Assimilating EO Data into Terrestrial Carbon Cycle Models

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The current challenge in C cycle research

Objective — To produce estimates & predictions of ecosystem carbon exchange with quantifiable uncertainty.

Complications — Observations have gaps & instrumental weaknesses.

Models tend to oversimplify and may miss key processes and linkages.

Solution — Data assimilation provides a method to combine models and data to produce a more accurate description of ecosystem dynamics.

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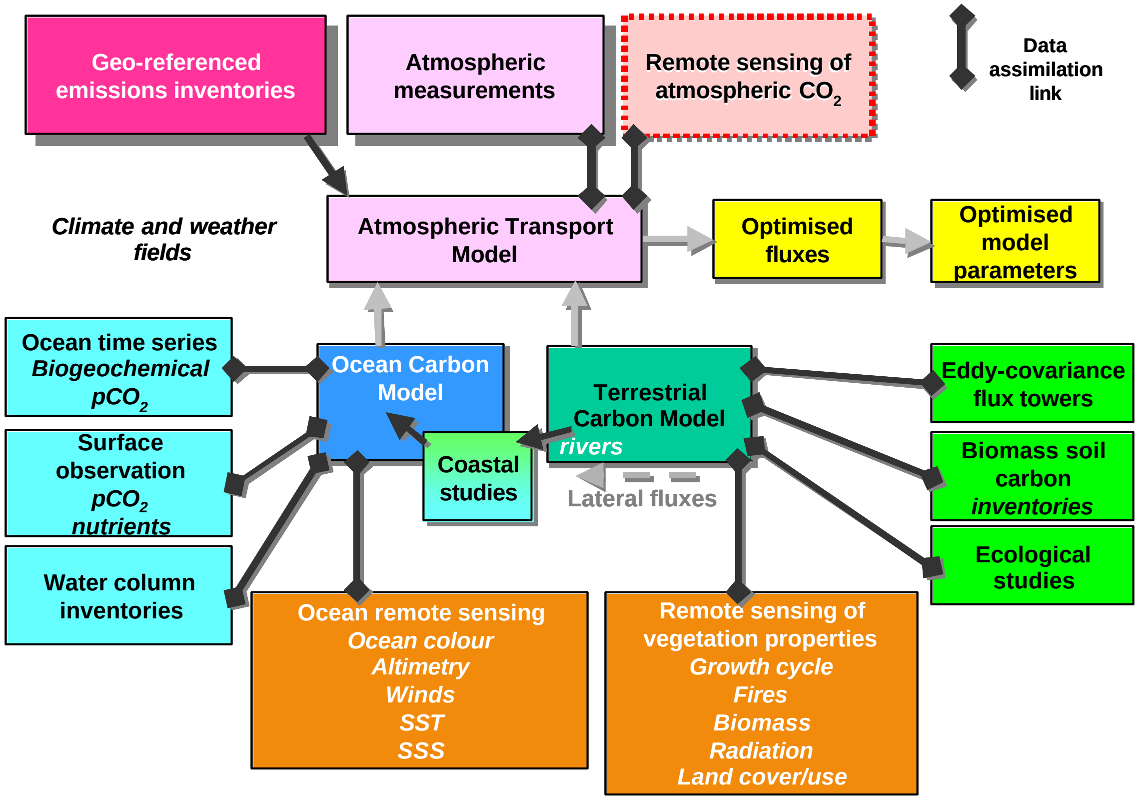
Global Carbon Data Assimilation System



Source: Ciais et al. 2003 IGOS-P Integrated Global Carbon Observing Strategy

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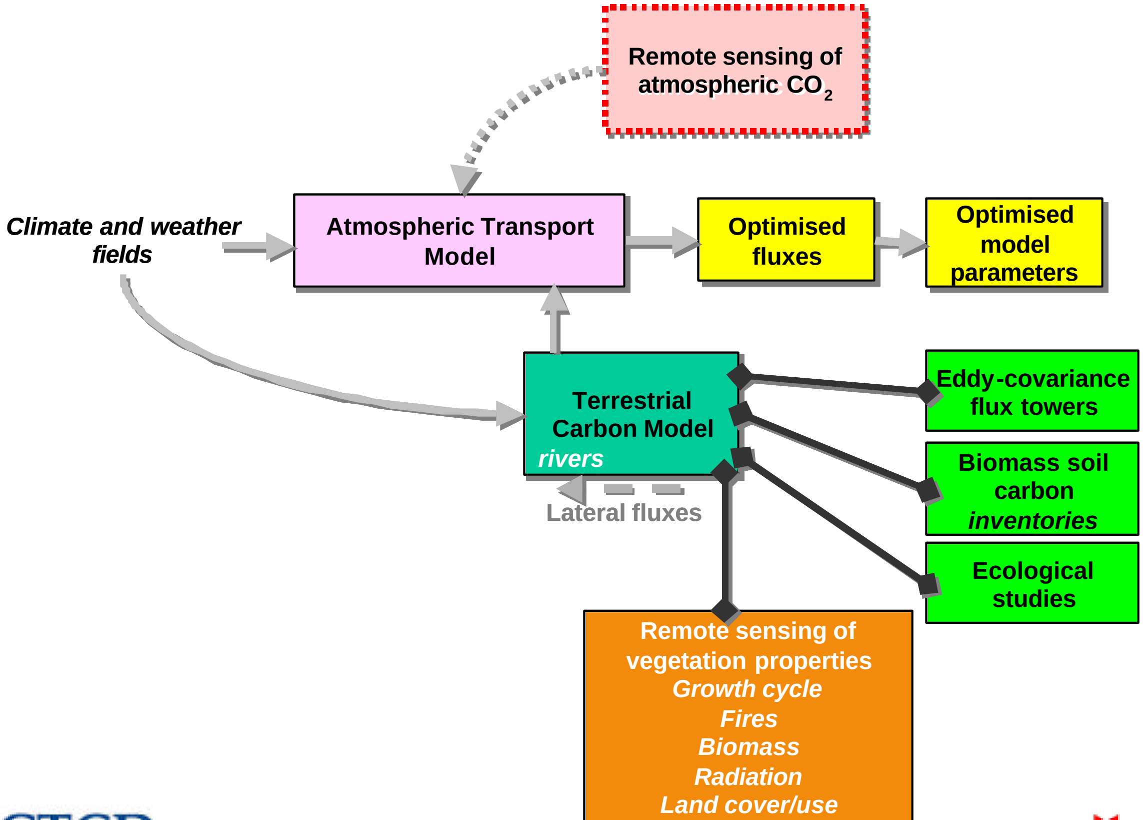
Terrestrial component



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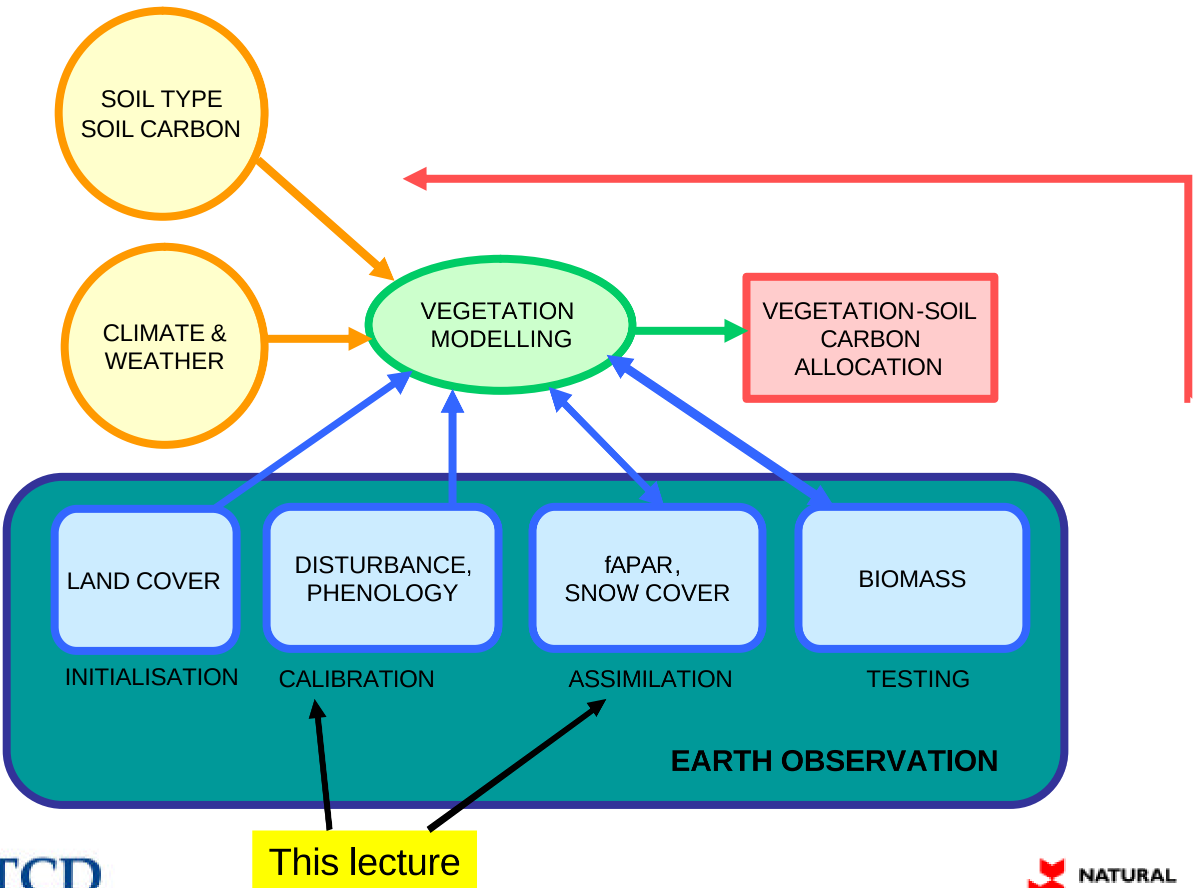
Carbon Cycle – Earth Observation Interfaces



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Issues

- Monitoring

  Consistency of models and data:

  - are model and measurement quantities compatible?

  - comparability of values

  Timescales (re-analysis)

- Prediction

  Are model internal processes and parameters testable and credible?

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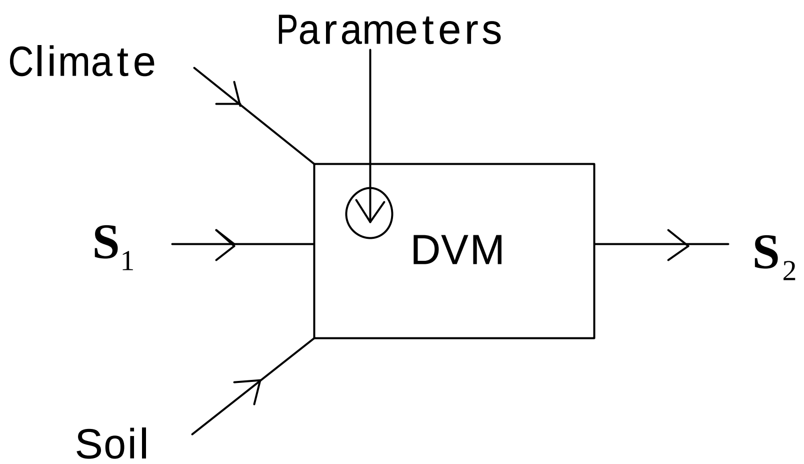
The Functioning of a DVM



S is the state vector describing the vegetation-soil system.

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Calibrating the SDGVM phenology module with EO data

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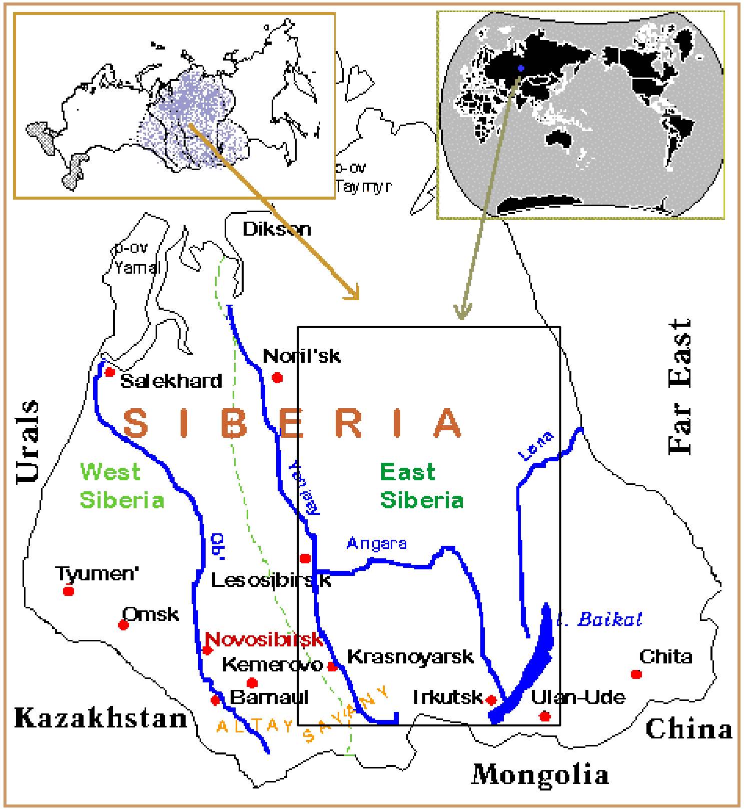
SIBERIA-II: Multi-Sensor Concepts for Greenhouse Gas Accounting of Northern Eurasia

5th Framework Project , 2002-2005



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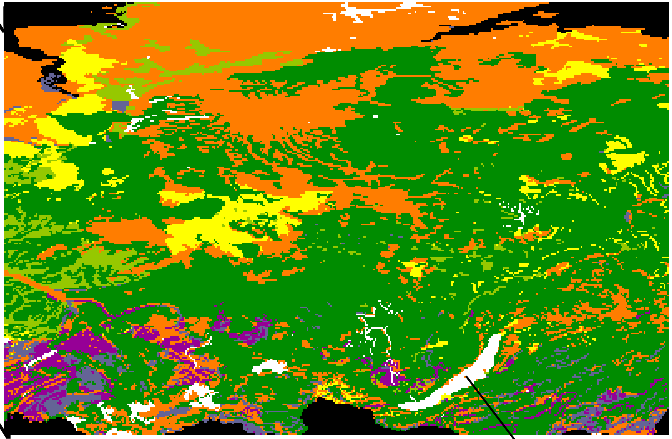
The Central Siberia dataset: ~ 2 M km^2



Land cover (IIASA)

Lake Baikal

1^o x 1^o forest map

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The CESBIO budburst algorithm

- Data set: SPOT-VEG 1999-2001
- Based on minimum in time-series of NDWI data
- Uncertainties in recovered budburst date ~ 7 days

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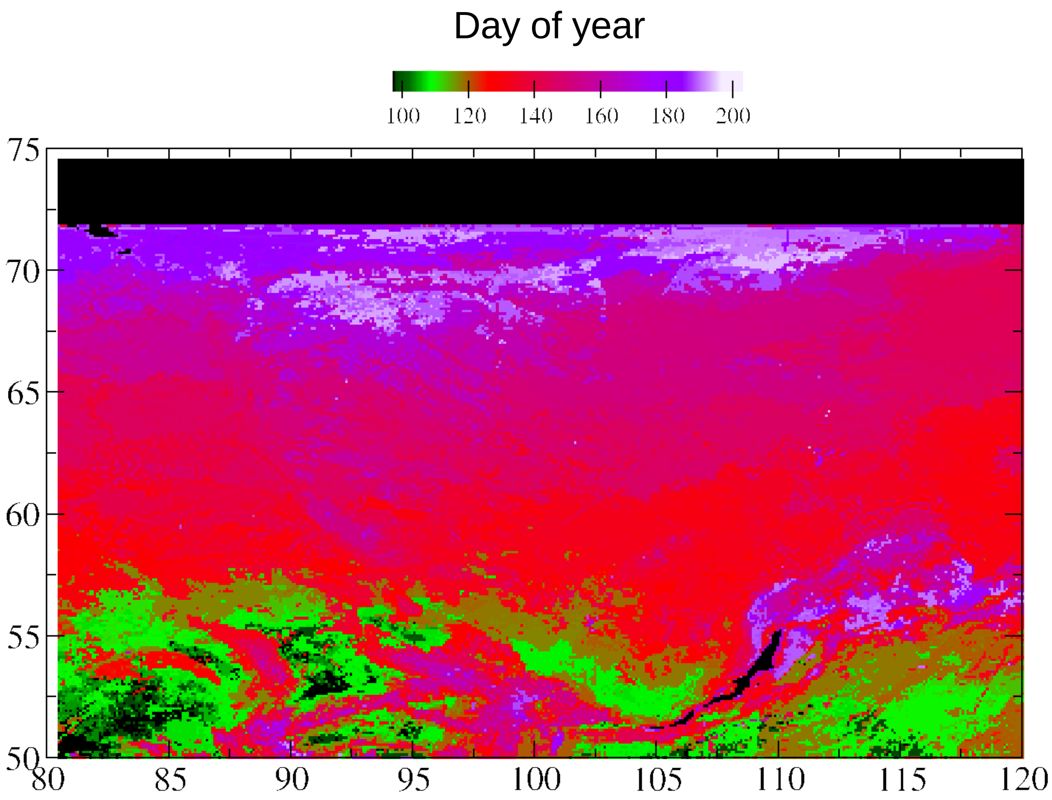
The Date of budburst derived from minimum NDWI (VGT sensor, 2000) N. Delbart, CESBIO



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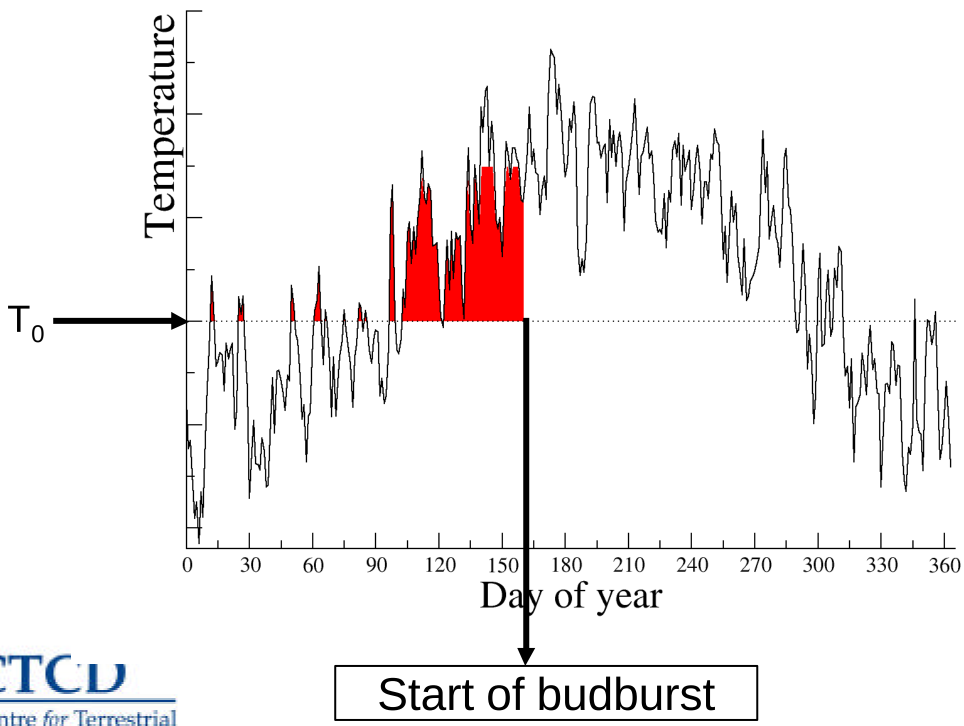
The SDGVM budburst algorithm

When $\sum_{days} \min(0, T - T_0) >$ Threshold, budburst occurs.

The sum is the red area. Optimise over the 2 parameters, Threshold and T_0 (minimum effective temperature).



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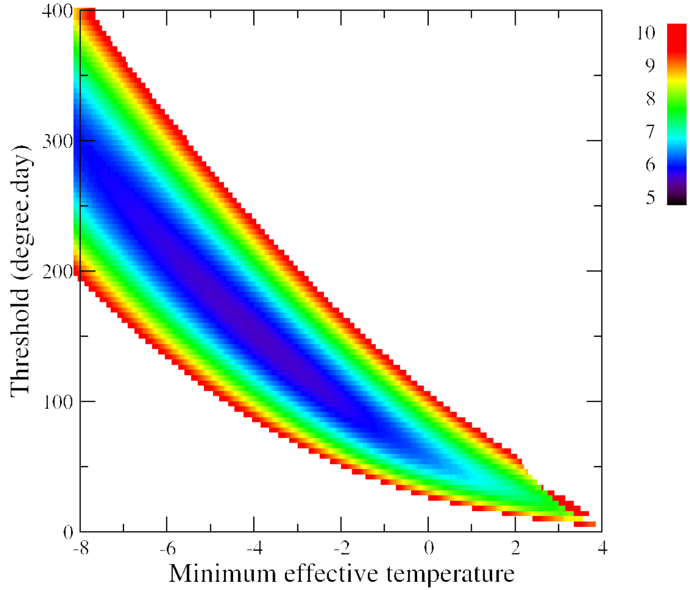
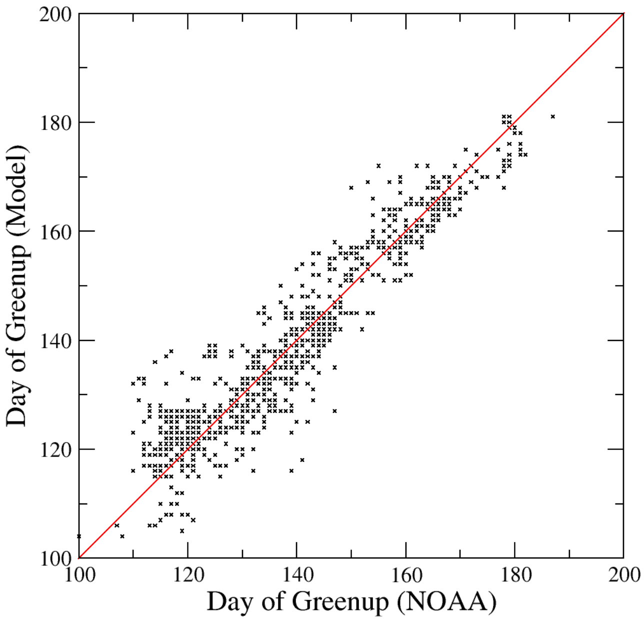
The calibration procedure





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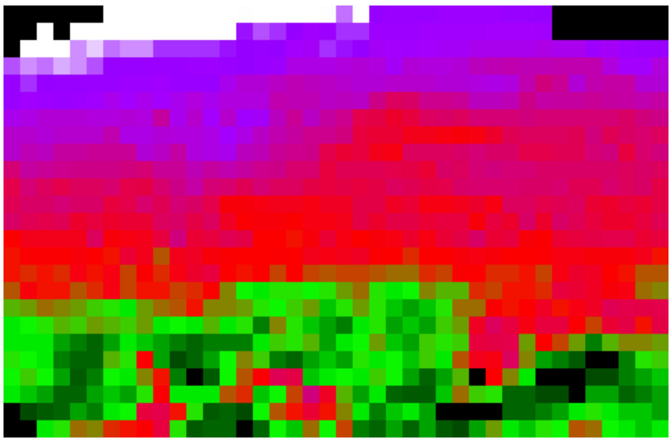
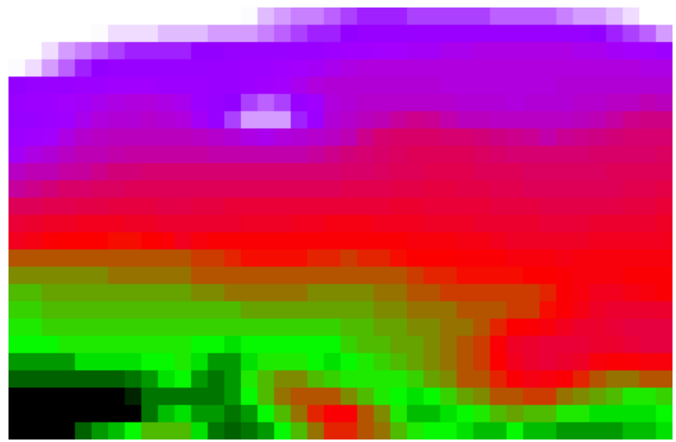
Data - model comparison 1999



Budburst from NDWI data



Model budburst: optimised parameters

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Calibration parameters (forest only)

Year	T_0 (degrees)	Threshold (degree-days)	MMSE (days)
1999	-2.9	117	6.0
2000	4.4	29	7.0

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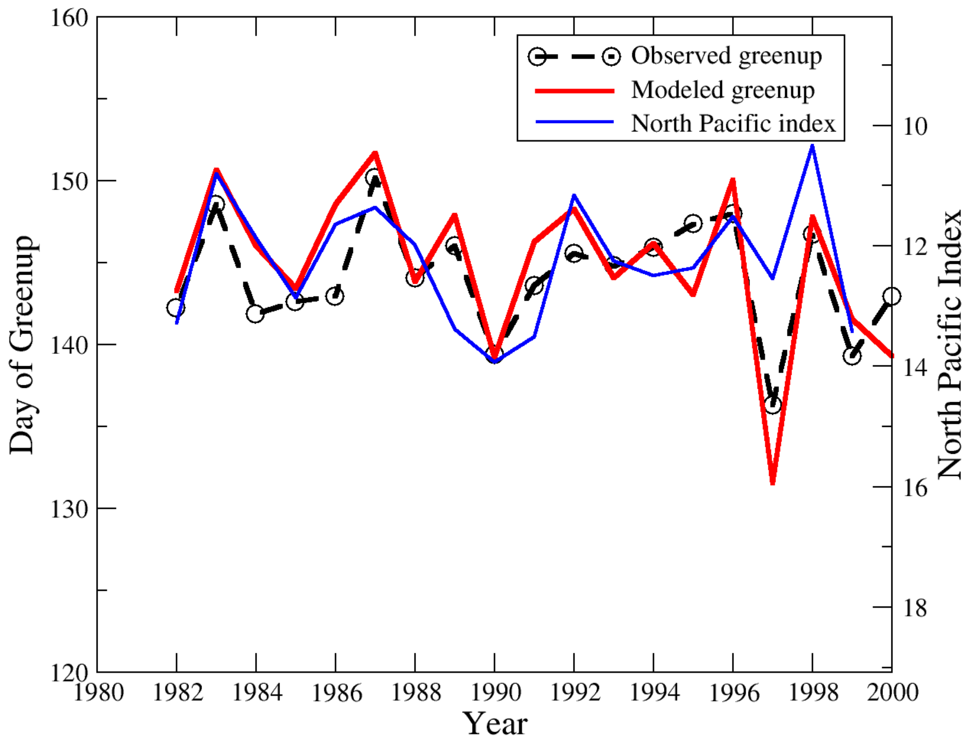
Green-up relation to N Pacific Index

The NP Index is averaged from April the previous year to March the present year



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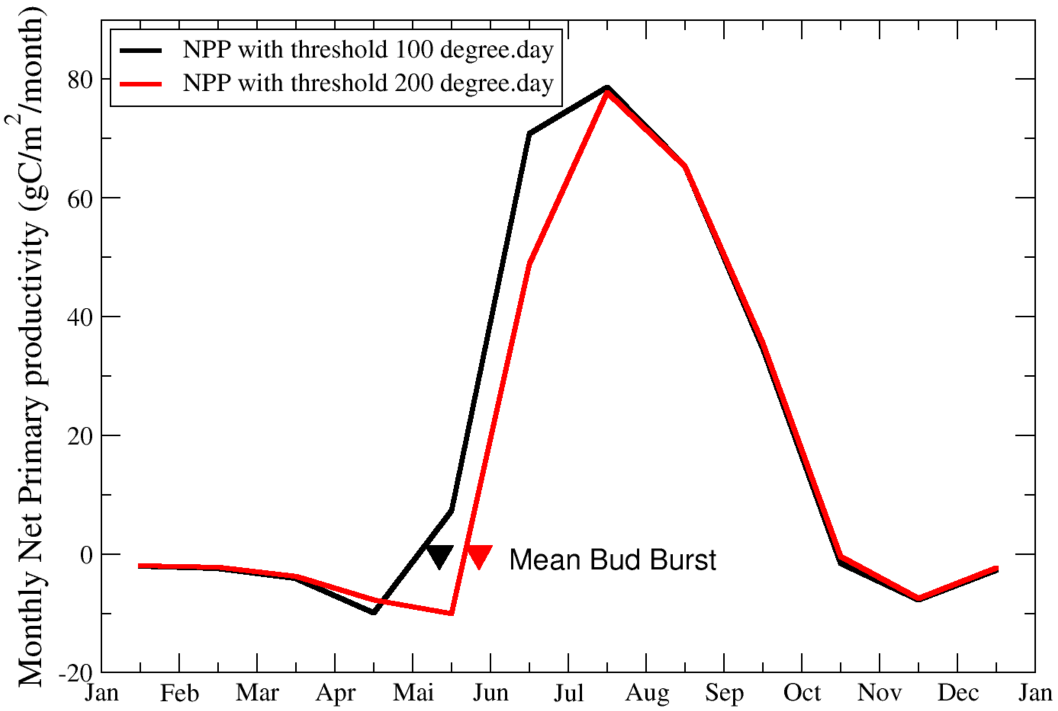
Effect of uncertainty in green-up day



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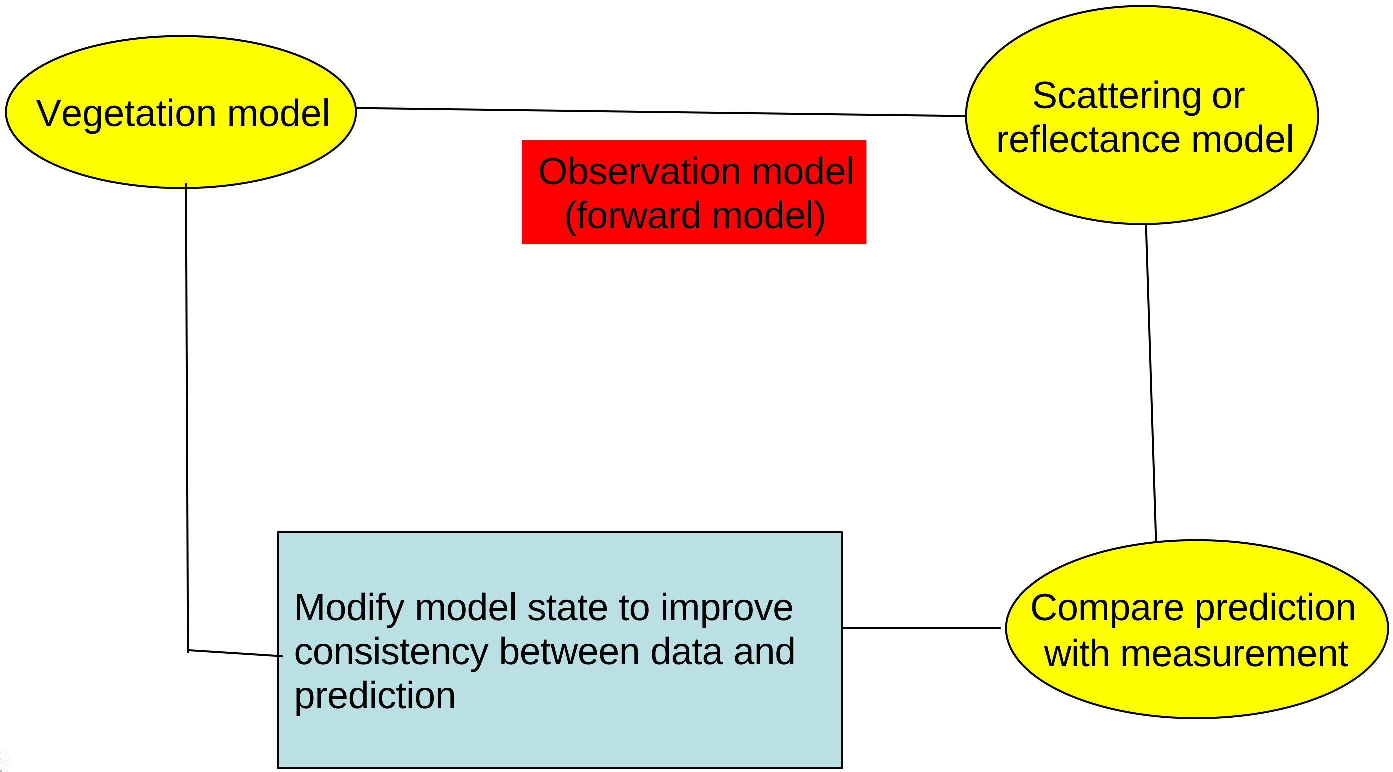
‘True’ Assimilation



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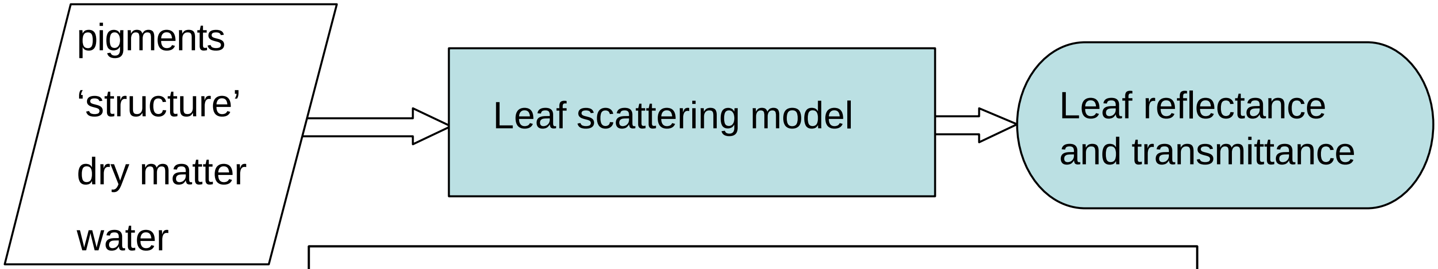
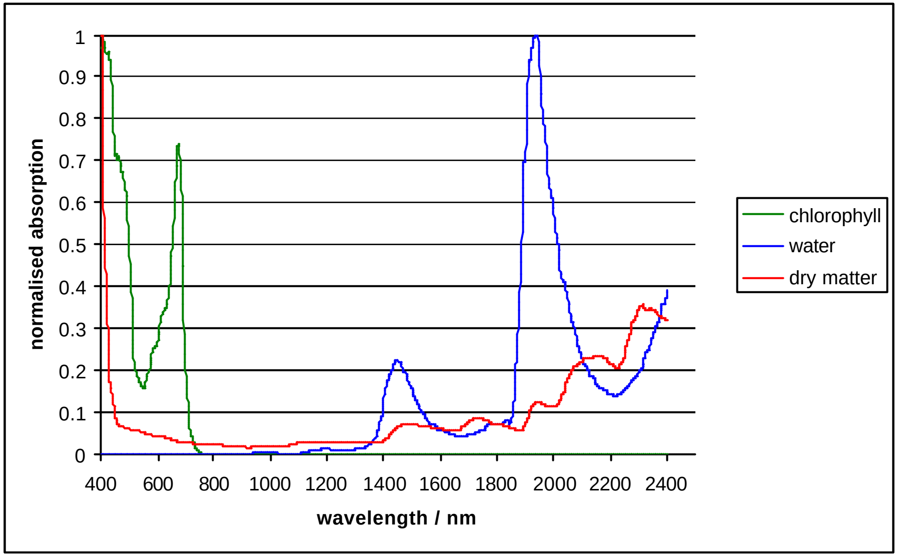
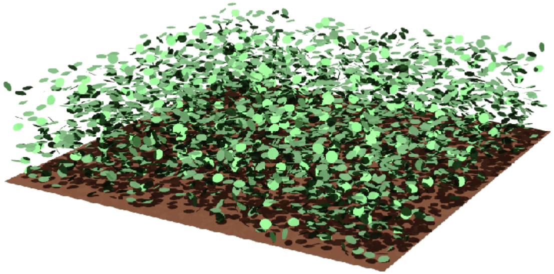
Basis of radiation models (optical)

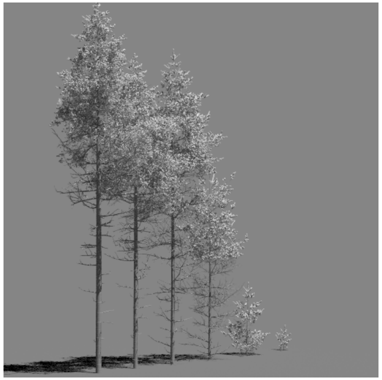




Basis of radiation models (optical)

- **Model of canopy scattering:**
  - Leaf properties
  - Scattering object density (LAI), orientation, and spatial distribution
  - Soil / understorey properties for low density canopies
- **solutions by analytical or numerical methods**





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Link to the C models

- **C models include concept of radiation model**
  - For calculation of intercepted radiation
- **Observation model**
  - Provides link from *subset* of C-model state variables to EO observation
  - Main linkages:
    - LAI, Density (for limited conditions)
    - leaf properties (hyperspectral data)
      - leaf dry matter, chlorophyll (nitrogen), water
      - xanthophyll cycle (light use efficiency)

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Exploiting quantities derived from radiance

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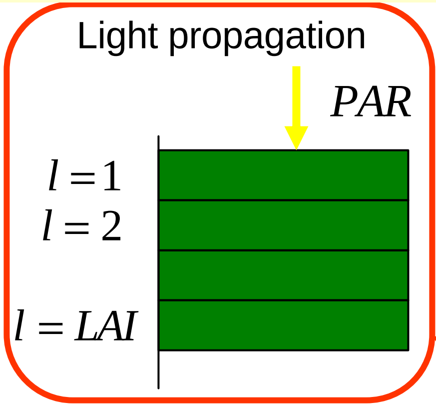
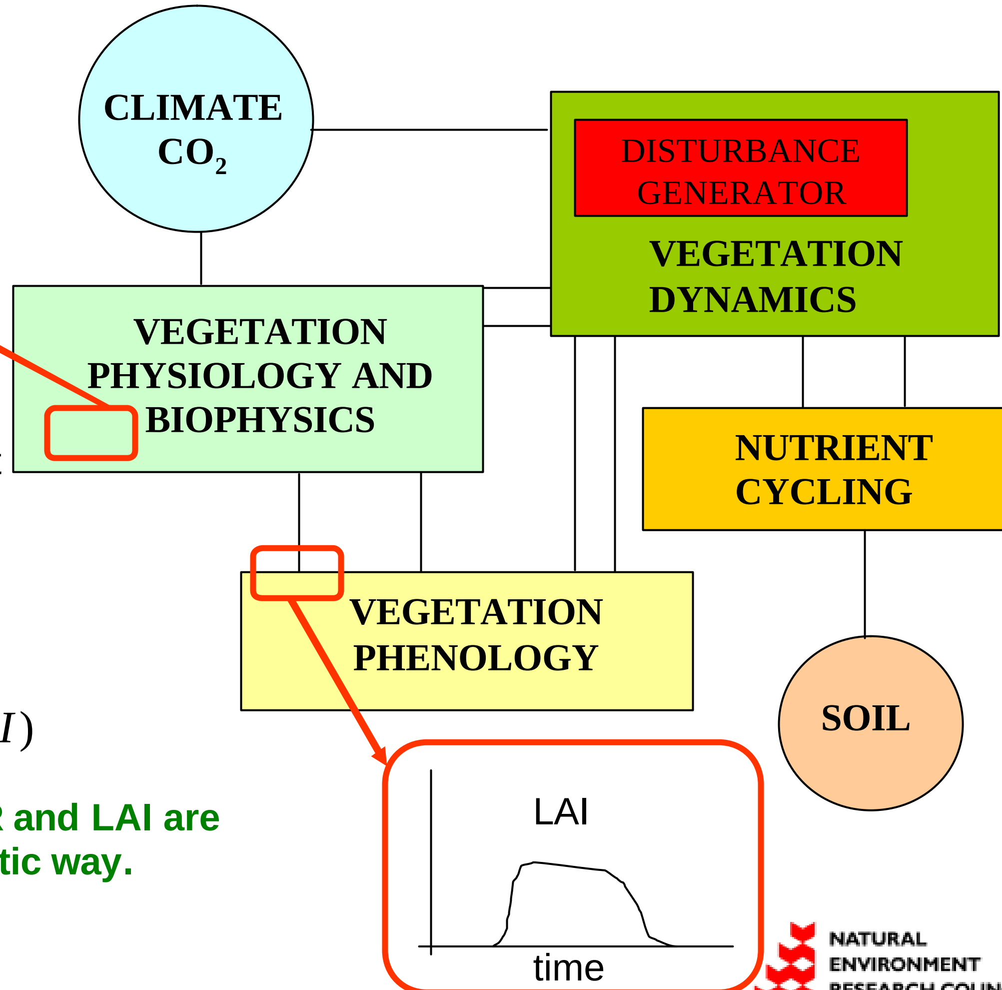
Sheffield Dynamic Vegetation Global Model





The propagation of the light follows the Beer-Lambert Law:

$$I(l) = PAR.\exp(-K.l)$$

One gets:

$$fAPAR = 1 - \exp(-K.LAI)$$

-> In SDGVMd, fAPAR and LAI are linked in a deterministic way.

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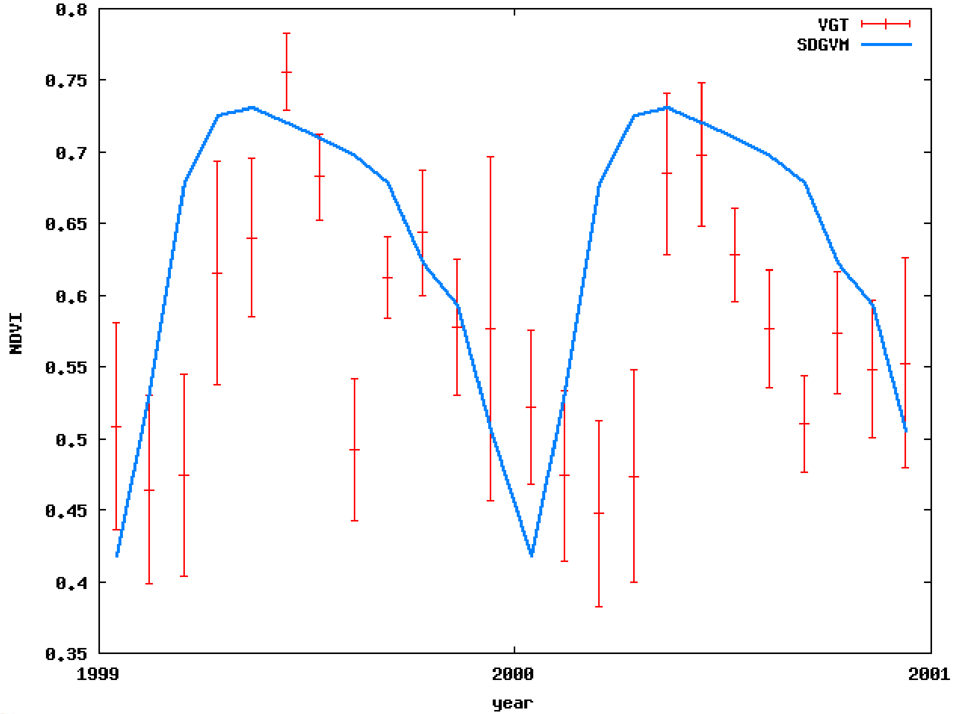
Application of the models

- **Testing C models (SDGVM)**
  - Confront predictions with observations



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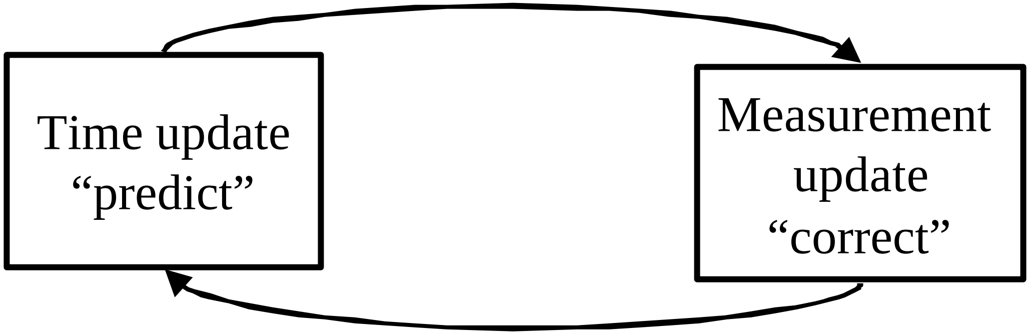
A prediction-correction system



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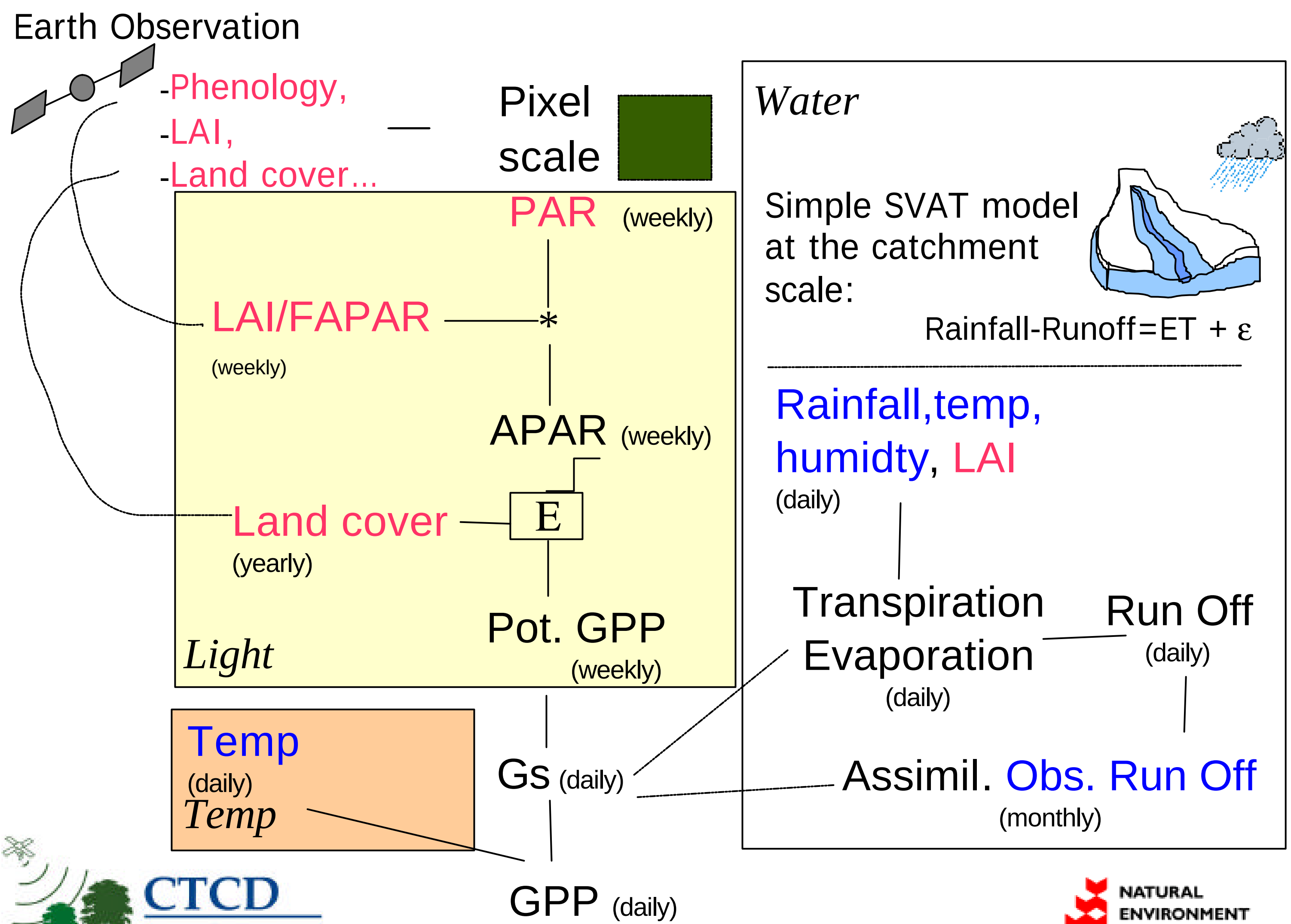

Earth Observation
-Phenology,
-LAI,
-Land cover...
Pixel scale
PAR (weekly)
LAI/FAPAR
(weekly)
*
APAR (weekly)
Land cover
(yearly)
E
Pot. GPP
(weekly)
Light
Temp
(daily)
Temp
Gs (daily)
GPP (daily)
Water
Simple SVAT model at the catchment scale:
Rainfall-Runoff=ET + ε
Rainfall,temp, humidty, LAI
(daily)
Transpiration
Evaporation
(daily)
Run Off
(daily)
Assimil. Obs. Run Off
(monthly)
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Williams et al., 2004

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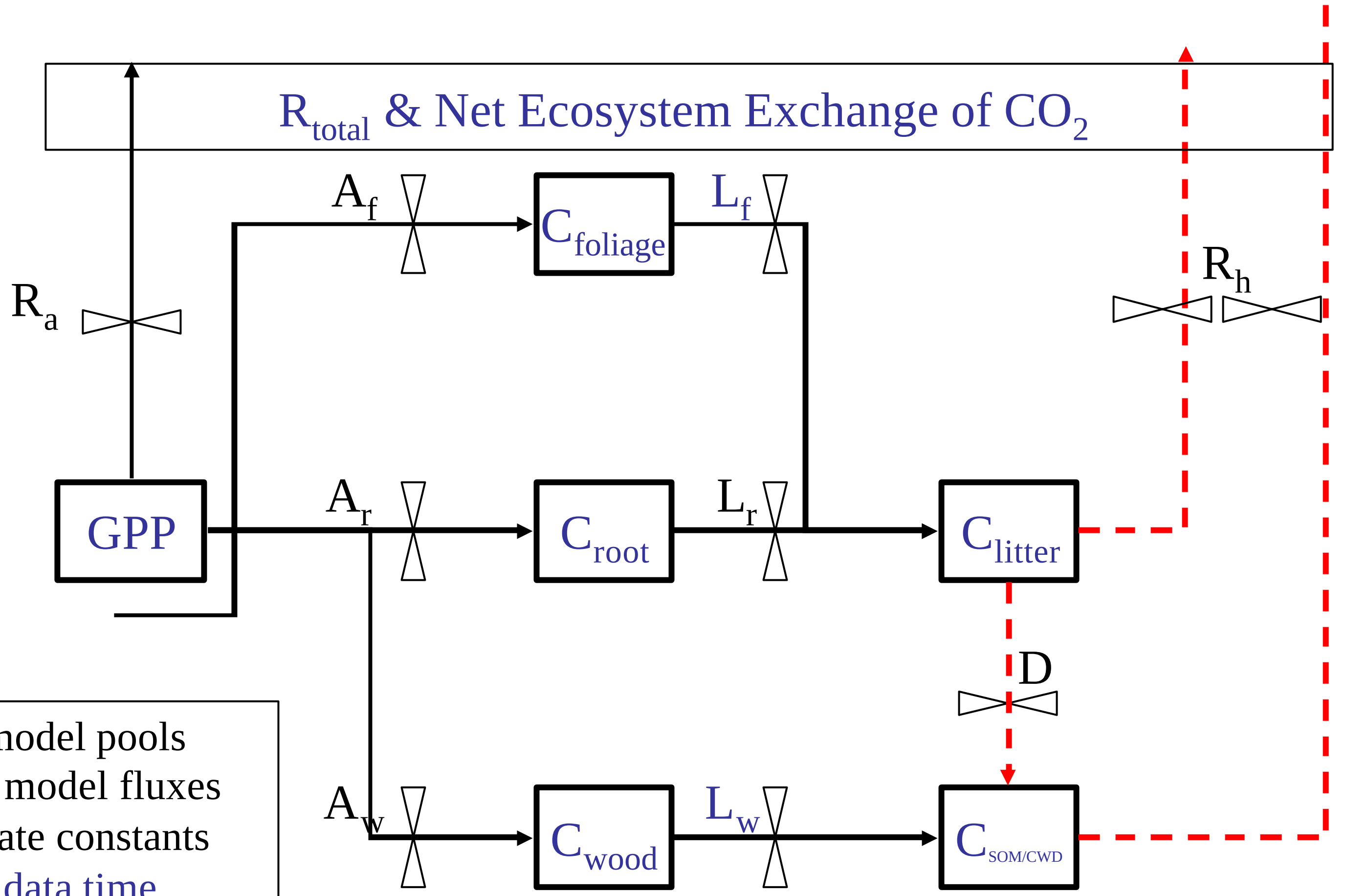

6 model pools
10 model fluxes
9 rate constants
10 data time series

C = carbon pools
A = allocation
L = litter fall
R = respiration (auto- & heterotrophic)

Temperature controlled

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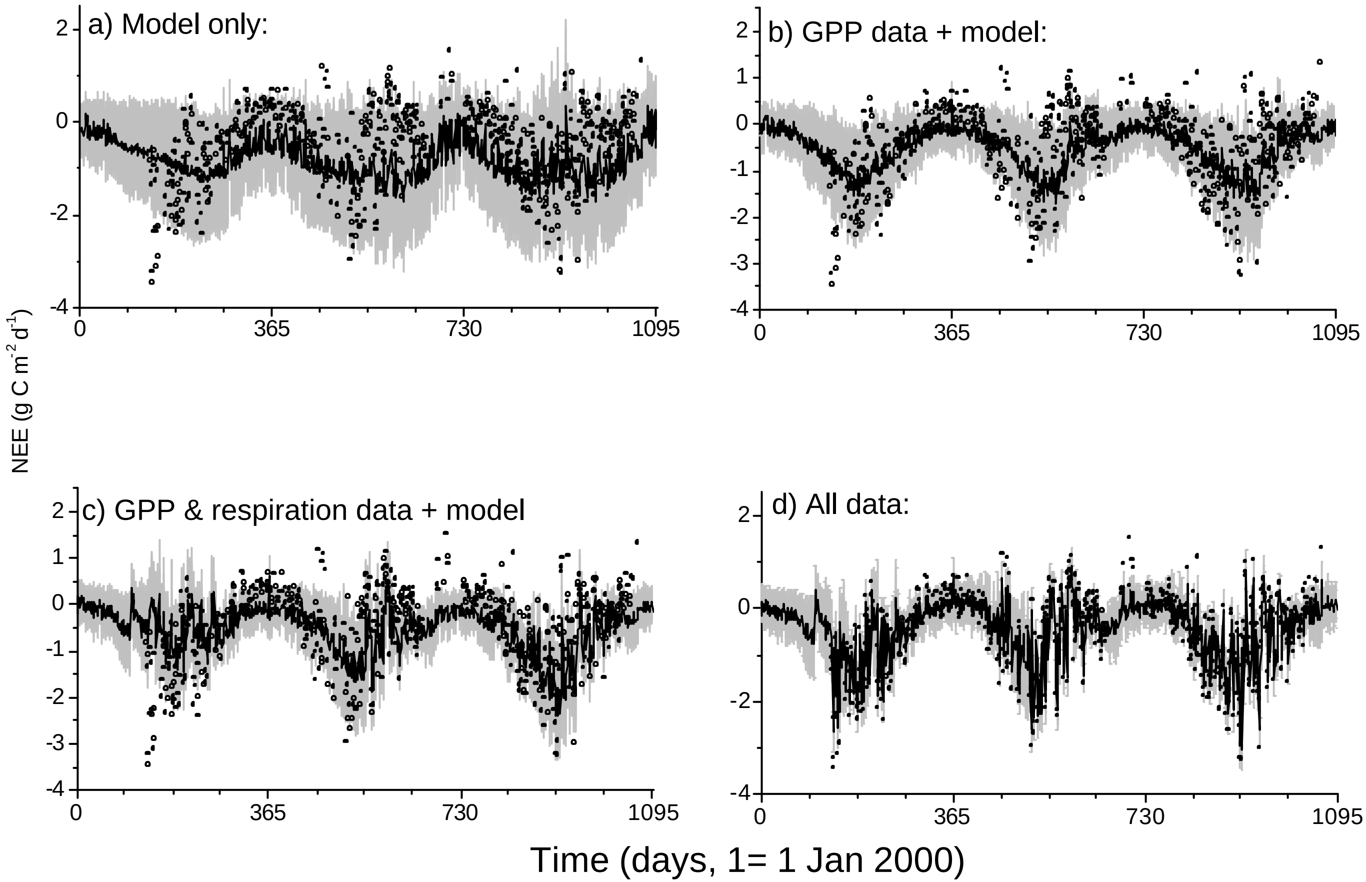

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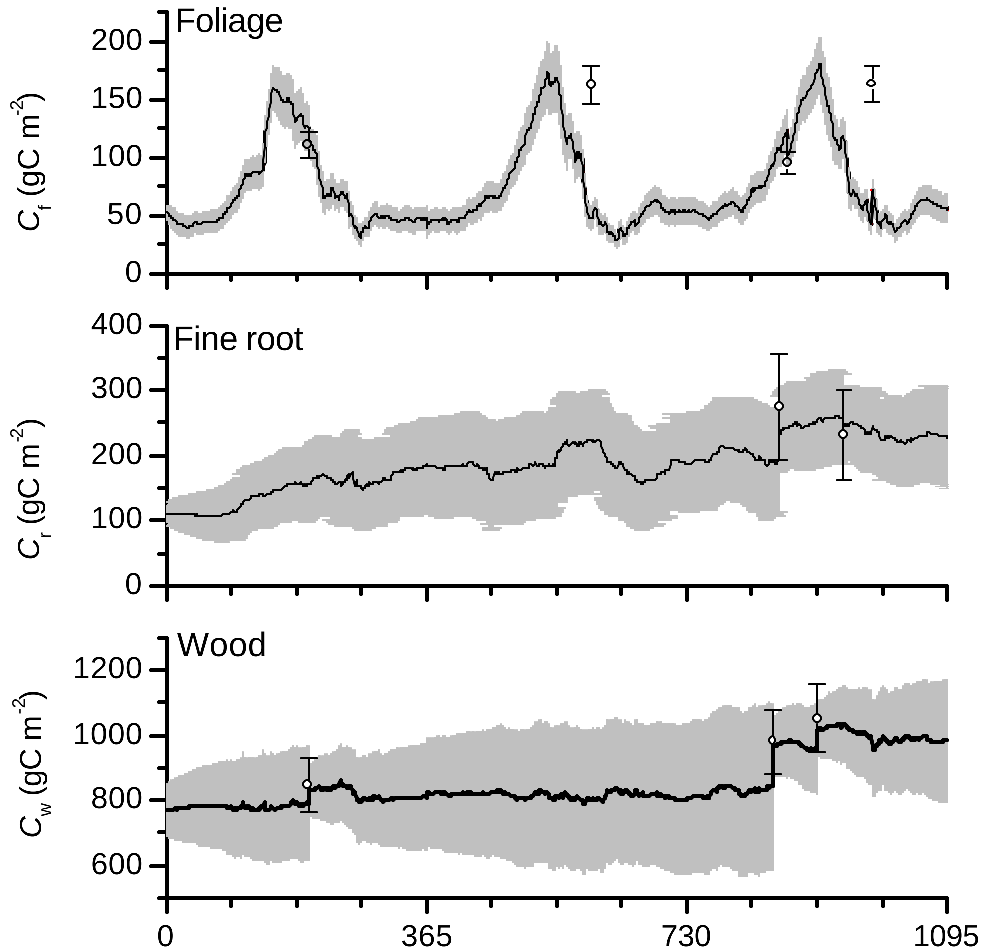

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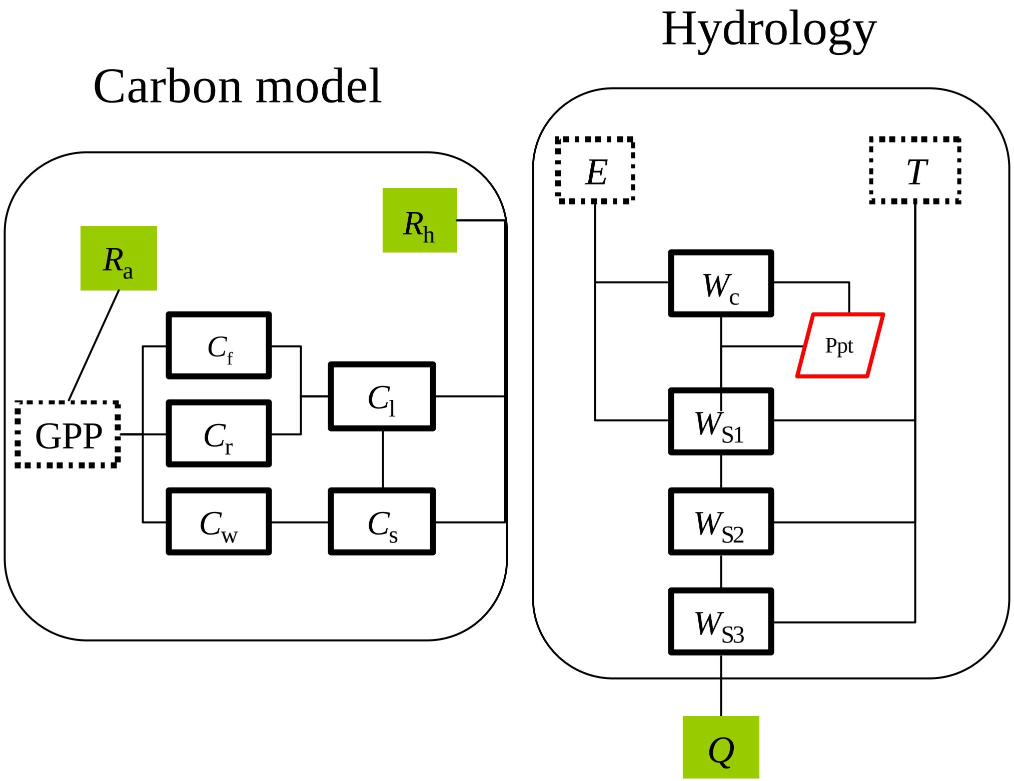
Pools and fluxes

Flux



Flux emulator

Predicted flux

State variable

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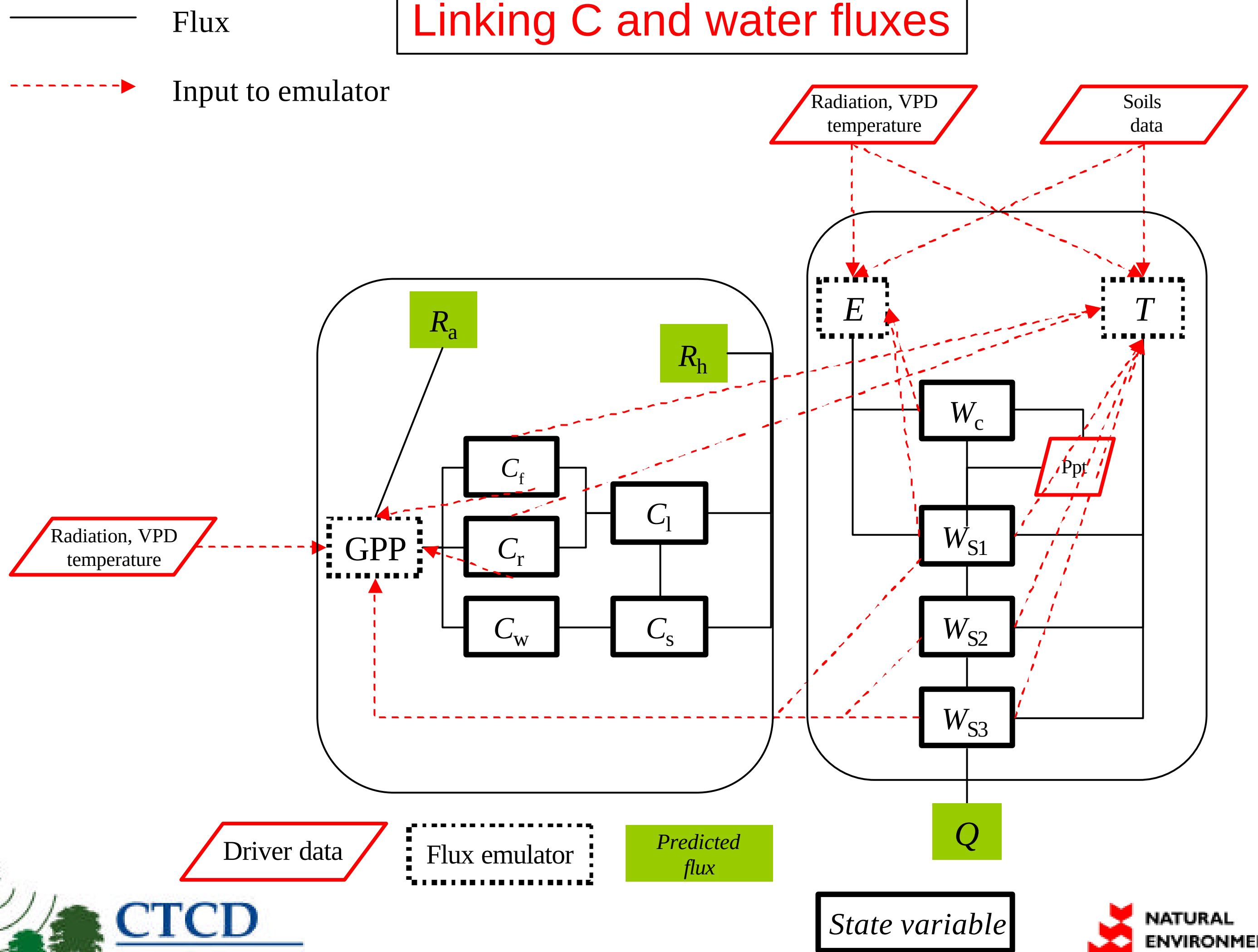
Linking C and water fluxes



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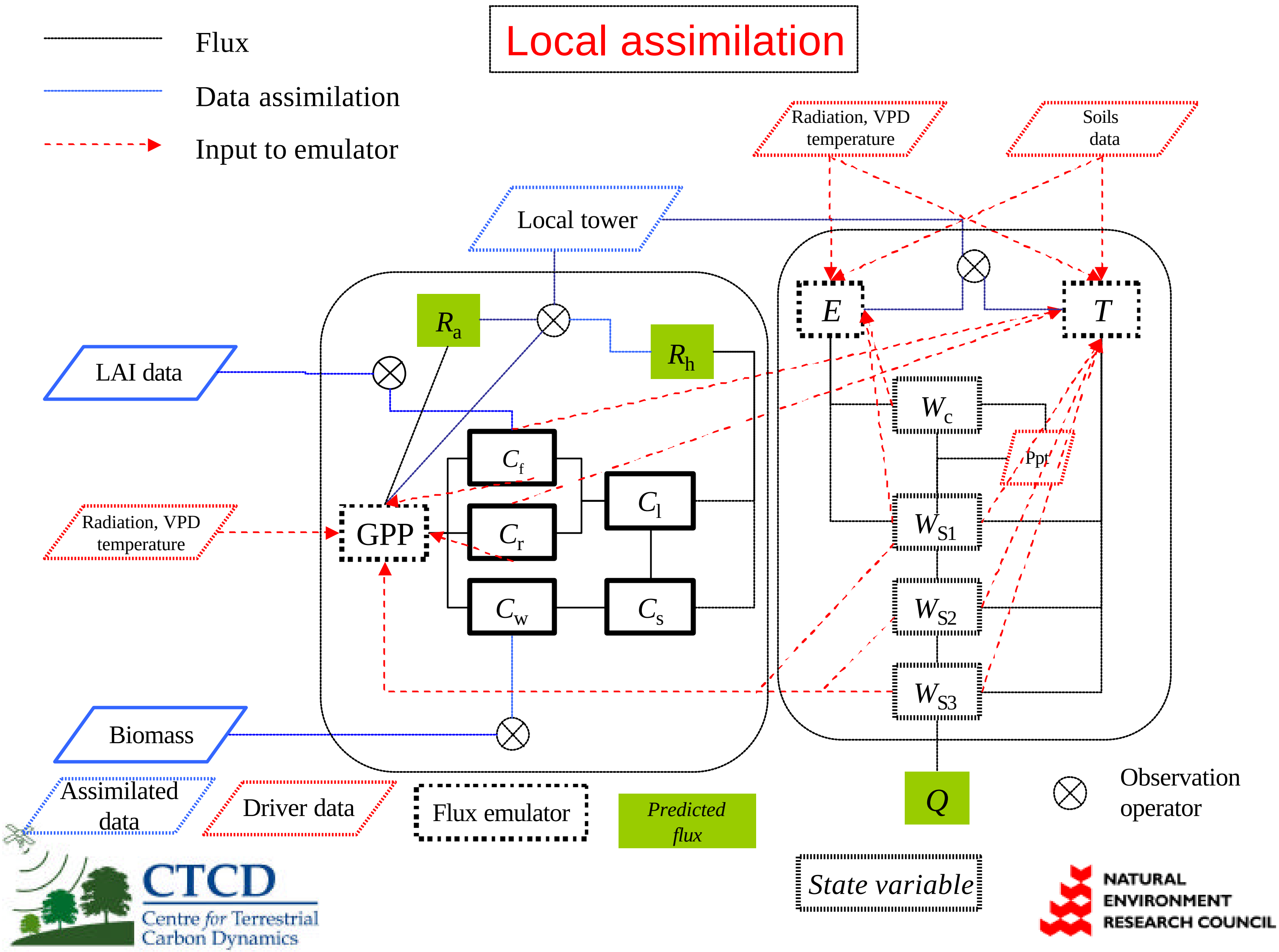
Flux
Data assimilation
Input to emulator
Local assimilation
Radiation, VPD temperature
Soils data
Local tower
LAI data
Radiation, VPD temperature
GPP
E
T
Q
Ppt
Biomass
Assimilated data
Driver data
Flux emulator
Predicted flux
State variable
Observation operator
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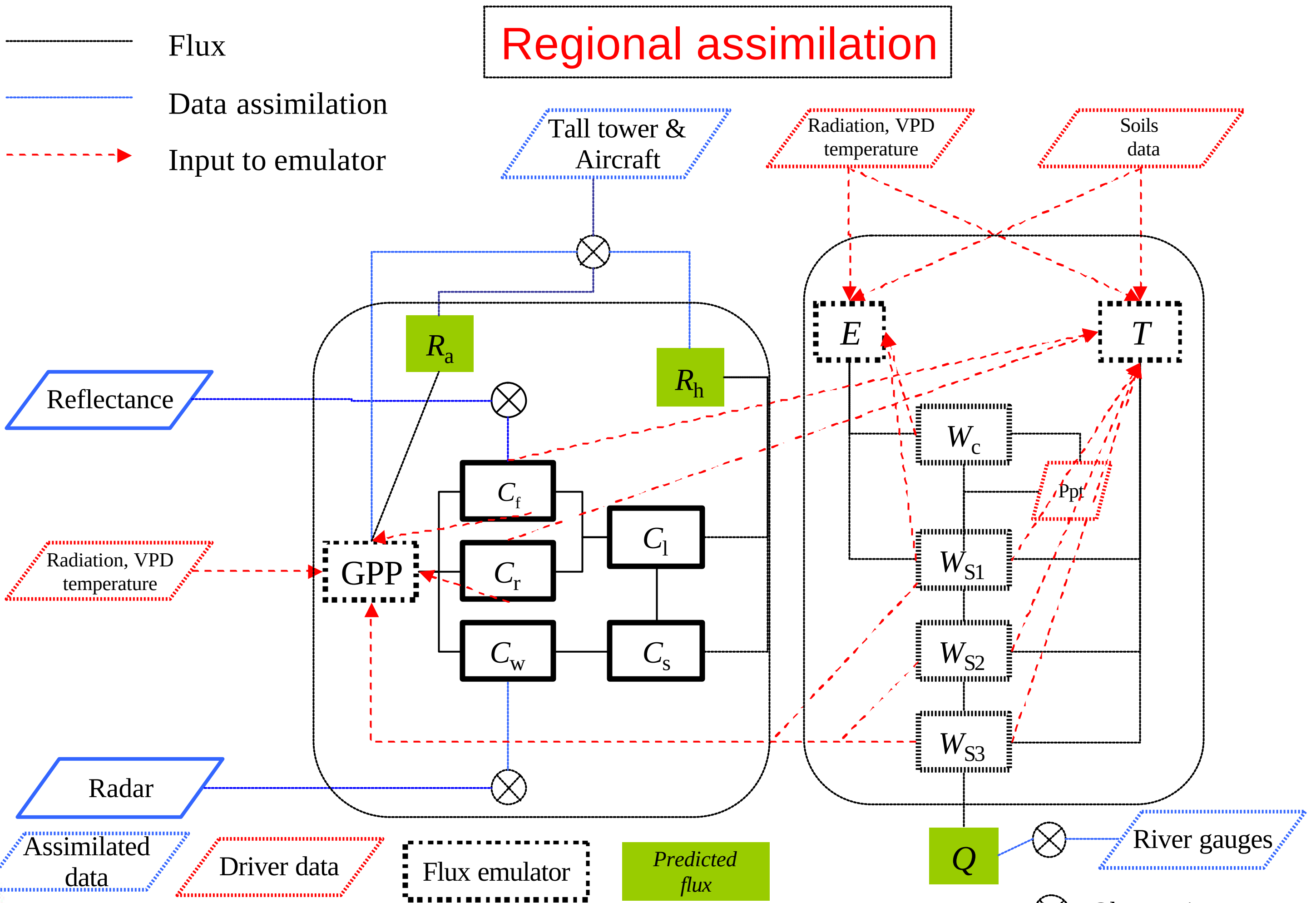

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Conclusions

- Calibration of DVM parameters with EO data provides a means to improve the predictive power of the models, e.g., phenology, fire.
- Well-developed forward models for scattering and reflectance exist; a current challenge is to interface them to biospheric models for monitoring and assimilation.
- Because of possible problems in derived products, such as fAPAR, assimilation of radiances sems preferable. However, this is dependent on how radiation absorption is represented in the biospheric model.
- Successful assimilation schemes have just been developed for biospheric models. By using existing forward models, these provide a framework for assimilating EO data.
- Watch this space!

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