Changes in air-sea fluxes over the North Atlantic during 1950-2019 as derived from ERA5 data

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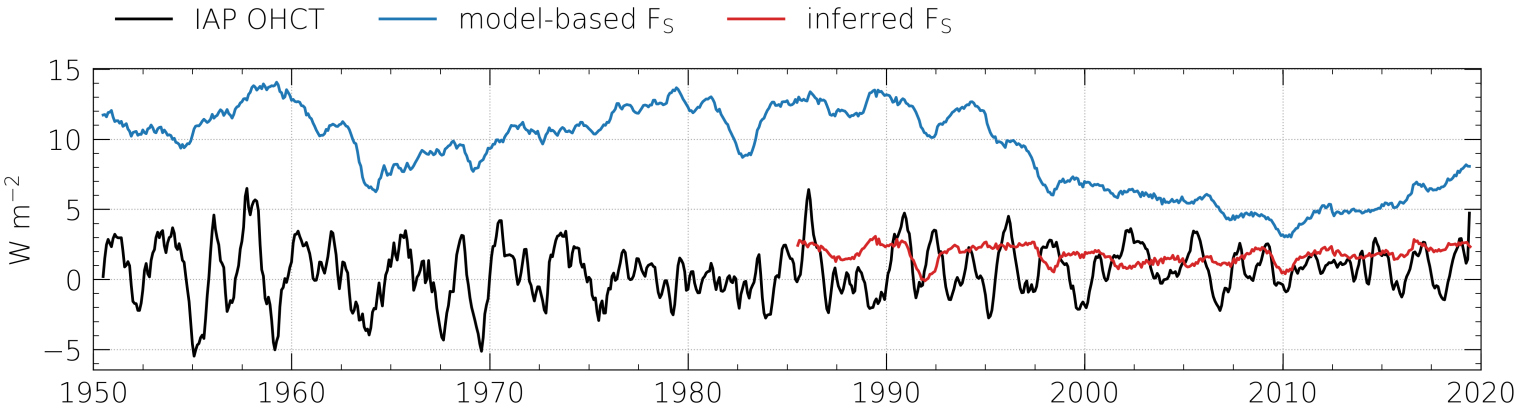
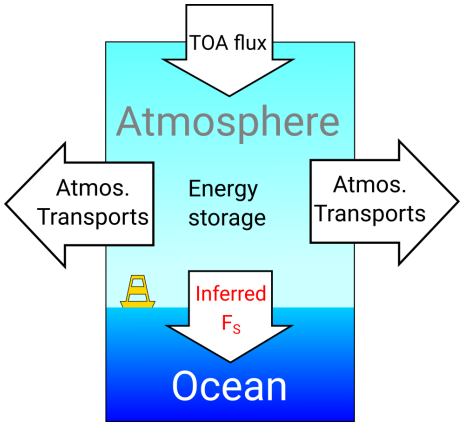
OS1.5, April 26th, 08:50–09:00

Motivation

- Understanding air-sea heat flux (F_S) trends in the North Atlantic basin.
- Observation-based data sparse and cover only a few decades.
- ERA5 provides global data for >8 decades → optimal for long-term studies.
- *How reliable are long-term trends of model-based surface fluxes from ERA5 forecasts?* → Inferred fluxes as reference (DOI: 10.24381/cds.c2451f6b)



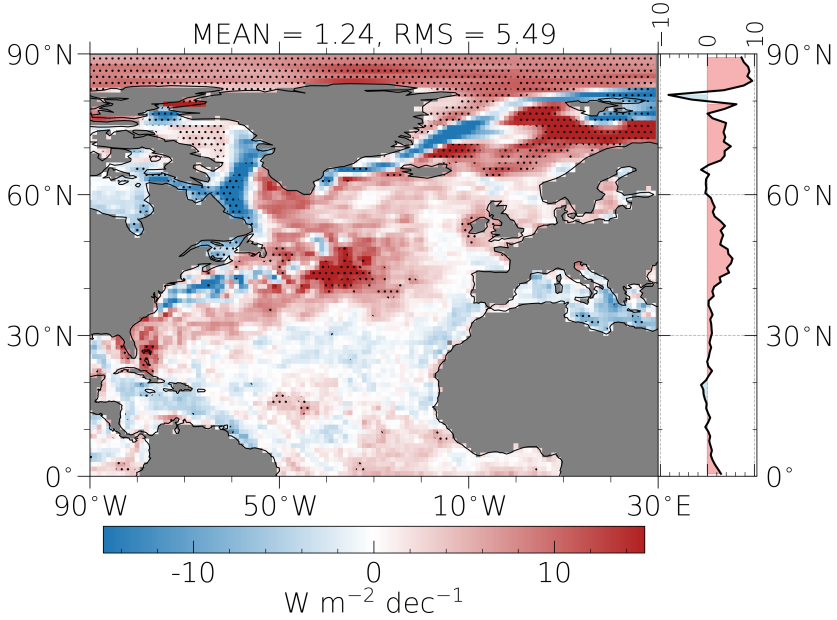


→ Correction of model-based F_S needed!

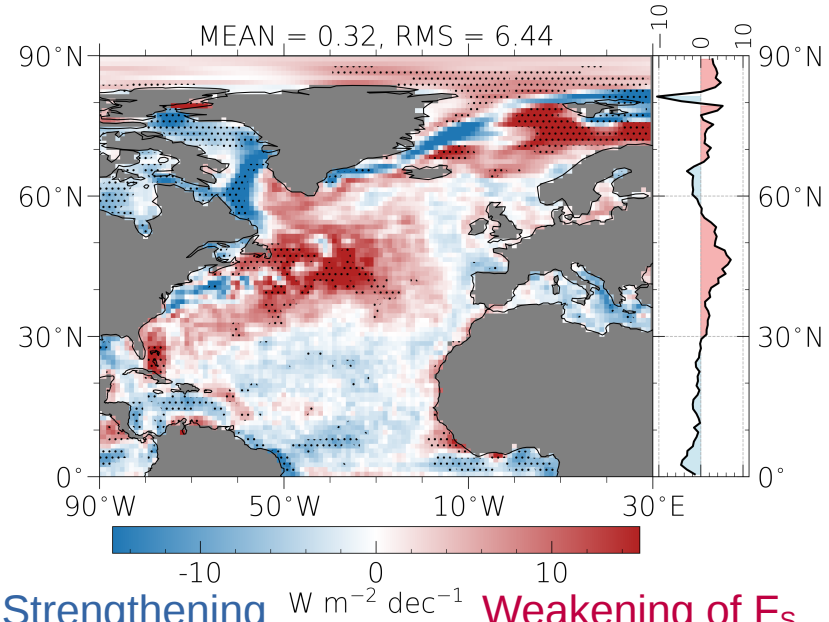
Flux correction

- Correction of regional fluxes based on difference between global ocean mean *OHCT* and *model-based* F_S → good agreement with inferred F_S trends
(pattern correlation r = 0.8; 1.2 W m^{-2} dec^{-1} instead of -1.4 W m^{-2} dec^{-1})

Globally adjusted model-based F_S trend



Inferred F_S trend

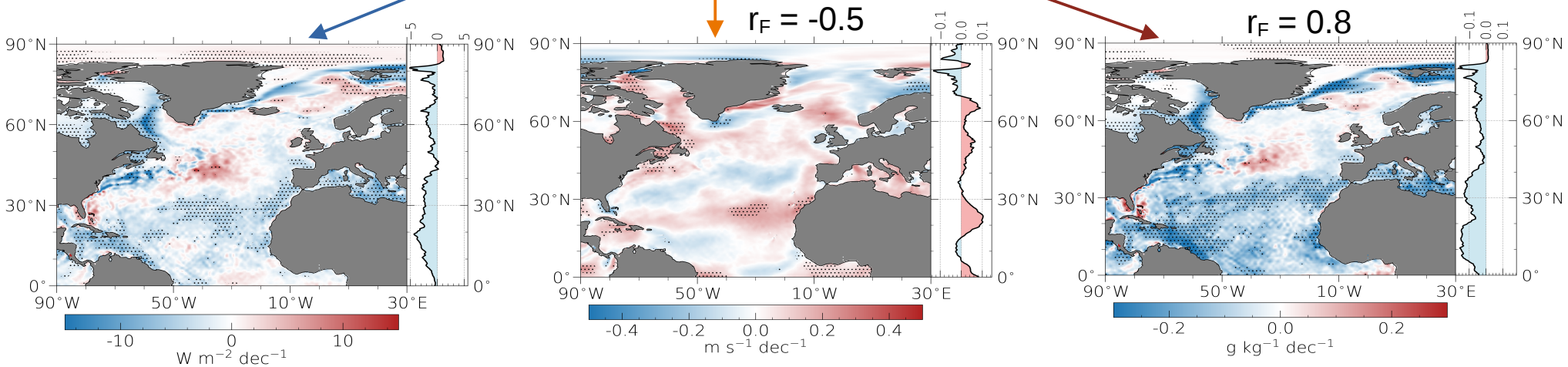


Strengthening — Weakening of F_S

1985-2019 DJF trends

- Latent heat flux trends can be attributed to changes in wind speed and moisture:

$$F_{LH} = C_Q \rho |U_{ml}| L_v (q_{ml} - q_{sfc})$$

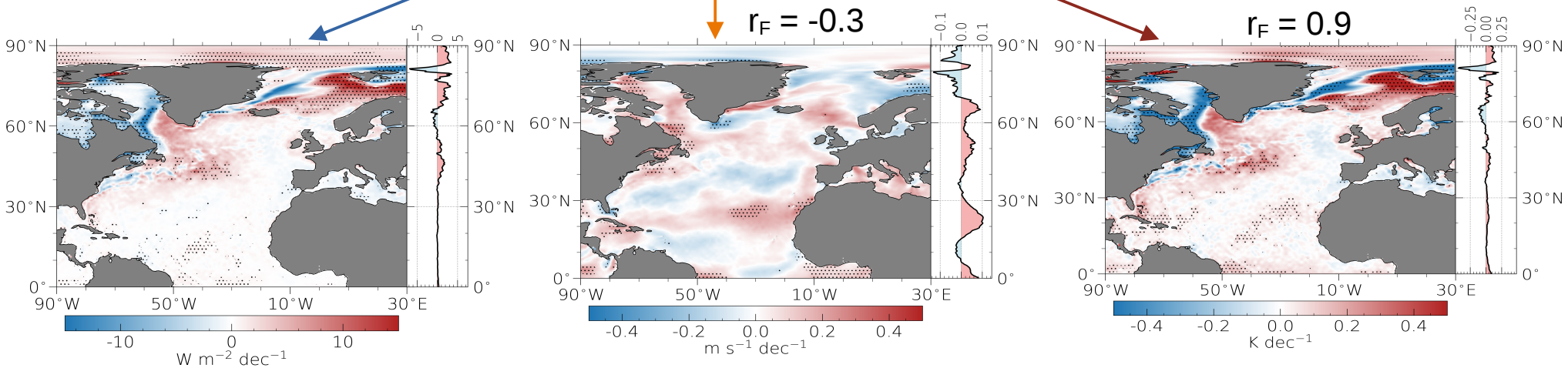


- Trends in q (and T) difference more important than changes in wind speed.
- Net surface heat flux trends at low (high) latitudes governed by F_{LH} (F_{SH}).
- Prior to 1985: weaker trends but similar driving forces. (more details in DOI:10.5194/esd-2023-8)

1985-2019 DJF trends

- Sensible heat flux trends can be attributed to changes in wind speed and temperatue:

$$F_{SH} = C_Q \rho |U_{ml}| c_p (T_{ml} - T_{skin})$$



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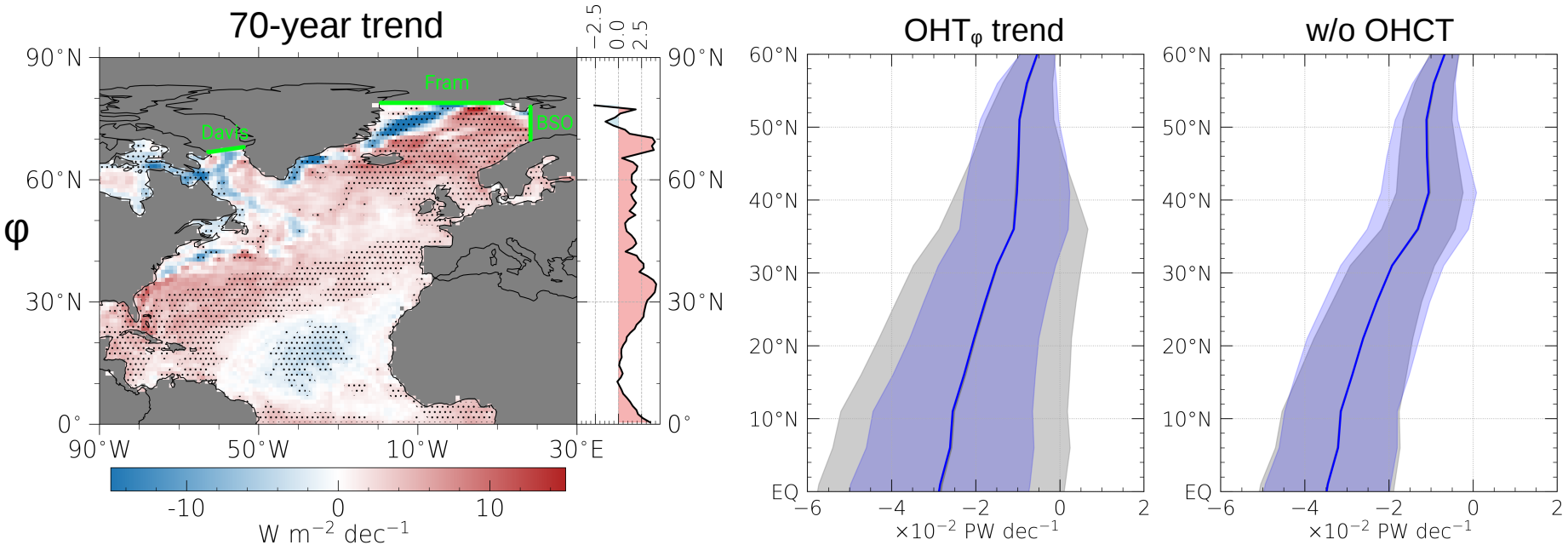
AMOC weakening

- Derived from ocean heat budget: $OHT_{\varphi} = OHT_{AG} - [F_S - OHCT]^{\varphi}_{AG}$



- Weakening of F_S in the North Atlantic basin (decreasing ocean heat loss) associated with weakening of the AMOC over 1950-2019.

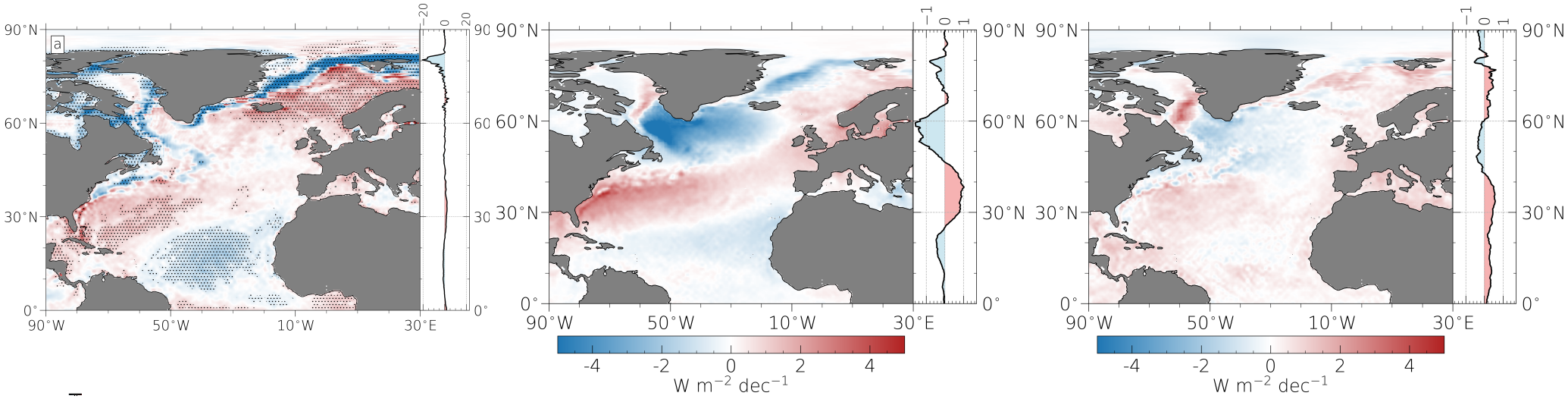
Summary

- Model-based air-sea heat fluxes require a global correction to remove spurious trends caused by changes in the observing system.
- Trends robust in terms of sign and spatial pattern.
- Trends mainly driven by the difference between moisture (temperature) in model level and surface; changes in wind speed play a secondary role.
- Decrease of negative air-sea heat fluxes (i.e., positive trends) associated with weakening of the AMOC.

References

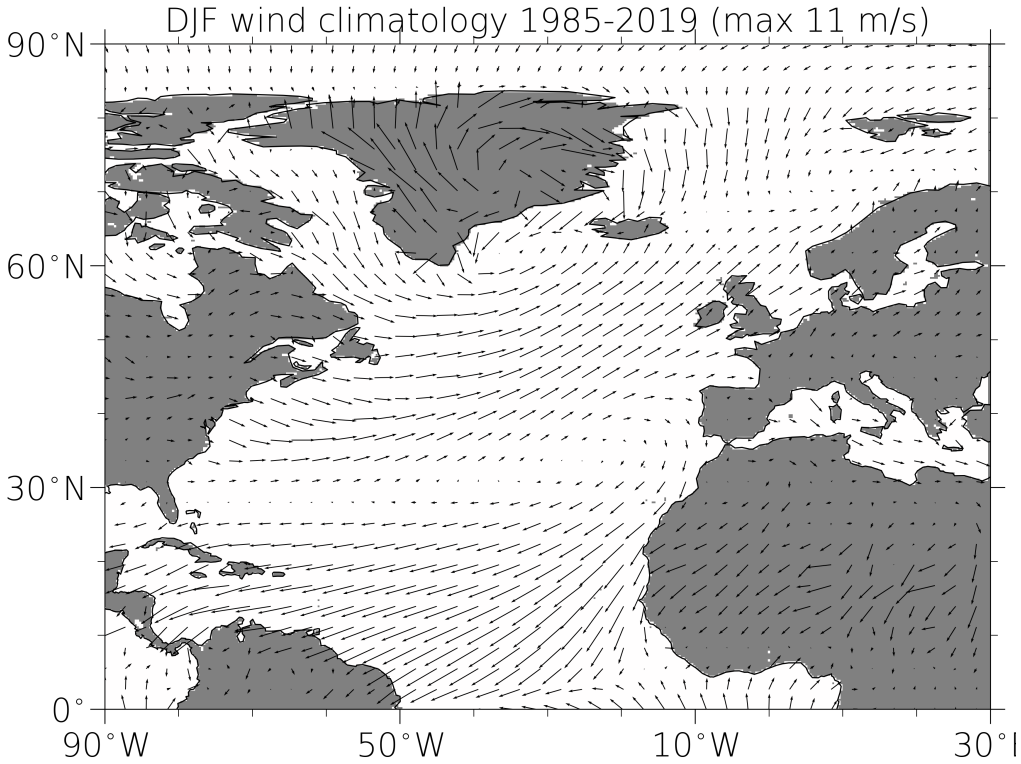
- Mayer, J., M. Mayer, and L. Haimberger. *Mass-consistent atmospheric energy and moisture budget monthly data from 1979 to present derived from ERA5 reanalysis*, v1.0, 2021. DOI: 10.24381/cds.c2451f6b.
- Mayer, Johannes, Michael Mayer, Leopold Haimberger, and Chunlei Liu. "*Comparison of Surface Energy Fluxes from Global to Local Scale*". In: Journal of Climate 35.14 (2022), pp. 4551 –4569. DOI: 10.1175/JCLI-D-21-0598.1.
- Mayer, J. , L. Haimberger, and M. Mayer. "*A quantitative assessment of air-sea heat flux trends from ERA5 since 1950 in the North Atlantic basin*". Submitted in Earth System Dynamics, under review (open for discussion https://doi.org/10.5194/esd-2023-8).

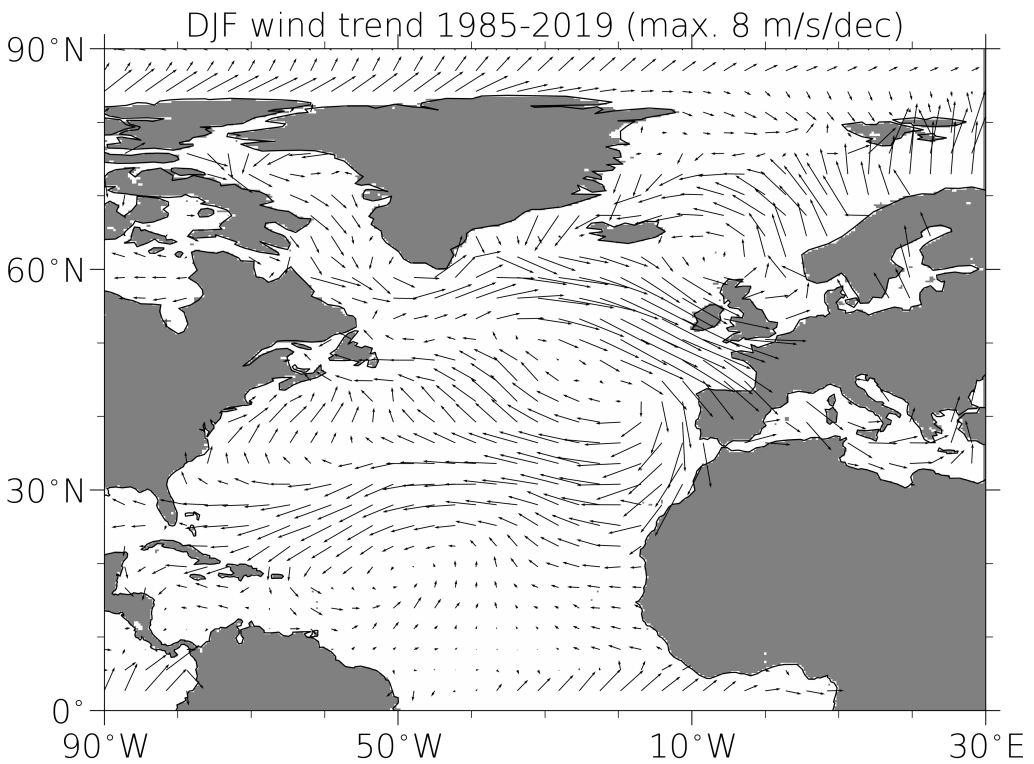
Appendix: NAO & AMO



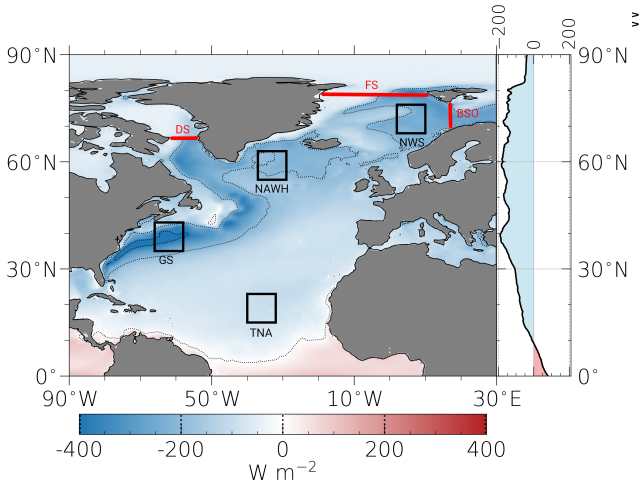
- More frequent positive NAO phases favours ocean heat loss in Irminger and Labrador sea.
- AMO forcing: pattern at higher latitudes similar to NAO but weaker.

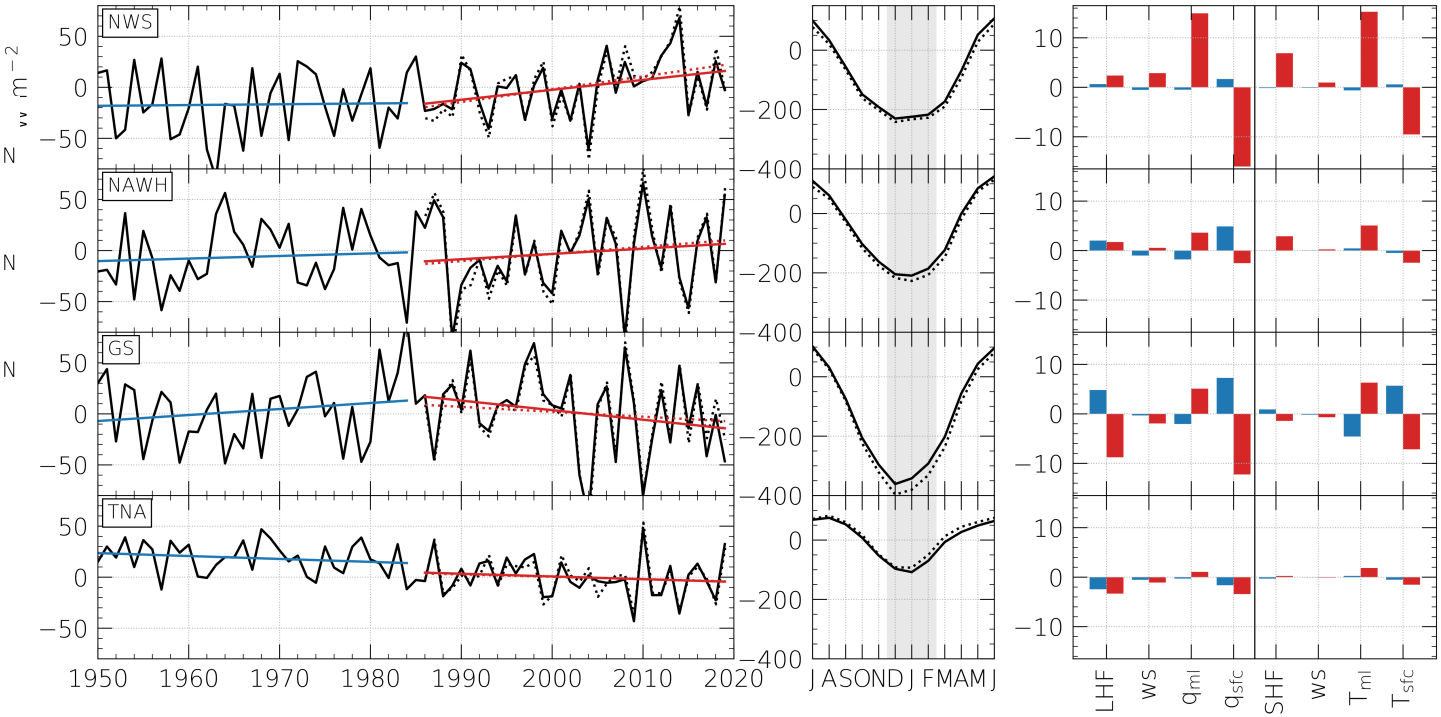
Appendix: Wind field





Appendix: Focus regions





Appendix: Analysis increments

AN-FC