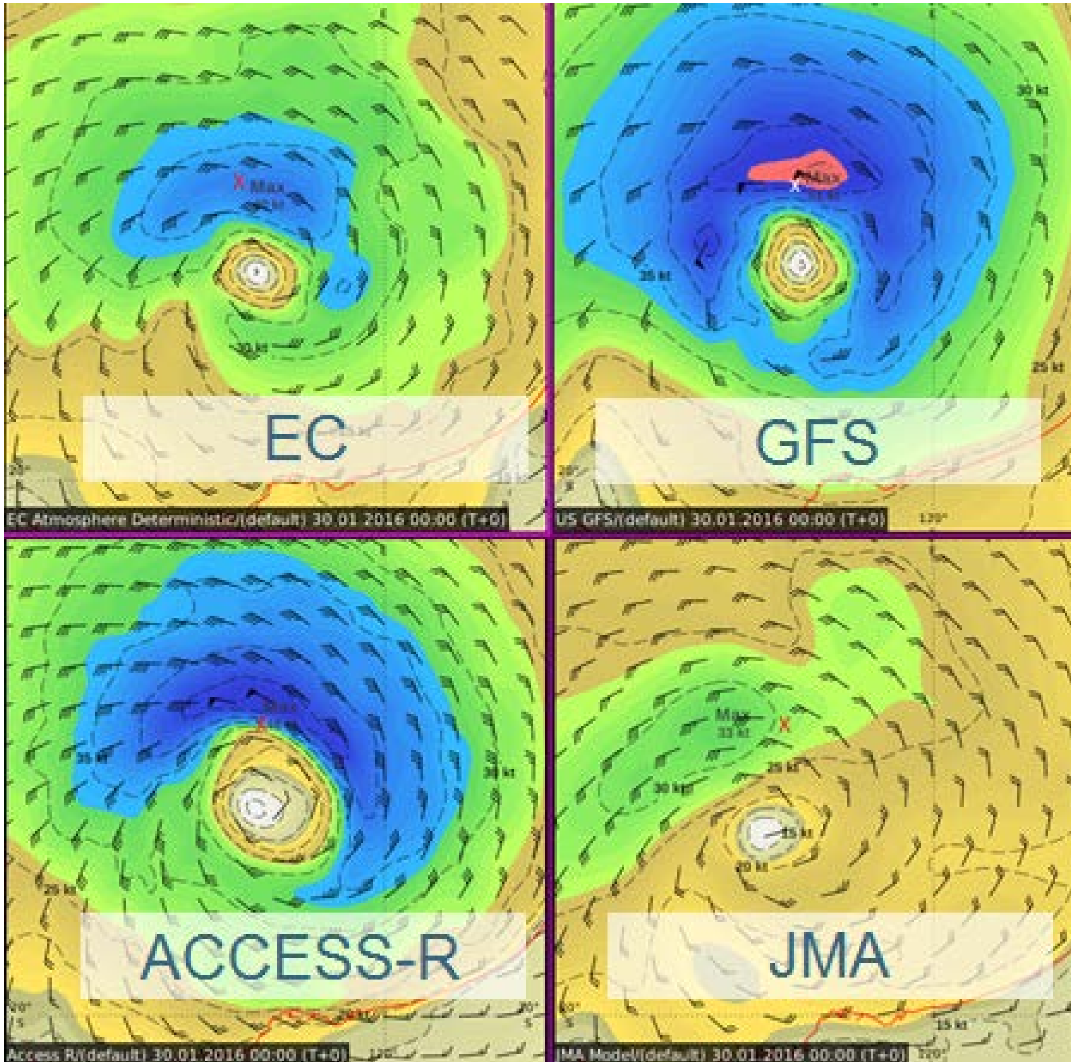
4. NWP: wind fields

Comparisons

Fields Vs numeric output (max extent)

towards ensembles…





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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, HWRF,  12, 145S, 1106E,  62,  983, XX,  34, NEQ,   72,   81,   65,   60,
SH, 15, 2017040606, 03, HWRF,  18, 149S, 1108E,  79,  972, XX,  34, NEQ,   60,  141,   99,   62,
SH, 15, 2017040606, 03, HWRF,  24, 154S, 1110E,  99,  962, XX,  34, NEQ,   66,  105,   90,   78,
SH, 15, 2017040606, 03, HWRF,  30, 157S, 1111E, 104,  956, XX,  34, NEQ,   60,   93,   91,   56,
SH, 15, 2017040606, 03, HWRF,  36, 160S, 1109E, 106,  951, XX,  34, NEQ,   67,  119,   94,   51,
SH, 15, 2017040606, 03, HWRF,  42, 163S, 1108E, 104,  949, XX,  34, NEQ,   74,  101,   86,   57,
SH, 15, 2017040606, 03, HWRF,  48, 165S, 1106E, 111,  946, XX,  34, NEQ,  240,   90,   99,   41,
SH, 15, 2017040606, 03, HWRF,  54, 169S, 1104E,  98,  969, XX,  34, NEQ,   67, [illegible],   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'

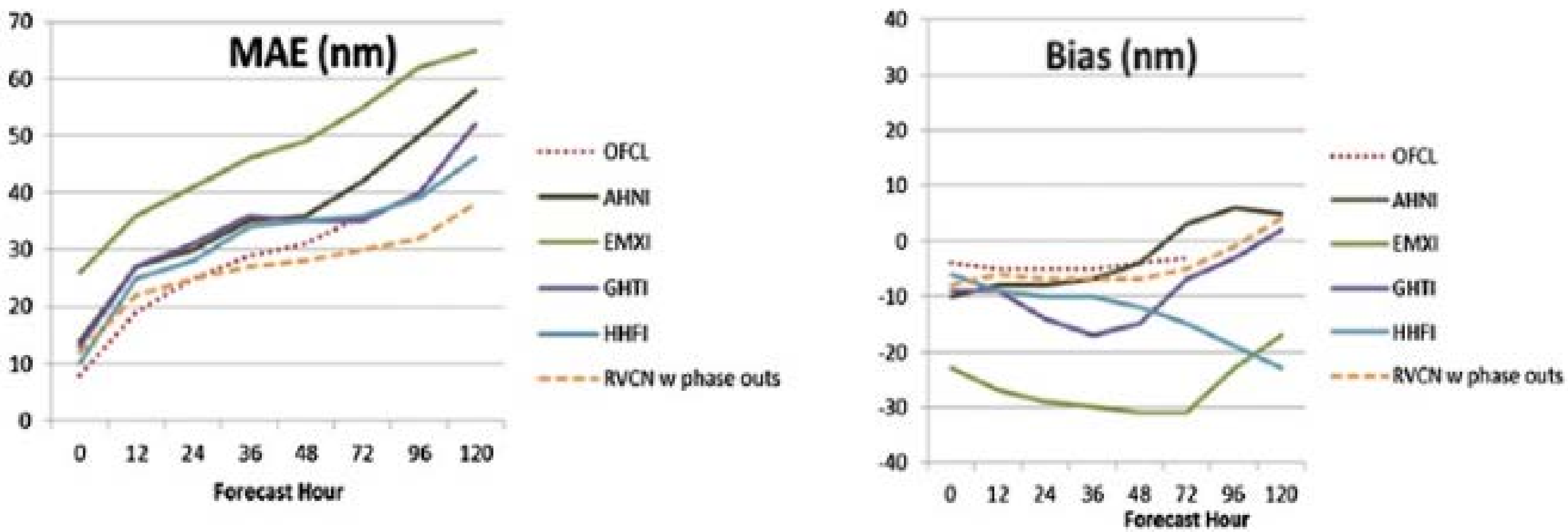

Fig 4 R34 verification for Atlantic 2012-14 from Sampson and Knaff 2015.

https://www.academia.edu/23044064/NCEP_NOTES_A_Consensus_Forecast_for_Tropical_Cyclone_Gale_Wind_Radii

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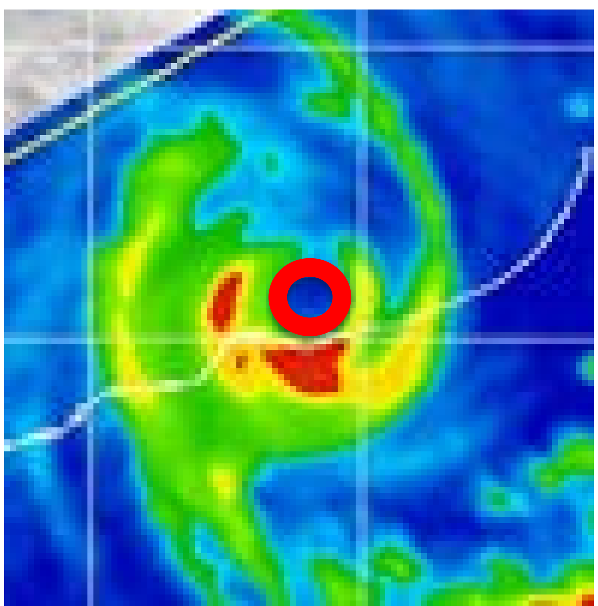
RMW variations
Inner-core dynamics

RMW: 'contraction' 35-65kn intensity

Variations for stronger systems related to eyewall changes

Not related to gale radius

Microwave imagery for RMW



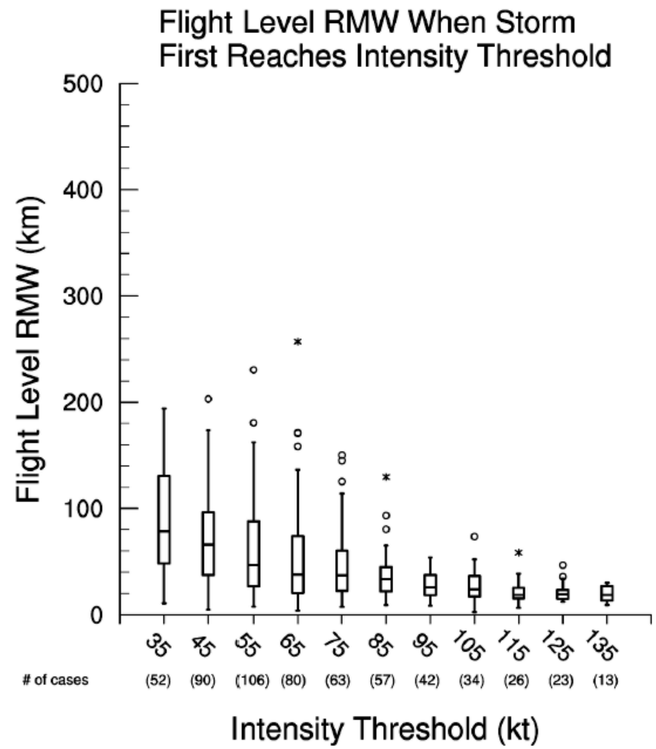


Figure 14. Box-and-whisker plot showing the observed flight level RMW at the time when each storm *first* ach
given intensity threshold. This plot was constructing by binning the RMW values only at the time point wh
interpolated Best-Track intensity of the storm first reaches the given threshold.
The 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 ≥ 35 kt and > 45 kt, etc.

IWTCVIII Topic 4.3 STRUCTURE CHANGE FORECASTING

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/T4_ChairSummary_NKitabatake.pdf

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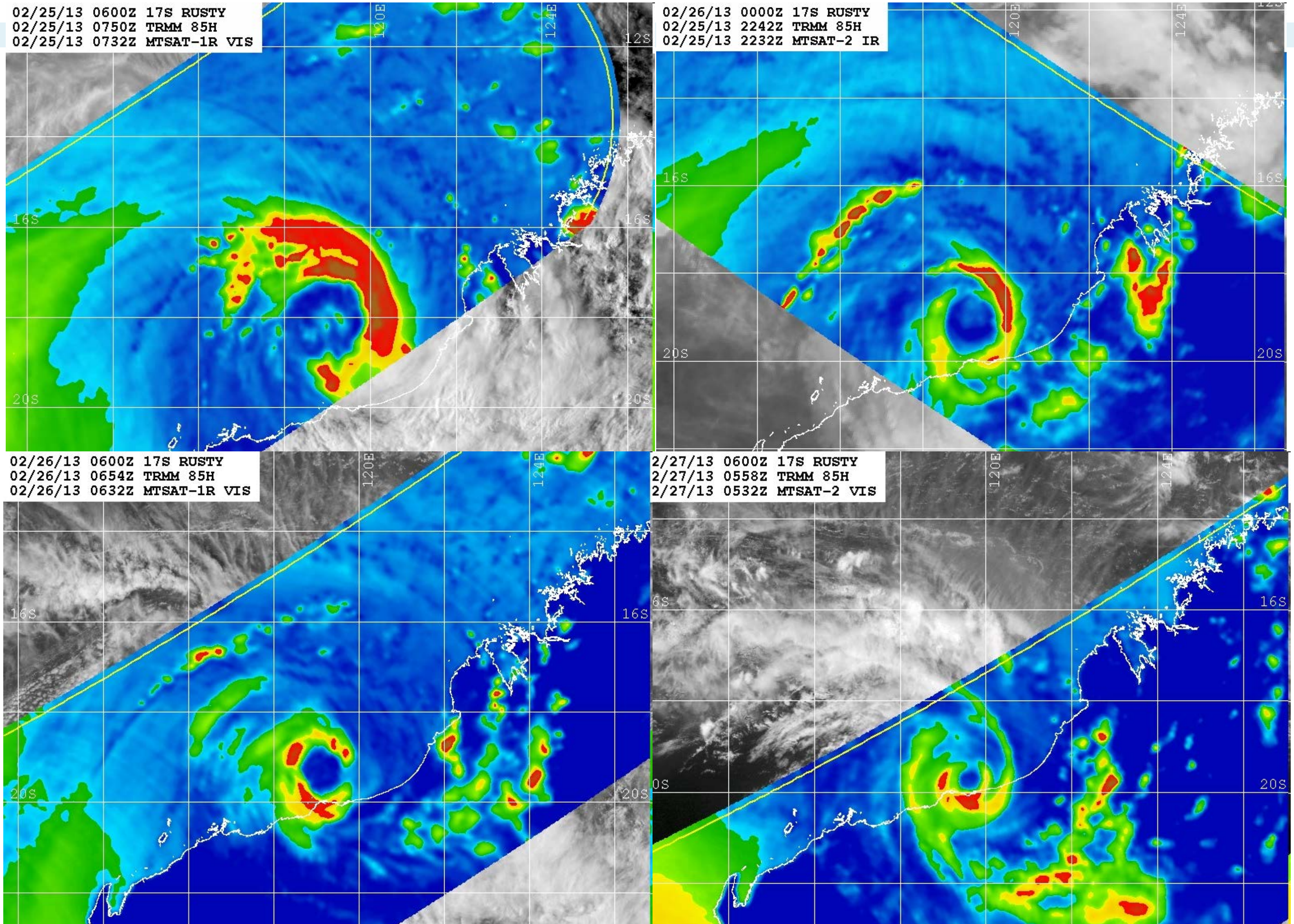
TC Rusty eye contraction TMI



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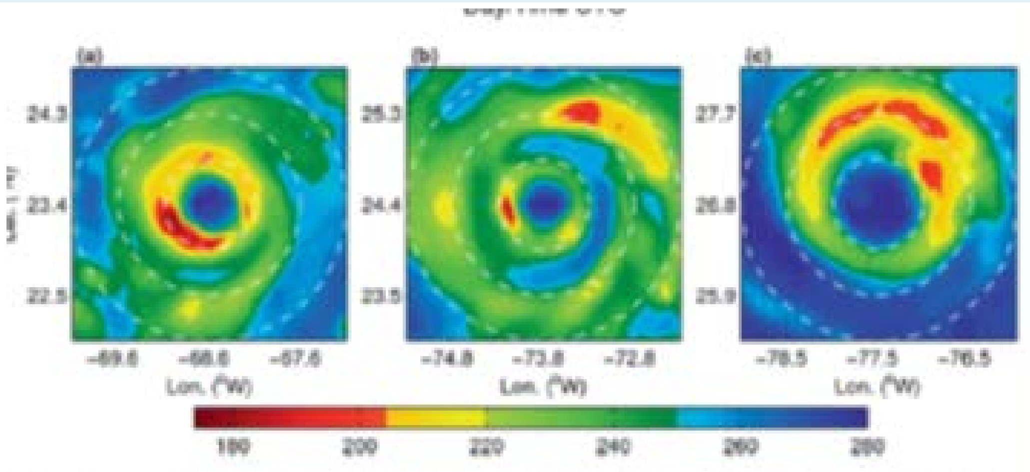
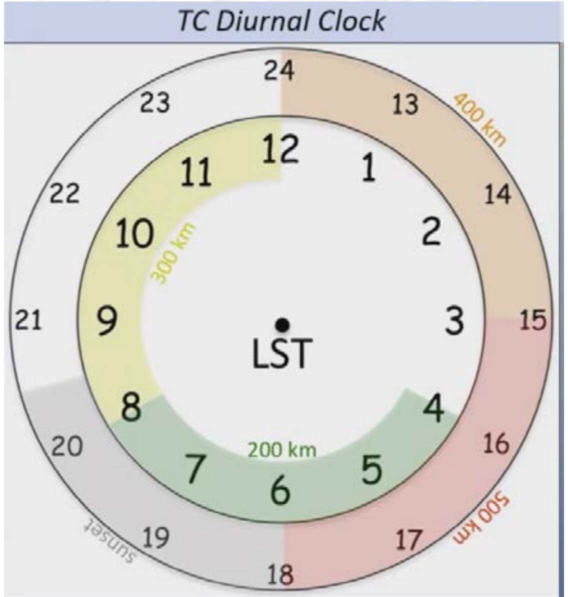
Structure changes: Other

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!