Integration of Fire and Land Cover CCI products into MPI ESM model

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with contributions from the JSBACH Team in Hamburg

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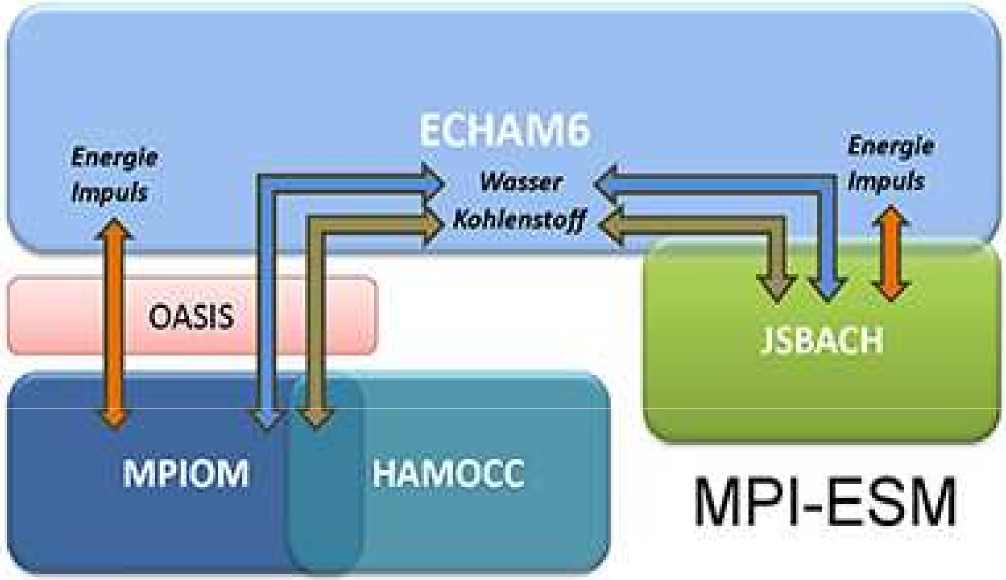
MPI-M ESM



Possible model set-ups:

a) Offline: land model, driven by observations or reanalysis climate data,

b) Partly coupled: land&atmosphere driven by model simulations,

c) Fully coupled:land&atmosphere& ocean

The MPI-ESM consist of

- Atmospheric model ECHAM6,

- The Ocean model MPIOM + ocean Biogeochemistry model HAMMOCC,

- Land-Biosphere model JSBACH (land carbon and nitrogen cycle, surface albedo, dynamic vegetation, fires)

- OASIS3 is the interface between the Ocean and Atmopshere

- Land and Atmosphere are coupled directly over water, energy & carbon (in CO2?) fluxes.

Fire CCI

Integration of the CCI Fire pre-curser dataset (GFEDv3) into the land model JSBACH

JSBACH - Jena Scheme for Biosphere-Atmosphere Coupling in Hamburg (JSBACH)

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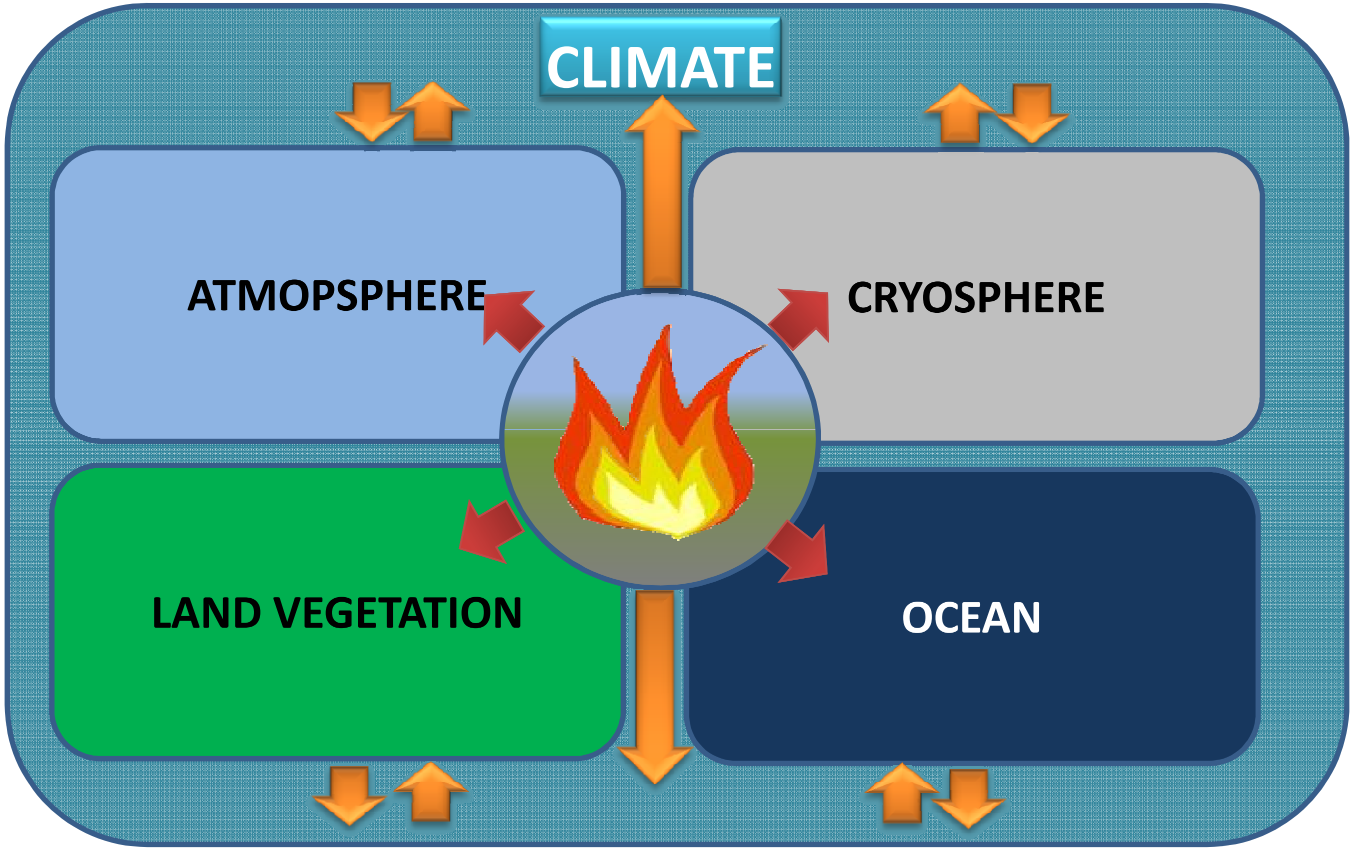
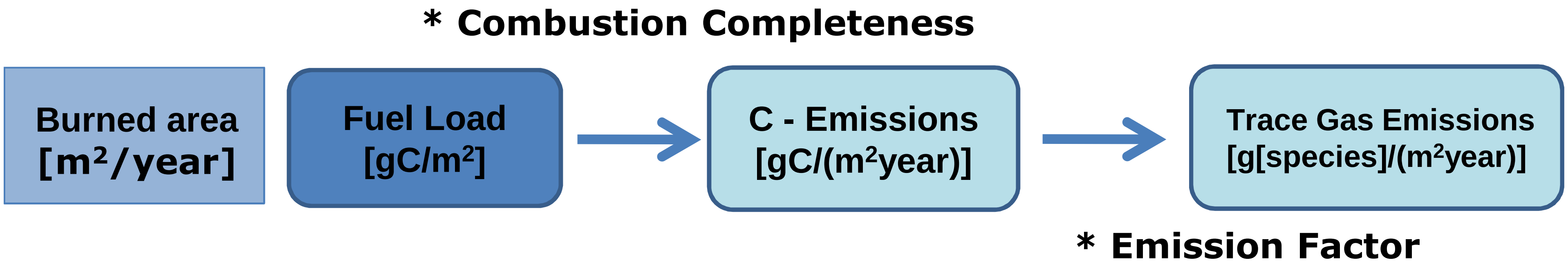
FIRES IN THE EARTH SYSTEM



At a global scale, changing levels of fire emissions influence 8 out of the 13 radiative forcing terms identified in the IPCC 4th Assessment (Bowman et al., 2009).

FIRE MODEL: CARBON EMISSIONS



- **Burned area**
  (a) simulated dynamically with a fire model implemented in a vegetation model
  (b) **prescribed as boundary condition from observations in a vegetation model**

- **Fuel Load (Biomass available for burning)**
  (a) **simulated dynamically within a vegetation model**
  (b) prescribed from observations (only limited observations are available)

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JSBACH MODEL SPIN-UP

- Dynamic simulations of fuel loads requires long spin-up phases (~600 years) to get the biomass that is stored in the different vegetation pools (stems, roots, soil, etc,) into equilibrium

- The fuel load simulated in the vegetation model depends on the burned area , which leads to the consumption of biomass and emissions of carbon into the atmosphere.

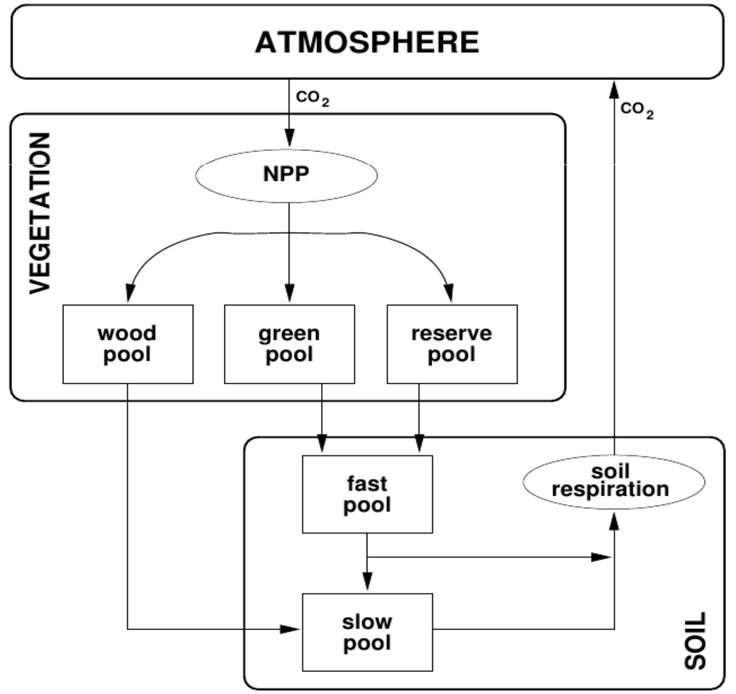
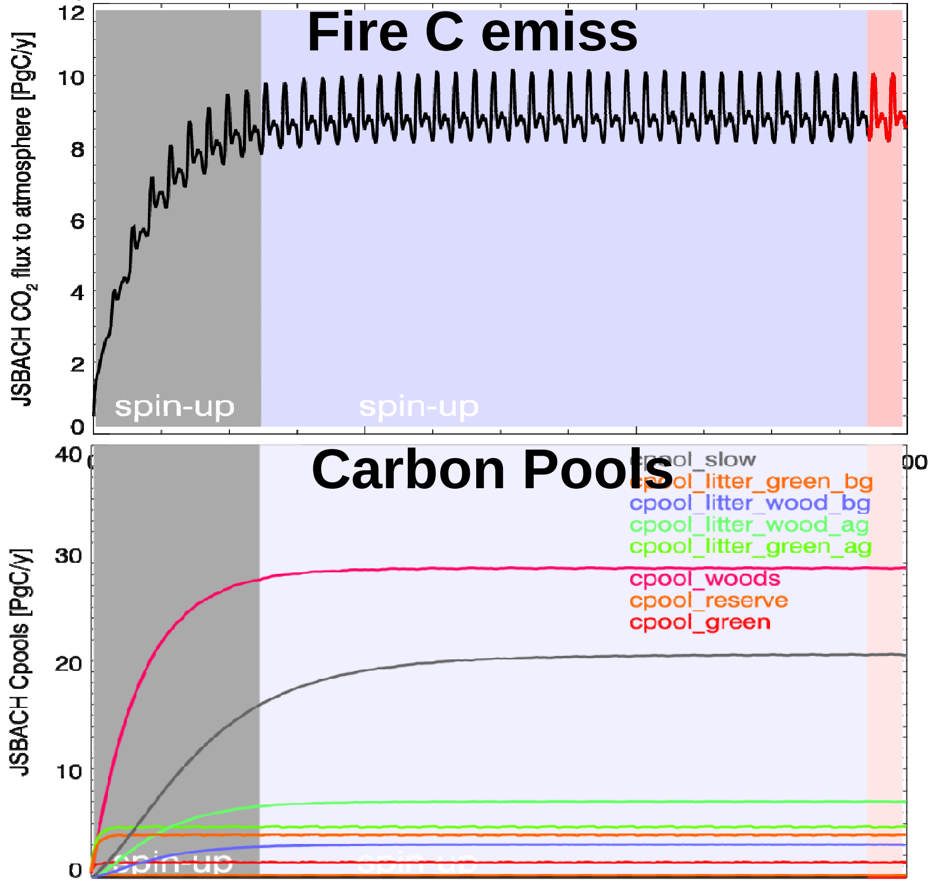


Figure 5.1: Carbon flow through the pools of the CBALANCE model



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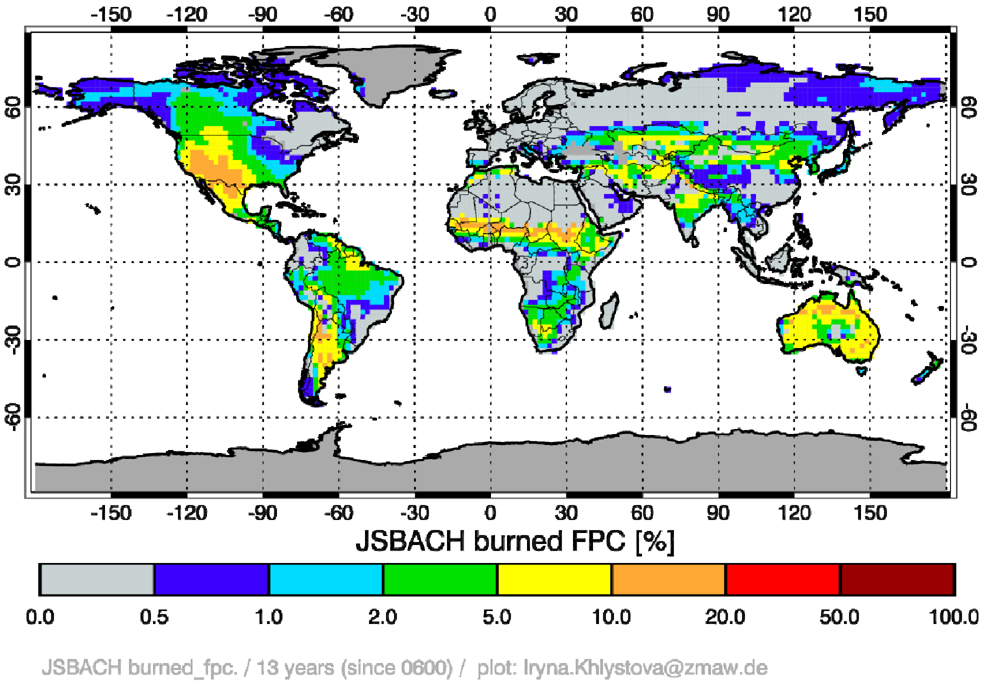
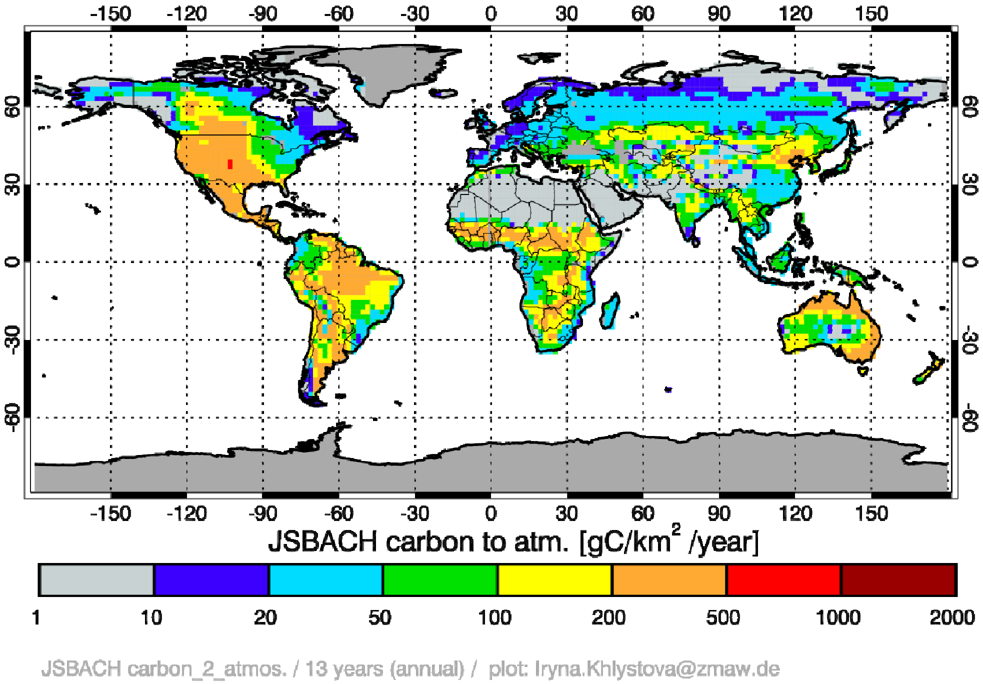
JSBACH FIRE MODEL: ORIGINAL

JSBACH Burned Area



JSBACH carbon emissions

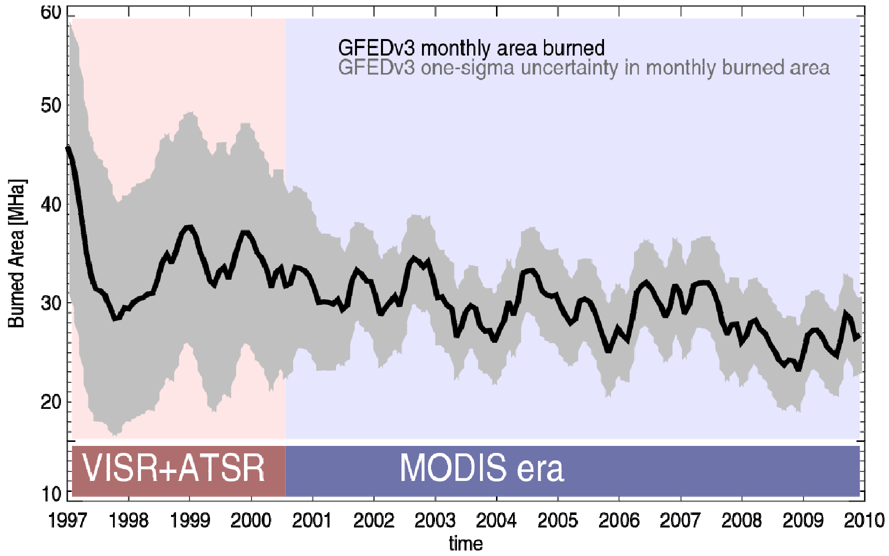


JSBACH has an standard fire algorithm based on thresholds of moisture and temperature.

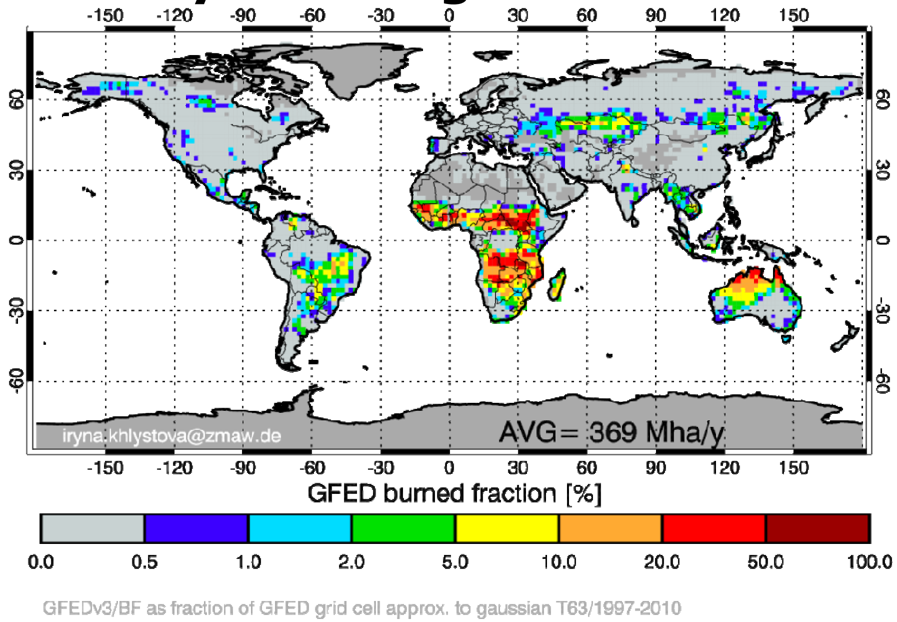
INTEGRATION OF BA

- GFEDv3 provides an excellent dataset on Burned area for the time period from 1997 – 2010 (based on ATSR/MODIS);
- For JSBACH, the interface was developed that allows to prescribe a satellite dataset (i.e. burned area) in the format similar to GFED (netCDF, monthly);

BA GFEDv3 available



13 years avrg. BA GFEDv3



PREPROCESSING OF SATELITE DATA

Observation data cannot be used directly in models!

- Pre-processing procedure is complex, each step requires detailed and careful data analysis.
- Otherwise high potential to lost the valuable information.

JSBACH Model

Merge to 14 month into one file

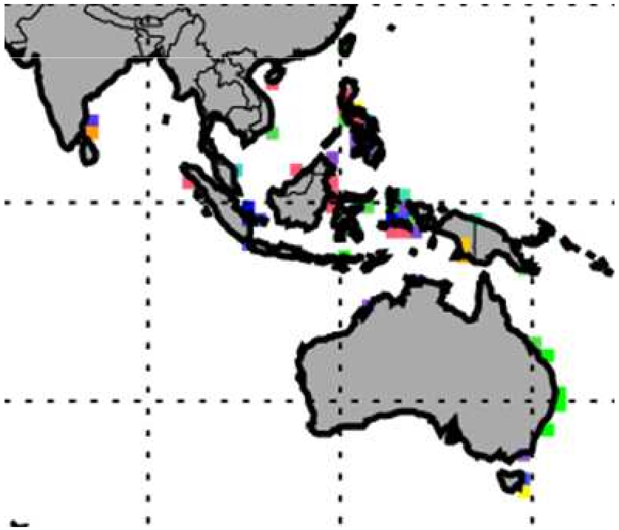
Assign occasion ocean burned pixel to land

Interpolate to model grid (0.5x0.5° to T63/T31)

Set the observations Sea-Land Mask (0.5x0.5°)

File format conversion (GFED HDF to netCDF)

Example for GFED TCD



Sea-Land mask difference between satellite and model results in a complex intermediate step for simultaneous transfer of ocean pixels to land.

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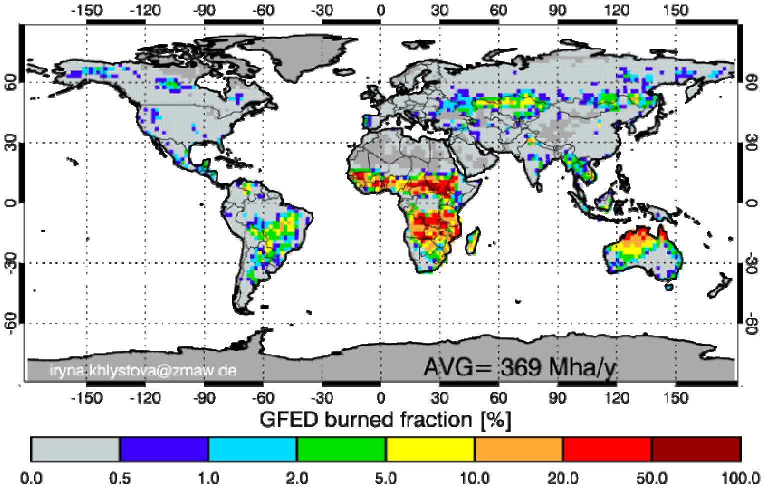
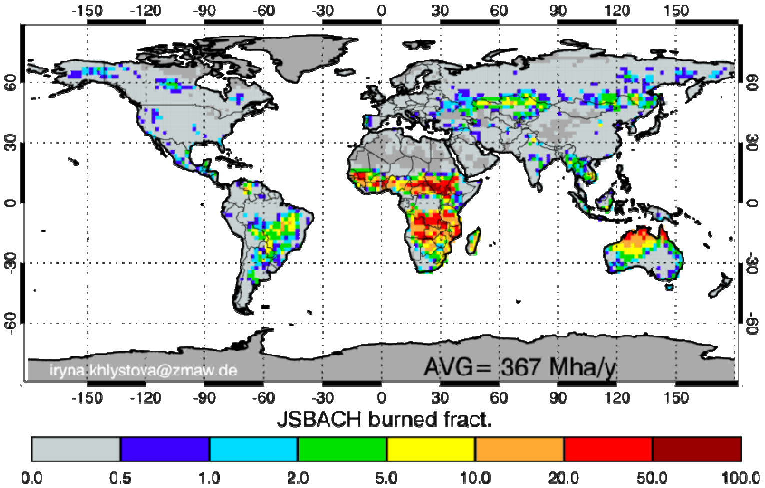
RESULTING CARBON EMISSIONS

GFEDv3 | GFEDv3 in JSBACH

Burned Area

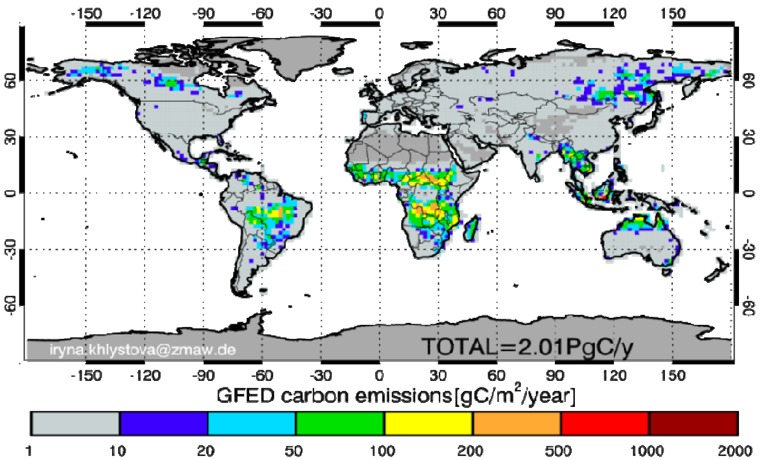


GFEDv3/BF as fraction of GFED grid cell approx. to gaussian T63/1997 2010

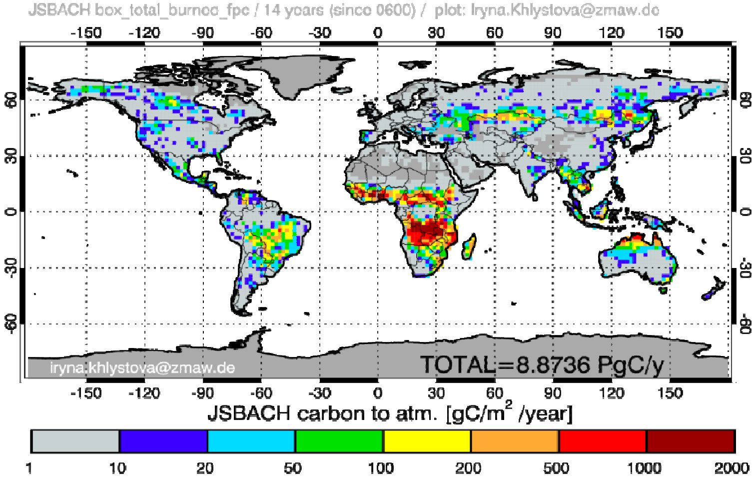


JSBACH box_total_burned_fpc / 14 years (since 0600) / plot: Iryna.Khlystova@zmaw.de

C emissions



GFEDv3 carbon emissions / Jan1997 - Dec2010/ plot: Iryna.Khlystova@zmaw.de

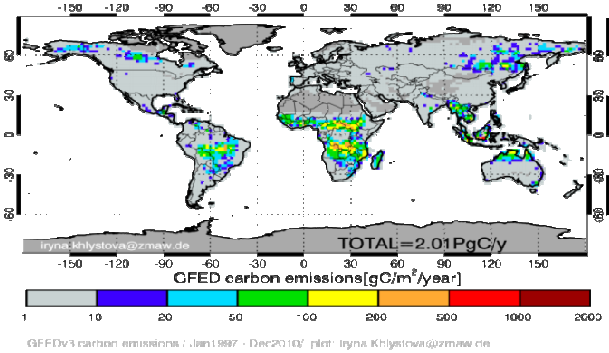


JSBACH box_CO2_flux_2_atmos. / 14 years avg. / MPI-H, 2012/ plot by: Iryna.Khlystova@zmaw.de

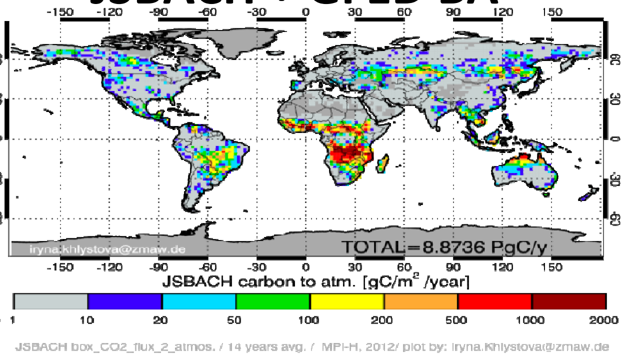
x4!

GLOBAL TOTALS

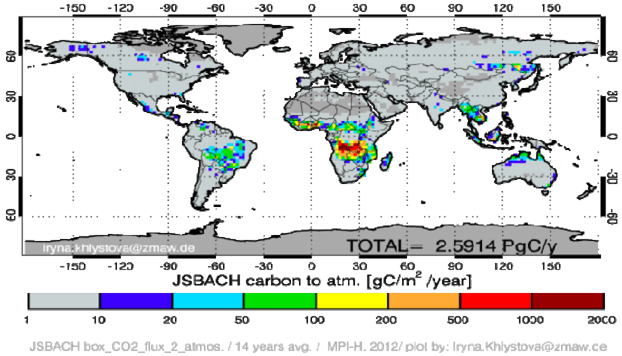
GFED model



JSBACH + GFED BA



JSBACH + GFED BA + GFED TCD



MODEL	C emission from fires [Pg C/y]	Equivalent CO_2 rate [ppm/y]
GFEDv3.1	2.0	1
JSBACH standart	~2.1	1
JSBACH +GFED BA	~8.8	2
JSBACH + GFED BA + GFED TCD	~2.5	1
TOTAL Anthropogen C. (Le Quiere et al, 2009)	8.7 Pg/y	3

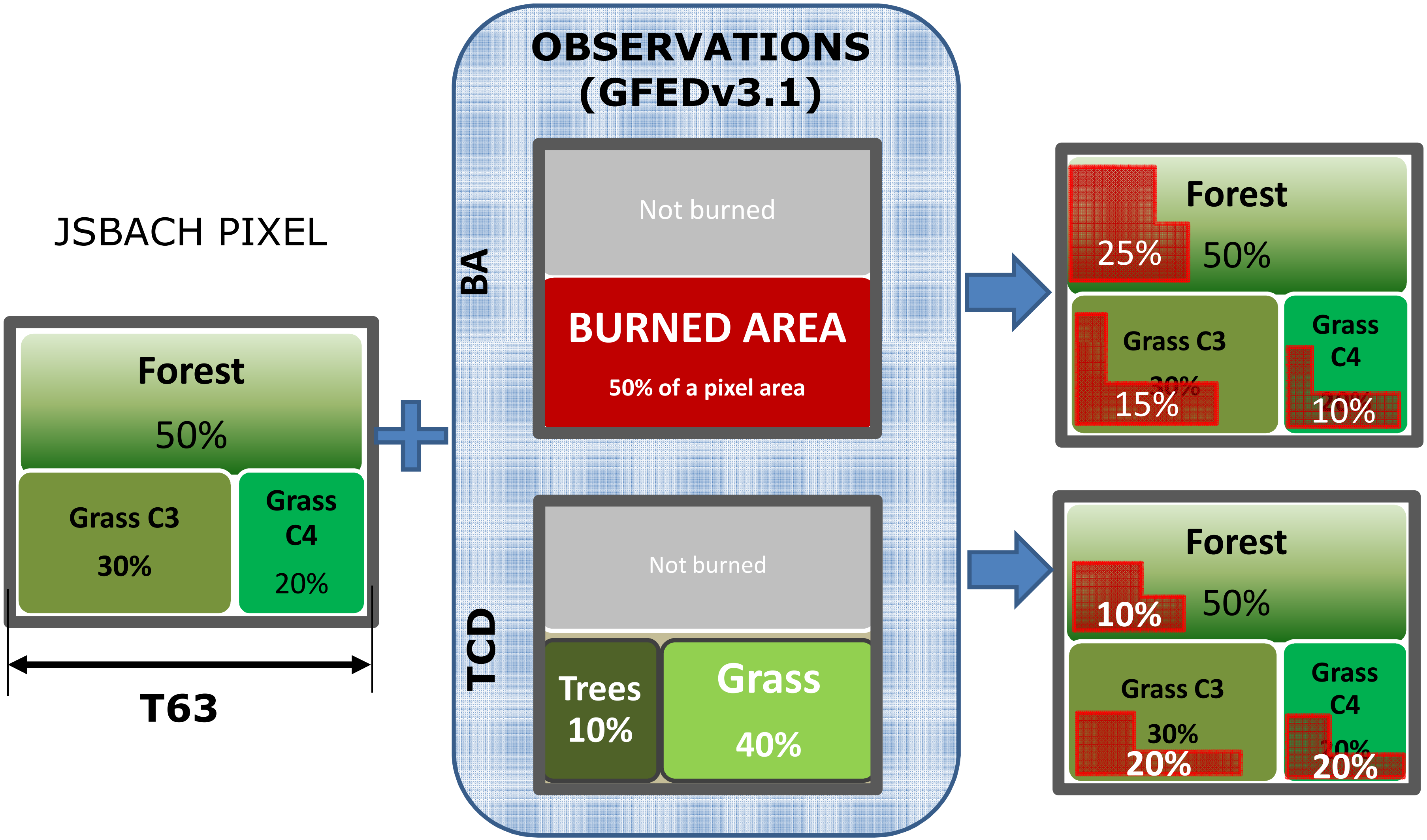
Total CO_2 (GFEDv3) = 48% * Dry Matter(CO_2+CO+CH_4) * EF(CO_2)

Coefficient according to van der Werf et al., 2010

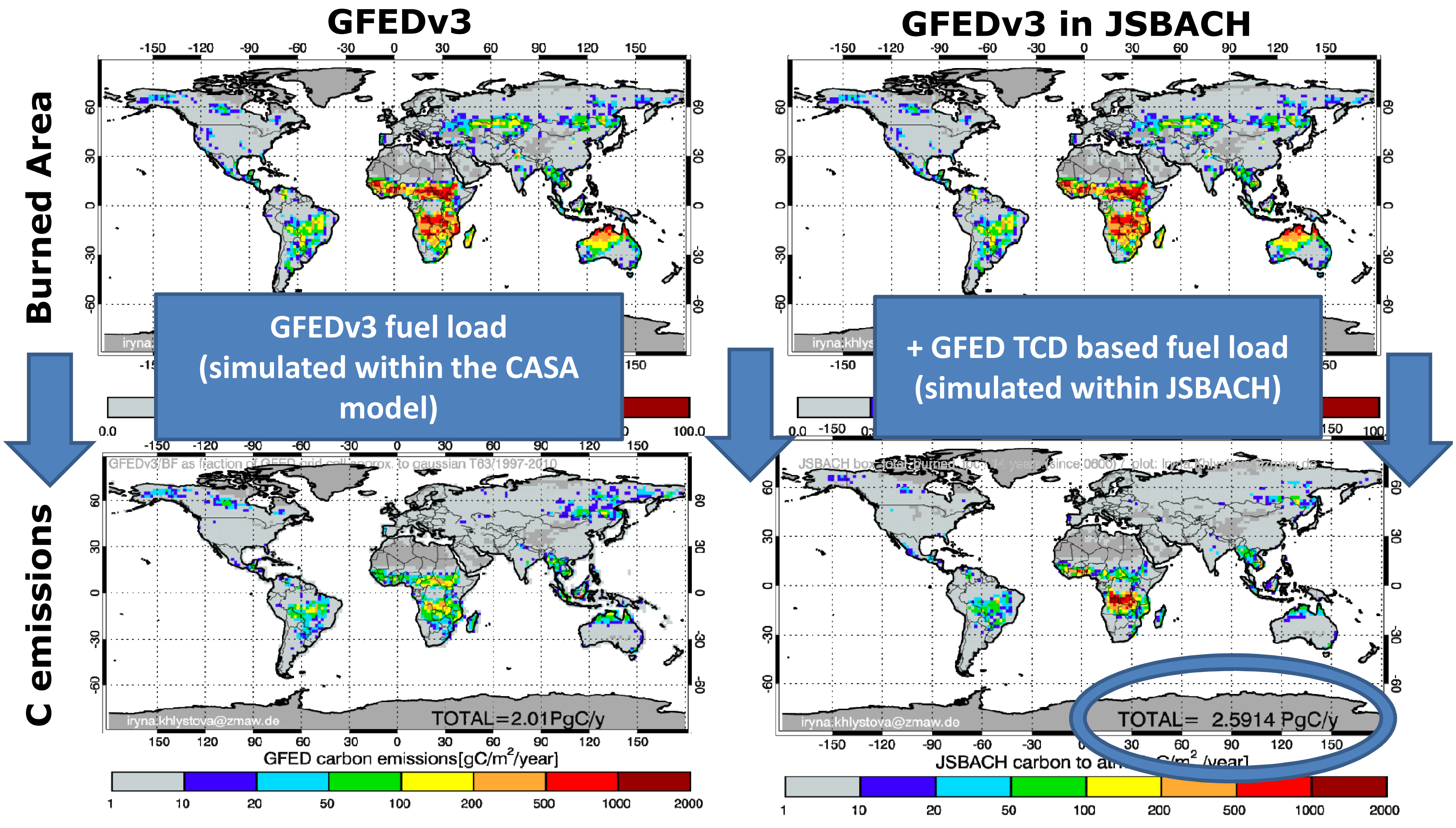
of the dry mass carbon content

Taken from Andreae and Merlet, 2001

JSBACH BA to Carbon Emissions



EXPERIMENT 2: PRESCRIBED TCD



Integration of CCI Land Cover

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SATELLITE LAND COVER CLASSES

NO WAY FOR DIRECT CONVERSION TO MODEL PFTs!

Satellite:
spectral classes

→ needed for semantic translation

→Resolve the satellite mixed classes

→Same class in different climates

Model:
functional classes (PFT)

Land Surface parameters are derived :
- –background surface albedo,
- –surface roughness,
- –length due to vegetation,
- –fractional vegetation cover,
- –leaf area index for the growing dormancy season,
- –forest ratio,
- –plant-available soil water holding capacity, and
- –volumetric wilting point

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ACCEPTED GENERAL SCHEMA

SAT CALSSIFICATION

↓

Generalization of types
Tree/Herbac/Crops/Bare

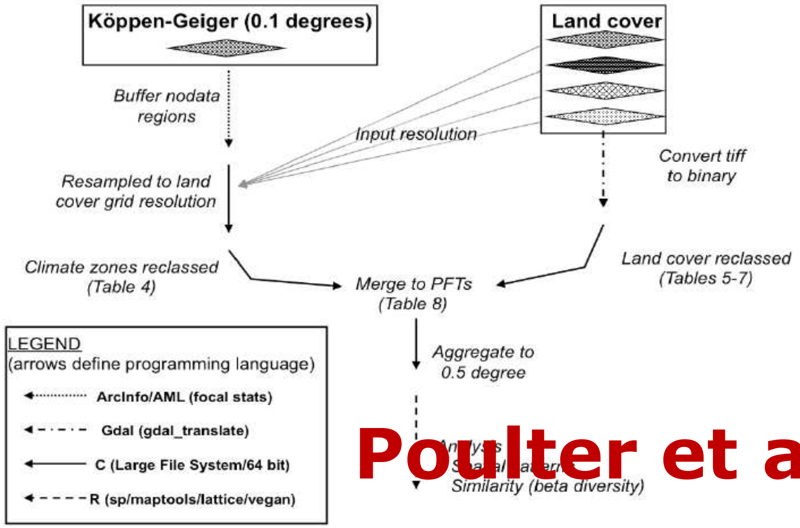
↓

Biome params
(threshould approach)

↓

Adjust MODELX PFTs

Plant Functional Type (PFT) used in LPJmL and Orchidee and CLM (PFT code in parentheses)	Biome	Phenology Class (phenology code in parentheses)	T_{min}	T_{max}
Tropical broadleaf evergreen (TrBe)	Tropical	Broadleaf evergreen (BrEv)	15.5	–
Tropical raingreen (TrRg)		Broadleaf deciduous (BrDe)	15.5	–
Temperate needleleaf evergreen (TeNe)	Temperate	Needleleaf evergreen (NeEv)	−2	22.2
Temperate broadleaf evergreen (TeBe)		Broadleaf evergreen (BrEv)	3.0	18.8
Temperate broadleaf summergreen (TeBs)		Broadleaf deciduous (BrDe)	−17.0	15.5
Boreal needleleaf evergreen (BoNe)	Boreal	Needleleaf evergreen (NeEv)	–	−2
Boreal needleleaf summergreen (BoNd)		Needleleaf deciduous (NeDe)	–	−2
Boreal broadleaf summergreen (BoBs)		Broadleaf deciduous (BrDe)	–	−2
Temperate herbaceous (NatGrassC3)	Temperate	Grass	–	15.5
Tropical herbaceous (NatGrassC34)	Tropical	Grass	15.5	–
Managed grass C3 (MGrassC3)	Temperate	Grass	–	15.5
			15.5	–



Poulter et al., 2011

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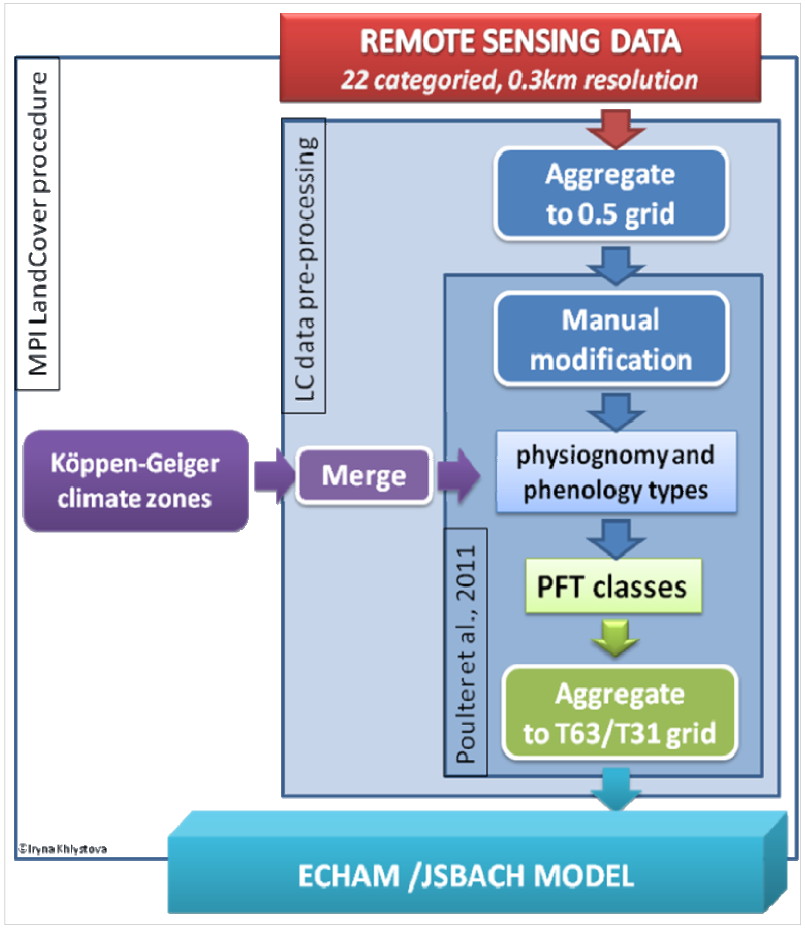
CONVERSION TO PFTs



Adapted from Poulter et al, 2011

Step 1 **File conversion and aggregation**
- Convert from TIFF to netCDF format
- Tile by type
- Reducing resolution to 0.5x0.5 (in order to apply other satellite datasets for further conversion, e.g. KG Biomes classification)

Step 2 **Reclassification (slightly modified schema by Poulter et al., 2011)**
- reduce to general types (forest, herbac, crop)
- apply biome mask (Climate classification)
- scale not used types (e.g. anthrop. water on land)

Step 3 **Regrid** to Model Resolution (T63/T31)

JSBACH PFT concept

The Plant-Functional Type concept is different for different models!

- MPI-M Land component JSBACH has 21 PFTs converted by a different method using the on Olson classification (AVHRR 1992, Olson 1994) with bio-climatic limits from (Stich et al. 2003) – older datasets.
- The PFT functionality includes: Photosynthesis, Vegetation (height, roughness length, litter, Carbon content., litter and leafs lifetime)

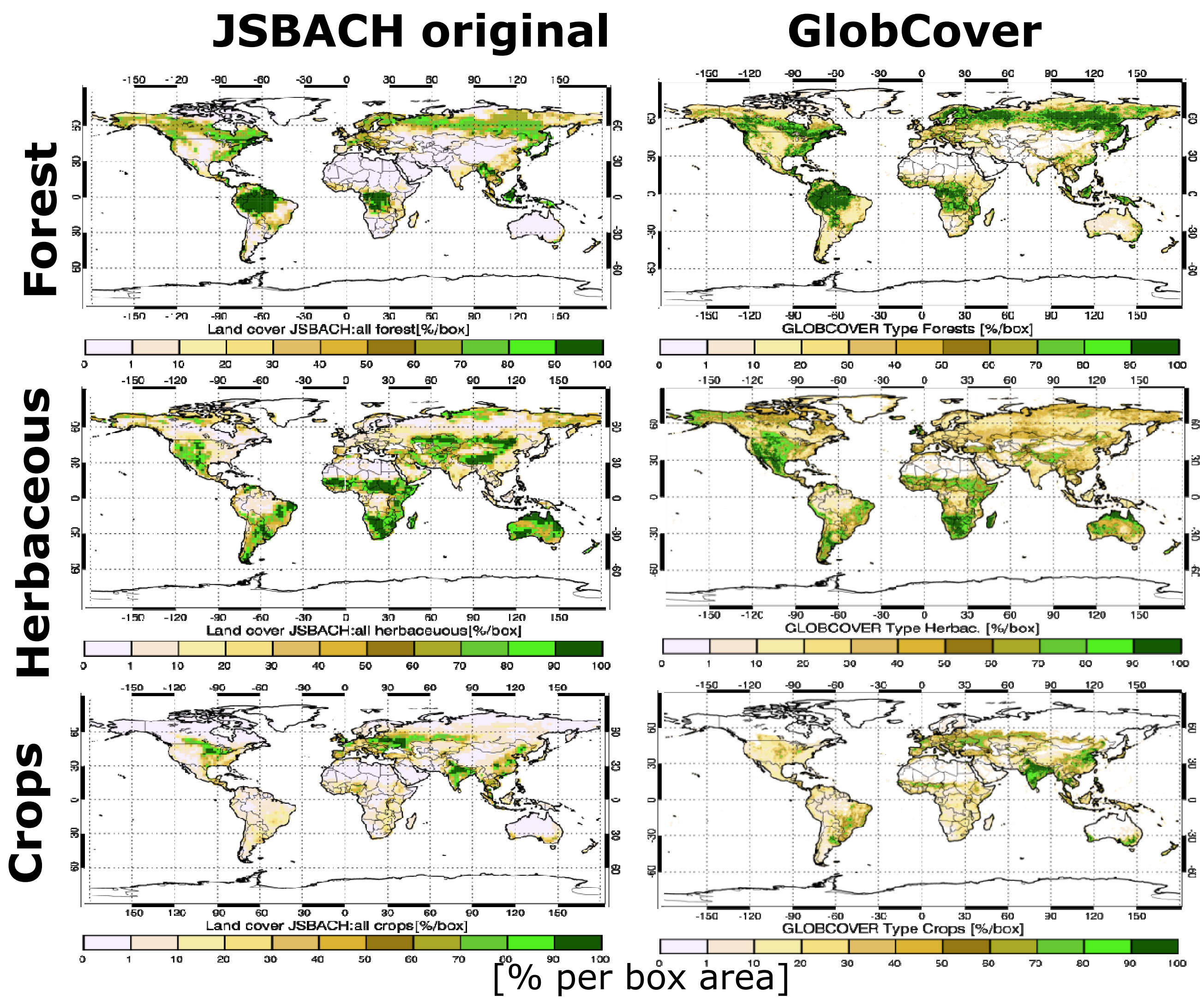
JSBACH Conversion Matrix (conversion step 1)

*** ASCII Table re-classification from GlobCov to Physiology (Poulter et al., 2011)

	BrEv	BrDe	NeEv	NeDe	NatGr	ManGrPs	ManGrCrop	ShrubAll	bare	water
glbcov_type11	0	0	0	0	0	0	1	0	0	0
glbcov_type14	0	0	0	0	0	0.5	0.5	0	0	0
glbcov_type20	0	0	0.1	0.1	0.1	0.25	0.45	0	0	0
glbcov_type30	0	0	0	0	0.25	0.25	0.25	0.25	0	0
glbcov_type40	0.5	0.5	0	0	0	0	0	0	0	0
glbcov_type50	0	1	0	0	0	0	0	0	0	0
glbcov_type60	0	1	0	0	0	0	0	0	0	0
glbcov_type70	0	0	1	0	0	0	0	0	0	0
glbcov_type90	0	0	0.5	0.5	0	0	0	0	0	0
glbcov_type100	0.25	0.25	0.25	0.25	0	0	0	0	0	0
glbcov_type110	0.2	0.2	0.2	0.2	0	0	0	0.2	0	0
glbcov_type120	0.1	0.1	0.1	0.1	0.2	0.2	0	0.2	0	0
glbcov_type130	0	0	0	0	0	0	0	1	0	0
glbcov_type140	0	0	0	0	0.5	0	0	0.5	0	0
glbcov_type150	0.1	0.1	0.1	0.1	0.4	0	0	0.2	0	0
glbcov_type160	0.5	0.5	0	0	0	0	0	0	0	0
glbcov_type170	0.5	0.5	0	0	0	0	0	0	0	0
glbcov_type180	0.1	0.1	0.1	0.1	0.2	0.2	0	0.2	0	0
glbcov_type190	0	0	0	0	0	0	0	0	1	0
glbcov_type200	0	0	0	0	0	0	0	0	1	0
glbcov_type210	0	0	0	0	0	0	0	0	0	1
glbcov_type220	0	0	0	0	0	0	0	0	1	0

Weighted assignment of GlobCover classes to general biomes is a subjective approach!

RESULTS FOR PRINCIPLE CLASSES



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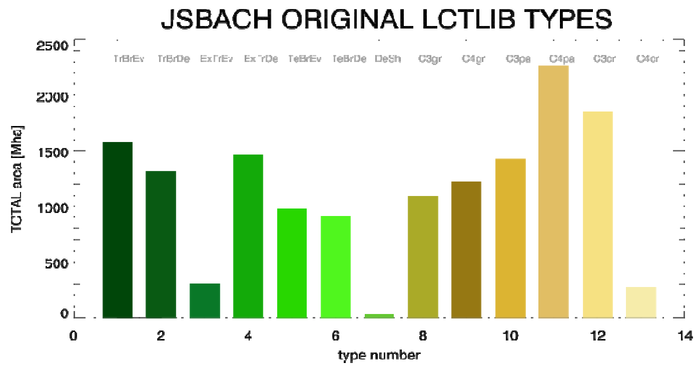
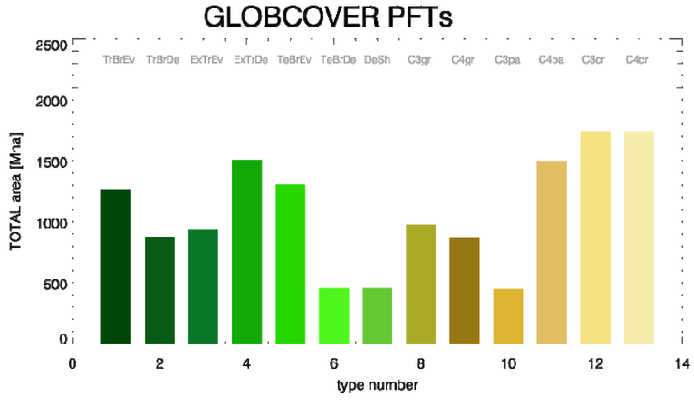
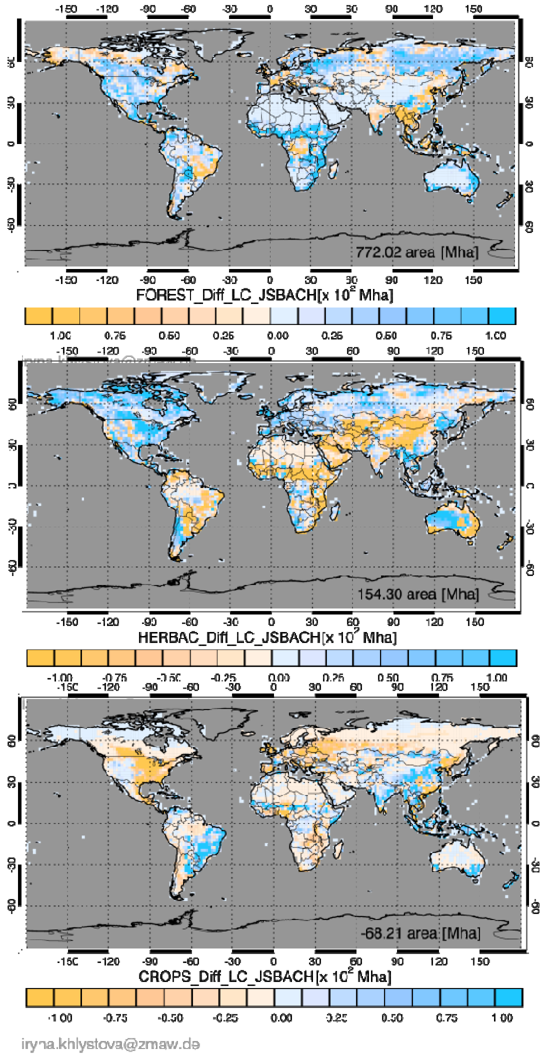
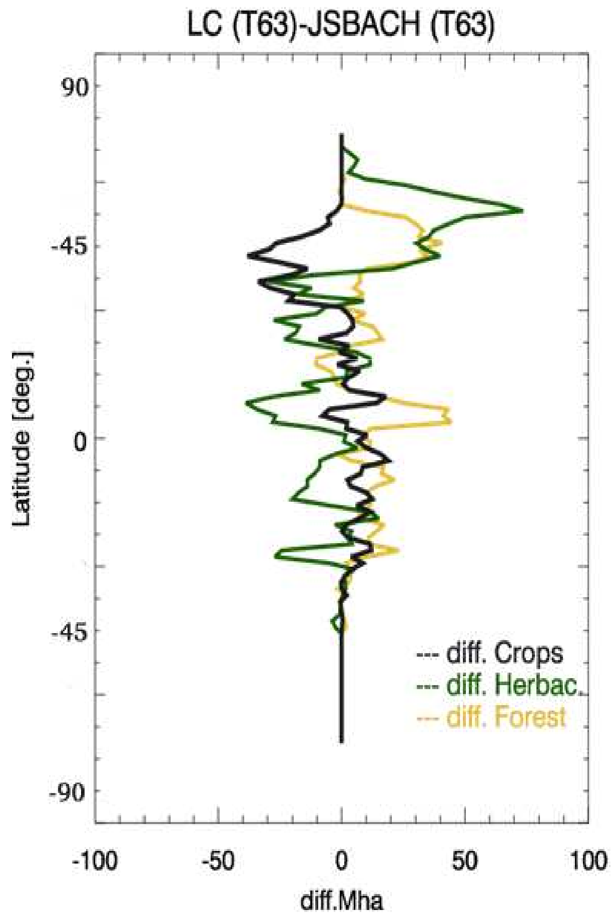
DIFFERENCES BETWEEN PRINCIPLE CLASSES

Even a small difference in tree/herbaceous definition may be of importance for models simulations!



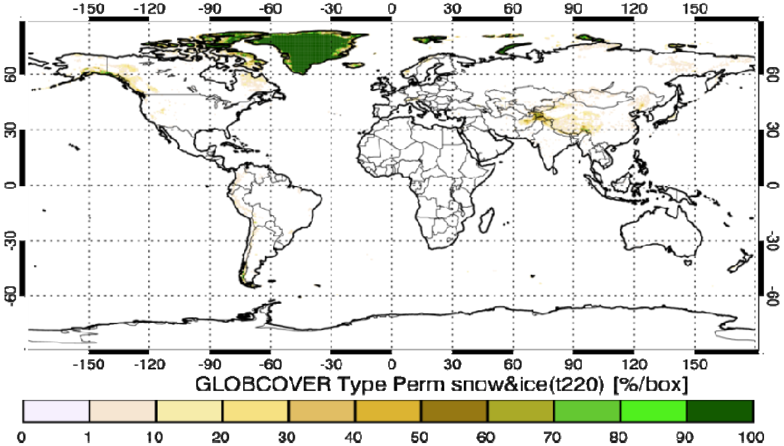




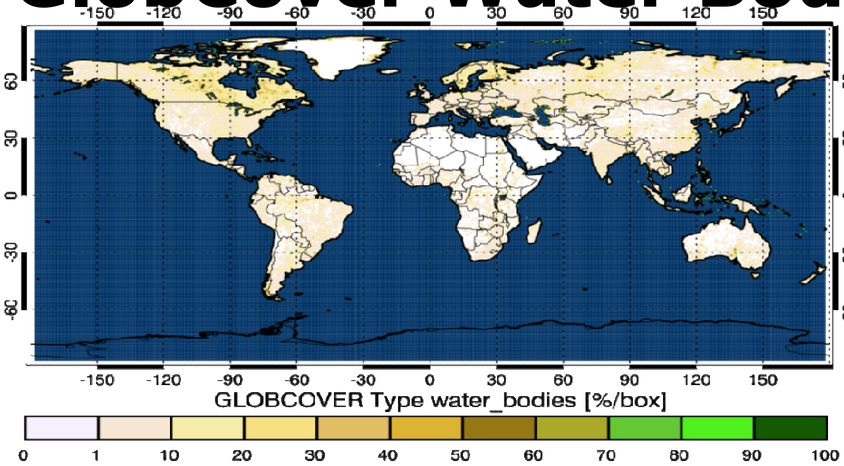


Diff. in classification and definitions

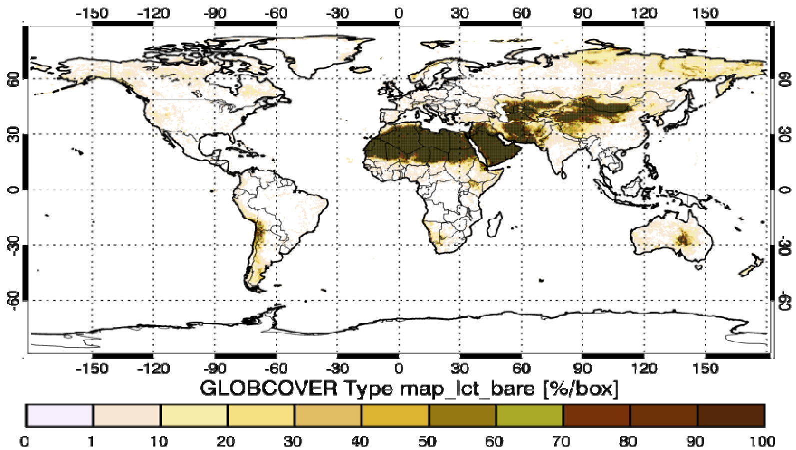
GlobCover Glacies



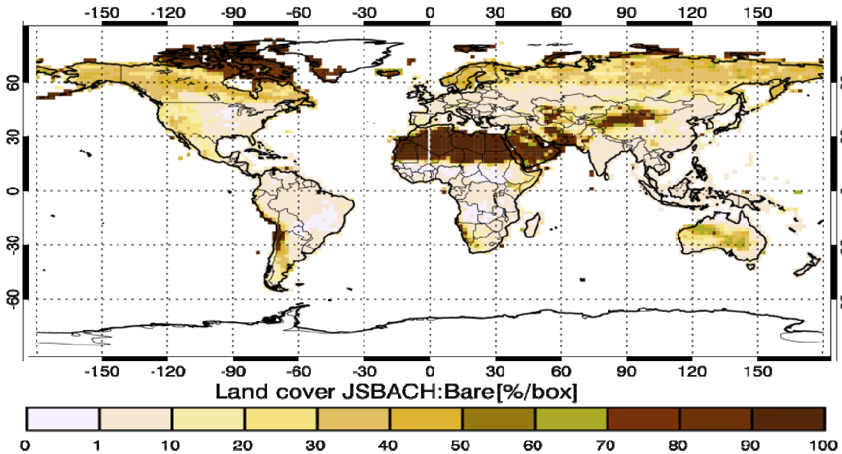
GlobCover Water Body



GlobCover BARE

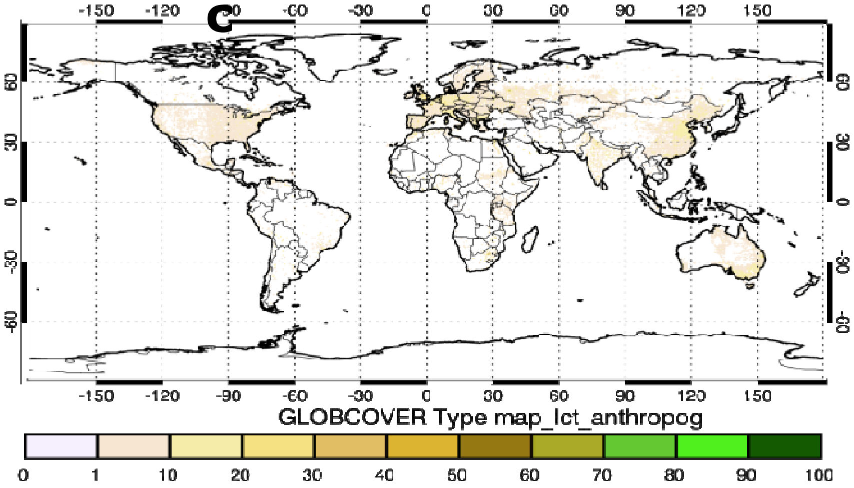


JSBACH BARE

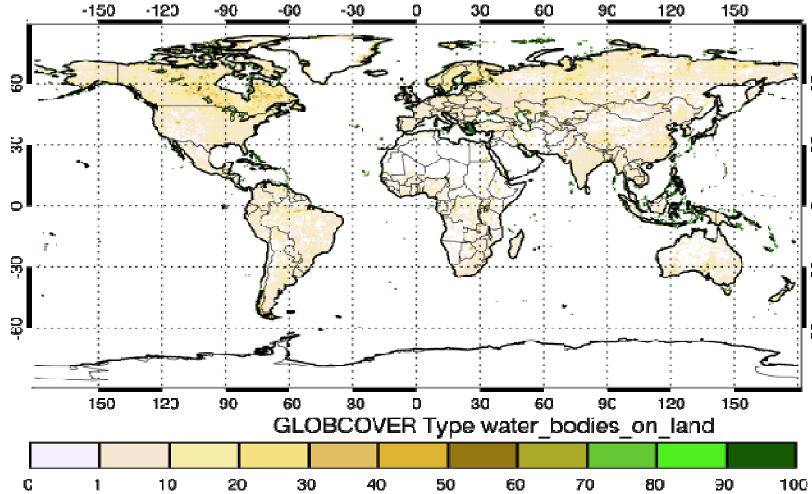


NEW PFTS?

+Anthropogenic



+ Water on land



Anthropogenic and inland water body → current deficit in models → model improvement needed!

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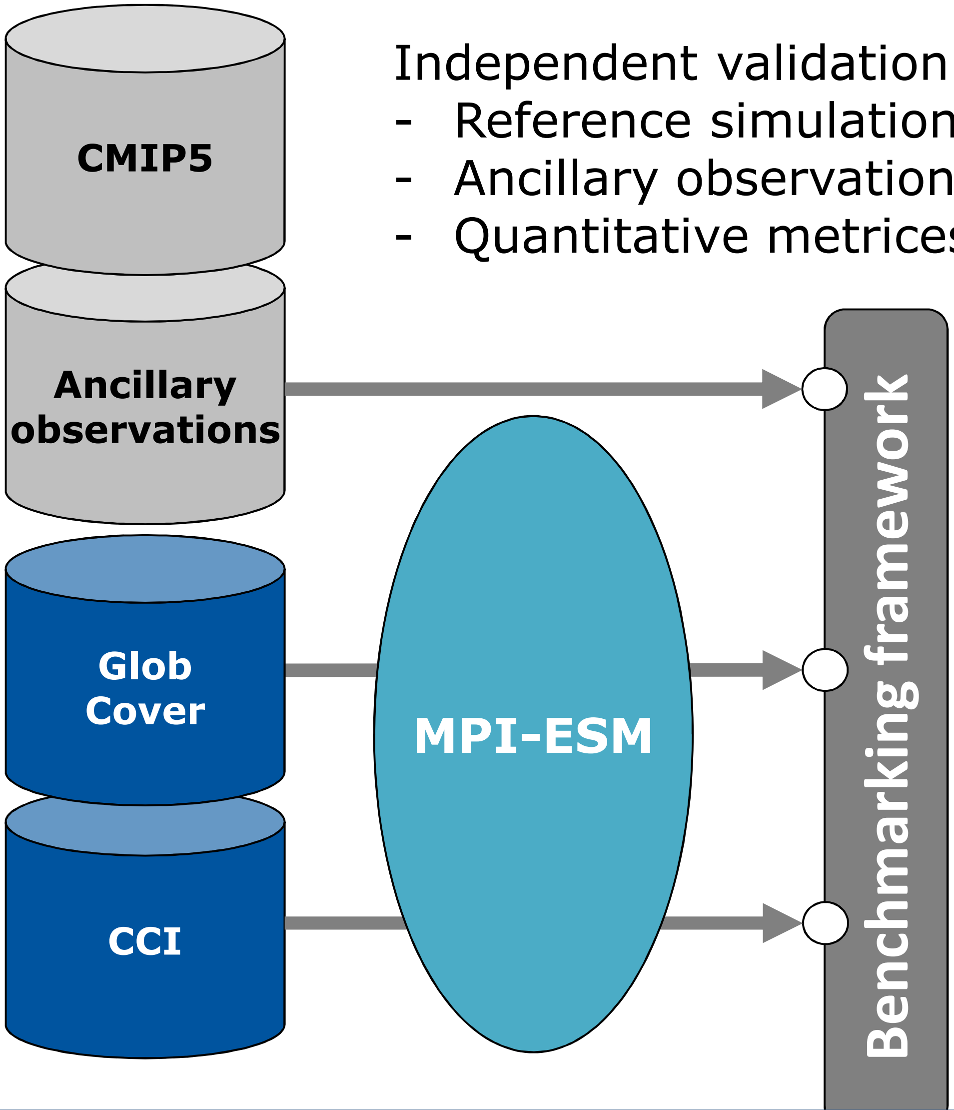
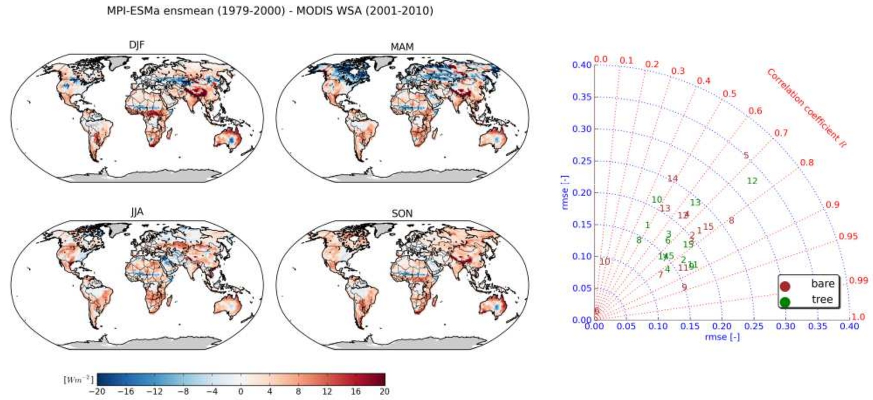
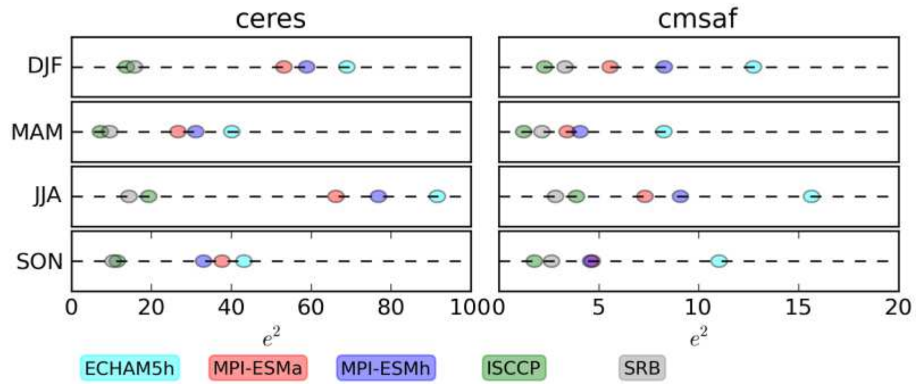
Model benchmarking suite

Independent validation of model performance:
- Reference simulations
- Ancillary observations
- Quantitative metrices (e.g. Reichler & Kim, 2008)







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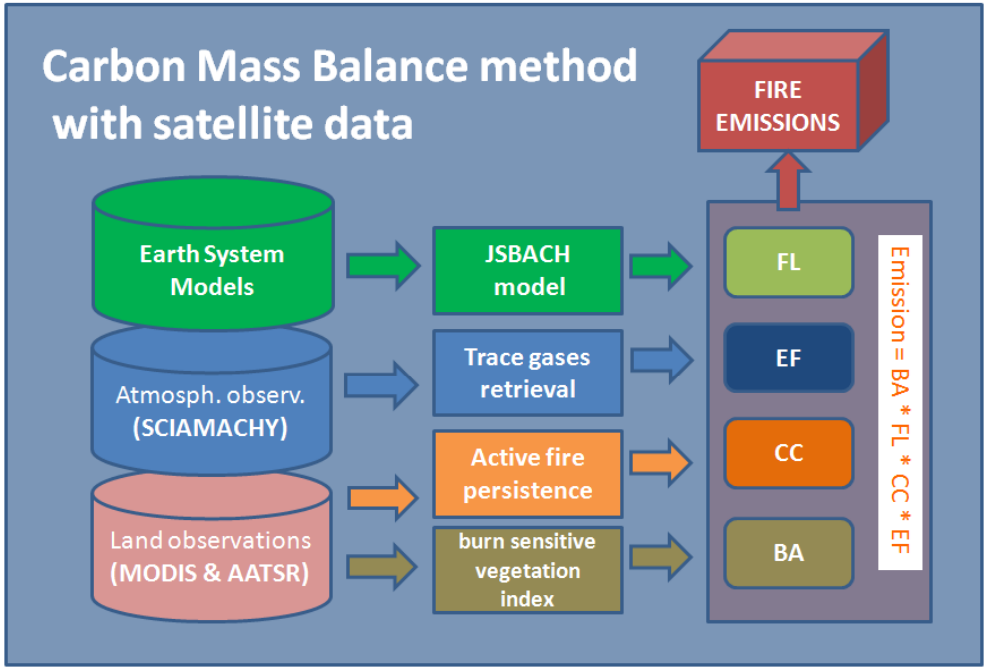
OUTLOOK: Fire CCI

model development:

- drive JSBACH with observed meteorology (instead of climate model data)
- Incorporate the daily representation of GFED information (Ma et al., 2011)
- Integration of alternative fire products (fire burned scars->BA or fire radiative power),
- Integration of SAT_EFs for calculation of other trace gases (similar to GFED trace gases);



Khlystova et al., EGU 2011

model application:

- investigate the impact of temporal resolution of the burned area (monthly/daily) on simulated fire carbon emissions
- investigate the impact of new land cover classification in JSBACH on simulated fire carbon emissions

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OUTLOOK: Land Cover CCI

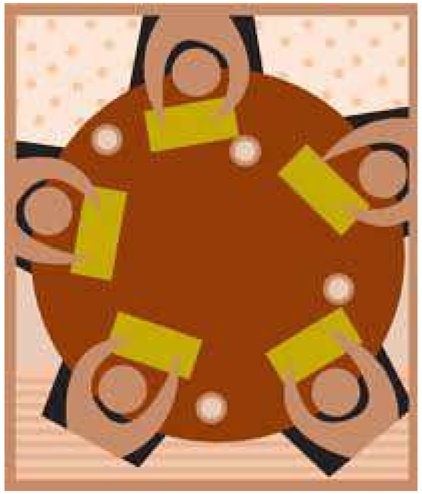
- Pre-processing of satellite data is a time-consuming procedure, as for fire as for land cover products!
- Land Cover transformation requires additionally a complex processing connected closely to some specific expert knowledge of a model PFT,
- Each product integration required some new model development, because no standard interfaces exist and because model functionality is often limited by thresholds (not considering any dependency on the new data) ,
- New dataset should be used for exchange of several model parameters (not only cover fraction, but also vegetation ratios and albedo need to be updated simultaneously!)
- Integration of Fire and Land products may be advantageous (e.g. calculation of the fuel load for Fires based on Land Cover),
- …

JOINT EXPERIMENT (Inter-model)

Joint experiments with LC CCI CRG

by CMUG + CRG of Land Cover-CCI

- Decided to perform a Coordinated set of experiments:
  - » Take Different models (JSBACH, OHIDEE, JULES,?),
  - » Use possible same forcing (climate, re-analysis),
  - » Make possibly simple first step simulations (offline, no dynveg),
  - » Use a consistent method to translate land cover data to PFTs,
  - » Same spatial resolution (spatial aggregation);



To be continued…

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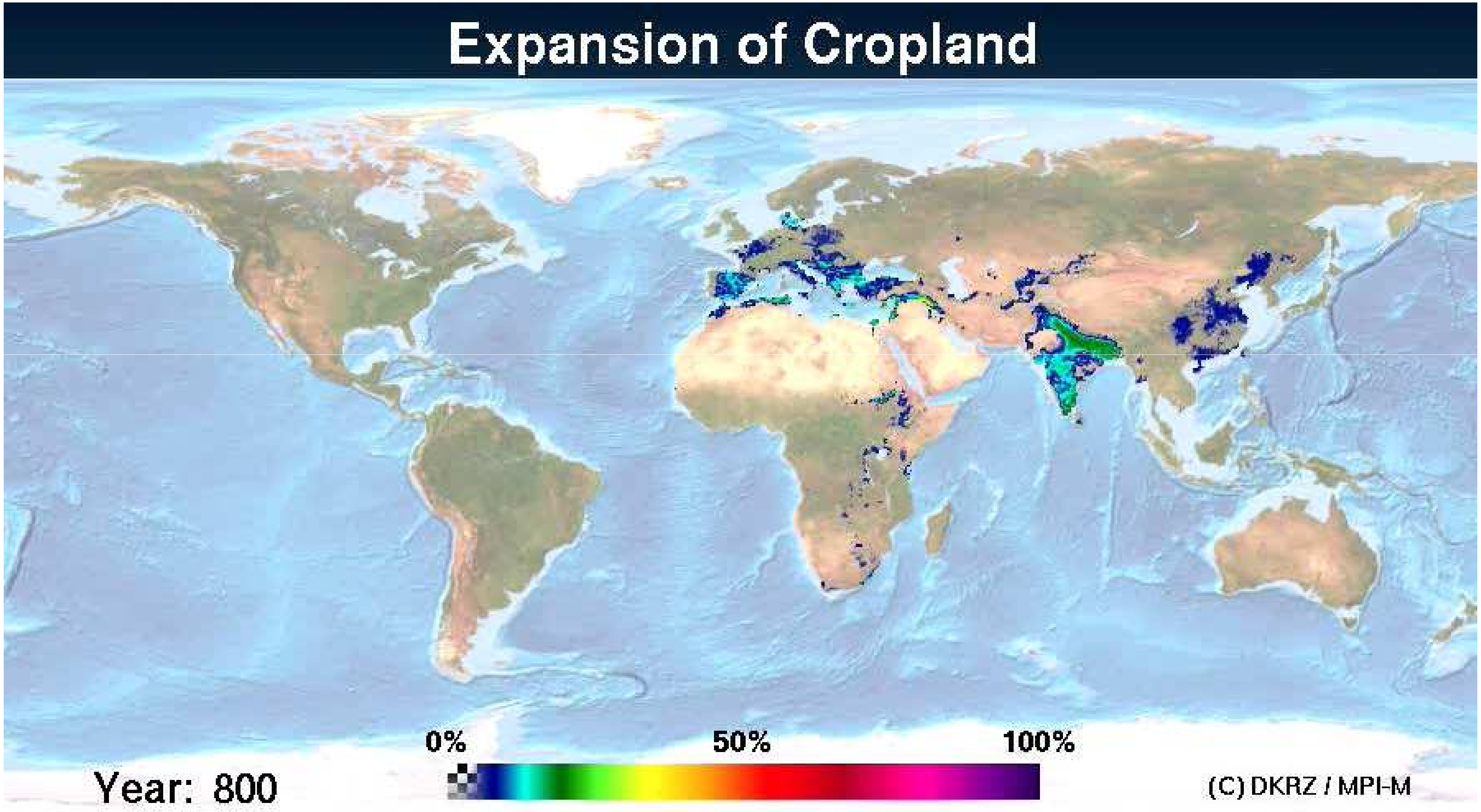
MPI-H Land Model JSBACH



JSBACH PFT CONCEPT

- JSBACH PFTs are based on Olson classification (Olson 1994) derived from International Geosphere Biosphere Program 1 km AVHRR data
- The bio-climatic climatic limits taken from (Stich et al., 2003)
- Land Surface parameters are derived :
  - background surface albedo,
  - surface roughness,
  - length due to vegetation,
  - fractional vegetation cover,
  - leaf area index for the growing dormancy season,
  - forest ratio,
  - plant-available soil water holding capacity, and
  - Volumetric wilting point
- JSBACH plant functional types (PFTs) concept is used in the Biosphere-Energy-Transfer-Hydrology Scheme (BETHY) (Knorr, 2000)