Project Report

Project:	1548
Project title:	TropEcS
Principal investigator:	Nils Brüggemann
Report period:	2025-11-01 to 2026-10-31

This DKRZ project aims to support the modelling activities of the TropEcS expansion of the Leibniz Institute for Marine Tropics (ZMT) in Bremen. The overall goal of TropEcS is to better represent coastal, biogeochemical, ecological and socio-economic dynamics in climate models. During the first year of this project, we made progress in implementing several processes or preparing their implementation. Since TropEcS is still being established (key research positions have not yet been filled), we relied heavily on collaborations with other partners. For the same reason, we were not able to fully utilise the requested computing resources (more information below).

Lagrangian particle simulations: In collaboration with the ELPHE project, we have implemented key steps to allow for particle advection with the Parcels[1] Lagrangian particle toolbox on the unstructured FESOM and ICON ocean grids. The Parcels software is ideally suited for the research anticipated in TropEcS since it allows for a flexible definition of particle properties that can be adapted to simulate different particle classes such as fish species, *Sargassum* or plastic pollutants, but also to trace water masses or test observational sampling strategies.

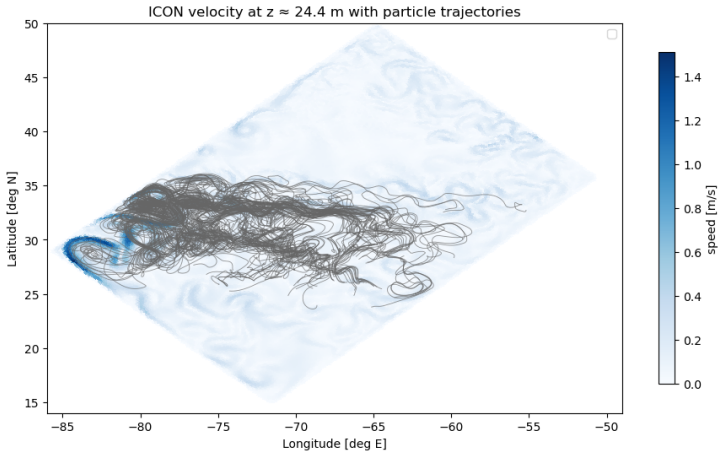


Figure 1: Idealized ICON double-gyre configuration. The color shading shows the surface velocity. Grey lines indicate trajectories of particles advected by Parcels using the ICON velocity output.

To use Parcels with the unstructured, triangular ICON and FESOM grids, new interpolation techniques had to be implemented in Parcels and tested with the models. An appropriate interpolation is essential to prevent particles from spuriously deviating from their correct paths, which can lead to severe displacements in turbulent flows.

First results in an idealized test configuration, which we established with our partners to compare FESOM and NEMO with ICON, were successful (Fig. 1). As a next step, we will apply Parcels in more realistic configurations. While the underlying developments were time-consuming, the computations were rather cheap and did not use up a considerable amount of our allocated node hours.

Surface wave coupling: In collaboration with the University of Hamburg, the Max Planck Institute for Meteorology and the German Weather Service (DWD), we are coupling the surface wave model ICON Waves to the ICON ocean component. The coupling involves three major modifications: (1) the surface waves modify the surface roughness and thereby the wind stress (nearly complete), (2) surface waves impact ocean mixing through wave dissipation, which drives turbulence, and through Stokes shear, which generates Langmuir turbulence (prototype version nearly ready), and (3) the wave-driven Stokes drift advects ocean tracers (prototype version exists). So far, we have used the ERA5 Stokes drift instead of the simulated Stokes drift from ICON Waves to advect tracers in ICON ocean. In the next step, this will be replaced by the Stokes drift from ICON Waves. Our preliminary results (Fig. 2) suggest that Stokes drift advection affects the ocean heat transport and its convergence.

Coupling mangroves to ICON land:

[1] `https://parcels-code.org/`

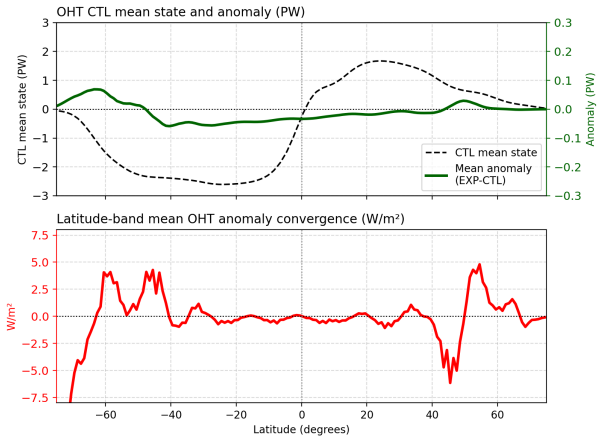


Figure 2: Global northward ocean heat transport (OHT) in the control (CTL) and Stokes-forced (EXP) simulations. Top: mean OHT in CTL and the EXP-minus-CTL anomaly. Bottom: convergence of the OHT anomaly, expressed as an equivalent latitude-band-mean heat flux.

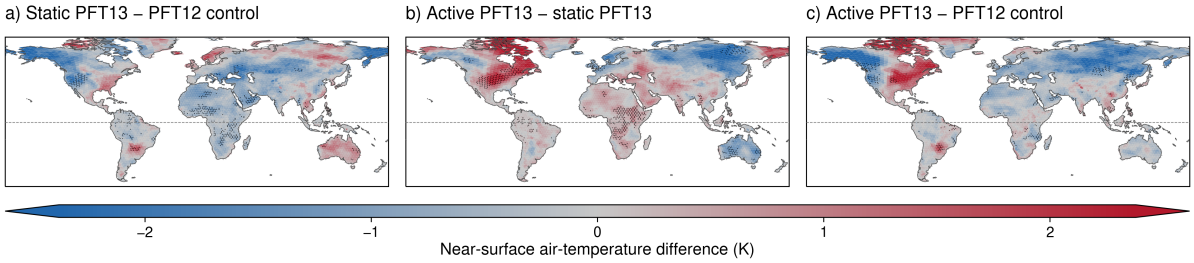


Figure 3: Mean 1980 near-surface air-temperature difference in short coupled ICON-A-ICON-Land simulations (R2B4): (a) static PFT13 minus PFT12 control, (b) active PFT13 minus static PFT13, (c) active PFT13 minus PFT12 control.

We are developing a new plant functional type (PFT) for tropical coastal vegetation in JSBACHv4, the land surface component of the ICON Earth system modelling framework. We focus on mangrove forests because of their importance as a sink of atmospheric carbon and their local impact on land-ocean carbon fluxes. Representing them requires changes to land-cover inputs, vegetation processes and model parameters.

First simulations (1979–1984) show that the climate-dependent mangrove traits alone, with unchanged land cover, alter mangrove leaf area, light absorption and productivity. Short coupled ICON atmosphere and ICON land simulations compared with the 12-PFT control show that adding mangroves, and then their trait variability, already changes near-surface air temperature (Fig. 3).

Developing high-resolution configurations: We are behind our anticipated schedule for running high-resolution ICON simulations because (1) the hiring of new staff was delayed and (2) planning discussions with new collaboration partners took longer than expected.

We moved the focus area of our SubMesoscale Telescope (SMT) simulation from the Cape Verde Islands to Central America to better match the interests of all our TropEcS scientists and of new collaboration partners from the National University of Colombia (a joint research proposal has been submitted). The new focus area allows us to study the Eastern Central Pacific, including a major upwelling system as well as the Eastern Tropical Pacific Marine Corridor, which is of interest to our collaboration partners. It also allows us to study the Caribbean Sea with its many coral reefs and the coast of Belize, both of which are the subject of new studies that we have started. Our previous plan to focus on the Cape Verde Islands will be revisited later in the course of a new DFG Schwerpunktprogramm proposal (FUTURO COAST), which is currently in preparation.

So far, we have generated the anticipated target grid and completed a 6-year spin-up with the 5 km ICON ocean model (R2B9). Currently, we are interpolating the data to the SMT target grid and will start the first target simulations next month, which will use up a substantial part of our remaining compute time.