Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

COSMO-CLM coupled to the Community Land Model: developments, applications and future directions

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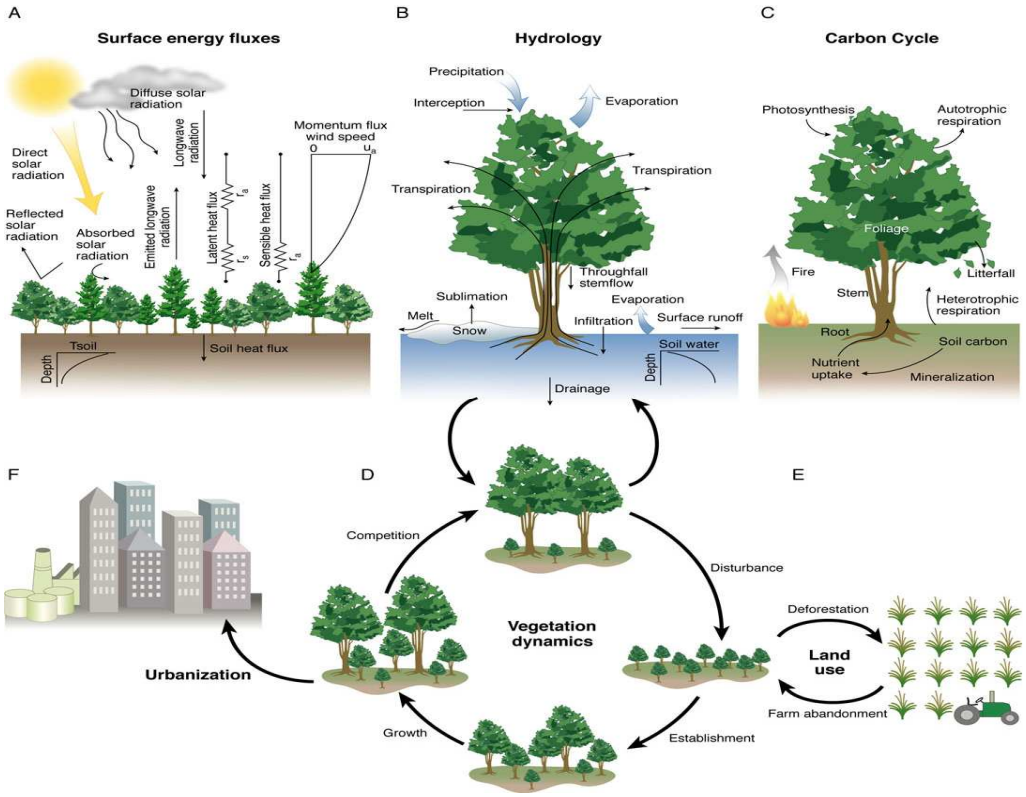
Motivations

- Find ways to improve model performance
  - Land surface processes are promising candidates

- Need for new model capabilities:
  - To simulate quantities of interest beyond temperature, precipitation (e.g, ecosystem variables; crop productivity)
  - To address novel scientific questions (e.g., role of vegetation feedbacks during heat waves)
  - To move toward “Regional Earth System Models”

Community Land Model

- Tile approach
- Multi layer snow
- Canopy layer
- Physiology and photosynthesis (3rd generation LSM)
- River transport (option)
- Urban module (option)
- Crop phenology and irrigation (option)
- Carbon/nitrogen cycle (option)
- Transient land use (option)
- Dynamic vegetation (option)
- Dust and BVOCs (option)

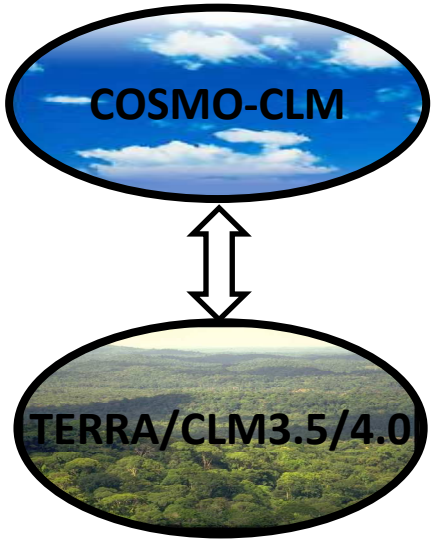


Bonan, 2008

Official web site: http://www.cesm.ucar.edu/models/clm/

COSMO-CLM²: development stages

- 2009:
  - COSMO-CLM version 4.0 coupled to CLM3.5 (by R. Stöckli and E. Davin)
  - “subroutine coupling”
  - Evaluation: *Davin et al., Clim. Dyn. [2011]*



- 2010:
  - Upgrade to COSMO-CLM version 4.8
  - Evaluation: *Davin and Seneviratne, Biogeosciences [2012]*

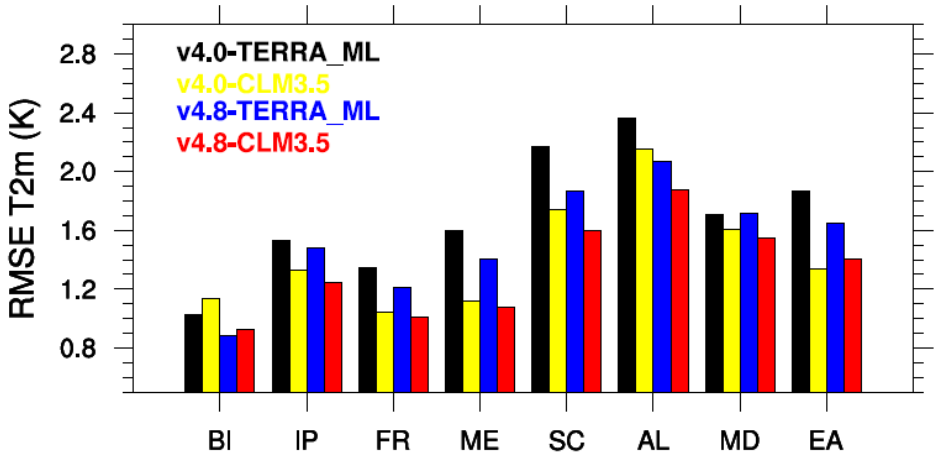
- 2011/2012:
  - Switch to OASIS3 coupler (by E. Maisonnave and E. Davin)
  - Upgrade to CLM4.0 (compatible with CLM3.5/CLM4)
  - Still not scientifically evaluated!

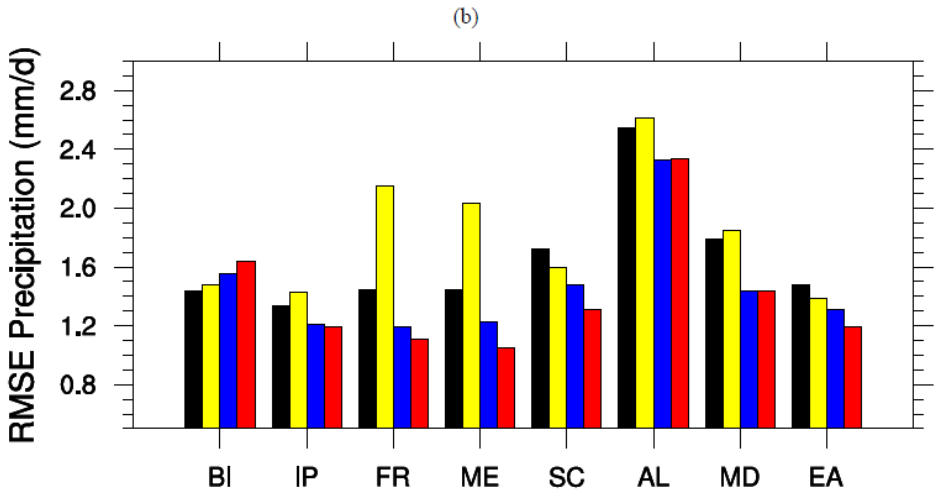
Methodology

- COSMO4.8-CLM11 with “subroutine” coupling to CLM3.5
- ERA40/ERAinterim boundary conditions
- 50km resolution

- Statistics based on 20 years (or more)
- Evaluation against E-OBS (T, P) and FLUXNET (surface fluxes)

Importance of land vs atmospheric model

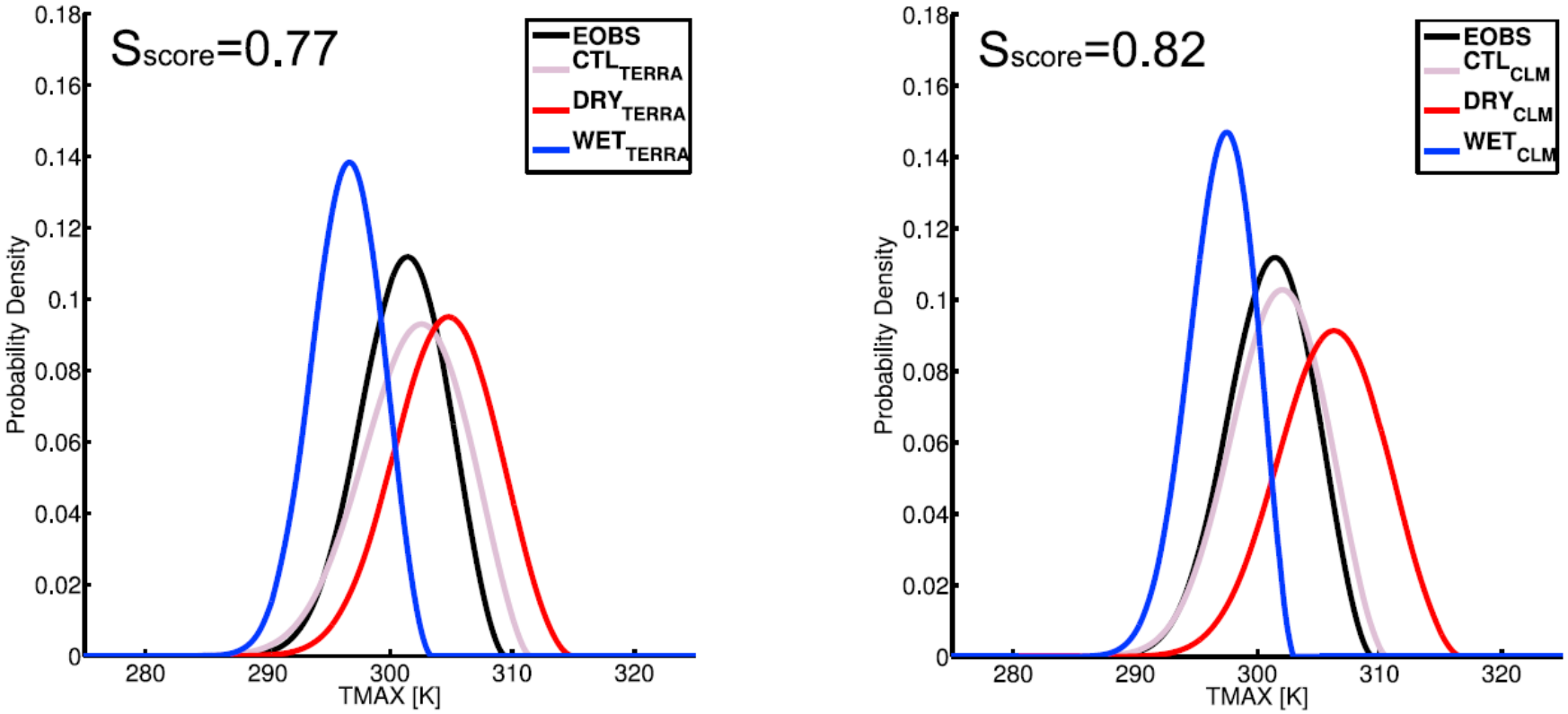




- Land model plays an important part in overall model performance

Davin and Seneviratne, Biogeosciences [2012]

Daily statistics: summer Tmax; Iberian peninsula

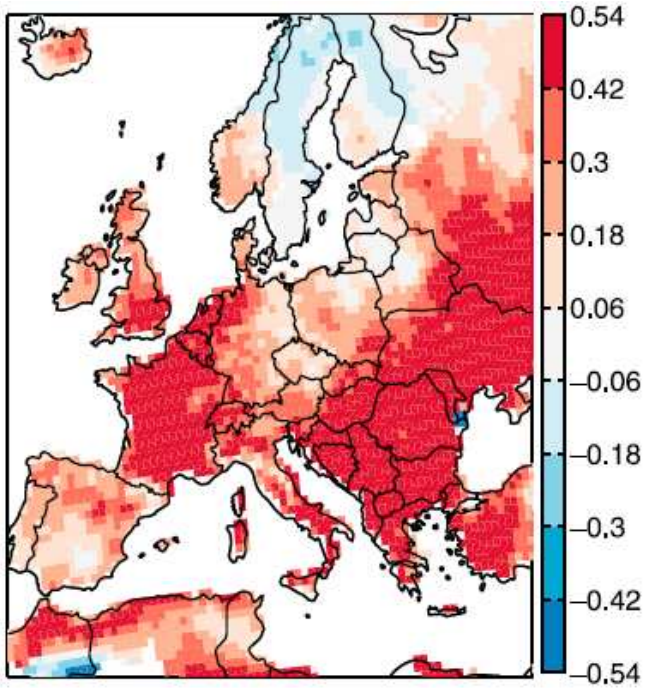


- Warm extremes are too extreme in Mediterranean regions → less pronounced with CLM3.5

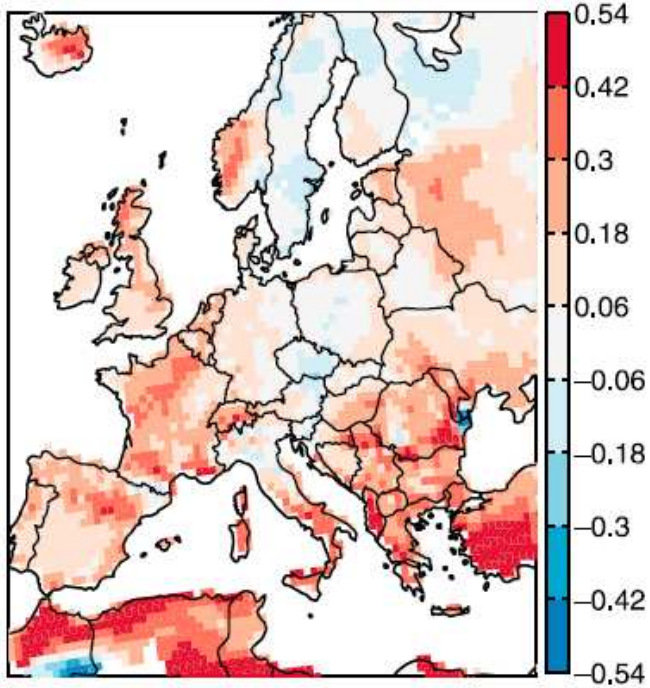
Lorenz et al., JGR [2012]

Interannual summer variability T2m

V4.8-TERRA – E-OBS



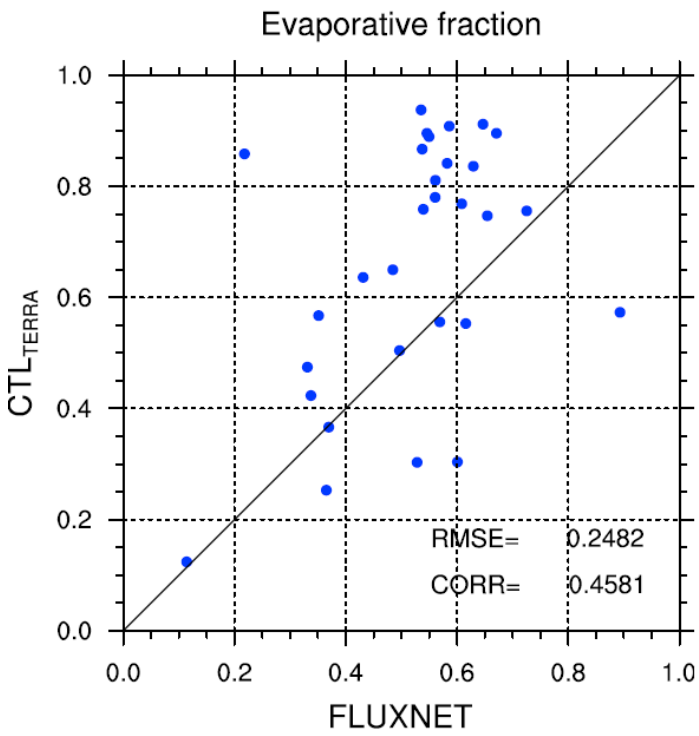
V4.8-CLM3.5 – E-OBS

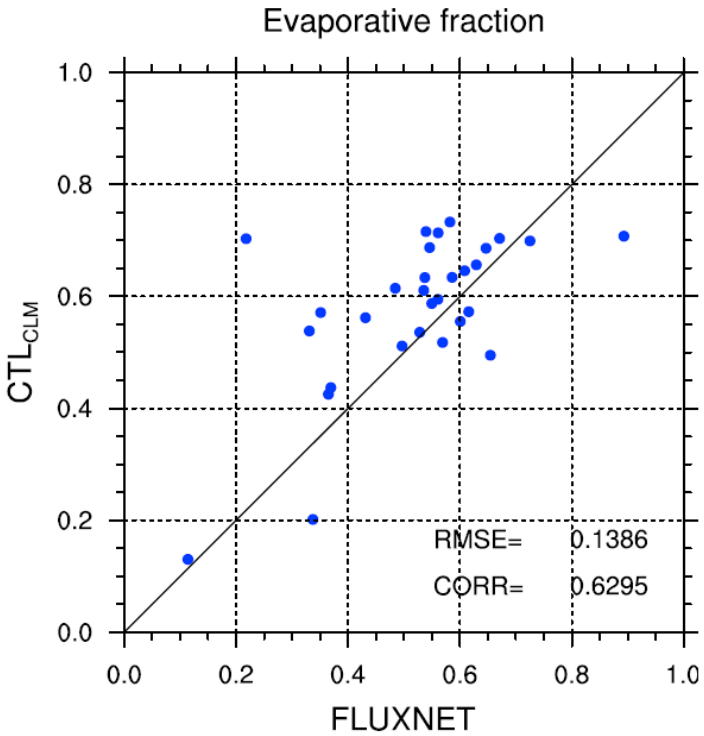


- Overestimation of interannual summer variability common feature in many RCMs *[see e.g., Jacob et al., 2007]*
- ➢ Partly alleviated when using CLM3.5

Lorenz et al., JGR [2012]

Evaporative fraction against FLUXNET





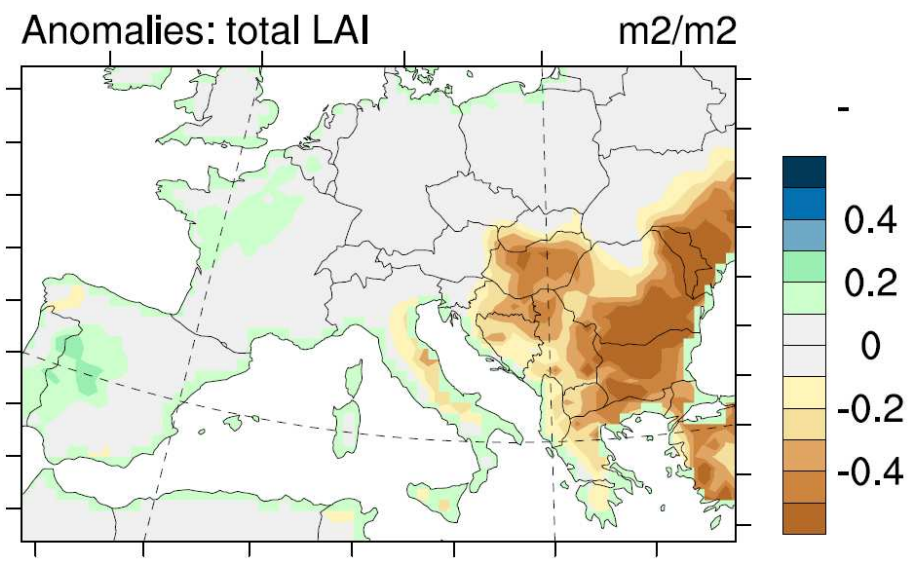
- Too high Evaporative fraction with TERRA alleviated with CLM3.5
- Too low SWnet (due to cloud cover overestimation) alleviated with CLM3.5 *[Davin et al, Clim. Dyn. 2011]*

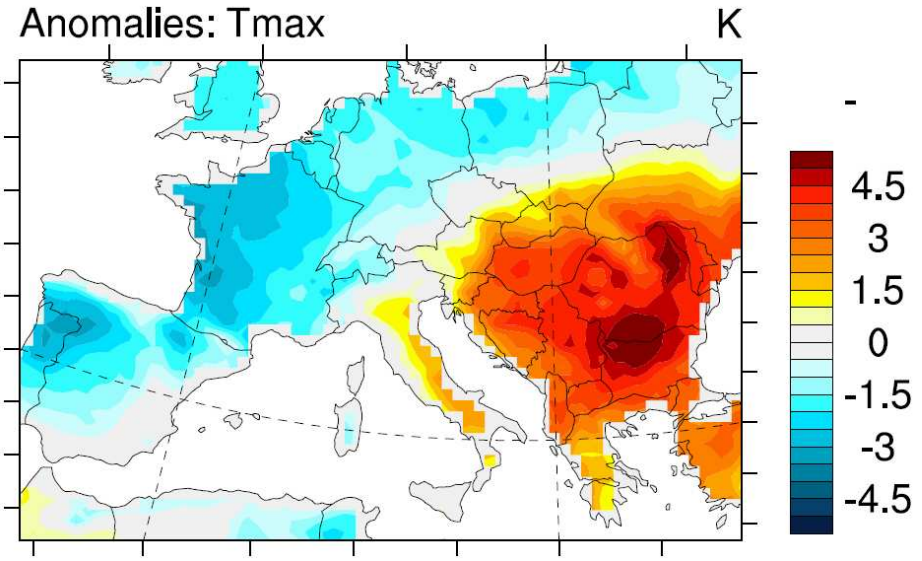
Lorenz et al., JGR [2012]

Current applications

- Effect of diffuse/direct radiation partitioning on plant transpiration
- Impact of Amazonian deforestation
- Impact of agricultural management on regional climate
- **Role of vegetation feedbacks during heat waves**
- **Regional climate-carbon cycle feedbacks**

2007 heat wave: Role of phenology vs soil moisture

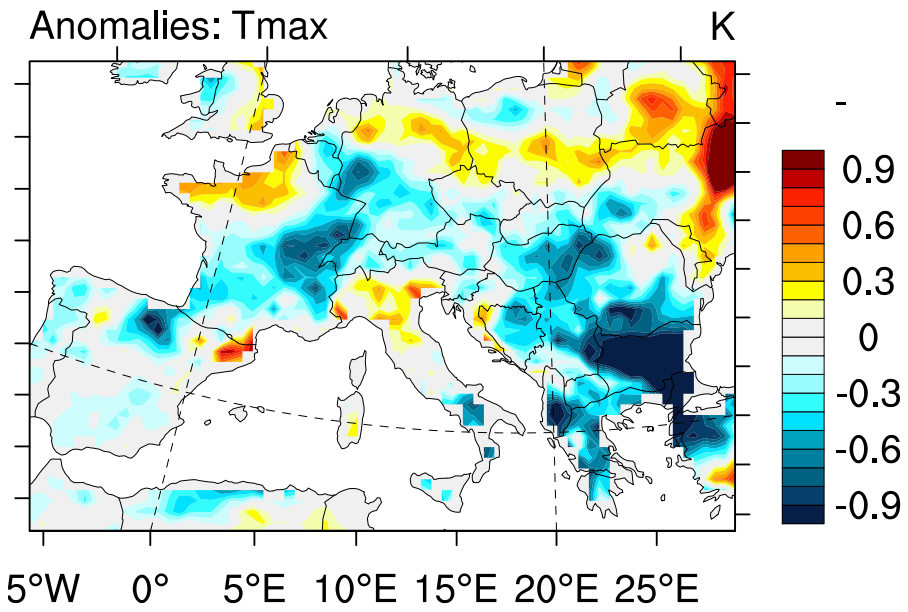




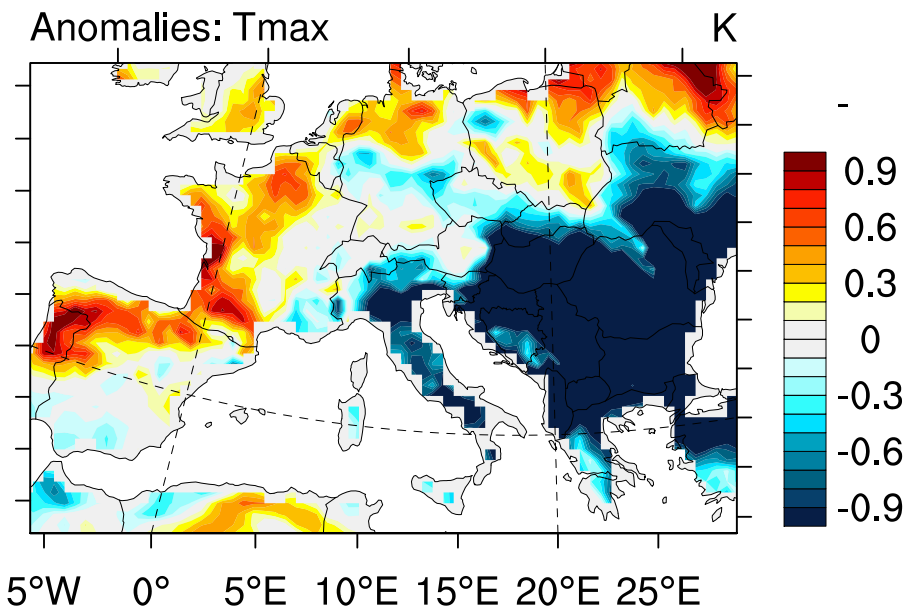
Lorenz et al., submitted

2007 heat wave: Role of phenology vs soil moisture

Phenology effect



Soil moisture effect

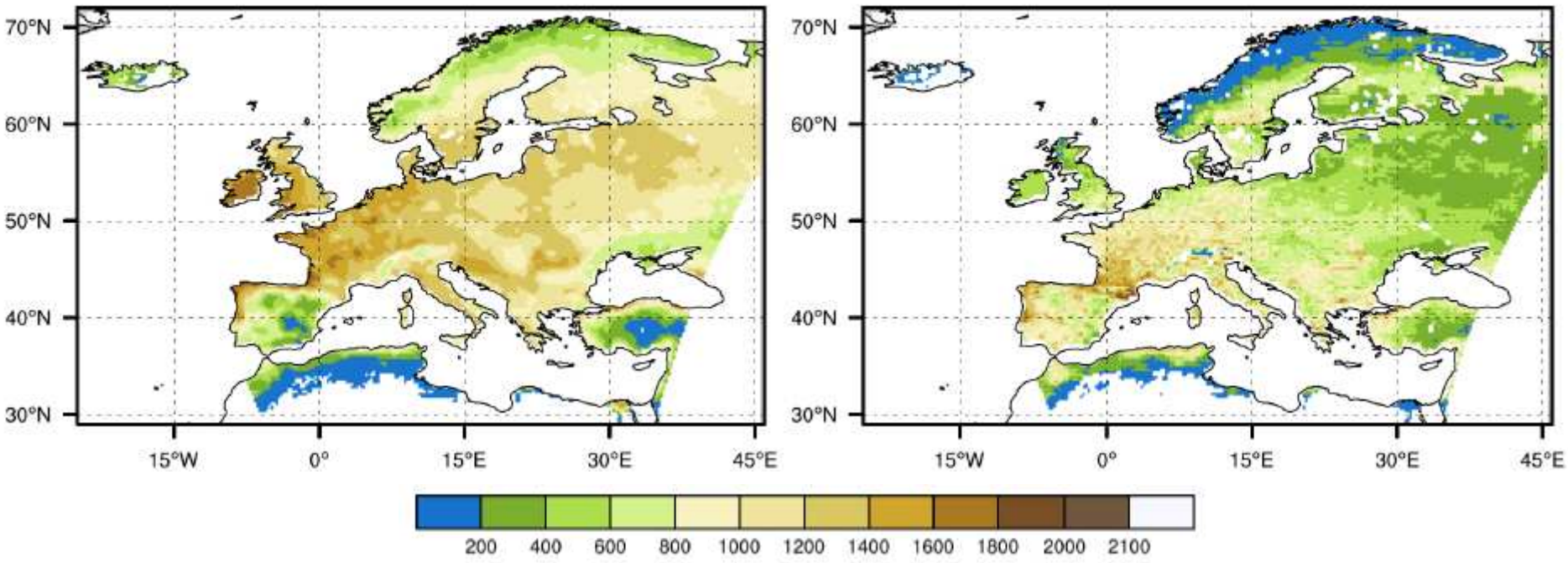


Lorenz et al., submitted

Coupling with Carbon-Nitrogen cycles

Upscaled FLUXNET

CLM4.0



Annual GPP ($gC/m^2/yr$)

PhD S. Mystakidis

Coupling with OASIS3(-MCT)

- Well established and supported coupler
- More flexibility (use of different grids, time stepping)
- Interface compatible with CLM4.0/CLM3.5
- Potential for better performance optimization
- Unified interface for land, ocean, 2-way nesting → cf OASIS Project Group

- Remaining technical issues: e.g. problem with restarts

Conclusions

- Land surface model development is a promising avenue for improving overall model performance
- Marked influence on temperature extremes
- Opportunities to explore novel research questions

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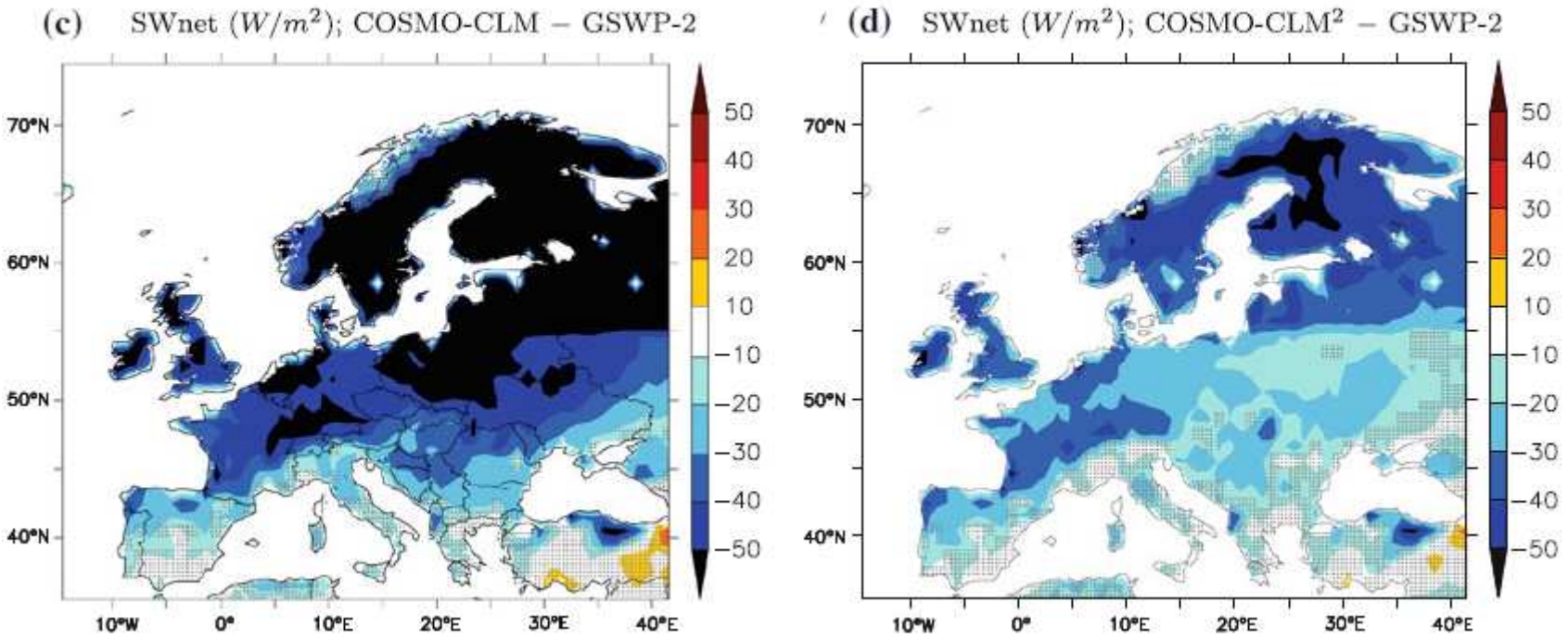
Thank you for your attention!

Comparison CLM3.5 vs TERRA



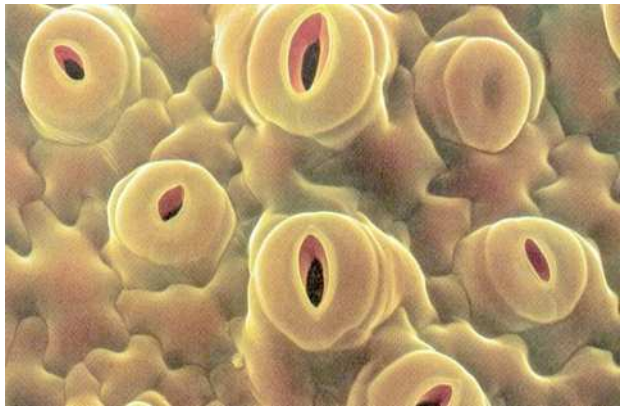
- Due to a reduced positive bias in cloud cover

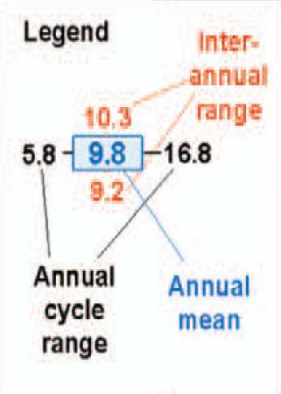
Davin et al., Clim. Dyn. [2011]

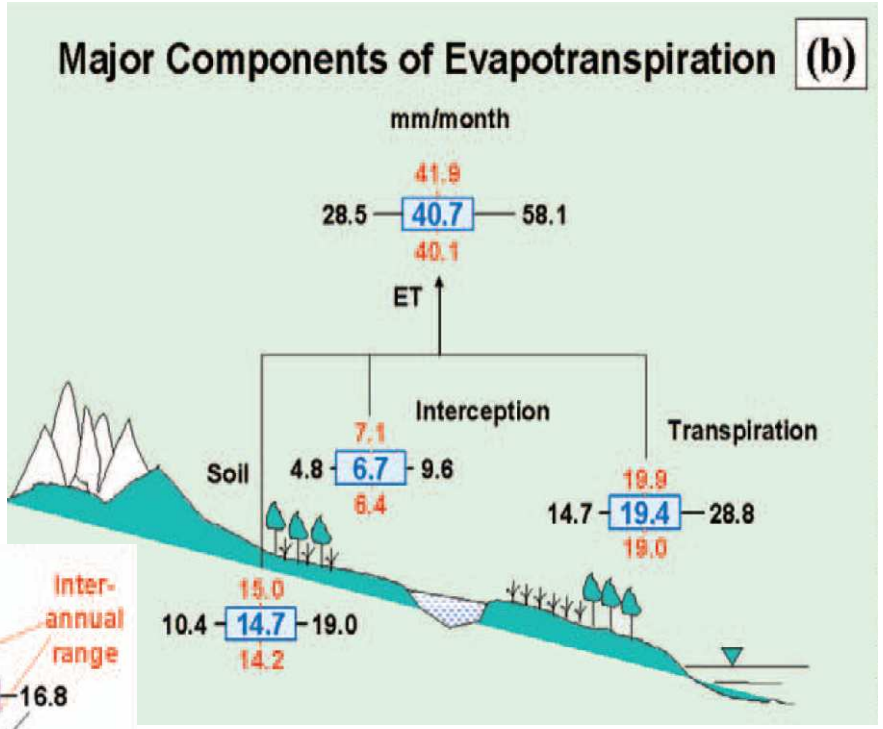
Biological dimension of land-atmosphere exchanges

- Transpiration: half of the water flux from the land to the atmosphere globally

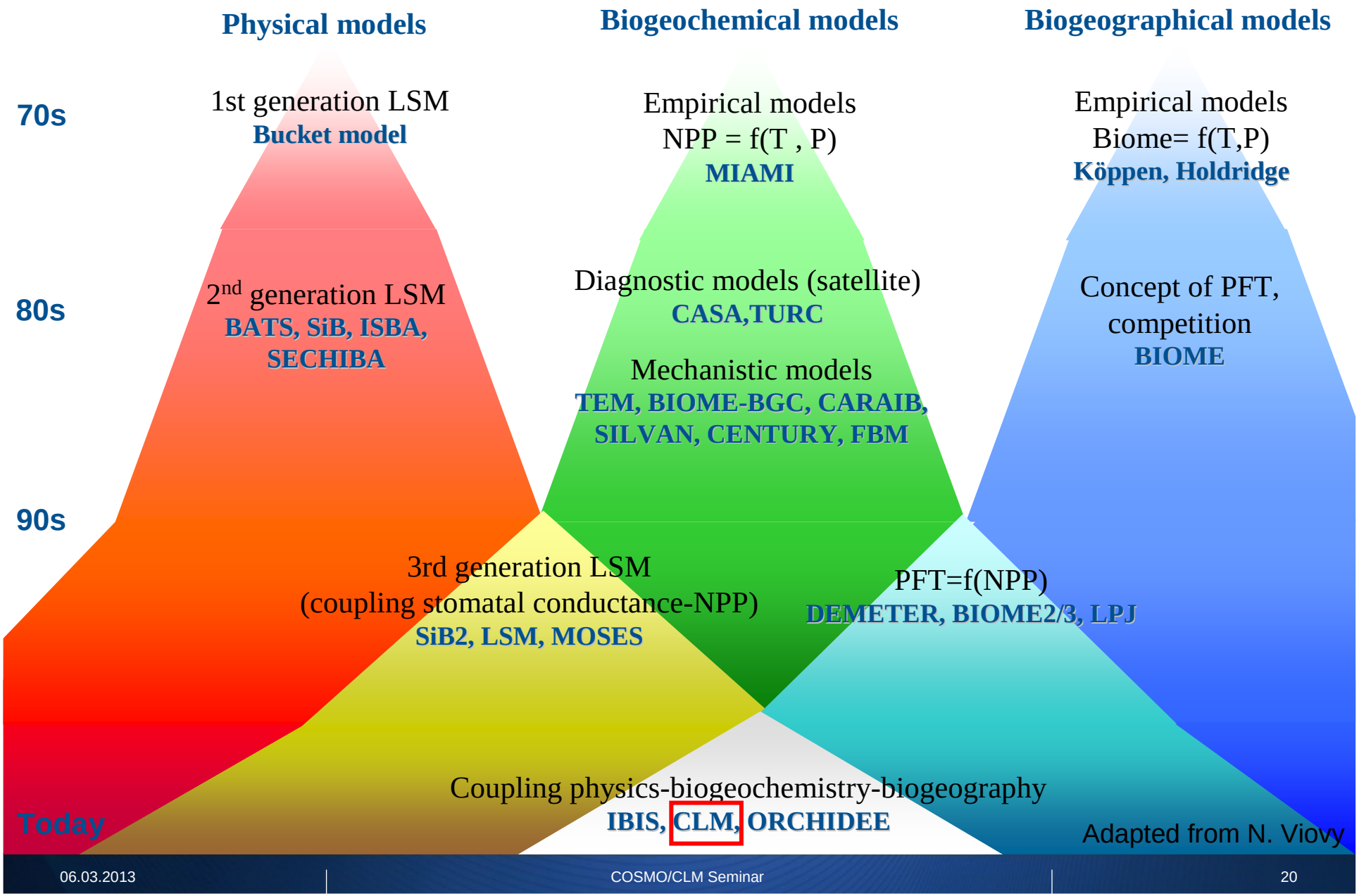
➢ Evapotranspiration is biologically regulated



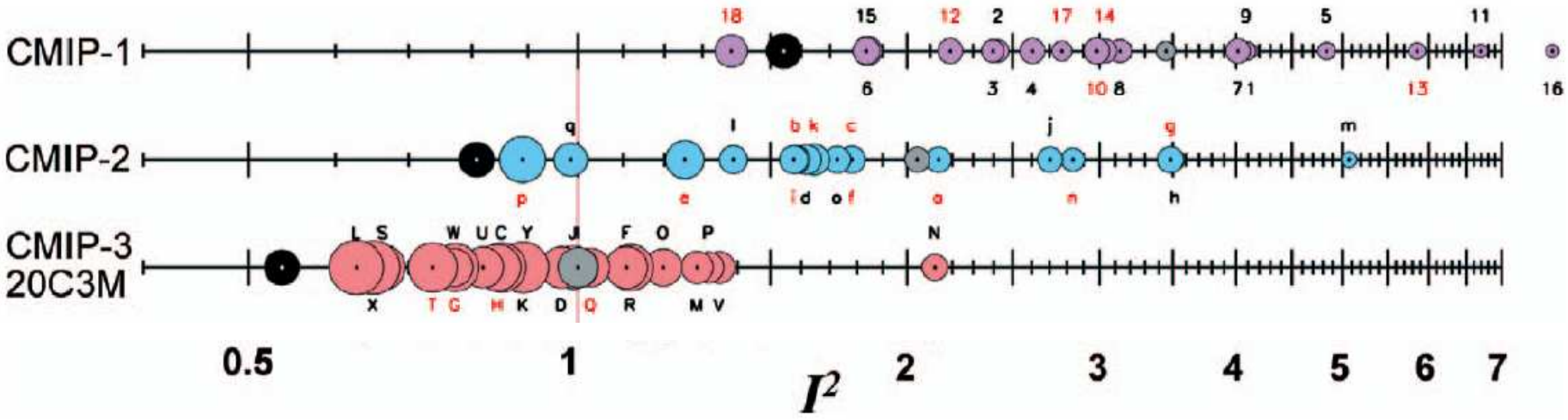




(Dirmeyer et al., 2006)


Physical models
Biogeochemical models
Biogeographical models
70s
80s
90s
Today
1st generation LSM
Bucket model
2nd generation LSM
BATS, SiB, ISBA, SECHIBA
Empirical models
NPP = f(T , P)
MIAMI
Diagnostic models (satellite)
CASA,TURC
Mechanistic models
TEM, BIOME-BGC, CARAIB, SILVAN, CENTURY, FBM
Empirical models
Biome= f(T,P)
Köppen, Holdridge
Concept of PFT, competition
BIOME
3rd generation LSM
(coupling stomatal conductance-NPP)
SiB2, LSM, MOSES
PFT=f(NPP)
DEMETER, BIOME2/3, LPJ
Coupling physics-biogeochemistry-biogeography
IBIS, CLM, ORCHIDEE
Adapted from N. Viovy

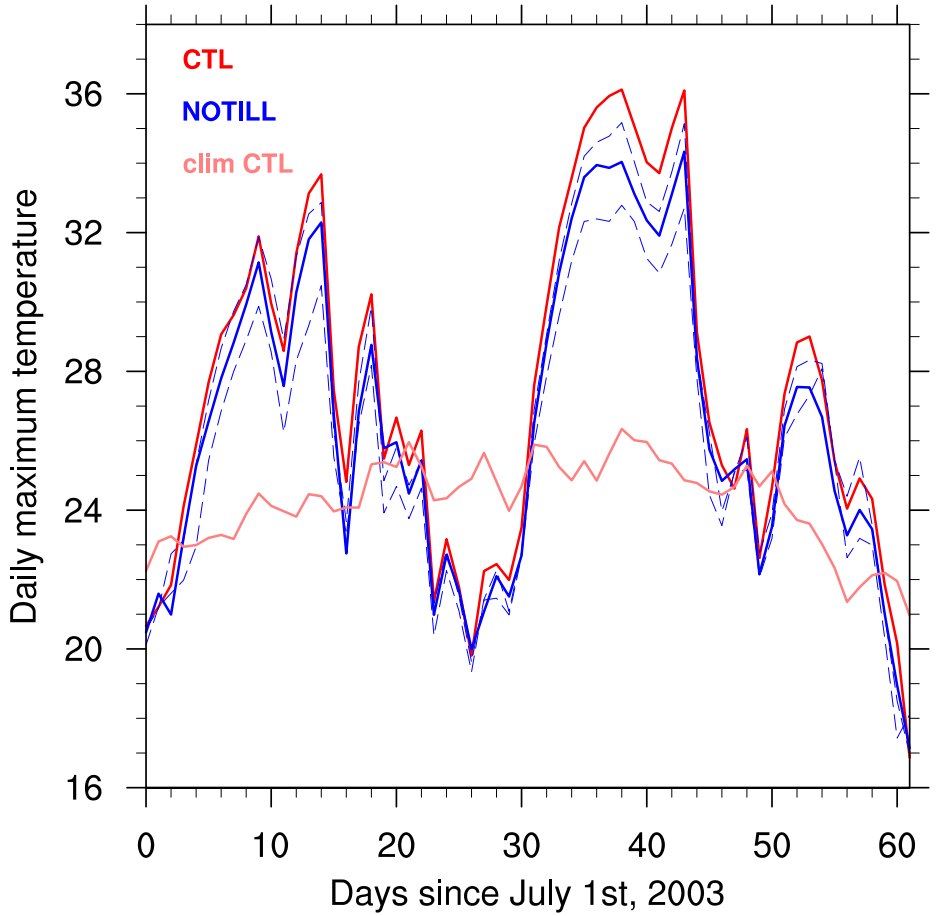
Climate models have improved



Reichler and Kim, BAMS, 2008

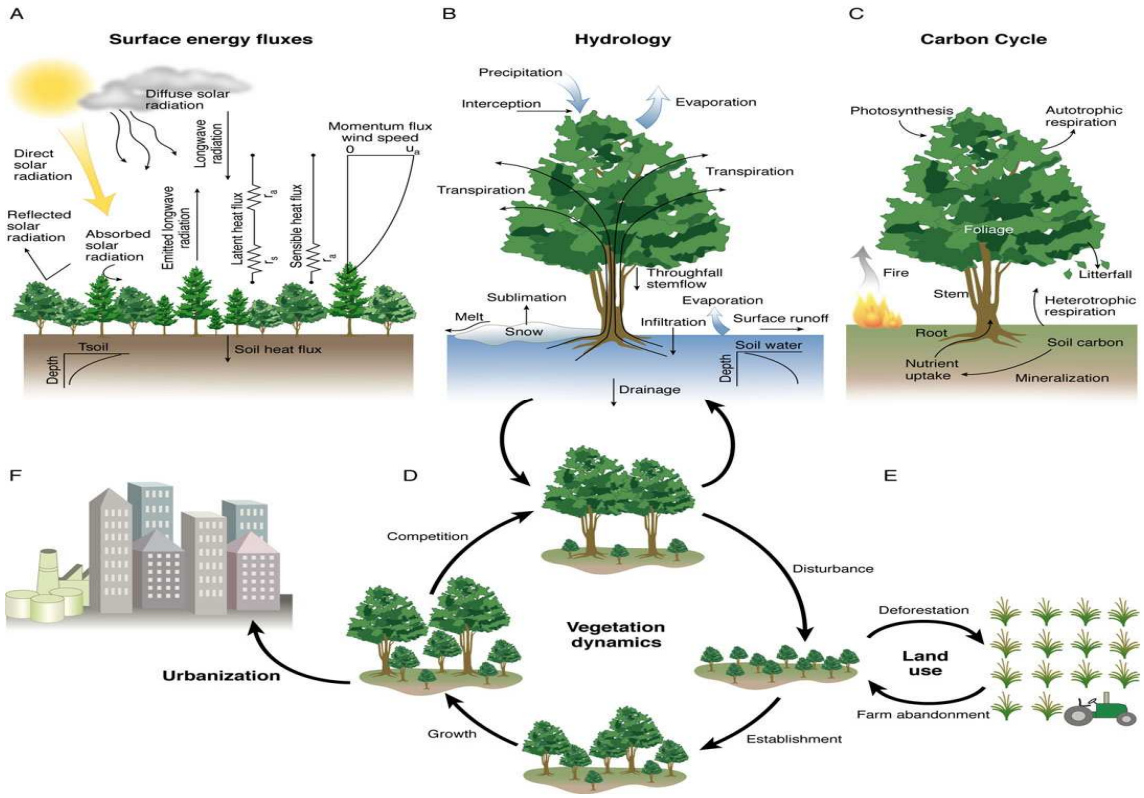
No-till farming and heat waves

- Climate mitigation potential (cooling effect) of no-till farming particularly strong during heat waves



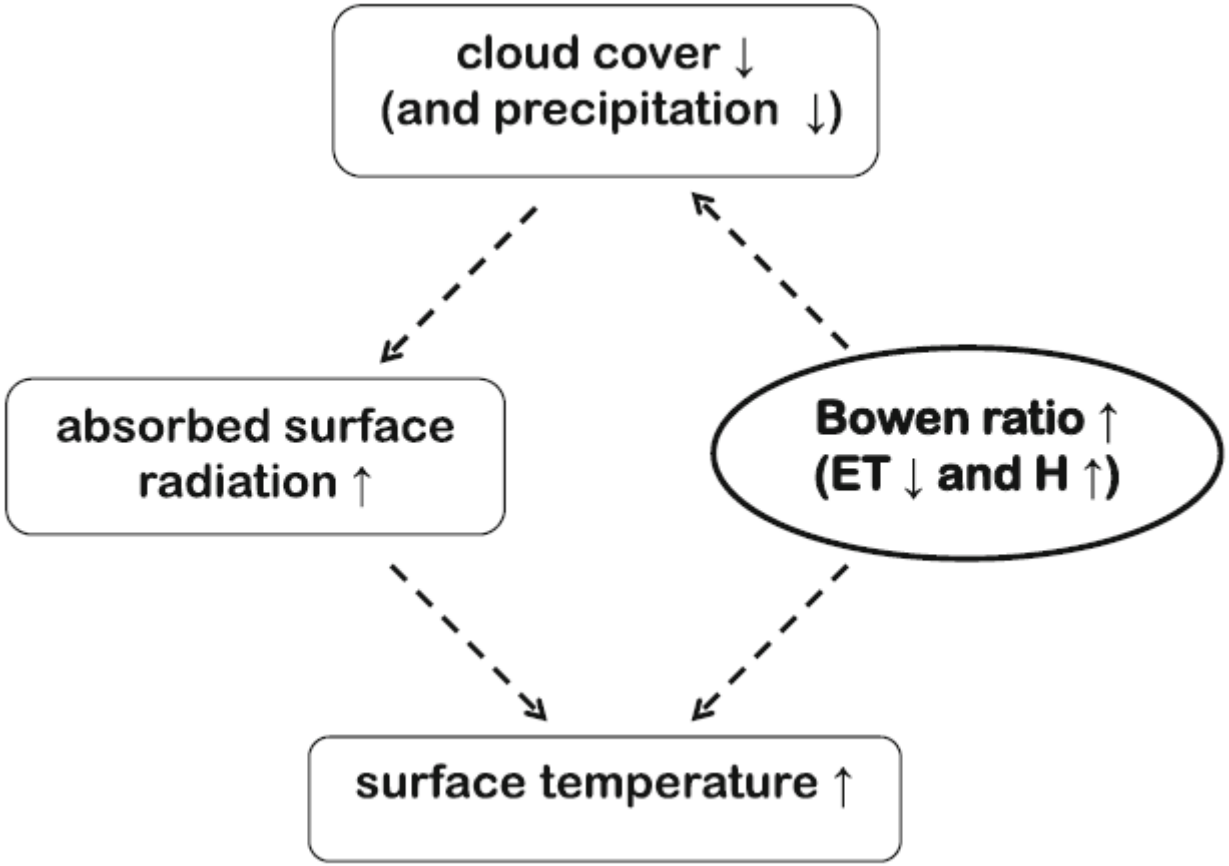
Community Land Model

- Open source
- Extensively documented and evaluated
- Comprehensive range of processes through a modular code structure
- Current version: CLM4, preceding version: CLM3.5



Bonan, 2008

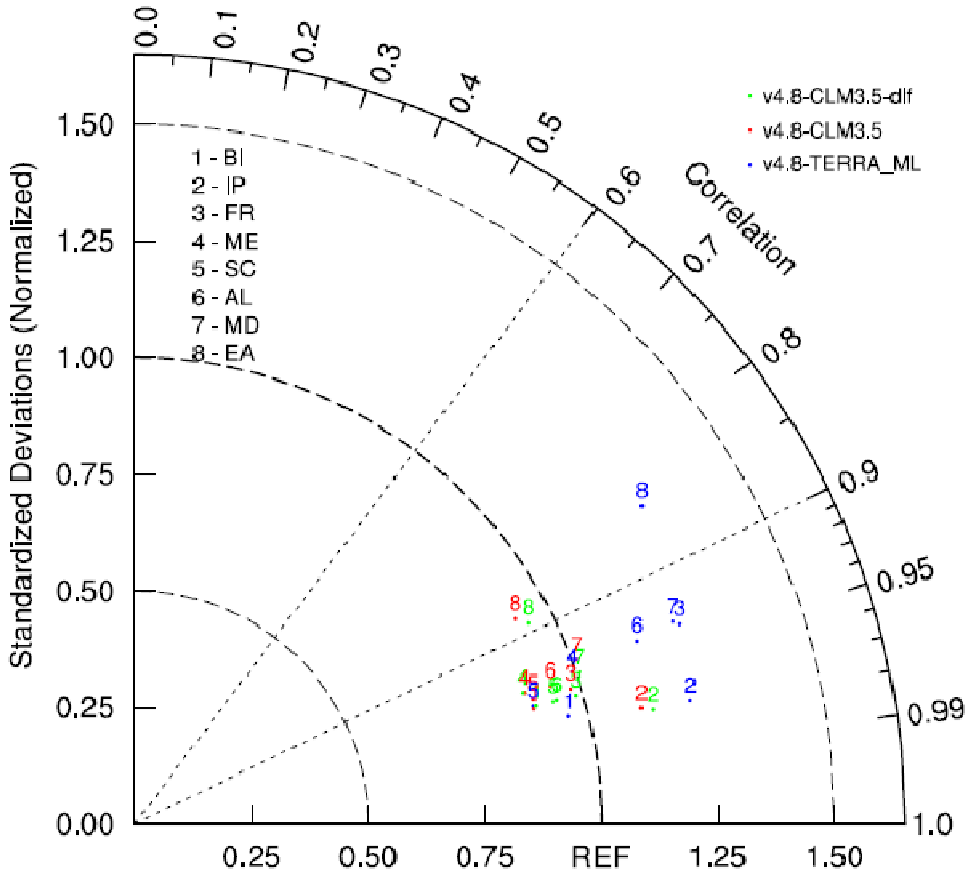
Overview of mechanism



Davin et al., Clim. Dyn. [2011]

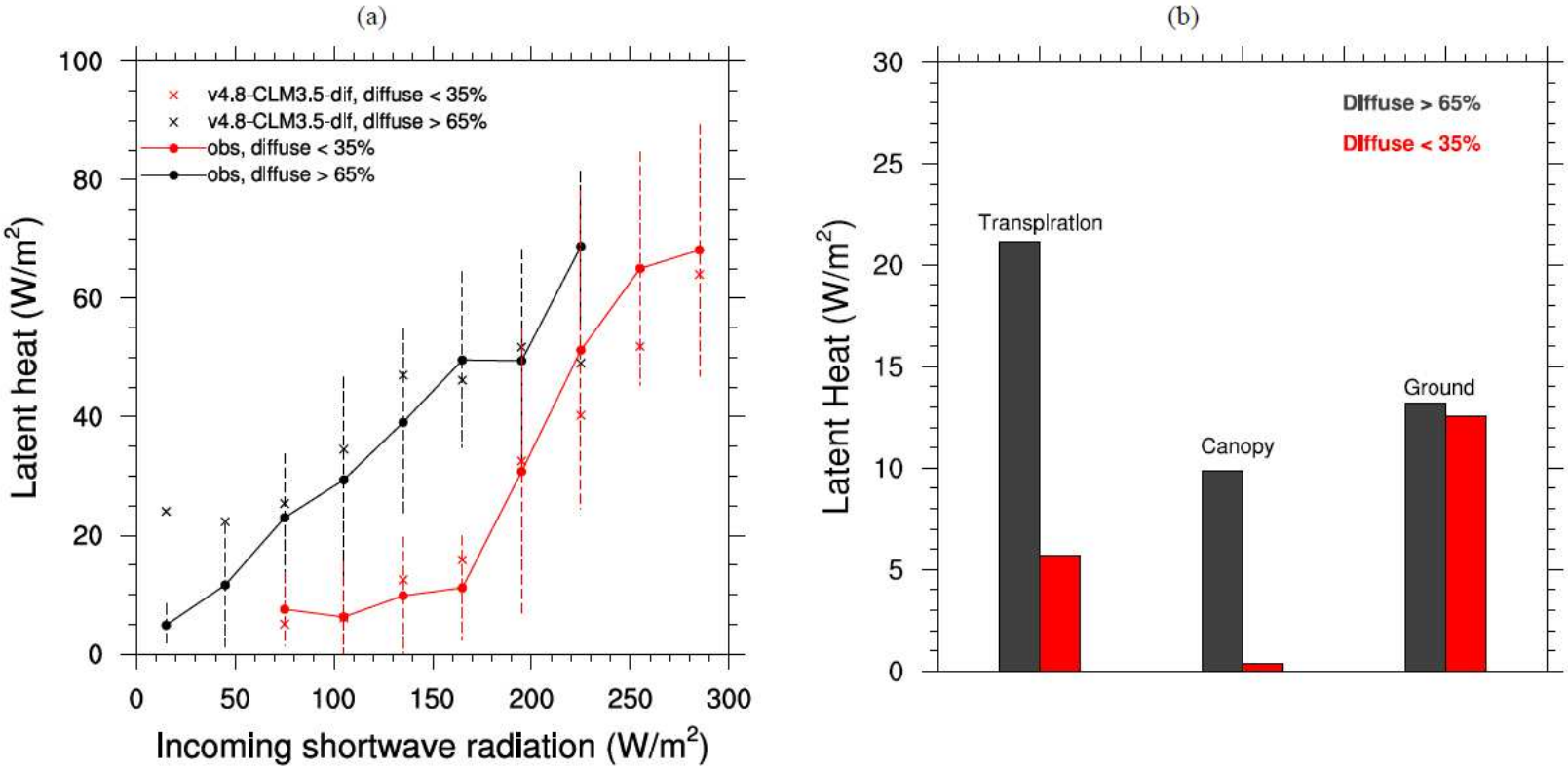
Impact on model performance

- Slight improvement in model skill when taking into account diffuse/direct partitioning
- Modest role compared to the overall effect of changing the LSM



Davin and Seneviratne, Biogeoscience [2012]

Role of diffuse radiation



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