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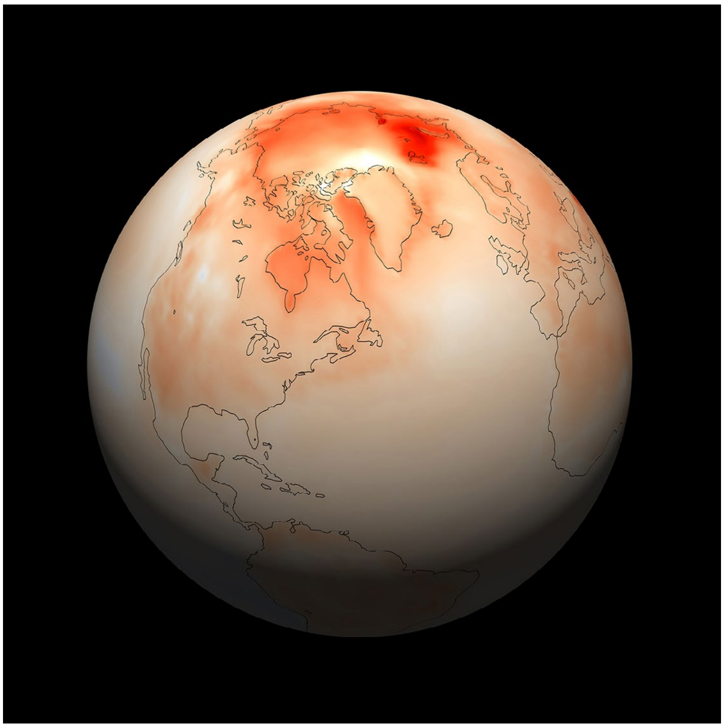
METEOROLOGY

The varied uses of OpenIFS



Cover image: Point-wise linear trend in surface temperature between 1979 and 2018 from ERA5

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The varied uses of OpenIFS

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The OpenIFS activity at ECMWF provides portable versions of ECMWF's Integrated Forecasting System (IFS) and single-column models for use by universities, the meteorological services of Member and Co-operating States, and research institutes. Some of these have used OpenIFS models since the activity was created in 2011 and now have well-established research and teaching activities using them. In this article, we highlight several such activities to illustrate the varied uses of the models provided. For more information on OpenIFS and how to obtain the models, please see the OpenIFS website at: *https://confluence.ecmwf.int/oifs/*.

Atmosphere–ocean single column model

Single-column models (SCMs) are tools that have been used for process studies and parametrization development for a long time. The benefit is that they nicely isolate vertical exchange processes, which are relevant for almost all parametrizations, from the advection tendencies. They also take very little time to run. There have been a number of model intercomparison projects for SCMs in which the focus has been on specific processes that rely heavily on parametrizations, such as turbulence in stably stratified conditions, the representation of the diurnal cycle, or the transition from stratocumulus to cumulus. Upper ocean turbulence has also been studied using SCMs, although to a lesser extent.

A fully coupled SCM was recently developed as an initiative within the Swedish e-Science Research Centre (*e-science.se*), partly funded through the APPLICATE Horizon 2020 project (*www.applicate.eu*). The Atmosphere–Ocean Single-Column Model (AOSCM) is based on OpenIFS for the atmosphere and NEMO/LIM for the ocean/sea ice. The two model components are coupled using the OASIS software (Figure 1). The first version of the AOSCM (AOSCM.v1_EC-Earth3) is described in detail in Hartung et al. (2018) and the code is available through the EC-Earth development portal. The motivation for developing the AOSCM is to be able to improve parametrized processes interacting closely with the surface and also to study the vertical coupling itself. Using the SCM framework enables us to test and generalise findings from idealised large eddy simulations. The AOSCM makes it possible to assess how processes, or the sensitivity to perturbations, depend on whether the surface conditions are prescribed or whether coupling with the surface is allowed.

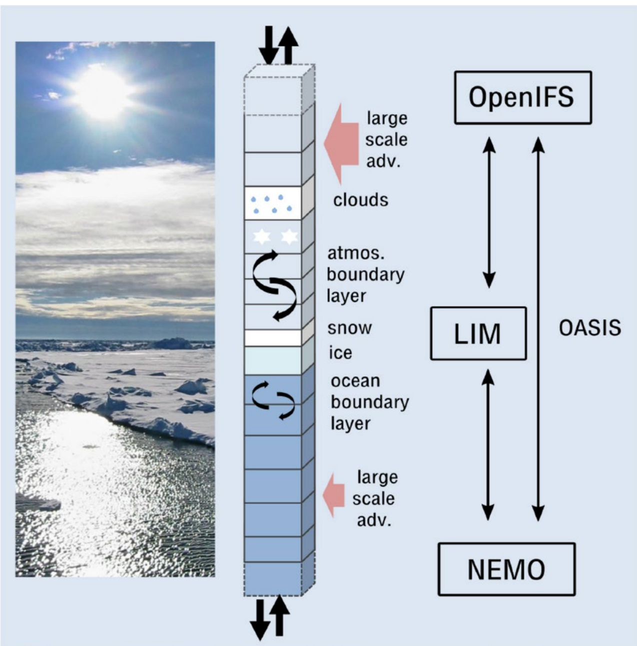

Figure 1 A fully coupled single-column model using OpenIFS has been developed at the Swedish e-Science Research Centre. It includes an atmospheric model (OpenIFS single-column model) and an ocean model (NEMO), which are coupled using the OASIS software. It also includes a sea ice model (LIM). (*Photo: Michael Tjernström*)

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One example application is to study in detail the coupling between the atmosphere and sea ice when several ice categories are used. The choice of variables to pass between the ocean and the atmosphere increases substantially in the presence of sea ice, and the resulting interaction also depends on the frequency of coupling. It is thus advantageous to be able to perform a multitude of sensitivity tests in a controlled large-scale environment with prescribed advection, at relatively small computational cost.

A case of warm air advection over sea ice in the Arctic, as observed by the Swedish icebreaker Oden in August 2014, is one of the first cases simulated by the AOSCM. In this situation, the advection of moisture is very important for the surface energy budget. However, it turns out that the difference in net surface radiation between coupled and uncoupled AOSCM simulations is as large as omitting moisture advection in the uncoupled large eddy simulation. (Kerstin Hartung, Hamish Struthers and Gunilla Svensson)

Ensemble prediction

The responsibility for advancing ensemble forecasting rests largely on the shoulders of major operational forecasting centres, like ECMWF, or big limited-area modelling consortia. The reason is that ensemble forecasting is computationally very demanding and requires means to generate ensemble spread through initial state and model perturbations. For the latter, OpenIFS includes the Stochastically Perturbed Parametrization Tendencies (SPPT) scheme to generate forecast ensembles. However, until recently no solution outside of ECMWF was available for the former.

Recently researchers at the Finnish Meteorological Institute recreated all 50+1 IFS operational ensemble initial states at a range of resolutions, so that both Ensemble of Data Assimilations (EDA) and singular vector (SV) perturbations can be used independently. Initial states covering one year (December 2016 to November 2017) twice a day were created with IFS Cycle 43r3 for TL639, TL399 and TL159 resolutions. The contributions of initial state perturbations and SPPT to OpenIFS ensemble skill are currently being assessed. Once this has been done, the dataset will be made available through an ftp-server under a Creative Commons licence.

Predicting Typhoon Damrey

To illustrate the potential of running your own ensemble experiments with OpenIFS, a case study of Typhoon Damrey, which severely affected Vietnam, is shown in Figure 2. Both ensembles consist of 19+1 OpenIFS forecasts produced at TL639 resolution (corresponding to a grid spacing of about 32 km). Ensemble spread here is the result of starting the forecasts from different atmospheric states (EDA + SV perturbations). The ensemble mean in the 96-hour forecast indicates that most ensemble members have propagated the typhoon too slowly and on a track that is too far south compared to what was observed (not shown). However, the ensemble spread indicates that several ensemble members place the typhoon further north and closer to the coast. The ensemble mean in the 48-hour ensemble forecast places the typhoon closer to the observed landfall location. The ensemble spread still indicates a range of possible landfall locations, but the most likely area starts to be relatively compact. (Pirkka Ollinaho)

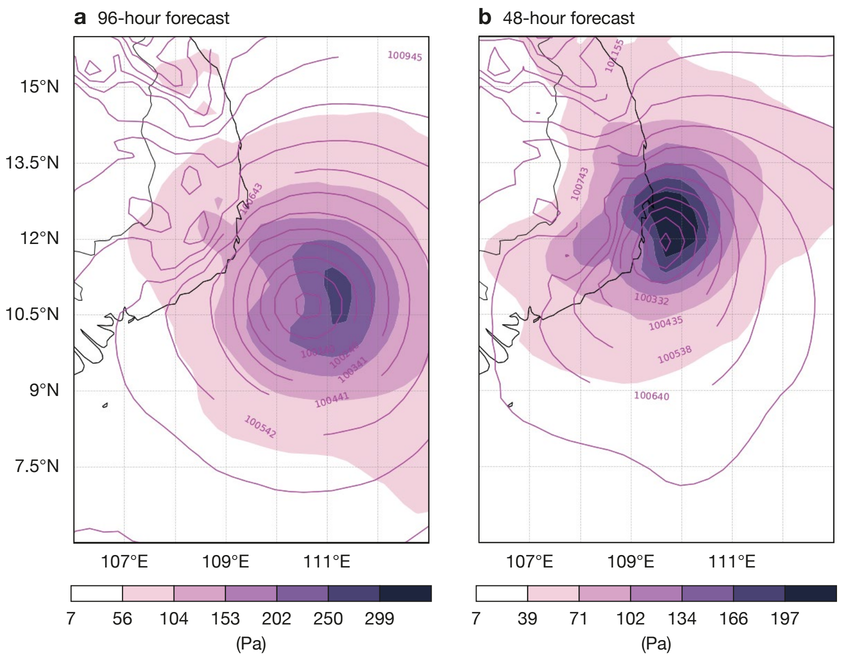

Figure 2 OpenIFS 96-hour (left) and 48-hour (right) ensemble forecasts at TL639 resolution with 19+1 members, starting from two of the ensemble initial states, valid at 00 UTC 4 November 2017 (landfall of Typhoon Damrey in Vietnam), showing the ensemble mean (contours, in Pa) and the ensemble spread (shading) for mean sea-level pressure.

Modern meteorological education

Several universities provide training in meteorological modelling and computing for Masters and PhD students. The courses at the École Nationale de la Météorologie of Météo-France, University of Helsinki and Eötvös Loránd University in Budapest, for example, aim to develop and improve their students' work-relevant skills, bridging the gap between their studies and real research using a state-of-the-art numerical weather prediction model with a variety of approaches. The courses strengthen the students' ability to work in teams and discuss questions in English, skills which are highly desirable in meteorology, where the best results are often achieved in international collaborations.

École Nationale de la Météorologie

The OpenIFS team returned to Météo-France for the third year in 2018 to run a training course for students at the school. The students followed a tutorial using ECMWF ensemble forecast data of Hurricane Nadine during the HyMeX (Hydrological cycle in Mediterranean experiment) observational campaign in 2012. The focus was on Nadine's life cycle when it interacted with the mid-latitude flow. The high forecast uncertainty of this situation (Figure 3) is ideal for teaching, as it demonstrates the need to produce ensemble forecasts. The exercises simulated a real forecast situation and put the students in the position of a duty forecaster supporting the HyMeX scientific director in decision-making for flight planning based on probabilistic forecast information. For more details on this event, see Carver et al. (2016).

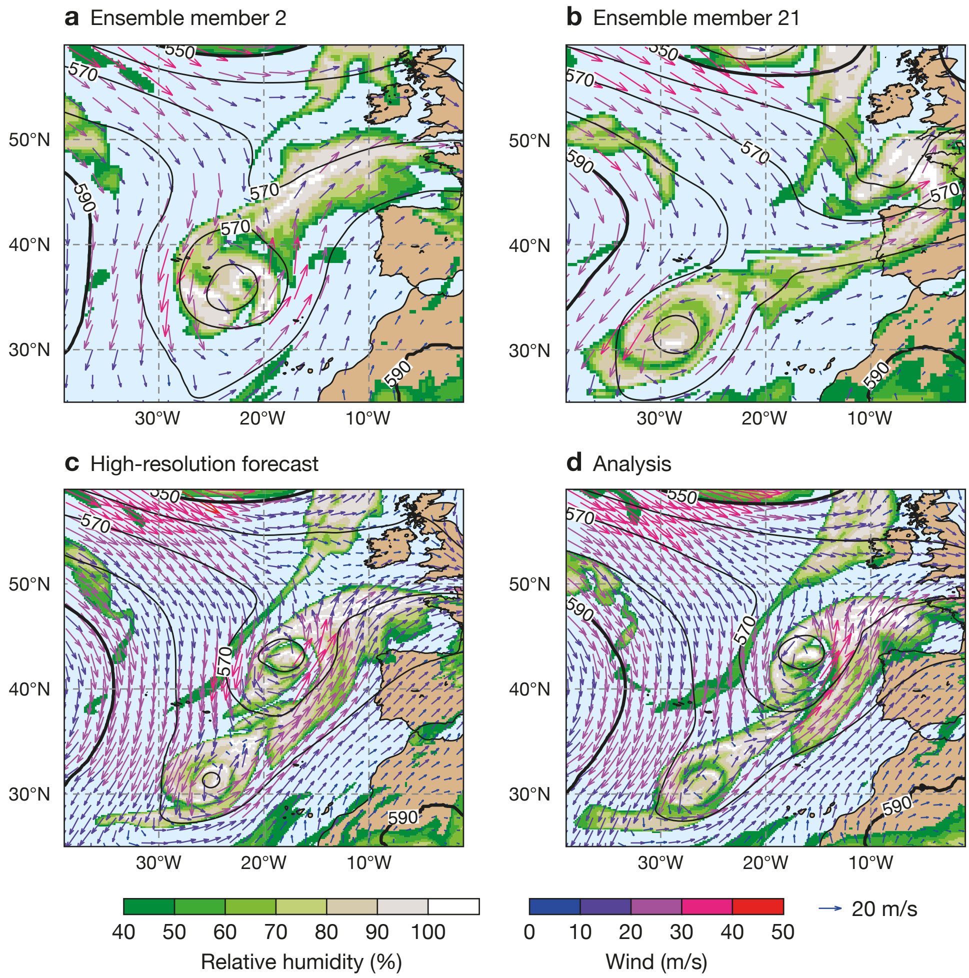

Figure 3 The charts show 60-hour forecasts of relative humidity at 700 hPa (shading), geopotential height (contours, in decametres) and wind (arrows) at 500 hPa at 12 UTC on 22 September 2012 according to (a) member 2 of ECMWF's operational ensemble forecast, (b) member 21 of the operational ensemble forecast, (c) the high-resolution forecast, and (d) the operational analysis. The ensemble members predict two substantially different scenarios for the interaction between Nadine and an Atlantic cut-off low. Member 2 represents a scenario where the two systems rotate around each other tending to merge, while member 21 shows that Nadine moves westwards while the cut-off low shifts eastwards. The high-resolution forecast indicated both moving eastward. The ECMWF operational analysis showed divergence between the two systems.

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University of Helsinki

The NumLab laboratory course has been taught at the University of Helsinki since the 1970s. OpenIFS has been used in NumLab since 2015, motivated by the fact that the EC-Earth model and the limited-area model HARMONIE, applied in climate research and operational short-term forecasts in Finland respectively, have the same or a similar atmospheric dynamical core as the IFS. In the first part of the course, the students are given an overview of OpenIFS and learn how to compile and run the model, post-process and analyse model outputs and improve their Linux and high-performance computing skills. In the second part, they work in small groups of three to four students on a small research project. A different scientific topic or specific historical weather event is selected each year. The students design their research questions and conduct numerical experiments. For example, in the year when the focus was on deep convection, a group explored the impact of entrainment on the cloudiness and convective precipitation over central Africa. To date more than 50 students have learnt how to use OpenIFS, and the university plans to open up the course to remote participation in the future.

Eötvös Loránd University

A two-semester Master's course is dedicated to numerical weather prediction and climate modelling at Eötvös Loránd University in Budapest. In the first term, meteorology students learn about the basics of meteorological modelling from modelling practitioners at the Hungarian Meteorological Service. In the following semester, applied mathematics students join them and form small teams with the meteorology students. The teams work on different modelling topics and conduct simulations with numerical models available for educational purposes, such as OpenIFS. In 2018, a group tested the evaluation tool developed at ECMWF for OpenIFS 40r1v2 before its release (Szépszó & Carver, 2018). The programme closes with the teams presenting the background of their chosen topic and the experiments they have carried out and discussing the conclusions that can be drawn from their results. (Gabriella Szépszó, Victoria Sinclair and Glenn Carver)

Further reading

Carver, **G.**, **S. Kertész**, **F. Váňa**, **F. Ferry** & **E. Chabot**, 2016: Météo-France hosts OpenIFS workshop, *ECMWF Newsletter* **No. 149**, 2–3.

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Szépszó, **G.** & **G. Carver**, 2018: New forecast evaluation tool for OpenIFS, *ECMWF Newsletter* **No. 156**, 14–15.