Tropical Forests Carbon Dynamics using 10-y SPOT-VEGETATION Time Series and Land-Surface Modelling
The VEGECLIM Project

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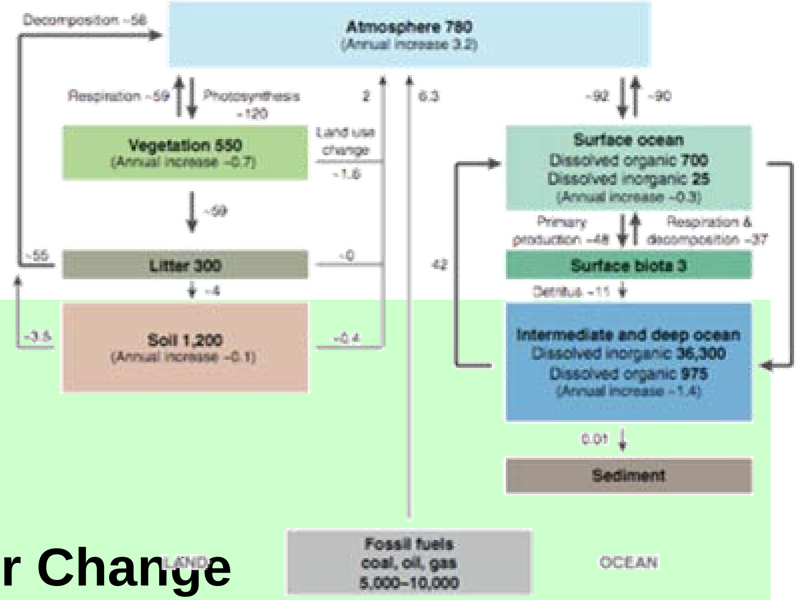
- A project of the STEREO II Program -

BELSPO DAY – 6 MAY 2010

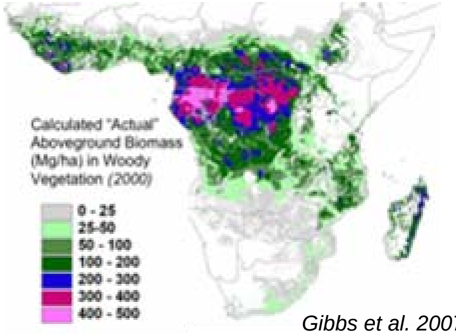
Rationale



R.A. Houghton (2007)
Annual Review of Earth and Planetary Sciences

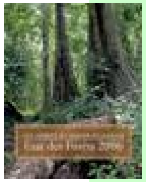
- Major role of **terrestrial Carbon dynamics** in global carbon balance.
- Major impact of **Land-Use Land-Cover Change** in the humid tropics on global carbon balance
- Critical knowledge gained from **C flux tower network and process-based ecosystem models**… but difficult to directly upscale to regions
- **Great spatial and temporal consistency of 10-y daily time series** of earth observation to describe vegetation types and their phenology
- *"Africa: one of the weakest links in our understanding of the global carbon cycle"* (Williams et al., 2007)

Rationale for Central Africa



Gibbs et al. 2007

- **Coarse estimation based on simplistic models**
- **CarboAfrica** network still **very sparse** and started a few years ago
- Central African forests are the **most pristine tropical forests** with less deforestation/degradation than in South America and SE Asia but the situation is changing…
- **Need for quantitative assessment and prediction of carbon stocks** in the context of climate change and mitigation policies like REDD



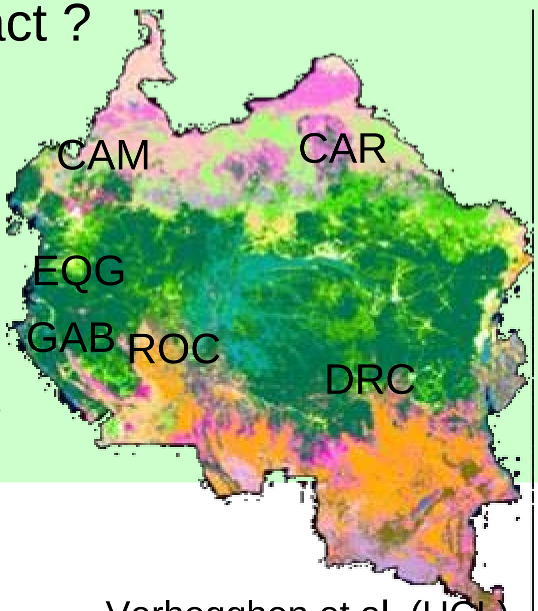
Global land-surface models like **ORCHIDEE need to be improved** in tropical regions where the seasonal/interannual variability of carbon fluxes is still uncertain

Total carbon stock in terrest. ecosystem	Cameroon	Congo Rep.	Gabon	Eq. Guinea	Cent. Afr. Rep.	Dem. Rep. Congo
Total country (State of Congo Basin Forest 2009)	5,251	4,758	4,557	448	5,840	27,928
Total country (Gaston et al. 1998)	3,131	2,822	3,892	349	3,740	16,316
Total country (Gibbs et al. 2007)	3,454-6,138	3,458-5,472	3,063-4,742	268-474	3,176-7,405	20,416-36,672

Nasi et al.,State of Congo Basin Forest 2009

Research Questions

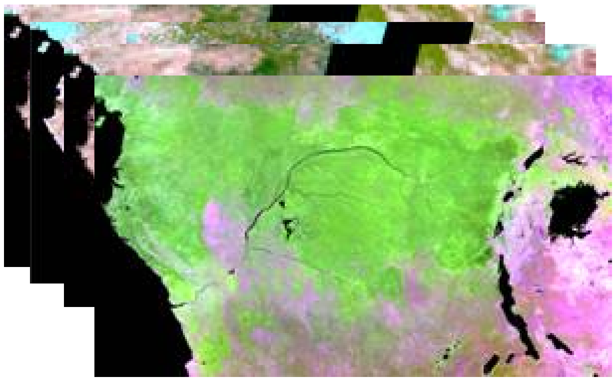
- Are Congo Basin mature forests absorbing or releasing C ?
- What is the net ecosystem productivity in Central Africa ? What are the trends and their variability ?
- How vulnerable are forest carbon stocks in Central Africa to climate change and direct human impact ?
- What should be expected from mitigation policies applied to both forest deforestation and degradation (Reducing Emissions from Deforestation and Forest Degradation in Developping Countries) ?



Verhegghen et al. (UCL),

Complex issues to be addressed thanks to already existing tools and achievements

Already processed daily SPOT-VGT since 2000

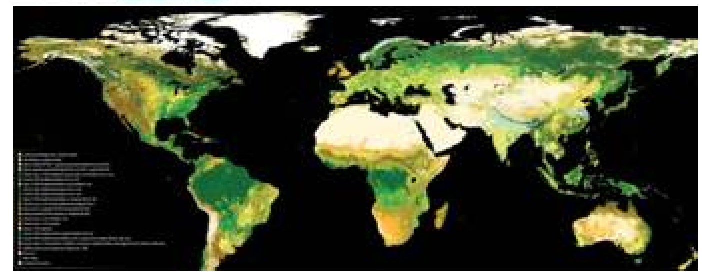


Vancutsem et al. 2008

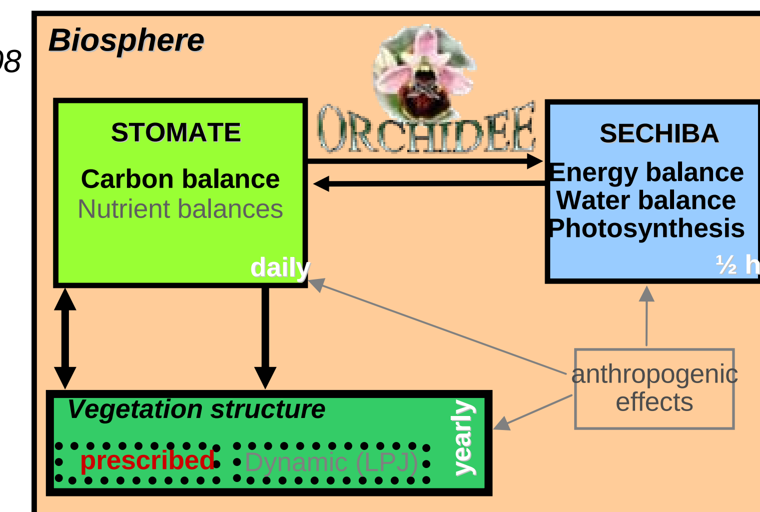
Congo Basin forest characterisation

de Wasseige et al. 2003, Vancutsem et al. 2008

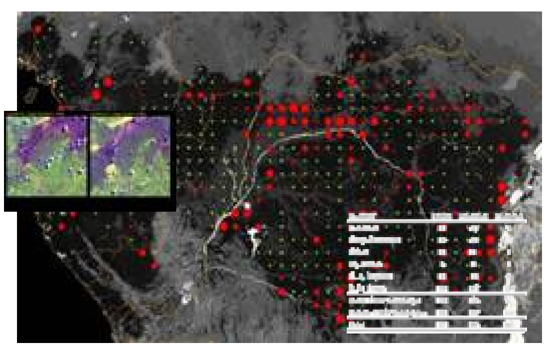
GlobCover Classification Module
Defourny et al. 2009



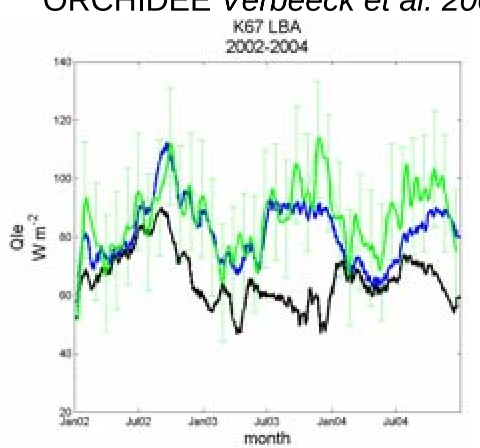
Validated Global Dynamic Vegetation Model
Ciais et al. Nature 2005



Forest Cover Change Assessment
UCL-JRC *Duveiller et al. 2008*



Assimilation techniques for ORCHIDEE *Verbeeck et al. 2008*



Research Strategy

- 10-y daily SPOT VEGETATION time series analysis for
  - mapping regularly the land cover and the plant functional types
  - quantifying the vegetation seasonality (LAI) and its inter-annual variability

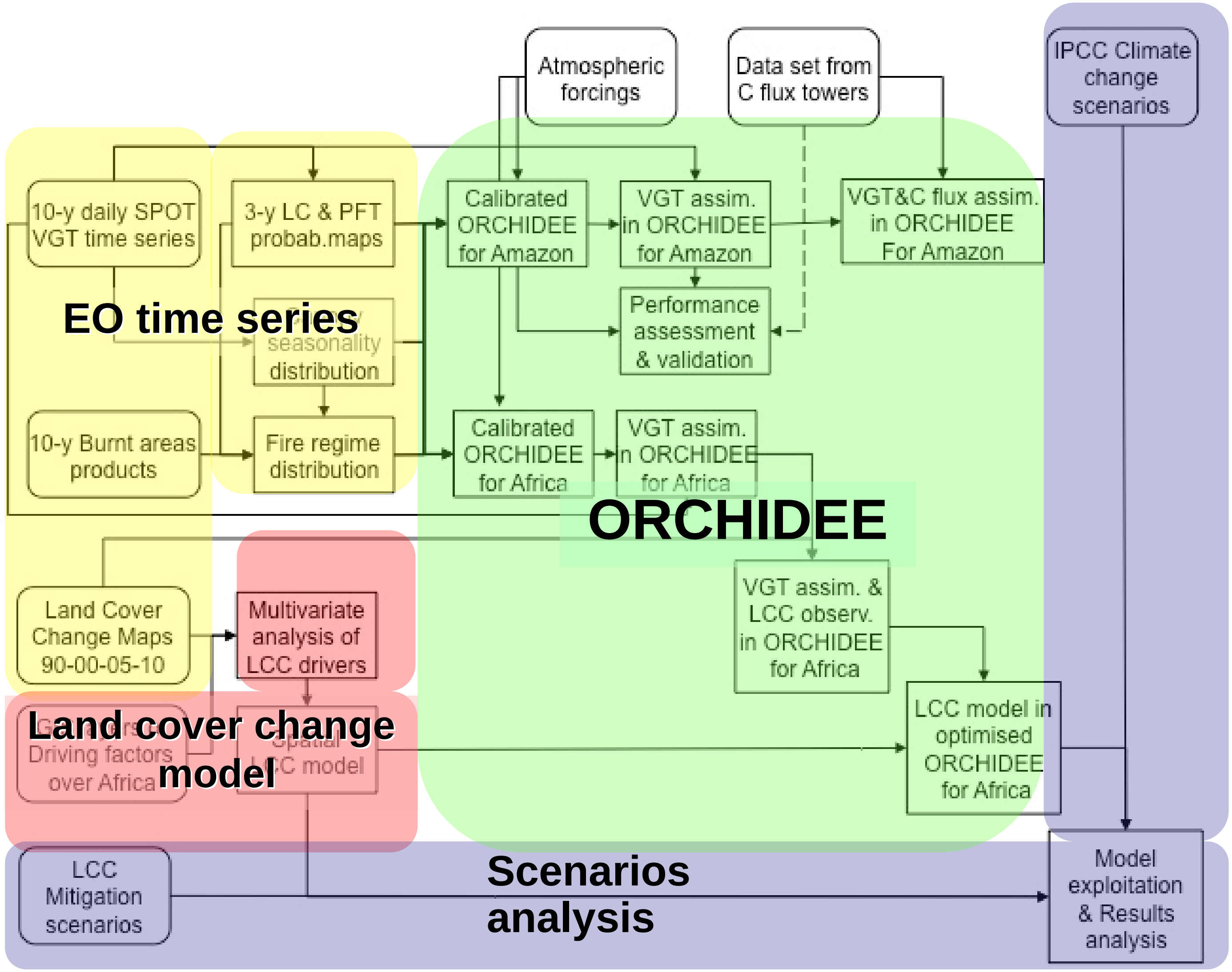
- ORCHIDEE calibration using SPOT-VGT- derived vegetation parameterisation
  - over the Amazon with and without Carbon flux measurements network
  - over the Central Africa on a 1 km grid covering the 6 countries of Congo Basin

  ⇒Relative performances assessment of ORCHIDEE due to EO assimilation

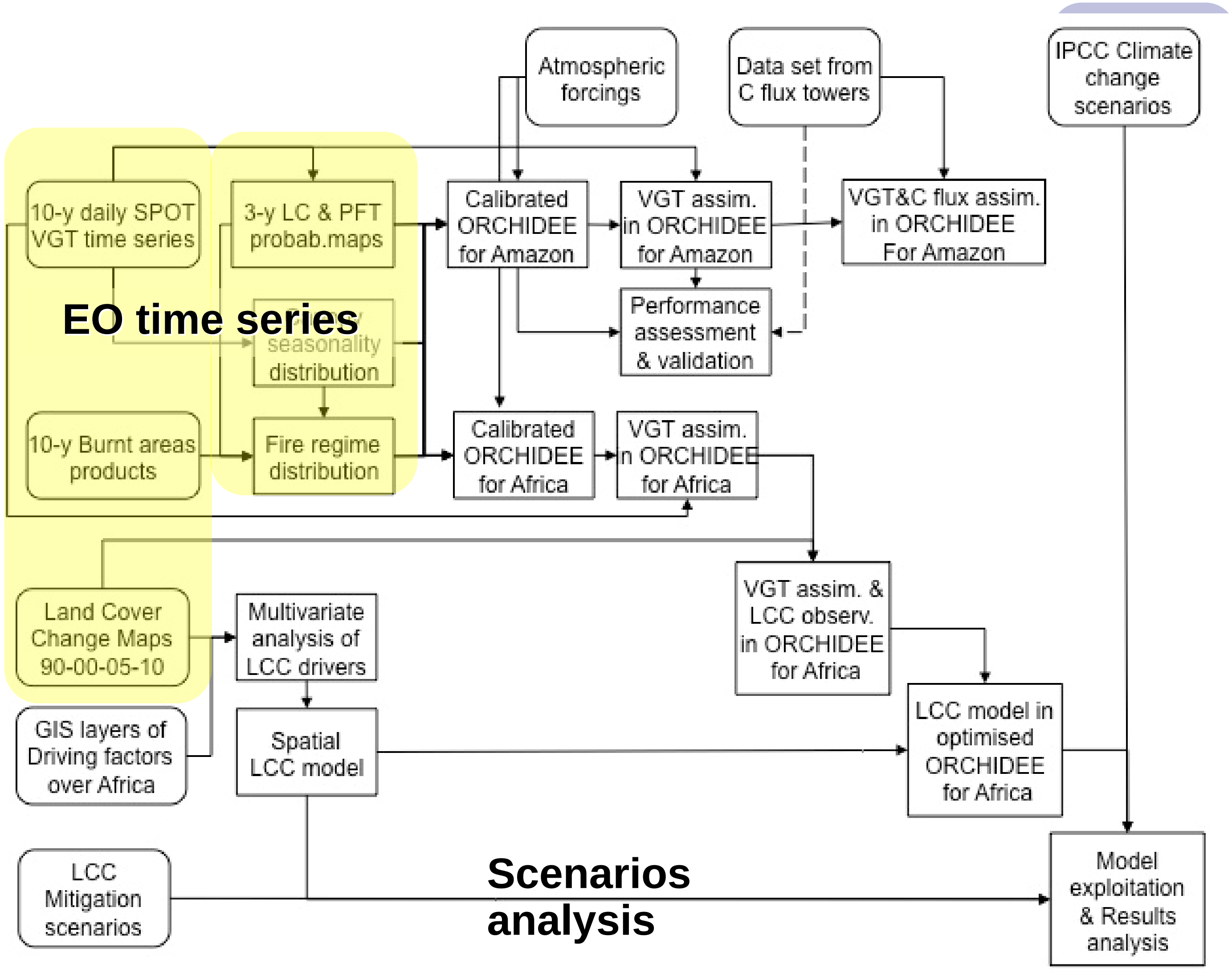
- Development of a Land Use Land Cover Change model based on drivers analysis to be coupled with the ORCHIDEE model

- Climate change / LULCC scenario definitions and model exploitation to assess future carbon strock and potential impact of climate change and mitigation policy

Overall flowchart



Overall flowchart



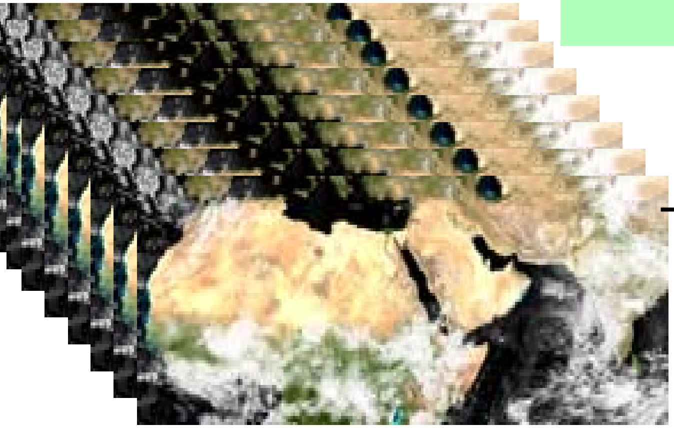
10-y SPOT Vegetation Analysis

First multi-year land cover (LC) map for different epochs

=> LC-specific seasonality characterisation

=> LC translation into PFT thanks to LCCS

=> LC-specific Burnt Areas interpretation



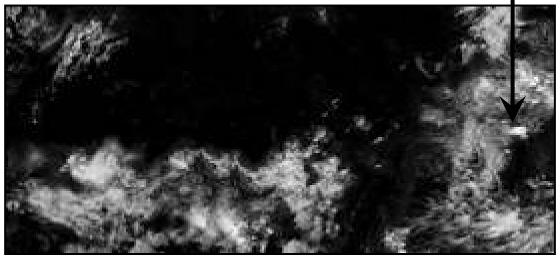
10-y Daily VGT S1 product

Quality control stage

I

Mean Composite (SWIR, NIR, RED)

0



Clouds, hazes and pixel anomalies

SPOT VGT assets

- **Mean Compositing algorithm** providing smooth temporal profiles of spectral reflectance
- **Great radiometric calibration over 10-**y
  (< 1% over 3 years, < 2% over 3 years)
- **Excellent geometric accuracy**
  (absolute location : RMSE 243 & 223 m)
- *Several already derived products (CYCLOPES LAI, FAPAR and L3JRC Burnt Areas)*

Land cover characterization from 3-y SPOT-VGT time series

Building up on the GlobCover experience acquired on 1-y Meris time series

- **Step 0:** A priori stratification

  ➪ Split the world in 22 equal-reasoning regions from ecological and remote sensing point of view

- **Step 1:** For each region, per-pixel (sup./unsup.) classification algorithm

  ➪ Homogeneous land cover classes

- **Step 2:** Per-pixel temporal characterization

  ➪ Robust temporal metrics computed per-object from 10-d multispectral composite and associated indices

- **Step 3:** Per-object classification algorithm

  ➪ Consistent unlabelled spectro- temporal classes

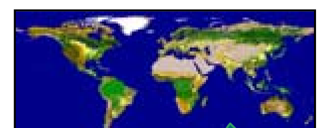
- **Step 4:** Labelling rule-based procedure

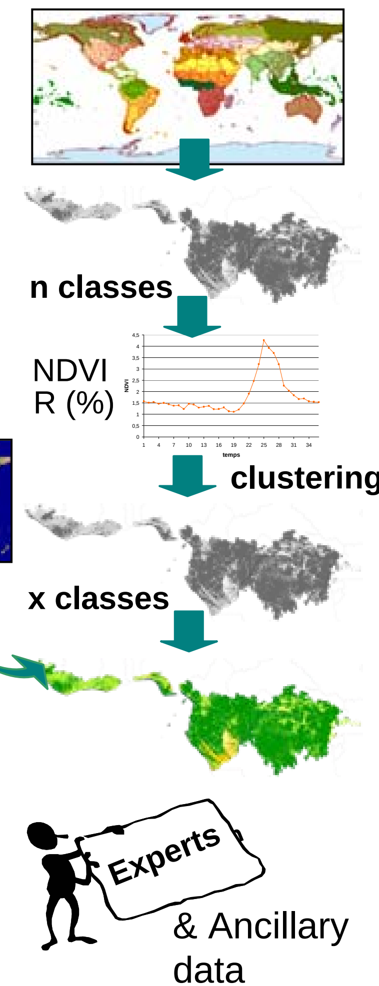
  ➪ Based on best existing DB using classifiers of LCCS land cover classes (PFT)

- **Step 5:** Calibration

  ➪ Adjustment for specific labelling thanks to interactive calibration by a network of experts

- **Step 6:** Independent Validation



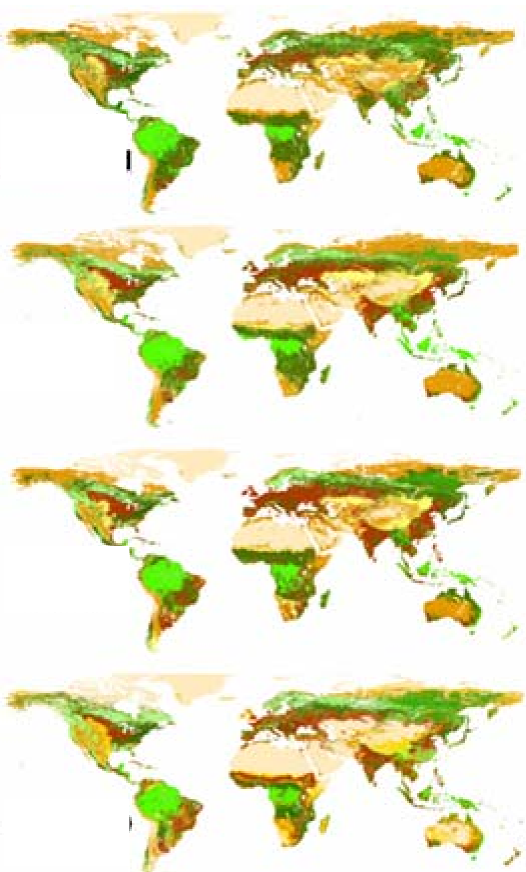


=> Production of maps of 1-km global VGT land cover

(99-01; 02-04; 05-07; 08-10)

FAO-LCCS typology linking land cover to plant functional type

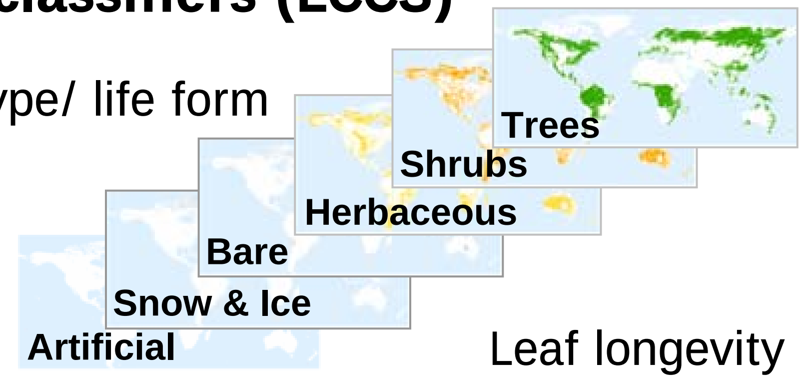
Land cover categories



Translation

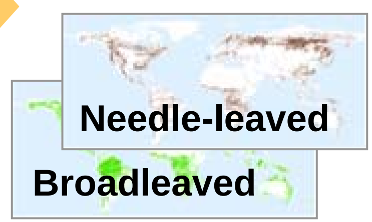
Common land cover classifiers (LCCS)

Cover type/ life form



Leaf longevity

Leaf type



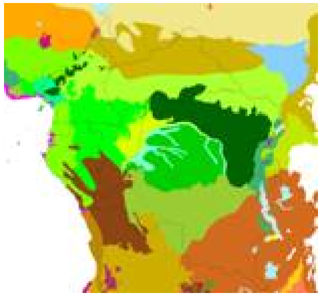
Terrestrial / aquatic+ regularly flooded

Cultivated and managed/

(semi-)natural

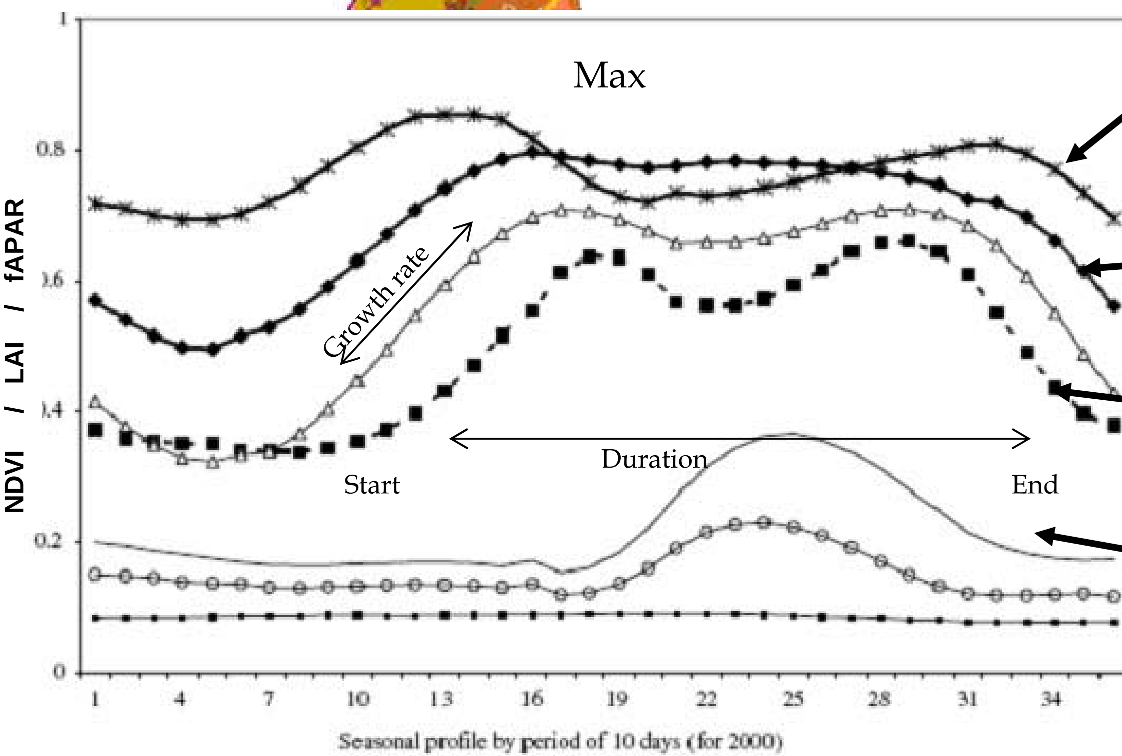
(Herold et al., 2009)

Vegetation temporal characterization per land cover and per ecoregion from 10-y SPOT-VGT time series

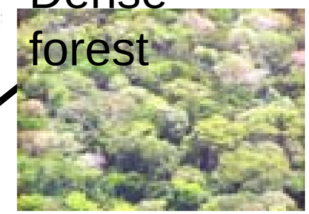


LAI profile over 10-y TS
Phenological metrics
Inter-annual variability

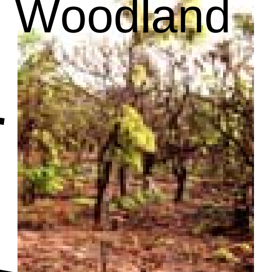
Fire Regime from
L3JRC products
Tansley et al. 2007



Dense forest



Woodland



© M. Schaijes

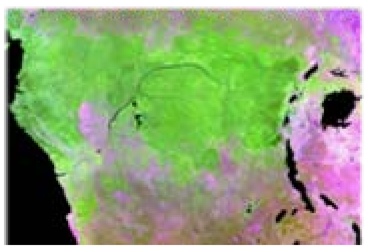
Mosaic Forest - Savana

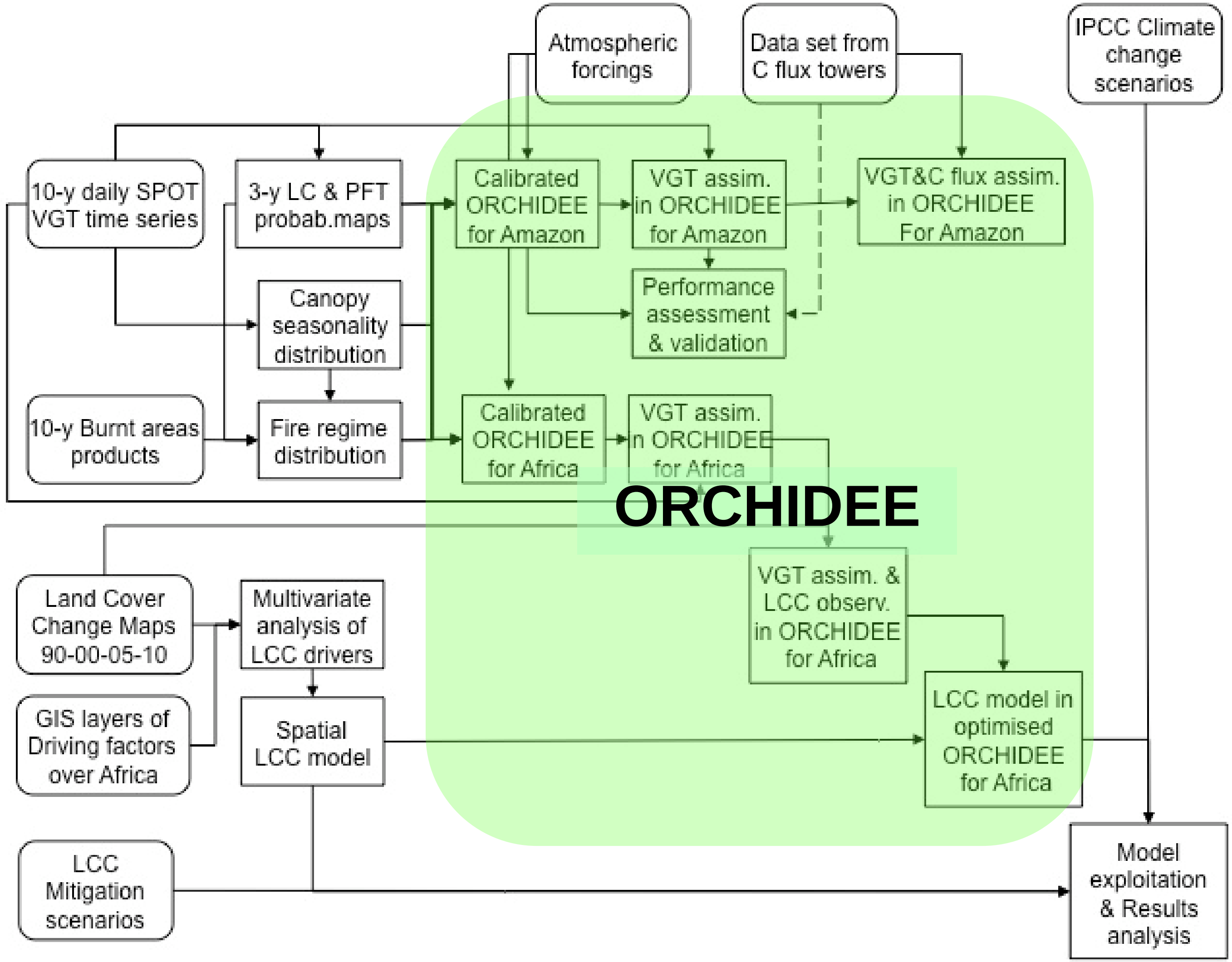
© H.-P.Eloma

Grassland

=> Vegetation foliage phenology reference data set

Overall flowchart



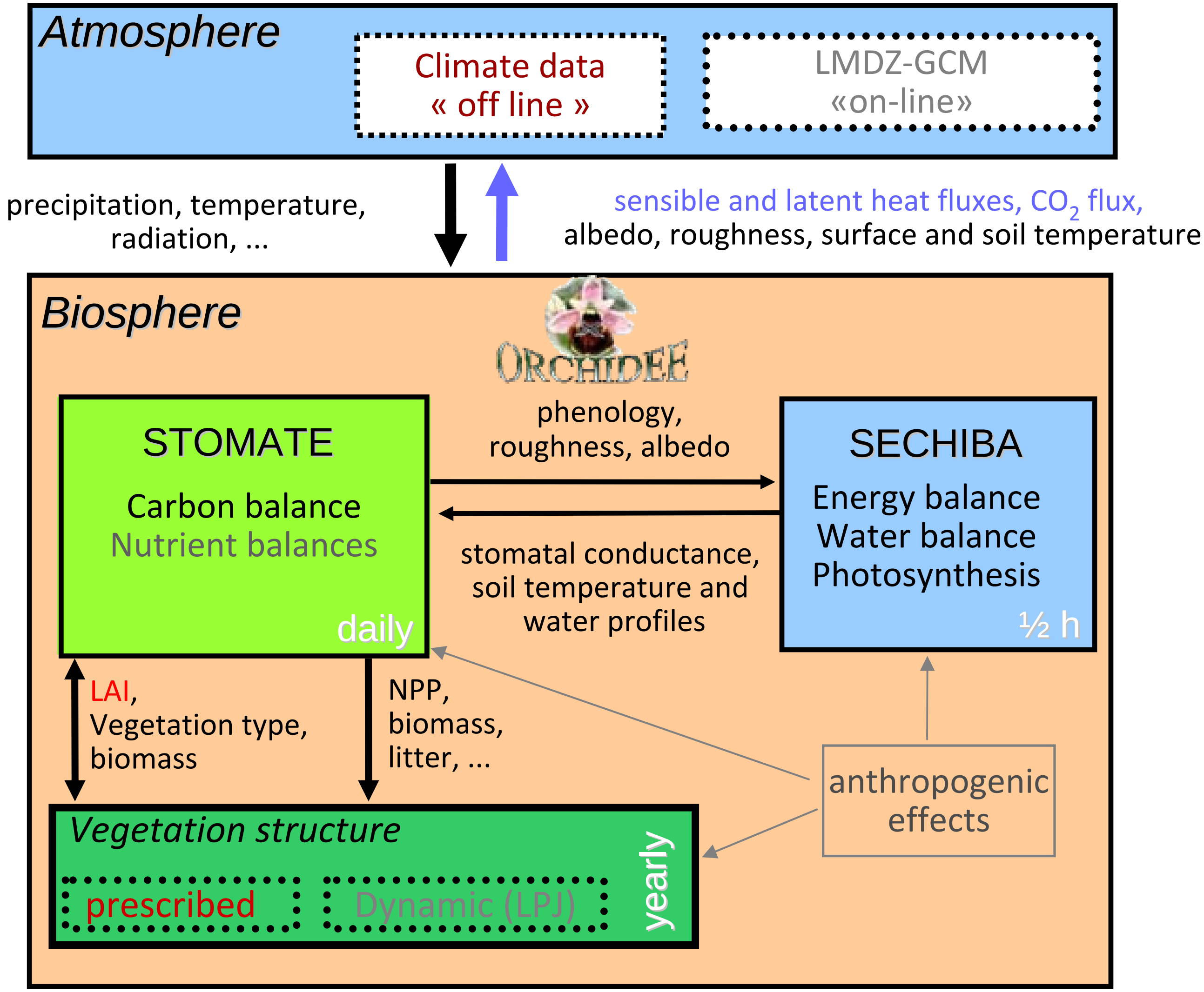


ORCHIDEE

ORganizing Carbon and Hydrology In Dynamic EcosystEms

- Process-driven global ecosystem model
- Energy, Water, Carbone, N, balances
- Plant Functional Types PFT’s approach
- Computes its own phenology

ORCHIDEE



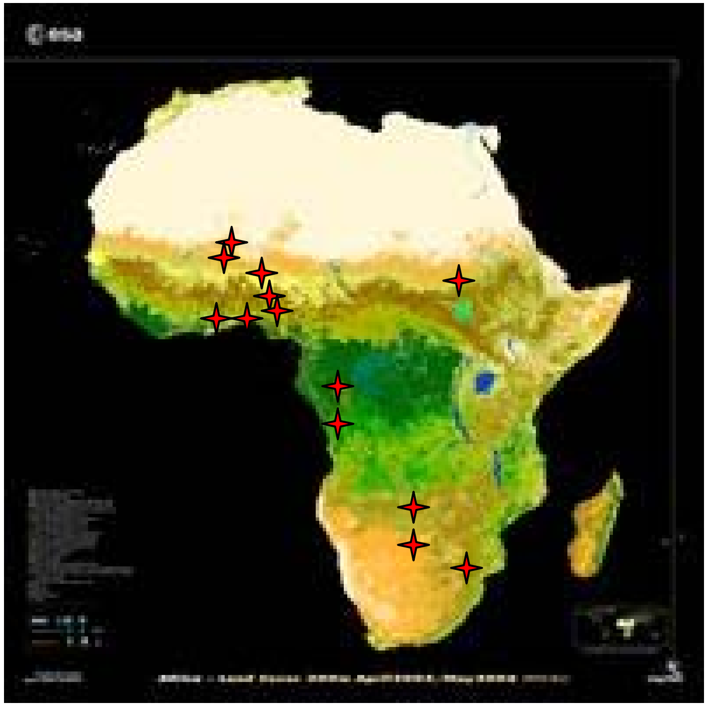
- 13 PFT's
- Need spin-up of C-pools

Using SPOT data to initialize ORCHIDEE

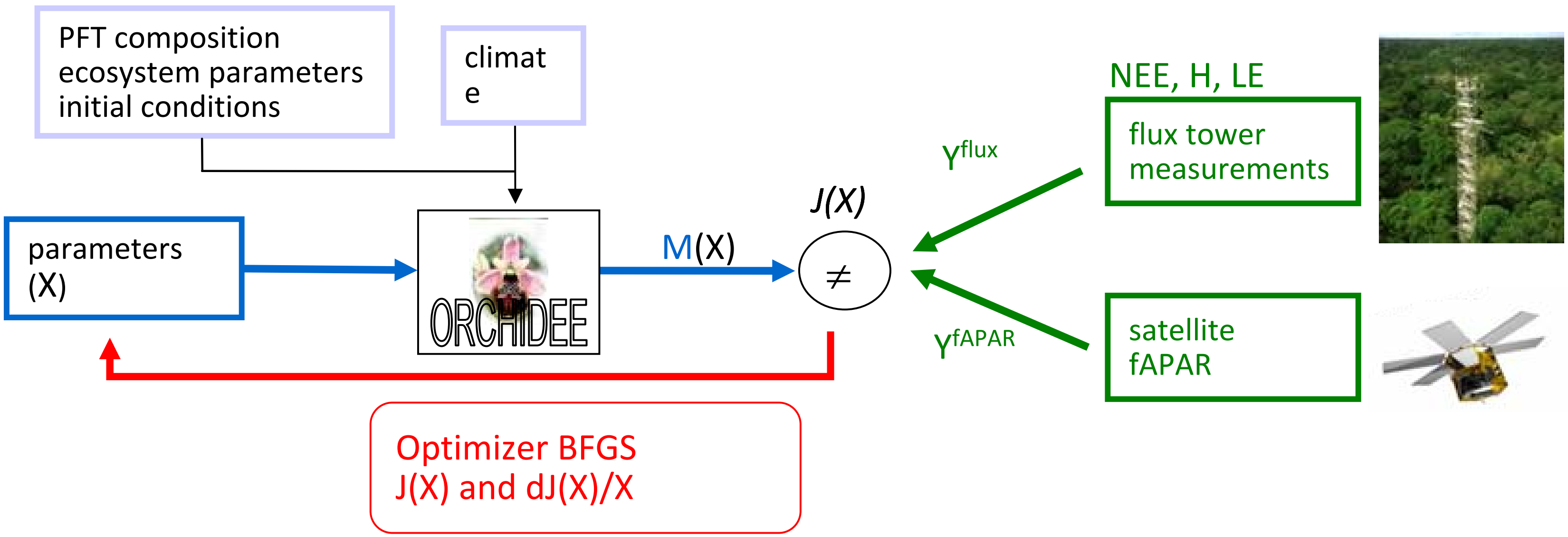
- Satellite data to initialize the model's PFT's. (Land-cover map) PFT composition of each grid point.

PFT1: bare soil
PFT2: tropical broadleaf evergreen forest
PFT3: tropical broadleaf raingreen forest
PFT4: temperate needleleaf evergreen forest
PFT5: temperate broadleaf evergreen forest
PFT6: temperate broadleaf summergreen forest
PFT7: boreal needleleaf evergreen forest
PFT8: boreal broadleaf summergreen forest
PFT9: boreal needleleaf summergreen forest
PFT10: natural C3 grass
PFT11: natural C4 grass
PFT12: agricultural C3 grass
PFT13: agricultural C4 grass

Poor availability of fluxtowers in Central Africa
=> methodological development in SAm
=> extension to Central Africa



Variational data assimilation system

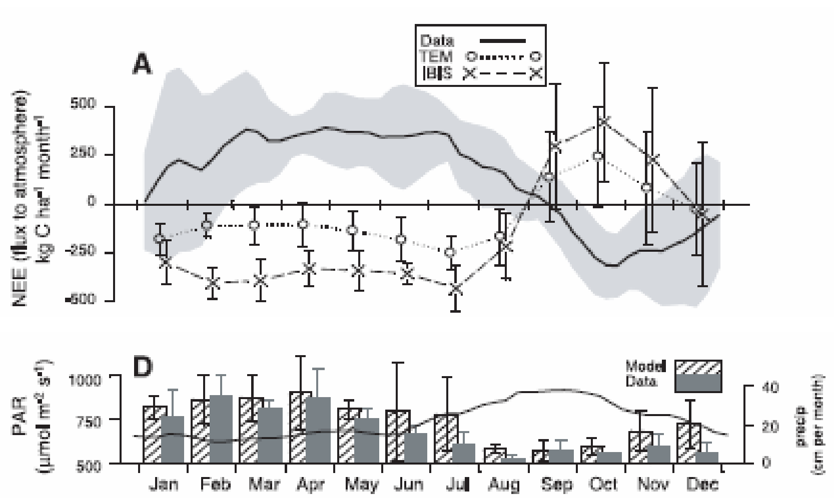


Governing processes and parameters to optimize

- Carbon assimilation → Kvmax, Gsslope, LAIMAX, SLA, ThetaLeaf
- Autotrophic respiration → frac_resp_growth, respm_T_slope, respm_T_ord
- Heterotrophic respiration → Q10, Hc
- Plant phenology → Kgdd, Leafage
- Hydrology → Soildepth, root profile

Counterintuitive seasonal NEE patterns at Tapajós km 67 site (Brazil)

Saleska et al. Science, 2003



Wet Dry

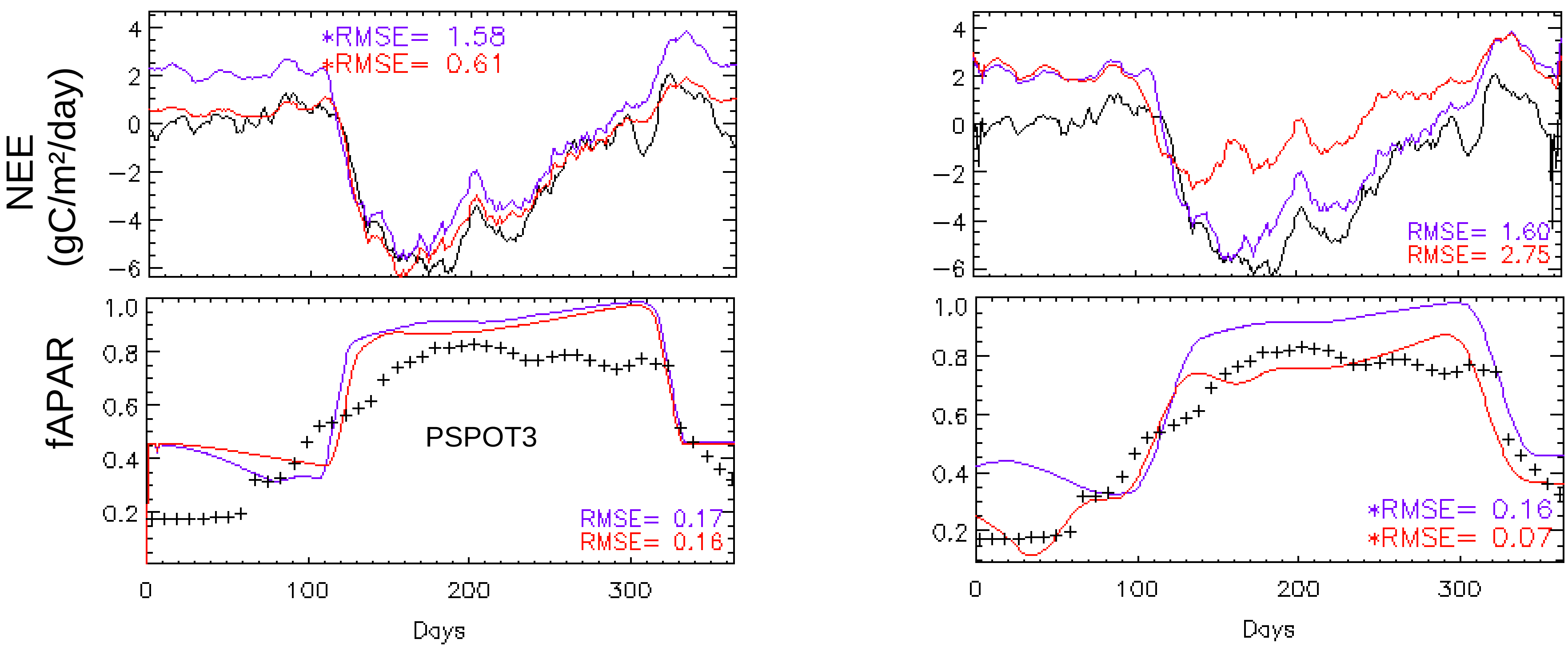
- Moisture effect on respiration dominates over GPP
- Deep rooting, deep soil columns with high water storage
- Hydraulic redistribution
- Phenology/photosynthetic response to high light levels during dry season

Fontainebleau: decideous forest

observation
prior
posterior

flux assimilation

fAPAR assimilation
PSPOT3

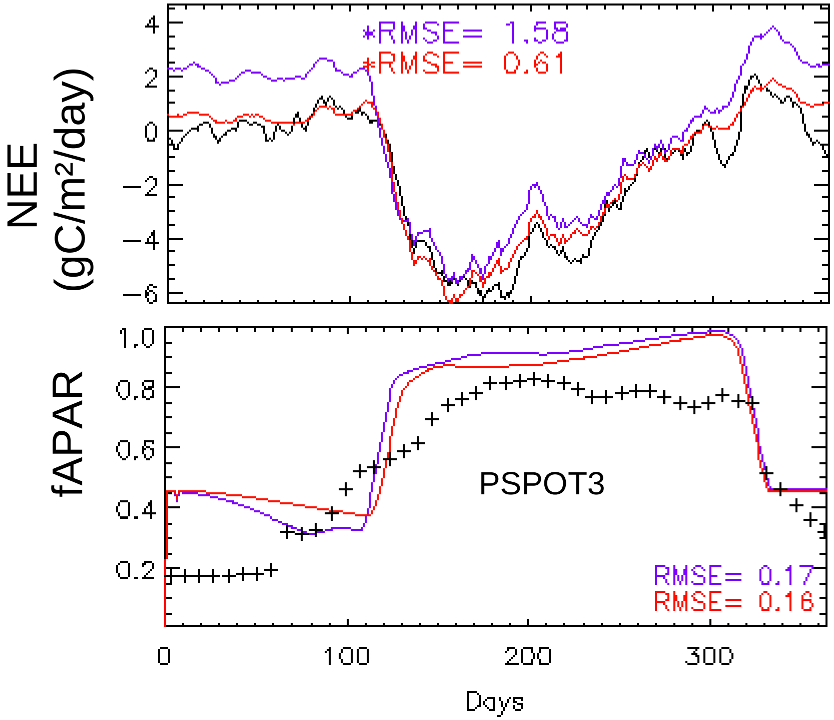


✓strong decrease of the carbon uptake during the growing season

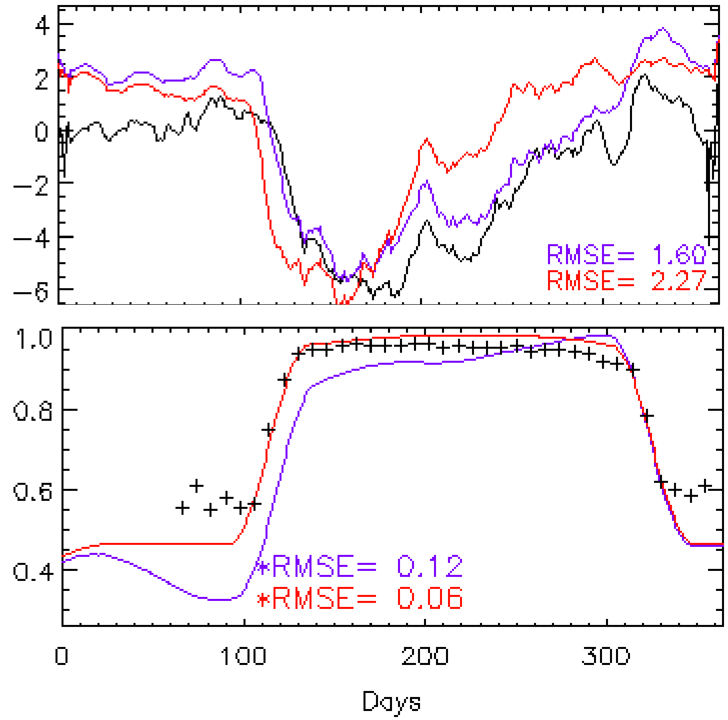
Fontainebleau: decideous forest

observation
prior
posterior

flux assimilation

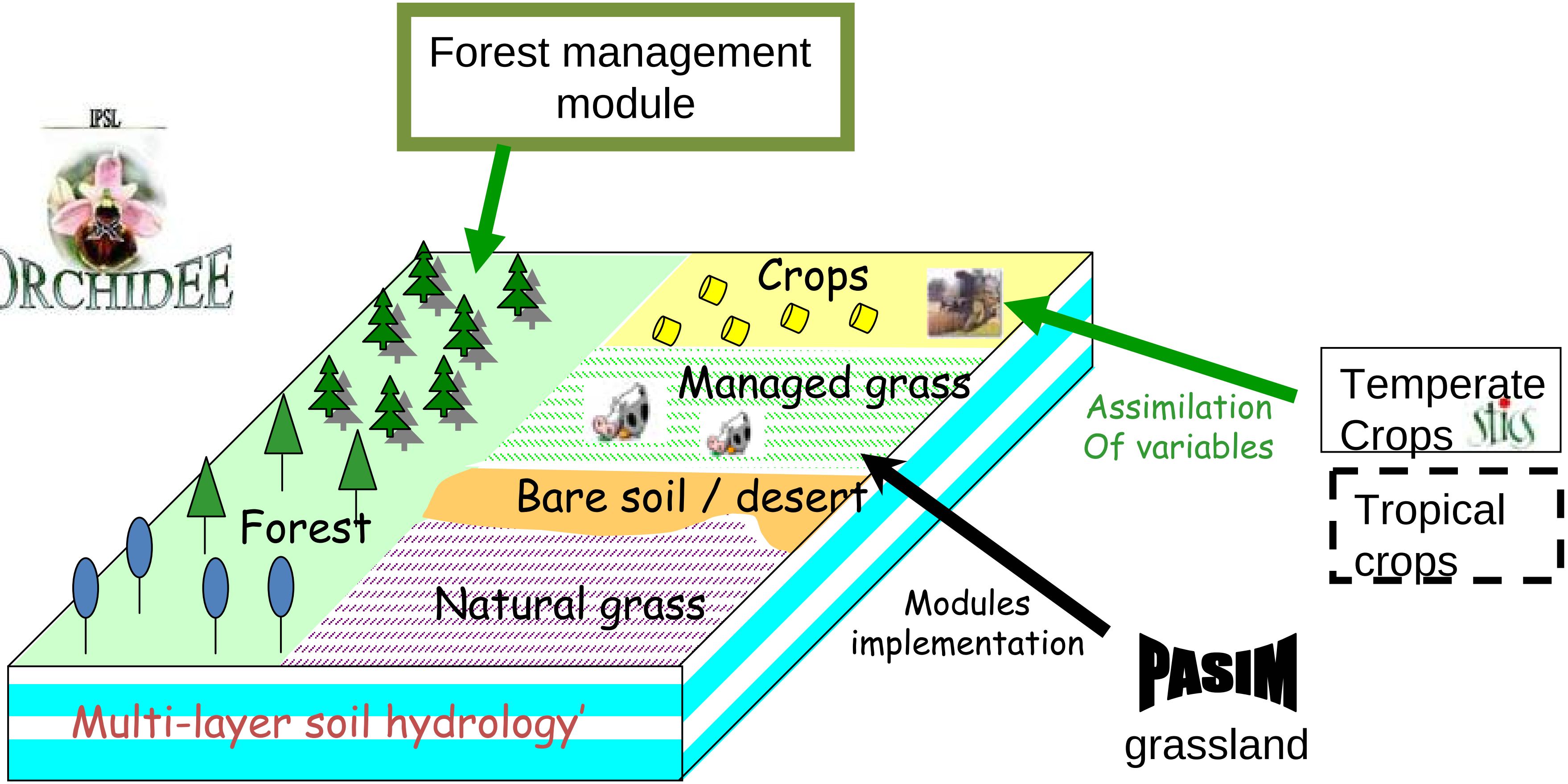


fAPAR assimilation
in situ



✓better agreement between ORCHIDEE and the various *in situ* data

Recent improvements of ORCHIDEE



A Forest Management Module for ORCHIDEE

ORCHIDEE, standard version

rainfall, temperature
solar radiation, CO_2
concentration, ...

Atmosphere
(prescribed or
simulated by a GCM)

sensible and latent heat fluxes,
albedo, roughness, surface
temperature, CO2 flux...

Biosphere

ORCHIDEE

STOMATE

Vegetation and soil
Carbon cycle

Prognostic phenology and
allocation, constant mortality

Δt=1 day

LAI, roughness,
albedo

Soil profiles of
water and temperature,
GPP

SECHIBA

Energy budget
Hydrology
+
Photosynthesis

Δt=1 hour

NPP, biomass,
litterfall ...

Vegetation types
biomass

Vegetation distribution

(prescribed or calculate by LPJ
Dynamic General Vegetation
model)

A Forest Management Module for ORCHIDEE

ORCHIDEE, coupled with FM module

rainfall, temperature
solar radiation, CO_2
concentration, ...

Atmosphere
(prescribed or simulated by a GCM)

sensible and latent heat fluxes,
albedo, roughness, surface
temperature, CO2 flux...

Biosphere

ORCHIDEE

STOMATE

Vegetation and soil
Carbon cycle

Prognostic phenology and allocation, ~~constant mortality~~

Δt=1 day

LAI, r
a

Soil p
water and

NPP, biomass,
litterfall ...

Vegetation types
biomass

Mortality, LAI

Woody NPP

Add-ons:

- *Progressive increase of LAI_max for 15 years after a clear-cut*
- *Age-related decline in NPP (LAI_max limited by height and v_max declines after 50 years)*
- *2.5% of branches die each year*

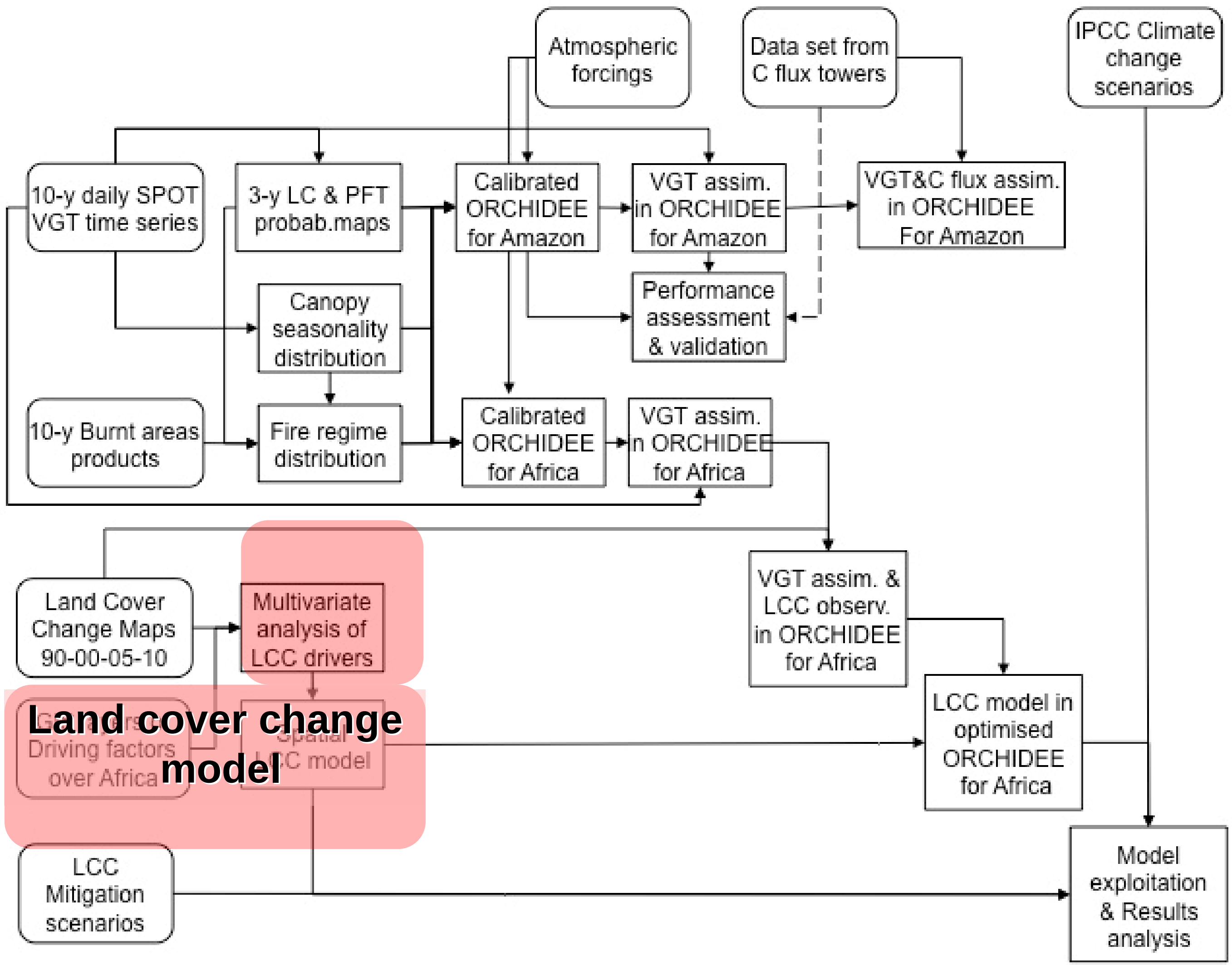
Vegetation distribution

(prescribed or calculate by LPJ Dynamic General Vegetation model)

Forest management (FM)

- Explicit tree distribution
- Explicit mortality due to self-thinning and human thinning
- LAI limited by thinnings

Project structure



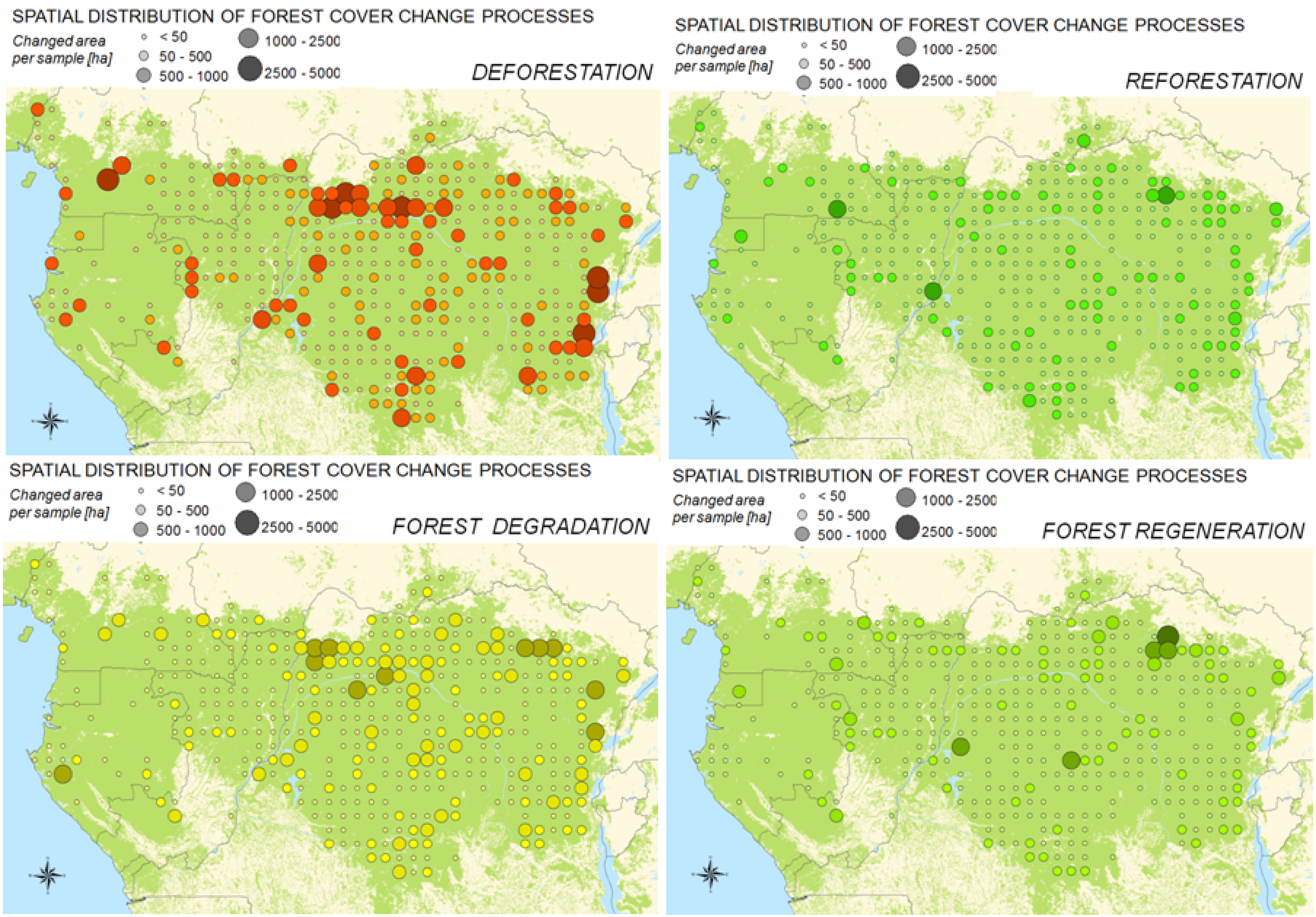
Land Use Land Cover Change Modelling

- Carbon emissions from land-cover change are equivalent to about **30%** fossil fuel emissions.

- Deforestation - degradation rate are best measured by HR data
  - Gross Deforestation: 0,21 % / yr
  - Net Deforestation: 0,16 % / yr
    => 46 000 km² in 15 yr
  - Degradation: 0.09% / yr

- Fire occurrence simulation parameterized with SPOT-VEGETATION burnt areas product

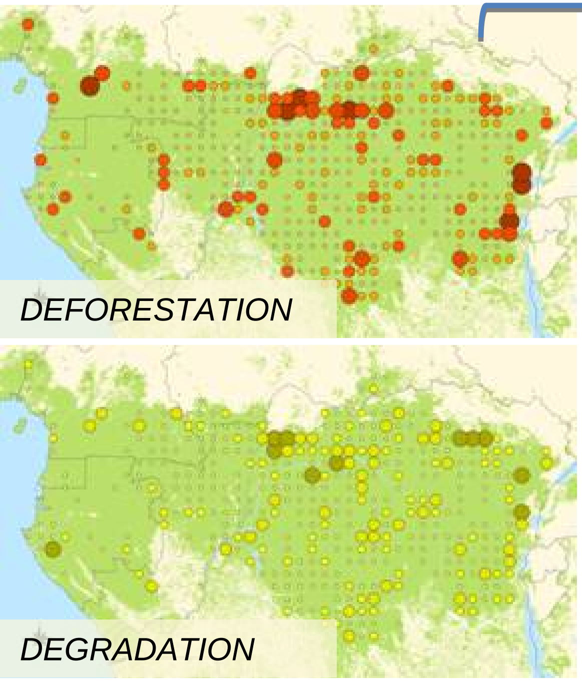
Forest cover change detection (+ forthcoming Figures from OFAC)



(UCL – Duveiller et al., RSE 2008)

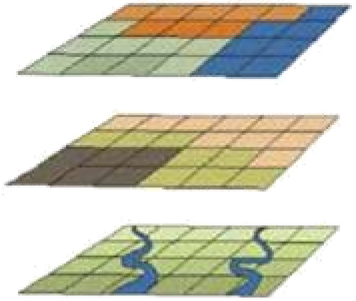
LULC change modelling

a predictive model allowing to account for forest deforestation/degradation based on current LC change observations and future estimates.



GIS information
(including new pop. map,
river/road accessibility map, legal status,…)

\+



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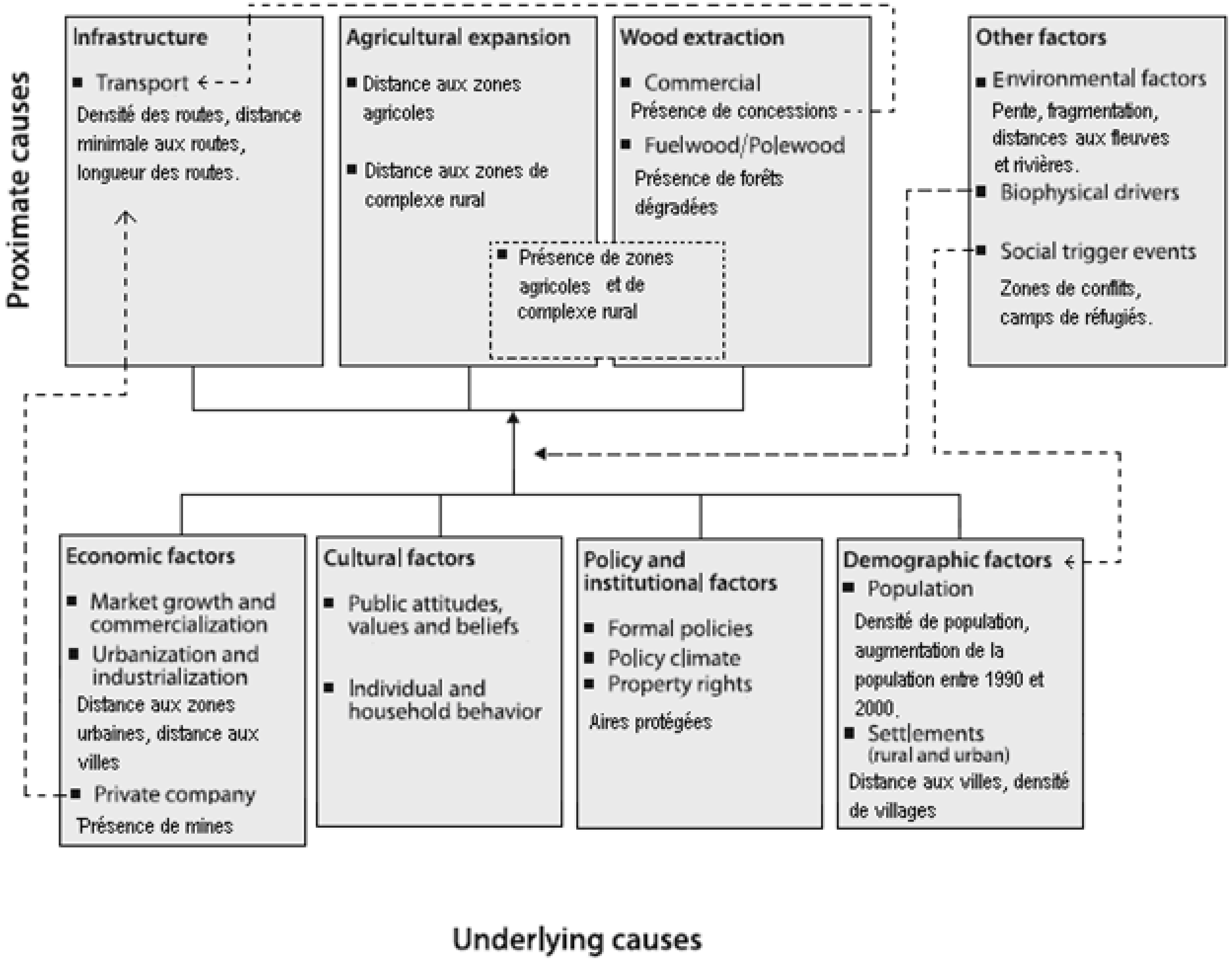
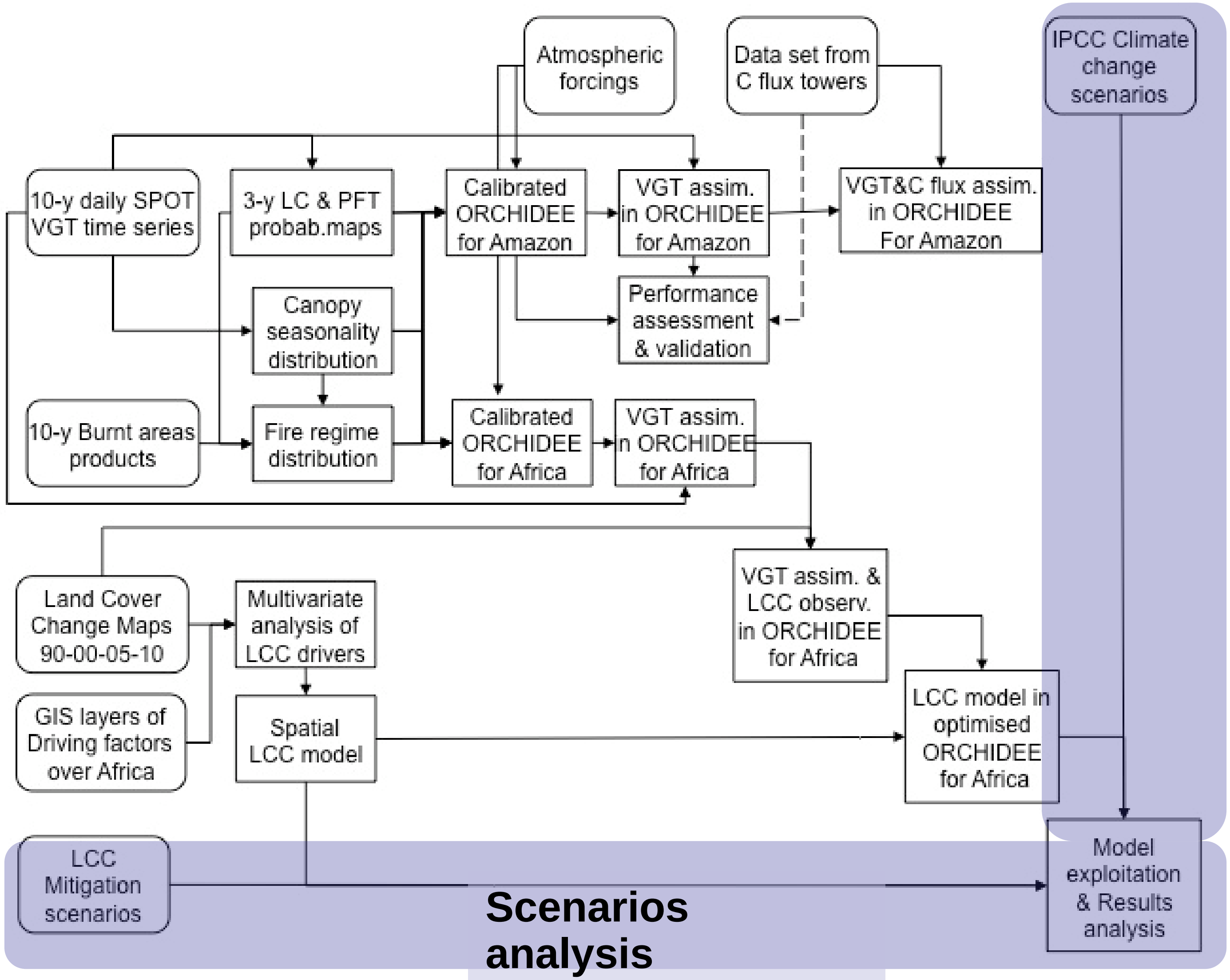
Cellular Automata Markov modelling approach combined with a multivariate analysis of LC change drivers

Possible LULC change drivers

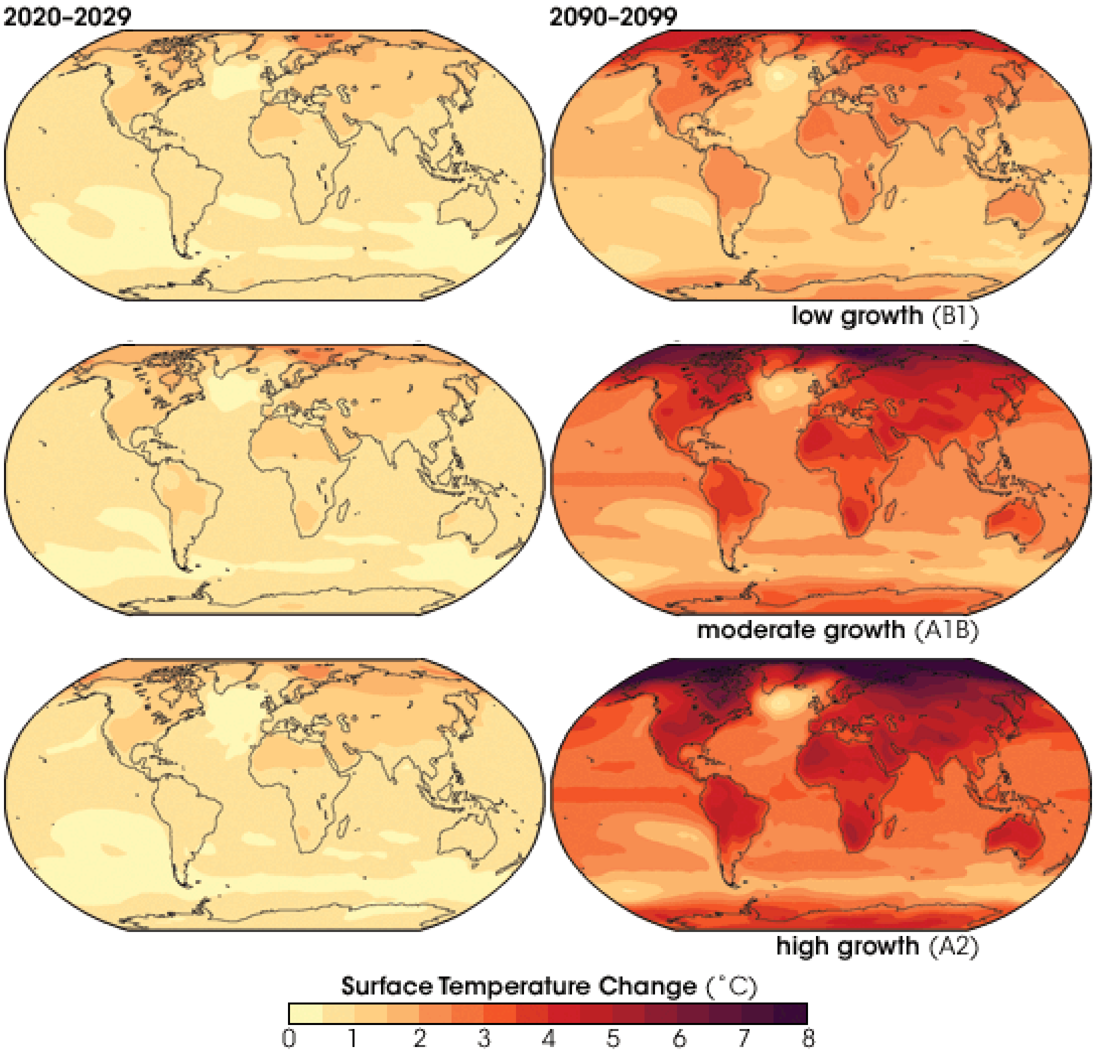


From on-going FAO/UN-REDD Drivers analysis in DRCongo (Delhage et al.)

Project structure



Climate change scenarios



Climate data like temperature, precipitations and atmospheric CO2 concentrations will be used as external forcings in the model. Three different "future climate" IPCC scenarios will be considered. Future climate forcings will be obtained from the IPSL coupled climate model.

IPCC Fourth Assessment Report (2007)

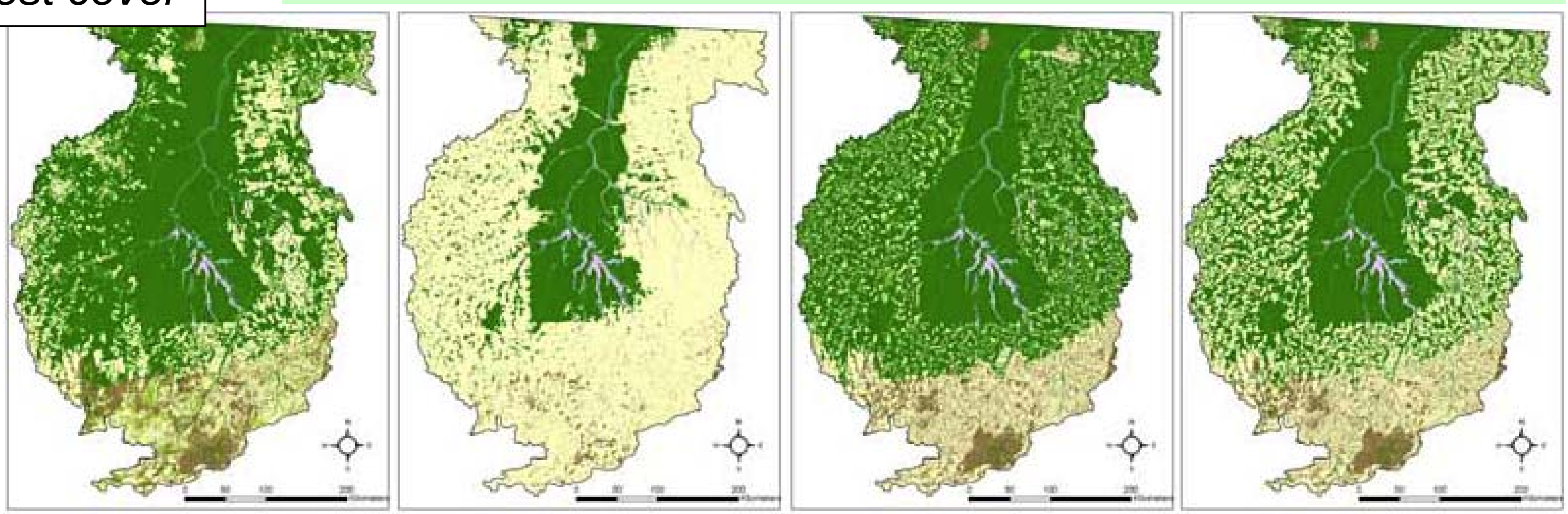
Land cover change scenarios

In the context of the REDD initiative, a precise definition of deforestation scenarios is currently undertaken. Unlike other regions, the “business-as-usual” scenario for Central Africa is rather unrealistic as deforestation rates have historically been very low.

We shall distinguish 3 different scenarios:

- REDD (same as present situation)
- Small increase principally due to population growth
- Large increase due to both population and economical growth

Forest cover



Current situation | Scenario A | Scenario B | Scenario C

Perspective

VEGECLIM is a great opportunity

to fully exploit the full SPOT VEGETATION TS 10-y after launch and to prepare PROBA-V mission exploitation

to better bridge the gap between the Carbon modelling community, EO community and LULC modelling community

to provide a significant Belgian contribution to the post-Kyoto REDD discussion with regards to Central Africa


Thanks for your attention