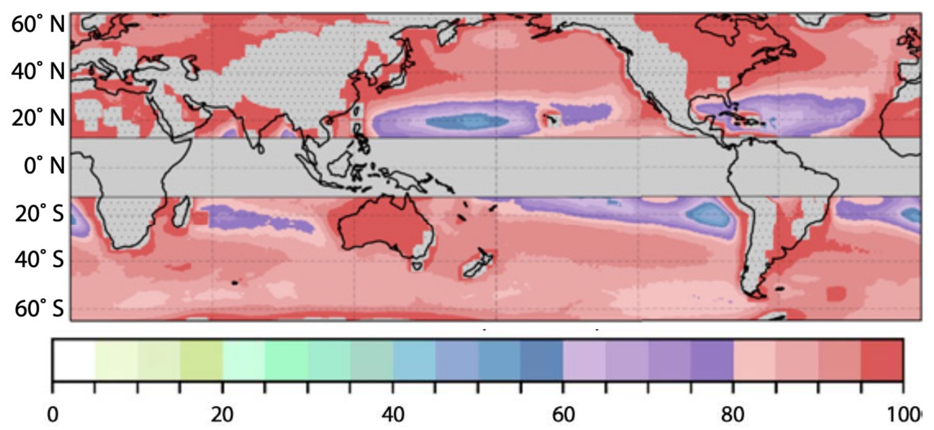
Some further thoughts on atmospheric fronts and frontal air-sea interaction

Rhys Parfitt - Florida State University, Tallahassee, Florida

Atmospheric fronts – the junction between mid-latitude weather and climate

Atmospheric fronts are responsible for much of the day-to-day variability in the mid-latitudes, but have also been shown to explain the time-mean structure of many fields such as precipitation and vertical velocity. As such, much of the oceanic impact on the climatological mid-latitude atmosphere can be understood through its impact on atmospheric fronts specifically.



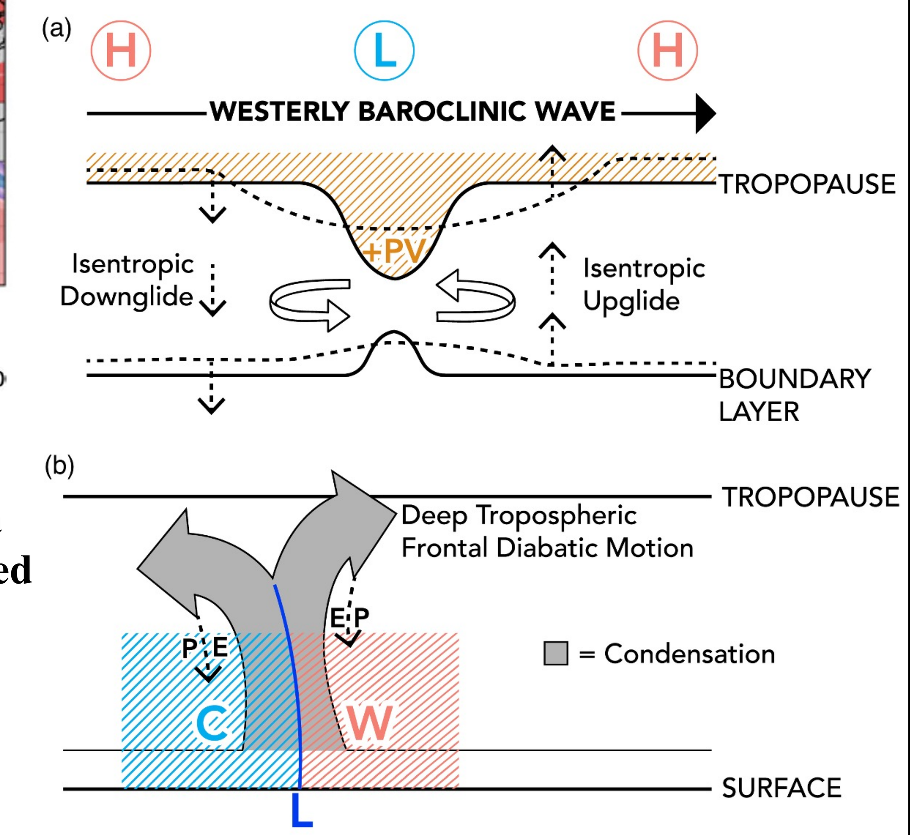
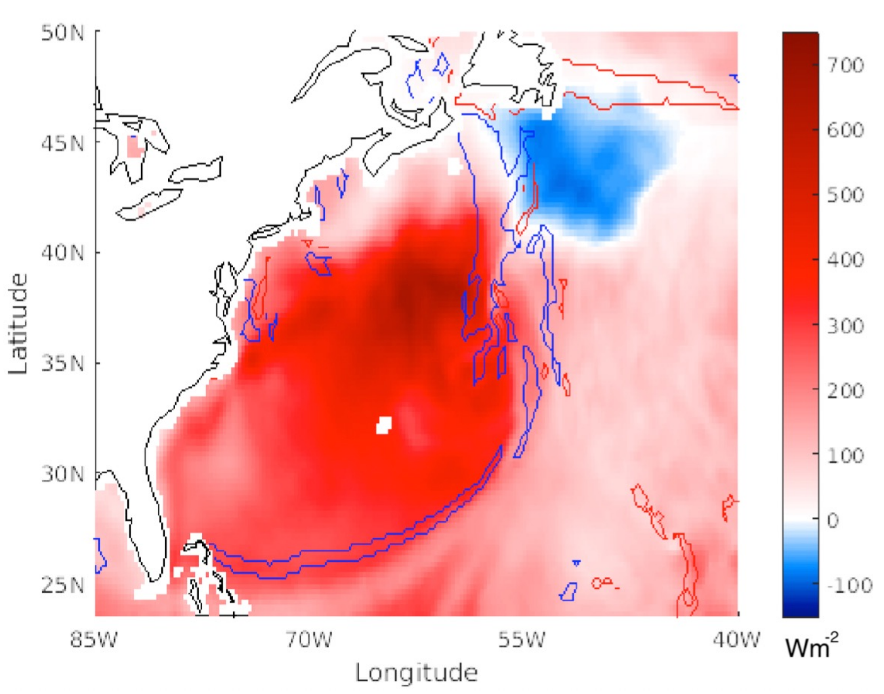


Fig 1. (above). Proportion of annual precipitation associated with an atmospheric front in ERA-5[1]. Fig 2. (right). Schematic illustrating the effect of a positive potential vorticity ∂-function superimposed on a westerly baroclinic flow[2]. (a) Isentropic upglide/downglide offers a large degree of cancellation in vertical velocity. (b) Deep tropospheric motion at an atmospheric front does not and is left as a "residual".

Ocean-atmospheric front interaction

Key to ocean-atmospheric front interactions are the extremely large changes in air-sea heat fluxes that occur across the atmospheric fronts.



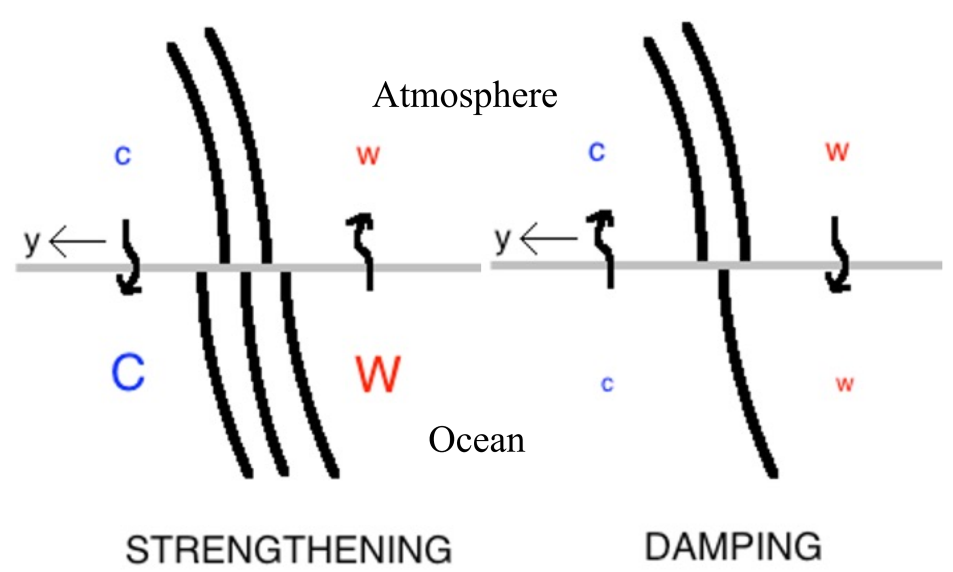


Fig 3. (left). Surface latent heat flux (LHF), 1200UTC, January 20th 1979, in the western North Atlantic, in ERA-5[3]. Fig 4. (right). "Thermal Damping and Strengthening". Cross-atmospheric frontal surface sensible heat flux (SHF) gradients can modulate atmospheric frontal activity[4].

These strong air-sea fluxes and their associated gradients can actively modify frontal systems[5] and their rainfall[6], thus modulating the time-mean structure[7], as well as pre-condition the atmosphere for extreme events[8], such as the extra-tropical transition of tropical cyclones[9]. Considerable debate still exists however on the relative role of the ocean vs. atmosphere in driving these fluxes. It is also not clear that we have the observational capacity to accurately measure them. General characteristics of air-sea fluxes associated with frontal passages are considered here[3] in wintertime, December-February (DJF) in the Northern Hemisphere (NH), and June-August (JJA) in the Southern Hemisphere, between 1979-2018 in ERA-5.

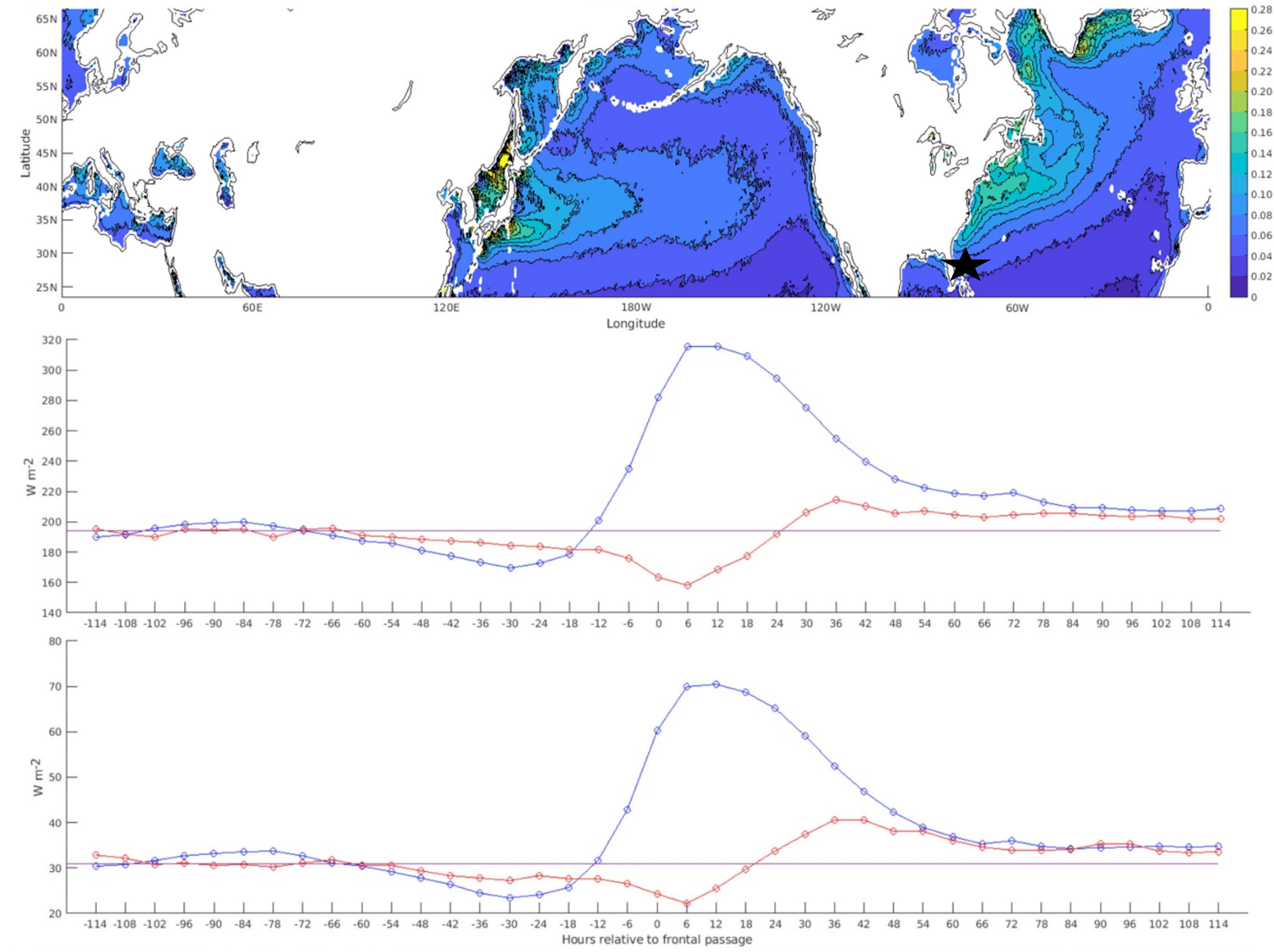


Fig 5. (top) Frequency of atmospheric cold fronts in the NH mid-latitudes as a fraction of the entire period DJF 1979-2018 in ERA-5. (middle) Average evolution of LHF at 78.5°W, 27.5°N (marked with a star in the top figure) relative to a cold (blue) and warm (red) frontal passage in the same period. Climatological LHF is 194.4Wm^{-2} (purple horizontal line). (bottom) As (middle) but for SHF. Climatological SHF is 30.9Wm^{-2}.

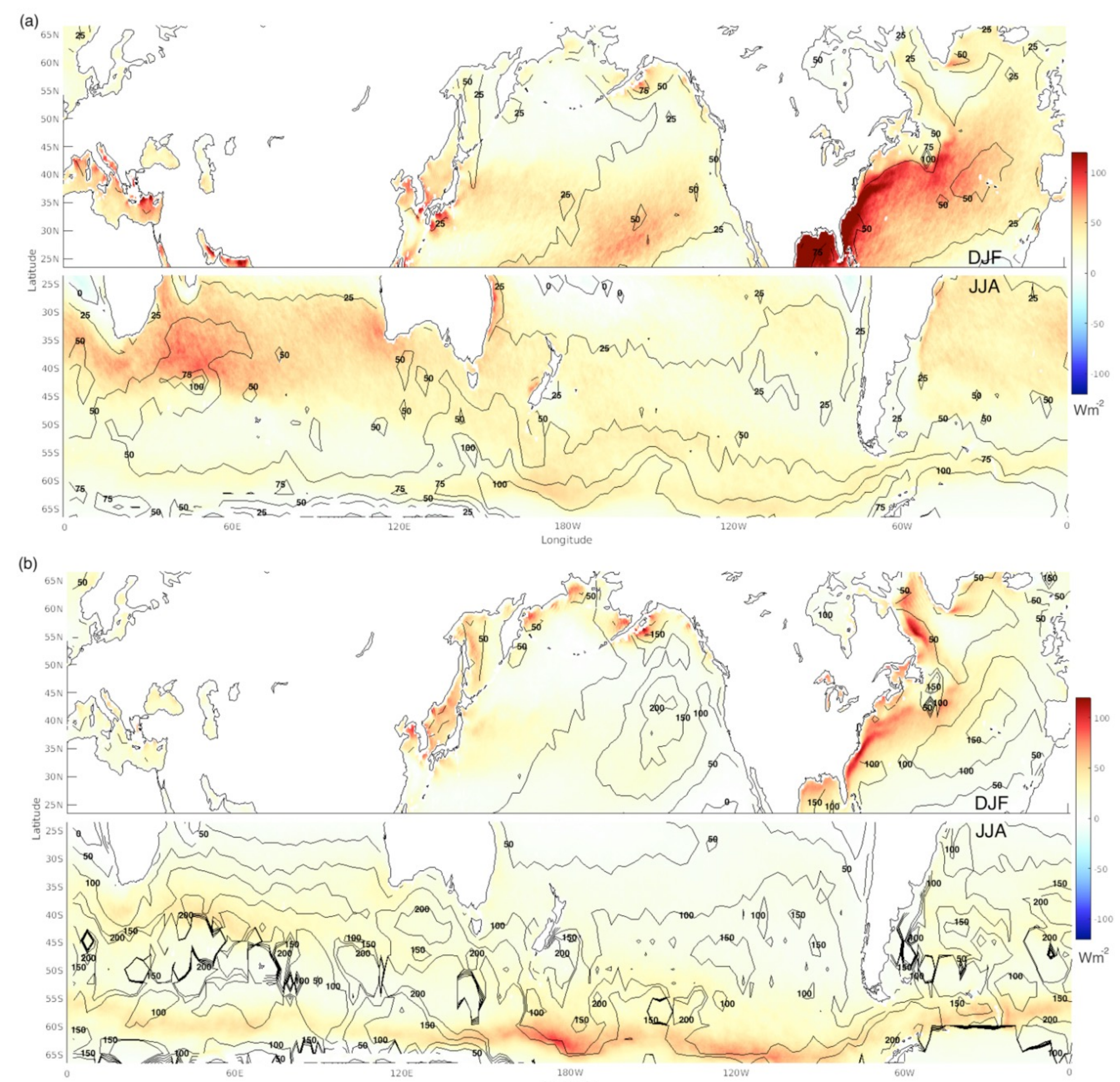


Fig 6. Average difference in wintertime (DJF in NH, JJA in SH) (a) LHF and (b) SHF from climatological wintertime average 6 hours after the passage of an atmospheric cold front (shown in color). Contours (interval 25% from -25% to 100% for LHF, and 50% from -50% to 200% for SHF) represent the percentage change from the climatological wintertime average.

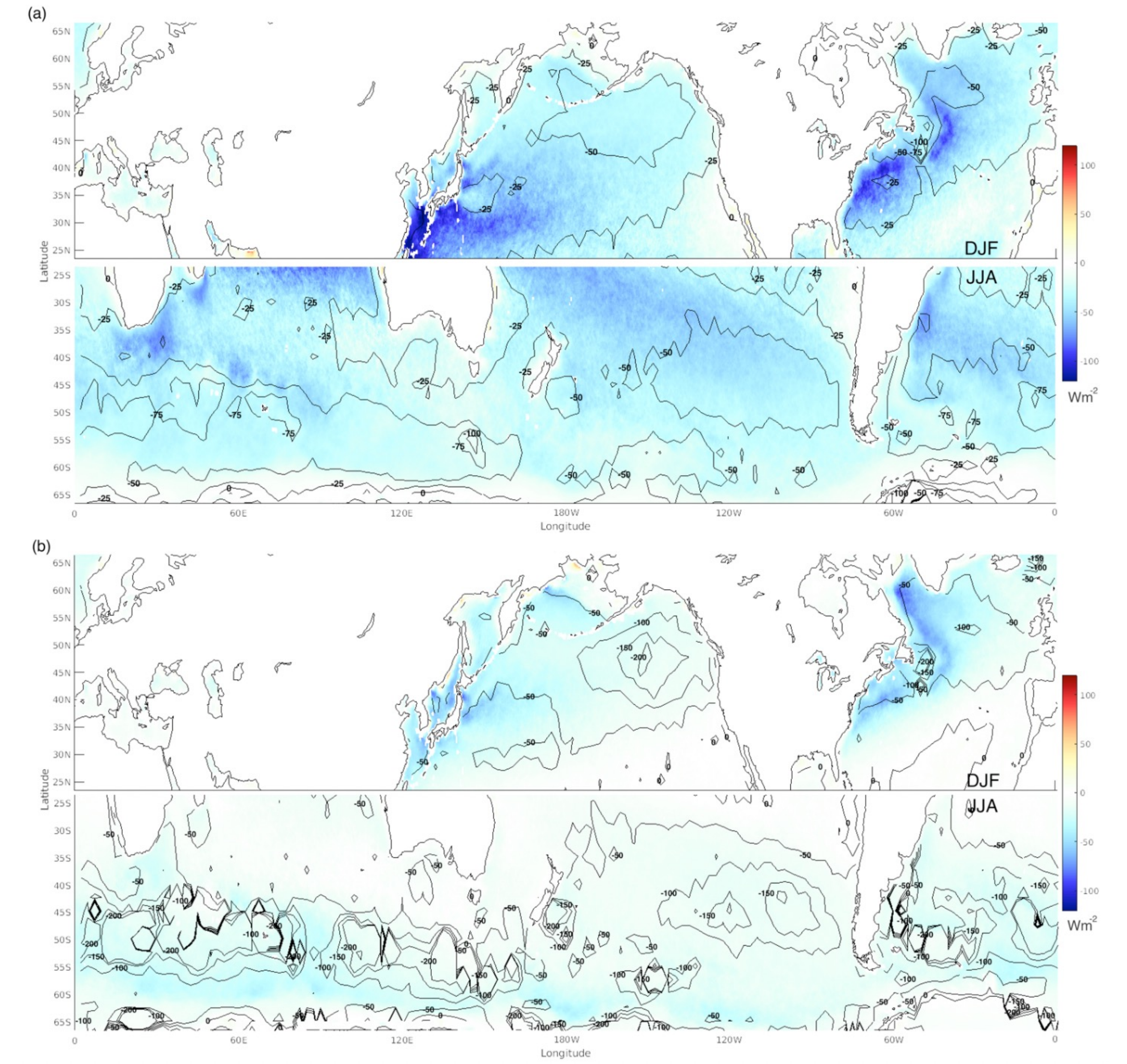


Figure 7. Average difference in wintertime (DJF in NH, JJA in SH) (a) LHF and (b) SHF from climatological wintertime average 6 hours after the passage of an atmospheric warm front (shown in color). Contours (interval 25% from -100% to 25% for LHF, and 50% from -200% to 50% for SHF) represent the percentage change from the climatological wintertime average.

Some points of discussion

1) 6 hours post-atmospheric front in wintertime, the average % change in LHF (SHF) from the wintertime climatological average ranges from 25-100% (50-200%); individual cases can be significantly larger. Regions of largest % change are not co-located with regions of largest absolute change. The rates of change suggest non-simultaneous measurements of bulk formulae variables will lead to extremely large errors, and provide an idea of hotspots observational efforts might target. 2) The importance of this is emphasized by comparing the typical post-atmospheric front LHF and SHF anomaly timescale with front frequency - with respect to the climatological average, LHF and SHF can always be considered as under the influence of an atmospheric front. 3) In certain regions, an imprint of the oceanic frontal/mesoscale appears in the average % change 6 hours post-atmospheric front, especially for SHF (e.g. Southern Ocean, Brazil-Malvinas Confluence). However, this is not the case in all regions usually characterized by strong ocean mesoscale variability.

References

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