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

SURFEXv7 - SURFEXv8

2013 - 2018

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Ramdane Alkama (JRC, Ispra)

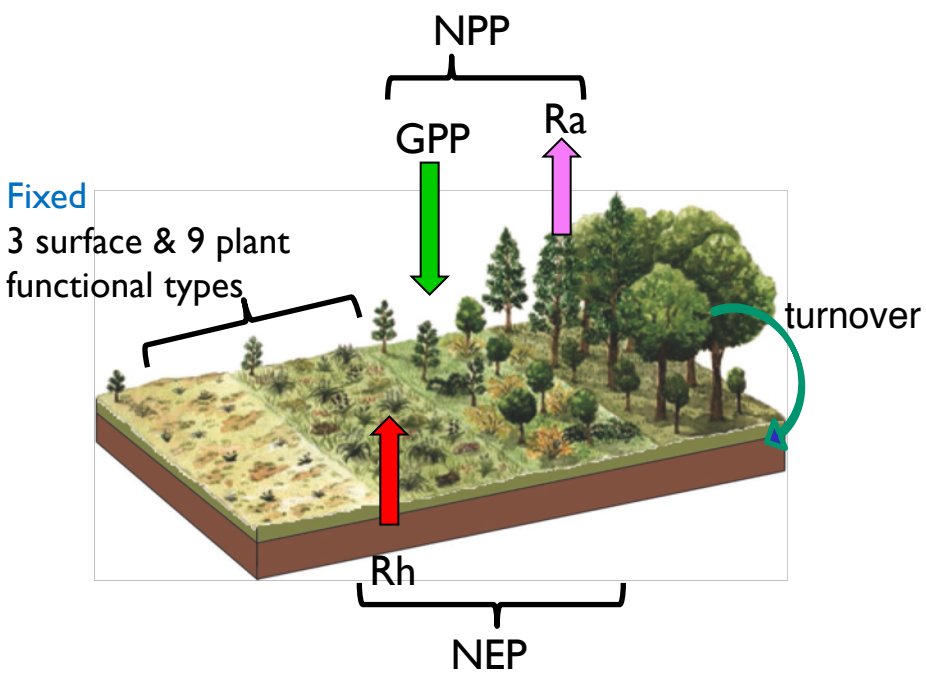
Summary of changes

C fluxes to atmosphere

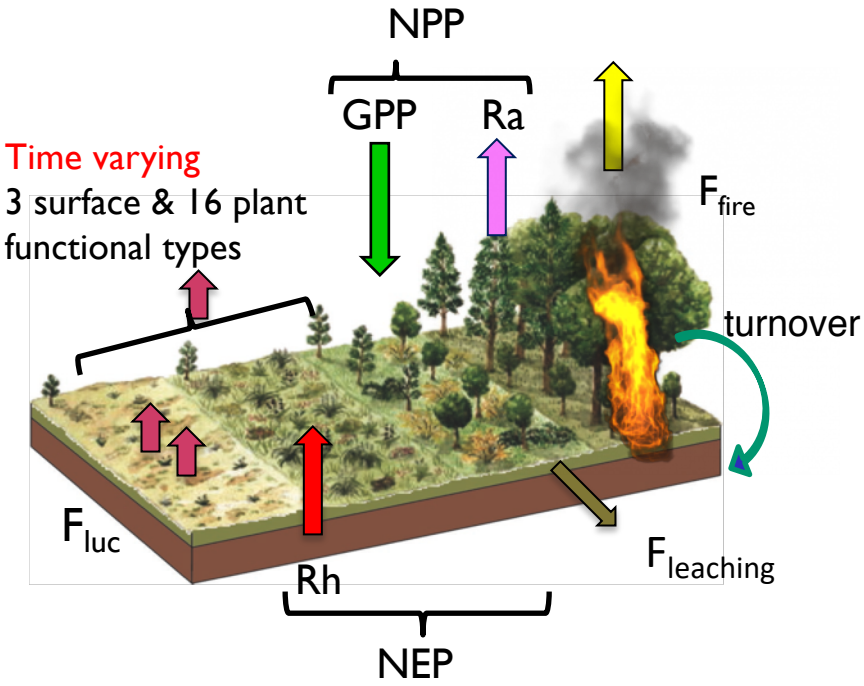
C fluxes to biosphere

C flux to ocean

SURFEX7



SURFEX8



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 *R. Alkama*

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
	4. TeBD : Temperate Broadleaf Deciduous trees
	13. TrBD : Tropical 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*

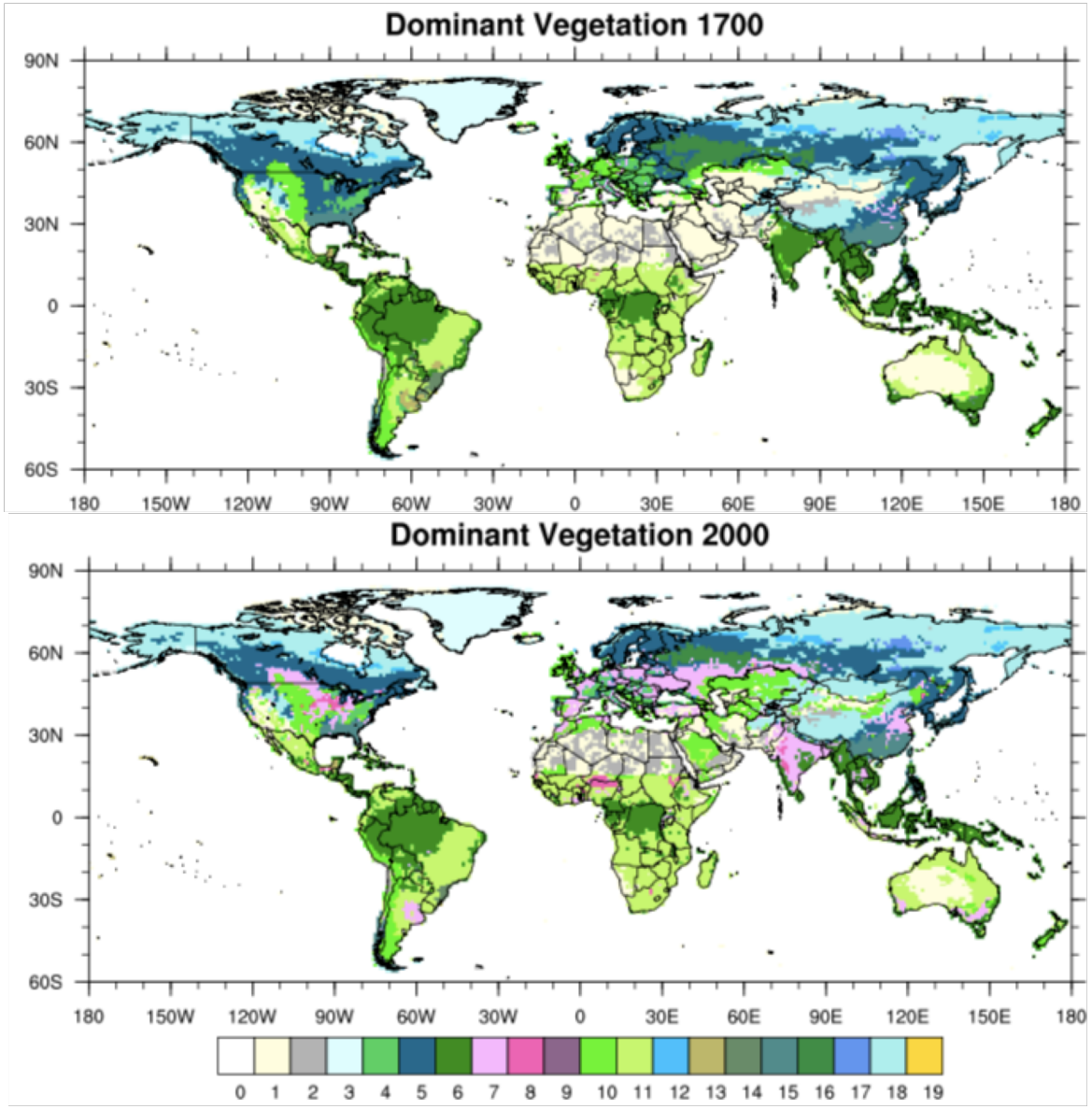
- Net land cover changes derived from the Land-Use Harmonized datasets *(Hurtt et al. 2006)*
  (LUH2.0h, http://luh.umd.edu/data.shtml)

- 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.

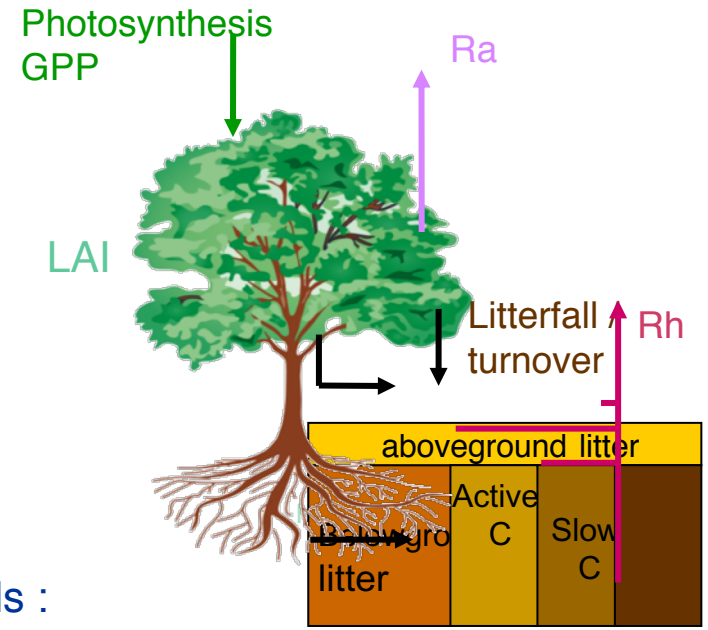
Land use, land cover changes *R. Séférian*



Updated processes / parameters

All PFTs

Nm (leaf nitrogen content)	TRY *(Kattge et al., 2011)*	LAI
SLA (specific leaf area index at reference CO2)	TRY	LAI
gmes (unstressed mesophyll conductance)	*Vcmax** TRY, *(Kattge et al., 2009)*	GPP photosynthesis
Am,max (max assimilation rate)	*Vcmax** TRY	GPP photosynthesis

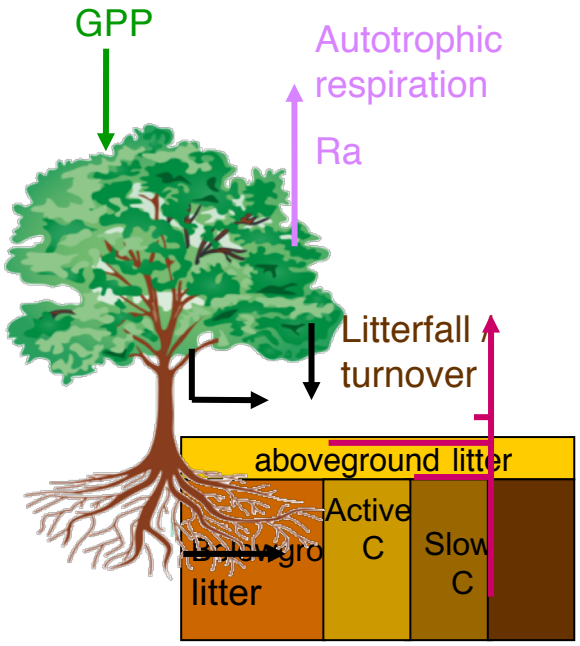


* Comparison Farquhar / Jacob photosynthesis models :

gmes = initial slope of Rubisco limited assimilation rate in Farquhar 1980

Am,max = 0.5 * *Vcmax*

Updated processes / parameters



All trees

leaf respiration	exponential decrease in canopy (*Bonan et al, 2011*)
sapwood respiration	added (*Kucharik et al, 2000*)

Ra

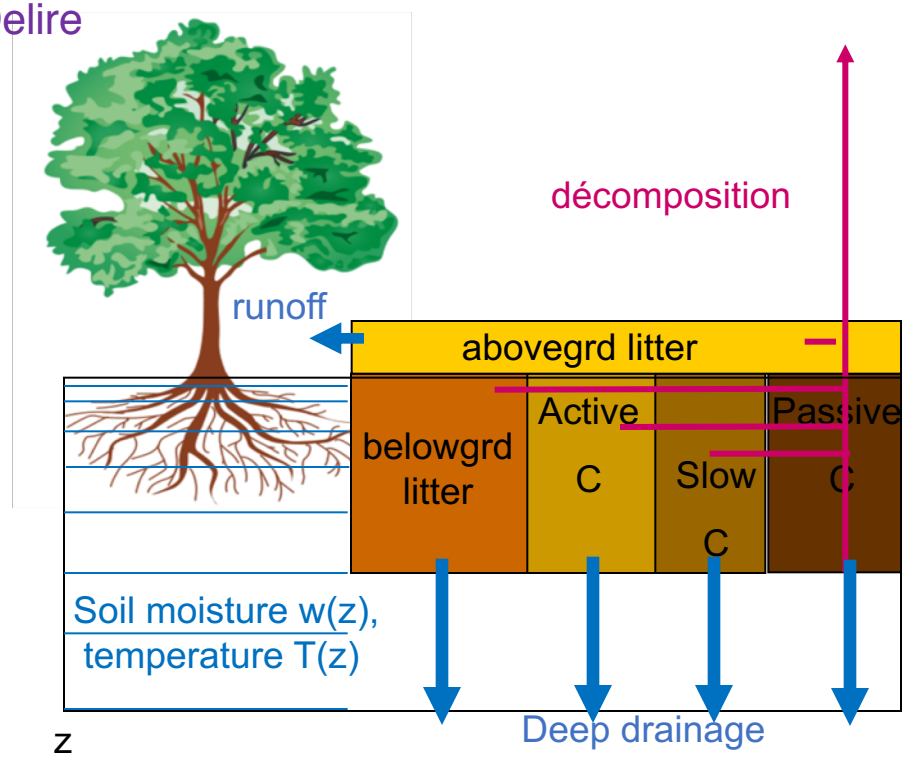
TrBE only

f0 unstressed ratio of intracellular to air CO2	*Domingues et al, 2013*
soil moisture stress	simplified

New processes :
a) Carbon-leaching module, Dissolved Organic Carbon

R. Séférian, F. Guérin, B. Decharme, C. Delire

Motivation : C input to ocean



Hyp: 1. fraction of organic matter dissolved in water during decomposition

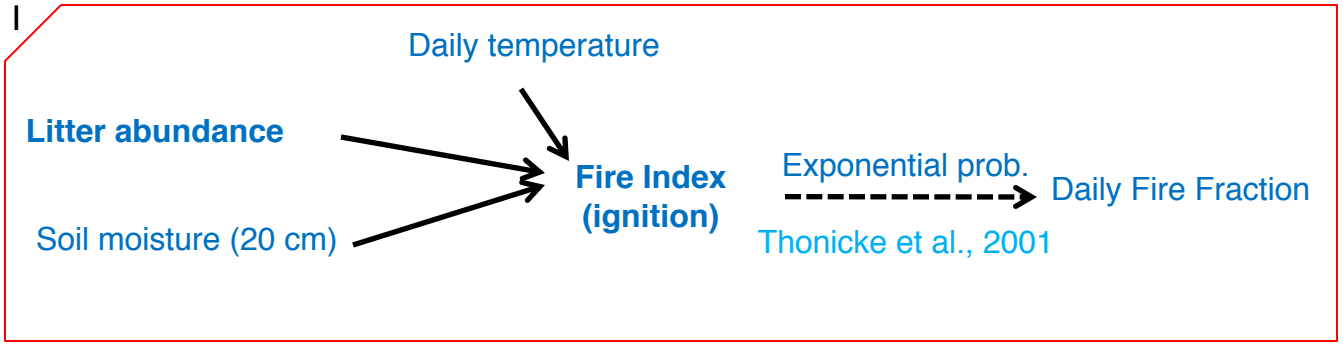
-> DOC controlled by same factors as decomposition : T, wg (CENTURY)

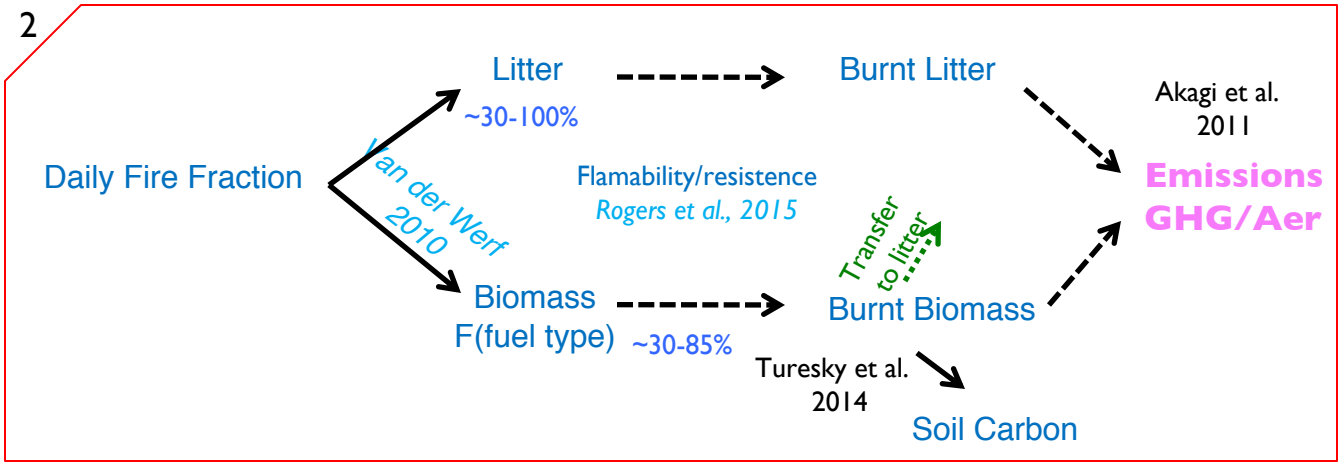
2. DOC is transported by rivers (no transformation)

New processes :
b) Natural fire module

R. Séférian & Internship C Porchier & S Jalladeau (2015)

Krinner et al, 2005; Thonicke et al 2001





Simulated carbon cycle

	SURFEX7	SURFEX8
Forcings :	CRU-NCEP 1901-2016 *(Viovy et al, 2018)*	CRU-JRA v1.1
CO2 :	observed	
Land use change :	ECOCLIMAP	LUHv2.0
Physics	Soil : DIF (14 layers) Snow : ES (12 layers) Hydrology : aquifers	

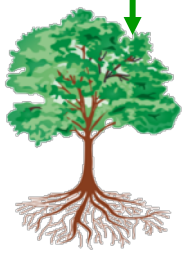
Spin up : 550 years, 400 with numerical acceleration of soil carbon module
forcing = 1901-1920 recycled
CO2 : 286.4 ppmv

Resolution : 1° x 1°

Results : mean values for last 30 years (depending on observed data)

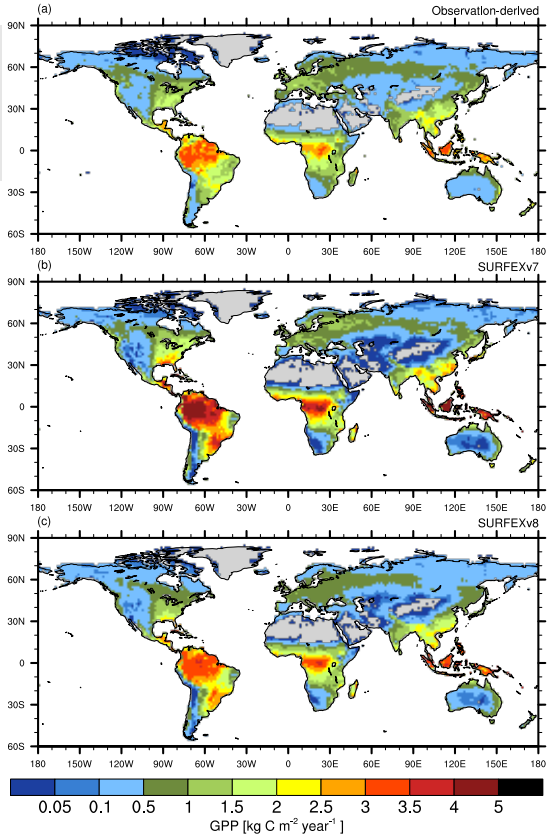
Photosynthesis

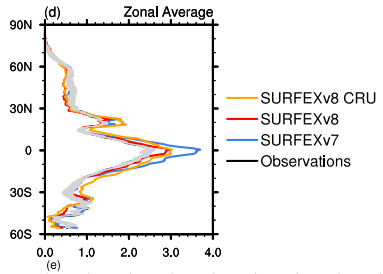
GPP



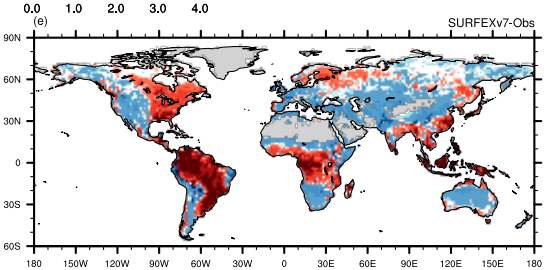
FluxComV1

(Jung et al, 2017; Tramontana et al., 2016)



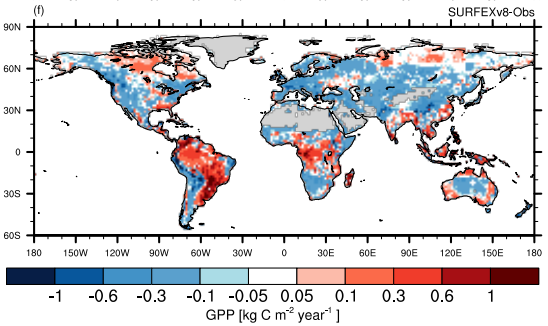


SURFEX7



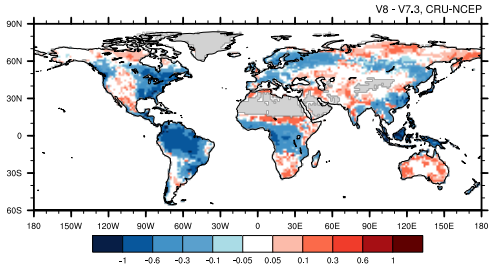
SURFEX7 - OBS

SURFEX8

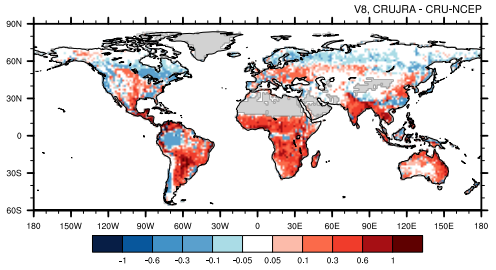


SURFEX8 - OBS

SURFEX8 - SURFEX7

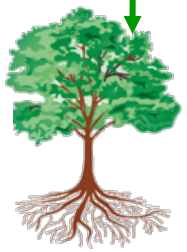


SURFEX8-J – SURFEX8



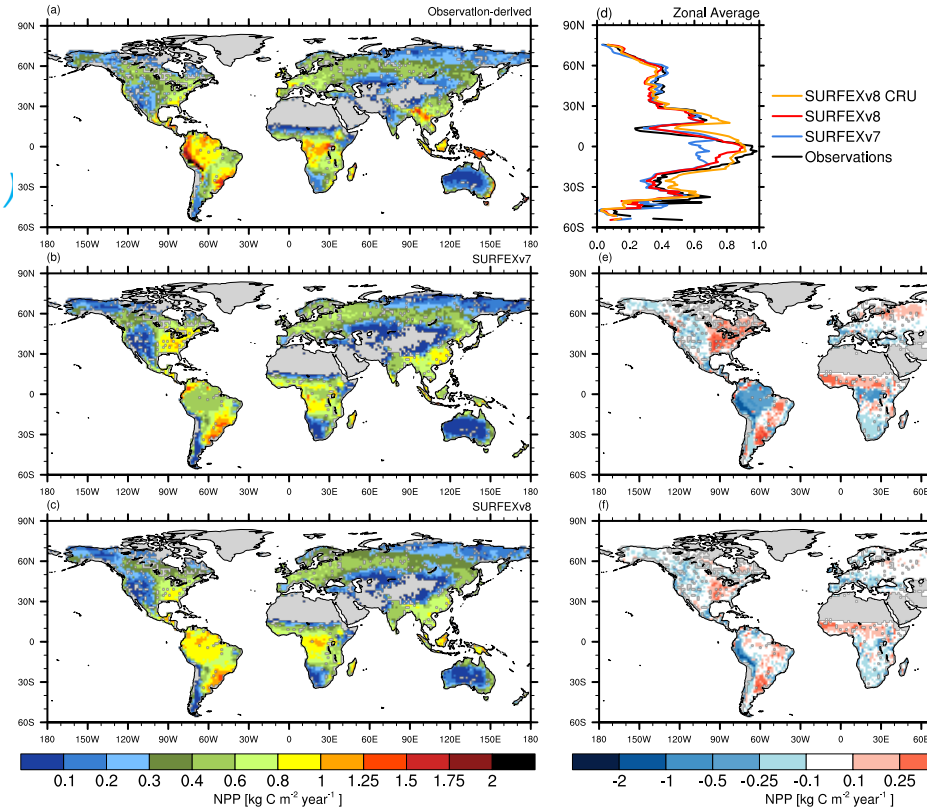
Net Photosynthesis

NPP



MODIS17A3

(Zhao et al, 2015;)

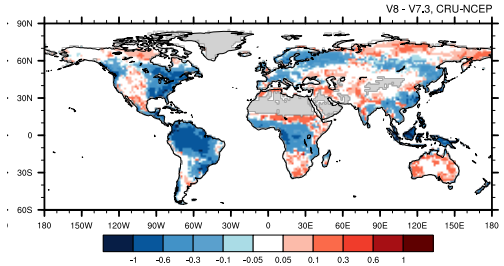


SURFEX7

SURFEX7 - OBS

SURFEX8

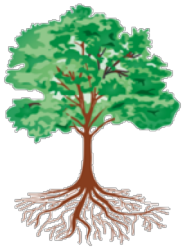
SURFEX8 - OBS



SURFEX8 - SURFEX7

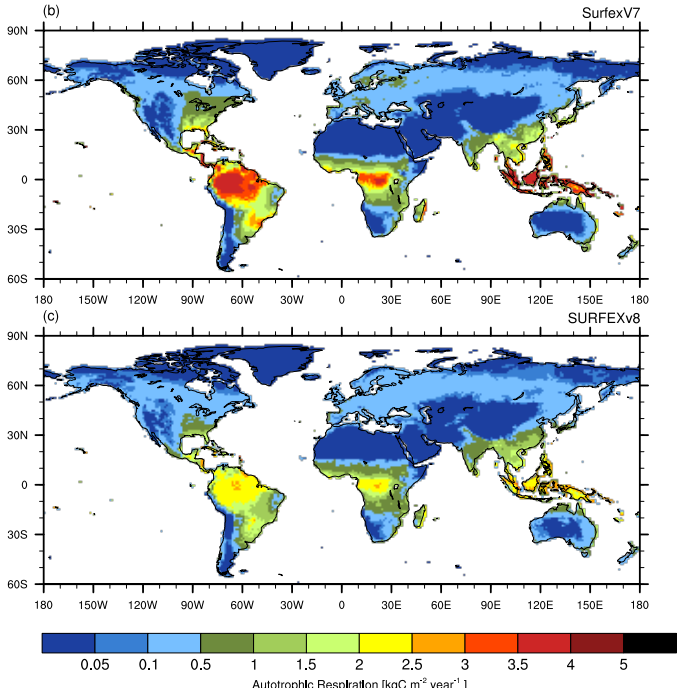
autotrophic respiration

Ra

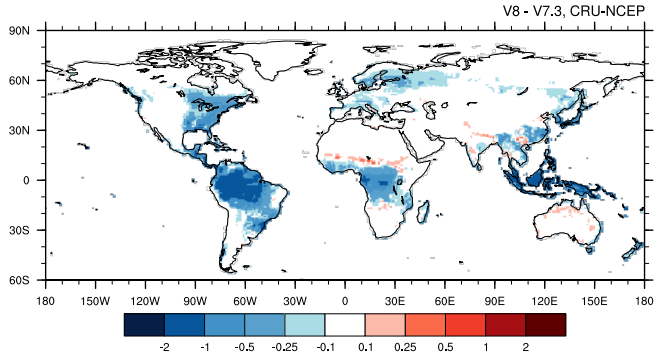


SURFEX7

SURFEX8



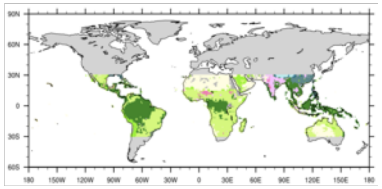
SURFEX8 - SURFEX7

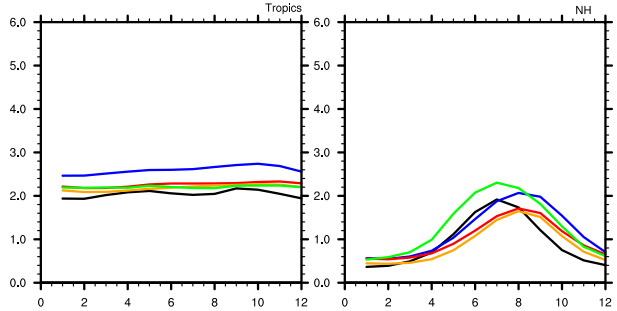


Average seasonal cycle of LAI

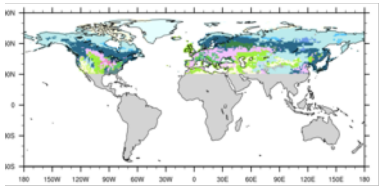
MODIS (LAI3g)
ECOCLIMAP
SURFEX7
SURFEX8
SURFEX8-J

Tropics

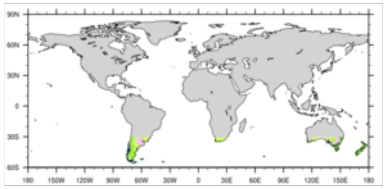


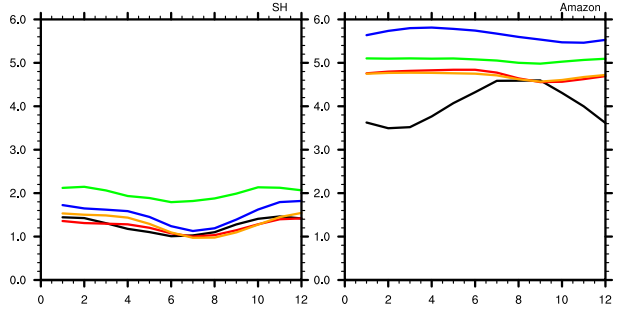


N Hem

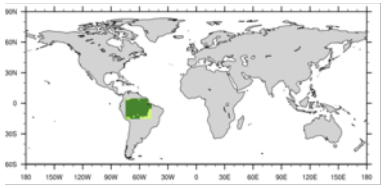


S Hem

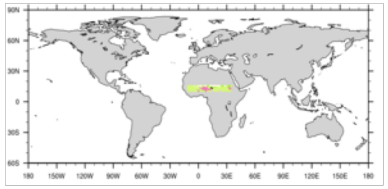


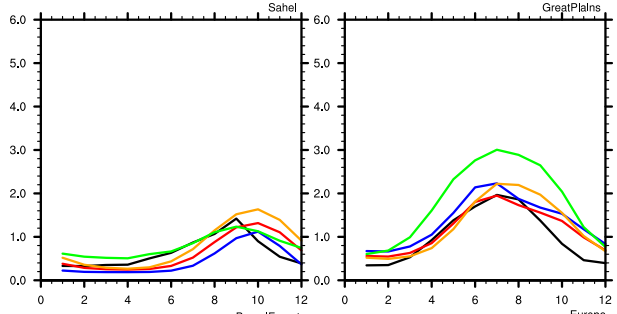


Amazon

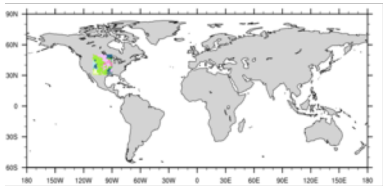


Sahel

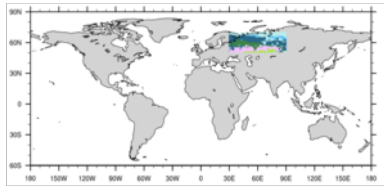


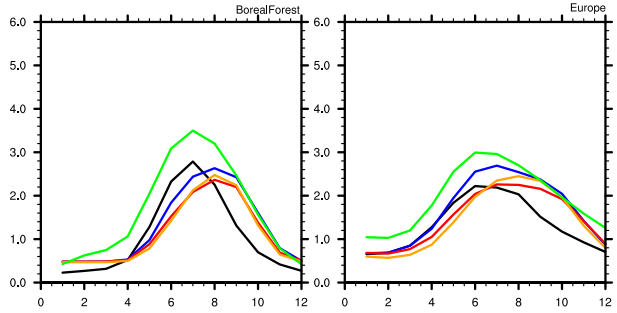


Great Plains

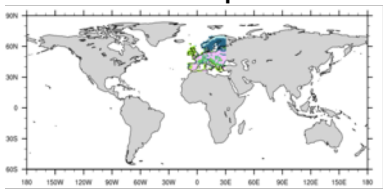


Boreal forest

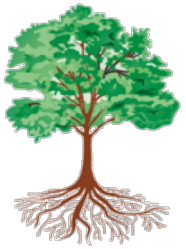




W Europe



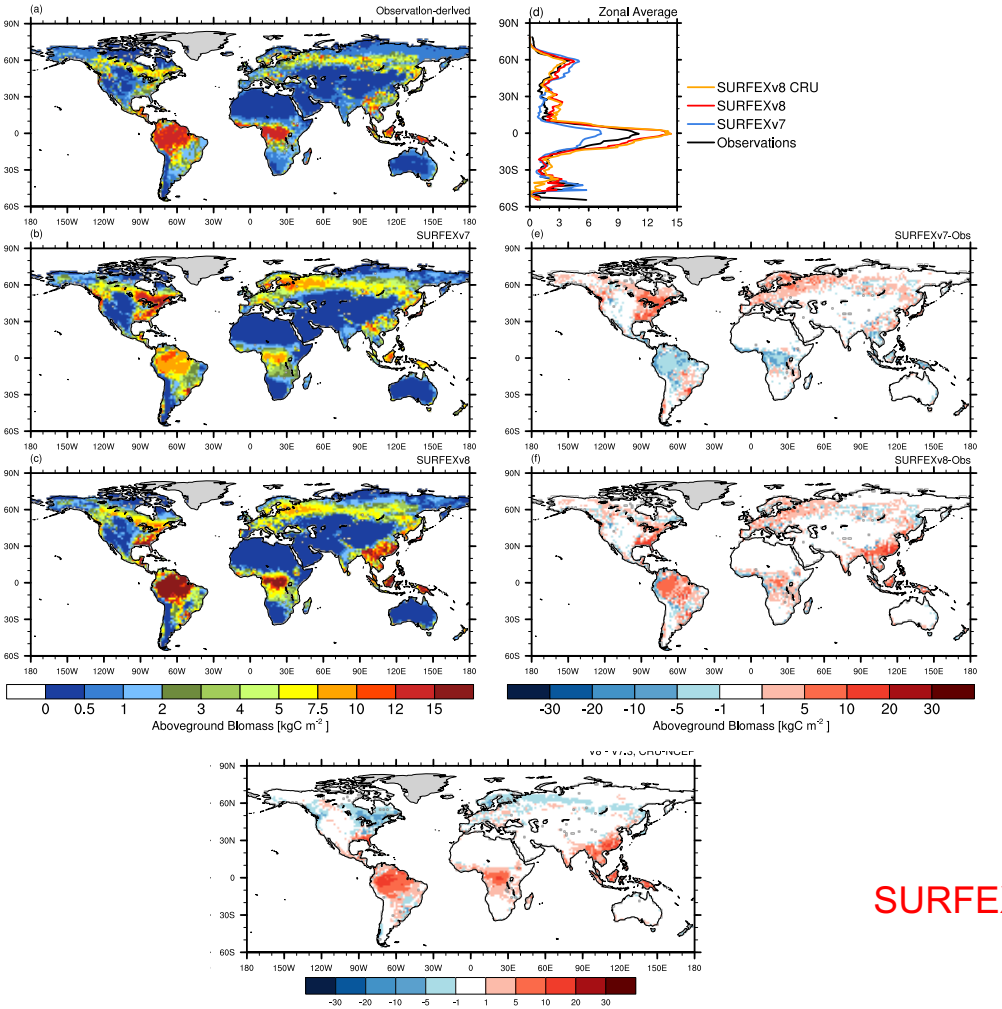
Aboveground biomass



ABC
(Liu et al, 2015)

SURFEX7

SURFEX8

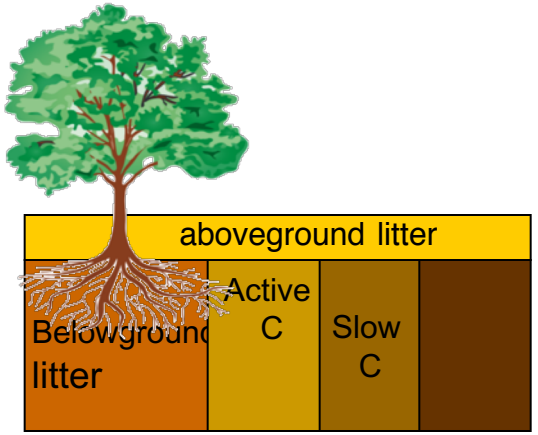


SURFEX7 - OBS

SURFEX8 - OBS

SURFEX8 - SURFEX7

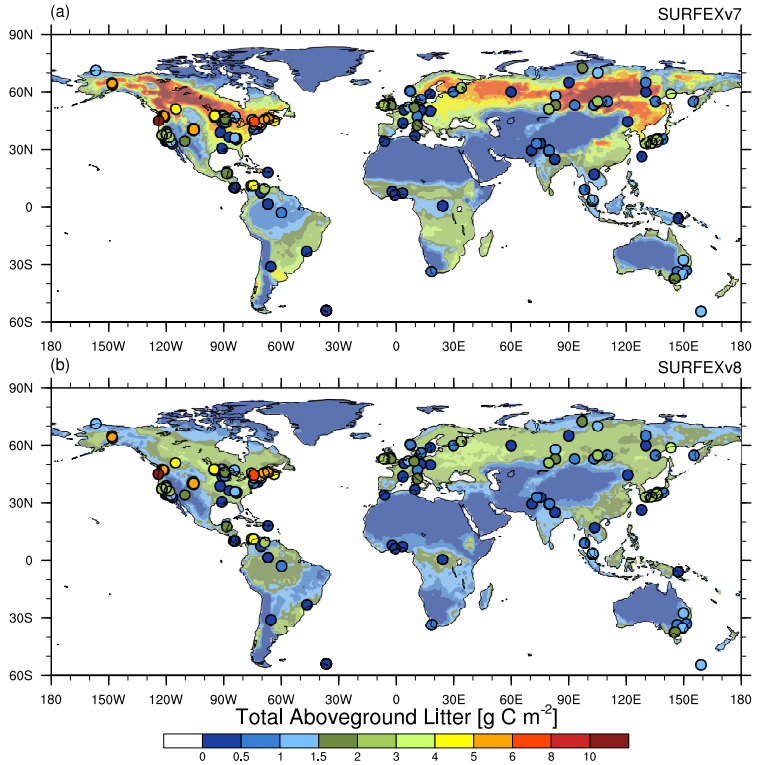
Aboveground litter



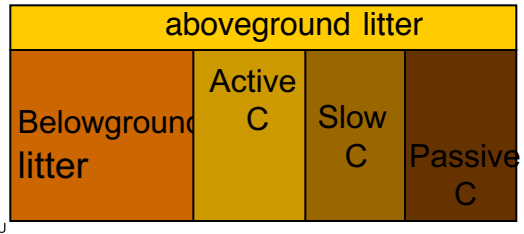
Global database
(Holland et al, 2015)

SURFEX7

SURFEX8



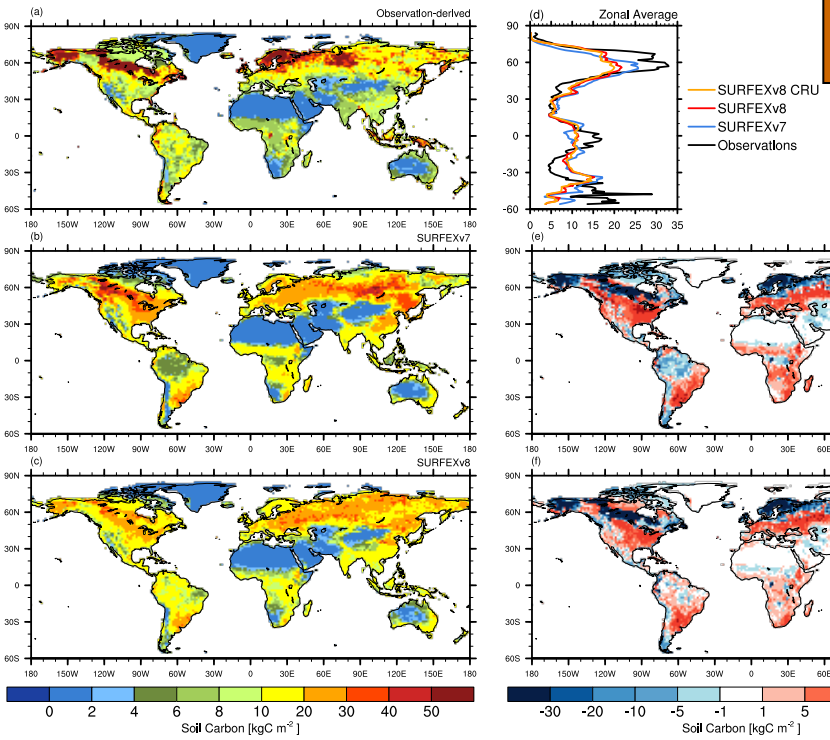
Soil Carbon



HWSD
(FAO/IIASA, JRC 2012)

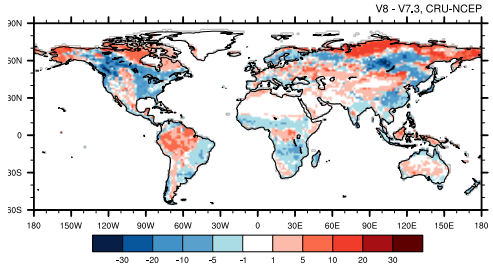
SURFEX7

SURFEX8



SURFEX7 - OBS

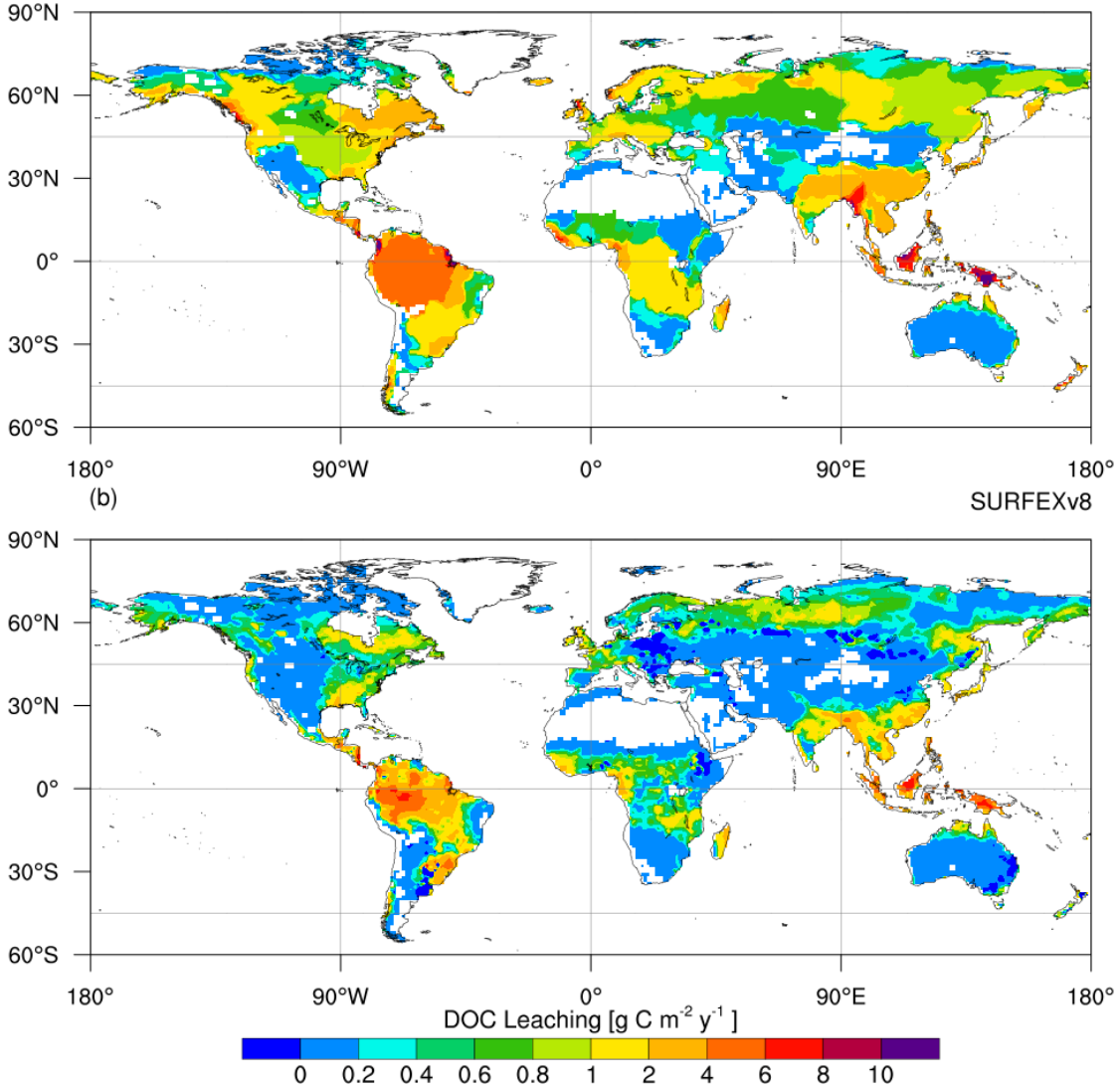
SURFEX8 - OBS



SURFEX8 - SURFEX7

Dissolved Organic Carbon

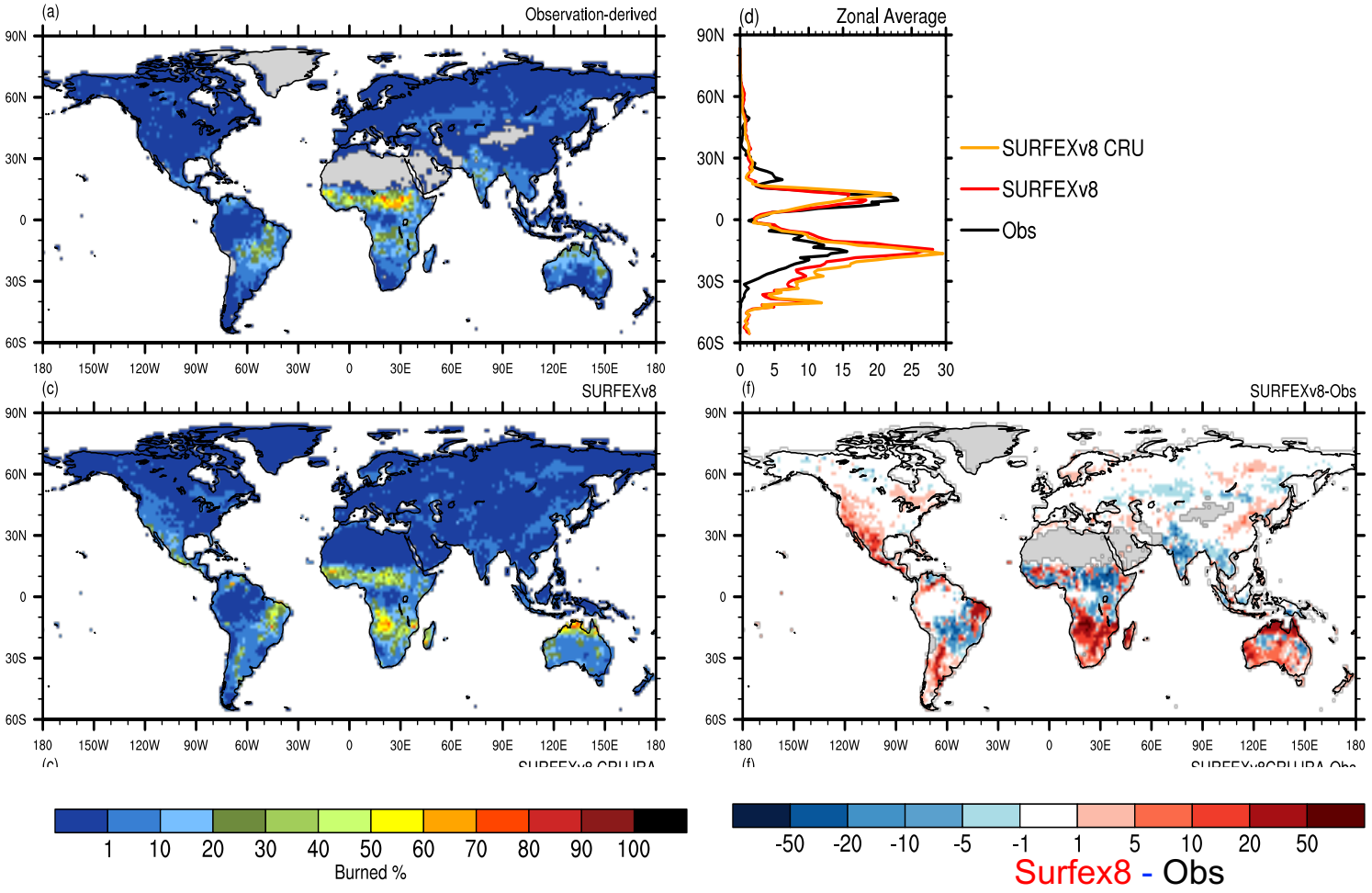
GlobalNEWS2
(Mayorga et al, 2010)



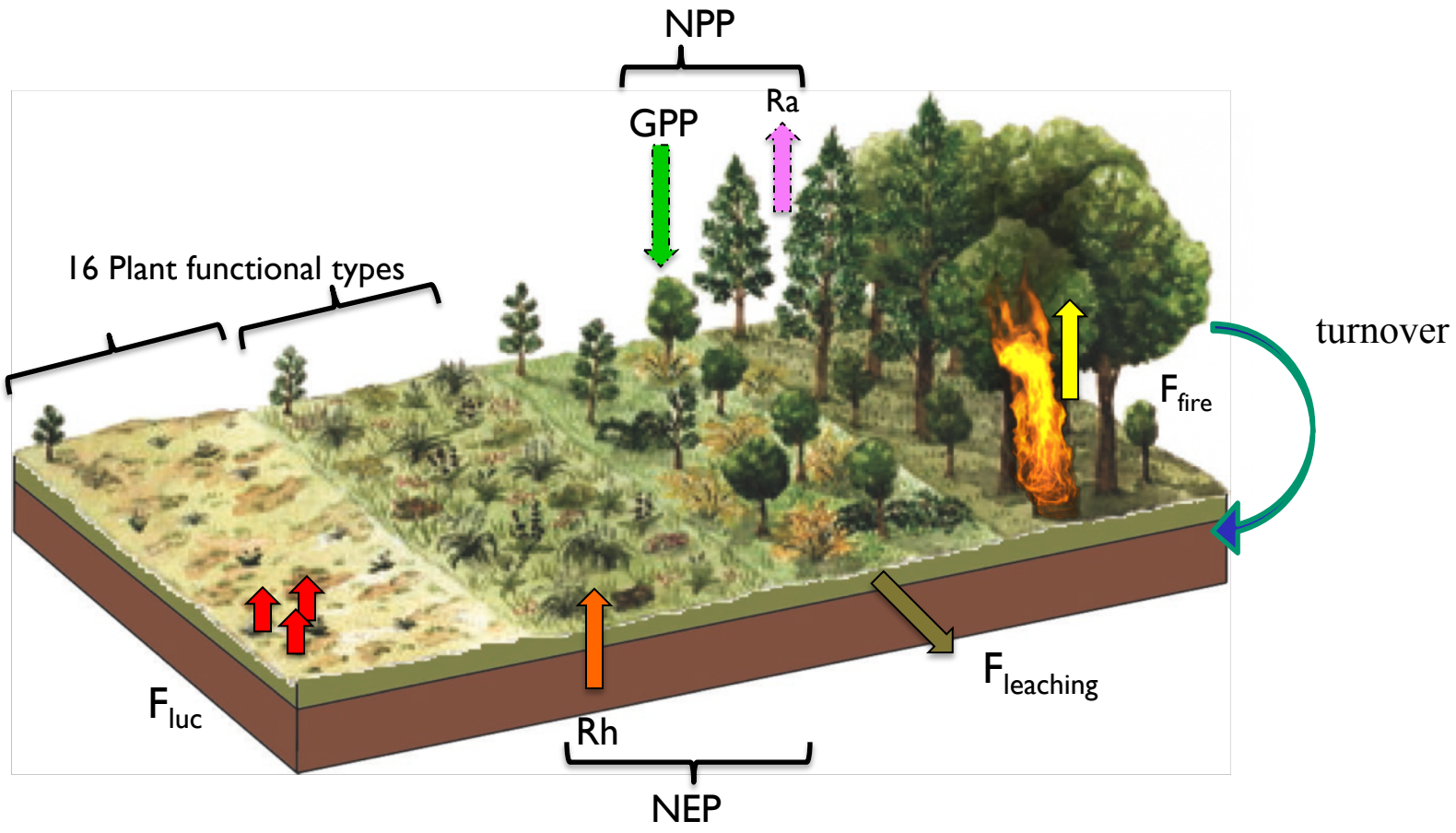
Burnt fraction

(Mouillot and Field, 2005)

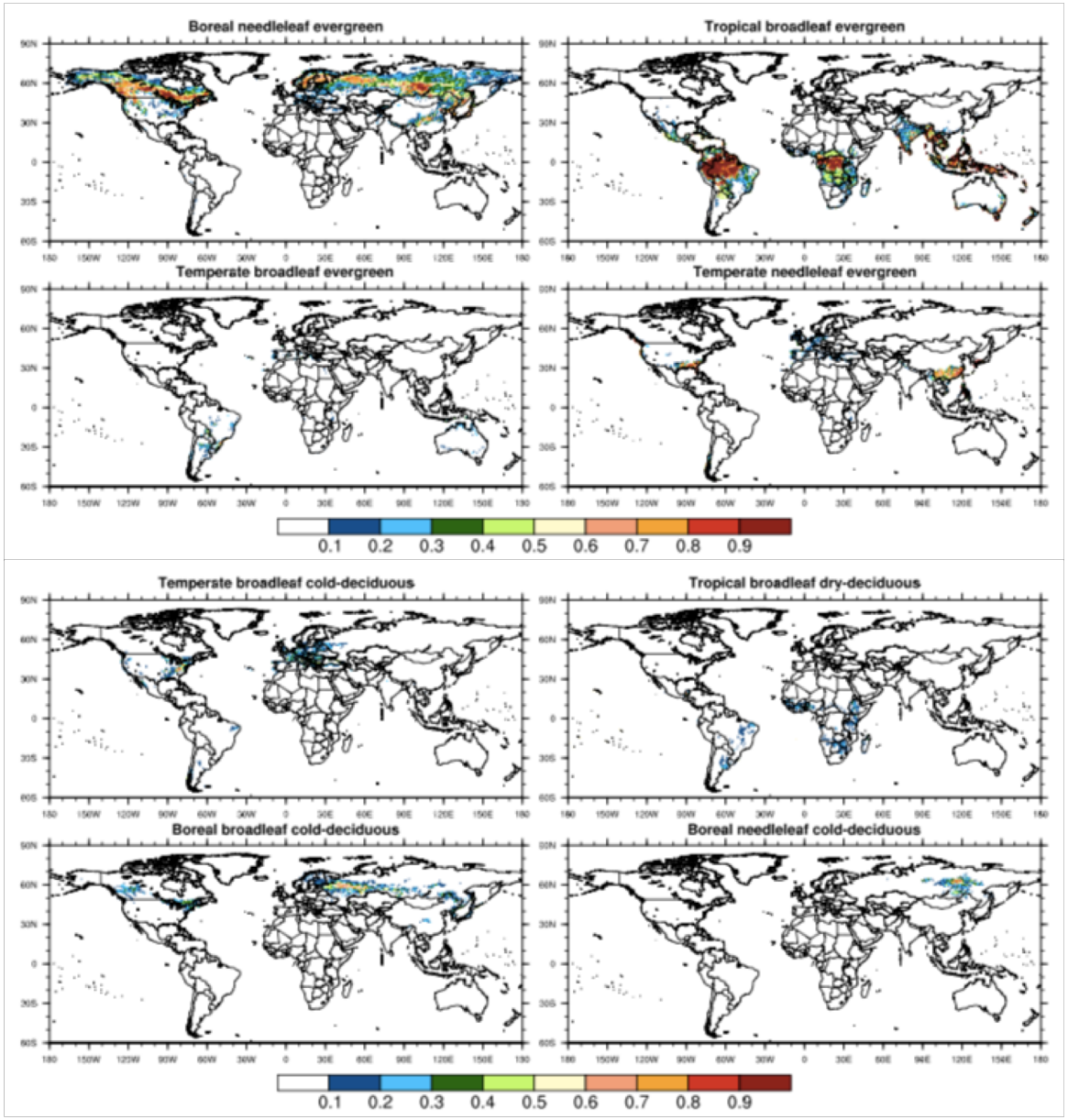
SURFEX8



Conclusion

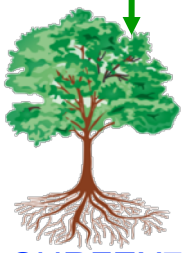

NPP
GPP
Ra
16 Plant functional types
turnover
F_{fire}
F_{luc}
Rh
$F_{leaching}$
NEP

9 → 16 vegetation types *R. Alkama*



FluxComV1
(Jung et al, 2017; Tramontana et al., 2016)

Photosynthesis
GPP



SURFEX7

SURFEX7 - OBS

SURFEX8

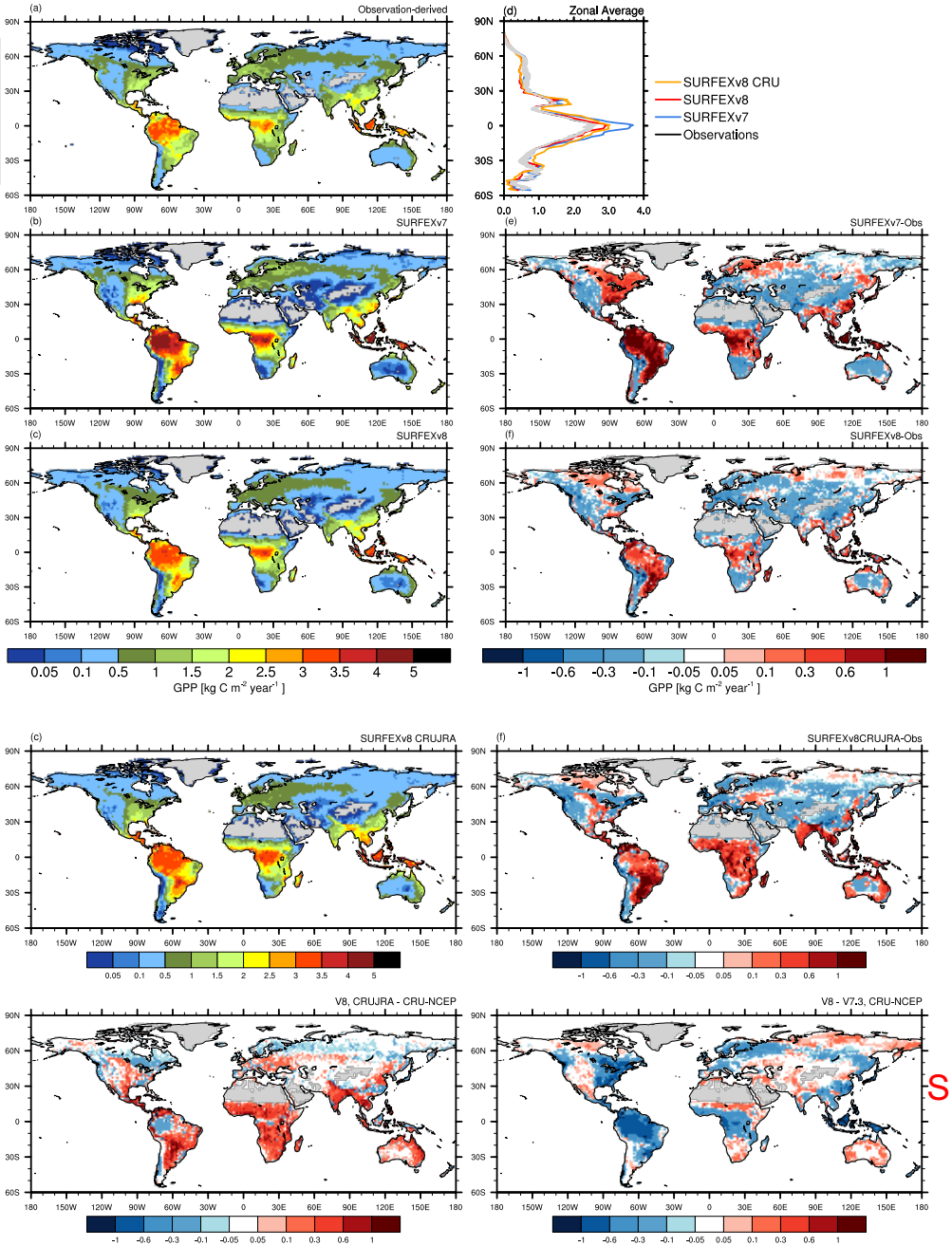
SURFEX8 - OBS

SURFEX8- J

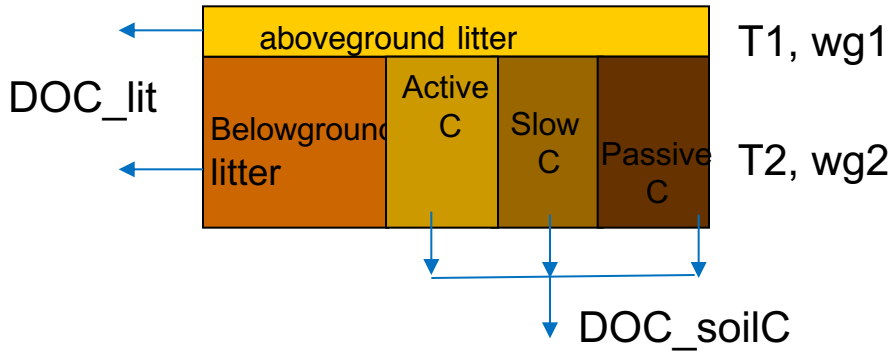
SURFEX8-J - OBS

SURFEX8-J – SURFEX8

SURFEX8 - SURFEX7



New processes : a) Carbon-leaching module, Dissolved Organic Carbon



ISBA : DOC_lit = f1(T1) *f2(w1) * mobil * max(fsat, fflood) / tau_lit

DOC_soilc = f1(T2) *f2(w2) * mobil * fsat / tau_soilc

f1, f2, tau_lit, tau_soilc from CENTURY, mobil = 0.005 (Irmler, 1982)

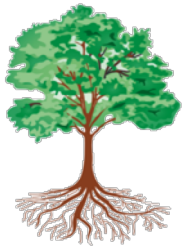
River transport model : CTRIP. Hyp: no modification of DOC

Updated processes / parameters

All PFTs	*Nm* (leaf nitrogen content)	TRY *(Kattge et al., 2011)*	LAI
	SLA (specific leaf area index at reference CO2)	TRY	LAI
	gmes (unstressed mesophyll conductance)	*Vcmax** TRY, *(Kattge et al., 2009)*	GPP photosynthesis
	Am,max (max assimilation rate)	*Vcmax** TRY	GPP photosynthesis
All trees	leaf respiration	exponential decrease in canopy (*Bonan et al, 2011*)	Ra
	sapwood respiration	added (*Kucharik et al, 2000*)	Ra
TrBE only	*f0* unstressed ratio of intracellular to air CO2	*Domingues et al, 2013*	
	soil moisture stress	simplified	

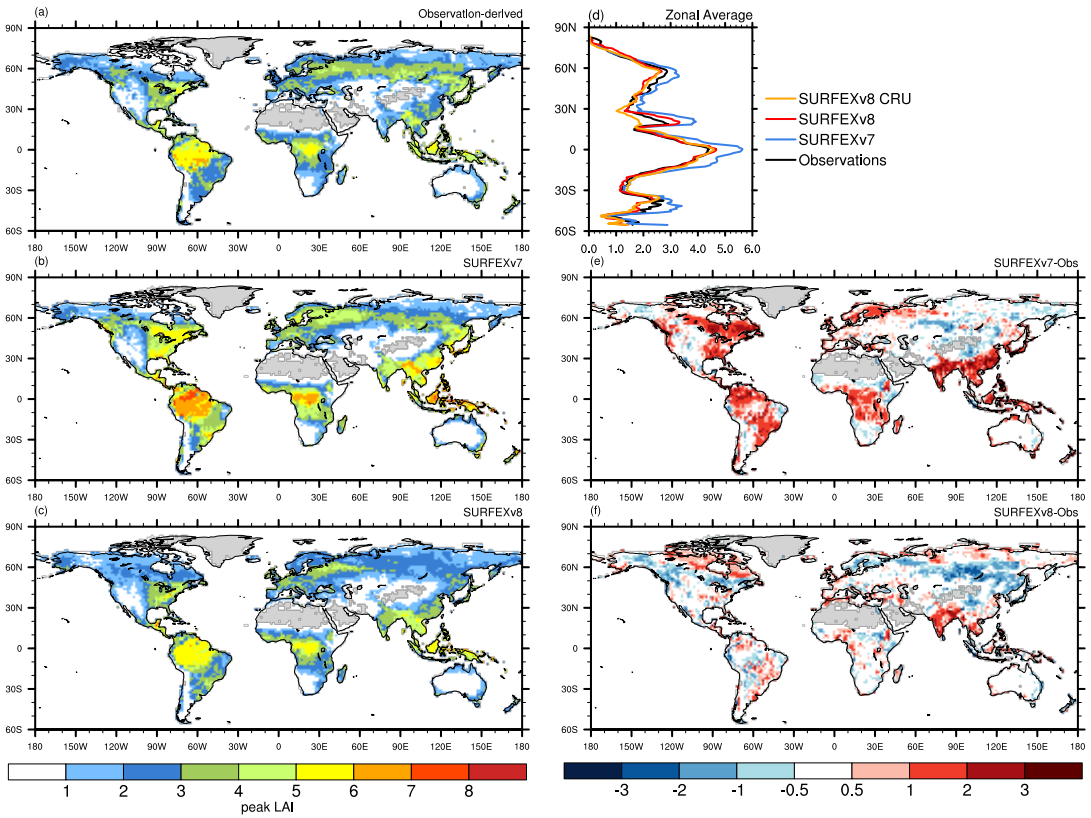
* Comparison Farquhar / Jacob photosynthesis models :
gmes = initial slope of Rubisco limited assimilation rate in Farquhar 1980
Am,max = 0.5 * *Vcmax*

Leaf Area Index



Mean peak LAI

LAI3g (MODIS)
(Zhu et al, 2013

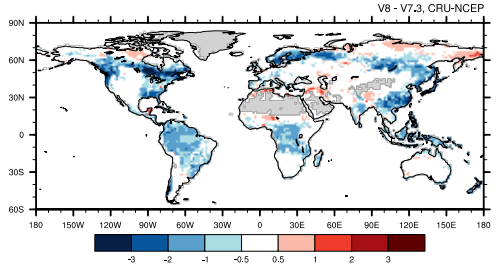


SURFEX7

SURFEX7 - OBS

SURFEX8

SURFEX8 - OBS



SURFEX8 - SURFEX7