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Report for Collaborative Oceanography and Monitoring for Protected Areas and Species (IVA5015)

Deliverable T5.2.2
User Guide to Hindcasts

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Report by: SAMS, MI, MSS
Report authors: Andrew Dale, Diego Pereiro, Dmitry Aleynik, Tomasz Dabrowski

Executive Summary

This document describes the hydrodynamic modelling component of the COMPASS project and provides a user guide to the hindcasts generated to simulate marine conditions across the INTERREG VA area during 2016-2020 (the final year of simulations are ongoing at the time of writing). Hindcasts provide daily temperature, salinity and currents at four levels in the water column, the surface, 10m, 30m and bottom, as well as the mixed layer depth. Separate hindcasts are provided for the two component models used, of the NE Atlantic, based on the ROMS platform, and a nested higher resolution model of Western Scotland, based on the FVCOM platform. Attempts to blend the two models' outputs were not satisfactory; guidance as to which of the two datasets should be used in a given context are provided. The intent of this user guide is to be relatively concise, however additional technical information has been provided in the Technical Report on Model Interfacing Methodology, Deliverable T5.1.1.

Contents

1. Introduction to the COMPASS project

The COMPASS project focusses on the marine environment adjoining the Northern Ireland, border counties of Ireland, and Western Scotland (the INTERREG VA region, Figure 1), providing resources in support of the monitoring and management of Marine Protected Areas (MPAs). These resources include a network of observational buoys and a modelling capability. Described here is one aspect of the modelling programming, the provision of region-wide hindcasts (simulations of past ocean conditions) of temperature, salinity and currents for a 5-year period from 2016 to 2020.

2. Hydrodynamic modelling within COMPASS

Hydrodynamic models simulate the changing currents, temperature, and salinity of a region under the influence of weather conditions and the properties of surrounding waters. The hydrodynamic modelling within COMPASS has drawn together two component models to provide this information across the INTERREG VA region. These models are complementary, consisting of a larger scale model of the northeast Atlantic (simulations by the Marine Institute, and including all Irish waters), within which is 'nested' a more detailed model of western Scotland (simulations by the Scottish Association for Marine Science. The Scottish model differs in the way in which the region is broken down into a network of calculation points; its unstructured mesh consists of triangular elements which vary in size, enabling it to represent scales that cannot be represented by the larger model yet are needed for the inclusion of important components of the marine environment of western Scotland. Most significantly these include narrow linkages between, or inshore of, islands through which substantial quantities of water pass.

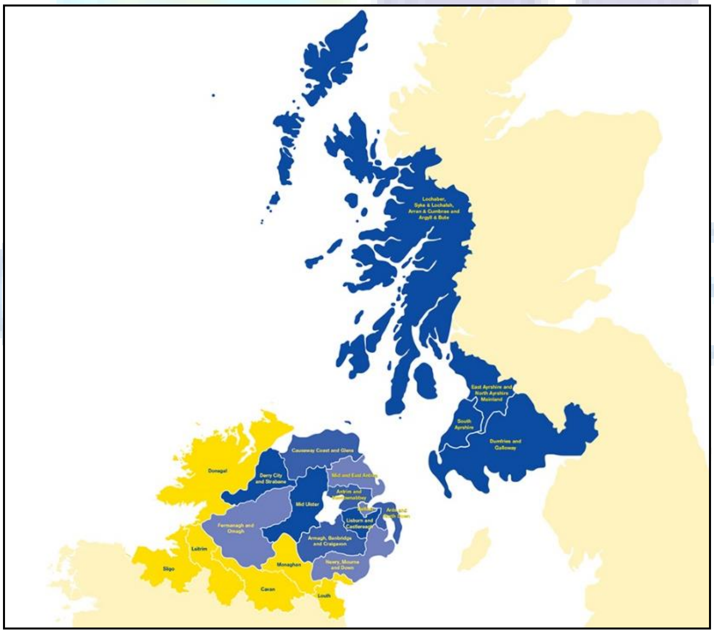

Figure 1: *The land areas within the INTERREG VA region which encompasses Northern Ireland, border counties of Ireland and Western Scotland.*

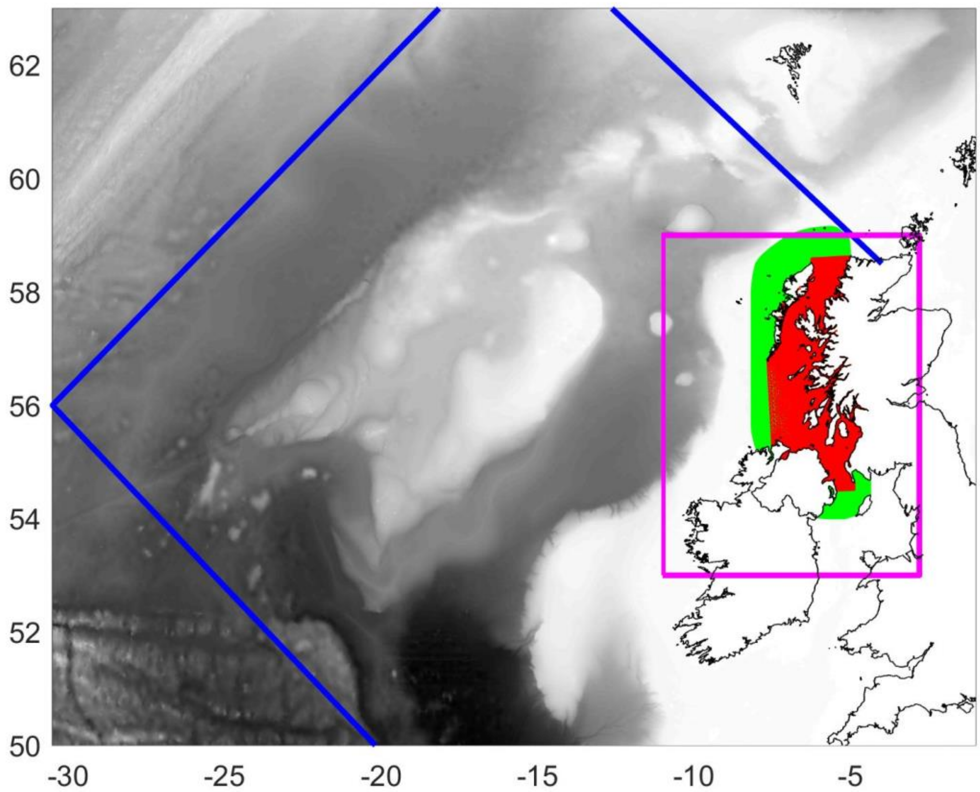

Figure 2: *Domains of the component COMPASS models: NE Atlantic ROMS (NEA-ROMS; blue line shows boundary), WestCOMS1-FVCOM (red) and the expanded WestCOMS2-FVCOM (green). Magenta shows the extent of the COMPASS gridded hindcast data products.*

3. Technical details of the component models

3.1 Northeast Atlantic ROMS (NEA-ROMS)

The Marine Institute's NE Atlantic model (Dabrowski et al, 2014, 2016) is based on the ROMS (Regional Ocean Modelling System) platform (Shchepetkin and McWilliams, 2005; http://myroms.org). The domain extends into the NE Atlantic beyond Hatton Bank, as well as covering inshore waters, including the Irish Sea, to the limit of resolution (Figure 2). Grid spacing varies across the domain with the highest resolution, 1.1-2.4 km, in Irish waters. Similar resolution is achieved in inshore Scottish waters although this is frequently inadequate to represent key features (Figure 3).

Oceanic boundary information is taken daily from the Copernicus 1/12° global model, so this NE Atlantic model is essentially nested within that model. Meteorological forcing is taken from ECMWF simulations. The NE Atlantic ROMS model is run operationally, with 3-day forecasts of hourly states available as well as weekly hindcasts accessible via servers at the Marine Institute.

3.2 Western Scotland FVCOM (WestCOMS-FVCOM)

The Scottish Association for Marine Science's Western Scotland model (Aleynik et al., 2016) is based on the FVCOM (Finite Volume Coastal Ocean Model) platform (Chen et al. 2003, 2006, 2011; http://fvcom.smast.umassd.edu/). This uses an unstructured computational mesh with variable element size, allowing complex inshore waters and straits to be adequately resolved. Boundary information is provided from NEA-ROMS. Meteorological forcing is from a custom high-resolution (2 km) implementation of the WRF model (Skamarock et al., 2005). WestCOMS is run operationally (weekly) to produce a hindcast of the previous week and a 5-day forecast.

Under COMPASS, the region covered by WestCOMS was expanded, most significantly by extending further west and including the west coast of the Western Isles as well as further south in the Irish Sea and north of Cape Wrath. The original and extended model domains are termed WestCOMS1 and WestCOMS2 in Figure 2. COMPASS hindcasts reflect this change, with the transition from WestCOMS1 to WestCOMS2 occurring at the beginning of April 2019. The minimum spacing of computational points in WestCOMS1 is 130 m, and this is reduced further in WestCOMS2, although spacing close to the offshore boundaries is typically larger than that of NEA-ROMS (Figure 3).

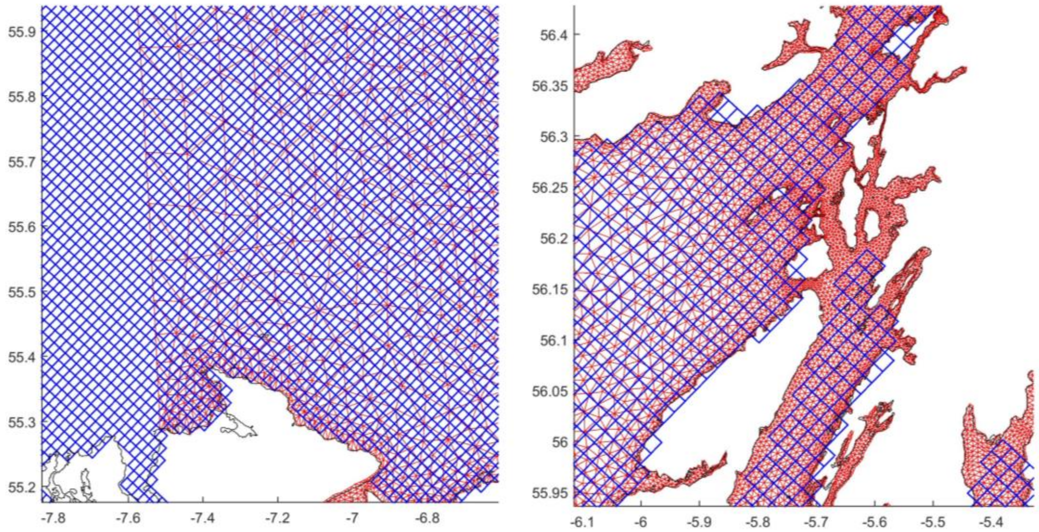

Figure 3*: Comparison between NEA-ROMS (blue) and WestCOMS-FVCOM (red) grids/meshes in two regions. Left: The offshore FVCOM boundary, north of Malin Head. Right: Inshore Scottish waters of the Firth of Lorn/Sound of Jura. Note the differing scales of these plots. The ROMS grid has similar spacing.*

4. Overview of hindcasts provided within COMPASS

A summary of details of the COMPASS hindcasts, the variables provided, and units used is given in Table 1. An example model state is shown in Figure 4

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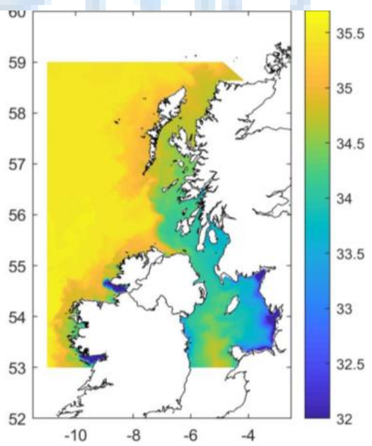

Figure 4*: Surface absolute salinity (g kg^{-1}) from NEA-ROMS at noon on 1st April 2018, showing the extent of the gridded COMPASS hindcast datasets.*

Period covered	12:00 on 1St Jan 2016 to 12:00 on 31st Dec 2020 (5 years)
Temporal resolution	Daily instantaneous (non-currents) or daily 25-hour averaged (currents)
Spatial grid	Regular spacings of 0.01°, from 53°N to 59°N, 11°W to 2.8°W
Parameters provided	Temperature, salinity, mixed layer depth, velocity

Variable name	*Units*	*Depth levels provided*	*Notes*
Potential Temperature	°C	Surface, 10m, 30m, bottom	Potential temperature referenced to the surface.
Absolute Salinity	g kg^{-1}	Surface, 10m, 30m, bottom	As defined by TEOS-10
Mixed layer depth	m	-	The depth at which potential density first exceeds the surface value by 0.03 kg m^{-3}.
Flow velocity eastward	m s^{-1}	Surface, 10m, 30m, bottom, and depth-averaged	25-hour averaged
Flow velocity northward	m s^{-1}	Surface, 10m, 30m, bottom, and depth-averaged	25-hour averaged

***Table 1**: Summary of hindcasts, the variables provided, and units used.*

4.1 Units used for temperature and salinity

The latest conventions for oceanic temperature and salinity are described by the Thermodynamic Equation of Seawater – 2010 (TEOS-10, www.teos-10.org). TEOS-10 recommends that temperatures are reported as conservative temperatures and salinities as absolute salinities. Before TEOS-10, temperatures were typically reported as either *in situ* or potential temperatures and salinities as practical salinities.

The component models used here do not themselves use TEOS-10 variables, so model output has been converted using the TEOS-10 Gibbs SeaWater Oceanographic Toolbox. While salinities are provided as TEOS-10 absolute salinities, temperatures are given as potential temperatures so that they are comparable with directly measured surface temperatures, although the difference from conservative temperature is relatively small (conservative temperature would typically be lower by a few hundredths of a degree Celsius). For comparison of the absolute salinity values with practical salinities it is recommended that conversions are made using the Gibbs SeaWater routines. Absolute salinity values (g kg^{-1}) can be expected to be higher than practical salinities ('psu') by between 0.16 and 0.17.

4.2 Averaging approach to velocities

Whereas temperature, salinity and mixed layer depth are provided as instantaneous values at noon of each day, velocities are averaged to reduce tidal effects. The velocity values provided are the average of the 25 hourly states centred at noon of each day, in other words from midnight to midnight inclusive. The rationale for a 25-hour averaging period is that the dominant tidal constituent, the lunar semidiurnal, has a period of 12.42 hours, so averaging over 25 hours more effectively removes this component than would a 24-hour average. This is a widely used approach to de-tiding model datasets and is a compromise between practical considerations (computational cost) and performance. Some tide is be retained in the dataset, and there is some loss of variability at longer periods (e.g. weather events).

4.3 Gridding of datasets

Datasets are provided on a grid that is evenly spaced in latitude and longitude with an interval of 0.01 degrees, a distance that varies between 636 m (east-west spacing at the northern boundary) to 1111 m (north-south spacing). Since this is not the native calculation grid of either source model, gridded values have been interpolated, both horizontally and vertically.

5. Recommendations, support, acknowledgment etc

5.1 Recommendation as to which model dataset to use

As described above, the COMPASS hindcasts are provided as two overlapping datasets from the two component models. The two models do not match perfectly where they overlap, so decisions need to be made as to which model should be used in a given context. In most cases, this decision will be straightforward. For applications within the region of NEA-ROMS but outside WestCOMS-FVCOM there is no choice. For inshore areas within the region of WestCOMS-FVCOM it would be recommended to use WestCOMS-FVCOM in view of its greatly enhanced resolution, including more realistically distributed freshwater sources, representation of connecting straits and the use of a high-resolution local meteorological model for forcing. Note that in offshore areas within the region covered by WestCOMS-FVCOM, the resolution of NEA-ROMS may actually be higher than that of WestCOMS-FVCOM however it is still generally recommended that WestCOMS-FVCOM is used for the reasons described above. The choice of models is less clear-cut when interest is in areas near the boundaries of WestCOMS-FVCOM or where interest spans the boundary. In such cases, a comparison between the two models is recommended.

5.2 Support

If you require further information or support regarding these hindcast datasets, please contact Andrew Dale at SAMS (andrew.dale@sams.ac.uk).

5.3 Acknowledgement

Use of datasets (e.g. in reports, papers or presentations) should acknowledge the COMPASS project and contain the following text:

> *"The COMPASS project has been supported by the EU's INTERREG VA Programme, managed by the Special EU Programmes Body"*

If you intend using the datasets contact the COMPASS modelling team in advance as they will can advise on acknowledgements (text and logos) and provide further advice on project data.

6. References

Aleynik, D., Dale, A. C., Porter, M., Davidson, K., 2016. A high-resolution hydrodynamic model system suitable for novel harmful algal bloom modelling in areas of complex coastline and topography. *Harmful algae*, 53, 102-117. https://doi.org/10.1016/j.hal.2015.11.012

Chen, C., Huang, H., Beardsley, R.C., Xu, Q., Limeburner, R., Cowles, G.W., Sun, Y., Qi, J., Lin, H., 2011. Tidal dynamics in the Gulf of Maine and New England Shelf: An application of FVCOM. *Journal of Geophysical Research: Oceans* 116(C12), C12010.

Chen, C., Beardsley, R. C., Cowles, G., 2006. An unstructured grid, finite-volume coastal ocean model (FVCOM) system. *Oceanography*, 19(1), 78-89.

Chen, C., Liu, H., Beardsley, R. C., 2003. An unstructured grid, finite-volume, three-dimensional, primitive equations ocean model: application to coastal ocean and estuaries. *Journal of Atmospheric and Oceanic Technology*, 20(1), 159-186.

Dabrowski, T., Lyons, K., Berry, A., Cusack, C., Nolan, G.D., 2014. An operational biogeochemical model of the North-East Atlantic: Model description and skill assessment. *Journal of Marine Systems,* 129, 350-367.

Dabrowski, T., Lyons, K., Cusack, C., Casal, G., Berry, A., Nolan, G. D., 2016. Ocean modelling for aquaculture and fisheries in Irish waters, *Ocean Sci.*, 12, 101-116, https://doi.org/10.5194/os-12-101-2016.

Shchepetkin, A. F., McWilliams, J. C., 2005. The regional oceanic modeling system (ROMS): a split-explicit, free-surface, topography-following-coordinate oceanic model. *Ocean modelling*, 9(4), 347-404.