Recent evolutions of ORCHIDEE, progress toward a 3rd generation land surface model.

The ORCHIDEE Team
ORCHIDEE: 20-yr of development

History:

Global GCM: W / E (SECHIBA)
(Laval et al., 1981)

80s

Inclusion C (ORCHIDEE)
(Ducoudré et al., 1993)
(Viovy et al., 1997)
(Polcher et al., 1998)

90s

Focus on Physic..
(Krinner et al., 2005)

2000

New dev. in biogeochemistry

2009

………
ORCHIDEE: 20-yr of development

Challenge:
- maintain coherence &
- describe feedback
- between Physic and Biogeochemistry

History:
- Global GCM: W / E (SECHIBA)
- Inclusion C (ORCHIDEE)
- Focus on Physic..
- New dev. in biogeochemistry

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90s (Ducoudré et al., 1993)
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Energie budget
- complex feedbacks

Water budget
Carbone / Nitrogen budgets
Overview

• The multi-layers soil hydrology scheme
• The new snow scheme & High latitude processes
• Swamps and floodplains
• Improved soil carbon decomposition
• A new multi-layers canopy energy scheme
• Conclusions
Recent improvements of ORCHIDEE

- Generalization of PFT concept (unlimited, currently 13)
- Analytical soil C spin-up
Multi-layer soil hydrology

• Why a “new” physically-based scheme (vs old double-bucket scheme)?
  – Better represent Infiltration vs Runoff processes
  – Plant water uptake:
    • Different plants have different root profiles
    • Compute hydraulic lift: from soil to leaf water potential
  – SOM decomposition is a function of W, T,..
Soil moisture evolution

Comparison with SMOS data

**REMEDHUS site in central Spain:**

- Lon: -5.3, lat: 41.3.
- 5 days average to reduce instrument noise

**REMEDHUS**: spread between 19 stations

- SMOS pixel
- **ORCHIDEE** forced by ERA
- **ORCHIDEE** by WFDEI

- The general annual cycle is rather well captured.
- The drying is stronger in SMOS and ORCHIDEE.
- SMOS signal is the most spiked observation.

*Polcher et al. RSE, 2015*
Multi-layer snow scheme

• 3 layers scheme to improve:
  – Snow dynamic (spring)
  – Snow – vegetation interactions (Shrub, grass, ..)
Evaluation on new snow scheme

Daily snow depth (density, SWE) for Northern Eurasia,
165 stations HSDSD (1979-1992)

Corr: 0.78 -> 0.83
RMSE: 0.12 -> 0.10 m
MBE: -0.05 -> 0

Wang et al., JGR, 2013
A new satellite-derived map of maximal fraction of floodplains and swamps

Initially for ORCHIDEE: GLWD (Lehner & Döll, 2004)
Applications: d'Orgeval & al. (2008)
Combines Prigent et al. Estimates and SAR observations.

Guimberteau et al., HESS, 2012
A new satellite-derived map of maximal fraction of floodplains and swamps

Maximal fraction within the mesh (%)

Guimberteau et al., HESS, 2012
A new satellite-derived map of maximal fraction of floodplains and swamps

Interannual variation of monthly water height index (m) on the Negro

Maximal fraction within the mesh (%)
Impact on the discharge at Óbidos

With GLWD map

Observations

With PRIMA map

With PRIMA map + $T_{fp}$ calibration

Nash: 0.40 → 0.80

Guimberteau et al., HESS, 2012
New soil carbon decomposition scheme

• Motivations
  – Current model (century) simple missing processes (i.e. priming)
  – Effect of temperature and moisture still relatively simple
New soil carbon decomposition scheme

• Motivations
  – Current model (century) simple, missing processes (i.e. priming)
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A NEW SOIL CARBON MODULE

- Discretized soil carbon (11 layers) + new pools introduced (DOC)

- New decomposition scheme (priming):

\[
\frac{\partial SOC}{\partial t} = I - k_{SOC} \times SOC \times (1 - e^{-c \times FOC}) \times \theta \times \tau
\]

<table>
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<th>Depth (mm)</th>
<th>For each layer</th>
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<tr>
<td>2000</td>
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</tbody>
</table>

For each layer:

- CO₂

Between layers:

- Decomposition
- Heterotrophic respiration
- (De) sorption
- Advection/liquid
- Diffusion/ Bioturbation

Runoff x DOC → → →

Drainage x DOC → → →
Impact of new scheme on total SOM

Soil Carbon stock (Gt C)

Global

New ORC
Old ORC

Modelled stock (Pg-C)

HWSD stock (Pg-C)

Slope = 0.95
NSD = 0.07
Pearson’s corr. = 0.95

Slope = 0.76
NSD = 0.09
Pearson’s corr. = 0.95

New World
Old World

As
N-Am
S-Am
Eu
Au

N-Am
S-Am
Eu
Au

New ORC
Old ORC
A new multi-layer energy balance scheme

• Why a multi-layer energy canopy scheme?

- Poorly represent site-level heat fluxes
- Canopy space and Trunk crown have different behaviours
- Under-storey vs over-storey representation?
- Link to atmospheric turbulence
Multi-layer scheme implementation

- Free number of layers
- E / W / C exchange at each level
- Turbulence mixing within air canopy
- Light penetration following Pgap model

Implementation constraints:
- Coupling with plant growth / harvesting module (variable plant height)
- Implicit coupling with Atmospheric model (30’ step)
- Parametrisation of intra-canopy turbulence

Ryder et al, GMD, 215
Site evaluation of the model

→ Availability of vertical profiles for Temp, Wind, Rh is crucial
Temperature profile at Tumbarumba site

Observations

Model

Ryder et al., GMD, 215
Multi-Layer Latent Heat Flux

Monthly average flux (months change from one site to the other)

Chen et al. In preparation
What can we learn from Data Assimilation?

- Optimization of ORC parameters
  - ✓ FluxNet data (70 sites)
  - ✓ ≈ 25 optimized parameters / PFT

- Parameter errors can be nearly as large as Structural errors
- Large param. error correlations
- Highlight model deficiencies

Cost function: \[ J(x) = \frac{1}{2} \left[ (y - M(x))^T R^{-1} (y - M(x)) + (x - x_b)^T P_b^{-1} (x - x_b) \right] \]

Puechabon Fluxnet site (2004)
Bacour et al. sub
Conclusion

• Soil physic (W, C, E), snow are critical..
• Escaping from the “big leaf” concept will be part of 3rd gen. LSMs.
• Parametrization are critical and may depend on scale considered.
• We need to better use data on plant traits and other ecological characteristics.
• Biogeochemistry & Biophysics should be developed together.
• Difficult to maintain coherence between various component!
Thanks for your attention.

ORCHIDEE
yesterday
(many branches)

ORCHIDEE
tomorrow
All developments into main Trunk