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Carbon, soil moisture and fAPAR assimilation

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[2] IES/JRC [3] QUEST / University of BRISTOL [4] LSCE [5] FastOpt

Overview

- **CO_2 – climate linkages**
- **Satellite fAPAR as soil moisture indicator**
- **Assimilation of fAPAR**

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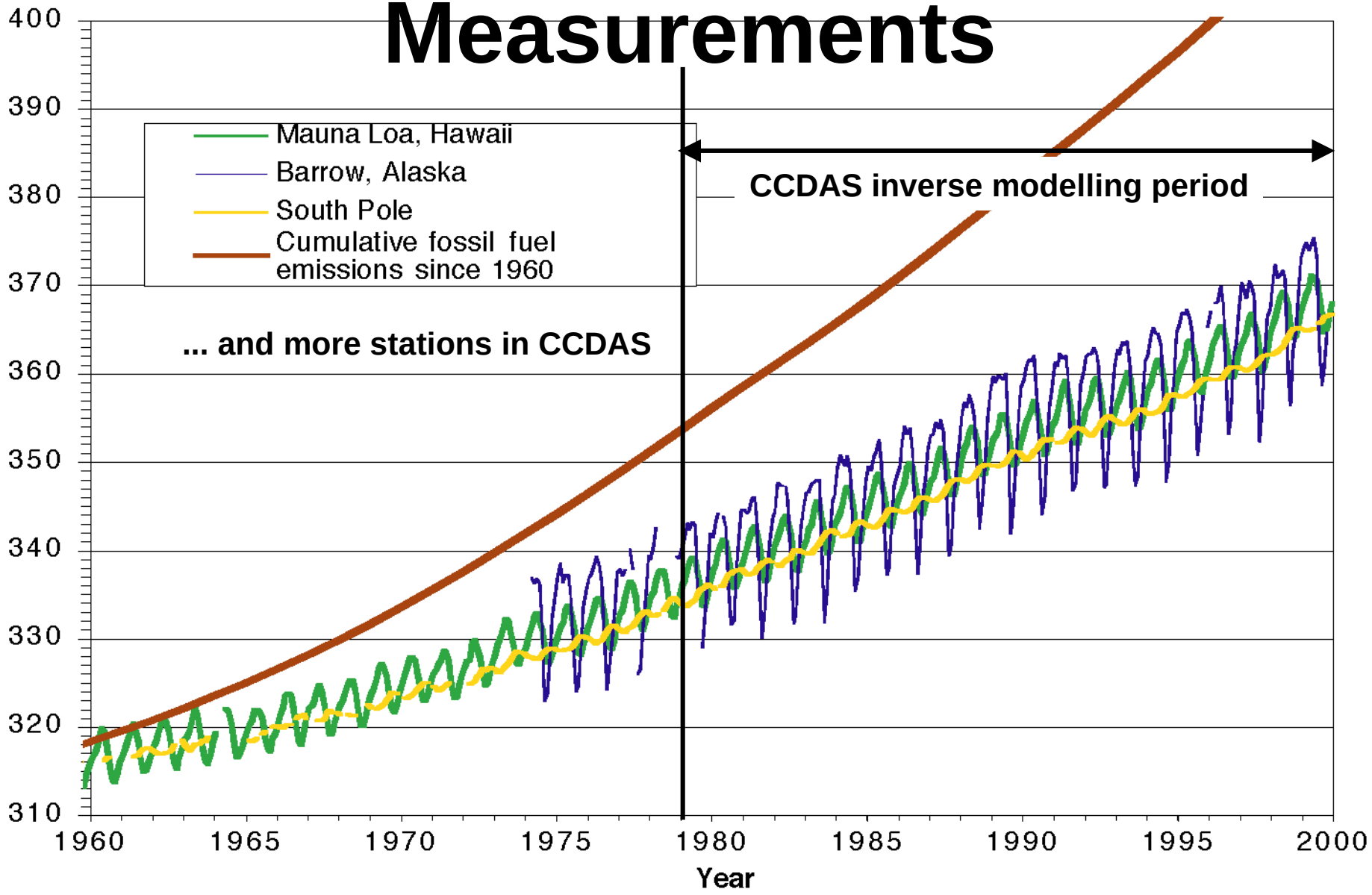
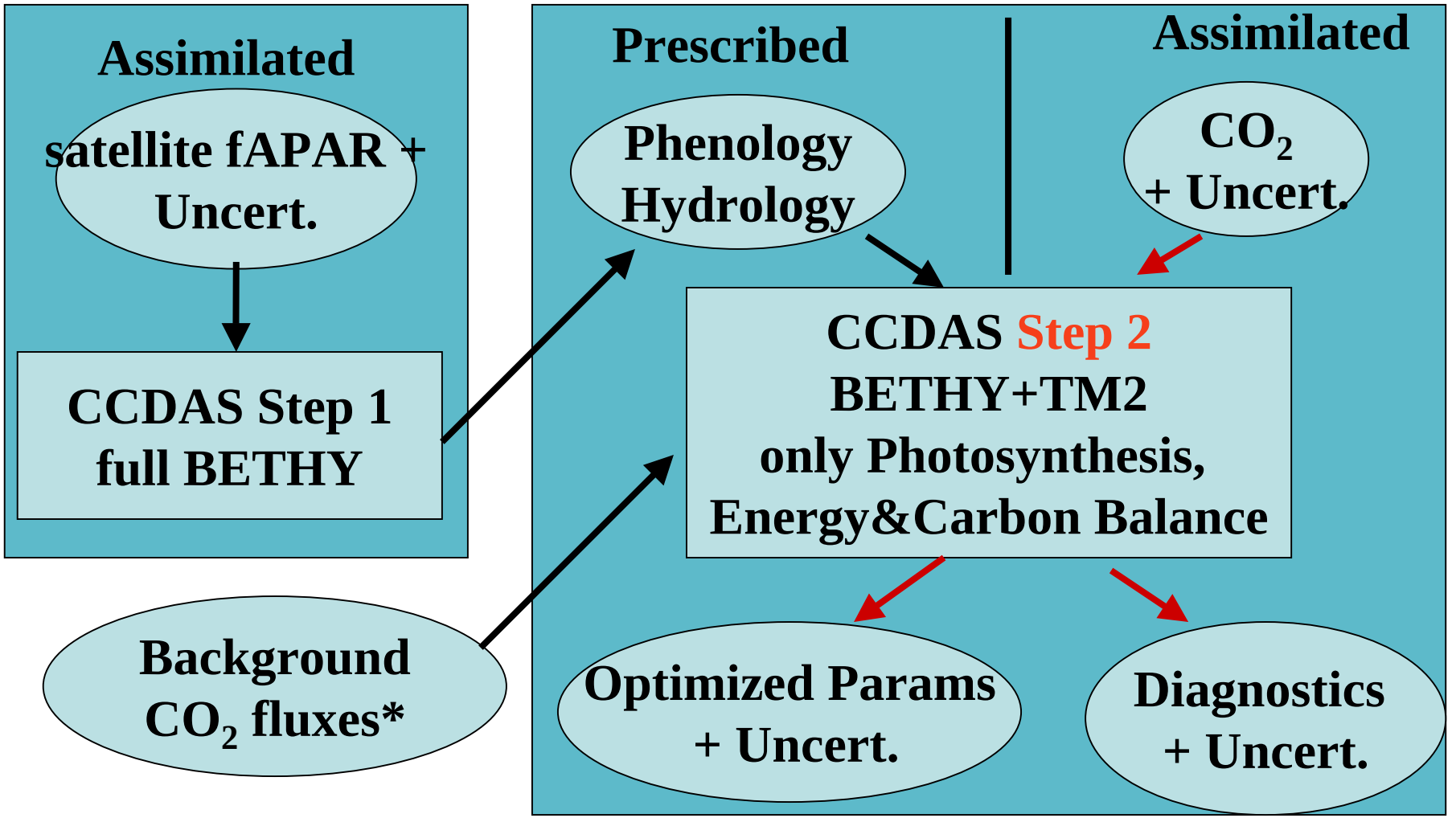
Atmospheric CO_2 Measurements



Carbon Cycle Data Assimilation System (CCDAS)



* **ocean:** Takahashi et al. (1999), LeQuere et al. (2000); **emissions:** Marland et al. (2001), Andres et al. (1996); **land use:** Houghton et al. (1990)

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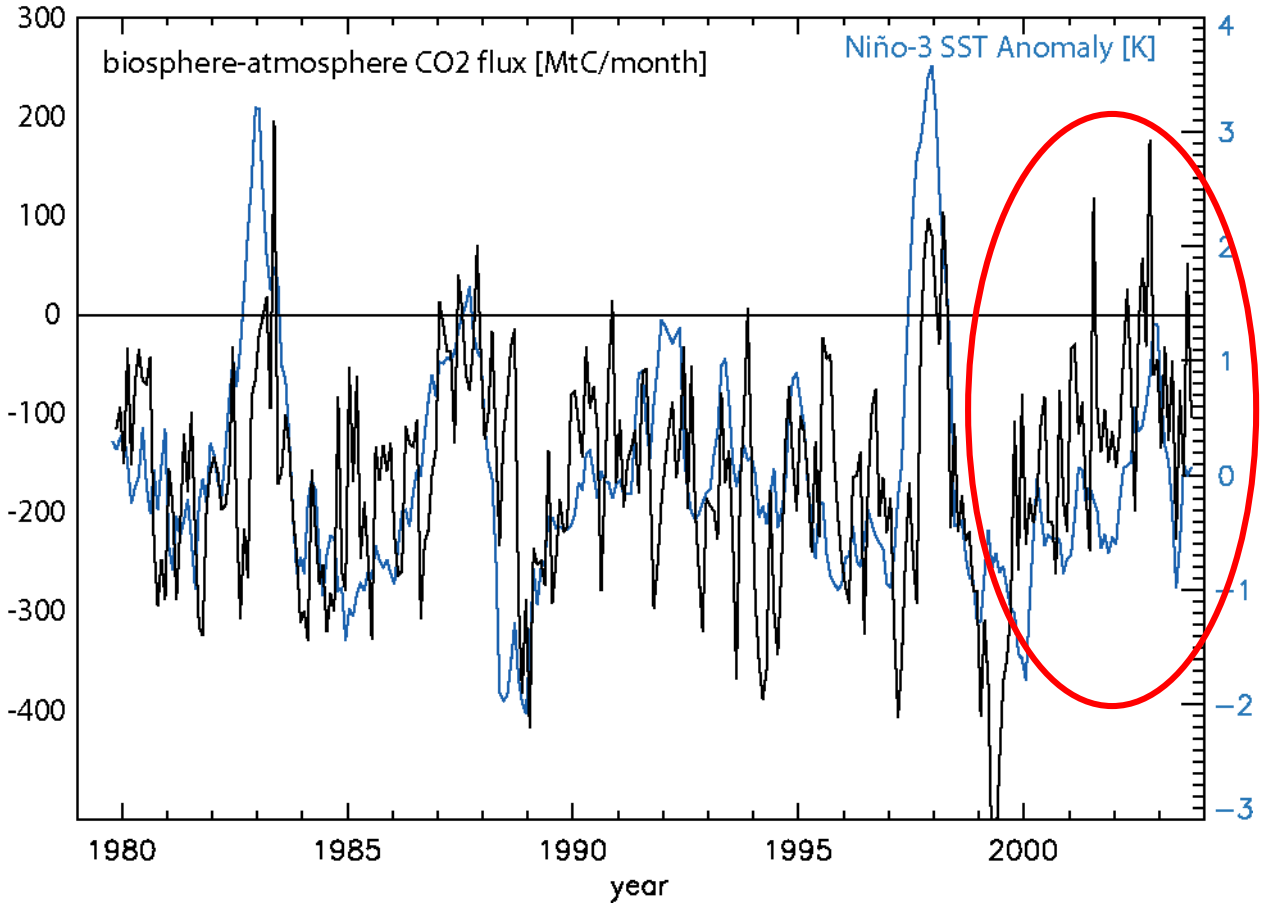
Terr. biosphere–atmosphere CO_2 fluxes

ENSO



… preliminary results from extended CCDAS run

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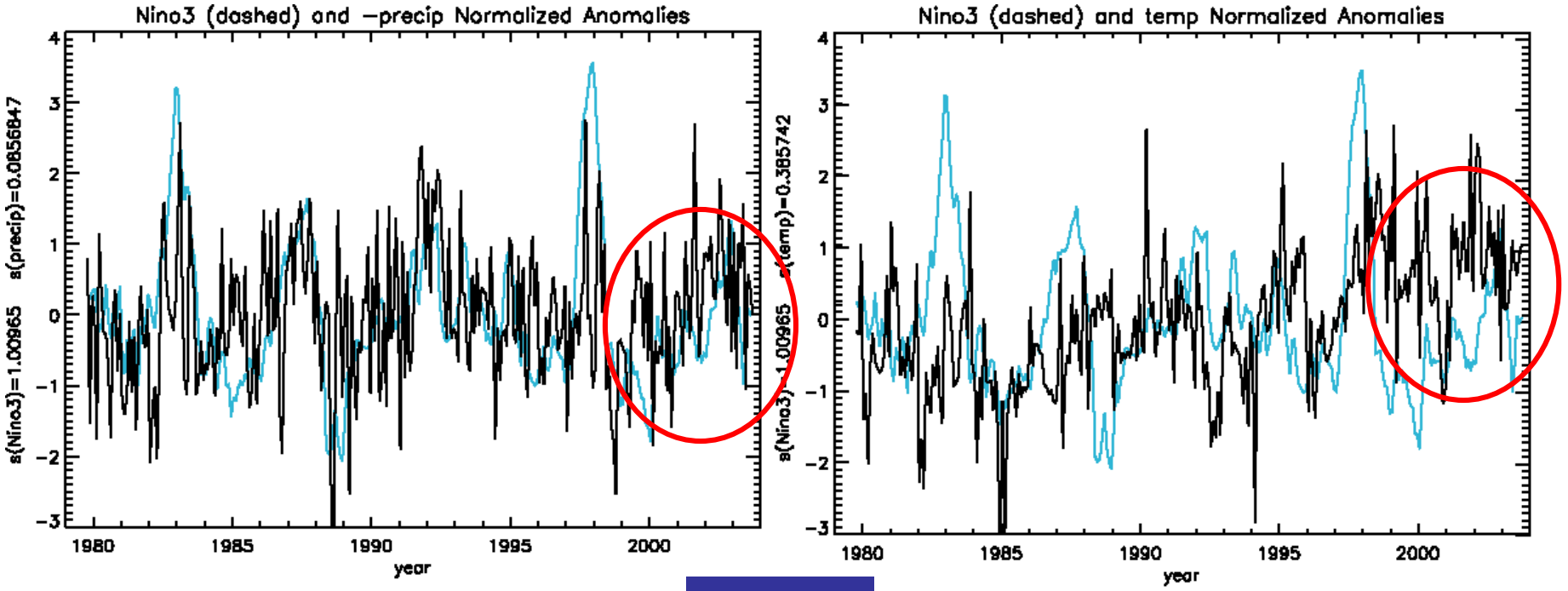
ENSO and global climate normalized anomalies



ENSO

–precipitation

temperature

… global drying and warming trend

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Week at a Glance

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Sharp CO2 rise divides opinions

Climate scientists are puzzled over the possible significance of rising levels of atmospheric carbon dioxide (CO2).

Many ice bodies from the poles to the tropics are in retreat

Some think a recent acceleration in CO2 increases could be a sign of imminent, rapid global warming.

But others say the evidence of just two years is inconclusive, and suspect that natural causes are likelier culprits.

The UK government's chief scientific adviser, Sir David King, says the rise appears on the evidence so far to be an aberration, not the start of a trend.

MYSTERIÖSE CO2-WERTE

Forscher sehen Anzeichen für Hitzespirale

Von Volker Mrasek

Die Erde könnte am Beginn eines galoppierenden Treibhauseffekts stehen. Der Kohlendioxid-Gehalt der Atmosphäre ist in den vergangenen zwei Jahren sprunghaft gestiegen, wie neue Messungen ergaben. Forscher vermuten, dass Ozeane und Wälder ihre Grenzen als Klimagas-Schlucker erreicht haben.

DDP

Luftverschmutzung: Industrialisierung brachte CO2-Schub

Verlieren Ozeane und Wälder ihre Funktion als Bremsklotz der Erderwärmung? Schlucken sie nicht mehr genügend Kohlendioxid? Messungen aus dem Pazifik schüren diese Befürchtung. Danach stieg der CO2-Gehalt der Erdatmosphäre sowohl 2002 als auch 2003 ungewöhnlich stark an.

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for more information see:

http://www.CCDAS.org

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- Assimilation of fAPAR

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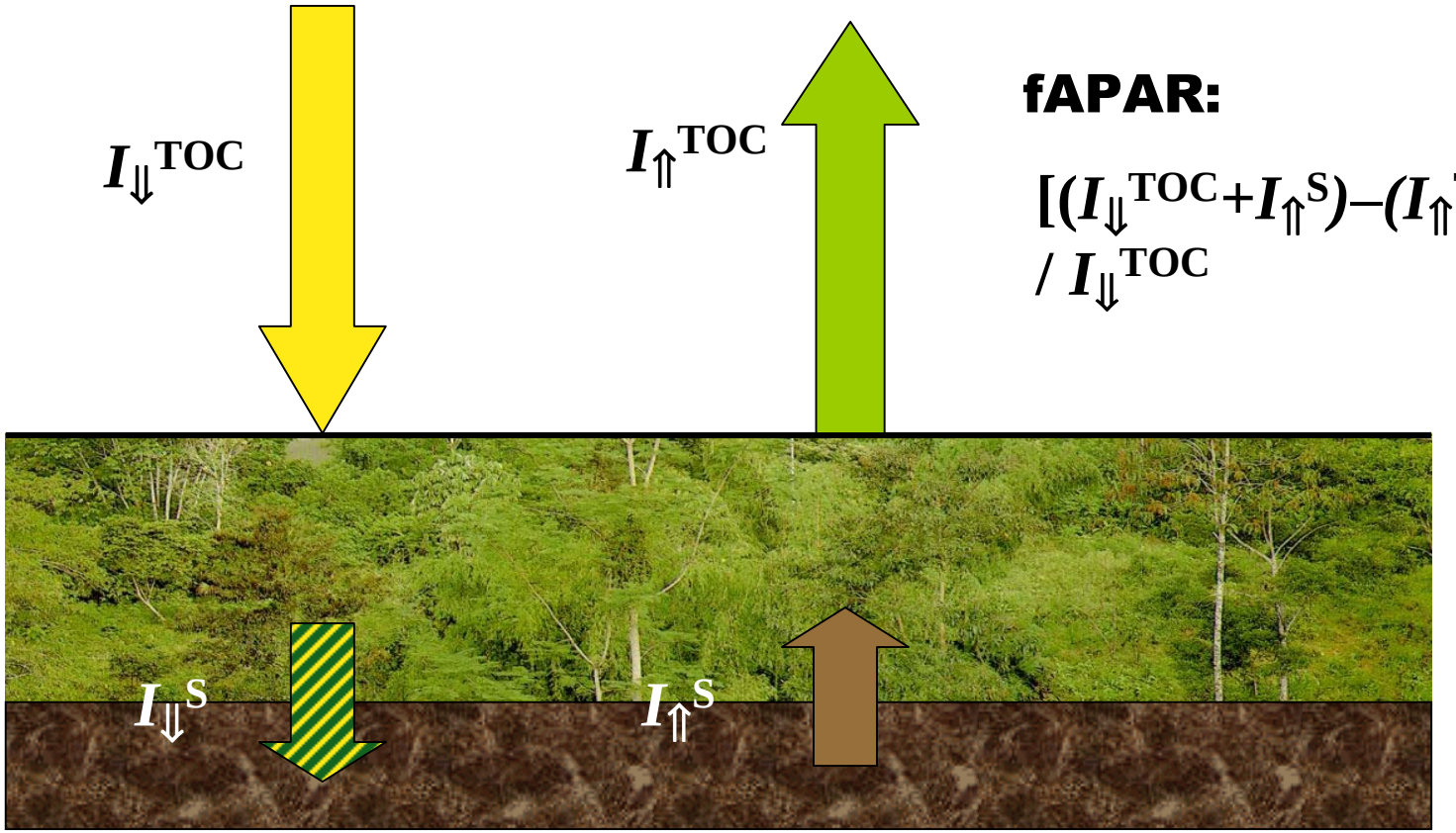
Remotely Sensed Vegetation Activity



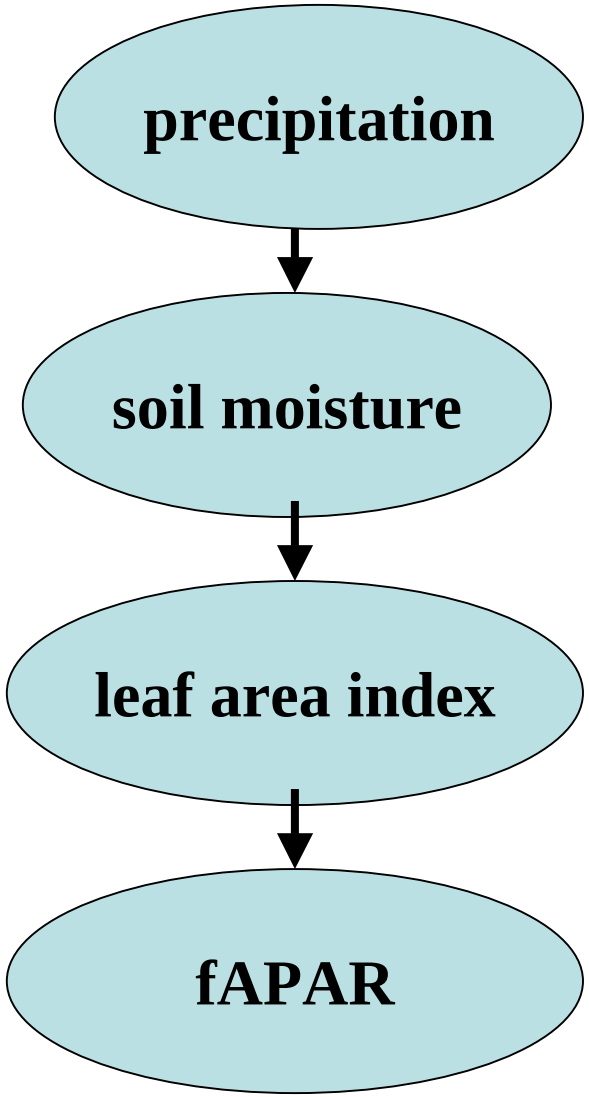
fAPAR:

$$[(I_{\Downarrow}^{TOC}+I_{\Uparrow}^{S})-(I_{\Uparrow}^{TOC}+I_{\Downarrow}^{S})] / I_{\Downarrow}^{TOC}$$

SeaWiFS fAPAR archive

- developed by Nadine Gobron, Bernard Pinty, Frédéric Melin, IES/JRC, Ispra
- 3-channel algorithm taylored to SeaWiFS ocean color instrument (blue, red, near-infrared)
- cloud screening algorithm
- requires no atmospheric correction
- starts 10/1997, continuing...
- being extended by same product for MERIS

Precipitation – fAPAR

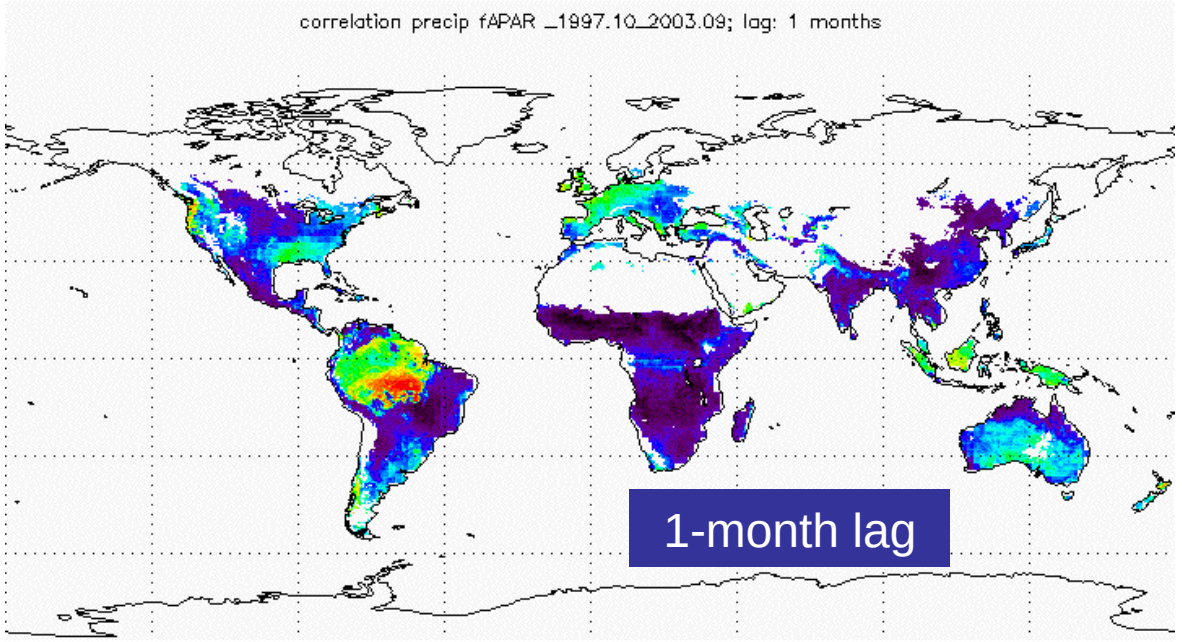


gridded station data

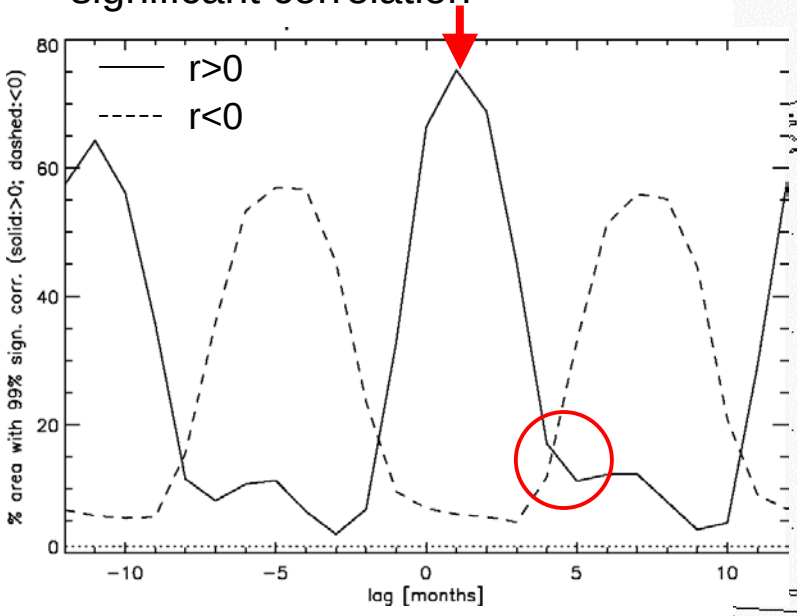
BETHY simulations

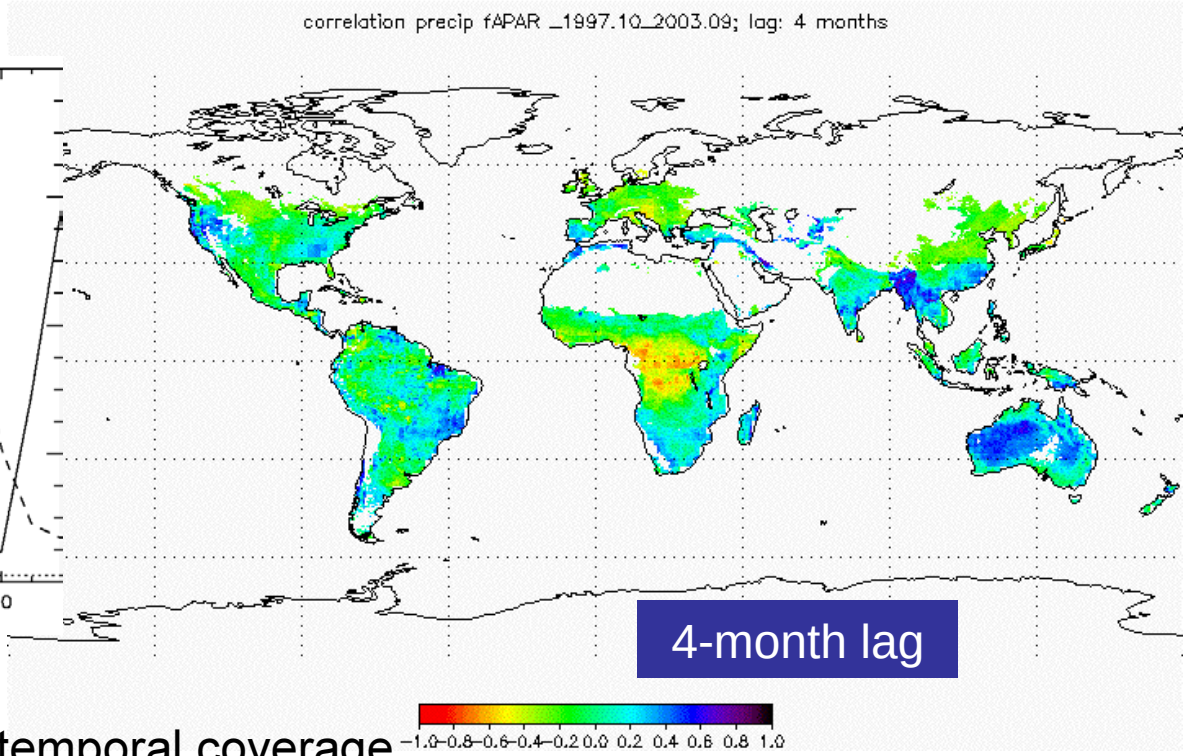
satellite observations
BETHY simulations

precipitation vs. fAPAR from SeaWiFS satellite obs.



percent area with 99% significant correlation

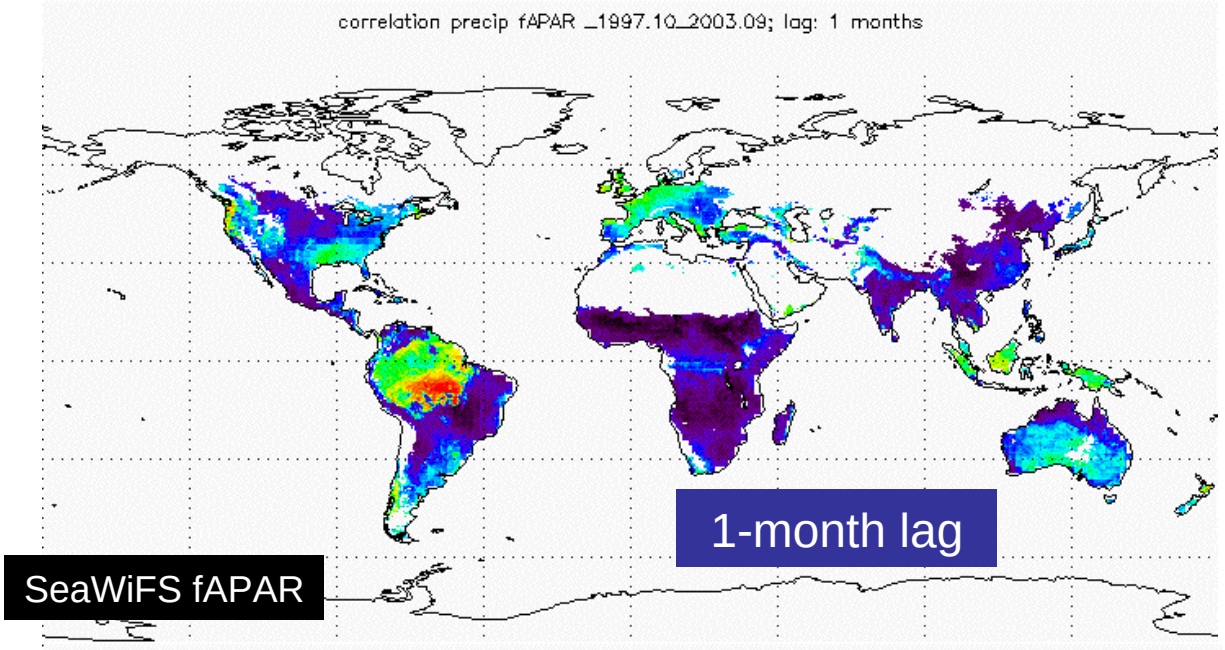




0.5°x0.5°, ≥50% cloud free, ≥75% temporal coverage

precipitation vs. fAPAR:

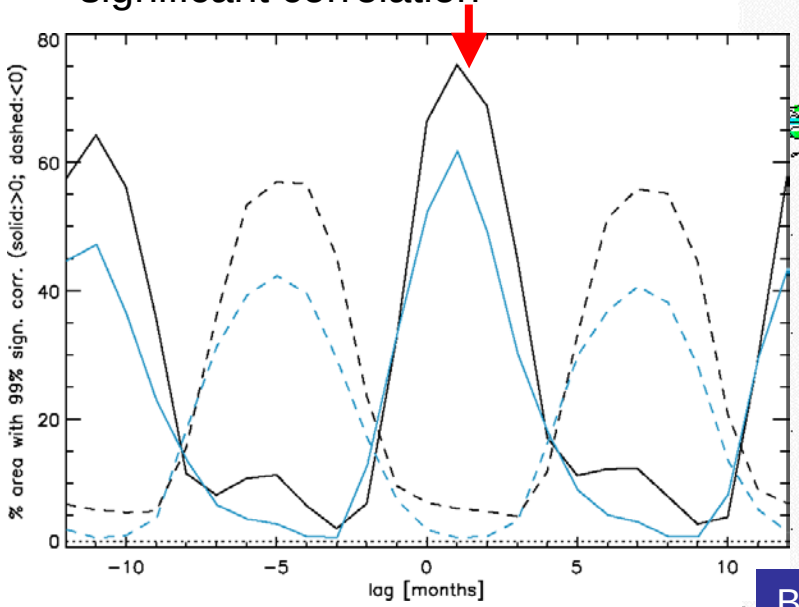
satellite and model

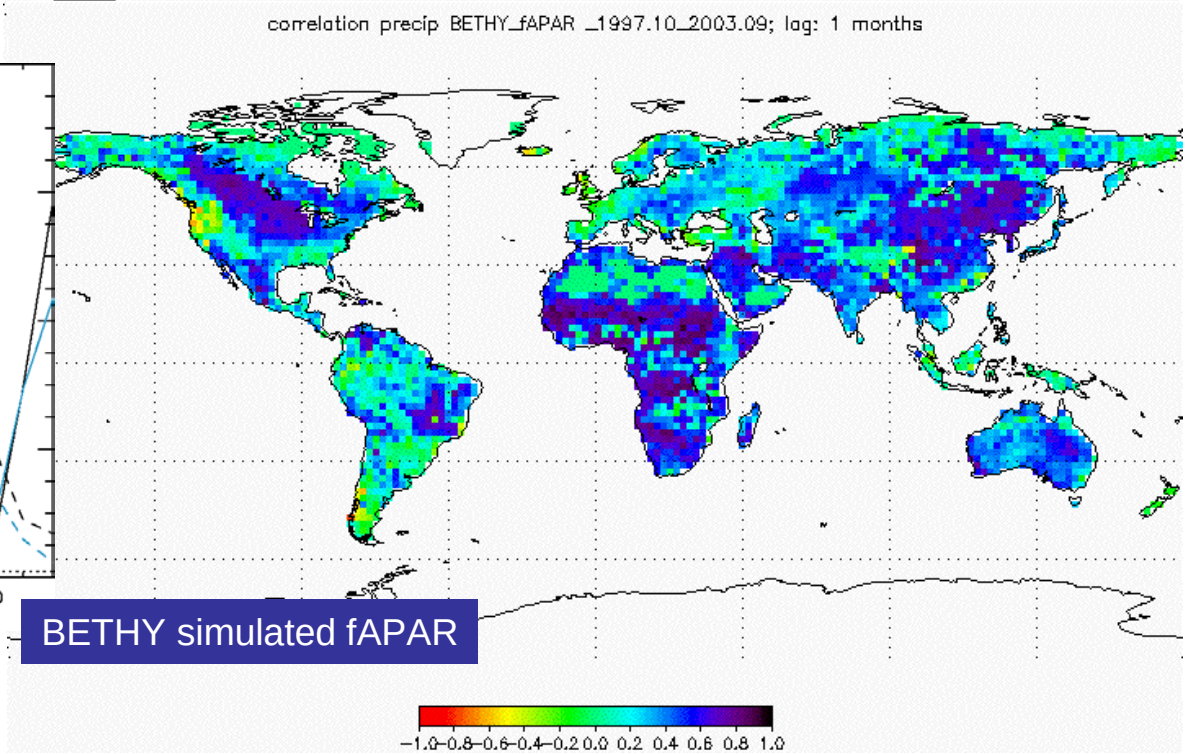


1-month lag

SeaWiFS fAPAR

percent area with 99% significant correlation

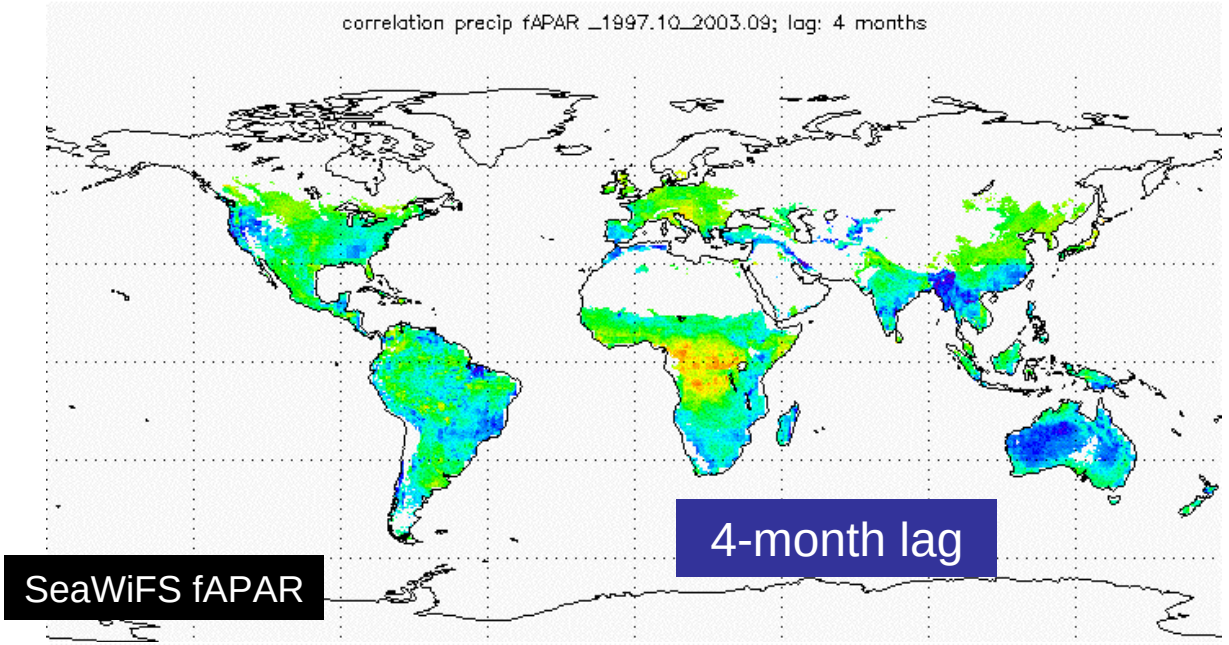




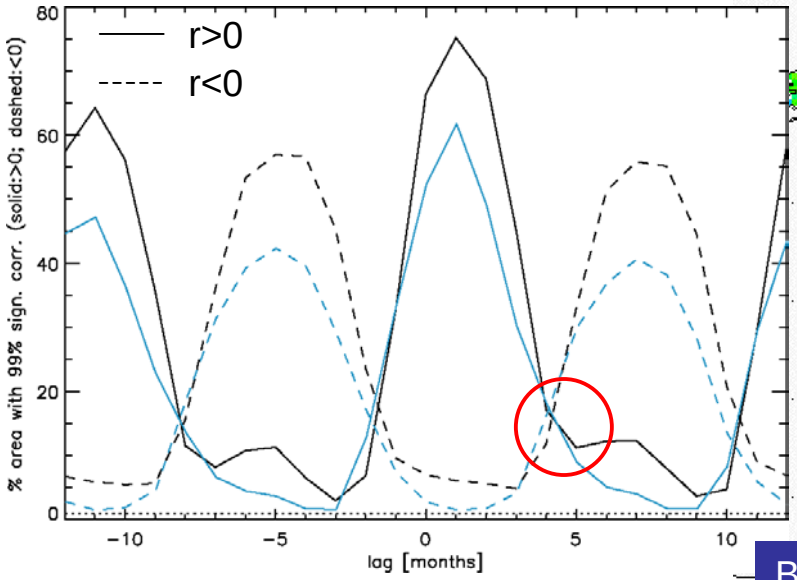
BETHY simulated fAPAR

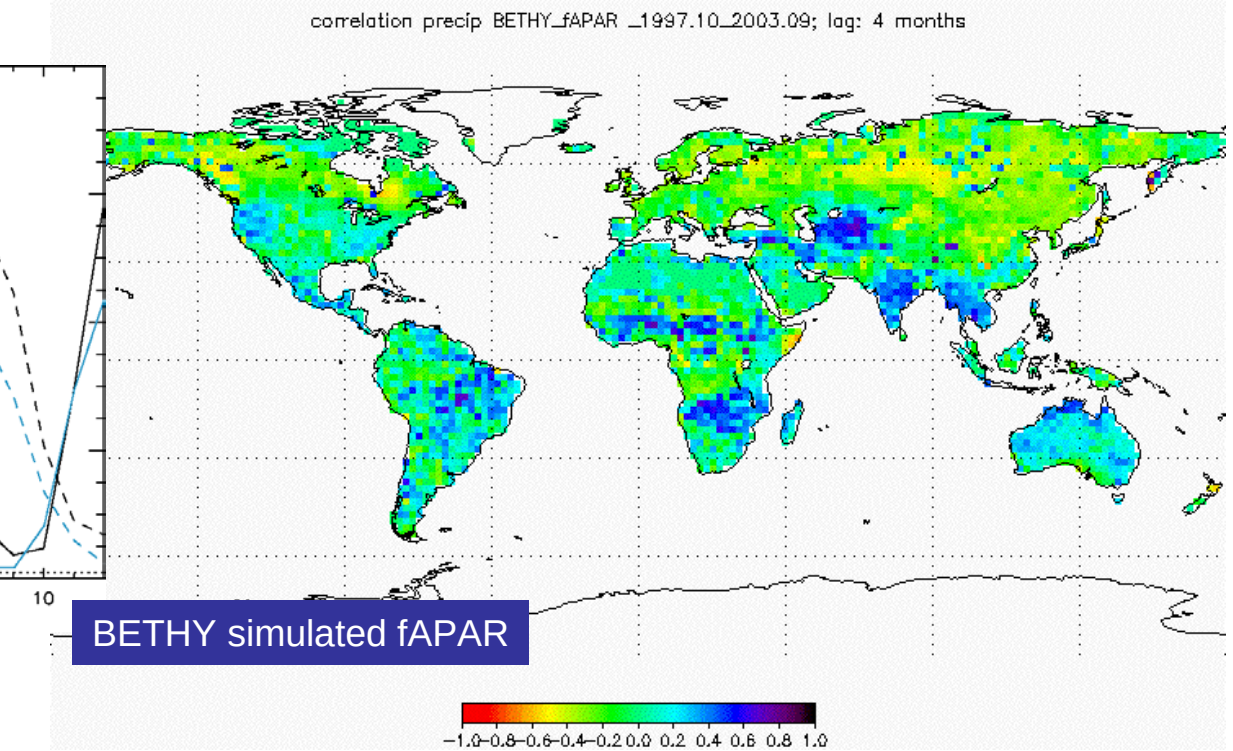
precipitation vs. fAPAR:

satellite and model

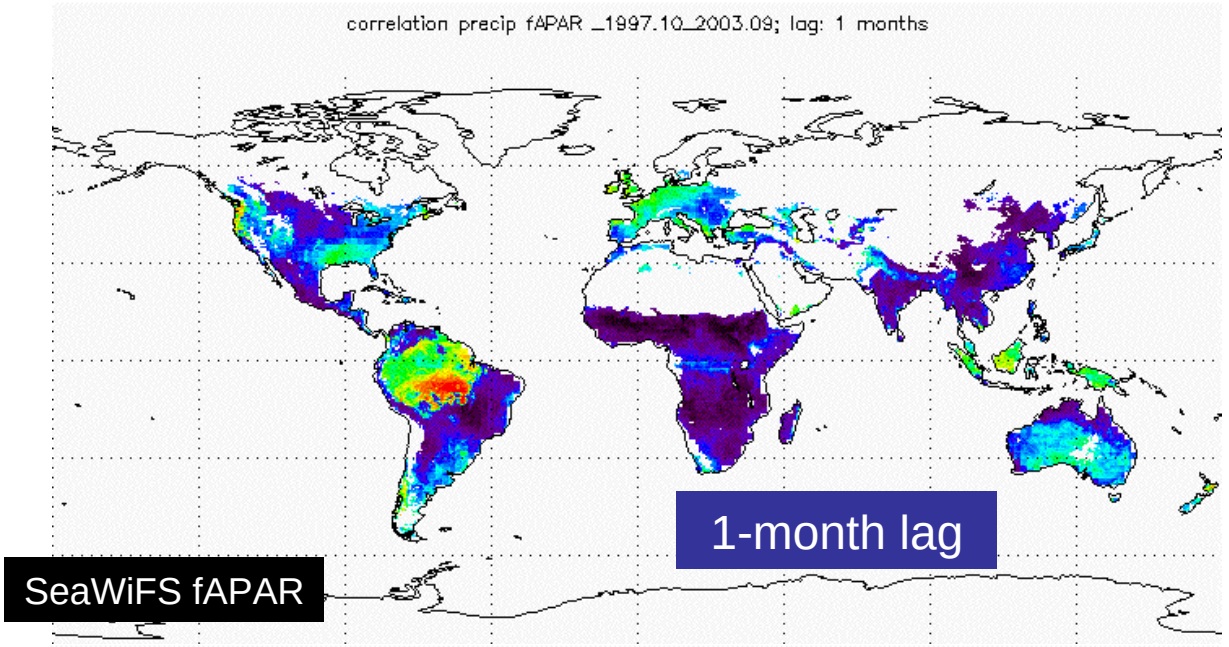


percent area with 99% significant correlation





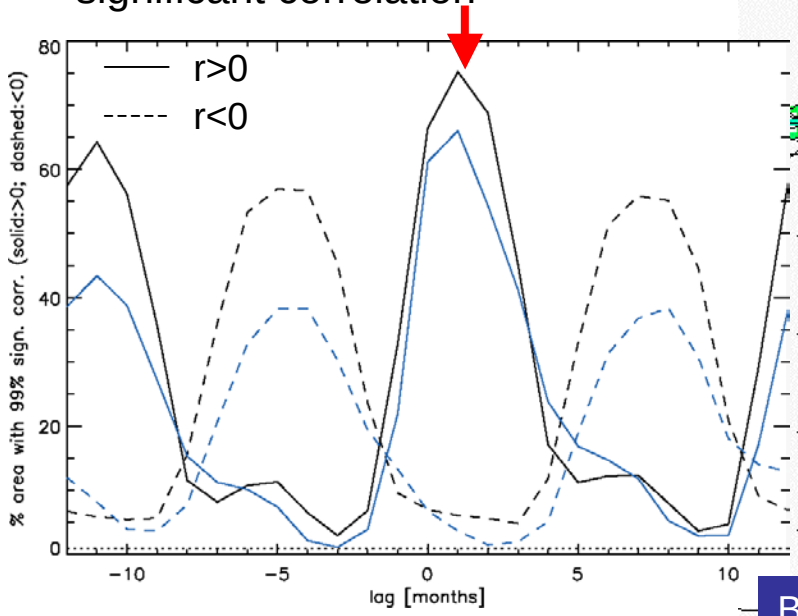
precipitation vs. satellite fAPAR and simulated soil moisture

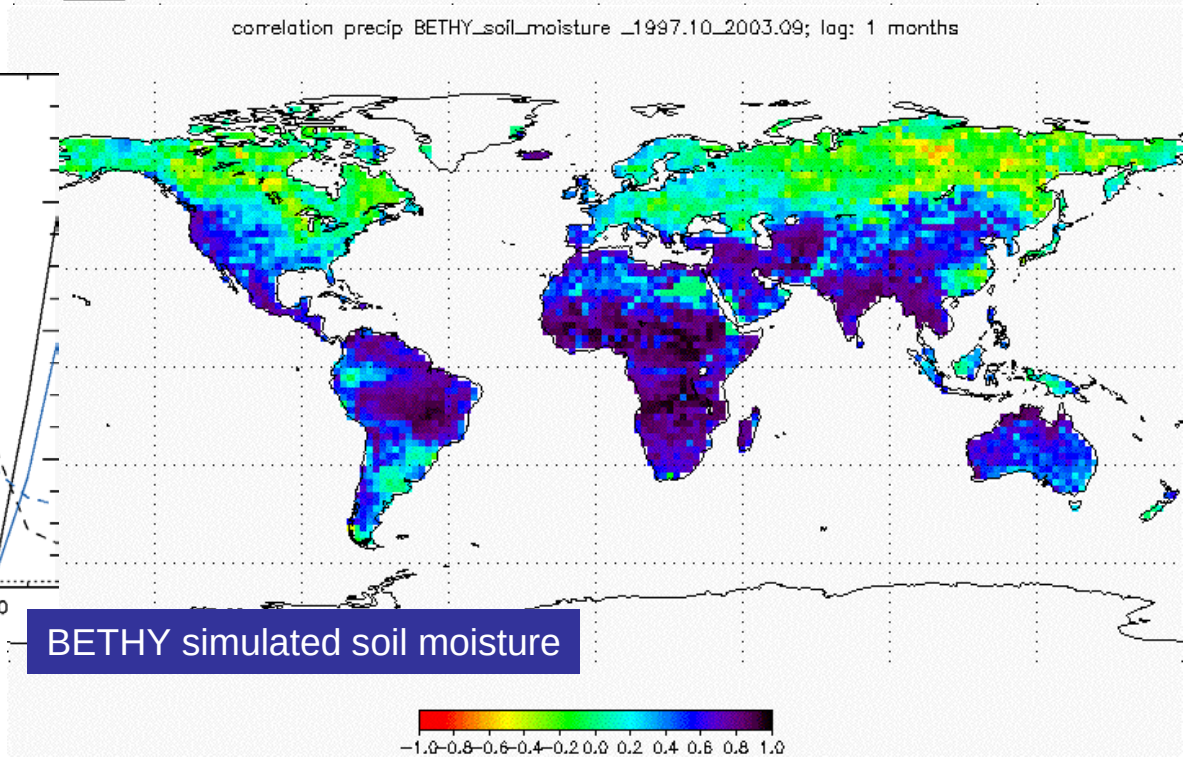


1-month lag

SeaWiFS fAPAR

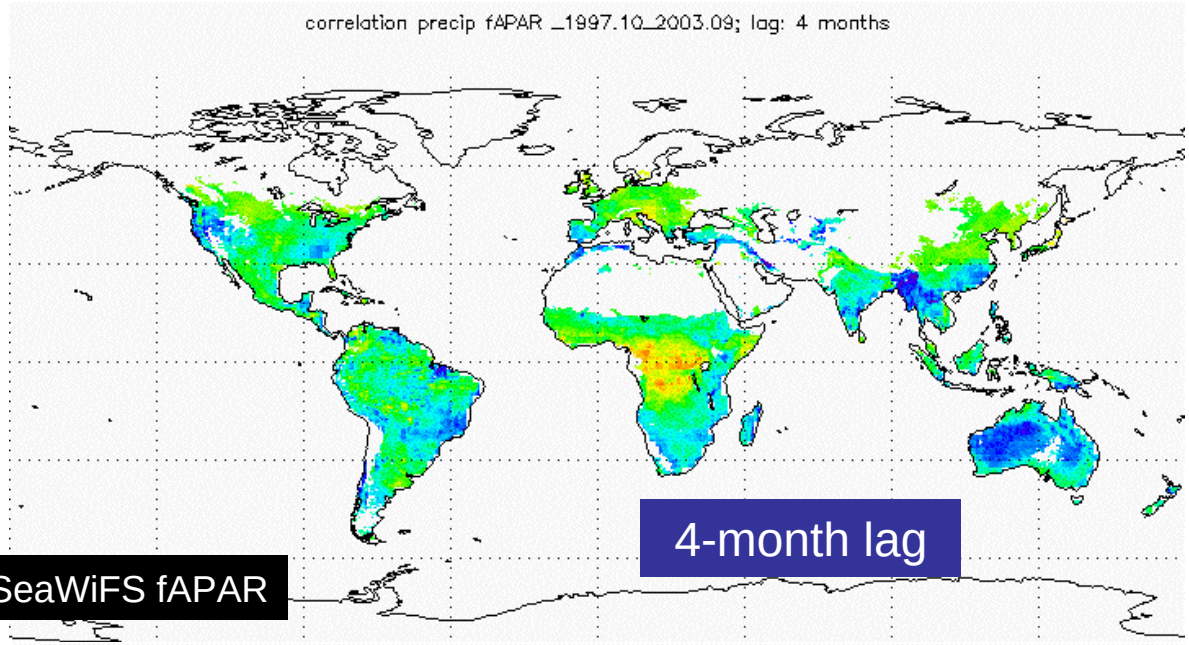
percent area with 99% significant correlation





BETHY simulated soil moisture

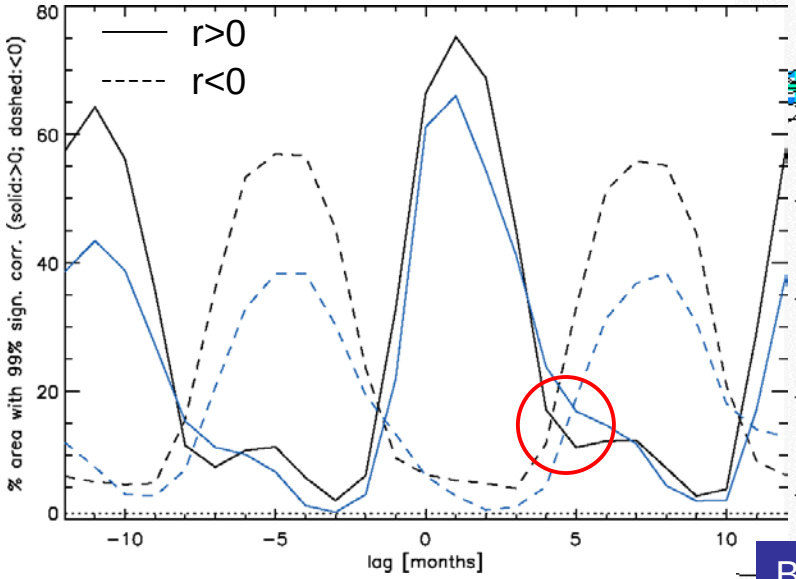
precipitation vs. satellite fAPAR and simulated soil moisture

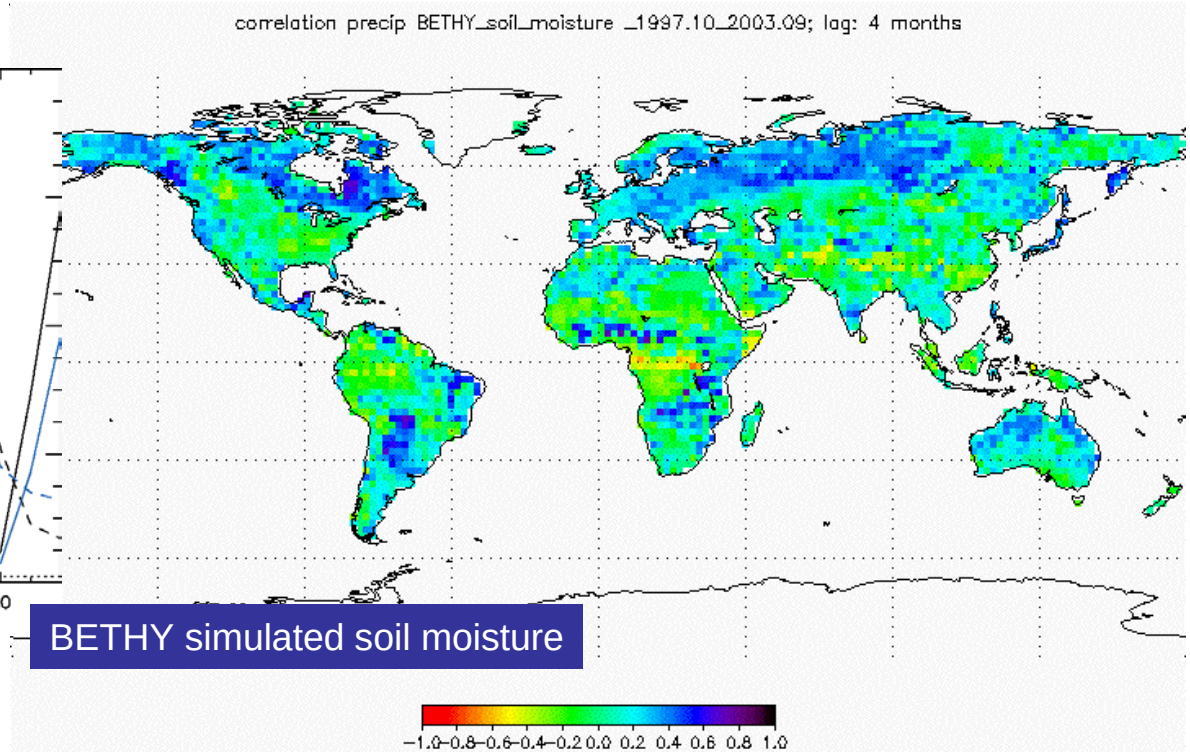


4-month lag

SeaWiFS fAPAR

percent area with 99% significant correlation





BETHY simulated soil moisture

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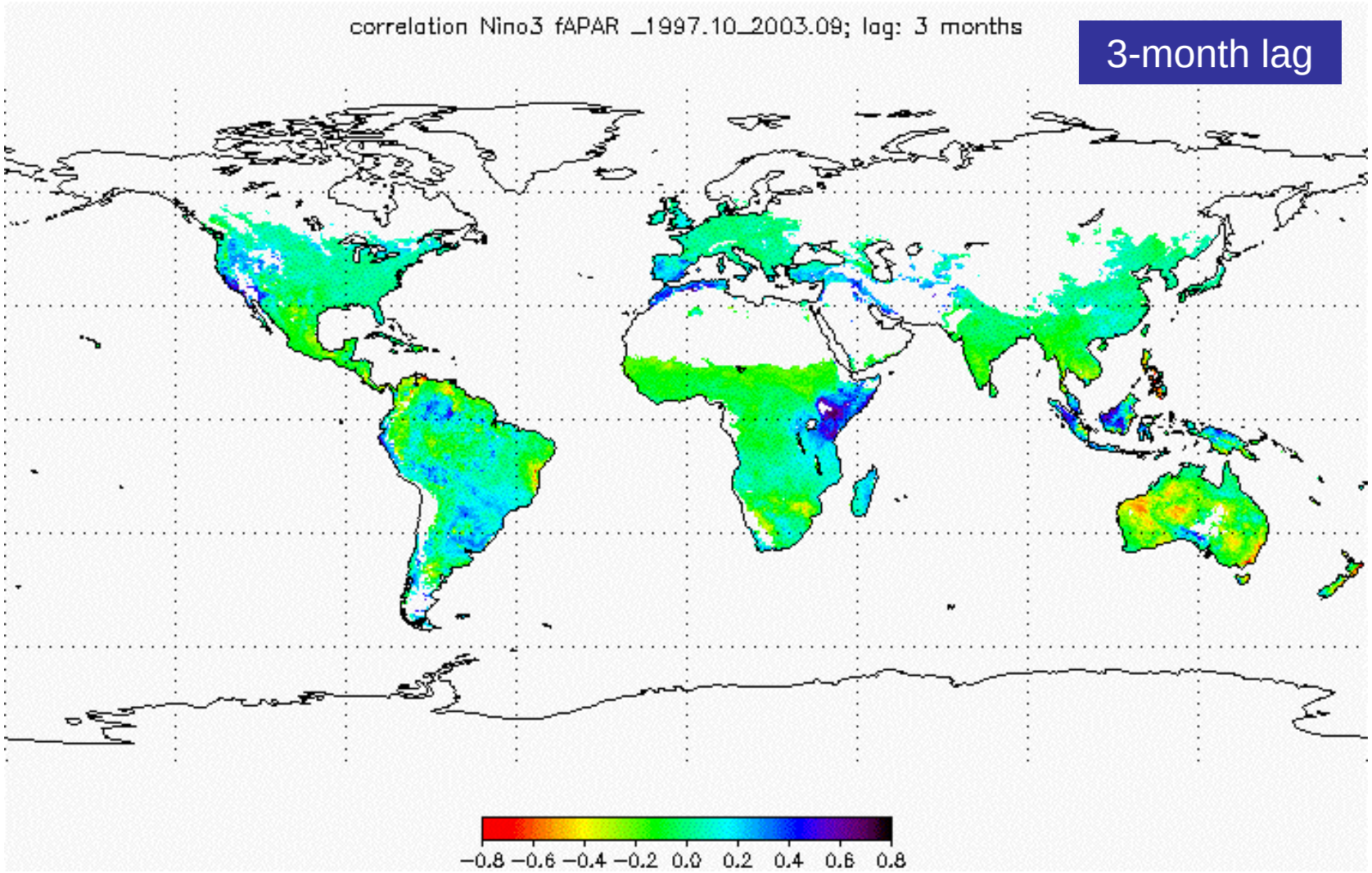
ENSO – SeaWiFS fAPAR lagged correlation



Overview

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- **Assimilation of fAPAR**

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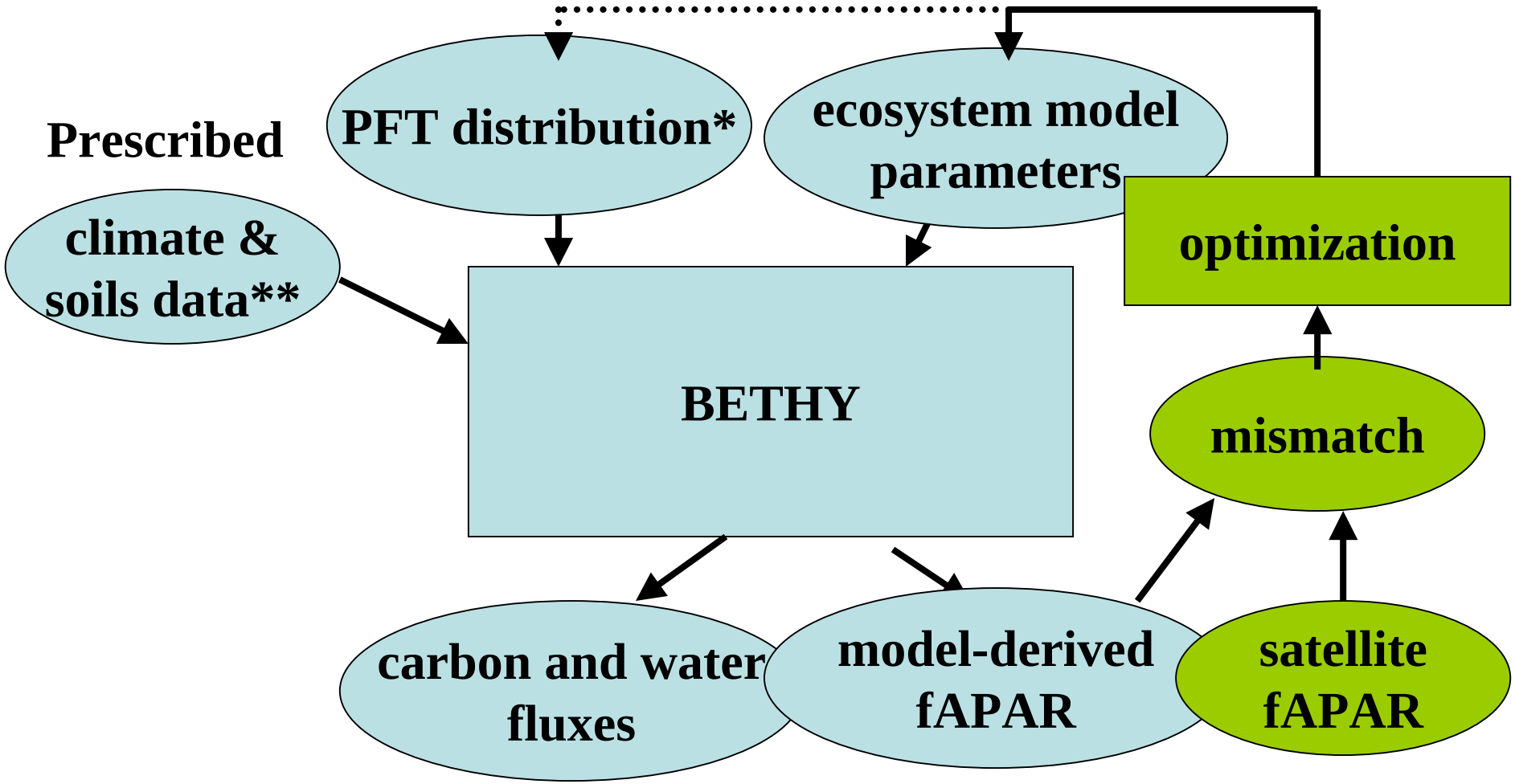
fAPAR Assimilation



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The Cost Function

Measure of the mismatch (cost function):

$$J(\vec{m}) = \frac{1}{2}[\vec{m} - \vec{m}_0]\mathbf{C}_{m0}^{-1}[\vec{m} - \vec{m}_0]^T + \frac{1}{2}[\vec{y}(\vec{m}) - \vec{y}_0]\mathbf{C}_y^{-1}[\vec{y}(\vec{m}) - \vec{y}_0]^T$$

model diagnostics

measurements

assumed model parameters

a priori parameter values

a priori error covariance matrix of parameters

error covariance matrix of measurements

aim: minimize $\mathbf{J}(\vec{m})$

[for each grid point separately]

The Parameters

parameter vector $\vec{m}=\{m_1,m_2,m_3\}$:			represents:	vector of prior parameter values m_0:
m_1	ΔT_ϕ	shift of leaf onset/shedding temperature	temperature limitation	$\Delta T_{\phi,0}=0$
m_2	w_{max}	maximum soil water holding capacity	water limitation	$w_{max,0}$ (derived from FAO soil map)
m_3	f_c	fraction of grid cell covered with vegetation	residual, unmodelled limitations (nitrogen, land use)	$f_{c,0}$ (function of P/PET and Temp. of warmest month)

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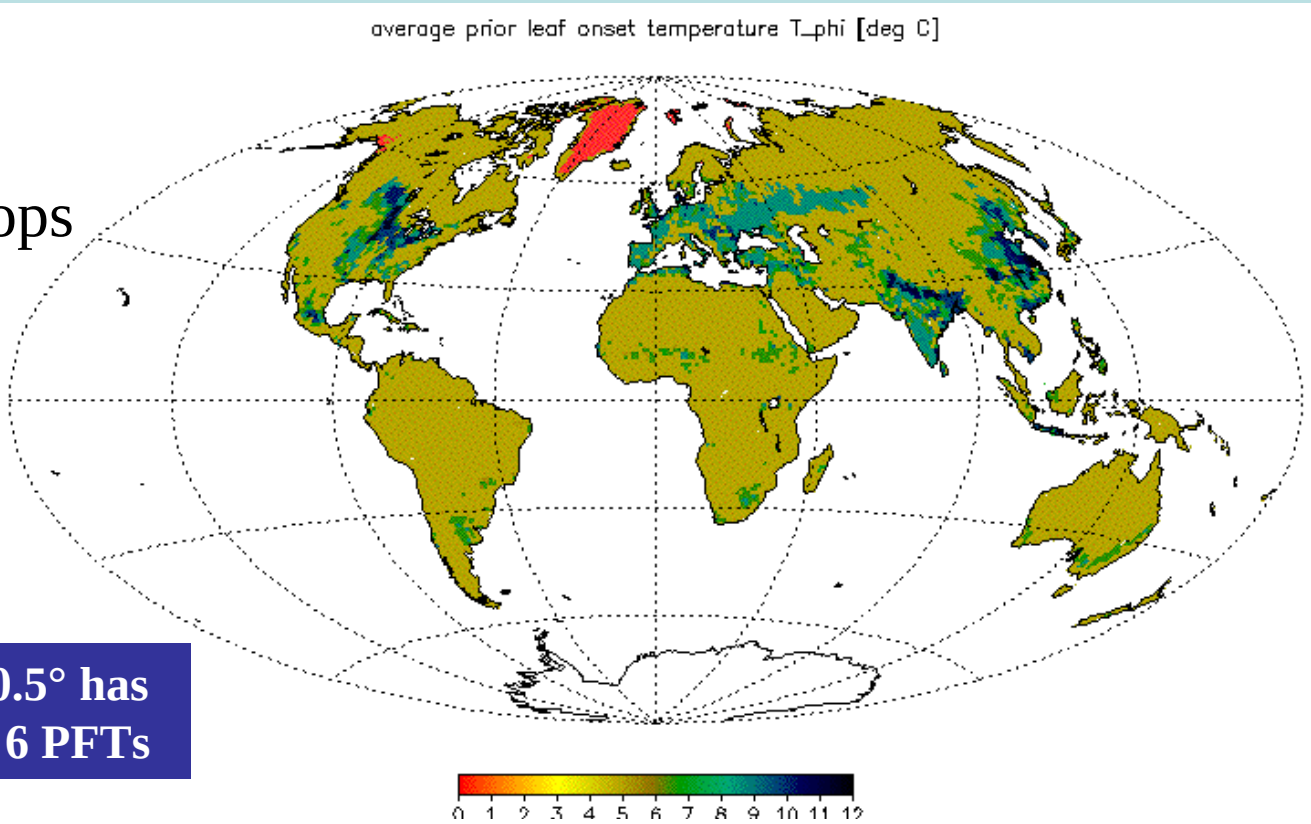
Prior Parameter 1

prior values:

T_ϕ=5°C

T_ϕ=12°C for crops

$\hat{T}_\phi$=15°C



note: each 0.5°x0.5° has mixture of up to 6 PFTs

map reflects presence of crops; red: unvegetated

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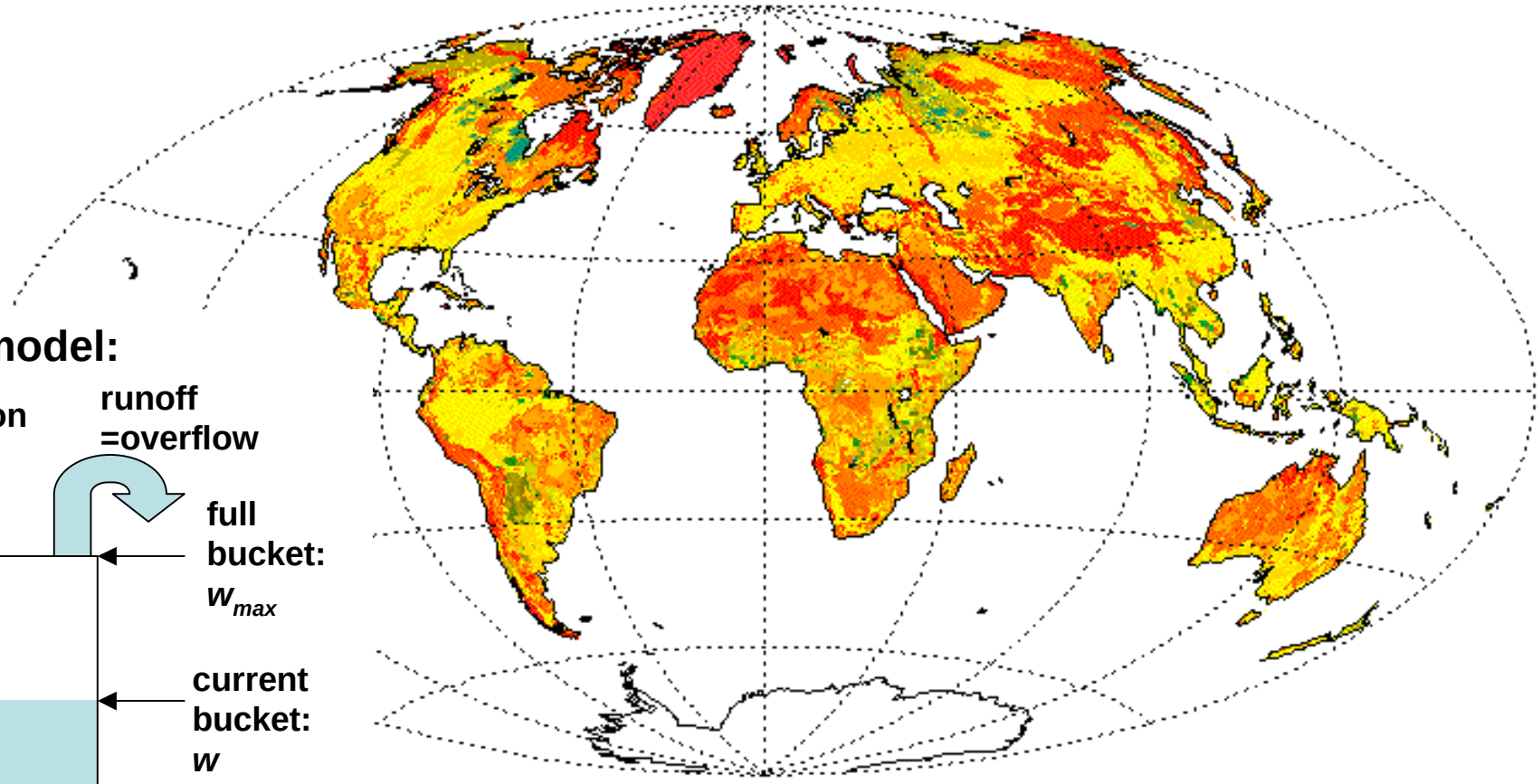
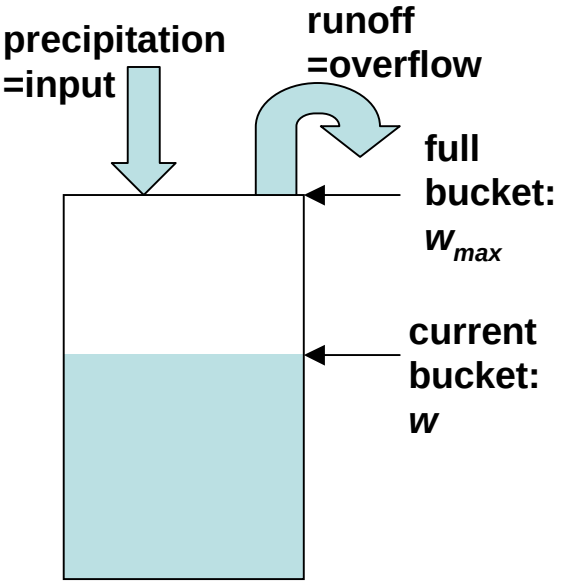
Prior Parameter 2

maximum soil water holding capacity [mm] prior



bucket model:



0 100 200 300 400 500

$w_{max,0}$ [mm]

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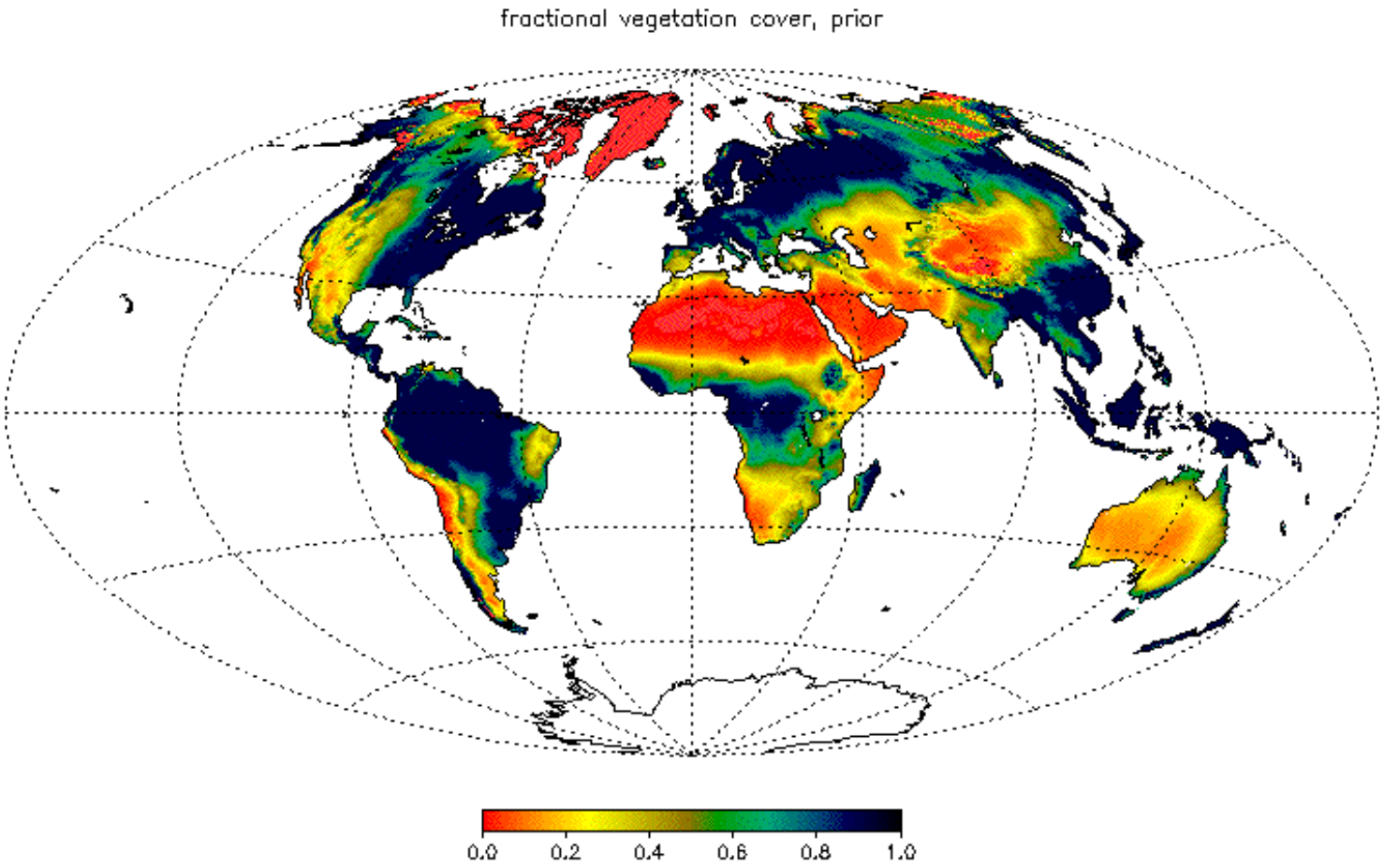
Prior Parameter 3



$$f_{c,0} = \mathrm{P}_{\mathrm{annual}} / \mathrm{PET}_{\mathrm{annual}} * \Lambda_W(T_{\mathrm{warmest\ month}}) / \hat{\Lambda}$$

Prior Parameter Errors

error covariance matrix of parameters C_{m0}:

$$\mathbf{C}_{m\,0} = \begin{pmatrix} 1\mathrm{K}^{2} & 0 & 0 \\ 0 & (2\,w_{\max,\;0})^{2} & 0 \\ 0 & 0 & 0.25^{2} \end{pmatrix}$$

$\Rightarrow$ off-diagonal elements assumed 0 here
= no prior correlation between errors of different parameters

The Assimilated Data

model diagnostics vector $\vec{y}=\{y_1,y_2,\ldots,y_{12}\}$:

y_i modelled fAPAR of month *i*

satellite-derived diagnostics vector $\vec{y}_0=\{y_{0,1},y_{0,2},\ldots,y_{0,12}\}$:

$y_{0,i}$ SeaWiFS derived fAPAR of month *i*

Prior Errors of Measurements

error covariance matrix of measurements C_y:

$$\mathbf{C}_{y\,i,j} \underset{i=j}{=} \begin{cases} 0.05^2 & \text{if valid measurement} \\ \infty & \text{if data gap} \end{cases}$$

$$= \sigma^2_{y,i}$$

$\Rightarrow$ off-diagonal elements again 0
= no prior correlation between errors of different months

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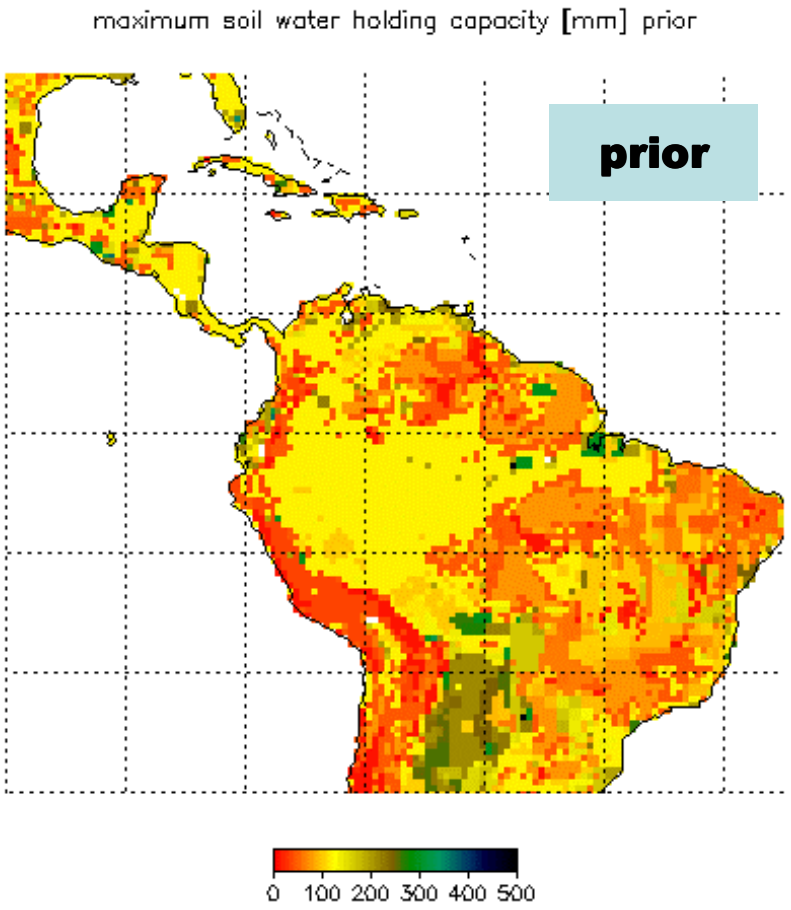
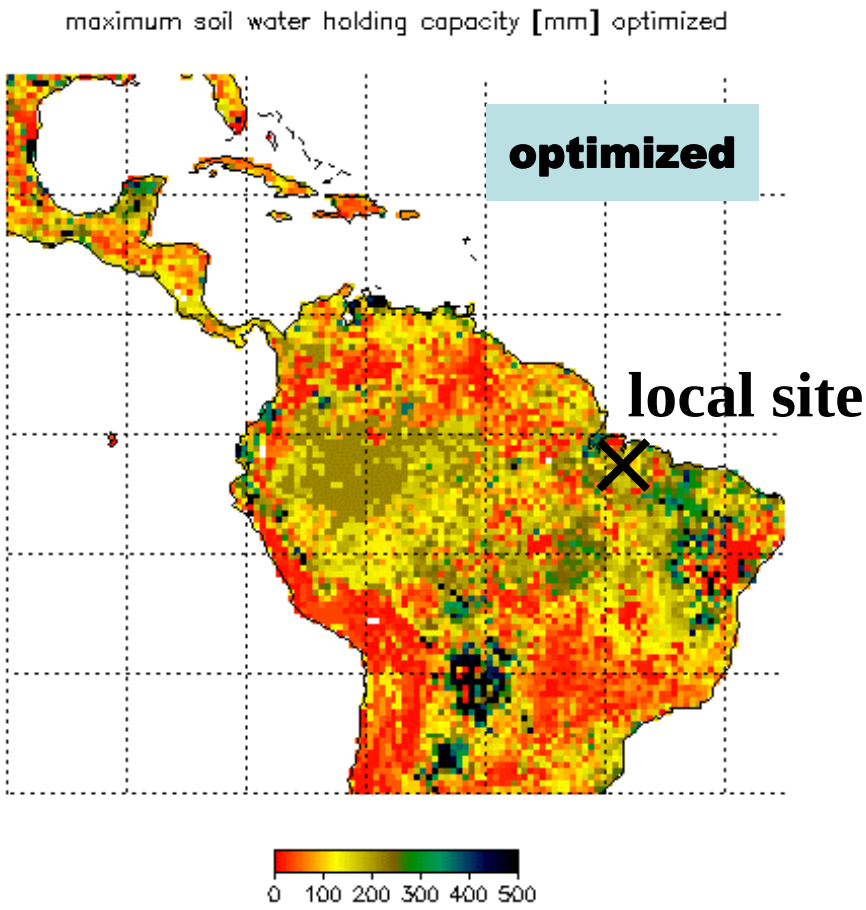
Parameter 2 (regional)

soil water-holding capacity





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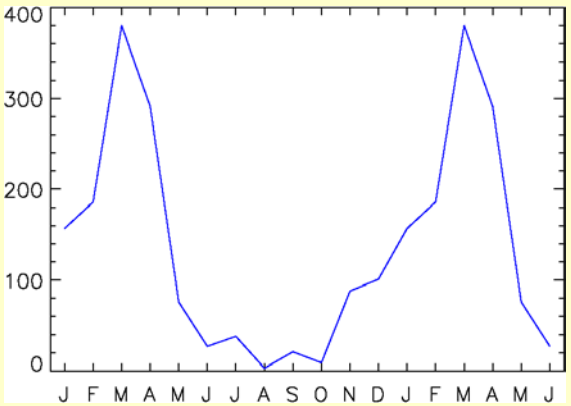
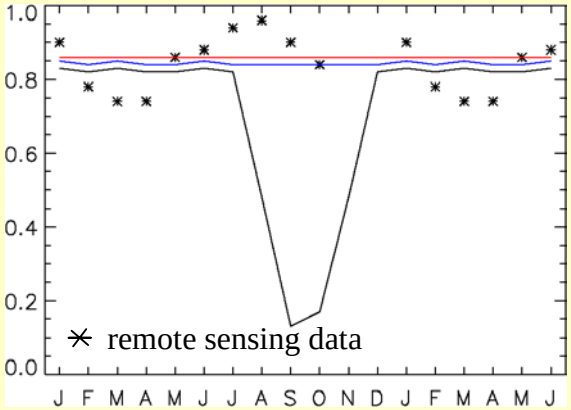
Local Simulations

precipitation [mm/month]



1992

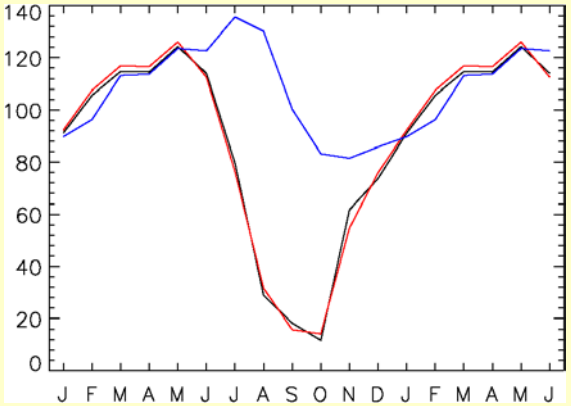
fAPAR



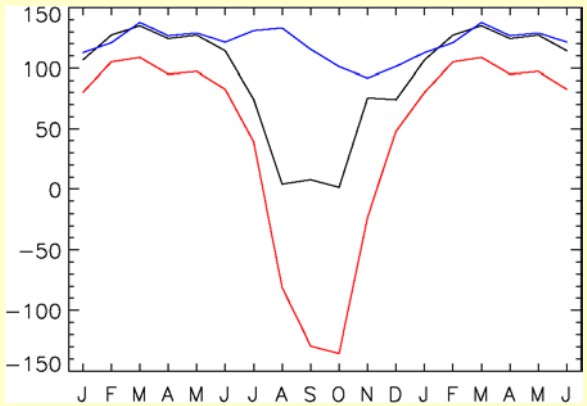
Paragominas
3°S 48°W 63 m

— no remote sens. data
— fAPAR prescribed
— fAPAR assimilated

evapotranspiration [mm/month]



NPP [gC/(m² month)]



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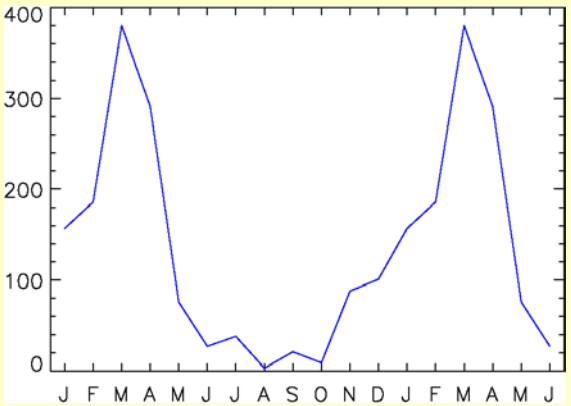
Measured Soil Moisture

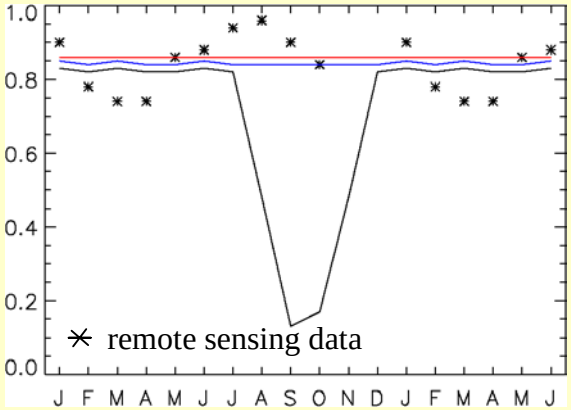
Paragominas
3°S 48°W 63 m

precipitation [mm/month]



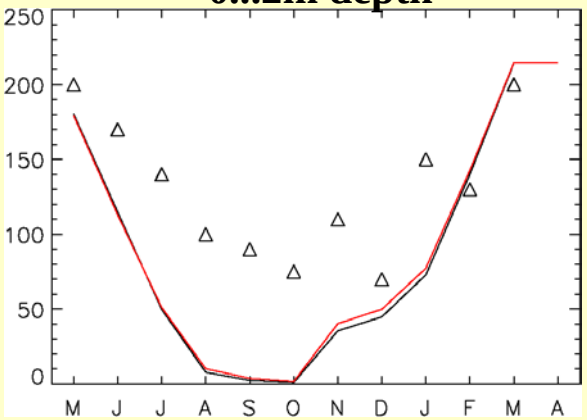
1992

fAPAR



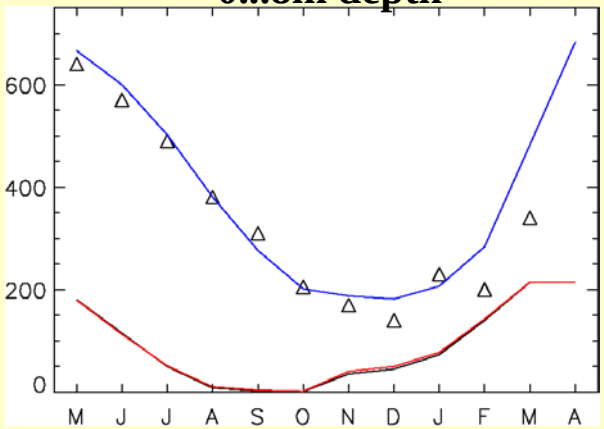
no remote sens. data
fAPAR prescribed
fAPAR assimilated

0...2m depth



1992

0...8m depth



1992

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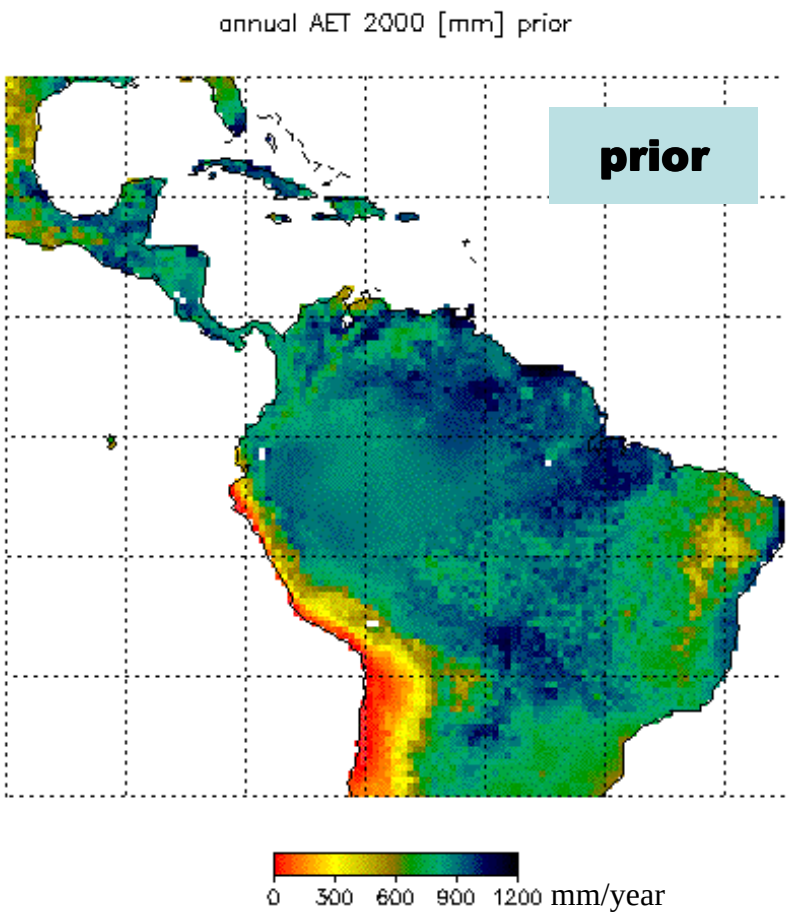
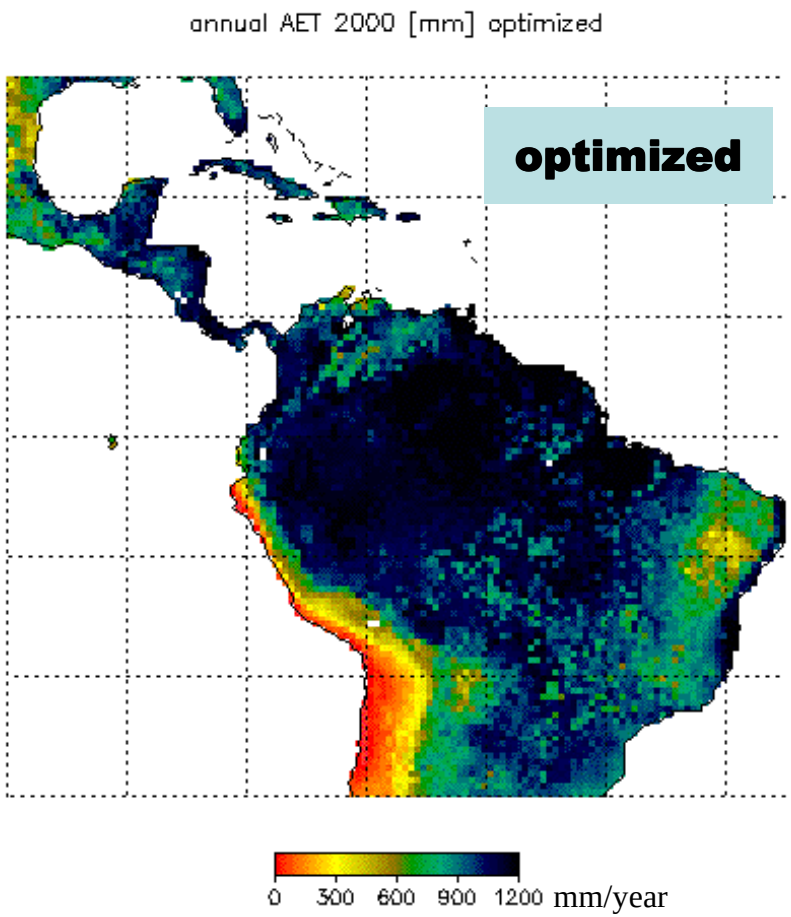
evapotranspiration (regional)





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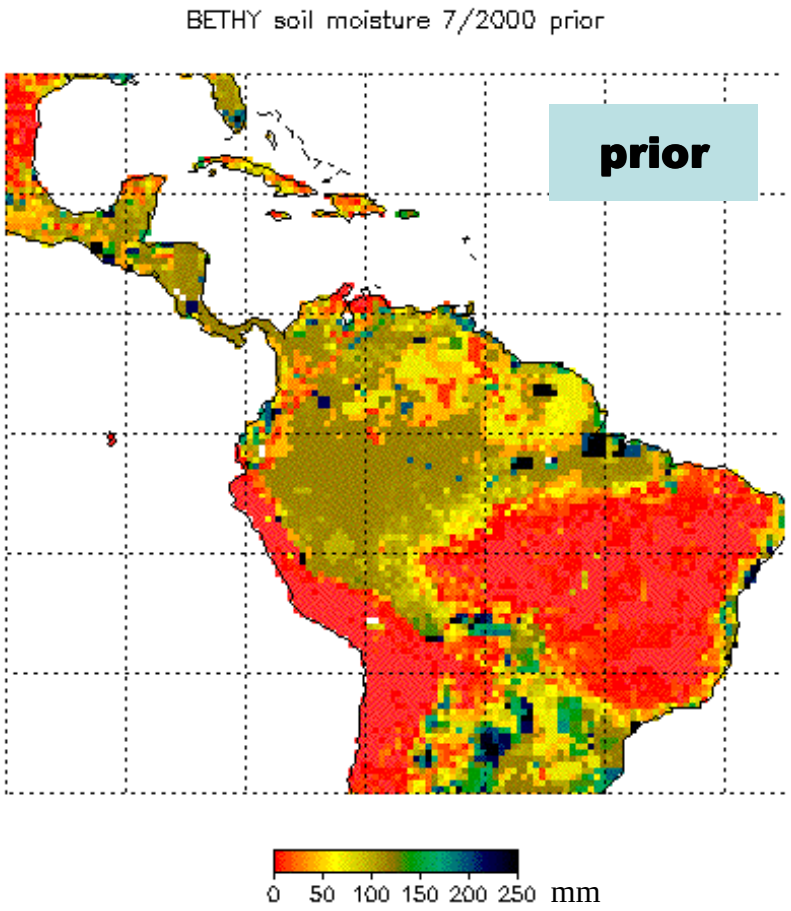
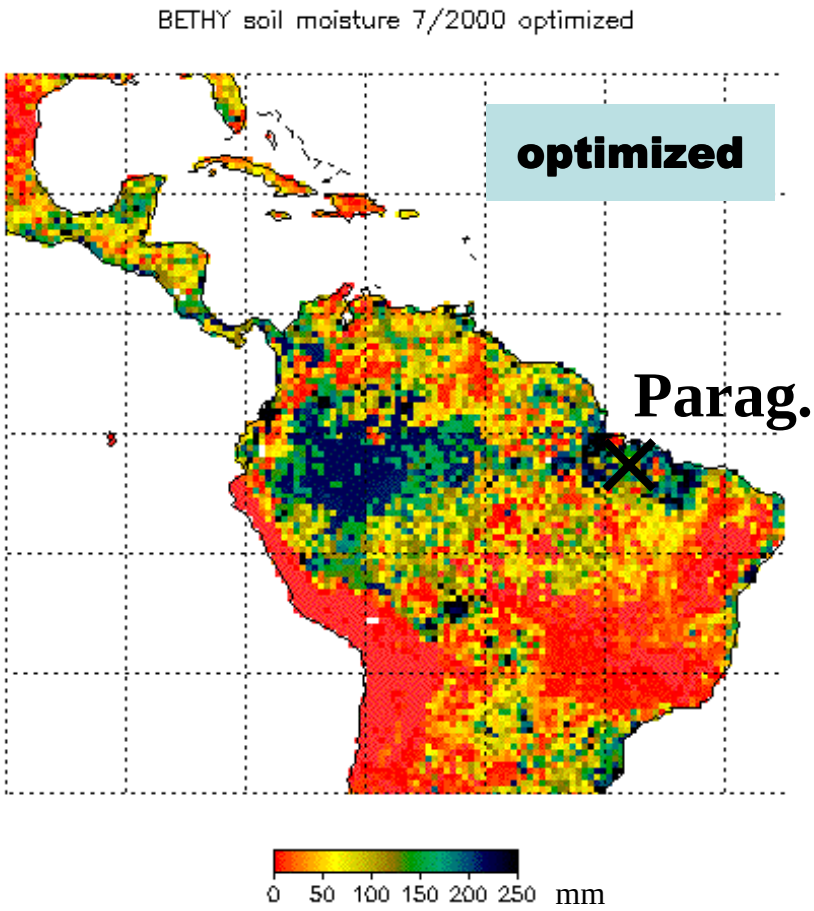
July soil moisture (regional, dry season)





Conclusions

- The carbon cycle is highly sensitive to climate fluctuations
- Vegetation can be quantified *reliably* from space
- fAPAR lags precipitation by ~1–4(?) months
- seems to behave similar to soil moisture
- assimilation of fAPAR can deliver valuable information on soil moisture status

Conclusions

- Need to improve *phenology* model
- Implement *sequential* 2-D var assimilation scheme
- Assimilate fAPAR into *coupled* ECHAM5-BETHY model

(hope not too distant)* goal: make fAPAR what SST is for ocean-atmosphere interactions... and improve *seasonal forecasts

Thank You For Your Attention!