The Meteorology Behind the 2022 Great Barrier Reef Mass Coral Bleaching Event

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Trade wind disruptions are found to drive the 2022 bleaching event. Following trade wind breakdown, the 4 m ocean temperature at Davies Reef increases from 28.6 °C to 30.5 °C over a 19-day period. After trade wind re-establishment, ocean temperatures rapidly fall back to seasonal norms.

Surface Wind Shifts and Ocean Heating

- From February 20th, wind speeds begin to drop while ocean temperatures rise.
- By February 25th, wind speeds reach their minimum as the wind direction shifts from trades to northerlies.
- From March 2nd-7th strong northerly winds bring high air temperature and humidity levels over the Reef, limiting surface cooling.
- After March 11th ocean/air temperatures and humidity levels plummet following a sudden wind shift back to trades and wind speed increase.

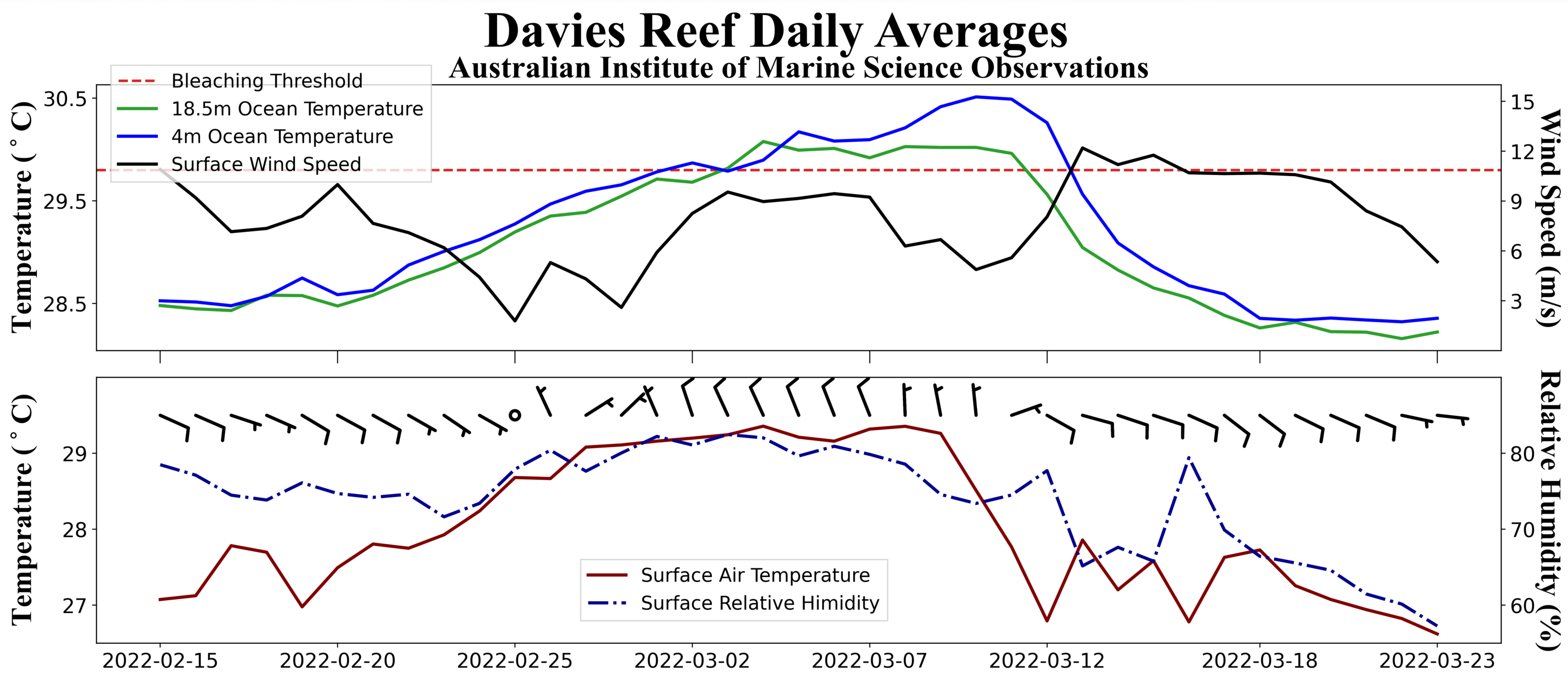

Figure 1: Atmospheric and oceanographic observations from the Australian Institute of Marine Science for Davies Reef.

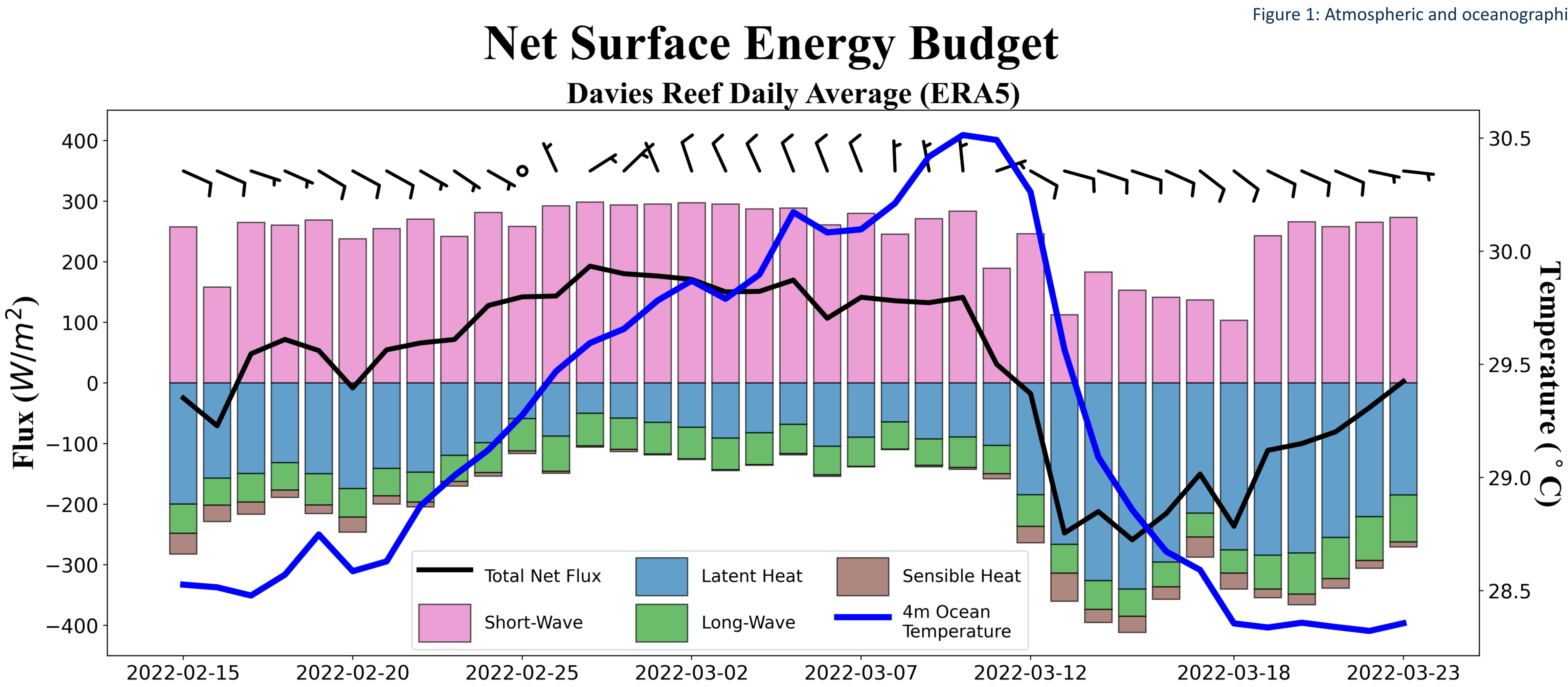

Figure 2: ERA5 daily averaged net surface energy budget at Davies Reef.

Latent Heat Flux Drives Heating

The latent heat flux (LHF) strongly regulates ocean cooling through surface evaporational cooling (Talley *et al.* 2011).

- The LHF is reduced rapidly from February 20th following the wind speed decline, with values remaining low while ocean heating is observed.
- Northerly winds bringing high humidity levels continue to supress the LHF even as wind speeds increase.
- Minimal changes in short-wave flux occur during ocean heating as values remain close to the clear-sky maximum.
- As the trades return on March 11th, LHF values triple and cloud cover returns to the Reef promoting rapid cooling.

Trade Winds Breakdown (25th FEB 2022)

- An area of low-pressure forms over the Reef promoting weak winds and reduced cloud cover
- At this time cloud cover and strong easterlies can be seen accelerating towards the cut-off low at 500 hPa.
- The cut-off low helped pull strong winds and cloud cover away from the Reef and towards Lismore during the 2022 NSW-QLD floods (Barnes *et al.* 2023).

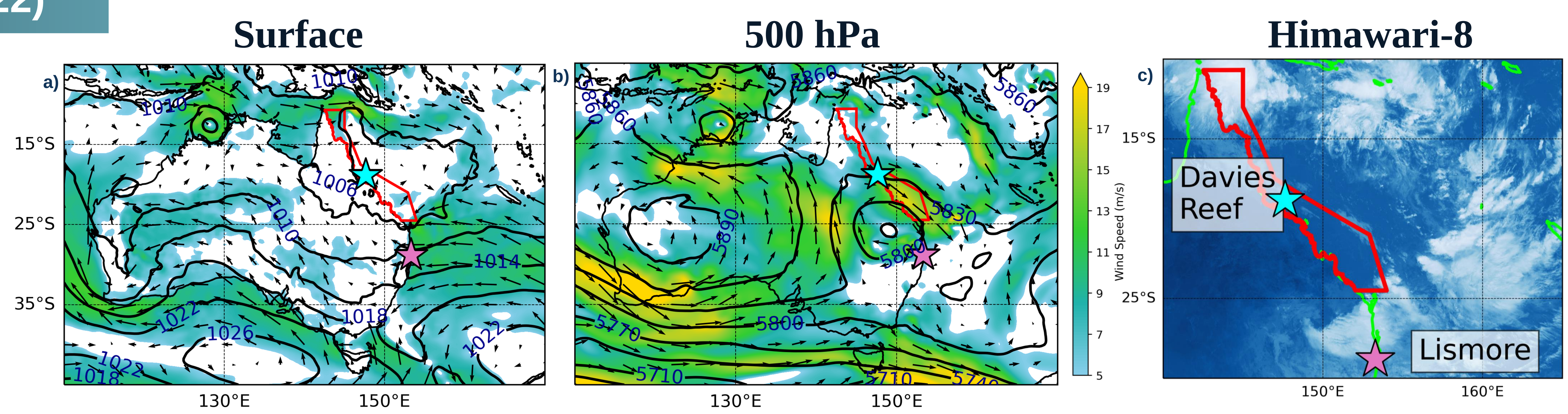

Figure 3: February 25th 2022 0000UTC, panels a) and b) show ERA5 horizontal winds (m/s) at 10m (a) and 500 hPa (b) with mean sea-level pressure (hPa) (a) and height (m) contours. Panel c) shows Himawari-8 band-13 satellite imagery focussed on Queensland.

Trade Winds Return (10th – 12th MAR 2022)

- The trade winds are re-established quickly as wind shifts and temperature/humidity drops occur over 1-2 hours.
- The process of coastal ridging (Holland and Leslie, 1986) is identified to drive trade re-establishment .
- Here, coastal ridging describes the process as the high-pressure in the Great Australian Bight moves east and pushed up the Australian east coast bringing strong pressure-gradients over the Reef.

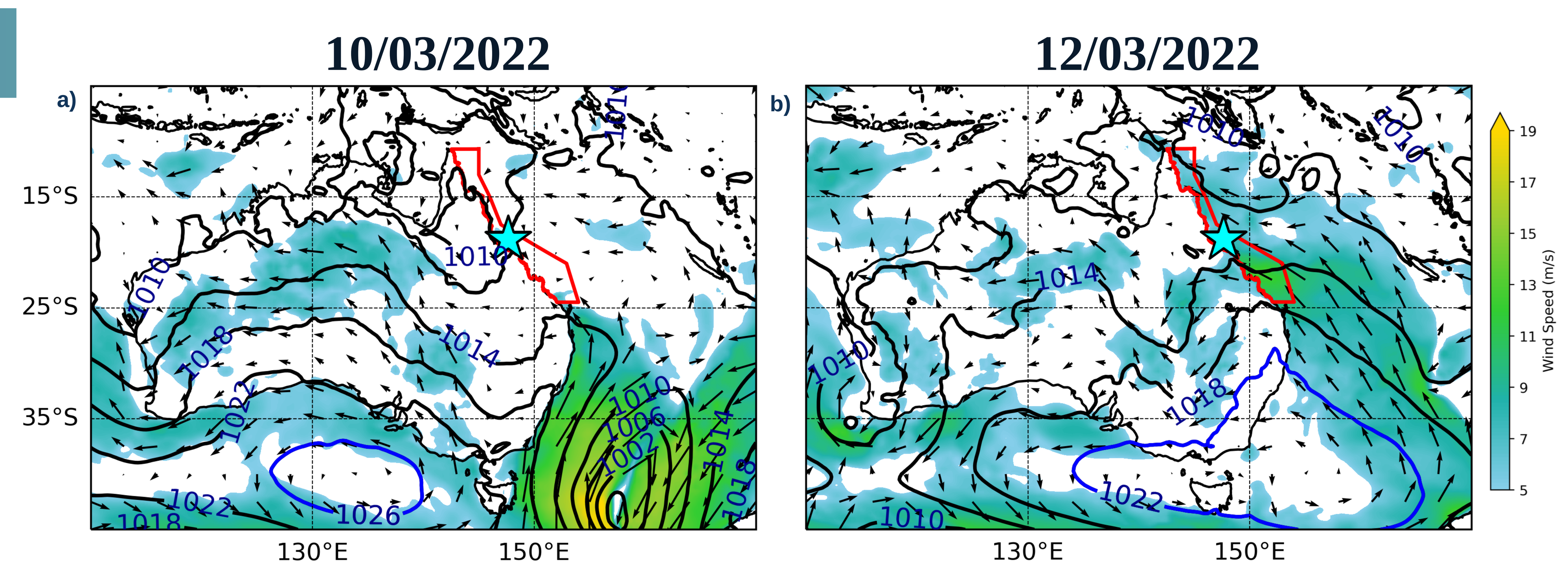

Figure 4: March 10th and 12th 2022 0000UTC ERA5 10m horizontal winds (m/s) and mean sea-level pressure contours (hPa).

References

Barnes, M., King, M., Reeder, M., and Jakob, C., 2023: The dynamics of slow-moving coherent cyclonic potential vorticity anomalies and their links to heavy rainfall over the eastern seaboard of Australia. *Quarterly Journal of the Royal Meteorological Society*, **149**, 2233-2251, DOI:10.1002/qj.4503

Holland, G., and Leslie, L., 1986: Ducted coastal ridging over S.E. Australia. *Quarterly Journal of the Royal Meteorological Society,* **112,** 731-748, DOI:10.1002/qj.49711247310

Talley, L., Pickard, G., Emery W., and Swift J., 2011: Mass, Salt, and Heat Budgets and Wind Forcing. *Descriptive Physical Oceanography*, DOI:10.1016/B978-0-7506-4552-2.10005-8

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