

Cloud and land surface interactions

Cathy Hohenegger¹ and Christoph Schär²

¹ Max Planck Institute for Meteorology, Hamburg, Germany

² ETH Zurich, Zurich, Switzerland

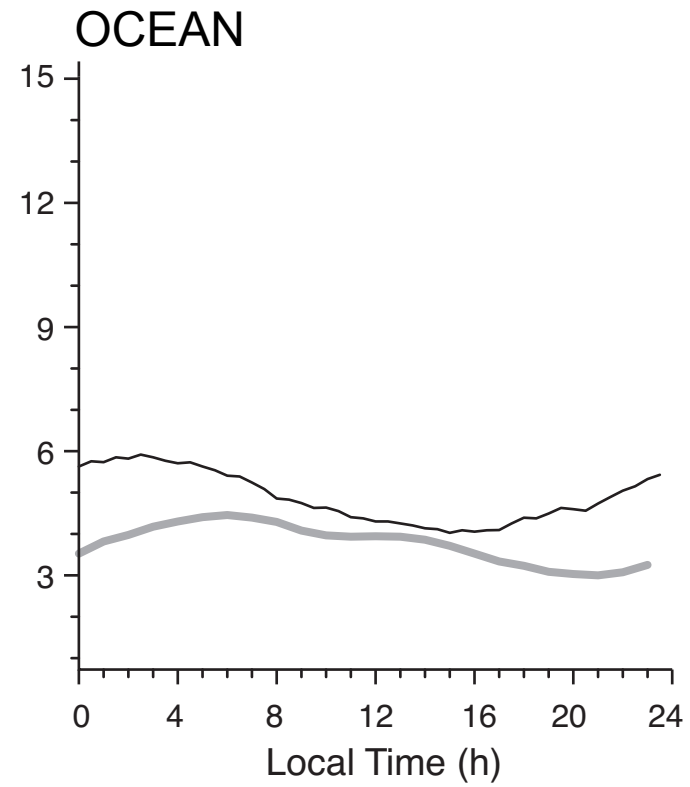
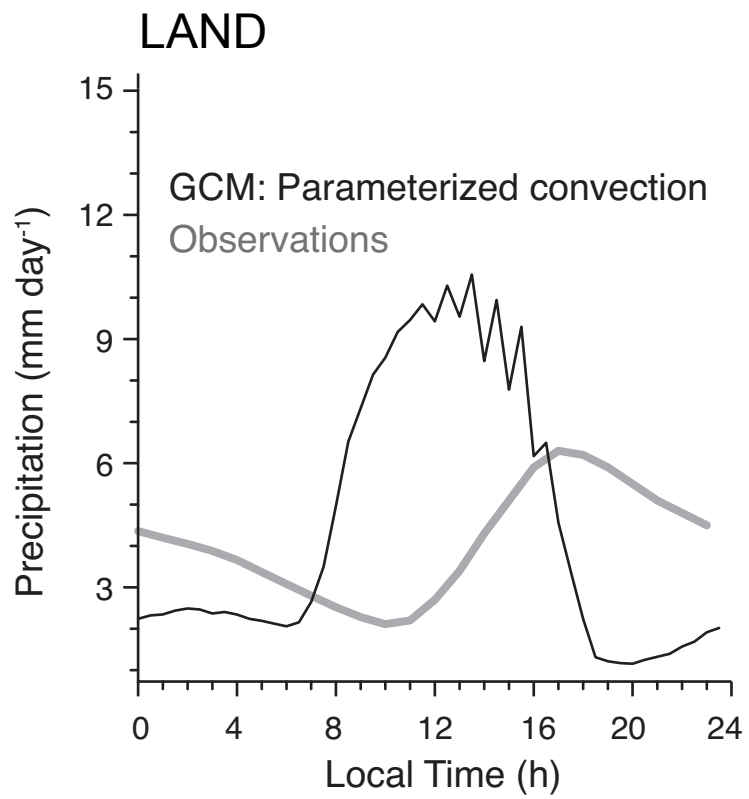


Max-Planck-Institut
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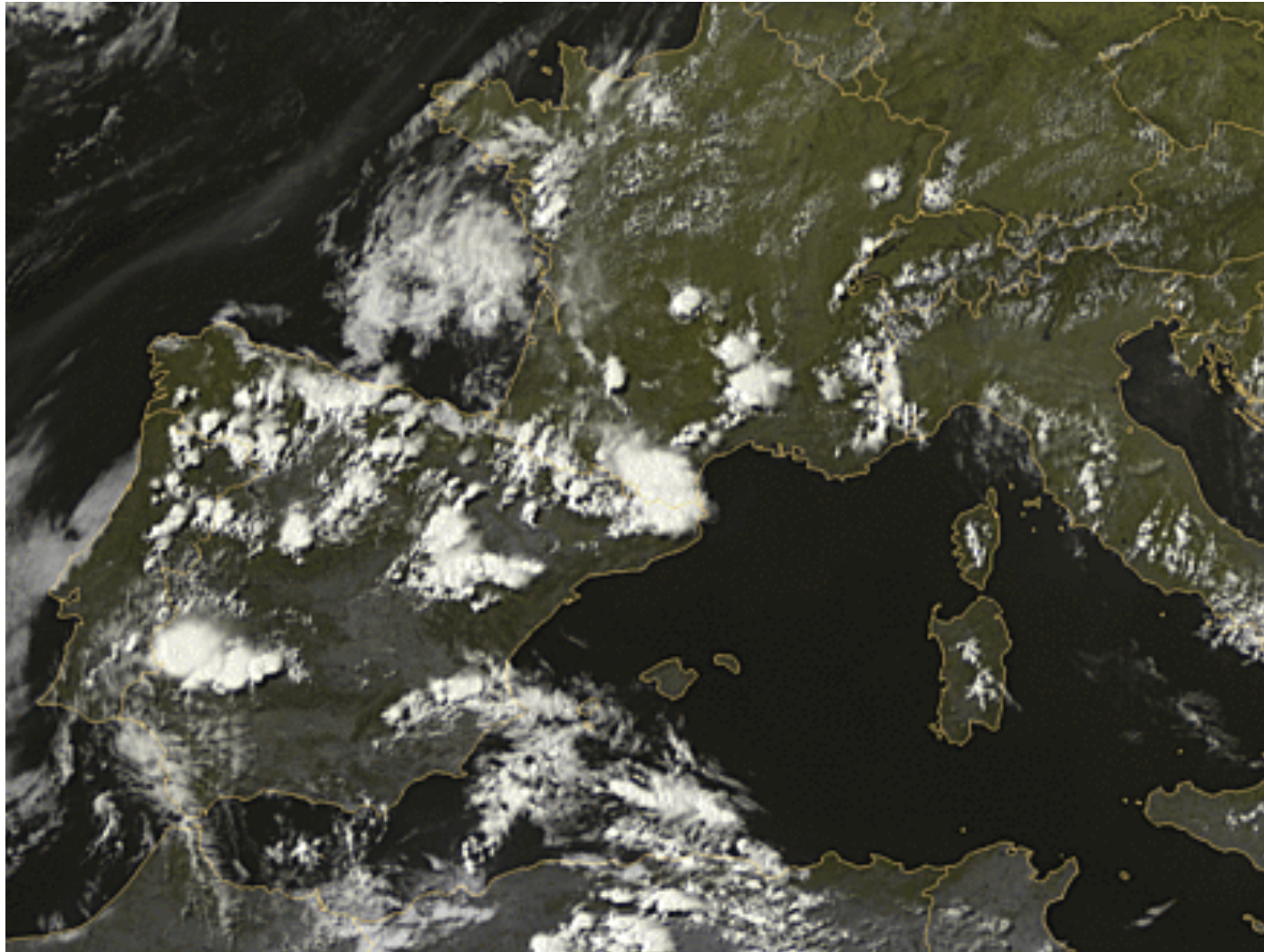
Deforestation in Amazon:

- Increases precipitation? 6
- Decreases precipitation ? most
- No effect on precipitation? 1





Convection, sunny summer day, Europe



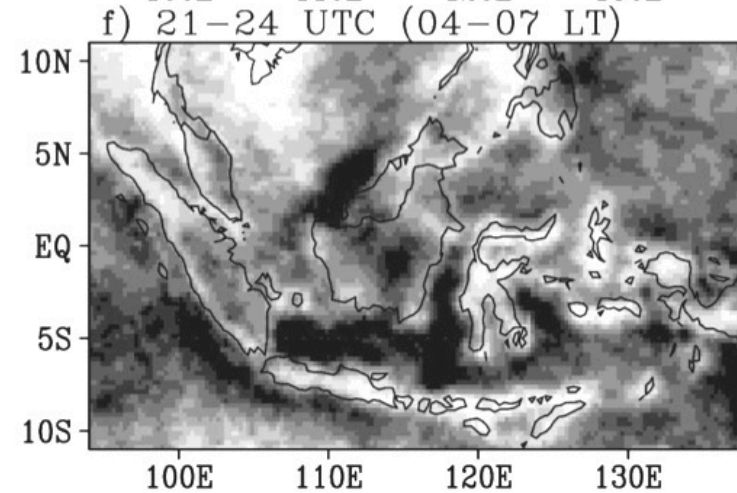
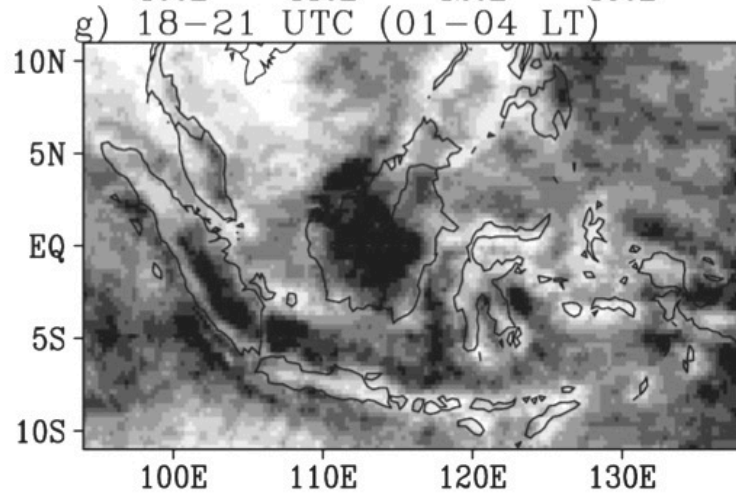
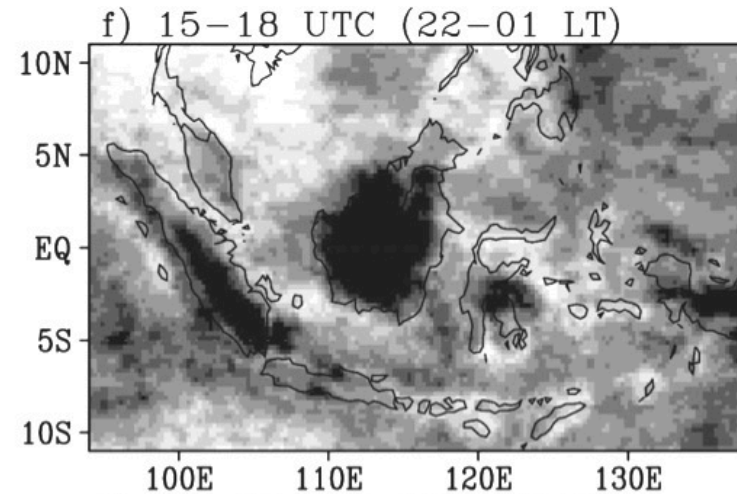
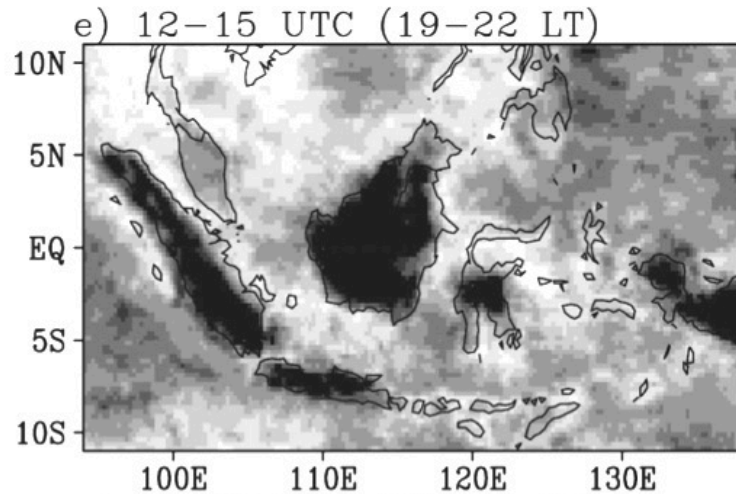
Convection, Amazon



(NASA Earth Observatory)



Precipitation, maritime continent

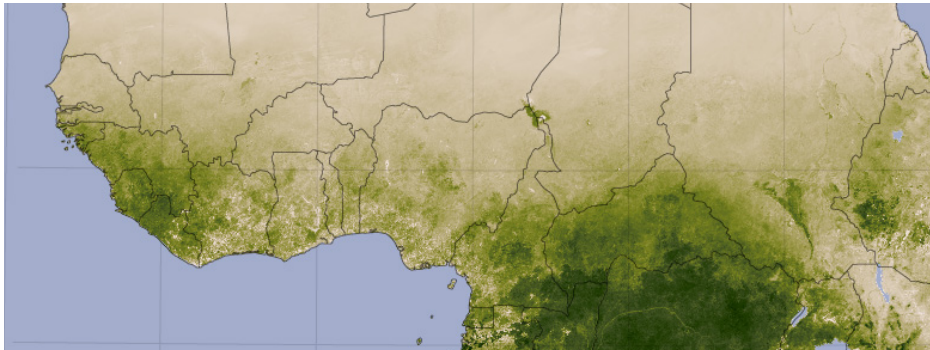


(Qian 2008)

Vegetation, precipitation, dry and wet seasons, Sahel

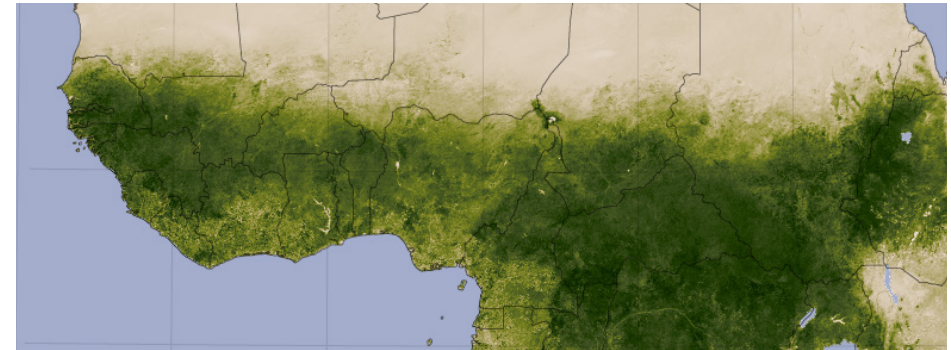
NDVI

March



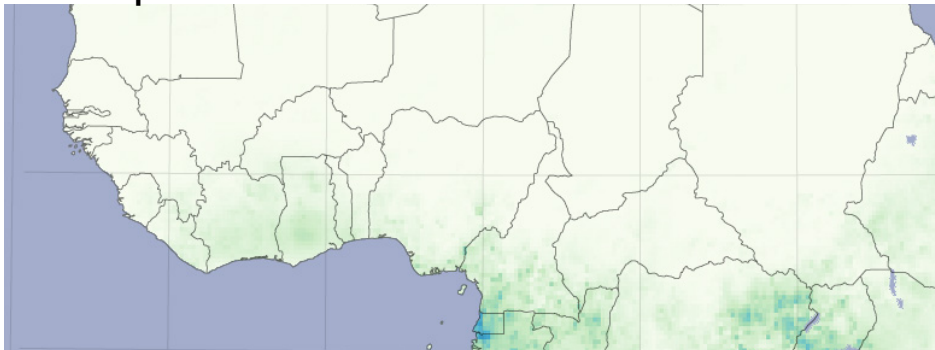
NDVI

September



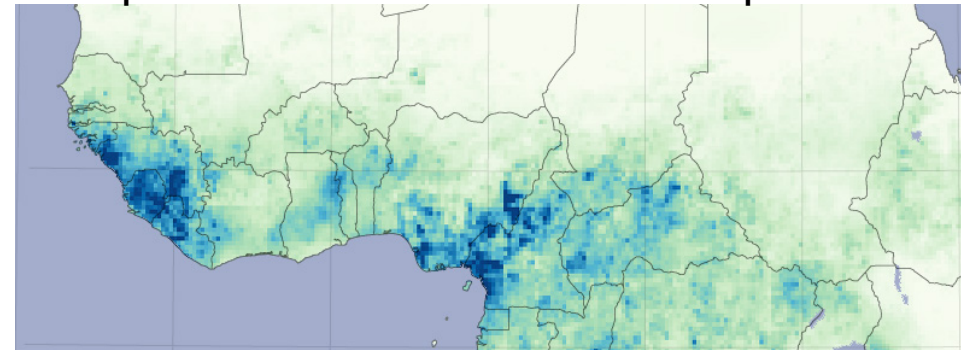
Precipitation

March



Precipitation

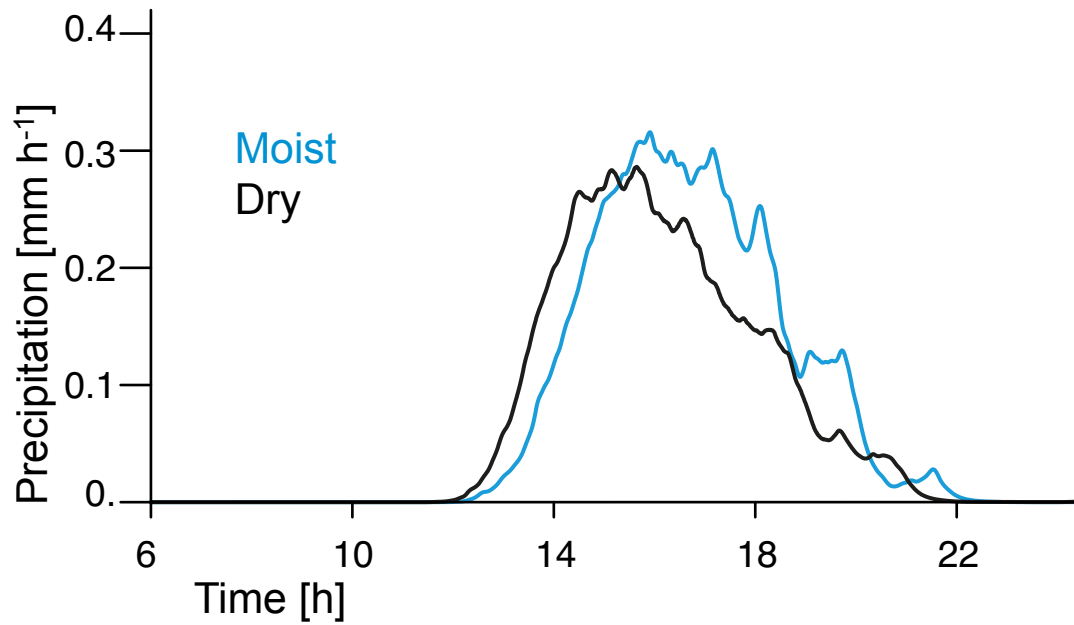
September



(NASA Earth Observatory)



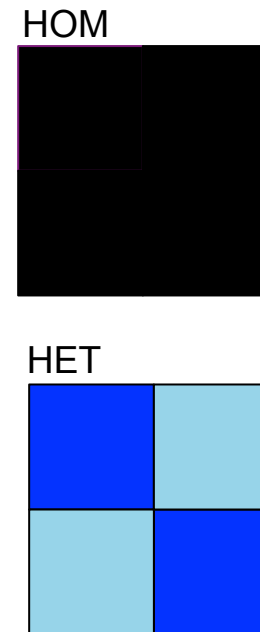
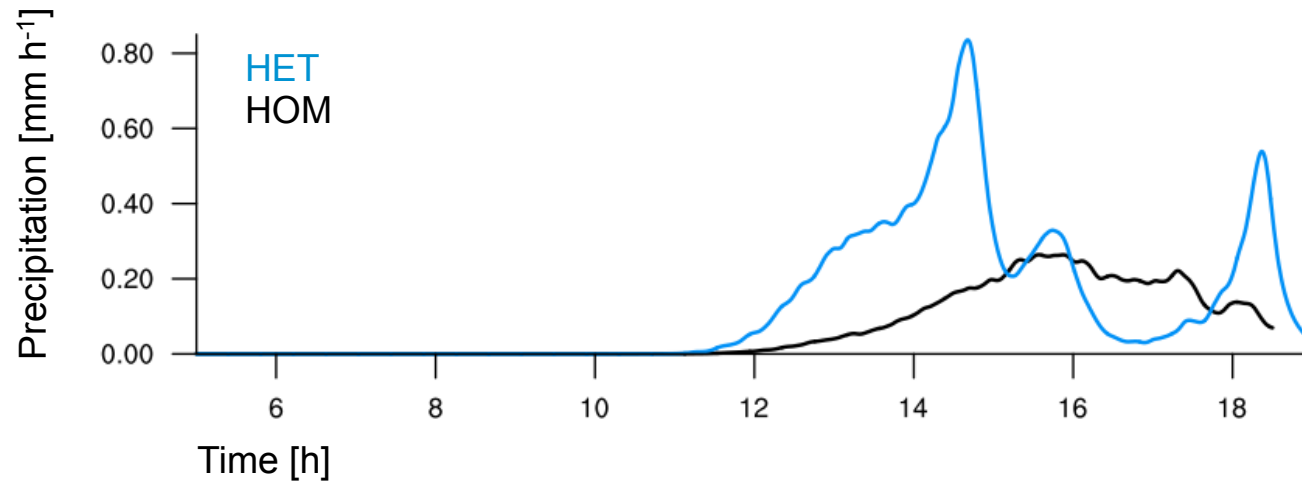
Precipitation over wet/dry surfaces



(Thomas Frederikse)



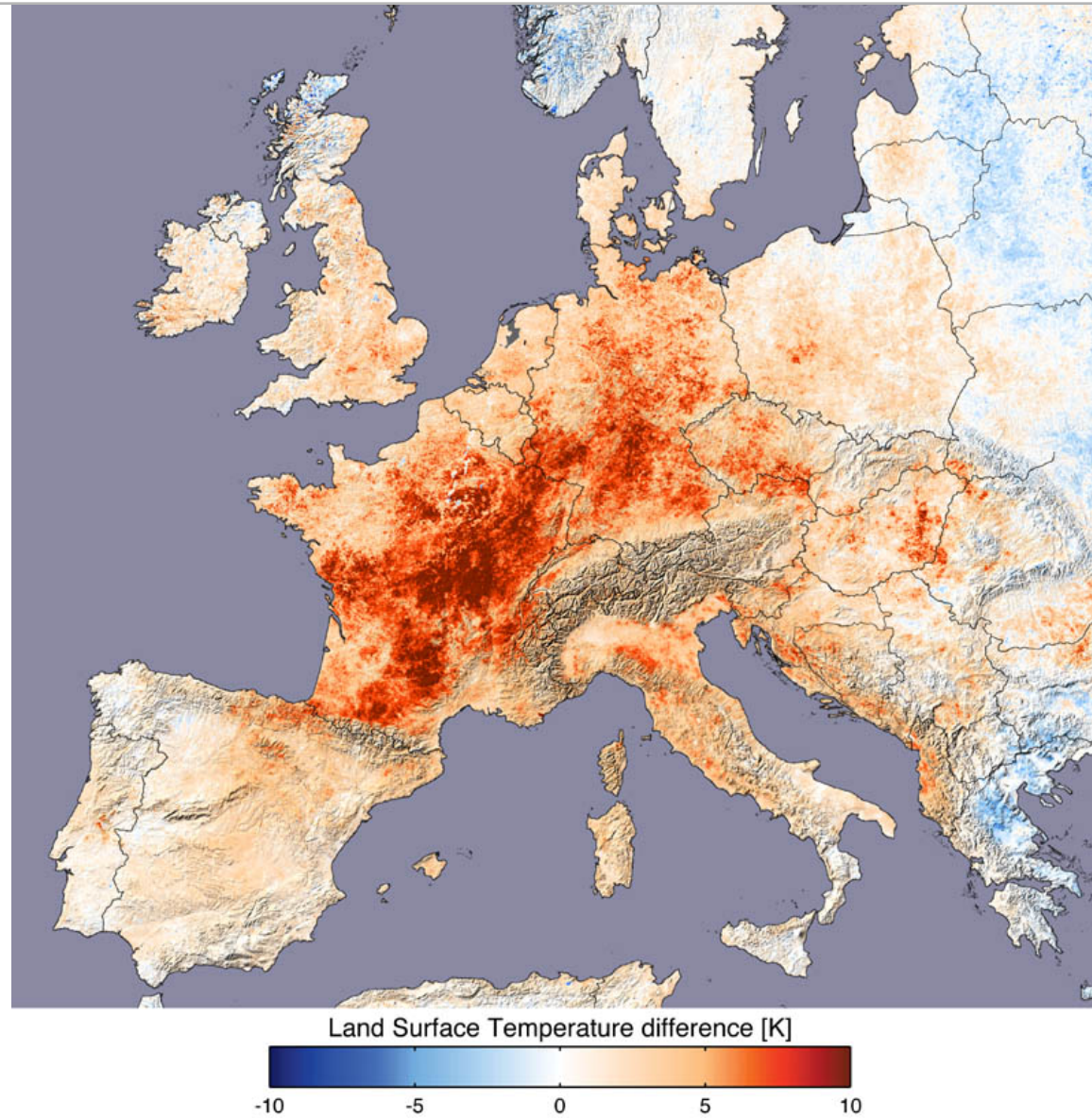
Precipitation over homogeneous/heterogeneous surfaces



(Malte Rieck)



Summer heat wave 2003



(Stockli et al.)

Land surface influences

- Location of clouds and precipitation
- Timing of clouds and precipitation
- Precipitation amounts

Generates typical spatial and temporal patterns

- the mean climate over a region
- climate extremes
- climate variability

Role of land surface for climate change



Goals

1. When and where is the land surface important for clouds and precipitation?
2. How does the land surface affect clouds and precipitation?
3. What are the possible effects of the land surface on clouds, precipitation and the overall climate?



Outline

1. Basic concepts and processes

When is land surface important?

2. Feedbacks

How does LS and RR couple?

1. Static heterogeneity
2. Homogeneous surface conditions
3. Dynamic heterogeneity

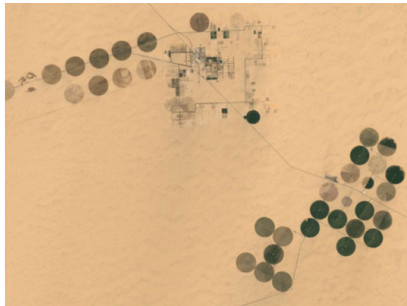
3. Extremes

Climatic effects?



What makes the land surface special...

Human influence



Spatial variability

Memory

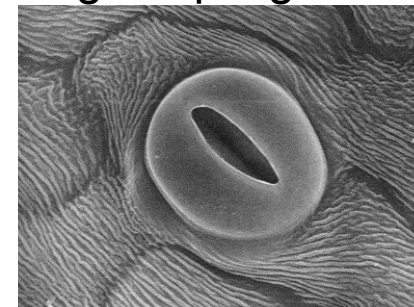


On average: 1-2 months

Temporal variability

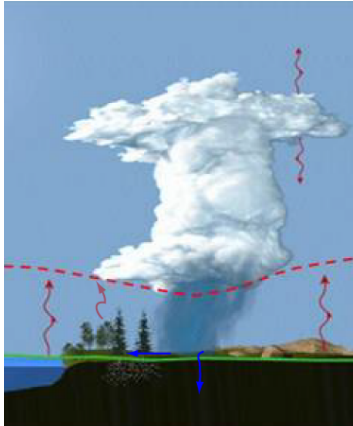


Strong coupling to climate



What makes it difficult....

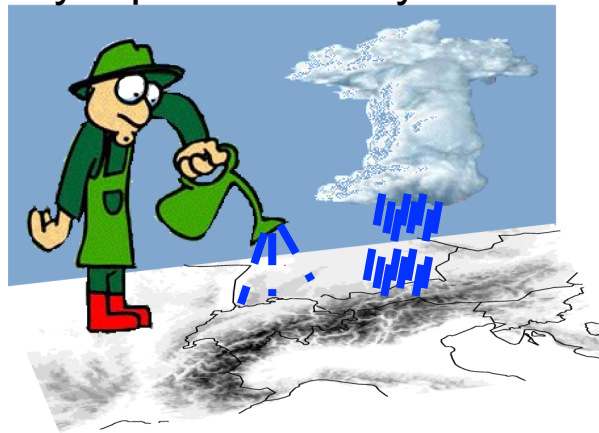
Scales



Mathematical description



Synoptic variability



Important relations

Basic concepts and processes



Important relations

Surface energy budget

$$SW_{net} + LW_{net} = SH + L \cdot ET + G$$

Water balance equation

$$\frac{\partial S}{\partial t} = \bar{P} - \overline{ET} - \bar{R}$$

Potential evapotranspiration

$$ET_{pot} = \rho \frac{q_{sat}(T_s) - q}{r_a}$$

Penman-Monteith combination formula

$$ET_{pot} = \frac{\Gamma}{L} (R_N - G) + (1 - \Gamma) \rho \frac{q_{sat}(T) - q}{r_a}$$
$$\Gamma = \frac{\frac{\partial q_{sat}}{\partial T}}{\frac{\partial q_{sat}}{\partial T} + \frac{c_p}{L}}$$

Evapotranspiration

$$ET = \rho \frac{q_{sat}(T_s) - q}{r_a + r_s}$$

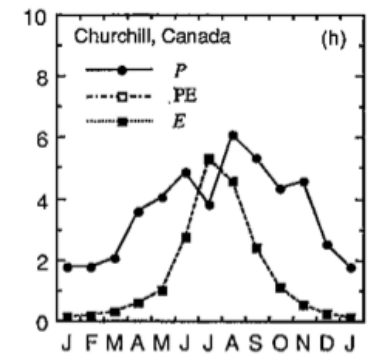
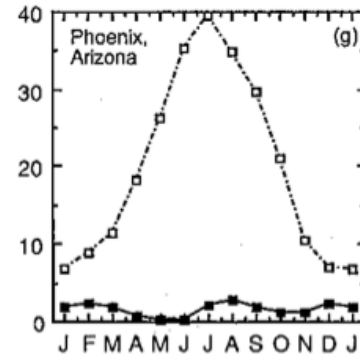
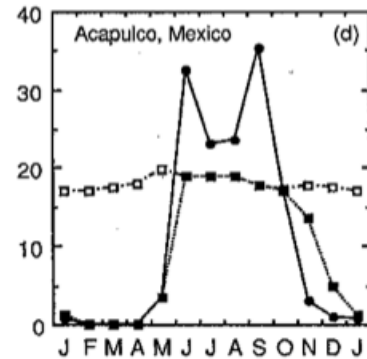
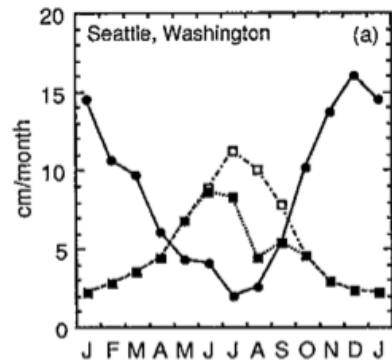
Evapotranspiration depends both on energy, atmospheric conditions, and land surface conditions!



Basic concepts and processes

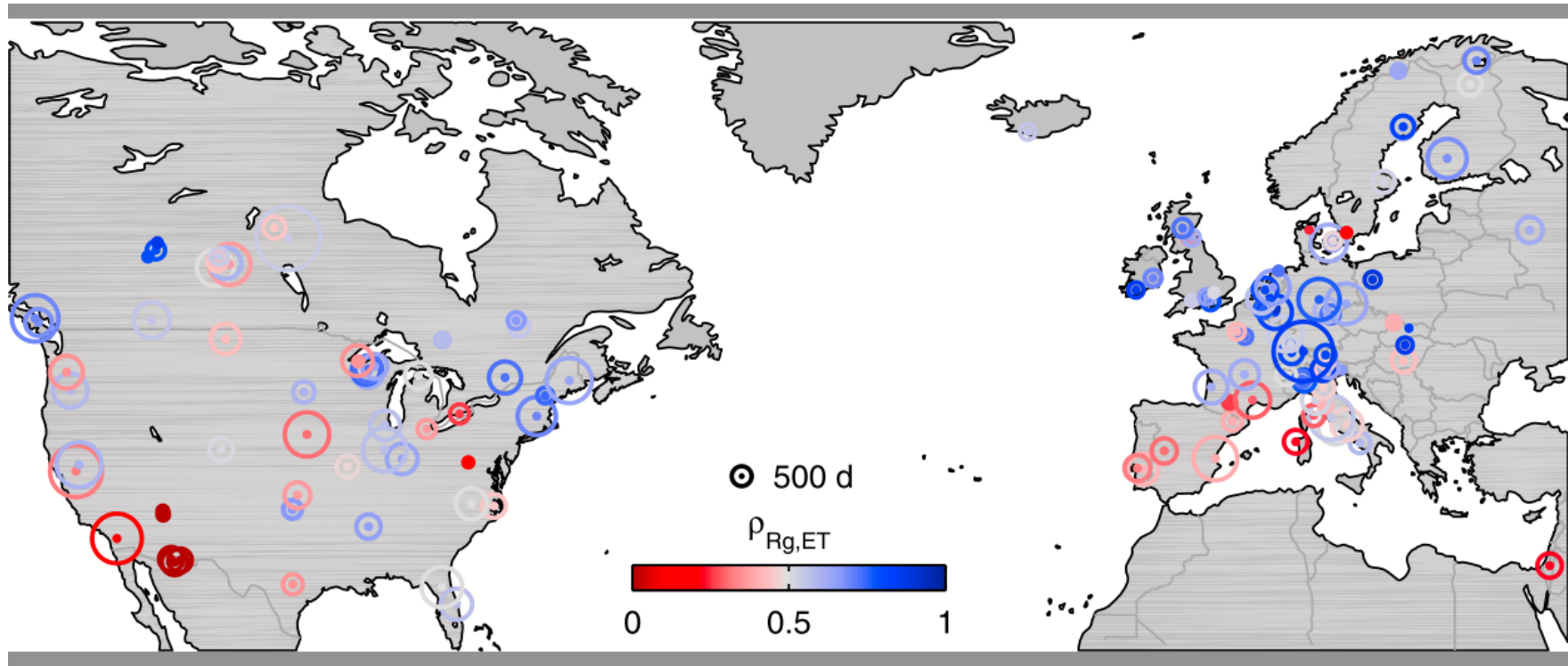
Control on ET

Basic concepts and processes



(Hartmann 1994)





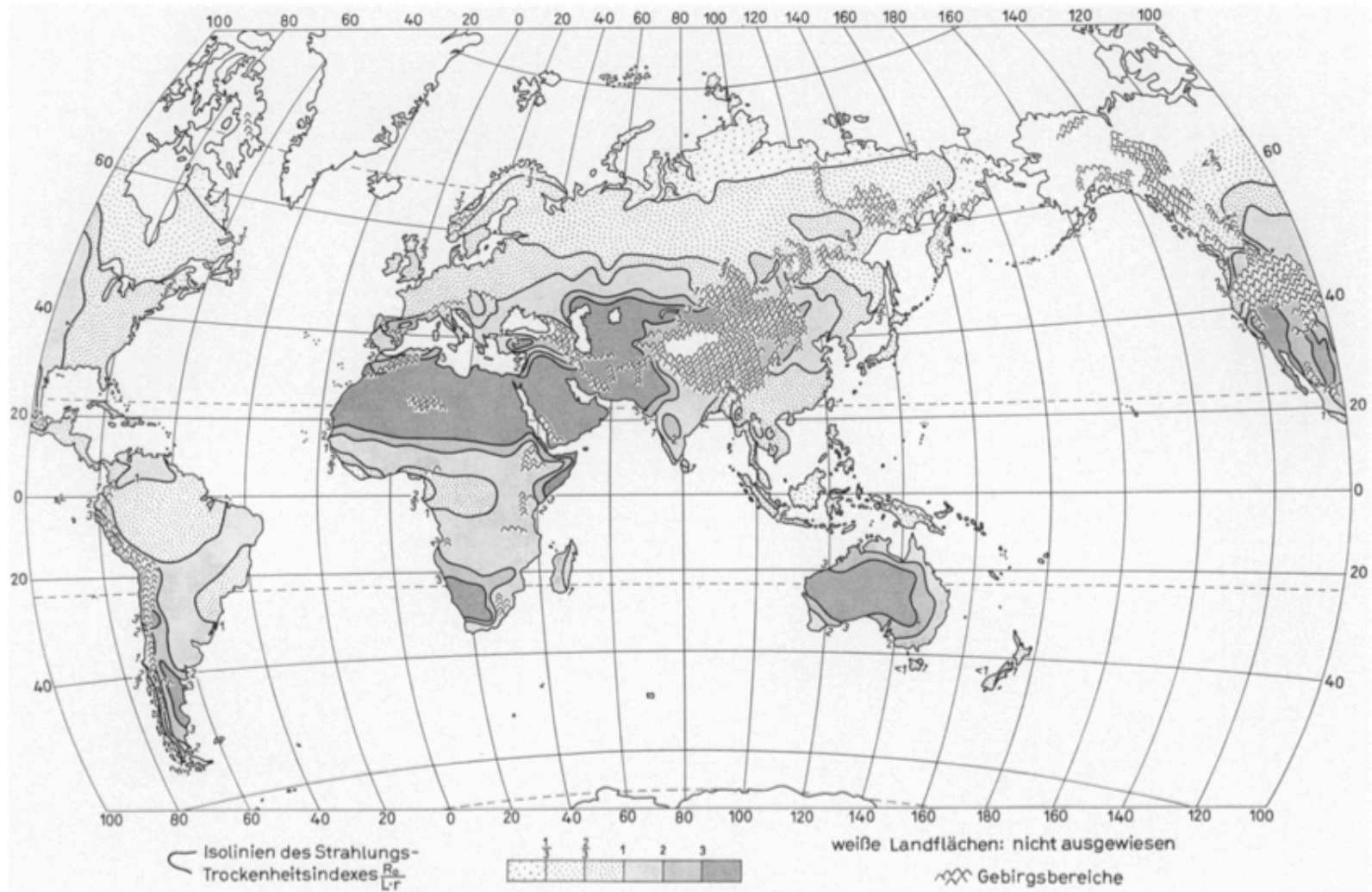
Rather surface controlled Energy controlled

(Teuling 2009)



Control on ET

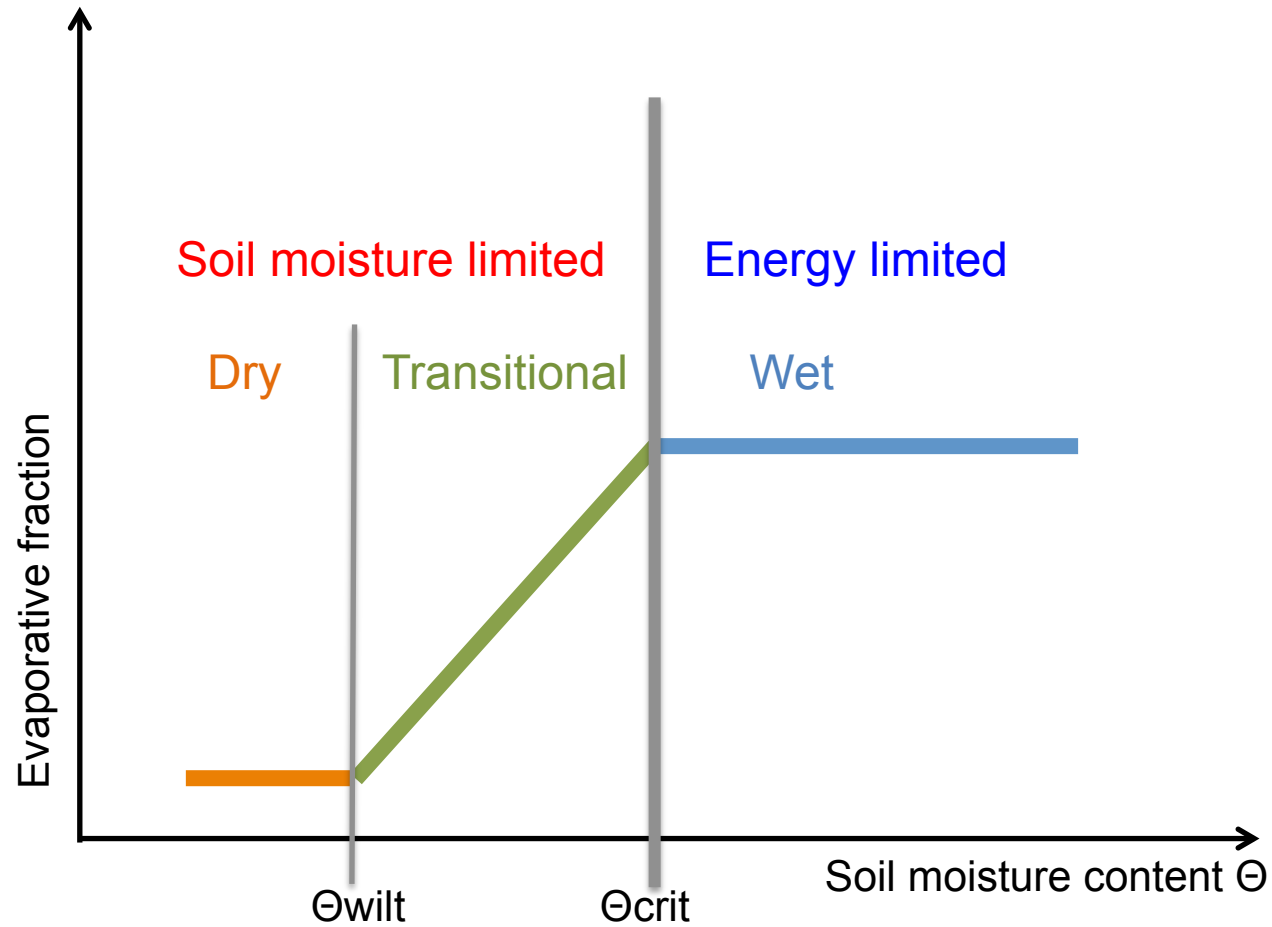
Basic concepts and processes

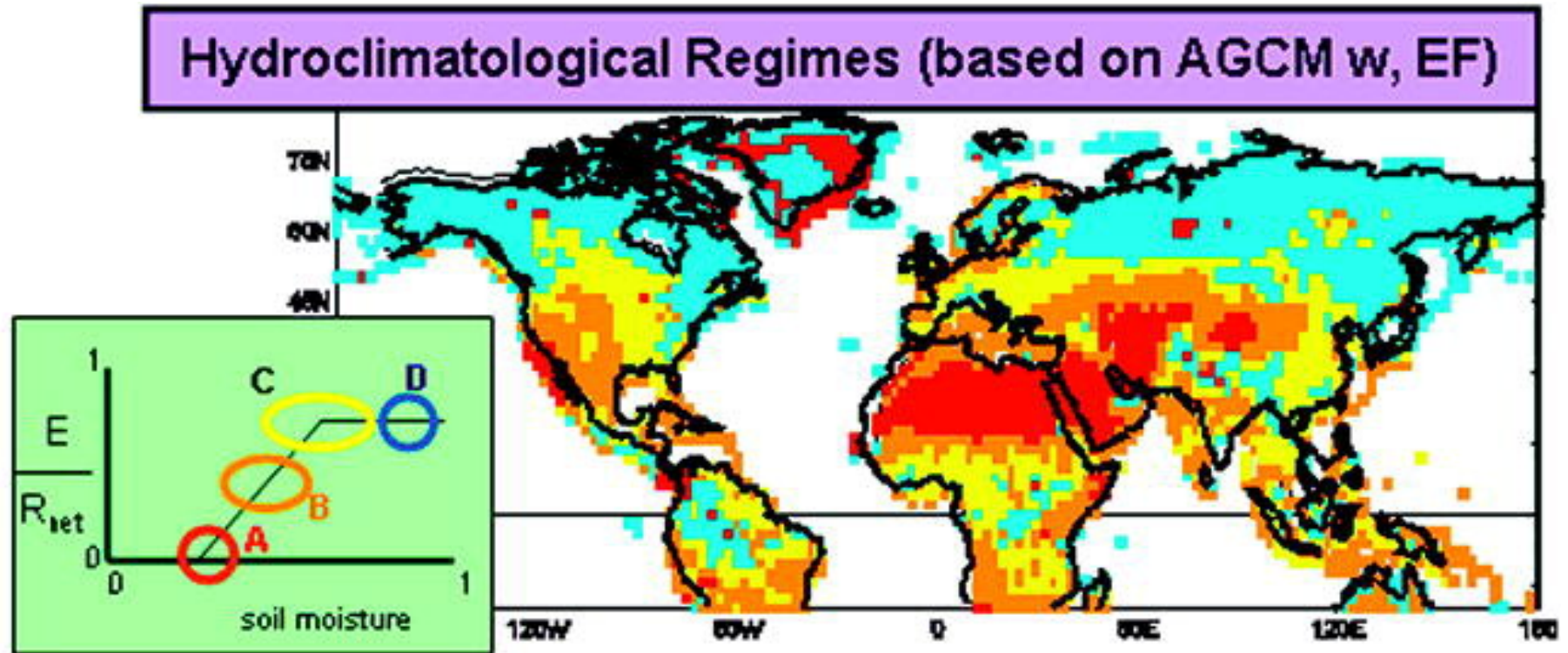


$$R_n/(L \cdot P)$$

(Budyko 1955)







(Koster et al. 2009)