A research project
on impacts of climate change
and land use change in
Amazonia

*Fact*sheet

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Earth System Modelling

AMAZALERT is using some of the world's most complex models to understand how climate change may take place in Amazonia. These models are being used to improve scientific understanding of the Earth system and, crucially, how it may respond to human activity.

AT A GLANCE

- Earth system models represent mathematically the processes that describe Earth system components and the interactions between them.
- Feedbacks in the Earth system have the potential to have significant impacts on global and regional climate change.
- Earth system models produce projections of future climates. They also allow the assessment of the role of feedbacks in the changes that are seen.
- Earth system models are always being developed, and observations play a central role in this work.

This factsheet describes what Earth system models are and the benefits they bring in developing understanding of the Earth system and how it responds to changes.

What is an Earth system model?

The first climate models simulated the atmosphere alone. They were composed of mathematical equations based on established physical laws that described, for example, changes in pressure, the movement of air, temperature and the formation of rain. In other words: the weather and climate. Over the years, as scientific understanding has advanced alongside technological developments in computing capability, these models have become more complex. More processes and components of the Earth system have been incorporated, and hence some are now termed Earth system models.

These represent mathematically the physical, chemical and biological processes that describe the atmosphere, the oceans, the cryosphere and the biosphere, and the interactions between them.

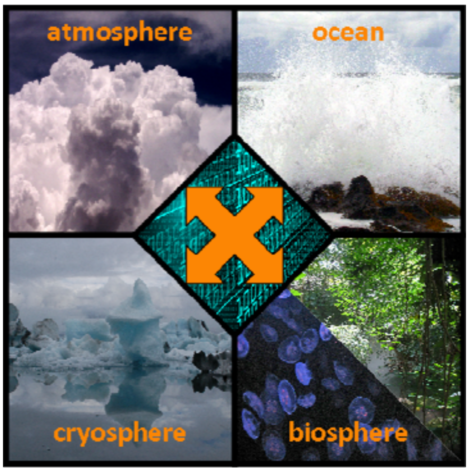

Figure 1. Earth system models simulate processes that describe the components of the Earth system, and the interactions between them

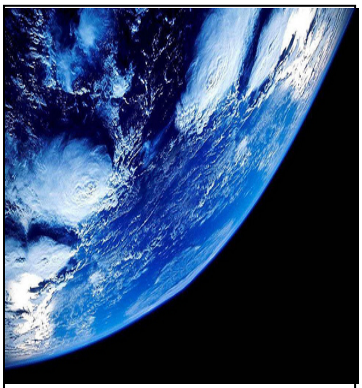

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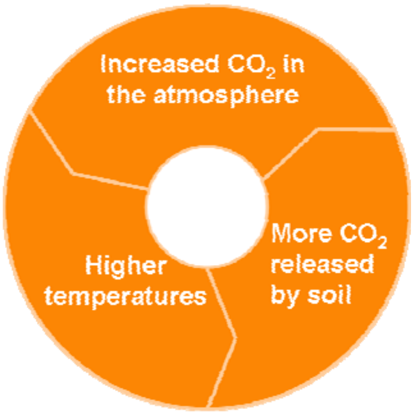
Figure 2 (right): An example of a positive feedback in the climate-carbon cycle. This cycle interacts with others within the Earth system.

Benefits of Earth system models

It is not just the physical elements such as clouds, oceans and ice that affect the climate. To give some examples, vegetation, soils and plankton can modify atmospheric concentrations of carbon dioxide (CO_2) through absorbing or releasing carbon. Aerosol particles can absorb or reflect sunlight, which has a heating or cooling effect, respectively, on the atmosphere. Chemical reactions determine the concentrations of some aerosols and non-CO_2 greenhouse gases (e.g. methane, ozone). Because all of these processes are occurring within the same model, it provides an internally consistent way to assess the impacts of climate change on our atmosphere, ecosystems and oceans.

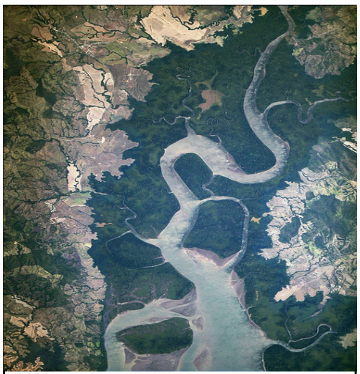
Furthermore, many of the Earth system components that affect climate are themselves affected by climate. 'Feedbacks' between the different Earth system components may act to amplify (positive feedback) or dampen (negative feedback) the original effects. For example, warmer temperatures accelerate soil decomposition and release of CO_2**.** The resulting increase in CO_2 in the atmosphere leads to further warming. This is a positive climate-carbon cycle feedback (Fig. 2). However, it should also be noted that different cycles interact and may have opposing effects on the same quantity. For example, under higher atmospheric CO_2 concentrations vegetation takes up more CO_2, which has a positive effect on vegetation productivity and a negative feedback on atmospheric CO_2 levels.



The combined effects of Earth system feedbacks have the potential to have significant impacts on global and regional climate change.

Using Earth system models

Models represent past, current or future climate by simulating the underlying climate system together with 'external' forcing factors such as solar energy, greenhouse gas concentrations and even aerosols ejected into the atmosphere from volcanoes. By running the model according to the forcing of the 20th century, for example, it generates the climate of the past hundred years. Driving the models with scenarios of different combinations of forcing factors, including changing greenhouse gas concentrations and land use, produce projections of climate to be made into the future. Earth system models also allow the assessment of the role of interactions and feedbacks in the changes that are seen.



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There is continuing effort to include further important processes in the models as well as improving the representation of existing ones, some of which are not as well understood as others. Observations are essential in helping us developing knowledge of these processes and how they are incorporated into the models. It should be noted, however, that observational records are not as complete as the ideal, either in space – at locations right across the world – or in time – some records go back longer than others, or are intermittent. This is particularly true for some of the 'Earth system processes' that are much more sparsely measured compared to relatively well-observed quantities such as rainfall and surface temperature. Observations are central to improvements in modelling, and it is an ongoing scientific challenge to maintain, increase and bring into use observational data.

One outcome of the scientific uncertainties that exist in our knowledge of the processes themselves and in their representation is that there is a greater spread in the results given by the models than when they are omitted. But by including these new processes we are beginning to better characterize our understanding of how climate change may evolve in an interacting Earth system.

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