Unexpected Feedbacks between Land Biota and Climate

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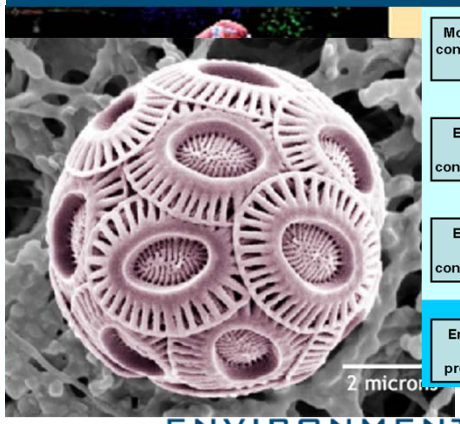
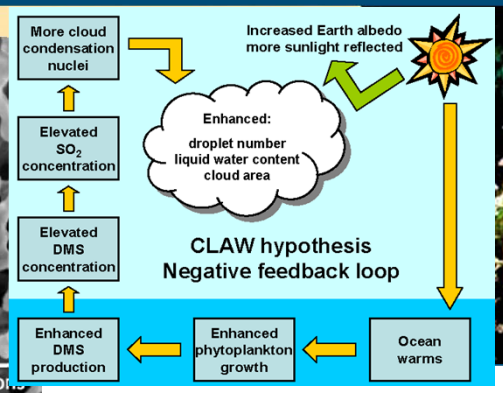
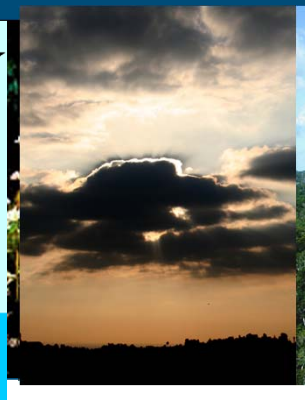
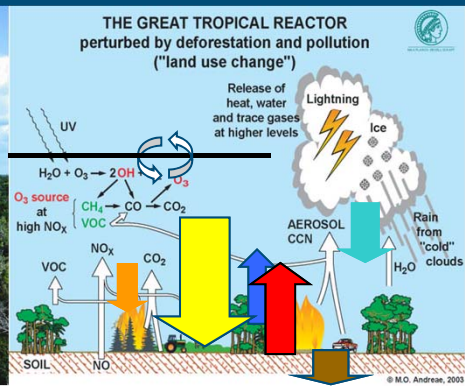
Chair, ILEAPS IGBP









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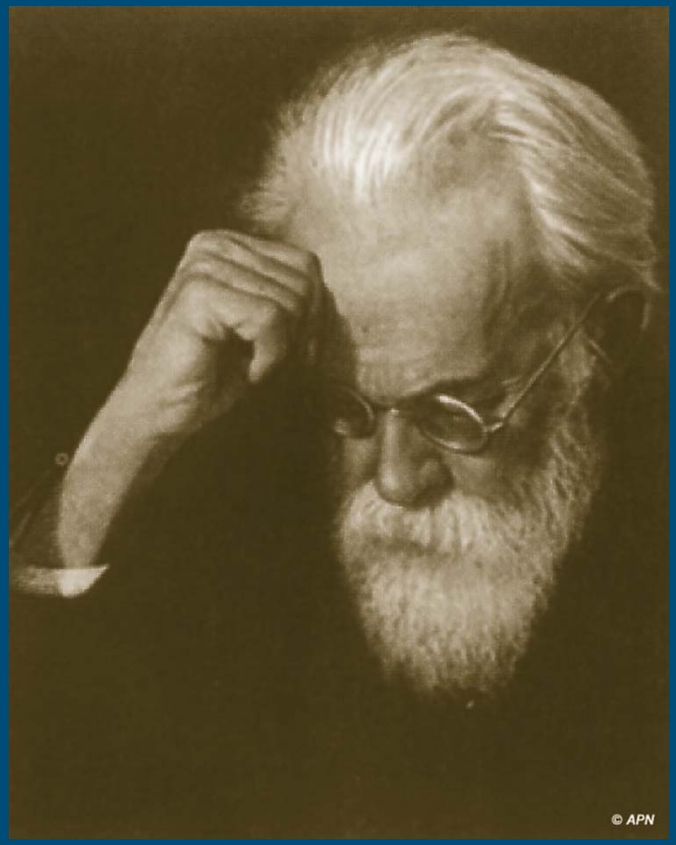
The Precursor: Wladimir I. Vernadsky



”The *biosphere* is a unique region of the Earth’s crust occupied by life.

There are no stronger chemical forces at the earth surface [...] than *living organisms* taken in their totality”.

1926

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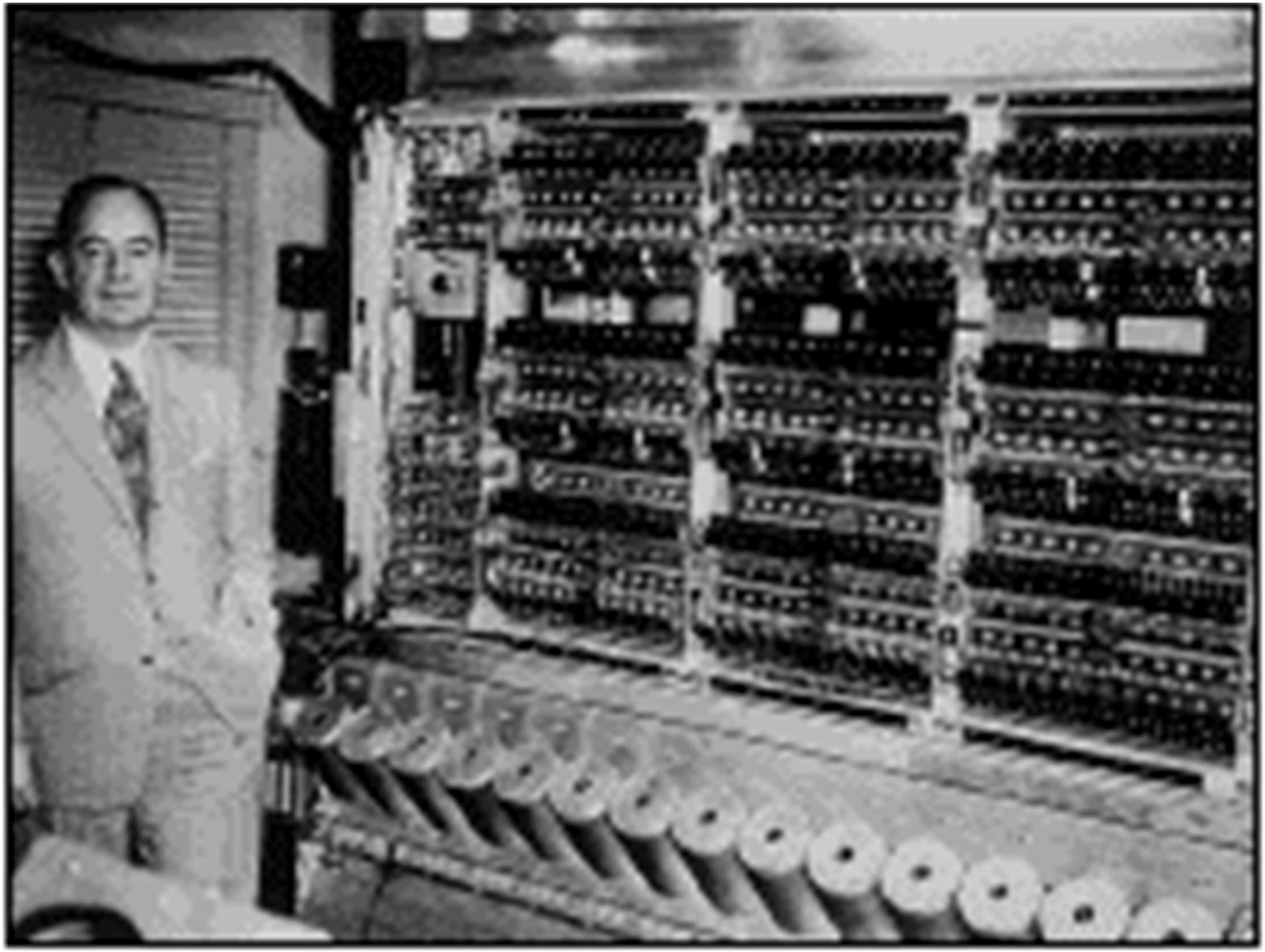
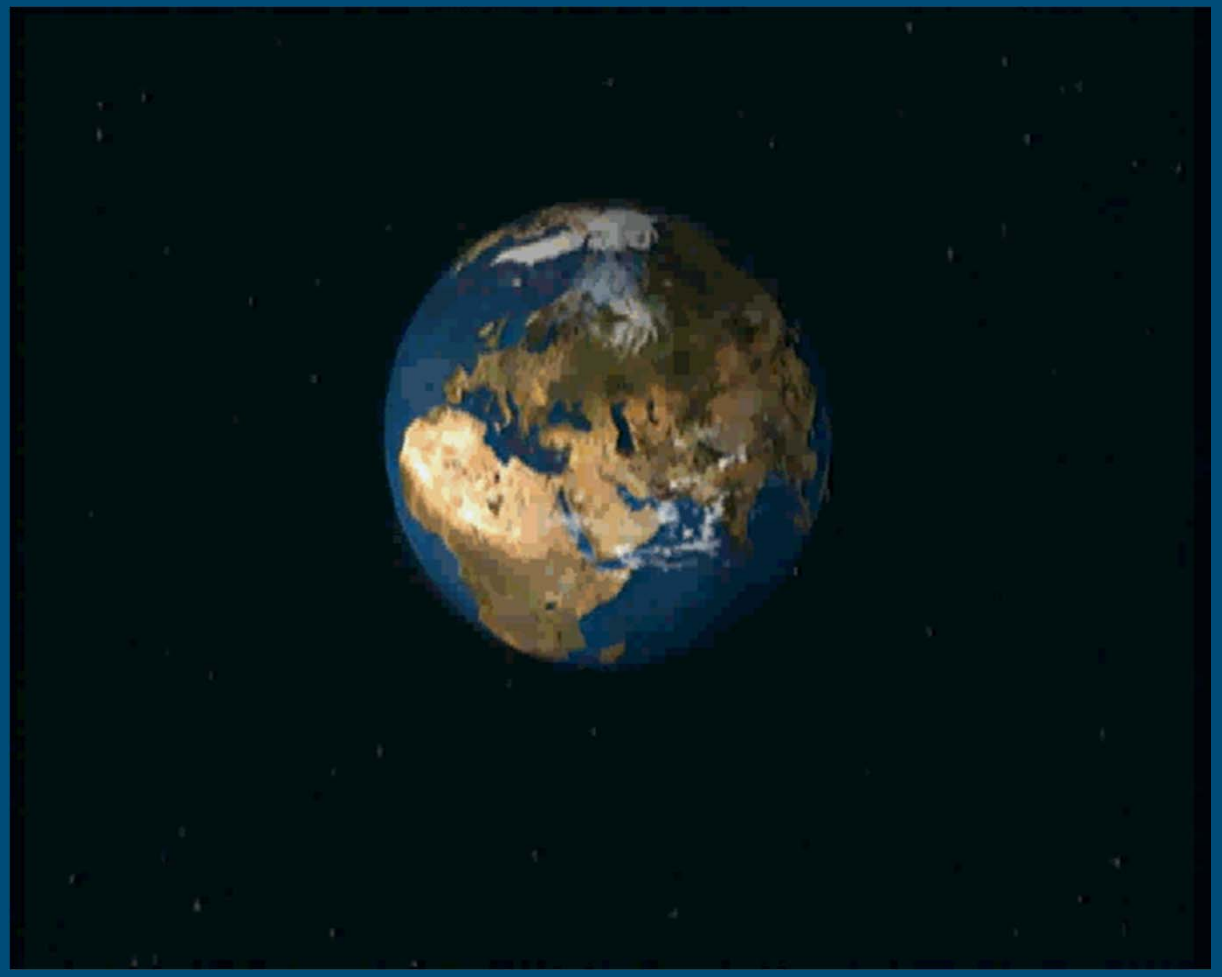


Global System of Geostationary Satellites



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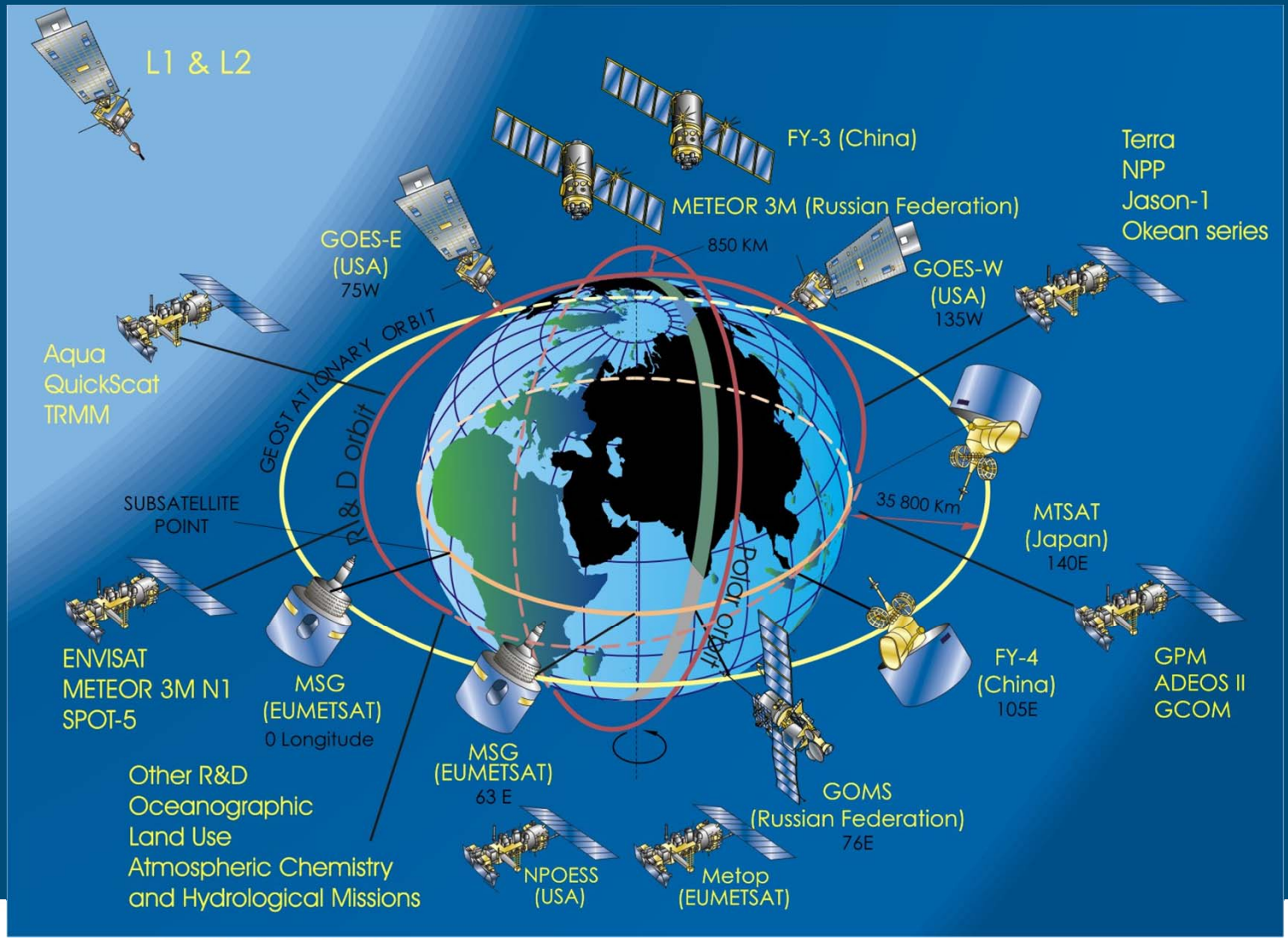
WMO WWW's space-based component of the Global Observing System (2004)



Unparalleled international cooperation has been achieved in satellite activities*

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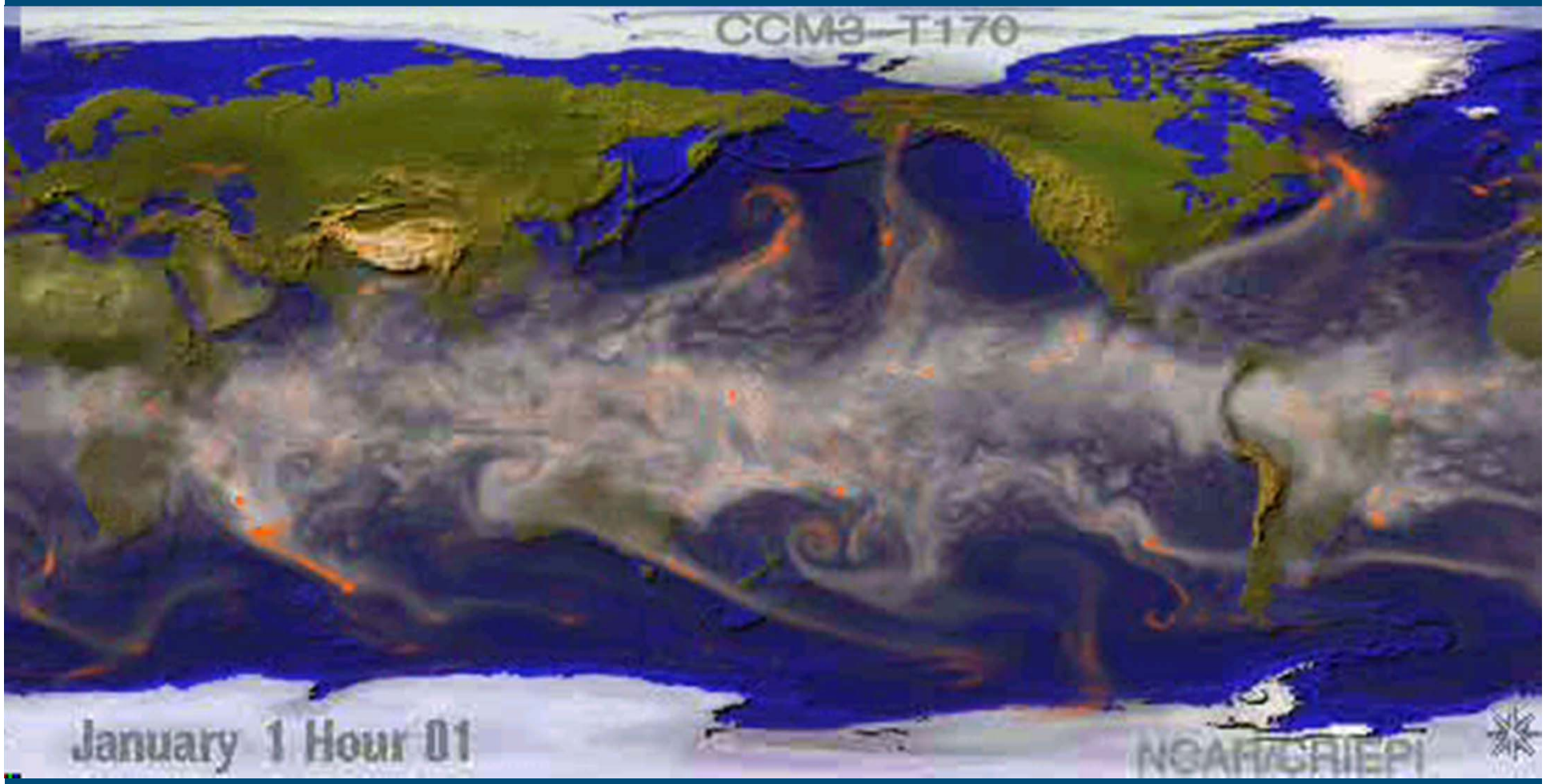

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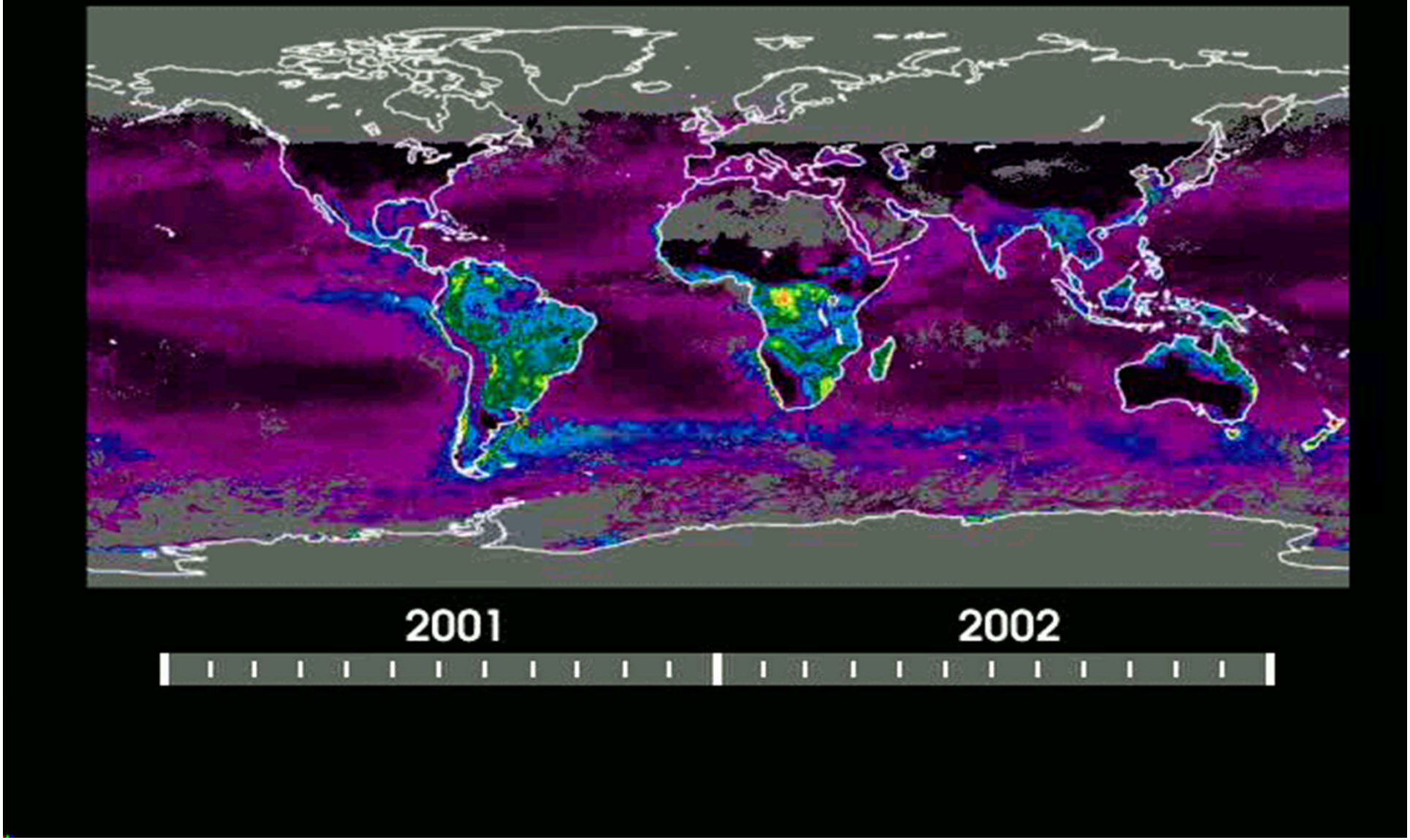
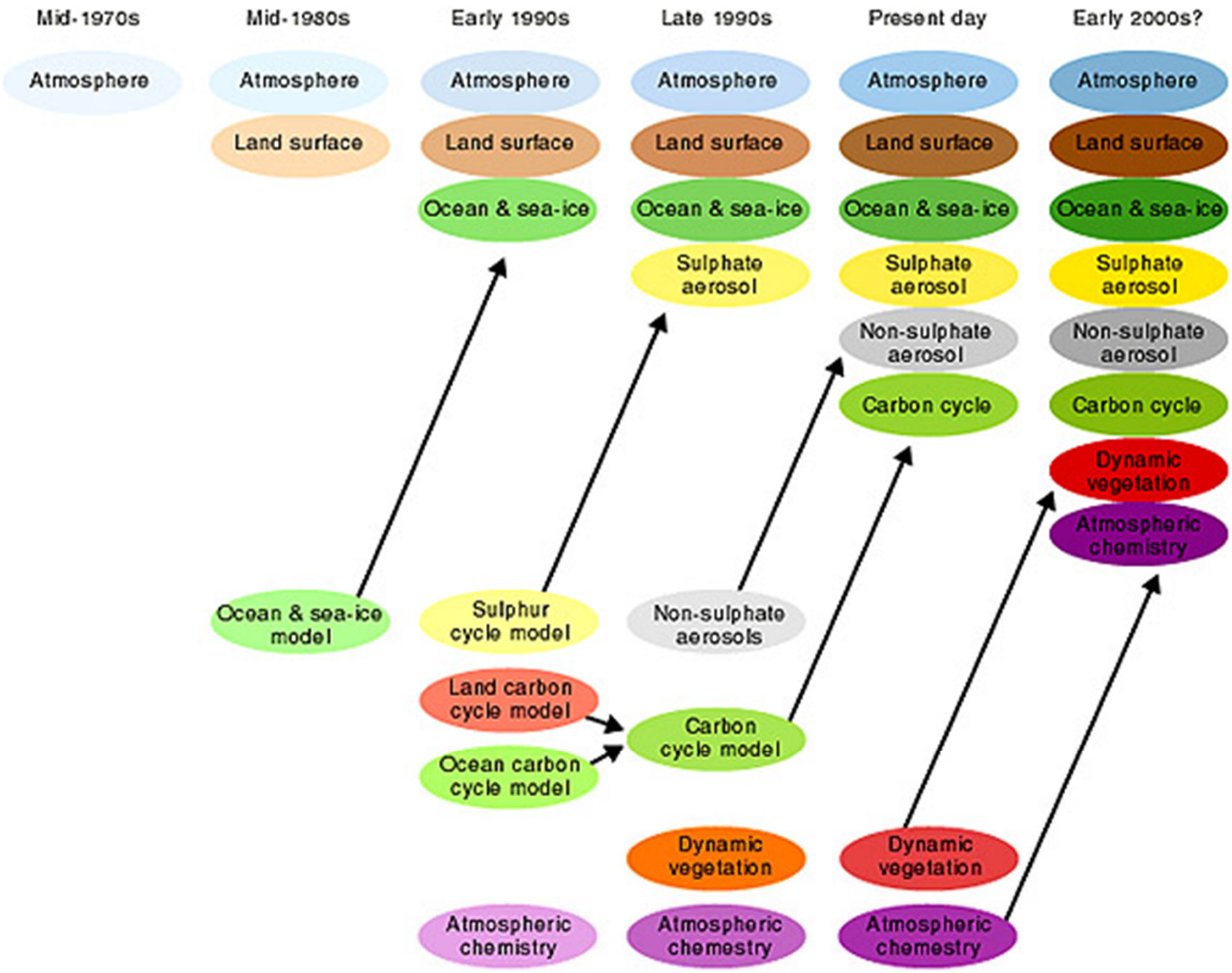
MODIS WEEKLY LAND+OCEAN GPP

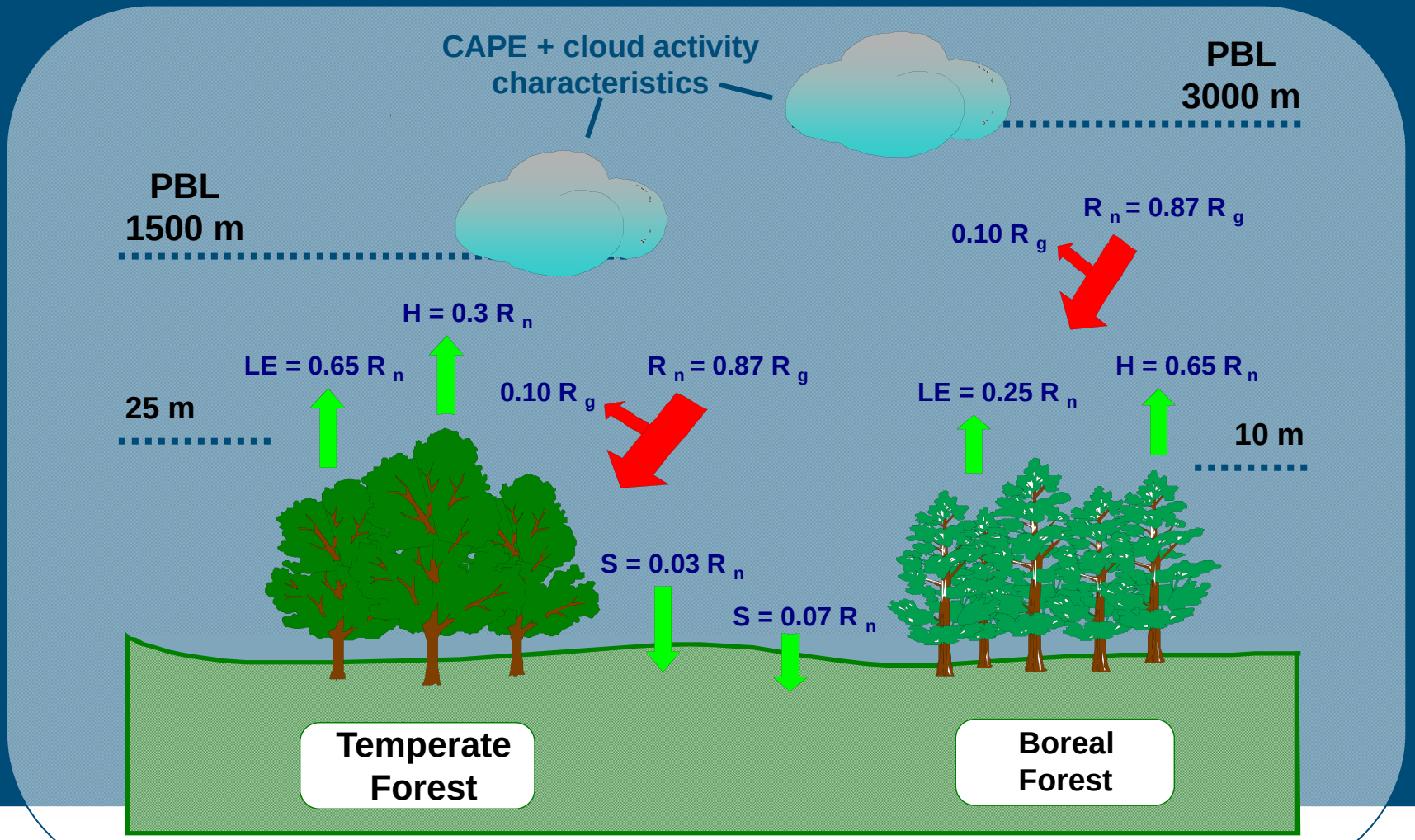


The Development of Climate models, Past, Present and Future



Coupling Principles - Energy Balance Link

$R_n = LE + H + S$



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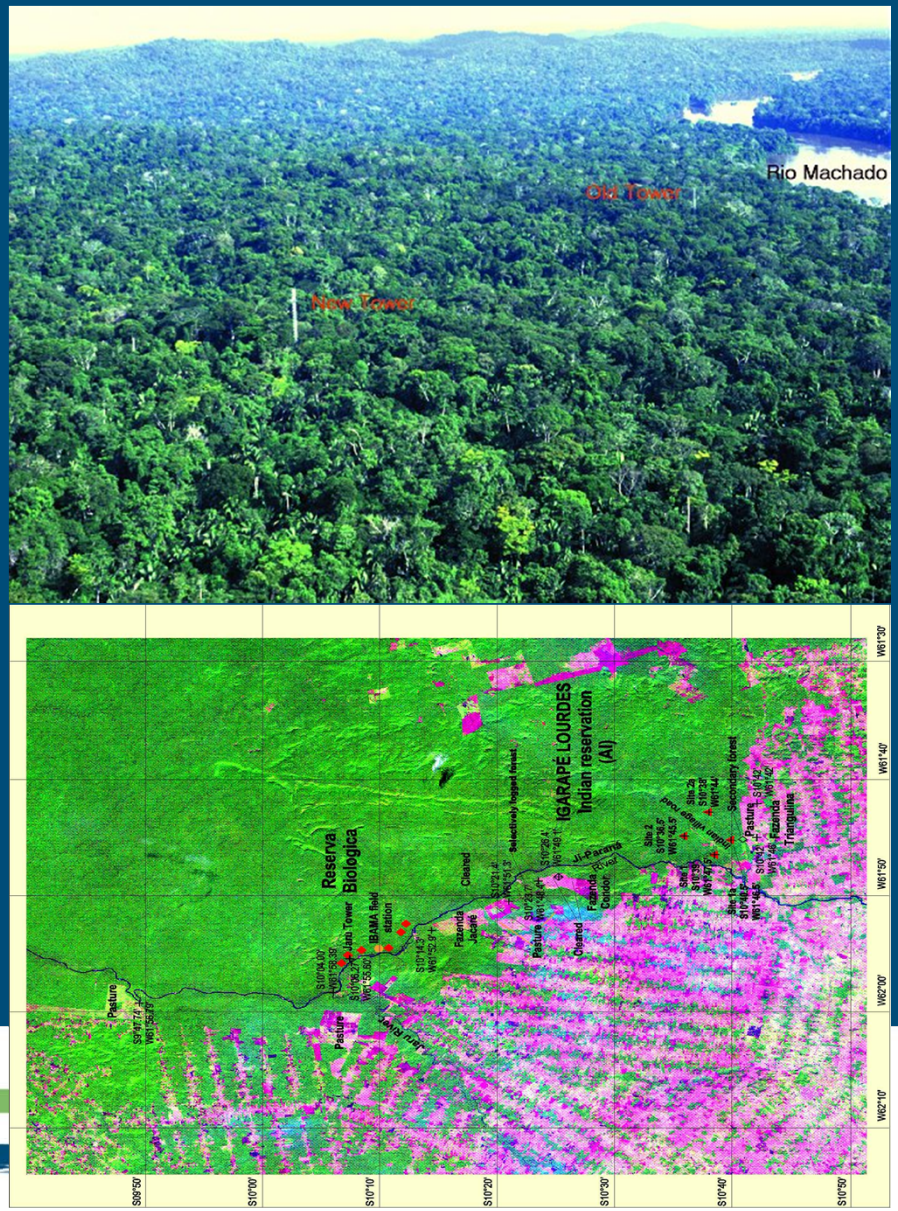
Regional Deforestation and Rainfall (Amazon)



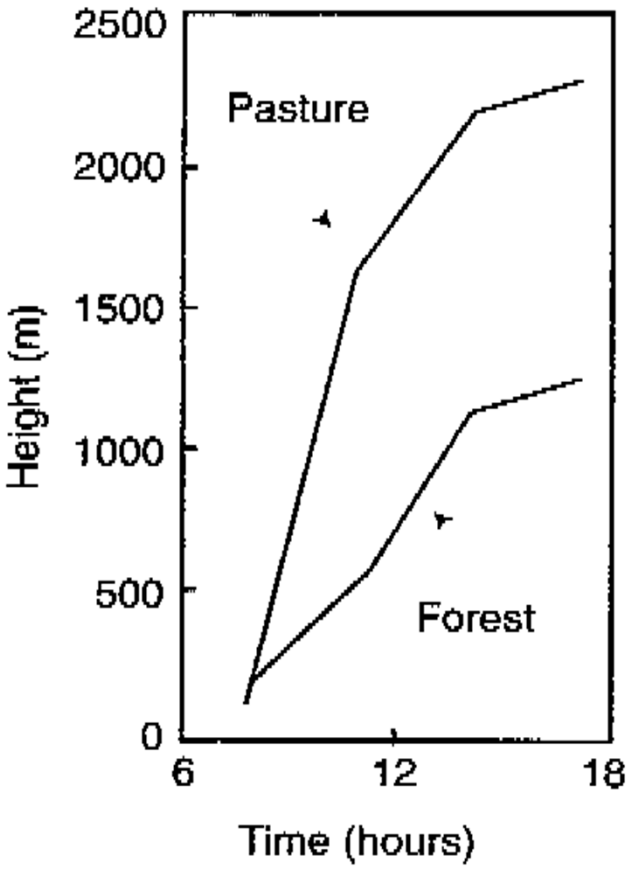


Figure 2. Comparisons of the average measured height of the convective boundary layer over the Ji-Paraná forest and pasture sites (adapted from Gash and Nobre, 1997).

Coupling Principles: Summary

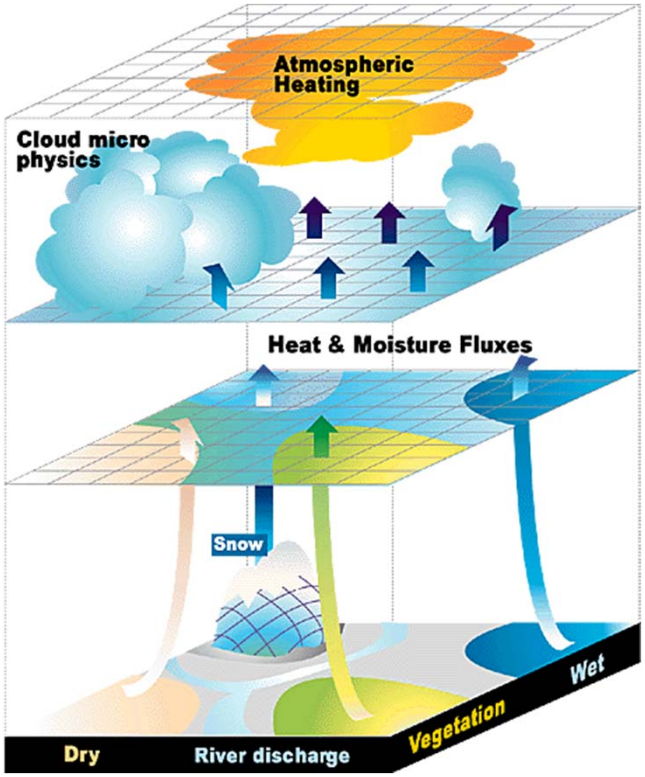
3 Effects on Convective Available Potential Energy (CAPE)

CAPE can considerably increases/decreases in response to surface moisture and surface temperature

1 Convective Boundary Layer (CBL) Effects

Boundary layer structure, including its depth, is directly influenced by the surface heat and

moisture fluxes

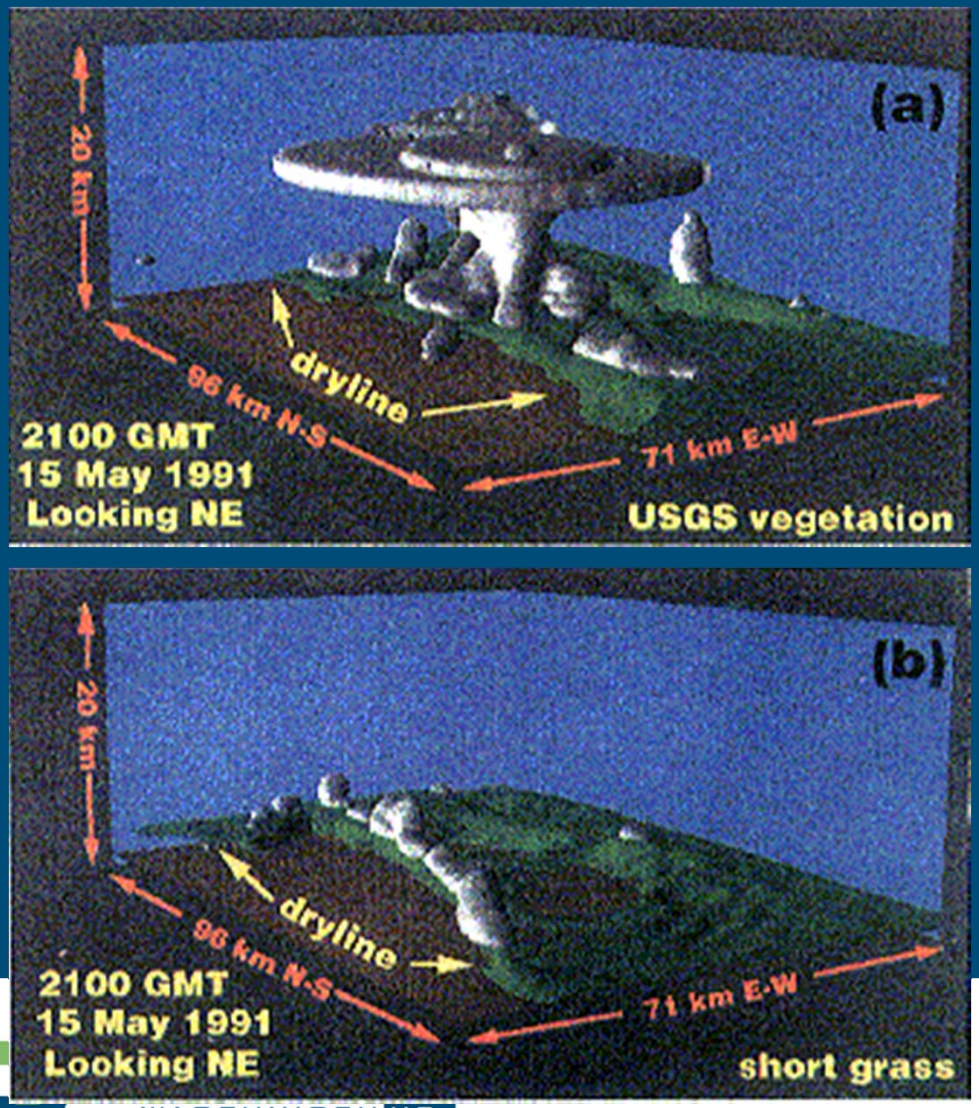


2 Local Wind and Mesoscale Circulation Effects

Local wind circulation lead to boundary wind convergence, which lead to increased measures of the potential for deep cumulus convection

Local and mesoscale (wind) circulations can subsequently result from horizontal variations in land surface heat fluxes and the depth of CBL (e.g. sea- and land breezes)

Land cover type and rainfall



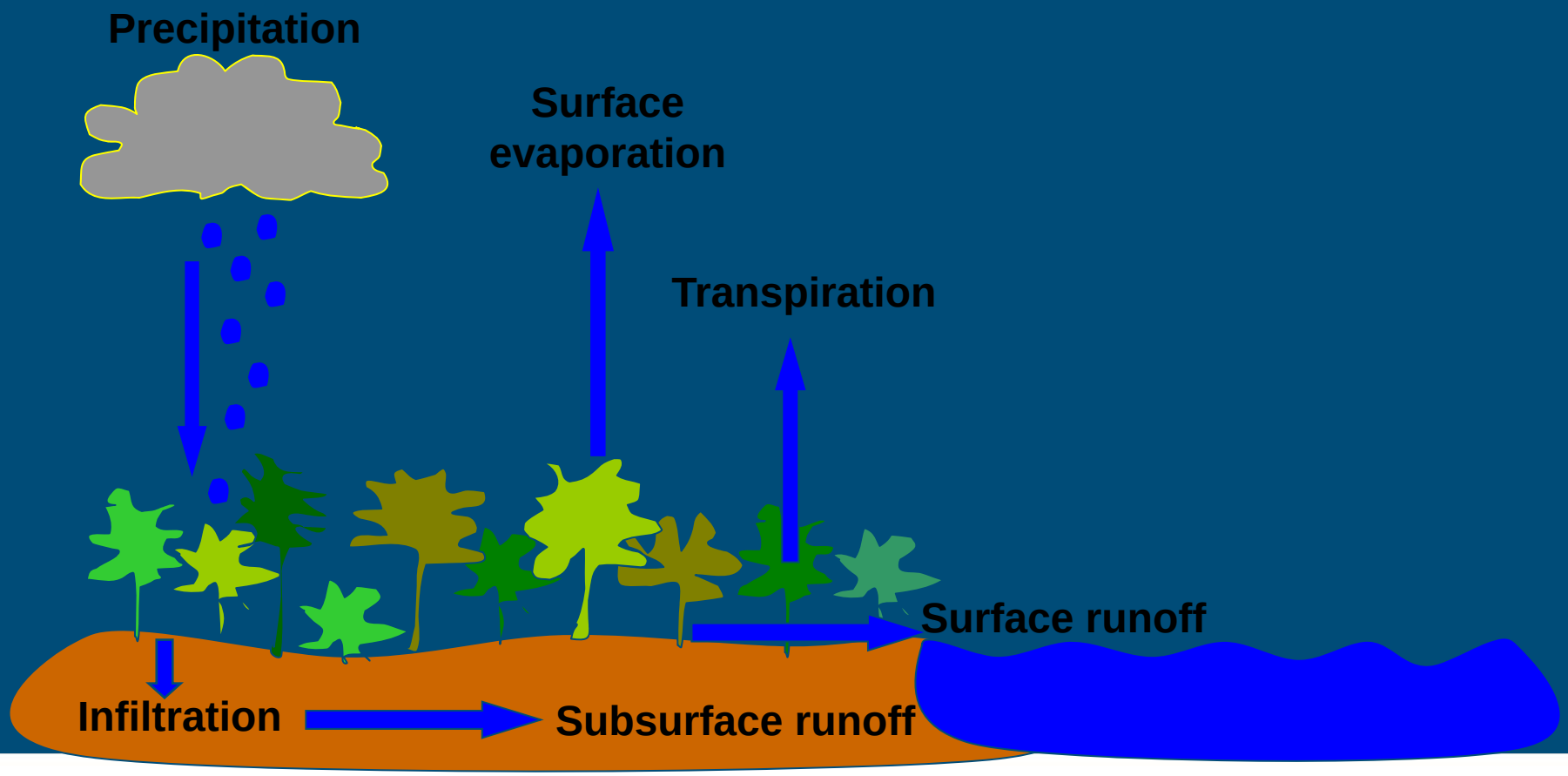
A mesoscale simulation of clouds at 21 GMT on 15 may 1991 over part of the USA

current landscape

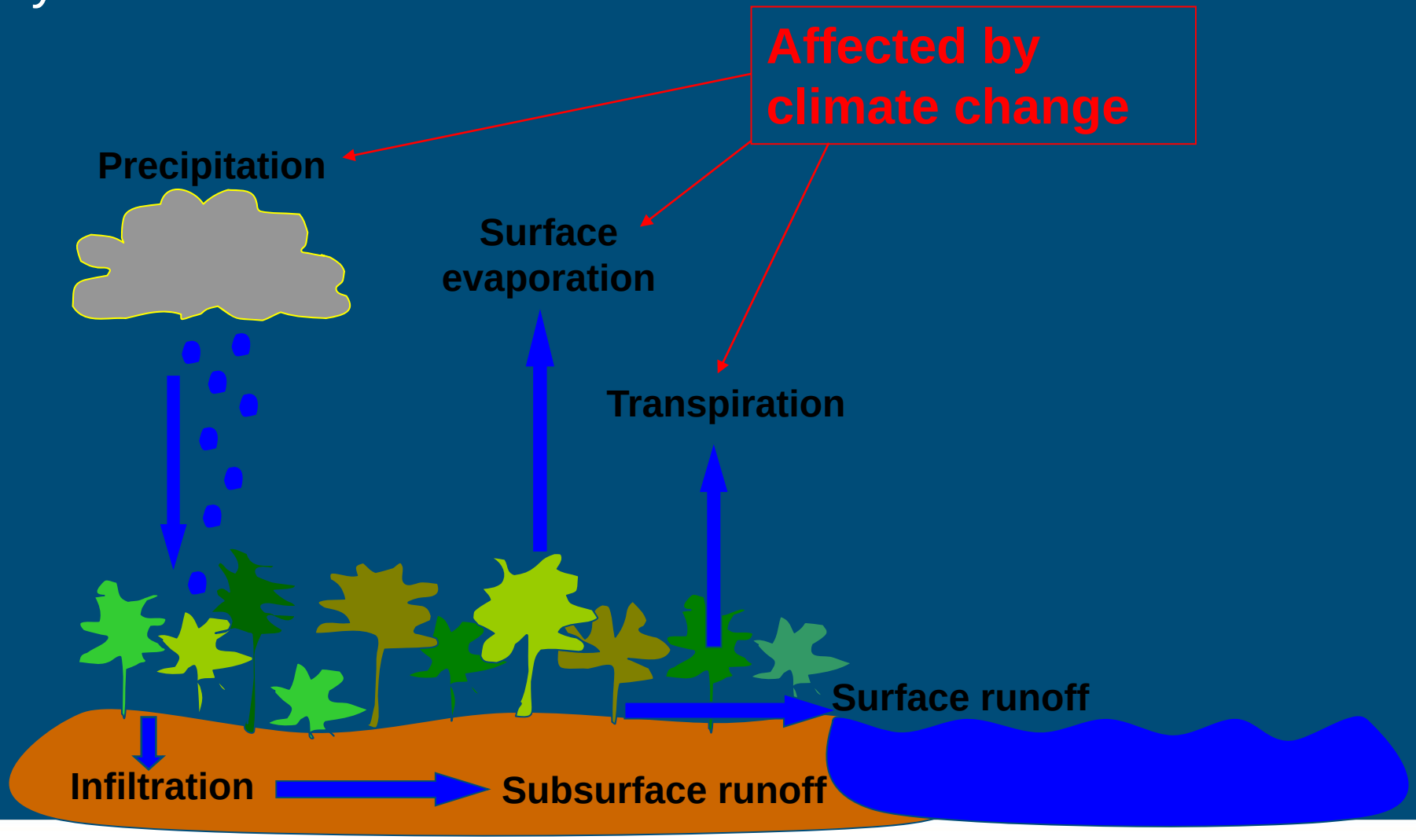
natural landscape, showing a significant impact on the development of clouds resulting from a change in land cover type

(adapted from Pielke et al, 1997)

CO_2 rise, climate change and the hydrological cycle



CO_2 rise, climate change and the hydrological cycle



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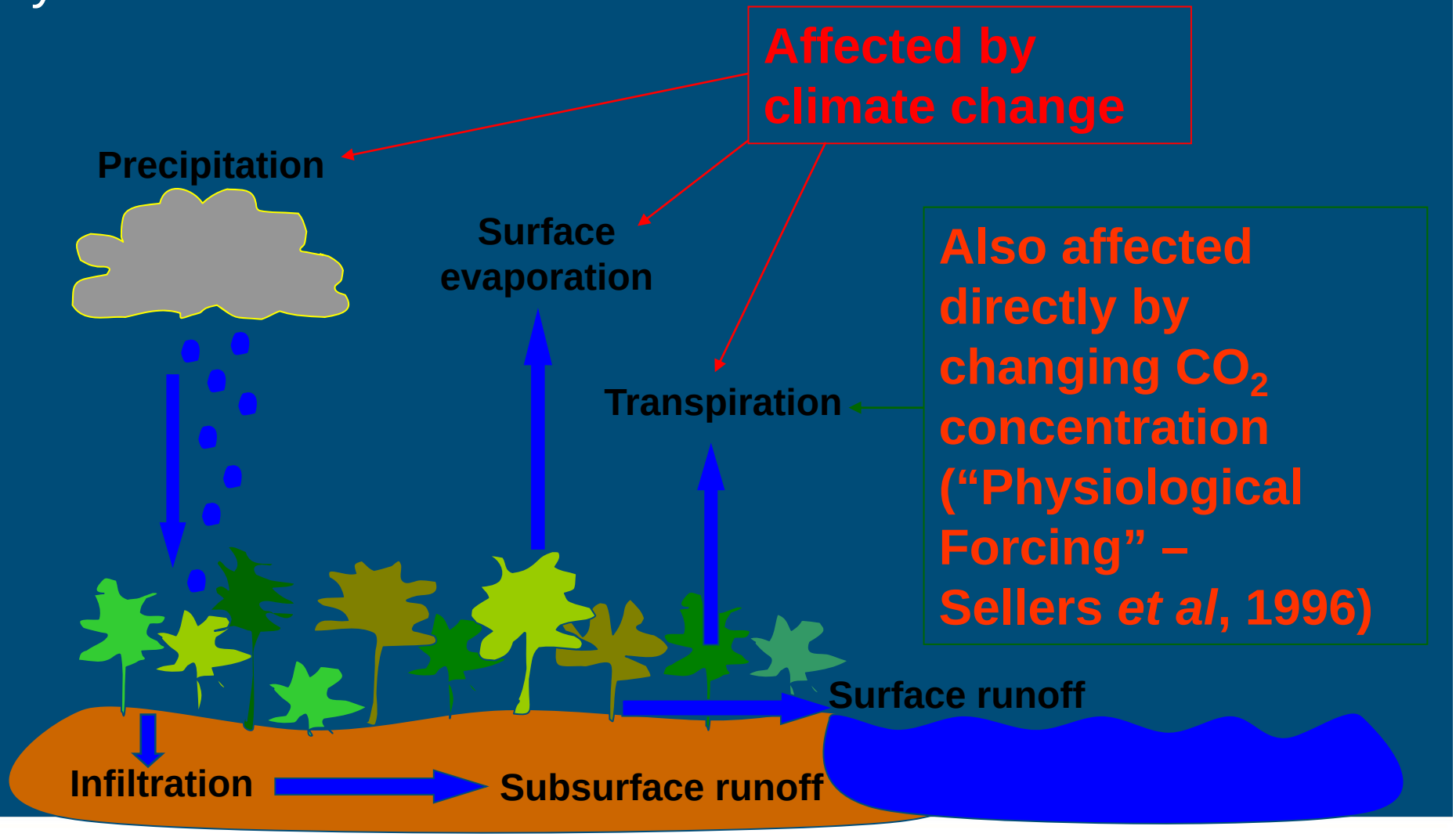
CO_2 rise, climate change and the hydrological cycle



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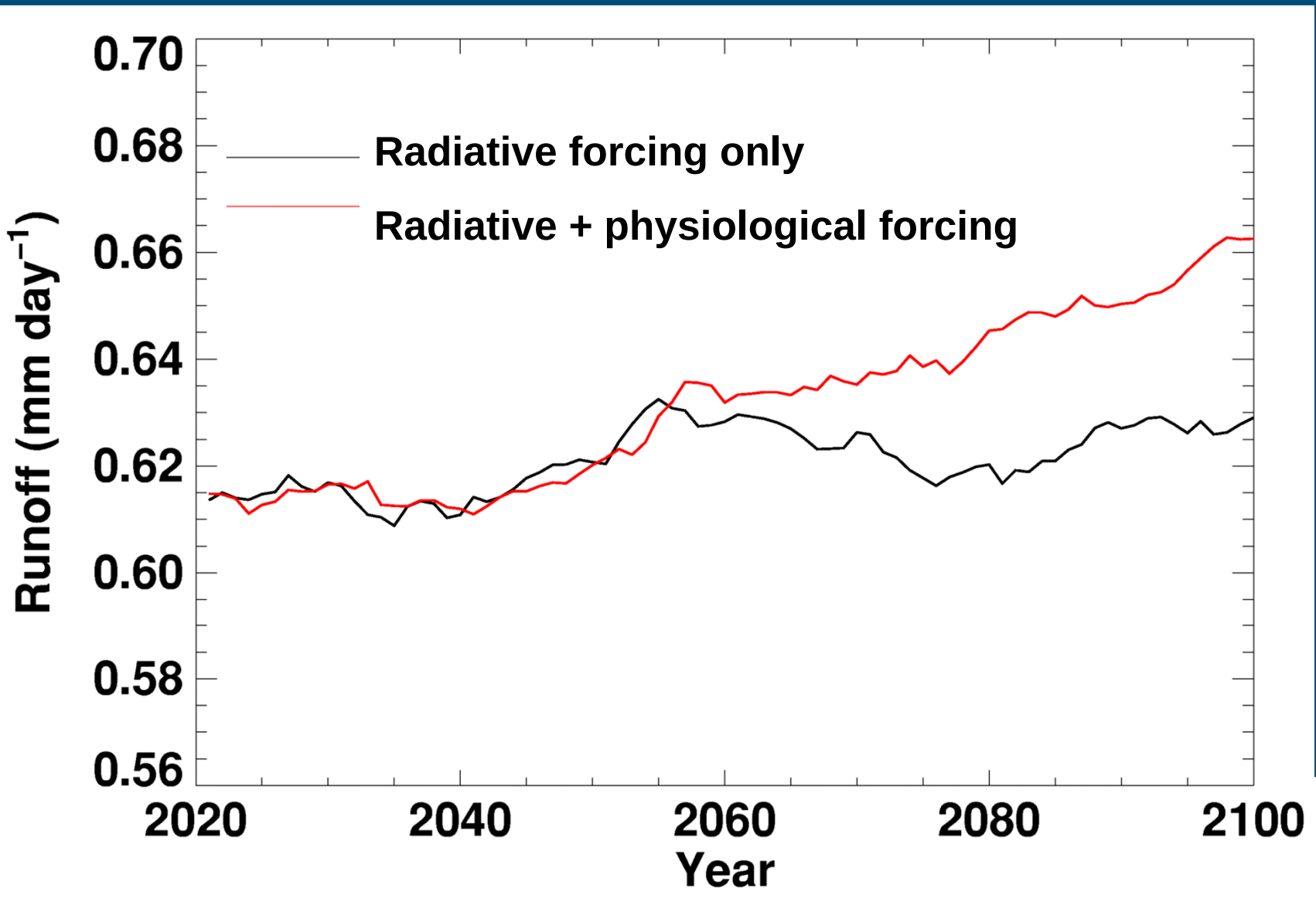
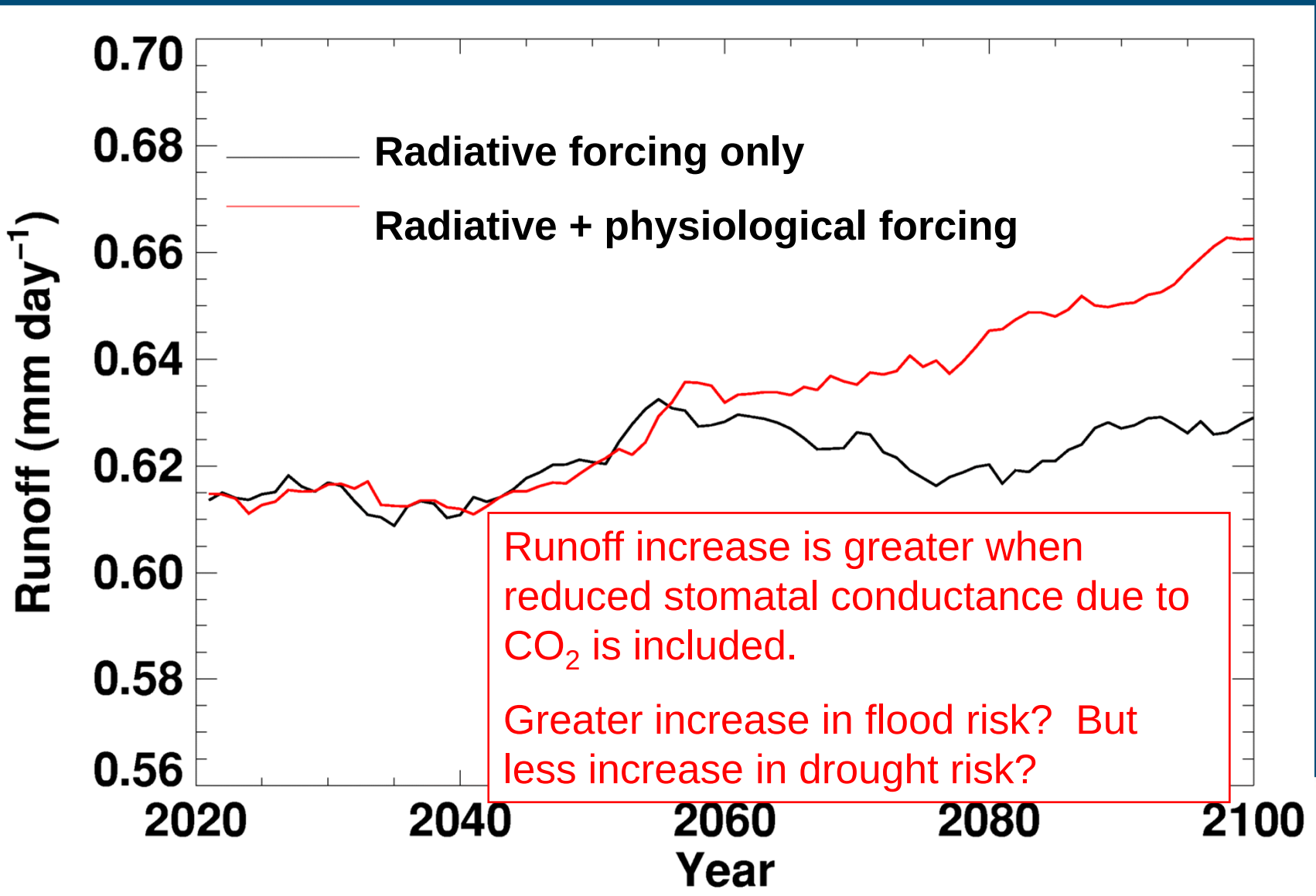
Global mean runoff (mm day^{-1}): HadCM3LC



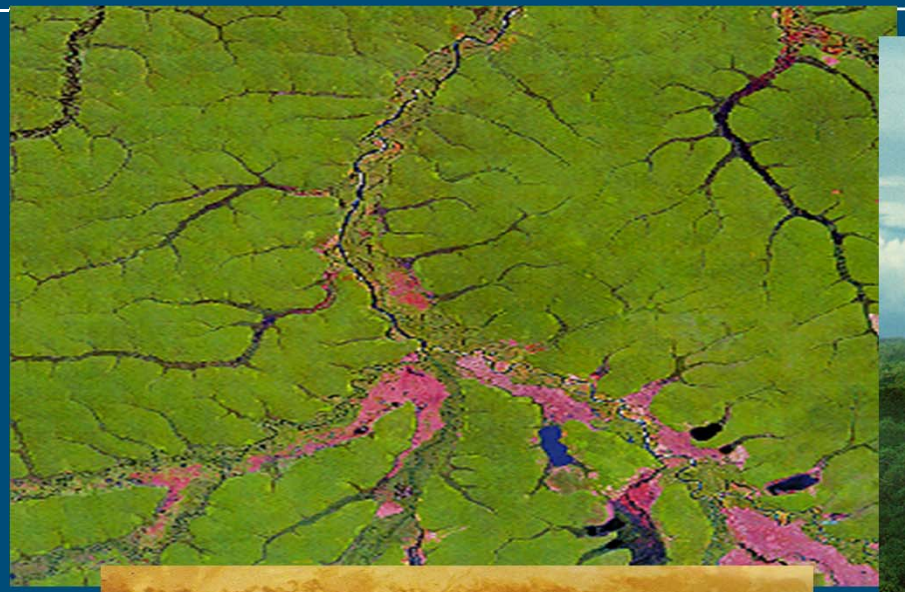
Global mean runoff (mm day^{-1}): HadCM3LC

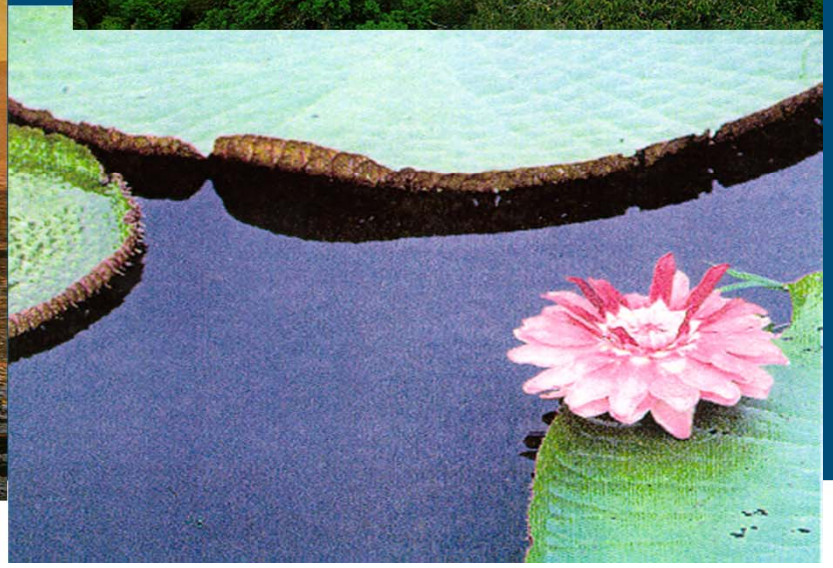


Runoff increase is greater when reduced stomatal conductance due to CO_2 is included.

Greater increase in flood risk? But less increase in drought risk?

The Amazon Basin…….





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The forest...

Biodiversity...

The rains...

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The rivers...

Population Growth and Land Use Change

- modern occupation of Amazonia (since 1500): negligible land use change up to the 1960's, but large loss of ethnic diversity due to colonization
- large lad use change in the last 30 years
- close to 600,000 km^2 deforested in Brazilian Amazonia (15%)
- high annual rates of deforestation (15,000 to 30,000 km^2/year)

Causes for Land Use Change:

- Government plans to “integrate” Amazonia
- road network throughout the region
- population growth in Amazonia: 3,5 million in 1970, up to 20 million in 2000, though 65% living in large and mid-size cities and towns
- colonization projects: rush of landless people to small scale, low tech agriculture
- subsidized cattle ranching
- destructive logging as a vector to subsequent deforestation

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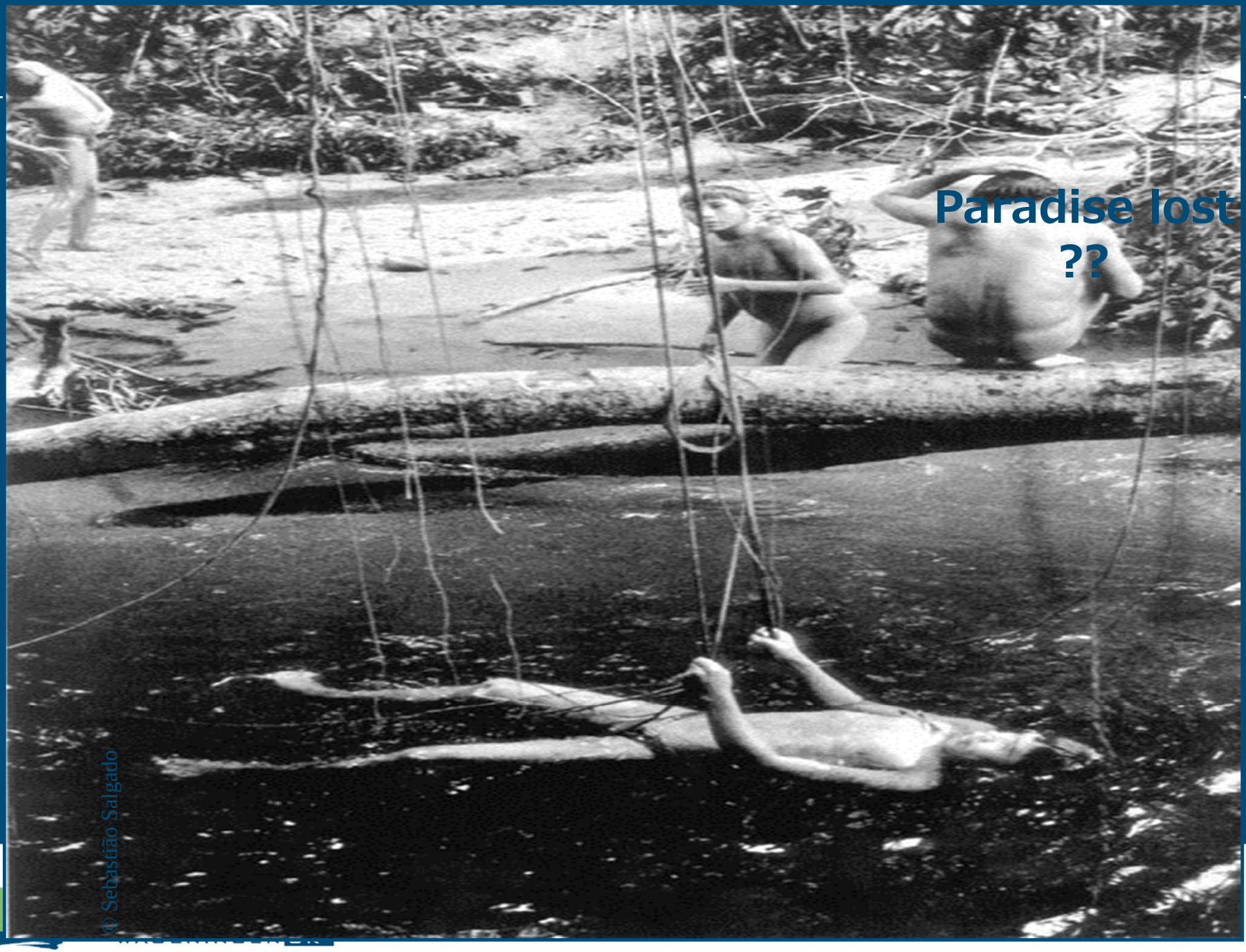
Paradise lost
??
© Sebastião Salgado

Integrated Earth System Research at regional scale

LBA

the Large scale Biosphere atmosphere experiment in Amazonia

- to better understand the functioning of the Amazon rainforest as a regional integrated (eco)system and its global interactions
- to study the biophysical, ecological and societal consequences of the Amazon deforestation, both regionally and as a part of the entire Earth system (global "tele-connections")
- to provide a wealth of data and other research information in order to support scenarios for sustainable development of the Amazon region, both in the regional (national) and global context

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IPAM - INSTITUTO DE PESQUISA AMBIENTAL DA AMAZÔNIA

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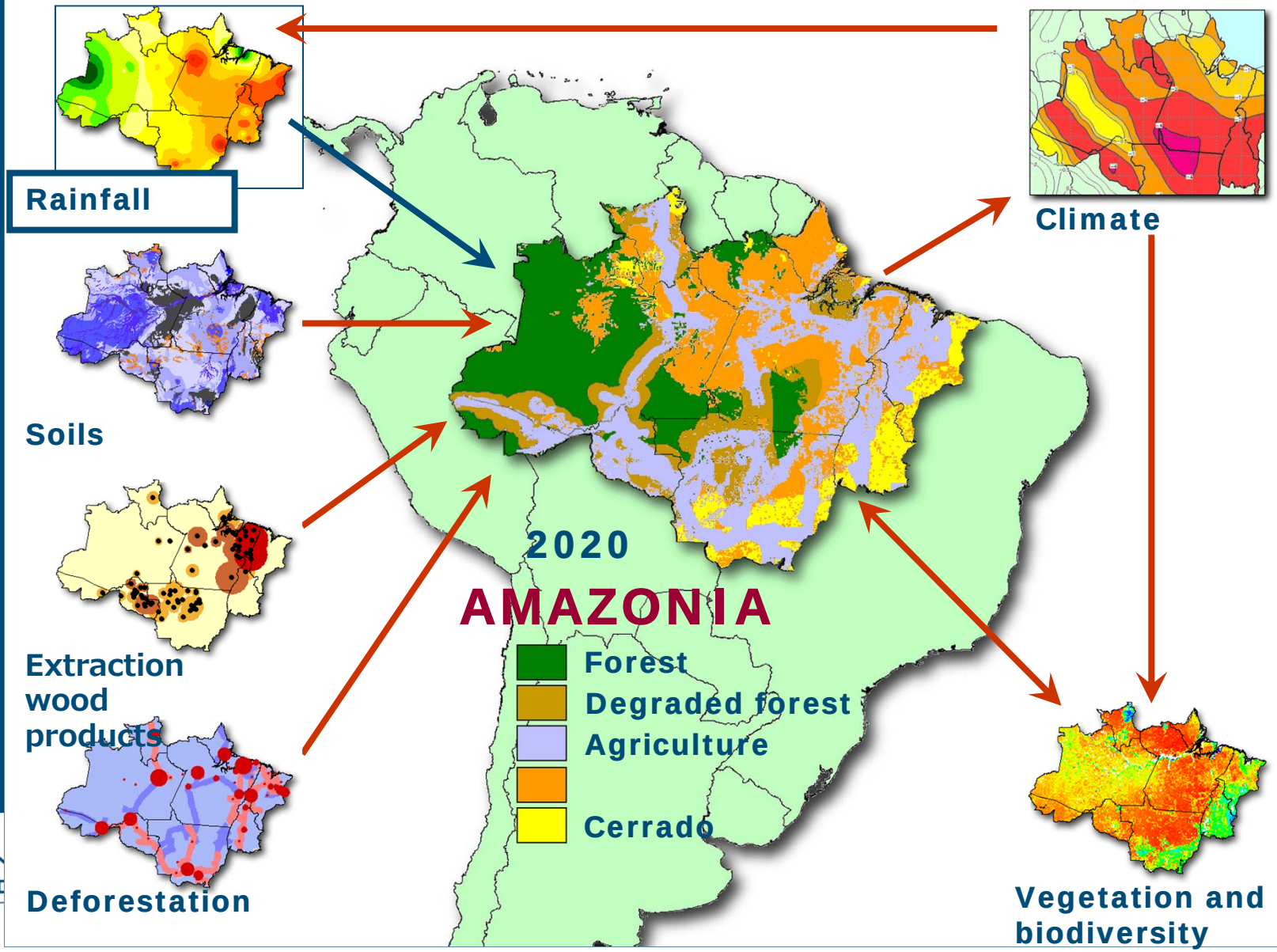
Cenarios da Amazonia

Social, economical and political effects of development strategies for Amazon: an **integrated approach**



However……

- We still seroiusly oversimplify the role and behaviour of the biosphere (vegetation) in our models (land surface models, climate models, earth system models…)
- ***Living*** biosphere in our models is actually a very *dead* biosphere
- Verdanski (and Kopffen) would not be happy at all…

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Living biosphere is……..like us humans

- Clever….???
- Lazy….
- Selfish and competitive (and often cruel)…..
- Selective and choosy…
- Amazingly resilient……
- Extremely vulnerable….

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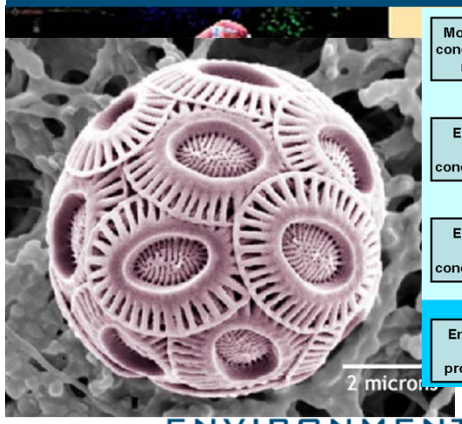
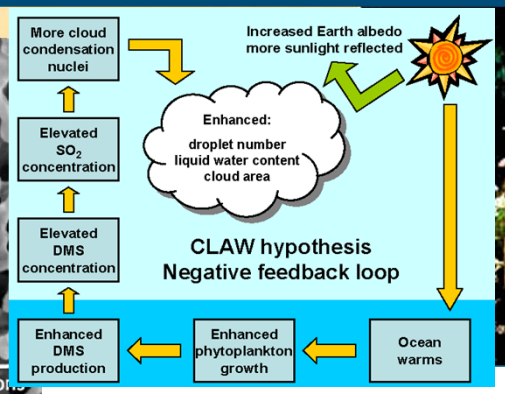
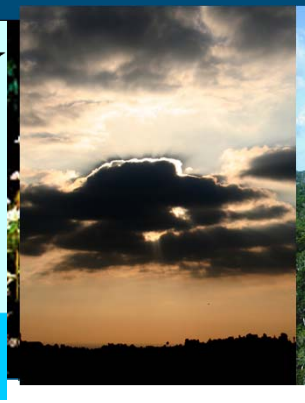
How could the local bio-chemical activity of terrestrial vegetation species evolve to serve in the altruism of planetary regulation?

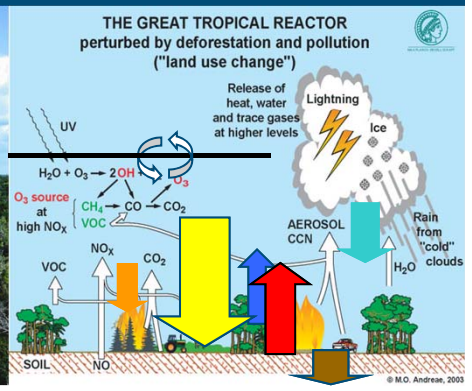
"Terrestrial CLAW hypothesis"

Pavel Kabat, Ruud Janssen,
Laurens Ganzeveld, Marku Kulmala, Andi Andreae,…









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- Marine CLAW-hypothesis
  - Hypothesis
  - State of the art
- Terrestrial equivalent
  - Hypothesis
  - Proposal
  - Simple vs. complex coupled models

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'**

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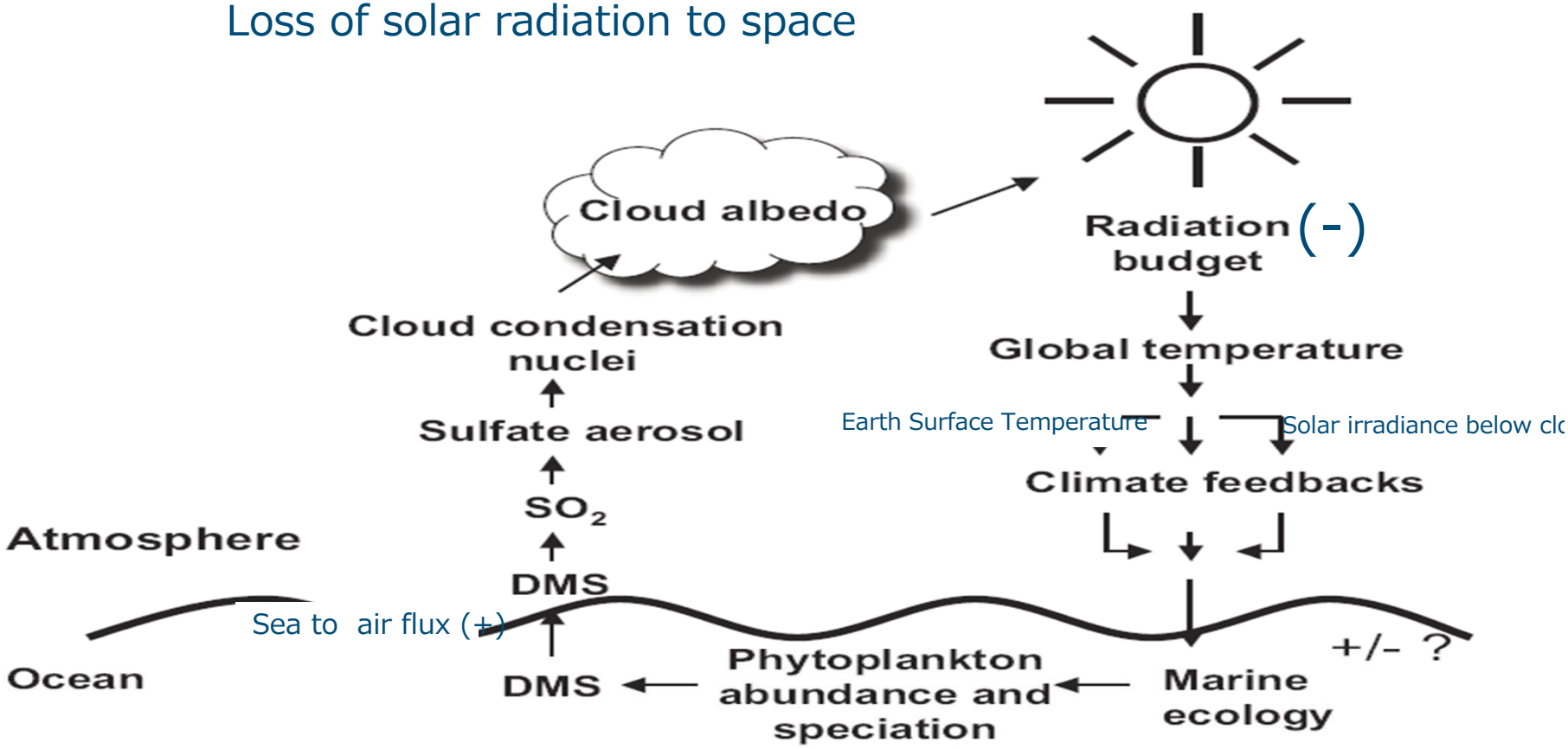
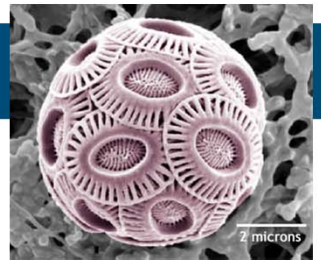
The DMS-feedback

Loss of solar radiation to space





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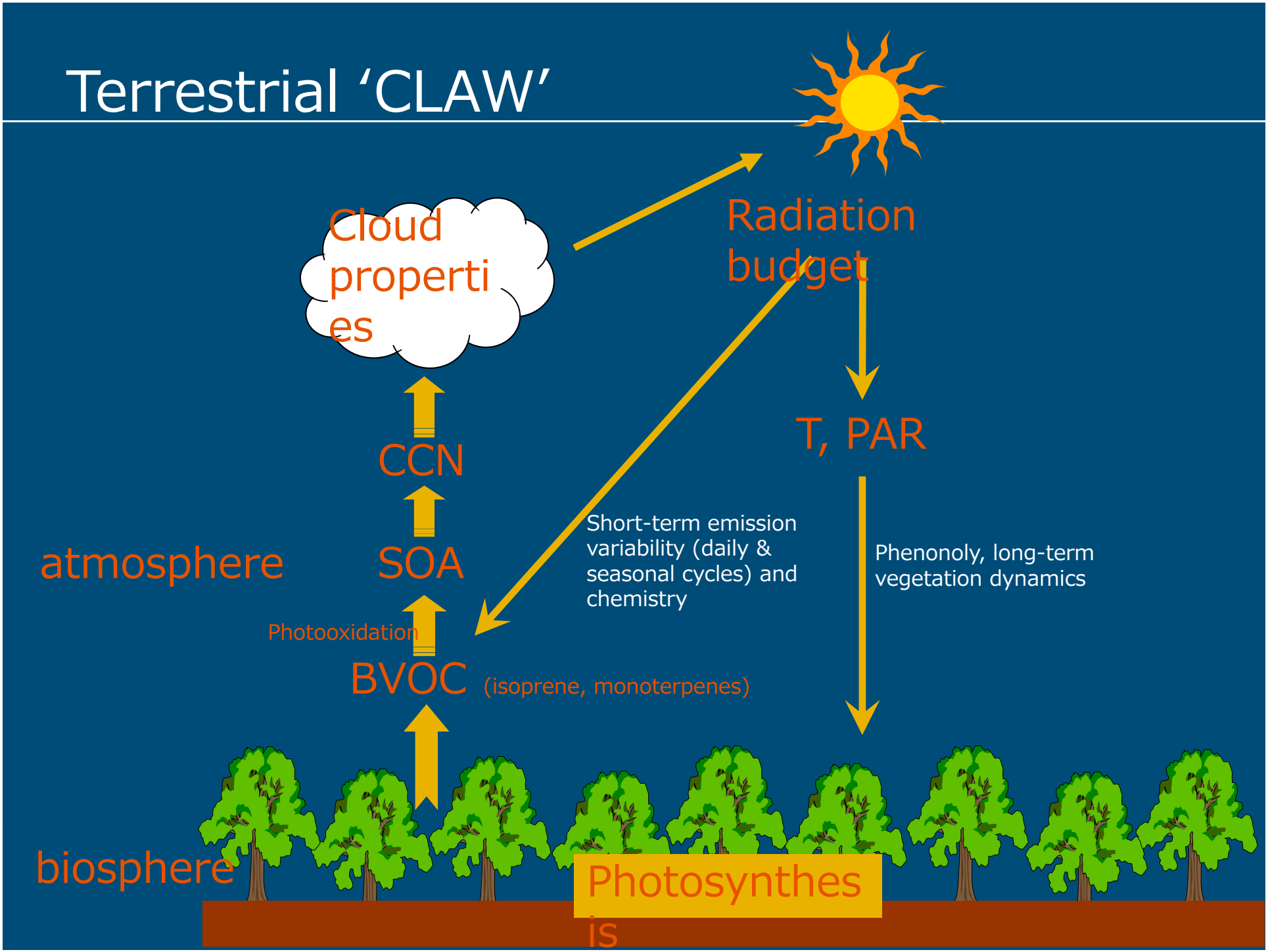
Terrestrial CLAW-equivalent: how this may work?

- 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)

Terrestrial 'CLAW'



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

- Side-products of photosynthesis
  - Defense against predation
  - Communication
  - Protection from high temperatures
- Or just emitted <u>because</u> 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..

Method: complex vs. simple models

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

Coupled model

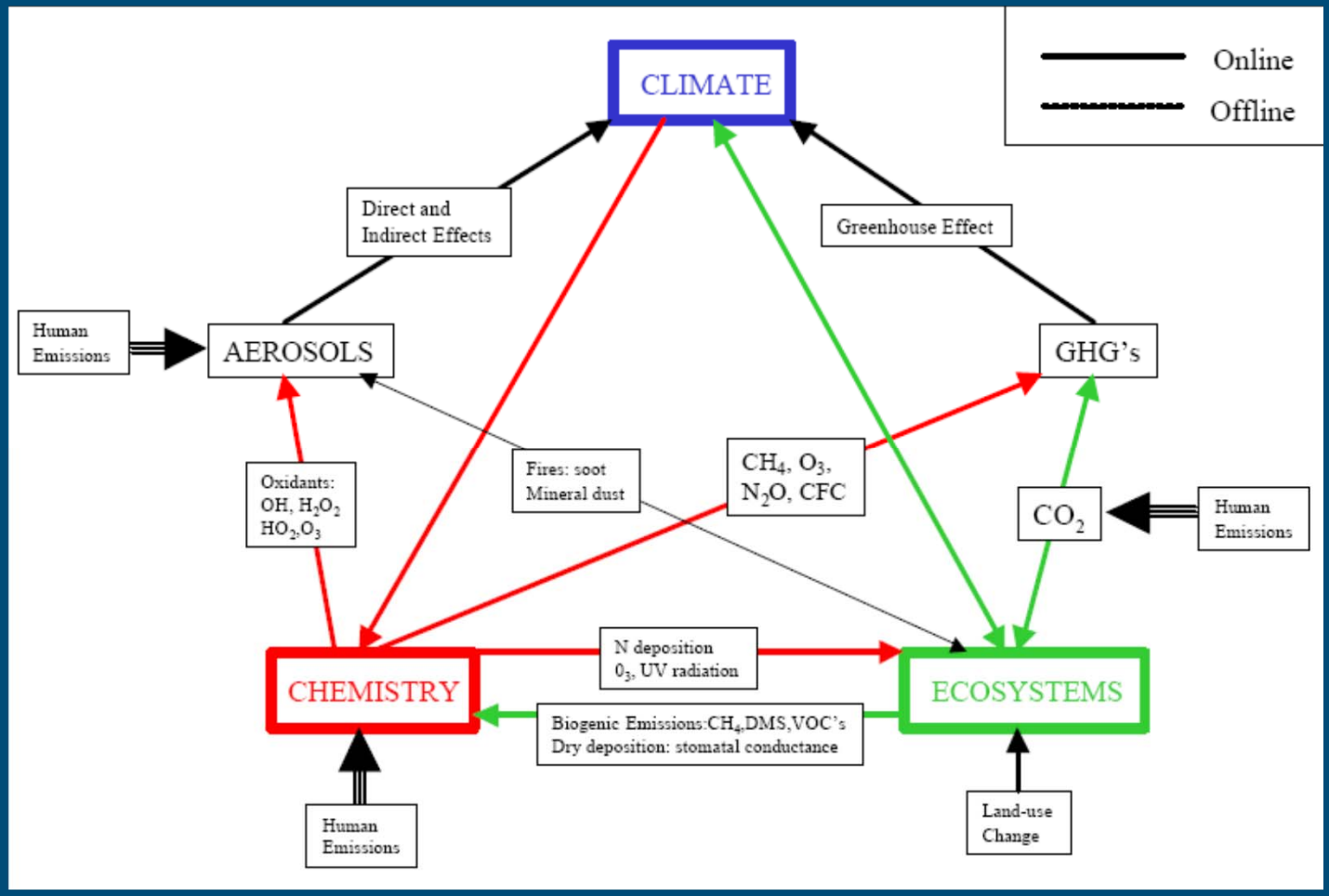

Image: Hadley Centre, Met Office, UK

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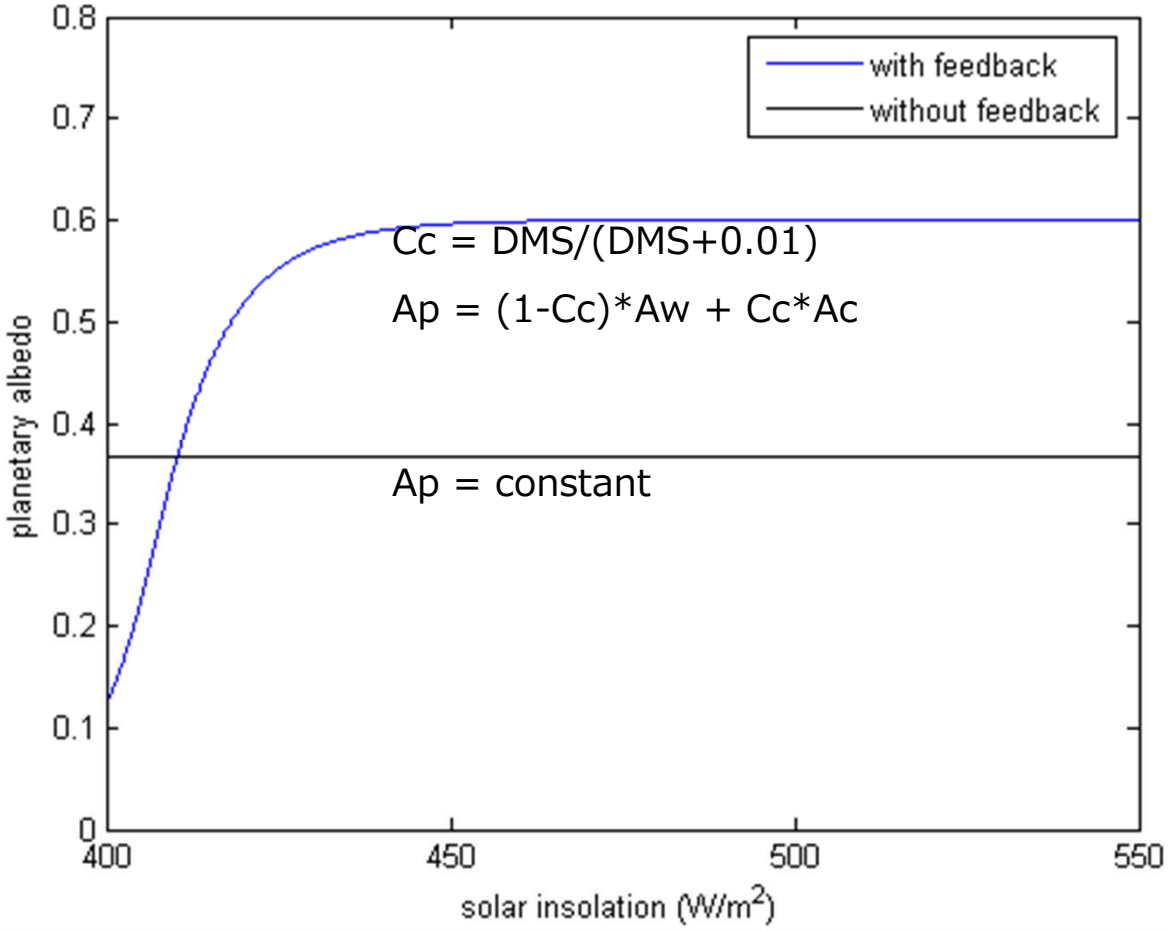
Example: simple model for DMS-



Ac: cloud albedo [-]

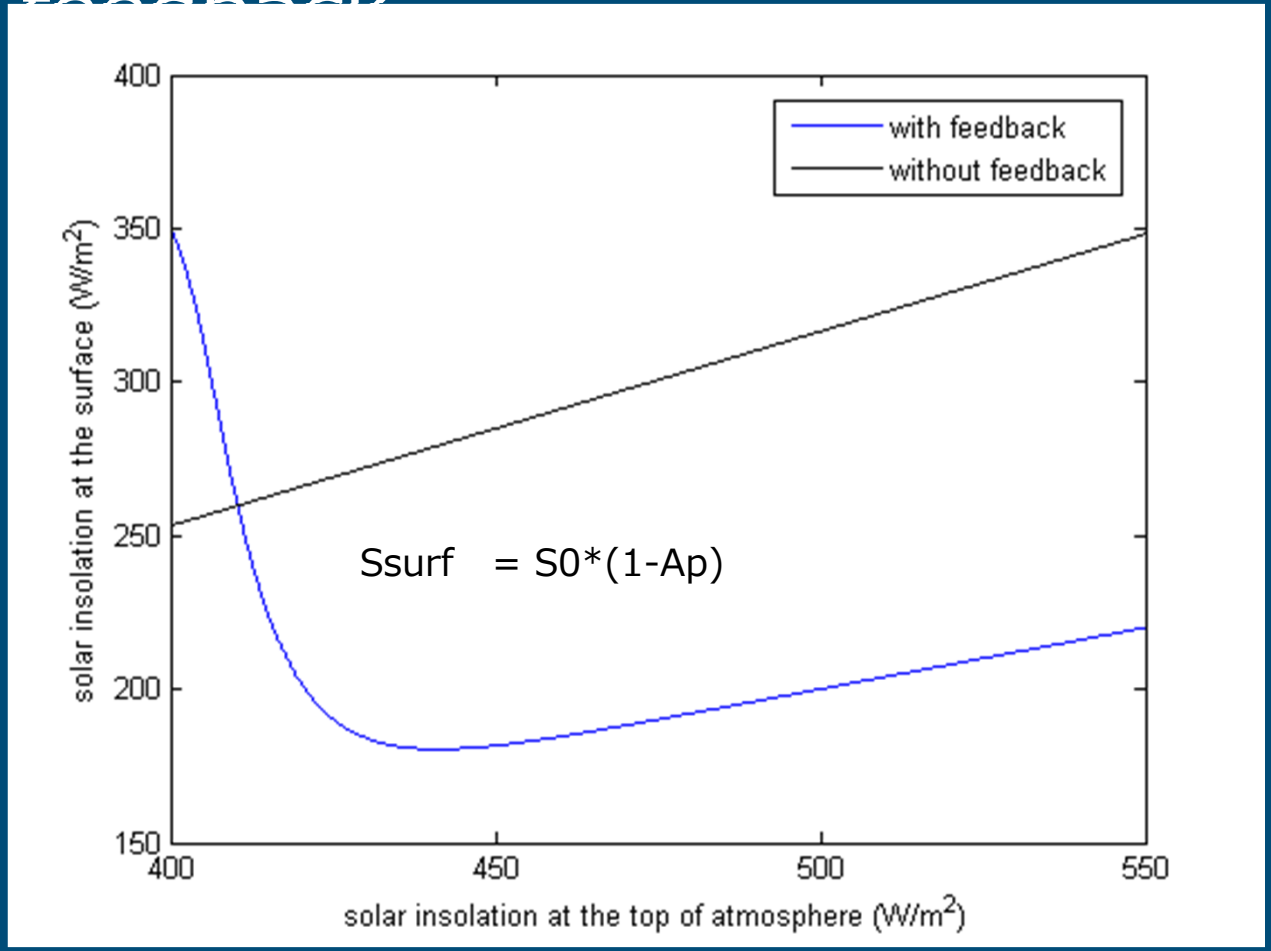
Ap: planetary albedo [-]

Aw: albedo of water [-]

Cc: cloud cover [-]

DMS: atmospheric DMS-burden [g S]

Example: simple model for DMS-feedback



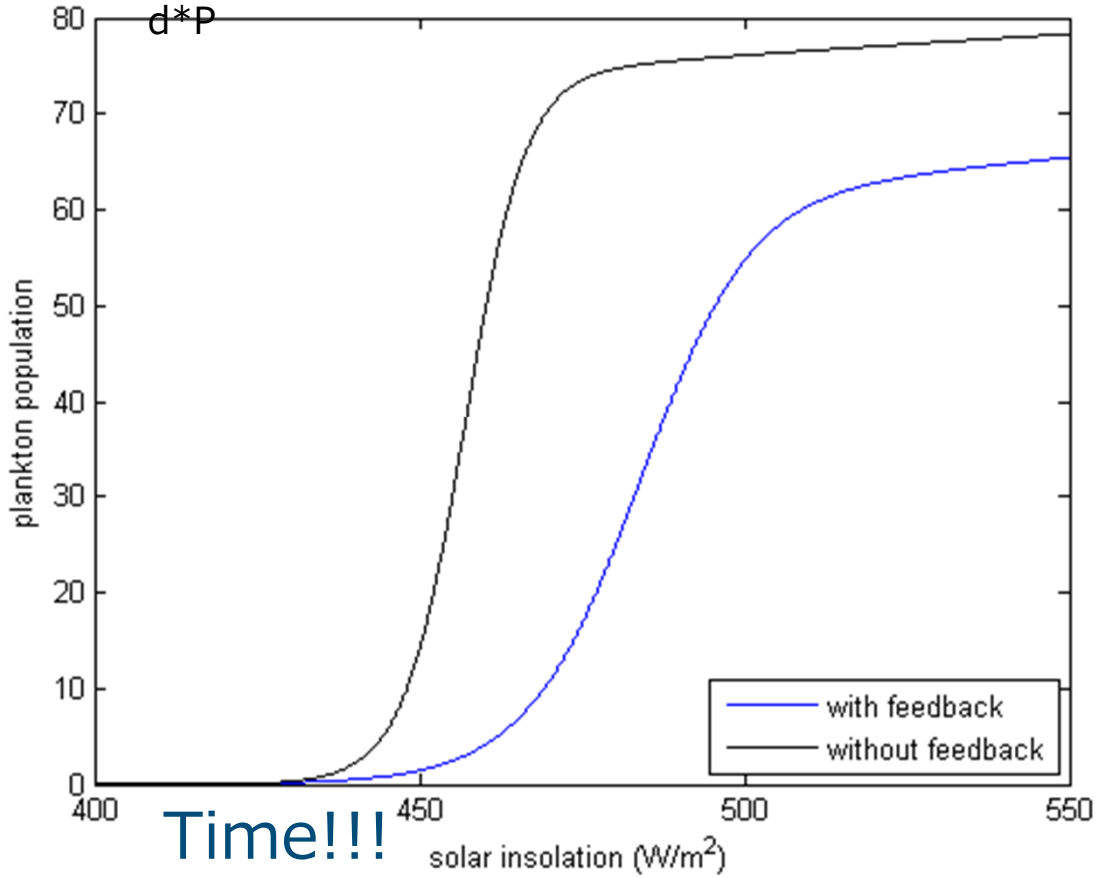
Ap: planetary albedo [-]

S0: solar insolation at the top of the atmosphere [W/m^2]

Ssurf: solar insolation at the earth's surface [W/m^2]

Example: simple model for DMS-feedback

dP/dSsurf (moet dt zijn…) = r*Ssurf*P*(1-P/K) - d*P



Time!!!

P: plankton population [kg C]

d: plankton mortality rate [T-1]

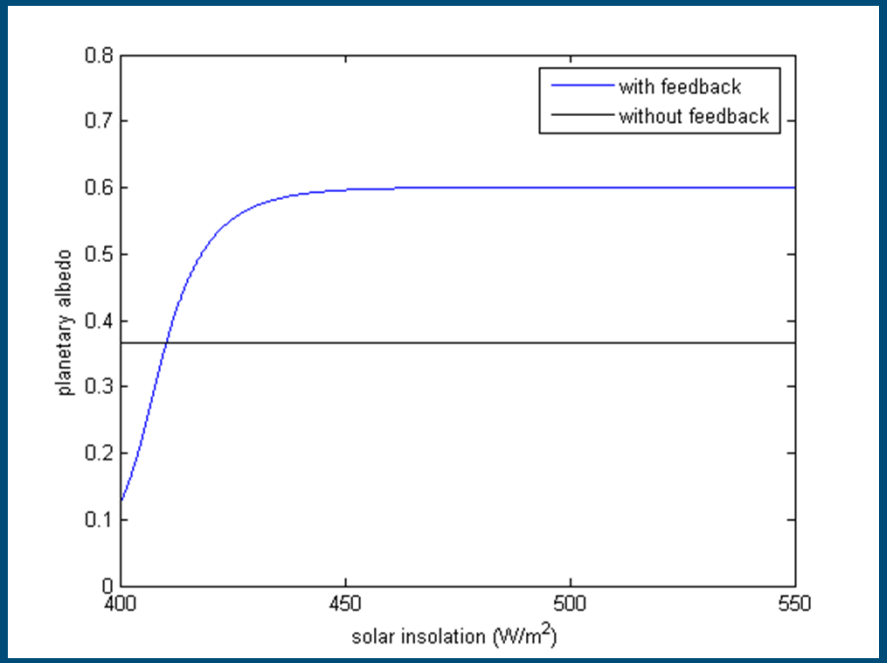
r: plankton growth rate

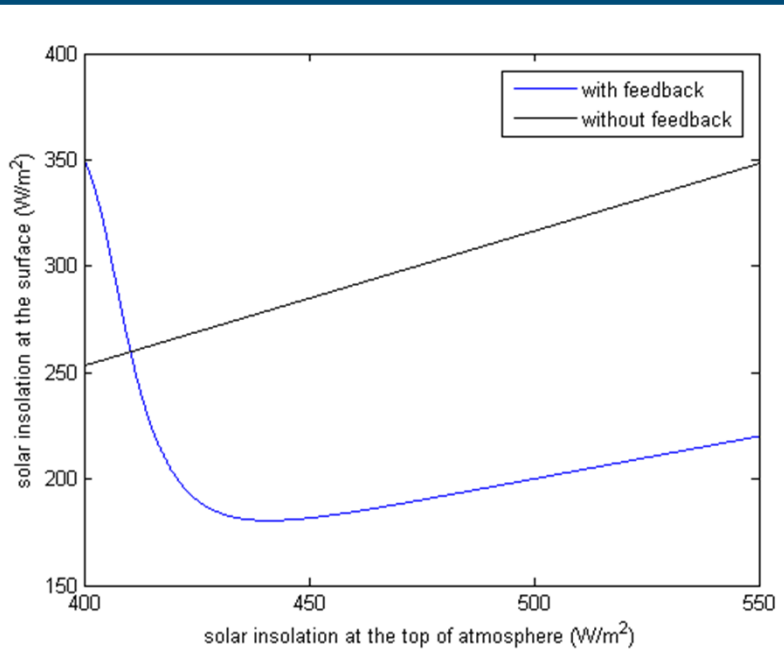
K: plankton carrying capacity [kg C]

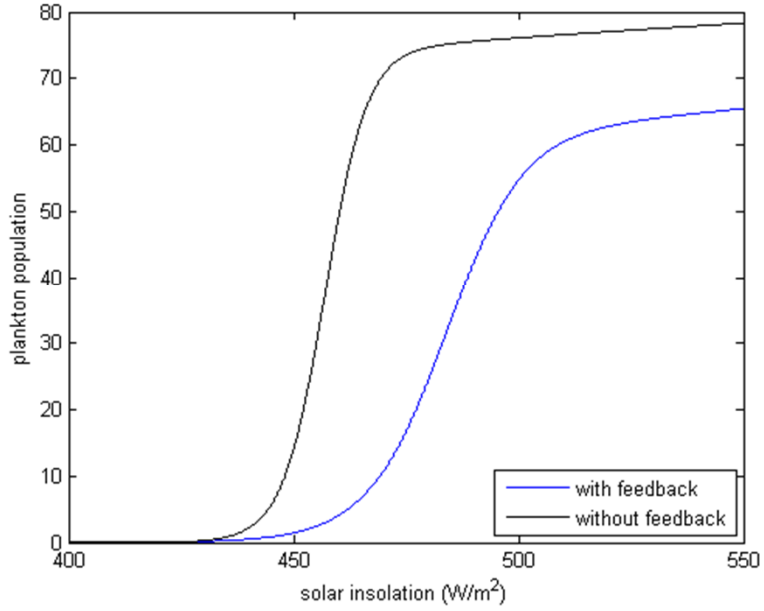
Ssurf: solar insolation at the earth's surface [W/m2]

Example: simple model for DMS-feedback

- Some very preliminary results







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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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Living biosphere in earth system models….how to get beyond the present state of the affaires?

- To collaborate with:

- Plant physiologists…
- Plant cell biologists…
- Plant behavior and cognition scientists…

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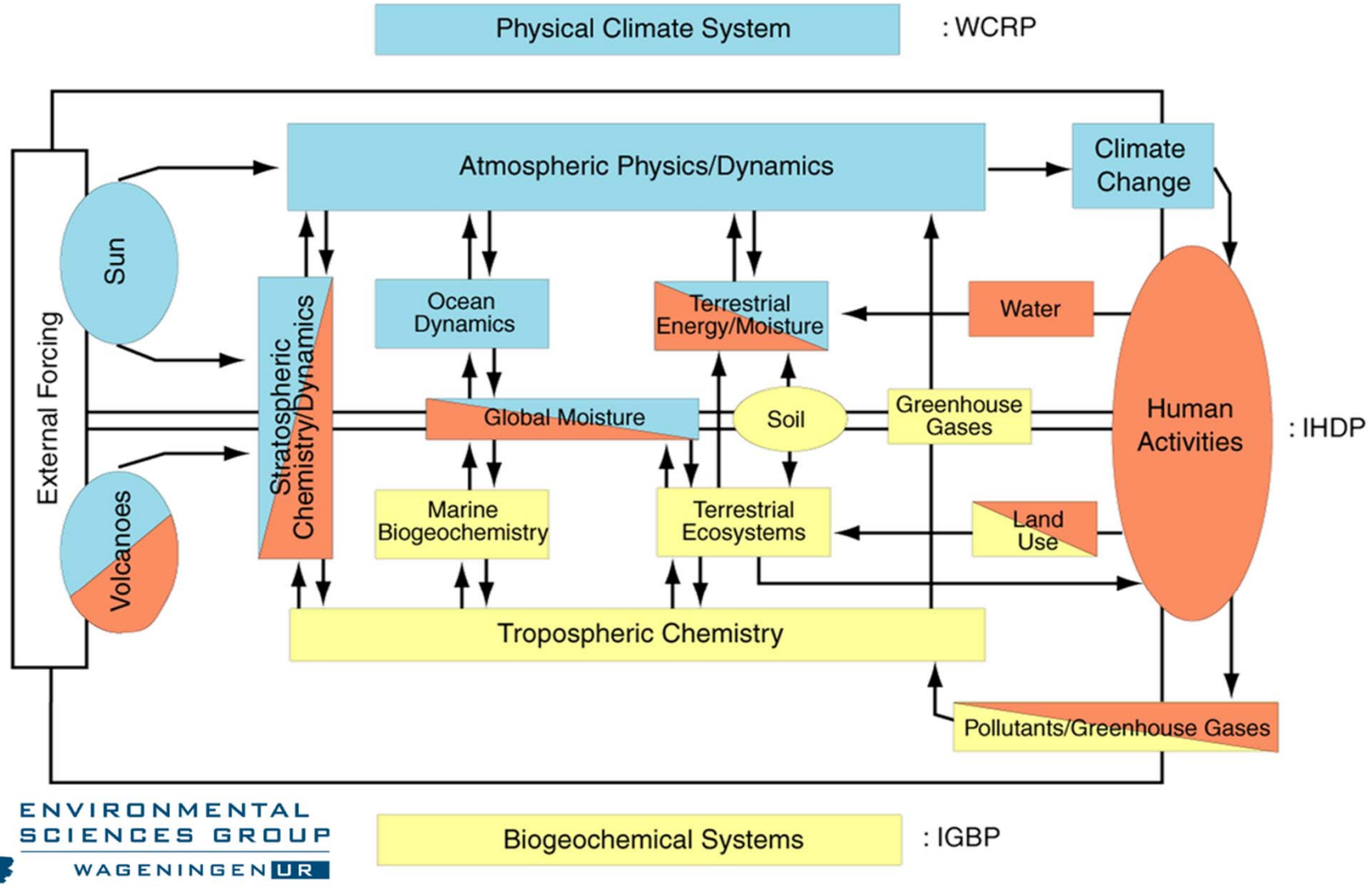
The Earth System: Coupling the Physical, Biogeochemical and Human Components



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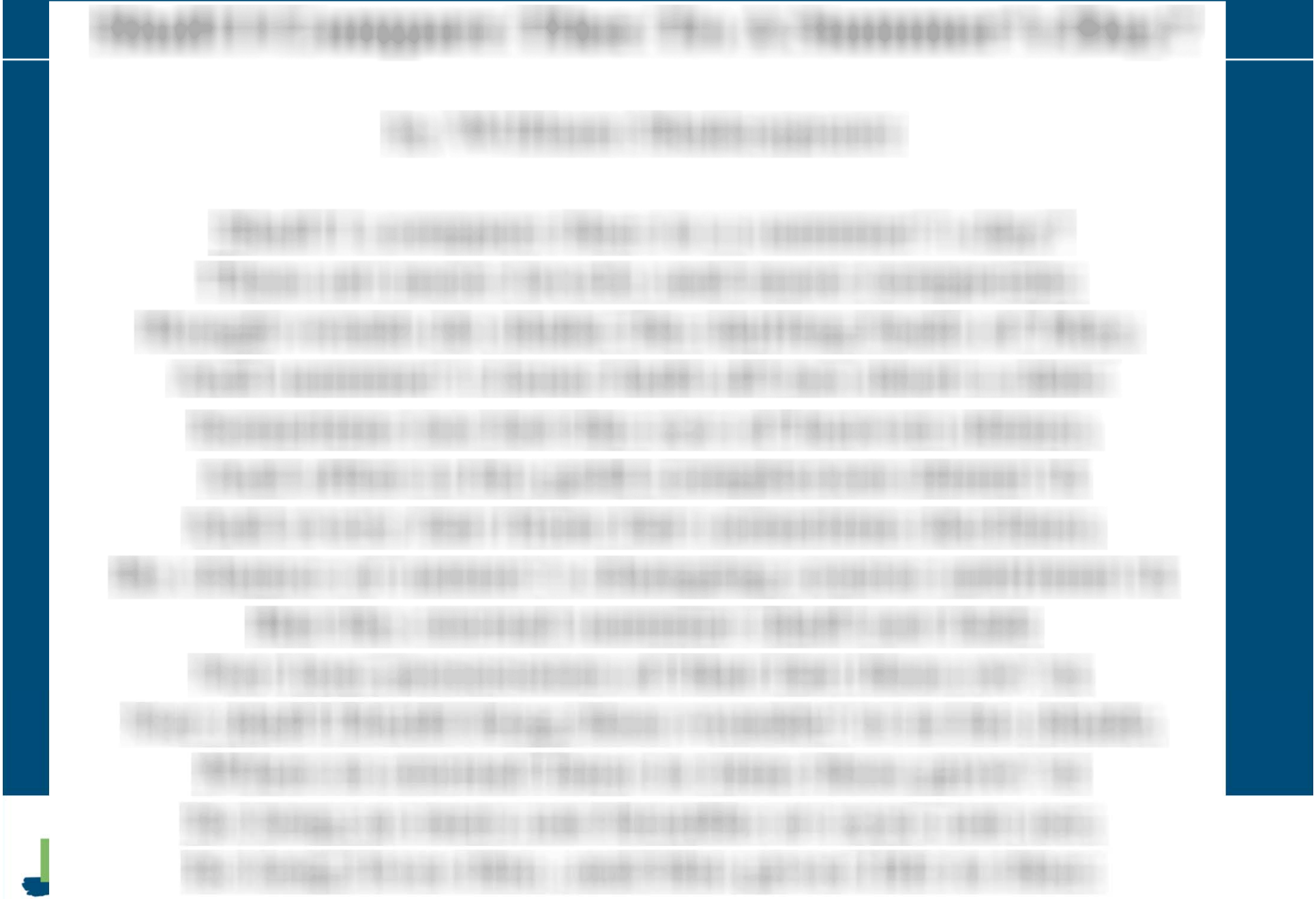


Summer

summer

temperate

Rough winds

summer

hot

fair fair

nature

summer

fair

shade

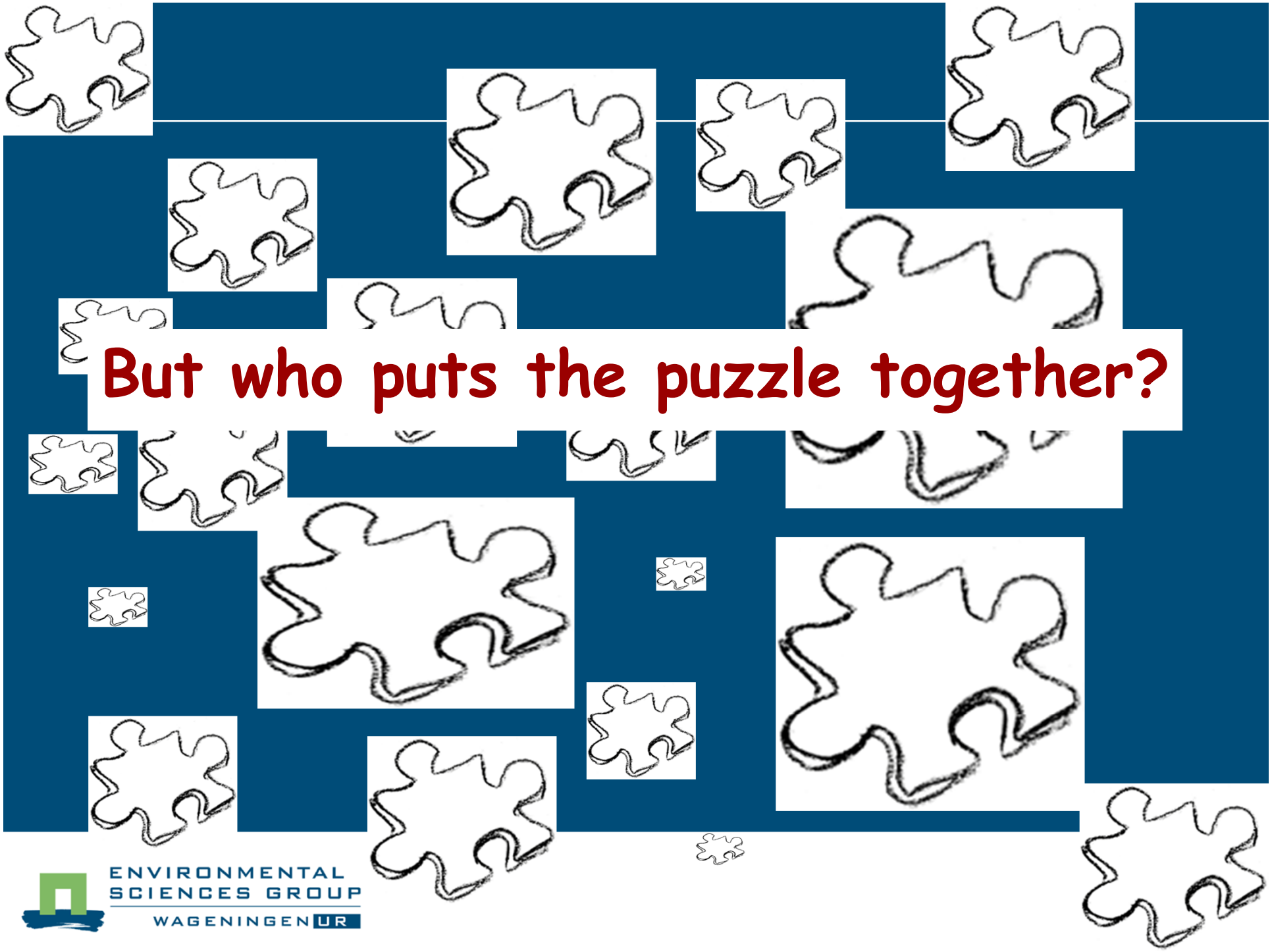
time

life

Shall I Compare Thee To A Summer's Day?

by William Shakespeare

Shall I compare thee to a summer's day?
Thou art more lovely and more temperate.
Rough winds do shake the darling buds of May,
And summer's lease hath all too short a date.
Sometime too hot the eye of heaven shines,
And often is his gold complexion dimm'd;
And every fair from fair sometime declines,
By chance or nature's changing course untrimm'd;
But thy eternal summer shall not fade
Nor lose possession of that fair thou ow'st;
Nor shall Death brag thou wander'st in his shade,
When in eternal lines to time thou grow'st:
So long as men can breathe or eyes can see,
So long lives this, and this gives life to thee.



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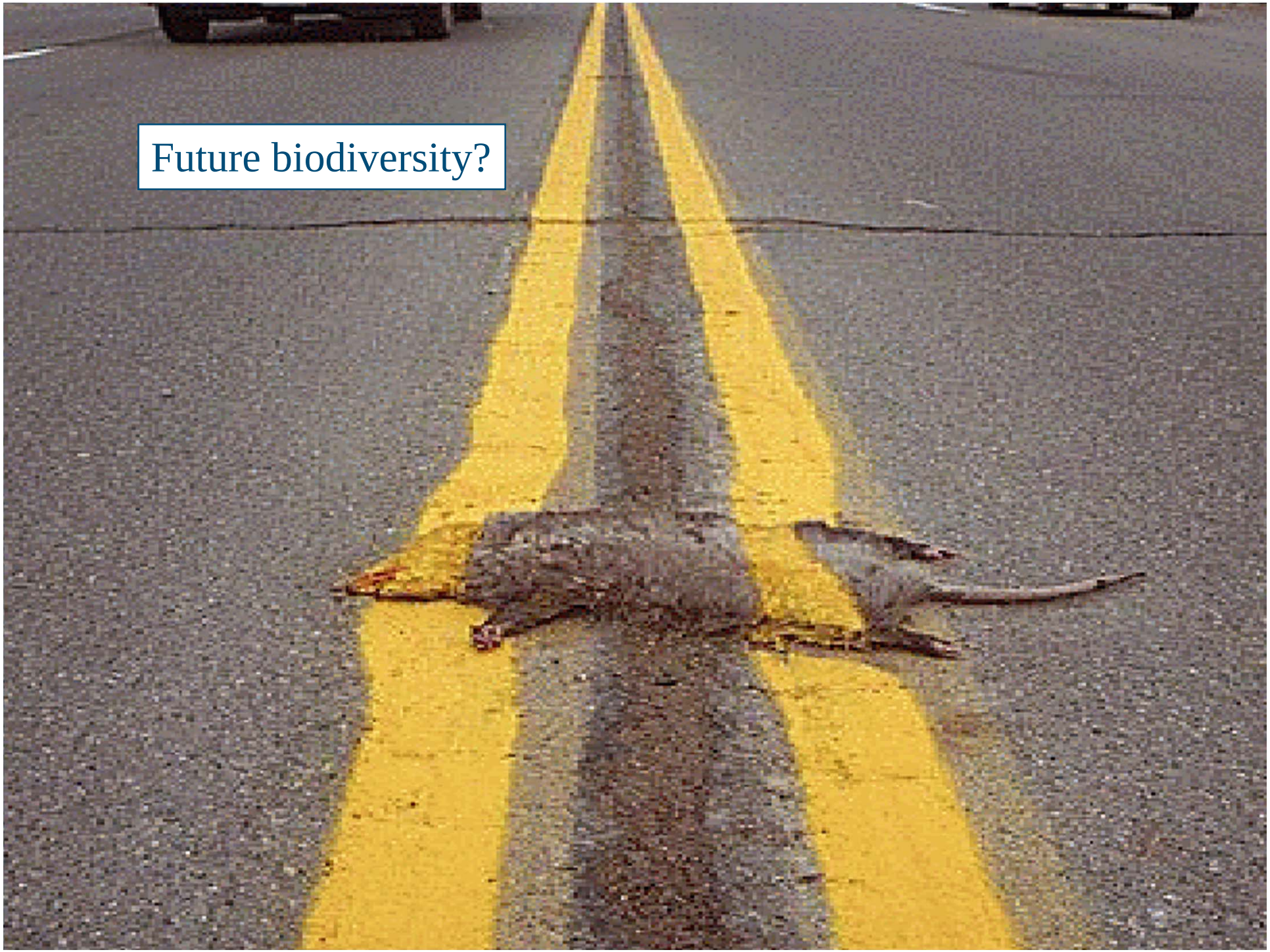
Future biodiversity?