ICON-Waves Regionalization

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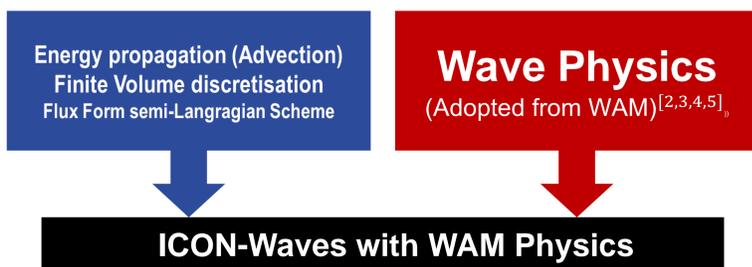
The project's goal is to develop a limited area mode (LAM) for the ICON-WAVES model. The ICON-WAVES development is an integral part of project "Earth System Model on the Weather Scale" (ESM-W) in cooperation with the GeoInfoDienst BW. The Limited Area Mode (LAM) of a numerical weather prediction model provides a high-resolution weather resolution weather forecast for a specific region of the earth. While the global weather forecast model simulates the entire earth's atmosphere. LAM concentrates on a limited region of the globe with a much finer spatial resolution. The main aim of ICON-WAVES regionalization is to is to expand the scope of the of wave modelling system for high-resolution predictions

I. ICON-WAVES

ICON-Waves is a spectral model designed to simulate the propagation of surface waves in the ocean, forming a important component of the larger ICON (Icosahedral Nonhydrostatic) framework [1] like ICON-Atmosphere (ICON-A) and ICON-Ocean (ICON-O). ICON was joint project, led by the German Weather Service (DWD), the Max Planck Institute for Meteorology (MPI-M), and other partners, aims to unify numerical weather prediction and climate modeling. ICON operates on a icosahedral grid, offering more uniform global coverage without the pole singularities present in traditional latitude-longitude grids. ICON-Waves, built on this flexible grid, delivers more accurate wave predictions, particularly in complex coastal areas, by accounting for physical processes such as wave generation, propagation, and dissipation.

The wave physics in ICON-Waves is grounded in methodologies developed by the WAMDI Group, as implemented in the state of art WAM model [2,5]. WAM's parameterizations of wind input [3], nonlinear wave interactions [4], and dissipation processes [5] provide a strong foundation for ICON-Waves' accuracy. The integration of ICON-Atmosphere advection with the WAM-derived wave physics creates a comprehensive system for global and regional wave simulations. This synergy enhances the ICON framework's versatility, enabling improved predictions for a wide range of environmental conditions, supporting both weather forecasting and climate modeling. ICON-Waves is developed by Mikhail Dobrynin (DWD) under Innovation Programme for Applied research and development (IAFE).

$$\frac{\partial E}{\partial t} + \nabla \cdot \left(c_g E\right) \quad = \quad s_{in} + s_{nl} + s_{dis} + \cdots$$

Energy propagation (Advection)
Finite Volume discretisation
Flux Form semi-Langragian Scheme

Wave Physics
(Adopted from WAM)[2,3,4,5]

ICON-Waves with WAM Physics

II. Coupled ICON-ATMOS-WAVES-LAM

The limited area model (LAM) in the coupled setup is designed for high-resolution simulations. In this LAM coupled ICON-Atmosphere and ICON-Waves models, both limited area models are run, and data is exchanged between them using the YAC [6] coupling library at specified intervals.
The physical processes modeled in ICON Waves, including wave growth, energy transfer, and dissipation, are based on the well-established methodologies developed by the WAMDI Group and implemented in the WAM model.

III. ICON-WAVES-LAM IMPLIMENTATION

- Grid Generation using ICON grid generator
- Generation of external parameter using ETOPO1 files
- Global run for initialization of LAM and generation boundary data
- Interpolation of data on LAM grid
- Define name list for limited area mode
- Temporal interpolation for LAM boundary coded
- Running LAM simulation
- Differences between local and global runs tested and visualized after LAM simulation

Coupled Experiment Limited Area Mode Setup
LAM Waves and Atmos Grid resolution R2B6 (~40 km)   Region: Northern Atlantic
Global Atmos and Waves grid R2B4 (~160 km)   Reduced radiation grid R2B3
Time step for Atm & wave simulation 5 min   Coupling time   5 min.

IV Results of Experiments

A comparison between Local Area Model (LAM) and global simulations was conducted over a 16 days period to identify potential inconsistencies in their implementation. To mitigate potential interference from interpolation errors, both cases were set to employ the same grid resolution then for different resolution. Parameters are significant wave height (Hs), Bathymetry , zonal and meridian wind (u10m, v10m)

i. Comarison for same resolution R02B06 (~40 km)
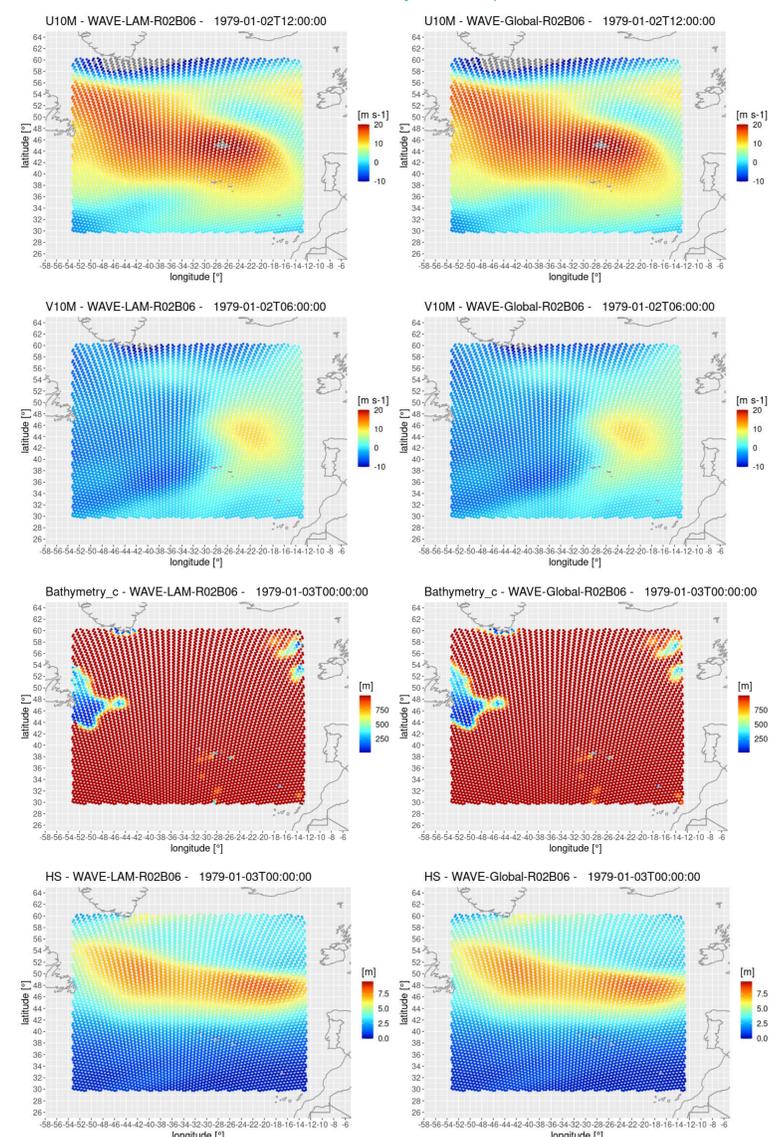
ii. Comarison for Hs in coupled mode having global resolution R02B04 and LAM resolution is R02B06
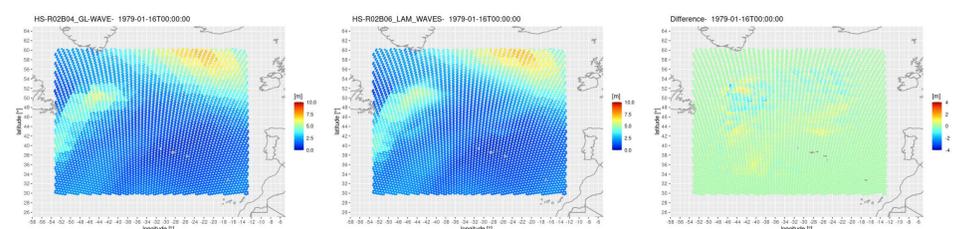
Conclusion:
• Coupled ICON-Waves-Atmosphere-LAM implementation
• Initial results show good agreement with the reference

1. Zängl, Günther and Reinert, Daniel and Rípodas, Pilar and Baldauf, Michael, The ICON (ICOsahedral Non-hydrostatic) modelling framework of DWD and MPI-M: Description of the non-hydrostatic dynamical core, Quarterly Journal of the Royal Meteorological Society , 141.687;563-579.
2. Hasselman. K., et al., (1988) The WAM model - A third generation ocean wave prediction model, Journal of Physical Oceanography 18.12, 1775-1880.
3. Hasselman K., etal., (1984) On the Existence of a Fully Developed Wind-Sea Spectrum, American Meteorological Society, 14.8;1271-1285.
4. Hasselman K., et al., (1985) Computations and parameterizations of the nonlinear energy transfer in a gravity-wave spectrum. Part II: Parameterizations of the nonlinear energy transfer of application in wave models, Journal of Physical Oceanography, 15,1378-1391.
5. Kormen GJ, Cavaleri L, Donelan M, Hasselmann K, Hasselmann S, Janssen PAEM. Dynamics and Modelling of Ocean Waves. Cambridge University Press; 1994.
6. Hankle, Moritz and Redler, Renee and Holfeld et.al., YAC 1.2.0: new aspects for coupling software modelling Geoscientific Model development, Copernicus Gmbh