Australian Government
Bureau of Meteorology

Detecting and forecasting TC Rapid Intensification

VLAB 2 October 2018, Joe Courtney BoM

Quiz at: b.socrative.com/

choose student login then room VLAB

Environment
(upper outflow, shear, SST, RH, low-level inflow)

Developed(ing) low-level circulation

Convection
(IR/Vis; microwave 37/85-91GHz)

Obs, scat, lightning

Rapid Intensification ?

NWP
(wind/vorticity)

RI index
(statistical-dynamic SHIPS)

Global forecast problem

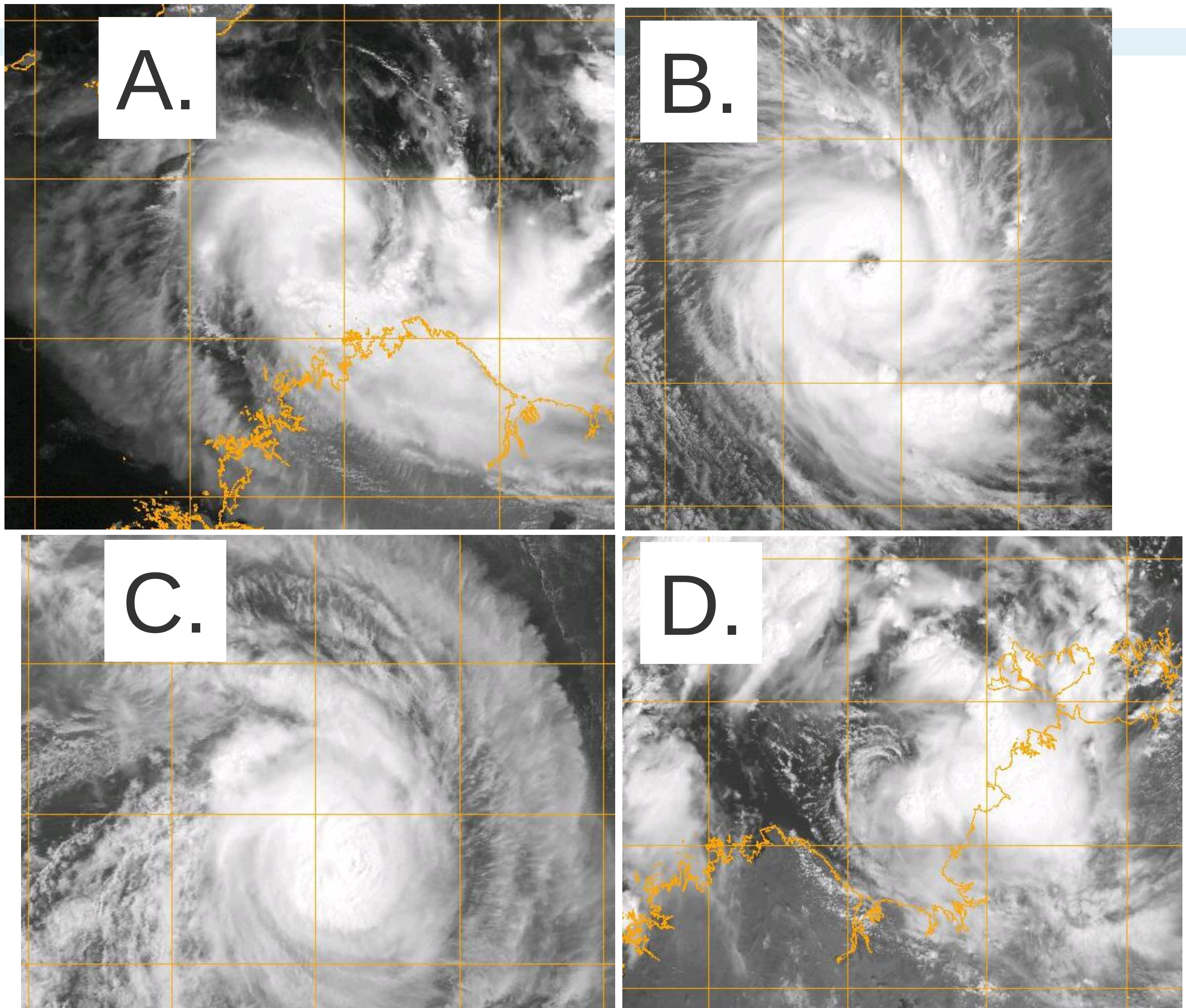
Most Severe TCs undergo RI

30kn/day or T1.5+/day

Difficult cases

Credit: NRL for microwave images

Quiz: Which one below is MOST likely to be undergoing RI?



Australian Government
Bureau of Meteorology

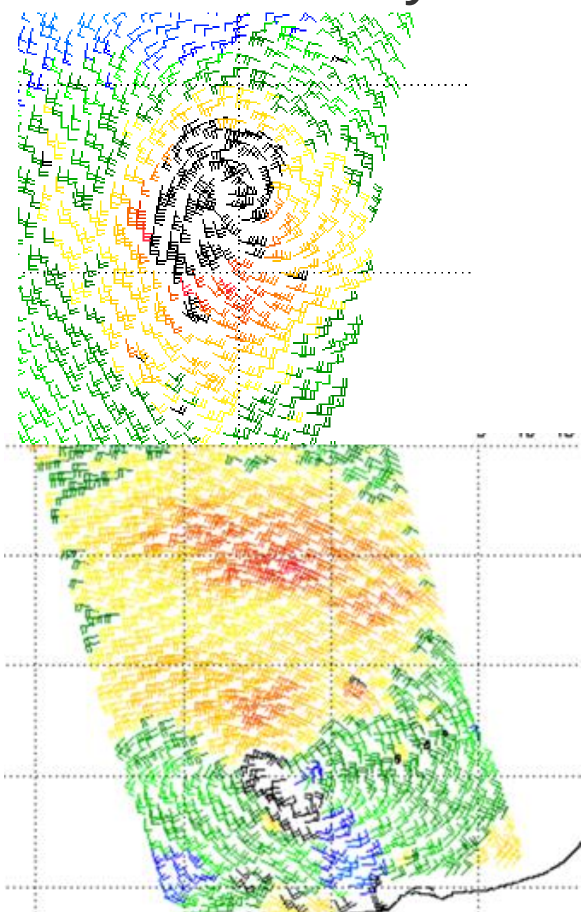
Detecting RI:

"RI is possible when there is
a developed low level circulation AND
successive bursts of deep convection near the centre
in a favourable environment"

Australian Government
Bureau of Meteorology

Detecting RI:
… developed low level circulation …

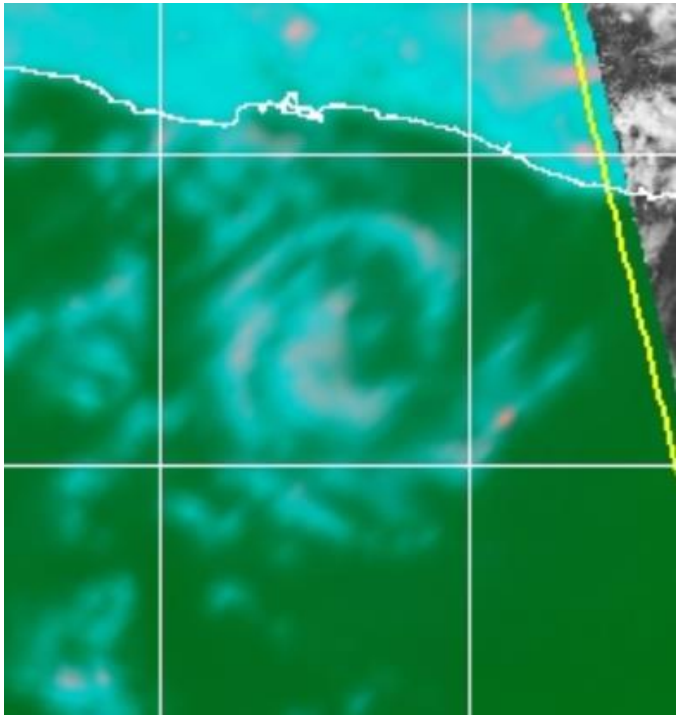
Scatterometry



Top: Ernie 26U 02Z 6 April 2017
Bottom: 22U; 13Z 22 March 2017

Vis/IR/microwave esp 37GHz

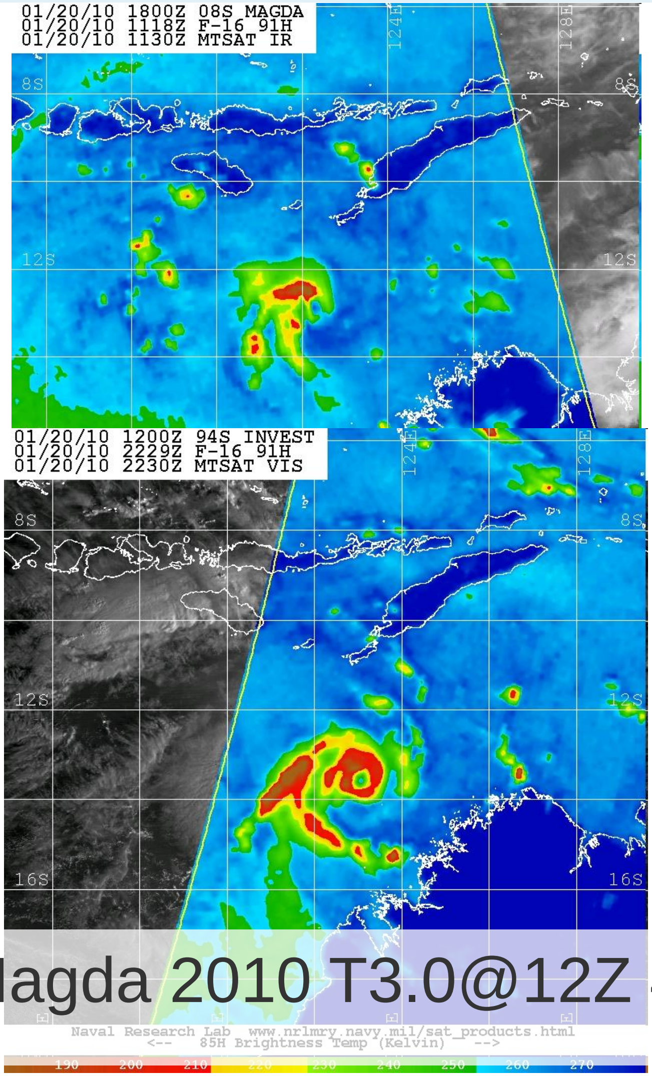
(Cempaka 0530 UTC 26/11/17)

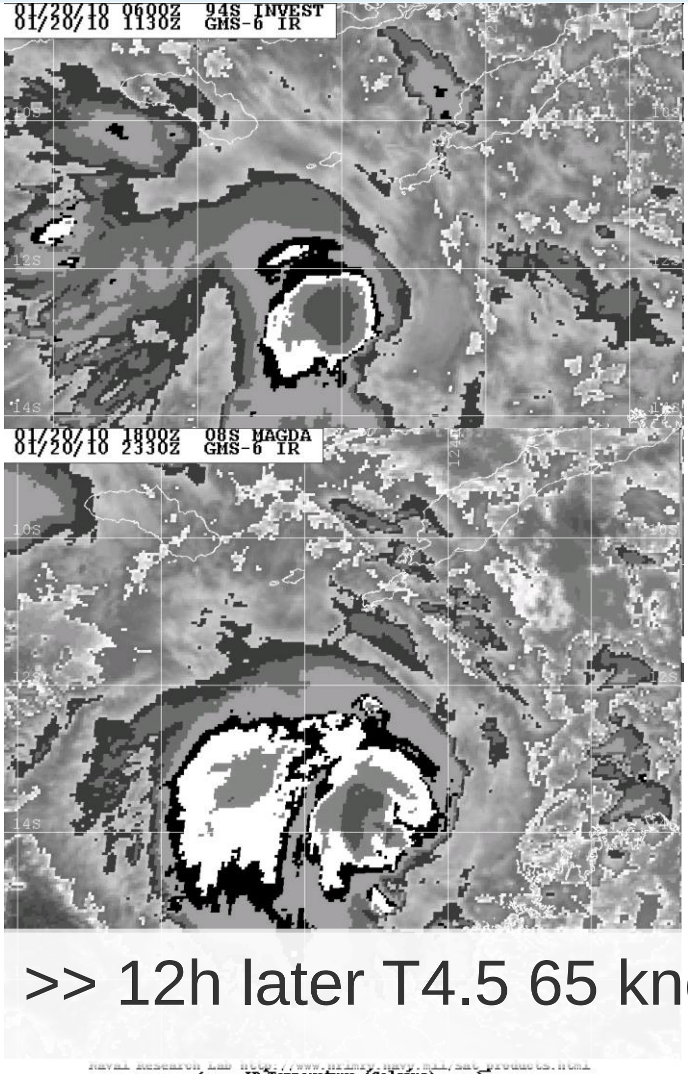


Otherwise use NWP wind fields

Australian Government
Bureau of Meteorology

Detecting RI:
…successive bursts of deep convection near the centre…
microwave and IR/Vis





Magda 2010 T3.0@12Z 45 knots >> 12h later T4.5 65 knots

Australian Government
Bureau of Meteorology

…in a favourable environment…

Review: What intensifies TCs?

A. Increased low level inflow

B. Increased upper-level outflow

C. Decreased wind shear

D. Moistening of low-mid levels -heavy precipitation

E. Warm Sea Surface Temperature

QUIZ: Which of these is MOST important for RI?

Australian Government
Bureau of Meteorology

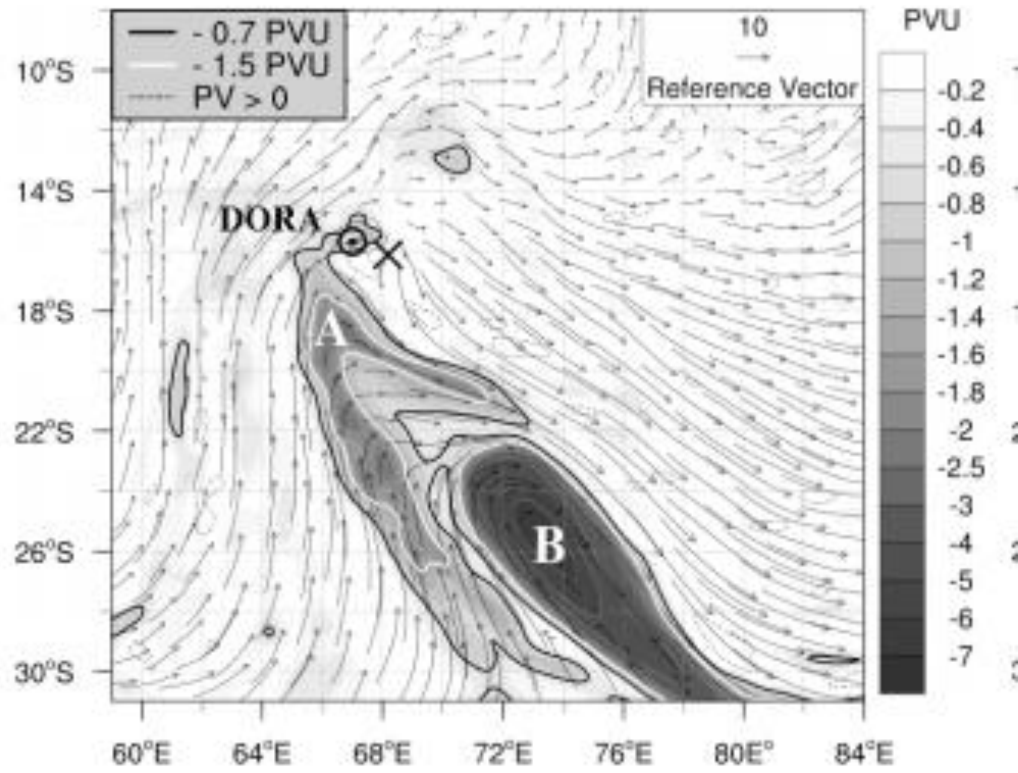
RI: upper level forcing is critical

e.g. Upper trough interactions: increase in divergence;

Amplifying mid-lat trough >>Downstream energy dispersion

Warm Air Advection

+ Shear for low latitudes



TC Dora (Southern Hemisphere)
200hPa Winds, PV shaded, x position

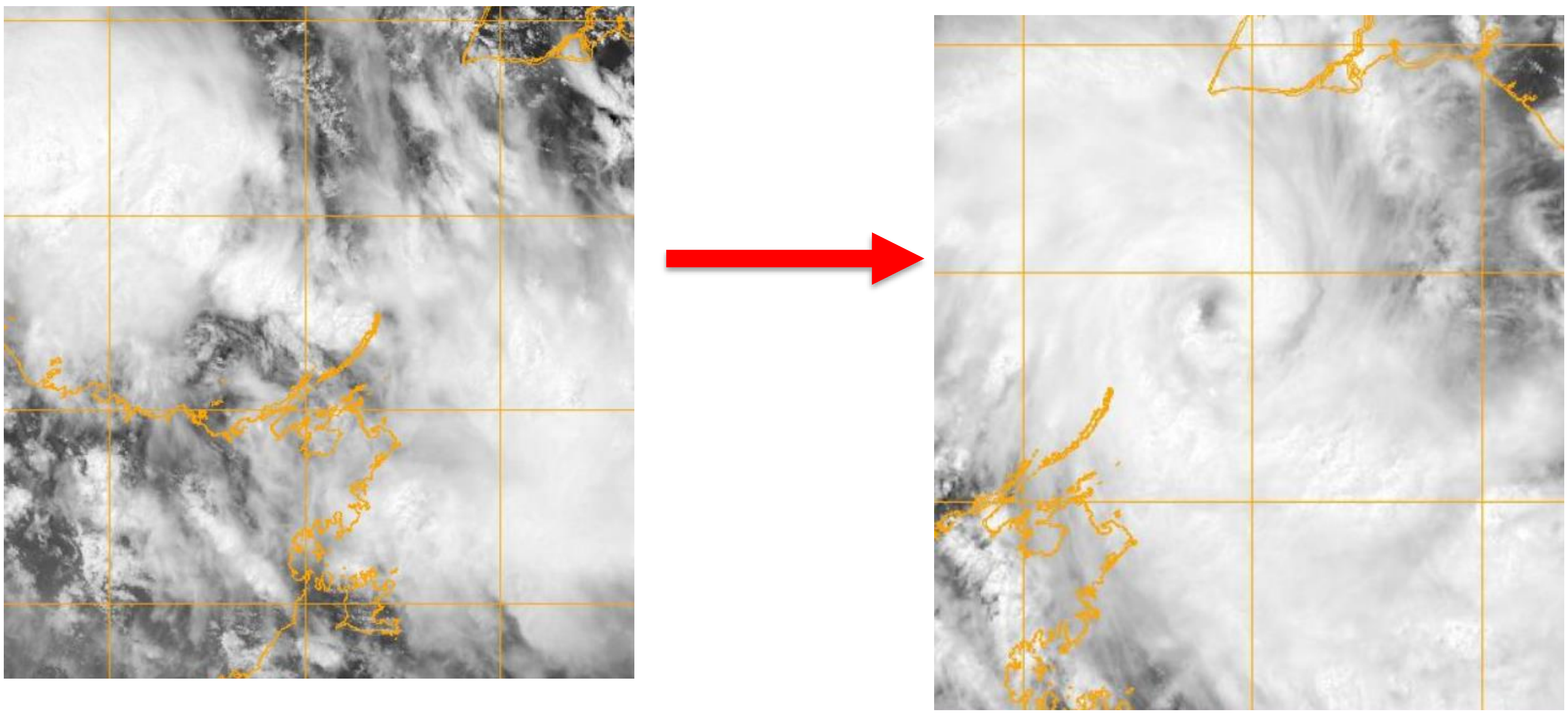
Leroux, IWTC VIII 2014

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/T2.5_IntensityChangeExternalInfluences_MDLeroux_7dec2014.pdf

Australian Government
Bureau of Meteorology

Detecting: Convection changes
Apply Dvorak MET thinking to look for D+ trend
Traditional thinking still applies!

increase near centre; colder cloud tops; increase in banding; appearance and changes in eye



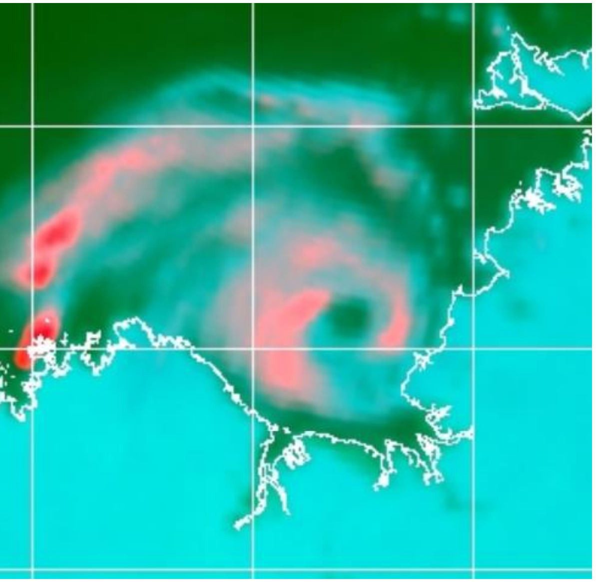
D+ 24h change on Vis Nora 04Z 22 to 23 March 2018

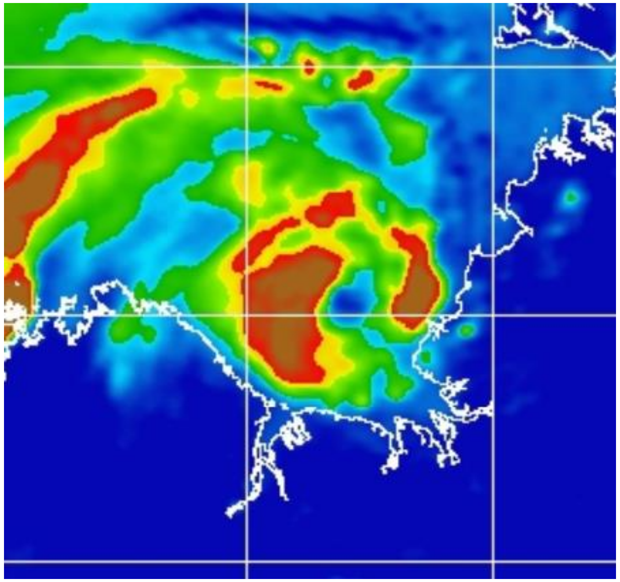
Australian Government
Bureau of Meteorology

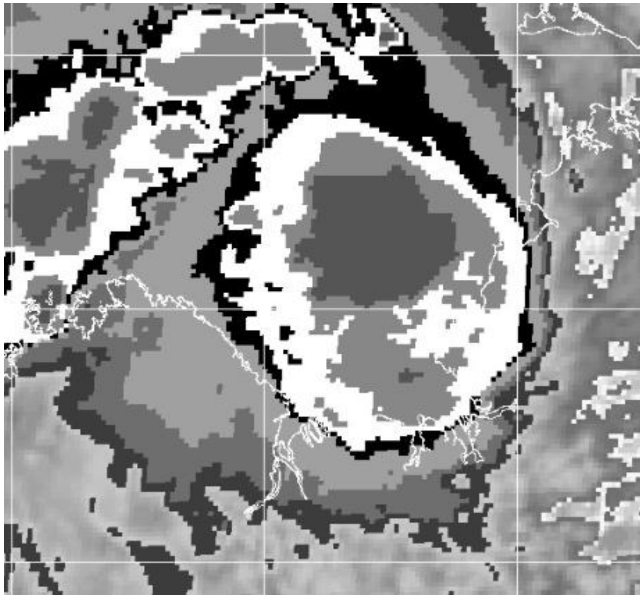
Detecting RI: evident microwave before IR/Vis Increased convection/banding; appearance of eye low level (37GHz) 'cyan ring' and convection (85-91GHz)

Recognising microwave patterns (often ‘blob’ stage in IR/Vis)

Low level organisation (37GHz vorticity) plus convection (85GHz)







AMSRE Marcus 16Z 17 March 2018

Kieper, M., and H. Jiang, 2012: Predicting tropical cyclone rapid intensification using the 37 GHz ring pattern identified from passive microwave measurements. Geophys. Res. Lett.,39, L13804,doi:10.1029/2012GL052115.

Australian Government
Bureau of Meteorology

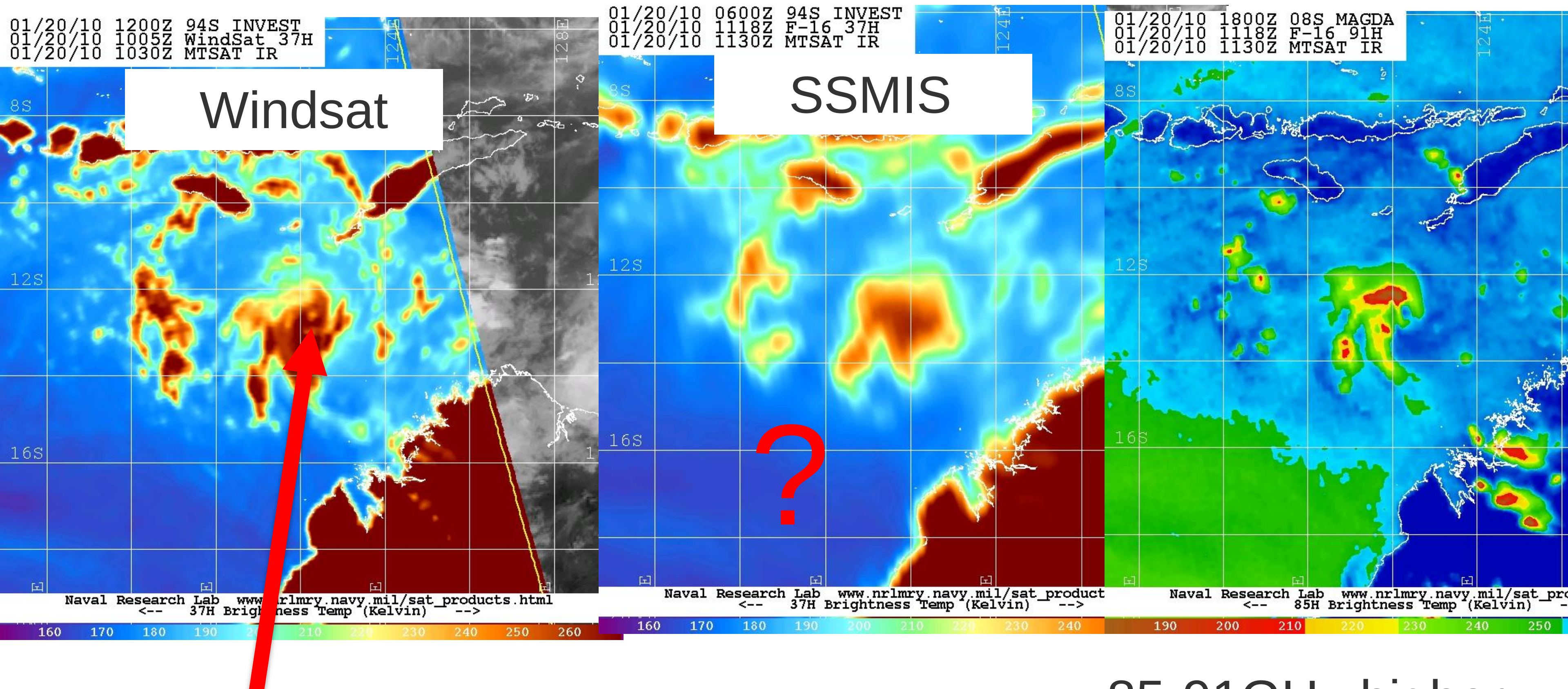
Difficult cases:
1. Small TCs R34 <60nm

- Spin (up and down) faster > more likely to undergo RI
  'vulnerable' to subtle environmental changes
- Analysis: Dvorak underestimates (vis)?; AMSU resolution limitation; use microwave pattern (not objective!)
- NWP underperformance inc. genesis
- RI starts earlier (30-45 kn) than for larger TCs (50+ kn)
- more likely to intensify overnight (diurnal cloud-top cooling)
- More common in Aust/Indonesian basin than elsewhere (esp NWPac and Atlantic)

Strategies: early detection; use microwave; high res NWP; part of uncertainty consideration.

Australian Government
Bureau of Meteorology

Note: Resolution quality 37GHz: Windsat is best



85-91GHz higher res than 37GHz

Magda Jan 2010

Australian Government
Bureau of Meteorology

Quiz. A TC was analysed at 40kn before. Which of these would indicate rapid intensification??

A. An eye appears on microwave.

B. Can see the centre on radar.

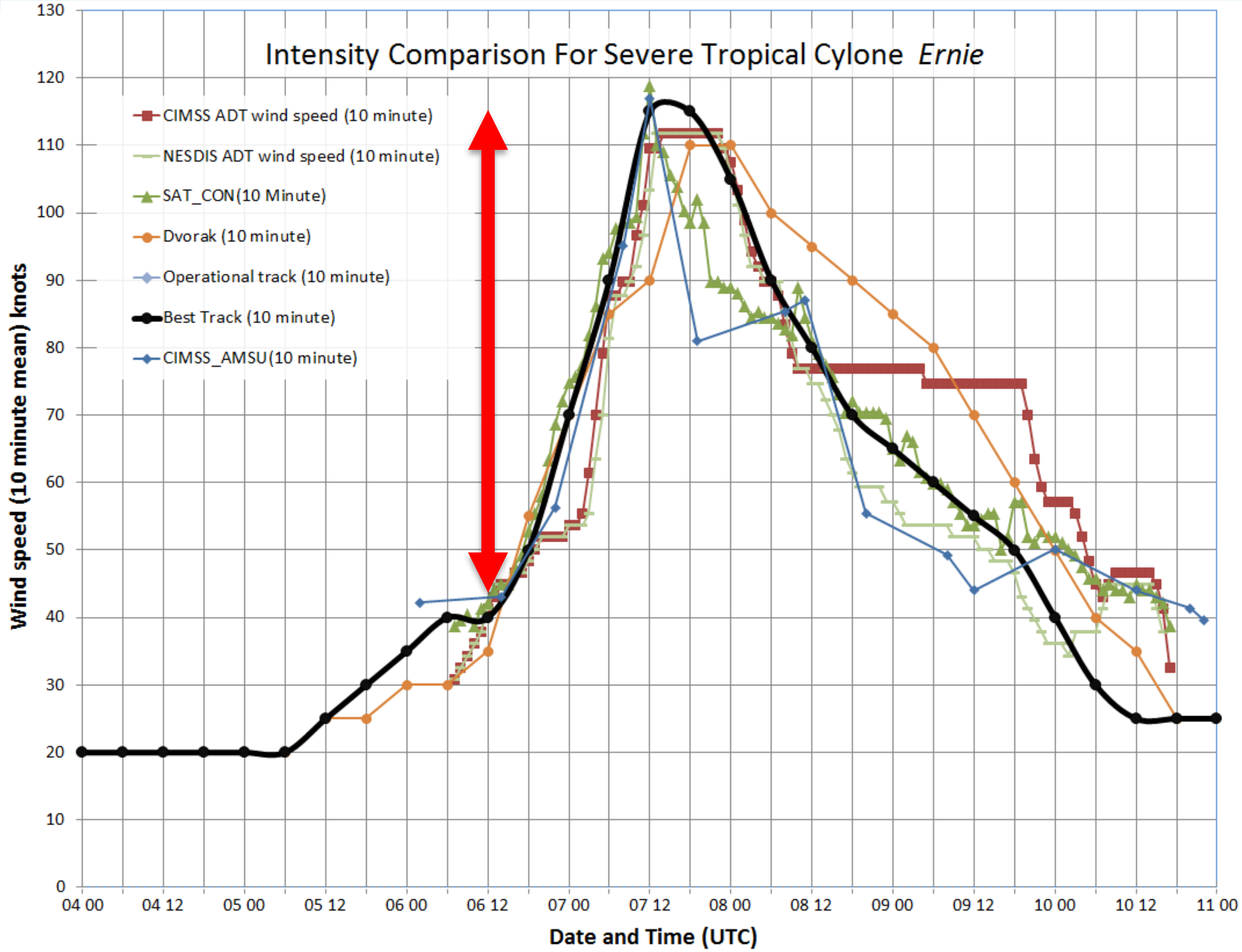
C. Scatterometry shows 45kn winds.

D. Can use curved band pattern on Dvorak.

E. All of the above.

Australian Government
Bureau of Meteorology

Difficult cases:
2. RI in moderate shear
TC *Ernie* 6-7 April 2017



40-115kn and DT 2.5 to 7.0 in 24 hours!

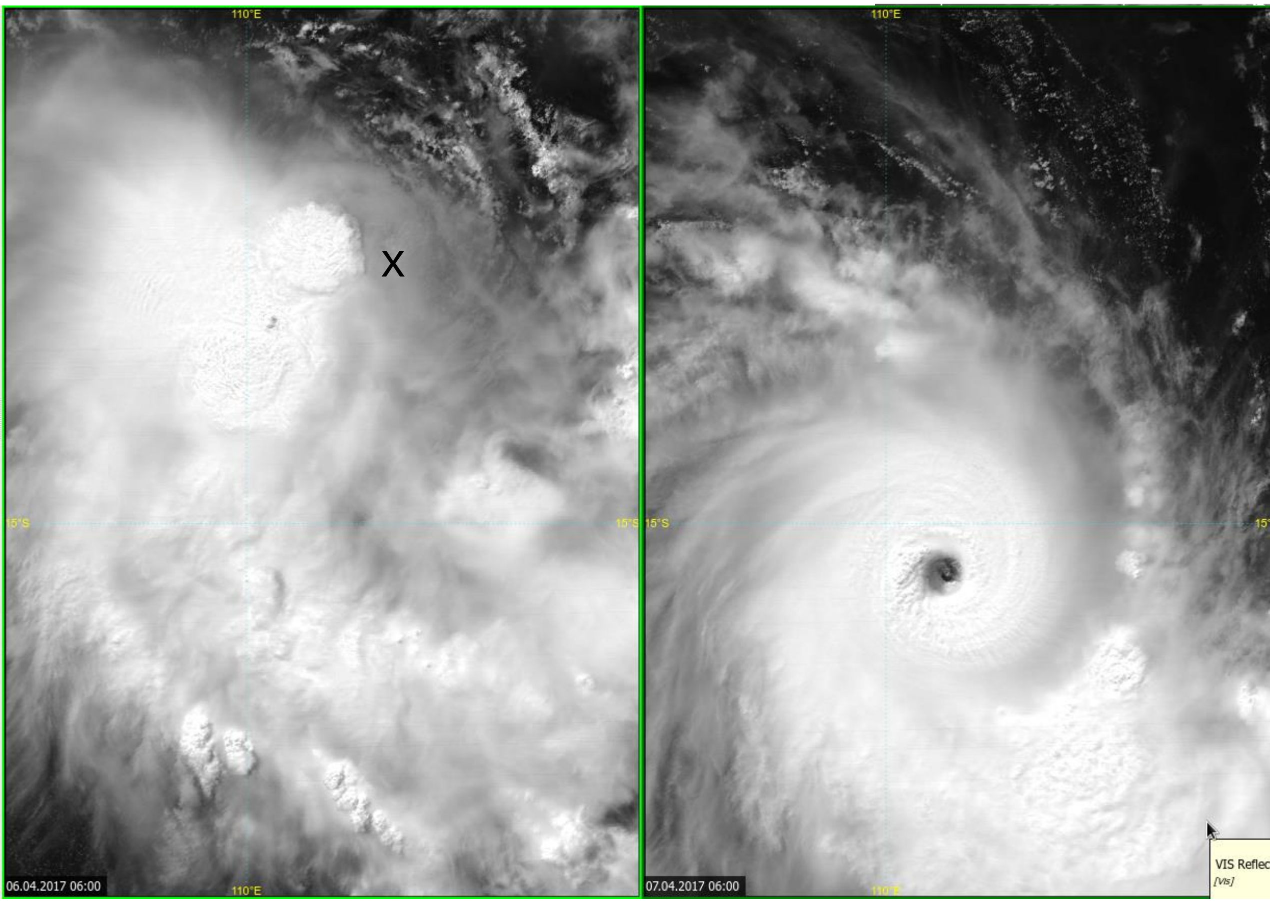
Australian Government
Bureau of Meteorology

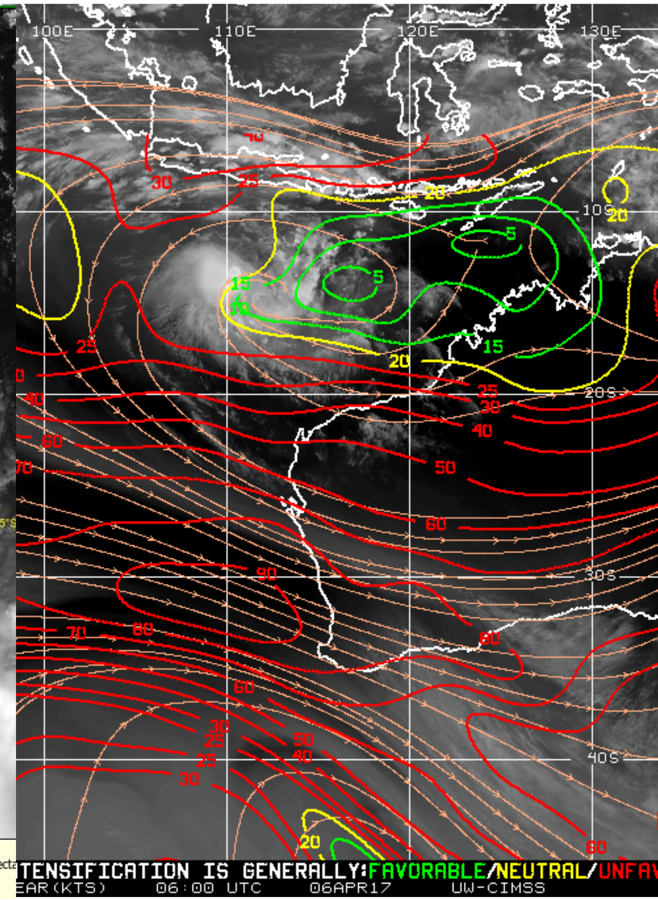
RI in moderate shear:

6 April moderate easterly shear

Vis at 06Z 6-7 April

CIMSS: ~15kn NE wind shear at 06Z





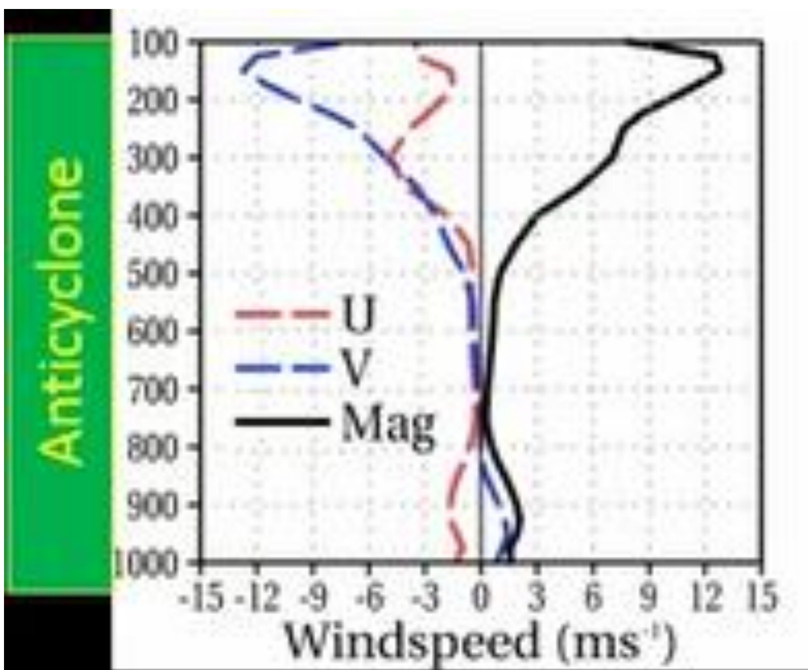
http://tropic.ssec.wisc.edu/archive/data/Australia/20170406/DeepShearLargeWest/20170406.06.Australia.DeepShearLargeWest.png

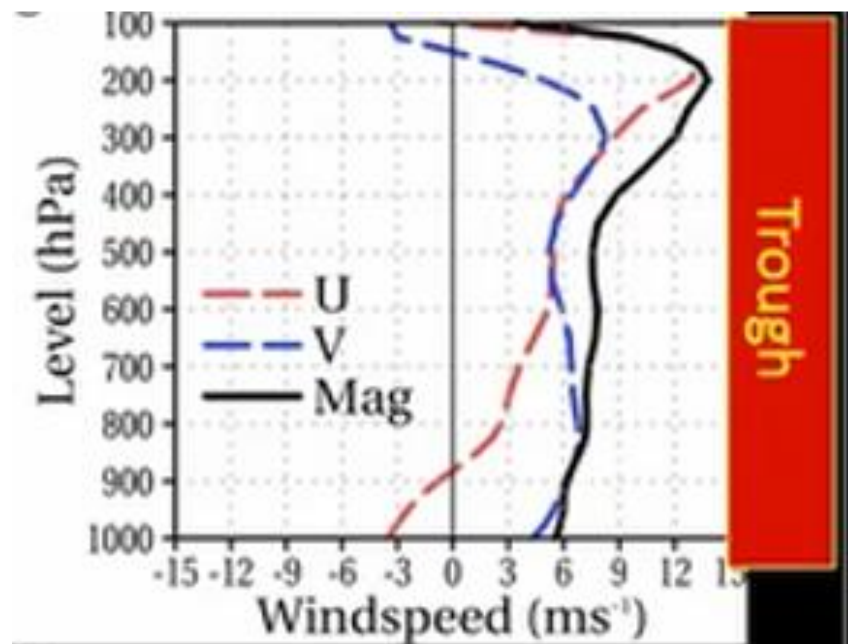
Australian Government
Bureau of Meteorology

Atypical RI in moderate shear
Recent research: the shear profile

Upper ridge nearby typically means higher winds confined to very high levels so low to midlevel shear is actually low – less tilt and easier to overcome.

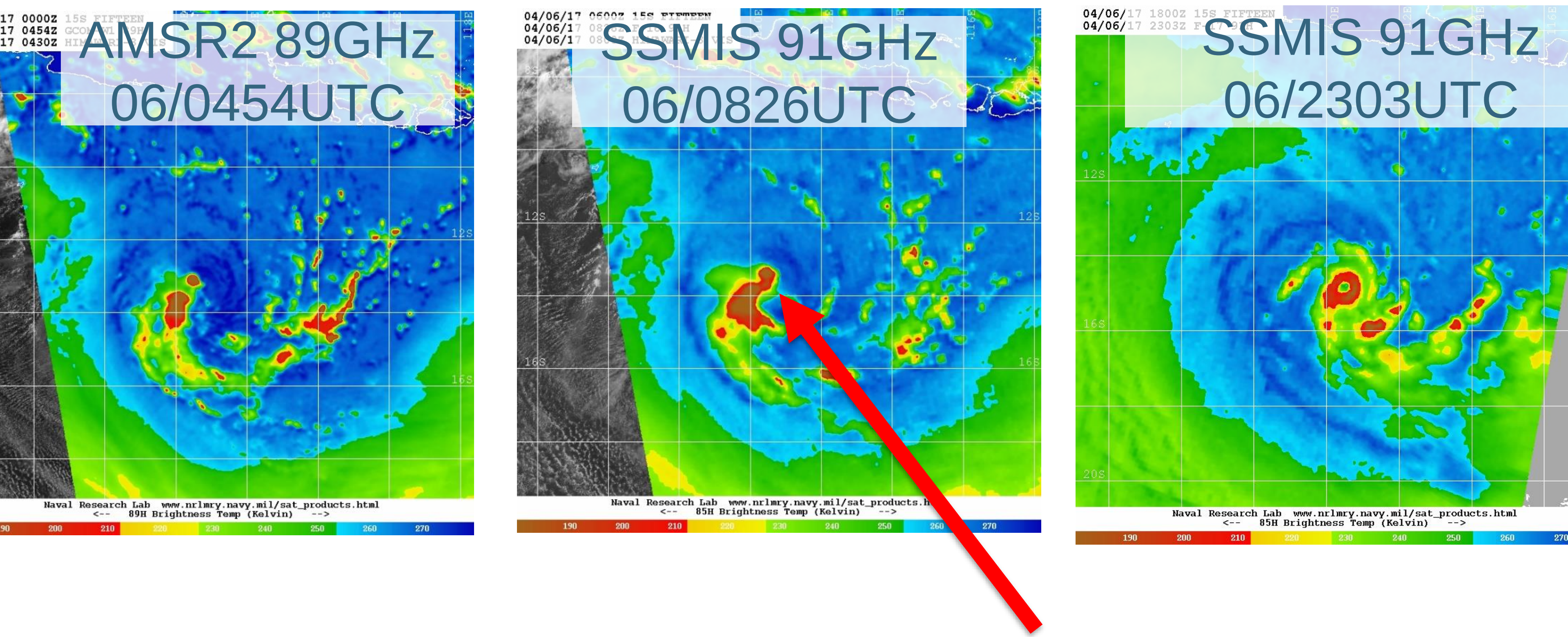
Shear from a trough is deeper and not associated with RI





Australian Government
Bureau of Meteorology

TC Ernie 6-7 April 2017
Microwave showing rapid development



Convective burst pushing upshear

Australian Government
Bureau of Meteorology

Atypical RI in moderate shear

Convective burst pushing upshear

e.g. northern side for easterly shear

can reduce the tilt of the upper circulation

create a 'protective shield' (convective outflow propagating upshear) for the circulation deflecting the environmental flow.

Episodic flareups

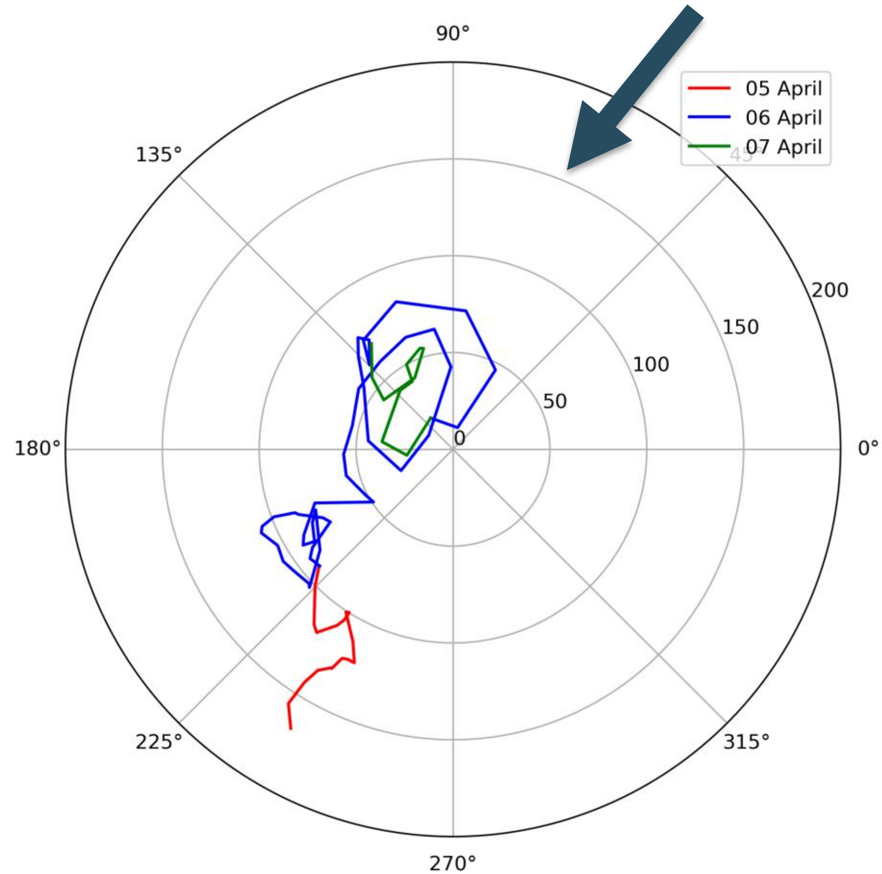
The Anatomy of a Convective Envelope in Sheared, Rapidly Intensifying Tropical Cyclones
James D. Doyle, NRL, Monterey, CA; and D. R. Ryglicki, J. H. Cossuth, D. Hodyss, Y. Jin, and K. C. Viner. https://ams.confex.com/ams/33HURRICANE/webprogram/Paper338731.html

Atypical RI in moderate shear: Ernie

Credit: Dave Ryglicki NRL

Australian Government
Bureau of Meteorology

- polar plot tracks the location of the coherent cloud structure (mid-level vortex)
- Starts red SW then moves upshear
- Precession of the tilt of the vortex (38h)



The Anatomy of a Convective Envelope in Sheared, Rapidly Intensifying Tropical Cyclones
James D. Doyle, NRL, Monterey, CA; and D. R. Ryglicki, J. H. Cossuth, D. Hodyss, Y. Jin, and K. C. Viner. https://ams.confex.com/ams/33HURRICANE/webprogram/Paper338731.html

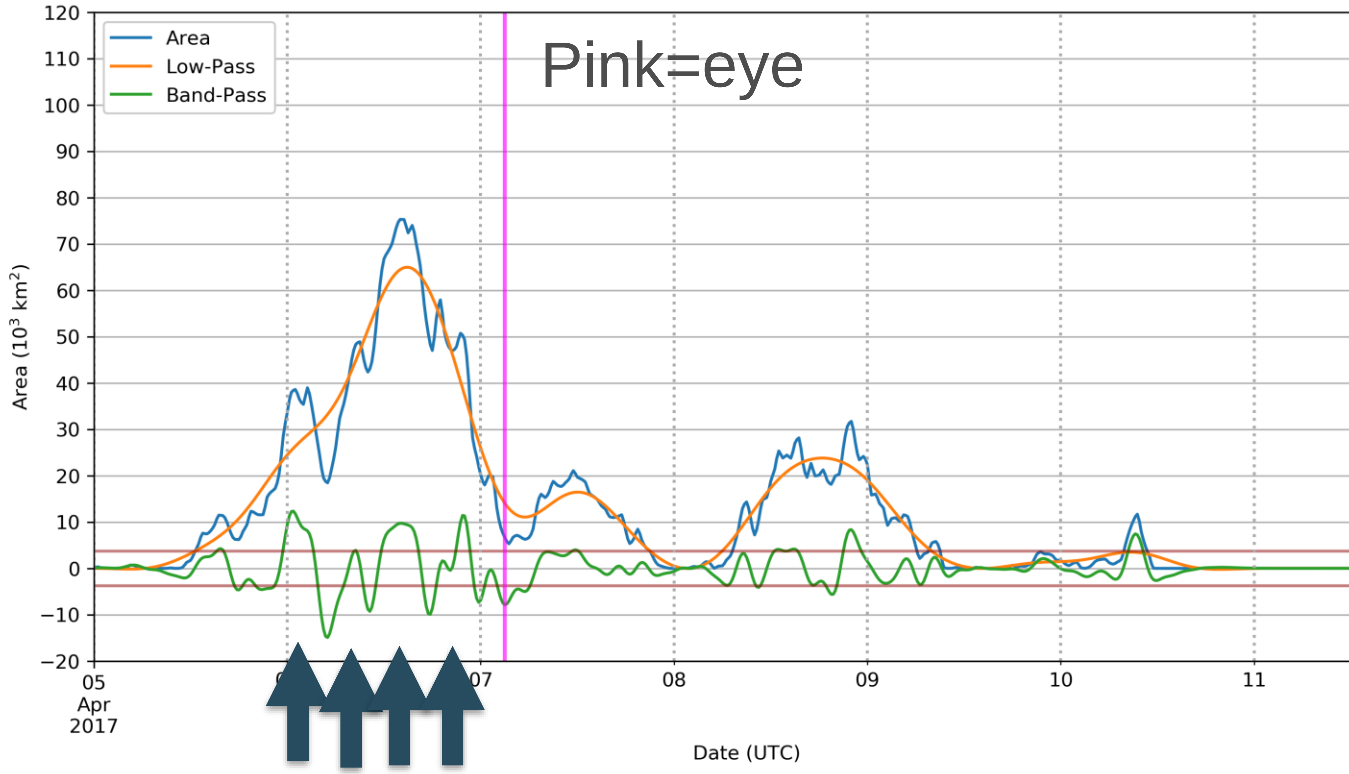
Atypical RI in moderate shear: Ernie

Credit: Dave Ryglicki NRL

Australian Government
Bureau of Meteorology

Cloud coverage within 250km (<-80C); filtered diurnal in green

4 convective bursts

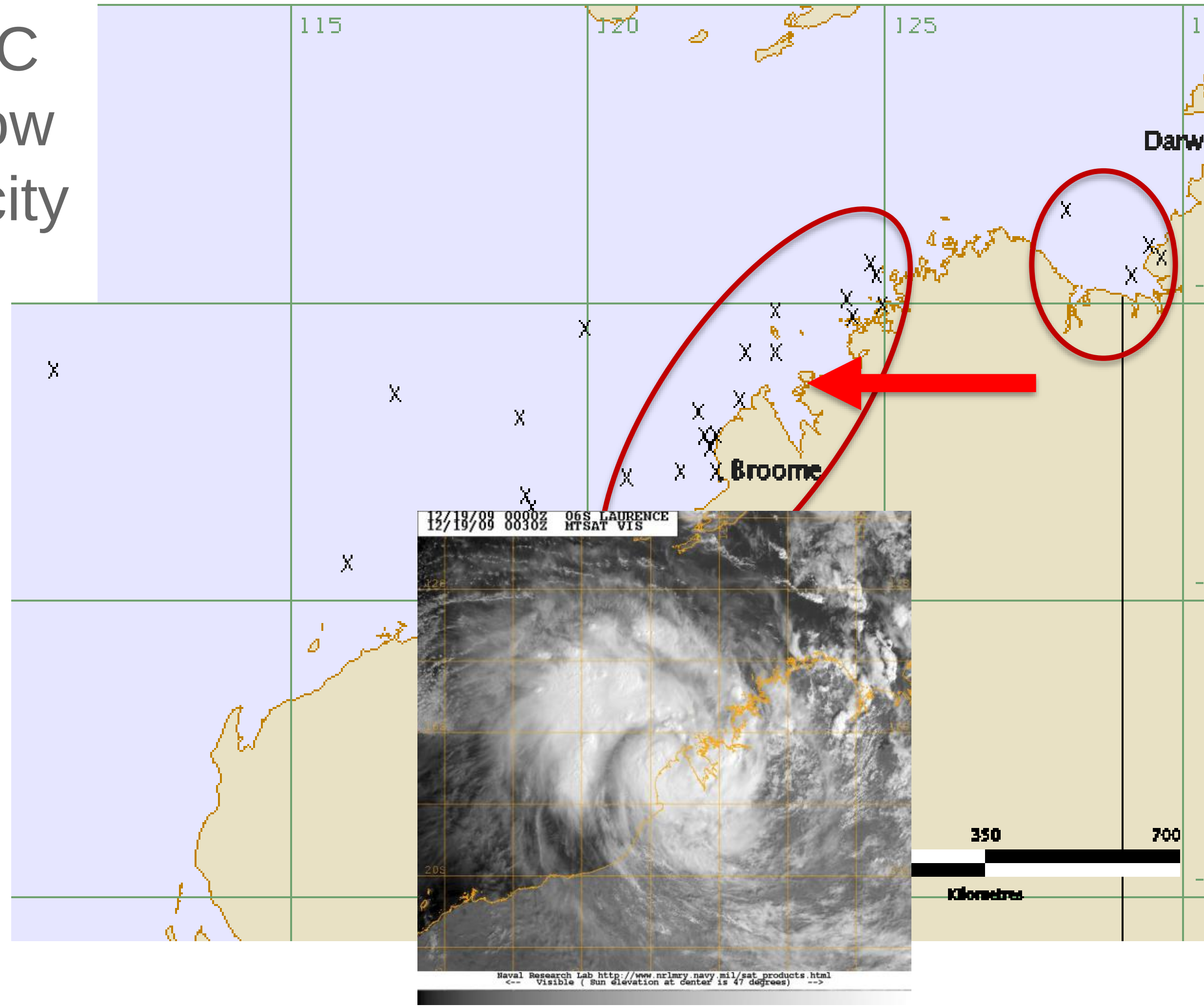


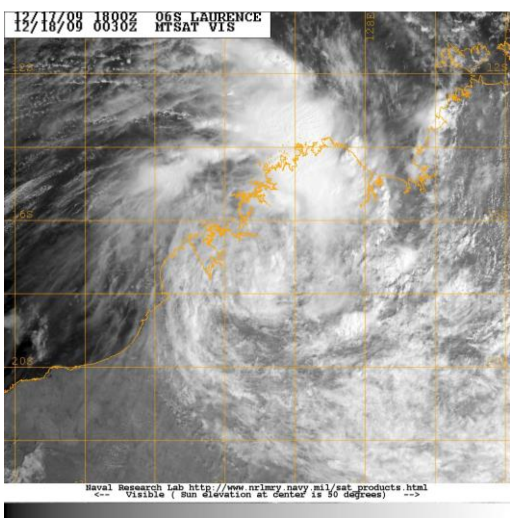
The Anatomy of a Convective Envelope in Sheared, Rapidly Intensifying Tropical Cyclones
James D. Doyle, NRL, Monterey, CA; and D. R. Ryglicki, J. H. Cossuth, D. Hodyss, Y. Jin, and K. C. Viner. https://ams.confex.com/ams/33HURRICANE/webprogram/Paper338731.html

Australian Government
Bureau of Meteorology

Difficult cases: 3. Moving offshore from coast (Broome to Darwin)

Positions when first a TC RI frequent if shear is low and enough initial vorticity



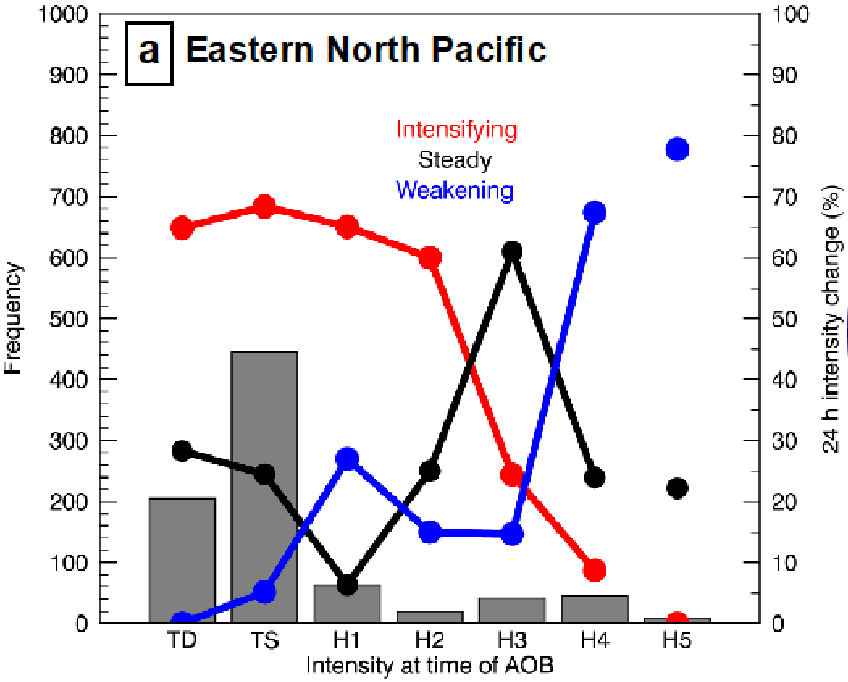


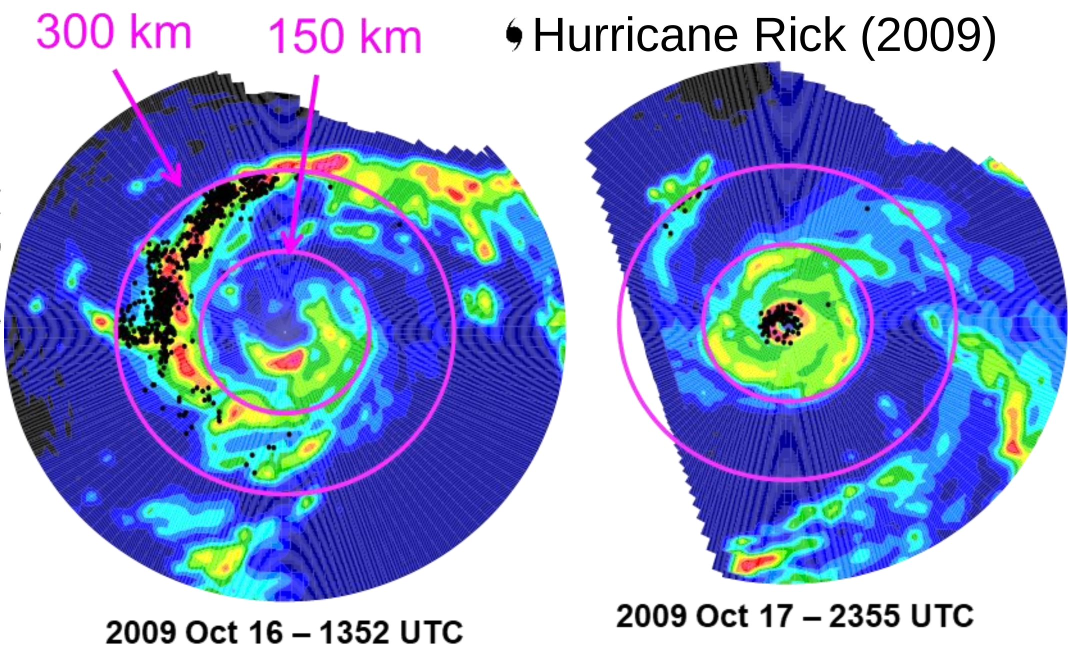
Australian Government
Bureau of Meteorology

Lightning and intensification: BEWARE - not straight forward! Inner core and outer band differences

electrification in <u>outer</u> bands leads to intensification for weaker TCs and is often a precursor to more symmetric convection

Stronger TCs more complex: Intensifying- bursts *<u>inside RMW</u>*





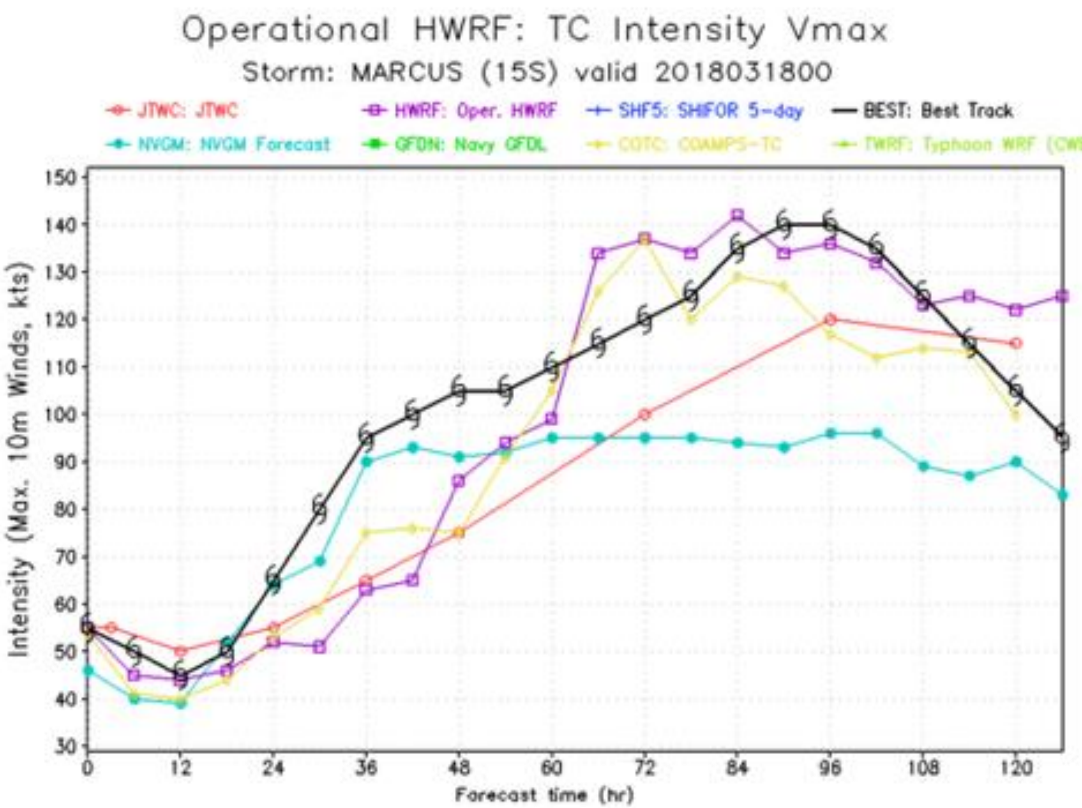
Credit: Stephanie Stevenson: Tropical Cyclone Intensity Change from a Lightning Perspective
https://ams.confex.com/ams/33HURRICANE/webprogram/Paper339151.html

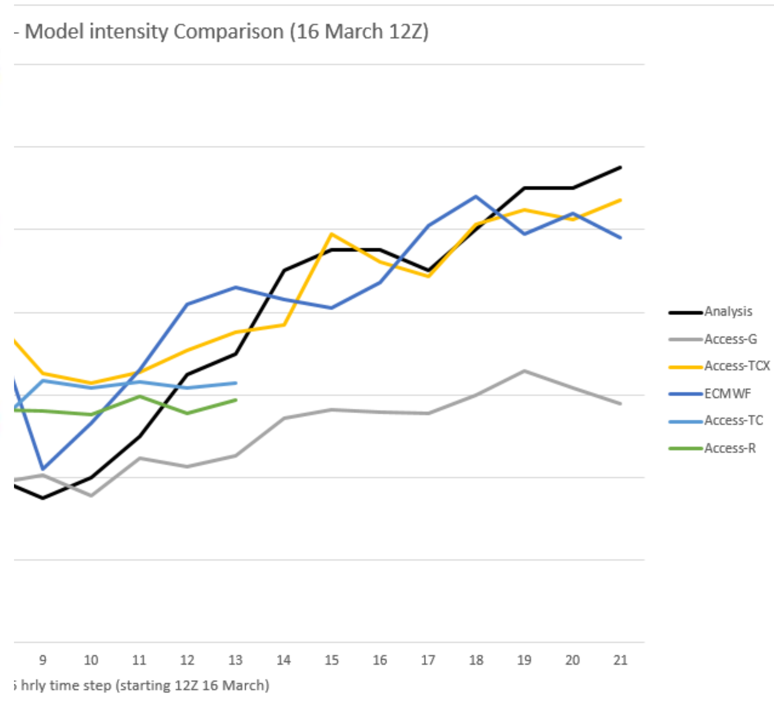
Australian Government
Bureau of Meteorology

NWP and RI: historically poor but now improving

NWP: some high resolution models are now picking RI

HWRF in particular (1.5km res at core)





Australian Government
Bureau of Meteorology

Intensity forecasting: SHIPS Rapid Intensification (RI) index

SHIPS: gives probability of a 30kn/24h intensity based upon predictors.

Predictors

Environment: Shear; OHC; RH; upper Div; Pot Intensity; T adv.(850-700hPa)

IR: predictors (5)

Vm: Vm; Vm 12h delta.

Calibration

~40% is a general threshold

>50% -RI is more definite!

Check consistency from run to run

Not that good for lows – better for 40+kn initial intensity

Source: J. Knaff, CIRA and B. Sampson, NRL

Australian Government
Bureau of Meteorology

Intensity forecasting: Rapid Intensification (RI) index

Rapid Intensification Guidance

SH152018 180319 00UTC
Storm Located at : -15.00 123.40
Guidance run with Vmax [kt]: 65.

Initial Conditions:

Predictor	Value	Favorable(F)/Unfavorable(U)
INTENSITY (VMAX) [kt]	65.00	N
12-H DELTA VMAX [kt]	20.00	F
CORE SIZE [km]	3.40	F
CONVECTION <-50C [%]	88.00	F
CONVECTION <-60C [%]	74.00	F
IR CORE SYMMETRY [K]	9.90	F
TC SIZE [%]	91.00	N

Forecast Conditions:

Predictor	Value 6	12	18	24	30	36	42	48	Favorable(F)/Unfavor(U) 6	12	18	24	30	36	42	48
Wind Shear [kt]	13.2	17.6	13.8	11.0	16.4	19.0	19.1	20.6	F	F	F	F	F	N	N	
Ocean Heat [kJ/cm^2]	75.0	74.0	76.0	85.0	89.0	82.0	79.0	74.0	N	N	N	N	F			
Potential [kt]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	N	N	N	N	N			
200mb Divg [10^6/s]	38.0	1.0	-18.0	-24.0	-3.0	-2.0	11.0	24.0	N	U	U	VU	U			
Humidity 700-500 hPa	48.0	43.0	46.0	45.0	43.0	43.0	44.0	44.0	U	VU	VU	VU				
T Advectio [10^6 K/s]	13.2	17.6	13.8	11.0	16.4	19.0	19.1	20.6	F	F	F	F	F	N		

Probabilities[%] of Rapid intensification

Thresholds	LDA-Method	LRE-Method	CONSENSUS
25kt / 24h	67.3%	76.2%	71.7%
30kt / 24h	67.3%	74.7%	71.0%
35kt / 24h	66.5%	74.7%	70.6%
40kt / 24h	51.2%	50.0%	50.6%
45kt / 36h	52.1%	59.3%	55.7%
55kt / 36h	52.1%	45.7%	48.9%
70kt / 48h	24.7%	14.7%	19.7%

Source: B. Sampson, NRL

Logistical-Regression Method BEST

Australian Government
Bureau of Meteorology

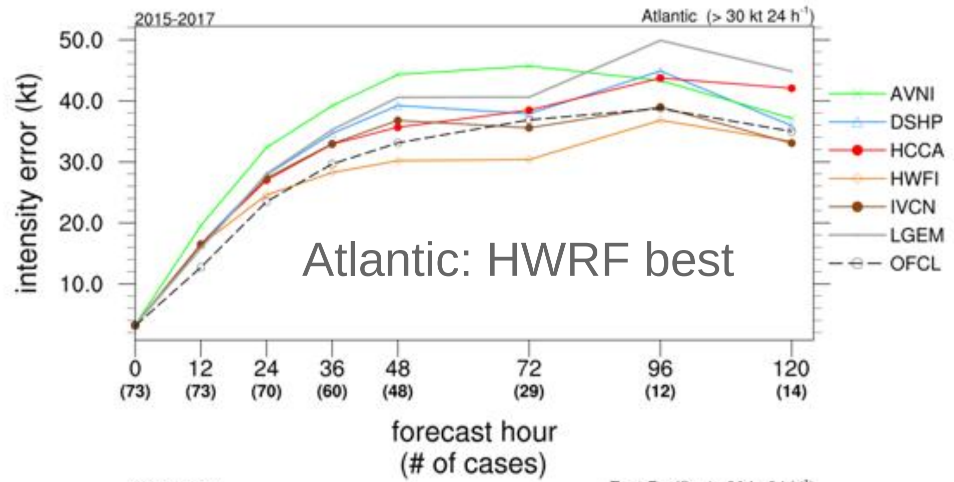
RI verification and future

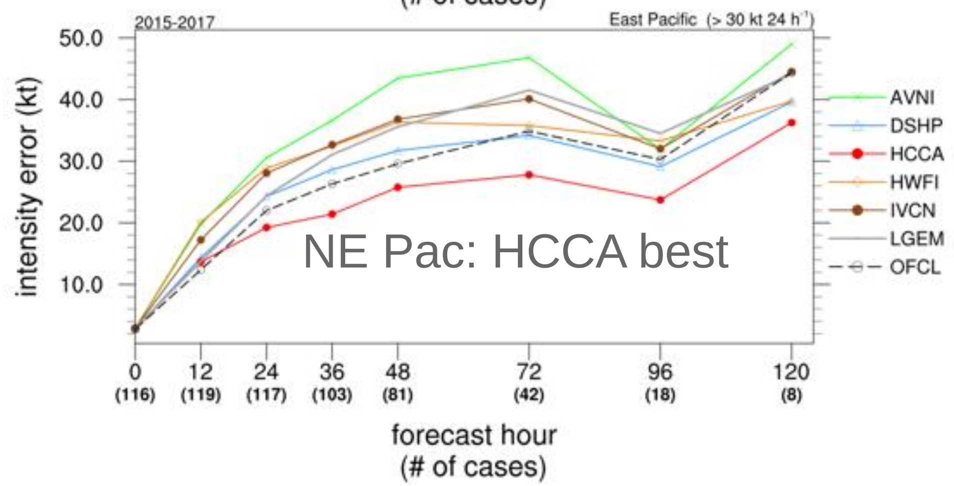
NHC verification: conflicting results in Atlantic and NE Pac for best guidance

NHC: DTOPS(Deterministic to Probabilistic Statistical Model)
Ondelinde&DeMaria 2018
https://ams.confex.com/ams/33HURRICANE/webprogram/Paper339346.html

Other agencies adapting RI index to local context

Important to document and share RI experiences inc. false alarms!





Source: IWTC IX Intensity change Dec 2018 (Courtney and Hendricks)

Resources on Intensity forecasting: 2018 AMS talks

Australian Government
Bureau of Meteorology

Intensity change talks
https://ams.confex.com/ams/33HURRICANE/webprogram/start.html#srch=words%7Cintensity%20change%7Cmethod%7Cand%7Cpge%7C8

Characteristics of Tropical Cyclone Rapid Intensification in Environments of Upper-Tropospheric Troughs
https://ams.confex.com/ams/33HURRICANE/webprogram/Paper339737.html

The Anatomy of a Convective Envelope in Sheared, Rapidly Intensifying Tropical Cyclones
https://ams.confex.com/ams/33HURRICANE/webprogram/Paper338731.html

Tropical Cyclone Intensity Change from a Lightning Perspective
https://ams.confex.com/ams/33HURRICANE/webprogram/Paper339151.html

Upper-Level Troughs, Jet Streaks, and TCs: An Objective Climatology and Features Associated with Rapid TC Intensity Change: Levi P. Cowan, Florida State Univ., Tallahassee, FL; and R. Hart
https://ams.confex.com/ams/33HURRICANE/webprogram/Paper339831.html

Assessing the Influence of Downdrafts and Surface Enthalpy Fluxes on the Intensity Change of Tropical Cyclones in Moderate Vertical Shear
https://ams.confex.com/ams/33HURRICANE/webprogram/Paper339528.html

Quantification of Shear-relative Precipitation Asymmetries of Tropical Cyclones in Different Intensity Change Stages and during the Evolution of Rapid Intensification Using 16 years of TRMM Data
https://ams.confex.com/ams/33HURRICANE/webprogram/Paper340061.html

An Operational Rapid Intensification Prediction Aid (RIPA) for the western North Pacific
https://ams.confex.com/ams/33HURRICANE/webprogram/Paper338736.html

Australian Government
Bureau of Meteorology

RI Summary

RI is possible when there is a developed low level circulation AND a successive bursts of deep convection near the centre in a favourable environment

Environment
(upper outflow, shear, SST, RH, low-level inflow)

Developed(ing) low-level circulation

Convection
(IR/Vis; microwave 37/85-91GHz)

Obs, scat, lightning

Rapid Intensification ?

NWP
(wind/vorticity)

All developing TCs – consider RI potential

RI index
(statistical-dynamic SHIPS)