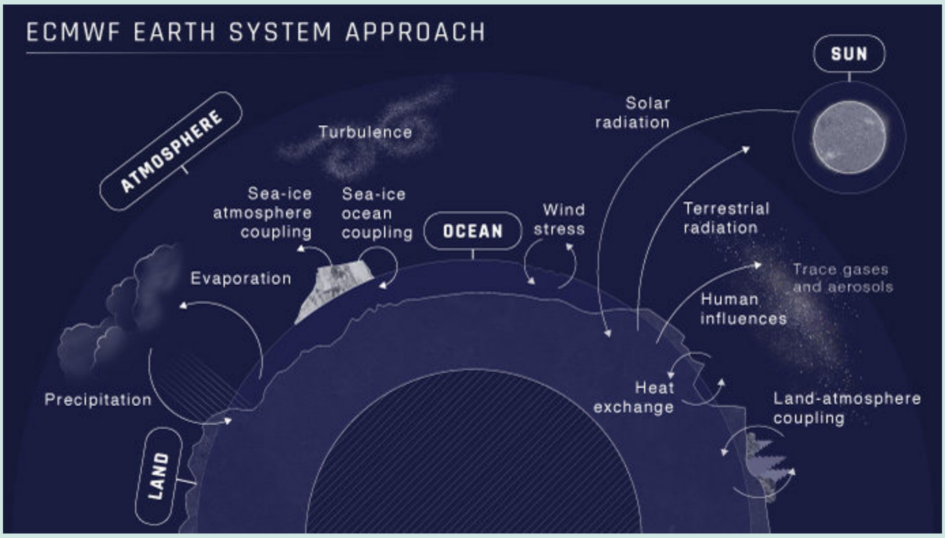

Earth system modelling at ECMWF

Why is Earth system modelling important for weather forecasting?

In addition to the atmosphere, Earth system components such as the ocean, ocean waves, sea ice, and the land surface can have a significant impact on the evolution of the weather. Accurately modelling the interactions between all these components in numerical weather prediction systems therefore improves weather forecasts. ECMWF's Earth system model aims to represent interactions between as many Earth system components as required, at the necessary level of complexity and as initialised by data assimilation, to achieve the Centre's forecasting goals.

What are the benefits for ECMWF forecasts?

Continuing to develop an Earth system approach is a key pillar of ECMWF's Strategy because it is essential for improving the skill of weather forecasts. ECMWF uses the same Earth system model across different timescales (medium, extended and long range) in a seamless prediction system. All Earth system model components interact with each other during the forecast simulation, and feedbacks between the components are explicitly modelled. Without an Earth system approach, such feedbacks would not be represented. This would, for example, lead to snow-covered surfaces in the wrong place in spring or autumn, or result in sea-ice cover where warmer temperatures have long removed it.

How is this approach useful for environmental services?

An Earth system approach can also provide a wide range of information about environmental conditions, such as soil moisture, flood and fire risk and air quality. That is why Earth system modelling underpins the work of the EU-funded Copernicus Climate Change Service (C3S) and Copernicus Atmosphere Monitoring Service (CAMS) implemented by ECMWF, as well as the Centre's contribution to the Copernicus Emergency Management Services (CEMS).

How does Earth system modelling fit into the forecasting system?

The data assimilation system combines the latest observations with model information to obtain the best possible estimate of the current state of the Earth system. Based on those initial conditions, the Earth system model is run to predict the likely evolution of the atmosphere and related parts of the Earth system. To produce ensemble forecasts, uncertainty estimates are used to perturb the initial conditions and the model to reflect the full range of possible outcomes. The data assimilation algorithms, the perturbation techniques and the full suite of model components together make up ECMWF's Integrated Forecasting System (IFS).

How does the atmospheric model work?

The atmospheric model divides the atmosphere into a three-dimensional grid comprising billions of grid boxes. Average values of variables such as wind and temperature are predicted for each grid box by numerically solving equations that describe advection by the wind, the balance of atmospheric pressure forces on a rotating planet and the redistribution of heat. The algorithms and their implementation on a supercomputer are called the dynamical core. When the impact on the flow by relatively small-scale processes cannot be resolved by the model, they are simulated separately in so-called parametrization schemes. Radiation, small-scale convection, turbulence and drag processes are examples of such unresolved processes. The dynamical core, the parametrization schemes and other Earth system model components have to work hand in hand to deliver successful weather predictions.

How are other Earth system components modelled?

The ocean model used in the IFS works in a similar way to the atmospheric model, but advection is slower and coastlines provide additional boundary conditions. Ocean waves are represented through a statistical description, while the sea-ice model represents the movement, formation and melting of sea ice in response to changing atmospheric conditions. A land-surface model is tightly coupled to the atmospheric model to represent the evolution of surface properties such as soil moisture, vegetation and snow. Atmospheric chemistry, greenhouse gases and aerosols are all represented within the atmospheric model.

What role does the model resolution play?

One way to improve forecast skill and make forecasts more detailed is to increase the horizontal and vertical resolution of Earth system model components. ECMWF's strategic aim is to go down to a horizontal atmospheric grid spacing of a few kilometres for ensembles of global forecasts. Research is under way to determine the changes in our Earth system model that are required to make this possible without overwhelming the computational capacity of the Centre's current and future supercomputers. This includes work on an alternative dynamical core and on adapting the existing parametrization schemes to grid spacings at which a growing number of physical processes start to be resolved.

How is Earth system modelling developing at ECMWF?

ECMWF scientists are constantly seeking to improve all aspects of the Earth system model. Earth system observations, including satellite observations, help us to understand Earth system processes and to model them successfully. Active areas of research include improved representations of the stratosphere as well as of soil moisture, vegetation, snow cover, sea ice and aerosols to extend the range at which useful forecasts can be made.