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CFORCE: Creating the Next Generation Datasets for Forcing Ocean – Sea-ice Coupled Models (based on ERA5)

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and co - authors

NSF National Center for Atmospheric Research, USA
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Why ERA5?

- A trusted reanalysis product.
- High spatial and temporal resolutions suitable for forcing high resolution (e.g., eddying, coastal) ocean and sea - ice models.
(0.25° and hourly)
- The reanalysis is up - to - date / near real time.
- Going back in time as far back as possible. (1940 – present)
- Buy- in, support, and collaboration from the ECMWF group producing the reanalysis product.
- Institutional commitment for continued production of the reanalysis datasets.
- No redistribution issues.



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JRA-55 based surface dataset for driving ocean–sea-ice models (JRA55-do)

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CFORCE largely follows the process described in Tsujino et al. (2018) with some updates .

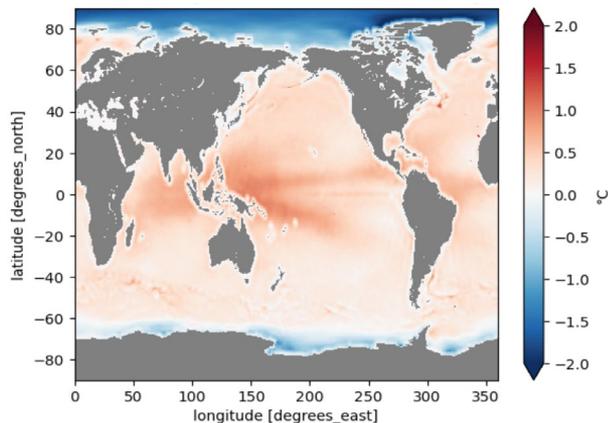
- Adjustments of main variables;
- River and glacier runoff / discharge; and
- Global heat and freshwater (balance) adjustments, but with a strategy to capture the historical warming trend.

Adjustments (All Completed)



Variable	Reference Datasets	Base Period	Adjustment Type	What's new compared to JRA55-do
Downward shortwave & longwave radiation	CERES-EBAF v.4.2	2000-2024	Multiplicative scaling	Updated version of reference dataset
Air temperature & Specific humidity	Weighted multi-reanalyses ensemble	1980-2015	Additive offset (T2M) Multiplicative scaling (Q2M)	Expanded and updated reanalysis ensemble
Wind speed and direction	CCMPv.3.1 (Cross Calibrated Multi Platform Satellite Product)	1993-2024	Vector adjustments via scaling + rotation	Cross-calibrated product replaces separate QuikSCAT and SSM/I datasets
Precipitation	ERA-5		No correction	No correction (in this dataset version)
River runoff	ECMWF CaMaFlood-based system (forced by ERA-5)	1940-present	Added (not provided in ERA-5)	CaMaFlood forced by ERA5 instead of JRA55
Greenland runoff	Mankoff et al. (2020) regional model-based product; Schmidt et al. (2025)	Reference datasets cover 1940-present	Added (not provided in ERA-5)	JRA55-do used Bamber et al (2018)
Antarctica runoff	Schmidt et al. (2025) dataset; based on satellite data	1997-2021	Added (not provided in ERA-5)	Replaces 2009 snapshot from Depoorter et al. (2013)

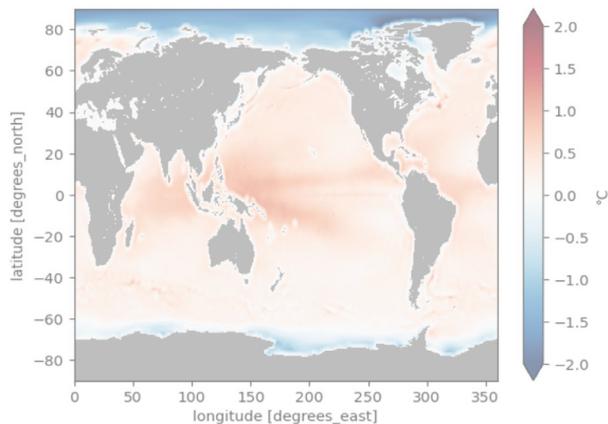
Temperature



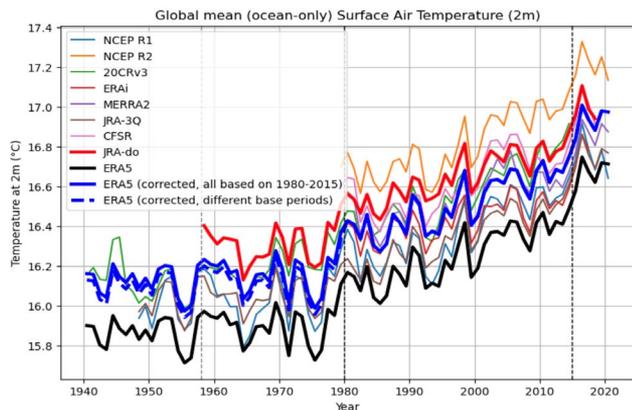
Mean offset applied to ERA-5 surface temperature

Known issue in ERA5: Warm bias in the Arctic Ocean.

- Compared to multi-reanalyses mean, ERA-5 has warm biases at polar latitudes and cold biases elsewhere.
- Temperature is corrected using weighted mean of several reanalyses products (NCEP R1/R2, ERA Interim, 20CRv3, MERRA2, JRA-3Q, CFSR)
- Monthly offset based on 1980-2015 reference period



Mean offset applied to ERA-5 surface temperature



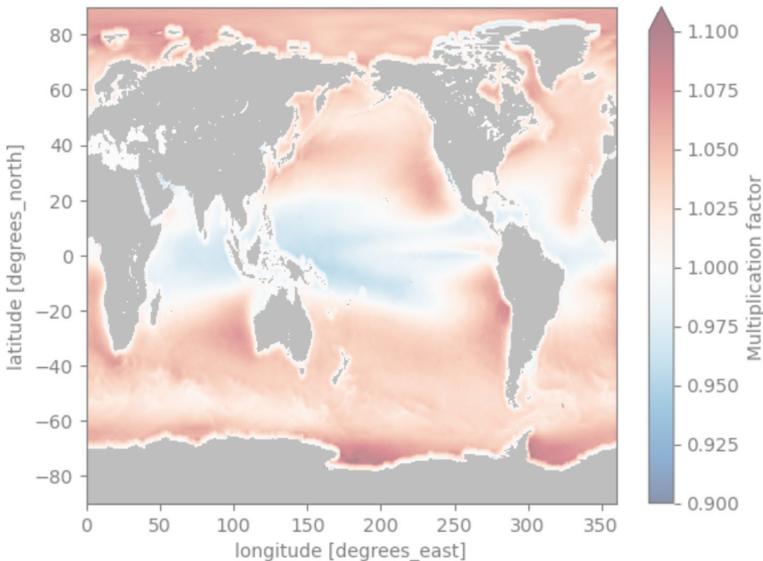
Known issue in ERA5: Warm bias in the Arctic Ocean.

- Also compared to multi-reanalyses mean, ERA-5 has warm biases at polar latitudes and cold biases elsewhere.
- Temperature is corrected using weighted mean of several reanalyses products (NCEP R1/R2, ERA Interim, 20CRv3, MERRA2, JRA-3Q, CFSR)
- Monthly offset based on 1980-2015 reference period

Corrected ERA-5 is closer to ensemble of other reanalyses data than the original ERA-5; however, it is lower than JRA55-do.

The correction does not introduce any spurious trends

Specific Humidity



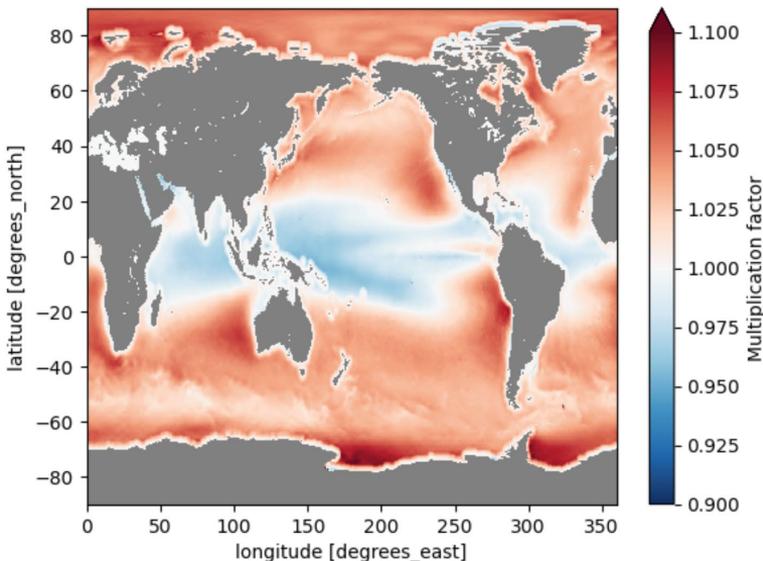
Mean multiplication factor applied to ERA - 5
specific humidity

Before main correction:

Preserve relative humidity when adjusting temperature by

- (1) recalculating **saturation - specific humidity** at the adjusted temperature and
- (2) update **specific humidity** using the original relative humidity and the new saturation value

Specific Humidity

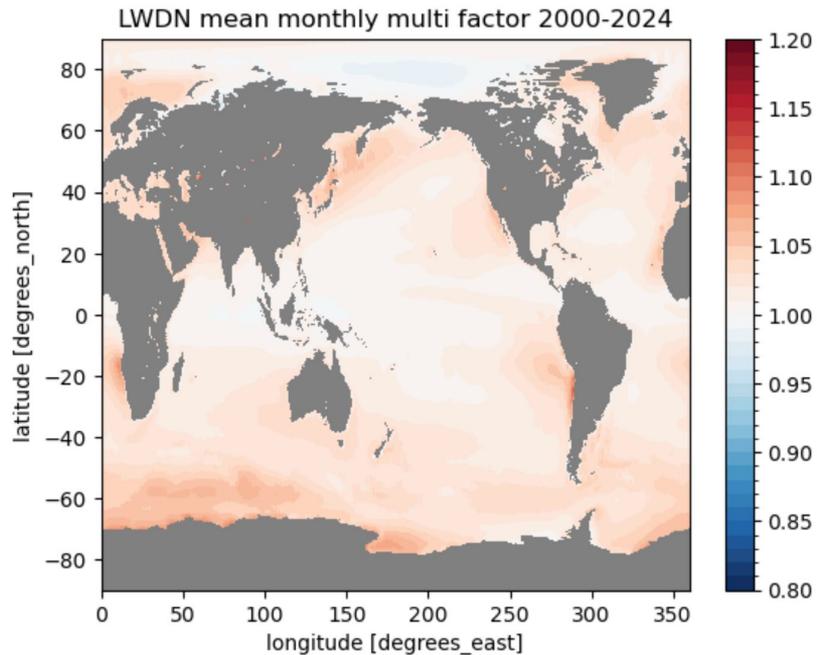
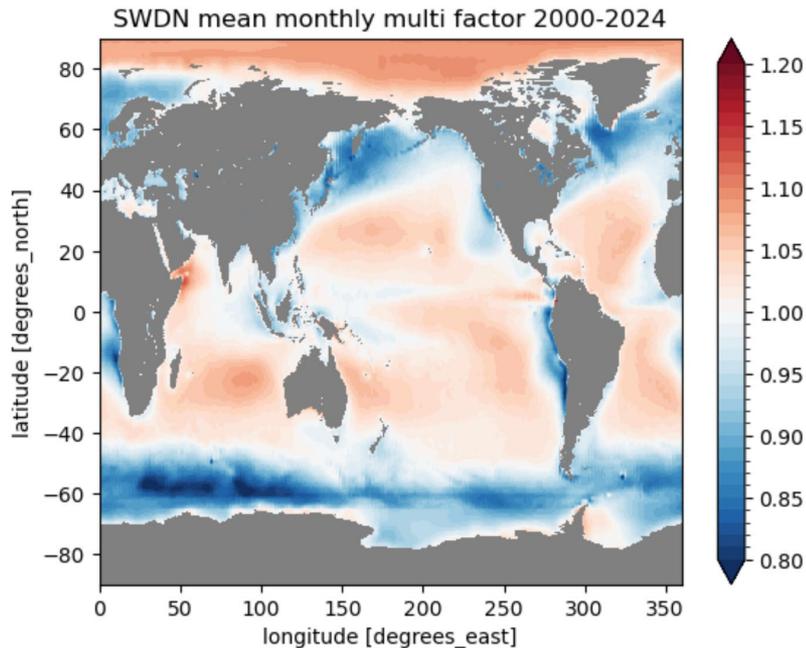


Mean multiplication factor applied to ERA specific humidity - 5

Before main correction:

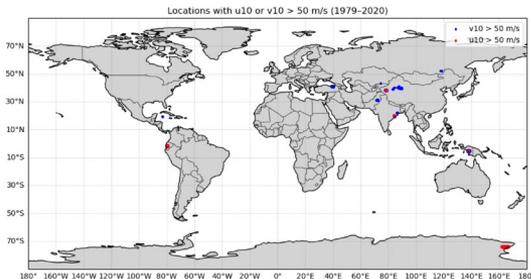
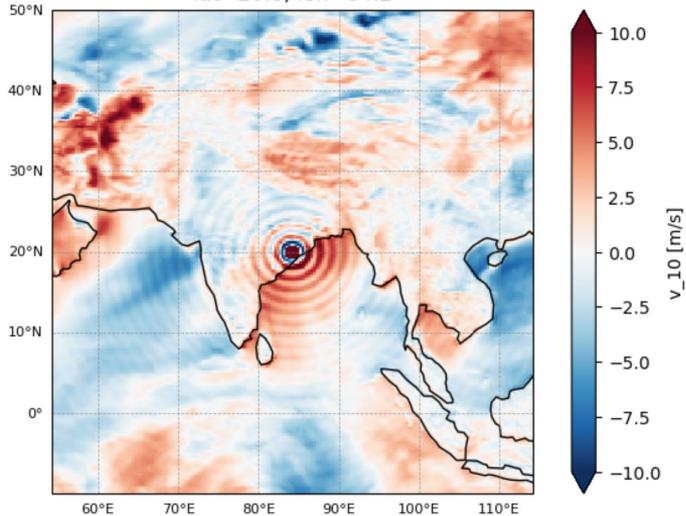
Preserve relative humidity when adjusting temperature by
(1) recalculating saturation - specific humidity at the adjusted temperature and
(2) update specific humidity using the original relative humidity and the new saturation value

- Applied monthly climatological correction using a multi - reanalysis ensemble
- Same idea as temperature correction, but using a multiplicative factor instead of an offset
- Compared to the multi - reanalysis mean, ERA5 has higher specific humidity in the ITCZ and lower humidity elsewhere
- Adjustments over most of the ocean are within 5%



*Mean multiplication factor applied to ERA - 5
downward short - and long - wave radiation*

Snapshot at peak: 1992-04-15 08:00
lat=20.0, lon=84.2

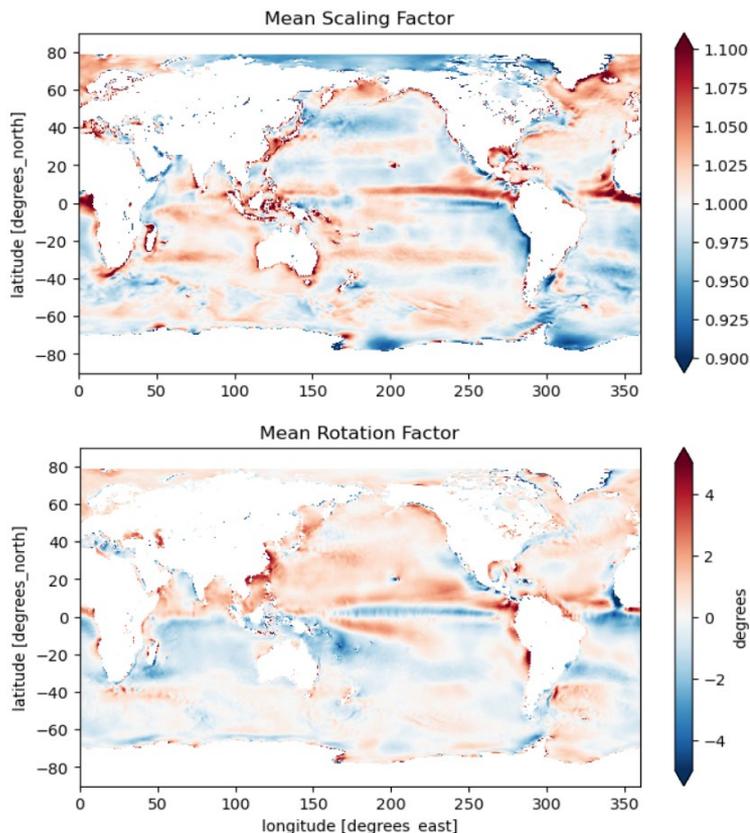


Stage 1: Despiking surface winds

Known ERA - 5 issue: rare 10 - m wind spikes (up to $\sim 300 \text{ m s}^{-1}$) linked to 4D-Var window edges.

Detected using a 50 m s^{-1} threshold (lower thresholds capture real storms); 82 events (1979–2024)

Time-space interpolation applied to u_{10} and v_{10} ($\pm 20^\circ$ footprint); same for T_{10} , q_{10} ; no artifacts in SLP, radiation, or precipitation.

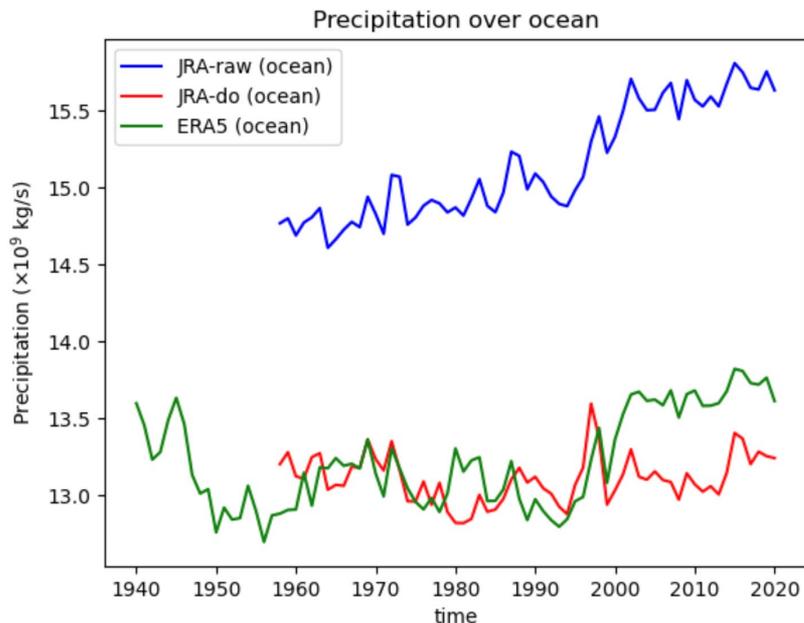


Stage 2: Correcting wind vectors

- Wind vectors are corrected using CCMP v3.1, a cross-calibrated multi-platform product blending all available scatterometer and radiometer data (ERA5 neutral-stability winds are used to fill gaps)
- CCMP shows negligible differences from ASCAT (the most advanced scatterometer) and covers 1993 – present
- Correction method follows Tsujino et al. (2018) (used in JRA55-do): applies scaling and rotation factors
- Scaling factor adjusts for wind speed differences between ERA5 and satellite products
- Rotation factor is based on the complex EOF method, which avoids spurious spikes in low-wind regions (in strong winds equivalent to Large & Yeager 2009)

$$\begin{pmatrix} u_{\text{adj}} \\ v_{\text{adj}} \end{pmatrix} = \frac{W_{\text{ERA5}} + c\Delta W}{W_{\text{ERA5}}} \begin{pmatrix} \cos\chi & -\sin\chi \\ \sin\chi & \cos\chi \end{pmatrix} \begin{pmatrix} u_{\text{ERA5}} \\ v_{\text{ERA5}} \end{pmatrix}$$

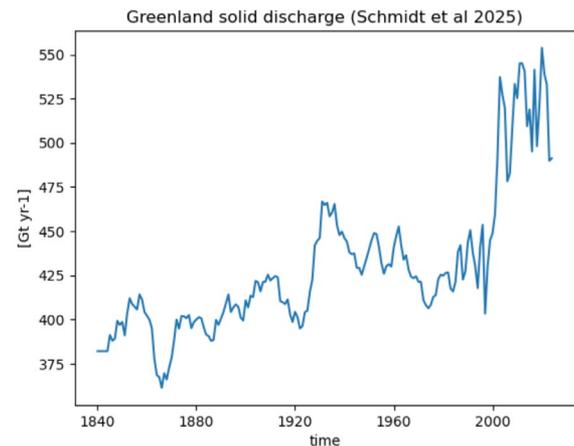
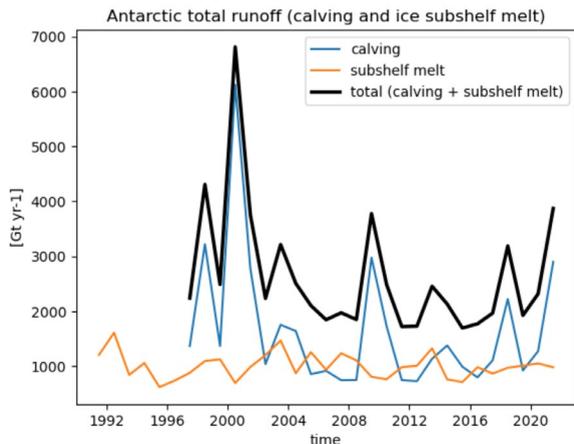
Precipitation



The raw (uncorrected) ERA - 5 precipitation is rather good over ocean compared to other observational - based datasets.

Therefore, no precipitation correction is applied, but refinements may be explored in future versions.

Runoff (solid and liquid)



Antarctic solid & liquid discharge: Schmidt et al. (2025).

Due to limited temporal coverage (1997 - 2021) and strong interannual variability, a **mean annual runoff of 0.084 Sv** is applied for all years and distributed circum -
Antarctically , with regional contributions proportional to the climatological pattern.

Greenland solid discharge: Schmidt et al. (2025)

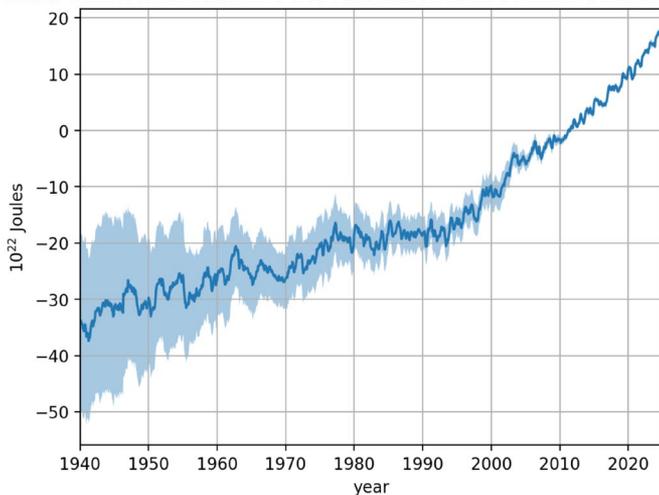
Greenland liquid discharge: Mankoff et al. (2020)

River runoff: CaMaFlood simulations forced by ERA - 5 (ECMWF), excluding Greenland coastal runoff to avoid double counting.

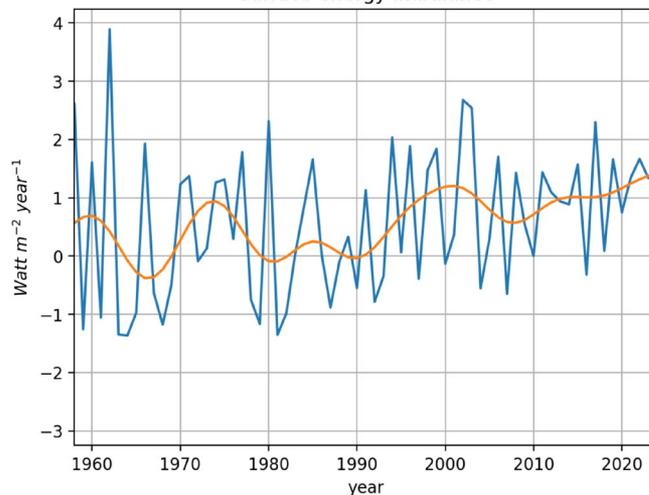
Global balance adjustment

$$a(Q_{SW} + Q_{DLW}) + Q_{ULW} + Q_{LAT} + Q_{SEN} + Q_{P+E+R} + Q_{IO} = \text{historical ocean surface energy imbalance (IAPv4)}$$

Global Ocean Heat Content 0-2000m relative to 2006-2015 baseline (IAPv4)



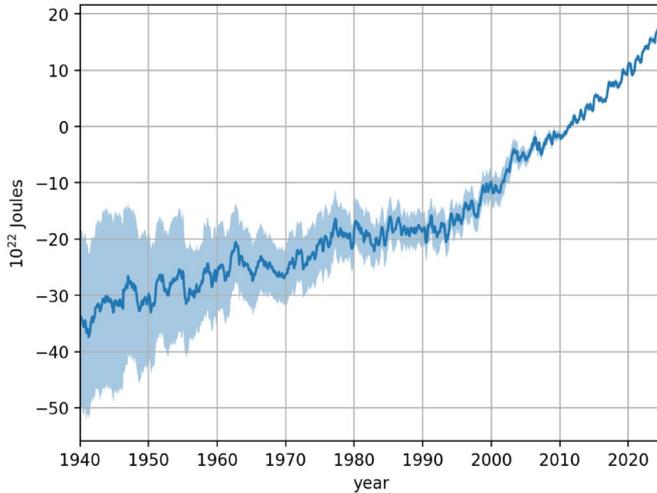
Surface energy imbalance



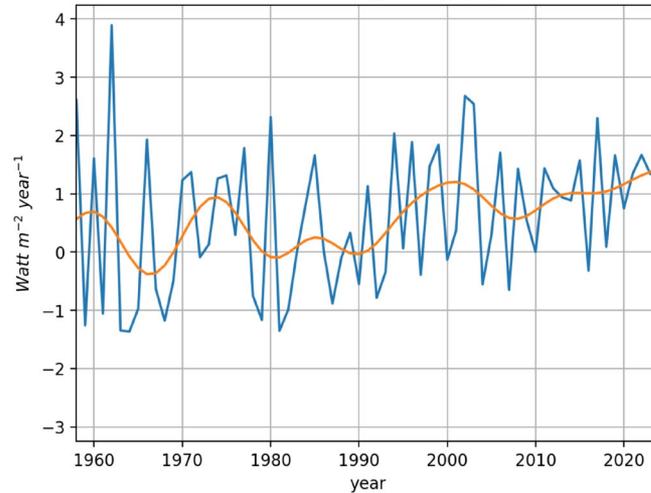
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Global Ocean Heat Content 0-2000m relative to 2006-2015 baseline (IAPv4)

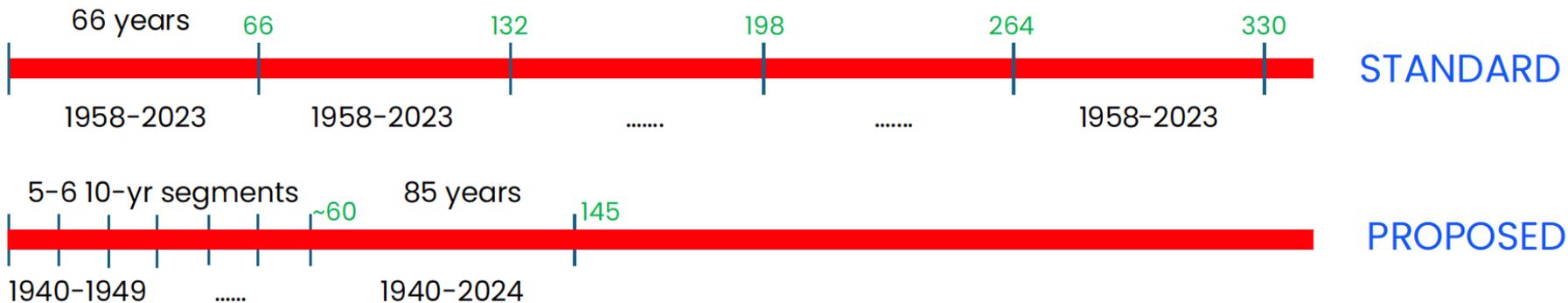


Surface energy imbalance



$$bP + E + R + S = 0$$

Proposed Spin - up Strategy



Aims to reduce end-of-cycle artifacts and reduces computational time

