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Intensity Forecasting

IWTC priority

Intensity forecasting still remains a huge forecasting challenge

References from IWTC IX 2018

https://www.wmo.int/pages/prog/arep/wwrp/tmr/IWTC9TopicReports.html

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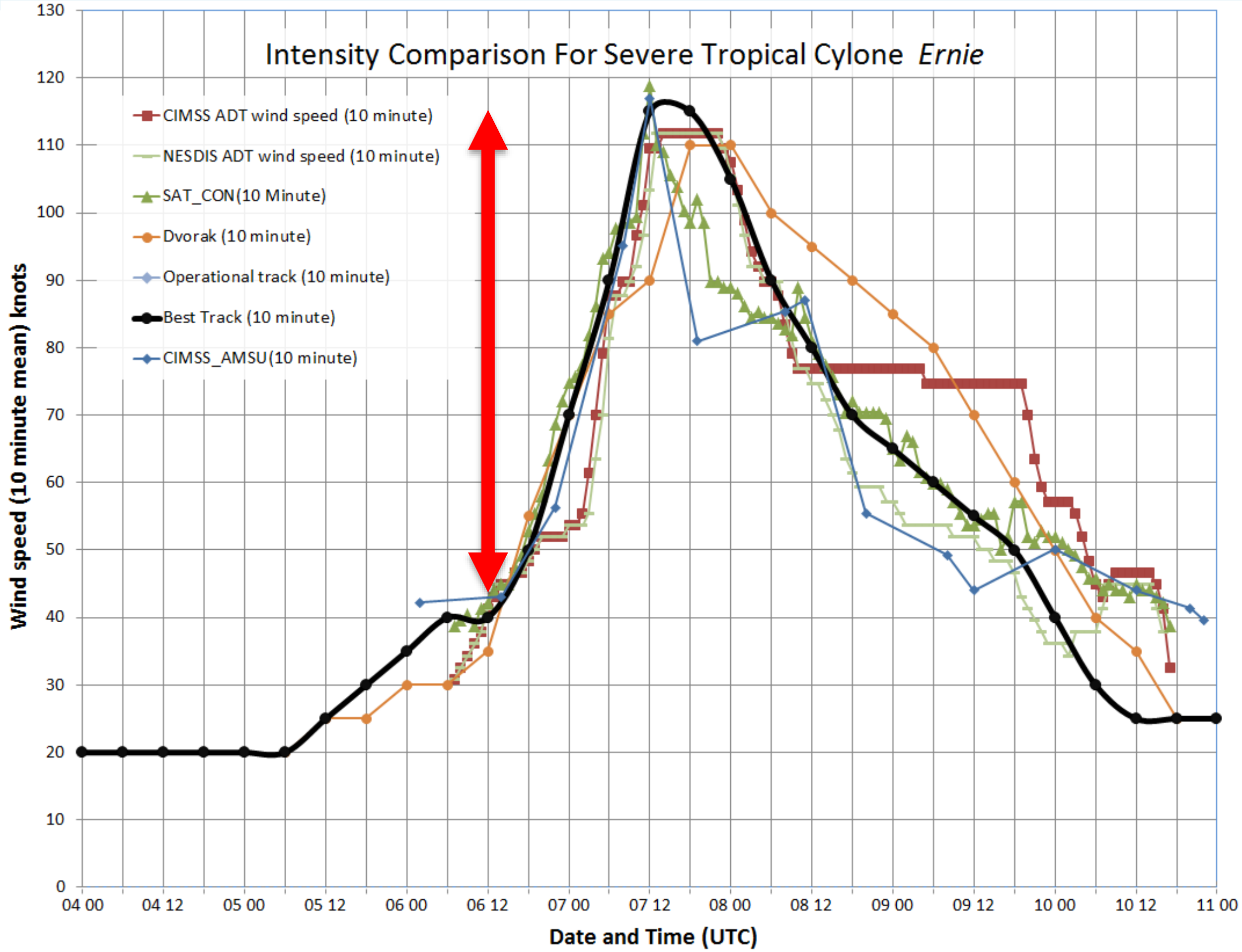
TCs can change intensity rapidly
TC Ernie 2017 Rapid Intensification



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

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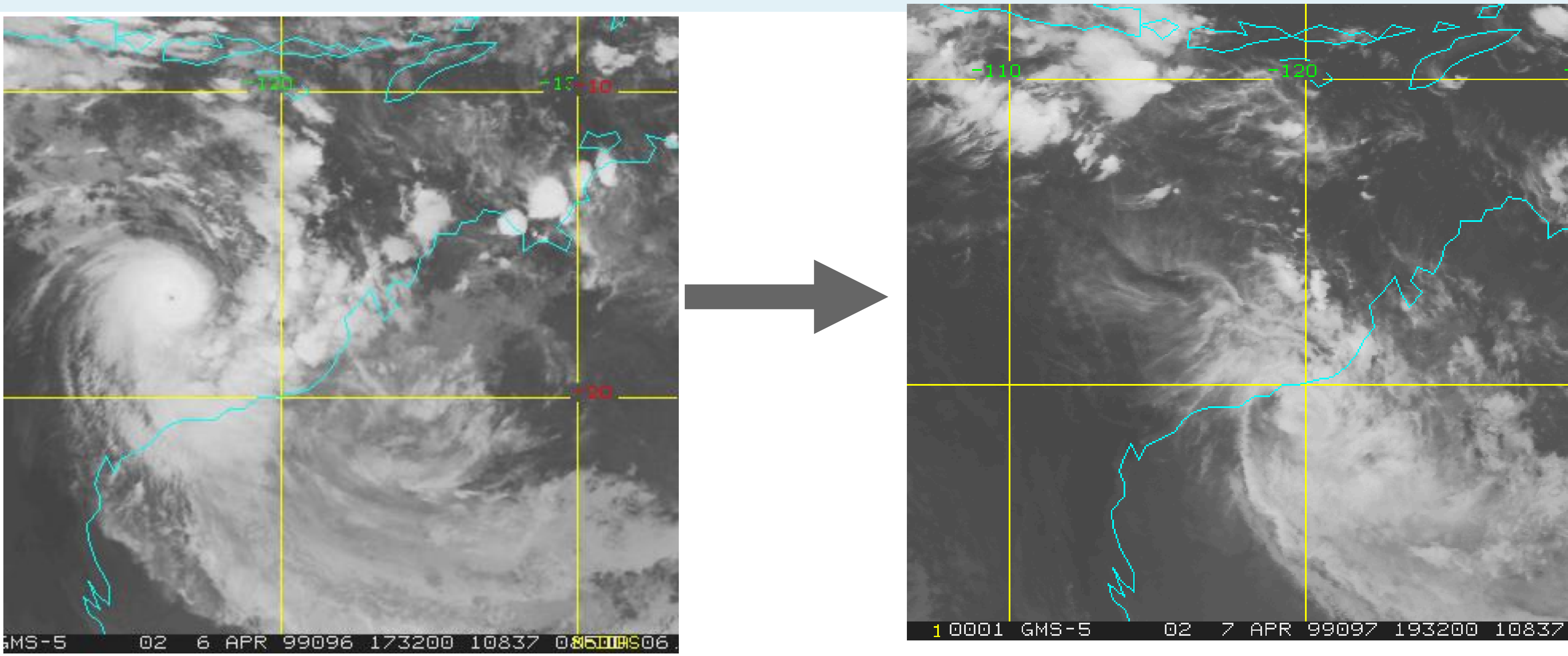
TCs can change intensity rapidly

Gwenda 1999 Rapid Weakening



Cat 5 (120 kn) to Cat 2 (55 kn) in 24 h!

and Cat 4 (90kn) to low (30kn) in 11 h

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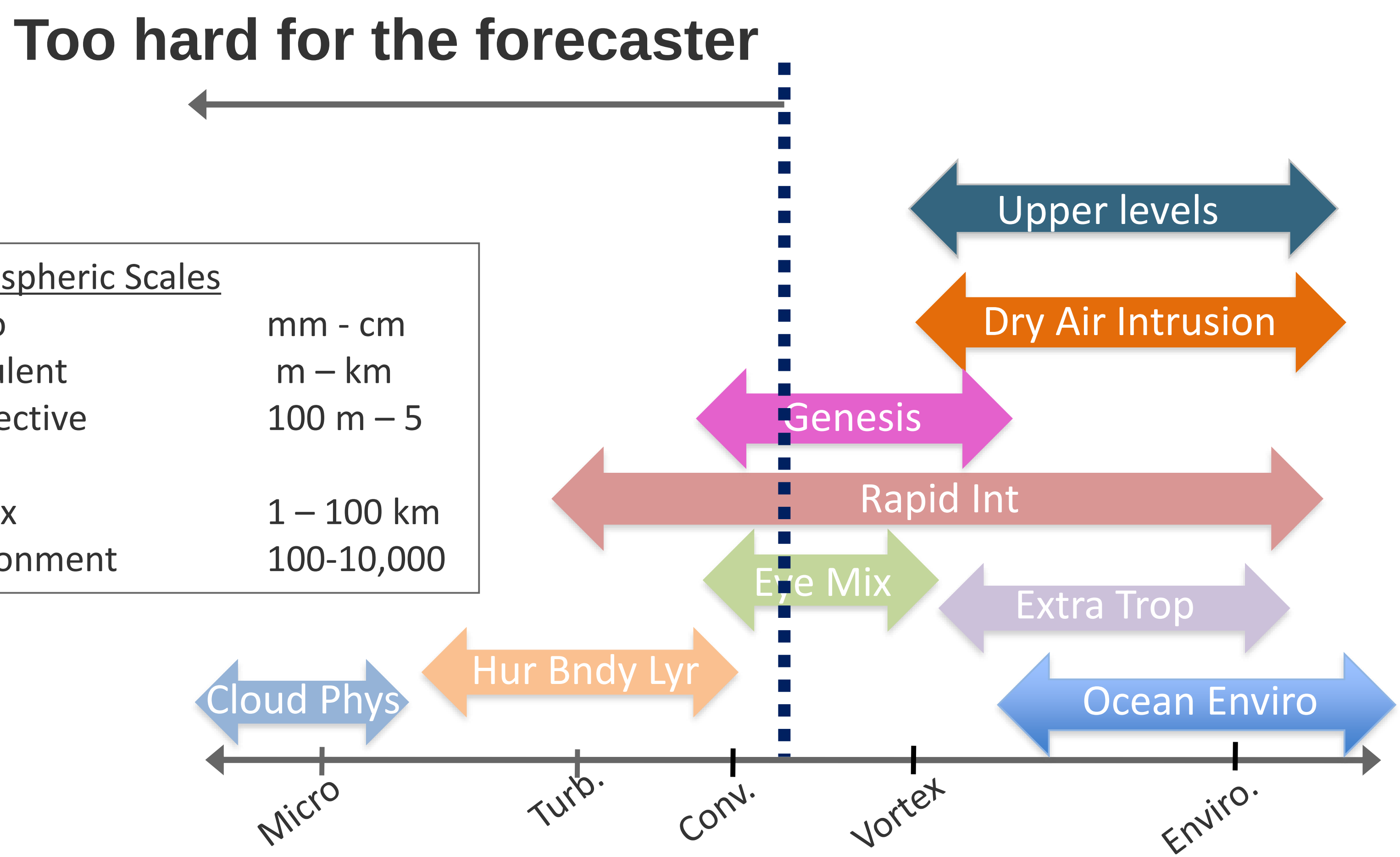
Intensity changes on different scales



Atmospheric Scales	
Micro	mm - cm
Turbulent	m – km
Convective	100 m – 5 km
Vortex	1 – 100 km
Environment	100-10,000 km

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Critical elements

1. Good Analysis and environment assessment
2. Persistence (esp. for first 12h)
3. Changes in the environment (NWP) Conceptual Models
4. Objective outputs:
   statistical-dynamical(STIPS/SHIPS),
   NWP trends & consensus (future); RI index
5. Existing policy- consistency "forecasting in honey”

⇒ Combining Subjective Vs Objective
⇒ Picking Rapid Intensification/weakening

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What intensifies TCs?

Strong Inflow (moisture, heat, angular momentum)

- Monsoon during development; moving along the coast esp hills

Increased Upper-level Outflow

Decrease in Wind Shear

Warm Sea Surface Temperature

Moistening of low-mid levels -heavy precipitation

=>>evidenced in the patterns of the convection and increased low-level relative vorticity

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What weakens TCs?

Movement Over Land

Strong Vertical Wind Shear

Dry air intrusion (coming into the circulation)

Restricted Outflow

Cool SSTs

Slow moving TCs (cooler SST by mixing)

Fast TC Motion (> 20 kn)

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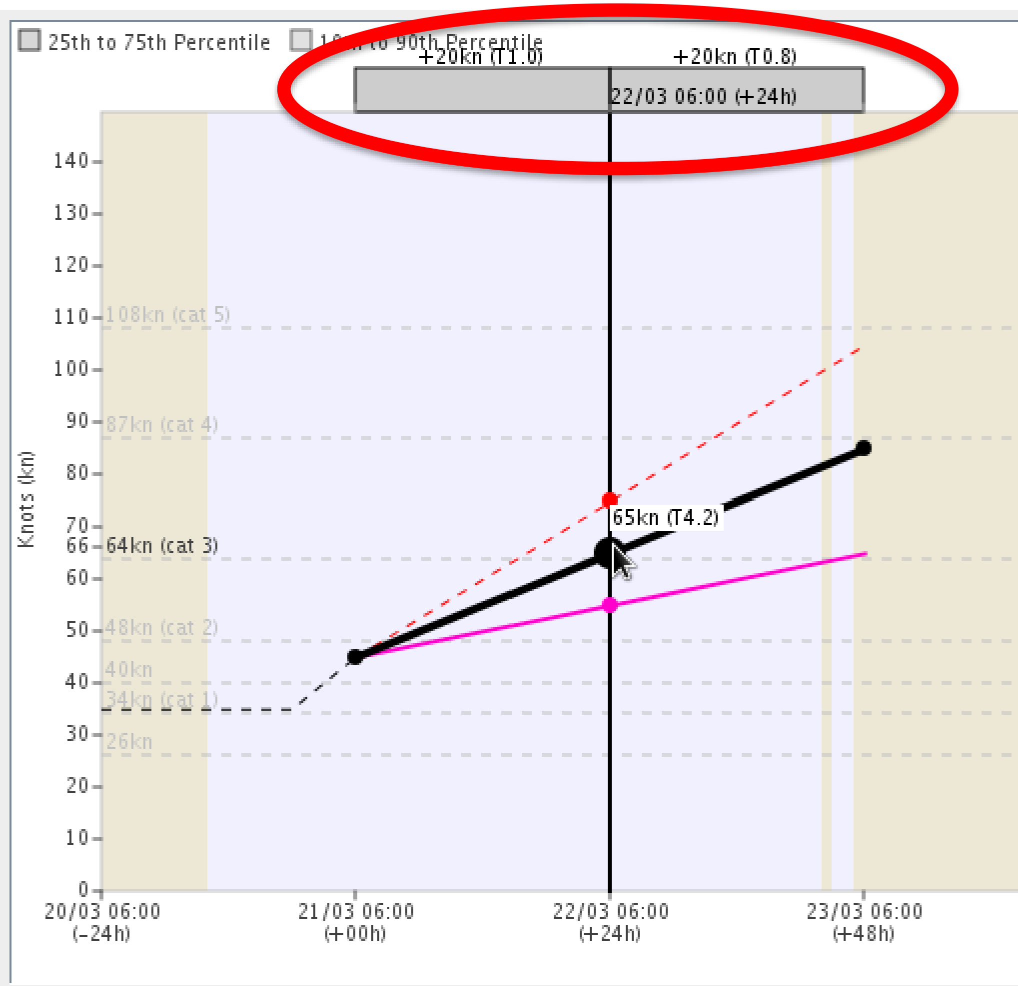
Traditional Forecaster framework in Dvorak T-no. changes

Slight T0.5/day
Standard T1.0/day
Rapid T1.5+/day

- In 24h increments
- Consider environmental influences
- TCModule software 'subjective Dvorak' track



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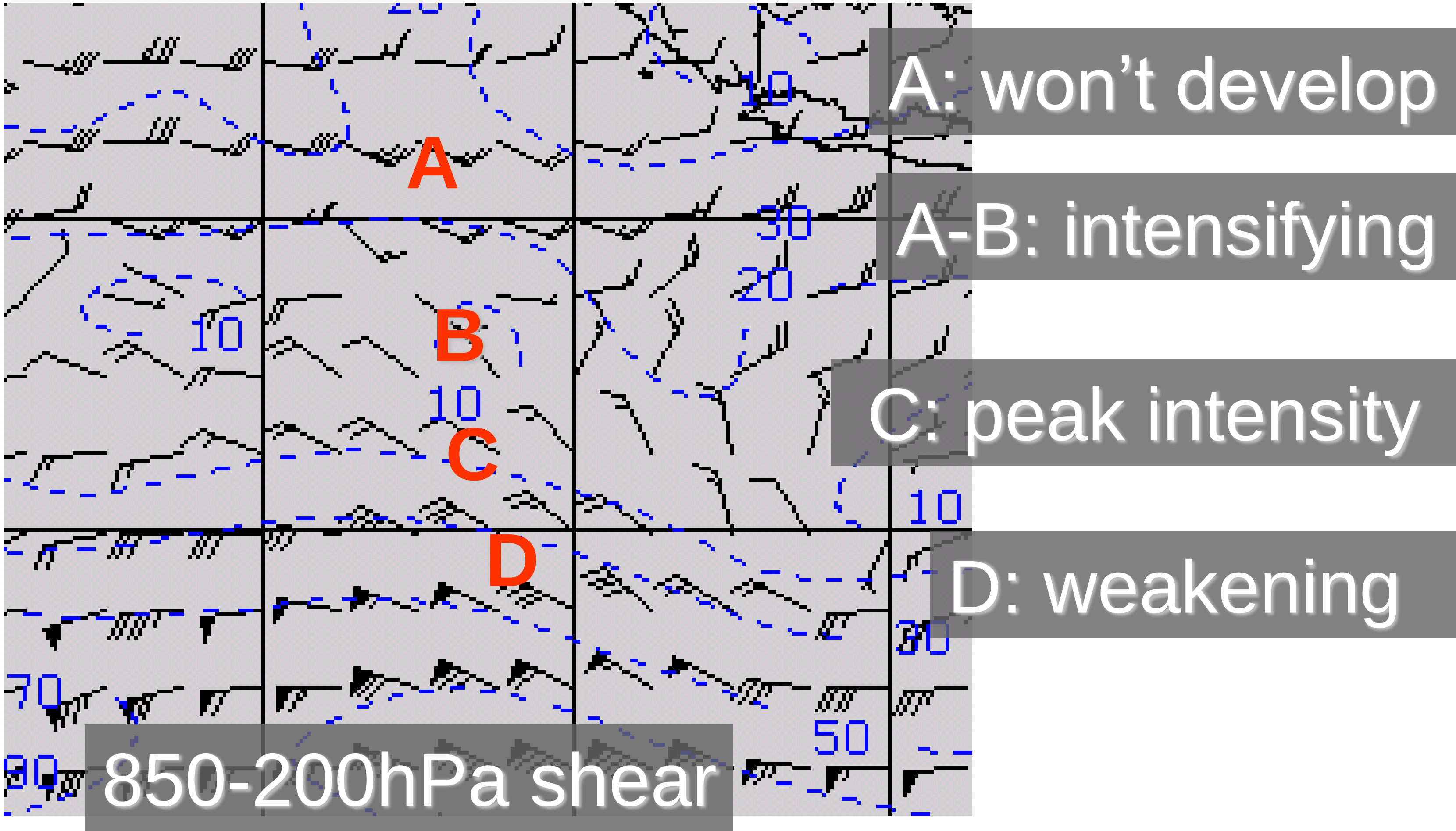
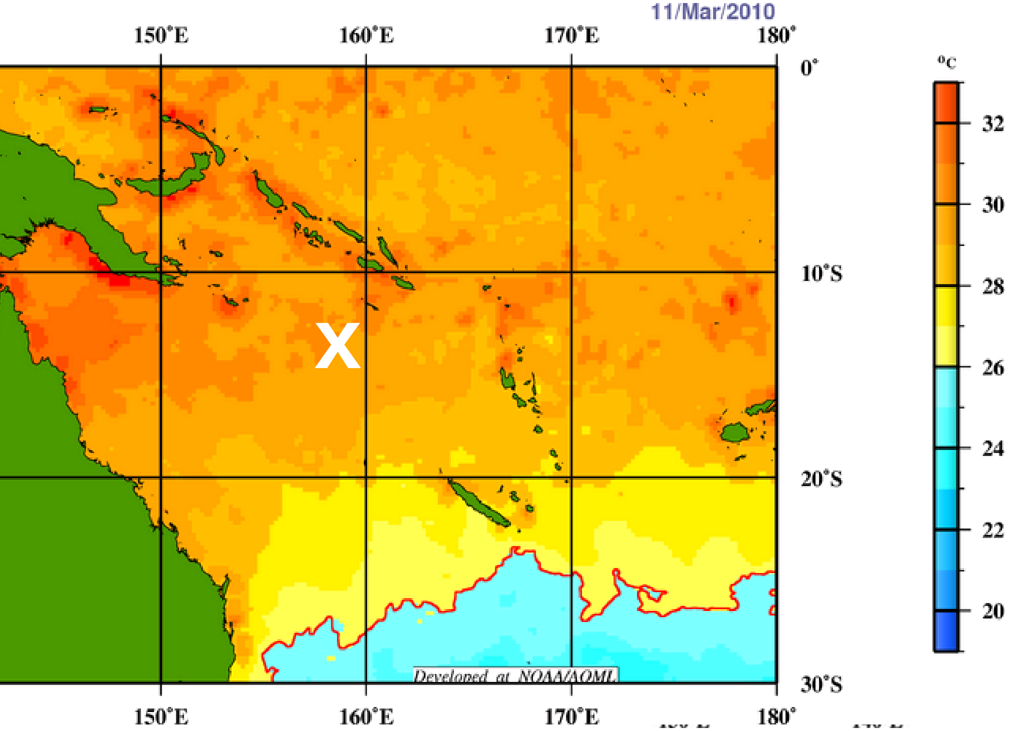
Subjective Approaches

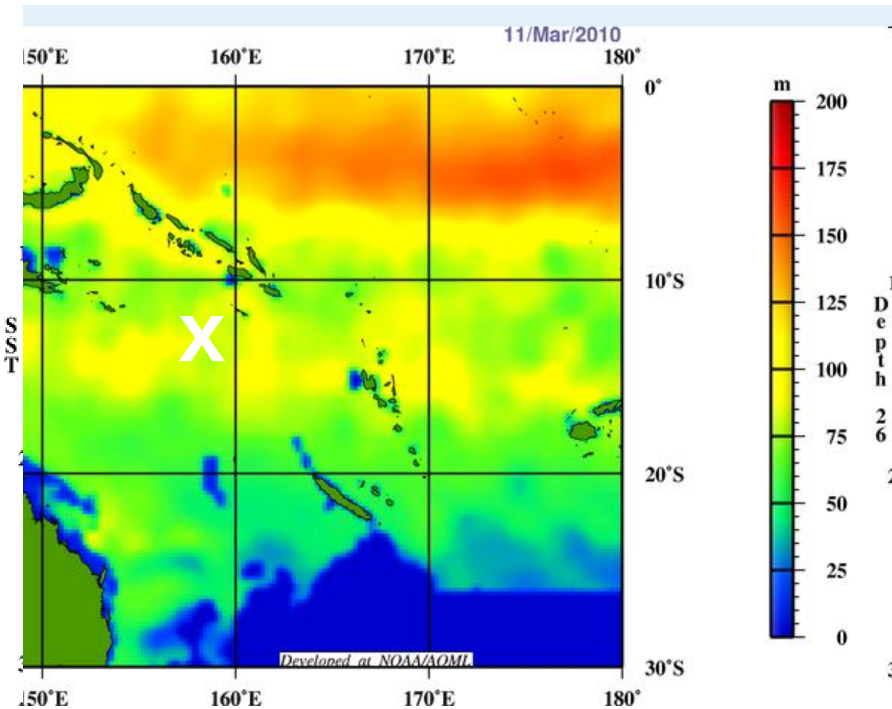
Shear: dominant influence in Aust/Pac

What intensity changes would you expect A-D?



Subjective Approaches: SST weakening due to own slow motion





Pre-Ului on 11 March : 30C SST 13S158E on 17 Mar

26C isotherm at 75m

In Deep Ocean

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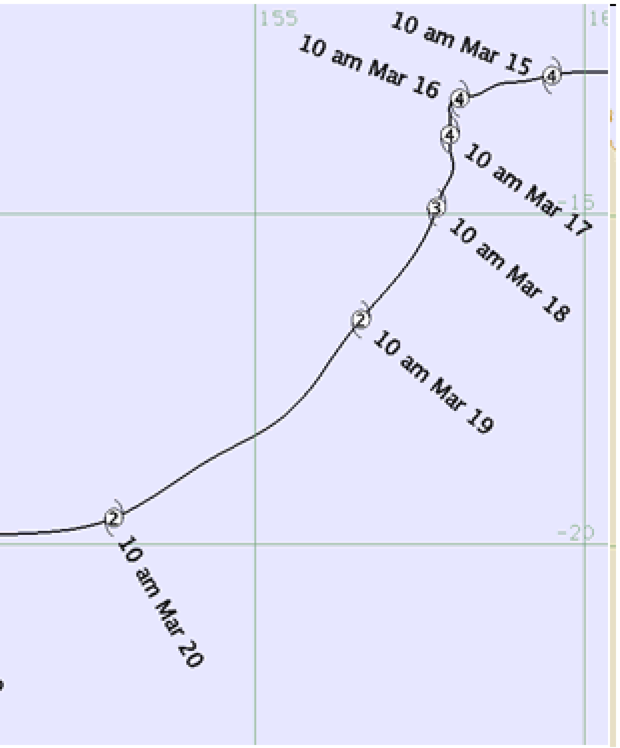
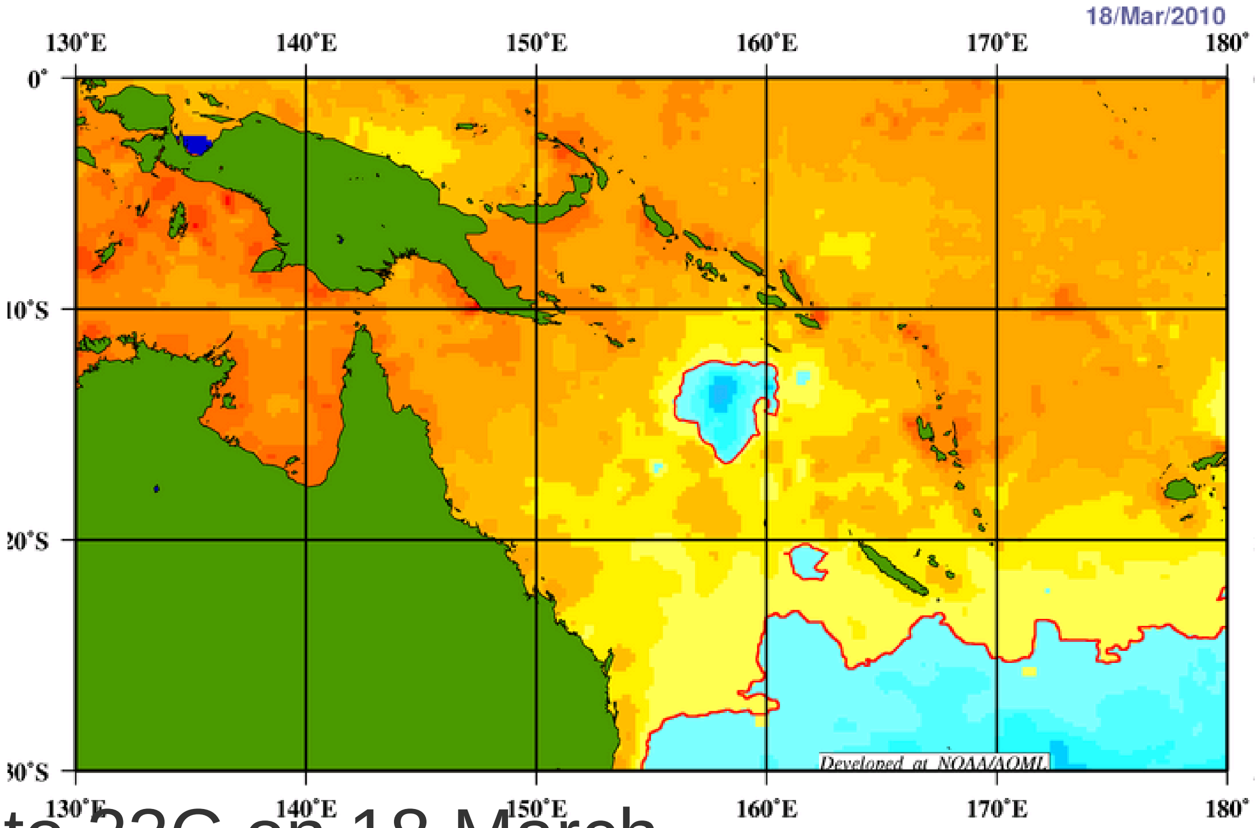
Subjective Approaches: SST

moving over cooler waters/upwelling





Waters cooled to 23C on 18 March

Ului: weakened from cat 4 to cat 2 17-19 March 2010

Moving at 2 knots 15-18 March

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Subjective Approaches: SST

TCs moving < 5kn consider upwelling

Upwelling related to motion, intensity, size
Cooling is rapid 12-24h for VSCS roughly 2+C for area of roughly storm force winds (rules of thumb)
Absolute SSTs most critical

- cooling from 31 to 29C not that significant
- Threshold of 28C for VSCS, 26C for CS rule of thumb

Depth of 26C isotherm also a factor – consider OHC
Difficult forecasting challenge given so many variables.

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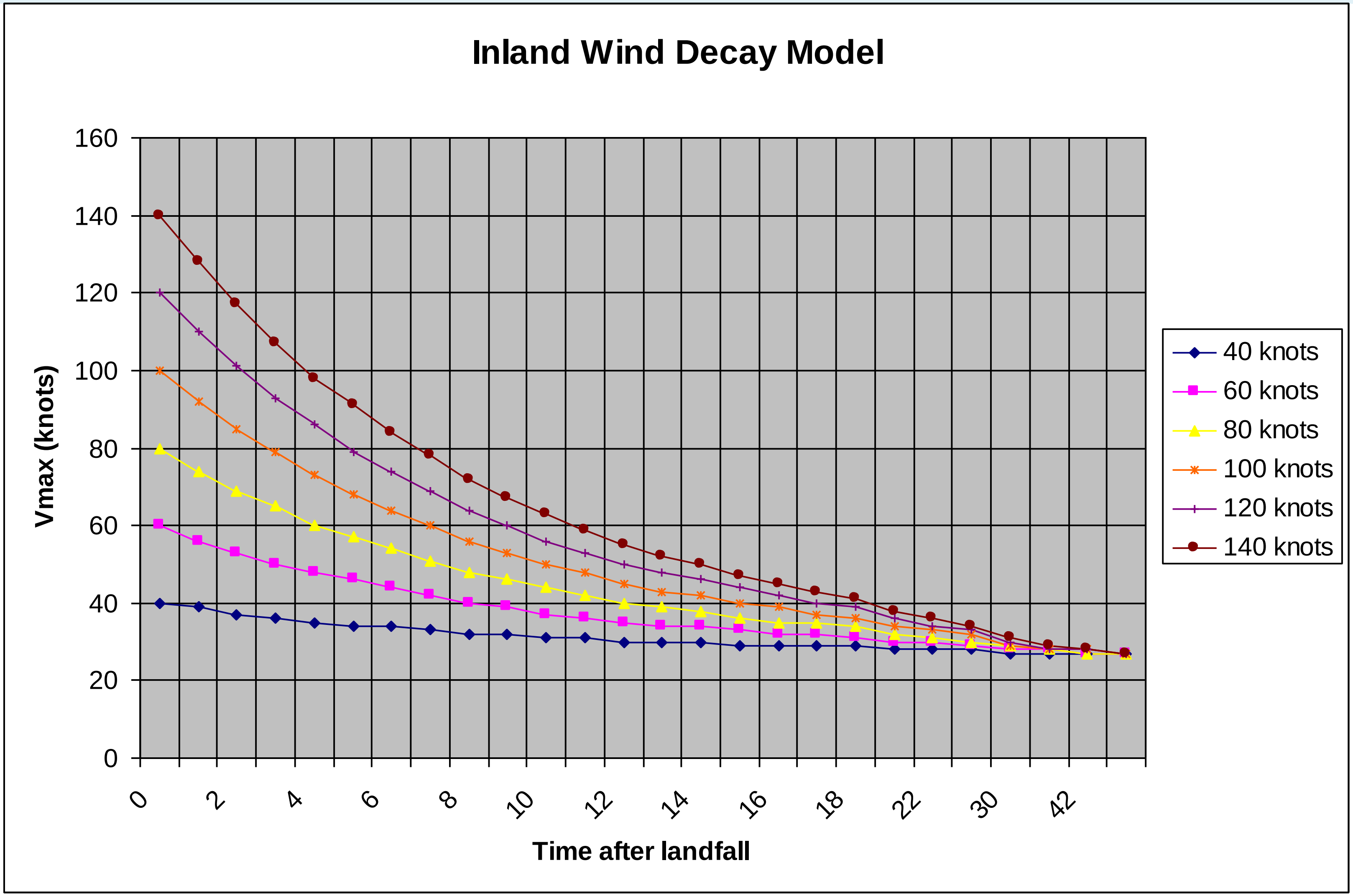
Subjective approaches: Landfall

Standard Decay rate + topography?



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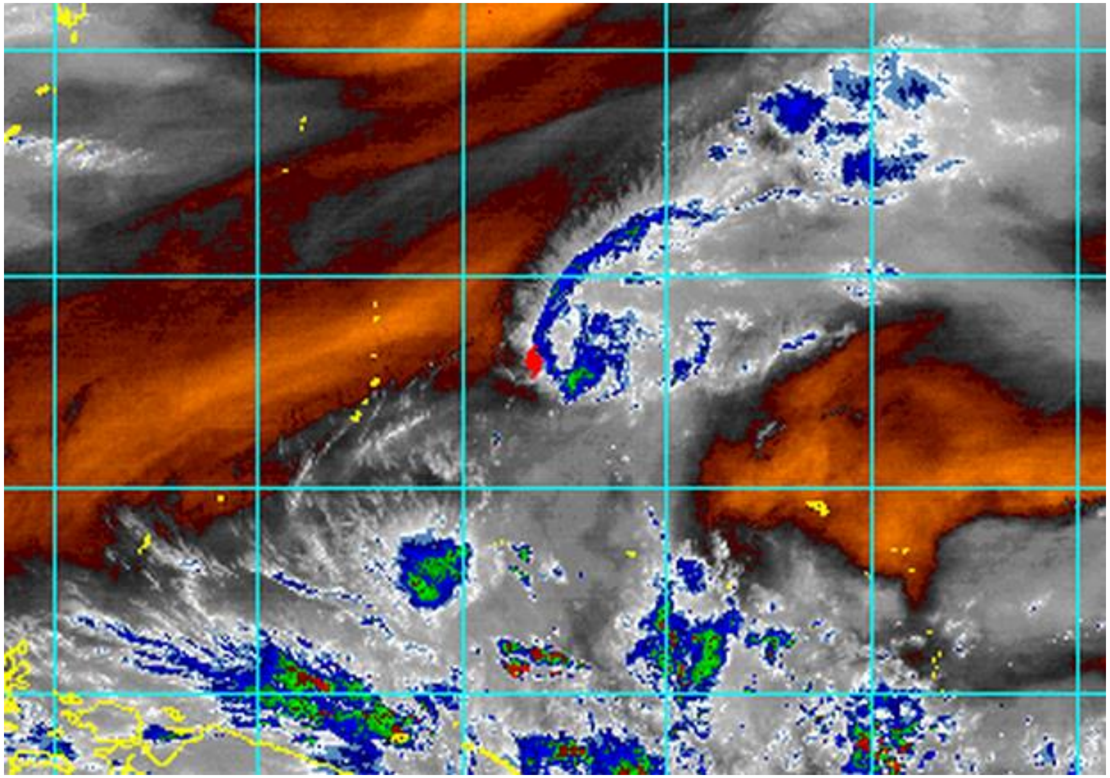
Dry air intrusion: need to look at with shear

Higos (WP Feb 2015)
http://rammb.cira.colostate.edu/products/tc_realtime/loop.asp?product=16kmgwvp&storm_identifier=WP022015&starting_image=2015WP02_16KMGWVP_201502090232.GIF&ending_image=2015WP02_16KMGWVP_201502110232.GIF



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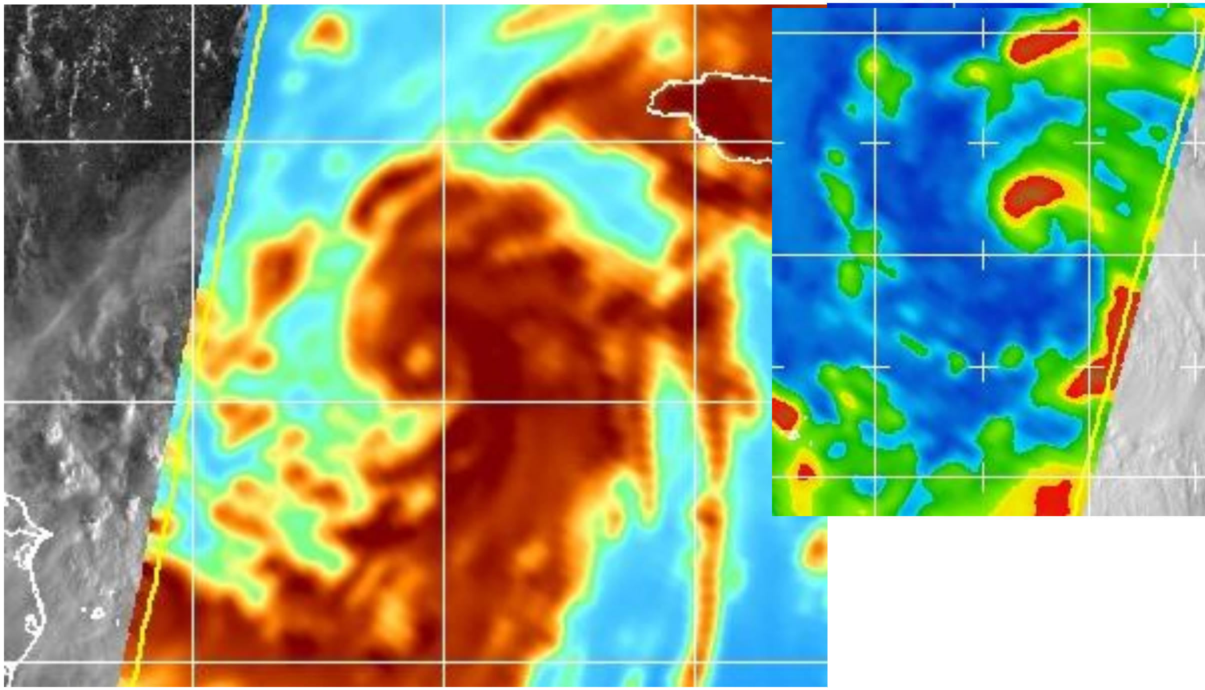
Value of microwave patterns

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

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

Wilma, 2005 at 65kn then intensified 95kn/24h

Windsat imagery highest resolution in 37GHz



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.

Objective Intensity Guidance: SHIPS – ICNW from JTWC 'aids' file

Statistical Hurricane Intensity Prediction Scheme

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Combines persistence, NWP predictors -calibrated, overland decay

ICNW=DSHA+DSHN+GHMI+CTCI+CHII+HWFI+RI30

(US models so excludes others such as EC, UK, JMA

Australian experience: quite good

LGEN/DSHN – SHIPS/LGEM using NAVGEM
- LGEA/DSHA – SHIPS/LGEM using GFS track and wind f
  and NAVGEM thermal fields
- CHIPS
- GFDN
- COAMPS-TC
- HWRF

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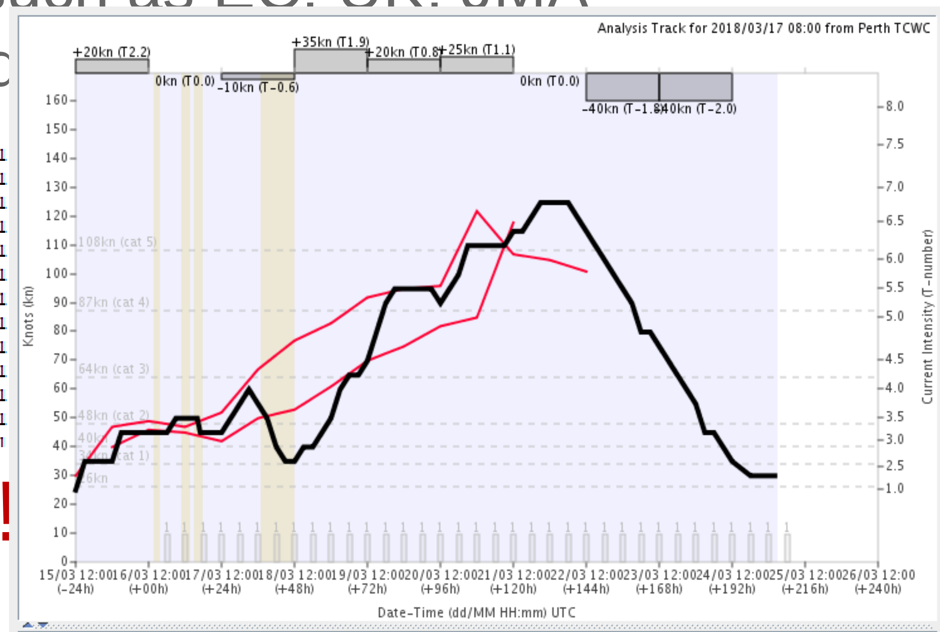
WARNING ACRONYMS!!



Marcus (2017): Black is analysis and red are two early ICNW forecasts

Source: Sampson&Knaff, IWTC

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/Topic2.7_AdvancesinIntensityGuidance.pdf

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Objective Intensity Guidance:

Most predictors averaged over period since analysis so slow response to changing synoptic environment.
Strong cyclones that move over land and back over water can have low bias
Typically underestimate peaks esp when RI occurs

LGEN/DSHN – SHIPS/LGEM using NAVGEM
• LGEA/DSHA – SHIPS/LGEM using GFS track and wind fields, and NAVGEM thermal fields
• CHIPS

• COAMPS-TC
• HWRF

Source: Sampson&Knaff, IWTC
http://www.wmo.int/pages/prog/arep/wwrp/new/documents/Topic2.7_AdvancesinIntensityGuidance.pdf

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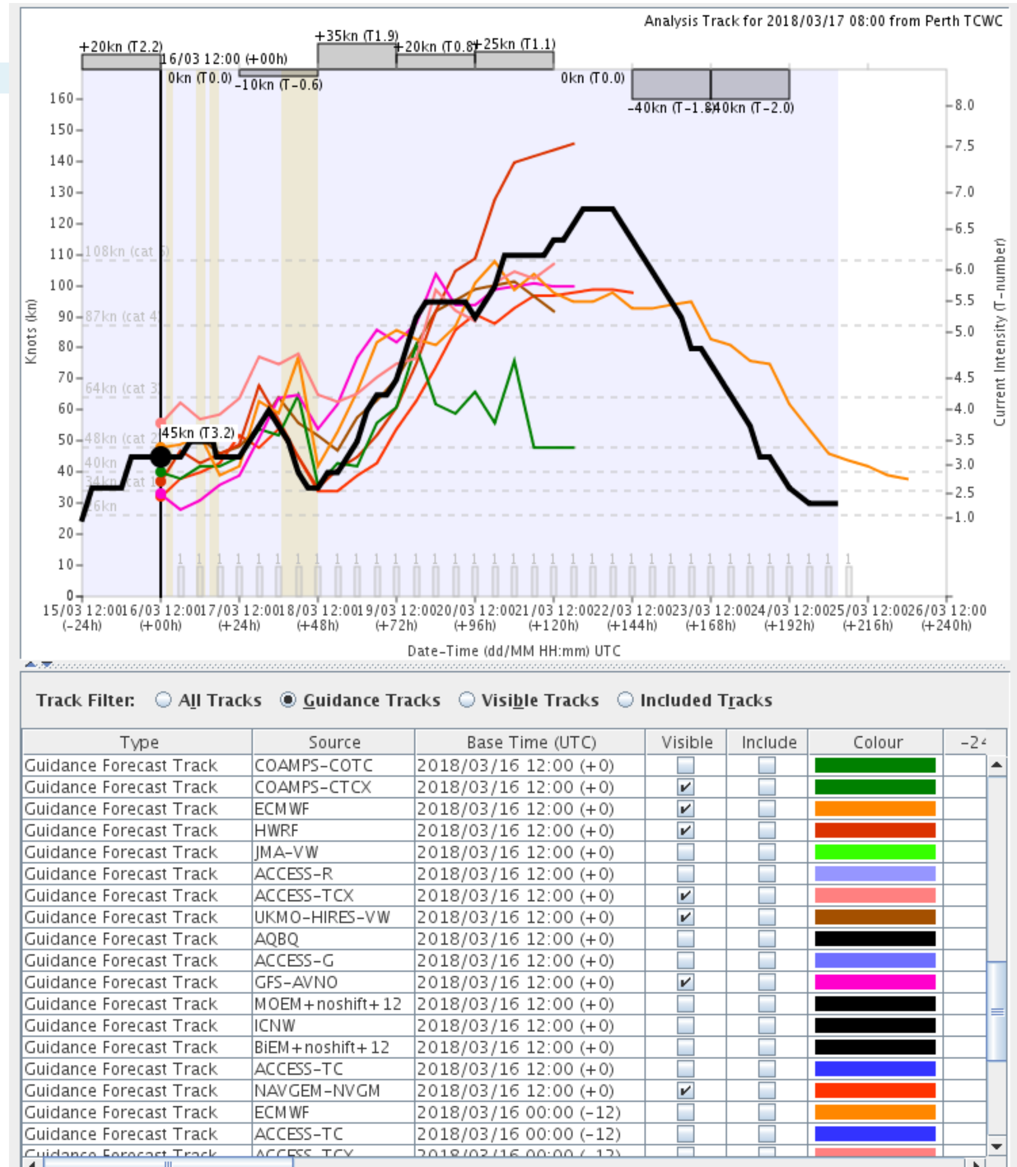
Intensity forecasting : visualizing in TCModule

Intensity plots make it easier for comparison

Marcus: models – best ever?



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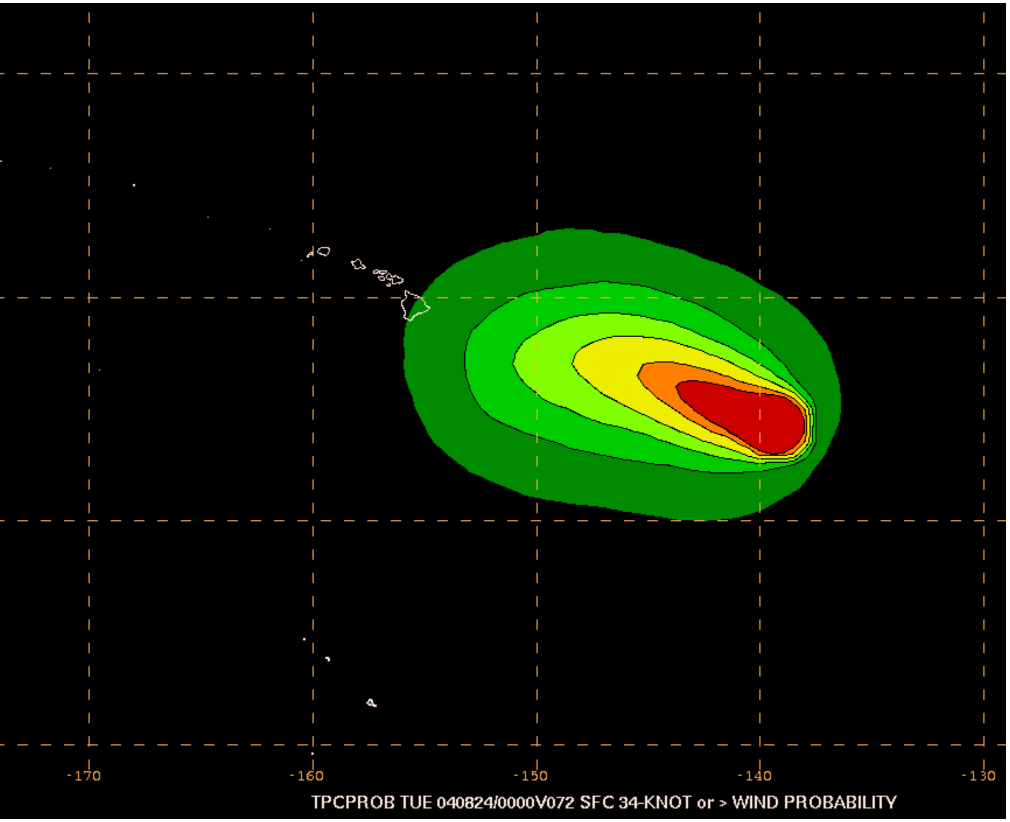
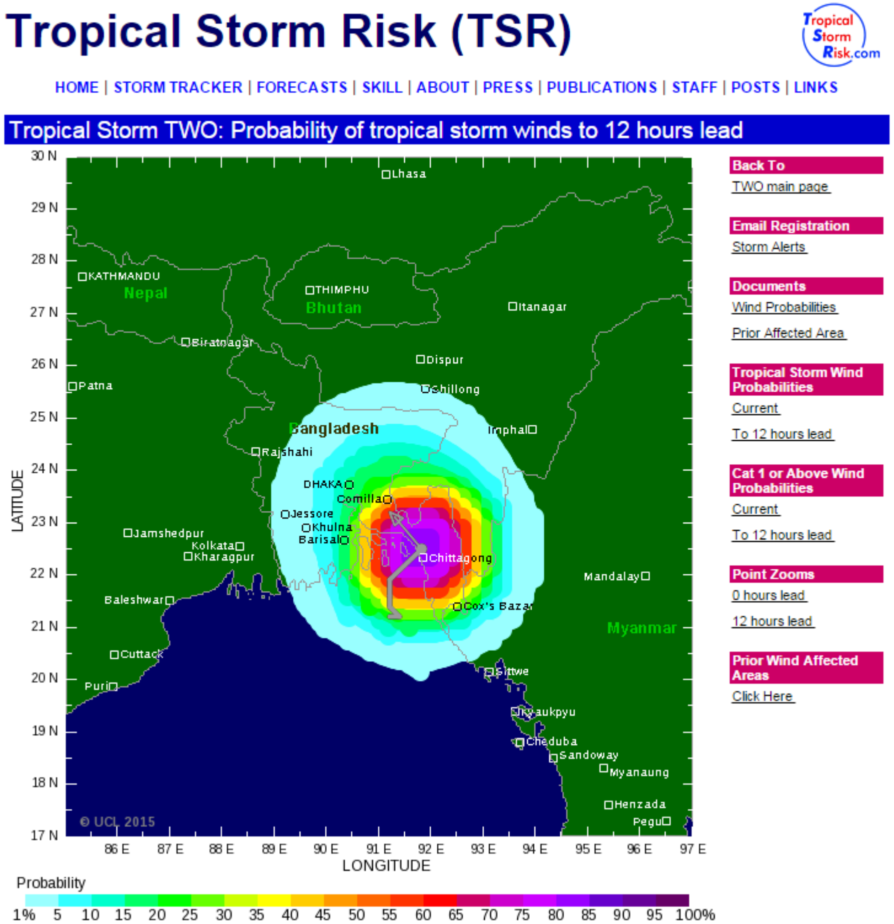
Moving to probability of impact – more info than peak intensity

http://www.nhc.noaa.gov/refresh/graphics_ep3+shtml/083822.shtml?tswind120#contents
http://www.tropicalstormrisk.com/
Coming: http://rammb.cira.colostate.edu/products/tc_realtime/season.asp?storm_season=2018





34 kt Cumulative

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Rapid Intensification: 30kn/day OR T1.5+/day

The difficult forecast - Will it? When?

Most SevTCs undergo RI at some stage (from 50+ kn)

RI index uses upper-level divergence, wind shear, previous 12h intensity change, inner-core symmetry Recognising pre-cursor signals in imagery

microwave patterns (often 'blob' stage in IR/Vis)

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

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Intensity forecasting: Rapid Intensification (RI) index

SHIPS: gives probability of a 30kn/24h intensity based upon 9 predictors.
Calibration
~15-40% consider RI
> 40% RI confident.
Note fluctuations in output

RII Predictors

1. Previous 12 h max wind change (persistence)
2. Maximum Potential Intensity – Current intensity
3. Oceanic Heat Content
4. 200-850 hP shear magnitude (0-500 km)
5. 200 hPa divergence (0-1000 km)
6. 850-700 hPa relative humidity (200-800 km)
7. 850 hPa tangential wind (0-500 km)
8. IR pixels colder than -30°C
9. Azimuthal standard deviation of IR brightness temperature

Source: B. Sampson

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Rapid Intensification: microwave patterns

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

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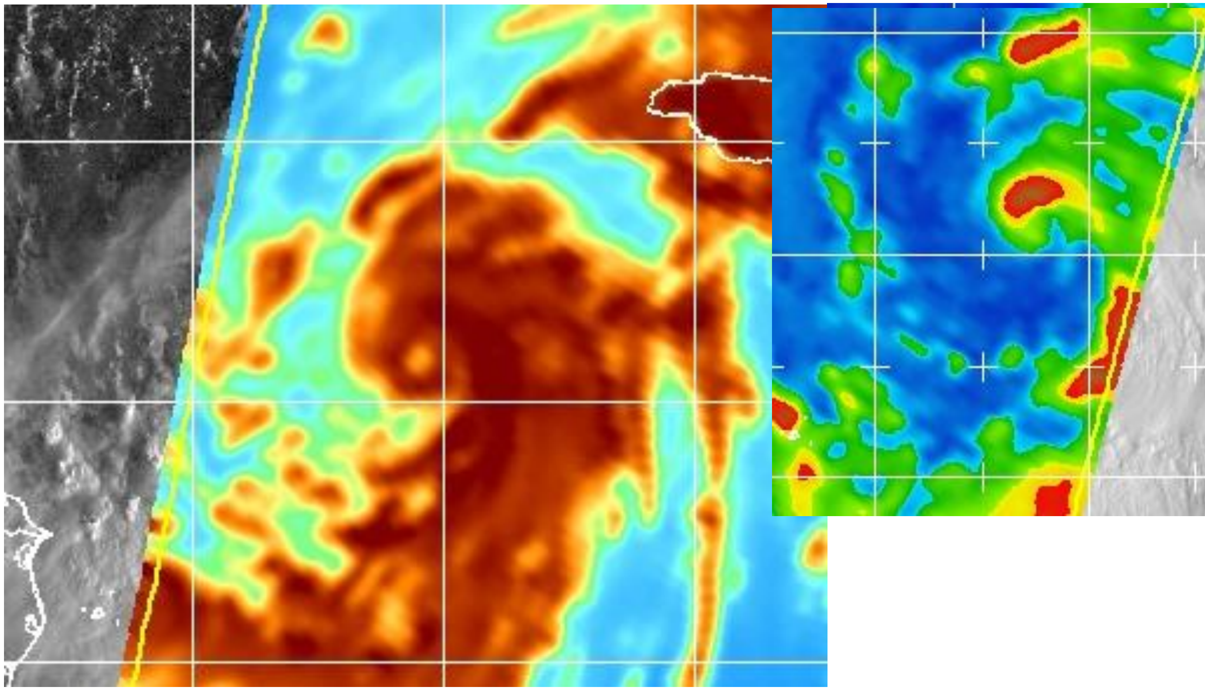

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Rapid Intensification: Small systems more likely to change intensity faster

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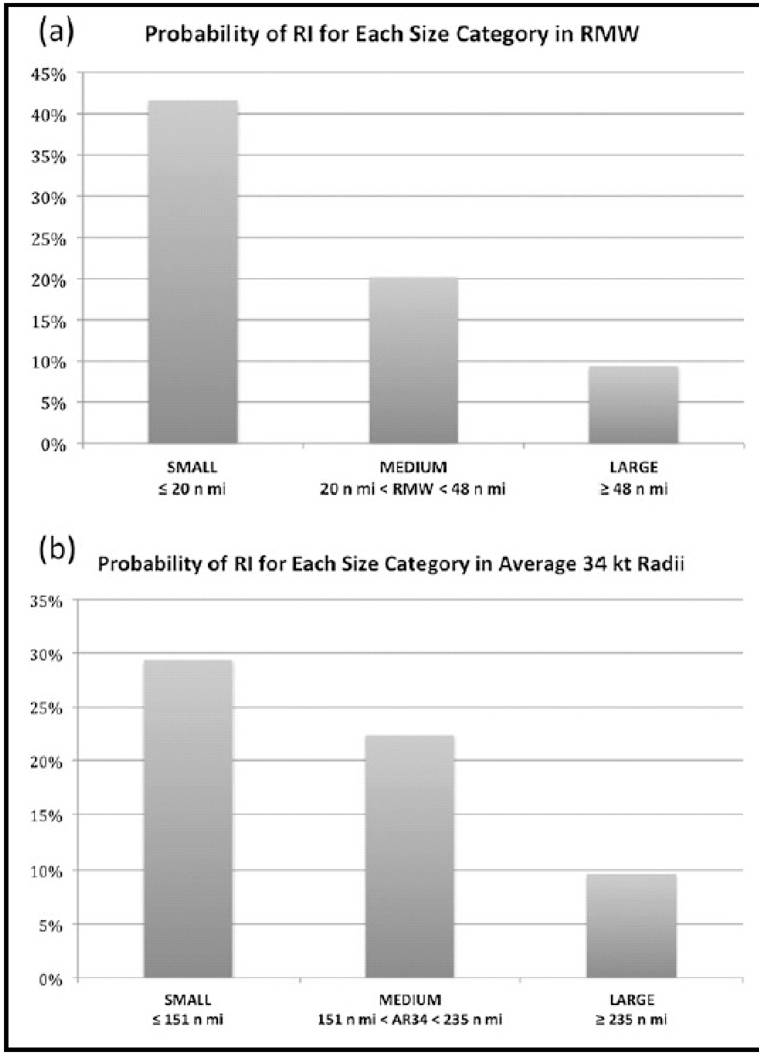
Probabilities for rapid intensification (RI) for three storm size categories as defined by:

Upper: radius of maximum winds

Lower : average radius of gale-force (34-kt) winds



Fogarty and Zhang, IWTC VIII 2014
http://www.wmo.int/pages/prog/arep/wwrp/new/documents/Topic4.pdf

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Special cases: Small (Midget) 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!)
- Genesis problem: models can miss them; non-MJO linked
- RI starts earlier (30 knots) than for larger TCs (50 knots)
- more likely to intensify at night (respond to nocturnal cloud-top cooling)
- More common in Aust basis than elsewhere?
  - Low-latitude/high SST

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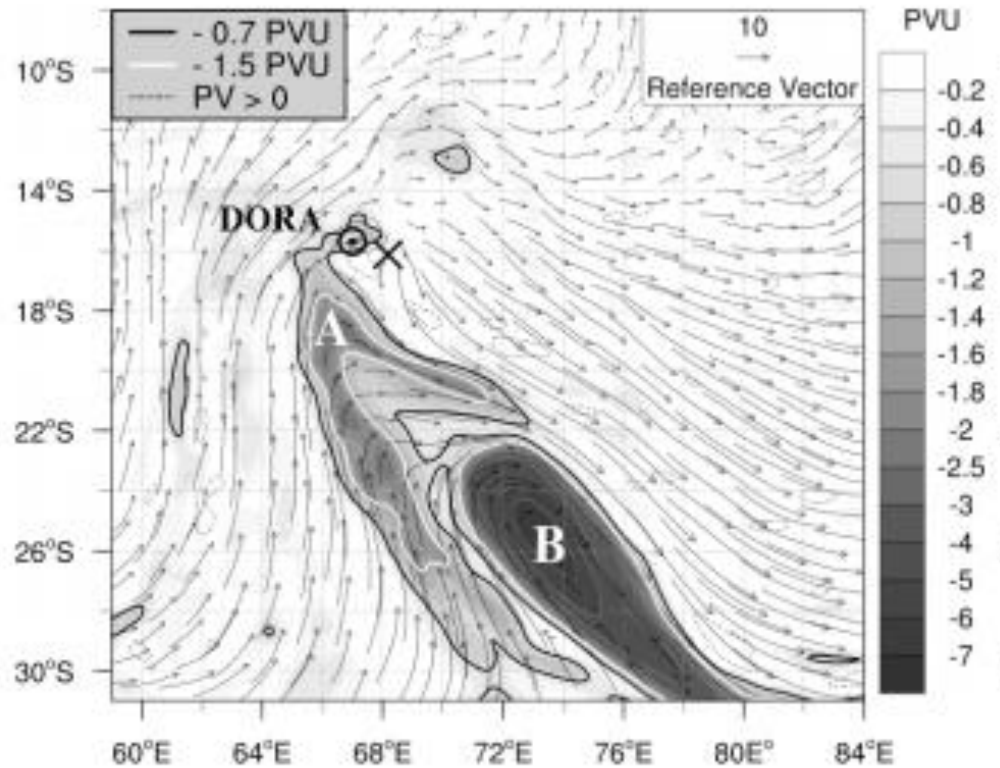
Rapid Intensification from bursts in convection caused by:

Upper trough interactions: increase in divergence;

Downstream energy dispersion (Rossby) – difficult

Warm Air Advection



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

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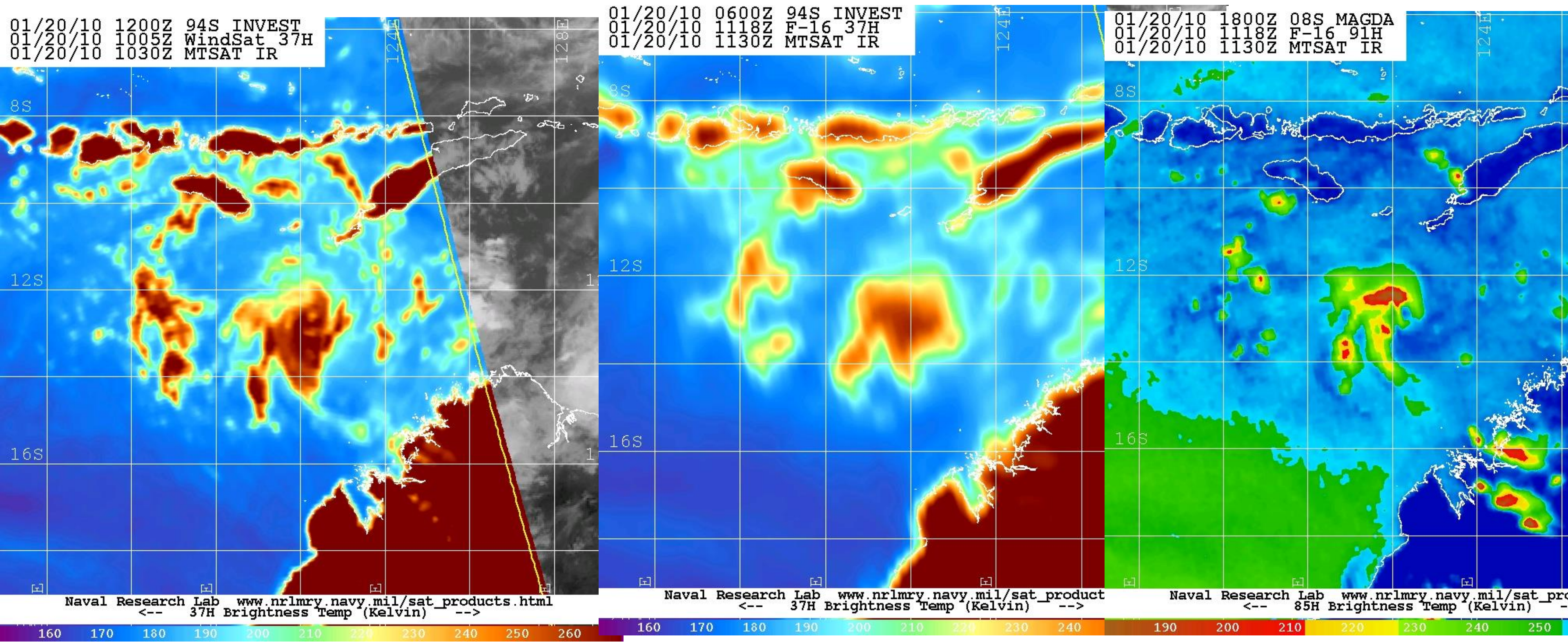
Resolution in the imagery Windsat has highest resolution to detect change in low levels



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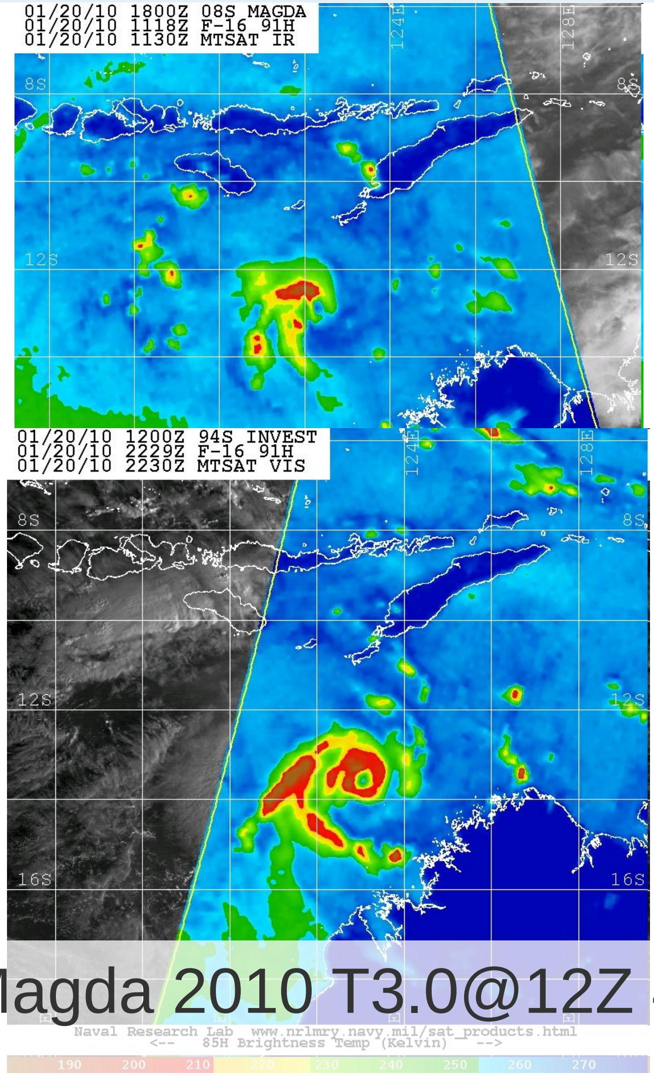
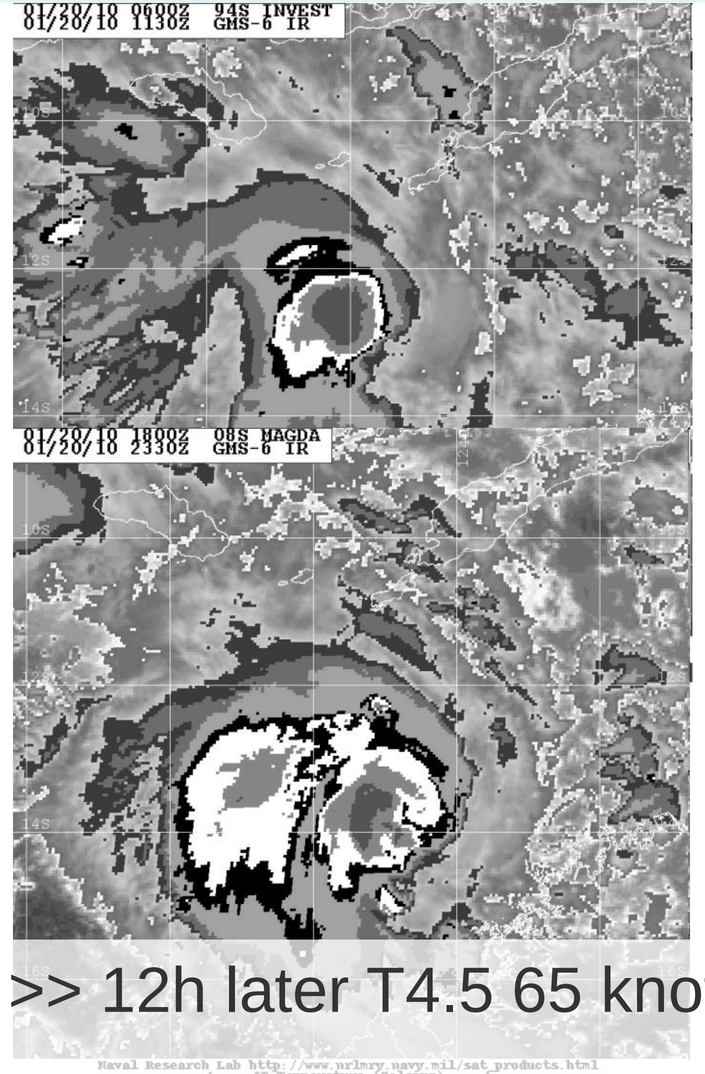
Rapid Intensification of Midgets seen on microwave before IR/Vis





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

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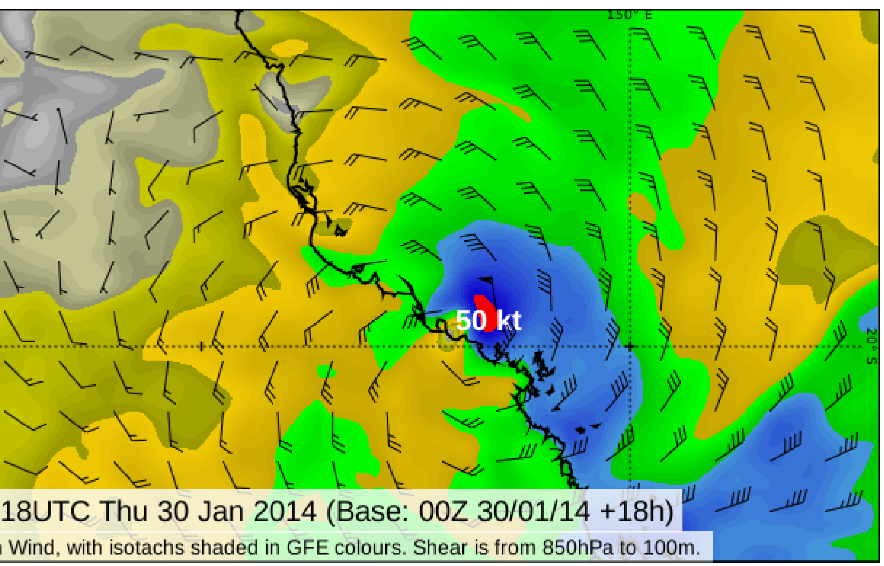
Intensity forecasting summary still tricky but…

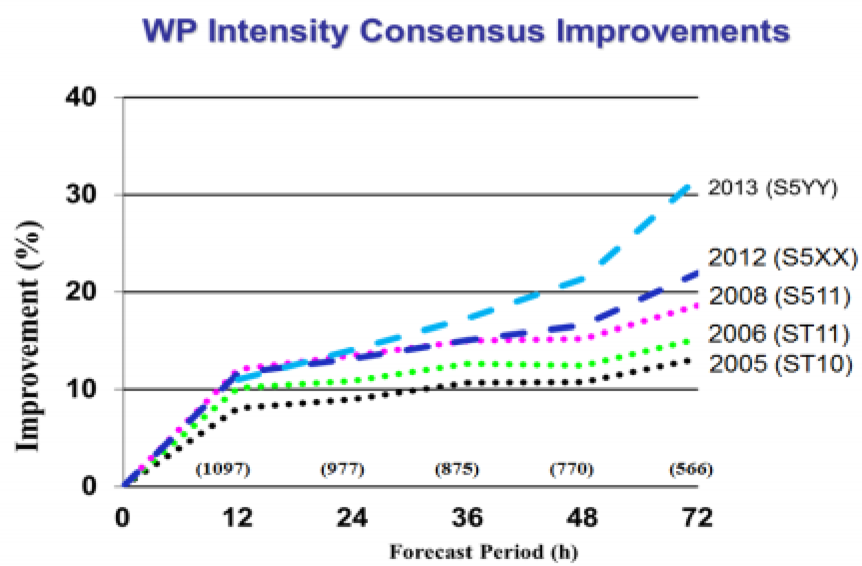
Inputs: manual (+- DT/24h); Objective Aids: SHIPS/LGEM;

Models: esp. HWRF (ensembles not yet that useful)

model sfc wind patterns; SHIPS/LGEM

Recognition of satellite signatures for rapid changes





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The intensity game

Roll dice for each;
low number means more favourable – high number not favourable
Assess likelihood of development at +24, +48, +72h

	Team 1	Team 2	Team 3	Team 4
Wind Shear				
Low-mid RH				
Upper outflow				
Low-level inflow				
SST				
Convection				
TC change +24				
+48				
+72				