Towards an atmospheric-waves coupled operational system at DWD

Mikhail Dobrynin*,
Daniel Reinert, Florian Prill, Günther Zängl,
Oliver Sievers, Thomas Bruns

German Weather Service (DWD)
Hamburg & Offenbach am Main, Germany

* mikhail.dobrynin@dwd.de

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

ICON modelling framework

ICON
Icosahedral Nonhydrostatic modeling framework

German Weather Service (DWD)
Karlsruhe Institute of Technology (KIT)
Max Planck Institute for Meteorology (MPI-M)
German Climate Computing Center (DKRZ)
Institute of Oceanography, Universität Hamburg

ICON-NWP
Numerical weather prediction model

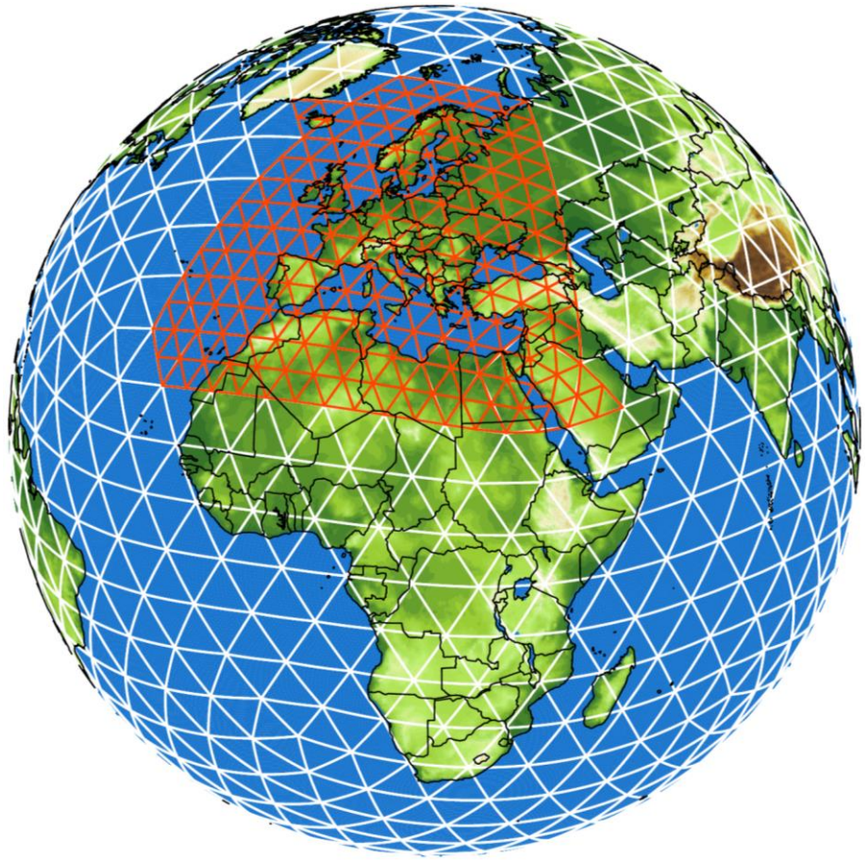
Operational weather forecast
(since Jan 2015)

ICON-ESM
Earth system model

Climate projections, seamless seasonal to decadal prediction
(work in progress)

ICON (Icosahedral Nonhydrostatic) Model

Schematic depiction of the icosahedral grid structure of ICON



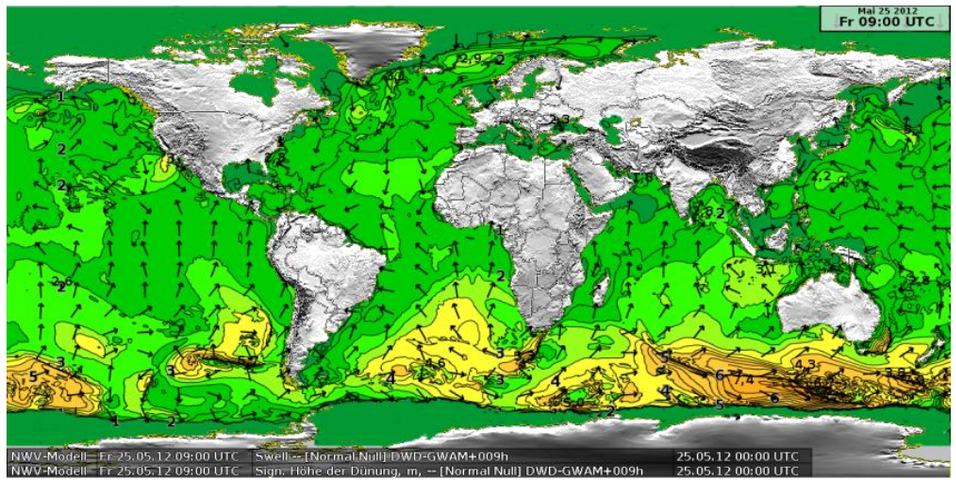
Example of an ICON grid with a refinement area

In the current operational version, the global ICON grid has 2,949,120 triangles, corresponding to an average area of 173 km² and thus to an effective mesh size of about **13 km**.

Current wave forecast system

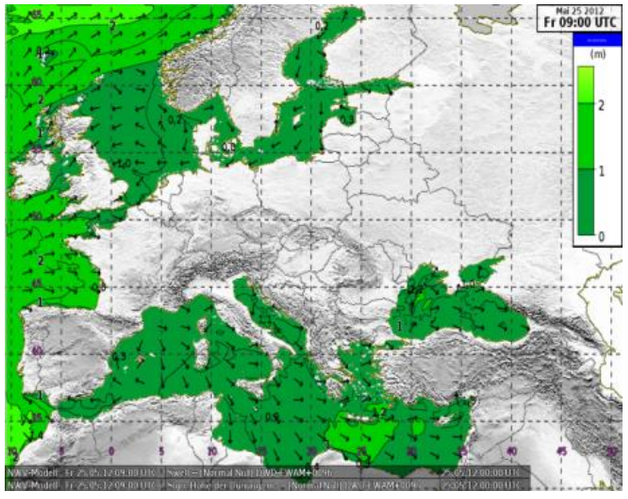
ICON / ICON-EU

Global (GWAM)
89.25°N – 86°S
0.25°x0.25° (25km)
30 frequencies, 36 directions
174 hours, hourly



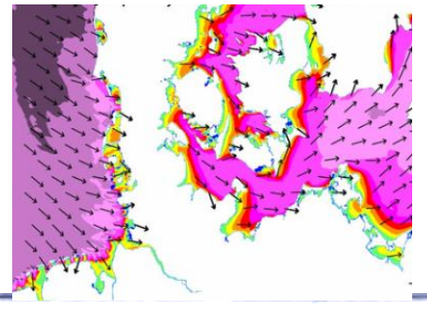
Boundary cond.

European seas (EWAM)
66°N and 10.5°W
0.05° x 0.1° (5 km)
30 frequencies, 36 directions
120 hours, hourly



Boundary cond.

German coast (CWAM-HBM)
~53°N and ~6°W
30‘‘ x 50‘‘ (~900m)
30 frequencies, 36 directions
78 hours , hourly

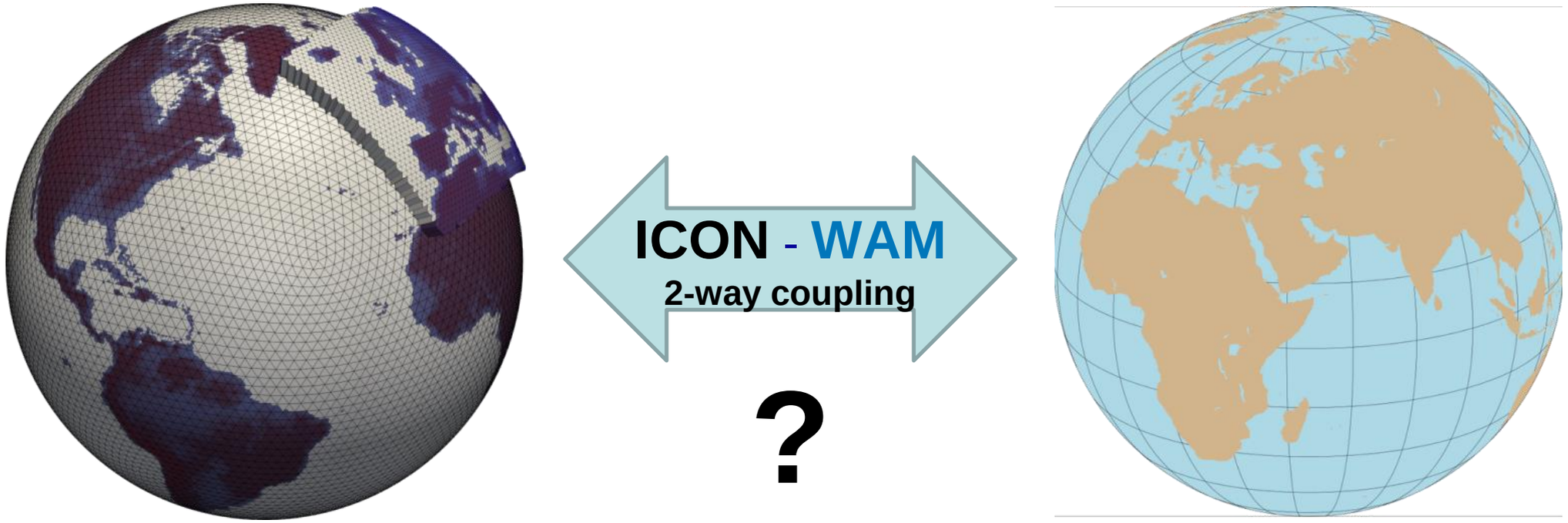


New forecast system

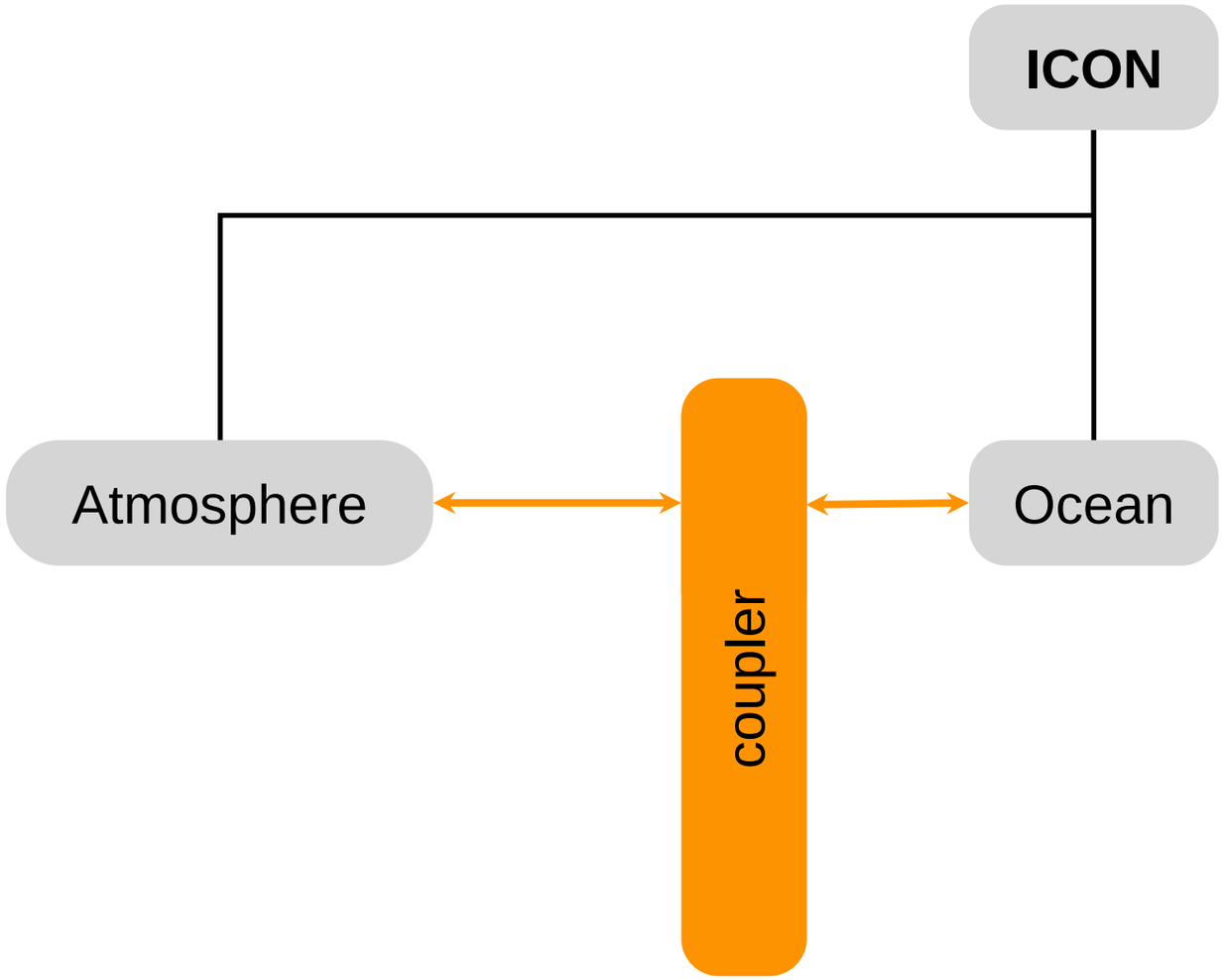
Innovation Programme for Applied Researches and Developments (IAFE)

Two way ICON-WAM coupling.

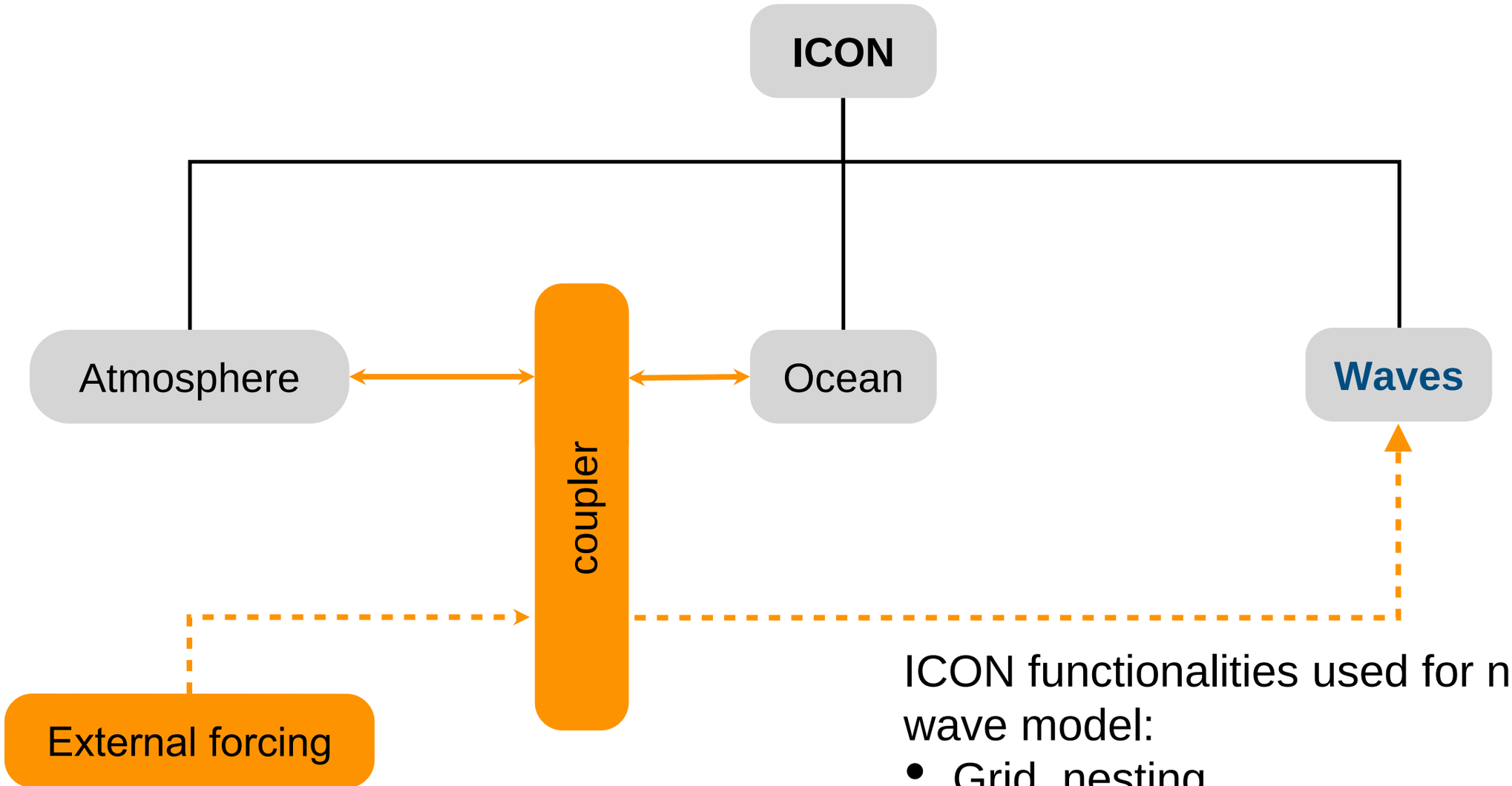
IAFE-Project 2WICWAM (03.2019 - 03.2023)



ICON-waves concept



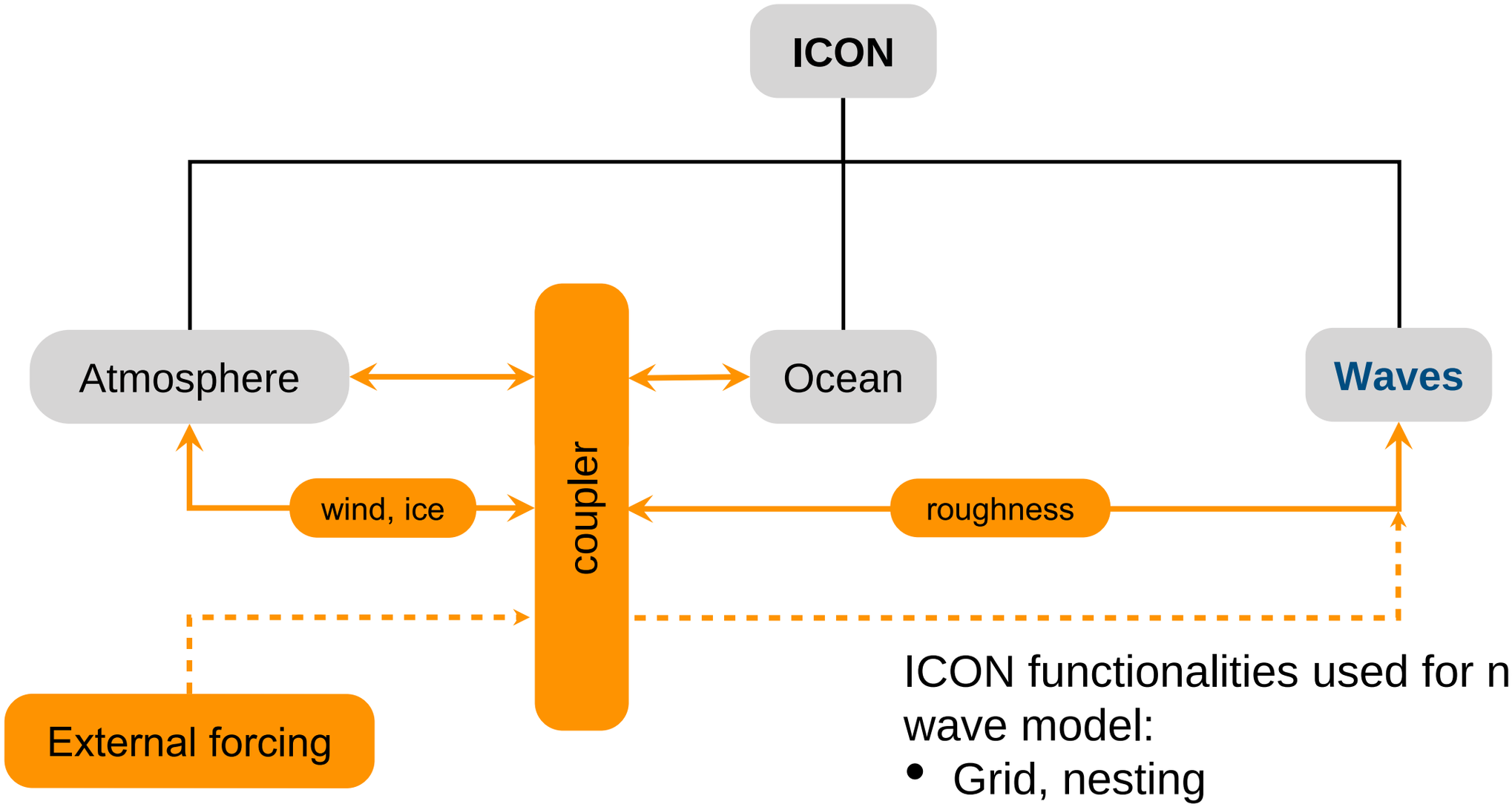
ICON-waves concept



ICON functionalities used for new wave model:

- Grid, nesting
- Domains decomposition
- Time control
- Advection of tracers
- I/O

ICON-waves concept



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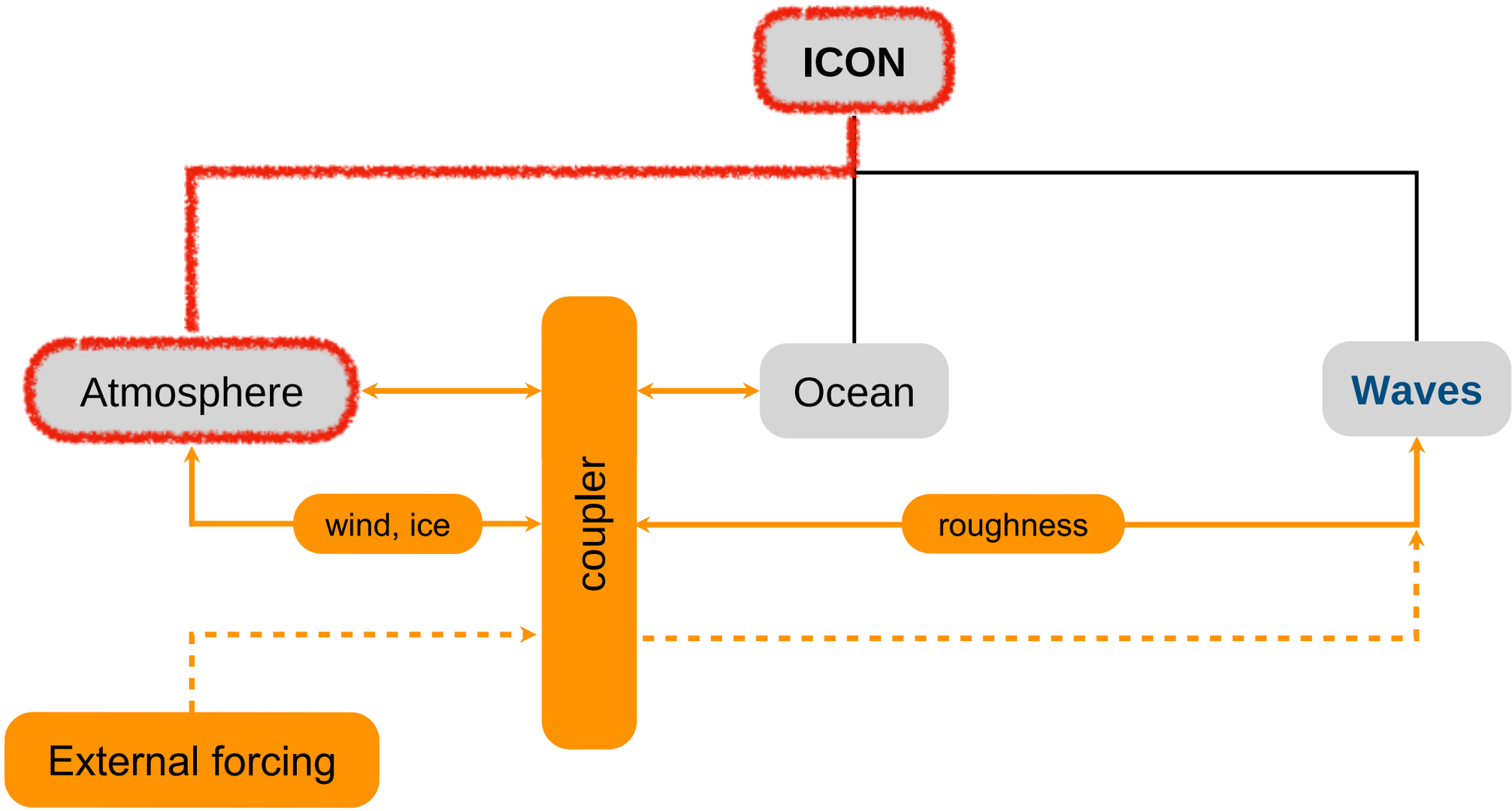
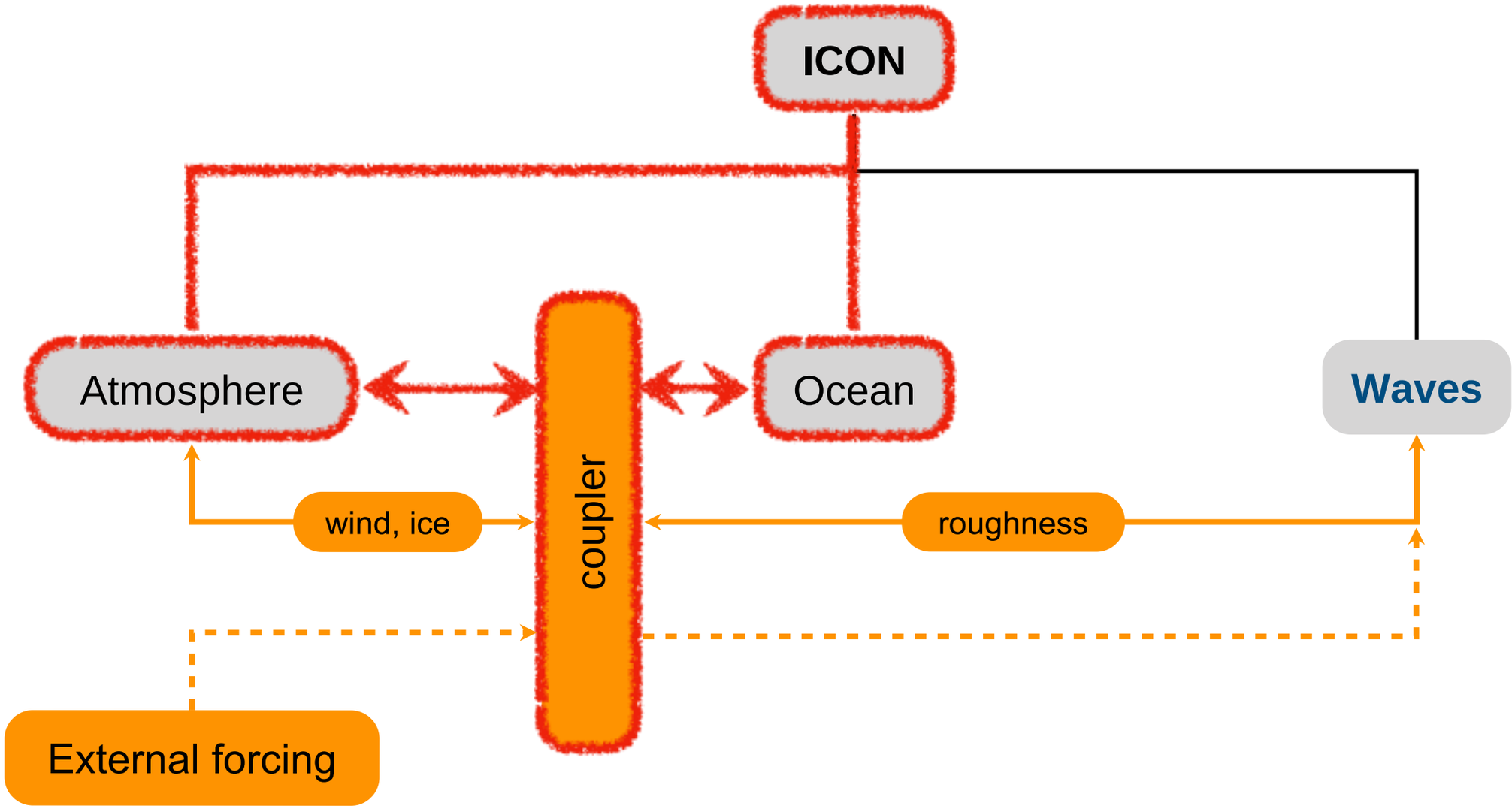
ICON-waves concept



Forecast system
ICON-NWP

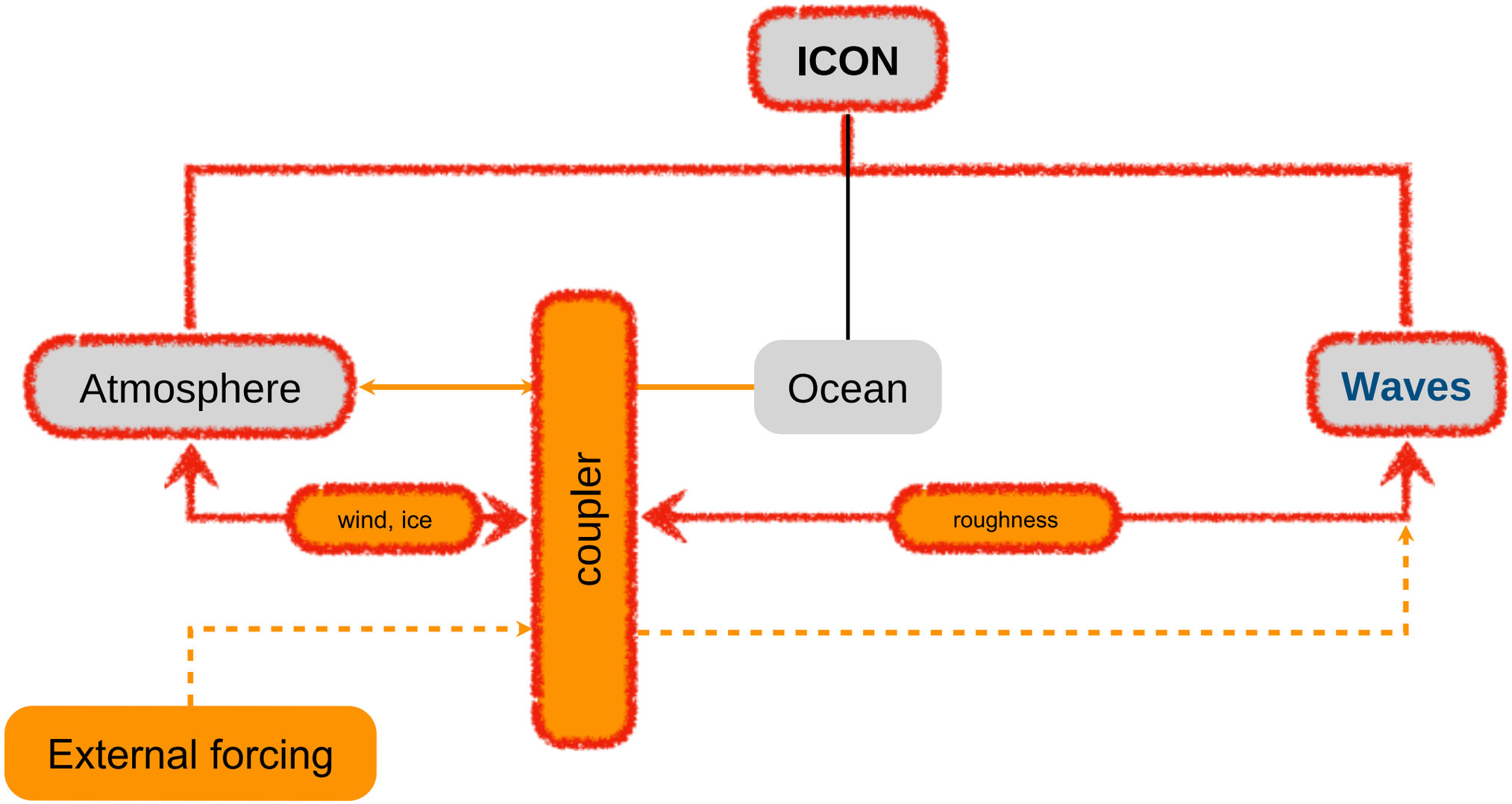
ICON-waves concept



Climate prediction system
ICON-ESM*

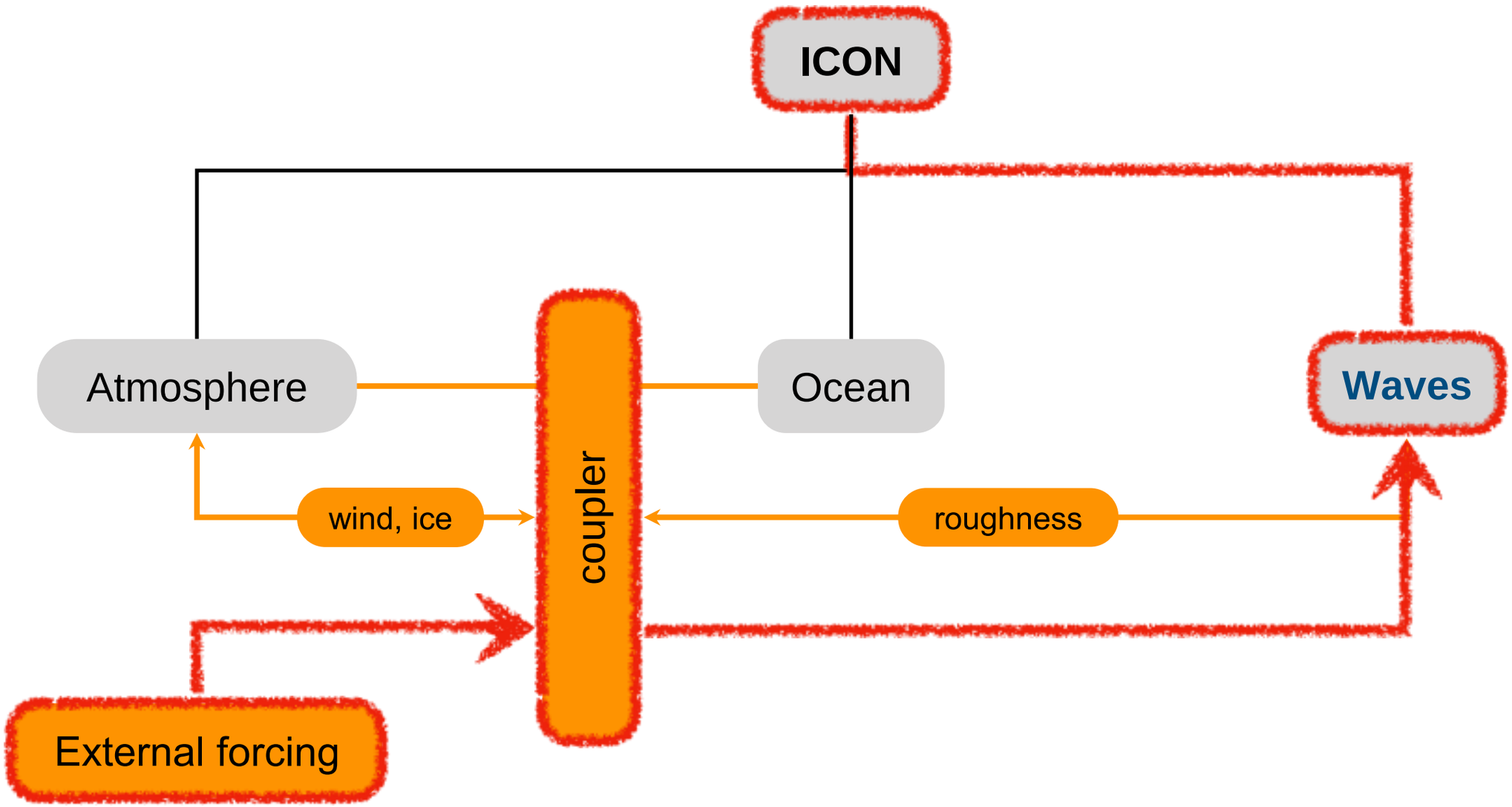
** land and ocean biogeochemistry models are not shown here*

ICON-waves concept



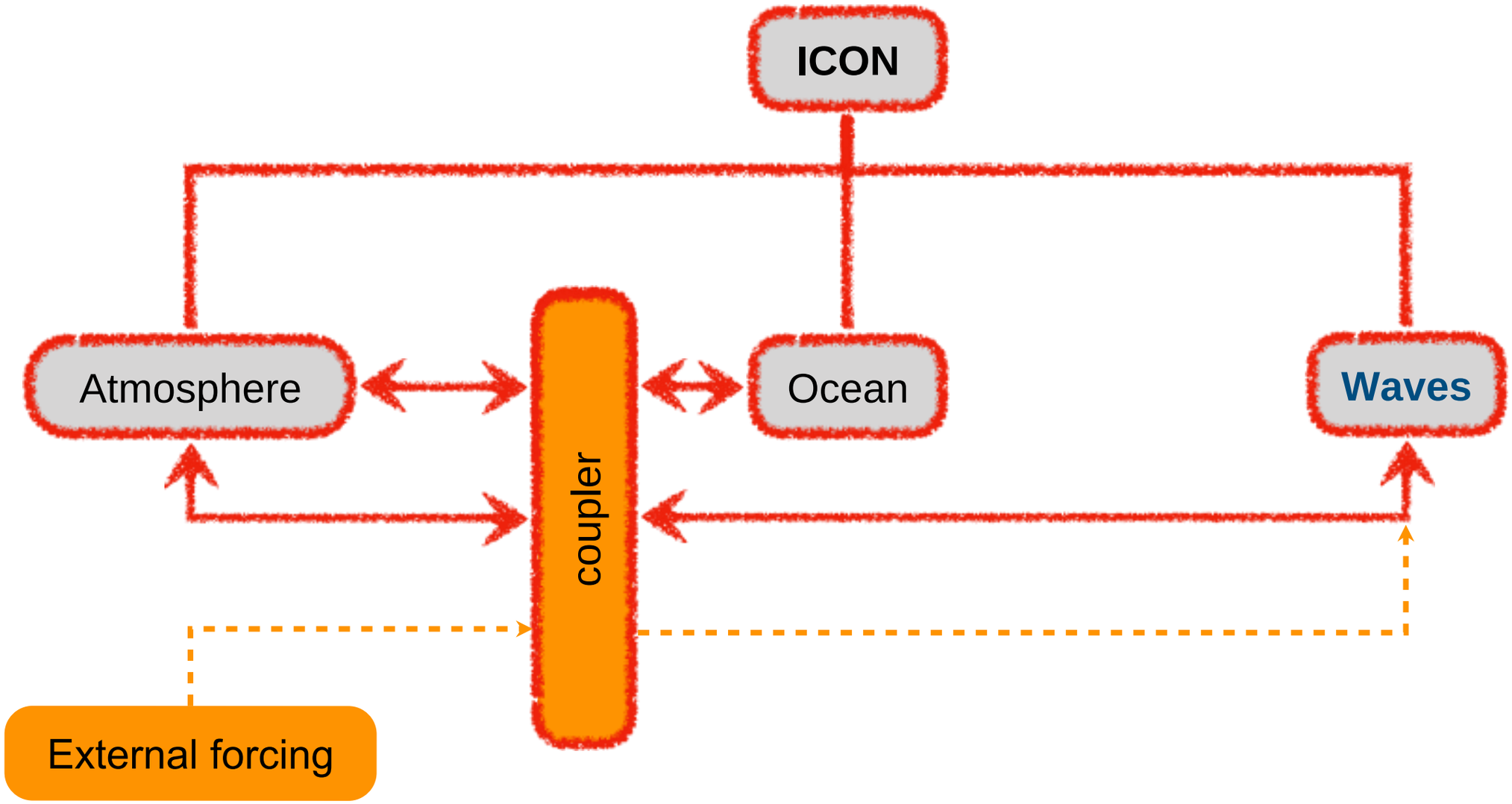
Forecast system
ICON-NWP-WAVES

ICON-waves concept



Forecast system
ICON-WAVES
stand alone

ICON-waves concept



Further ideas
ICON-NWP + **OCEAN** + **WAVES**
or **ICON-ESM** + **WAVES**

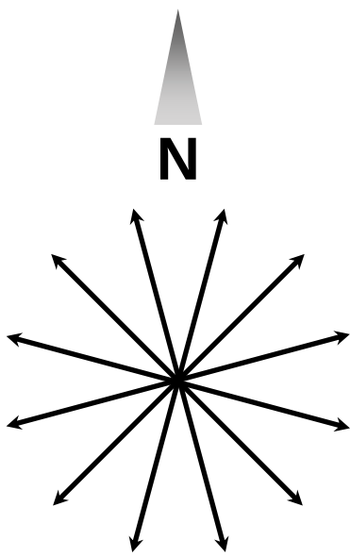
Simulation of wave spectrum

$$\frac{\partial E}{\partial t} + \nabla(c_g E) = S = S_{in} + S_{dis} + S_{nl}$$

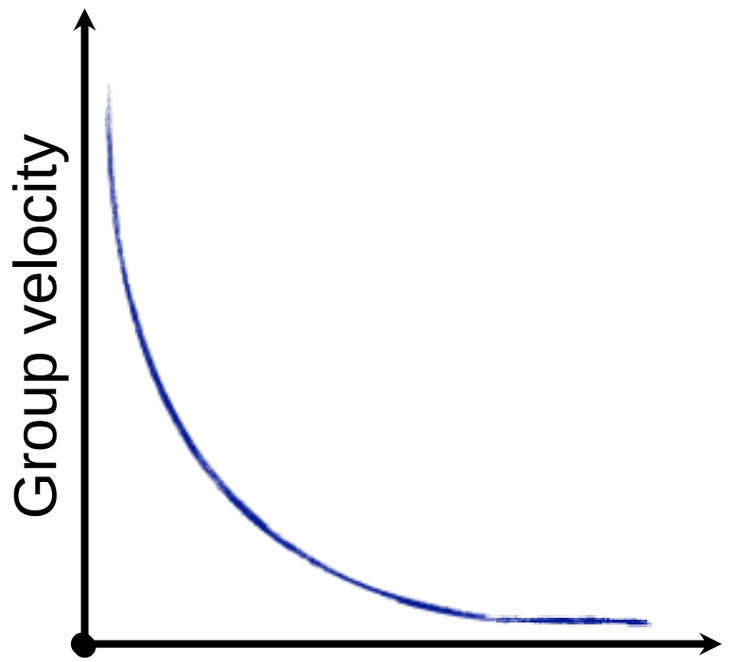
Propagation of energy

Wave physics

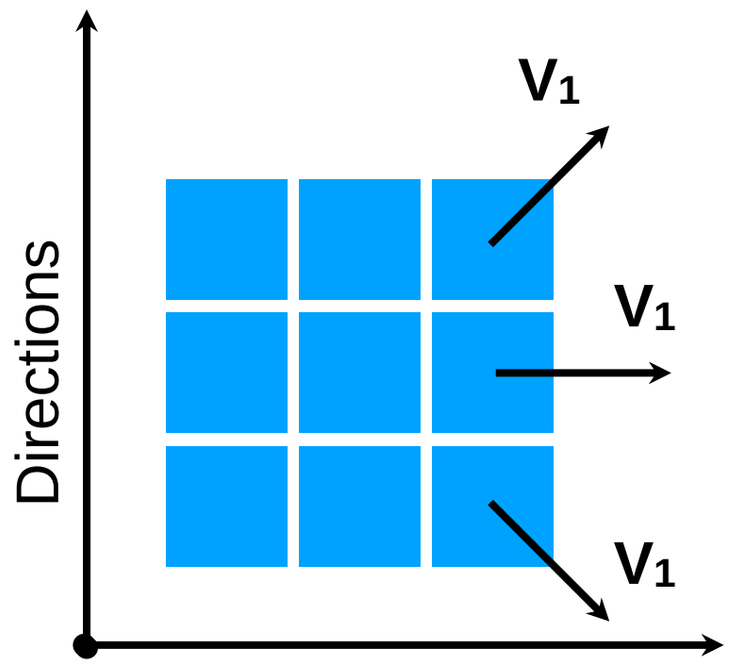
Simulation of wave spectrum



Directions



Frequencies



Frequencies

Wave spectrum as a collection of energy bins “tracers” that can be advected

Existing ICON advection schemes can be used

ICON-waves: proof of concept

$$\frac{\partial E}{\partial t} + \nabla(c_g E) = S = S_{in} + S_{dis} + \cancel{S_{nl}}$$

ICON advection

Adopted from WAM**

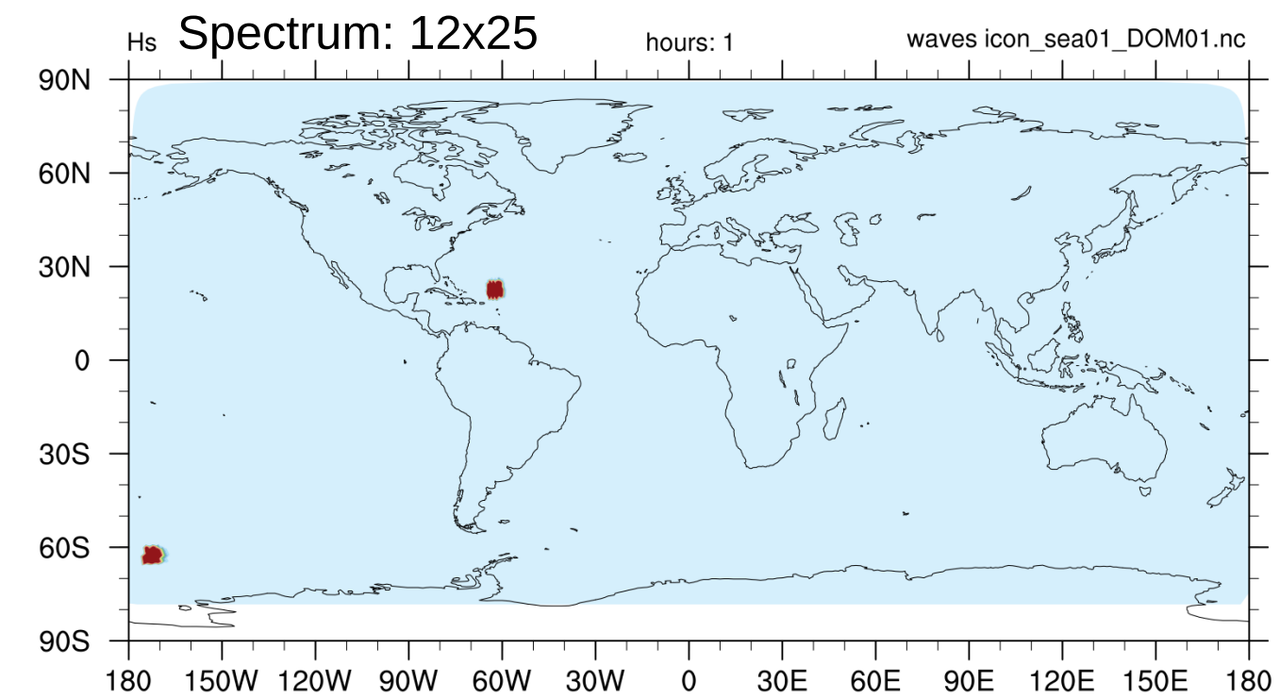
Finite volume discretisation Flux Form Semi-Langrangian (FFSL) scheme*

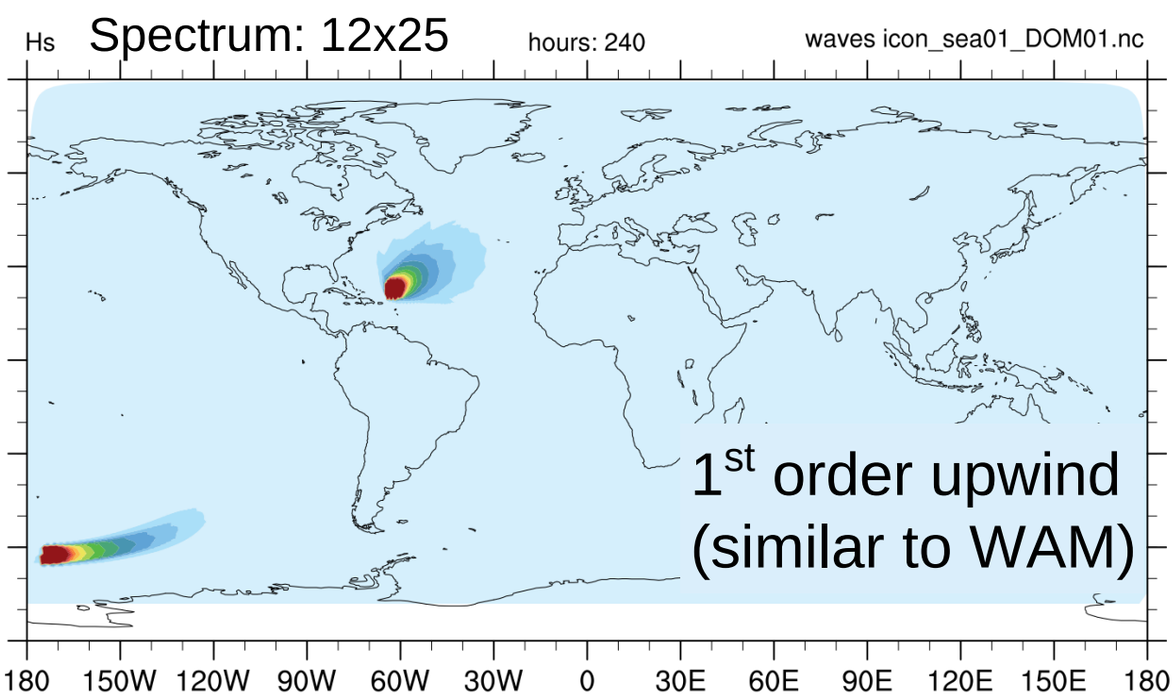
First advection tests:

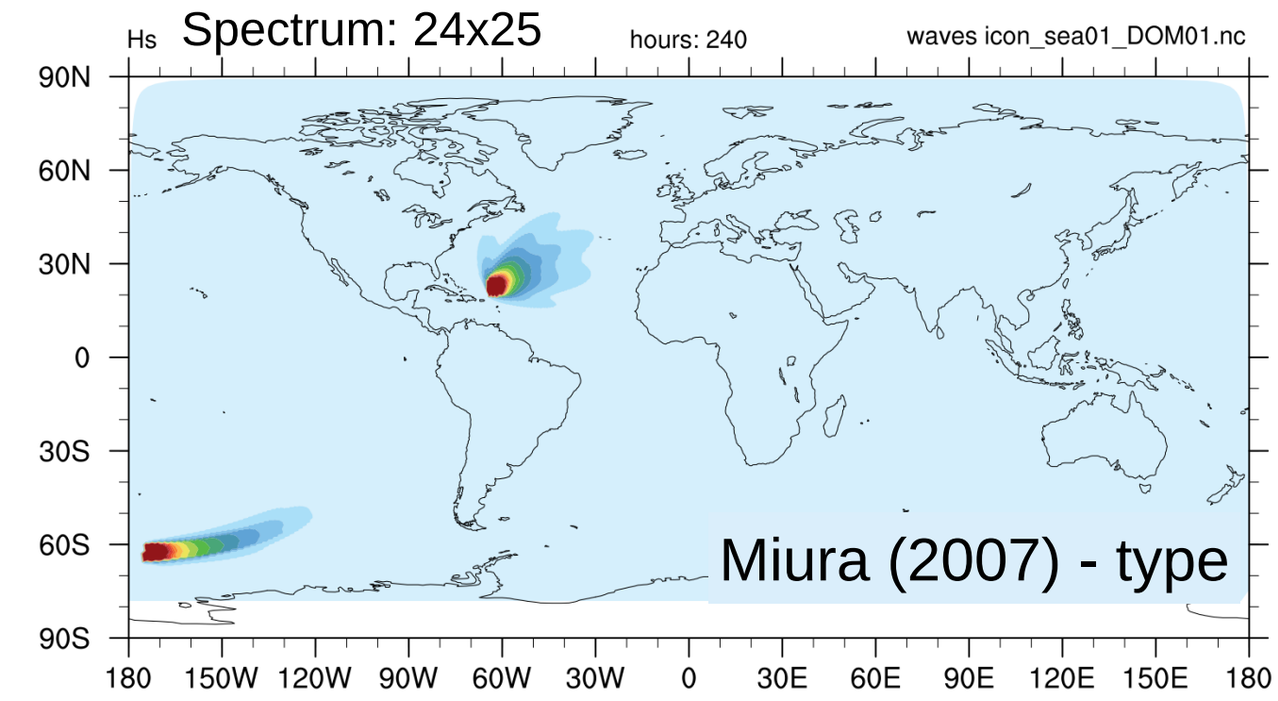
- Deep ocean
- Initial JONSWAP spectrum
- Constant wind in two regions
- No non-linear effects

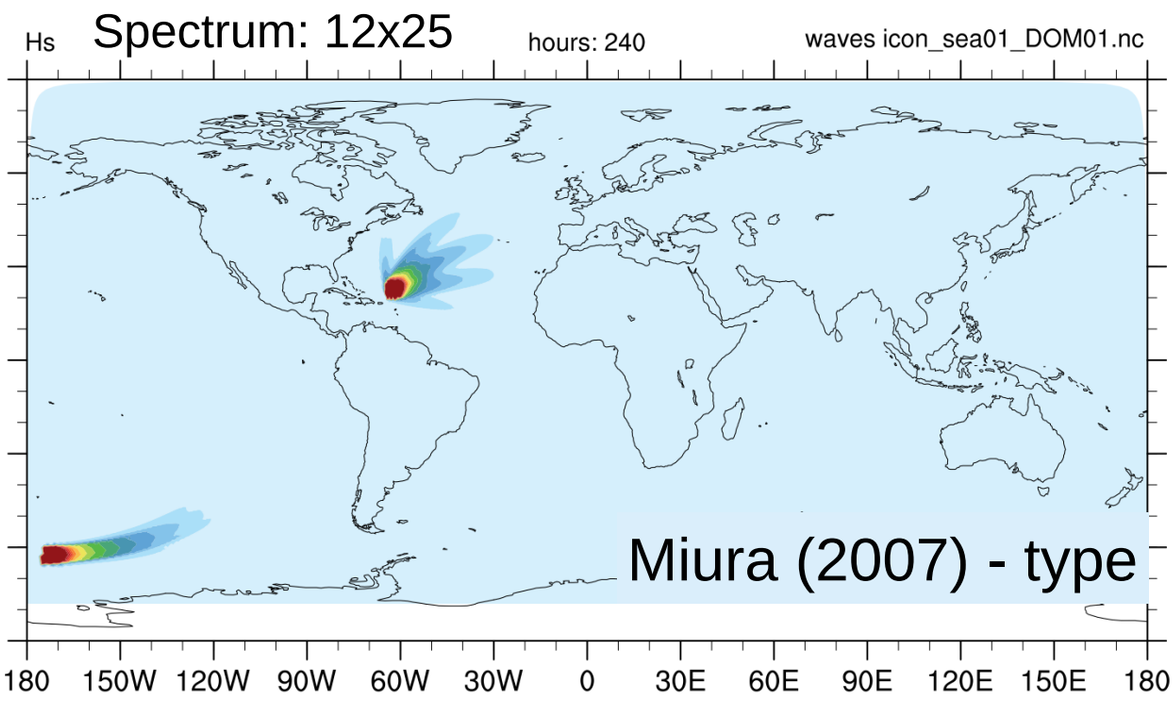
* Lauritzen, P. H., C. Erath, and R. Mittal, 2011a: On simplifying 'incremental remap'-based transport schemes. *J. Comput. Phys*., 230, 7957–7963.
* Lauritzen, P. H., R. D. Nair, and P. A. Ullrich, 2010: A conservative semi-Lagrangian multi-tracer transport scheme (CSLAM) on the cubed-sphere grid. *J. Comput. Phys*., 229, 1401–1424.
* Komen, G. J., S. Hasselmann, and K Hasselmann, 1984: On the existence of a fully developed wind-sea spectrum. *Journal of physical oceanography,*14.8*,* 1271-1285.

ICON-waves: proof of concept









Miura, H., 2007: An upwind-biased conservative advection scheme for spherical hexagonal-pentagonal grids. Mon. Weather Rev., 135, 4038–4044.

In a few months…

- Analyse advection tests comparing to similar WAM setup
- Complete wave physics
- Switch to coupled mode with real forcing

Thank you for your attention

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