



University of
Zurich ^{UZH}

Advanced Earth Observation to Quantify Mechanisms of Feedback, Interaction and Scale in the Earth System

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Content

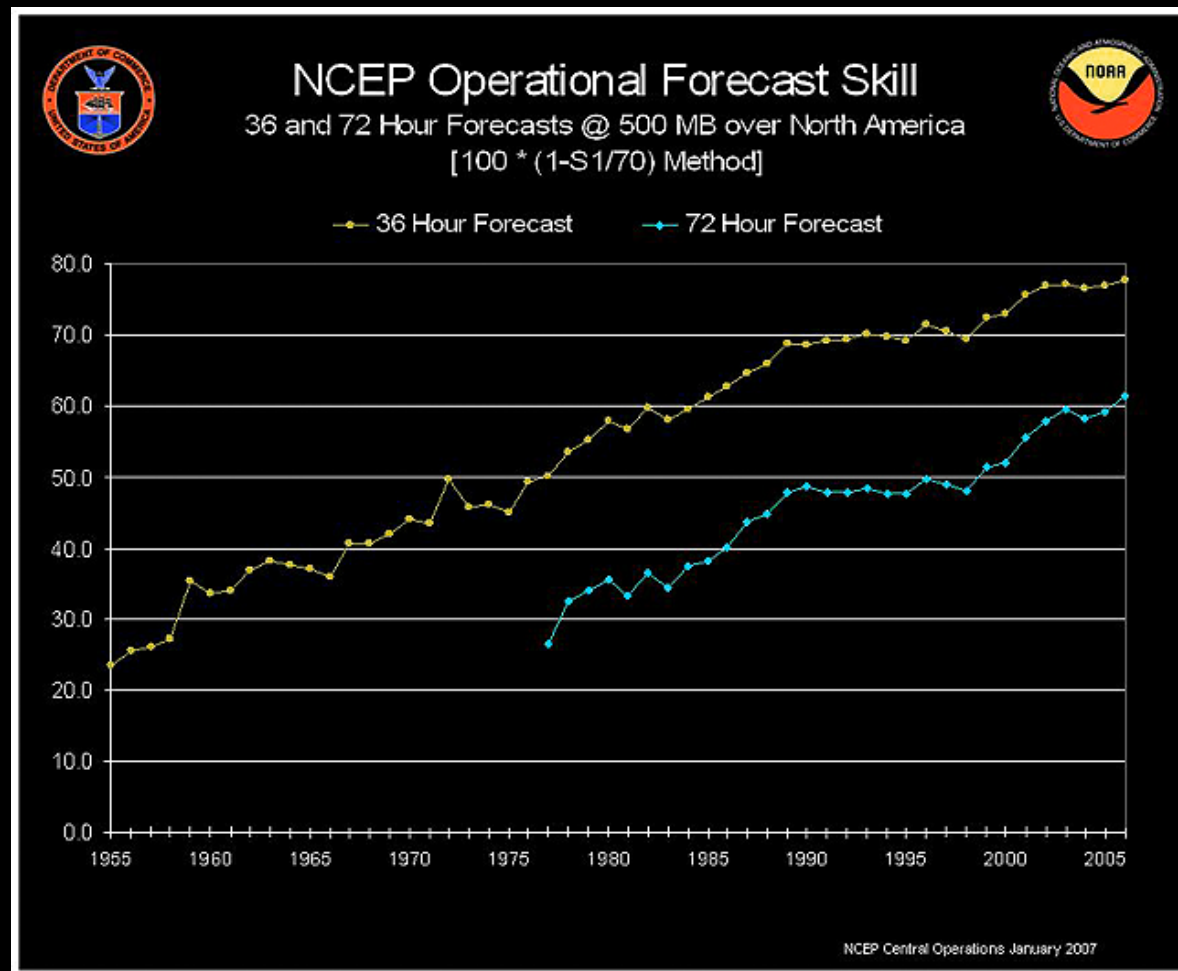
- Aspects of computational challenges and data
- Mechanisms of integration, feedback and scale
- Dynamic vegetation and quantifying human impact
- Conclusions and outlook

Aspects of computational challenges and data



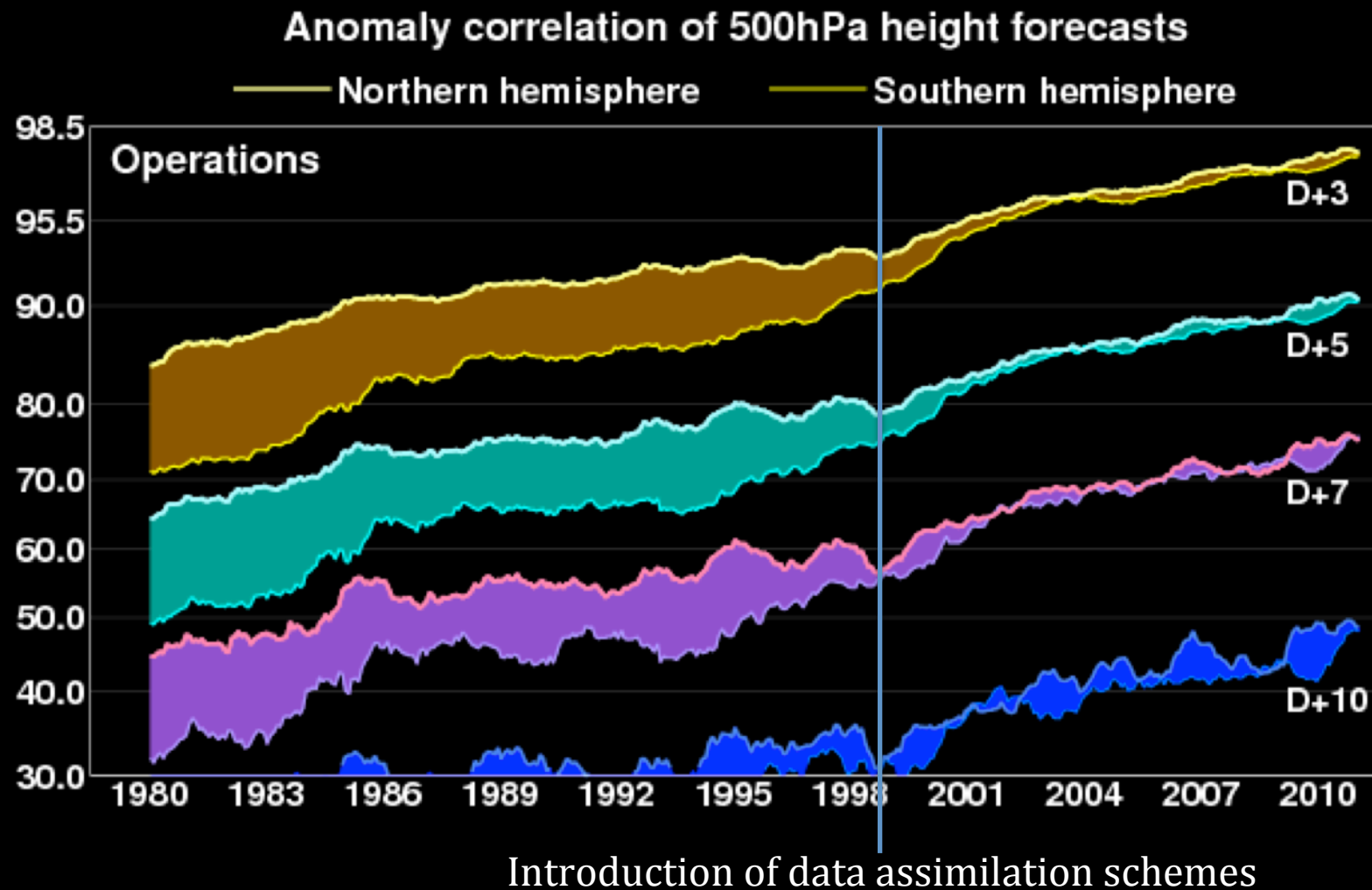
The Horn that Matters ...

Evolution of Forecast Skills

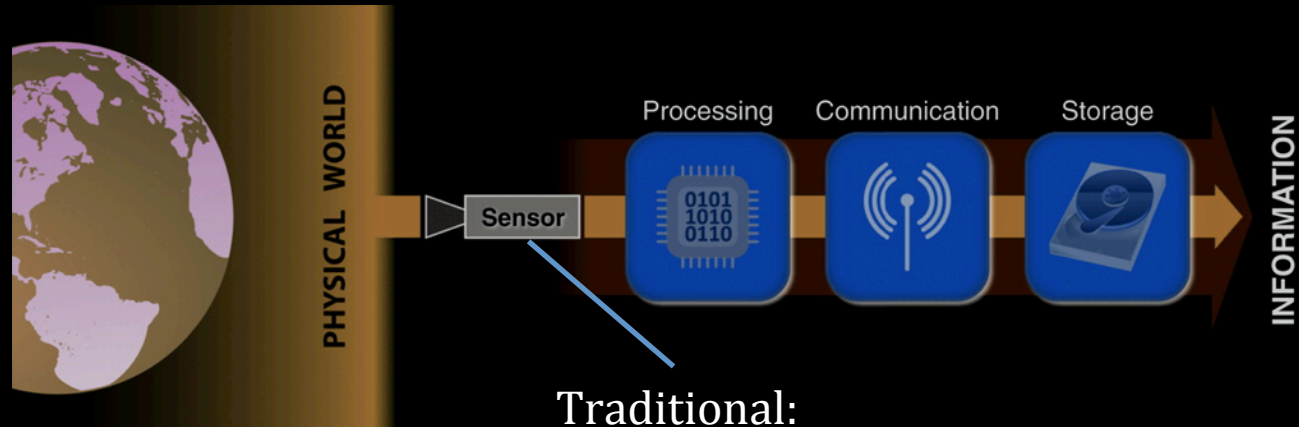


Improvements in forecasts come from
repeated challenges to models by data over time

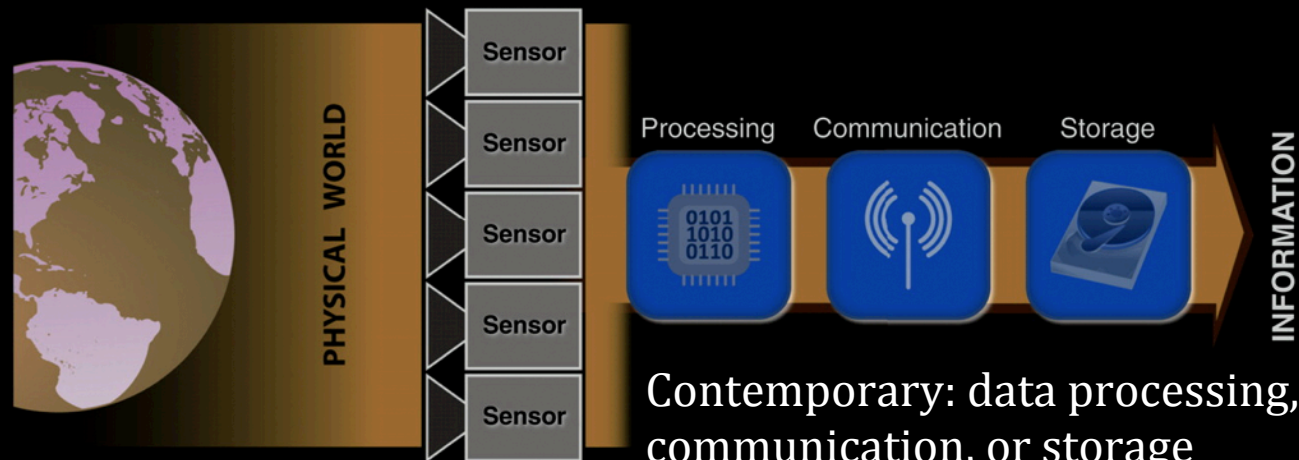
Evolution of Analytical Methods



Transition of the Operating Environment (Data Deluge)

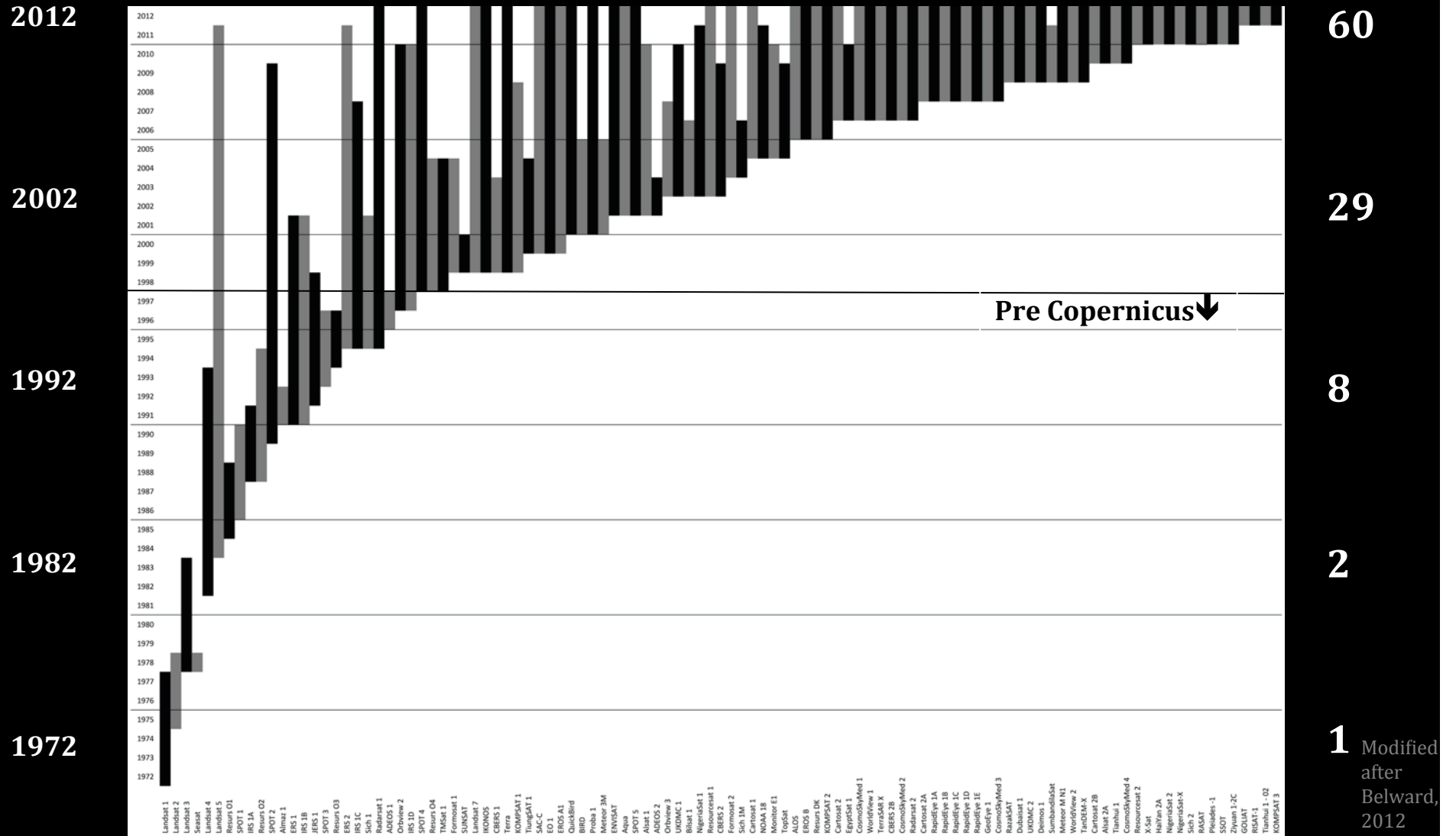


Traditional:
Sensor is the bottleneck

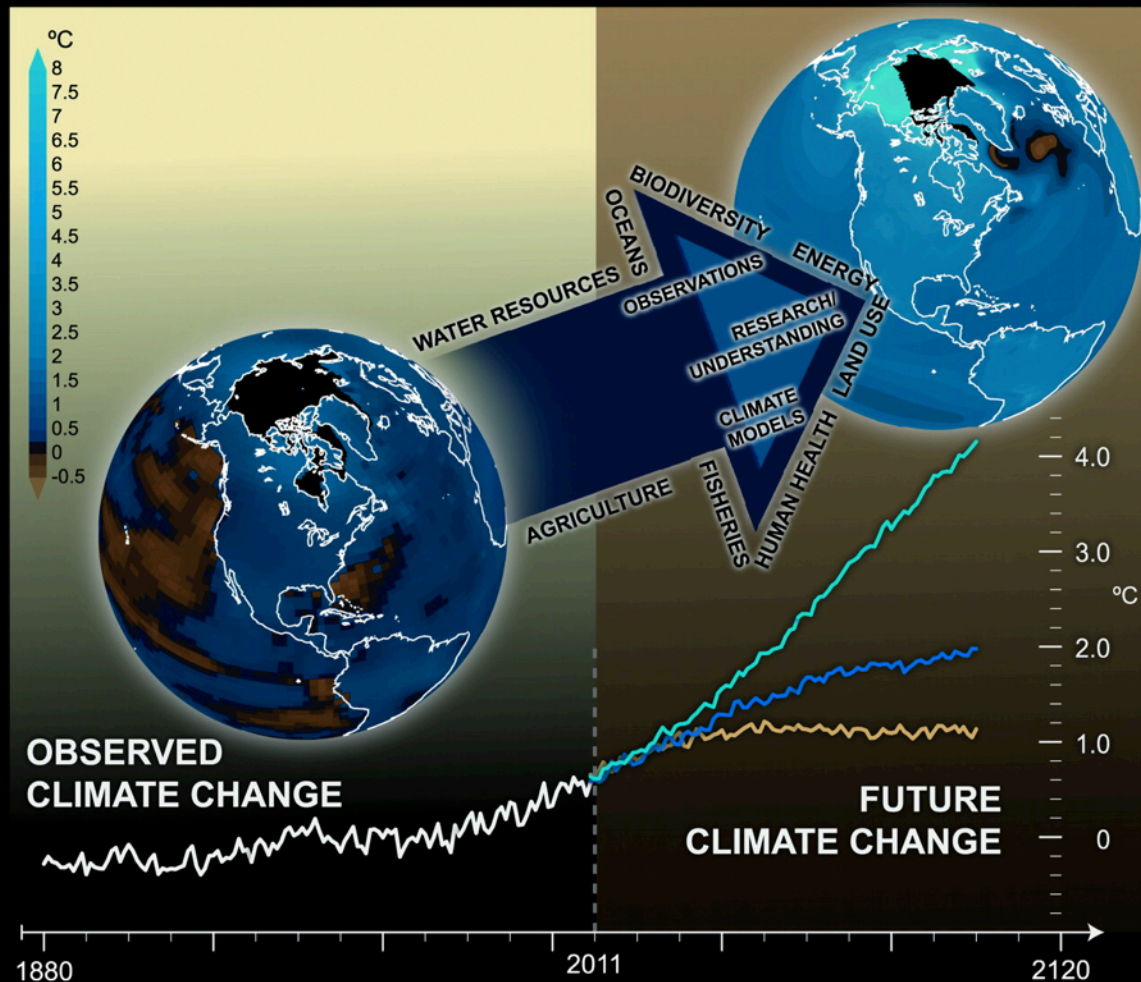


Contemporary: data processing,
communication, or storage
subsystem is bottleneck

Polar orbiting imagers operating per decade (<100m resolution)



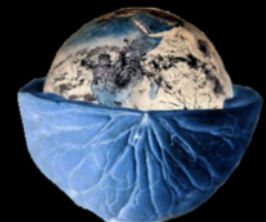
Observed and Future Climate Variability



Climate data (and other!) dramatically increase in volume and complexity.

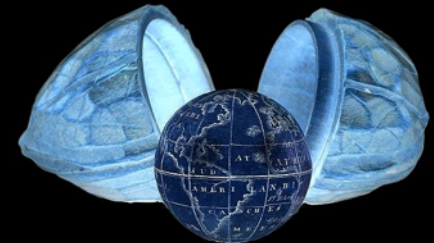
In a data nutshell

- Nearing the 4th paradigm change in research (1. Theory, 2. Experiment, 3. HPC (numerical modelling), 4. BigData)
- In transit from data-poor to data-rich approaches
- Infrastructure as a service (IaaS) has become a commodity (Modeling as a Service (MaaS) not yet!)
- Data replication and reproducibility
 - In 2009 global data production exceeded global storage capacity production
 - New strategies and workflows must consider data that is not stored/archived



Data in another nutshell

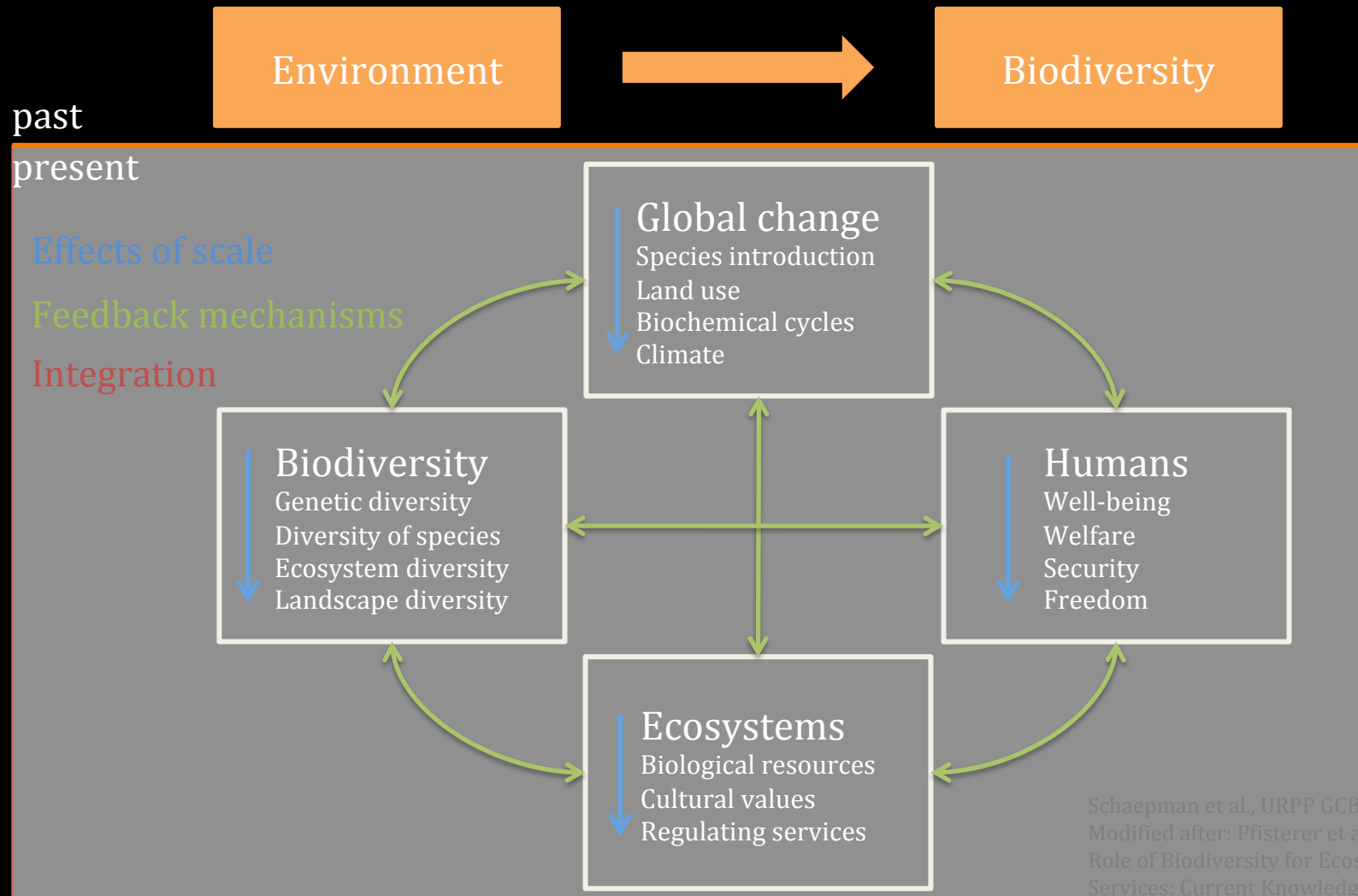
- ... or the human dimension of data
 - Policy measures for science information and data management
 - Governance of a (world-wide) data-sharing attitude
 - Serving both, scientists and non-scientists with observed and predicted data, as well as advice
 - Attribution, environmental justice, and liability



Mechanisms of integration, feedback and scale

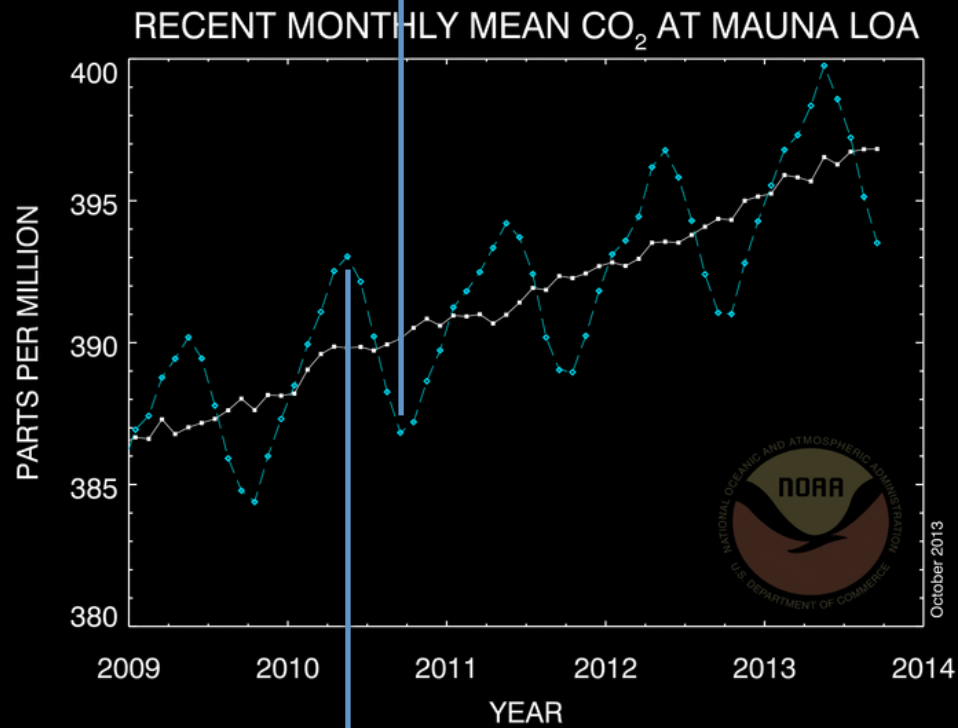


Changing views



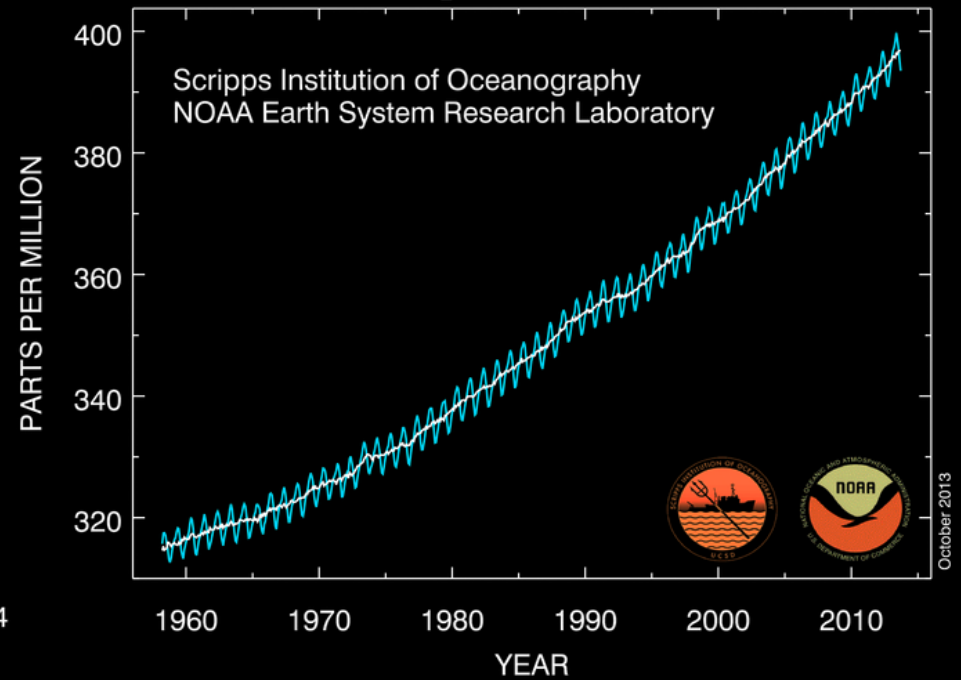
The Knowns

September – low

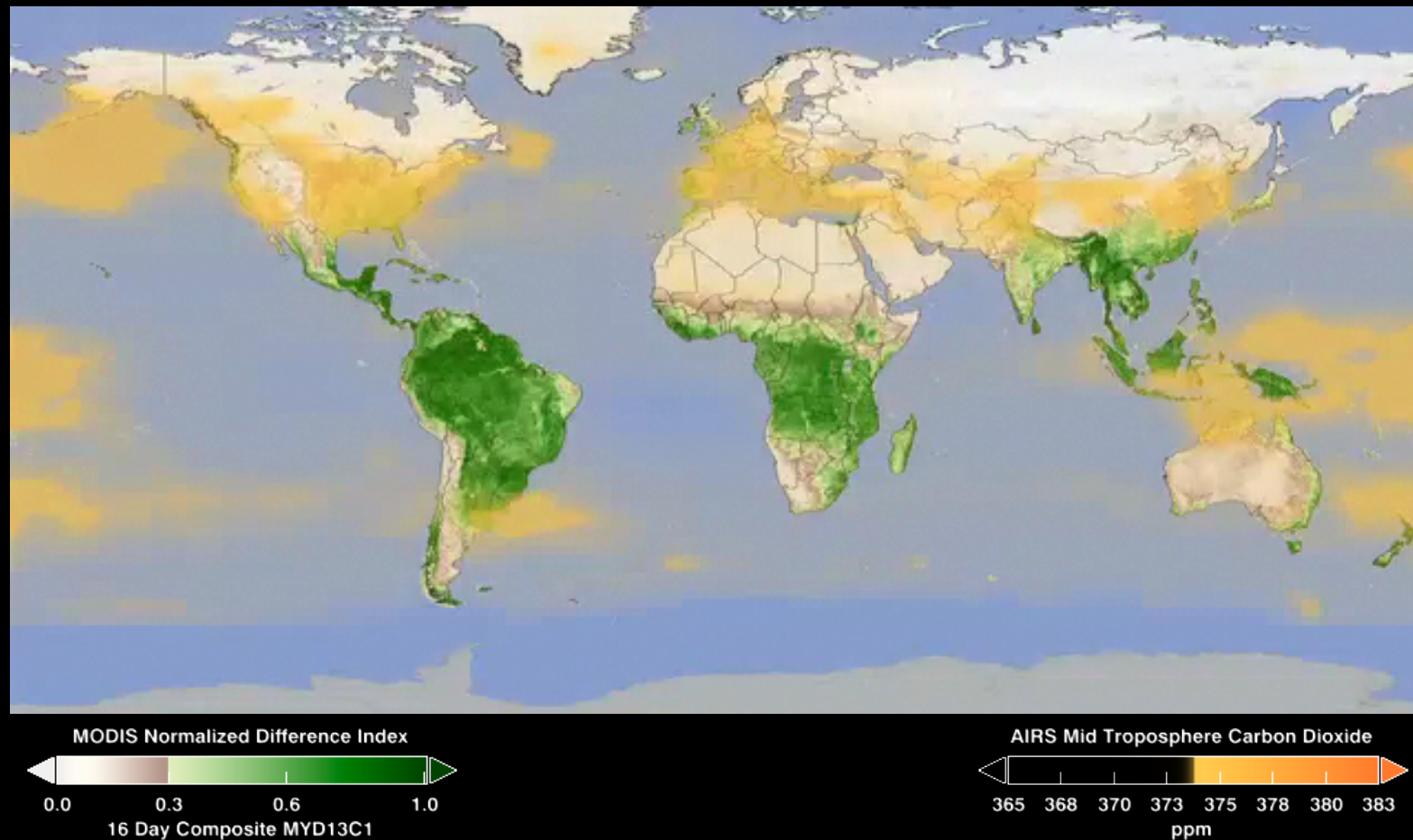


May – high

Atmospheric CO₂ at Mauna Loa Observatory

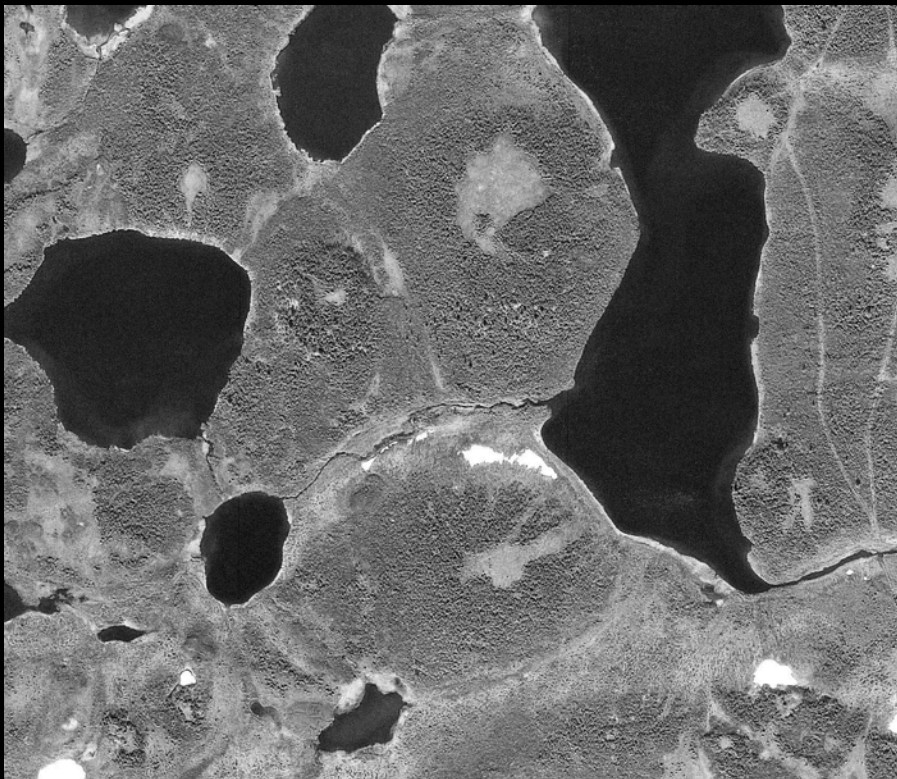


The not so well knowns

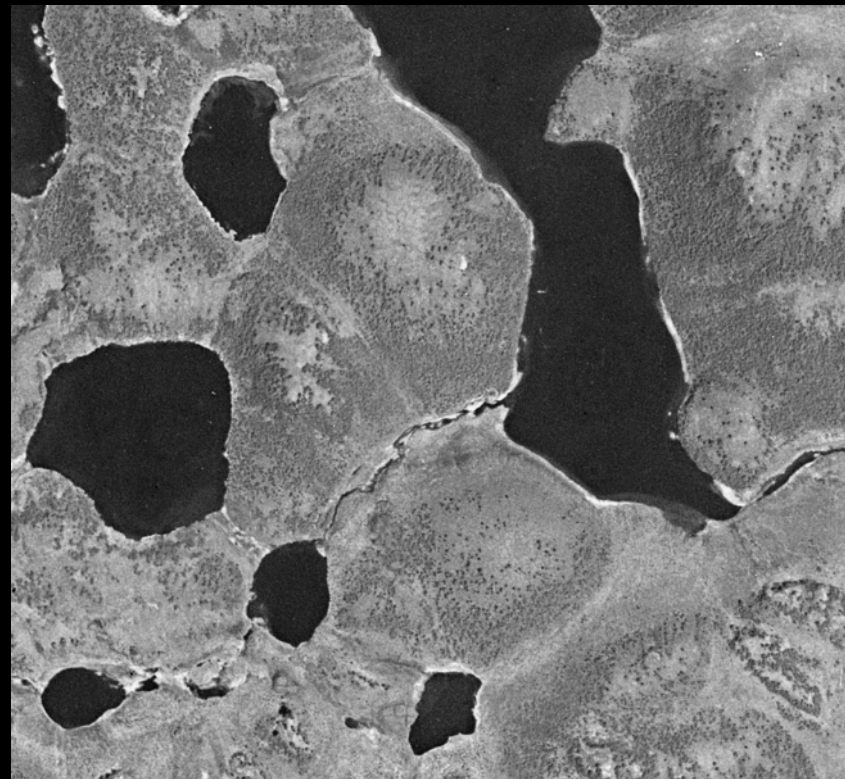


Seasonal cycle of vegetation and the concentration
of carbon dioxide in the atmosphere

Migrating Siberian shrubs



2009



1966

Feedback mechanisms

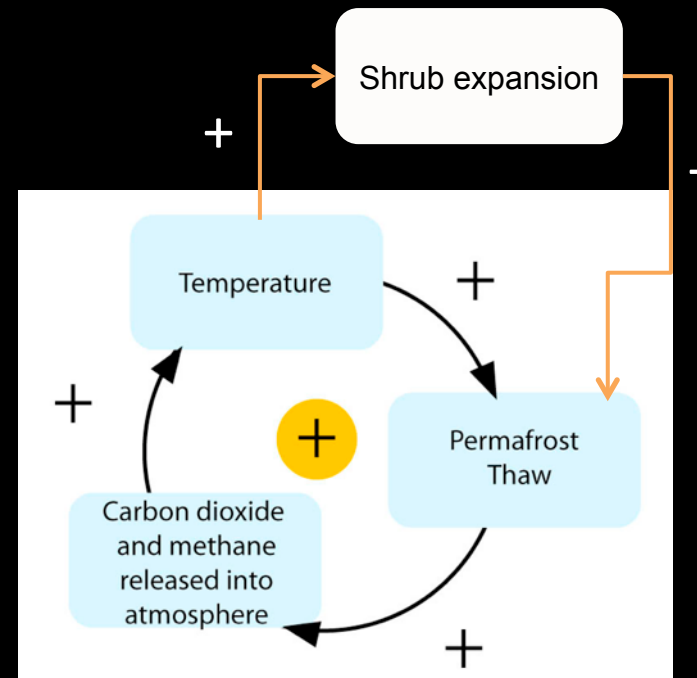
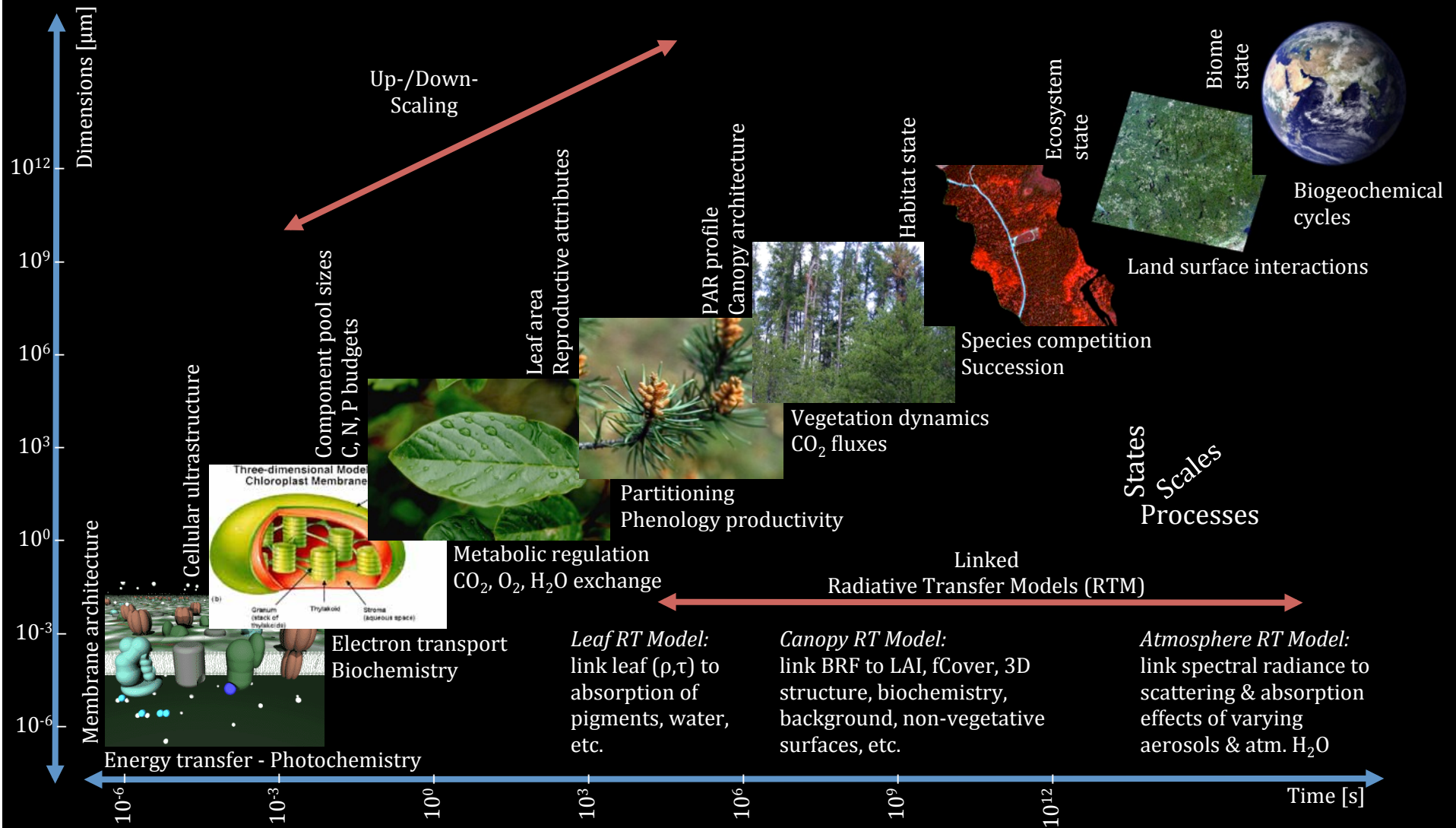
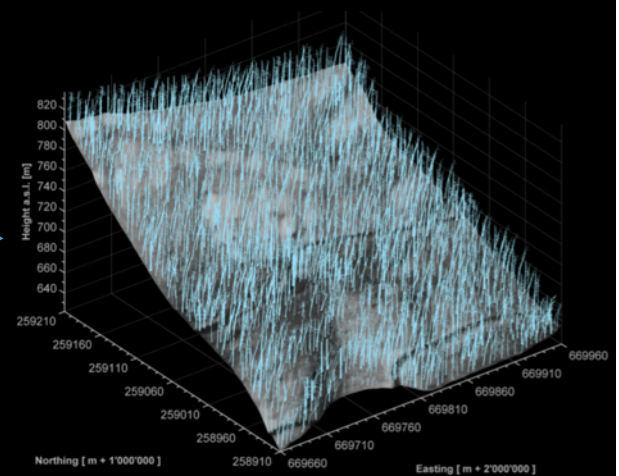
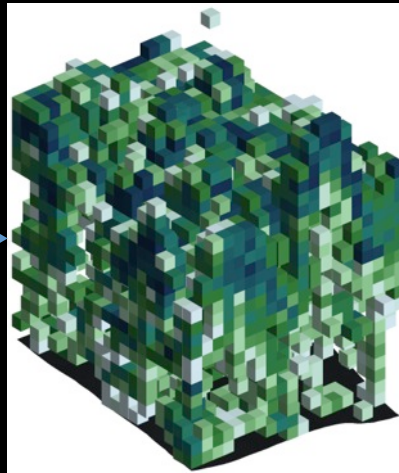
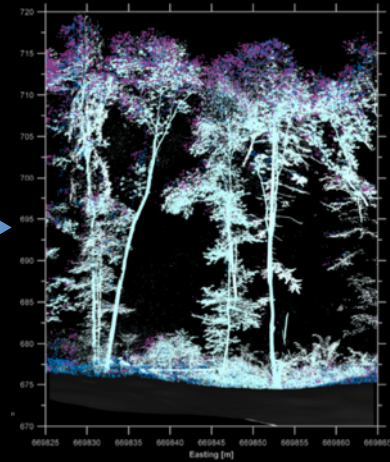
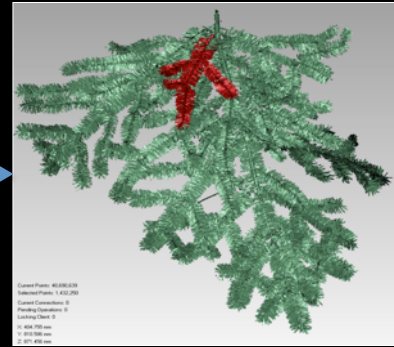


Photo: M. Schaepman, July 2013, Kytalyk research station, Yakutia
Blok D. et al., (2010). Shrub expansion may reduce summer permafrost
thaw in Siberian tundra. *Global Change Biology* 16: 1296-1305.

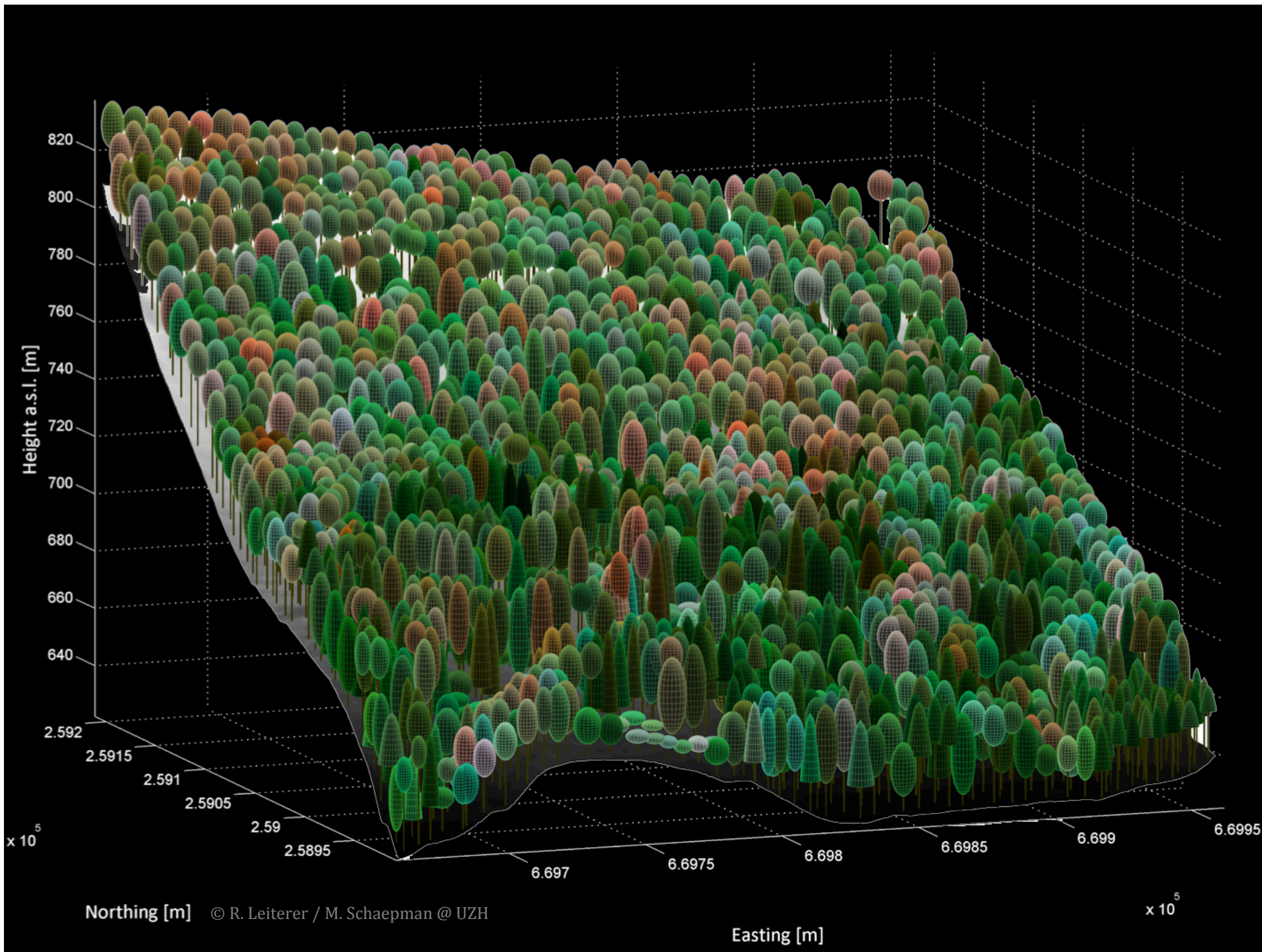
Effects of scaling: physical baseline



From needles to canopies



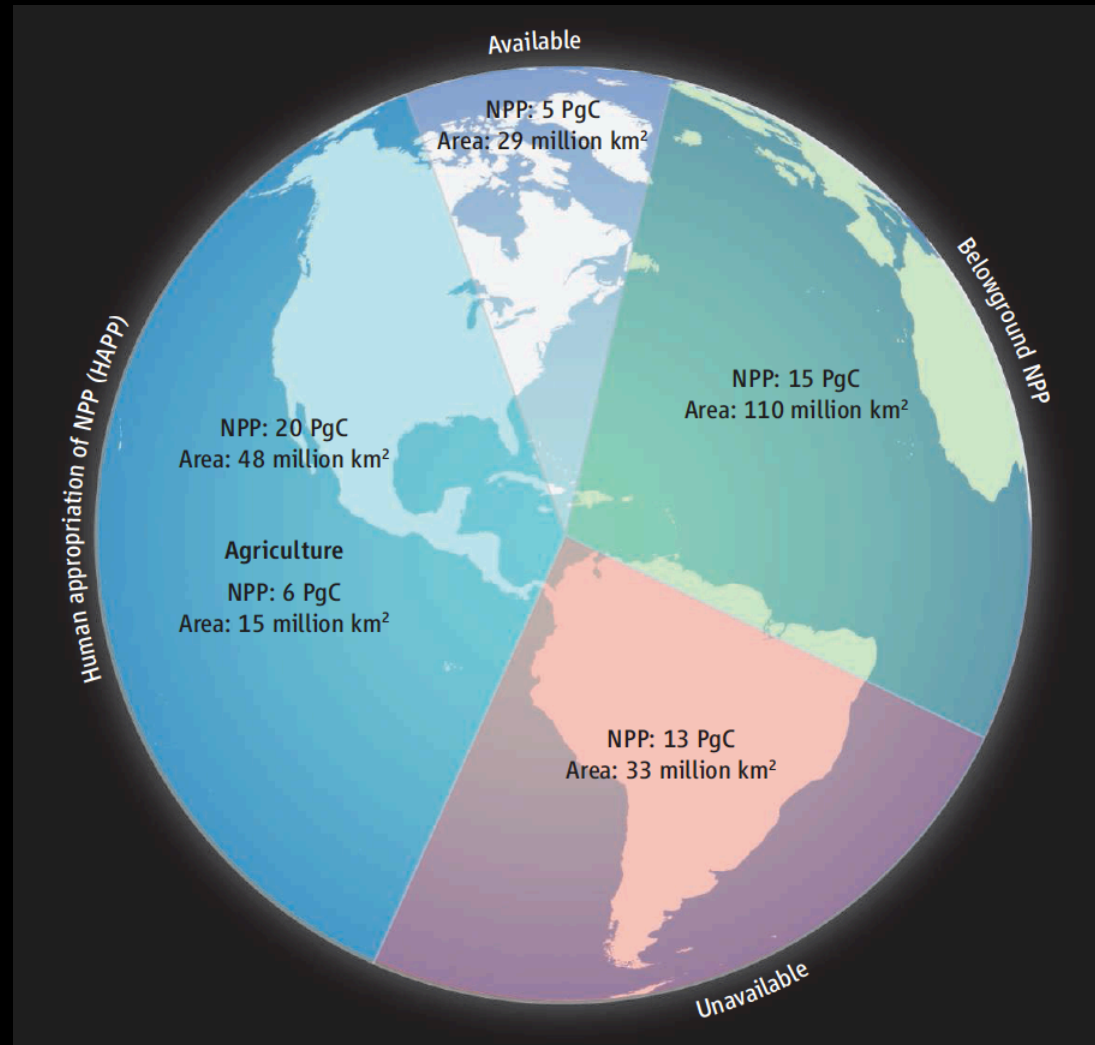
Pfeifer et al; Leitterer et al. 2014
Yanez-Rausell, L., Minimizing Measurement Uncertainties of
Coniferous Needle-Leaf Optical Properties, Part I:
Methodological Review. IEEE JSTARS, in press, 2014
Rautiainen, M. et al. A note on upscaling coniferous needle
spectra to shoot spectral albedo. RSE, 117, 469-474, 2012



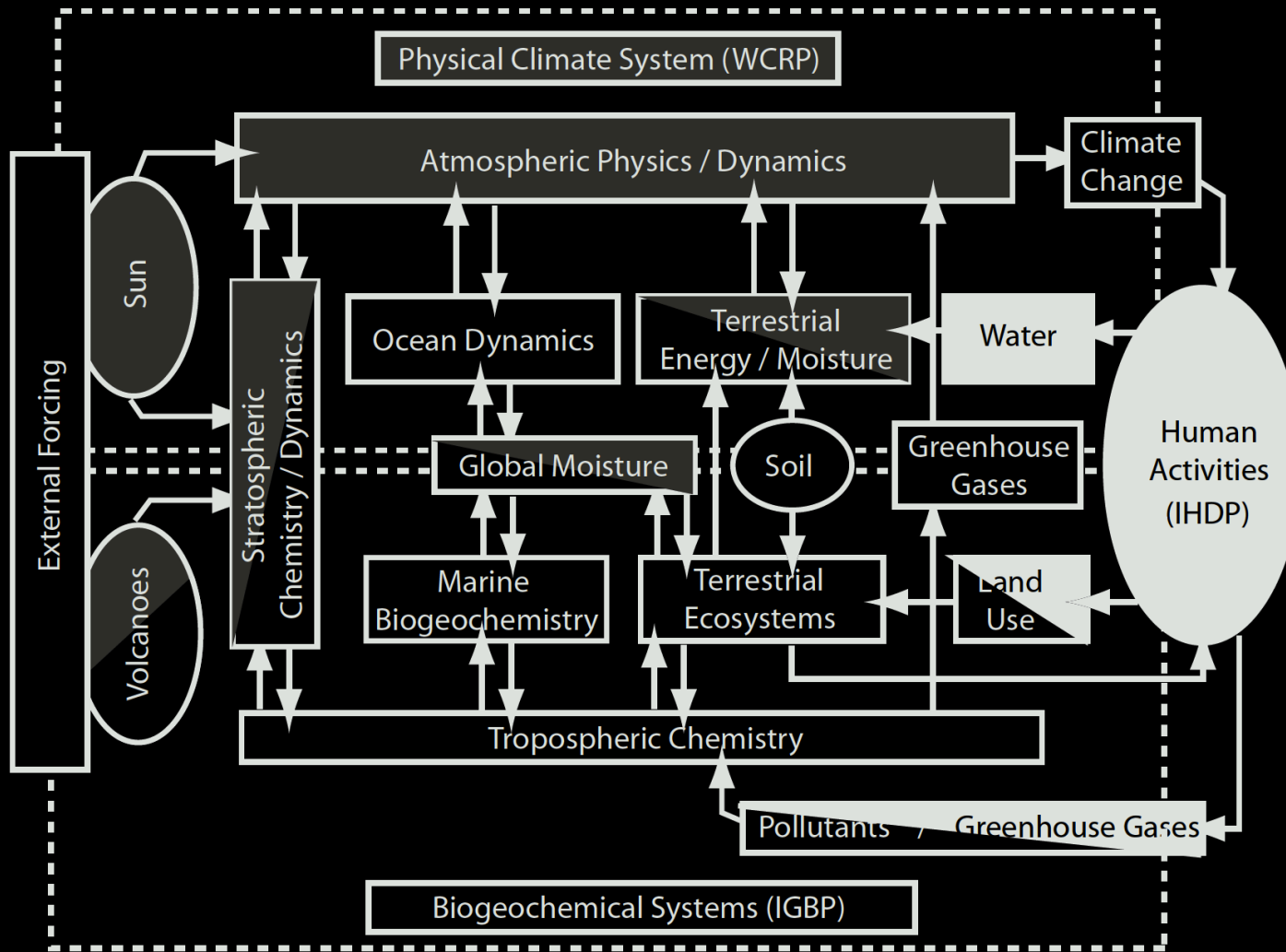
Dynamic vegetation and quantifying human impact



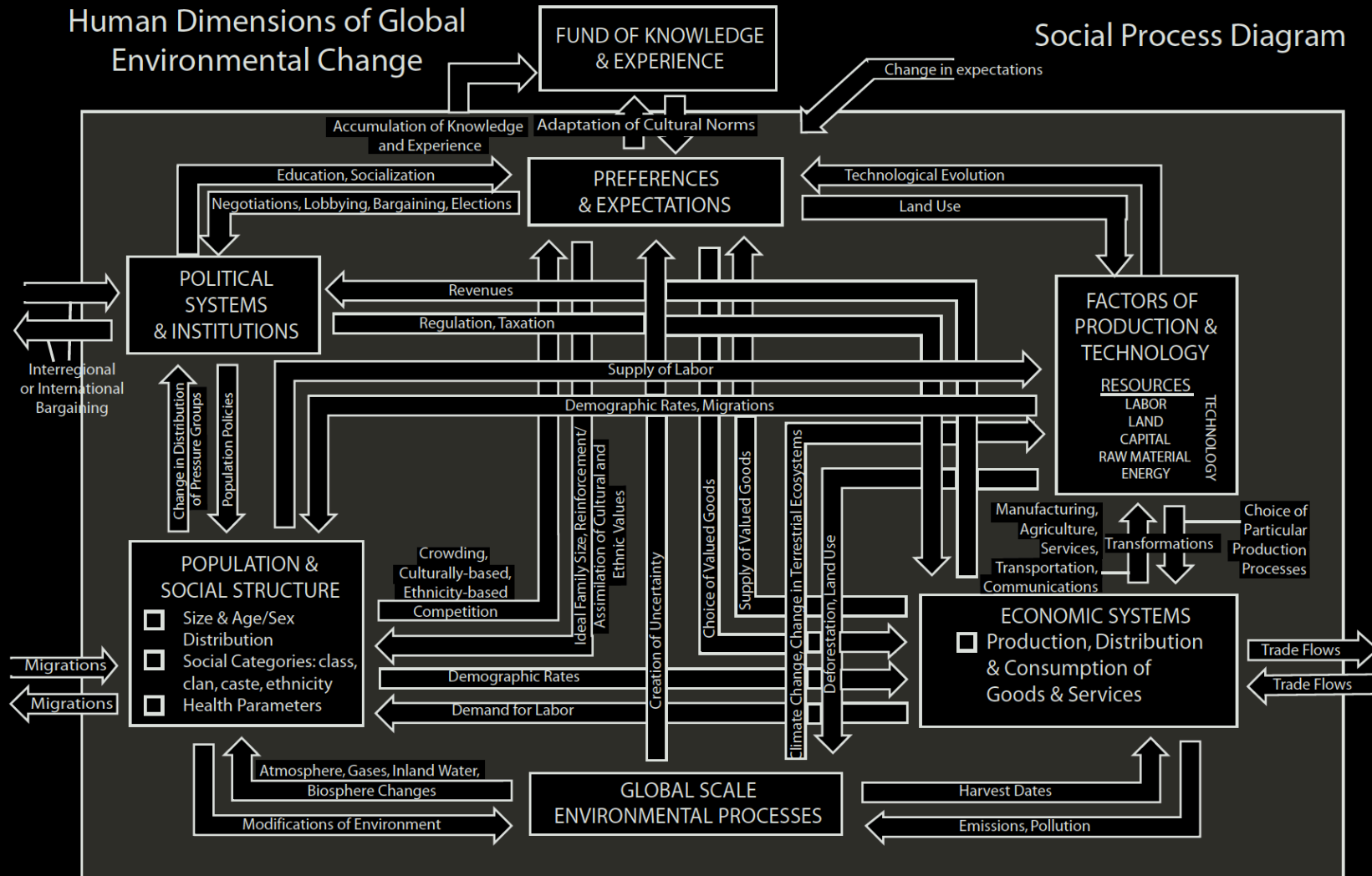
A measurable planetary boundary for the biosphere



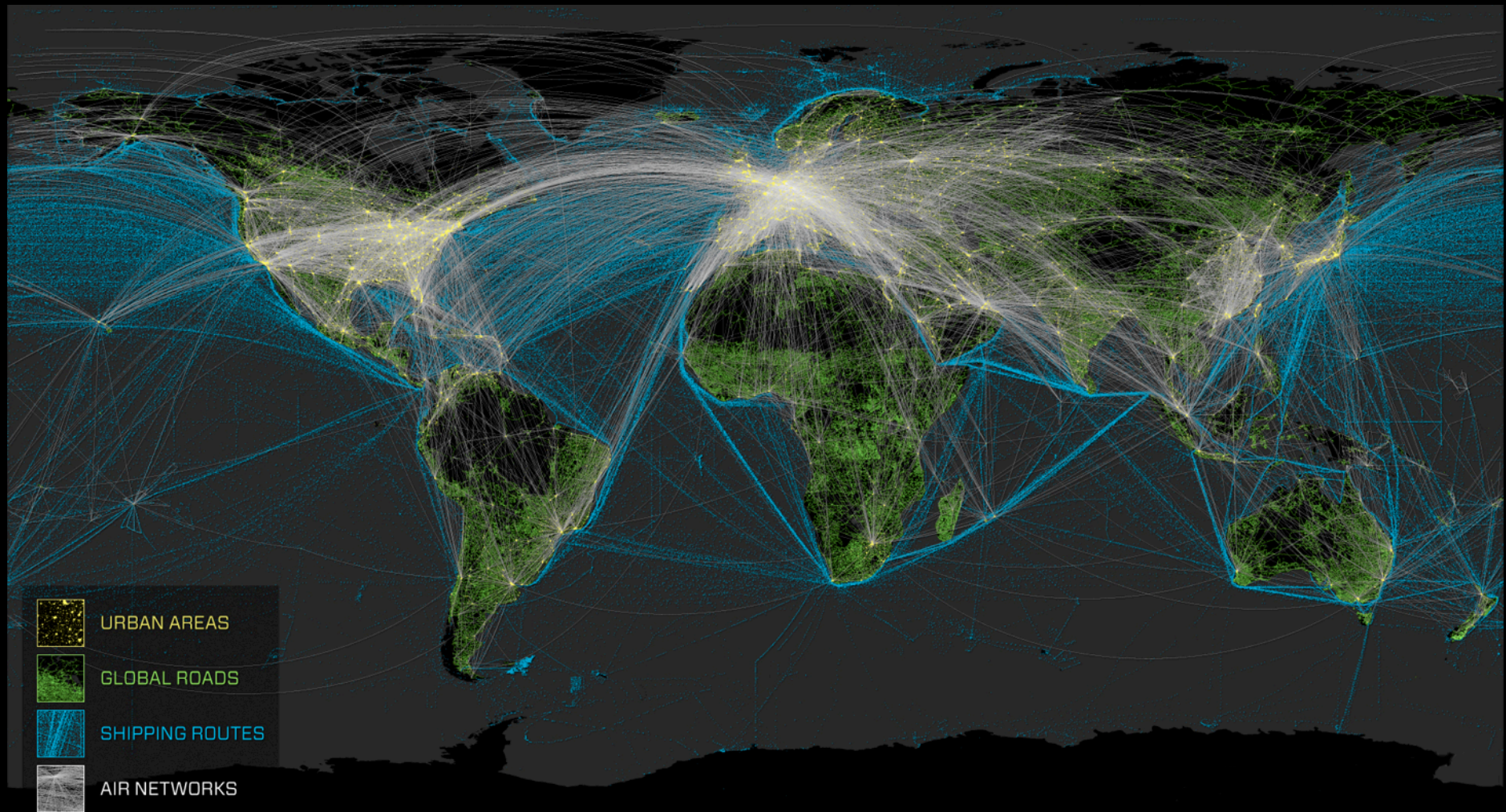
Conceptual Model of the Earth System



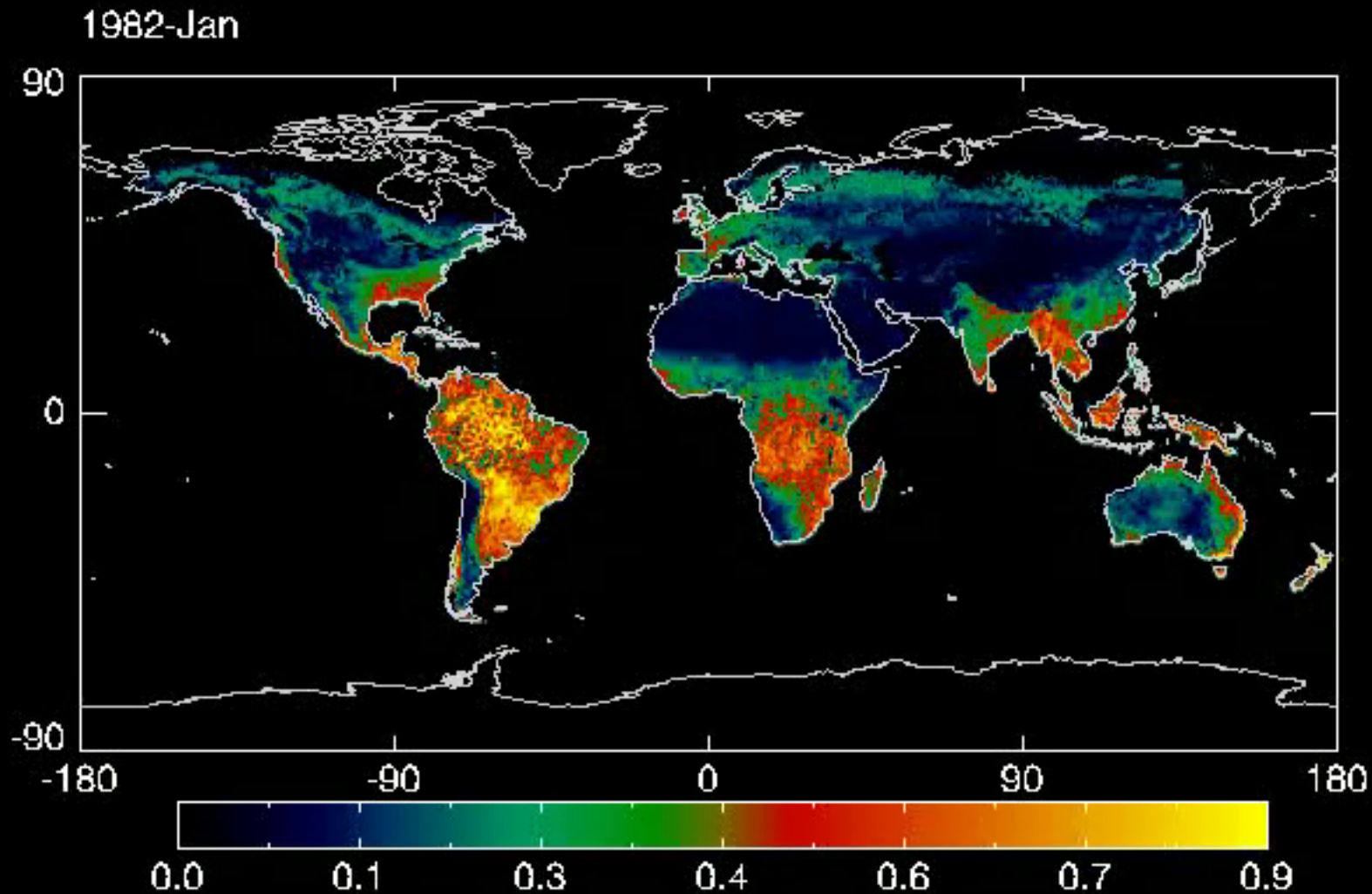
Human Dimensions of Global Environmental Change



Global transportation system

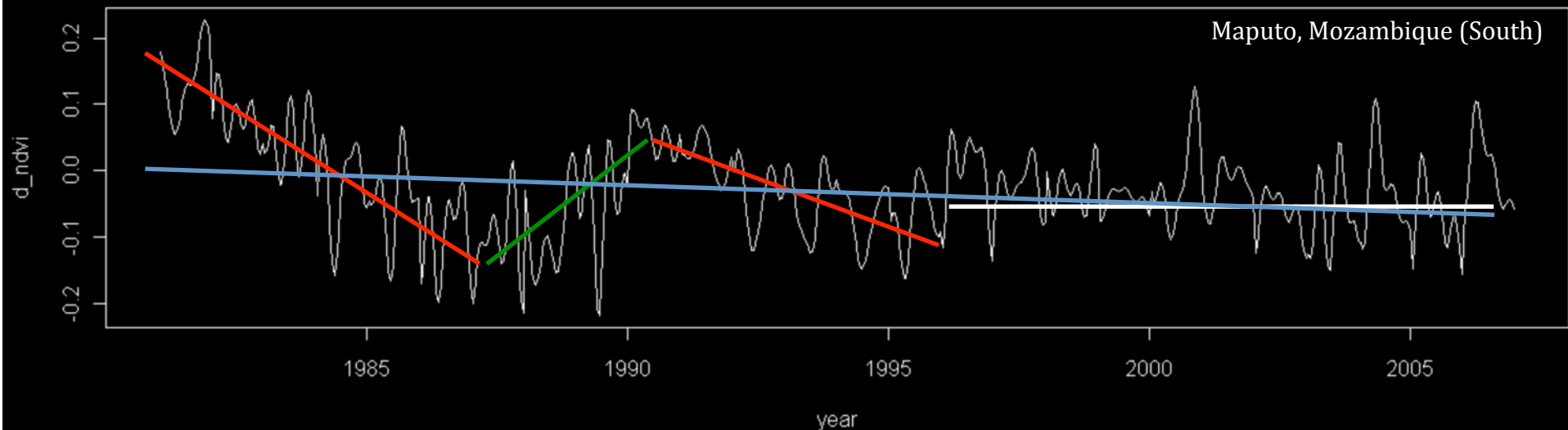


Global vegetation dynamics



Vegetation trend changes

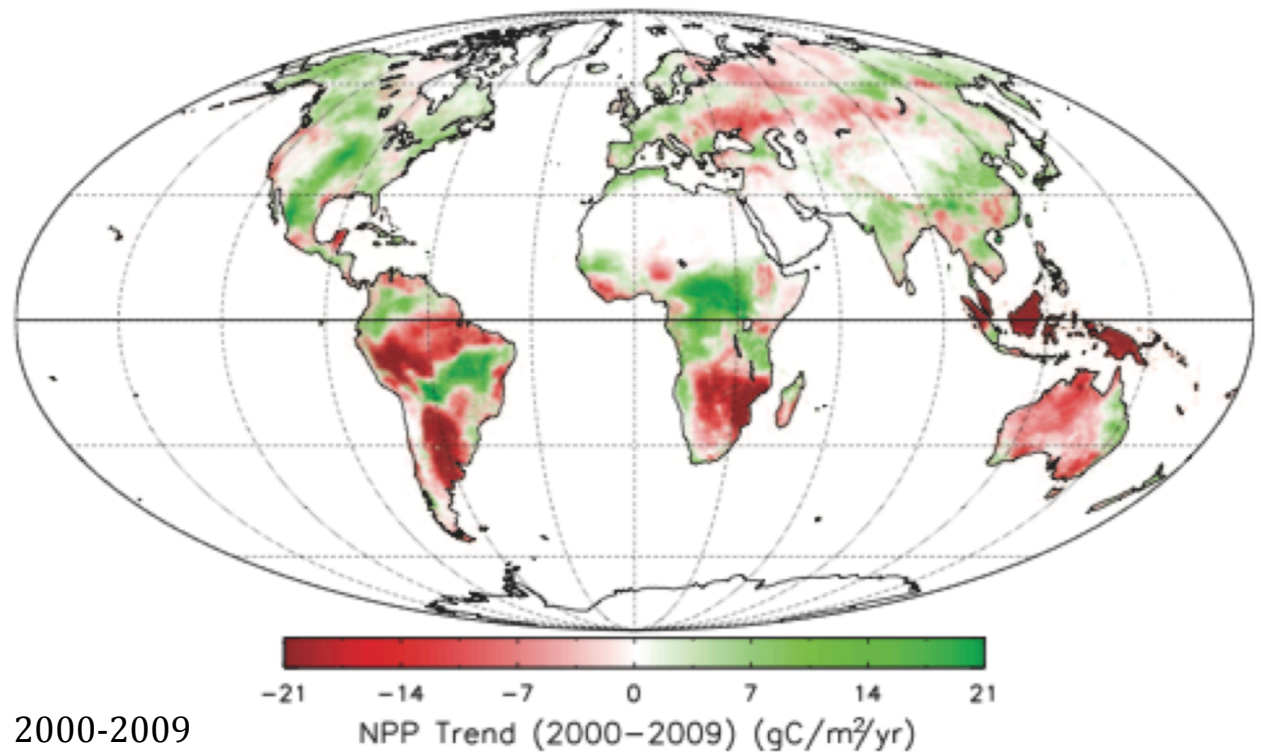
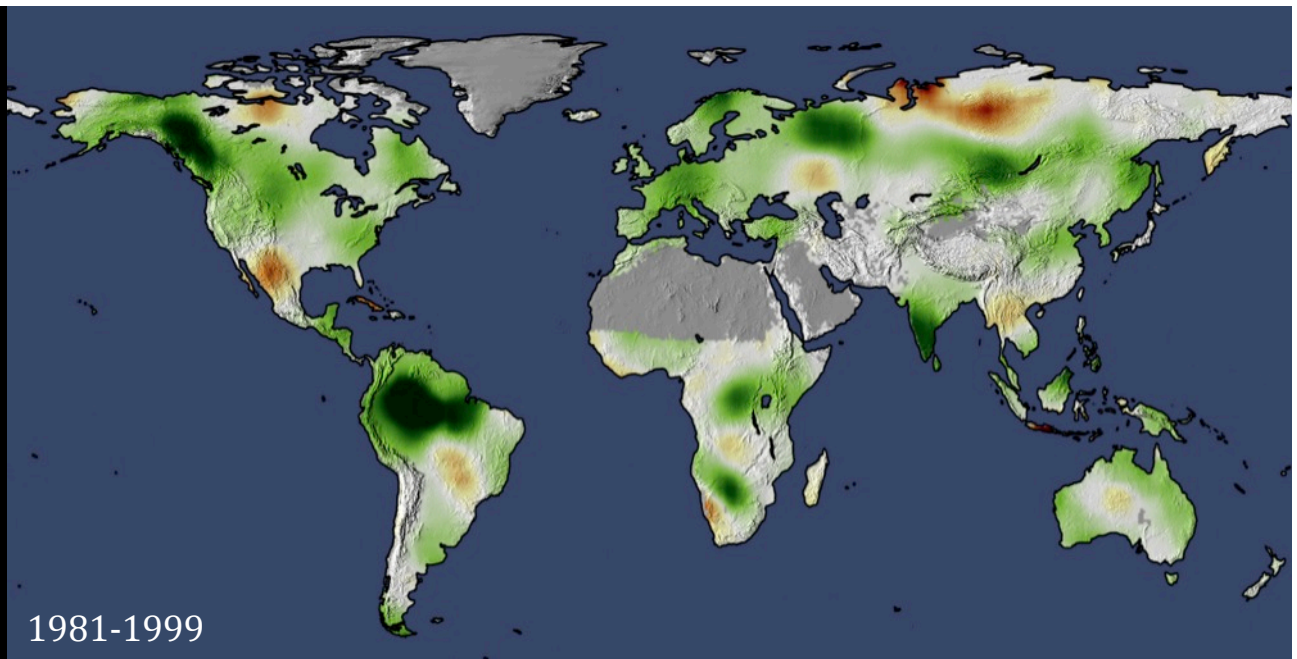
Short term changes vs. long term trends



Biospheric trends: decadal changes

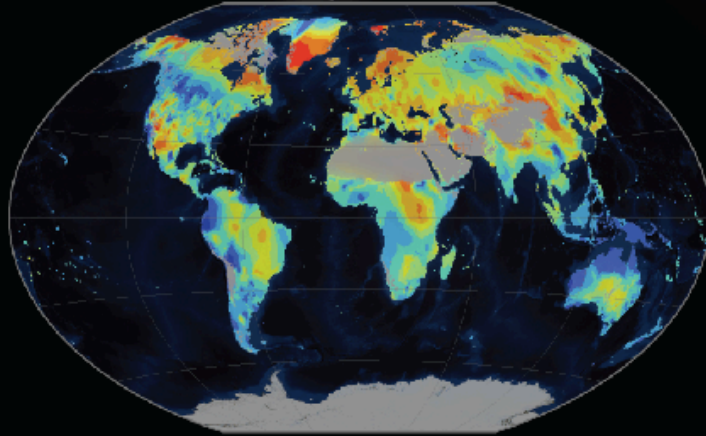
Nemani RR, Keeling CD, Hashimoto H et al. (2003) Climate-Driven Increases in Global Terrestrial Net Primary Production from 1982 to 1999. *Science*, 300, 1560-1563.

Zhao M, Running SW (2010) Drought-Induced Reduction in Global Terrestrial Net Primary Production from 2000 Through 2009. *Science*, 329, 940-943.

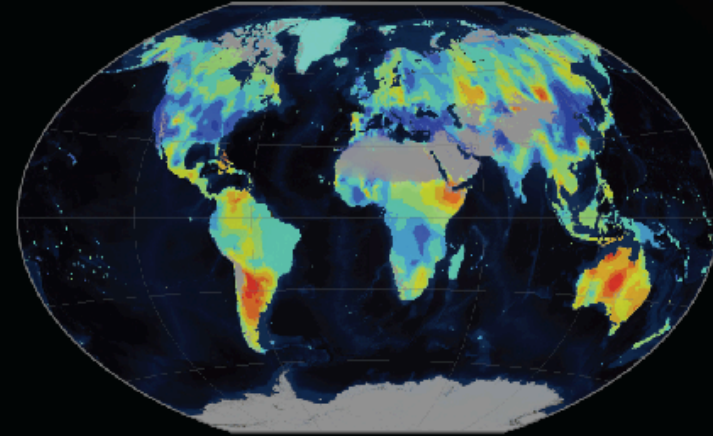


Trend changes in global climatologies

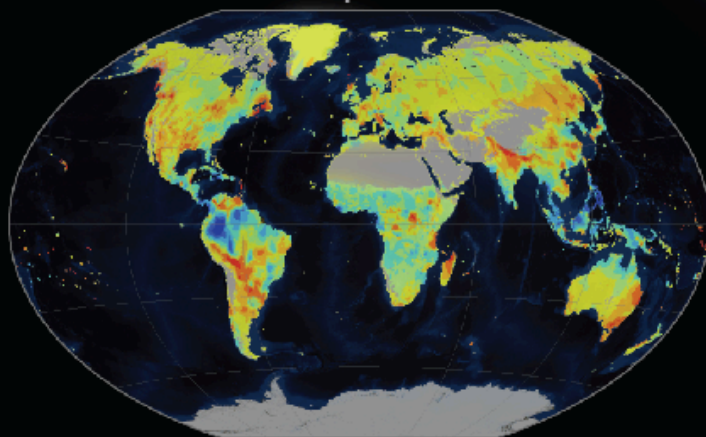
Temperature



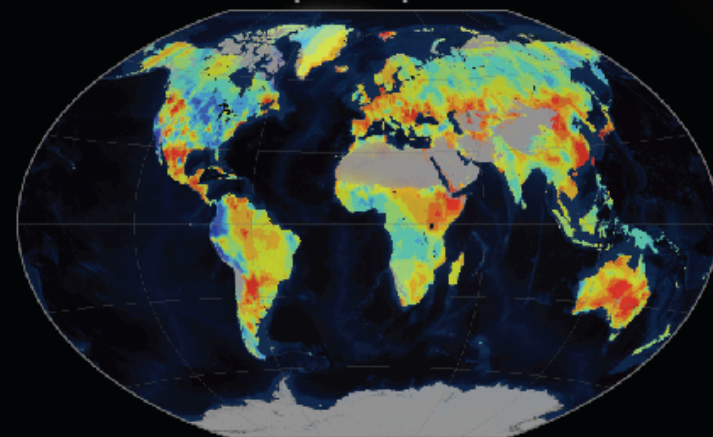
Cloudiness



Precipitation

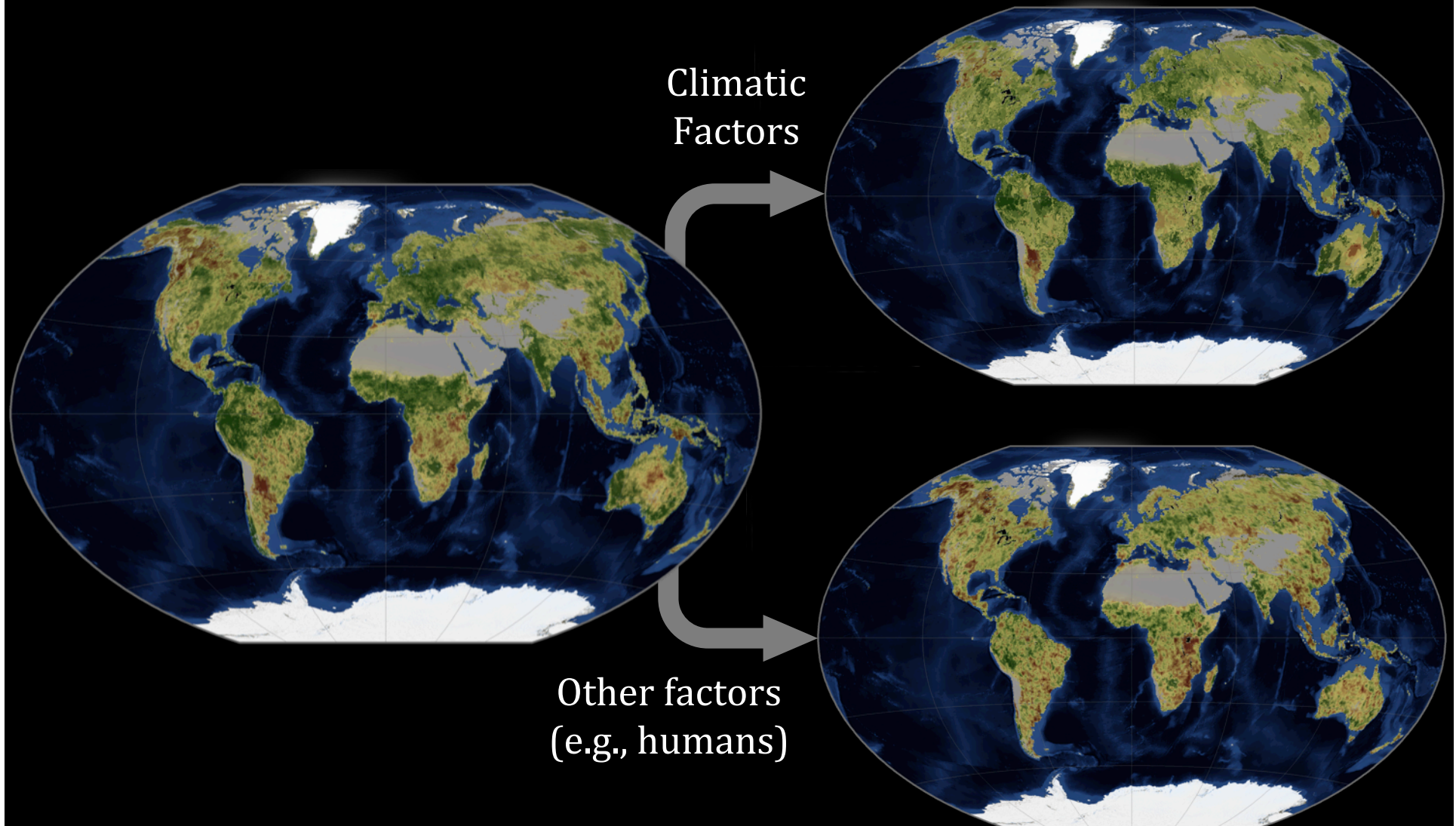


Evapotranspiration



Mitchell TD, Jones PD (2005) An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *International Journal of Climatology*, 25, 693-712.

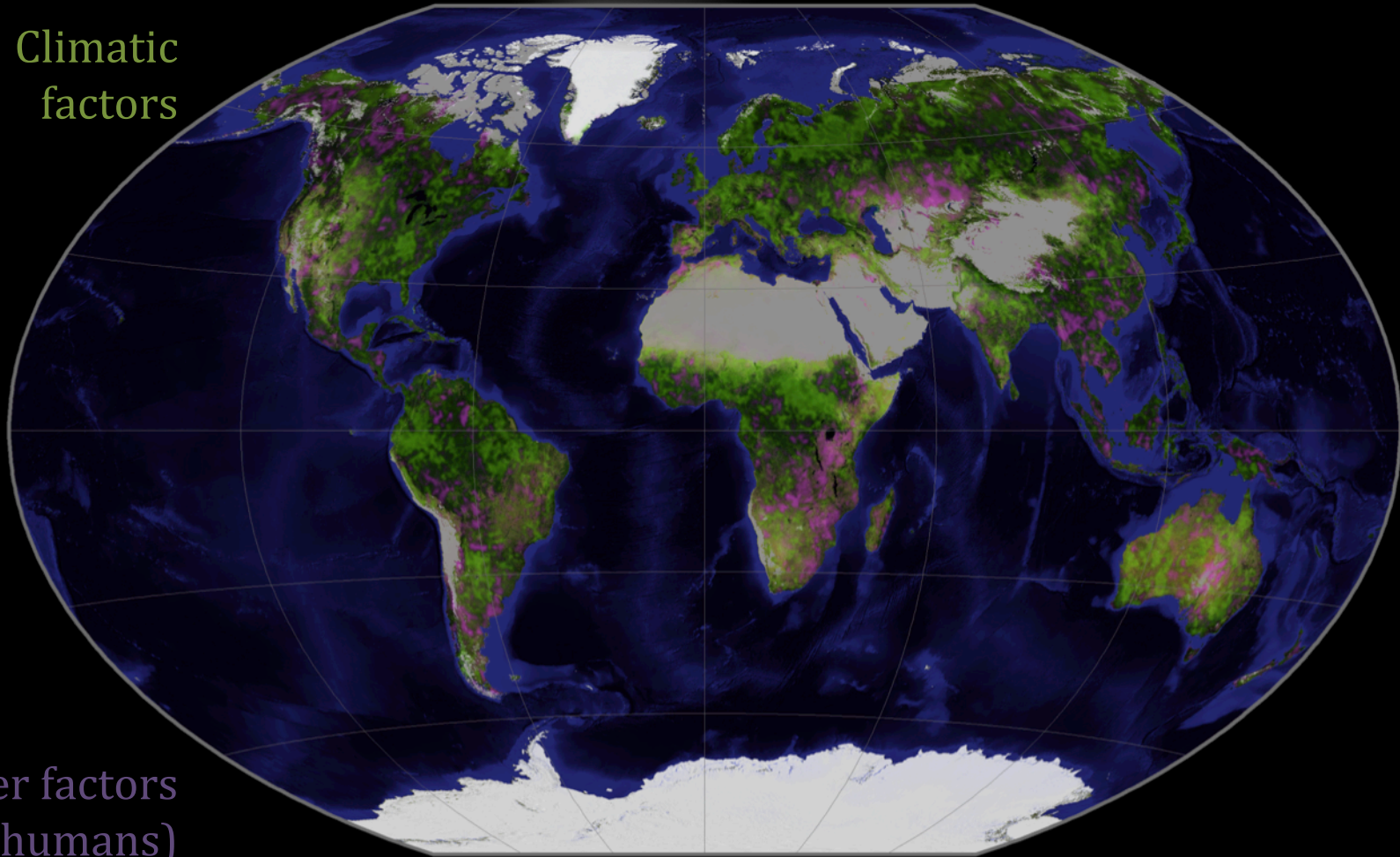
Vegetation changes: Factors



De Jong R, Schaepman ME, Furrer R, De Bruin S, Verburg PH (2013) Spatial relationship between climatologies and changes in global vegetation activity. *Global Change Biology*, 19, 1953-1964.

Influencing factors

Climatic
factors



Other factors
(e.g., humans)

De Jong R, Schaepman ME, Furrer R, De Bruin S, Verburg PH (2013) Spatial relationship between climatologies and changes in global vegetation activity. *Global Change Biology*, 19, 1953-1964.

Conclusions and outlook



Conclusions and outlook

- A big gap still exists in *tackling 3rd (HPC) and 4th (BigData) paradigm changes* in science plans and work flows
- Coupling physical Earth system models to *models of social interactions* is still in its infancy
- Filling *observational data gaps (CO₂ fertilization, O₃, NO_x, P)* will be key to future use of observational data in Earth models
- Key to sustainable use of big data will be sophisticated *data selection systems*
- Emerging Earth System Science curricula must educate *next generation science professionals*

Thank you for your attention!

