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n01: Oceans and Shelf Seas consortium

- Motivation
- Current examples
- A brief historical perspective
- The NEMO consortium
- Progress towards exascale

Andrew Coward (acc@noc.ac.uk) : ARCHER2 celebration of science, Edinburgh 7th March 2024

n01: Motivation

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Ditlevsen and Ditlevsen 2023

nature communications

Article

https://doi.org/10.1038/s41467-023-39810-w

Warning of a forthcoming collapse of the Atlantic meridional overturning circulation

Received: 3 March 2023

Accepted: 29 June 2023

Published online: 25 July 2023

Peter Ditlevsen [1,3] & Susanne Ditlevsen [2,3]

The Atlantic meridional overturning circulation (AMOC) is a major tipping element in the climate system and a future collapse would have severe impacts

BBC NEWS

Science & Environment

Will the Gulf Stream really collapse by 2025?

The Guardian

Gulf Stream could collapse as early as 2025, study suggests

A collapse would bring catastrophic climate impacts but scientists disagree over the new analysis

The Atlantic is at risk of circulation collapse – it would mean even greater climate chaos across Europe

THE CONVERSATION

Academic rigour, journalistic fair

van Westen et al. 2024

SCIENCE ADVANCES | RESEARCH ARTICLE

OCEANOGRAPHY

Physics-based early warning signal shows that AMOC is on tipping course

René M. van Westen*, Michael Kliphuis, Henk A. Dijkstra

One of the most prominent climate tipping elements is the Atlantic meridional overturning circulation (AMOC), which can potentially collapse because of the input of fresh water in the North Atlantic. Although AMOC collapses have been induced in complex global climate models by strong freshwater forcing, the processes of an AMOC tipping event have so far not been investigated. Here, we show results of the first tipping event in the Community Earth System Model, including the large climate impacts of the collapse. Using these results, we develop a physics-

CNN World

Critical Atlantic Ocean current system is showing early signs of collapse, prompting warning from scientists

The Guardian

Atlantic Ocean circulation nearing 'devastating' tipping point, study finds

Collapse in system of currents that helps regulate global climate would be at such speed that adaptation would be impossible

NewScientist

Environment

Atlantic current shutdown is a real danger, suggests simulation

The most detailed computer model run so far shows that melting ice sheets could cause the collapse of the major ocean current that warms Europe, but it's still unclear how likely this is to happen

By Michael Le Page

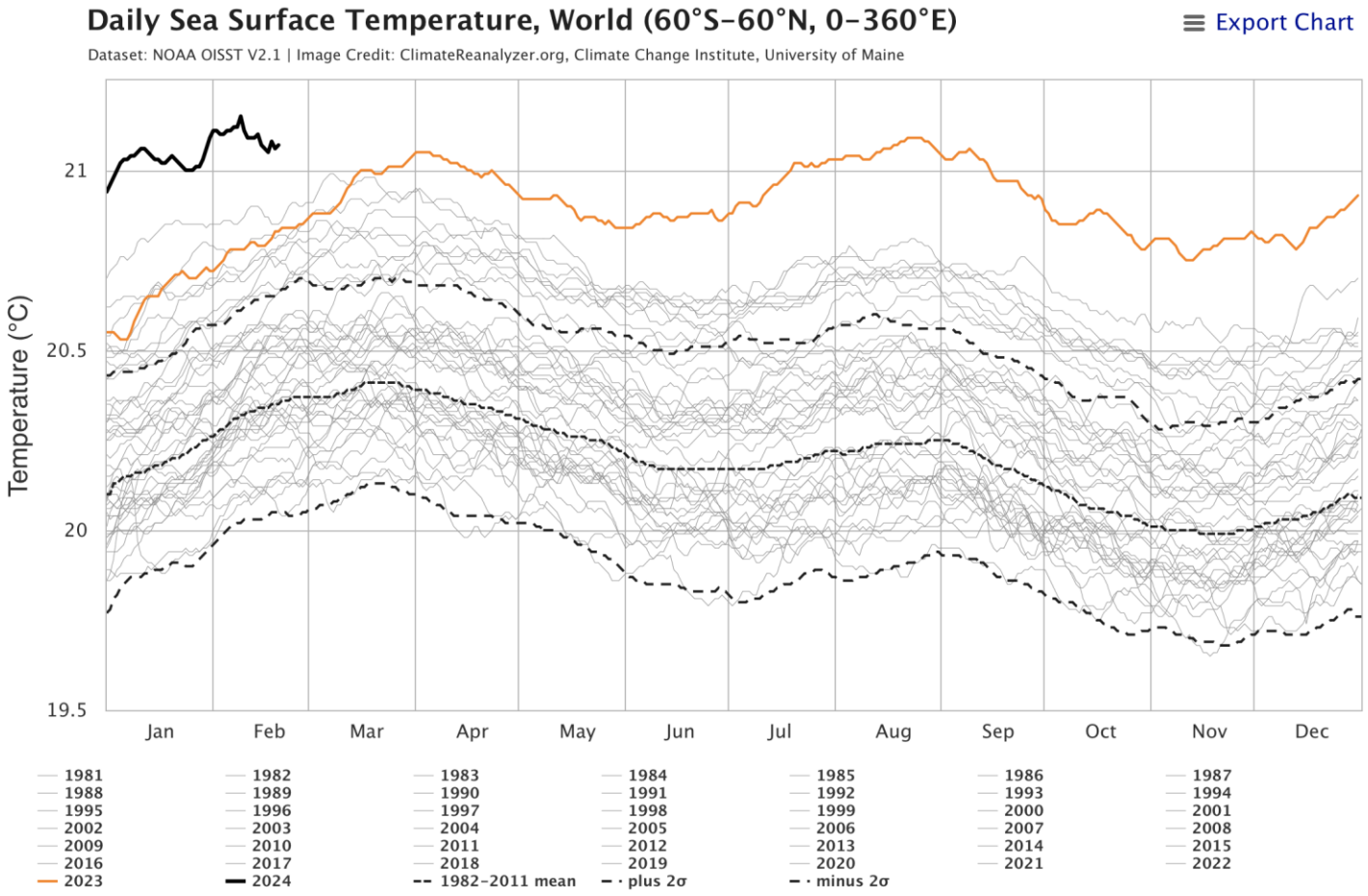
9 February 2024

INDEPENDENT

System of Atlantic Ocean currents approaching 'Day After Tomorrow' calamity, study suggests

An abrupt shutdown could put large parts of Europe in a deep freeze

n01: Motivation



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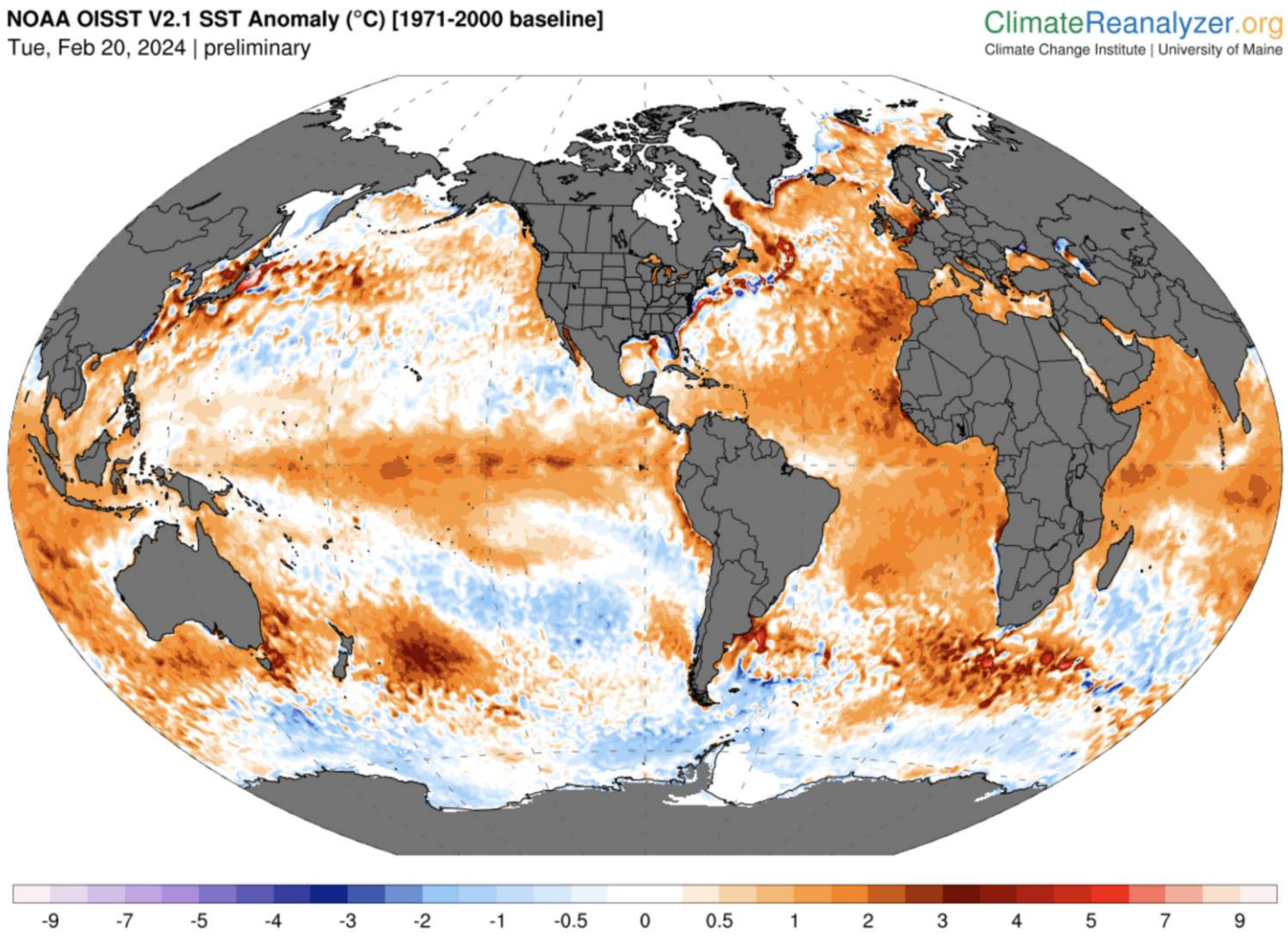
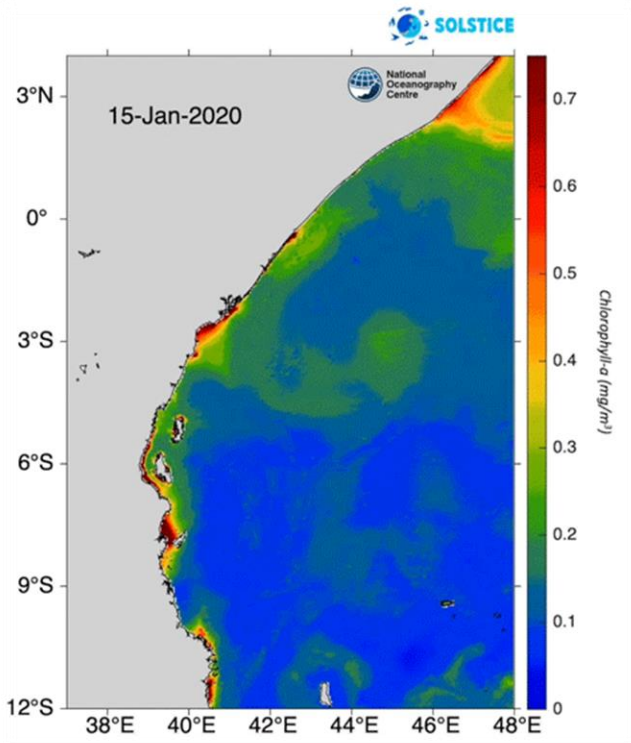


n01: Motivation



n01: Current examples – 3 model resolutions

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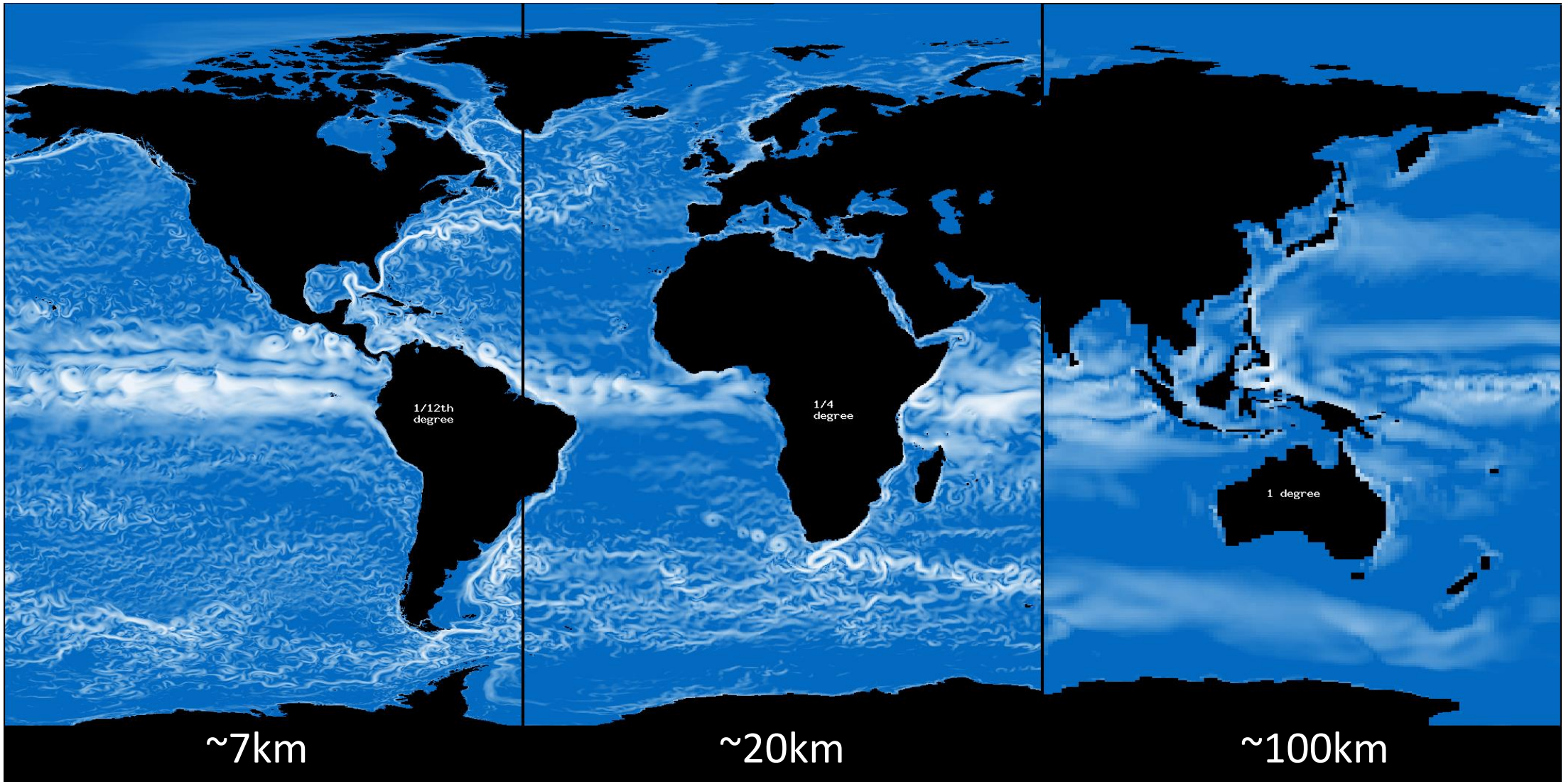

n01: Current examples

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n01: Current examples

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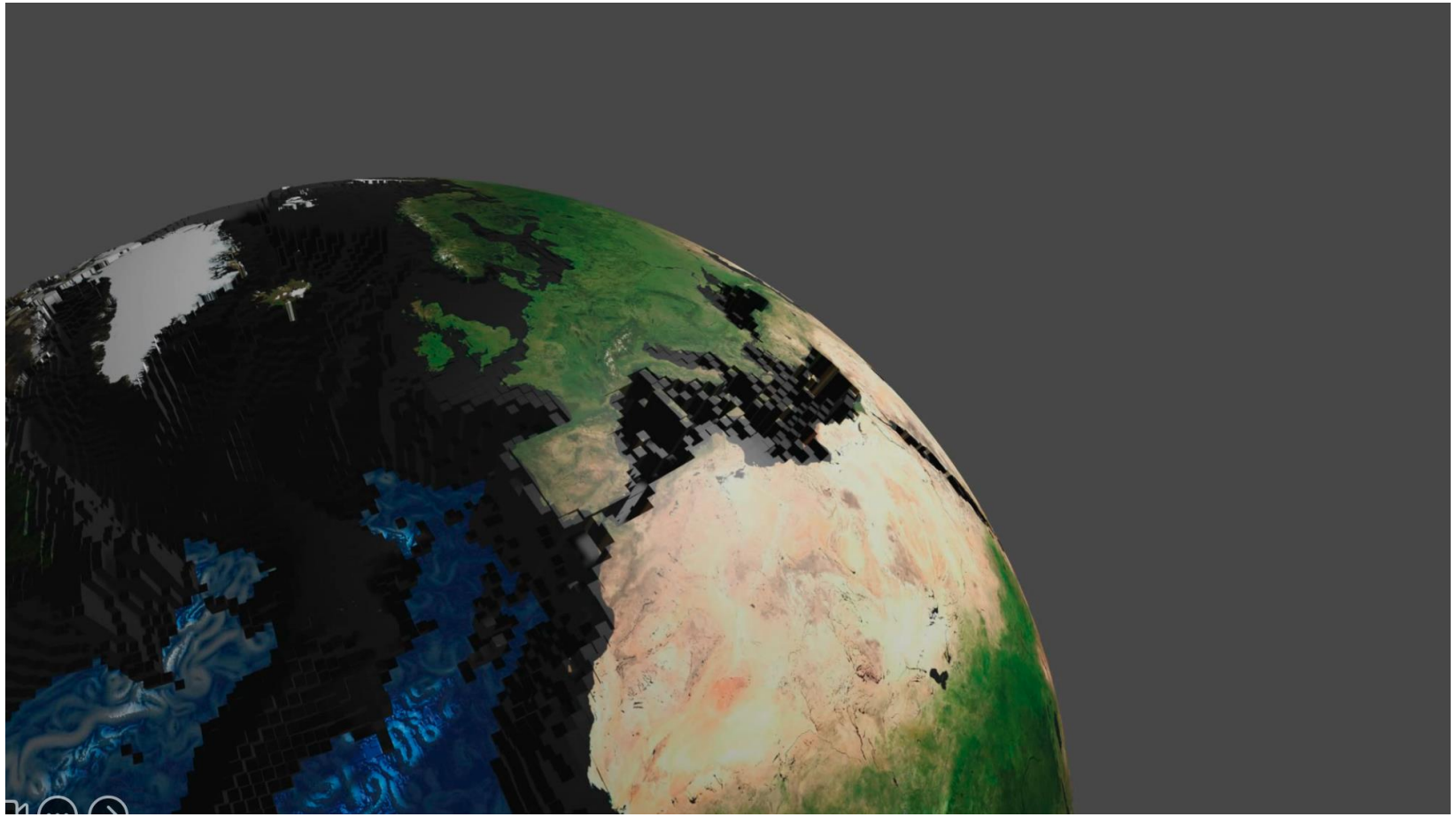
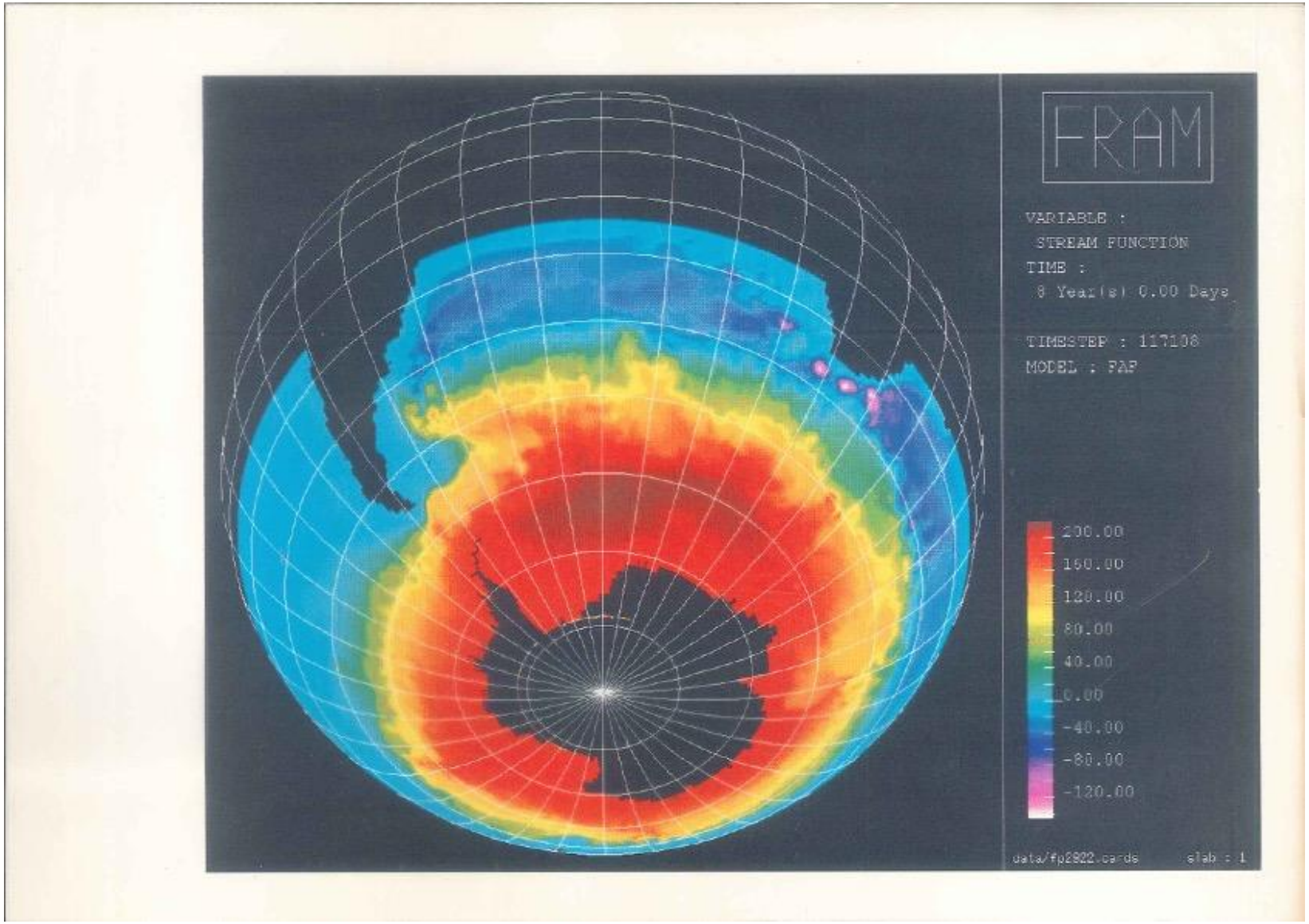


n01: Historical perspective

Circa 1990!
1/4° x 1/2°
Southern Ocean model

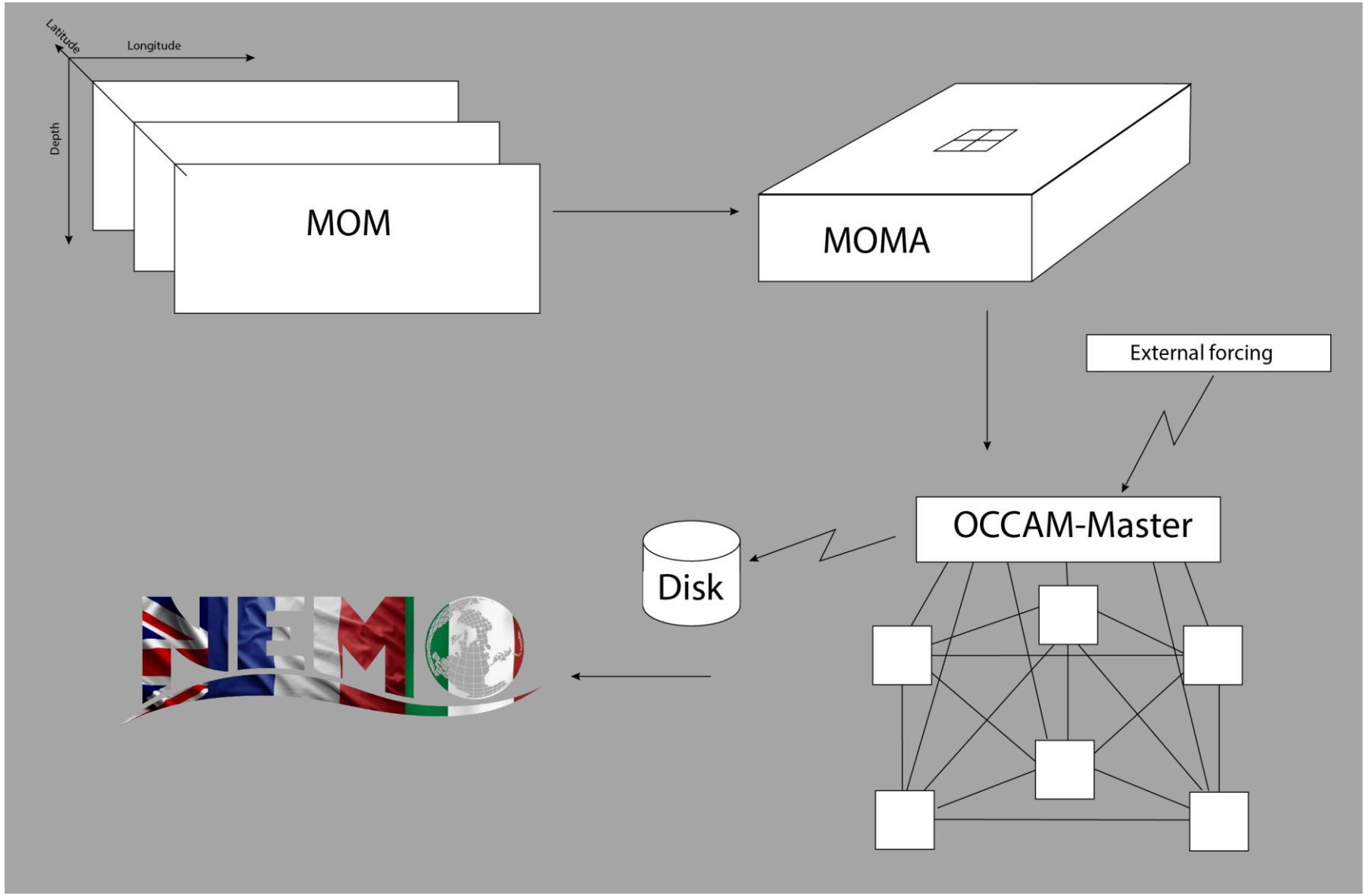


n01: Historical perspective

Introduction

1. Historical context
2. Outline of the model physics
3. Design considerations for a production model
4. Development strategy
5. Porting to the CRAY-T3D
6. Experiences in production mode
7. Ongoing development
8. Summary and example results from the high resolution global model

Southampton Oceanography Centre



Circa 1995

n01: The NEMO consortium

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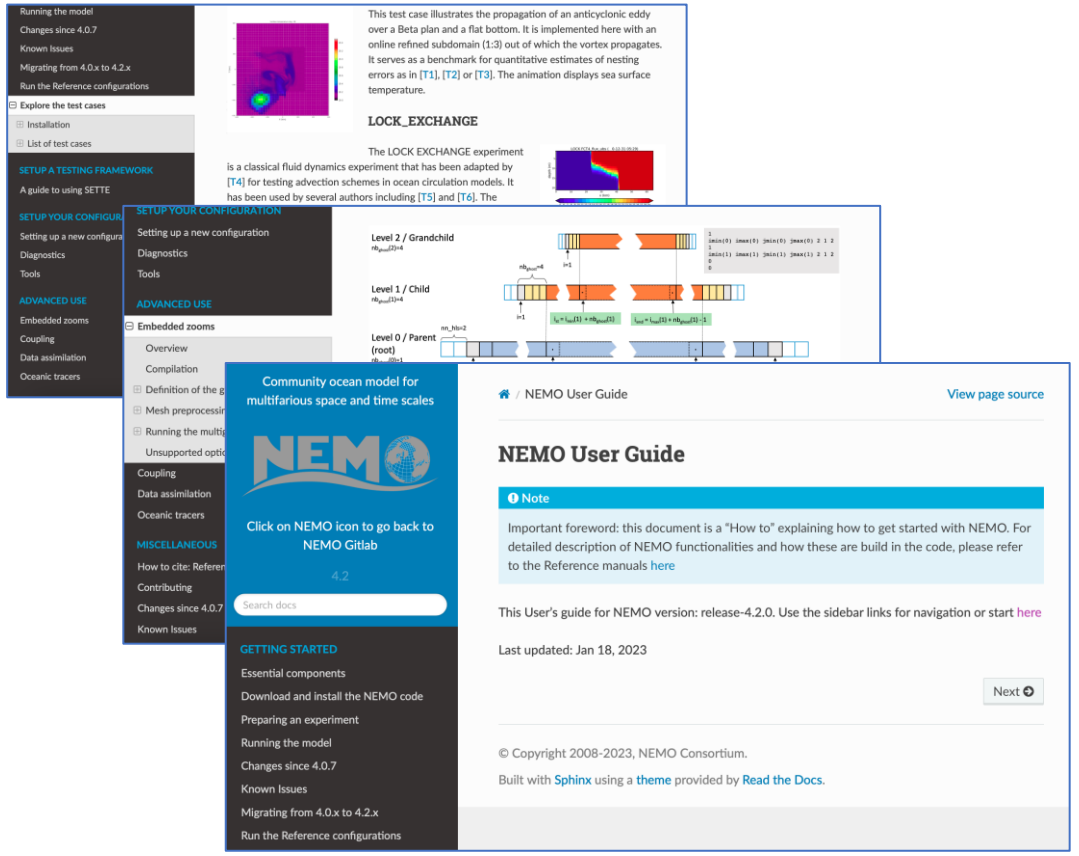
NEMO System team development

- 5 full consortium members + associates
- Each consortium member guarantees 1 man-year of effort p.a.
- Annual workplan agreed by development committee; aligned with rolling 5-year development strategy
- High level steering committee to leverage opportunities
- Open-source development with moderation of external contributions (Gitlab-based)



Current release of NEMO 4.2.2 (very soon 5.0-beta)

https://sites.nemo-ocean.io/user-guide/
https://forge.nemo-ocean.eu/nemo

n01: Progress towards exascale

Science and Technology Facilities Council

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1. Original source code

```
za (: ,:) = 0.0 _wp
DO_2D( 1, 0, 1, 0 )
  za(ji,jj) = zb(ji+1,jj) - zb(i,jj)
END_2D
```

CPP preprocessing
and macro expansion

2. Preprocessed source code

```
za (: ,:) = 0.0 _wp
DO jj = ntsj-(1), ntej+(0) ; DO ji = ntsi-(1), ntei+(0)
za(ji,jj) = zb(ji+1,jj) - zb(ji,jj)
END DO ; END DO
```

Psyclone 1st stage

3. PSyclone Internal Representation (PSyIR)

```
[...]
  0: Assignment []
     ArrayReference[name:'za']
[...]
  1: Loop[type='lat', field_space='None', it_space='None']
[...]
       Schedule []
         0: Loop[type='lon', field_space='None', it_space='None']
[...]
            Schedule []
              0: InlinedKern []
                   Schedule []
                     0: Assignment []
[...]
```

Psyclone transformation
(external script)

Transformed PSyIR

Transformed F90

4. Compiler-ready source code

```
!$acc kernels
za (: ,:) = 0.0 _wp
!$acc loop independent collapse(2)
do jj = ntsj - 1, ntej + 0, 1
do ji = ntsi - 1, ntei + 0, 1
   za(ji,jj) = zb(ji + 1,jj) - zb(ji,jj)
end do
end do
!$acc end kernels
```

n01: Proof of concept

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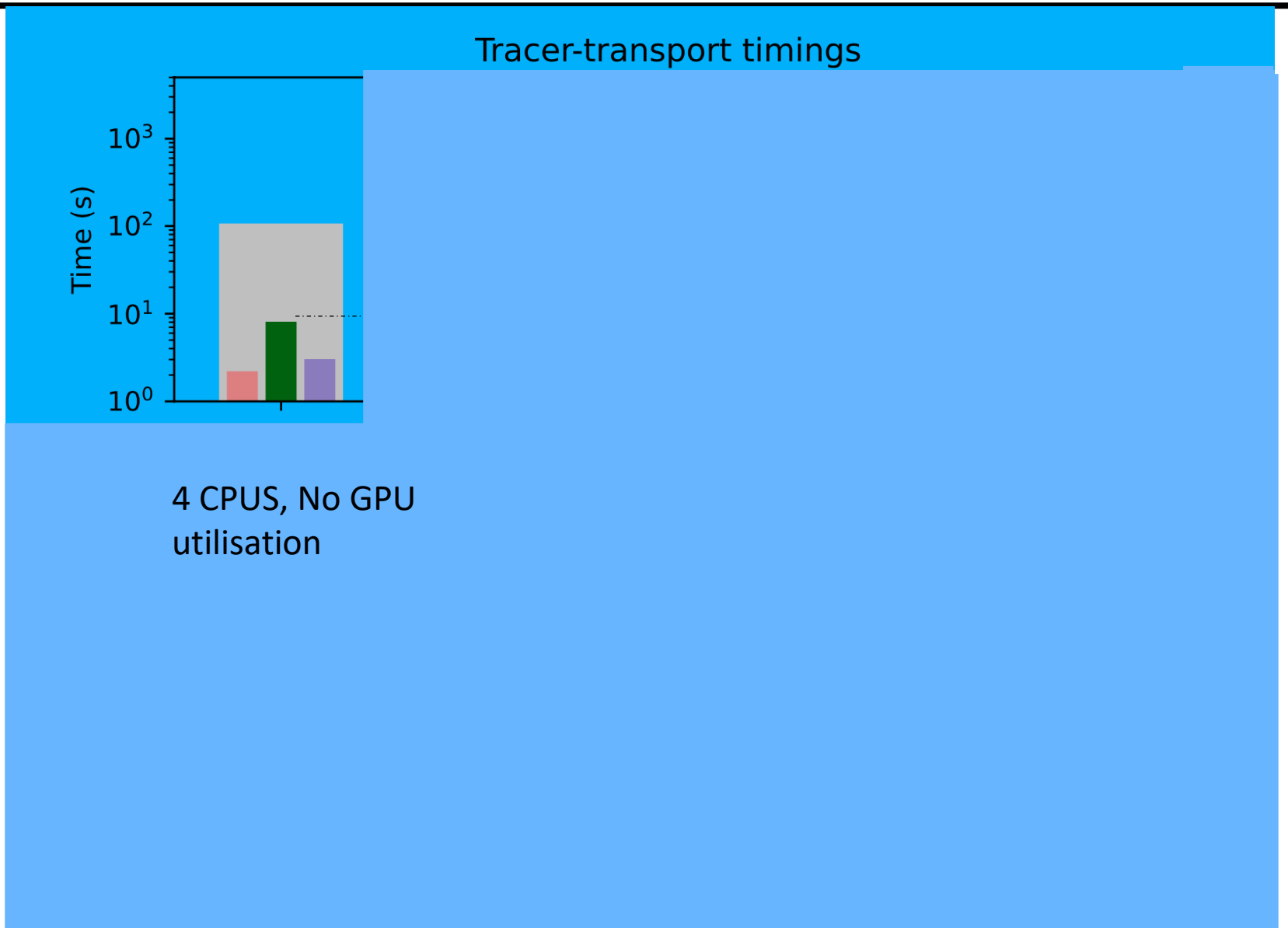
GPU-resident tracer transport in the (slightly simplified) NEMO BENCH configuration

(Simon Müller, NOC)



4 CPUS, No GPU utilisation

n01: NEMO 5, GPU acceleration, and the PSyclone approach

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- Integration of PSyclone source-code generation in the NEMO 5 build system
- NEMO 5 compatible with relevant Fortran compilers:
  GNU, Intel, Cray (as available on ARCHER2), NVIDIA HPC SDK
- Ongoing support for new PSyclone releases; feedback into PSyclone development
- PSyclone generates OpenACC kernels regions covering relevant code sections
  - Sufficient for GPUs with memory management based on a page-fault mechanism
  - Alternatively, PSyclone can manage data residency on GPUs

    ```
    !$acc enter data copyin([. . .])
    ```

    and updates in the main memory

    ```
    !$acc update if present host([. . .])
    ```

  - ..but there are unresolved compatibility issues when using the Fortran compiler available on ARCHER2

Different approaches (e.g., OpenMP offload) are also available

https://github.com/stfc/psyclone
https://www.openacc.org

n01: Next steps

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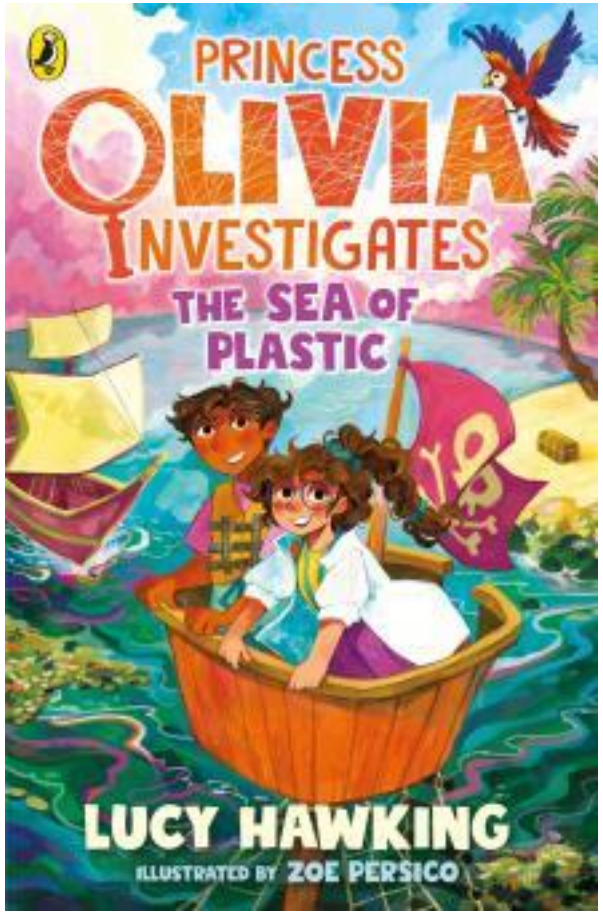
- Resolution of compatibility issues between PSyclone and Cray Fortran compiler
- In the interim: semi-manual data management via PSyclone script
- Exploration of MPI communication between GPUs
- Scaling tests on (large) multi-node systems

n01:



•The book brings to life the science research from world leading NOC scientists Dr Chelsey Baker, Dr Sara Fowell, Prof Steph Henson, Dr Alice Marzocchi and Dr Katsia Pabortsava.

•The story aims to educate and inspire young readers to protect our ocean and even become plankton poo scientists of the future.

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