Project 11 (TWP1): Development of the new IPSL-CM6 model to improve the energy flow within the climate system

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Position offer: Improving the radiative energy flow in the new version of the IPSL-CM6 climate model

The excellence laboratory L-IPSL of the Institut Pierre-Simon Laplace offers a post-doc position of 1 or 2 years to join a collaborative effort to develop the new version of the IPSL-CM climate model. The approach is to improve first the energy flow within the climate system, in particular through better parametrization of surface albedo over ocean and continent. This work can be extended in a second year with multi-parameters adjustments and tuning of the whole climate system.

Context: IPSL has developed an Earth System Model (IPSL-CM5) that includes a representation of the physical and the biogeochemical (carbon cycle, aerosols, chemistry...) processes at the global scale, for the atmosphere, land surface, ocean and sea-ice. The climate models include many parameterizations, which are approximate descriptions of sub-grid processes. These parameterizations are formulated via a series of parameters that are usually not directly observable and must be tuned so that the parametrizations fit as well as possible the statistical behaviour of the physical processes.

We are now developing a new version of the model, IPSL-CM6, and one of our objective is to improve the characteristics of the simulated climate. The energy budget within the climate system (i.e. within the atmosphere, the ocean and at the surface) has a very strong impact on how the model simulate many climate phenomena (circulation, precipitation, MJO...). Until recently, only the net, SW and LW) fluxes at the TOA were estimated with enough accuracy to be used as strong and useful constrains during the final phase of the adjustment of climate models. Recent estimates of the fluxes as the surface and within the atmosphere have been largely improved, and the main objective of the proposed post-doc is to take advantage of such new estimates to improve the energy flow simulated by the IPSL model.

Description of work: The main objective of the proposed post-doc is to improve the energy flow within the climate system, with a focus on the radiative flux. The development and the adjustment of the relevant parameterizations will be done using a suite of tests going from individual parameterizations in individual model components (atmosphere, ocean, land surface,...) to the full coupled climate model.

The work will be first focussed on clear sky flux. We propose to include an ocean surface albedo model that depends on meteorological (wind speed) and biogeochemical (plankton) variables in addition to the solar zenith angle. In the current continental surface model, ORCHIDEE, the albedo depend on the soil type, soil moisture and vegetation, the later being either prescribed or computed, and a validation, tuning and possible improvement are required. In the atmosphere, the development, the evaluation and the tuning will be done starting from clear sky conditions, then considering aerosols, and finally including clouds.

During the first year, the development and the adjustment of the relevant parameterizations will be done in each model components (atmosphere, ocean, land surface,...) using mainly forced simulations. In the second year, fluxes will be considered within the full coupled model and the work will contribute to the final phase of the adjustment and the evaluation of the fully coupled climate model.

The candidate should have a good knowledge in climate sciences, a solid experience in climate modelling, and a good general knowledge in FORTRAN and shell programming.

Supervision team: The work will be conducted at IPSL under the main supervision of J-L Dufresne, O. Boucher, F. Hourdin, L. Bopp, P. Peylin and in close connection with other researchers and engineer of the IPSL Climate Modelling Centre (J. Ghattas, P. Cadule, C. Etthé...).

Duration and salary: The engineer will be recruited for 12 months with a net monthly salary around 2000 Euros, commensurate with experience. This includes social services and health insurance.

Contact for applications: Applications should include a curriculum vitae, a statement of interest and the names of at least two references including their e-mail addresses and telephone numbers. Applications should be submitted by e-mail to J.-L. Dufresne (Jean-Louis.Dufresne@lmd.jussieu.fr).

Results:

IPSL-CM6 adopts a new radiative transfer scheme known as the rapid radiative transfer model or RRTM (Clough et al. 2005). Sunghye Baek worked on the parallelization of the RRTM code in order to ensure consistent results throughout different parallelization levels (sequential/MPI/OpenMPI). The test has been done on several machines and compilers either on local PC or remotely on the IDRIS supercomputer. She also worked on transport and optimization of LMDZ on the Turing machine (Blue Gene/Q, IBM) at IDRIS with Laurent Fairhead. Turing is the last generation of supercomputers at IDRIS which is designed to serve to massively parallelized code with MPI and OpenMP.

Oceans cover 70% of the total surface of the Earth. A precise estimation of the ocean surface albedo (OSA) is therefore important for the Earth's radiation budget and climate modelling. Ocean surface albedo in climate models is often treated in a simple way and parametrizations only depend on latitude and/or solar zenith angle. We have developed a new parameterization of OSA in collaboration with Roland Séférian (CNRM), which allows us to include dependencies on surface wind speed, chlorophyll content, wavelength and solar zenith angle. With the new radiative transfer scheme RRTM recently implemented in LMDZ, we have treated the spectral albedo in up to six wavebands in the visible instead of just a broadband albedo as was the case before.

We have decomposed the albedo according to the direct or diffuse character of the incoming solar radiation (leading to a direct albedo and a diffuse albedo term). For each of the direct and diffuse term, we compute the contributions from the different reflection processes, i.e. a Fresnel surface albedo and an ocean volume albedo, depending on the place where the reflection occurred. We choose to adapt the parameterization of Jin et al. (2004), which shows good agreement with previous work as compared as shown in Li et al. (2006). Robert Séférian adapted the fitting of Jin et al. (2004) for the wavelength range 200 to 800 nm. We added a whitecap effect following Whitlock (1982) and Koepke (1984) and extended the wavelength range from 800 to 4000 nm to adjust it with RRTM shortwave range.

The surface direct albedo is the most important component in comparison to the other terms. Fig. 1 shows our new scheme of surface albedo which depends not only on solar zenith angle but also on wind speed. The overall value is consistent with previous works such as Preisedorfer and Mobley (1986) or Taylor et al. (2002) which has been used in some climate models.

Simulations have been performed for AMIP and climatological SST in order to validate the scheme against monthly (and if possible daily) CERES retrievals of surface and top-of-atmosphere clear-sky albedo. Figs. 2 and 3 show how the new parametrization improved significantly the comparison to CERES. Further simulations have been performed to investigate how surface albedo may change under 4xCO2 conditions. These simulations are now being analyzed.

In addition to this work on radiation, a second post-doc has been recently hired to help the development with a focus on the latent heat flux over ocean. The link between its bias in AMIP runs and the SST bias in coupled runs has already been established, and work to improve the latent heat formulation is in progress.

References

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Li, J. et al., Ocean surface albedo and its impact on radiation balance in climate models, Journal of Climate, 19, 6314-6333, 2006.

Morel, A.,and B. Gentili, Diffuse reflectance of oceanic waters: its dependence on sun angle as influenced by the molecular scattering contribution, Applied Optics, 30, 4427-4438, 1991.

Preisendorfer, R. W., and C. D. Mobley, Albedos and glitter patterns of a wind-roughened sea surface, Journal of Physical Oceanography, 16, 1293-1316, 1986.

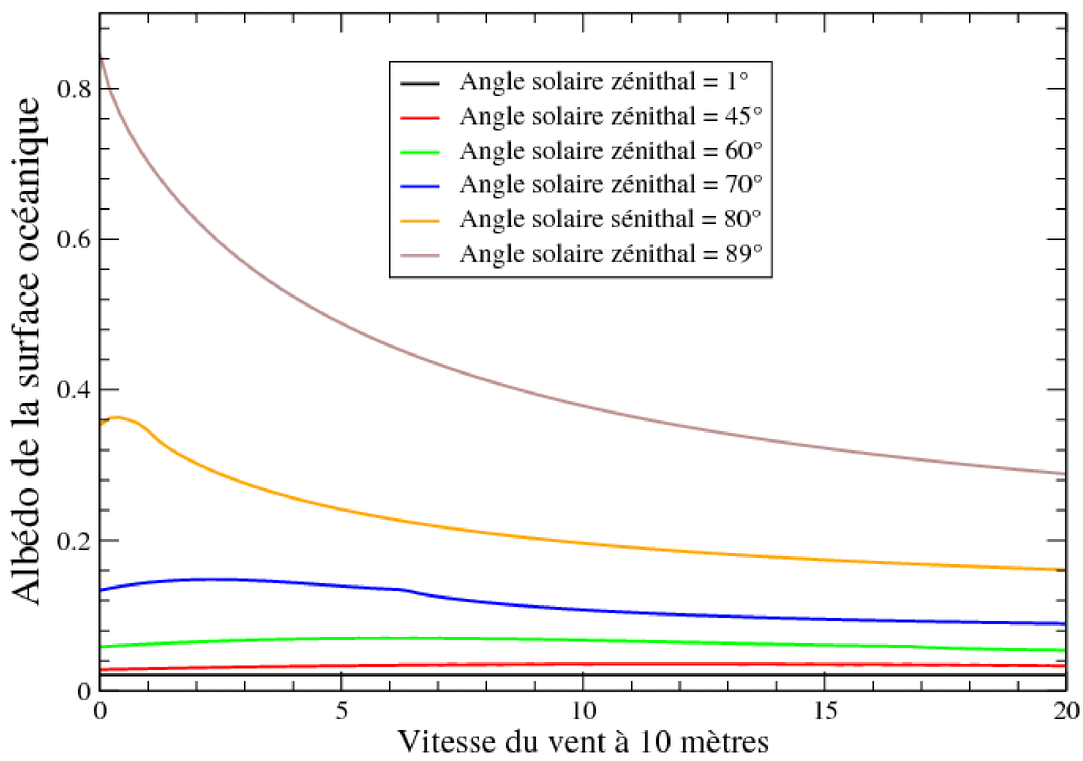

Fig. 1. Different surface direct albedo as a function of the 10 meter wind speed for a range of fixed solar zenith angles (SZA) following the fitting of Jin et al. (2004). The albedo is an average over a broad range of wavelengths from 200 to 4000 nm.

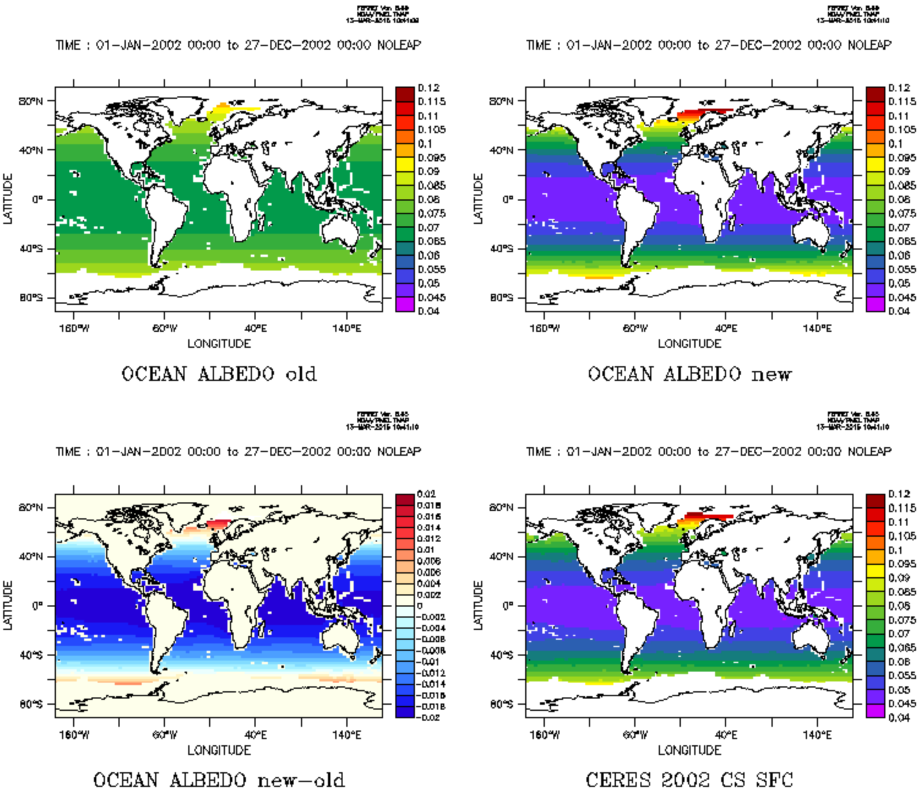

Fig. 2: Comparison between the annually-averaged surface clear-sky albedo for the old scheme, the new scheme and the CERES data for the year 2002.

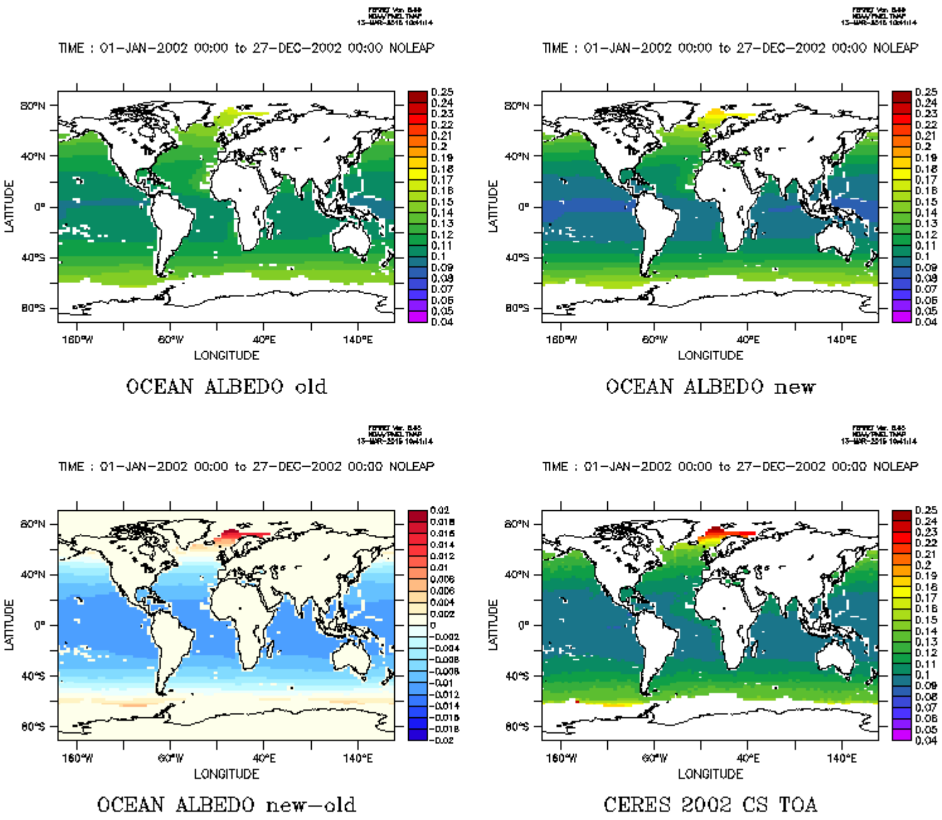

Fig. 3: same as Fig. 2 but for top-of-atmosphere clear-sky albedo.