The two-way online-coupled model ICONGETM: Regridding strategy and capabilities provided by the X-Grid structure from ESMF

Fifth Workshop on Coupling Technologies for Earth Models – CW 2020

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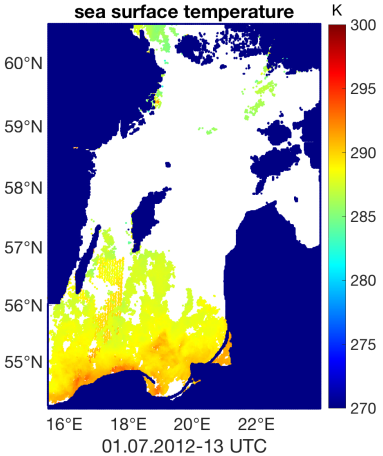
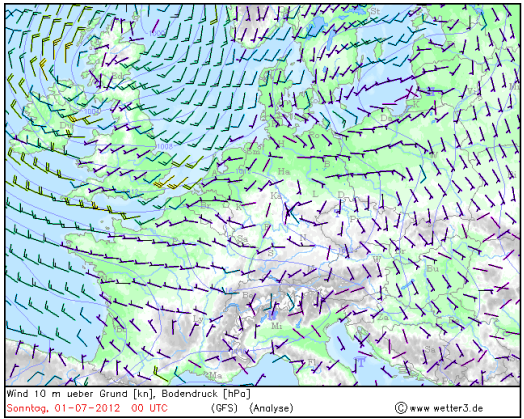
Coastal upwelling – Central Baltic Sea: July 01 - July 21, 2012



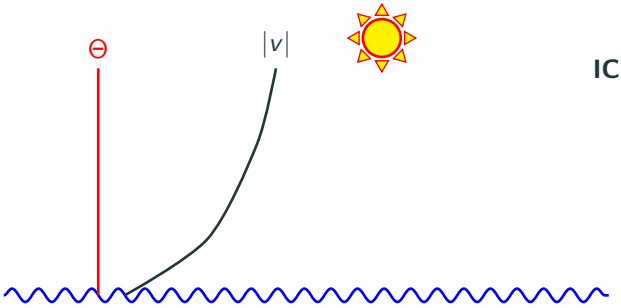
https://podaac.jpl.nasa.gov/ (21.02.2019)



Wind map of central Europe

www.wetter3.de (14.03.2019)

Physics of air-sea interface: How are/should data exchanged?



ICON

GETM

θ potential temperature

$|\mathbf{v}|$: wind

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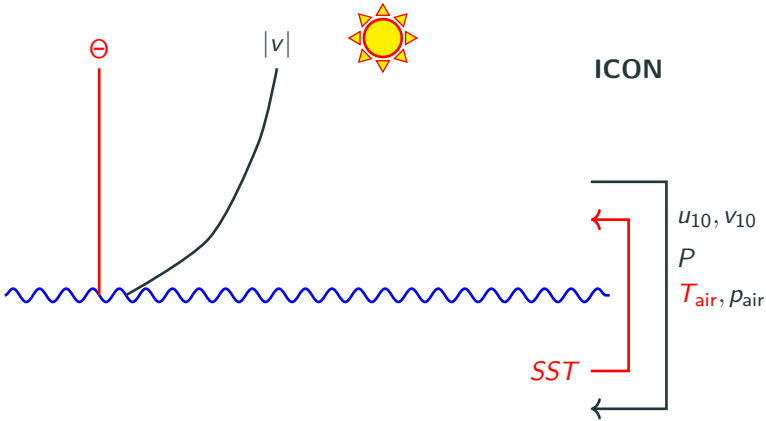

P:	precipitation
T_{air} :	air temperature
SST :	sea surface temperature
θ	potential temperature
u_{10}/v_{10} :	u/v-wind at 10 m
$\|\mathbf{v}\|$:	wind
p_{air} :	air pressure

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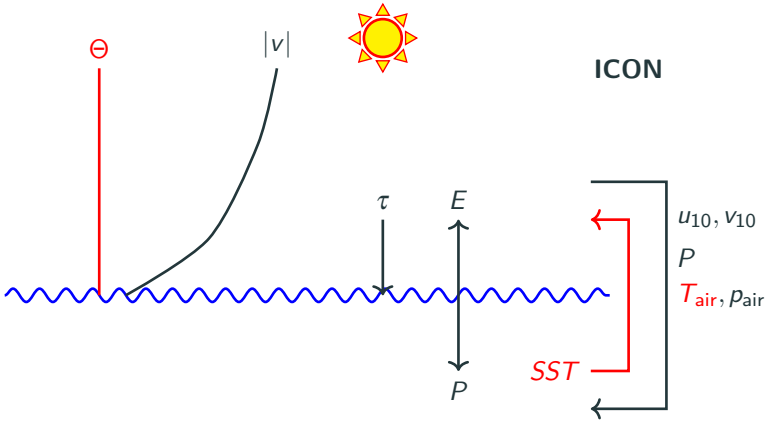

τ:	shear stress
E:	evaporation
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T_{air} :	air temperature
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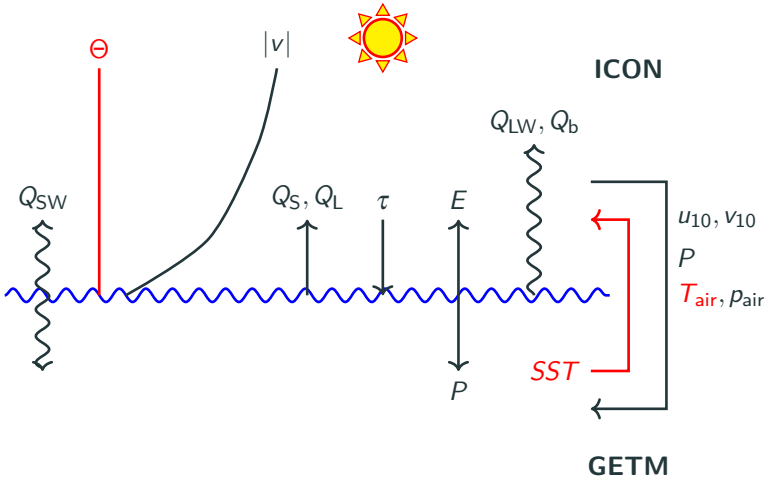

Q_s, Q_l:	sensible/latent heat flux
Q_{SW}:	solar short wave radiative flux
Q_{LW}:	terrestrial long wave radiative flux
Q_b:	long wave net radiative flux
τ:	shear stress
E:	evaporation
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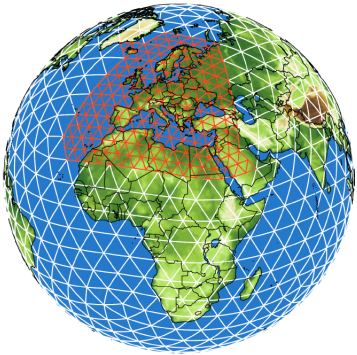
ICON – ICOsahedral Non-hydrostatic modeling framework (Atmosphere)

- Developed by German Weather Service (DWD) and Max Planck Institute for Meteorology (MPI-M)
- Unified modeling system for global numerical weather prediction and climate modeling
- Flexible grid nesting capability and usage of non-hydrostatic equations
- Operational weather forecast at DWD (13 km global + 6.5 km local resolution)



Icosahedral triangular horizontal grid with fairly uniform resolution on sphere and simple regional grid refinement

Zängl et al., 2015; Giorgetta et al., 2018

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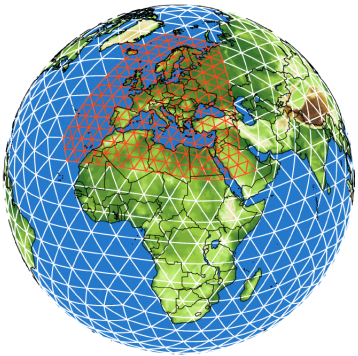
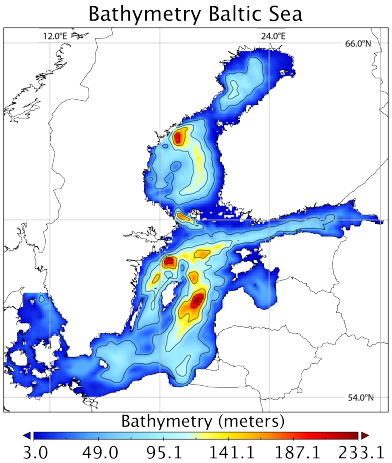
- Operational weather forecast at DWD (13 km global + 6.5 km local resolution)
- *Central Baltic Sea: approx.* 2500 m
- *Simulation configuration based on DWD forecast*

Zängl et al., 2015; Giorgetta et al., 2018



Icosahedral triangular horizontal grid with fairly uniform resolution on sphere and simple regional grid refinement

GETM – General Estuarine Transport Model (Baltic Sea)



- Co-developed at IOW (`www.getm.eu`)
- Modeling baroclinic bathymetry-guided flows including drying and flooding processes
- Reproducing baroclinic features such as upwelling, internal seiches and stratified flows
- Simulating flows and transport on larger scales than estuarine scales, e.g. salt water inflows in the Baltic Sea
- Usage of structured rectangular grid

Burchard et al., 2004; Holtermann et al., 2014; Klingbeil et al., 2018

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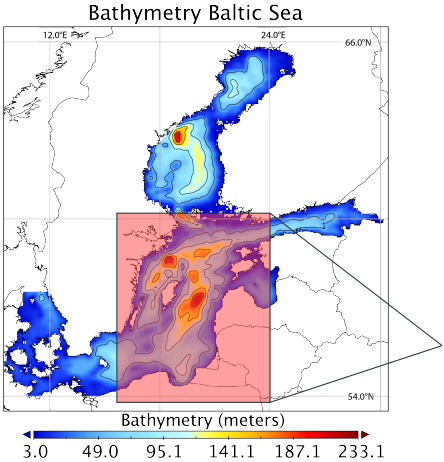

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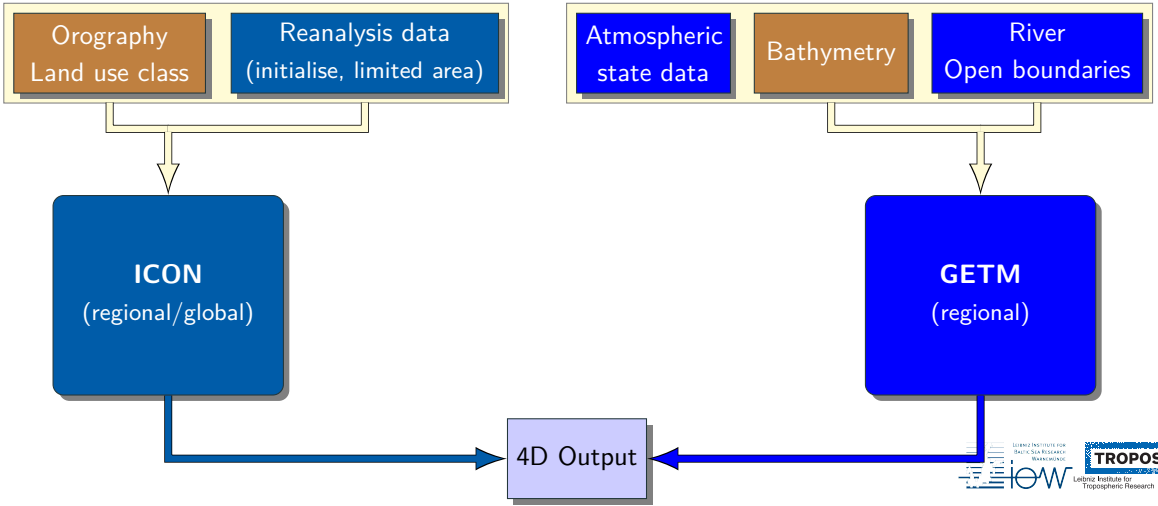
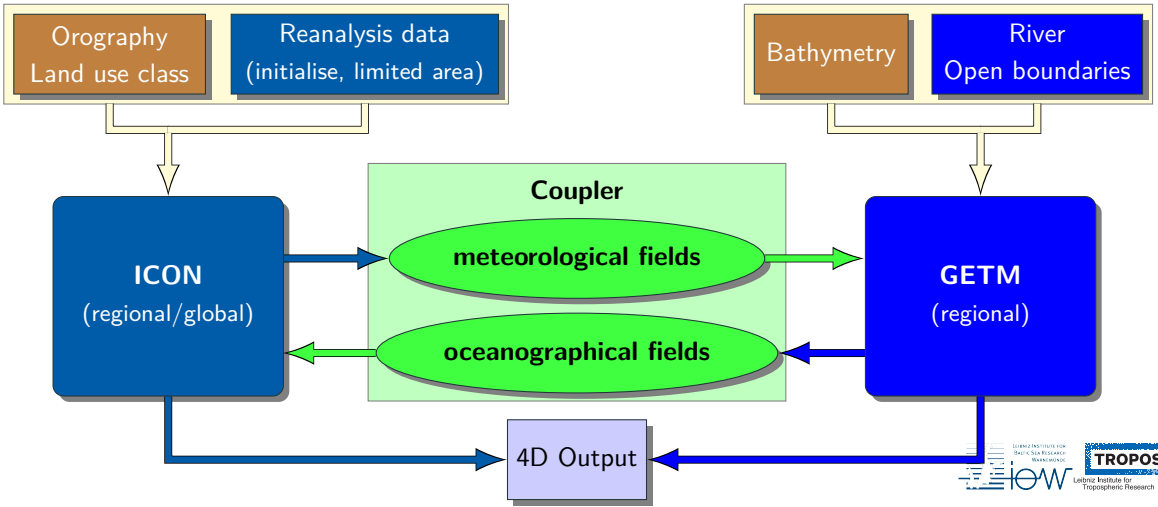
- Simulating flows and transport on larger scales than estuarine scales, e.g. salt water inflows in the Baltic Sea
- Usage of structured rectangular grid
- *Area of interest: Central Baltic Sea (approx.* 600 m*)*
- *Simulation setup from Holtermann et al., 2014*

Burchard et al., 2004; Holtermann et al., 2014; Klingbeil et al., 2018

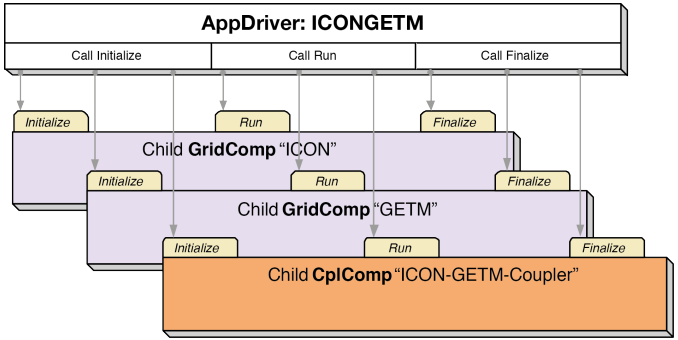
ICON & GETM: Model Scheme



ICONGETM: Model Scheme



ESMF: Coupling Strategy (with NUOPC)

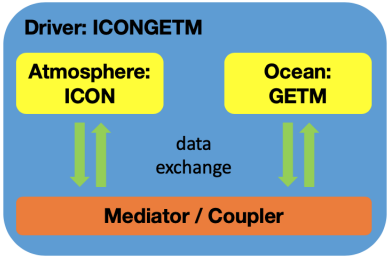


AppDriver: supervising of coupled model run

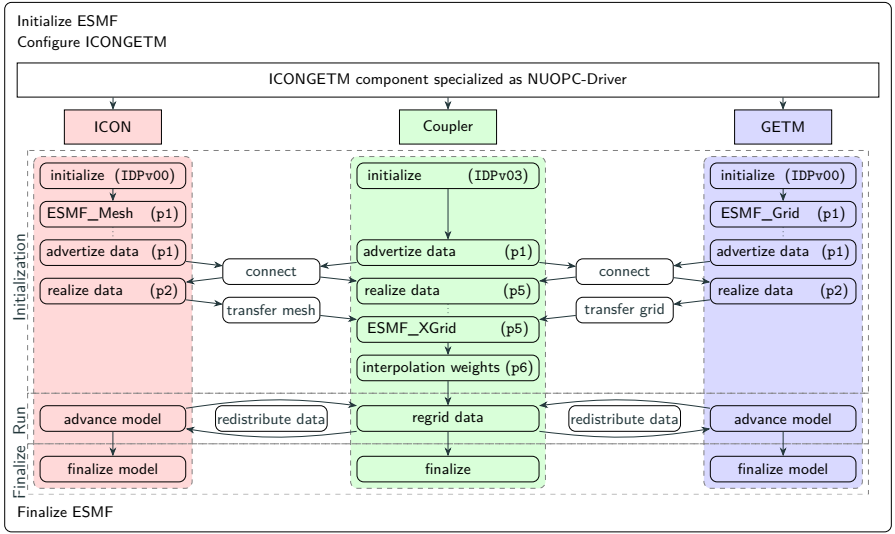
GridComp: running of original models

CplComp: interpolation/exchange of data

- Concurrent coupling structure
- Use of NUOPC interface layer



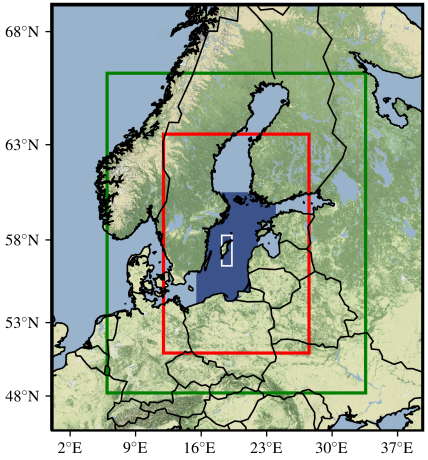
ICONGETM: Simulation sequence



ICON: NUOPC-Model
GETM: NUOPC-Model
Coupler: NUOPC-Mediator
→ NUOPC-Connector

Interpolation issues due to grid structure

Area of interest:



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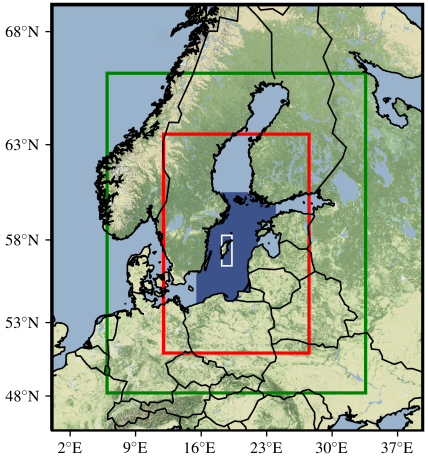
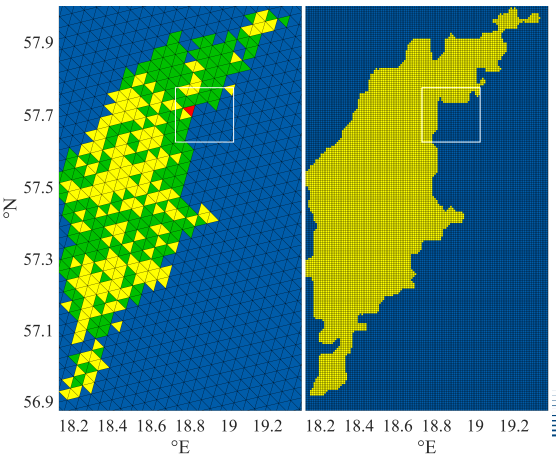


Grid structure and coast line:



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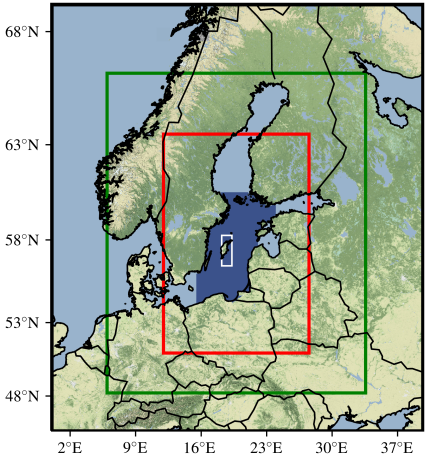

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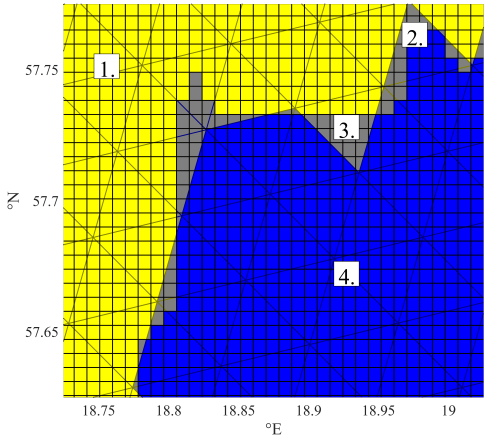
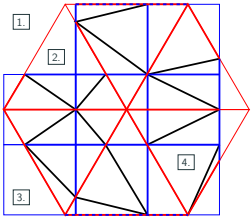


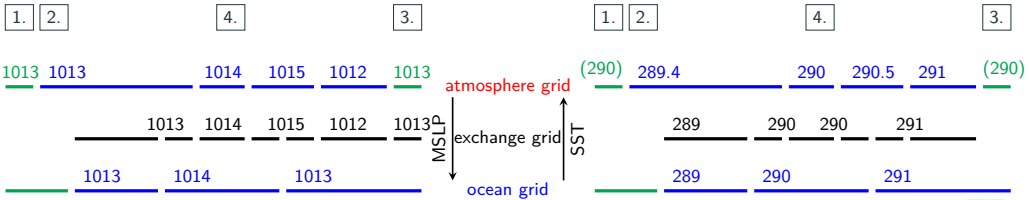
1. Both models show land
2. ICON shows water & GETM land
3. ICON shows land & GETM water
4. Both models show water

Interpolation issues due to grid structure – ESMF_XGrid

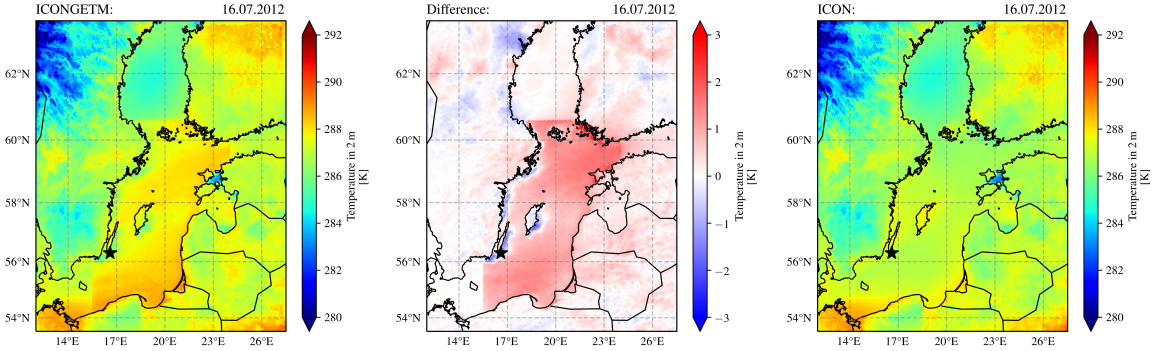
- Interpolate data from **ESMF_Grid to ESMF_XGrid** and vice versa
- Interpolate data from **ESMF_Mesh to ESMF_XGrid** and vice versa

with sparse matrix multiplication





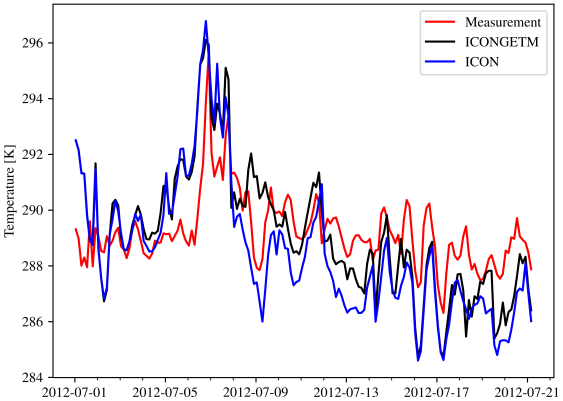
Demonstration: Central Baltic Sea July 2012: Air-temperature



Air-temperature in 2 m height over Baltic Sea

- Complex feedback on sea surface temperature, wind and air pressure at surface
- Differences, 16th of July 12UTC: approx. 2 K

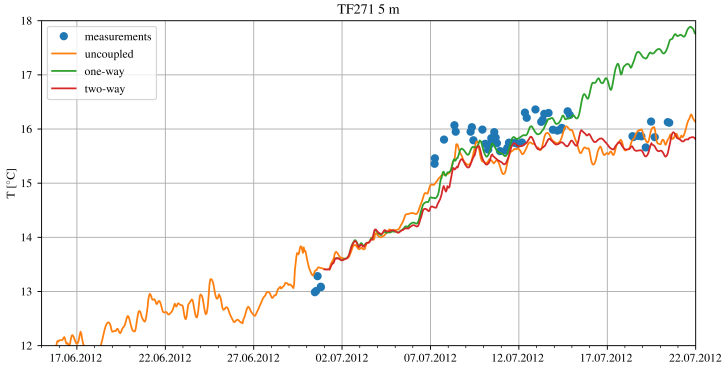
Demonstration: Central Baltic Sea July 2012: Air-temperature



Air-temperature at 29.1 m height

- Two-way coupled, one-way coupled/uncoupled simulations vs. measurement from RV Meteor
- Underestimation of temperature up to 2.5 m in ICON
- Better agreement of temporal development in ICONGETM vs measurement, especially after 10 days
- Overall, more realistic representation of weather conditions

Demonstration: Central Baltic Sea July 2012: Water-temperature

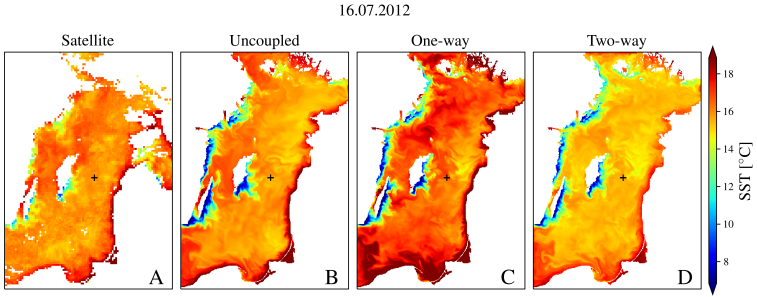


Water-temperature in 5 m depth

- Overestimation of water-temperature after 12 days in one-way coupled simulation
- Heat flux calculation in two-way coupled simulation based on GETM-SST

Summary

- Coupling of ICON and GETM using coupler ESMF
- Addressing various problems, e.g.: representation of the physics at air-sea interface, controlling of model runs, interpolation issues due to grid structure and horizontal resolution



Summary

- Coupling of ICON and GETM using coupler ESMF
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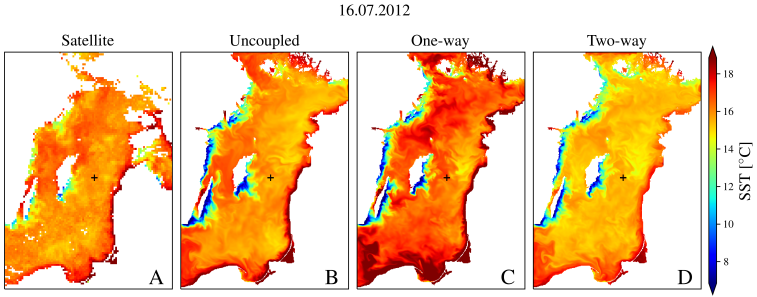
- *Bauer, Klingbeil, Holtermann, Heinold, Radtke, and Knoth, 2020 (submitted)*



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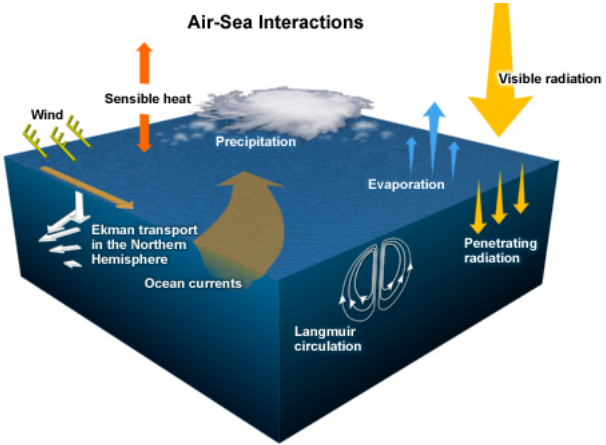
What happens at the water surface?



www.eumetsat.int (03.08.2016)

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Linking of atmosphere and ocean via transfer of momentum, heat and gases e.g.

- Wind and atmospheric pressure generate waves and currents
- Ocean absorbs heat from the sun, greenhouse gases like carbon dioxide
- Warming/cooling of the atmosphere from below