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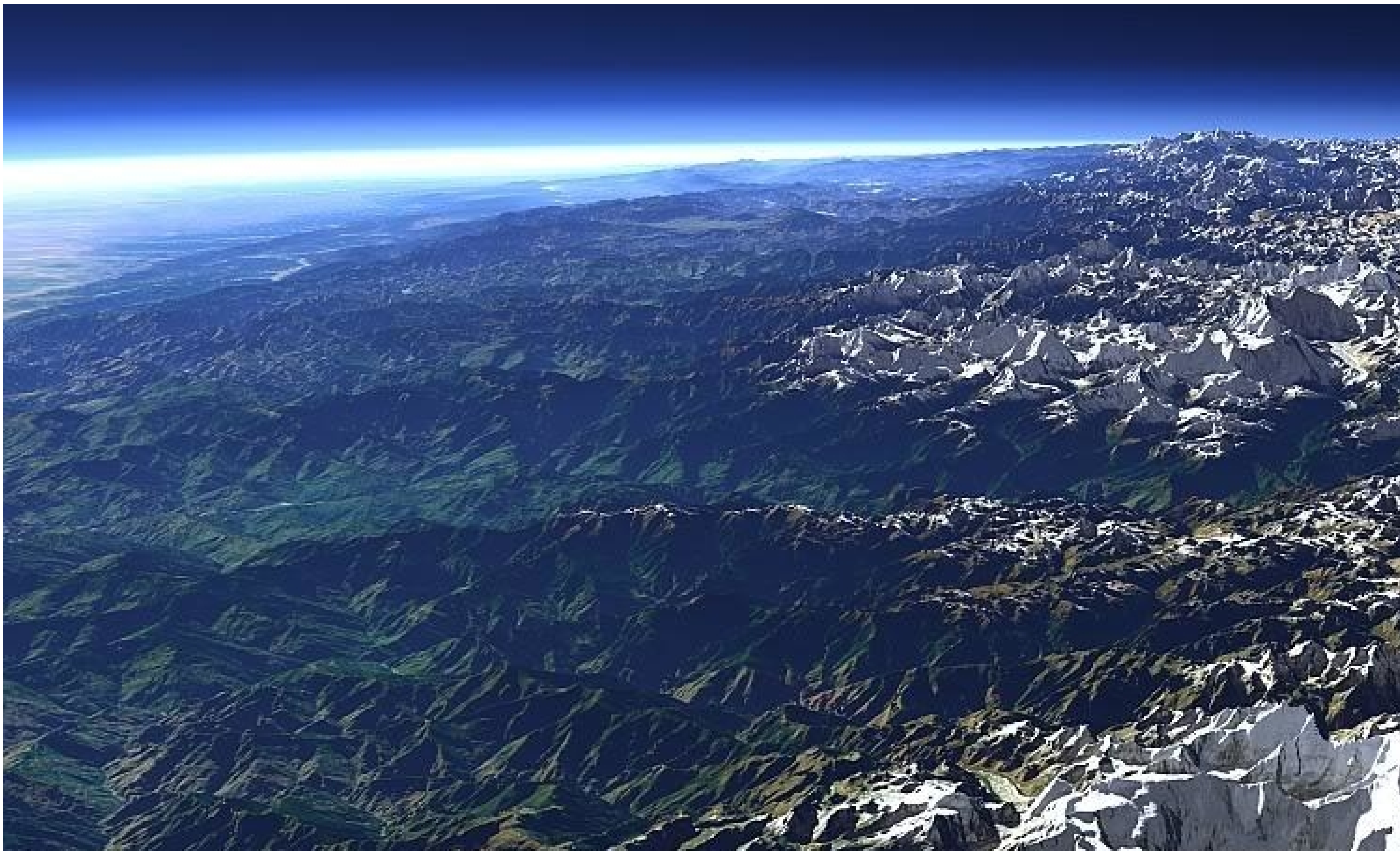
Land-atmosphere coupling and predictability



Studying the land surface environment is of uttermost importance as it is the environment we live in. Fortunately, the land-atmosphere interactions provide predictability at seasonal to decadal timescales, thanks to the memory of hydrological reservoirs (soil moisture, snow, glacier ice).

Summary

A crucial component of climate models: land surface schemes

The land surface is a crucial component of the Earth's environment, but our understanding on its role in weather and climate variations has been limited until recently. This is partly due to the scarcity of large-scale observations and the complexity of process parameterizations, which approximates phenomena occurring on very small time scale. Land surface models, used both in stand-alone configurations or as part of atmospheric-ocean general circulation models are widely used to understand the physical links between the climate system and the land surfaces, at regional to global and daily to decadal timescales.

How the land surfaces determine the regional climate conditions

A large part of the terrestrial atmospheric circulation is driven by the temperature contrast between lands and oceans. The main examples are the monsoons systems like the southern Asian and the African monsoons, which are in a first place driven by the land-sea thermal contrast. Orography also generates the propagation of atmospheric waves that concern local, regional and global scales. Some key region, such as the maritime continent, Tibetan Plateau or the Andes have thus a very large impact on large scale circulation. The resolution of current climate models is generally too coarse to simulate realistically the triggering of these waves.

The topography of land surfaces is also a key factor of the climate system, since it induces upward air movements liberating water when air is cooled in altitude, generating precipitation in downwind slopes. This process explains that around half of the continental water discharge originates from mountainous areas. Forecasting the climate in mountainous regions is therefore of a prime importance to predict the evolution of water resources.

How the land-atmosphere coupling affects the climate system

Taken into account the large role of land surface and orography on the global climate, fluctuation of the land surface such as snow cover, depth and albedo, soil moisture and vegetation can affect substantially the climate system. The atmospheric response to changes in land surface condition further impacts land, this is the so called land-atmosphere coupling. An example is the relation between soil moisture content and heat wave occurrence in the mid-latitudes: the evaporation which occurs when the soil is moist prevent the occurrence of heat waves. On the contrary, dry soil favour the warming of surface temperature and can lead to the occurrence of extreme temperature. Another well-known coupling between the surface and the atmosphere is the snow albedo feedback: a warmer atmosphere decreases the snow cover extent, a response that directly lowers the surface albedo, increase the absorption of the solar radiation at the surface and finally enhances atmospheric warming. This feedback is the main cause for the polar amplification of climate changes. Land surfaces also significantly drives the carbon cycle, since forest and permafrost consists in carbon pools that are likely to induce significant warming if released into the atmosphere at decadal to centennial time scales. In addition, the land-use changes, like deforestation for example, is known to affect atmospheric temperature trough albedo increase and evapotranspiration decrease.

What is the potential climate predictability related to land-surface coupling?

Over the last years, the land-atmosphere coupling and its associated feedbacks have been an active research topic since they have been recognized as potential sources for seasonal to decadal predictability. Soil moisture is known to affect temperature, evapotranspiration, and then precipitation trough clouds formation. Soil moisture, and more generally the land surface hydrology, is therefore a source of climate predictability at seasonal scales. Snow is another surface component that affects the lower troposphere variability from fall to spring. Snow cover and depth also affects some atmospheric circulation patterns and teleconnections, for example the Asian monsoons variability. The North Atlantic Oscillation is also partly driven by snow cover, a signal robustly demonstrated with the observations and still badly caught by general circulation models:

positive anomalies of snow cover in Siberia form a cold air mass that generates a vertical propagation of stationary waves that slow downs the polar jet. Transferred to the stratosphere, these anomalies lead to a weakening of the polar vortex that project onto negative phases of the North Atlantic Oscillation some weeks later on the surface.

Objectives

The objectives of the land-atmosphere coupling and predictability research line are:

- Understanding the drivers of the middle-to-high latitude atmospheric variability related to surface processes at seasonal to decadal timescales.
- Gaining insight into the systematic errors of climate models to reproduce the land surface interactions with the atmosphere.
- Exploring the role of land-atmosphere coupling processes in climate prediction skill.