The interface between land-surface schemes and atmospheric GCMs

Jan Polcher

Laboratoire de Météorologie Dynamique du CNRS / IPSL

- A proposal for a general interface between land-surface schemes and general circulation models : Based on : J. Polcher, B. McAvaney, P. Viterbo, M.-A. Gaertner, A. Hahmann, J.-F. Mahfouf, J. Noilhan, T. Phillips, A. Pitman, C.A. Schlosser, J.-P. Schulz, B. Timbal, D. Verseghy and Y. Xue (1998), *Global & Planetary Change*, **19**, pp 263-278
- Implementing the general interface defined during the PILPS-4 project : Based on work by the ORCHIDEE team : M.-A. Foujols, P. Friedlingstein, G. Krinner, N. de Noblet, J. Polcher, N. Viovy.

I P S L

Full Screen

Quit

1. Proposing a general interface for coupling land-surface schemes to the atmosphere

1.1. Why do we need a general interface ?

The increasing complexity of land-surface surface schemes require that :

- different land-surface schemes (LSSs) can be coupled to the same atmospheric model to perform sensitivity experiments and
- the same code of the LSS can be used for off-line and coupled simulations.

But each scheme interacts differently with its host GCM :

- Land-surface scheme fulfill different tasks in the GCM.
- The numerical schemes used for the coupling vary.
- The calling procedures differ.

Our aim is to find a general communication protocol that can be used between GCMs and LSSs.

LMD/CNRS

I P S L

1.2. What are the tasks of a land-surface scheme within a GCM ?

The LSS should provide the lower boundary conditions to the atmosphere. Three solutions are possible :

1. Compute the fluxes at the boundary (Neumann closure),
2. Variables at the surface are exchanged (Dirichlet closure),
3. A mixed closure .

For each physical process the solution best adapted has to be chosen. A few practical considerations will offer guidance :

- The interface should be robust for energy conservation,
- No restrictions on numerical schemes should be placed,
- Calculations should not de duplicated in the LSS,
- The interface should not limit new developments.

1.3. Providing lower boundary conditions to the radiation

Short-wave radiation

- Energy conservation is ensured by exchanging net SW radiation and albedo.
- To enable the LSS to compute albedo the solar zenith angle and the fraction of diffuse radiation are needed.

Long-wave radiation

- Downward long-wave radiation is provided to the LSS
- The LSS returns a radiative surface temperature and the emissivity

The time averaging of the radiative temperature has to conserve the flux :

$$\overline{\epsilon}\,\overline{T_{rad}^4} = \frac{1}{n}\sum_{t=1}^{n} \epsilon\, T_{rad}^4 \qquad (1)$$

Full Screen
Quit

1.4. Closing the hydrological cycle

To ensure energy conservation :

- the GCM has to provide the latent heats of sublimation and evaporation and,
- rainfall and snowfall have to exchanged separately.

The distinction between stratiform and convective precipitation is specific to current GCM parameterizations. The sub-grid variances of rainfall and snowfall should be transfered instead.

The LSS needs to return the continental runoff along the coast lines in order to close the hydrological cycle in coupled Ocean-Atmosphere models.

1.5. Coupling the turbulent fluxes

These processes are among the most difficult to treat numerically and the interface should be compatible with the existing diversity.
Two questions remain open and thus both solutions have to be covered :

- Should the GCM or the LSS determine the turbulent transfer coefficients of the surface layer ?
- Should the momentum transfer and the interaction with orography be covered by the GCM of the LSS ?

The LSS should provide the turbulent fluxes :

$$LE^{t+1} = L\rho C_h|\vec{V}|\beta(q_a^j - q_{sat}(\theta_s^i)) \quad (2)$$

$$H^{t+1} = \rho C_h|\vec{V}|(\theta_a^j - \theta_s^i). \quad (3)$$

$i = t+1, j = t+1$ **:** Implicit coupling,

$i = t, j = t+1$ **:** Semi-implicit coupling,

$i = t+1, j = t$ **:** Explicit coupling.

$i = t, j = t$ **:** Open-explicit coupling.

Coupling the turbulent fluxes (cont.)

The two main methods used in current GCMs are :

Implicit coupling

- The LSS needs to be solved within the PBL.
- There is no need for the LSS to compute C_h in this case.
- θ_a^{t+1} and q_a^{t+1} will be provided as a functions of θ_s^{t+1}.
- It is used in the following GCMs : LMD, UKMO, ECMWF, Météo-France.

Explicit coupling

- The LSS can be called outside of the PBL as the newest atmospheric values are not needed.
- The LSS needs to compute C_h for stability reasons.
- It is used in the following GCMs : NCAR, BMRC/BASE.

To make both methods possible in the GCM, the general interface needs to be called within the vertical diffusion scheme.

Coupling the turbulent fluxes (cont.)

The following variables need to be provided to the LSS to allow all numerical methods to be used.

- Lowest level variables (θ, q, u, v),
- The sensitivity of the lowest layer variables to the surface fluxes,
- Surface layer diffusivity (C_h by GCM).

In return the GCM will receive :

- Surface fluxes,
- surface roughness and displacement height (C_h by GCM),
- Surface layer diffusivity (C_h by LSS),
- Actual over potential evaporation (C_h by GCM),

It should be noted that if the LSS and the GCM use different models to compute the transfer coefficients of the vertical diffusion it may lead to discontinuities.
Passive tracers will follow the same rules as moisture.

2. Implementing the general interface

Work on the implementation of this general interface is underway in various centers :

- IPSL, work completed,
- COLA, work underway,
- DMI, will start in early 2001.
- A wider application in Europe is planed within the PRISM project.
- The Global Land-Atmosphere System Study (A WCRP/GEWEX project) as adopted this interface as its standard for future coupled inter-comparison projects.

I P S L

2.1. The link to the PBL is the key issue of coupling

- The time-step of the PBL has to be used for solving the energy balance at the surface (±30 minutes). Slower processes such as the evolution of the vegetation or the river routing will use longer time-steps.
- The spatial resolution of the LSS will be the one of the PBL. This can obviously be higher than the one of the atmosphere if a multi-PBL or multi-column scheme is used (Vintzileos and Sadourny, MWR 1997).
- Calling the LSS from within the PBL is needed to ensure that the most up-to-date atmospheric information is provided :
  - Schulz et al. (JAM, 2000) implemented two numerical coupling schemes in one LSS/GCM combination to show the sensitivity to the timing issue.
  - The flux coupler at NCAR, which calls the LSS at the same time level as the ocean, has shown the limits of this approach (A. Hahmann Personal Communication).

2.2. The case of ORCHIDEE

ORanizing Carbon and Hydrology In Dynamic EcosystEms, the land-surface scheme of IPSL, solves for the surface energy balance, the water and carbon cycles and simulates the evolution of the vegetation. To allow for this evolution, the scheme has been totally redesigned two years ago with the general interface in mind.

- An implicit scheme is used when coupled to the GCM. In forced mode the explicit coupling method is applied.
- The scheme is coded in F90 and only operates on arrays gathered over the continental points.
- The information coming through the interface is sufficient to :
  - dimension the code,
  - read the surface description from high resolution data sets,
  - extract and interpolate the information for the computational domain.
- The interface is a subroutine call and exchanges over the land-surface computational domain : 18 variables on input, 11 variables on output and one variable is updated.

3. Conclusions

This proposed interface can be implemented in all current GCMs and LSSs. Some points might need rethinking as new interactions between the surface and the atmosphere are introduced.

The main advantages of such an interface are :

- Plug-compatibility of LSS,
- A greater independence of the GCM from it's surface scheme,
- Exactly the same code of the LSS can be used in a coupled or forced mode.

This interface has clearly allowed the ORCHIDEE team to increase its productivity. Any development in ORCHIDEE can now directly be used for all fields of application of the scheme

Could this interface not also be useful for fast processes in the ocean or for coupling sea-ice model ?

See also : http://www.lmd.jussieu.fr/pilps4c.html

Full Screen
Quit