

# Mixed-precision ocean modelling at ECMWF

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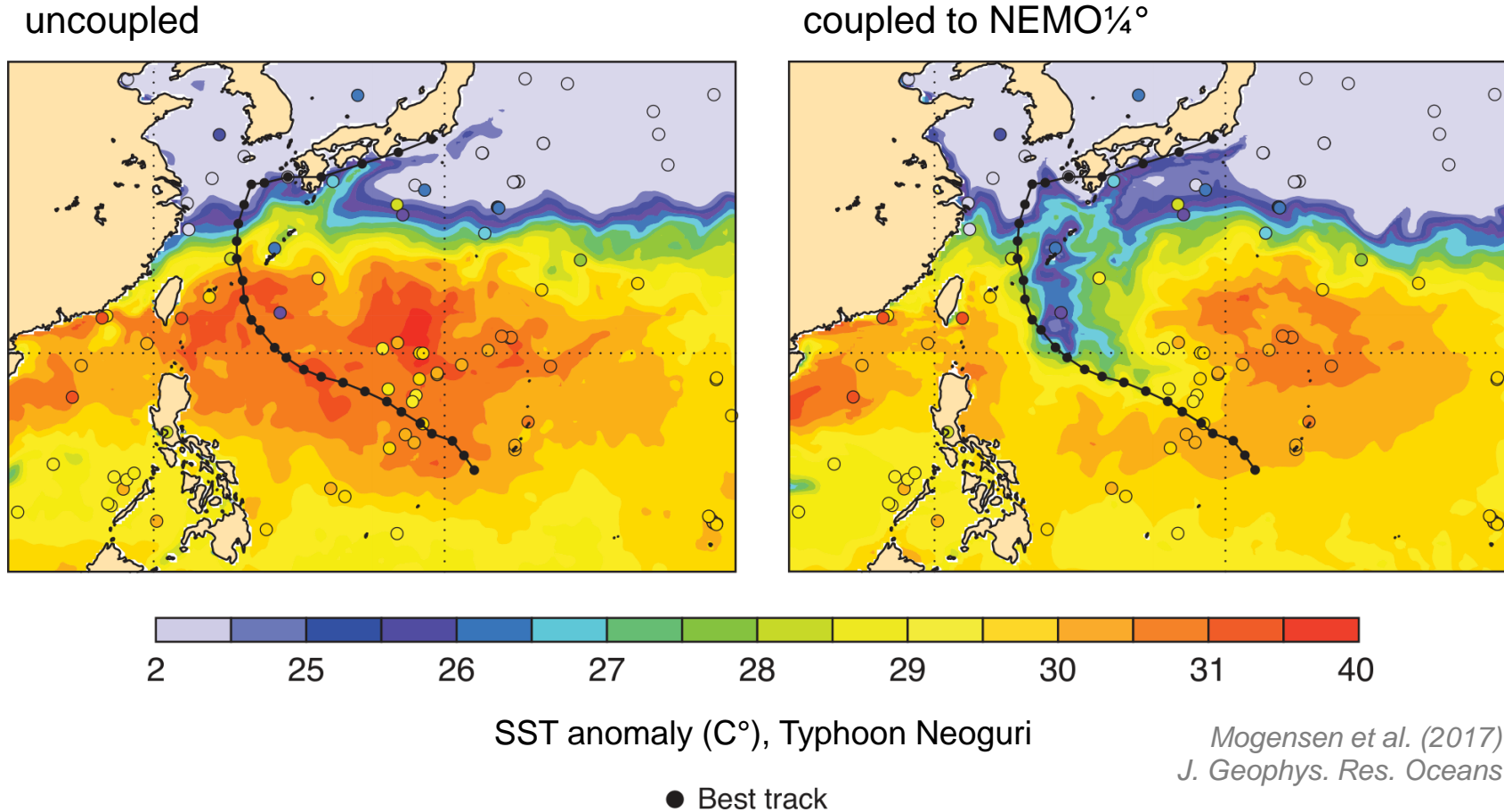


esiwace  
CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER  
AND CLIMATE IN EUROPE

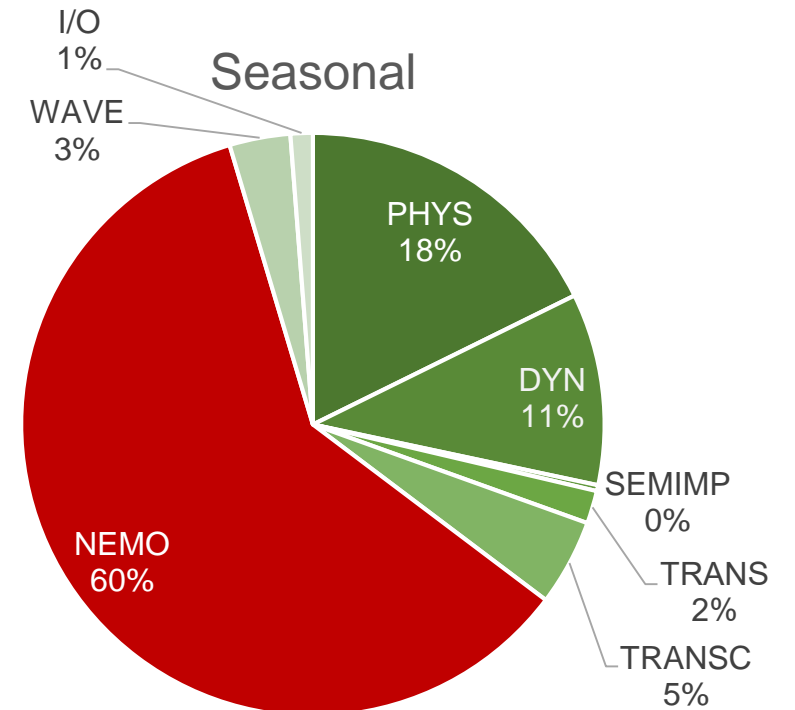
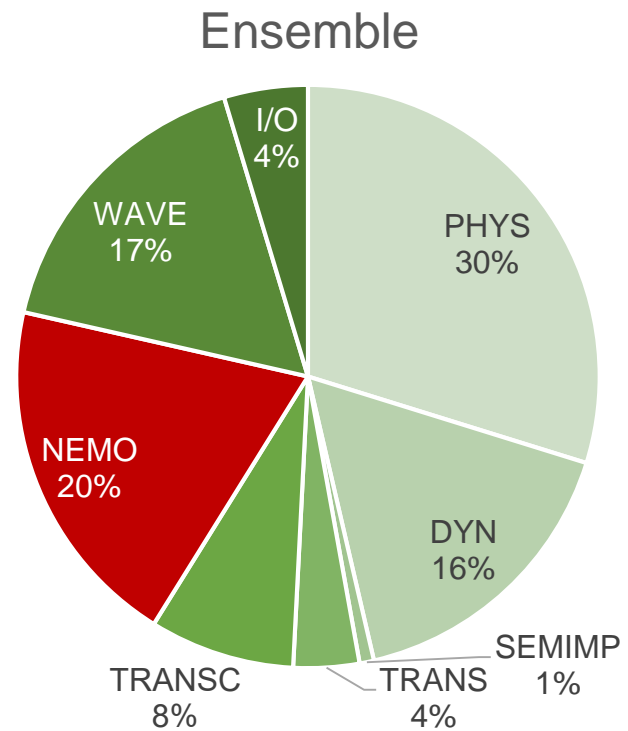
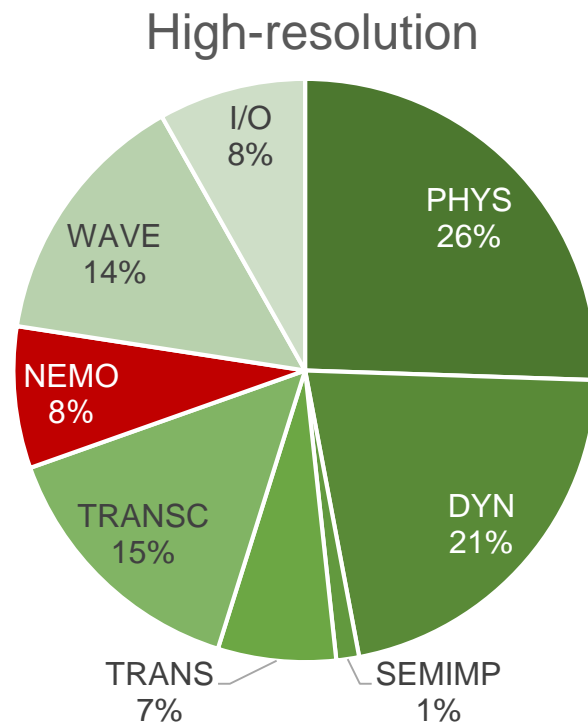


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# Impact of ocean on medium-range weather forecasts

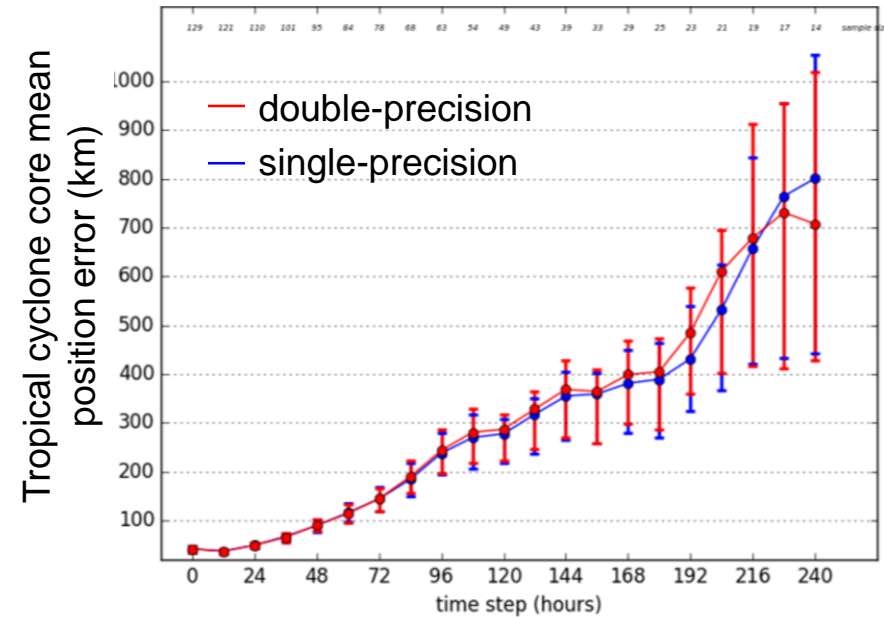
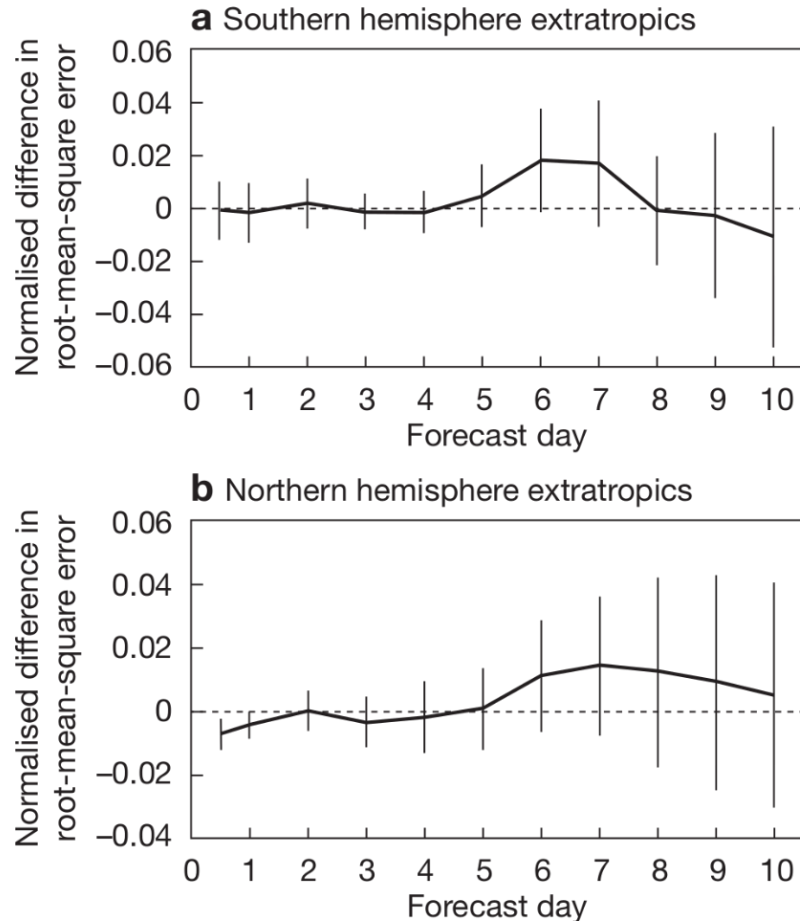


# Cost of ocean modelling



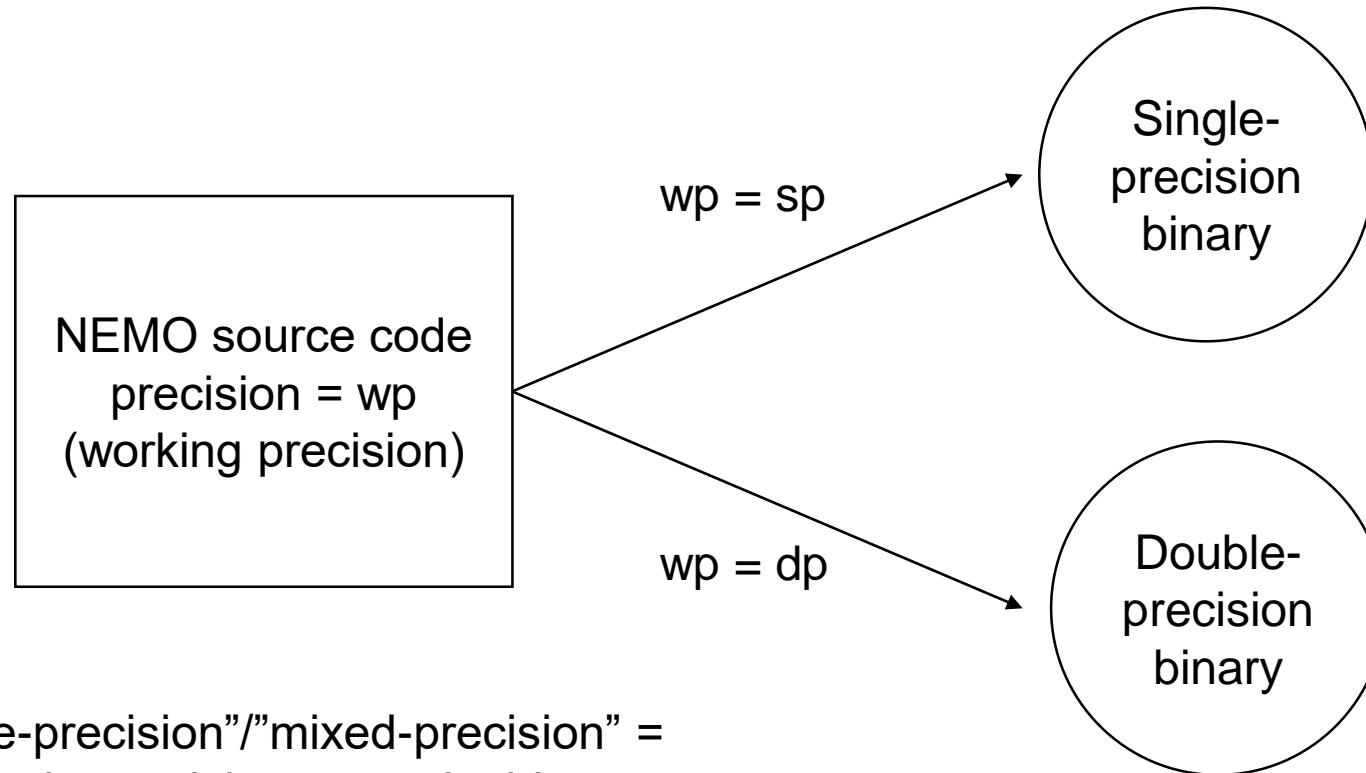
# Single-precision in the atmosphere

Z500



**1.7x speed-up** (40% reduction in wall-clock time)  
**Default** for 1.5 km IFS experiments  
Data assimilation not considered yet

# Single/mixed-precision ocean modelling at ECMWF



**Note:** “single-precision”/”mixed-precision” =  
~99% single-precision, ~1% double-precision

# Two types of error when reducing precision

## “Catastrophic” errors

- Divide-by-zero from small sea-ice concentrations
- Overflows from comparisons with large numbers
- Cause model crashes

**Assumption:** these errors are edge cases that have no physical significance and can be eliminated with careful recoding

## “Graceful” errors

- Slow unavoidable build-up of rounding errors
- Loss of conservation
- Don’t cause model crashes

**Assumption:** these errors are small compared with model/observation uncertainty

# Examples of catastrophic error (NEMO 4.0.1)

## Example #1 (Lagrangian floats trajectories)

```
! Original code
ztxfl(jfl) = 1.E99 ! <- overflow!

! New (single-precision compatible) code
ztxfl(jfl) = HUGE(0.0_wp)
```

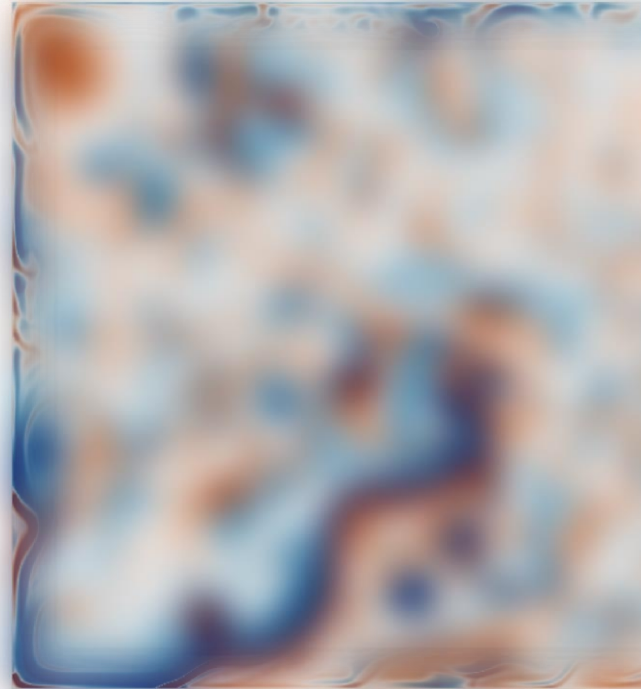
## Example #2 (sea-ice thickness distribution)

```
! Original code
WHERE (sea_ice_conc >= 10**-20)
    t_surf = zaTsfm / sea_ice_conc
ELSEWHERE
    t_surf = 273.15
END WHERE

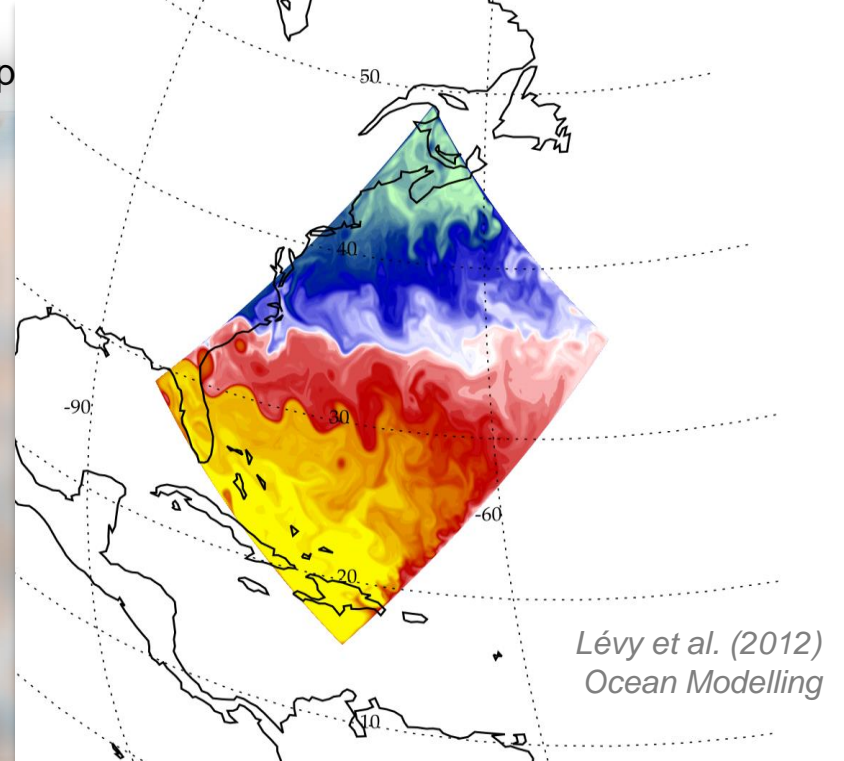
! New code
WHERE (sea_ice_conc >= 10**-6)
    t_surf = zaTsfm / sea_ice_conc
ELSEWHERE
    t_surf = 273.15
END WHERE
```

# GYRER27 comparison with double-precision

Relative vorticity after 2 years spin-up



Which is double-precision?

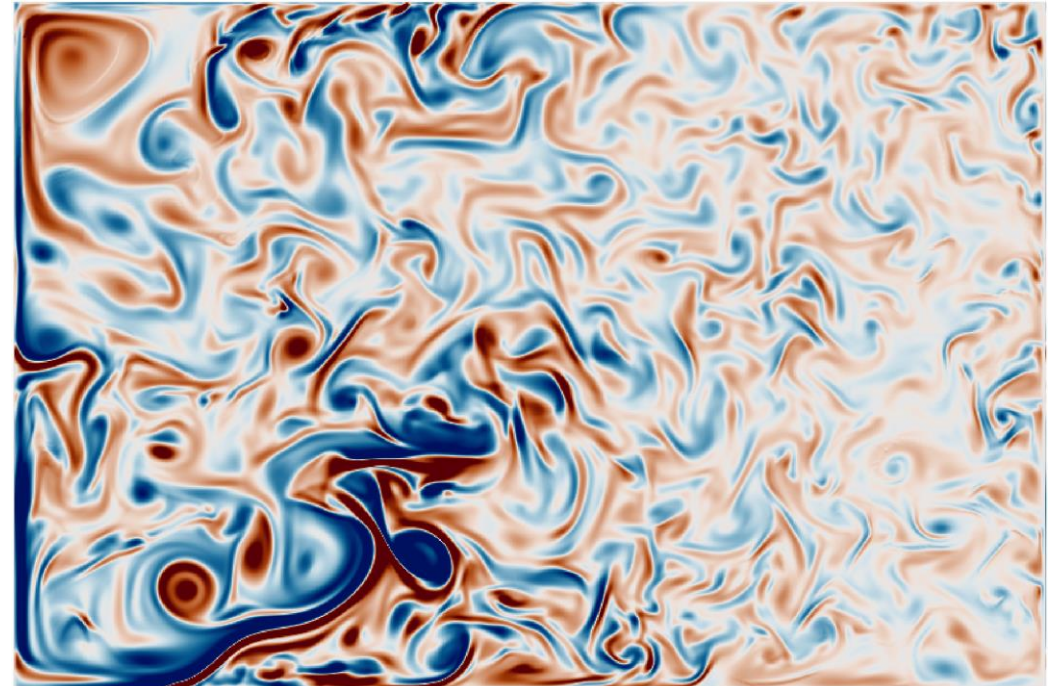
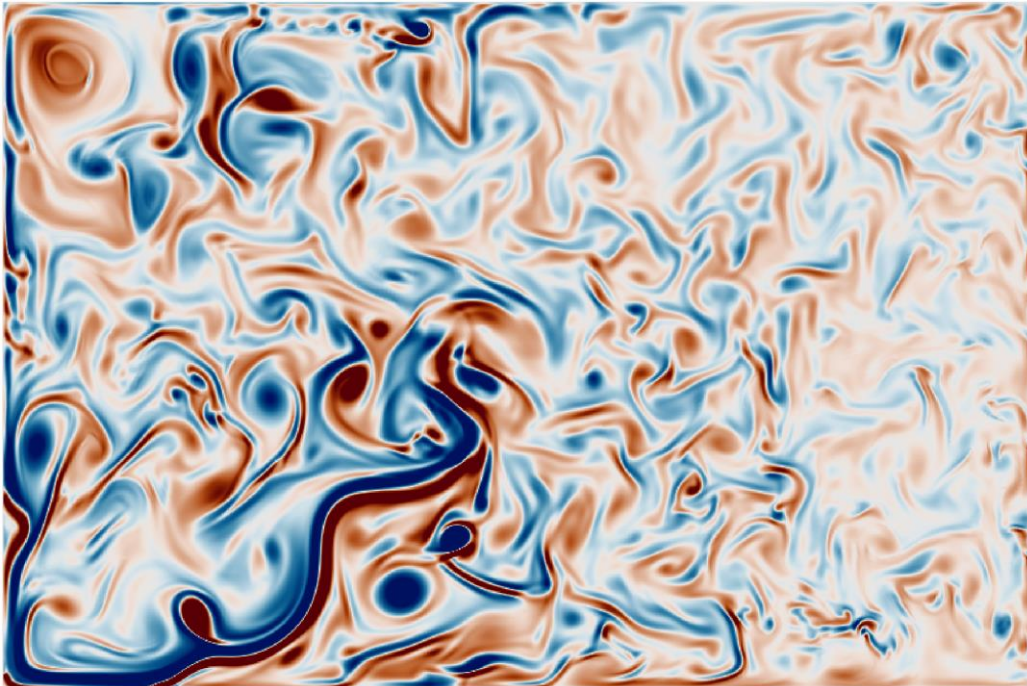




# GYRER27 comparison with double-precision

**Which is double-precision?**

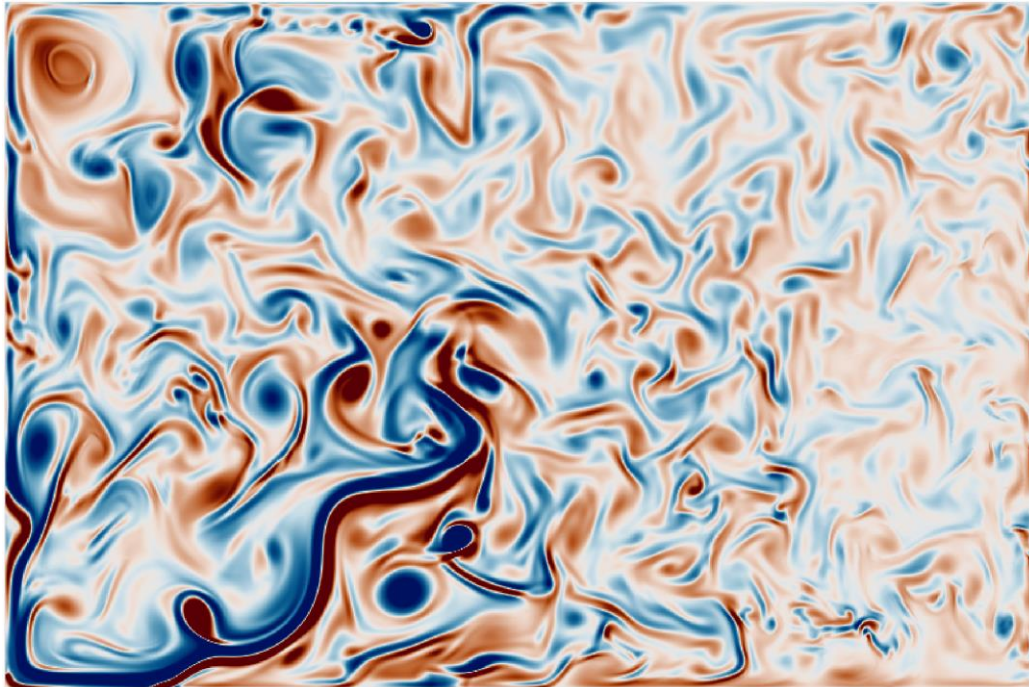
Relative vorticity after 2 years spin-up from rest



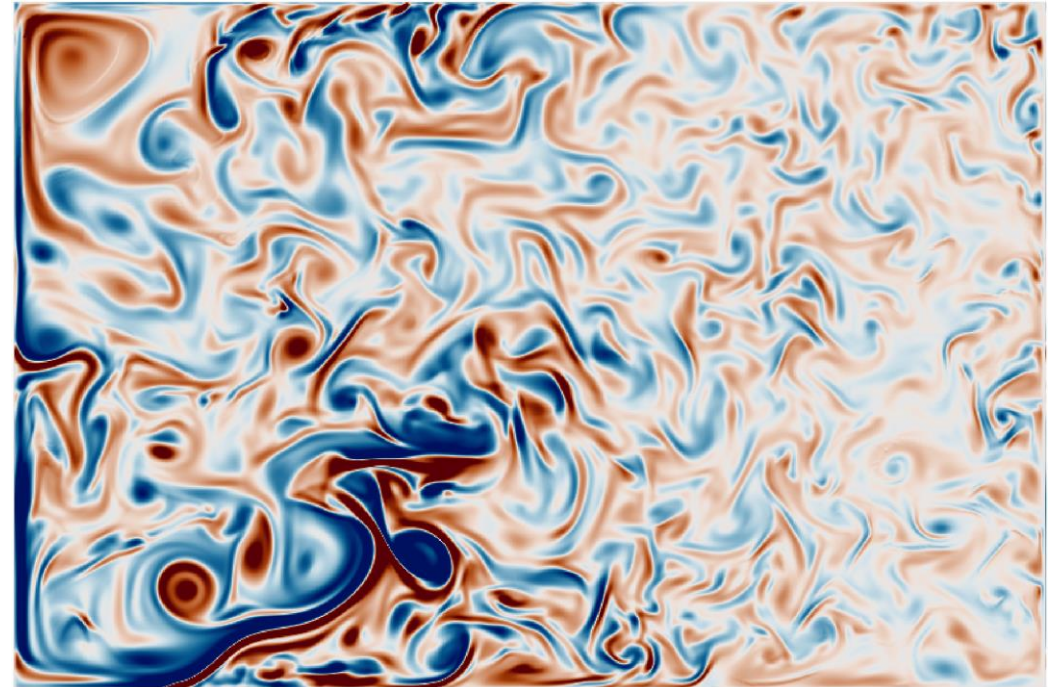
# GYRER27 comparison with double-precision

## Which is double-precision?

Relative vorticity after 2 years spin-up from rest



Mixed-precision



Double-precision

double-precision, day 0

ORCA $\frac{1}{4}^\circ$  sea-surface salinity



mixed-precision, day 0



# ORCA 1/4° profile

Subroutine	Purpose	% of DP cost	Speed-up MP:DP
icedyn_rhg	Sea-ice rheology	11%	1.17
tra_adv	Tracer advection	9%	1.48
zdf_phy	Vertical ocean physics	9%	2.24

*576 cores, 6 month integration*

Overall speed-up from mixed-precision: **1.5x**

i.e. ~35% reduction in cost

**10 free extra ensemble members** in seasonal forecast

# Floating-point errors

- Overflows:  $10^{40}$  ✓
- Divide by zero:  $1/0$  ✓
- Invalid:  $\sqrt{-1}$  ✓
- Underflow:  $10^{-40}$  ?
- Inexact:  $1000+10^{-5}$  ?

} Catchable

