EVALUATING WRF-ARW V3.4.1 SIMULATIONS OF TROPICAL CYCLONE YASI

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14th Annual WRF User's Workshop
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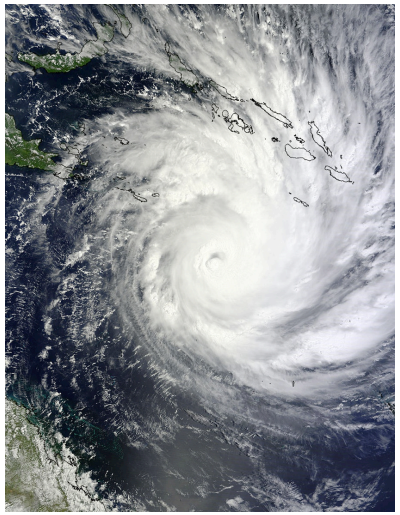
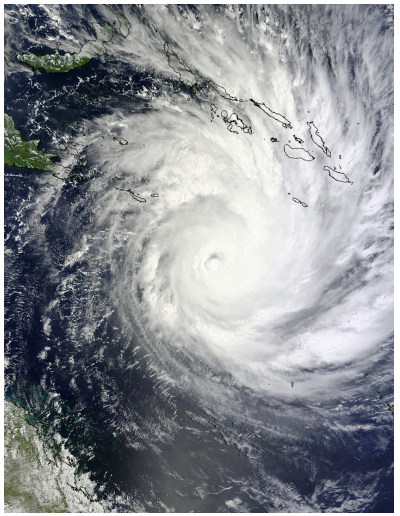


Outline

- Background of Case Study Tropical Cyclone Yasi
- WRF v3.4.1 model set up
- Physics Sensitivity Simulations
- Results and Analysis
- Conclusions



YASI

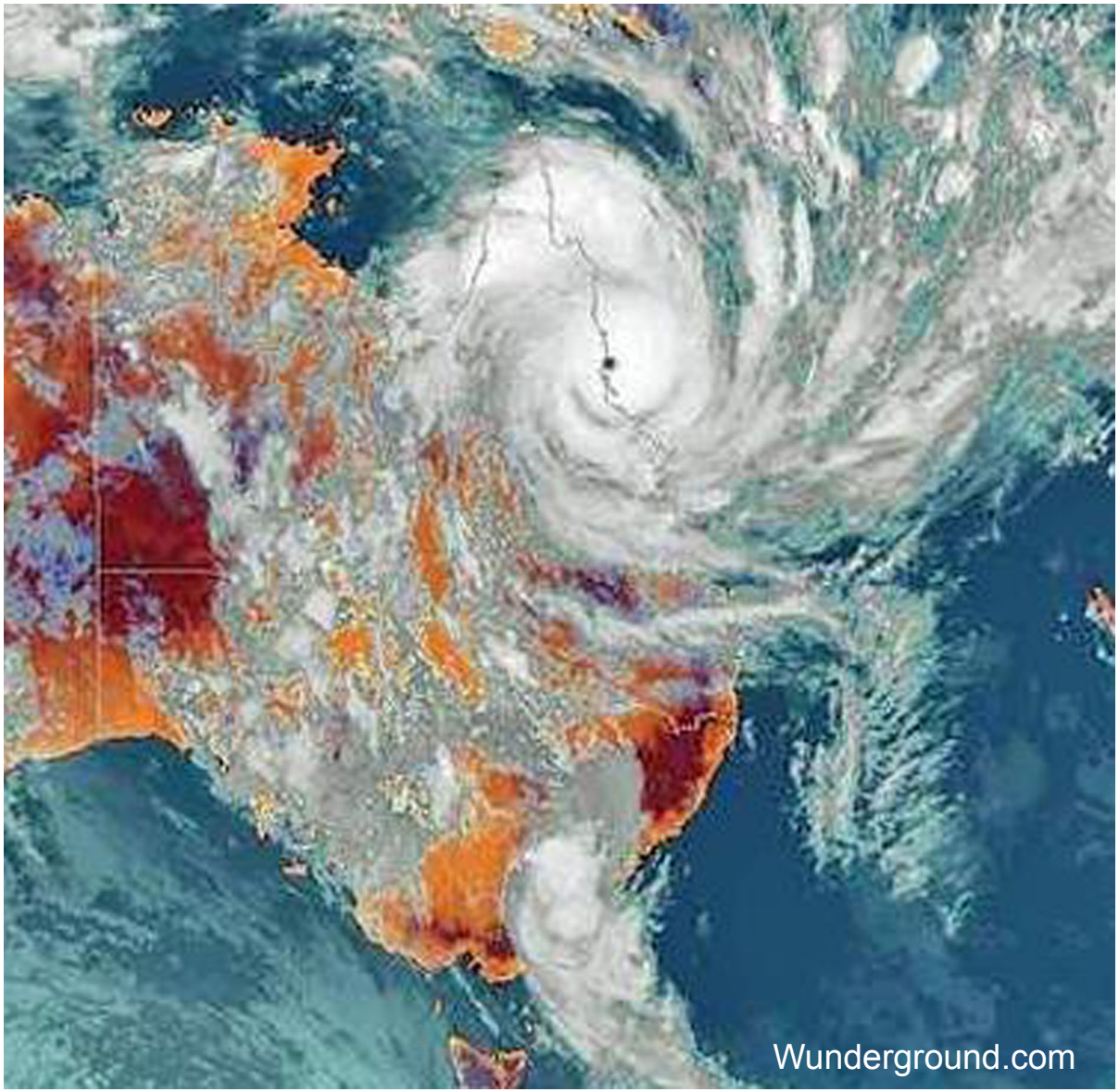
Rapidly intensifying, category 5 storm.

Cyclogenesis northeast of Fiji on 29th Jan, landfall on the Queensland coastline in early hours Feb 3rd 2011.

600km wide, eye 35km wide.

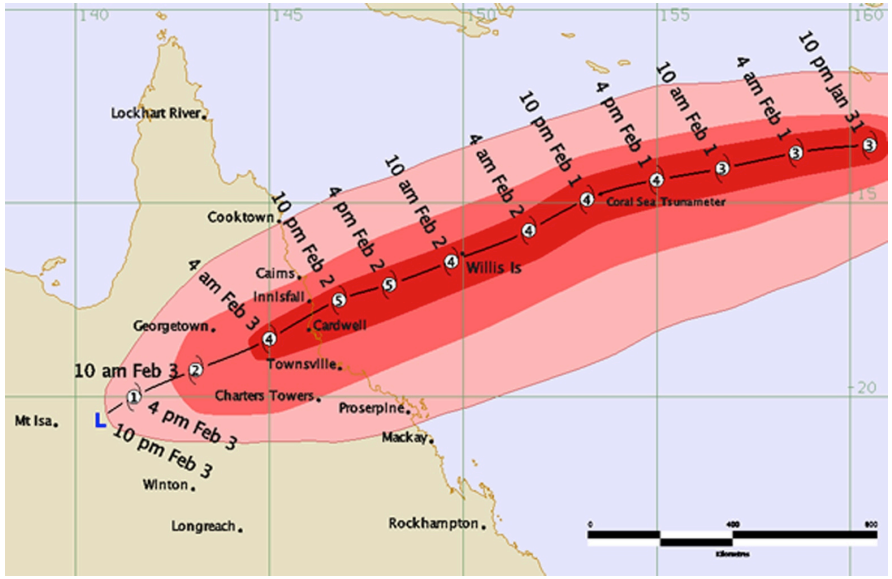
6m storm surge. Wind speed up to 300 km/h.

929hPa minimum low



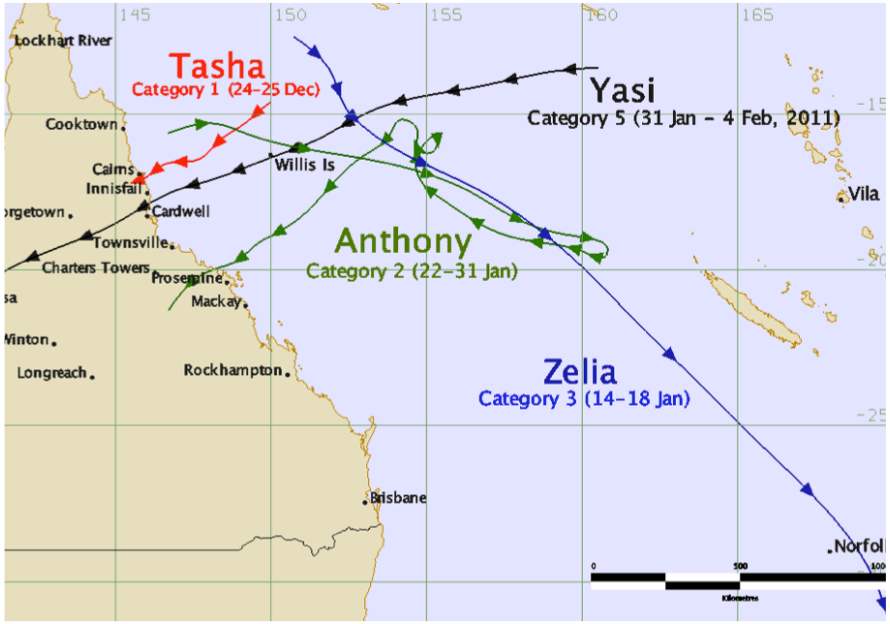
LIFE CYCLE

YASI



Australian Bureau of Meteorology, 2011

2011 CYCLONE SEASON



Australian Bureau of Meteorology, 2011

MODEL SET UP

d01, 36km

d02, 12km

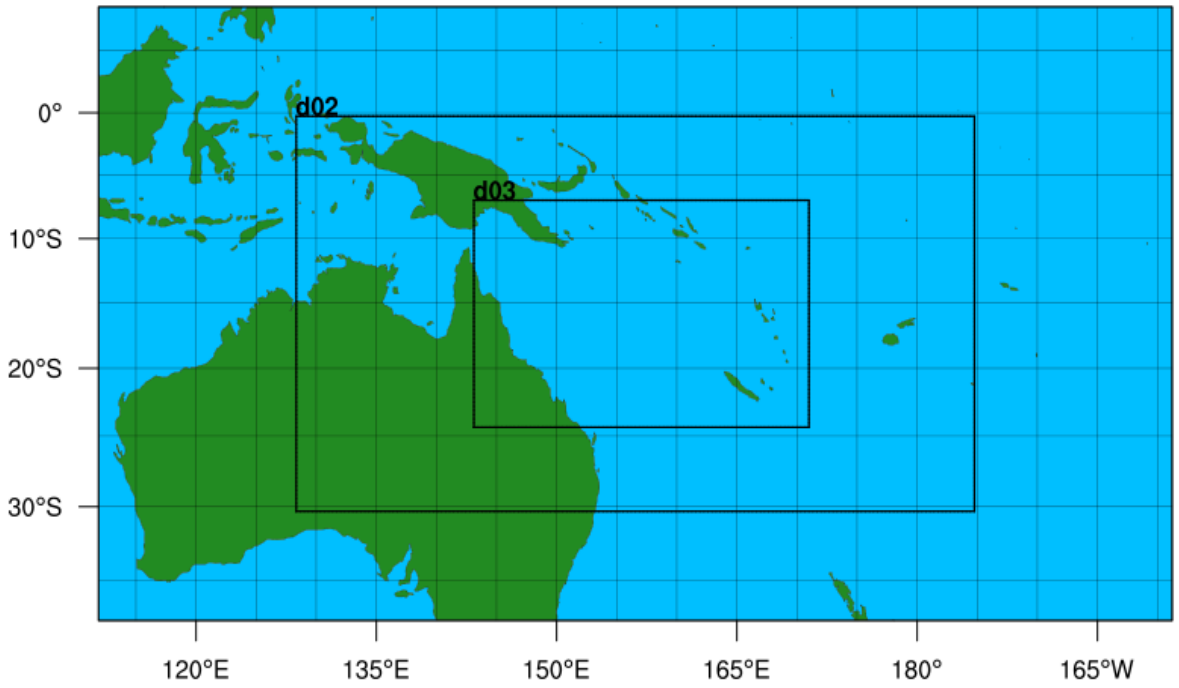
d03, 4km

27 vertical levels

ptop: 50hPa

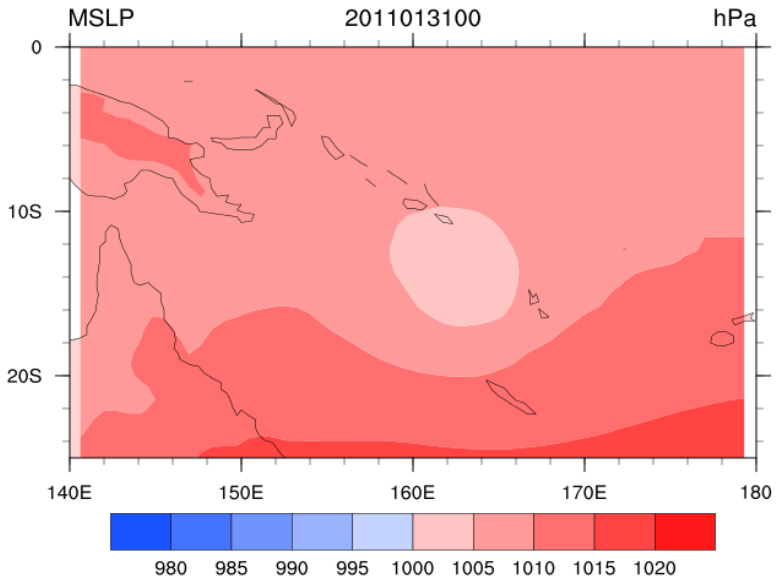
4day simulations from Jan 31st 00:00 to Feb 4th 2011 00:00 UTC.

- Shortwave: Dudhia
- Longwave: RRTM
- Surface layer: MM5 Monin-Obukhov
- Land surface: Unified Noah LSM

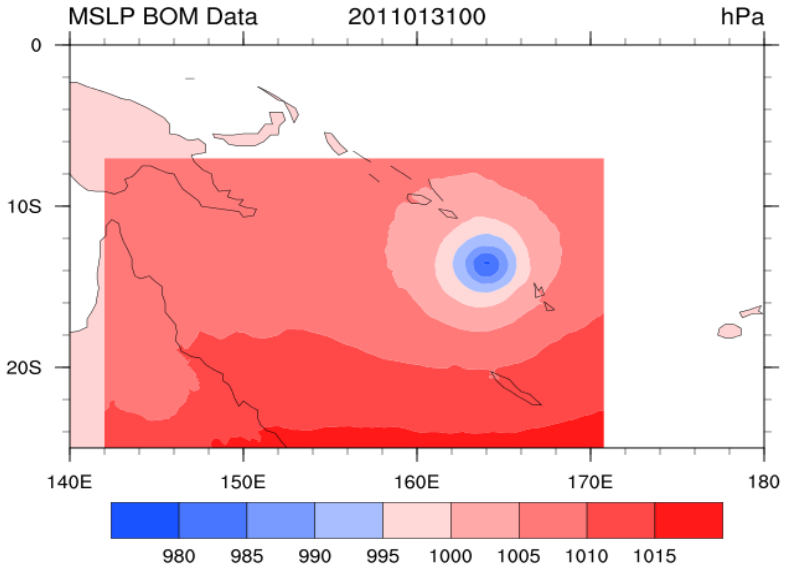


INITIALISATION and FORCING DATA

ERA INTERIM Reanalysis data, ~80km resolution



Bureau of Meteorology Initialisation, 4km resolution



Physics package trials

- Cumulus parameter (CU):

CU number	Scheme name
0	Default, None
1	Kain-Fritsch new Eta
2	Betts Miller Janjic
3	Grell Devenyi Ensemble
5	Grell 3D
6	Modified Tiedtke

- Microphysics (MP):

MP number	Scheme name
0	Default, None
1	Kessler
4	WSM 5-class
5	Ferrier new Eta
6	WSM 6-class graupel

- Planetary Boundary Layer (PBL):

PBL number	Scheme Name
0	Default, None
1	YSU
5	MYNN 2.5 level TKE

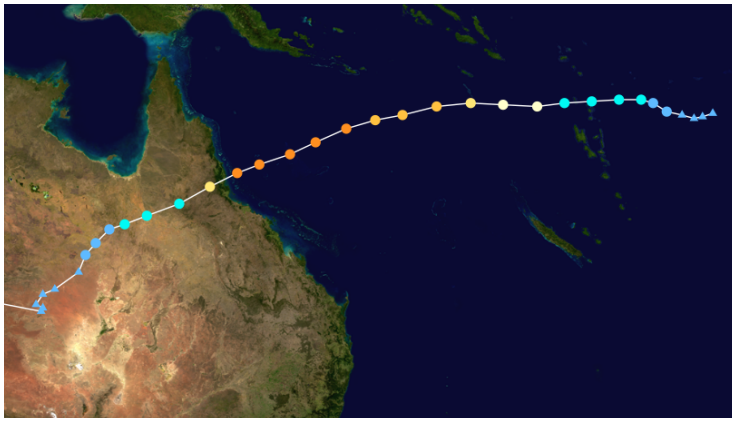
- ISFTCFLX: off or with 2, Donelan Cd + Garrett scheme
- OMLCALL: off or with 50m 1D simple ocean mixed layer. (Land Surface: Thermal Diffusion Scheme)

Simulated TC Tracks

Track Colour key:
Black = Cu = 0 None
Green: Cu = 1 K-F
Yellow: Cu=2 BMJ
Cyan: Cu = 3 G-D
Blue: Cu=5 Grell 3D
Red: Cu=6 Tiedtke

Runs with CU 6 cluster the most throughout the whole simulation even after landfall and get the closest to the correct landfall location.

Runs with CU 1 show the most southerly motion of the track and the greatest deviation from the landfall location.



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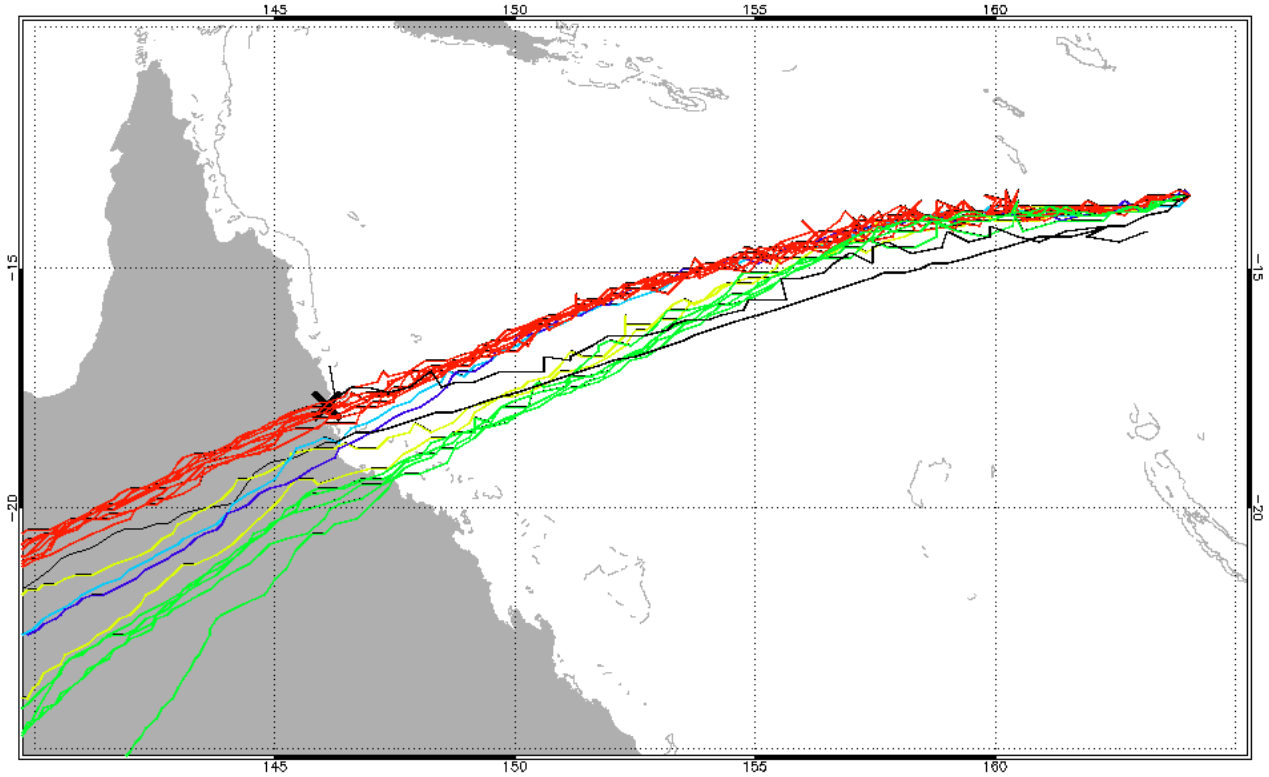
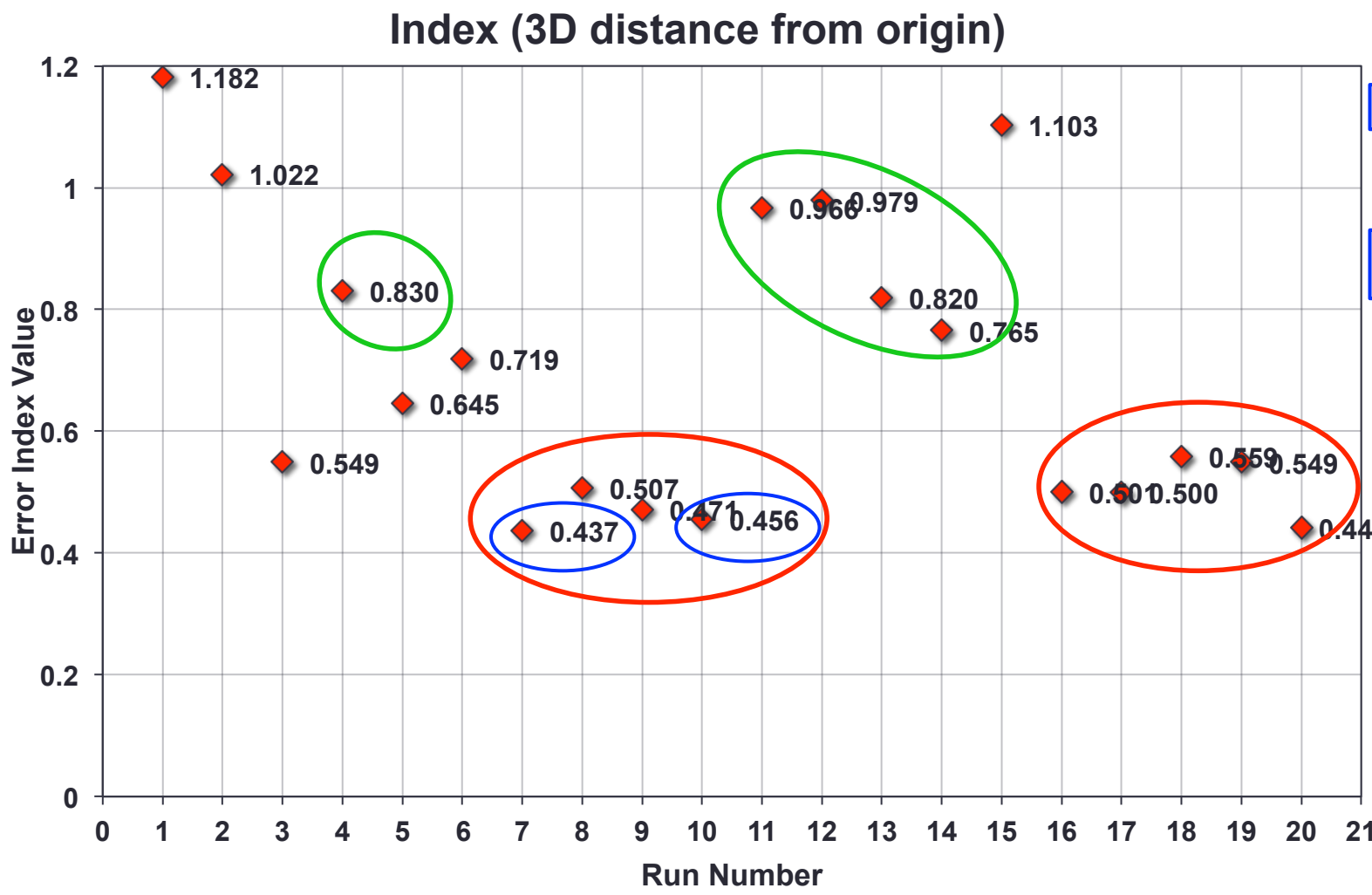


Normalised Root-Mean-Square Error Index:

Landfall location, timing and central pressure



1) ERA Default
2) ERABOM Default
3) CU2MP4PBL1
4) CU1MP5PBL1
5) CU3MP5PBL1
6) CU5MP5PBL1
7) CU6MP5PBL1
8) CU6MP6PBL1
9) CU6MP6PBL1 ISFLX
10) CU6MP6PBL1 ISFLX OML
11) CU1MP6PBL1
12) CU1MP6PBL1 ISFLX
13) CU1MP6PBL1 ISFLX OML
14) CU1MP6PBL5 ISFLX OML
15) CU2MP1PBL1 ISFLX OML
16) CU6MP5PBL1 ISFLX
17) CU6MP5PBL1 ISFLX
18) CU6MP5PBL5 ISFLX OML
19) CU6MP6PBL5 ISFLX OML
20) CU6MP4PBL1

Statistical ANOVA test

- All the components account for ~76% of variance in the calculated error index and this is statistically significant.
- Variance in CU parameter individually is statistically significant in predicting the error index variance.
- Changing MP parameter also individually affects the variance of the error index but to a lesser significance.
- None of the other physics parameters have a statistically significant relationship with predicting the error index individually.

Coefficients:

	Estimate	Std.Error	t value	Pr(>|t|)	
(Intercept)	1.103	0.071	15.600	3.02e-10	***
YASI$CU	-0.074	0.012	-6.150	2.52e-05	***
YASI$MP	-0.037	0.017	-2.192	0.046	*
YASI$PBL	-0.002	0.024	-0.089	0.930	
YASI$ISFLX	0.082	0.082	0.999	0.335	
YASI$OML	-0.017	0.093	-0.187	0.854	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

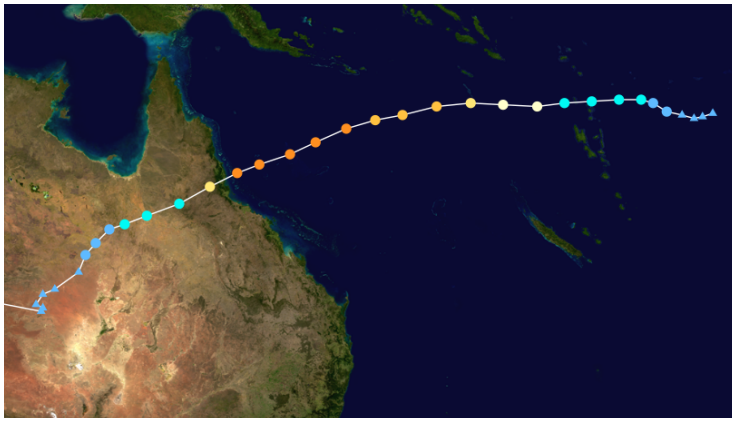
Residual standard error: 0.1181 on 14 degrees of freedom

Multiple R-squared: 0.8251, Adjusted R-squared: 0.7626

F-statistic: 13.21 on 5 and 14 DF, p-value: 6.947e-05

SLP and Track

- CU 1 K-F more accurate minimum sea level pressure (SLP) values and evolution of values and therefore intensity.
- CU 6 Tiedtke more accurate track evolution and landfall location.
- For almost all runs, the minimum in SLP occurs over the open ocean around 08:00 1st Feb 2011 UTC which is too early and then weaken towards landfall.



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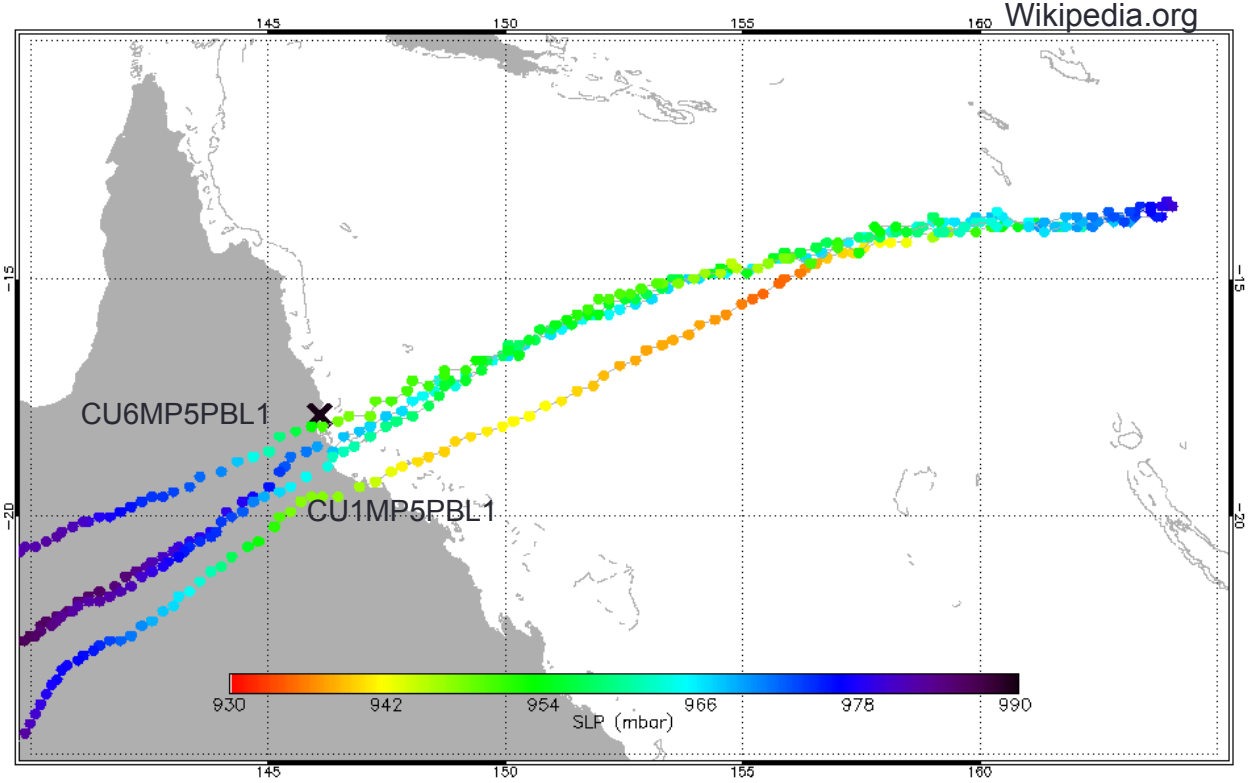
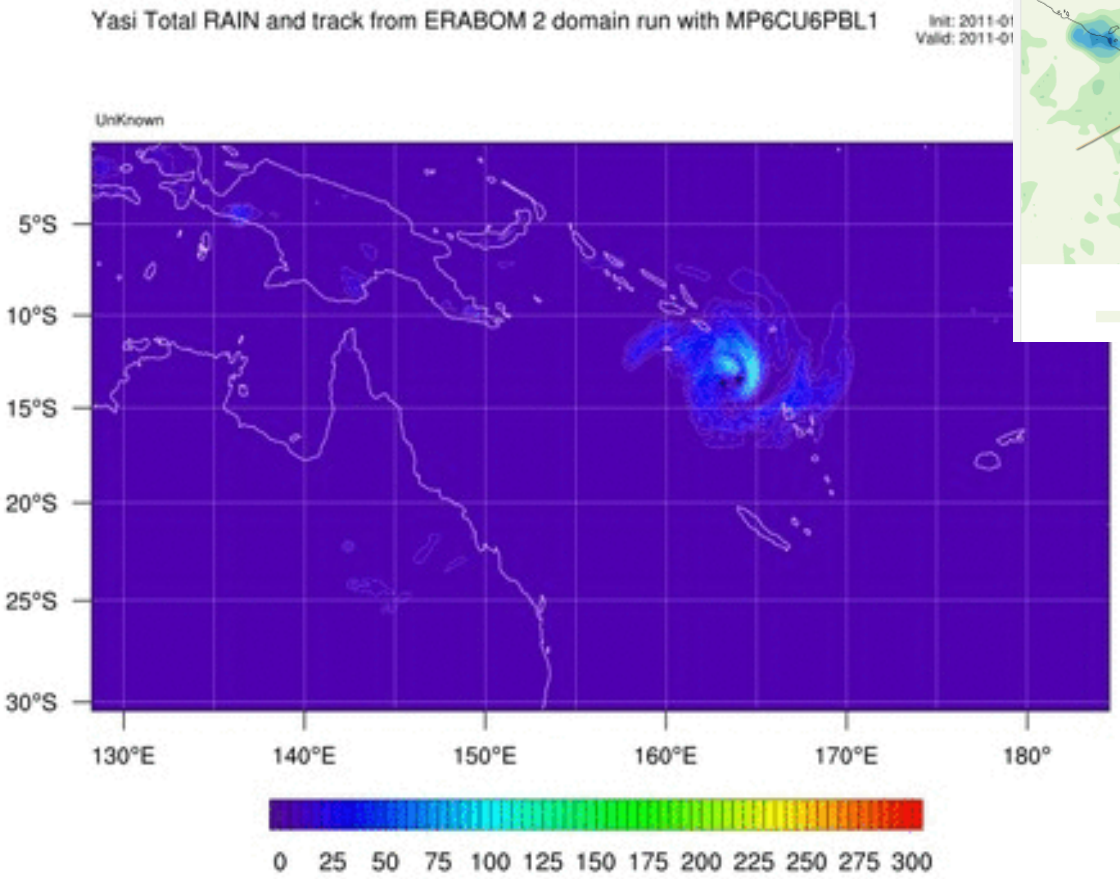
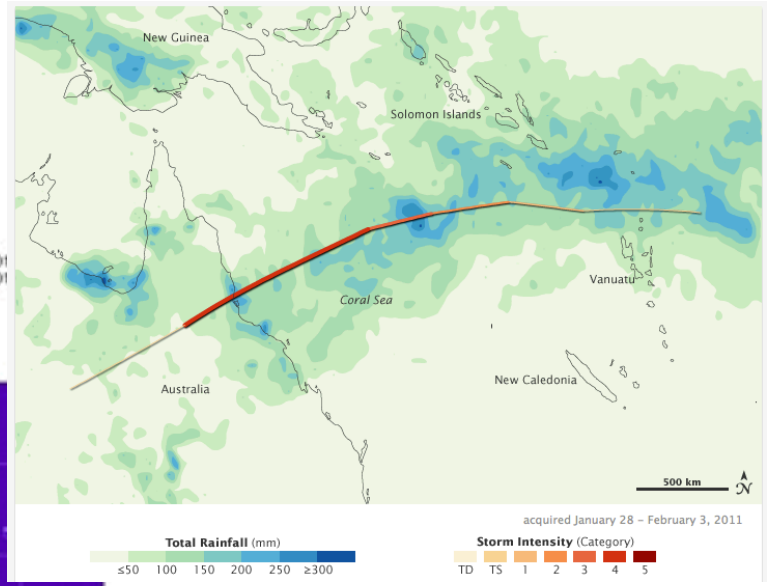


WRF Output: Total Accumulated Precipitation, Tiedtke-WSM 6-YSU





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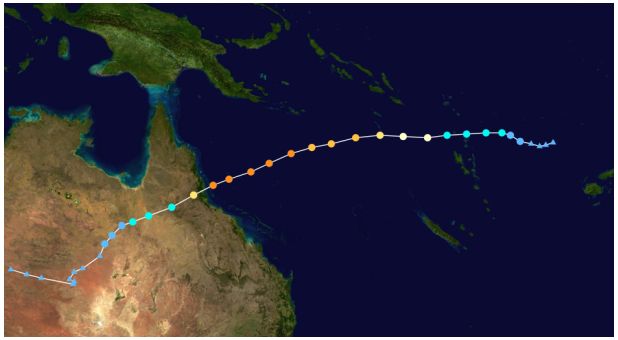
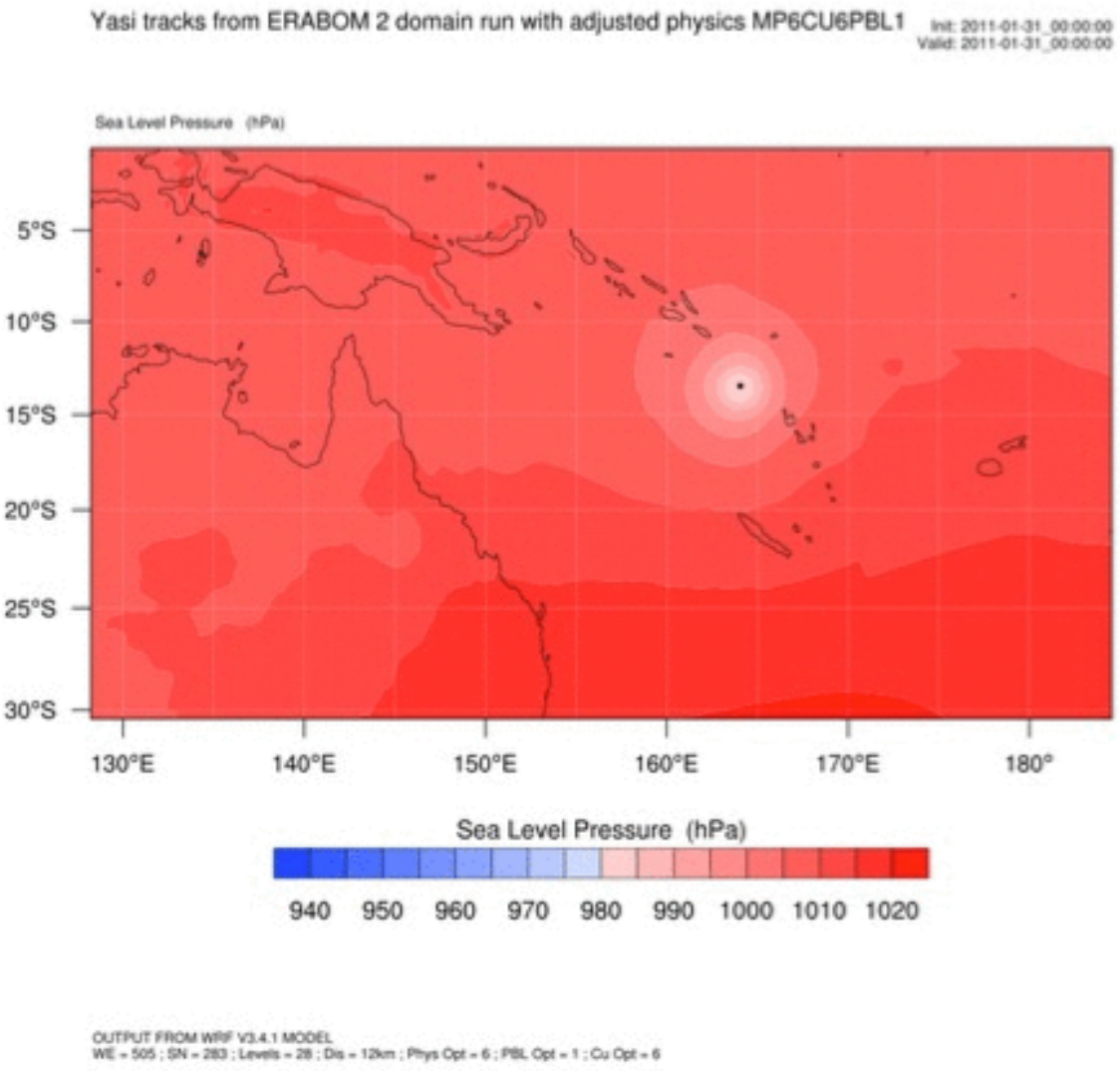
WRF output: Sea Level pressure and track, Tiedtke-WSM 6-YSU





Conclusions

- Prescribing physics parameters key in improving the accuracy of the simulated TC Yasi and reducing the calculated error.
- Cumulus parameter had the biggest effect on altering the produced TC and the calculated error index by affecting the pressure, timing and location of the TC throughout the lifecycle and especially at landfall.
- Kain-Fritsch scheme produces a closest to accurate simulation of pressure and landfall timing but the greatest deviation of distance. Modified Tiedtke scheme produces the most accurate track.
- 'Best' simulations according to the error index use Modified Tiedtke-Ferrier-YSU or when implementing ISFTCFLX and OML then Modified Tiedtke-WSM6-YSU
- Still problems with TC life cycle simulation even in these 'best' cases.
- Still more schemes to test such as Thompson MP scheme and other PBL schemes and other output parameters and differences to consider.

Acknowledgements

- Amanda Lynch, Masha Tsukernik, Henry Johnson (Brown University).
- Todd Arbetter (CRREL)
- Noel Davidson (Bureau of Meteorology, Australia)

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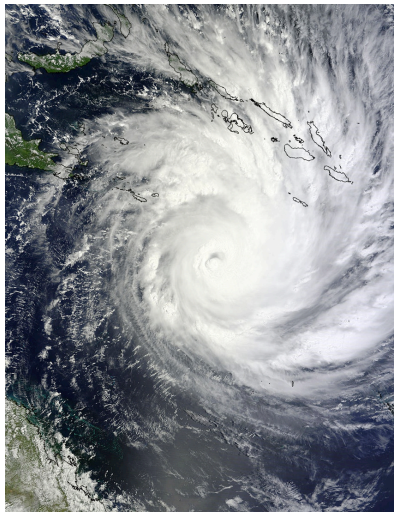
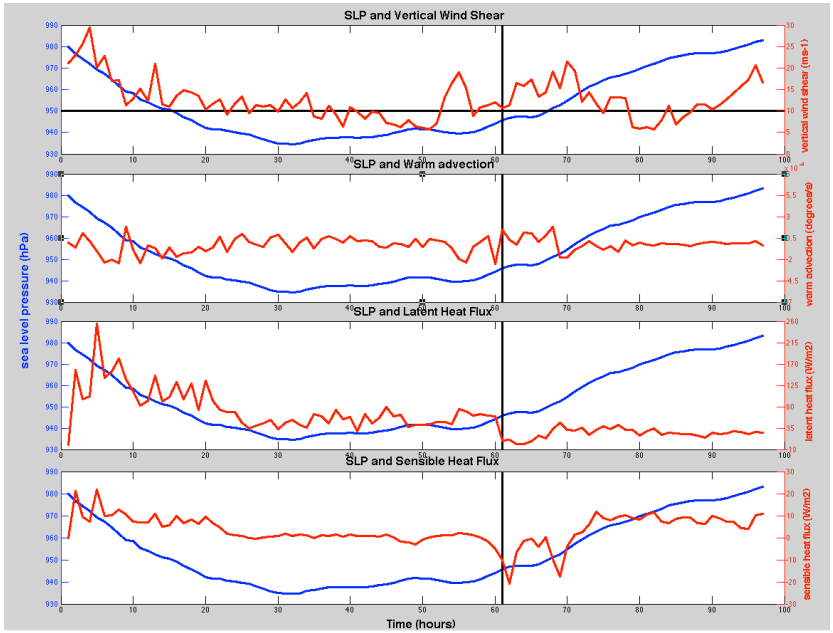
Thank You!

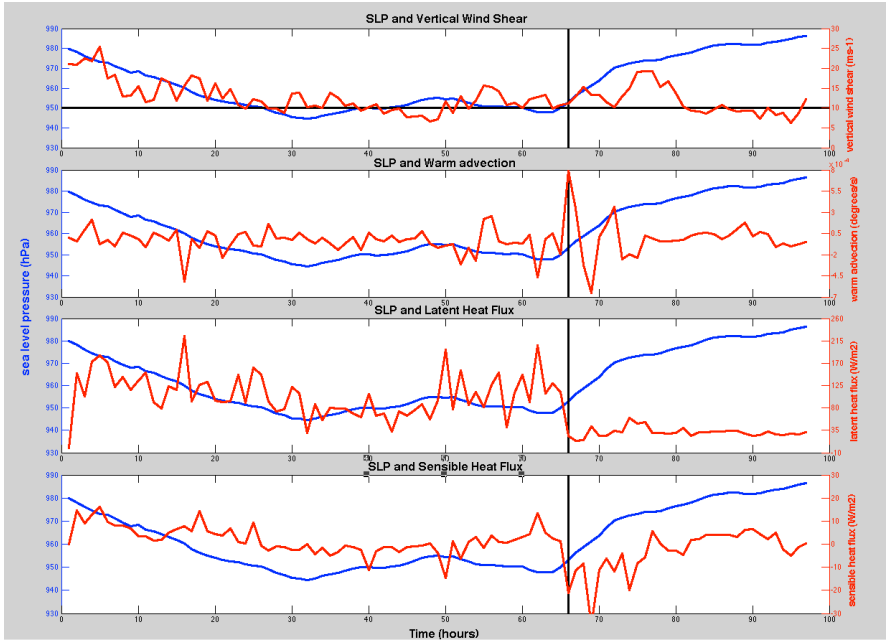


Wind Shear, Warm Advection, Latent and Sensible Heat Fluxes

CU1 MP5 PBL1



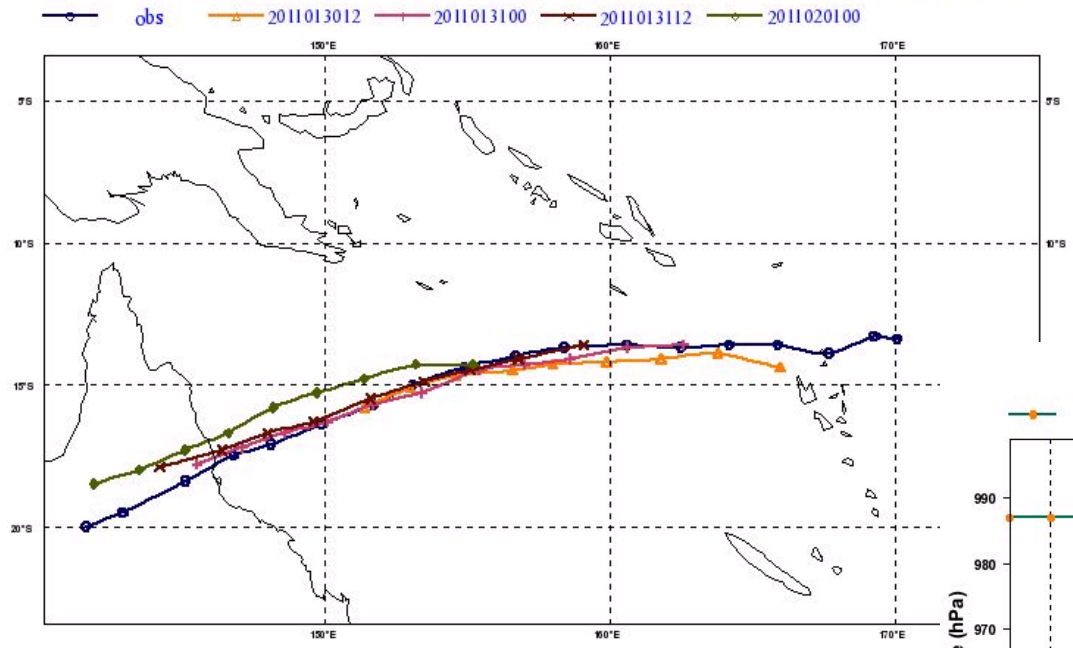
CU6 MP5 PBL1

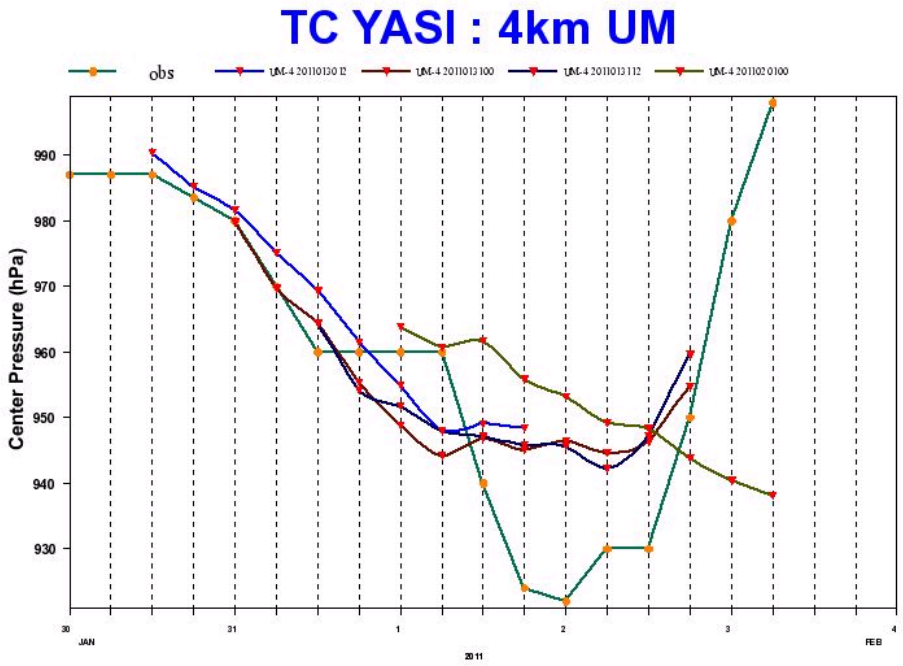


Next Steps

- Also consider size and wind fields in skill score.
- Further analyse the output from the physics trials particularly for wind shear, warm advection, latent and sensible heat.
- Choose the most appropriate simulation and its physics combination to move forward.
- Add a high resolution sea surface temperature (SST) field in to the WRF simulation to see how TC Yasi changes.
- Further test the TC's sensitivity to SST by manually altering the SST magnitudes and gradients across the western South Pacific in the vicinity of Yasi's track.
- ROMS? COAWST?

Illustrative Example: TC YASI Forecast and Observed Tracks and Intensities from ACCESS-TC at 4km resolution





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