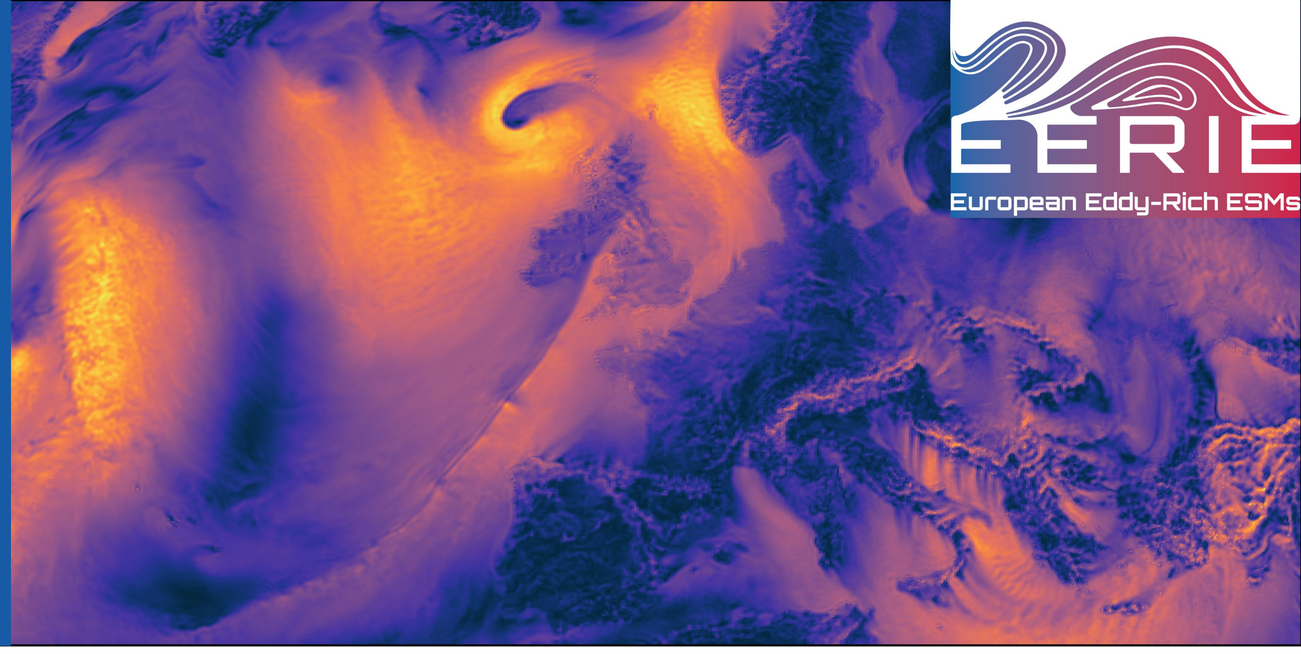
The EERIE project presents high-resolution **atmosphere-only simulations** of the IFS and UM models



Multi-decadal high-resolution reference and idealized simulations with the ECMWF global atmosphere model

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INTRODUCTION

- European Eddy-Rich Earth System Models (EERIE) is a Horizon Project that aims to ***"quantify the role of ocean mesoscale** processes in **shaping the climate trajectory"***
- ECMWF contribution: atmosphere-only (AMIP) experiments with observed and idealized boundary conditions

EERIE ATMOSPHERE-ONLY SIMULATIONS

Atmosphere model	Horizontal resolution	Period	Ensemble size	Corresponding coupled model
IFS	Tco1279 (~9 km)	1980-2023	1 member	IFS-NEMO IFS-FESOM
IFS	Tco399 (~28 km)		10 members	
UM	N640 (~20 km)	1980-2023	1 member	HadGEM3-UM-NEMO
UM	N216 (~60 km)		1 member	

EERIE COUPLED SIMULATIONS

Model	Horizontal resolution	Period
IFS-NEMO	Tco1279 (~9 km), eORCA12 (~8 km)	Spinup-1950 (>50 years) Control-1950 (>100 years) 1950-2100
IFS-FESOM	Tco1279 (~9 km), 4.5-13 km	
ICON	10 km	
HadGEM3-UM-NEMO	Atmosphere: 31, 93, 208 km, ocean: 8, 25, 100 km	piSpinup (>200 years) piControl (>200 years) 1850-2100

IFS CONFIGURATION

- IFS CY48R1.0 [1] with additions, similar to nextGEMS [6] & Destination Earth climateDT
  - Tuning of top-of-atmosphere radiation, no reduced cloud base mass flux
- 1980-2023 historical forcing, closely aligned with HighResMIP [4,7]
  - CMIP6 forcing, historical + SSP370
  - CMIP6 ozone & volcanic aerosols
  - CONFESS tropospheric aerosols [8]
- Tco1279 (1 member) and tco399 (10 members)
- The full data is archived on MARS, and a large subset is available on DKRZ's Levante HPC

Sea surface temperature forcing: ESA CCI version 3 [2]

- Shows best temporal consistency of the available products
- Distributed at 0.05 x 0.05 regular grid, effective feature resolution > 15 km
- Not eddy-resolving in the early period (<~ 1985)

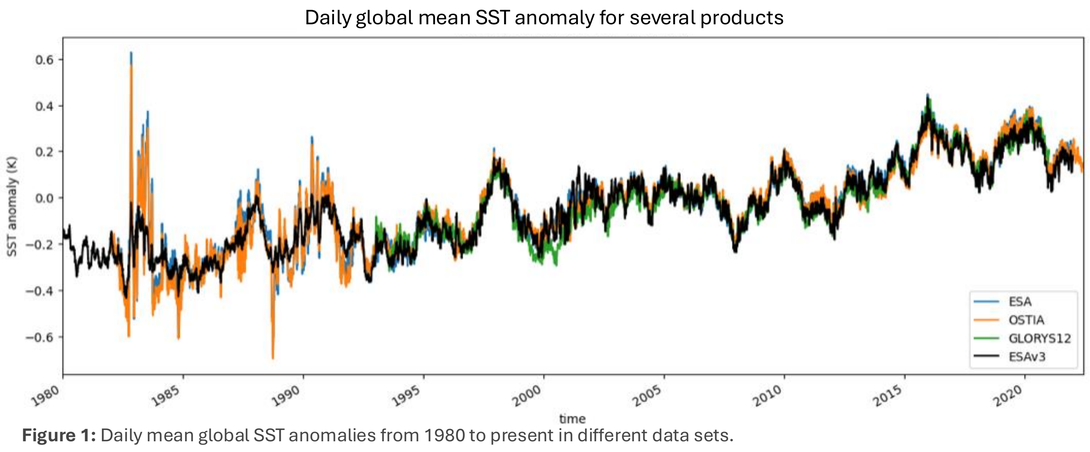

Figure 1: Daily mean global SST anomalies from 1980 to present in different data sets.

FILTERING

- Study the role of ocean eddies in the AMIP configuration by spatial filtering
- gcm-filters[5] supports spatially varying filter lengthscale following the Rossby radius
- Idealized simulations by removing ***time-varying mesoscale*** or ***climatological fronts***
  - Observed SST with spatial low-pass filtering of the time-varying ocean mesoscale
  - Observed SST with spatial low-pass filtering of the daily climatology (only tco399)

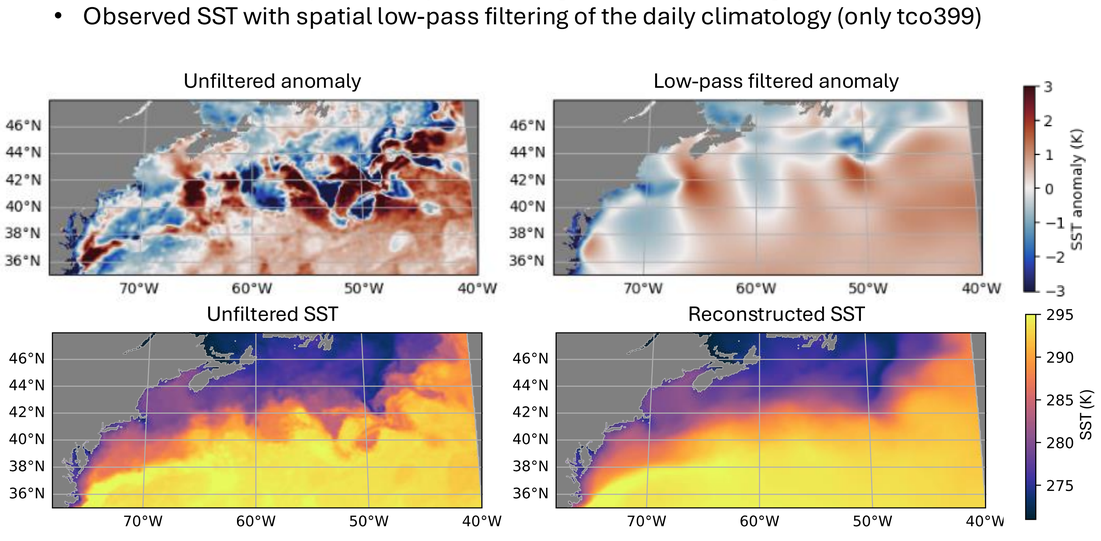

Figure 2: Spatial low-pass filtering of one snapshot of daily ESA-CCI v3 SST anomaly (top left) with a filter length scale of 20 times the local Rossby radius removes the time-varying mesoscale (top right). Adding the daily climatology results in a reconstructed SST field without the time-varying mesoscale (bottom right), compared with the original SST (bottom left).

EVALUATION

- IFS and UM at their respective resolutions capture long-term trends and interannual variability in (Figure 3), which partly reflects the strong constraint from the SST boundary conditions.

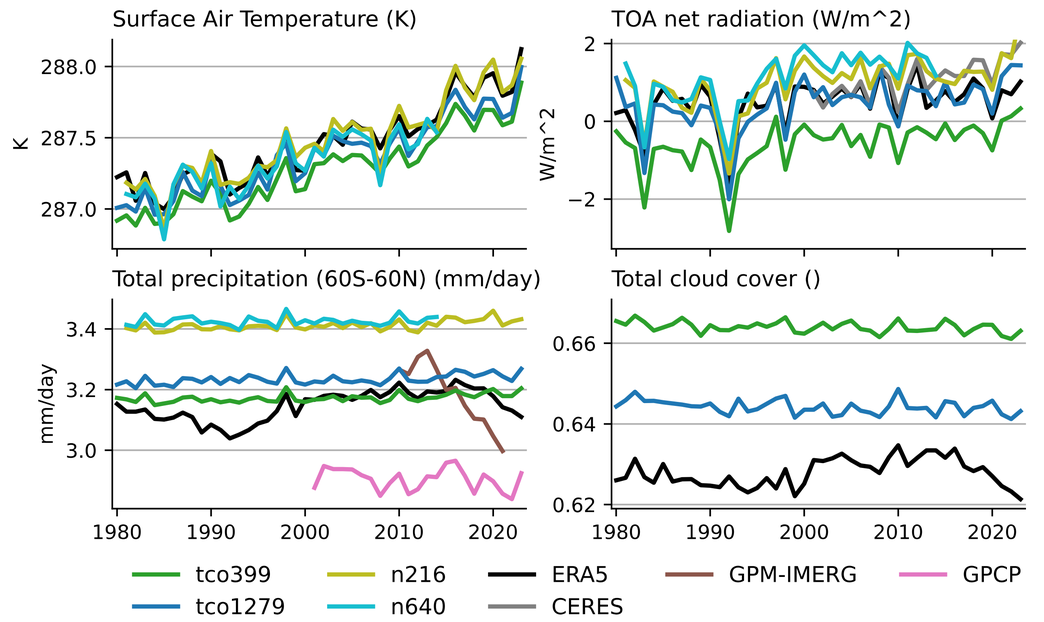

Figure 3: Global mean (or quasi-global mean) time series of 2m temperature, TOA net radiation balance, total precipitation, and total cloud cover in atmosphere-only simulations. IFS simulations are tco399 & tco1279, UM simulations n216 and n640. Time series are plotted as annual means and are compared to equivalent data from ERA5 (black), GPM-IMERG (brown), GPCP (pink) and CERES (grey).

IMPACT OF TIME-VARYING MESOSCALE (preliminary)

- Much (<= 65 %) larger SST variability with time-varying mesoscale
- Local and remote impacts, noticeable change in temperature and precipitation patterns

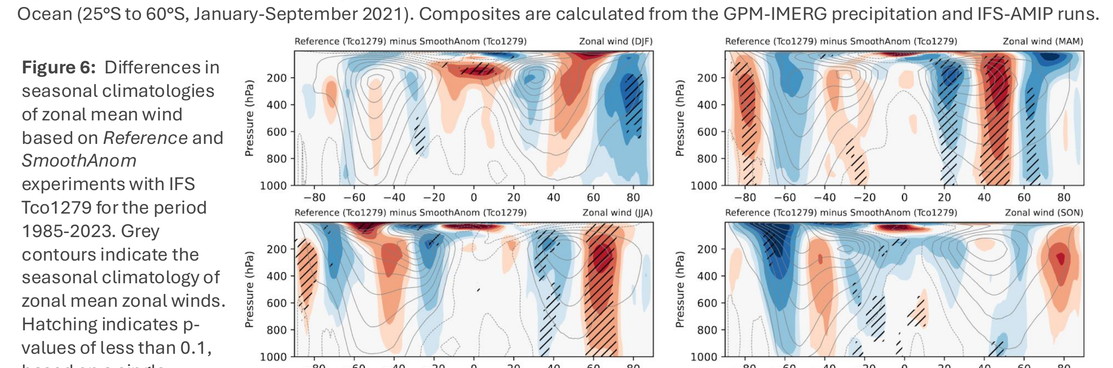

Figure 4: Impacts in the Gulf Stream region, presented as the change of "mesoscale present" minus "mesoscale removed". Shown are percentage change in daily SST variability (left), and the time-mean change (over 1980-2023) of surface air temperature (centre) and precipitation (right).

- Eddy composites (Figure 5):
  - Precipitation composites of similar magnitude to observations
  - Low-pass filtering SST anomalies reliably removes the eddy signature
- Small systematic impact on zonal mean winds (Figure 6), indicating slight poleward shifts in the tropospheric eddy-driven jet, with significant disagreements between models and resolutions.

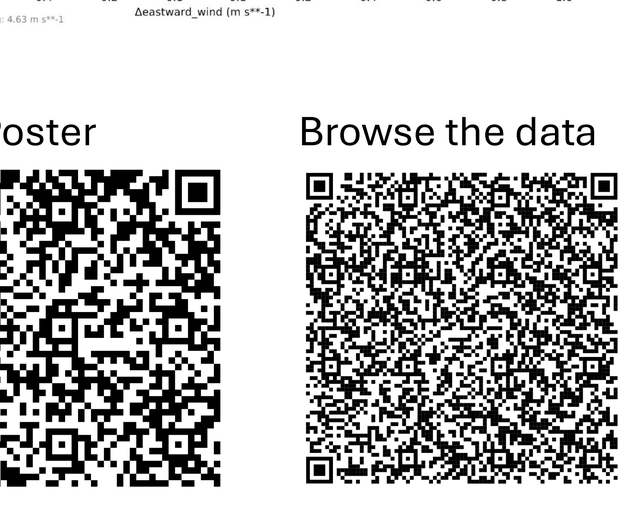

Figure 5 : Eddy-composite means of high-pass filtered precipitation over AVISO-based anticyclonic eddy locations in the Southern Ocean (25°S to 60°S, January-September 2021). Composites are calculated from the GPM-IMERG precipitation and IFS-AMIP runs.

Figure 6: Differences in seasonal climatologies of zonal mean wind based on *Reference* and *SmoothAnom* experiments with IFS Tco1279 for the period 1985-2023. Grey contours indicate the seasonal climatology of zonal mean zonal winds. Hatching indicates p-values of less than 0.1, based on a single-sample t-test.

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