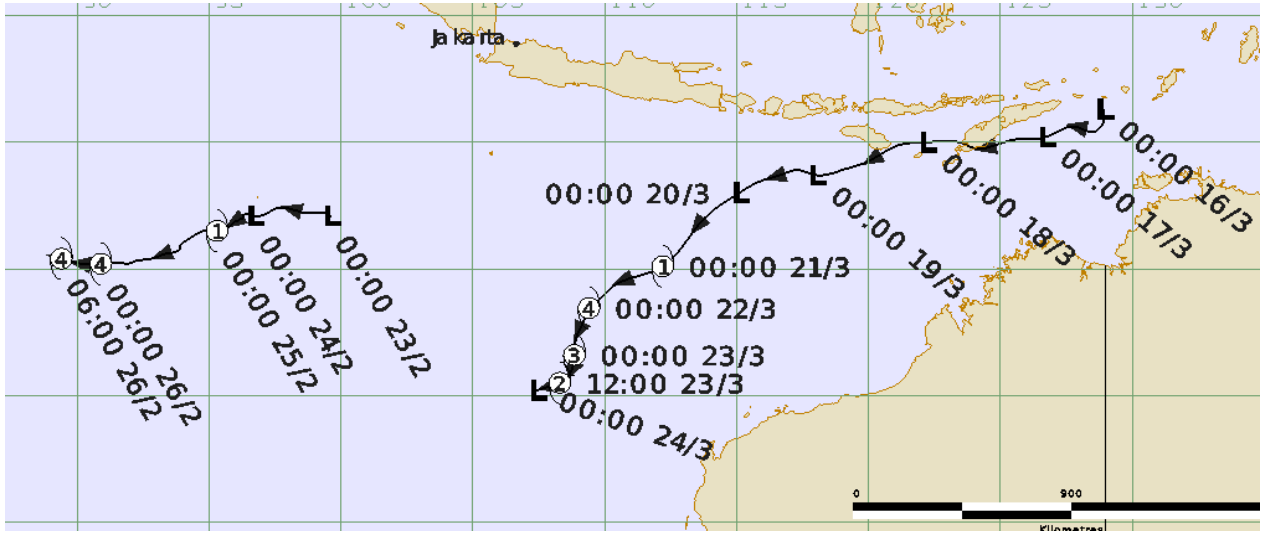
On the rapid intensification and weakening of Tropical Cyclones Vernon and Charlotte

Australian Government
Bureau of Meteorology

Joe Courtney VLAB 29 March 2022

Rapid Intensity changes remains difficult forecasting challenges

Highlight satellite signatures of recent events



Socrative: socrative.com

Login as student

Room: VLAB2022

Acknowledgements:

microwave NRL https://www.nrlmry.navy.mil/tc-bin/tc_home2.cgi

Scatterometry NOAA https://manati.star.nesdis.noaa.gov/datasets/ASCATData.php

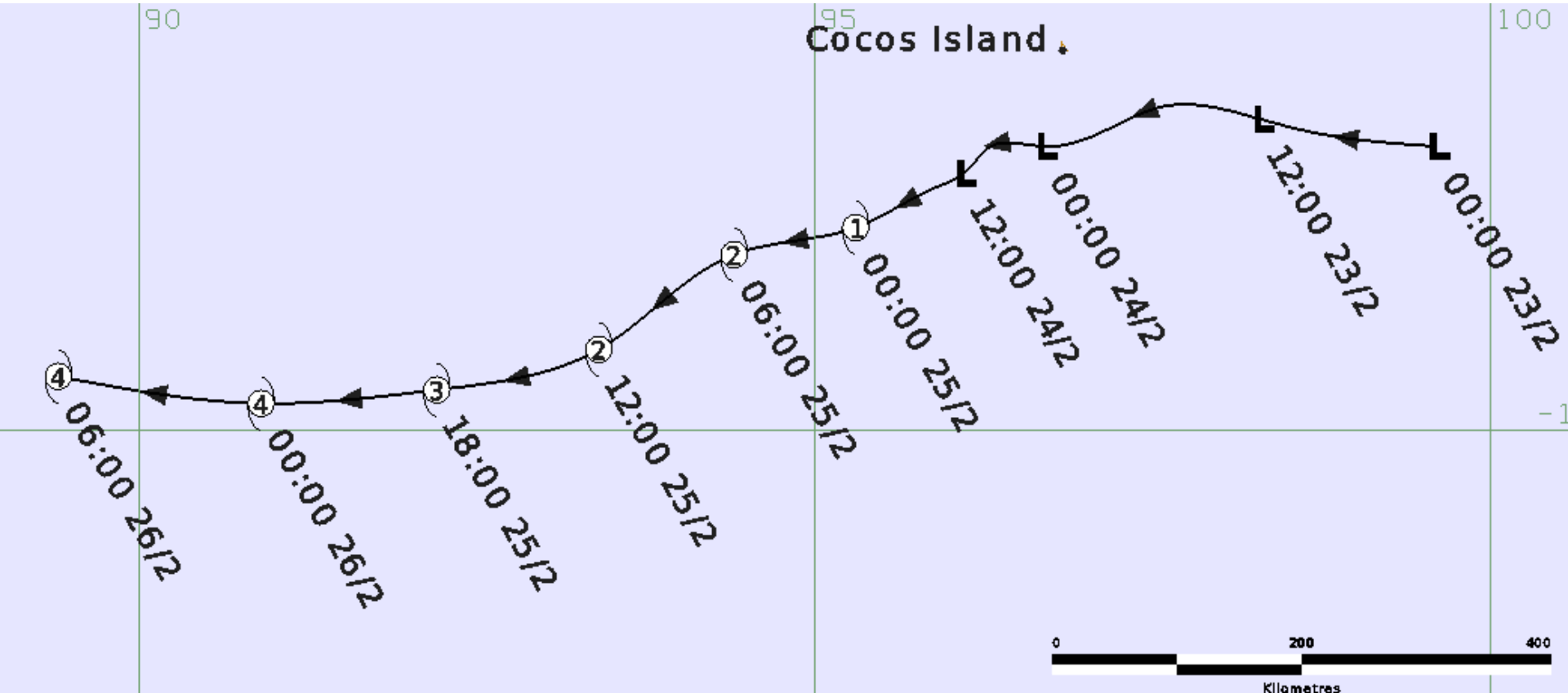
Other imagery: CIRA https://rammb-data.cira.colostate.edu/tc_realtime/

…some slides not shown…

TC Vernon Feb 2022

Developed rapidly 25-26 March then weakened 26-27 March

Small system that overcame moderate shear (Ryglicki RI work)



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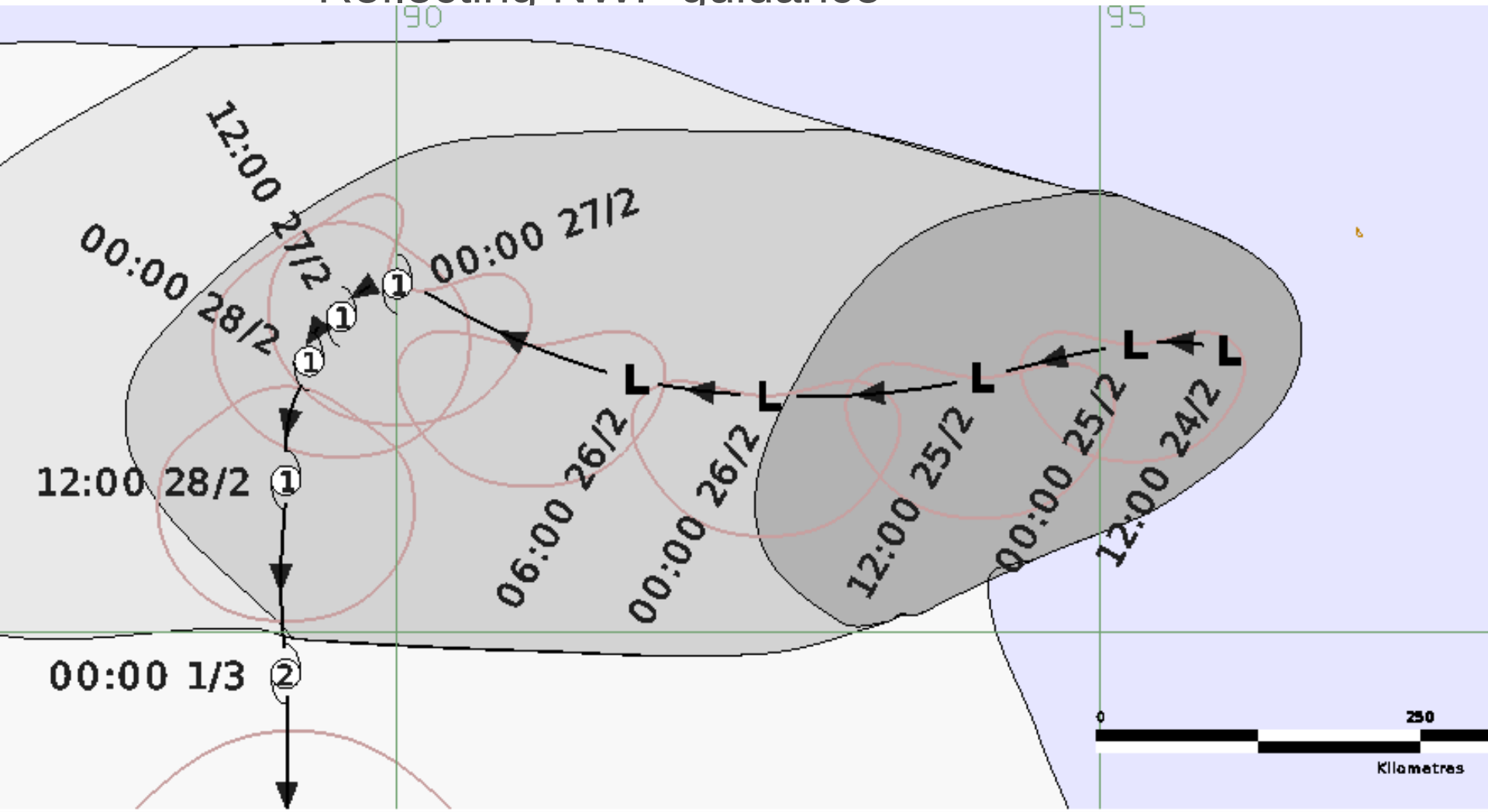
TC Vernon 24/12UTC

Australian Government
Bureau of Meteorology

Forecast: gales on southern side but not a TC until +54h at 26/18UTC before 90E

Reflecting NWP guidance



…some slides not shown…

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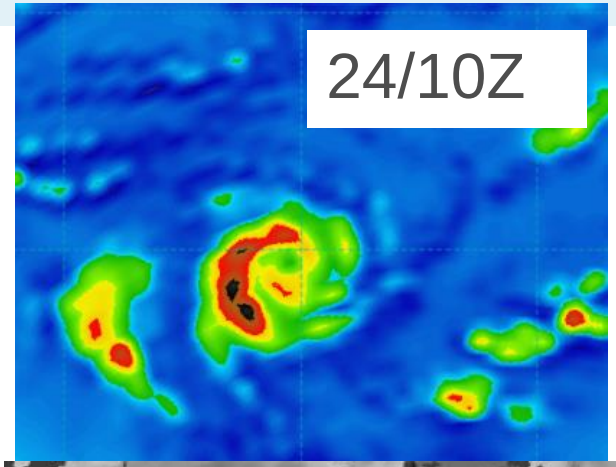
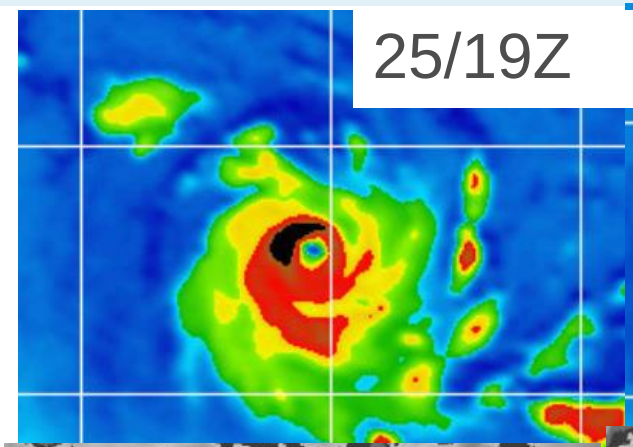
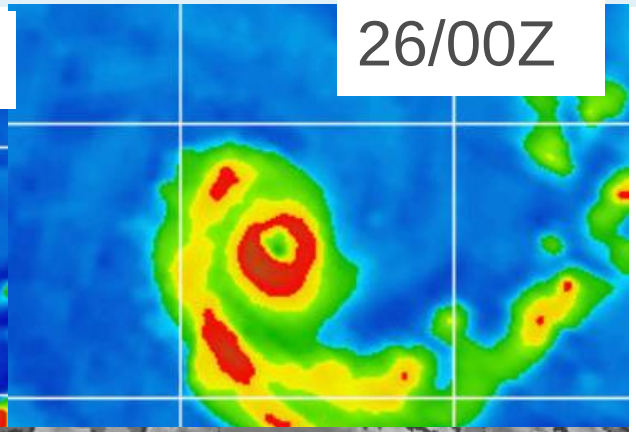
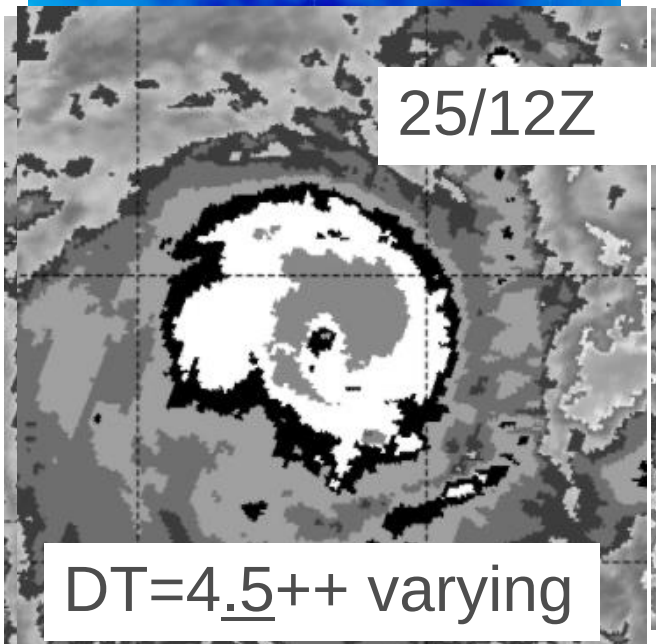
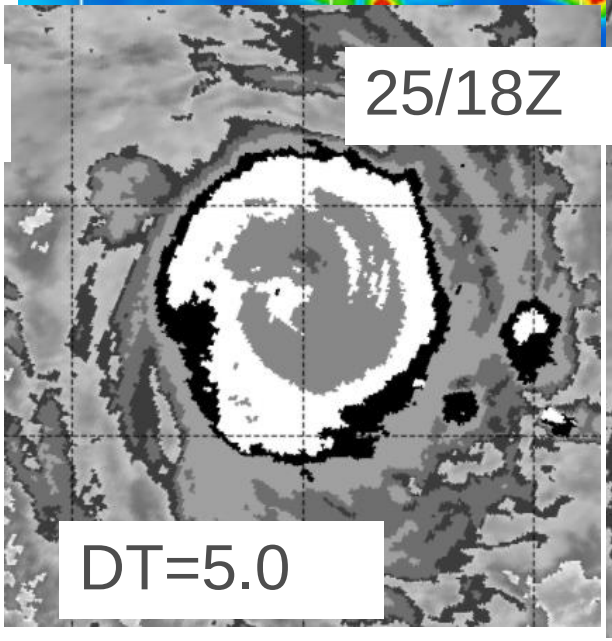
25-26 Feb eye pattern

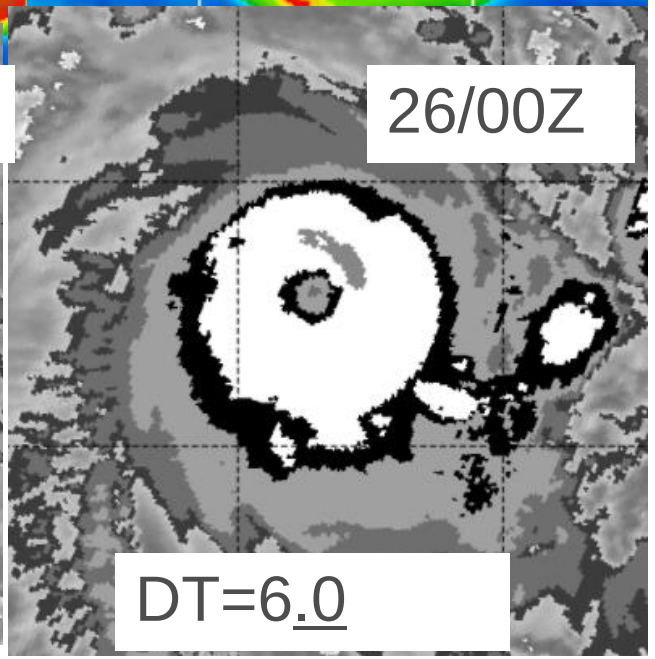












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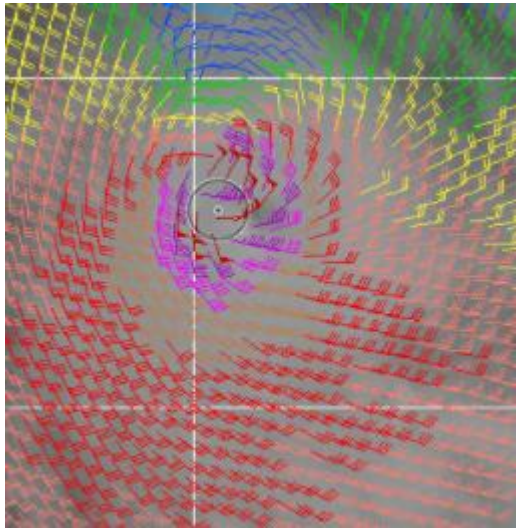
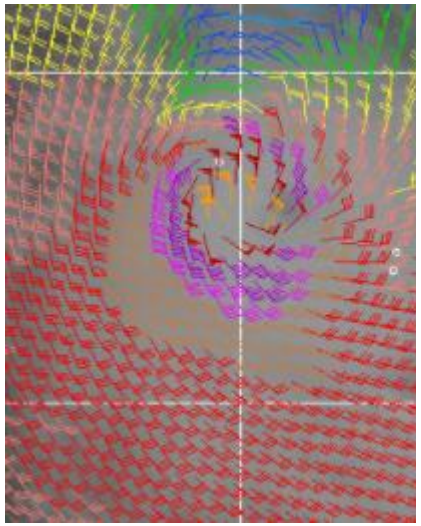
Scatterometry/Radiometry 24 Feb

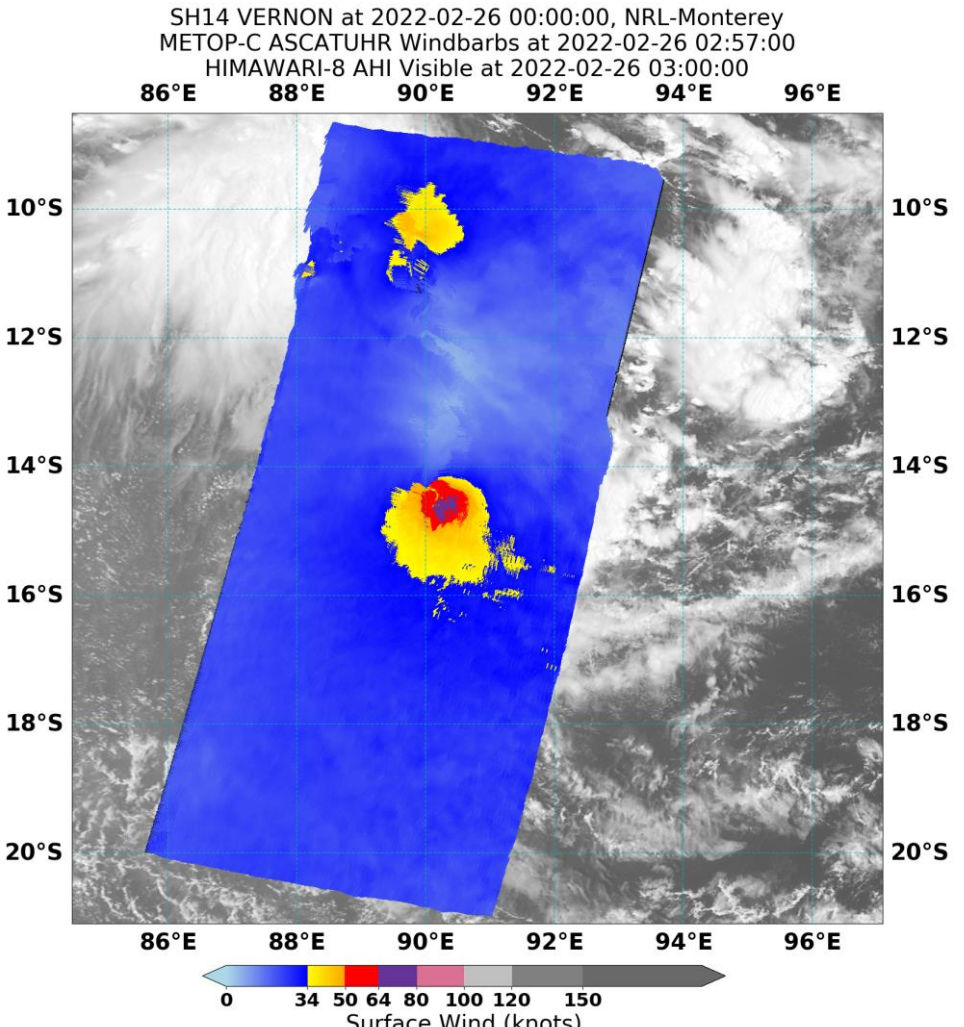
Australian Government
Bureau of Meteorology

ASCAT-C 26/0301UTC



ASCAT-B 26/0348UTC





ASCATC UHR winds >64k

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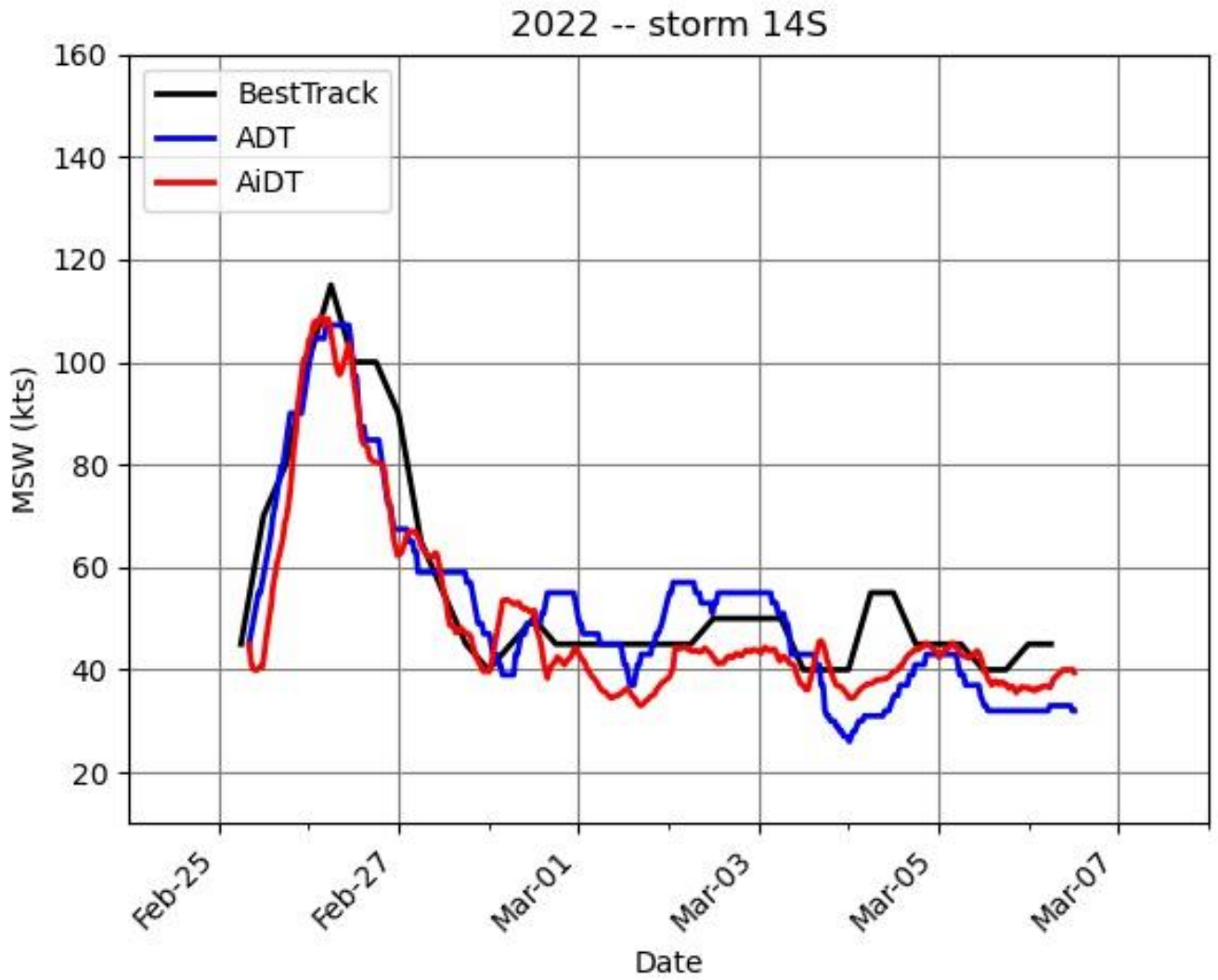
AiDT

Late initiation, rapid intensification and weakening 25 to 26 Feb



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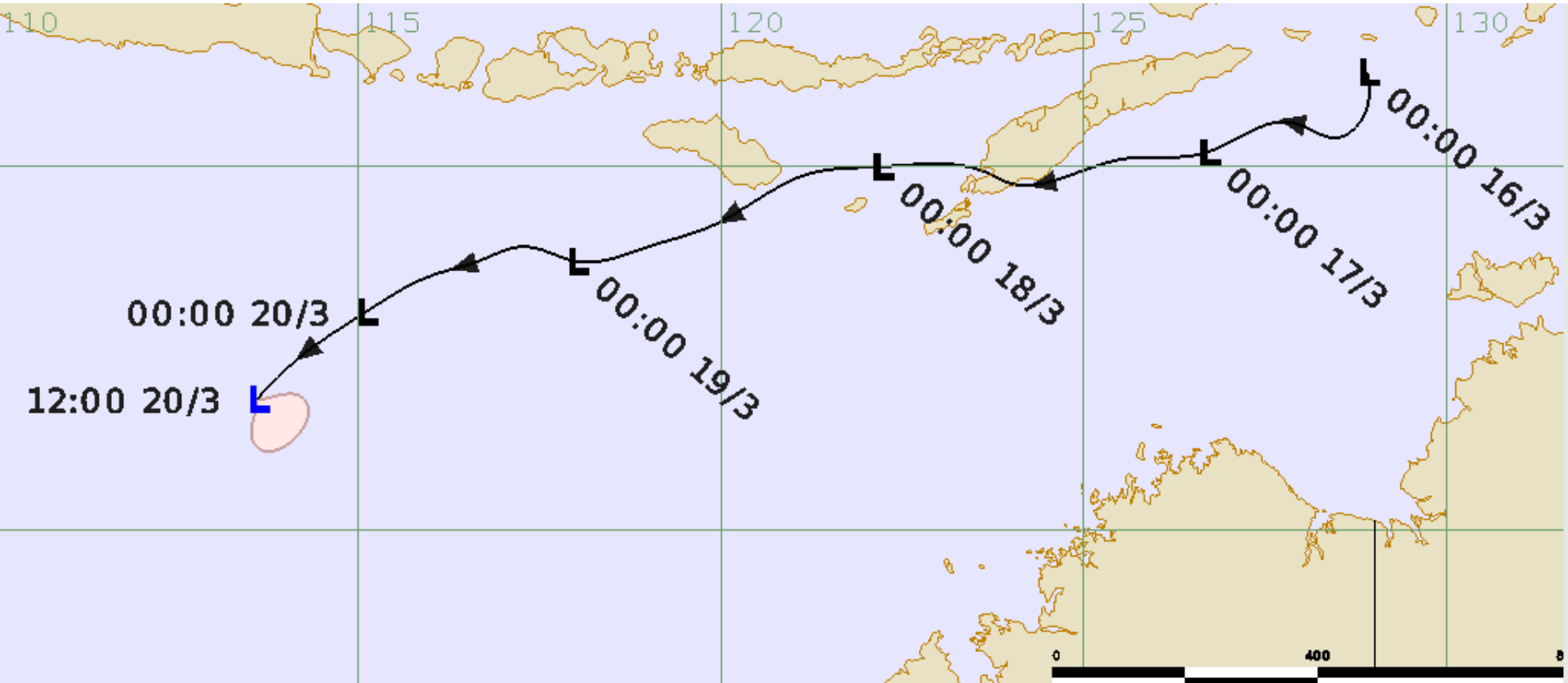
Bureau of Meteorology

Pre-TC Charlotte 12UTC 20 March 2022

Been under easterly shear restricting development but has developed in past 24h over open waters
Varying NWP guidance on intensity



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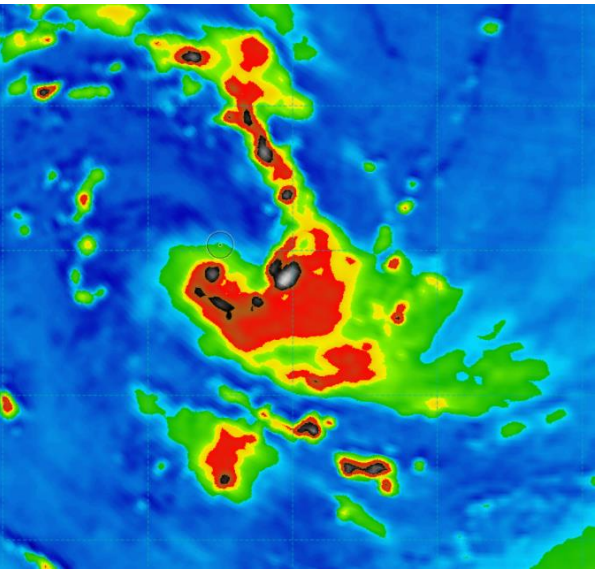
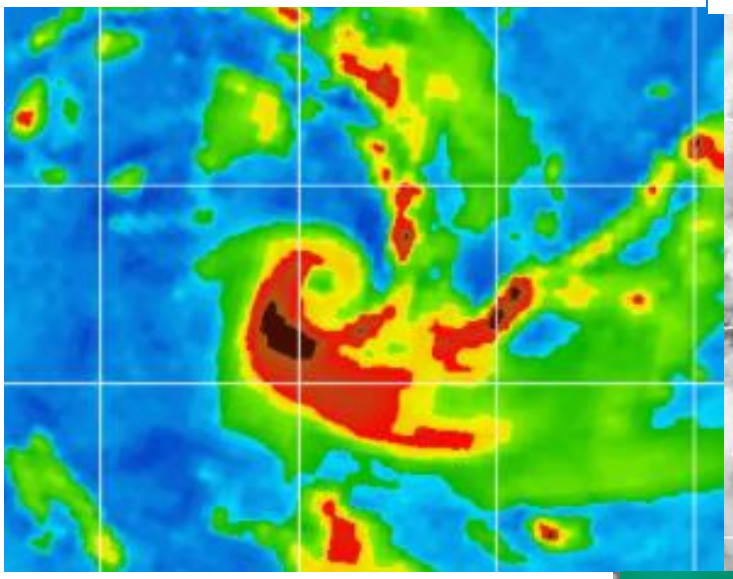
Microwave series 20/18 to 21/06UTC

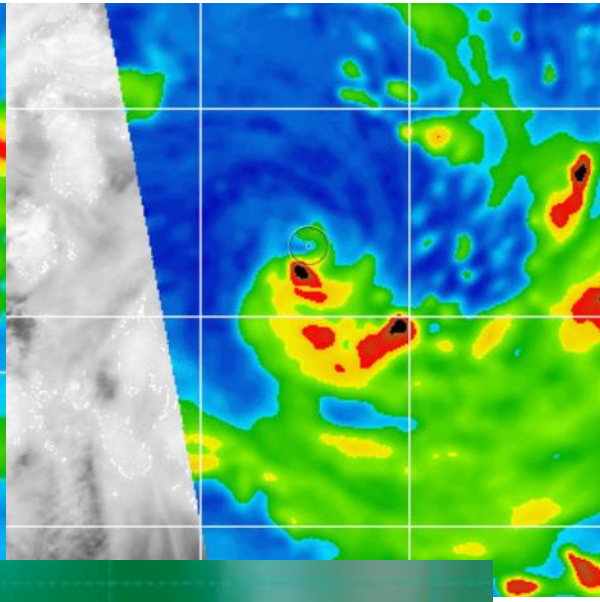
AMSR2 20/1736UTC



SSMIS 20/2250UTC



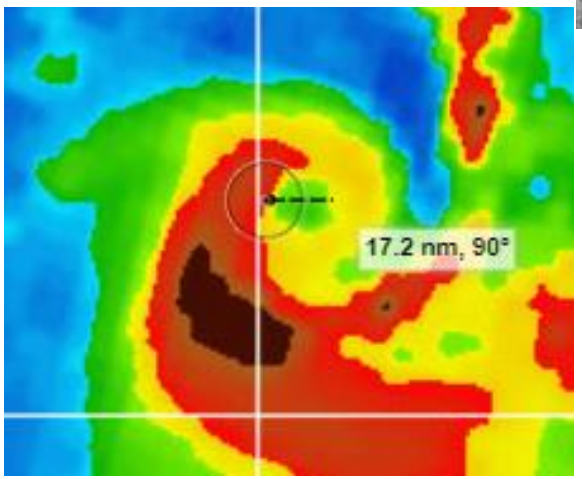
SSMIS 21/0552UTC

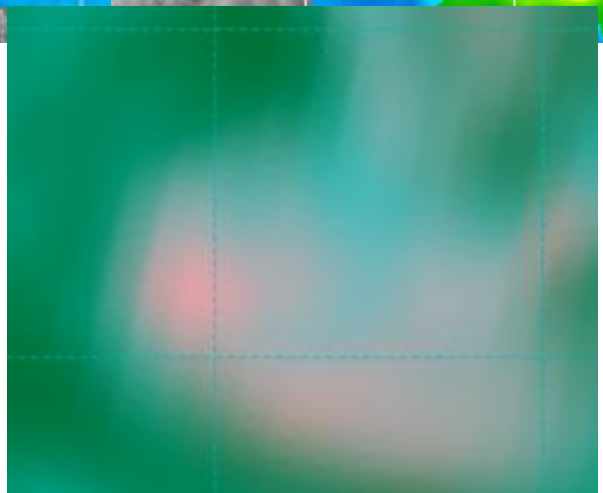


Small inner core

RMW<10nm

Detect Vm?





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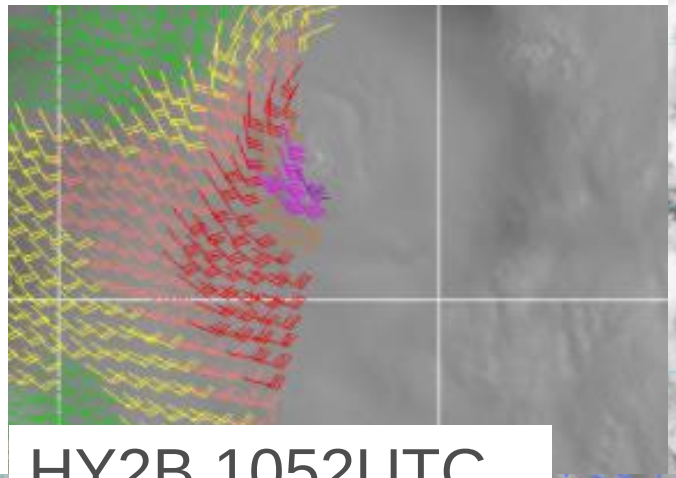
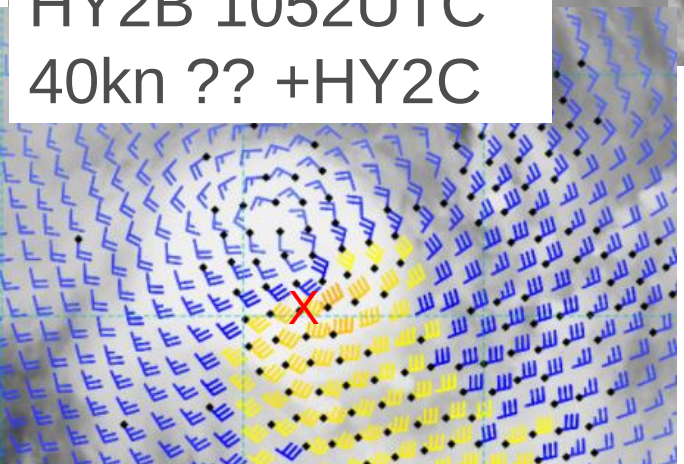
Scatterometry/Radiometry 21 Mar

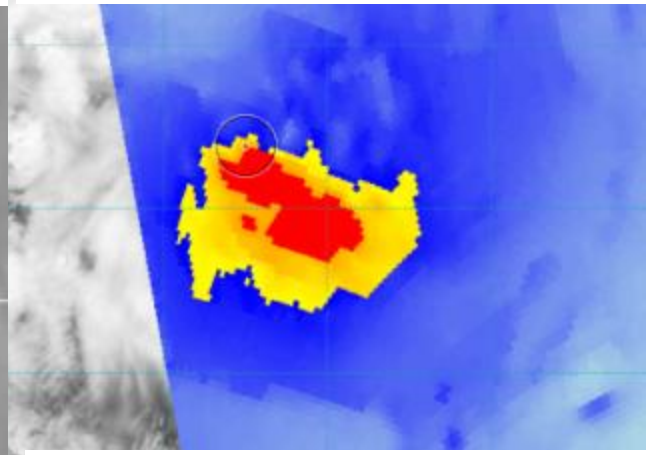
ASCATC 0144UTC
45kn



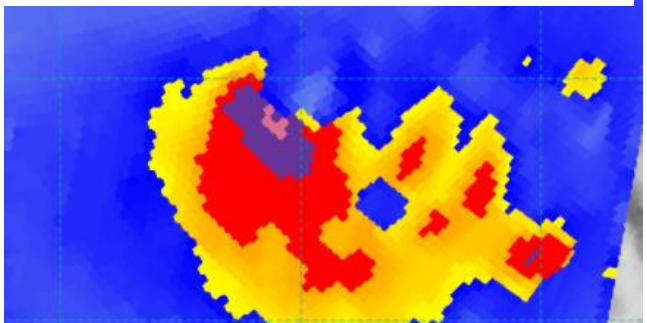
HY2B 1052UTC
40kn ?? +HY2C



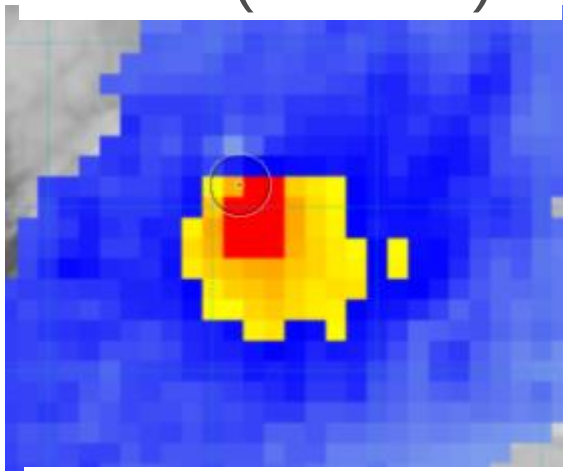
AMSR2 0550UTC
>50kn



AMSR2 1820UTC
>80kn



SMOS 1021UTC
>50kn (+SMAP)



SMOS 2244UTC
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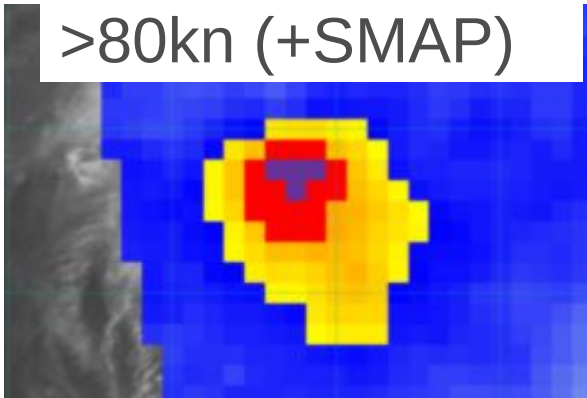

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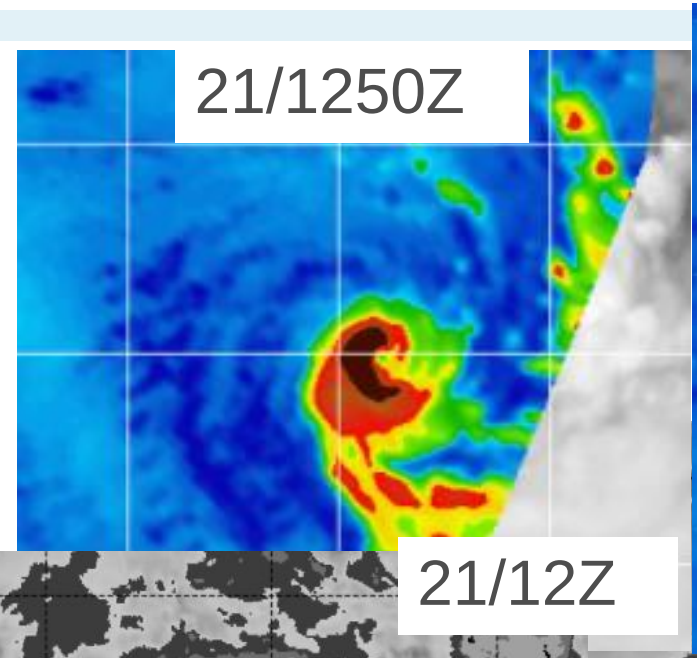
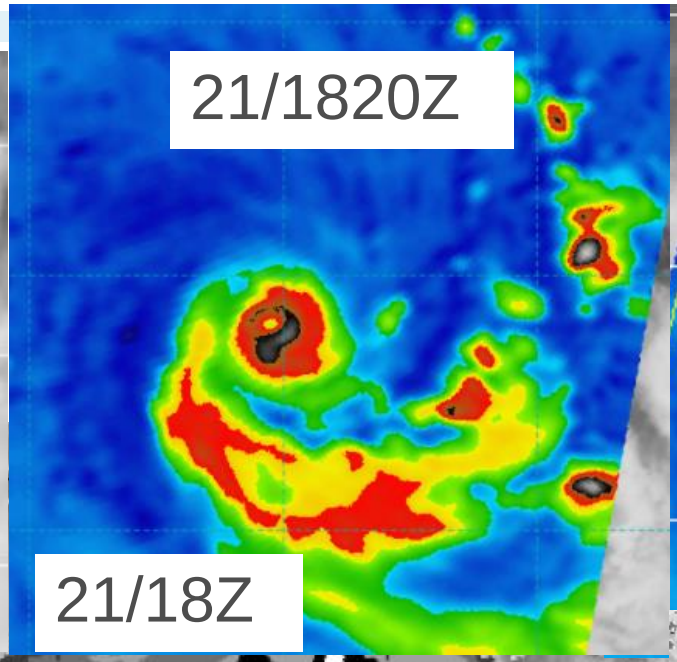
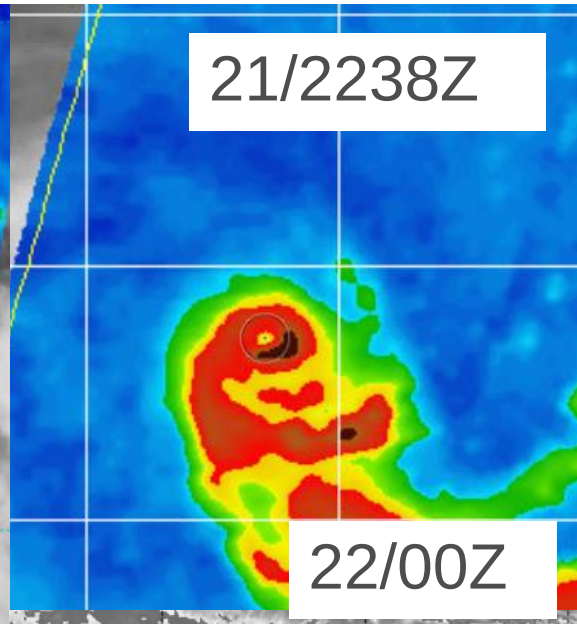
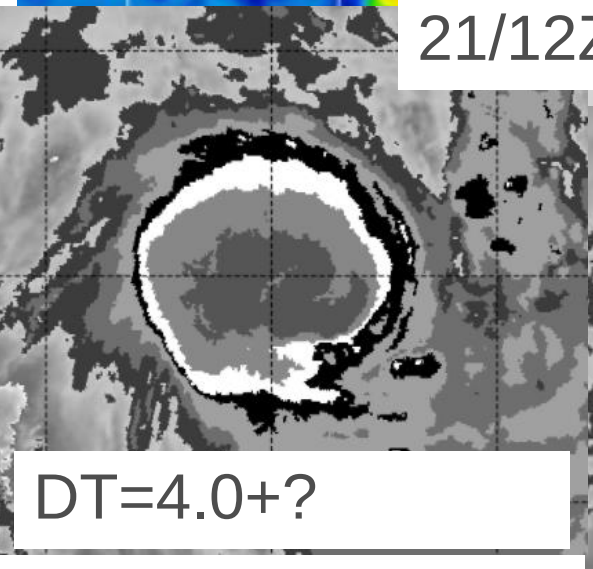
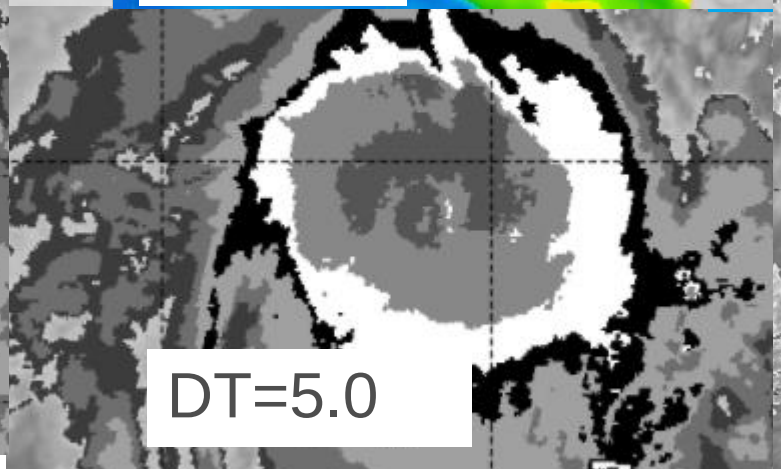
21 Feb eye pattern?
Vmax=90kn (CI=5.5)

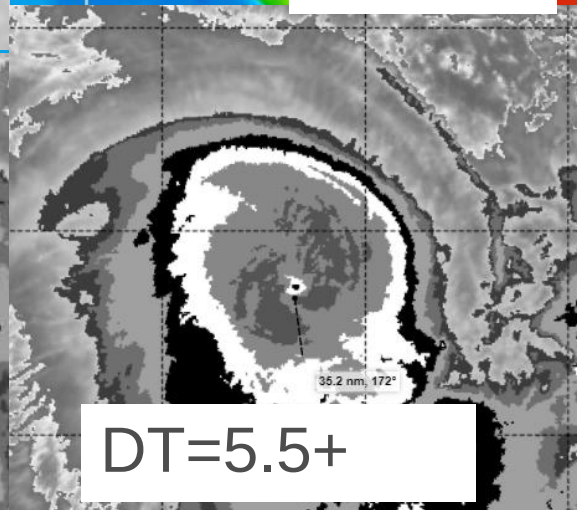












Australian Government
Bureau of Meteorology

Objective guidance: no CIMSS ADT/SATCON/AiDT available NESDIS ADT underestimate

22/00UTC CI=4.8 but when eye pattern detected raw T no. =6.4

Small systems!!!

2022MAR21	120000	4.3	981.8	72.2	4.3	4.3	3.2	MW	ON	OFF	OFF	-68.61	-65.42	UNIFRM	N/A	20.1	-15.80	-110.80	FCST	HIM-8 38.9
2022MAR21	123000	4.4	980.0	74.6	4.4	4.4	3.2	MW	ON	OFF	OFF	-68.61	-64.19	UNIFRM	N/A	20.1	-15.84	-110.76	FCST	HIM-8 38.9
2022MAR21	130000	4.4	980.0	74.6	4.4	4.4	3.3	MW	ON	OFF	OFF	-76.16	-69.55	UNIFRM	N/A	20.1	-15.86	-110.42	FCST	HIM-8 39.3
2022MAR21	133000	4.4	980.0	74.6	4.4	4.4	3.3	MW	ON	OFF	OFF	-72.60	-68.31	UNIFRM	N/A	20.1	-15.91	-110.37	FCST	HIM-8 39.3
2022MAR21	140000	4.4	980.0	74.6	4.4	4.4	3.3	MW	ON	OFF	OFF	-78.01	-68.47	UNIFRM	N/A	20.1	-15.95	-110.33	FCST	HIM-8 39.4
2022MAR21	143000	4.4	980.0	74.6	4.4	4.4	3.3	MW	ON	OFF	OFF	-77.64	-68.71	UNIFRM	N/A	20.1	-16.00	-110.29	FCST	HIM-8 39.5
2022MAR21	150000	4.5	978.2	77.0	4.5	4.5	3.4	MW	ON	OFF	OFF	-75.69	-68.08	UNIFRM	N/A	20.1	-16.04	-110.24	FCST	HIM-8 39.5
2022MAR21	153000	4.5	978.2	77.0	4.5	4.5	3.4	MW	ON	OFF	OFF	-74.98	-69.06	UNIFRM	N/A	20.1	-16.09	-110.20	FCST	HIM-8 39.6
2022MAR21	160000	4.5	978.2	77.0	4.5	4.5	3.5	MW	ON	OFF	OFF	-73.49	-70.15	UNIFRM	N/A	20.1	-16.13	-110.16	FCST	HIM-8 39.7
2022MAR21	163000	4.5	978.1	77.0	4.5	4.5	3.5	MW	ON	OFF	OFF	-74.98	-71.15	UNIFRM	N/A	20.1	-16.18	-110.12	FCST	HIM-8 39.7
2022MAR21	170000	4.5	978.1	77.0	4.5	4.5	3.6	MW	ON	OFF	OFF	-76.04	-74.44	UNIFRM	N/A	20.1	-16.22	-110.08	FCST	HIM-8 39.8
2022MAR21	173000	4.6	976.2	79.6	4.6	4.6	3.7	MW	ON	OFF	OFF	-76.29	-75.44	UNIFRM	N/A	20.1	-16.26	-110.04	FCST	HIM-8 39.8
2022MAR21	180000	4.6	976.2	79.6	4.6	4.6	3.8	MW	ON	OFF	OFF	-74.98	-75.59	UNIFRM	N/A	20.1	-16.35	-109.84	SPRL	HIM-8 40.1
2022MAR21	183000	4.6	976.2	79.6	4.6	4.6	3.9	MW	ON	OFF	OFF	-73.15	-75.92	UNIFRM	N/A	20.1	-16.39	-109.70	SPRL	HIM-8 40.2
2022MAR21	190000	4.6	974.2	79.6	4.6	4.6	3.9	MW	ON	OFF	OFF	-72.82	-76.14	UNIFRM	N/A	20.1	-16.28	-109.62	SPRL	HIM-8 40.3
2022MAR21	193000	4.6	974.1	79.6	4.6	4.6	3.9	MW	HOLD	OFF	OFF	-71.09	-76.36	UNIFRM	N/A	20.1	-16.41	-109.58	SPRL	HIM-8 40.4
2022MAR21	200000	4.6	974.2	79.6	4.6	4.6	3.8	MW	HOLD	OFF	OFF	-69.32	-76.33	UNIFRM	N/A	20.1	-16.34	-109.65	SPRL	HIM-8 40.3
2022MAR21	203000	4.6	974.1	79.6	4.6	4.6	3.8	MW	HOLD	OFF	OFF	-64.97	-75.66	UNIFRM	N/A	20.1	-16.47	-109.71	SPRL	HIM-8 40.3
2022MAR21	213000	4.6	974.1	79.6	4.6	4.6	6.4	MW	HOLD	OFF	OFF	-25.09	-77.58	EYE/P	-99 IR	16.1	-16.42	-109.53	SPRL	HIM-8 40.4
2022MAR21	220000	4.6	974.1	79.6	4.6	4.6	[illegible]	MW	HOLD	OFF	OFF	-62.55	-77.37	[illegible]	N/A	16.1	-16.55	-109.49	SPRL	HIM-8 40.5
2022MAR21	223000	4.6	974.1	79.6	4.6	4.6	6.4	MW	HOLD	OFF	OFF	-27.67	-77.75	EYE/P	-99 IR	16.1	-16.57	-109.45	SPRL	HIM-8 40.6
2022MAR21	230000	4.6	974.1	79.6	4.6	4.6	6.4	MW	HOLD	OFF	OFF	-27.34	-77.69	EYE/P	-99 IR	24.9	-16.60	-109.41	SPRL	HIM-8 40.6
2022MAR21	233000	4.8	970.2	84.8	4.8	5.0	6.3	MW	AdjEnd	OFF	OFF	-28.17	-77.28	EYE/P	-99 IR	24.9	-16.62	-109.48	SPRL	HIM-8 40.6
2022MAR22	000000	4.8	970.2	84.8	4.7	4.1	[illegible]	NO	LIMIT	ON	OFF	-68.61	-77.00	[illegible]	N/A	24.9	-16.55	-109.33	SPRL	HIM-8 40.7
[illegible]																				

…some slides not shown…

Australian VLab Centre of Excellence Regional Focus Group meeting

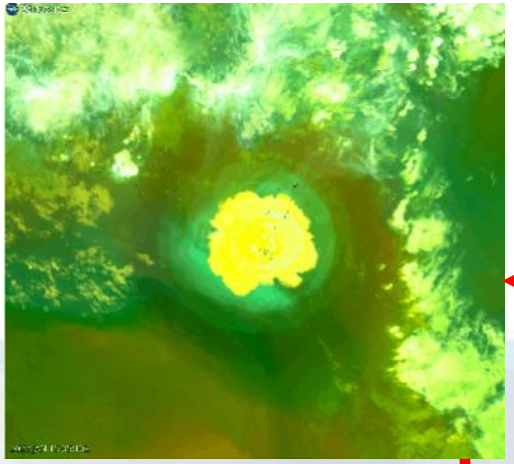
24 February 2022

The eruption of Hunga Tonga-Hunga Ha'apai volcano, 15th January 2022

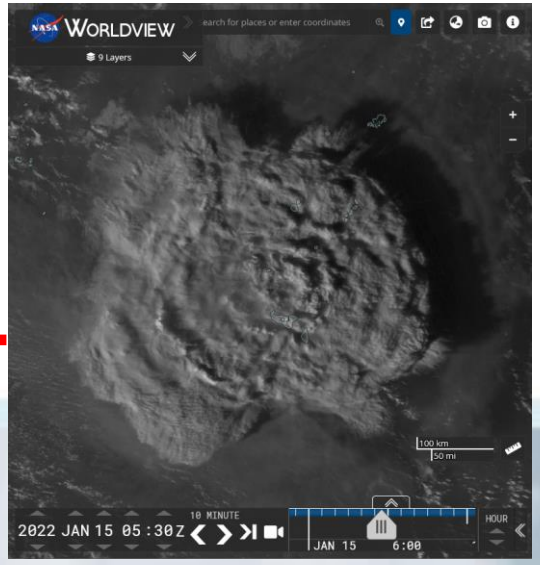
Bodo Zeschke Australian VLab Centre of Excellence Point of Contact

…some slides not shown…

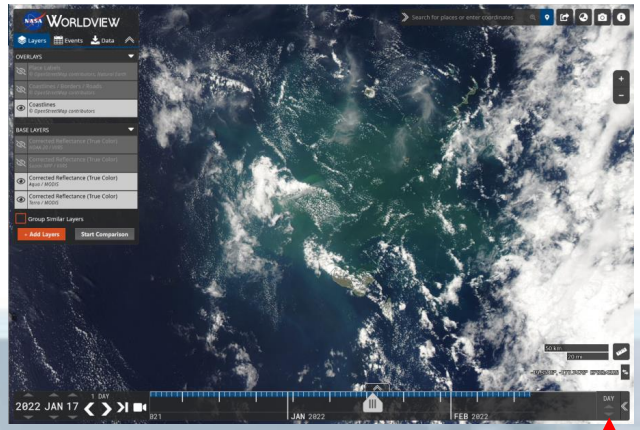
The eruption of Hunga Tonga-Hunga Ha'apai volcano, 15th January 2022: Topics of interest examined here



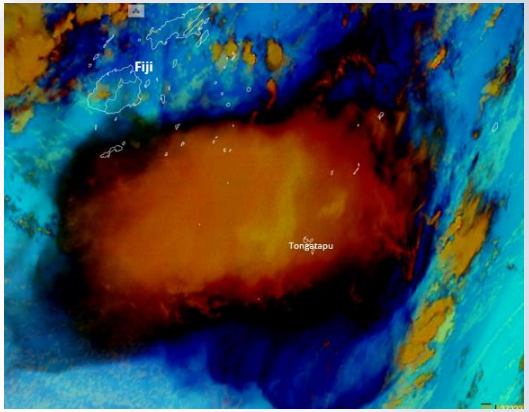
2: The shock wave of the eruption

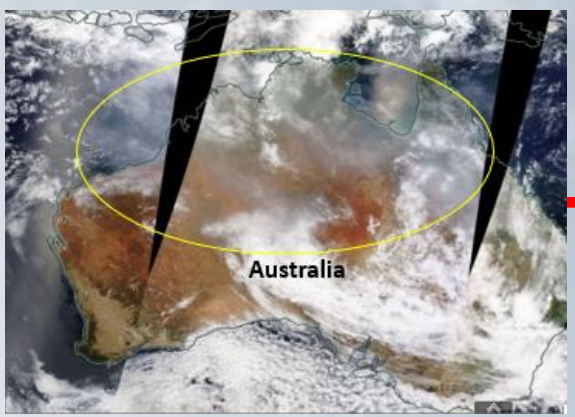


1: Introduction

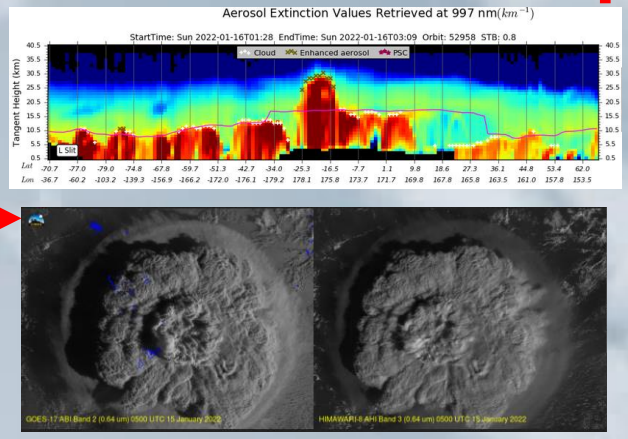


5: Marine conditions around the eruption





3: Spreading out of the ash/SO2 from the eruption



4: The height of the eruption

…some slides not shown…

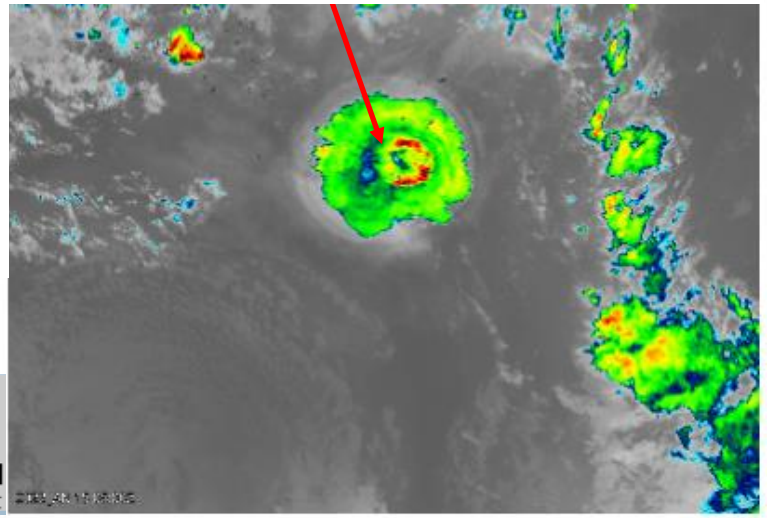
images courtesy NASA Worldview

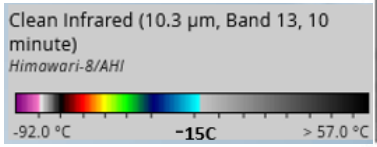
The eruption as rendered in various satellite bands and the Airmass RGB

Tonga area (0510UTC 15th January 2022)

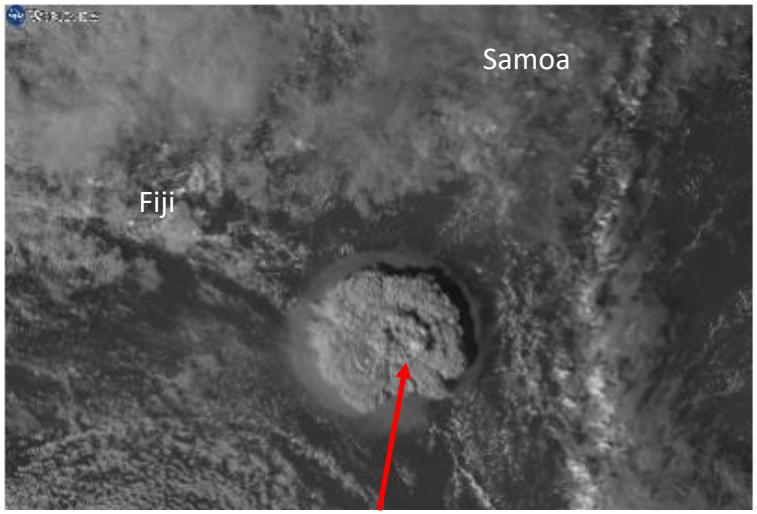
Enhanced IR Band 13

Plumetop temperatures are useful but there are limitations as the plume penetrates the warmer stratosphere





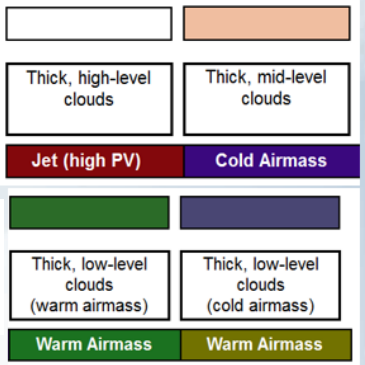
Himawari-8 Visible Band 3



Shows up plumetop features well as a stratospheric / mesospheric intrusion.

Airmass RGB

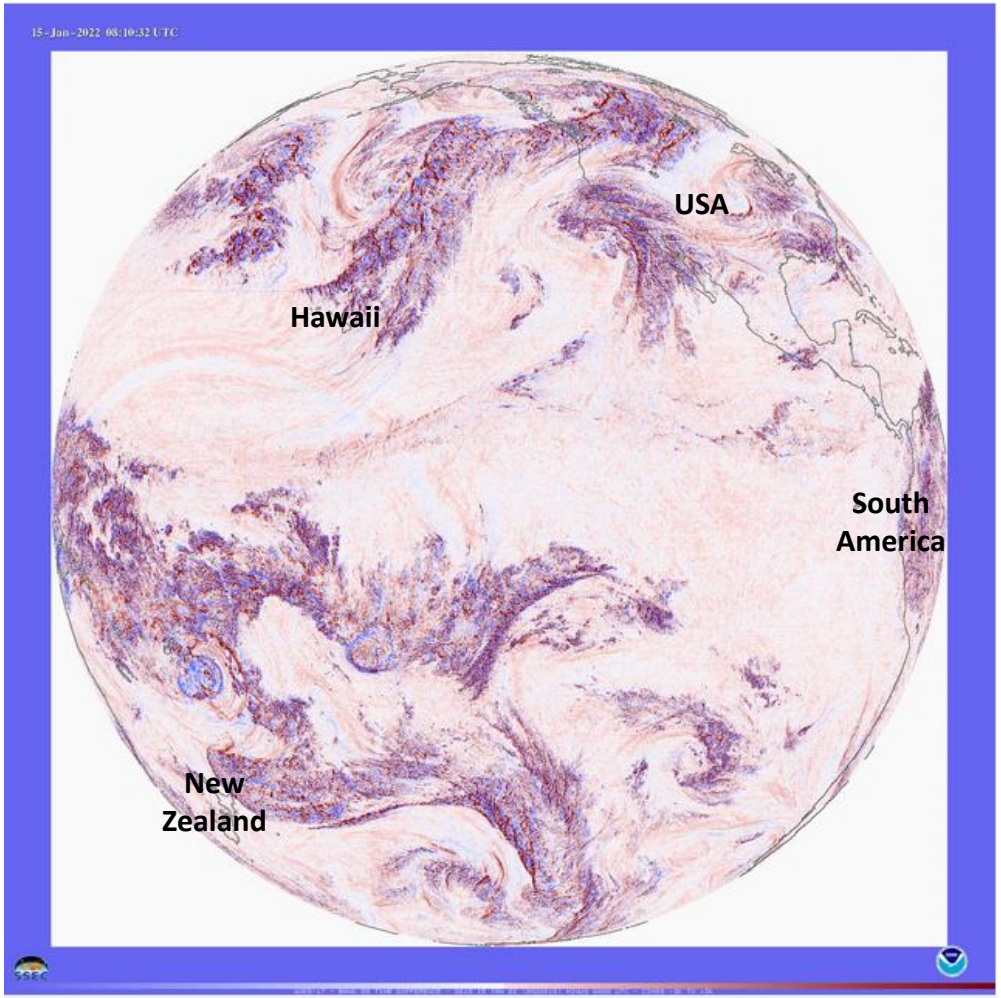
(Ok Hee Kim of KMA alerted me to the usefulness of the Airmass RGB composite in rendering the shock wave of the eruption)



…some slides not shown…

The shockwave propagating across the Pacific Ocean.

https://cimss.ssec.wisc.edu/satellite-blog/archives/category/volcanic-activity



Propagation of the volcanic shock wave across the Pacific Ocean could be followed in GOES-17 *(GOES-West)* Mid-level Water Vapor (6.9 µm) Time Difference images

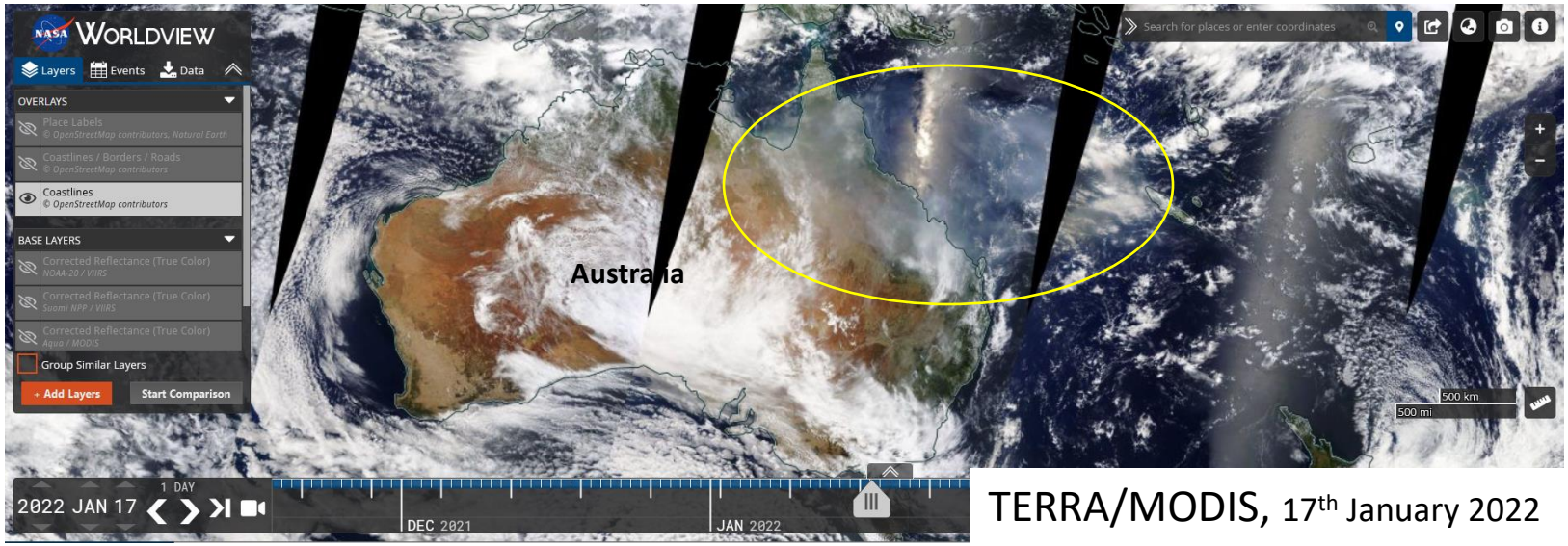
GOES-17 Mid-level Water Vapor (6.9 µm) Time Difference images (credit: Tim Schmit, NOAA/NESDIS/ASPB)

…some slides not shown…

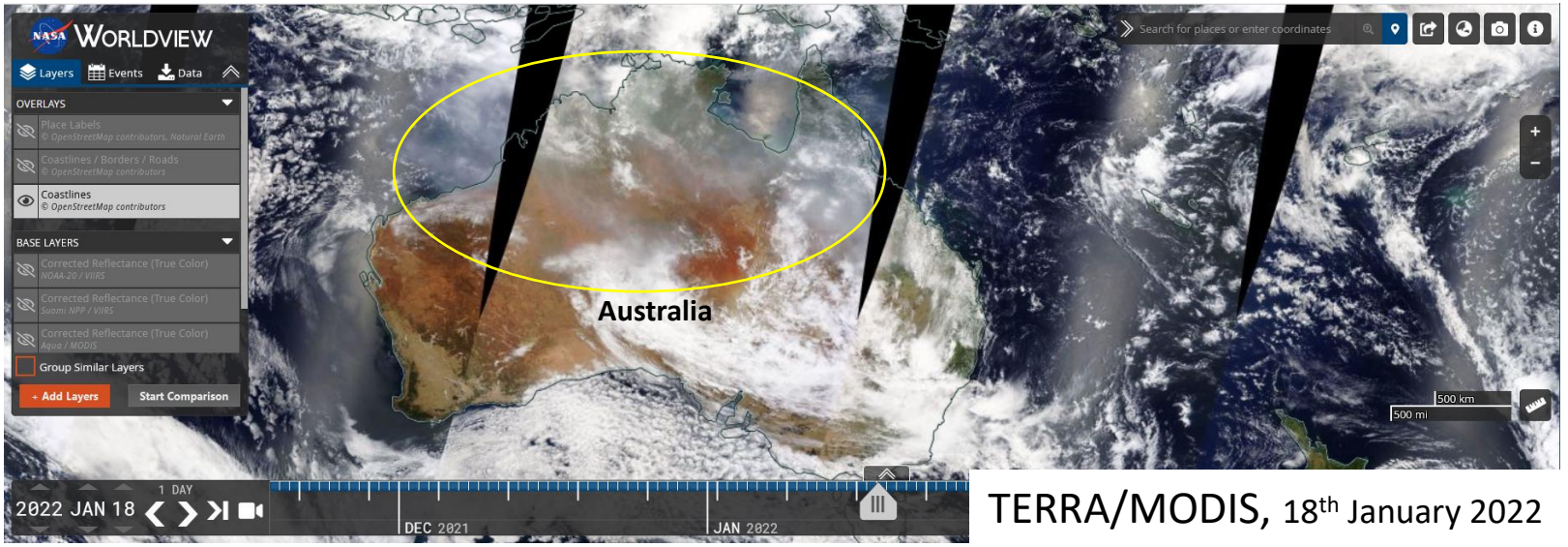
images from NASA Worldview

Propagation of the volcanic ash

from the NASA Worldview site https://worldview.earthdata.nasa.gov/



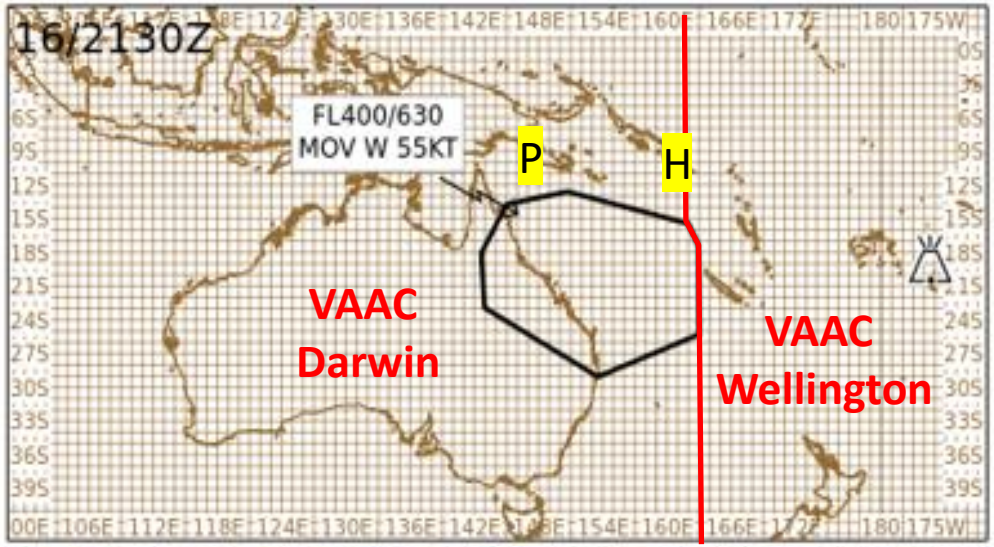
TERRA/MODIS, 17th January 2022

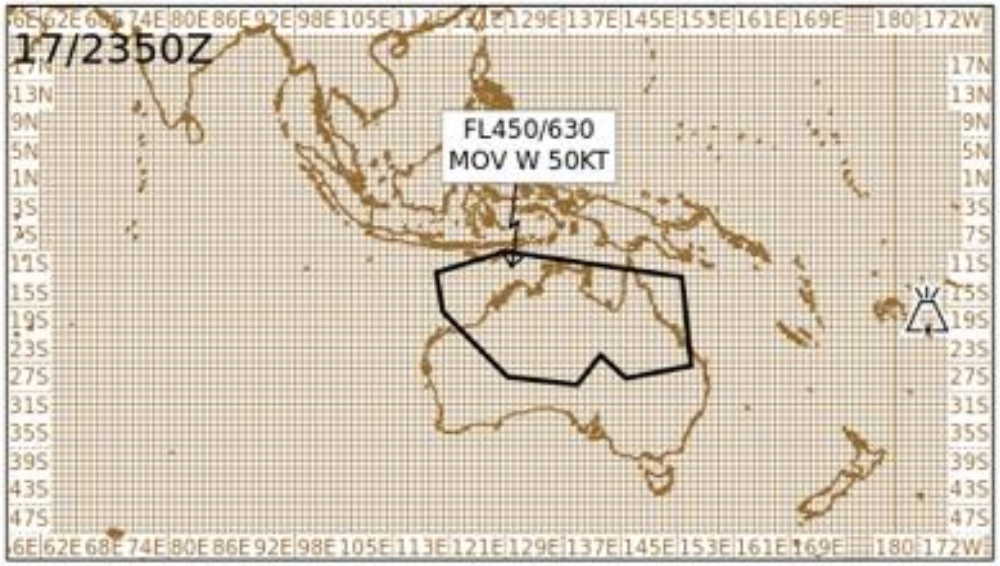


TERRA/MODIS, 18th January 2022

Darwin VAAC Advisory for Hunga-Tonga 16/18 January 2022

images and information kindly forwarded by Anjelica Chang Darwin VAAC



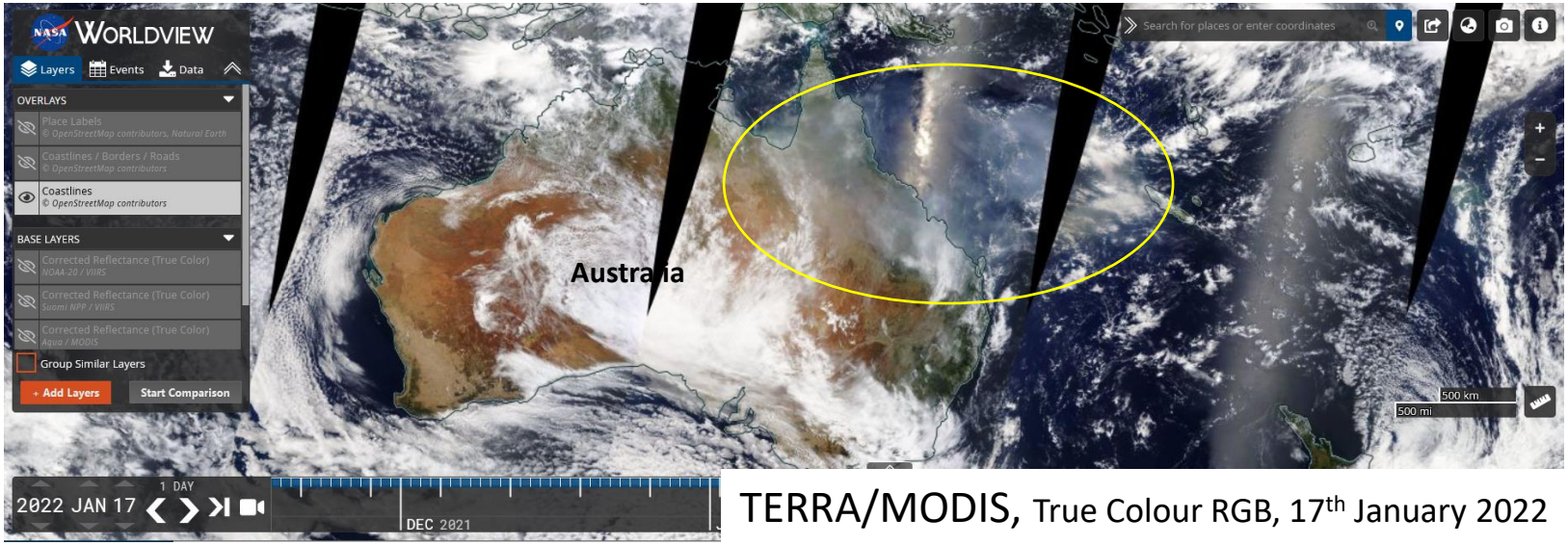


Communication between Darwin VAAC and Wellington VAAC

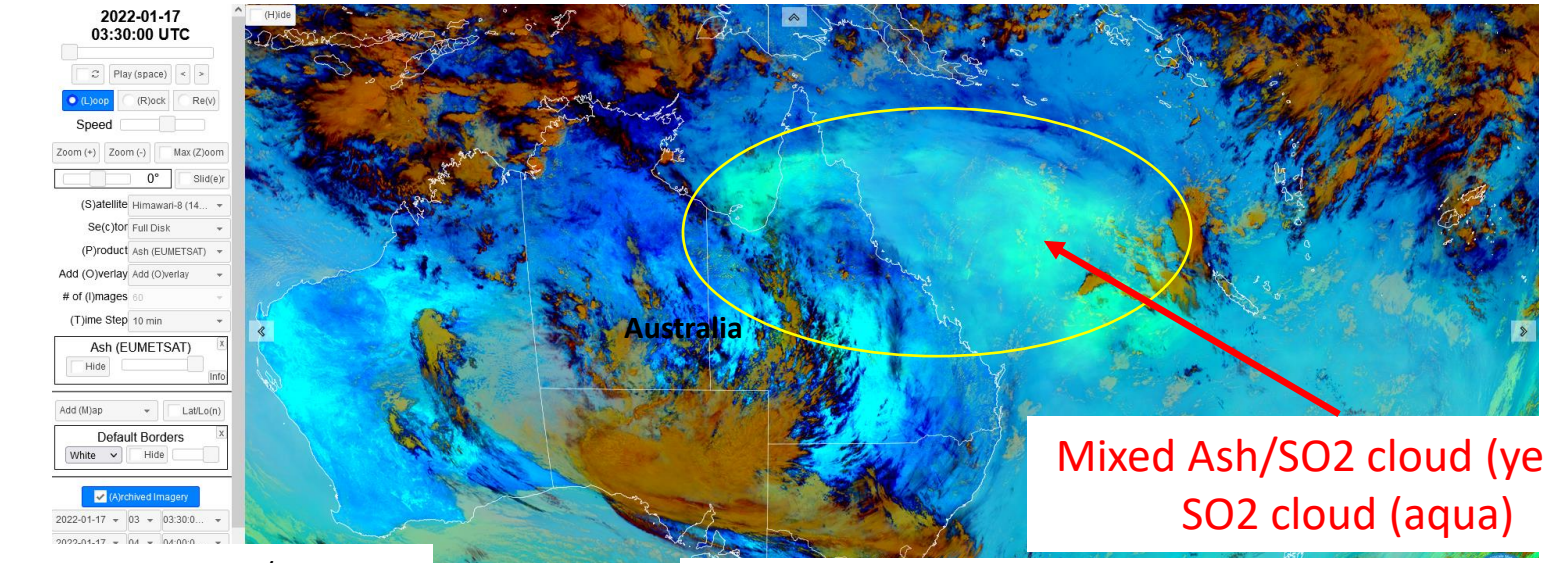
- Darwin and Wellington VAACs share a teams channel. We had multiple meetings to discuss border consistency and just general thoughts on the ash (particularly heights) and forecasts.
- Tonga Met Service lost their communication channels but were able to communicate with Wellington VAAC via satellite phone.
- Tonga Met Service provided information about Colour Code Change and visual reports on the activity of Hunga Tonga.

…some slides not shown…

The volcanic ash signal in the True Colour and Ash RGB



TERRA/MODIS, True Colour RGB, 17th January 2022



Mixed Ash/SO2 cloud (yellow)
SO2 cloud (aqua)

image courtesy RAMMB/CIRA
https://rammb-slider.cira.colostate.edu/

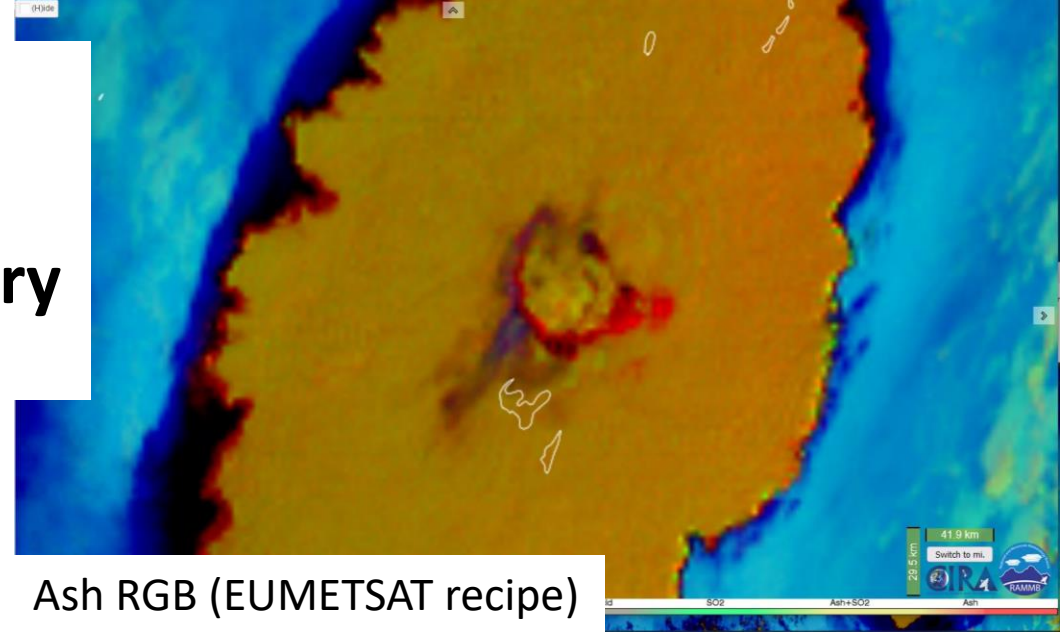
Himawari-8 , Ash RGB 0340UTC 18th January 2022

…some slides not shown…

Comparing stereo height retrieval to features observed in satellite imagery

0450UTC 15th January 2022

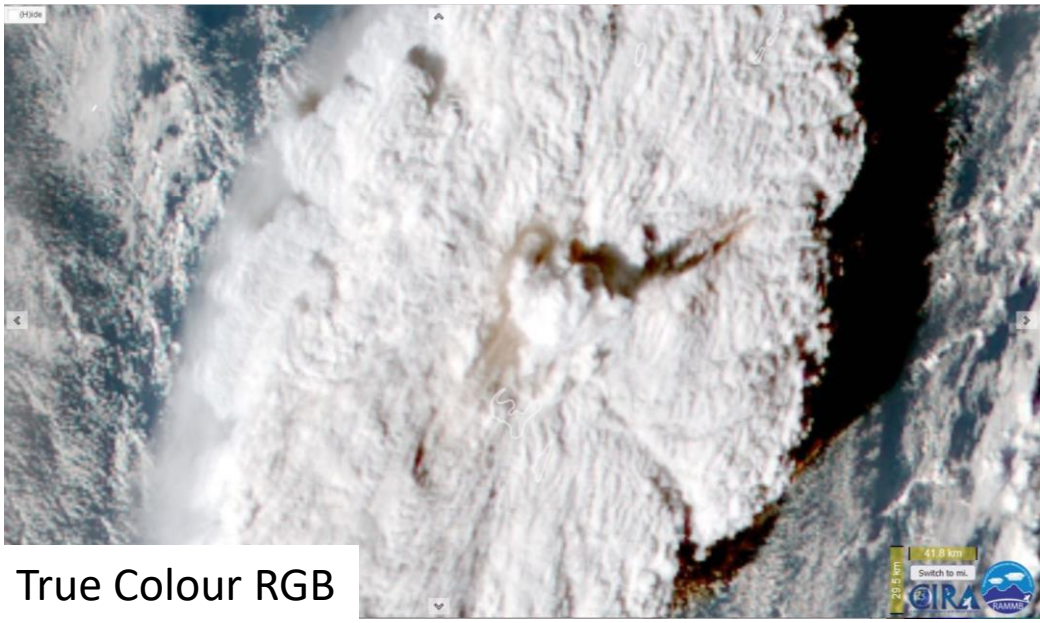
	Volcanic ash
	SO2
	Mixed ash /SO2
	Thin high clouds
	Thick high clouds



Ash RGB (EUMETSAT recipe)

According to https://earthobservatory.nasa.gov/images/149474/tonga-volcano-plume-reached-the-mesosphere?fbclid=IwAR11kdX3w-rJ8S_Mg5BHhcXhdYQjlmvUOBjUGh_ib3FvyvVVO-dy2J0n_Do

At this point the plume expands within the stratosphere. The authors provide an animation indicating that the plume once again intrudes into the mesosphere.



True Colour RGB

images courtesy RAMMB/CIRA https://rammb-slider.cira.colostate.edu/

…some slides not shown…

Comparing stereo height retrieval to features observed in satellite imagery

0450UTC 15th January 2022

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	SO2
	Mixed ash /SO2
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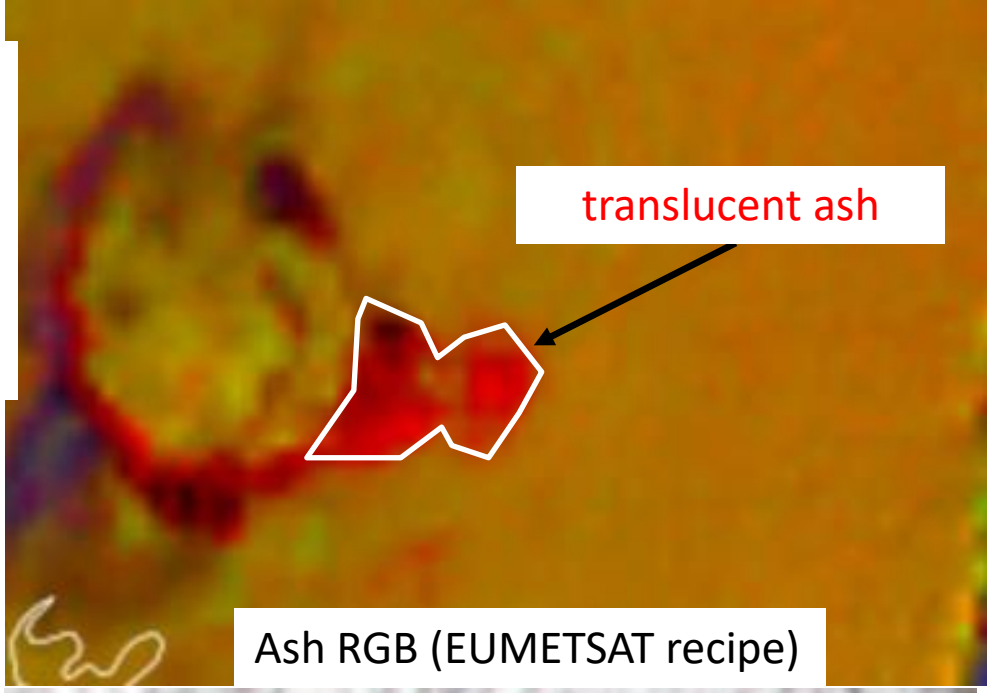

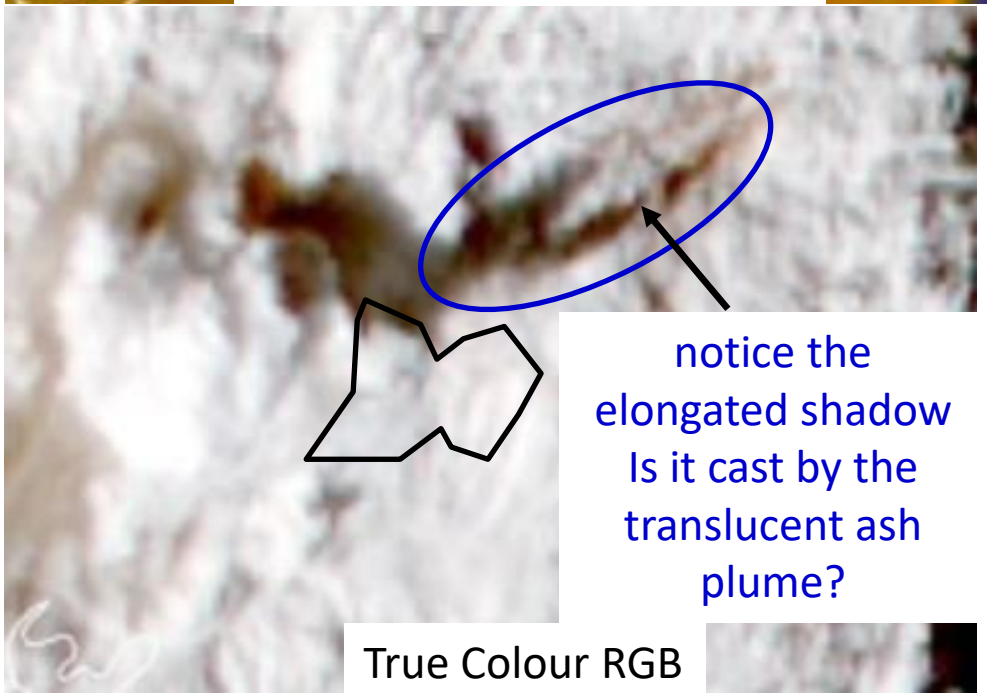

images courtesy RAMMB/CIRA https://rammb-slider.cira.colostate.edu/

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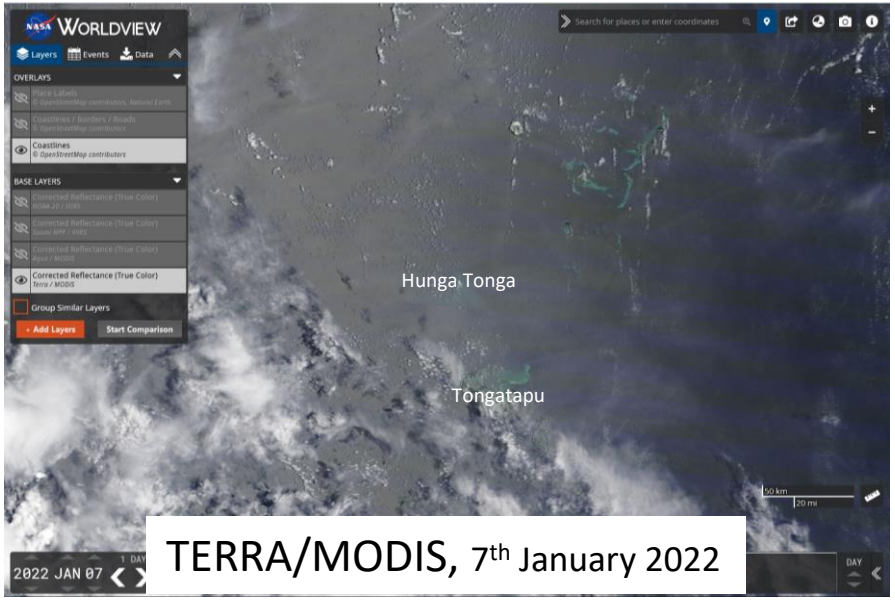
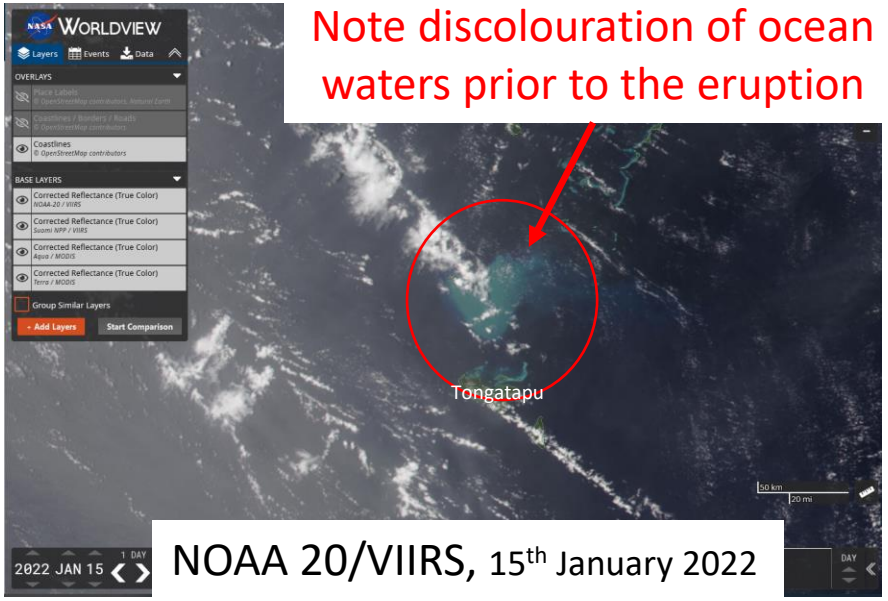
Appearance of the maritime areas around the eruption.

Polar orbiting satellites, True Colour RGB https://worldview.earthdata.nasa.gov/



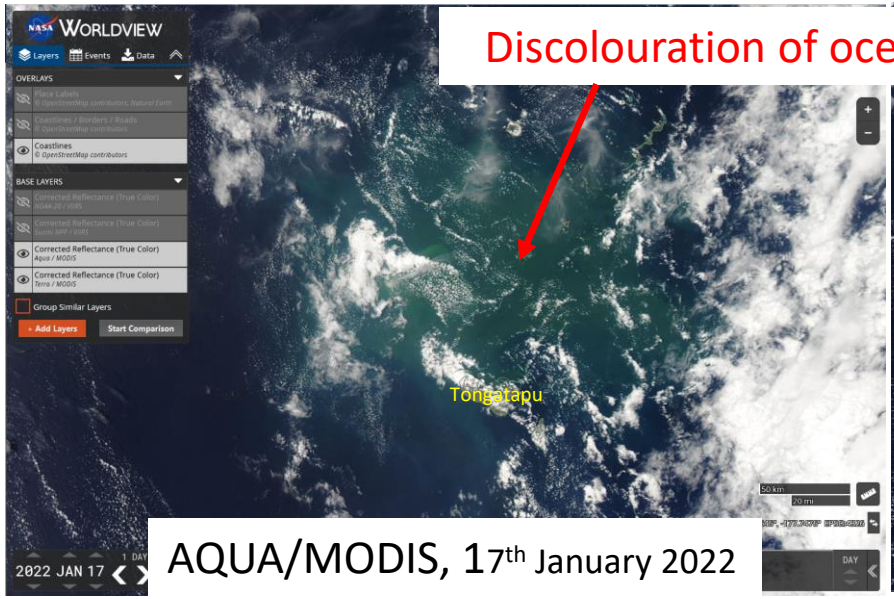
TERRA/MODIS, 7th January 2022

Note discolouration of ocean waters prior to the eruption

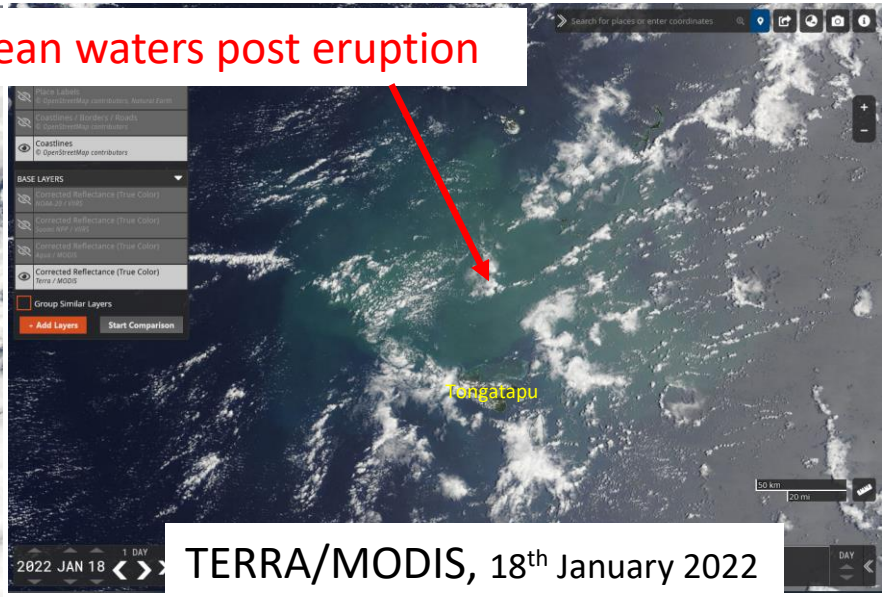


NOAA 20/VIIRS, 15th January 2022

Discolouration of ocean waters post eruption



AQUA/MODIS, 17th January 2022



TERRA/MODIS, 18th January 2022

…some slides not shown…

Australian VLab Centre of Excellence Regional Focus Group meeting
20 July 2021

The remarkable development of Sumatra Squall Line SQL-31 "Xavi"

Bodo Zeschke Australian VLab Centre of Excellence Point of Contact

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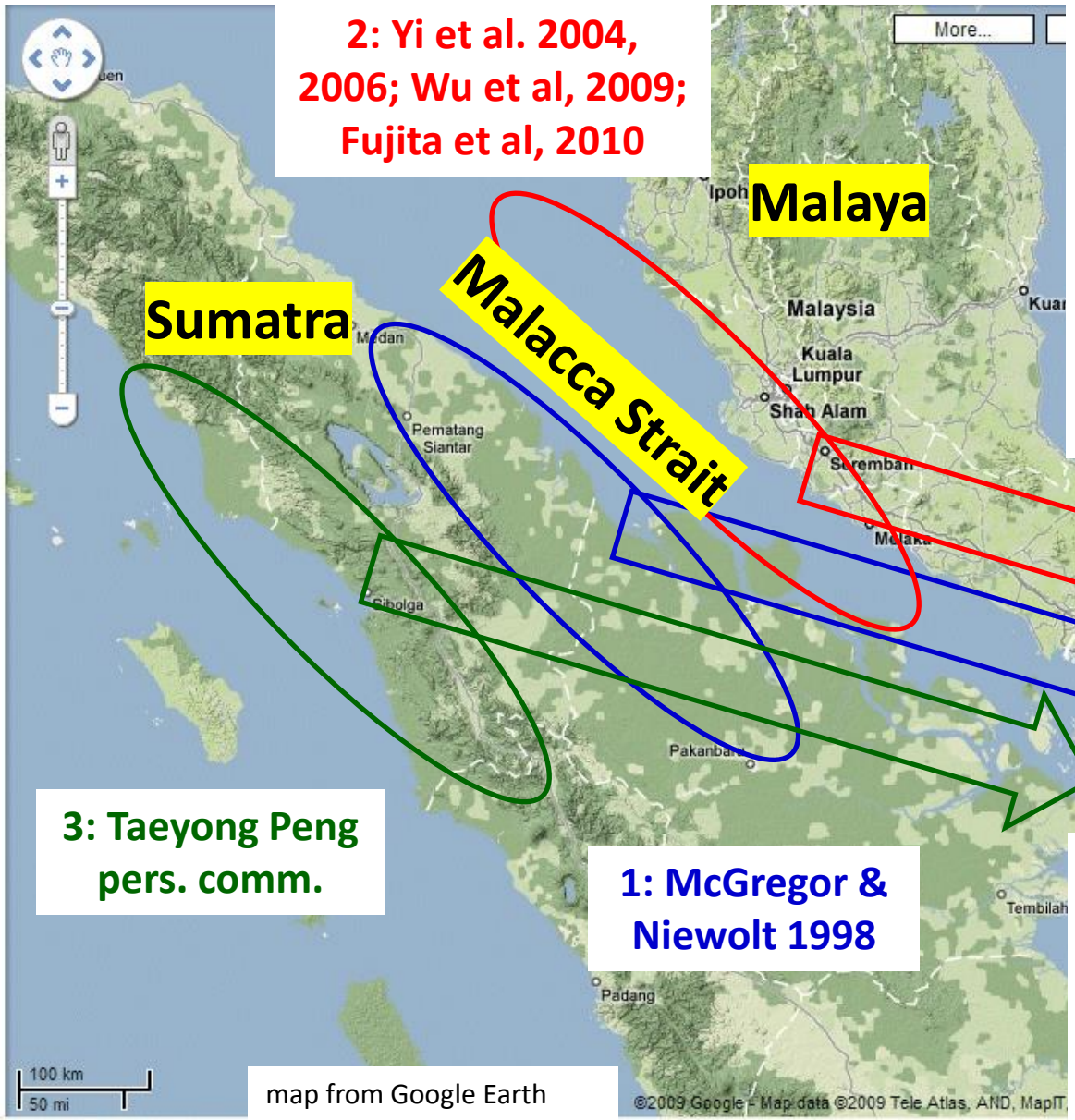
Sumatra Squall Line formation and development



Key processes:

- Thermal contrast between land and sea (heating over Sumatra during the afternoon (1), warm SST in the Malacca Strait (2)
- Convergence of SW/NW low level winds due to topography (2)
- Convergence of land breezes in the Malacca Straits at night, enhanced by convection (1,2).
- Overnight cloud top cooling (2).
- W/SW steering winds (1,2,3).
- Squall lines crossing Sumatra at night may weaken before redeveloping over the Malacca Straits early morning (3).

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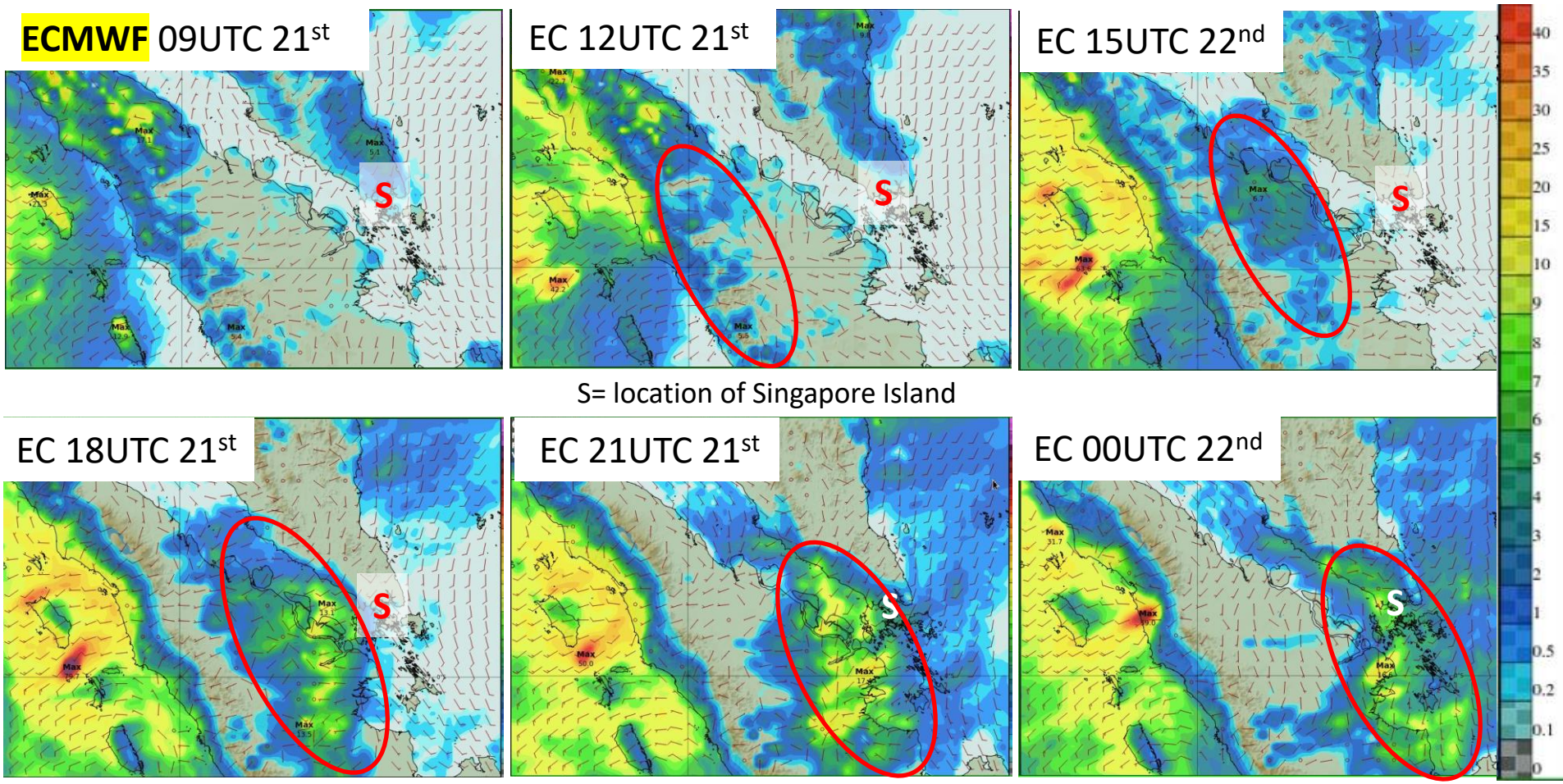
images courtesy BOM

ECMWF 6 hour precipitation forecast (00UTC 21st June NWP analysis)



S= location of Singapore Island

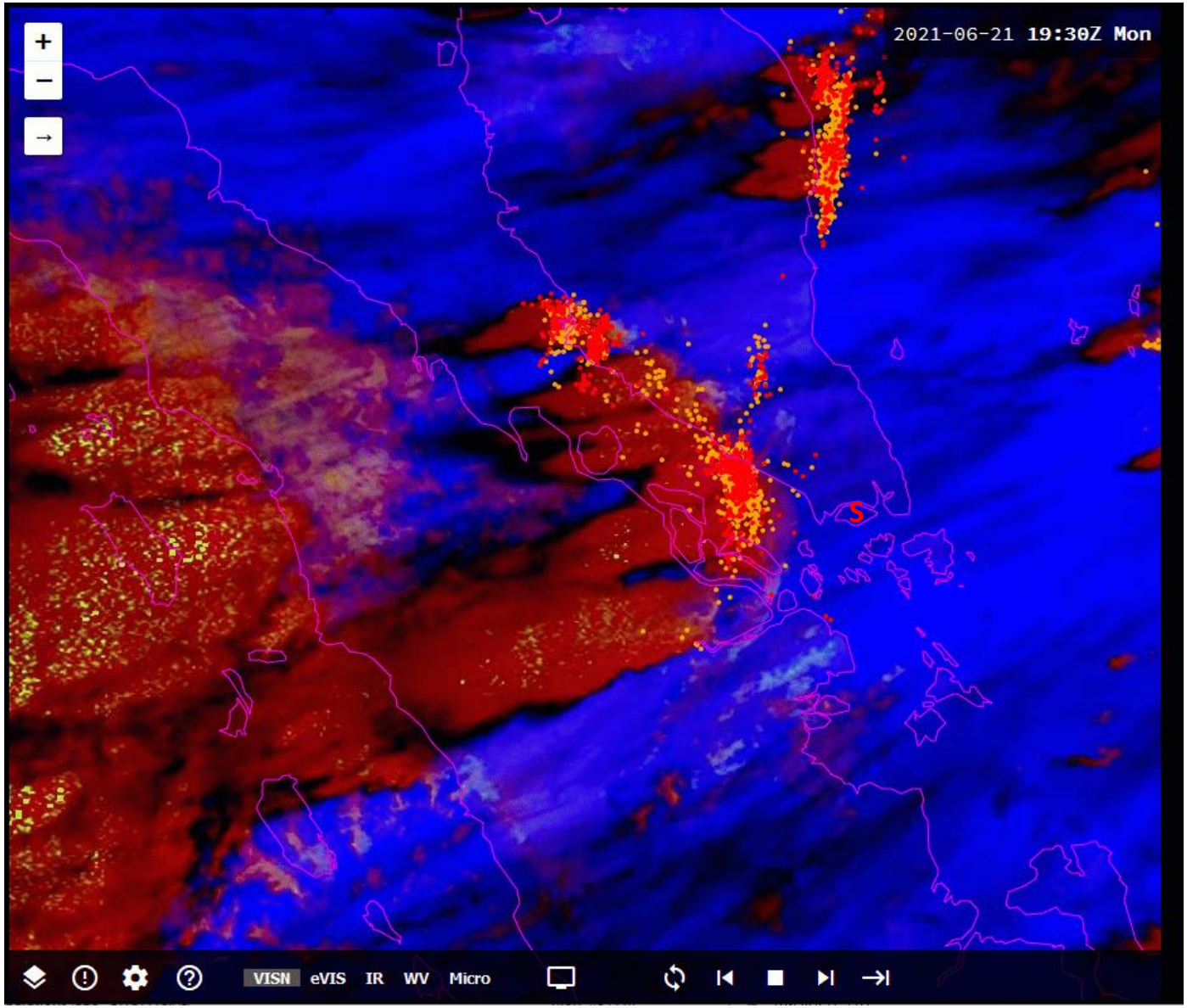
- Note the development of a **north-south oriented region of enhanced precipitation**, moving to the east in the forecast.
- Arrival in Singapore around 21UTC, 21st June, weakening afterwards.

…some slides not shown…

animation courtesy JMA/BOM, lightning data from WeatherZone

Animation 3: Xavi, the "Singapore Heartbreaker"

(Night Micro / True Colour RGB, and lightning 1930UTC 21st June - 0400UTC 22nd June)



Night Microphysics RGB colour palette

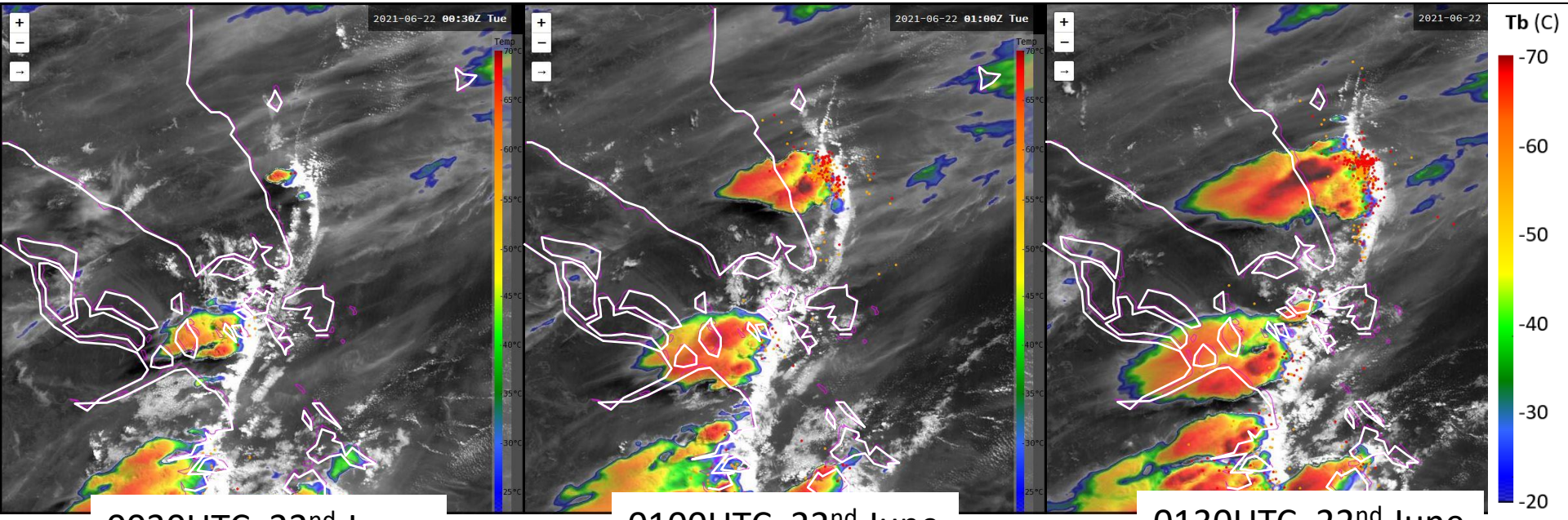
- Thick high cloud
- Thin Cirrus
- Thick mid-level cloud
- Thin mid-level cloud
- Low cloud/fog (warm)
- Low cloud/fog (cold)
- Ocean
- Land

Location of Singapore as "S"

…some slides not shown…

animation courtesy JMA/BOM, lightning data from WeatherZone, RADAR data forwarded Songhan Wong, Avester Lau, NEA Singapore

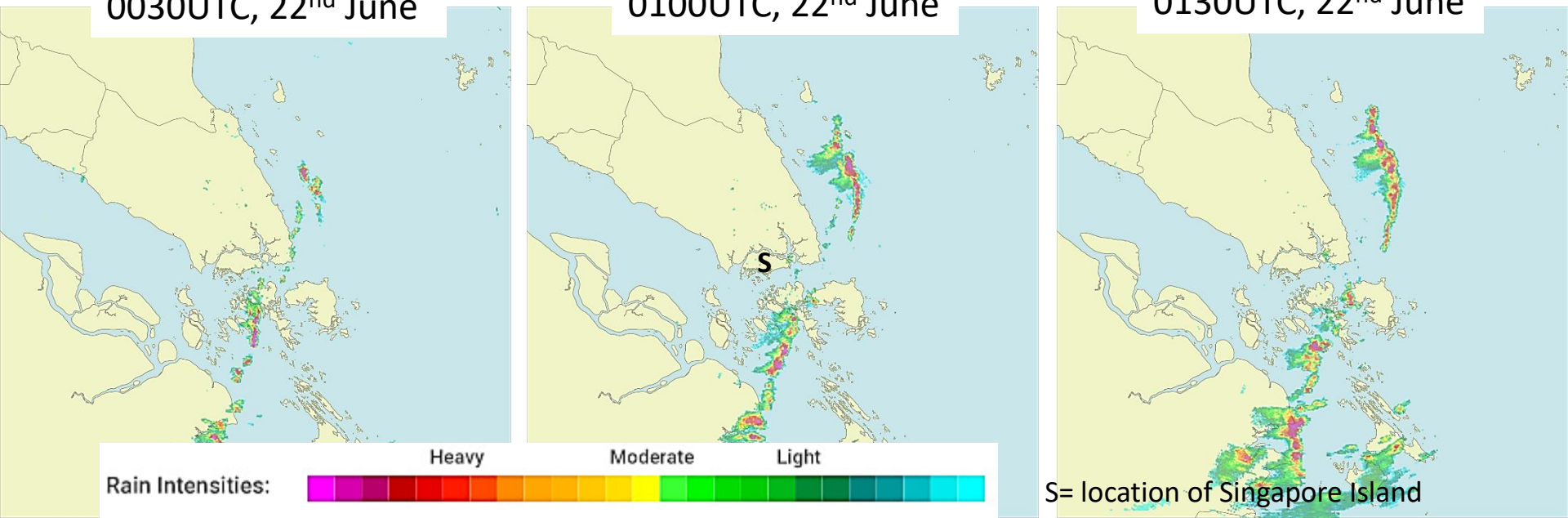
True Colour RGB and NEA Singapore RADAR



0030UTC, 22nd June

0100UTC, 22nd June

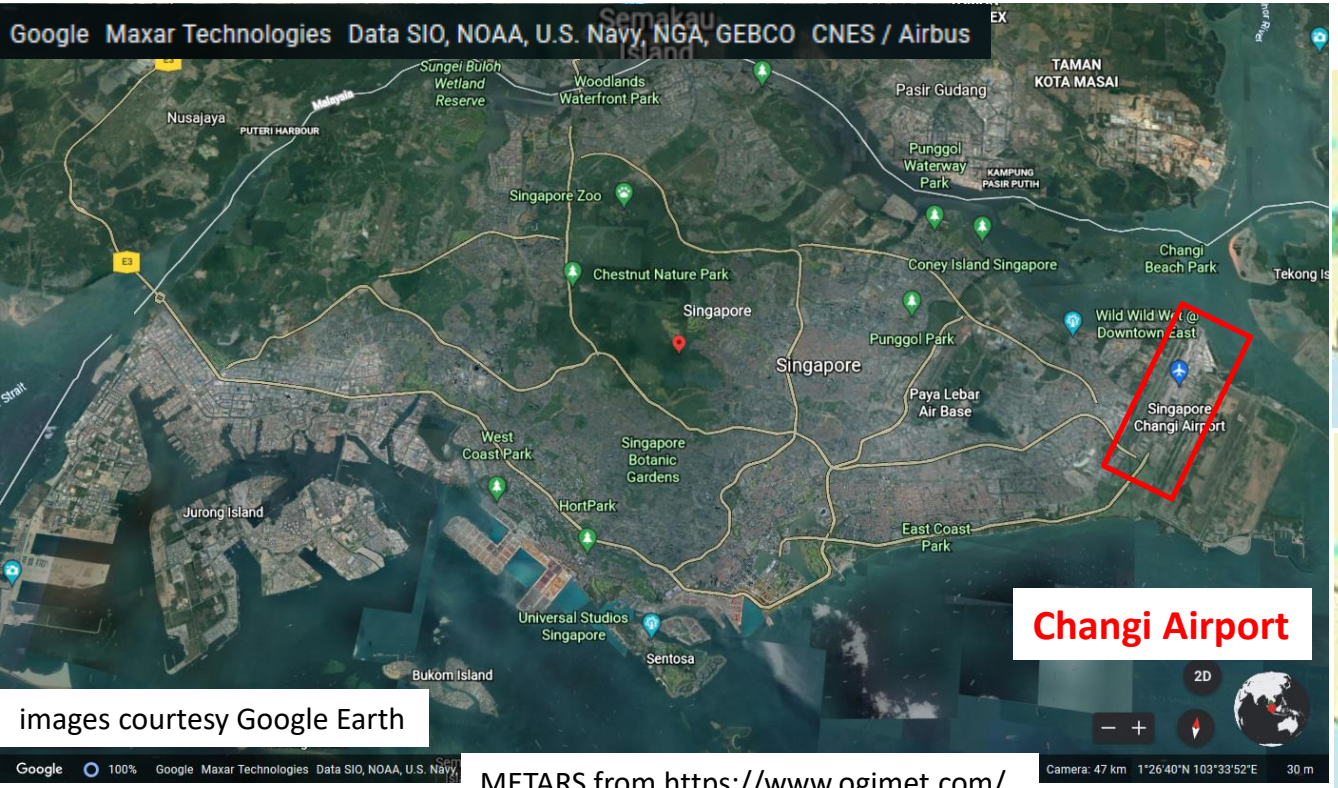
0130UTC, 22nd June



S= location of Singapore Island

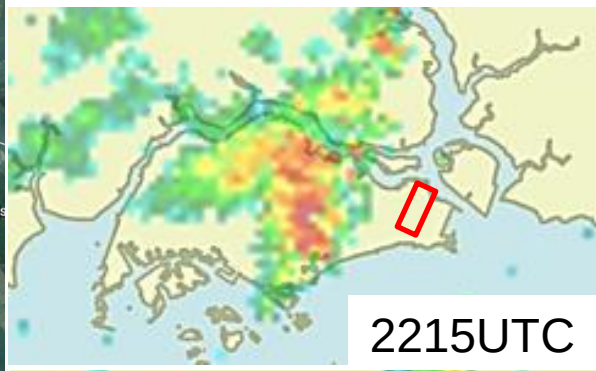
…some slides not shown…

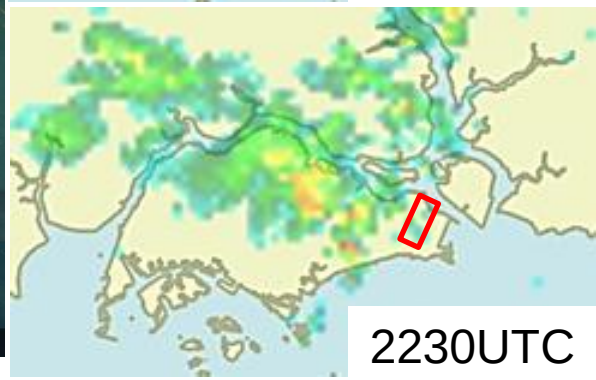
Impact on Changi Airport



images courtesy Google Earth

RADAR images forwarded by Songhan Wong, Avester Lau, NEA Singapore





METARS from https://www.ogimet.com/

21/06/21 21:30Z	**METAR WSSS 212130Z 19002KT 9999 FEW016 FEW017CB FEW018TCU SCT060 27/25 Q1010 TEMPO FM2200 TL2245 25015G25KT 3000 TSRA=**
21/06/21 22:00Z	**METAR WSSS 212200Z 25006KT 200V300 9000 -TSRA FEW010 FEW015CB SCT016TCU 27/23 Q1011 TEMPO TL2240 4000 BECMG FM2240 TL2300 NSW=**