Improvements in the carbon cycle between the CMIP5 and CMIP6 versions of ISBA

SURFEXv7 - SURFEXv8
2013 - 2018

Christine Delire, Roland Séférian, Bertrand Decharme, Emilie Joetzjer, Ramdane Alkama (JRC, Ispra)
Summary of changes

**SURFEX7**

Fixed
3 surface & 9 plant functional types

- NPP
- GPP
- Ra
- turnover
- Rh
- NEP

**SURFEX8**

Time varying
3 surface & 16 plant functional types

- NPP
- GPP
- Ra
- turnover
- Rh
- NEP
- F\text{fire}
- F\text{leaching}

**C fluxes**
- to atmosphere
- to biosphere
- to ocean
Summary of changes

Vegetation distribution

• 16 plant functional types instead of 9 (+ bare soil, rock, permanent snow/ice)
• land-use / land cover changes: yearly input maps

Updated Processes on major biomes of the world

• ecophysiological observations for rainforest (E. Joetzjer PhD, 2014, Joetzjer et al, GMD, 2014-15)
• ecophysiological database, TRY, to update parameters for other PFTs

New processes

• C leaching from soil to river → ocean
• Natural fires

New processes in development

• New discretized soil C model, anaerobic decomposition, CH4 emissions, gas diffusion (X. Morel PhD, 2018, Morel et al, JAMES 2019)
• Agricultural systems (M. Rocher PhD, soon)
9 → 16 vegetation types  

1. No
2. Rock
3. Permanent Snow/ice

6. EVER -> TrBE Tropical Broadleaf Evergreen
7. C3 crop
8. C4 crop
9. C4 irrigated crop
11. TROG: Tropical grassland C4
12. PARK: Peat, Swamp, bog

4. TREE
16. BoBD: Boreal Broadleaf Deciduous trees
14. TeBE: Temperate Broadleaf Evergreen trees
19. SHRB: Shrub

5. CONI
5. BoNE Boreal Needleleaf Evergreen
15. TeNE Temperate Needleleaf Evergreen
17. BoND Boreal Needleleaf Deciduous

10. GRASS
10. C3 grassland
18. Boreal grass
Land use, land cover changes  

R. Séférian

- Net land cover changes derived from the Land-Use Harmonized datasets (*Hurtt et al. 2006*) (LUH2.0h, [http://luh.umd.edu/data.shtml](http://luh.umd.edu/data.shtml))

- Yearly time step

- Net land-cover changes only

- Projection on ISBA PFTs:
  - Ecoclimap fraction of rock and permanent ice mostly unchanged
  - LUH2.0h C3 and C4 crops → directly ISBA C3 and C4 PFTs
  - LUH2.0h anthropogenic pasture and rangeland → grasslands and shrubs for ISBA
  - other PFTs (forested areas) scaled using remaining fraction of land as given by LUH2.0h and partition between PFTs from ECOCLIMAP.
Land use, land cover changes  

R. Séférian
Updated processes / parameters

<table>
<thead>
<tr>
<th>All PFTs</th>
</tr>
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</table>
| $N_m$ (leaf nitrogen content) | TRY
| ($Kattge et al., 2011$) |
| $SLA$ (specific leaf area index at reference CO2) | TRY |
| $g_{mes}$ (unstressed mesophyll conductance) | $V_{c,max}^*$ TRY, ($Kattge et al., 2009$) |
| $A_{m,max}$ (max assimilation rate) | $V_{c,max}^*$ TRY |

* Comparison Farquhar / Jacob photosynthesis models:
  
  $g_{mes} = $ initial slope of Rubisco limited assimilation rate in Farquhar 1980
  
  $A_{m,max} = 0.5 * V_{c,max}$
Updated processes / parameters

- Leaf respiration: exponential decrease in canopy (Bonan et al., 2011)
- Sapwood respiration: added (Kucharik et al., 2000)

For TrBE only:
- $f_0$: unstressed ratio of intracellular to air CO2 (Domingues et al., 2013)
- Soil moisture stress: simplified
New processes:

a) Carbon-leaching module, Dissolved Organic Carbon

Motivation: C input to ocean

Hyp: 1. fraction of organic matter dissolved in water during decomposition
   -> DOC controlled by same factors as decomposition: T, wg (CENTURY)

2. DOC is transported by rivers (no transformation)
New processes:
b) Natural fire module

Krinner et al, 2005; Thonicke et al 2001
Simulated carbon cycle

<table>
<thead>
<tr>
<th>Forcings</th>
<th>SURFEX7</th>
<th>SURFEX8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CRU-NCEP 1901-2016</td>
<td>(Viovy et al, 2018)</td>
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<td>CRU-JRA v1.1</td>
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<td>observed</td>
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<td>CO2</td>
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<tr>
<td>Land use change</td>
<td>ECOCLIMAP</td>
<td>LUHv2.0</td>
</tr>
<tr>
<td>Physics</td>
<td>Soil : DIF (14 layers)</td>
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<td></td>
<td>Snow : ES (12 layers)</td>
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<td>Hydrology : aquifers</td>
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</tbody>
</table>

Spin up: 550 years, 400 with numerical acceleration of soil carbon module
forcing = 1901-1920 recycled
CO2: 286.4 ppmv

Resolution: 1° x 1°

Results: mean values for last 30 years (depending on observed data)
FluxComV1 (Jung et al, 2017; Tramontana et al., 2016)

Photosynthesis

GPP

SURFEX7

SURFEX7 - OBS

SURFEX8

SURFEX8 - OBS

SURFEX8 - SURFEX7

SURFEX8-J – SURFEX8
Net Photosynthesis

MODIS17A3 (Zhao et al, 2015; )

SURFEX7

SURFEX8

SURFEX8 - OBS

SURFEX7 - OBS

SURFEX8 - SURFEX7

NPP
Average seasonal cycle of LAI
Aboveground biomass

ABC
(Liu et al, 2015)

SURFEX7

SURFEX8

SURFEX8 - OBS

SURFEX7 - OBS

SURFEX8 - SURFEX7
Global database
(Holland et al, 2015)

SURFEX7

SURFEX8

Aboveground litter

Belowground litter

Active C

Slow C

Total Aboveground Litter [g C m²]

0 0.5 1 1.5 2 3 4 5 6 8 10
**HWSD**
*(FAO/IIASA, JRC 2012)*

### Soil Carbon

<table>
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<th>aboveground litter</th>
<th>Active C</th>
<th>Slow C</th>
<th>Passive C</th>
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<tbody>
<tr>
<td>Belowground litter</td>
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#### Belowground litter
- [SURFEX7](#)
- [SURFEX8](#)

#### Aboveground litter
- [SURFEX7](#) - OBS
- [SURFEX8](#) - OBS
- [SURFEX8](#) - SURFEX7

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*Mobilization fractions*

Br. Irmler, 1982

- *Active C*
- *Slow C*
- *Passive C*

- *Aboveground litter*
- *Belowground litter*
Dissolved Organic Carbon

GlobalNEWS2
(Mayorga et al, 2010)
Burnt fraction

(Mouillot and Field, 2005)
Conclusion

16 Plant functional types

NPP

GPP

Ra

F_{\text{fire}}

F_{\text{leaching}}

F_{\text{fu}}

Rh

NEP

turnover

16 Plant functional types
9 → 16 vegetation types  R. Alkama
FluxComV1
(Jung et al, 2017; Tramontana et al., 2016)

ISBA: \[ \text{DOC}_{\text{lit}} = f_1(T_1) \times f_2(w_1) \times \text{mobil} \times \max(\text{fsat, fflood}) / \tau_{\text{lit}} \]

\[ \text{DOC}_{\text{soilc}} = f_1(T_2) \times f_2(w_2) \times \text{mobil} \times \text{fsat} / \tau_{\text{soilc}} \]

\[ f_1, f_2, \tau_{\text{lit}}, \tau_{\text{soilc}} \text{ from CENTURY, mobil} = 0.005 \text{ (Irmler, 1982)} \]

River transport model: CTRIP. Hyp: no modification of DOC
### Updated processes / parameters

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﻿using exponential decrease in canopy (Bonan et al, 2011)

| $g_{mes}$= initial slope of Rubisco limited assimilation rate in Farquhar 1980 |
| $Am_{max} = 0.5 \times V_{c_{max}}$ |
Leaf Area Index

LAI3g (MODIS) (Zhu et al, 2013)

Mean peak LAI

SURFEX7

SURFEX8

SURFEX7 - OBS

SURFEX8 - OBS

SURFEX8 - SURFEX7