Mixed-precision ocean modelling at ECMWF

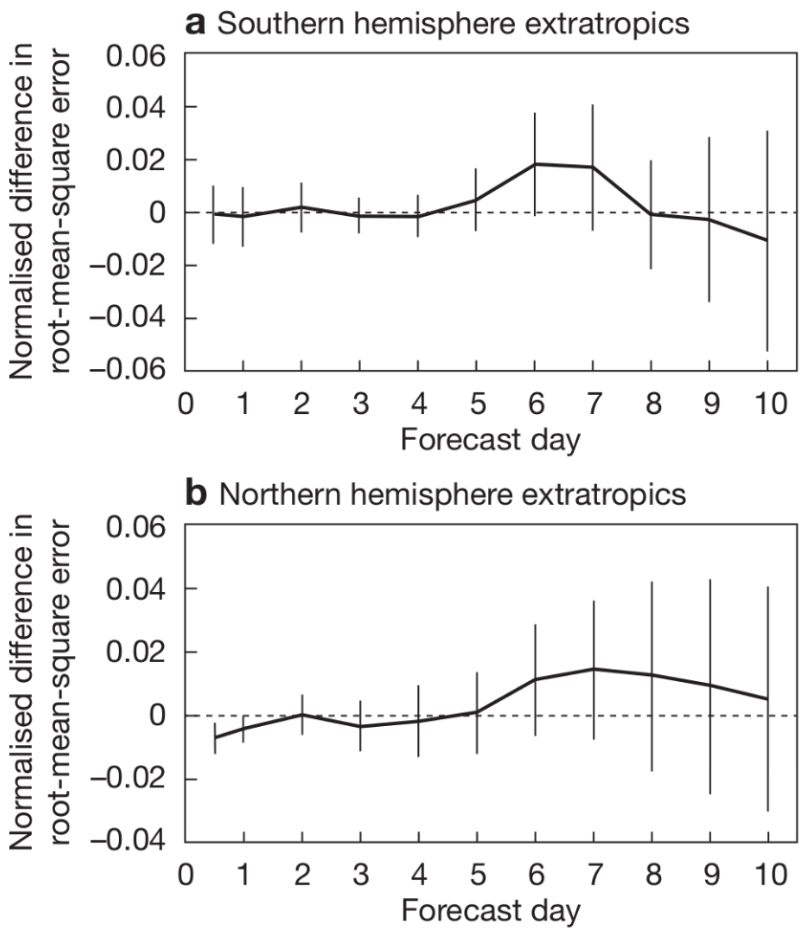
Sam Hatfield, Kristian Mogensen, Peter Düben, Nils Wedi

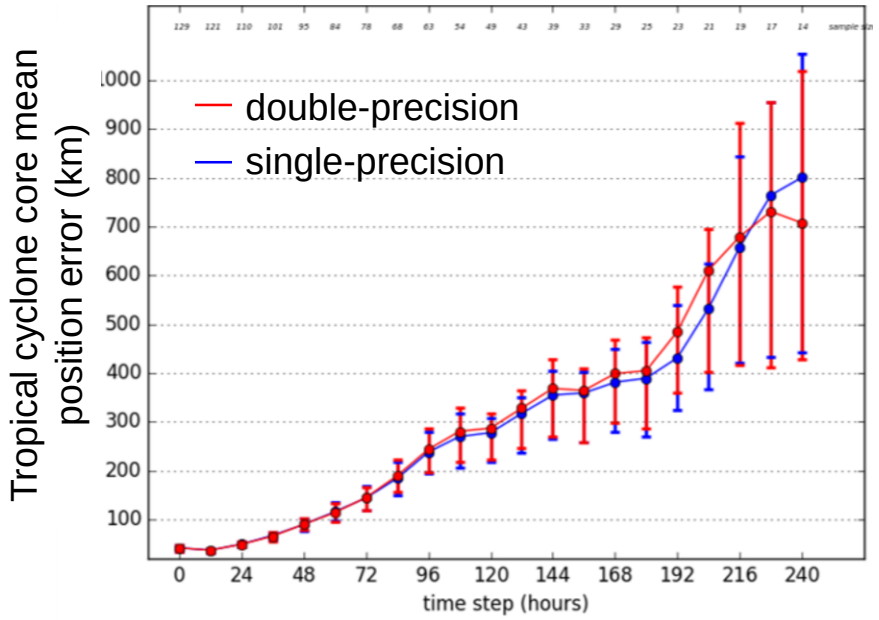
samuel.hatfield@ecmwf.int

ESiWACE2 has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 823988
© ECMWF May 25, 2020

Single-precision at ECMWF (atmosphere)

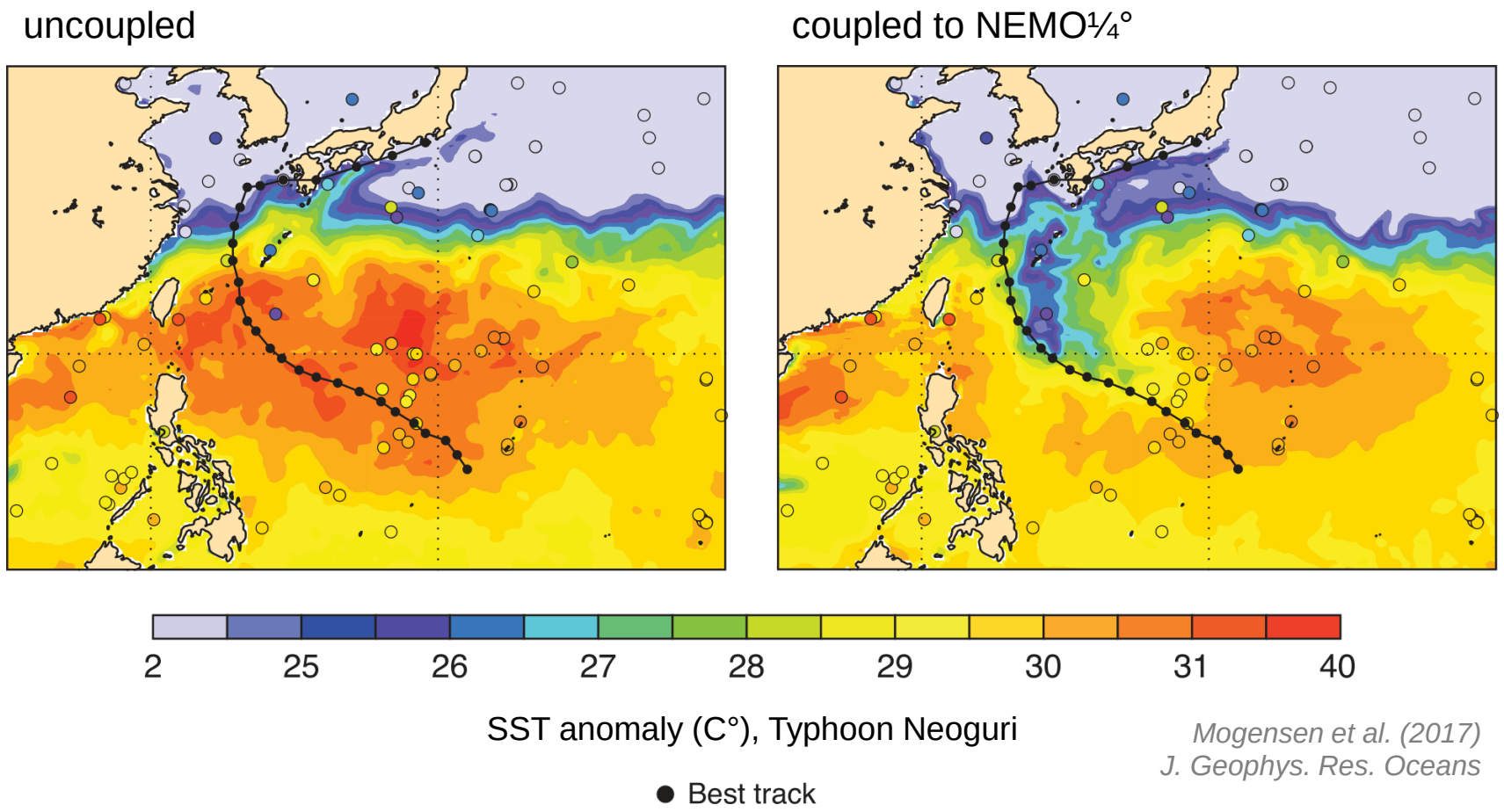
Z500





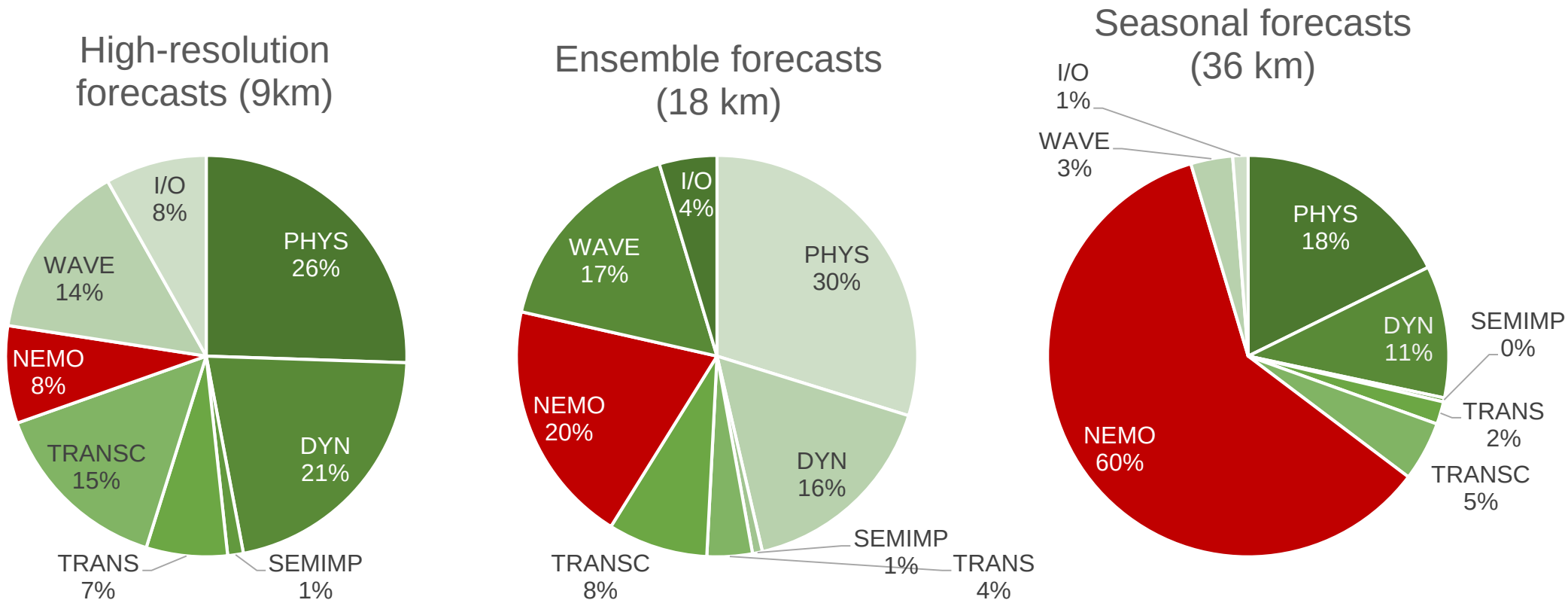
1.7x speed-up (40% reduction in wall-clock time)
Operational in 2021
Data assimilation not considered yet

Ocean modelling at ECMWF

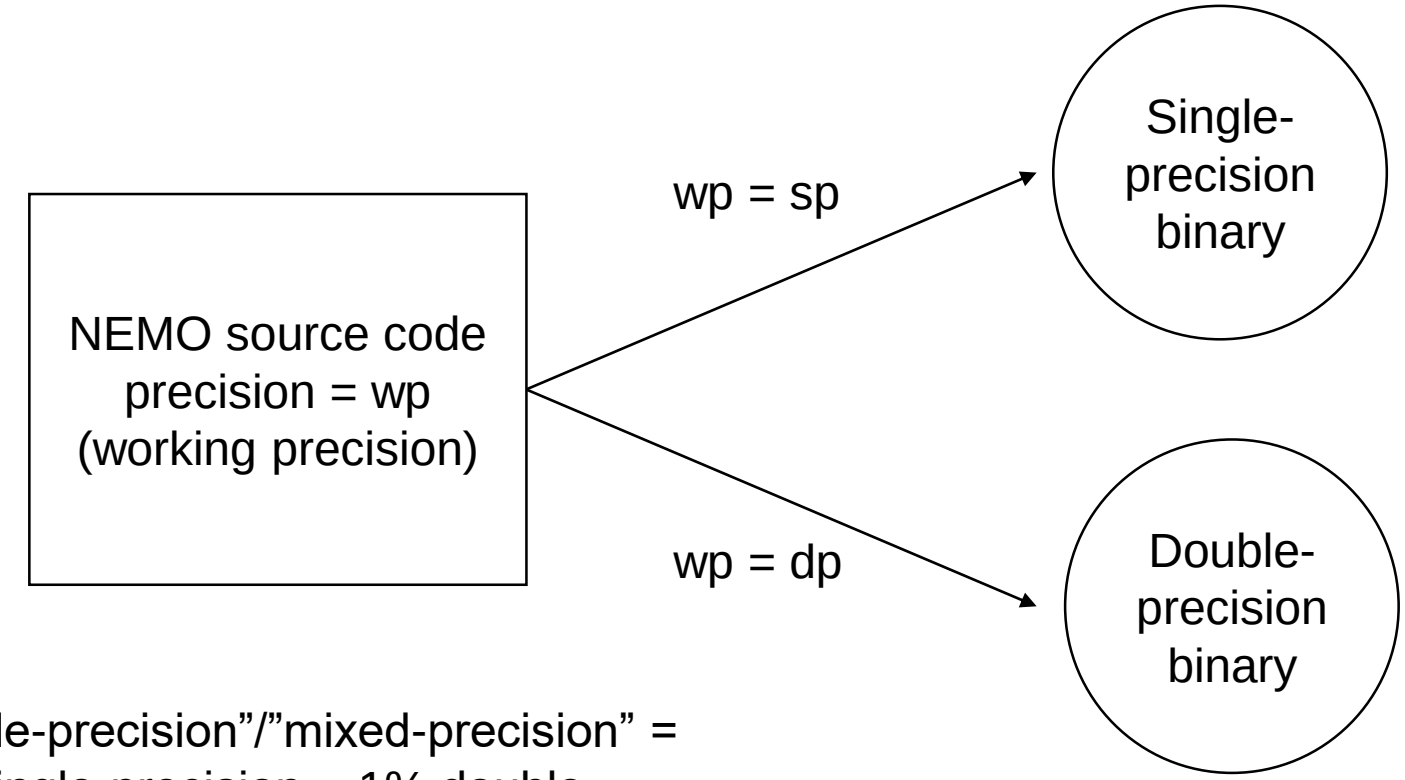


Mogensen et al. (2017)
J. Geophys. Res. Oceans

Cost of ocean modelling



Reducing precision in the ocean

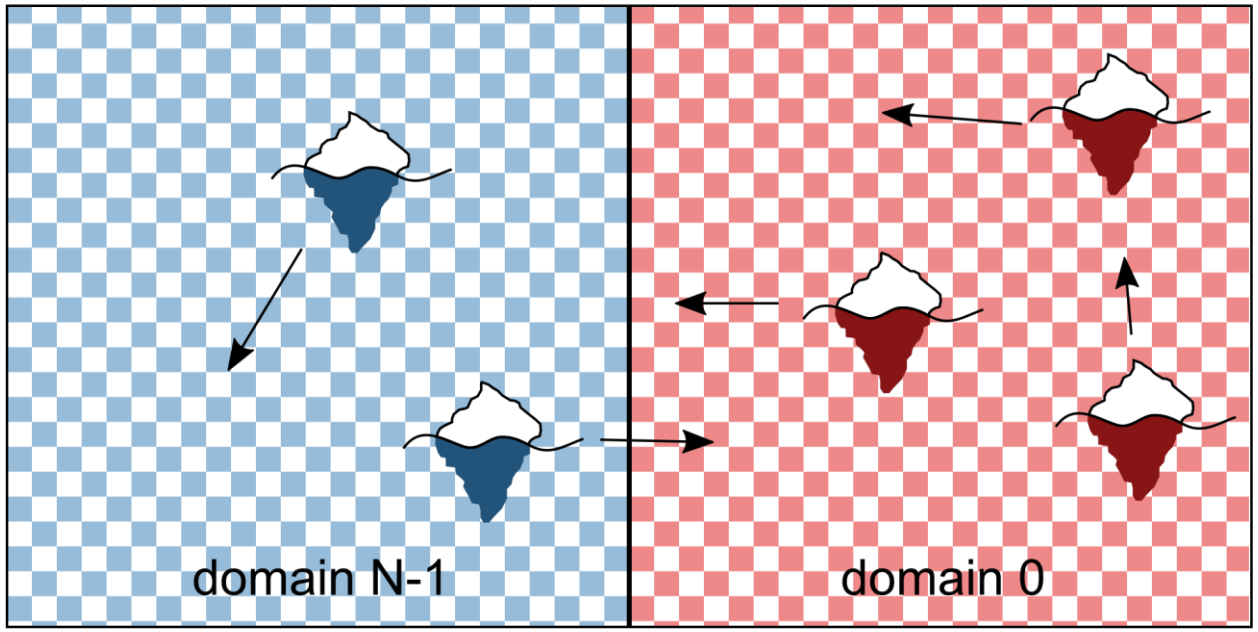


Note: “single-precision”/”mixed-precision” = ~99% single-precision, ~1% double-precision

Single-precision problem areas (easily solvable)

Problem:

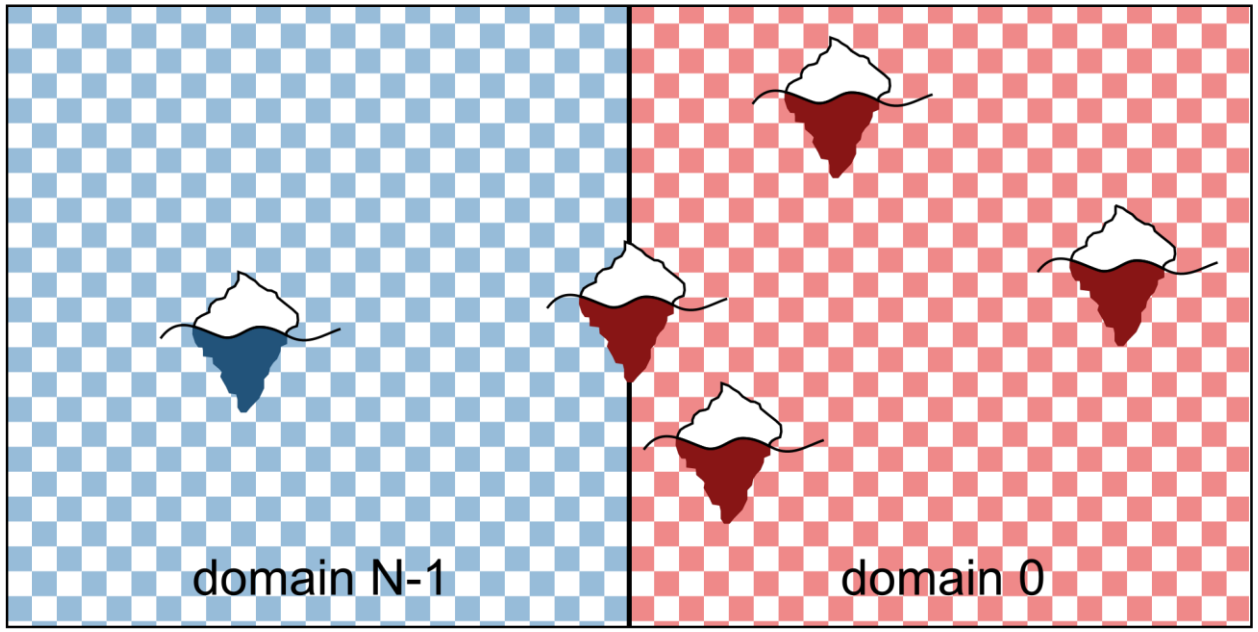
- Icebergs get trapped between subdomains because of rounding errors



Single-precision problem areas (easily solvable)

Problem:

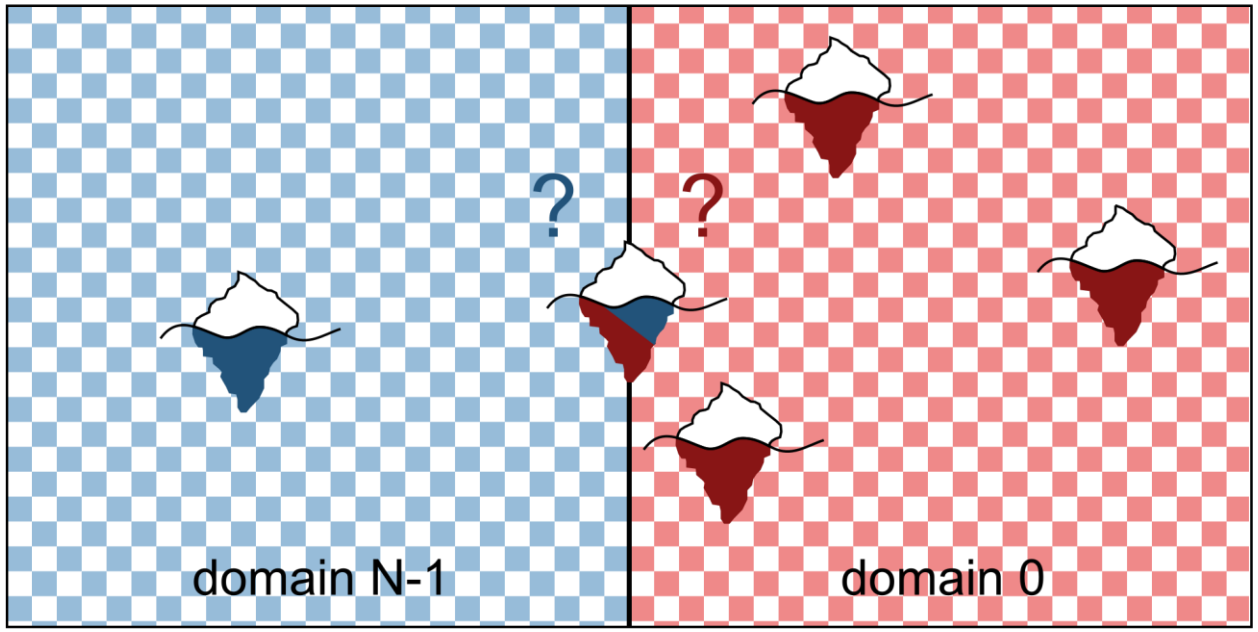
- Icebergs get trapped between subdomains because of rounding errors



Single-precision problem areas (easily solvable)

Problem:

- Icebergs get trapped between subdomains because of rounding errors



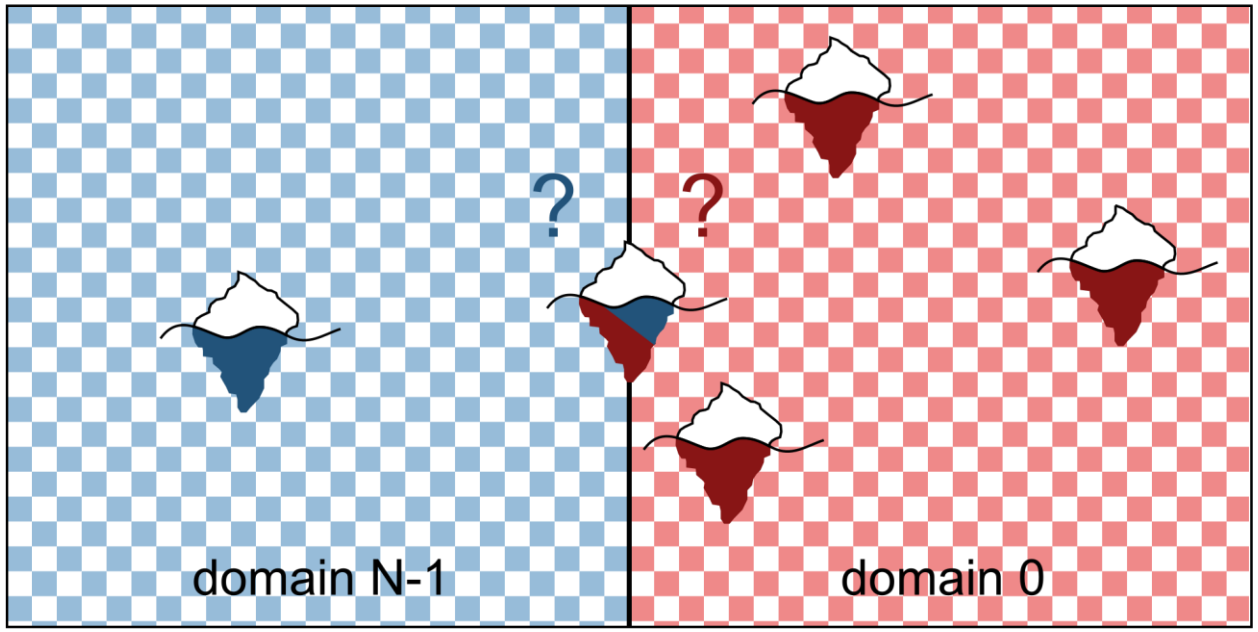
Single-precision problem areas (easily solvable)

Problem:

- Icebergs get trapped between subdomains because of rounding errors

Solution:

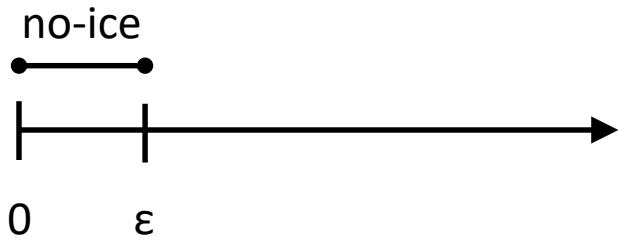
- Redefine subdomain boundaries so they are “stretchy”



Single-precision problem areas (more complicated)

How do we define “ice-free”?

e.g. sea-ice concentration:



- $\varepsilon = 10^{-20}$ for double-precision → **too small for single-precision**
- Change ε to e.g. 10^{-8}
- Does it matter?

~mitochondrion

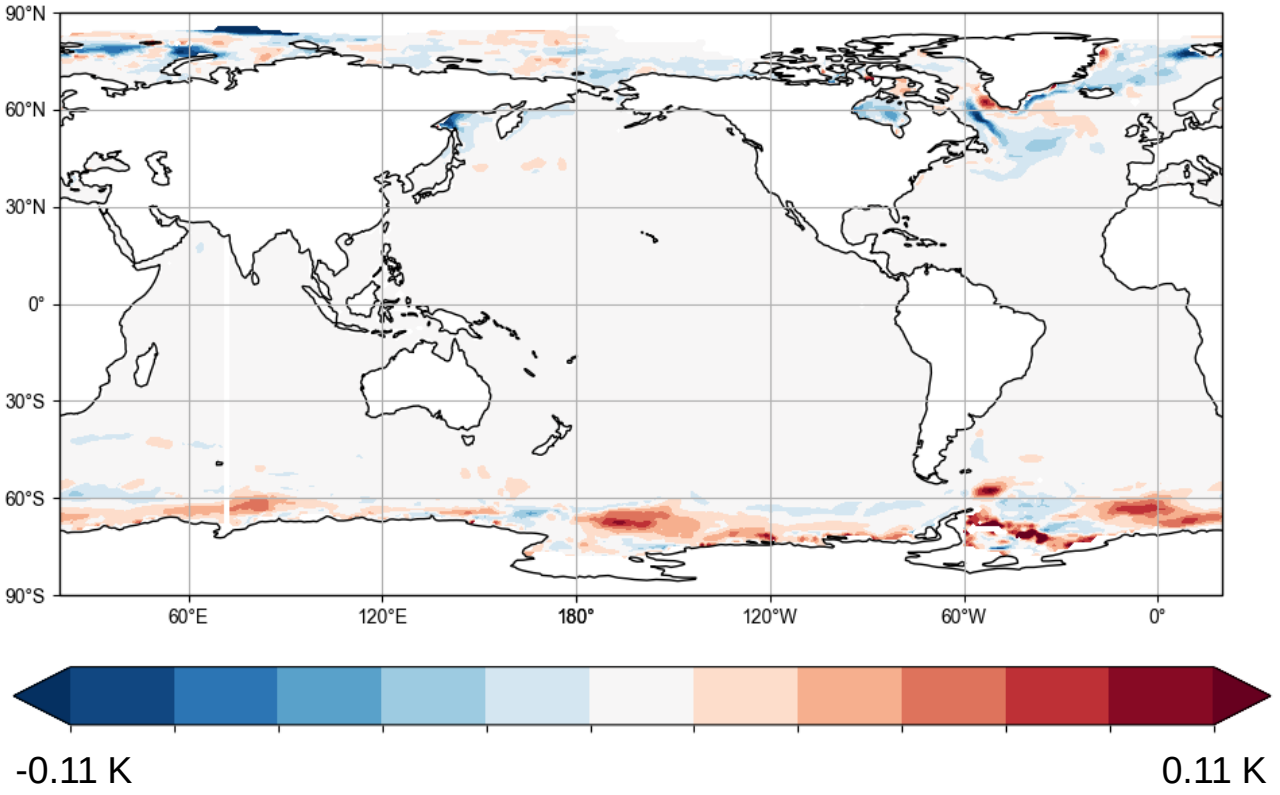
```
! Original code
WHERE (sea_ice_conc >= 10**-20)
    t_surf = zaTsfn / sea_ice_conc
ELSEWHERE
    t_surf = 273.15
END WHERE
```

~trampoline

```
! New code
WHERE (sea_ice_conc >= 10**-8)
    t_surf = zaTsfn / sea_ice_conc
ELSEWHERE
    t_surf = 273.15
END WHERE
```

Verification (1° resolution)

- Verify through long-term forced ocean/sea-ice simulations
- Forcing fields derived from ERA5
- Reference period:
  - 1979 – 2016
- eORCA1 (global 1°) resolution: single-precision is ~**error neutral** compared with double-precision
- Increase in SST RMSE **~10 times lower than changing NEMO version**
- eORCA025 (global ¼°) resolution experiments ongoing



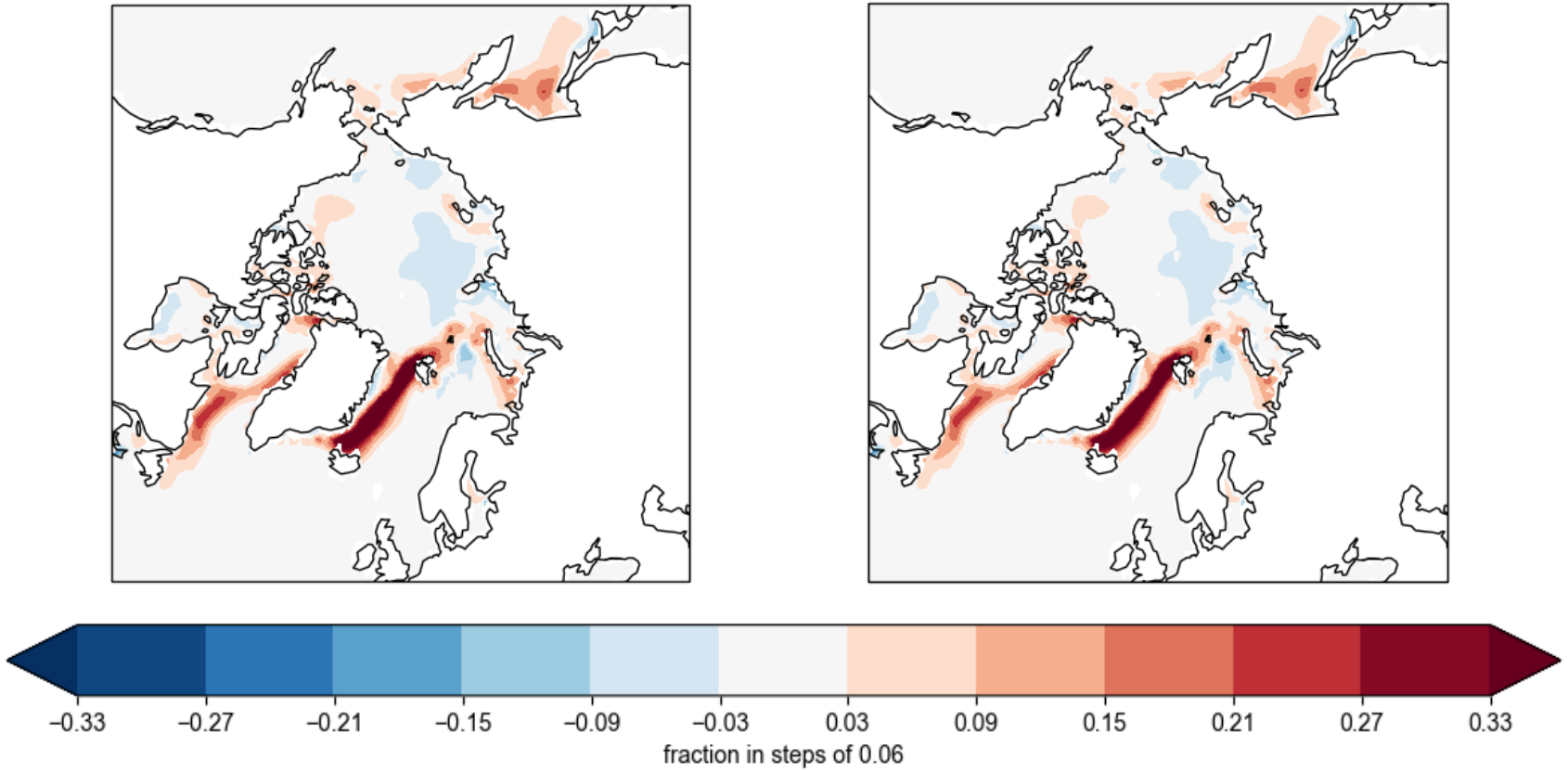
Change in SST RMSE (w.r.t. analysis) after switching to single-precision

Verification (1° resolution)

Sea-ice concentration bias w.r.t. observations

double-precision

single-precision



Computational profile (tentative)

Subroutine	Purpose	% of DP cost	Speed-up SP:DP
`tra_adv`	Tracer advection	12%	**1.63**
`zdf_phy`	Vertical ocean physics	10%	**1.98**
`icedyn_rhg`	Sea-ice rheology	5%	**1.14**

288 cores, 1 month integration, ORCA025 resolution

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

But reduces to ~1.2x when using XIOS

Conclusion

- Single-precision has been used successfully in the atmosphere at ECMWF, with ~1.7× speed-up
- Single-precision ocean shows promise
  - Domain expertise helpful
  - eORCA1 is error neutral compared with double-precision
  - eORCA025 (operational resolution) under testing
- Single-precision in the ocean provides ~1.5× speed-up, but remaining questions about cost of I/O