iLEAPS

Integrated Land Ecosystem - Atmosphere Processes Study

GLOBAL IGBP CHANGE

What is iLEAPS?

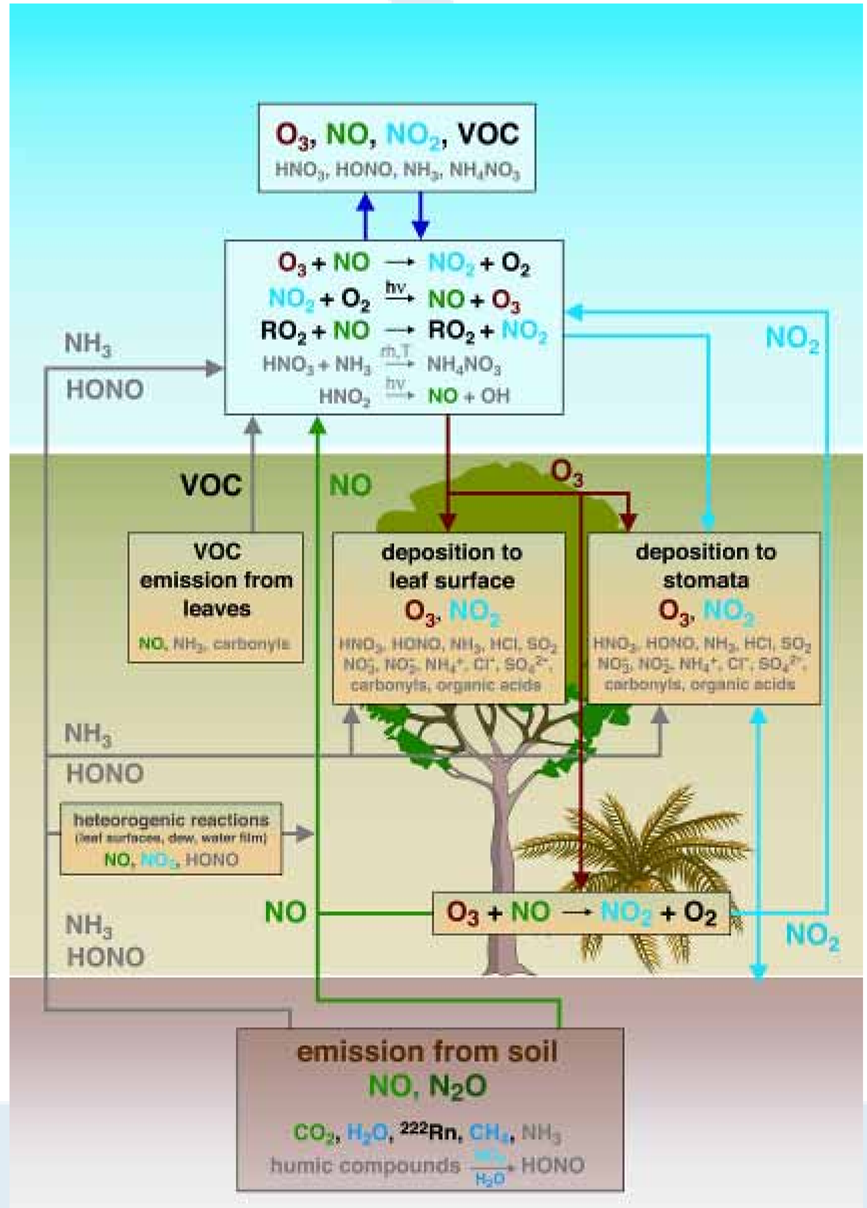
iLEAPS is the land - atmosphere interface reseach project of the International Geosphere - Biosphere Programme (IGBP).

The objective is to study how interacting physical, chemical and biological processes transport and transform energy and matter through the land-atmosphere interface.

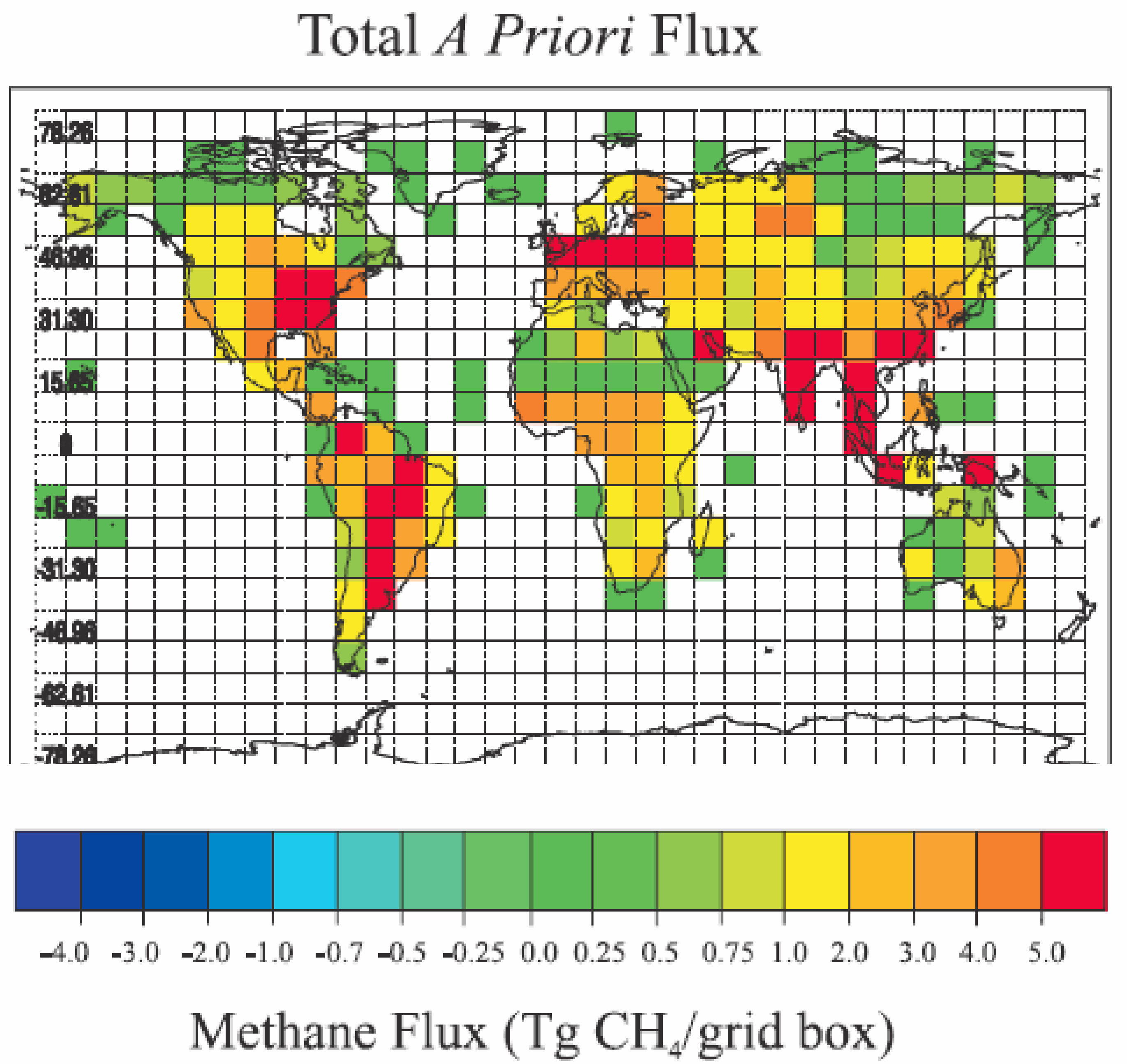
Focus 1

Land-atmosphere exchange of reactive and conservative compounds: Key feedbacks in the Earth System

- CO_2 fluxes at interlinked scales, controls, couplings
- **Control of interannual variation of CH_4 fluxes**
- Relationship of VOC fluxes to carbon exchange and Net Biome Production
- Feedbacks hydrology/aerosols/VOC
- Self-regulation of VOC fluxes
- Nitrogen species cycling

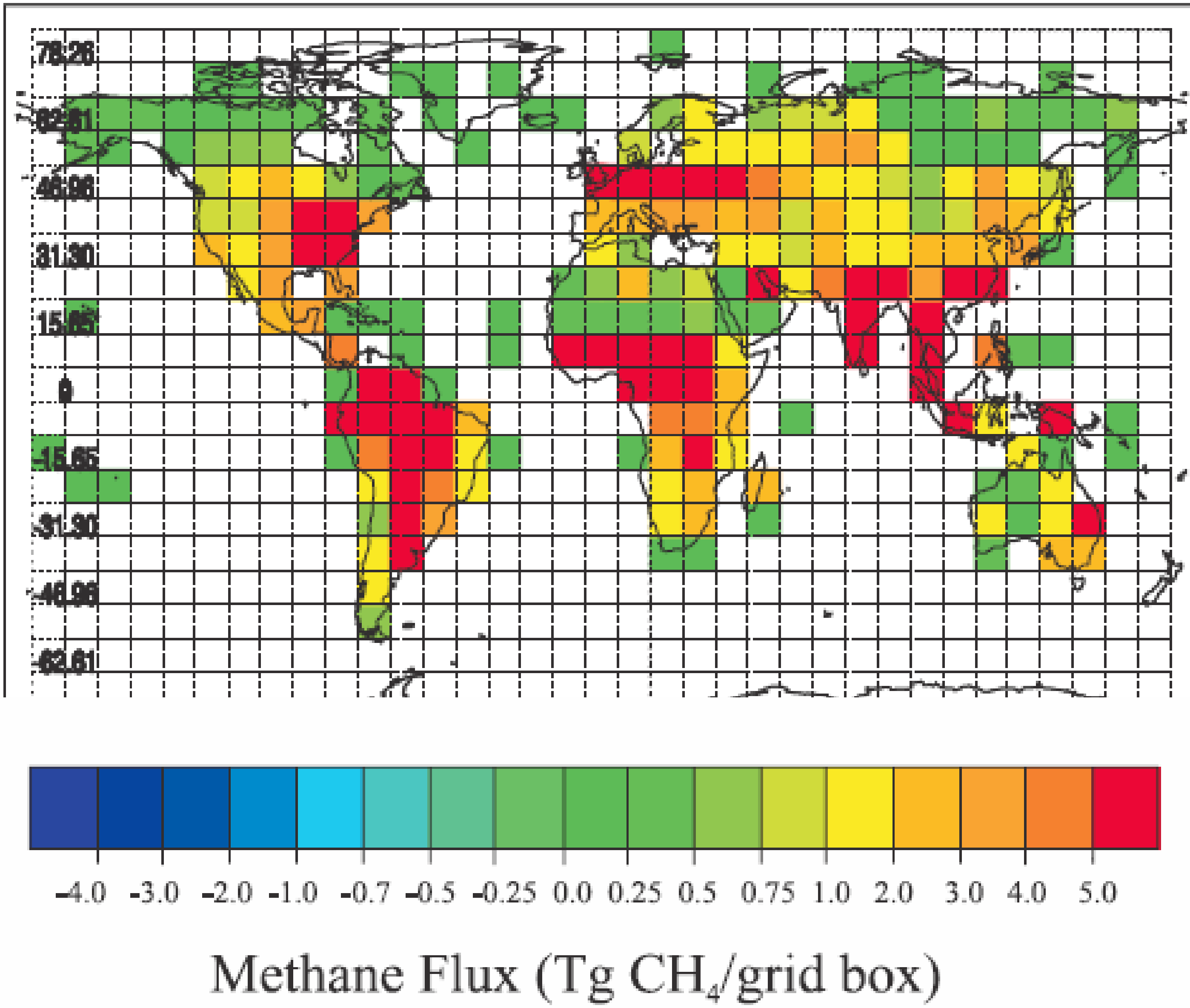


CHANGE



Source: Mikaloff-Fletcher *et al.* (2004) *Global Biogeochemical Cycles*

Total *A Posteriori* Flux



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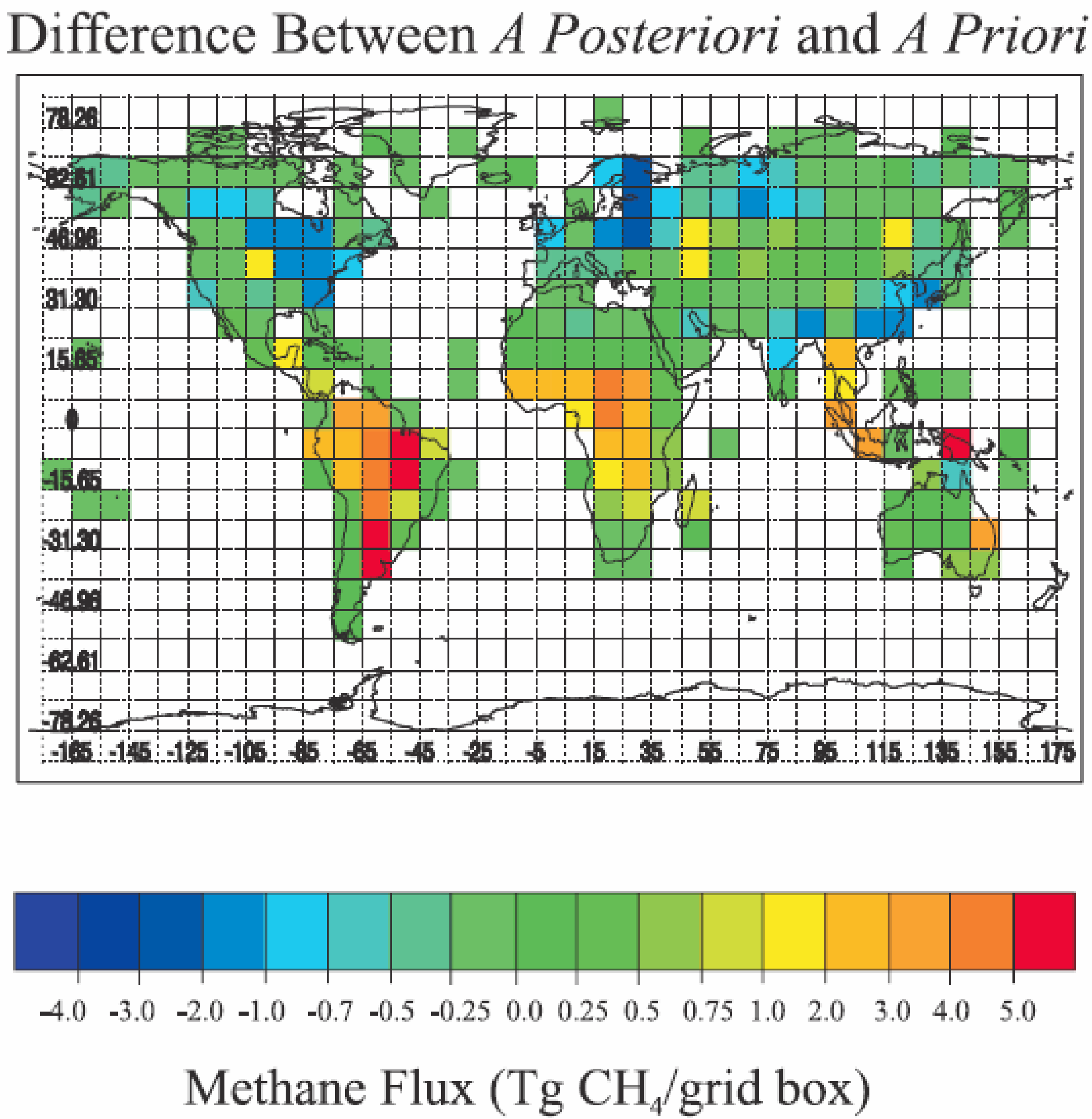
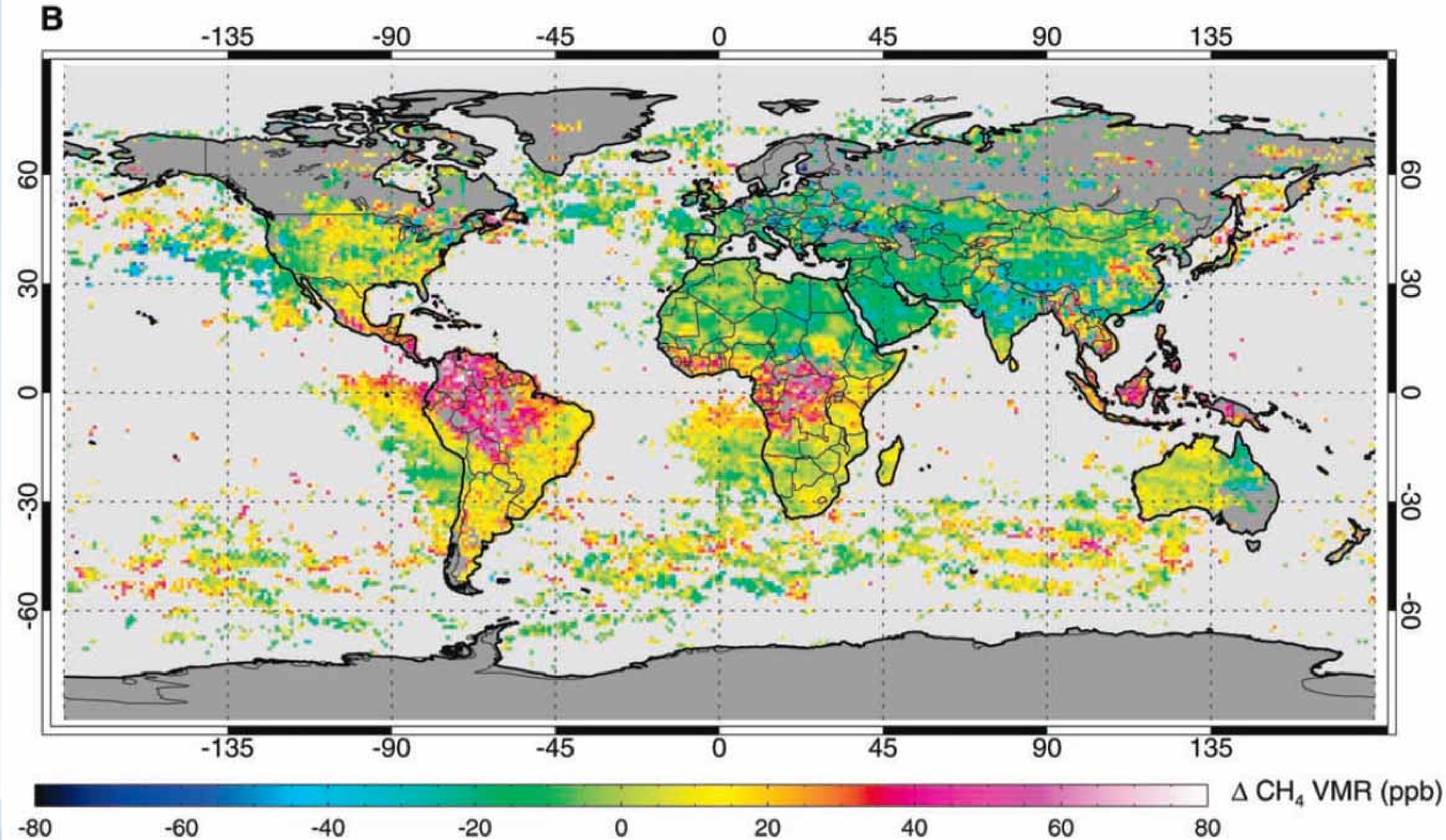


Source: Mikaloff-Fletcher *et al.* (2004) *Global Biogeochemical Cycles*

SCIAMACHY Retrieval – Model Source



Source: Frankenberg *et al. Science* 2005

An Amazon CH_4 Anomaly?

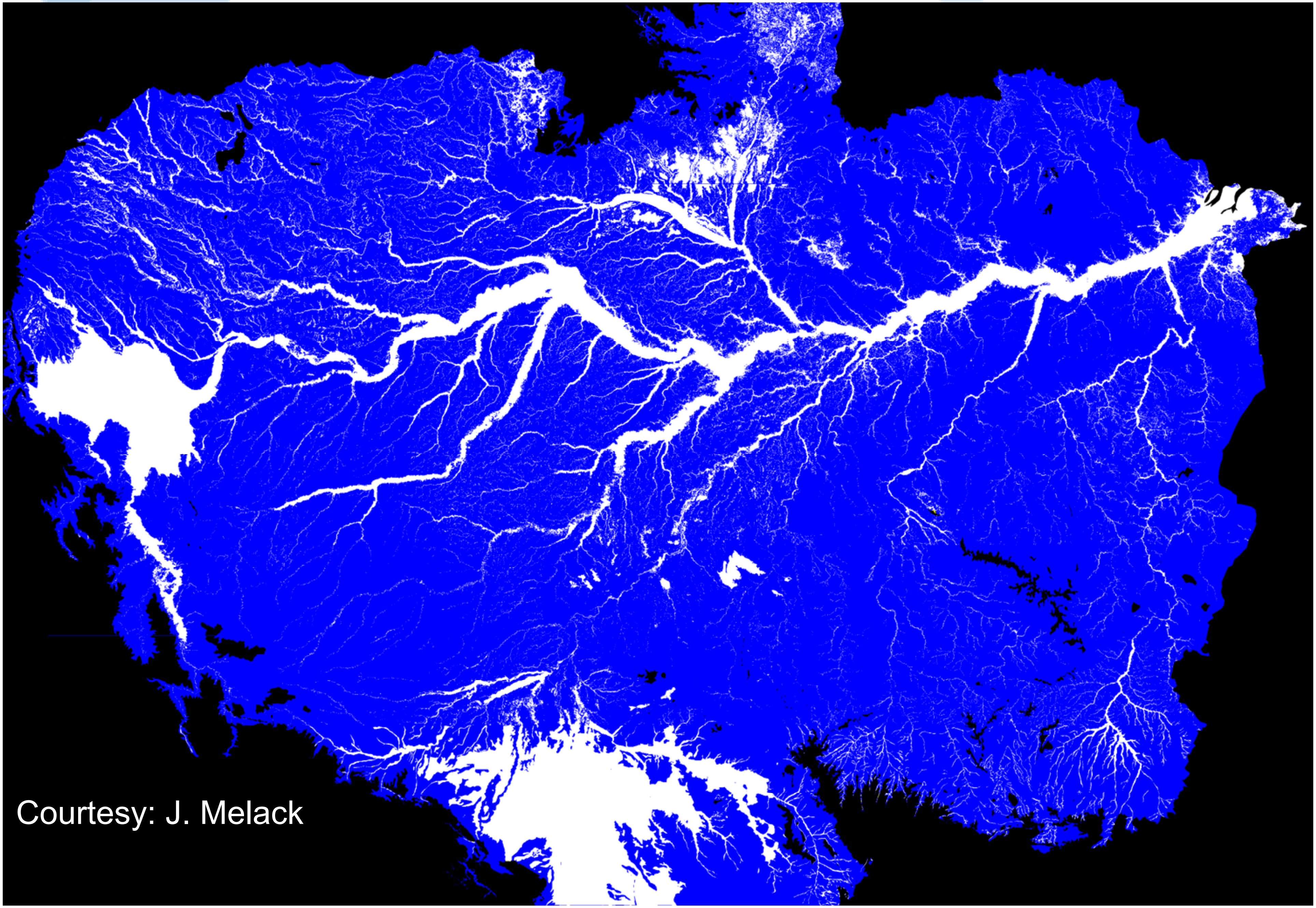
- Excess ~26 Tg CH_4 y^{-1} over the Amazon region in 1998-1999 according to Mikaloff-Fletcher et al. 2004

- Excess ~90 Tg CH_4 y^{-1} over all tropical forest assuming that fluxes for August to November 2003 can be extended to the full year (~45 Tg CH_4 y^{-1} for the Amazon)

Candidate Sources

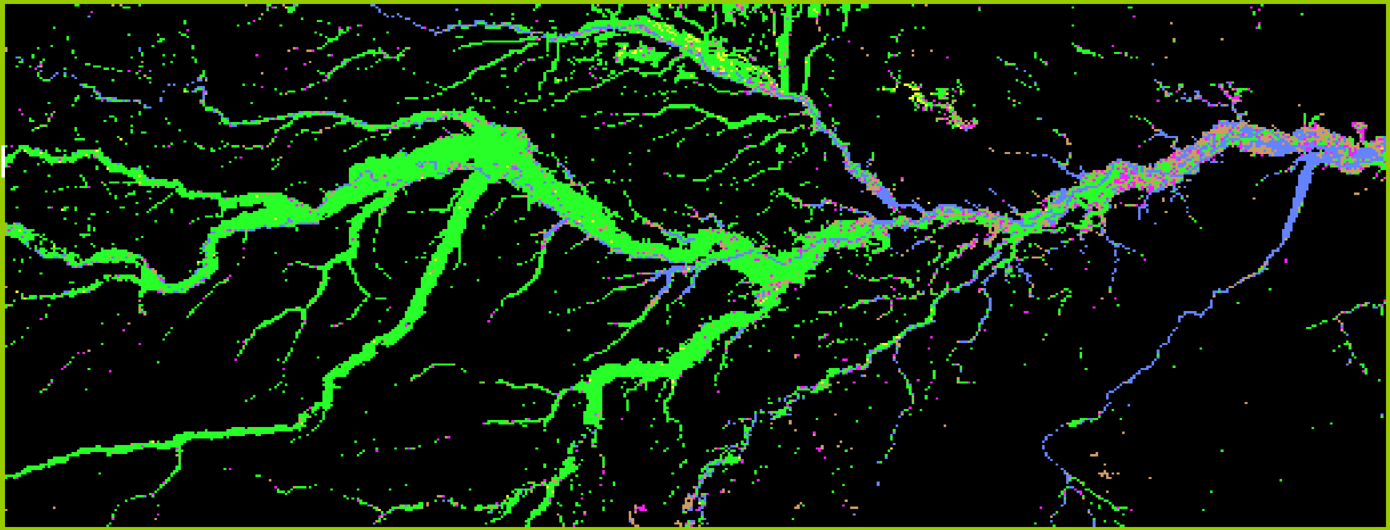
- Wetlands (Melack et al. 2004)
- Land Use Changes (Steudler et al. 1996; Keller et al. 2005)
- Upland Forest (Carmo et al. 2006 + unpublished data)

Amazon Basin below 500m: wetlands 17%, uplands 83%

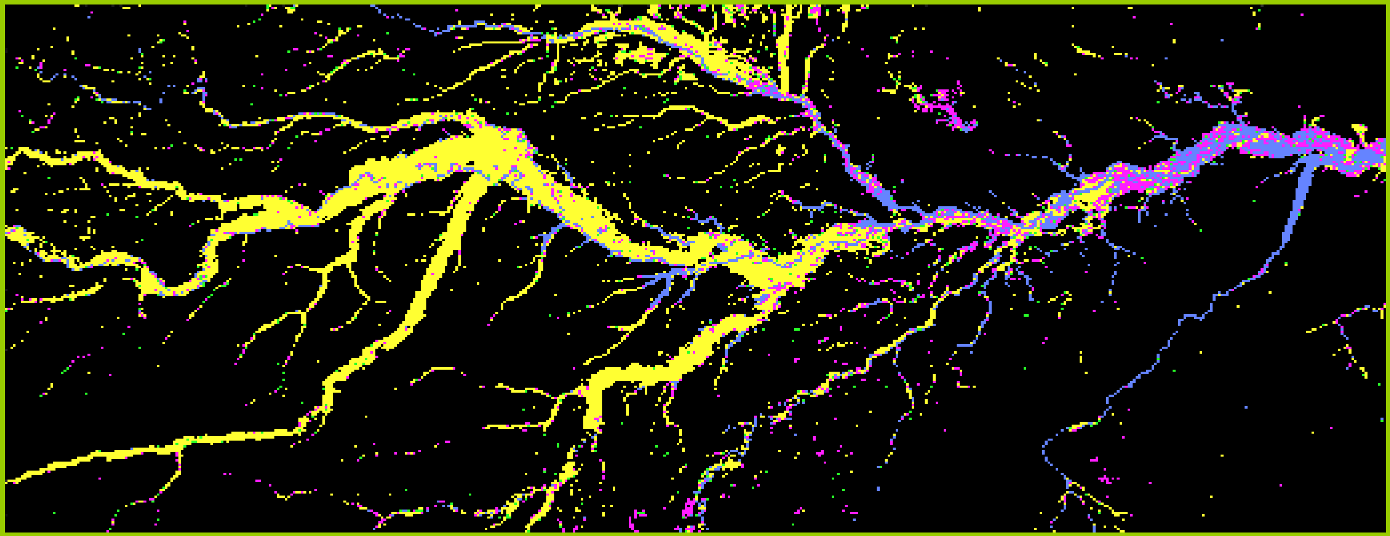


Classified JERS-1 Mosaics: Low and High Water

Low Water



High Water



- Non-wetland mask
- Open water
- Soil, grass, low shrub
- Flooded grass, shrub, treetop
- Forest
- Flooded forest

Hess et al. 2003

Amazon River Floodplain

	Methane Emission, Tg C y^{-1}
Aquatic macrophytes	0.63 ± 0.1
Flooded forest	0.61 ± 0.2
Open water	0.087 ± 0.02
River channel	0.008 ± 0.001
Total	1.3 ± 0.3

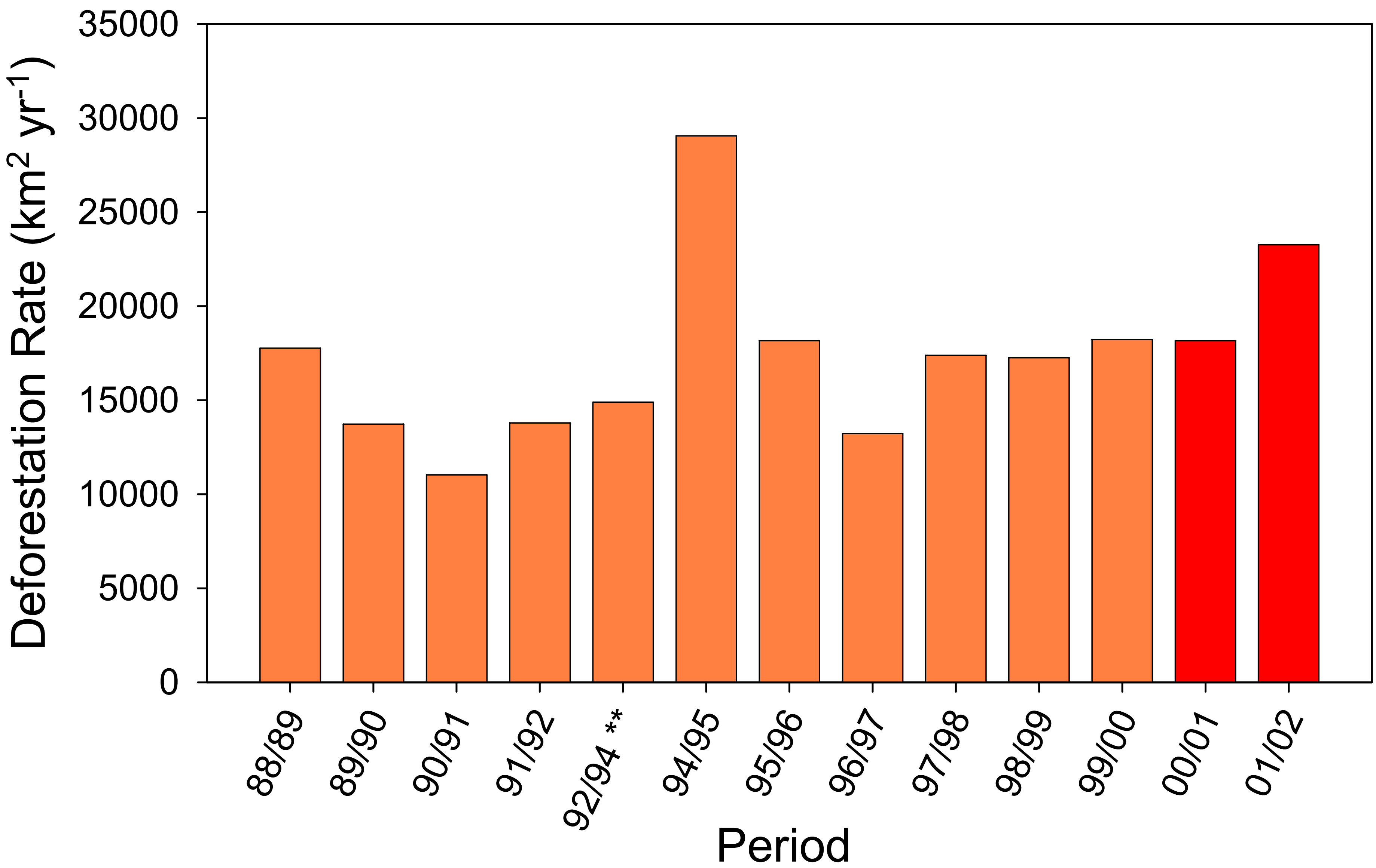
Melack et al. 2004

Lowland Amazon Basin
(<500 m asl)
(5.19 million km^2)

Methane Emission **29 Tg CH_4 y^{-1}**

Source: Melack et al. (2004) *Global Change Biology*

Deforestation: Brazilian Amazon $(km^2\ y^{-1})$



Land Use Change: Amazon

(Steudler et al. 1990; Keller et al. 2005)

	Tg CH_4 y^{-1}
Biomass Burning	1.0
Cattle	1.3
Pasture Soils	0.2
Logging Soils	0.7 (±0.4)
Total Land Use	~3.2

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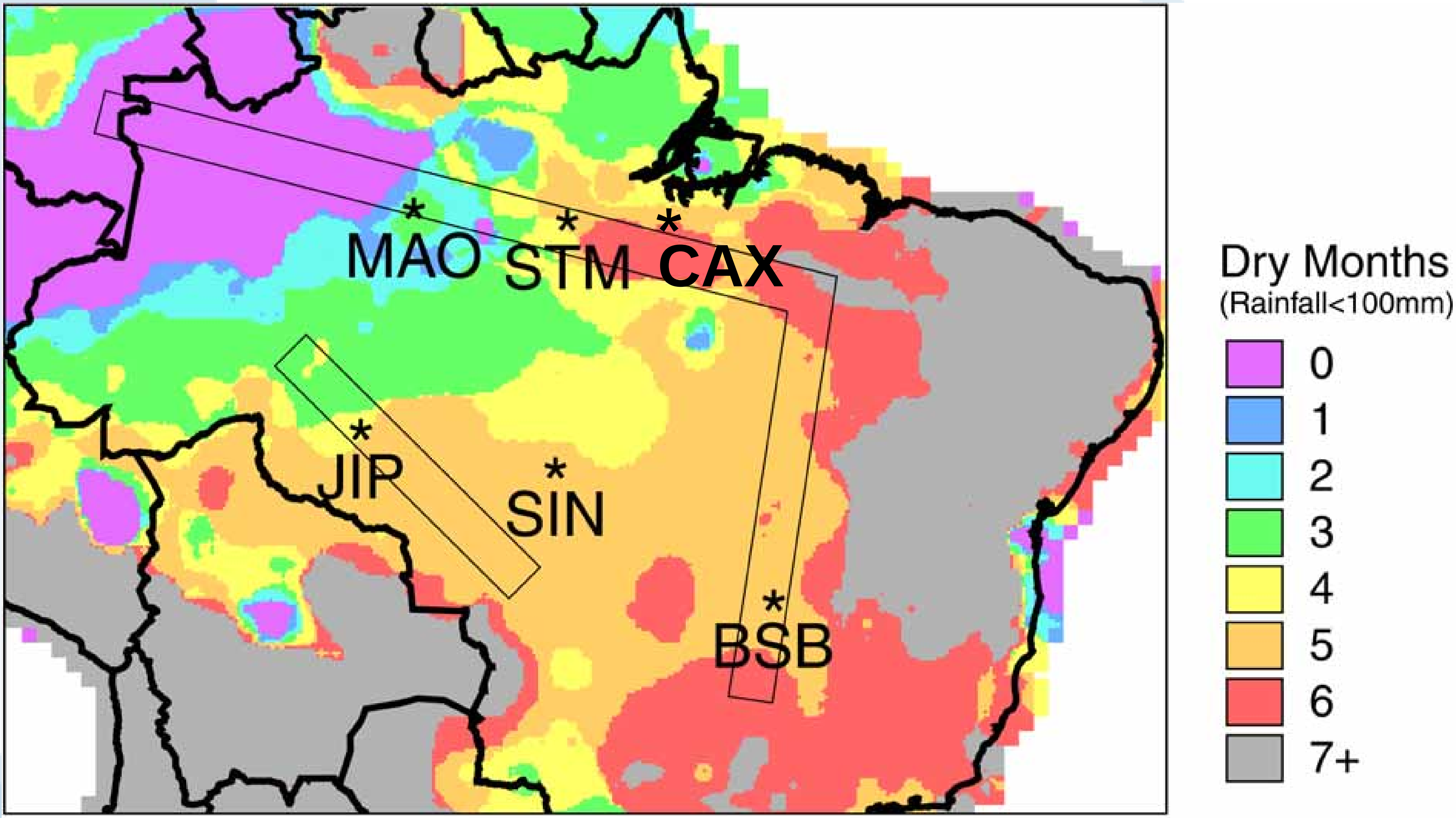
Surprising Result!

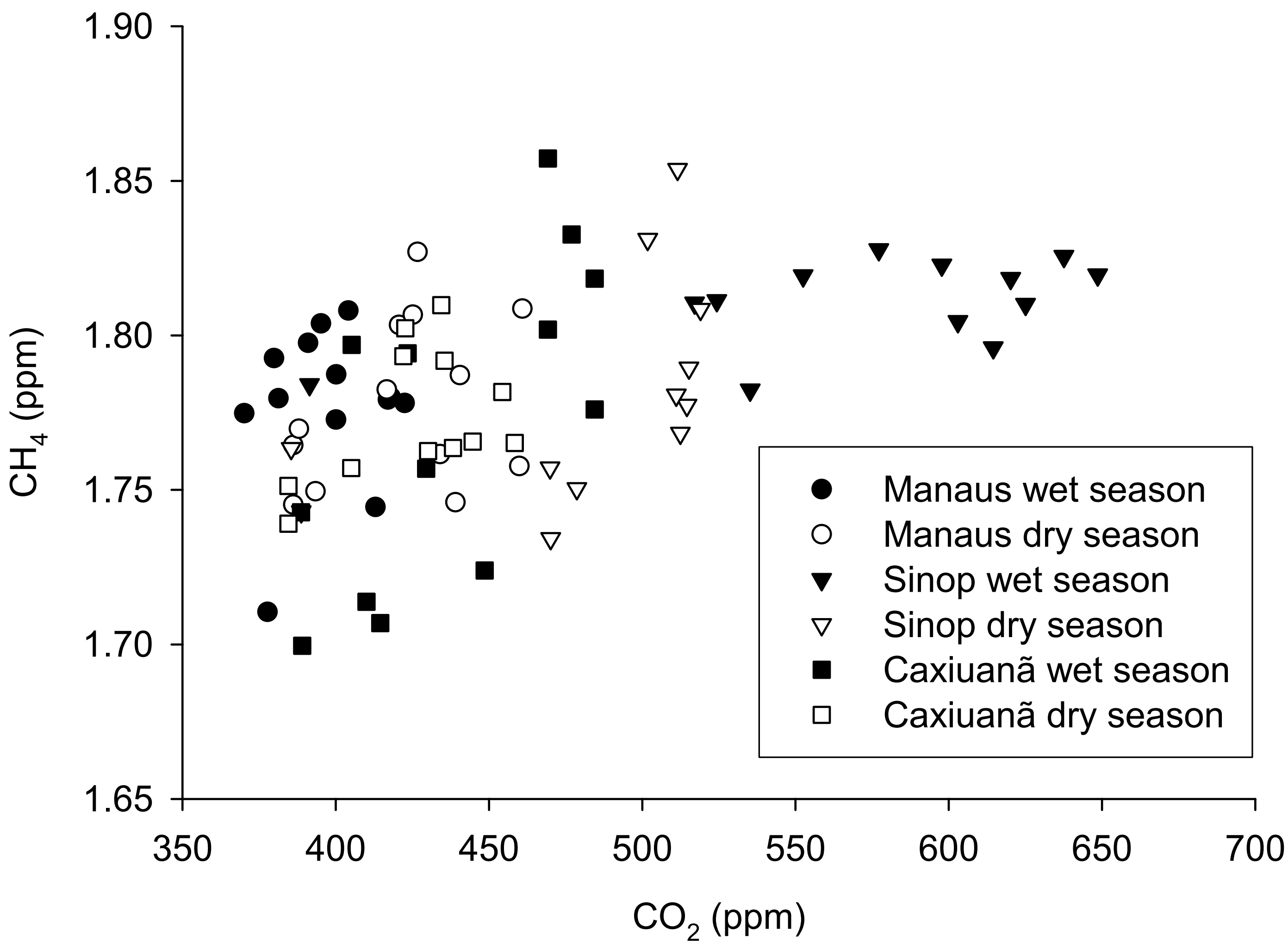
- Atmospheric measurements from 4 LBA tower sites show that upland forests are a source of methane [Carmo et al. (2006) GRL 33, L04809]

LBA Tower Sites



Based on precipitation data from Wilmott & Webber, 1999
Provided by LBA-HYDRONET

Graphical Summary of Sampling



Source: Carmo *et al.* (2006) *GRL* 33, L04809

Simplified Estimation of CH_4 Flux

$$P_{CH4} \approx \rho J_{CO2soil} \frac{d[CH_4]}{d[CO_2]}$$

ρ = ratio of ecosystem flux to soil flux = 2.4 for tropical forest (Chambers *et al.* 2004)

Summary of Flux Estimates

Site	Season	*d* [CH_4] / *d* [CO_2]	Soil CO_2 Flux (± Std Err.) (μmol m^{-2} s^{-1})	CH_4 Flux (mg CH_4 m^{-2} d^{-1})
Caxiuanã	Wet	0.0010*	6.1 (1.4)	20.6
Caxiuanã	Dry	0.0004	5.1 (1.5)	6.9
Manaus	Wet	0.0002	5.4 (1.4)	3.6
Manaus	Dry	0.0002	5.5 (1.1)	3.7
Sinop	Wet	0.0001*	5.8 (1.1)	2
Sinop	Dry	0.0005*	3.0 (0.5)	5.1

Source: Carmo *et al.* (2006) *GRL*

Site	Season	dCH4 / dCO2	Soil CO_2 Flux $\mu mol\ m^{-2}\ s^{-1}$	Factor ρ	CH_4 Flux $\mu mol\ m^{-2}\ s^{-1}$	CH_4 Flux $mg\ m^{-2}\ d^{-1}$
km67	Wet	0.0017	2.8	2.8	0.0131	18.1
km67	Dry	0.0003	1.9	2.8	0.0016	2.2
km67	Wet	0.0017	3.6	2.8	0.0168	23.3
km67	Dry	0.0003	2.7	2.8	0.0022	3.1
km83	Wet	0.0003	2.8	2.8	0.0024	3.3
km83	Dry	0.0015	1.9	2.8	0.0078	10.8
km83	Wet	0.0003	3.6	2.8	0.0031	4.2
km83	Dry	0.0015	2.7	2.8	0.0111	15.4
					Average	10.0
Factor ρ from km67 autochambers = 2.75						
and comparison to windy night (u*>0.2) NEE at km 67 and km 83						
	Martens et al. 2004; Goulden et al. 2004; Saleska et al. 2003					

Upland Forest CH_4 Source

- Extrapolating to the area of upland forest in the Amazon region (~5 million km^2) leads to a source of **4 to 38 Tg CH_4 y^{-1}.**

- Origin: Distributed anaerobic sites, termites, plants(?)

Summary of Amazon Methane Fluxes

	Tg CH_4 y_{-1}
Amazon Basin (1998, 2003)	**48 - 53**
Wetlands	**29**
Land Use Change (1990)	**3**
Upland Forest	**4 -38**

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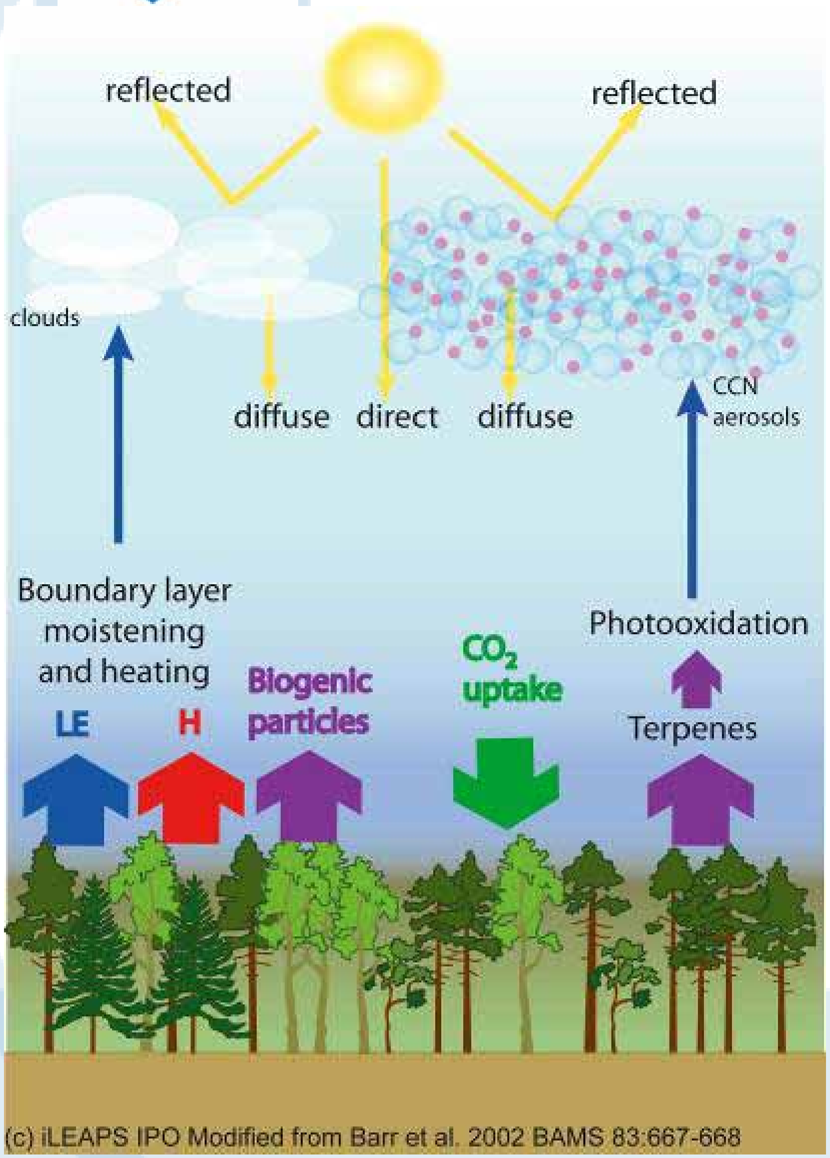
Focus 2A

Interactions and feedbacks between biogenic/ anthropogenic aerosol production, cloud processes, climate and the water cycle



What controls natural aerosol and CCN abundance

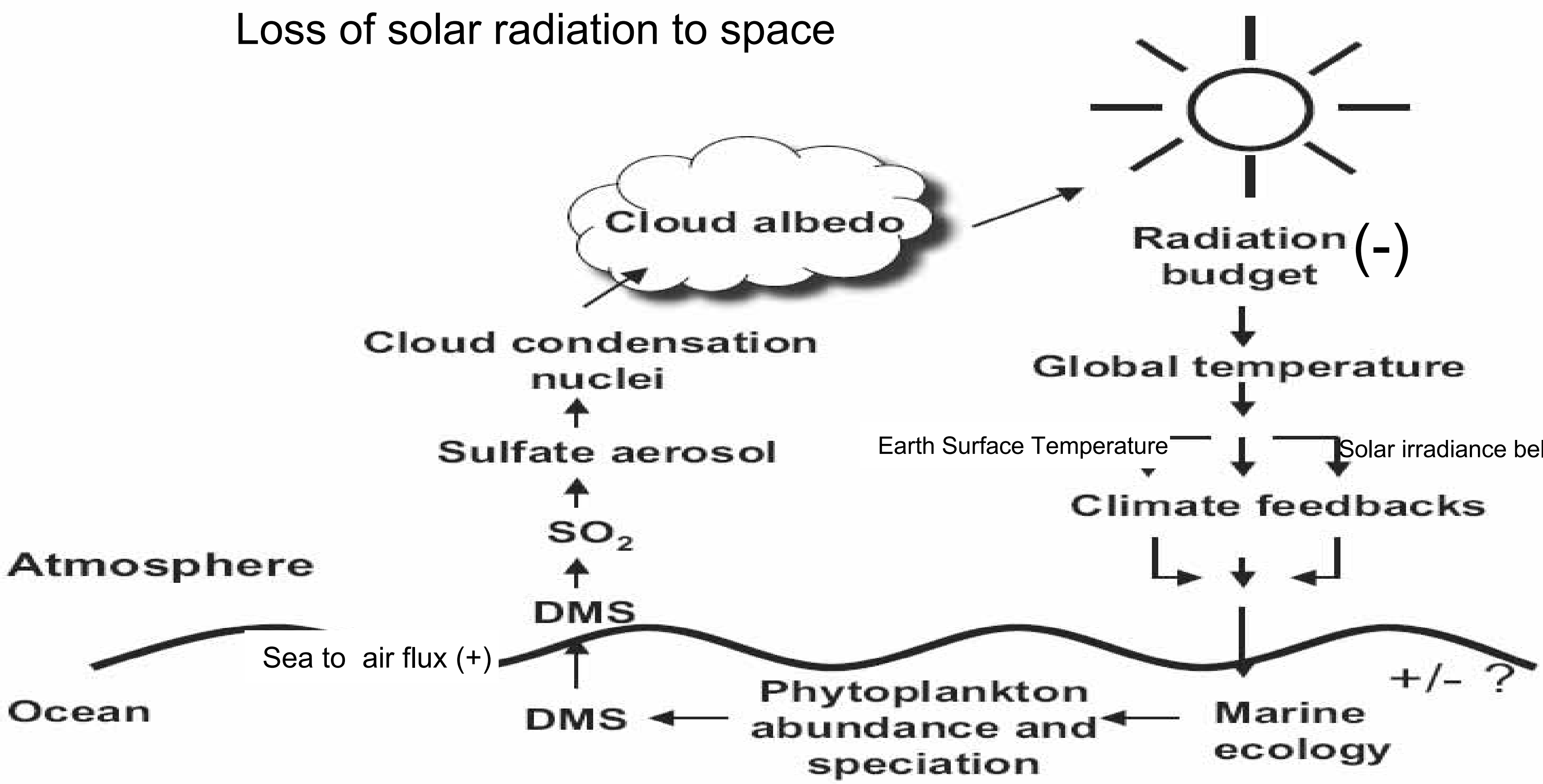
- How changes in aerosols (esp. CCN) affect the cycles of water, energy and chemical species
- Chemical/microphysical effect of terrestrial (biogenic, smoke, dust) aerosols?
- Dust: cloud effects, anthropogenic perturbation
- **Aerosol/light interactions (absorption/scattering) in ecology and climate change**
- Representation in climate models

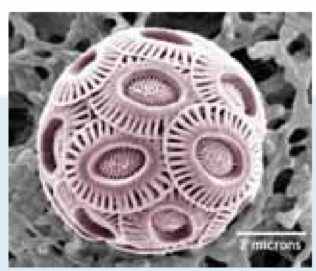
Aerosol-mediated feedback loop on forest carbon uptake

Marine CLAW hypothesis (DMS-feedback

- Charlson, Lovelock, Andreae & Watson (CLAW) 1987, Nature
- Coupling marine biology, marine & atmospheric chemistry and atmospheric physics
  - DiMethylSulphide largest precursor for CCN production over oceans
- Negative feedback: biological control on climate through modification of planetary albedo, surface radiation and consequently on biological processes
- **Earth System “Self-regulation”, ‘Homeostasis**’

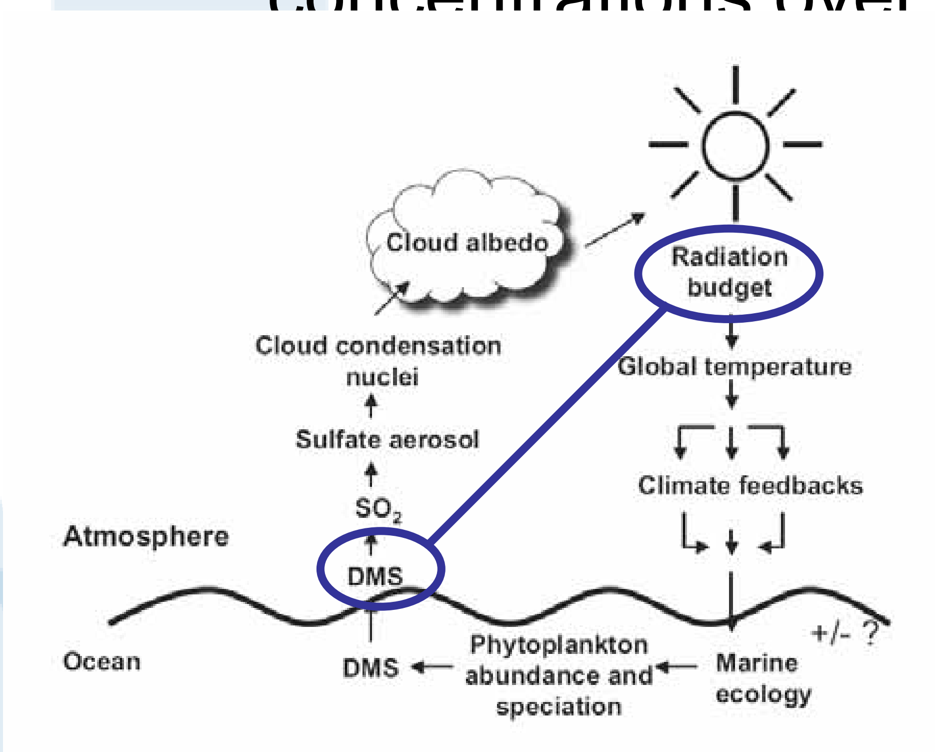
The DMS-feedback

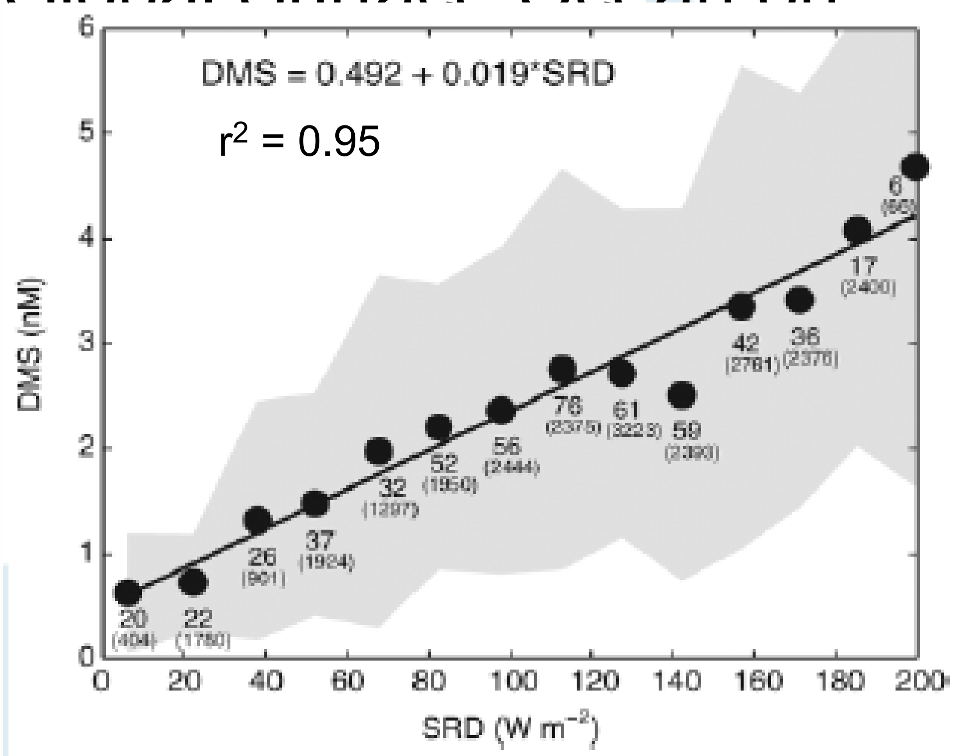




DMS-feedback mechanism: observations

- Vallina et al., 2007, Science
  - Solar Radiation Dose (measure for incoming solar radiation at the surface) accounts for 95% of variance of monthly surface DMS concentrations over Global Surface Ocean on



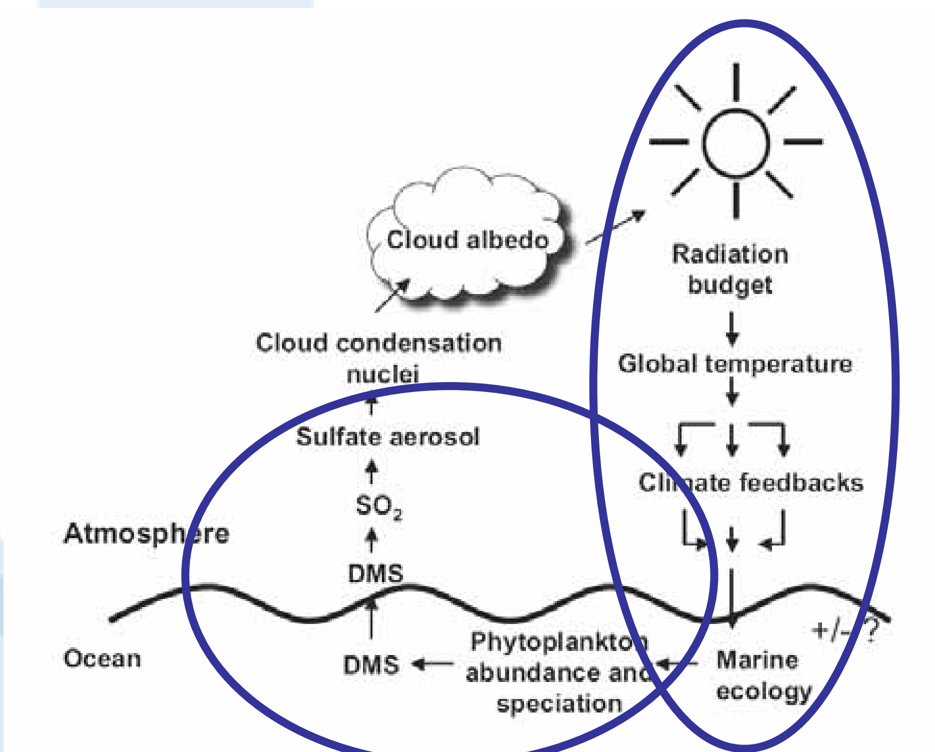


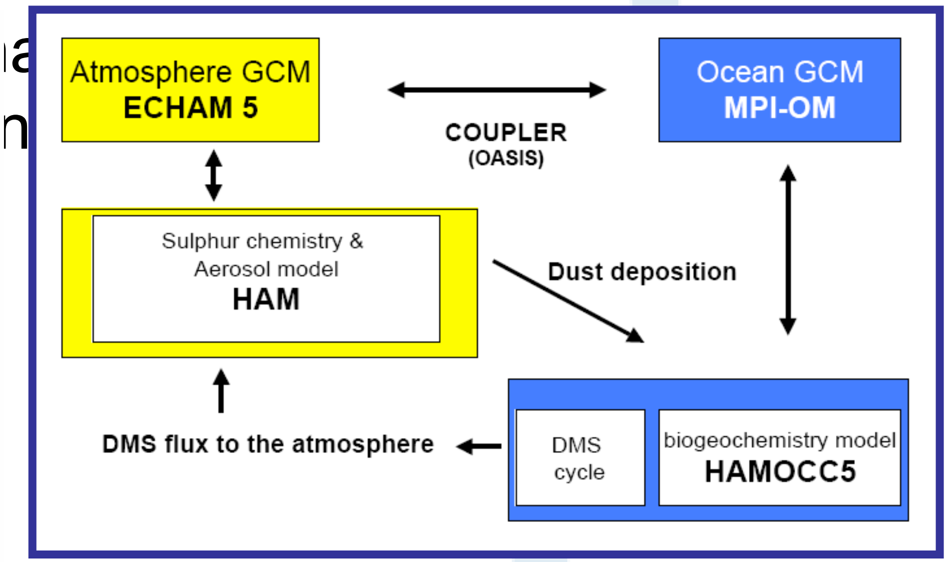
Vallina et al, 2007 (cont)

- daily-averaged solar radiation received in upper mixed layer (UML), or UMLsolar radiation dose (SRD), from measured data of daily averaged surface irradiance, underwater light extinction coefficient, and mixed layer depth (MLD).
- Measured at 41 30′N, 2 48′E (coastal Mediterranean, east of Barcelona) and 32 10’N, 64 30’W (Sargasso Sea) and derived from global data set over 1972-2003
- Irrespective of latitude, temperature, trophic status

DMS-feedback mechanism: global model

- Kloster et al., 2007, JGR
  - First coupled global marine-atmosphere model, including marine biogeochemistry and aerosol model (link of atmospheric DMS-concentration to cloud properties is still missing)





Kloster 2006
PhD-thesis

Decrease in ocean-atmosphere DMS-flux

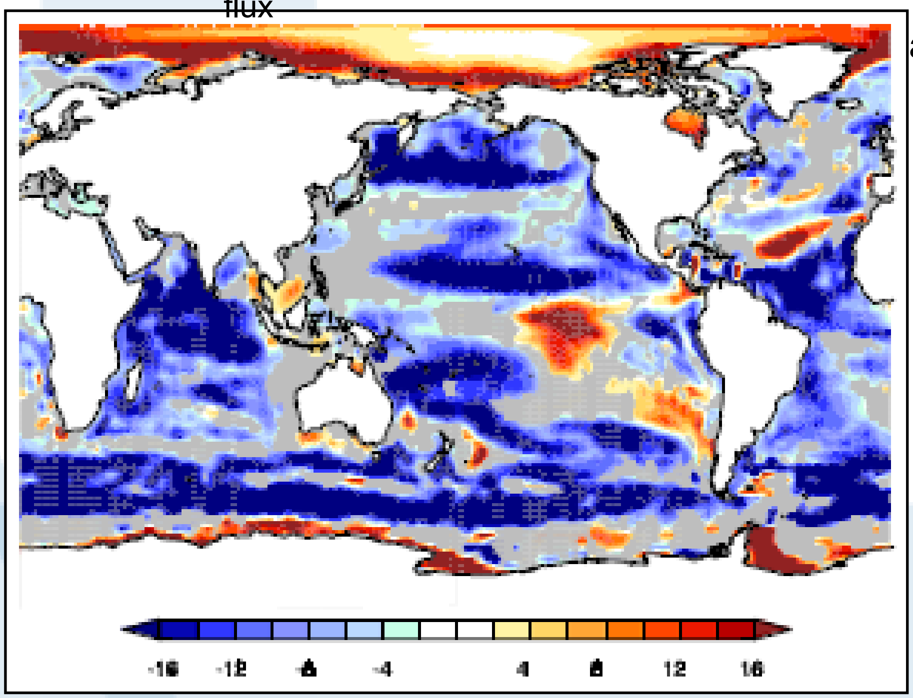
- Model result
  - Biological production and consequently DMS-production <u>decrease</u> with global temperature increase (1861-1890 vs. 2061-2090)

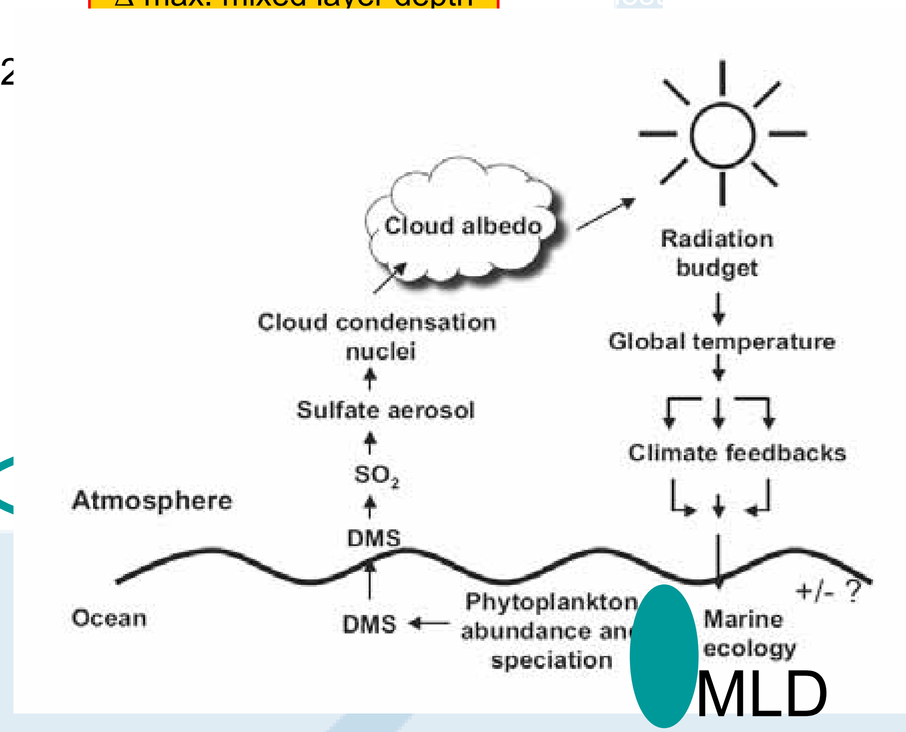
Δ ocean-atmosphere DMS flux

Δ max. mixed layer depth

lost

an 2





Terrestrial CLAW-equivalent: how this may work?

- Plants emit Volatile Organic Compounds (VOC) under influence of light and temperature
- VOC's are partially converted into Secondary Organic Aerosols (SOA)
- These SOA work as Cloud Condensation Nuclei (CCN)
- More CCN lead to a higher cloud albedo, longer cloud lifetimes and lower precipitation efficiency
- Less incoming solar radiation received by the Earth's surface
- Suppression of emission of VOC's (directly and by suppressing photosynthesis)

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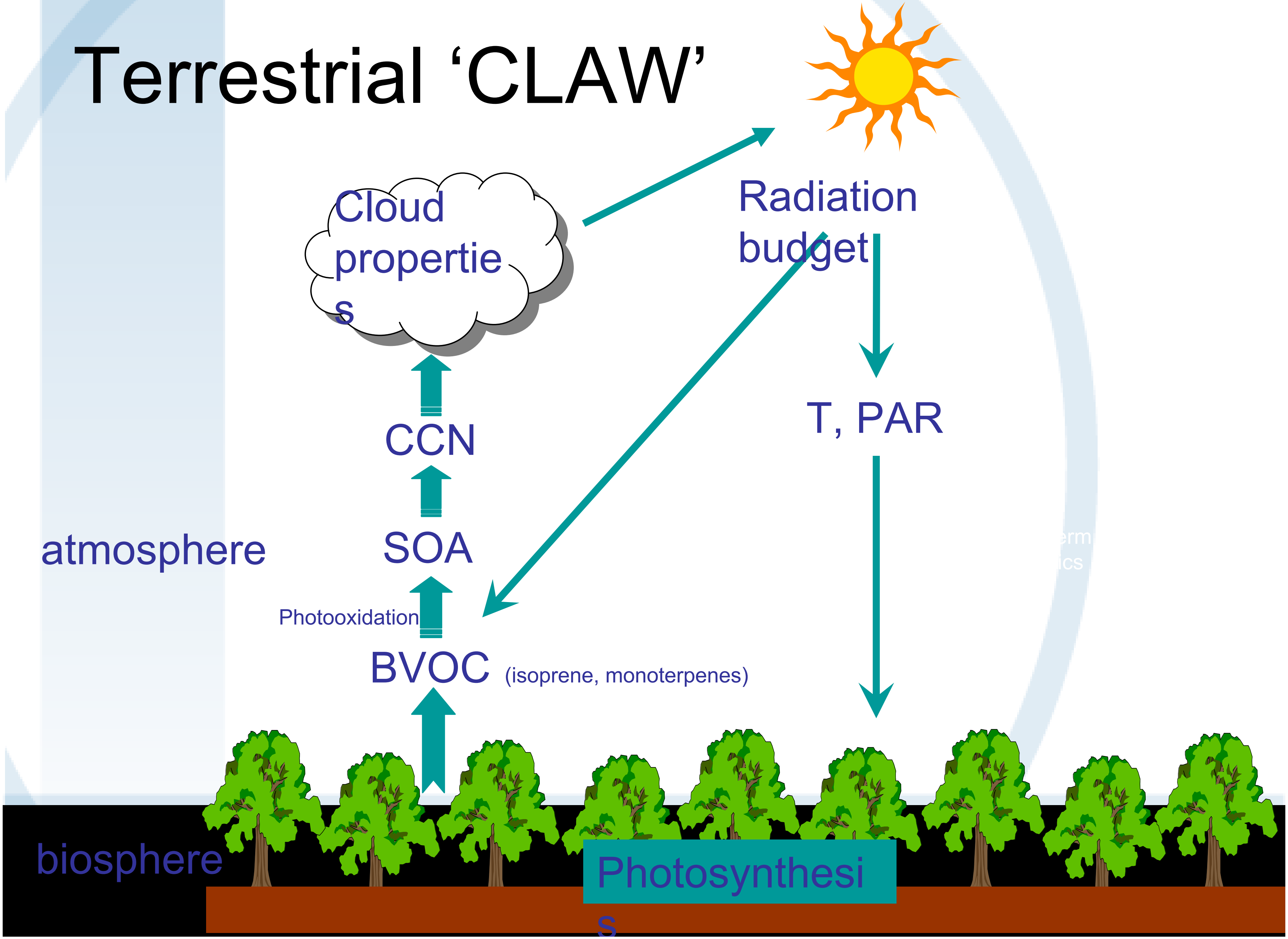
Terrestrial ‘CLAW’



Some numbers

- Global BVOC emission: 1.15 Pg C/y (Guenther, 1995, JGR)
- Global GPP: 120 Pg C/y (IPCC, 2007)
- Global NPP: 104.9 Pg C/y (Field, 1998, Science)
  - ~1% of assimilated carbon lost as VOC (up to 10 % in the tropics)
- SOA production: 0.0112-0.270 Pg/y (Bonn, 2005, J. Atm. Chem.)
- total anthropogenic aerosol production: 0.16 Pg/y (Feichter, 2004, J. Clim.)
  - Natural aerosol prod. ~10% of anthopogenic aerosol prod.
- Especially important over remote areas (tropics, boreal zones)

BVOC's: a component of an "intelligent" self-regulation??

- Side-products of photosynthesis
  - Defense against predation
  - Communication
  - Protection from high temperatures
- Or just emitted because they are volatile?

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Examples of self-regulation hypothesis

- Contrasting effects for contrasting regimes:
- “Resilience” boreal forest to climate change
  - Higher temperatures > more BVOC > more cloud formation > less insolation > lower temperatures
- Resilience Amazon to drying (global warming)
  - Higher temperature > higher BVOC > lower insolation > lower temperature
  - Higher BVOC-emissions > more CCN > more precipitation above forest > sustained soil moisture> etc..

Terrestrial ‘CLAW’-hypothesis

- Issues:
- Do interactions between vegetation, biogenic aerosols, clouds, rainfall and radiation impose a (negative) feedback on the climate-vegetation system? If yes, how strong is that feedback?
- How important is the feedback mechanism compared to other climate-vegetation feedbacks?
- How does the combination of these feedbacks influence the resilience of the system?
- What is the effect of this aerosol feedback on long-term vegetation dynamics?

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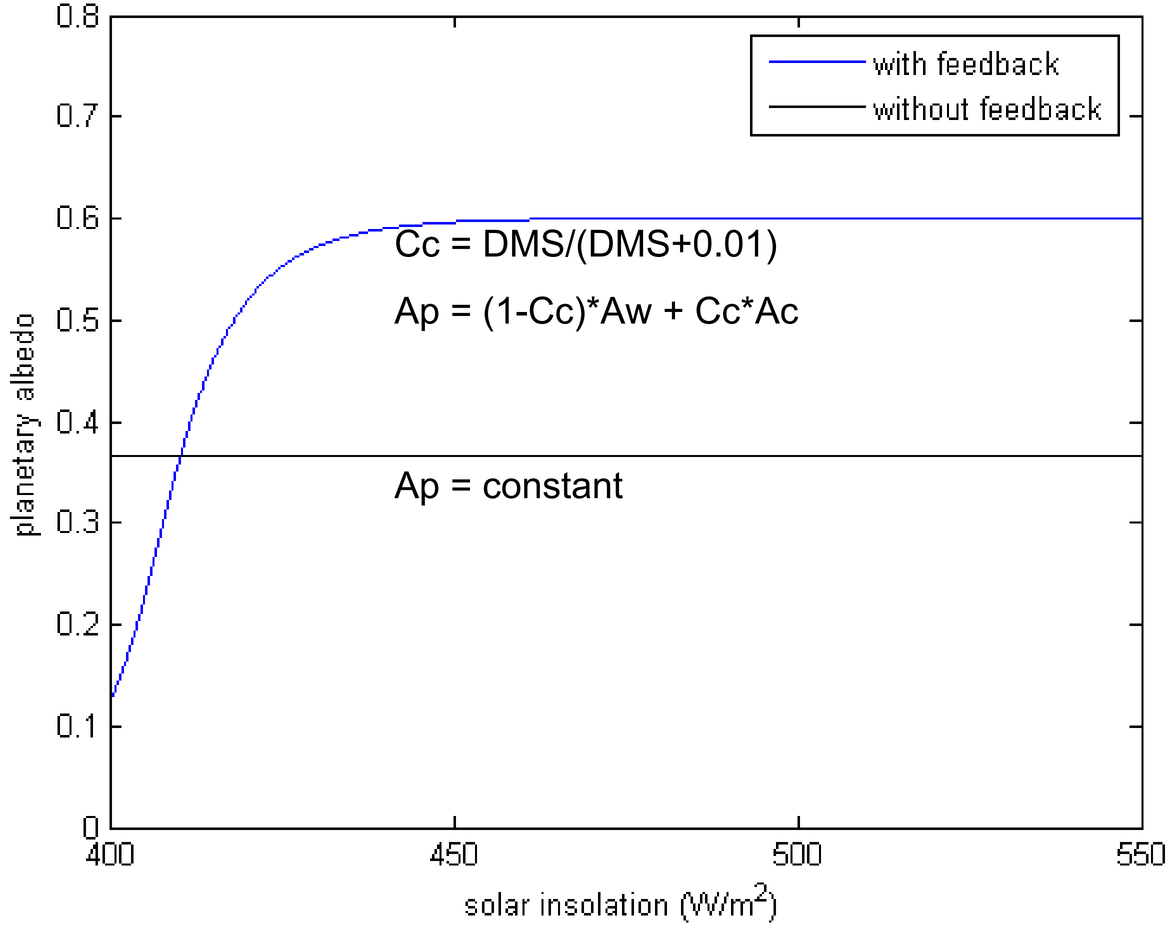
Method: complex vs. simple models

- Coupled models
  - Detailed parameterizations of processes
  - Suited for future projections
  - Hard to analyze

- Simple models
  - First-order representation of processes
  - To gain insight in mechanisms
  - Explore parameter space
  - Find thresholds

Example: simple model for DMS-feedback



Ac: cloud albedo [-]

Ap: planetary albedo [-]

Aw: albedo of water [-]

Cc: cloud cover [-]

DMS: atmospheric DMS-burden [g S]

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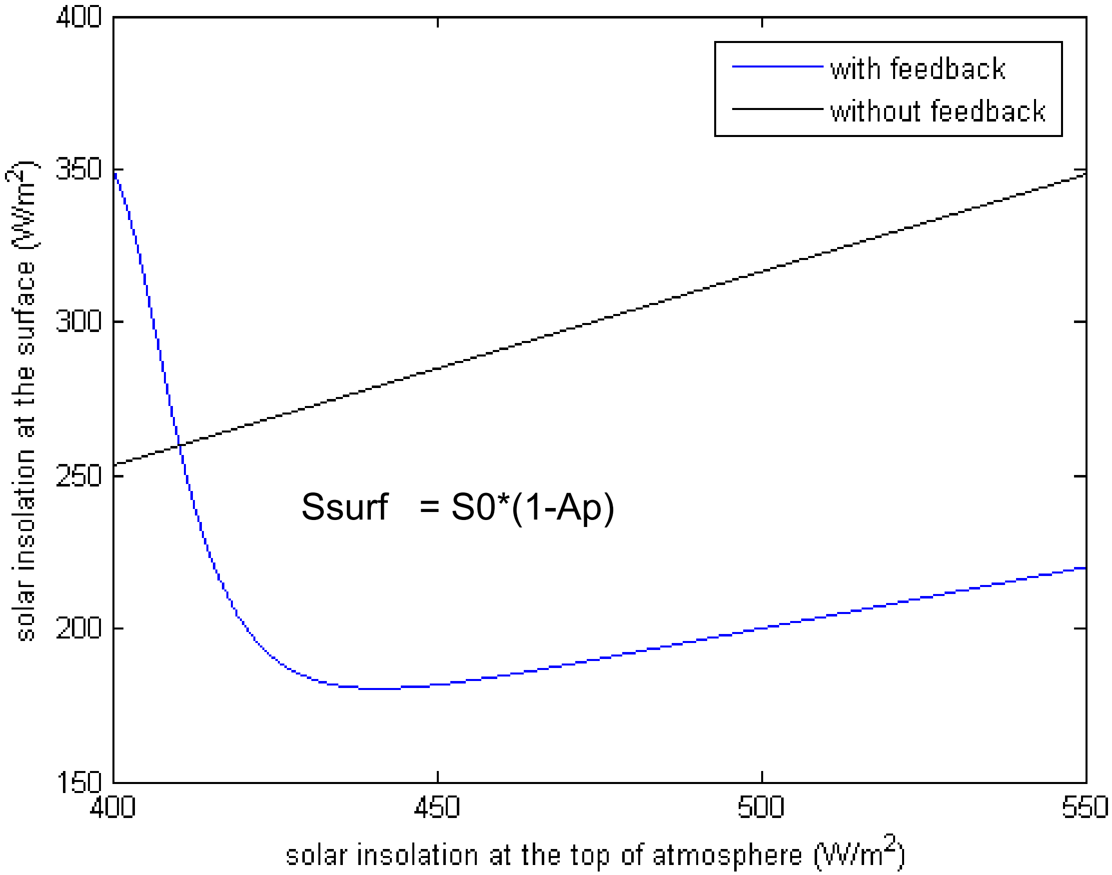
Example: simple model for DMS-feedback

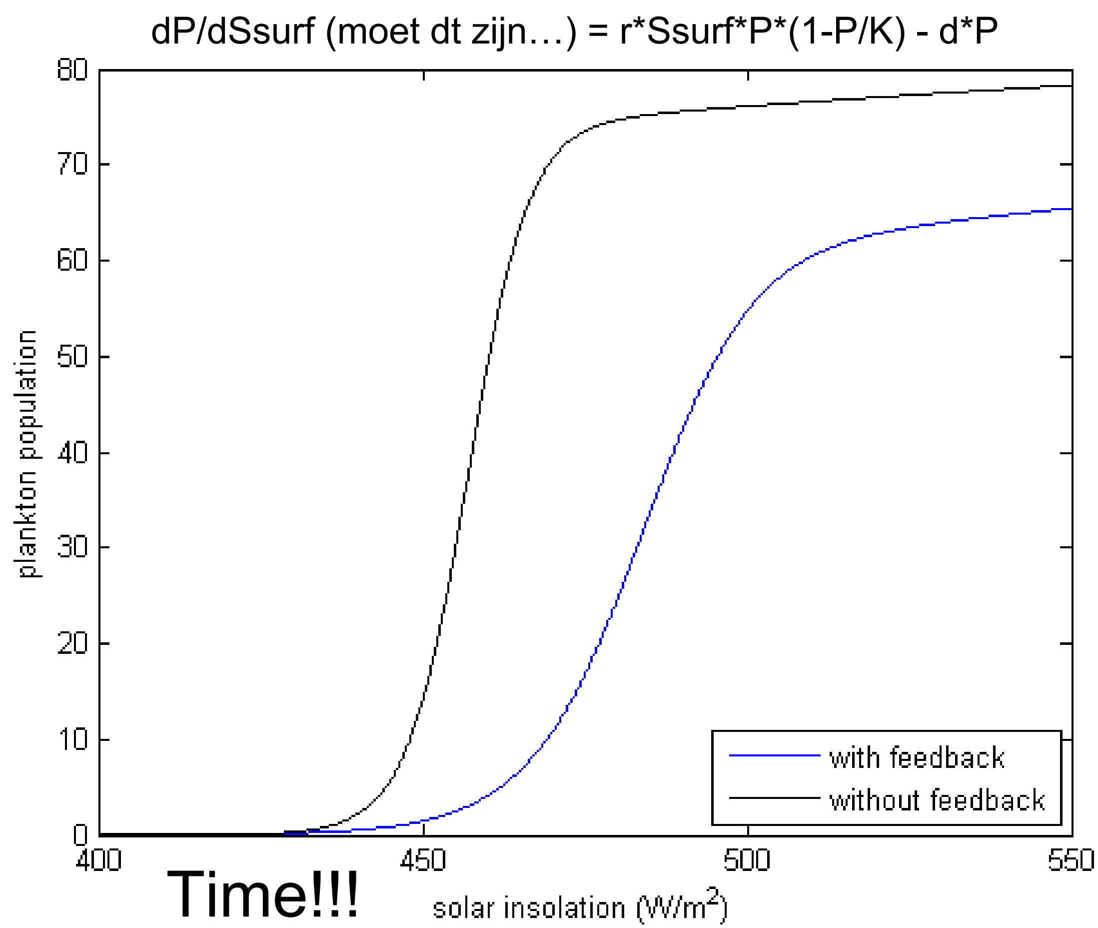


Ap: planetary albedo [-]

S0: solar insolation at the top of the atmosphere [W/m²]

Ssurf: solar insolation at the earth's surface [W/m²]

Example: simple model for DMS-feedback



P: plankton population [kg C]

d: plankton mortality rate [T-1]

r: plankton growth rate

K: plankton carrying capacity [kg C]

Ssurf: solar insolation at the earth's surface [W/m2]

T- CLAW feedback mechanism important for Earth System temperature self-regulation (homeostasis) and long term resilience???

- White daisies in Gaia can do it, DMS can do it, so why not BVOCs???

- Key importance for understanding of climate system feedbacks (negative feedback)

- Sensitivity:
- Doubling of present DMS emission rates may counteract global warming of up to 2 deg!
- Doubling of present DMS and BVOCs rates may counteract global warming of up to 4 deg…..
- Need better understand biology and chemistry of BVOC emissions: here is where we need ecologists/plant biologists to join us!!!!

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Focus 2B

Surface-atmosphere exchanges and the self-cleansing mechanism of the atmosphere

Role of terrestrial biosphere in self-cleansing (NO_x, VOC, …)

- Effects of global change (land-use, climate) on biospheric inputs to self-cleansing
- Effects of changing self-cleansing on biosphere (via oxidants, UV, …)
- Effects of vegetation fires on self-cleansing

Focus 3

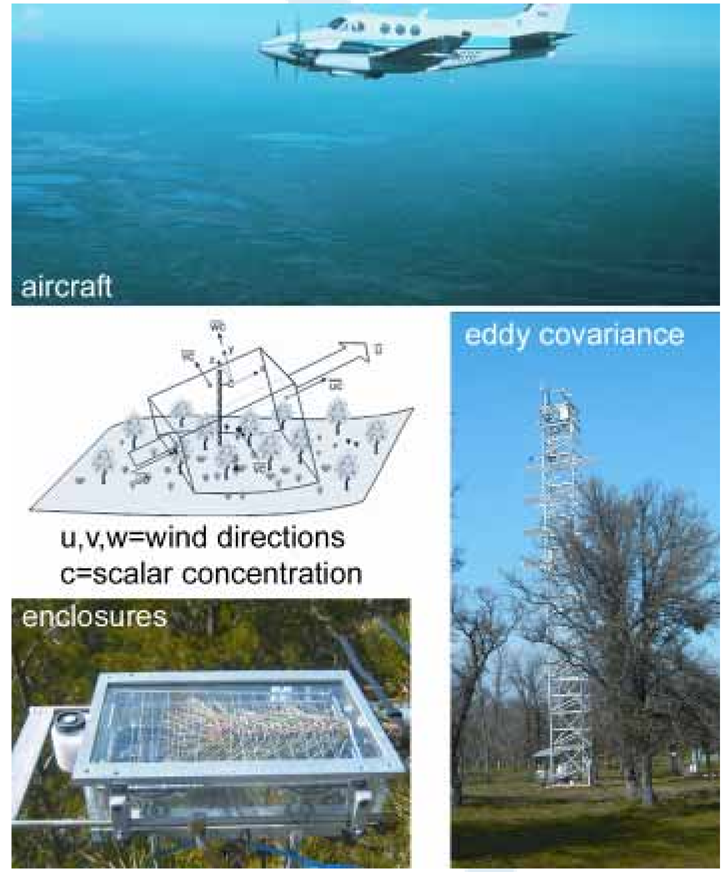
Feedbacks and tele-connections in the land surface vegetation - water – atmosphere system

Effects of land-use and vegetation dynamics on climate, including the water cycle

- Interactions of soil moisture with energy and water flux
- Multiple stable states, and what are the thresholds between them?
- Relative importance of human-induced changes (land-use, greenhouse gases, aerosols) on climate
- Effects of changing radiation fields

Focus 4

Transfer of materials and energy in the soil/canopy/ boundary-layer system: Measurements and Modelling

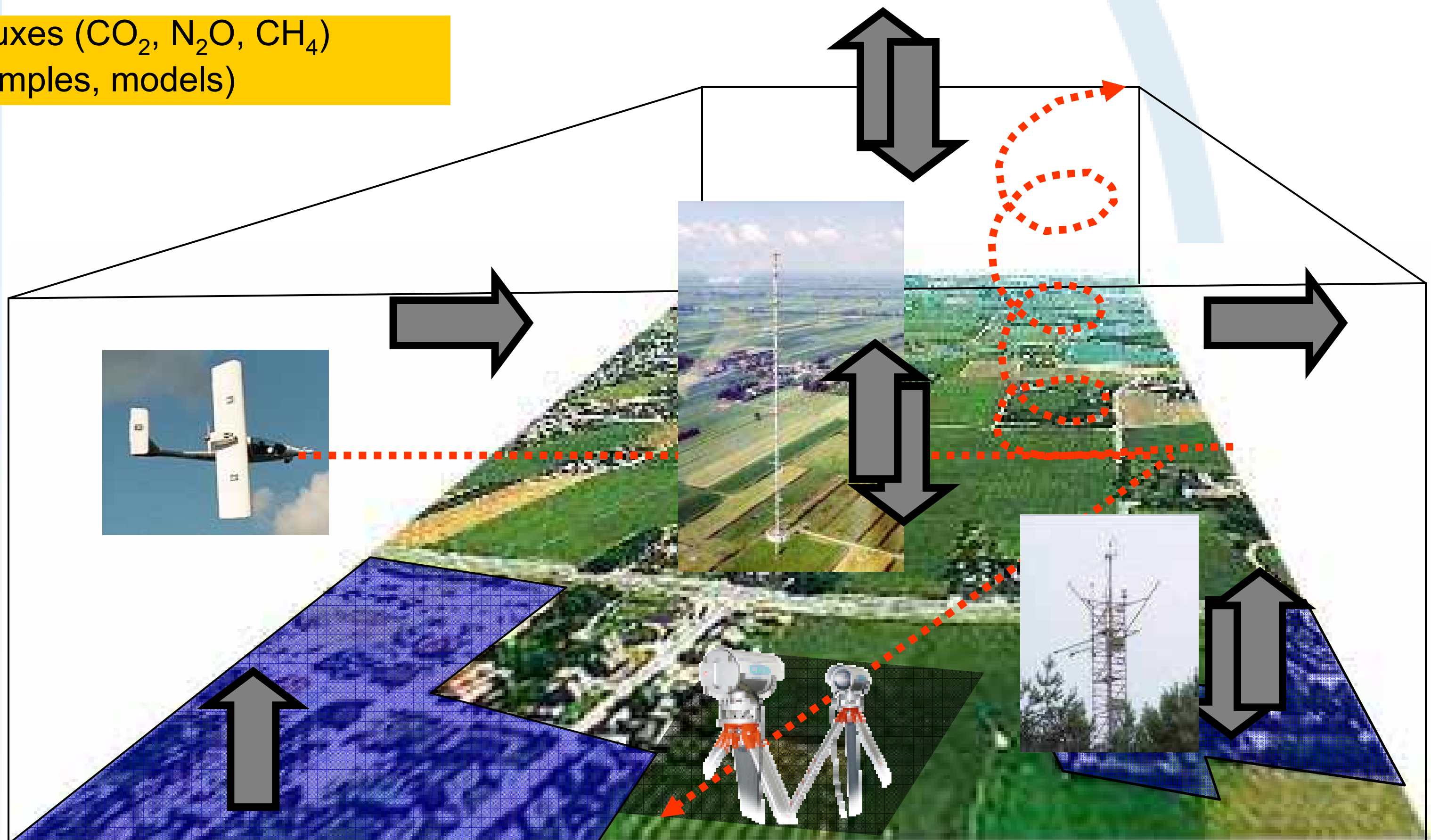


- Surface flux measurements
  - validation, increase of accuracy
- Boundary layer budget methods
  - validation, scaling
- Aircraft flux measurements
- Remote sensing
- Turbulent fluxes and dry deposition
- Integration, model development and evaluation

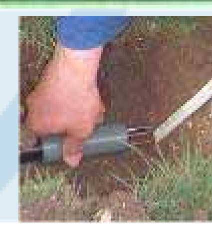
Monitoring: Multiple constrain

Regional scale fluxes
ABL budgets
(Airborne platforms, scinti's, models)

Ecosystem scale fluxes (CO_2, N_2O, CH_4)
(flux towers, soil samples, models)



Inventories:
Ecosystems carbon pools Anthropogenic emissions
(soil samples, emission inventory map)



The issue….. (1)

- Land-atmosphere fluxes key component of our understanding how the Earth- and Climate System function in the past, present and in future

- Advancement of process understanding and modeling of land-atmosphere exchanges over last two decades; Europe’s leading role in global context (IGBP BAHC, WCRP ISLSCP; Hadley Center, ECMWF)

- Comprehensive (tower based) flux monitoring networks started to be developed from mid eighties when new technology (high frequency EC systems and reliable/robust gas analyzers) became available; Europe’s central position (Fluxnet)

- Regional and global climate models started to use surface flux information to parameterize and their schemes

- Numerical weather prediction centers started to use surface flux data to improve their parameterizations and seasobal forecasting skills (ECMWF)

- Space based global observing communities (GEO) started a “serious” dialogue with terrestrial observing communities (GTOS, IGOS-P Carbon, ..)

The issue….. (2)

- Spatial coverage of tower based flux observations still not representative for heterogeneous landscape (bias towards forest); up-scaling (and spatial representativeness of “point” measurements not satisfactory resolved; major hinder for use in climate and earth system models

- Measurements protocols, data QA/QC, processing software and data information flow to users not yet standardized and consolidated across Europe

- After initial success of trans-disciplinary approach (meteorologists, ecologists, modelers), the (measurement) communities tend to separate again; need to include new disciplines (atmospheric chemistry) and to add more measurements (CH_4; N_2O, VOCS; aerosols….)

- Numerical weather prediction centers wish to on-line “assimilate”” surface data and fluxes in their calculation scheme’s; this wouls significantly enhance the intra- and inter-seasonal weather forecasting skills, but not possible with current state of flux monitoring networks (OA/QC, accuracy, on-line availability)

The issue….. (3)

- Direct and continuous measurements of surface GHG fluxes (sources and sinks) will become of a crucial importance for “post-Kyoto” mitigation efforts; especially in Europe (from Tier 1 to Tier 2/3)

- Comprehensive (tower based) flux monitoring networks started to be developed from mid eighties when new technology have enjoyed sustained and almost continuous funding from EU and national programmes; however this is expected to end and at present, there is no Europe-wide coordination mechanism in place to assure continuity of these very important measurements;

- Dialogue with GEO/GMES about surface (flux) operational monitoring networks becoming an equal partner to space based systems (also funding-wise) so far inconclusive

iLEAPS products

- Synthesis papers
- √ Journal special issues
- √ Science Plan
- √ Website
- √ Email bulletin, quarterly
- √ Email alert
- √ Newsletter, biannual
- √ Flyers
- √ Posters
- √ PowerPoint presentations
- √ Press releases
- √ Media interviews
- √ Workshops
- √ Summer school
- √ Science Conference, biennial
- √ People database
- Synthesis book

www.atm.helsinki.fi/ileaps

iLEAPS recognized activities

An International Network Measuring Terrestrial Carbon, Water and Energy Fluxes Across Daily to Inter-Annual Time Scales

African Monsoon Multidisciplinary Analyses

Volatile Organic Compounds in the Biosphere-Atmosphere System

Fire-Land-Atmosphere Regional Ecosystem Studies

Land Ecosystem-Atmosphere Reactive Nitrogen

Inter-American Network for Atmospheric/Biospheric Studies

FIRE Task

Integrated Fire Research Activity

iLEAPS recognized activities

Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate, Chemistry, Aerosols, and Transport

Northern Eurasia Earth Science Partnership Initiative

Isotopes in the Project for Intercomparison of Land-surface Parameterization Schemes

iLEAPS/GEIA INITIATIVE

vegetation dynamics-BVOC interactions, GDVM

Aerosol-Climate-Air Quality Interactions

LUCID

Land-use and climate

WATCH

Water and Global Change

Scientific steering committee

2007 →

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John Finnigan, Australia	Chandra Venkataraman, India
Laurens Ganzeveld, Germany	Xiaodong Yan, China
Sandra Harrison, UK	Kazuyuki Yagi, Japan

Thank you!