

The Response of Tropical Cyclone Characteristics to Projected Climate Change through WRF simulations and Pseudo Global Warming Technique

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BROWN

17th Annual WRF Users' Workshop

Regional Climate

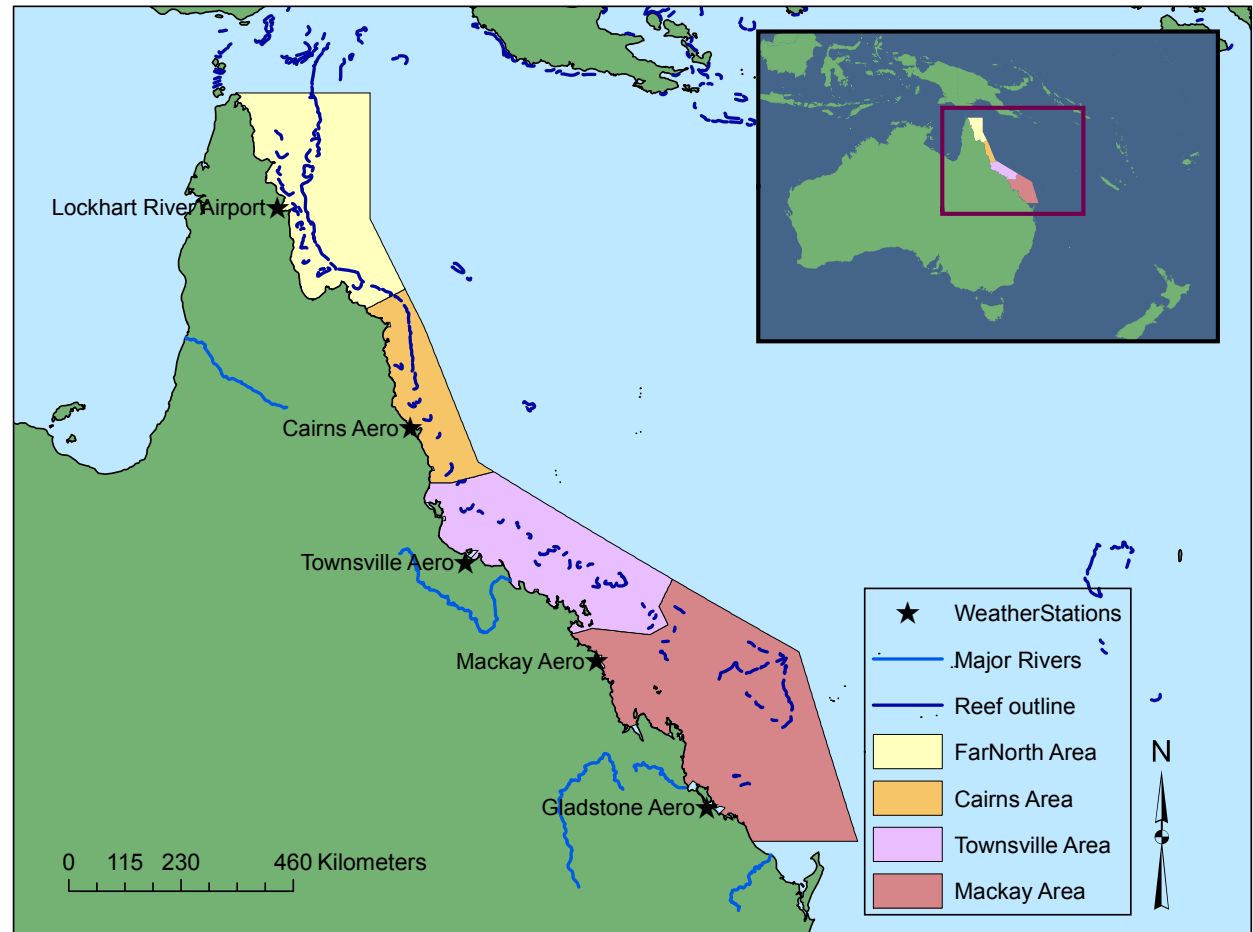
Wednesday 29th June 2016

Study Area and Motivation: The Great Barrier Reef

The world's largest coral reef ecosystem.

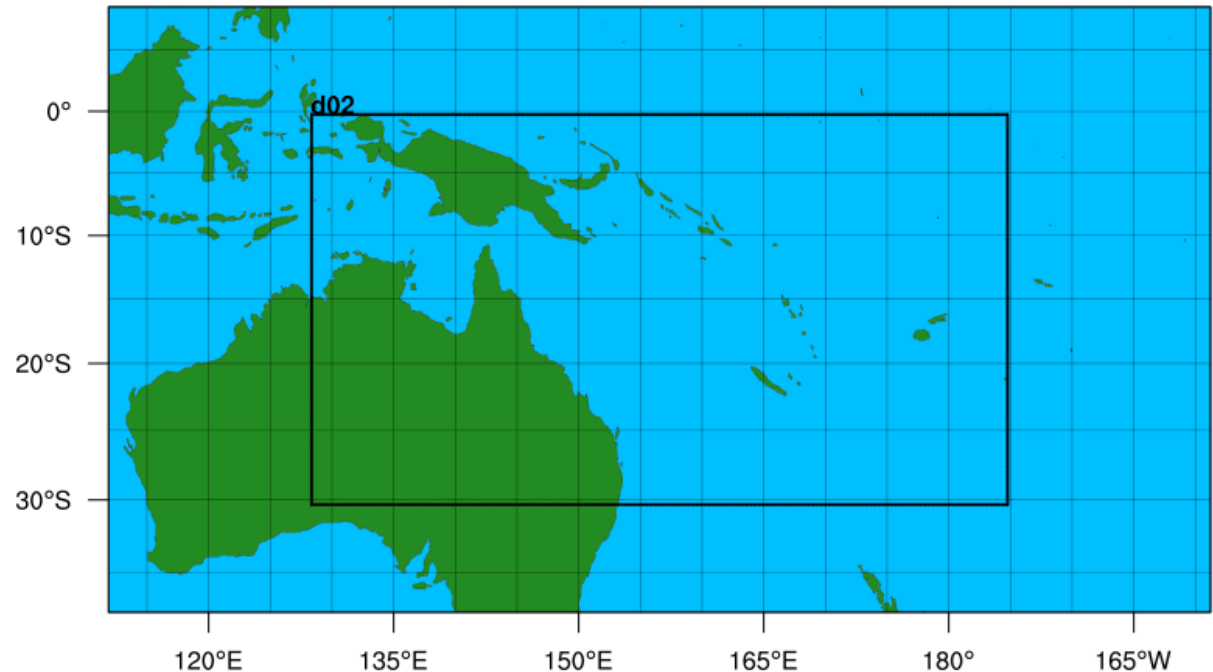
Area of 350,000 km², extending >2,300 km along Australia's northeast coast.

Ecosystem services generate \$5.7 billion AUD and 69,000 full time equivalent jobs annually



Experimental Design: WRF

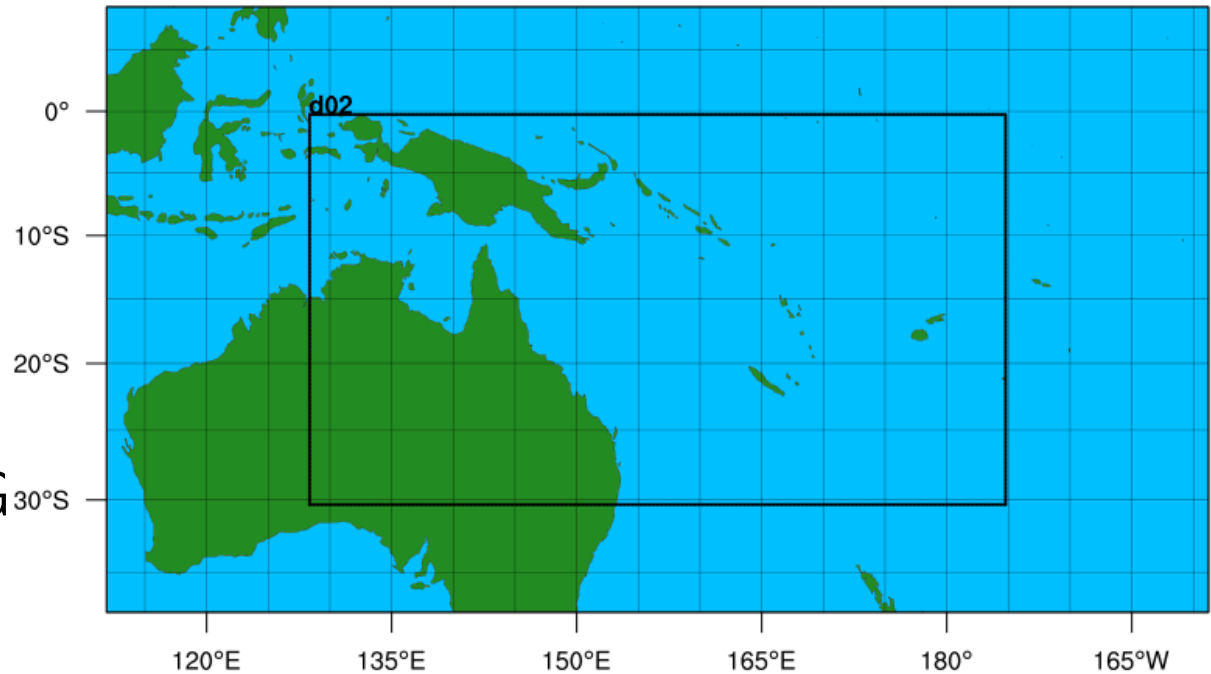
- WRF v 3.4.1
- 2 Domains
- Horizontal Grid Spacing: 36/12km
- Vertical Levels: 36 levels
- Simulation length: 3-5 days
- ERA-I data for boundary conditions
- 4km Initial Conditions provided by Australian Bureau of Meteorology ACCESS-TC



Initialization Data: courtesy of Noel Davidson,
Bureau of Meteorology, Australia

Experimental Design: WRF

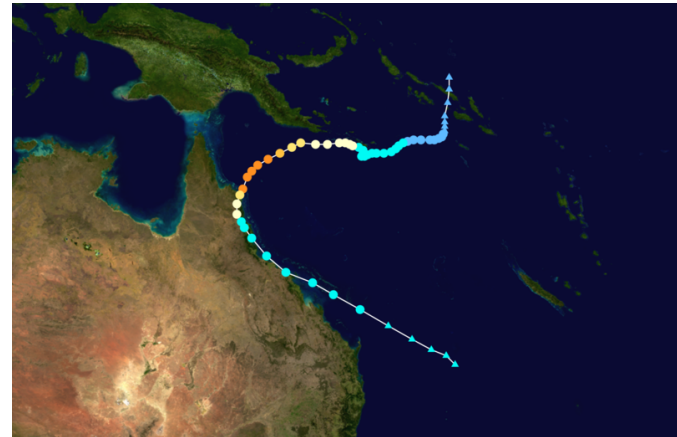
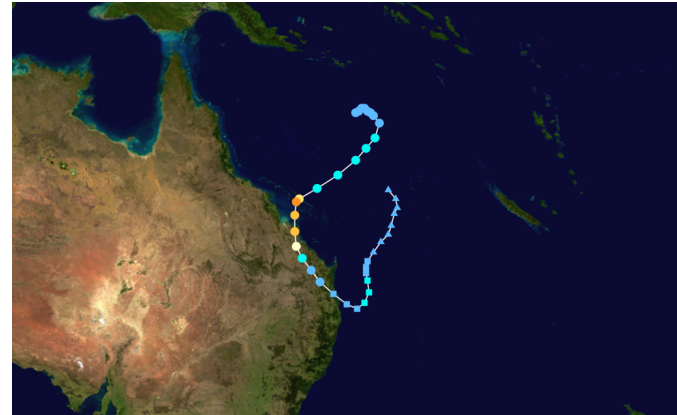
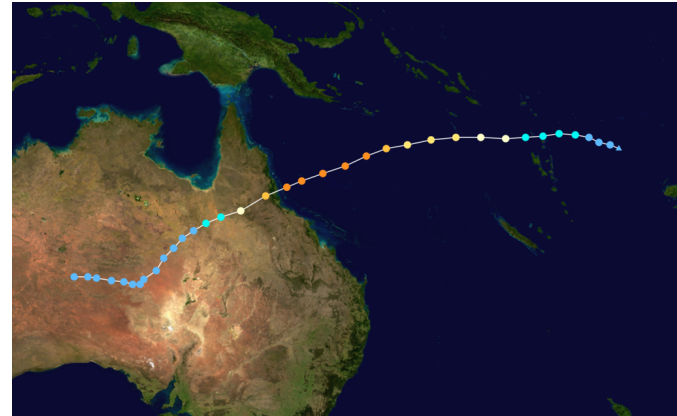
- Sfclay: Monin Obukhov Scheme
- Surface: Unified Noah LSM
- MP: Ferrier Scheme
- PBL: YSU Scheme
- SW/LW Radiation: RRTMG
- SST Update: OFF
- CU: Kain Fritsch and Tiedtke
- Digital Filter Initialization



Initialization Data: courtesy of Noel Davidson,
Bureau of Meteorology, Australia

Experimental Design: Case Studies

- Yasi, January 2011:
 - Lowest Pressure: 929hPa
 - Maximum wind speed: 135knots
 - Landfall: 3rd February
- Marcia, February 2015:
 - Maximum intensity: 930hPa
 - Maximum wind speed: 116knots
 - Landfall: 20th February
- Ita, April 2014:
 - Maximum intensity: 930hPa
 - Maximum wind speed: 140knots
 - Landfall: 12th April



Methodology: Pseudo Global Warming Technique

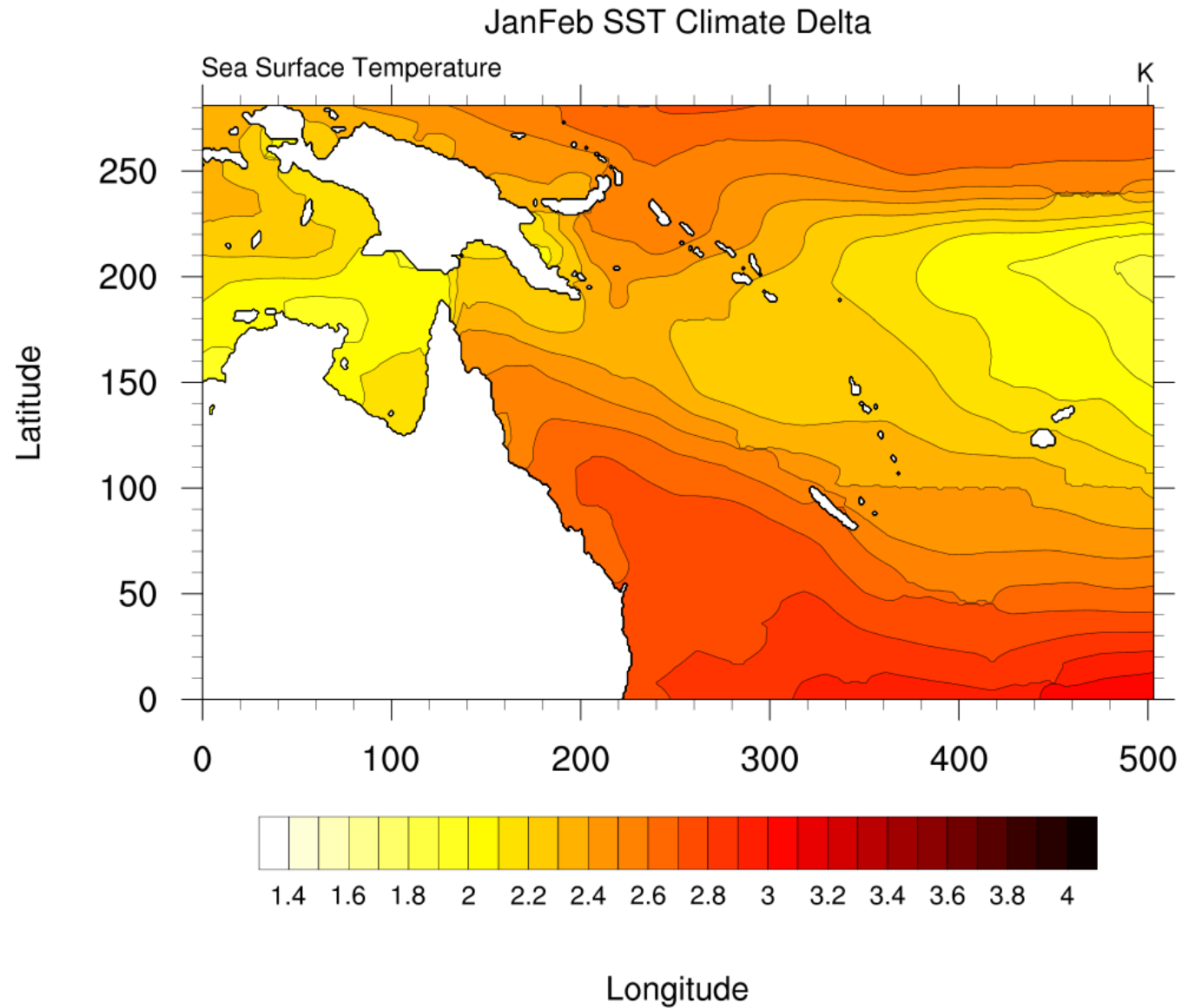
Climate Scenario	Boundary Conditions	CO ₂ Concentration (ppm)
Current	ERA-Interim	379
Future	ERA-Interim + ΔCC	935

1. Climate Change Delta (ΔCC) = CESM 2071-2100 – CESM 1976-2005
2. CESM 2071-2100 = monthly average RCP 8.5 scenario
3. CESM 1976-2005 = monthly average 20th Century simulations

Methodology: Pseudo Global Warming Technique

Δ CC to 3D Fields	Δ CC to 2D Fields
Temperature	Sea Surface Temperature
Relative Humidity	Skin Temperature
U, V Winds	Soil Moisture
Pressure	Soil Temperature
Geopotential Height	Surface Pressure
	Sea Level Pressure

Climate Change Delta: SST



Climate Change Delta: Environmental Profile

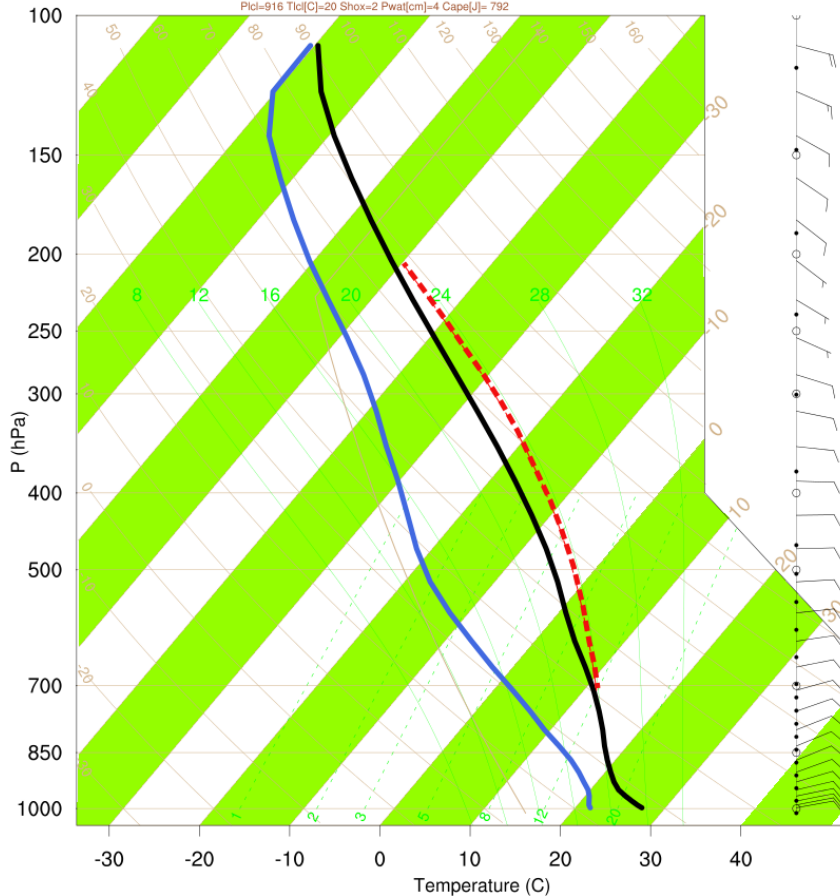
CAPE: Current: 792J, Future: 1164J

CIN: smaller

Warmer and more moist

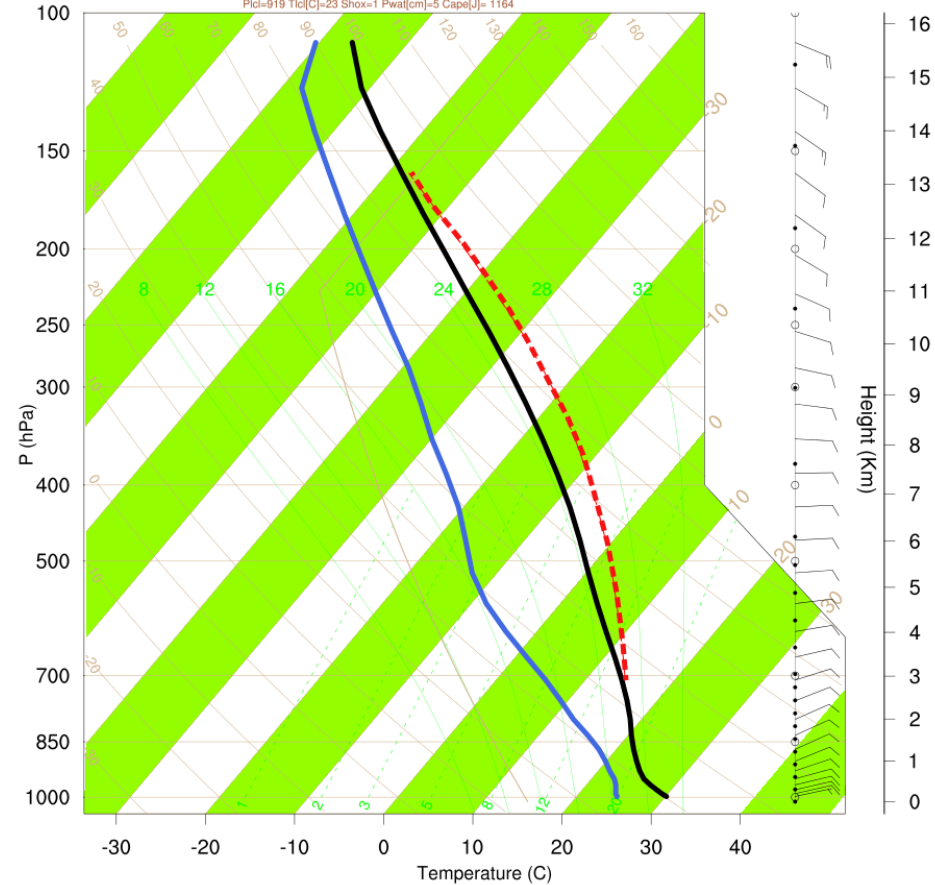
Yasi Current Environment Skew T, ts0

Ptcl=916 Tlcl[C]=20 Shox=2 Pwat[cm]=4 Cape[J]=792



Yasi Future Environment Skew T, ts0

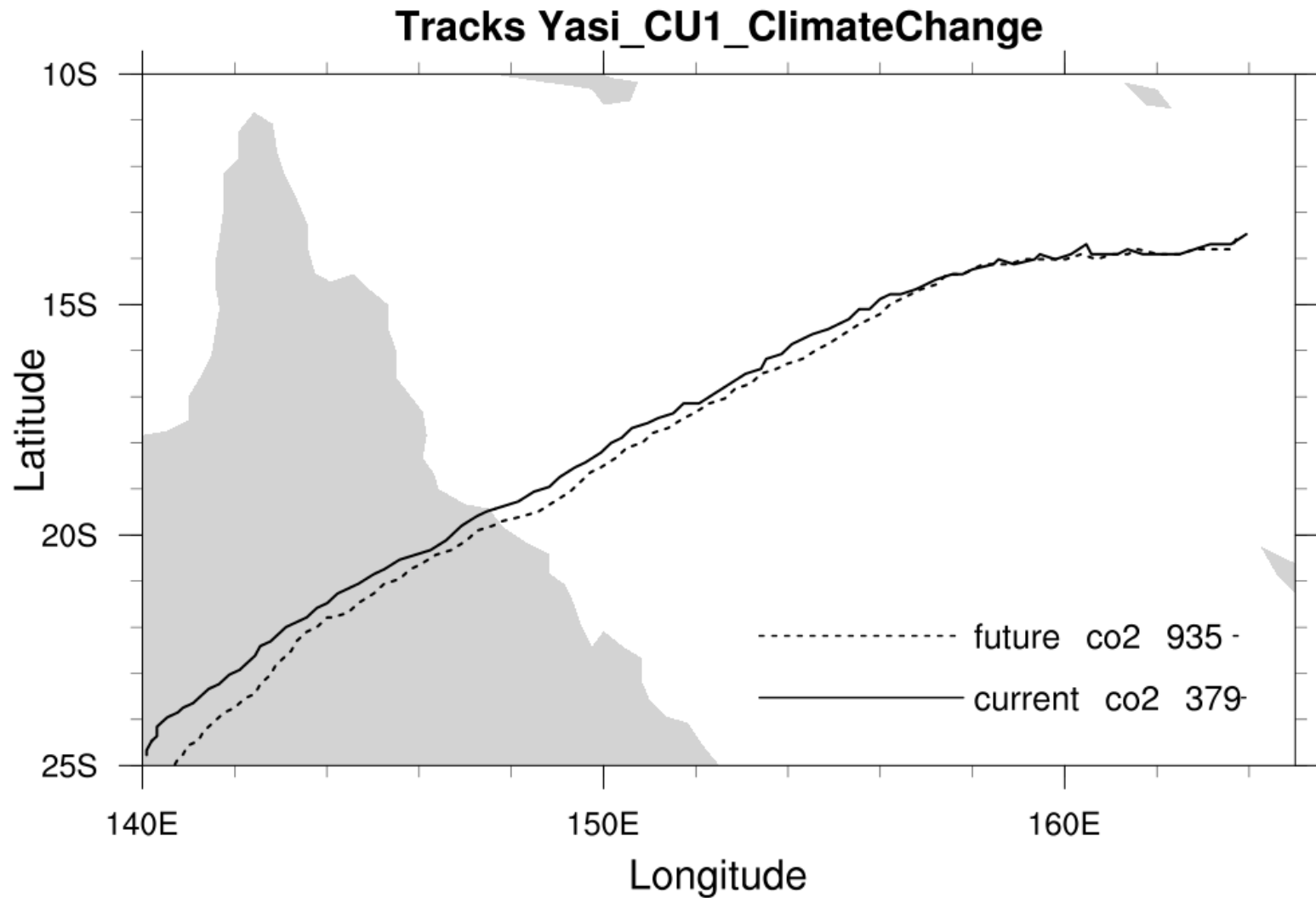
Ptcl=919 Tlcl[C]=23 Shox=1 Pwat[cm]=5 Cape[J]=1164



Results

Response of case studies to ΔCC

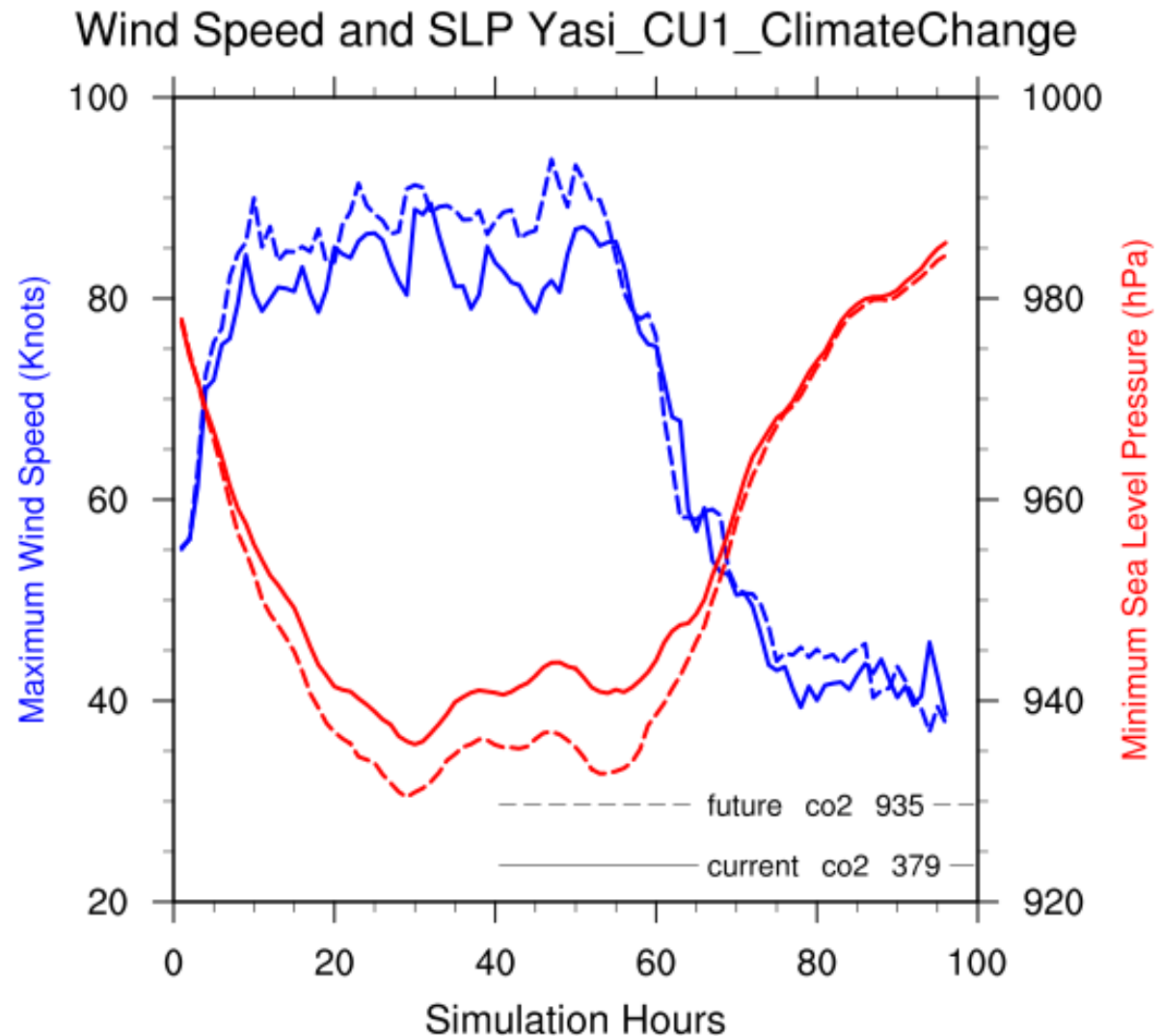
Results: Yasi Trajectories



Results: Yasi SLP, Wind Speed

Current → Future

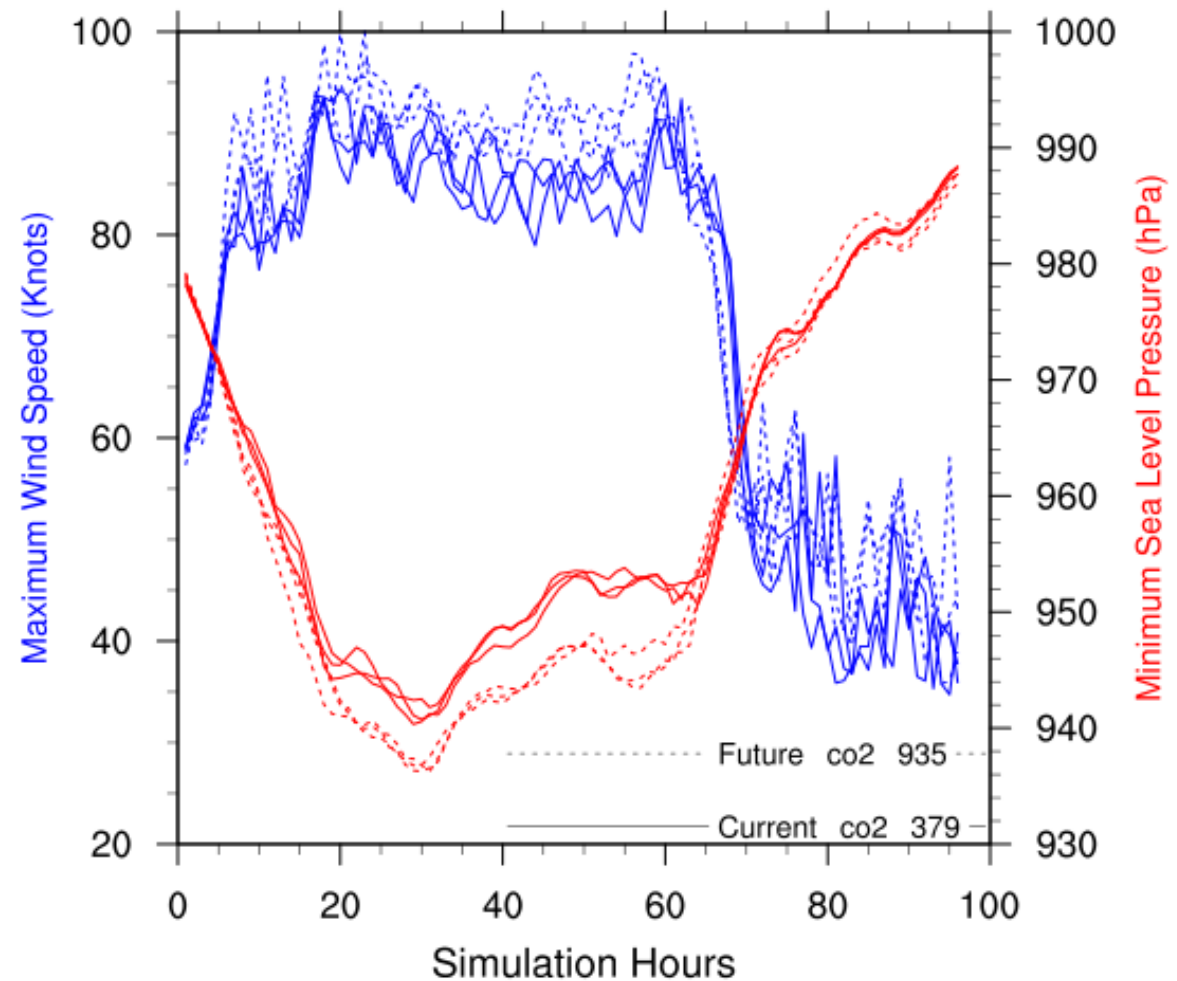
- Up to **17%** increase in max wind speed
- Decrease in central pressure to **10hPa**



Results: Model Internal Variability

Climate Scenario	DFI Initialization
Current	1 Hour
	2 Hours
	3 Hours
Future	1 Hour
	2 Hours
	3 Hours

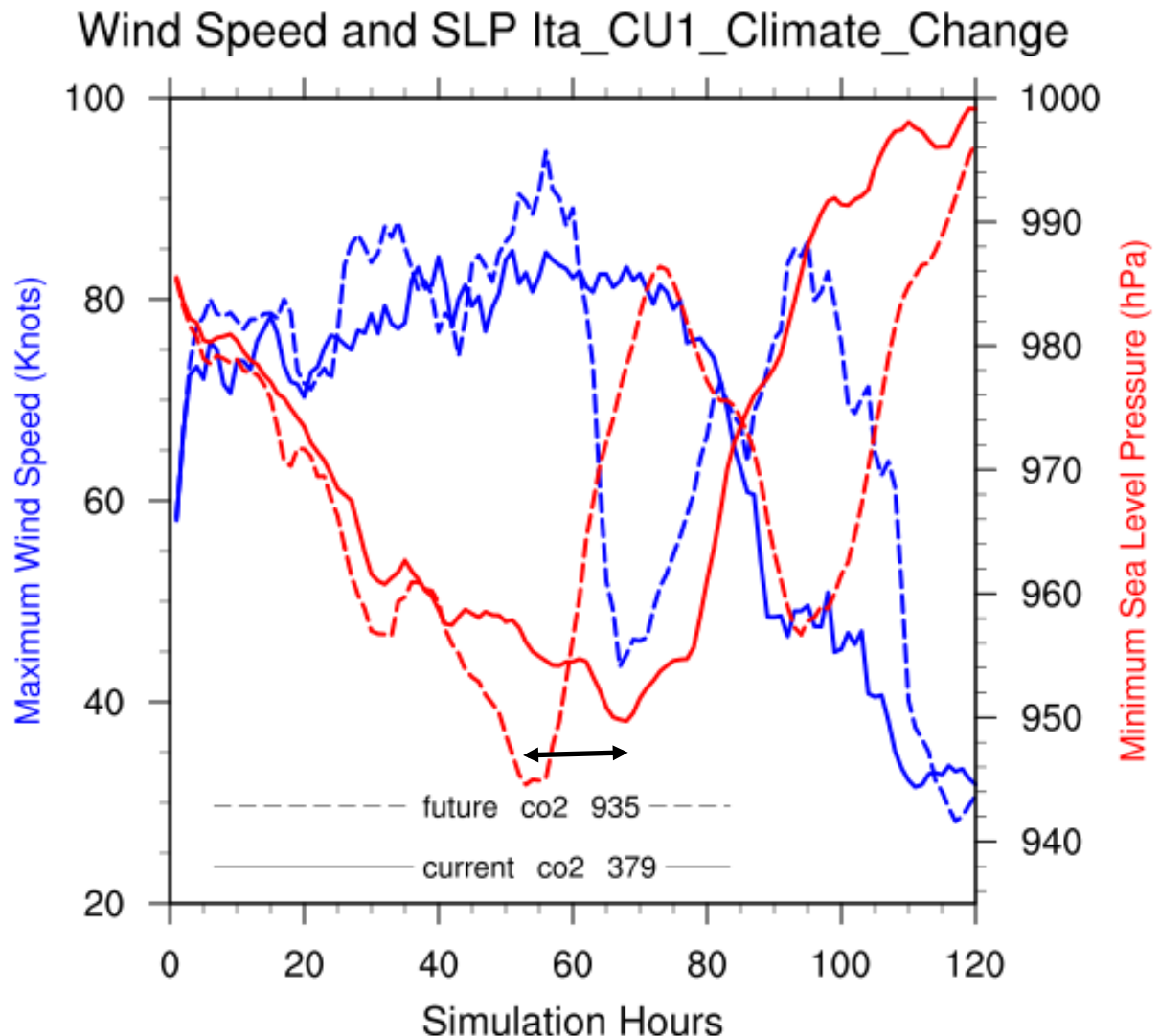
Wind Speed and SLP Yasi_InitialCondition_Ensembles



Results: Ita SLP, Wind Speed

Current → Future

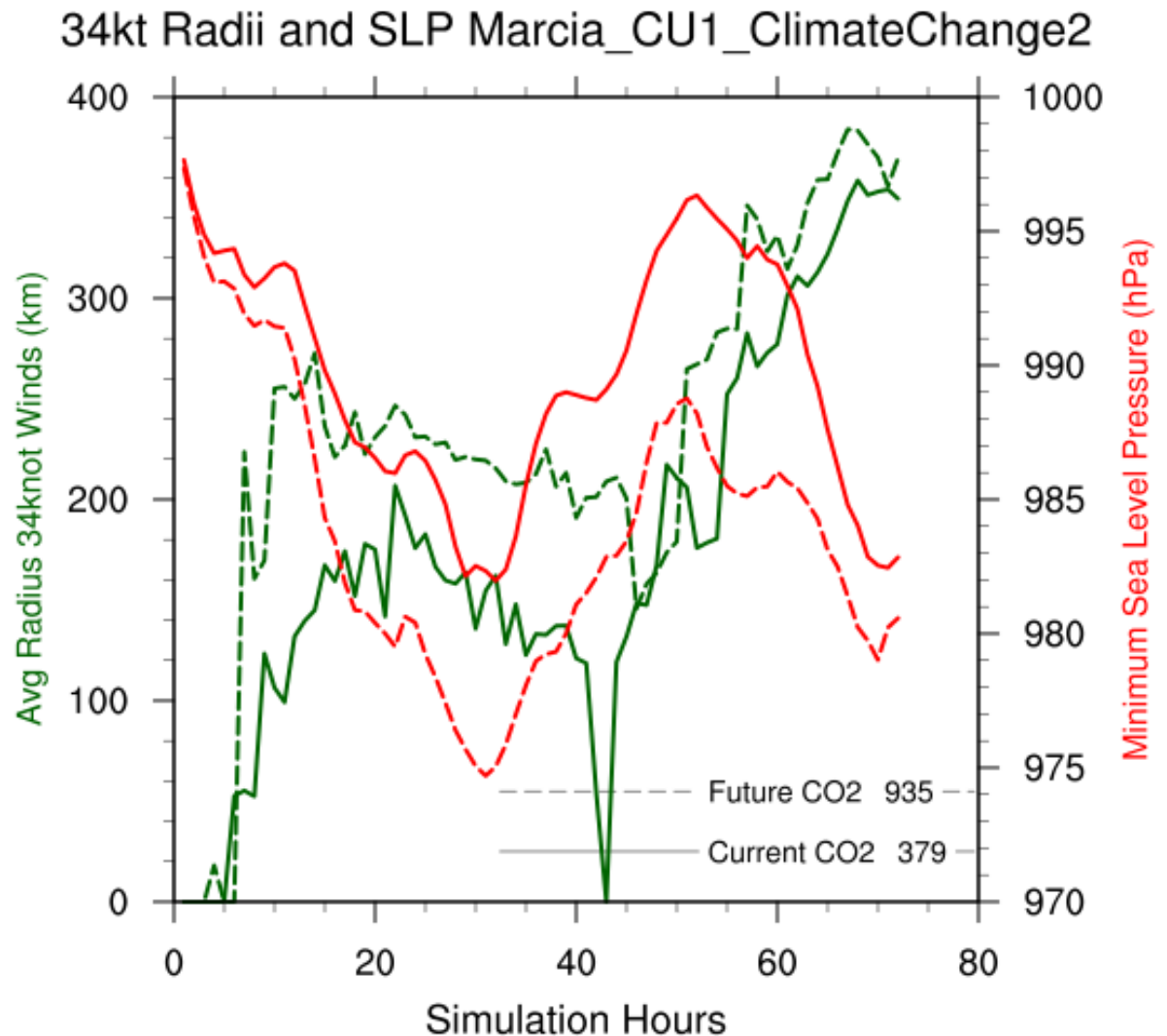
- Up to **14%** increase in max wind speed before landfall
- Decrease in central pressure to **12hPa**
- Average **25%** increase in translation speed



Results: Marcia SLP, Wind Speed, Size

Current → Future

- Decrease in central pressure to **10hPa**.
- Average **40%** increase in size.
- Up to **20%** increase in max wind speed before landfall and **30%** increase after landfall.

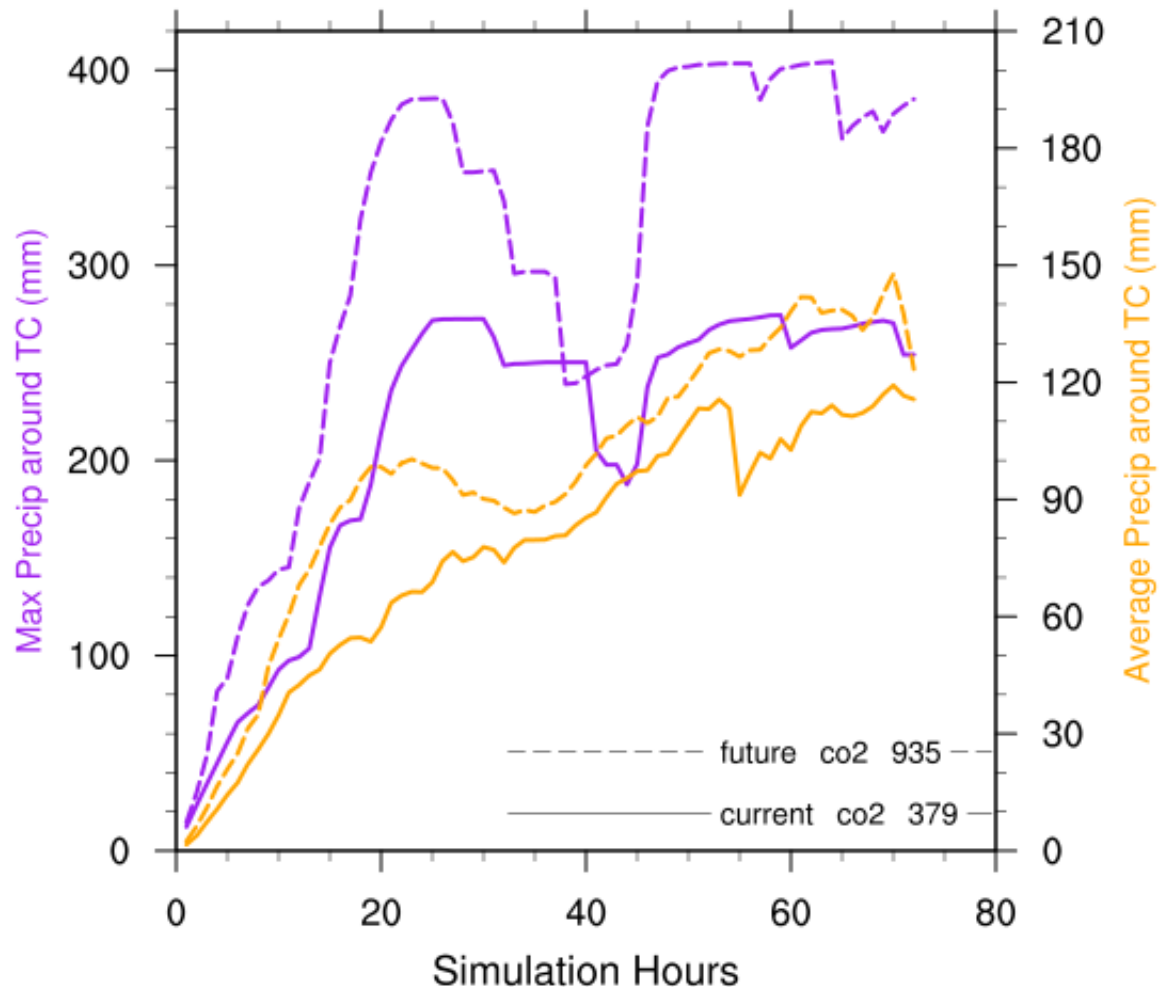


Results: Marcia Precipitation

Current → Future

- On average **32%** increase in average precipitation.
- On average **46%** increase in maximum precipitation.

Maximum and Average Precip Marcia_CU1_ClimateChange



Conclusions

- Future climate results in:
 - Central pressure decreases ~ 10 hPa.
 - Wind speed increases $\sim 15\%$, up to 30% .
 - Precipitation average increases $15-30\%$, maximum increases $15-45\%$ along the track and coastline.

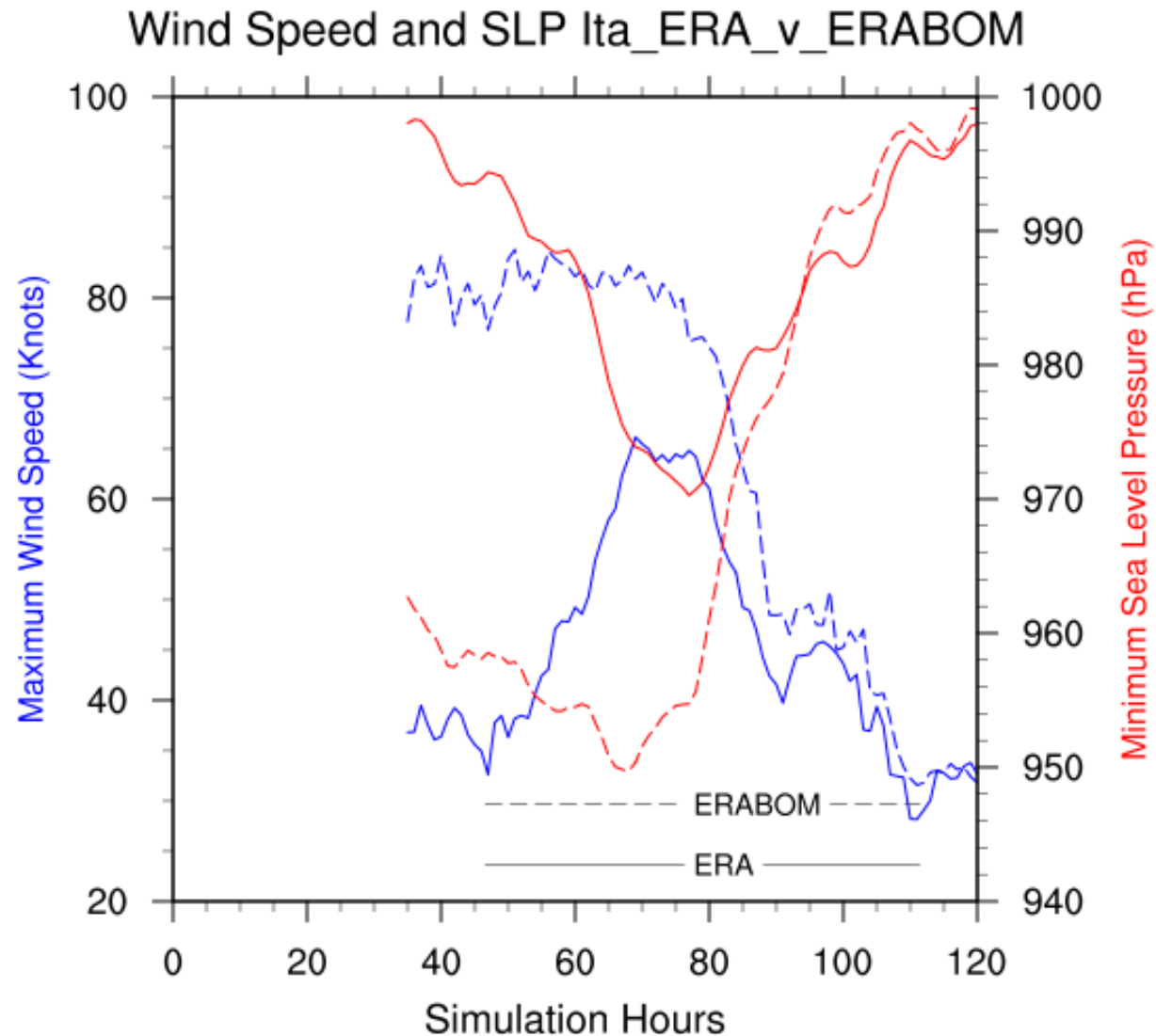
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 - The smallest, weakest storm Marcia increases in size by average 40% .
 - Ita demonstrates an average increase in translation speed of 25% .

Conclusions

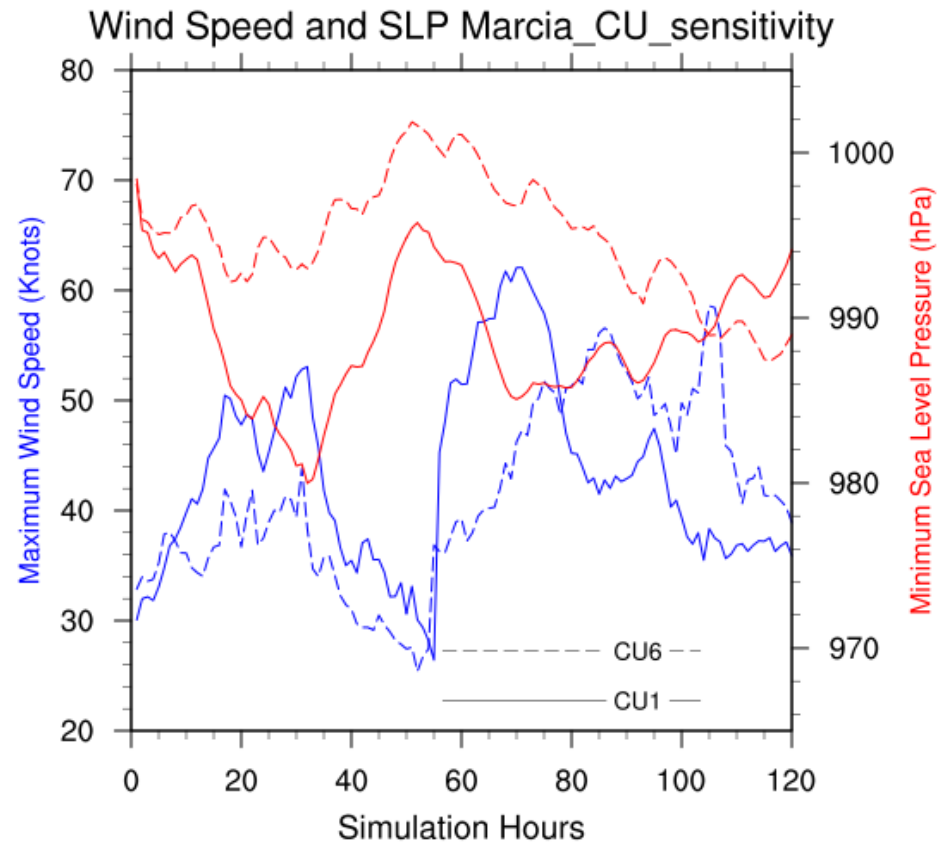
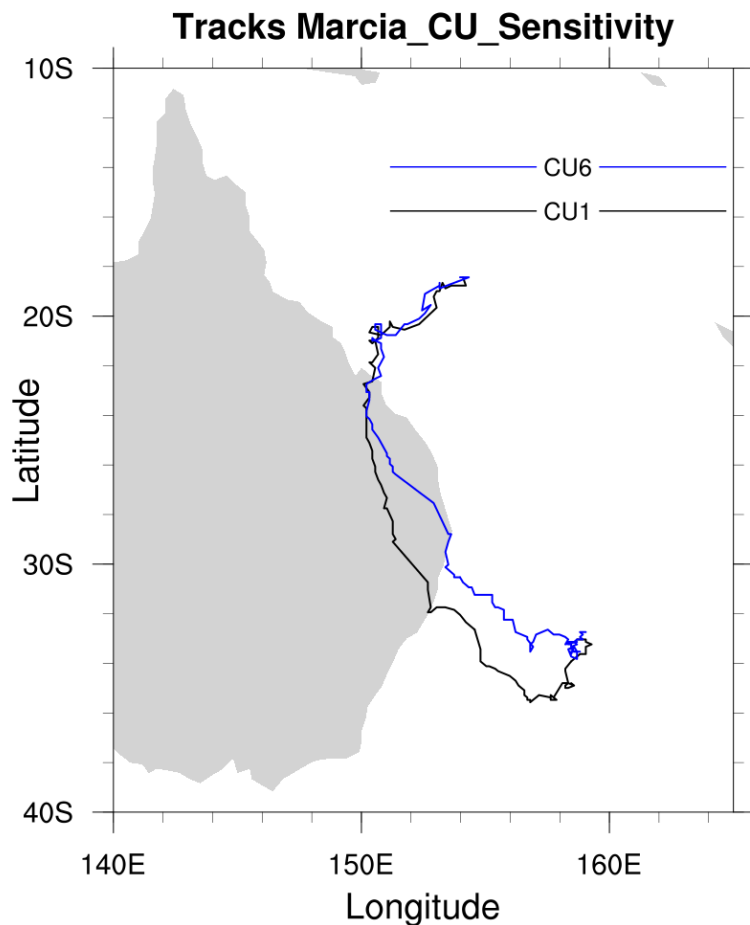
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 - The smallest, weakest storm Marcia increases in size by average 40%.
 - Ita demonstrates an average increase in translation speed of 25%.
- Cumulus schemes produce same overall change in TC characteristics with future climate, but magnitude of change can be sensitive to the scheme.

Ita: ERA-I v ERA-I BOM Initialization



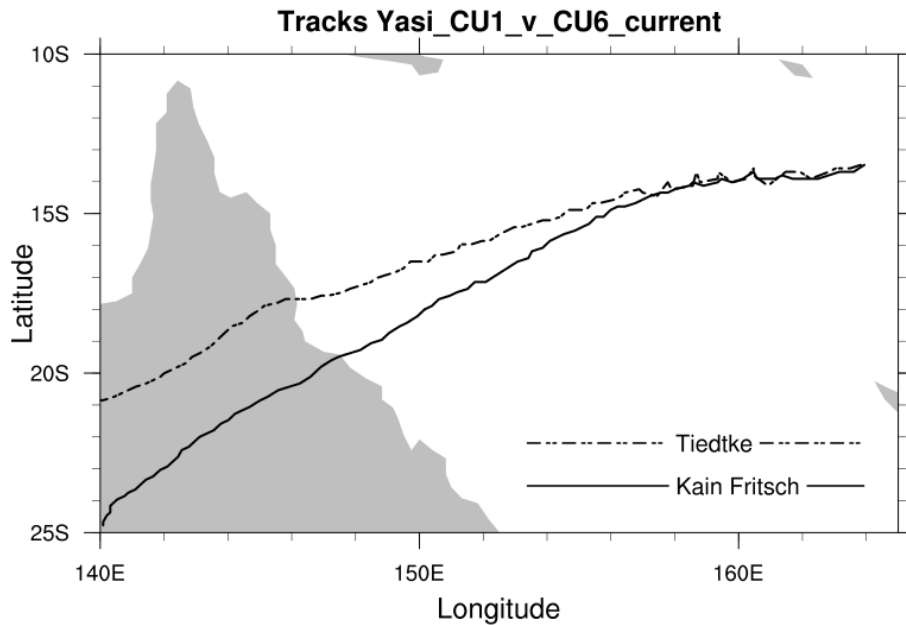
2. Results: Cumulus Sensitivity

TC Marcia 2015, track and intensity sensitivity to Kain Fritsch vs Tiedtke CU scheme



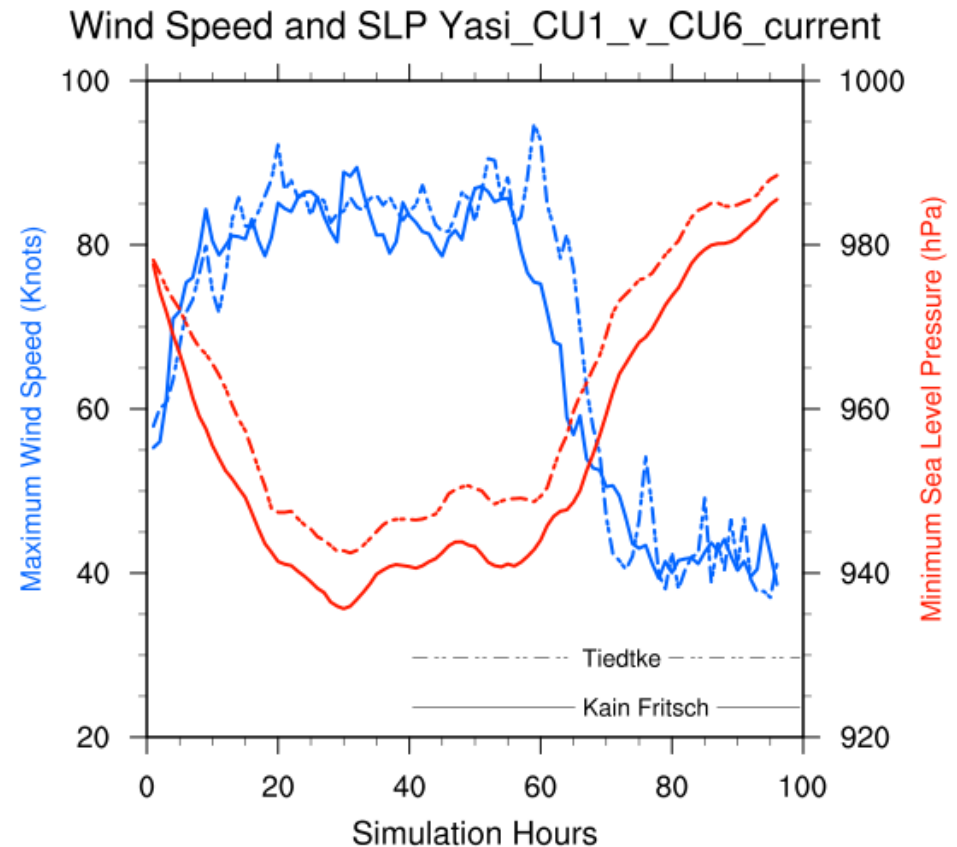
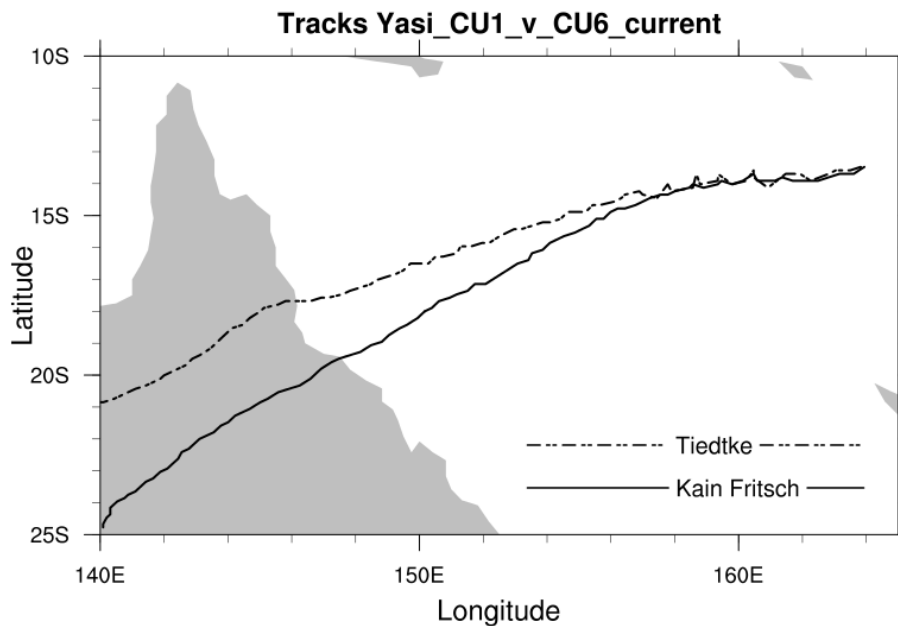
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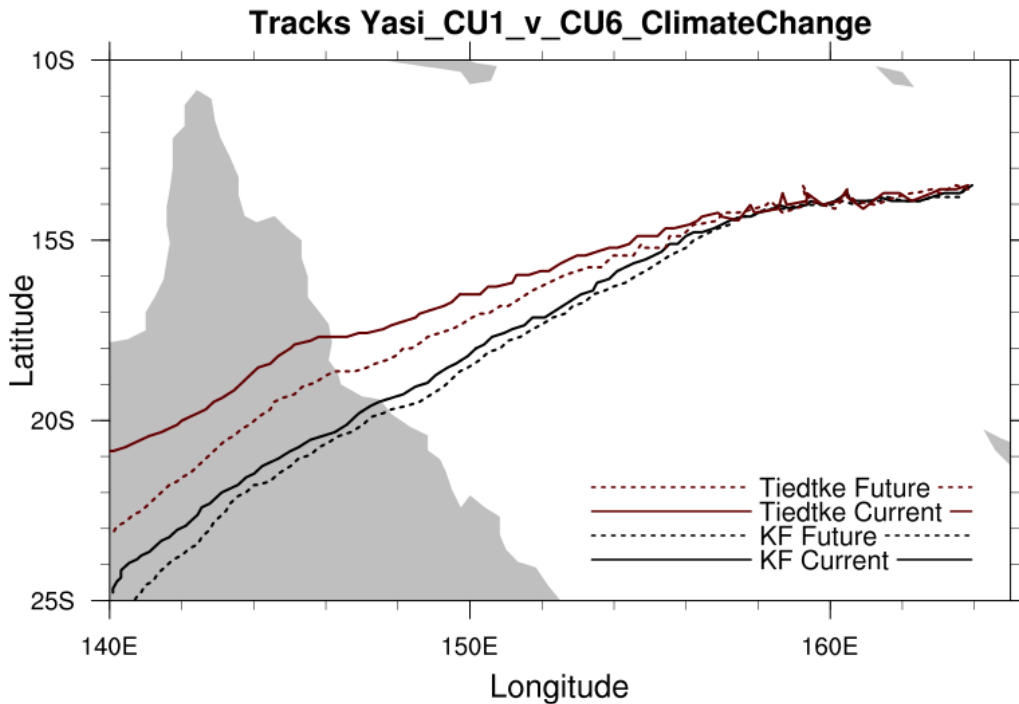
2. Results: Cumulus Sensitivity

TC Yasi 2011, track and intensity sensitivity to Kain Fritsch vs Tiedtke CU scheme



3. Results: Future Projection Sensitivity to Cumulus

TC Yasi 2011, future track and intensity sensitivity to Kain Fritsch vs Tiedtke CU scheme



Current → Future

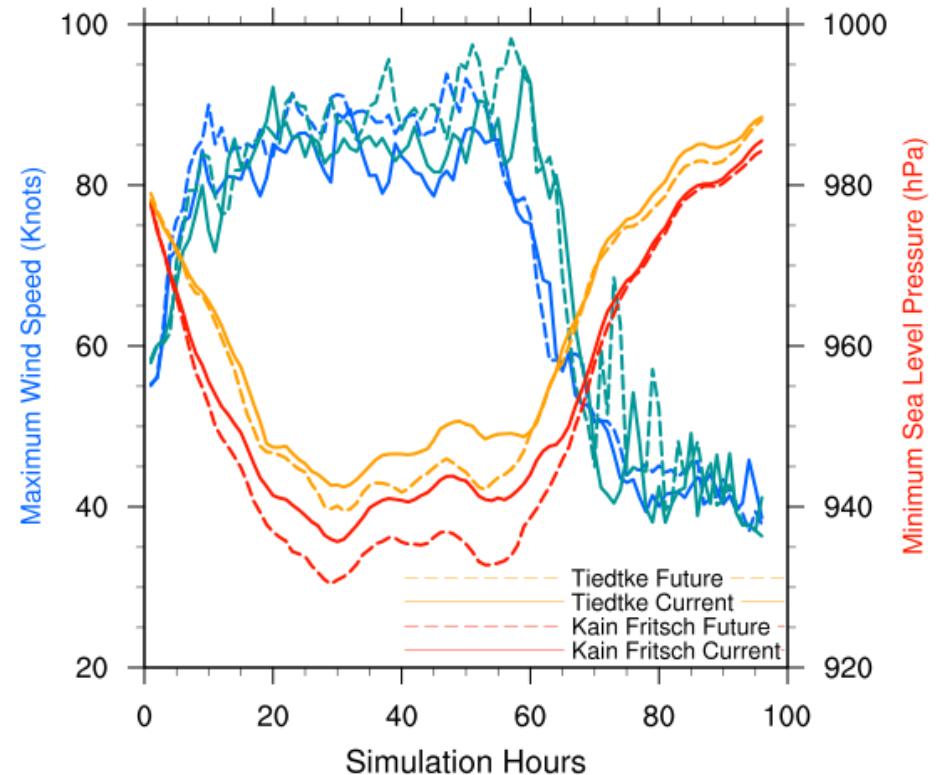
- Similar overall trends.
- Tiedtke scheme: further poleward shift in trajectory.

3. Results: Future Projection Sensitivity to Cumulus

TC Yasi 2011, future track and intensity sensitivity to Kain Fritsch vs Tiedtke CU scheme

Change in Characteristic	Kain Fritsch	Tiedtke
Max SLP (hPa)	-8.14	-6.73
Max % change wind speed	4.24	1.76
Mean % change avg precip	14.33	24.71
Mean % change max precip	16.07	15.32

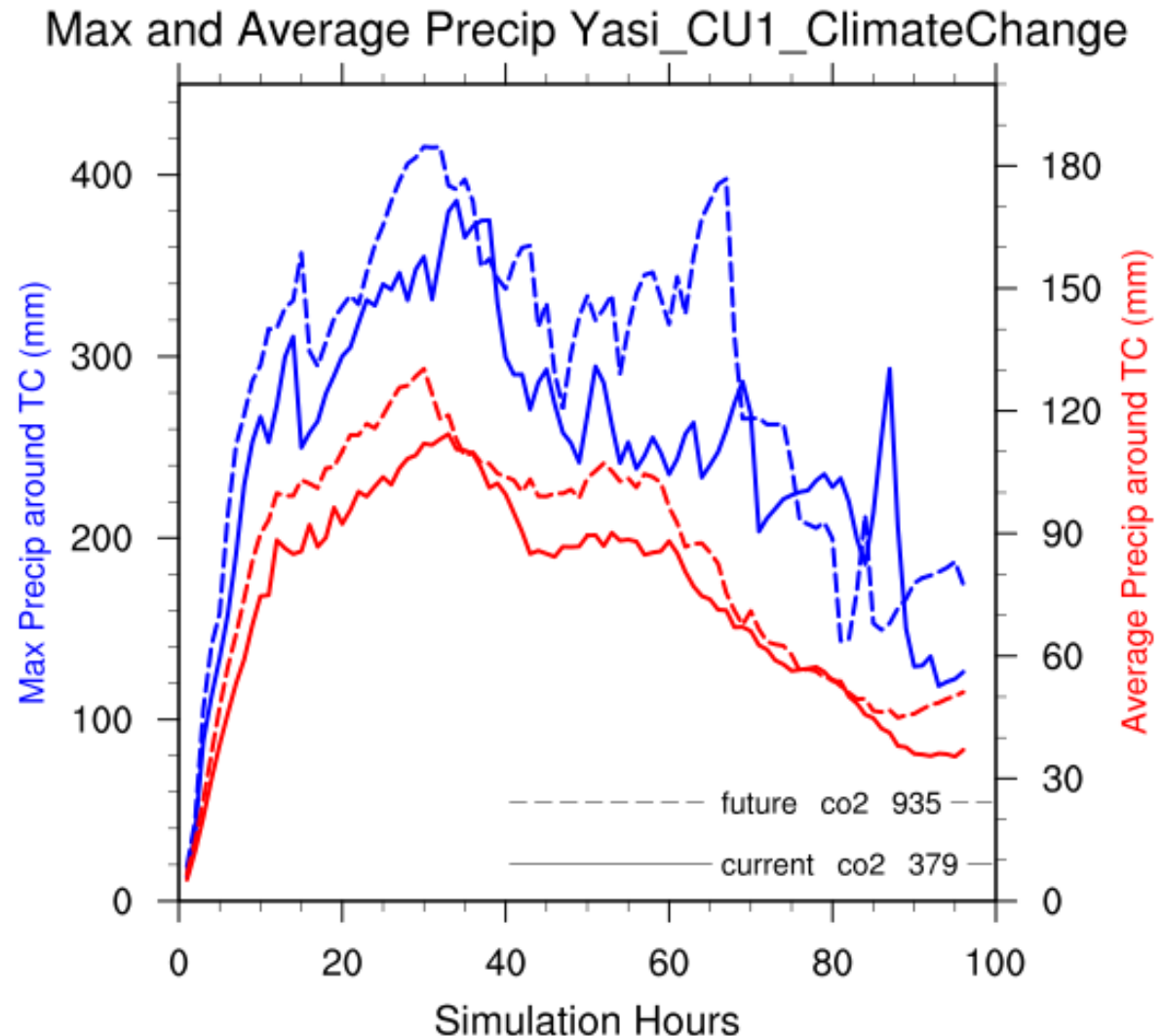
Wind Speed and SLP Yasi_CU1_v_CU6_ClimateChange



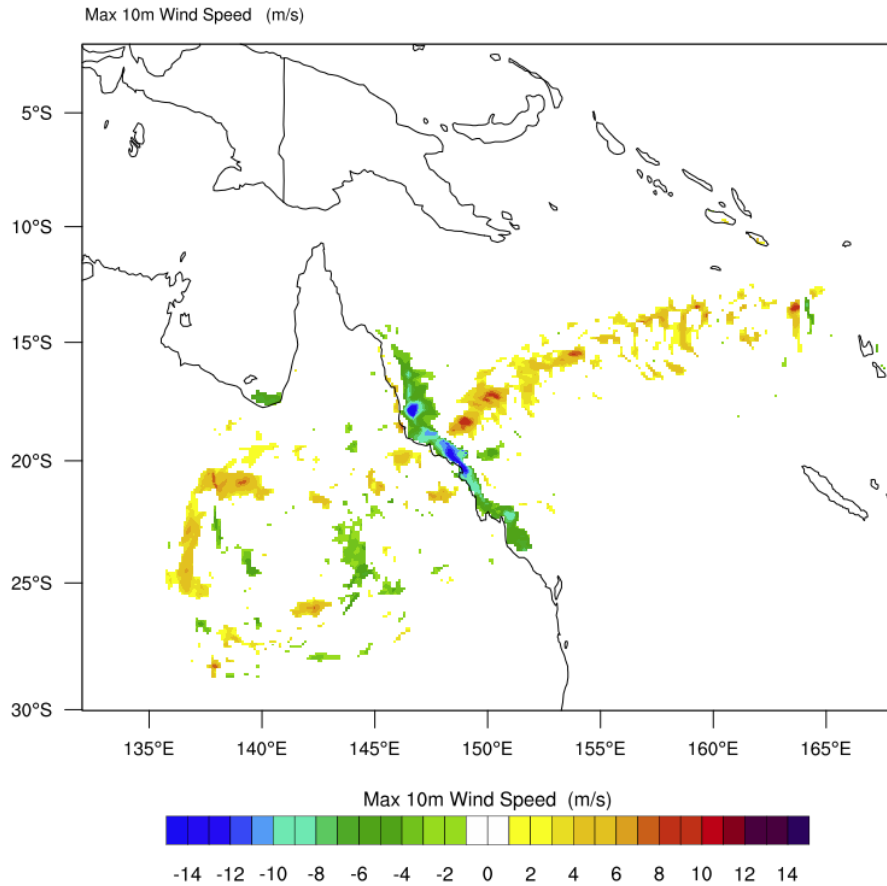
Yasi: Precipitation

Current → Future

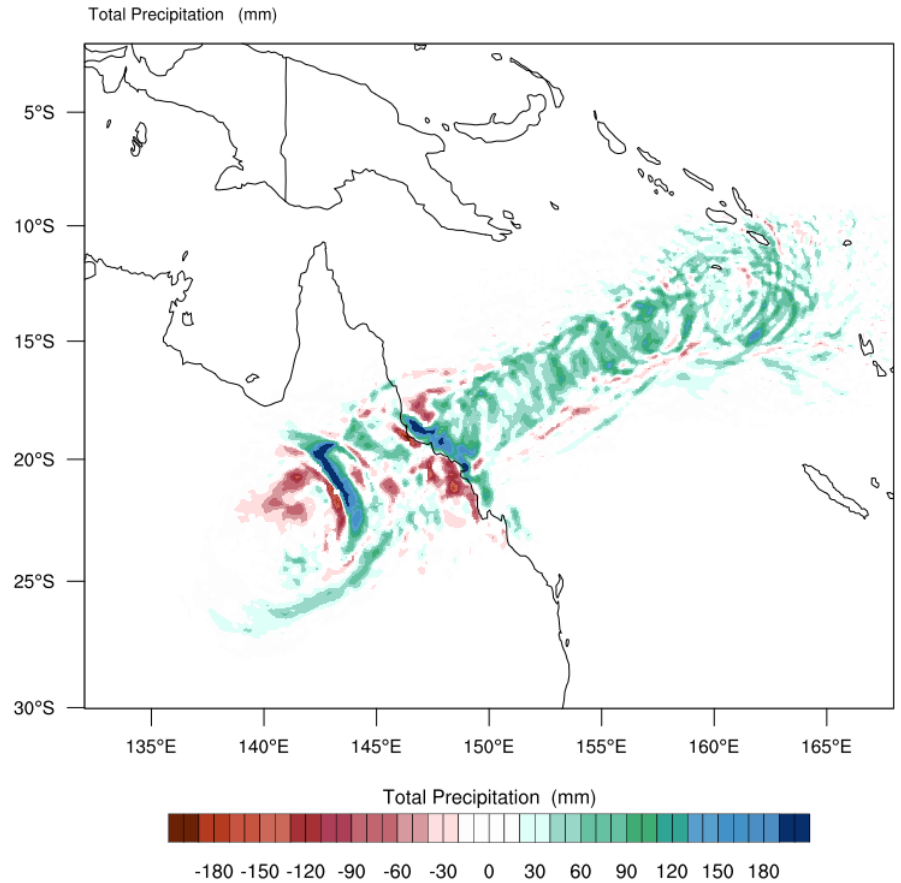
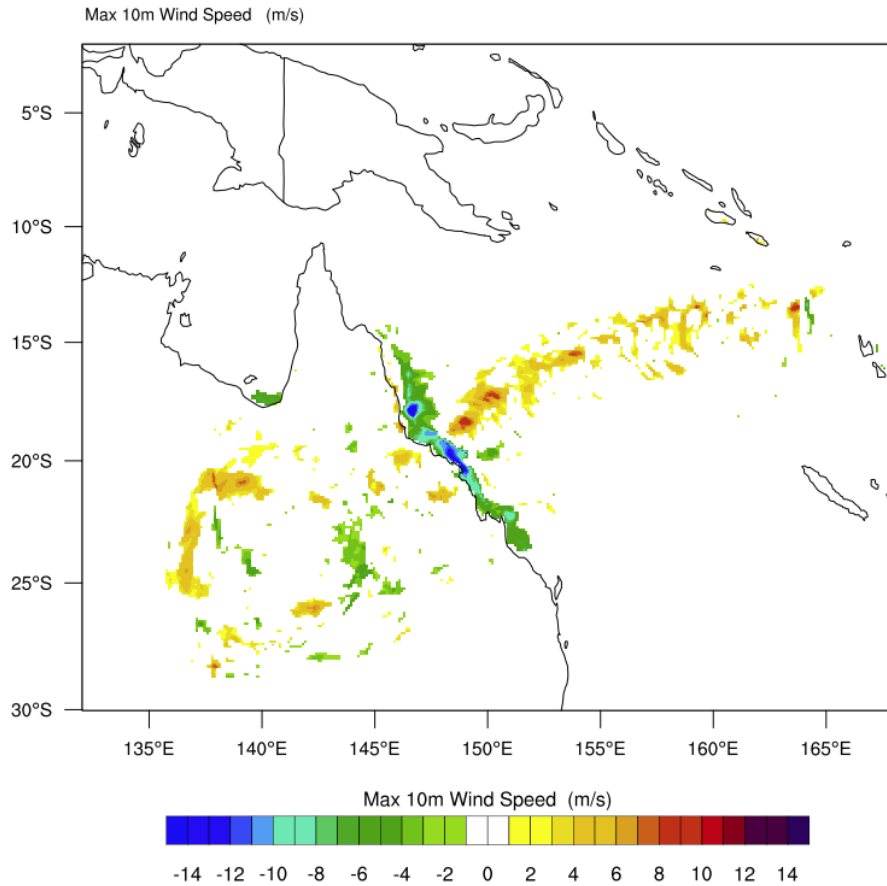
- Up to **25%** increase in average precipitation.
- Up to **61%** increase in maximum precipitation.



Yasi: Wind and Precipitation Swath



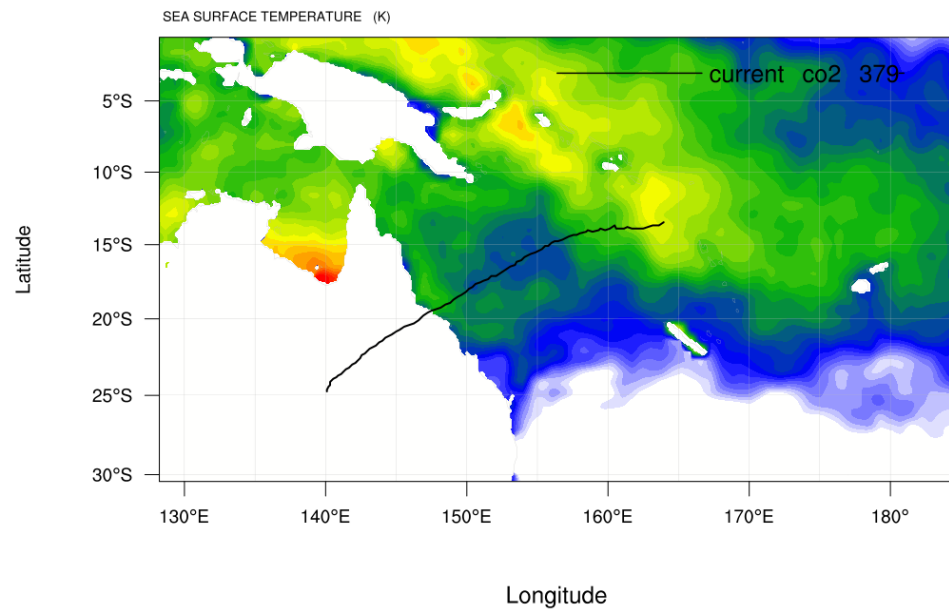
Yasi: Wind and Precipitation Swath



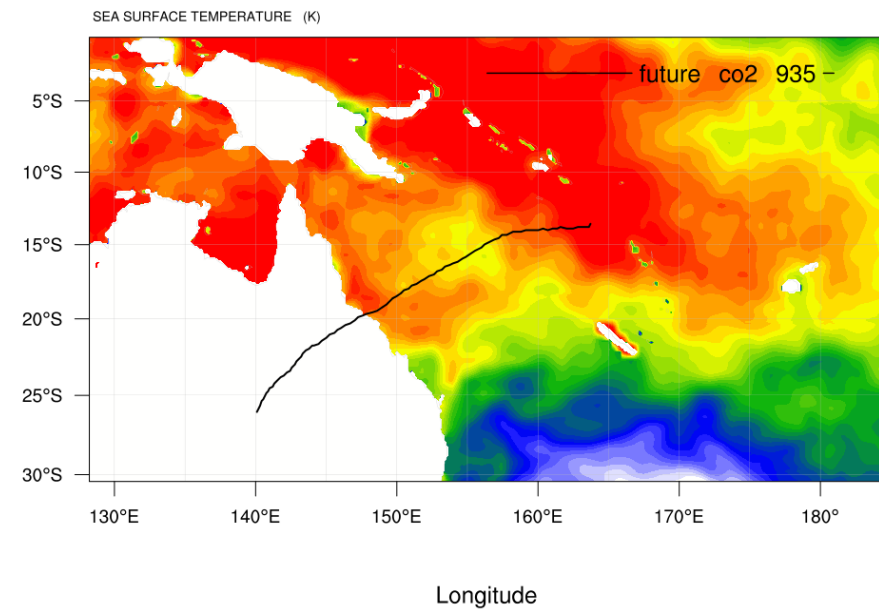
Yasi: SSTs

Init: 2011-01-31_00:00:00

Init: 2011-01-31_00:00:00



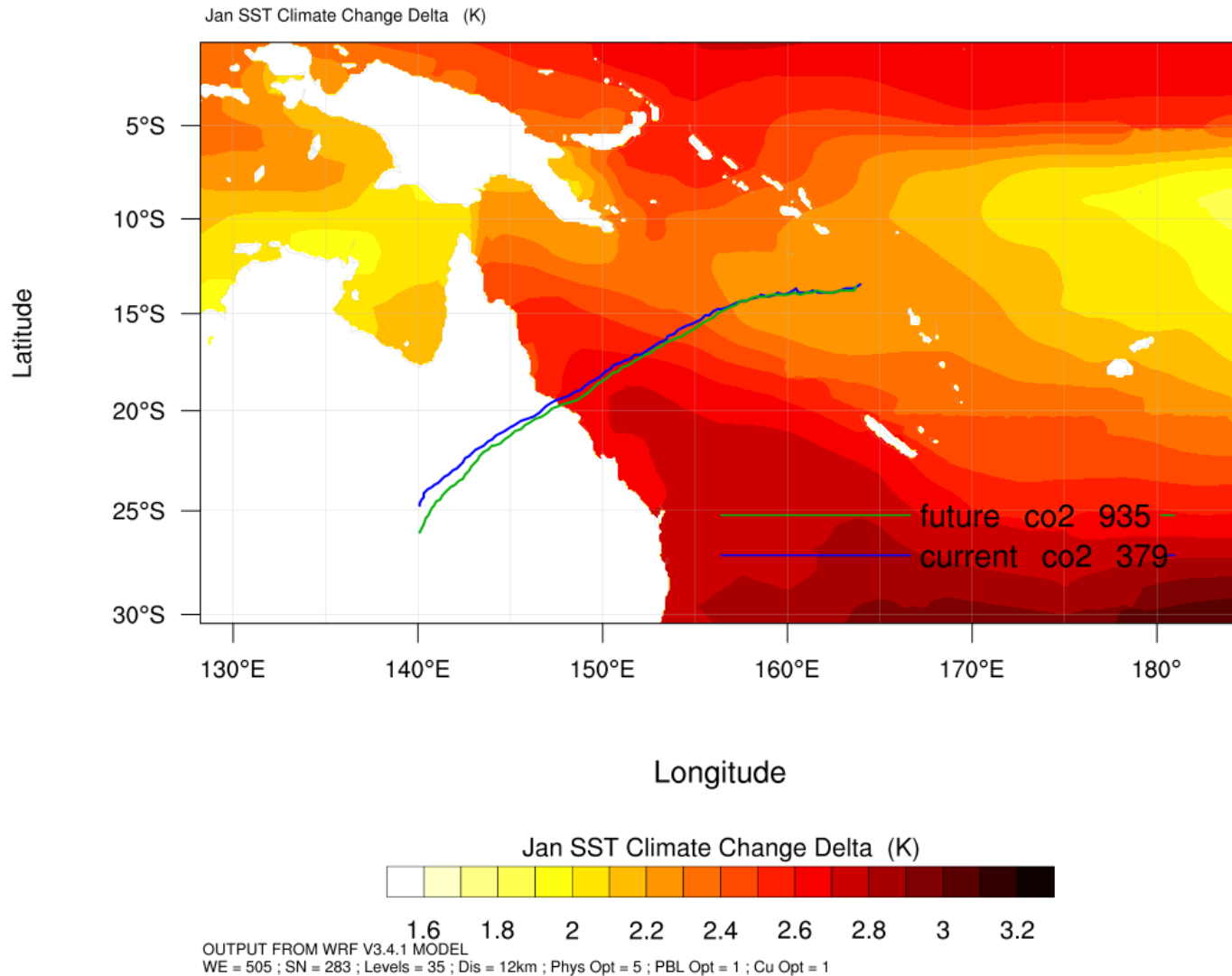
OUTPUT FROM WRF V3.4.1 MODEL
WE = 505 ; SN = 283 ; Levels = 35 ; Dis = 12km ; Phys Opt = 5 ; PBL Opt = 1 ; Cu Opt = 1



OUTPUT FROM WRF V3.4.1 MODEL
WE = 505 ; SN = 283 ; Levels = 35 ; Dis = 12km ; Phys Opt = 5 ; PBL Opt = 1 ; Cu Opt = 1

Climate Change SST Delta Jan

Init: 2011-01-31_00:00:00



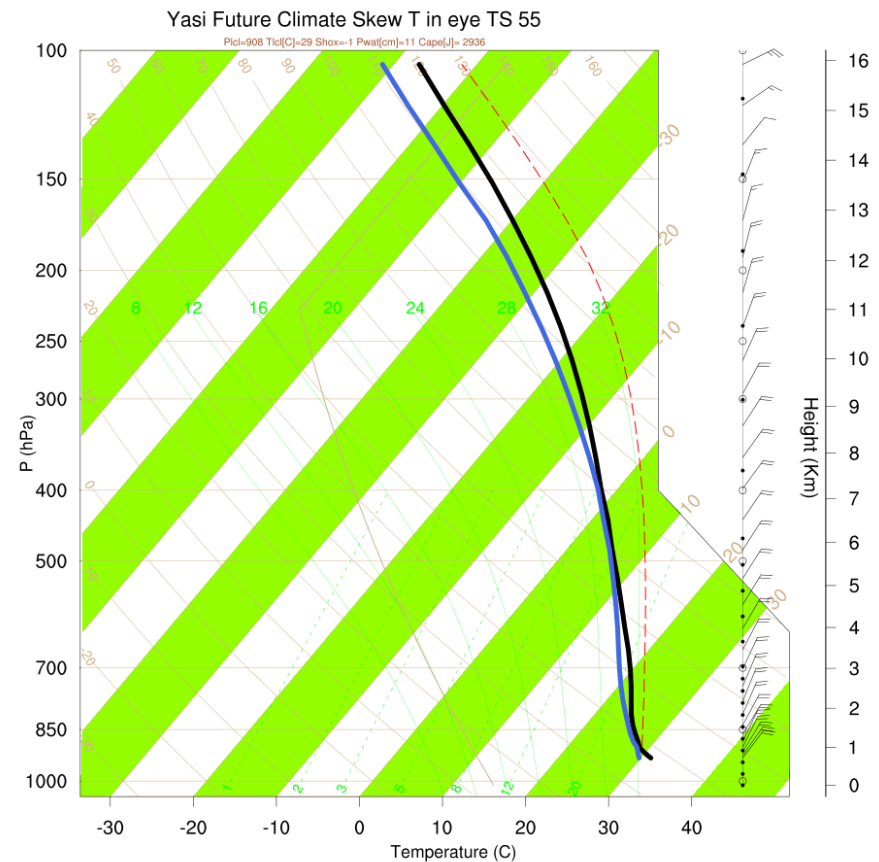
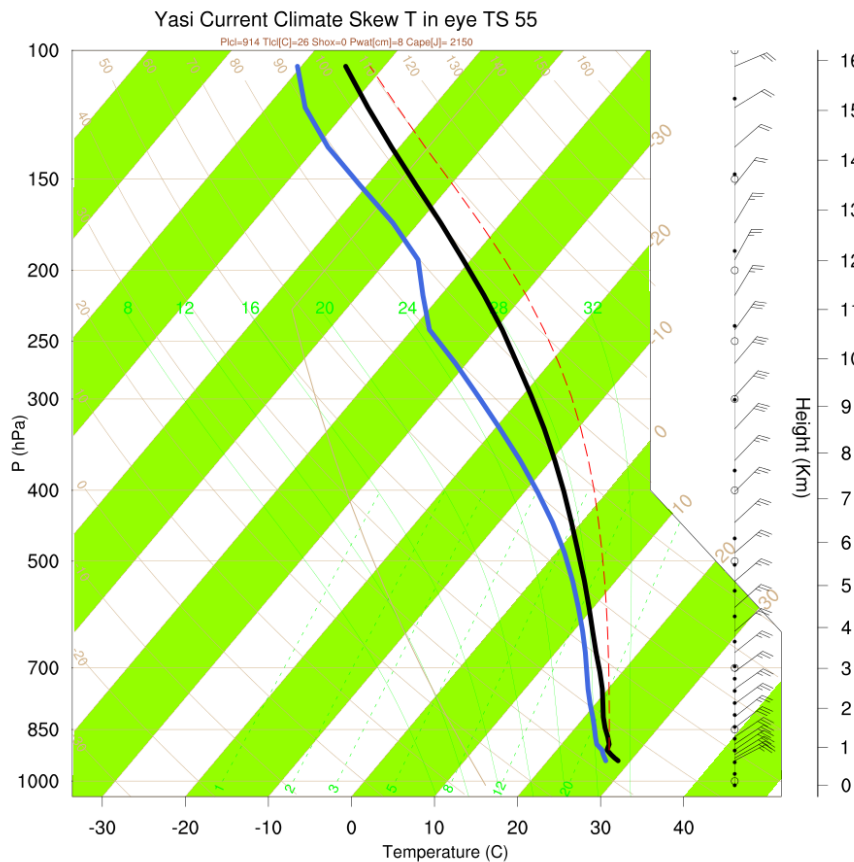
Yasi: Skew Ts from Eye

CAPE: Current: 2150J, Future: 2936J

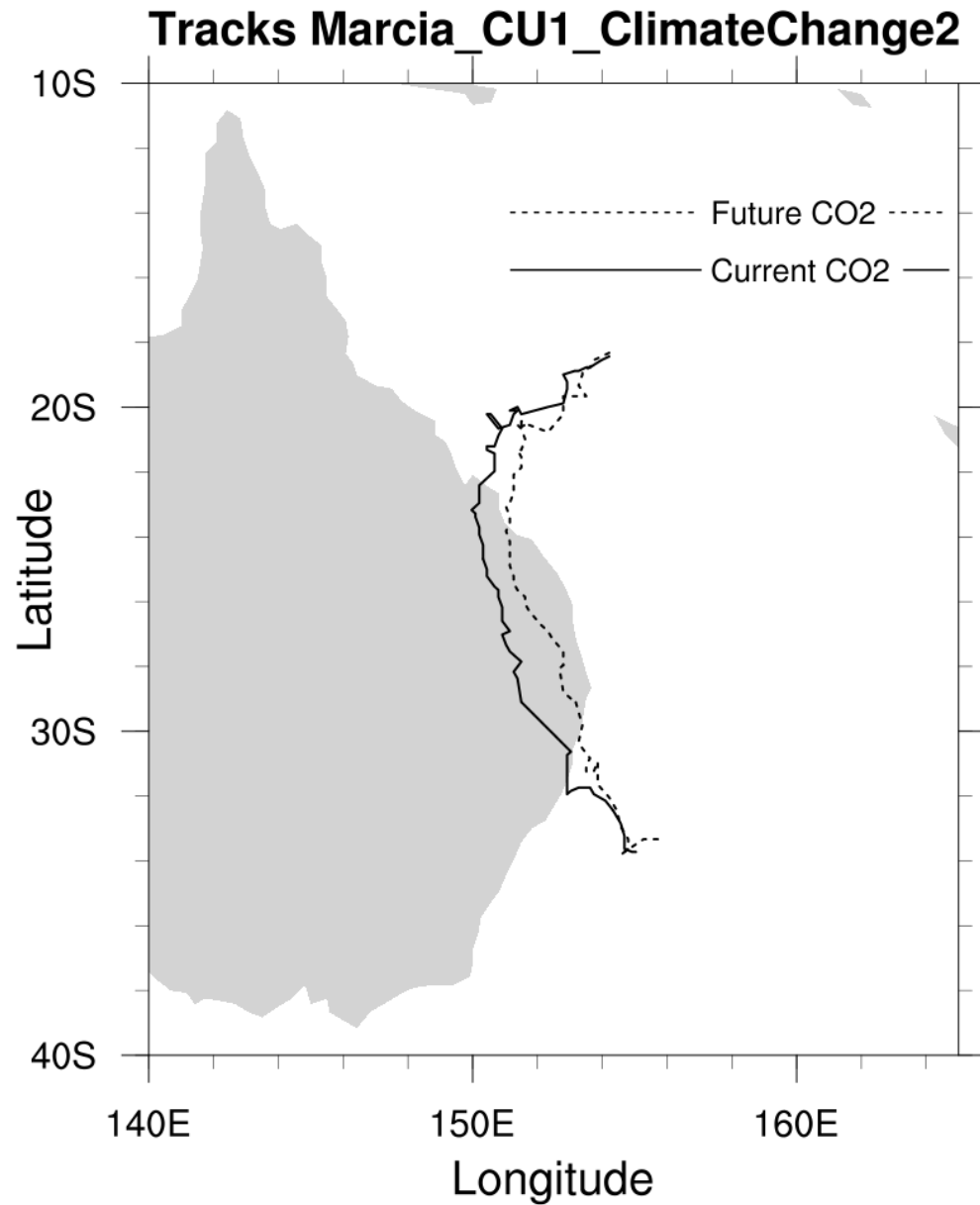
CIN: smaller

Temperature Inversion: smaller

Moisture: greater aloft



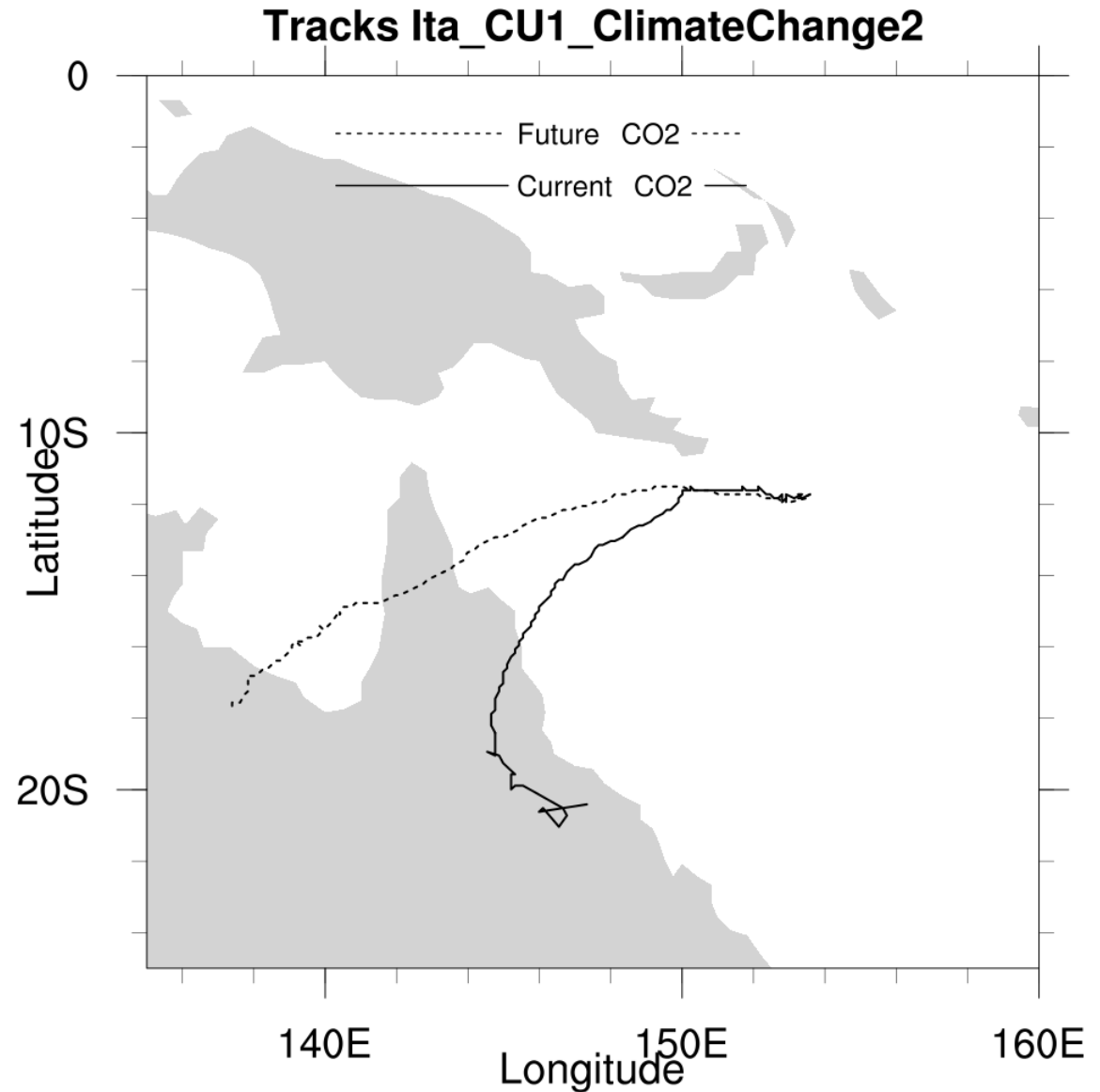
Marcia: Trajectories



Ita: Trajectories

Current → Future

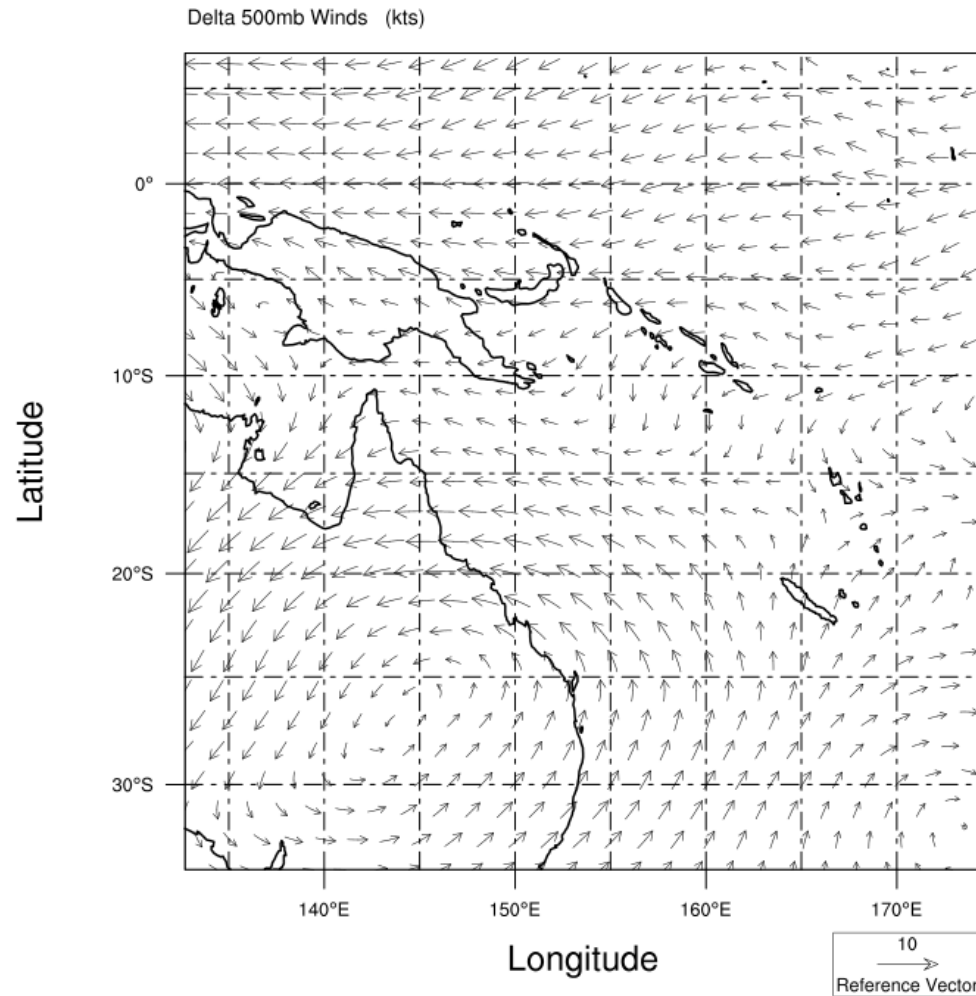
- On average **25%** increase in translation speed to landfall



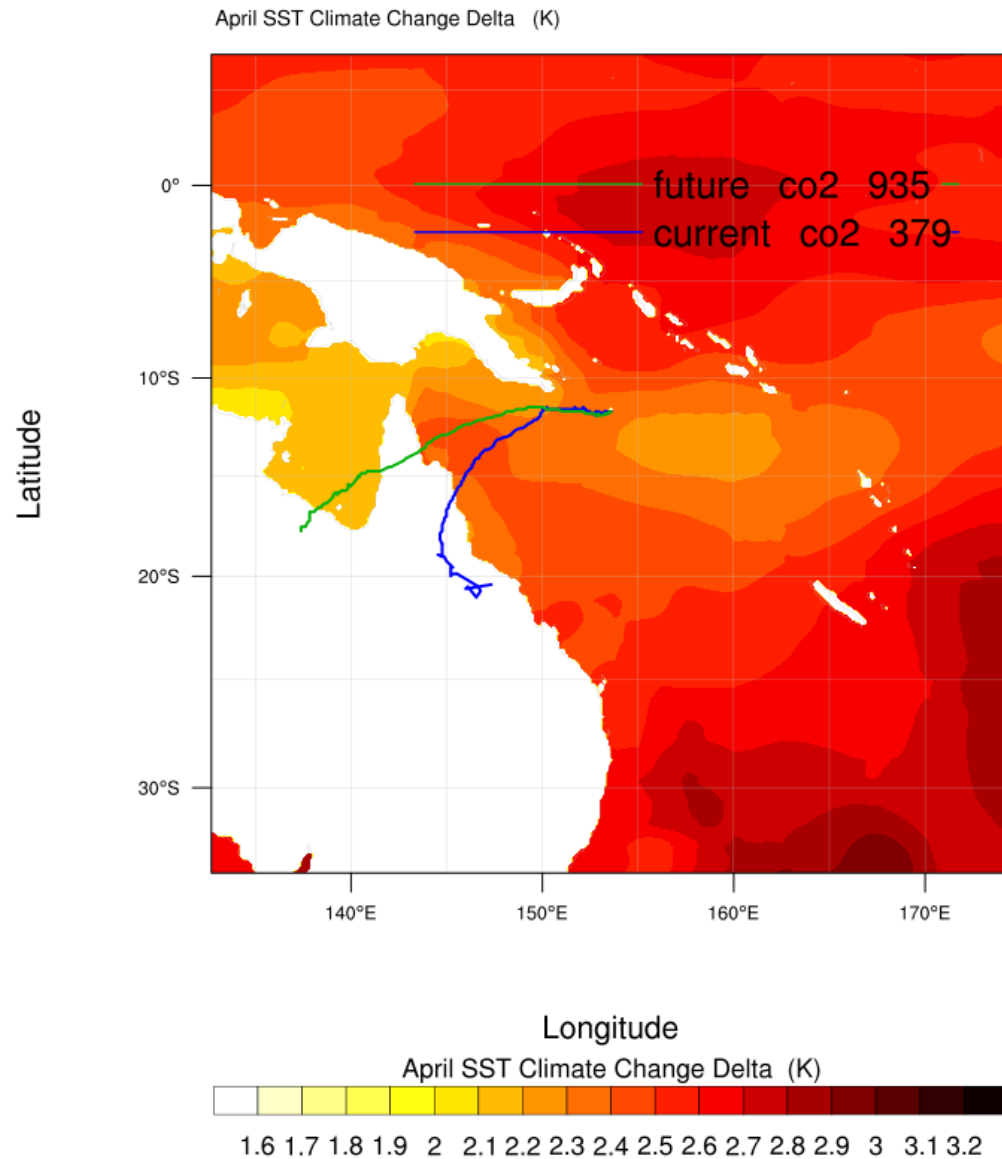
April 500mb delta

April 500mb(kts) Climate Delta

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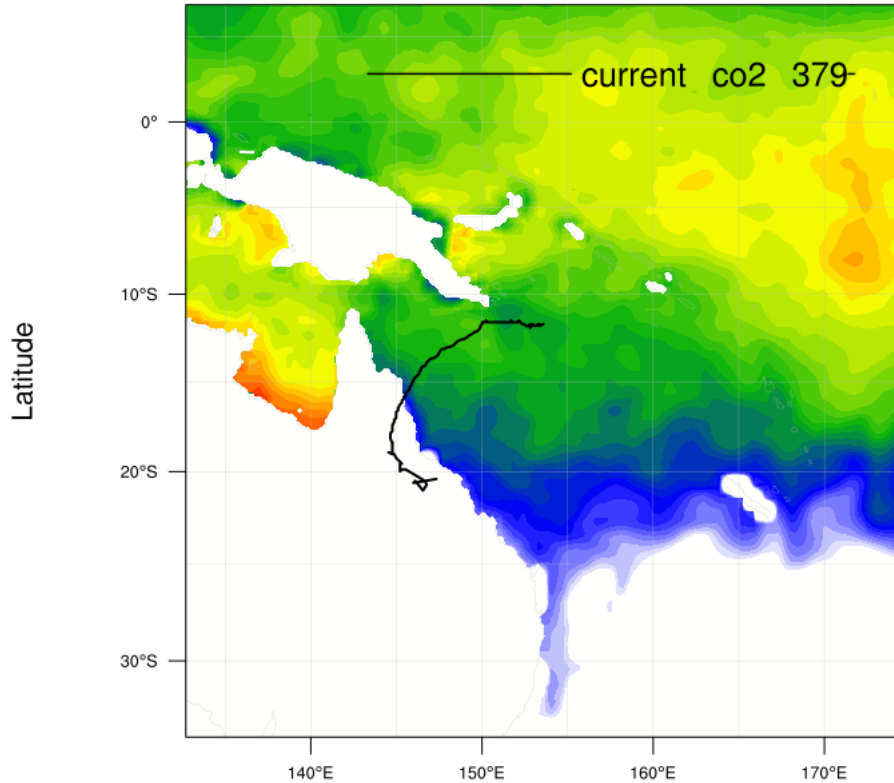


Climate Change SST Delta April

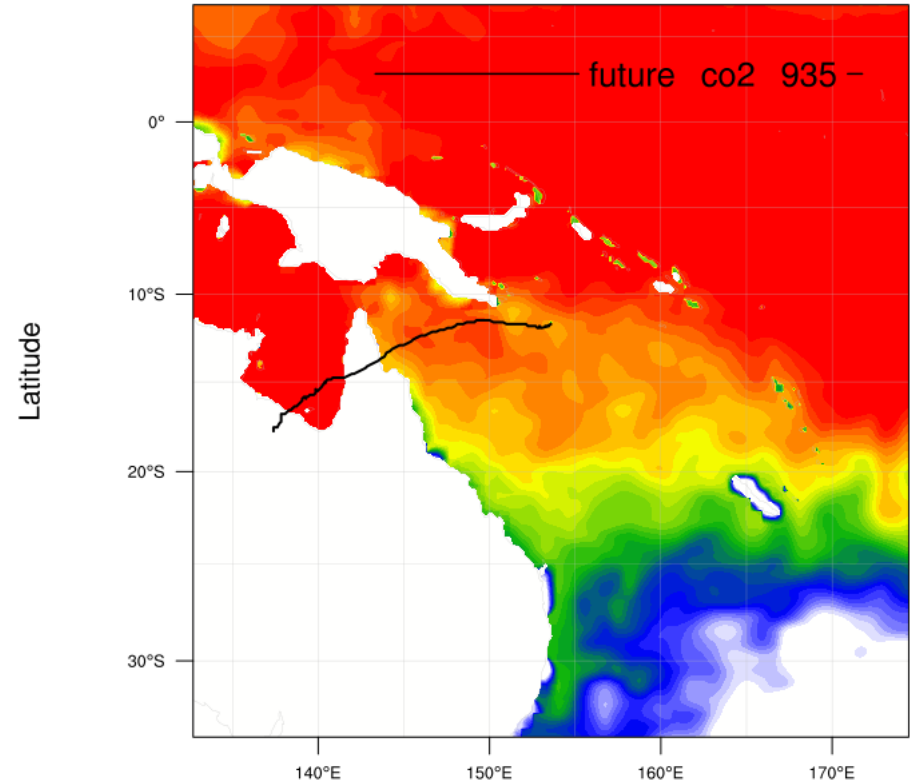


Ita: SSTs

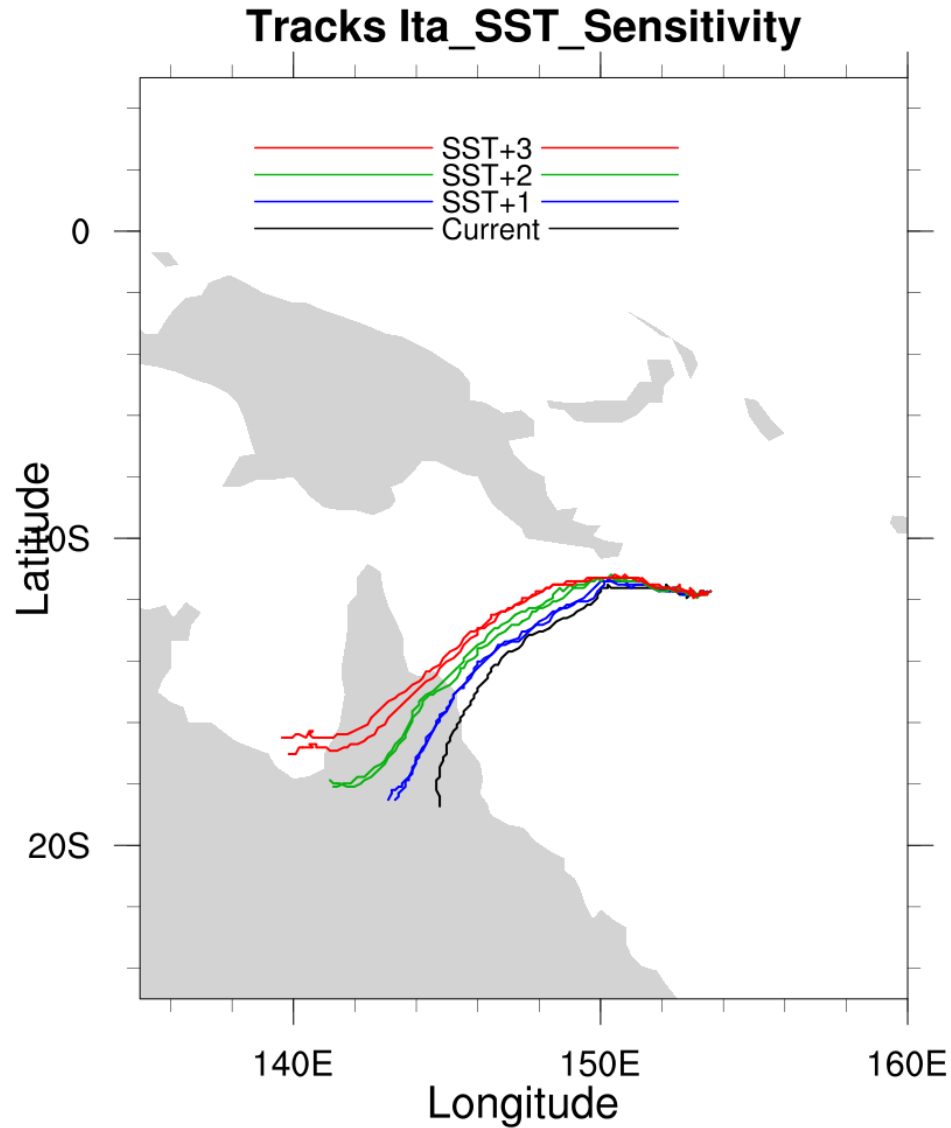
SEA SURFACE TEMPERATURE (K)



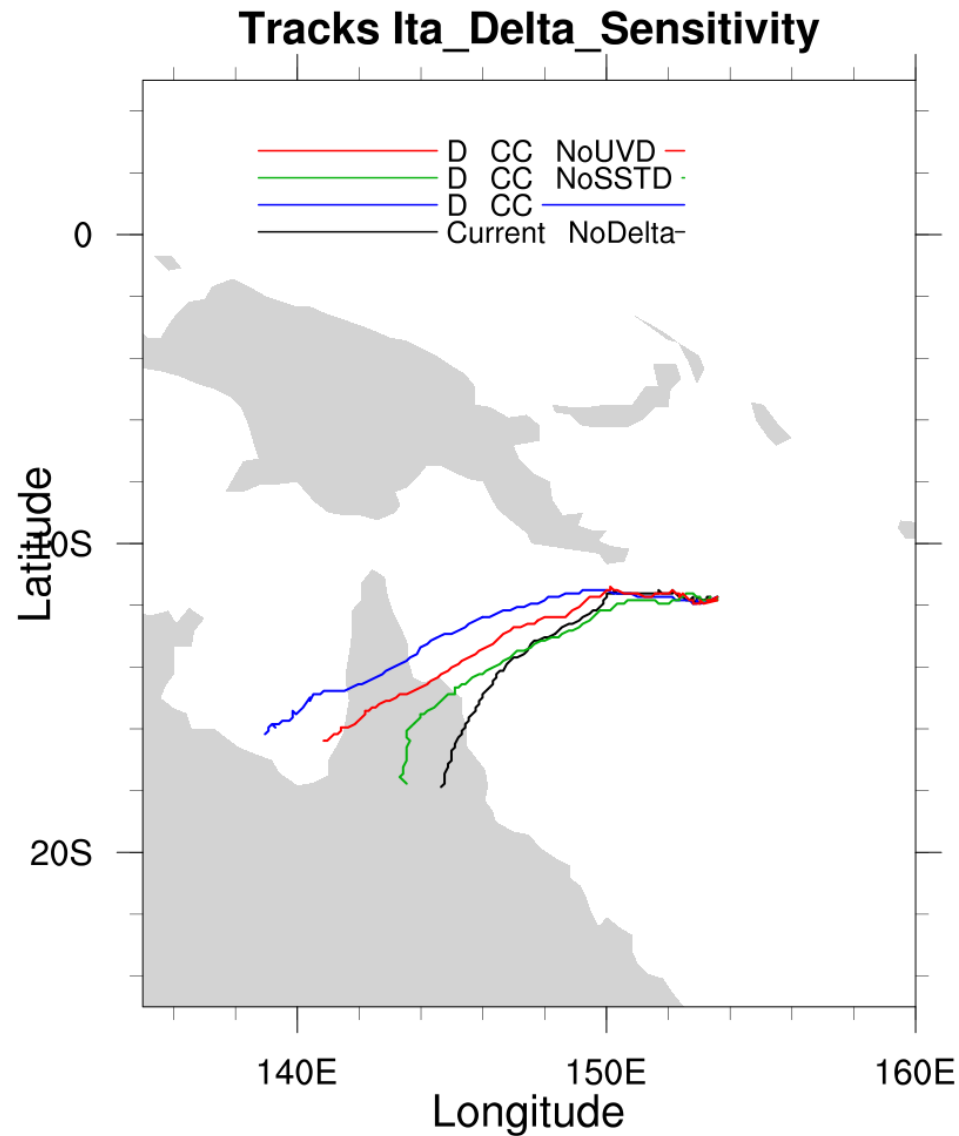
SEA SURFACE TEMPERATURE (K)



ITA 2014: SST Sensitivity



ITA 2014: Delta Sensitivity



Ita: Skew Ts from Eye ts 45

CAPE: Greater
CIN: smaller
Temperature Inversion: smaller
Moisture: greater aloft

