Soil modelling and land-atmosphere interactions with the COSMO model: Results from the SOILVEG and COLOBOC initiatives

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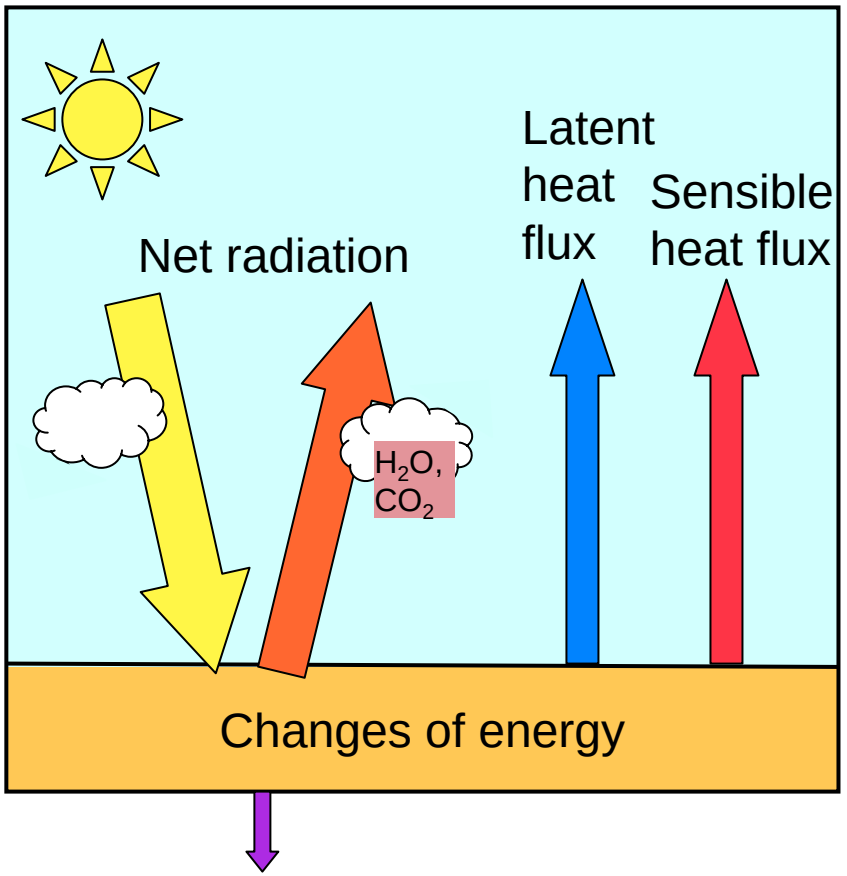
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

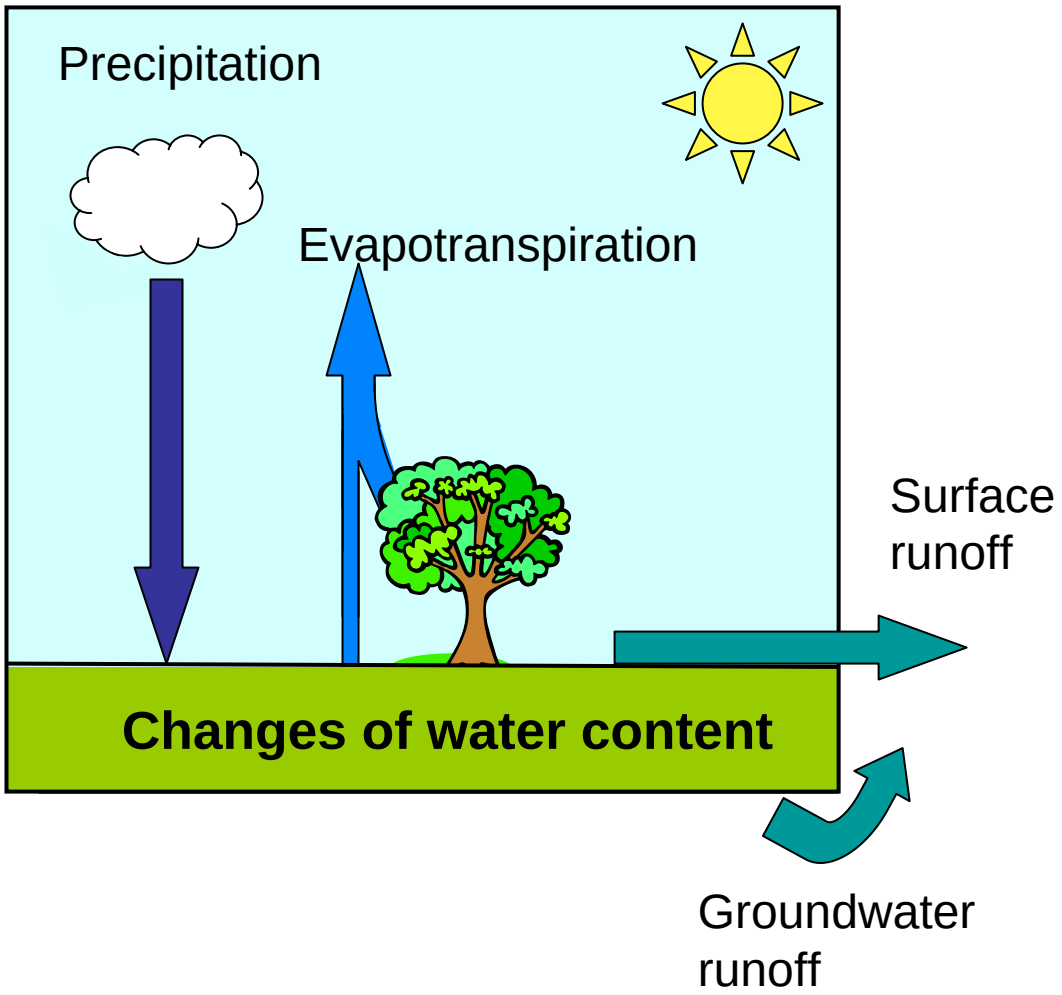
CONSORTIUM FOR SMALL SCALE MODELING
COSMO

Introduction: Land energy and water balances

Land energy balance



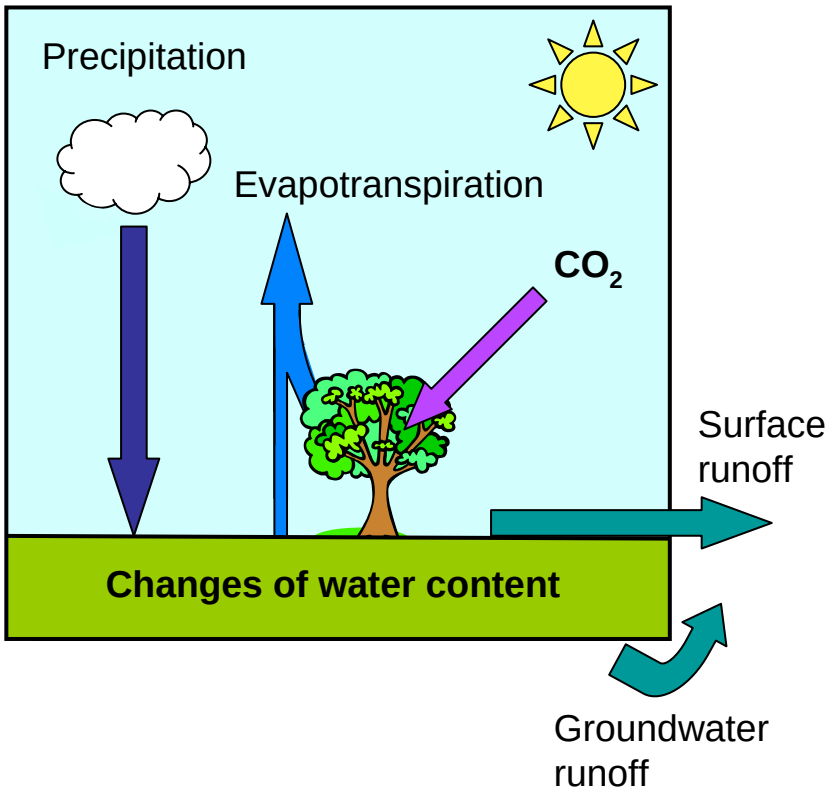
Land water balance

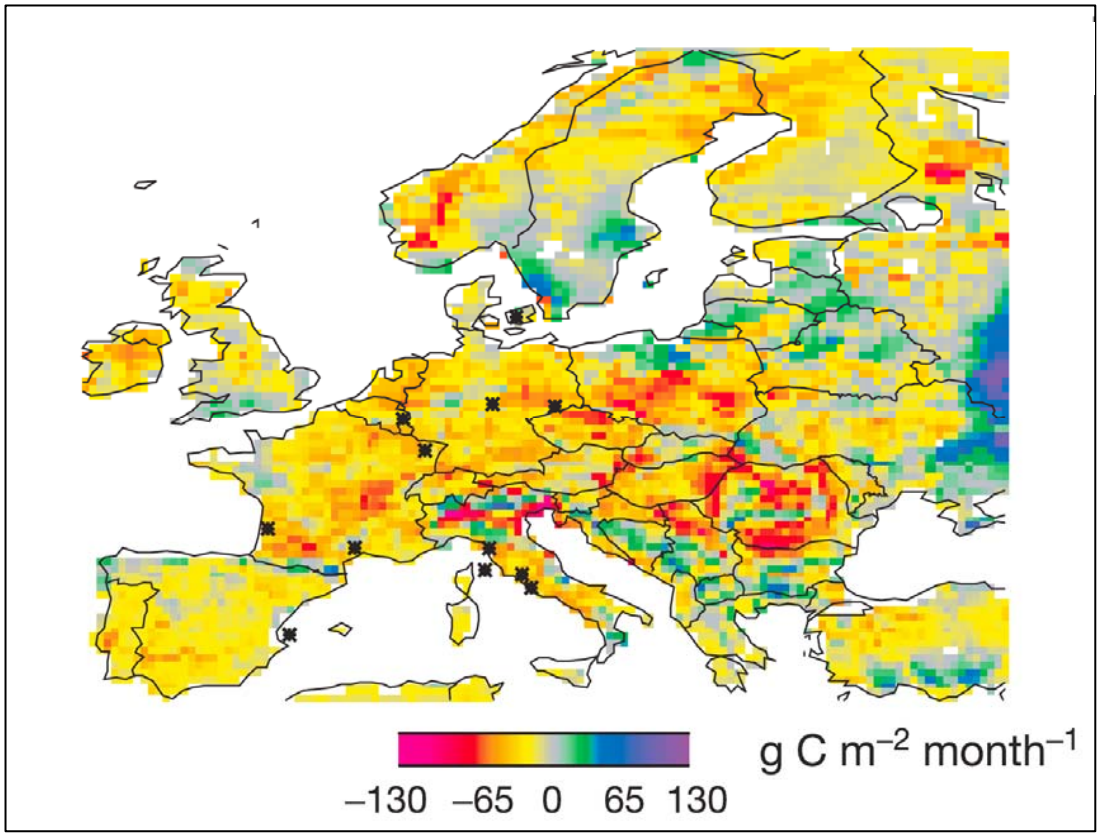


Introduction: Vegetation - CO_2 interactions

Vegetation - CO_2 interactions

Europe transformed in carbon source in summer 2003 (heat wave/drought)





(Ciais et al., Nature, 2005)

COSMO/CLM: SOILVEG and COLOBOC initiatives

Climate Local Model SoilVeg Working Group

- Chair (2008-2010): S.I. Seneviratne, ETH Zurich
- Deputy chair (2008-2010): G. Schädler, IMK/FZK

Goal: coordinate soil/land/vegetation modelling activities within C-CLM community; informal collaborations

COSMO Priority Project COLOBOC (COnsolidation of LOwer BOundary Conditions) – 2008-2010

- Project leader: J.-M. Bettems, MeteoSwiss
- Subproject leader: J. Helmert, DWD

Goal: consolidate previous developments related to the lower boundary condition in the form of well documented and tested software packages

SOILVEG & COLOBOC initiatives: Main activities

- Tests and new implementations in Terra-ML
- Alternative land modules:
  Terra-ML vs Veg3D vs Community Land Model
- External parameters: Soil parameters, vegetation
- Model validation, Validation datasets
- Applications, modeling experiments
- Further developments/submodules: e.g. Urban modelling, snow models

- Future: Current status of SOILVEG and COLOBOC, plans

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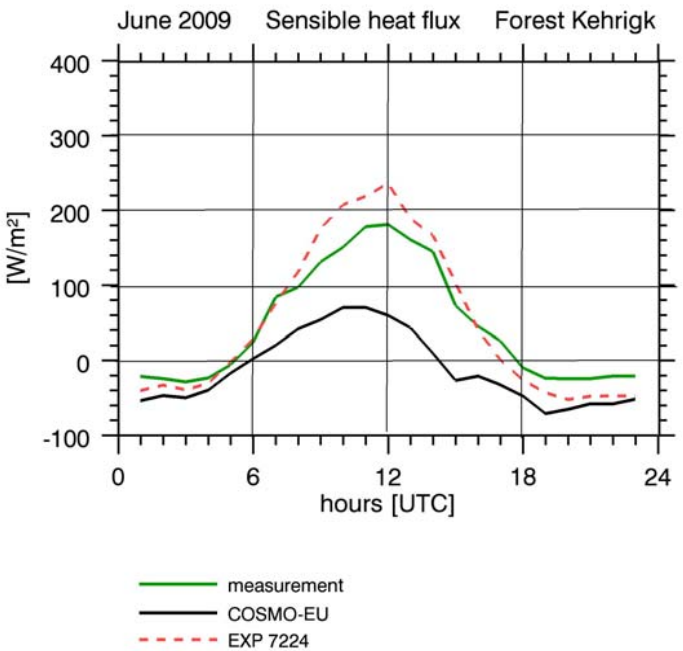
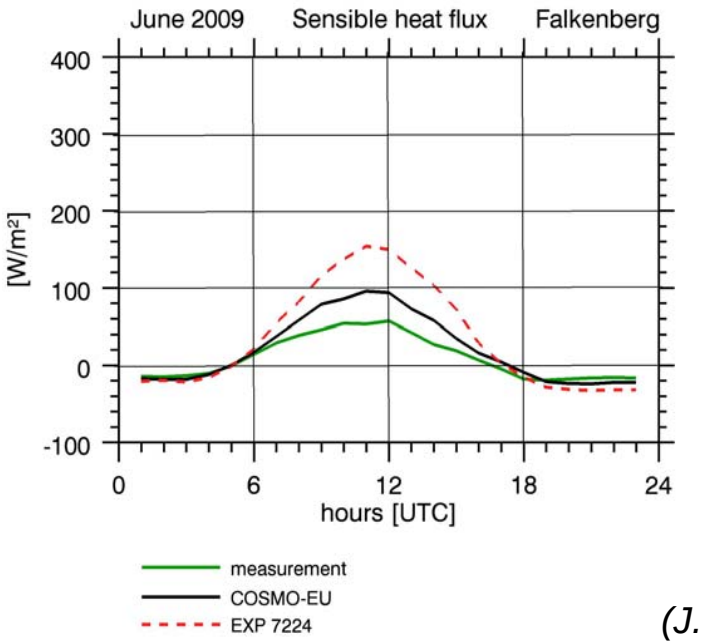
Tests and implementations in TERRA-ML

- Several implementations within COSMO/CLM community (e.g. tiling approach, modified soil or vegetation parameters, 3D soil parameters)

- So far, no “single best” version





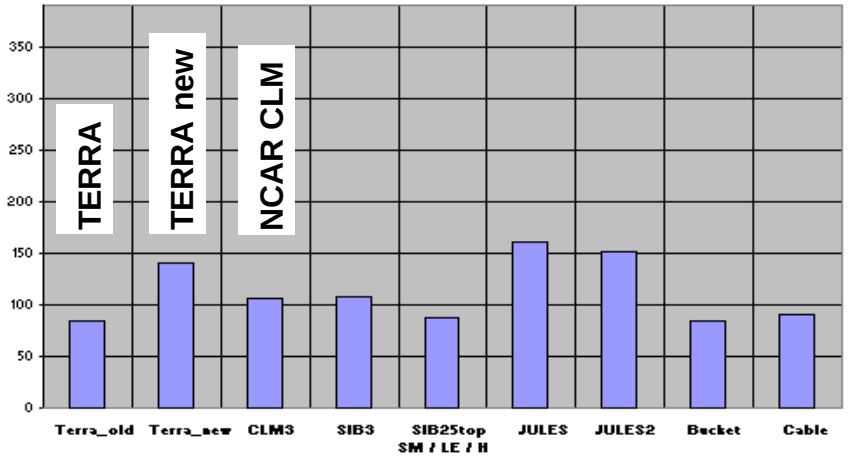
(J. Helmert, DWD)

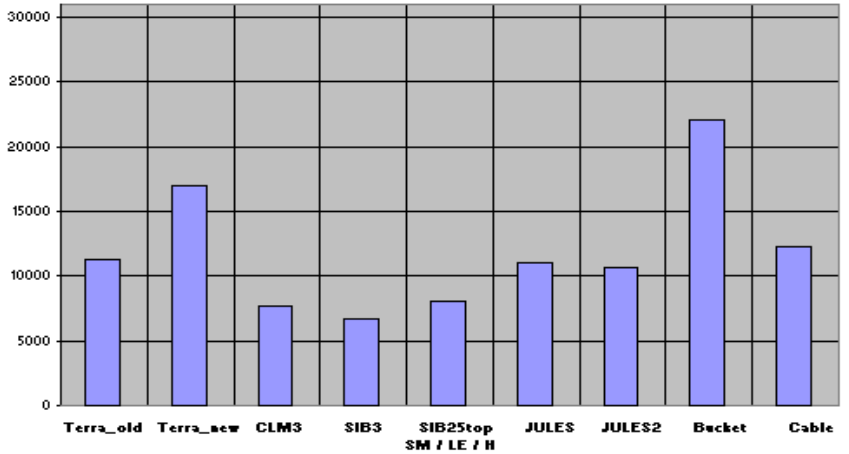
Soil model intercomparison (MSc R.Orth)

Mean error

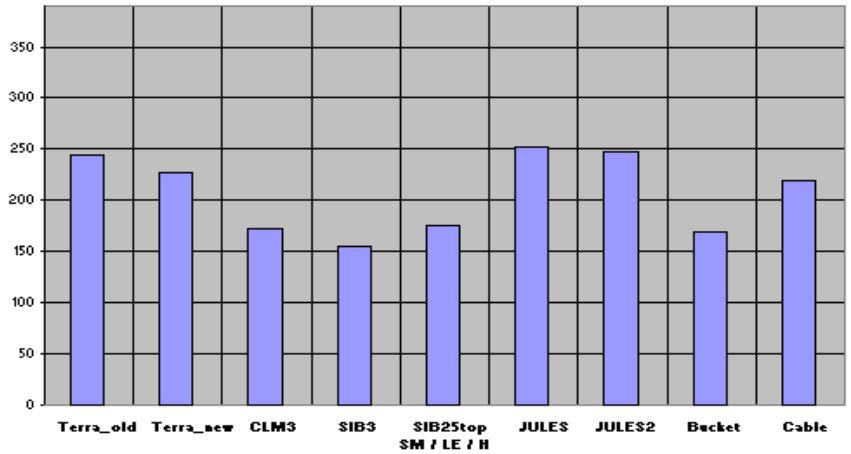
Standard deviation

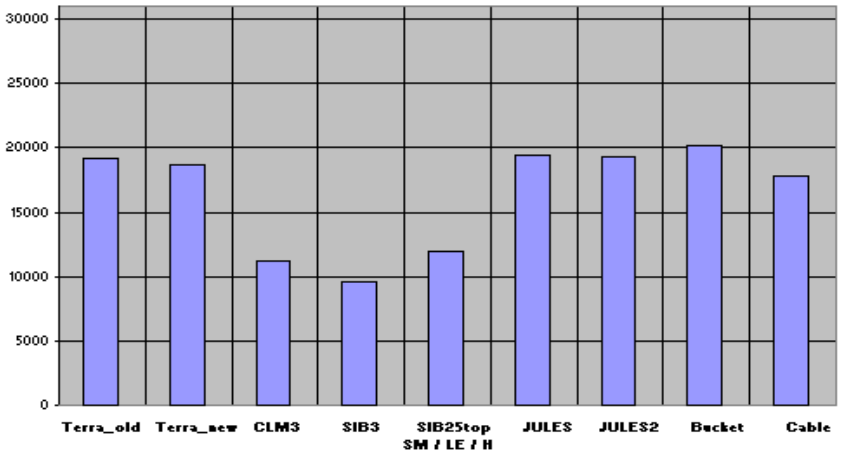
Latent heat flux





Sensible heat flux





Observation driven SVATs / Verification with measured fluxes / 9 sites / 5-9 years time series

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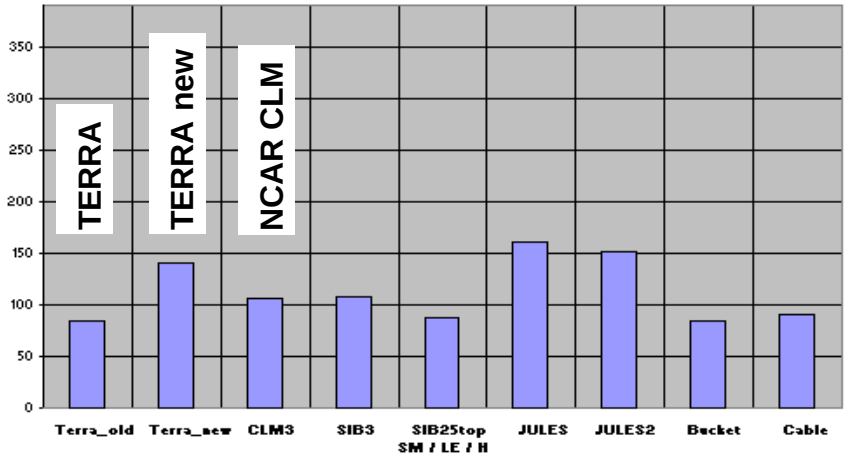
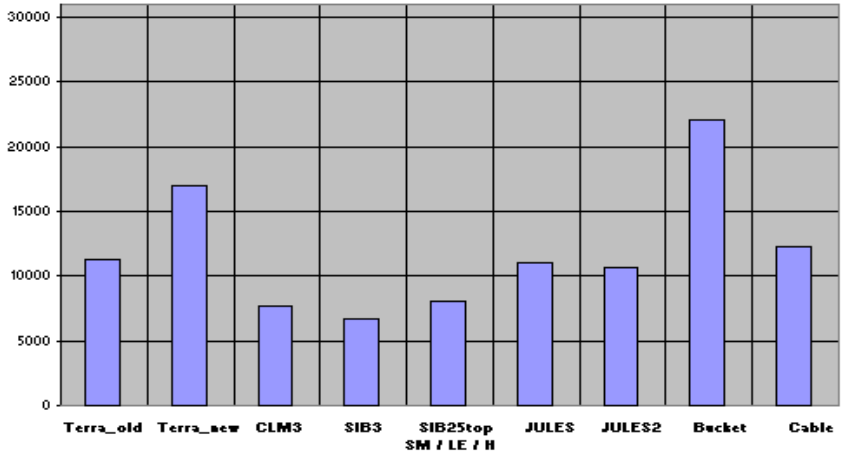
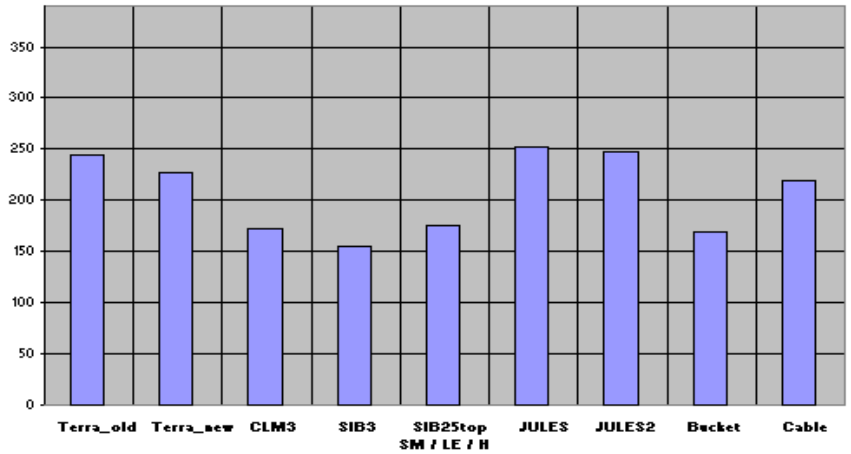
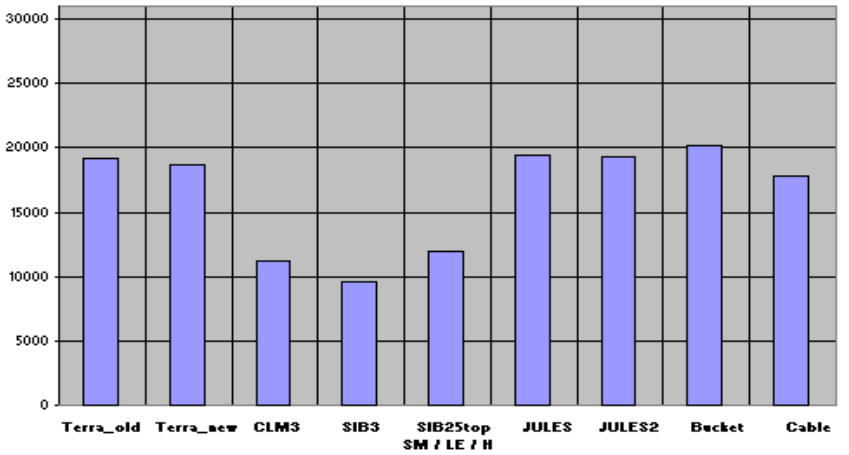




Sensible heat flux





Observation driven SVATs / Verification with measured fluxes / 9 sites / 5-9 years time series

Fundamental issues with TERRA?

COSMO/CLM: SOILVEG and COLOBOC initiatives

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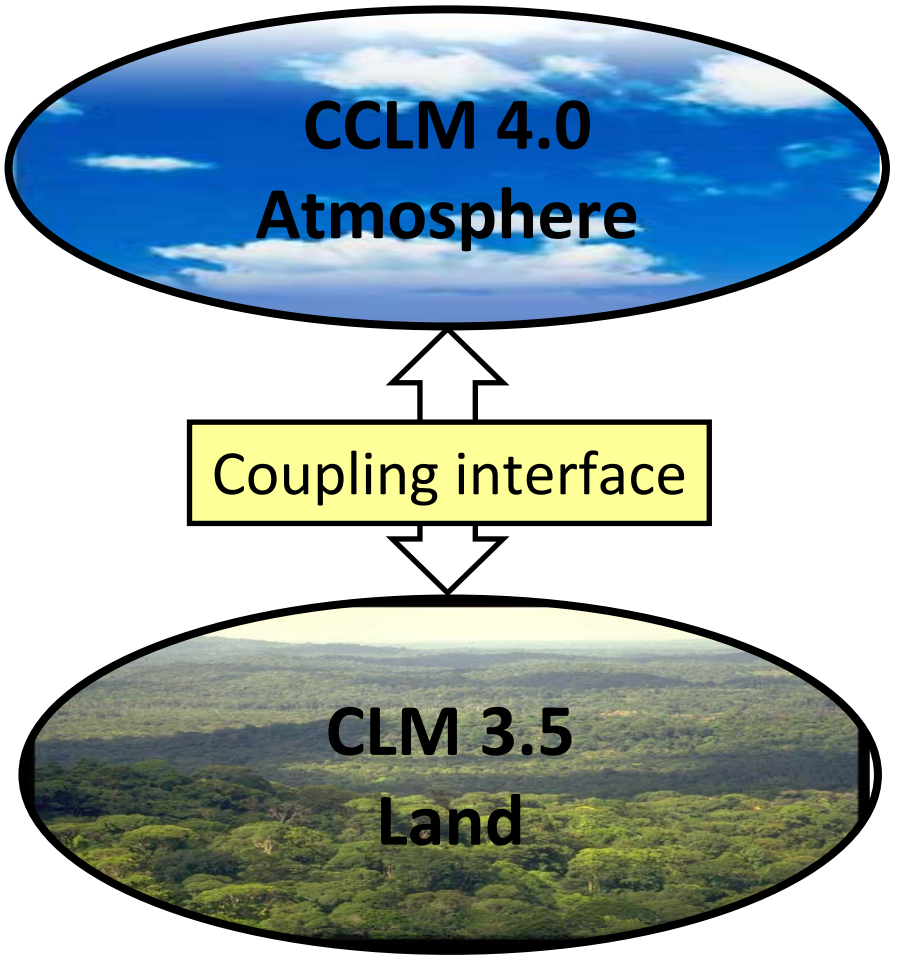
The coupled COSMO-CLM²

- CLM (Community Land Model): Land surface model developed at NCAR

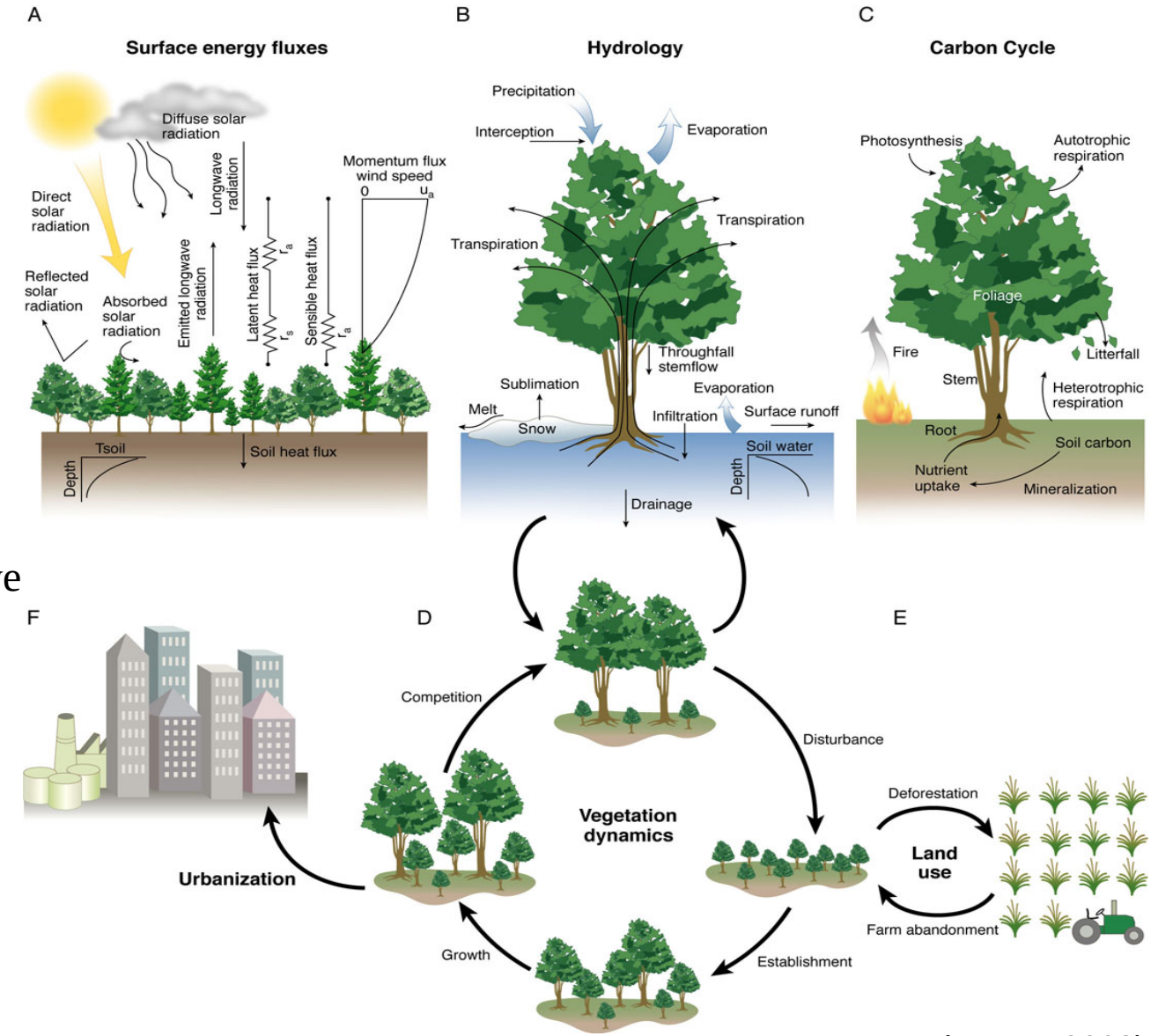
- COSMO-CLM and CLM codes kept (almost) unchanged (facilitate version updates)



(E. Davin, ETH Zurich)

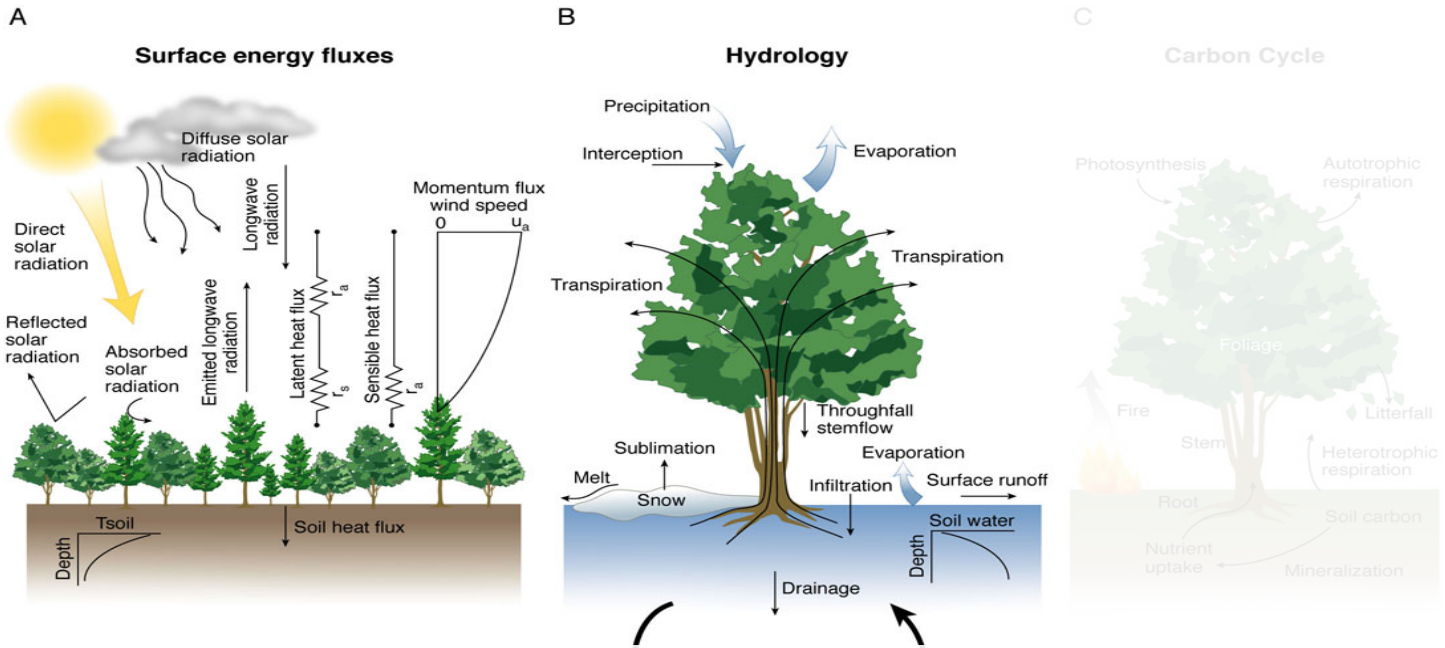
Why CLM3.5?

- Open source
- Well documented
- Extensively evaluated (e.g., *Oleson et al., 2008; Stöckli et al., 2008*)
- Modular structure
- Maintained by a large community
- State-of-the-art, comprehensive vegetation LSM



(Bonan, 2008)

Experiments



COSMO-CLM experiment with the standard COSMO-CLM

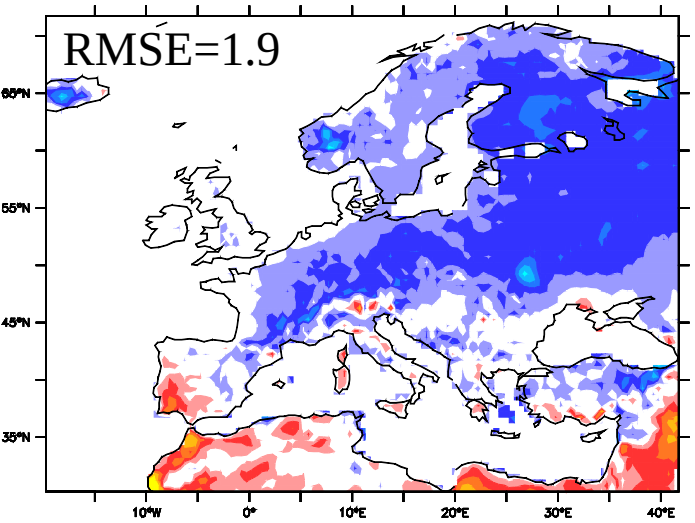
COSMO-CLM^2 experiment coupled with CLM

- COSMO-CLM version 4.0; CLM version 3.5
- Resolution: 50km
- Boundary conditions: ERA40 reanalysis
- Period: 1980-2006 (first 6 years used as spinup)
- CLM: Biogeochemical modules and vegetation dynamics switched off

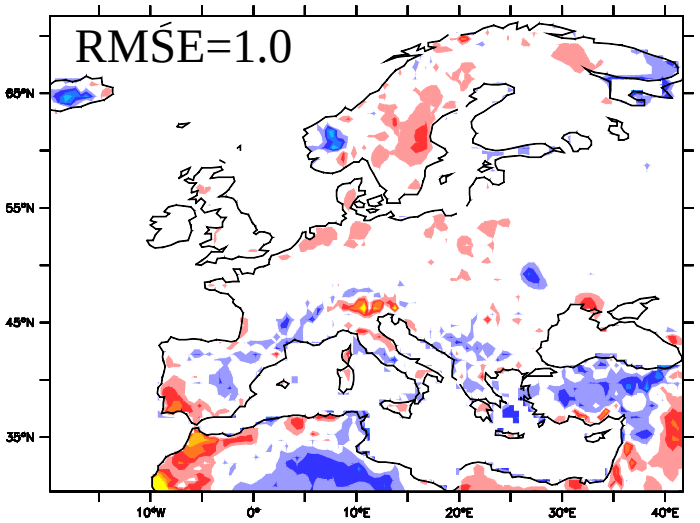
Temperature and precipitation

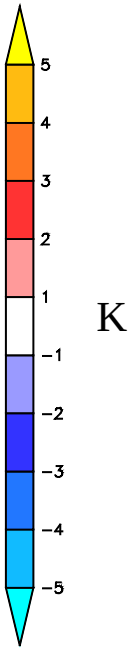
2-meter temperature (model – CRU)

COSMO-CLM



COSMO-CLM²





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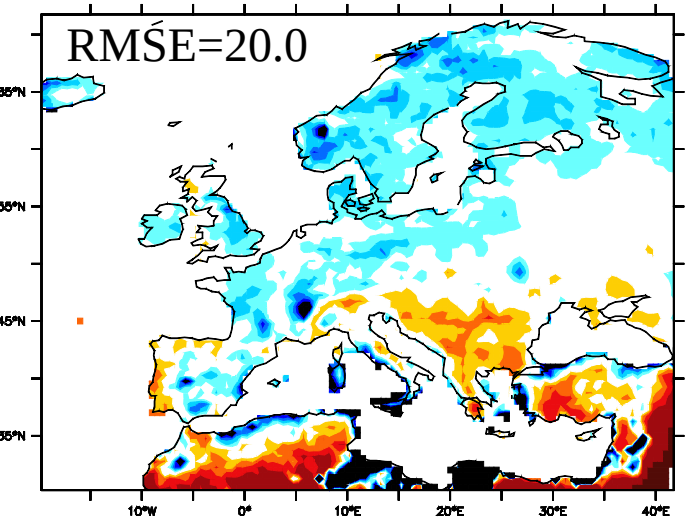
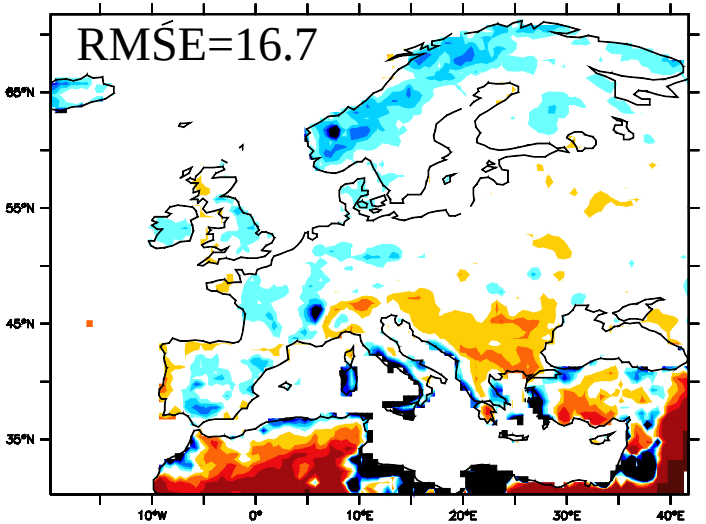
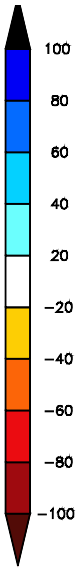
Precipitation (model – CRU)







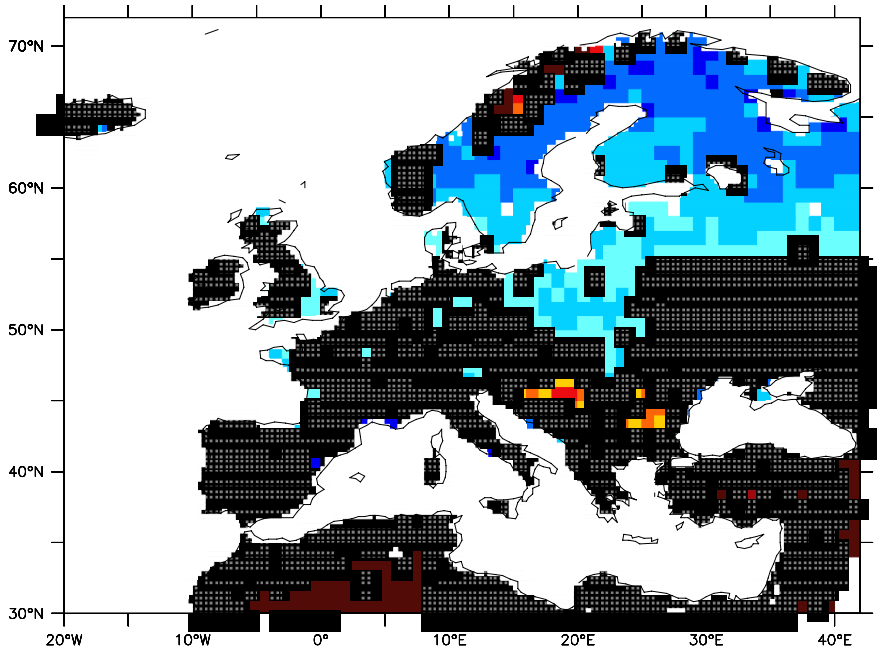
%

(E. Davin)

Bowen ratio (SH/LH)

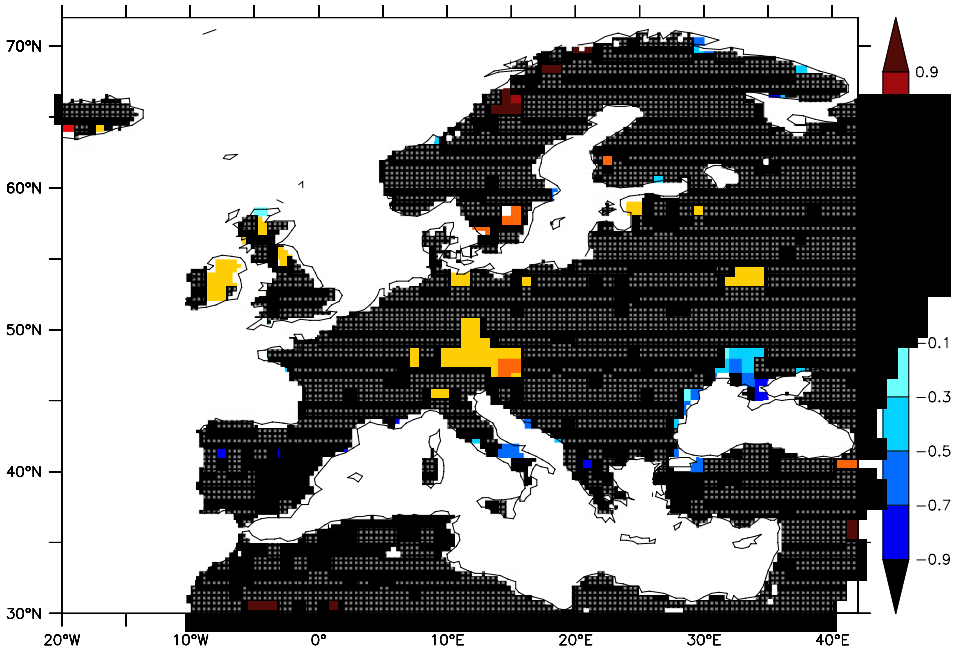
Model minus GSWP-2 (JJA)

COSMO-CLM



Too humid, too low B

COSMO-CLM^2



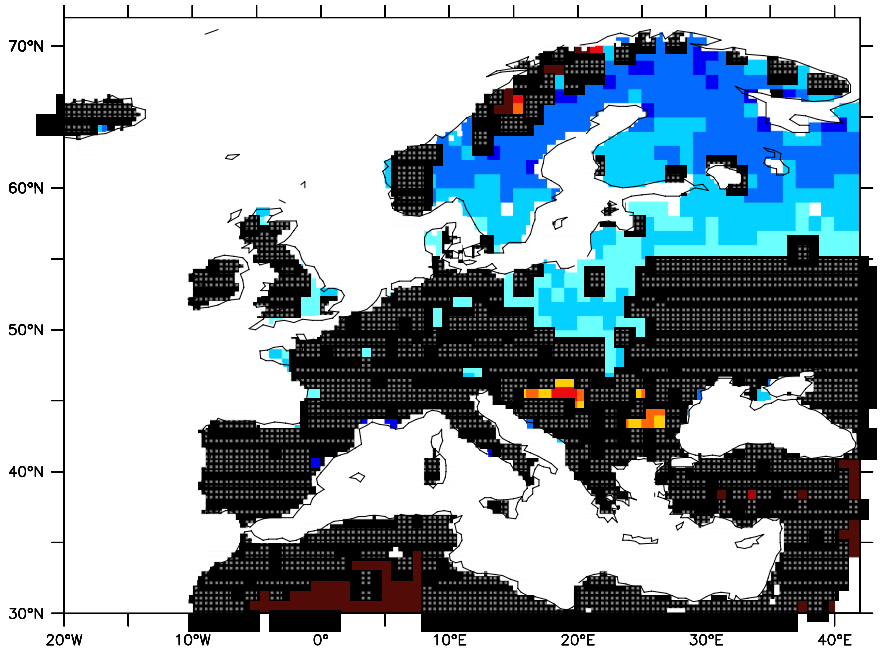
Improved partitioning

(E. Davin)

Bowen ratio (SH/LH)

Model minus GSWP-2 (JJA)

COSMO-CLM



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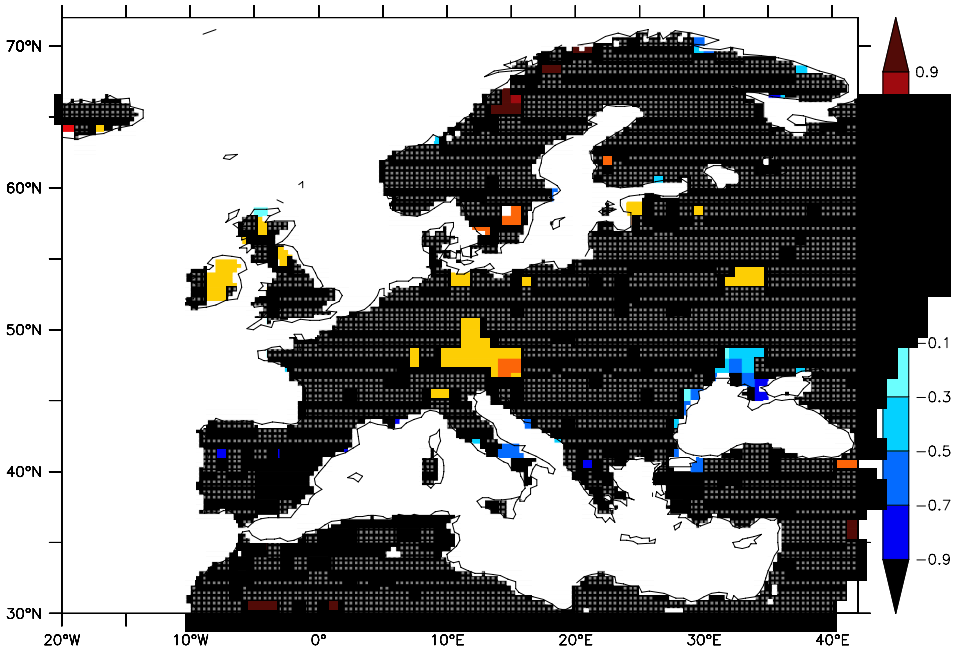


Improved partitioning

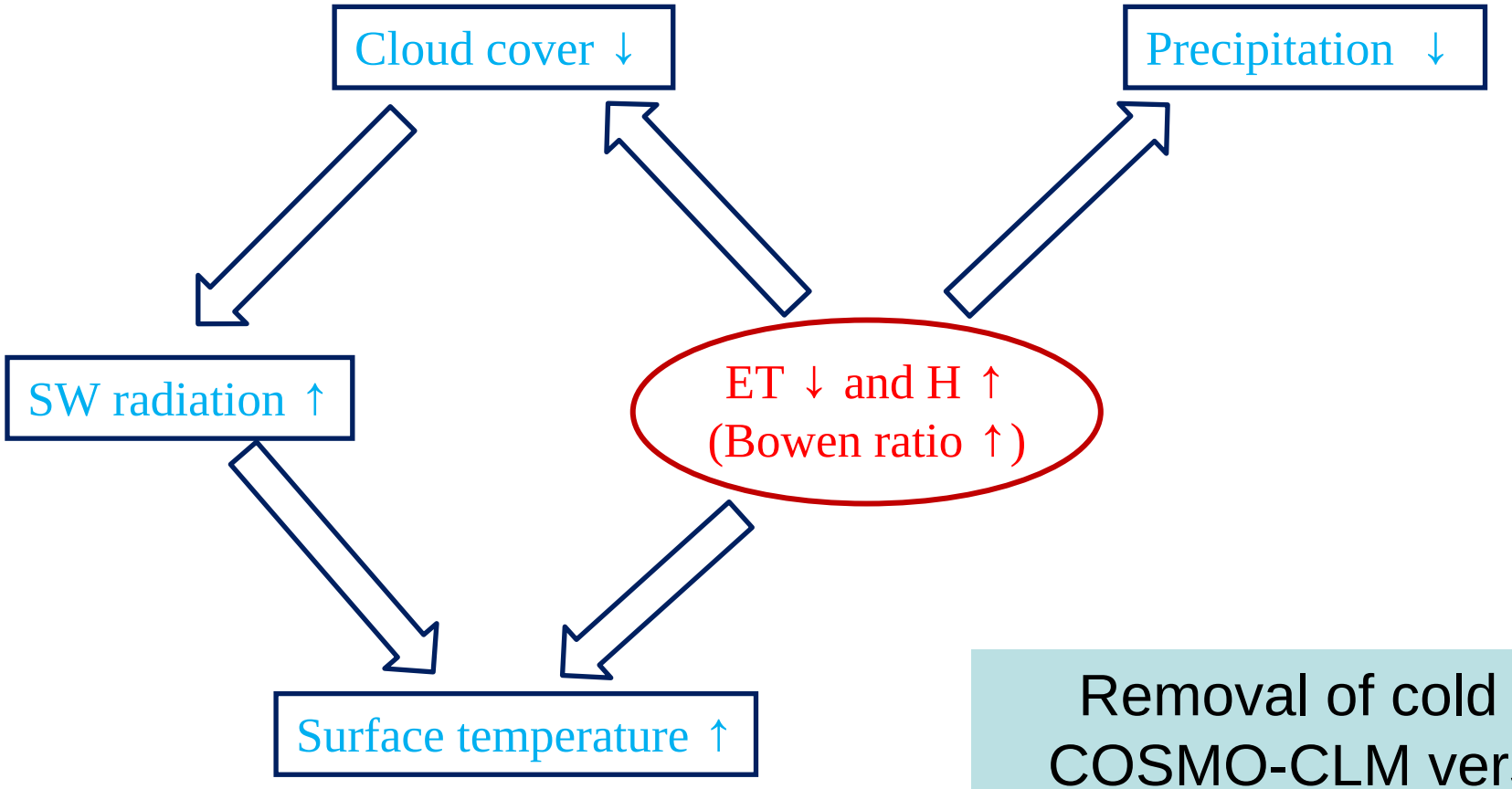
Comparison against FLUXNET measurements:

- Out of 10 sites, 8 sites show that the Bowen ratio in COSMO-CLM^2 is closer to observations
- 2 sites show similar performances for the 2 model versions

(E. Davin)

Mechanism for differences

Changes in COSMO-CLM^2 compared to COSMO-CLM



Removal of cold bias in COSMO-CLM version 4.0

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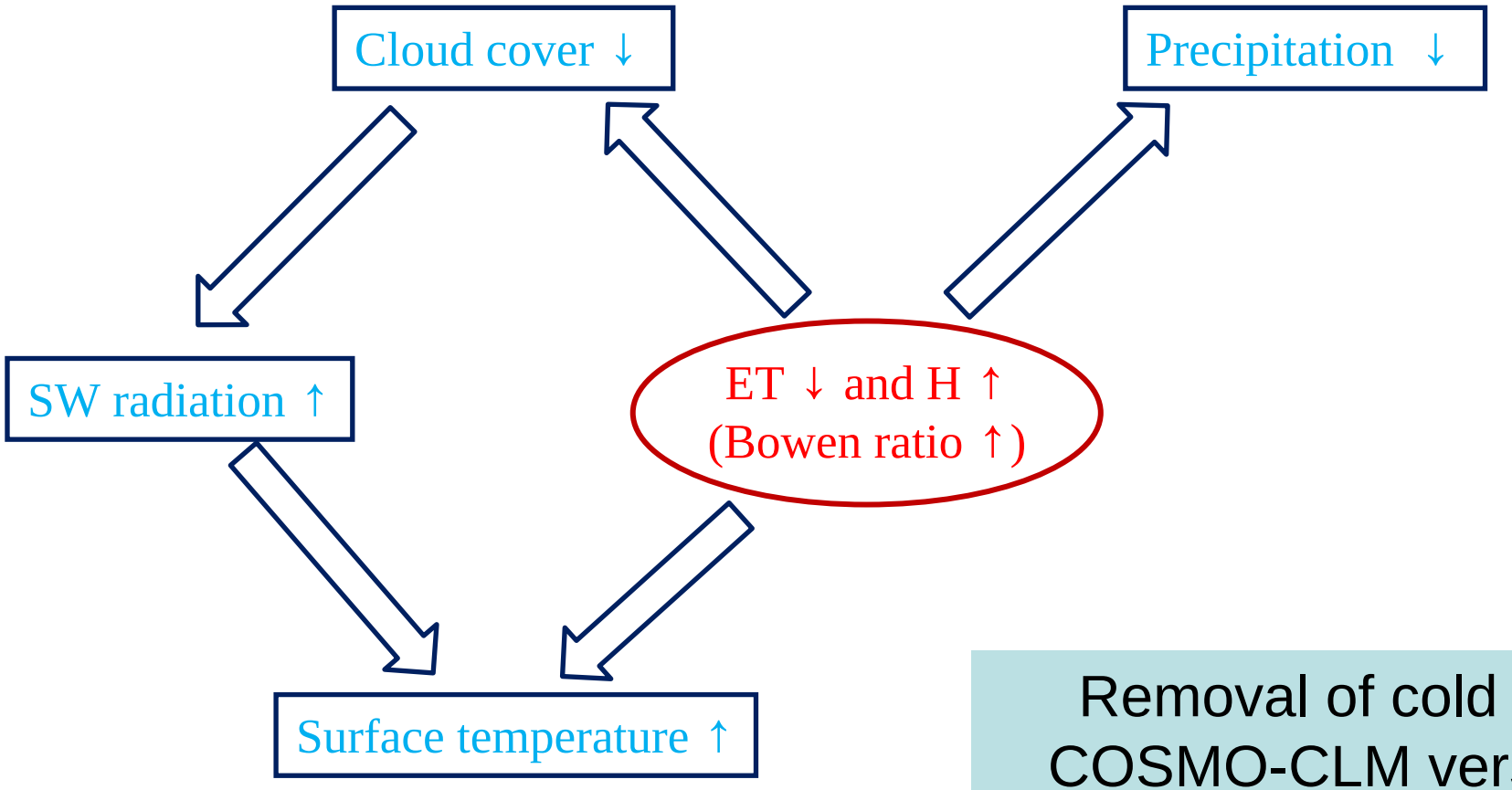

Removal of cold bias in COSMO-CLM version 4.0

Publication in preparation:
E. Davin, R. Stöckli, E.B. Jaeger, S. Levis, S.I. Seneviratne

Community Land Model Meeting in Zurich 29/01/2010

- Several groups plan to use COSMO-CLM² :
  - JRC Ispra → model evaluation, carbon cycle
  - KU Leuven → vegetation dynamics, urban module
  - UFZ Leipzig → parameter optimization
  - Uni Bonn → mosaic approach within COSMO-CLM²
  - EMPA Zurich → coupling with COSMO-ART
  - ETH Zurich → model evaluation, phenology, soil moisture, land use change…

Coupling to COSMO-CLM 4.8

Preliminary results from A. Dosio (JRC) suggest:

- No deterioration overall with coupling to NCAR's CLM
- Slight improvement in summer (cooling): Opposite behaviour to 4.0 (!)
- Slight deterioration in spring

Still preliminary results: Additional analyses are on-going

COSMO/CLM: SOILVEG and COLOBOC initiatives

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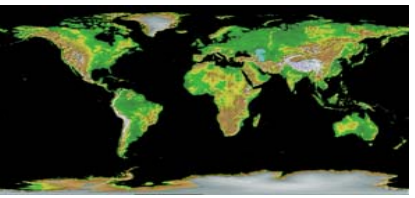
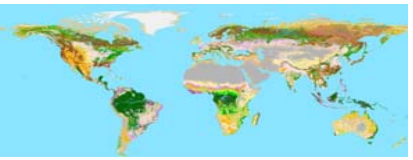
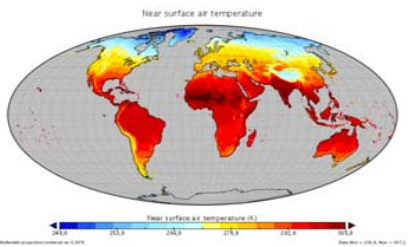
Consolidation of software for the generation of external parameters and extension with new raw data sets (Hermann Asensio, DWD)







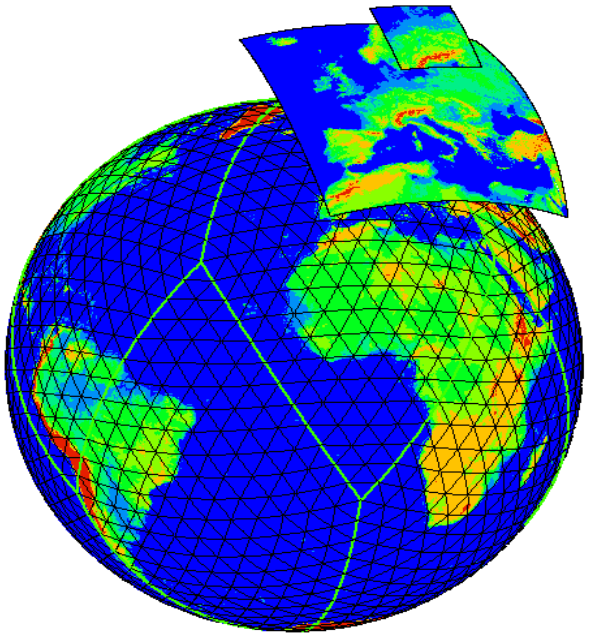
orography
GLOBE

soil data
DSMW

land use
GLC2000

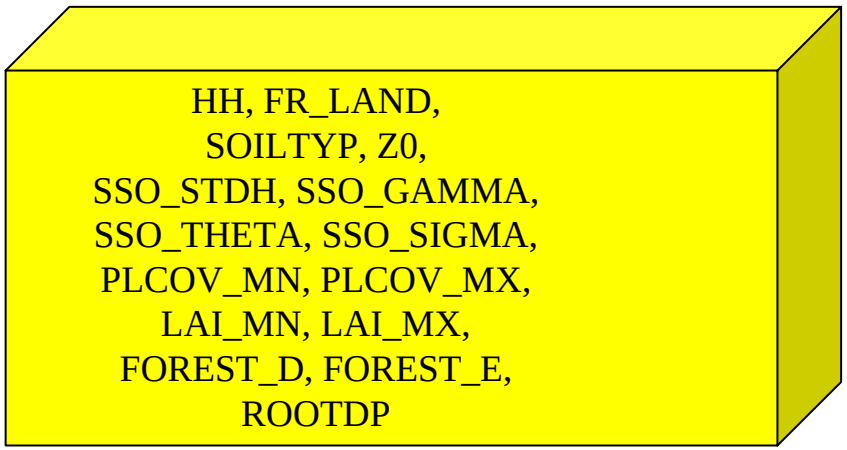
temperature
climatology
CRU

external
parameters
on
target
grid

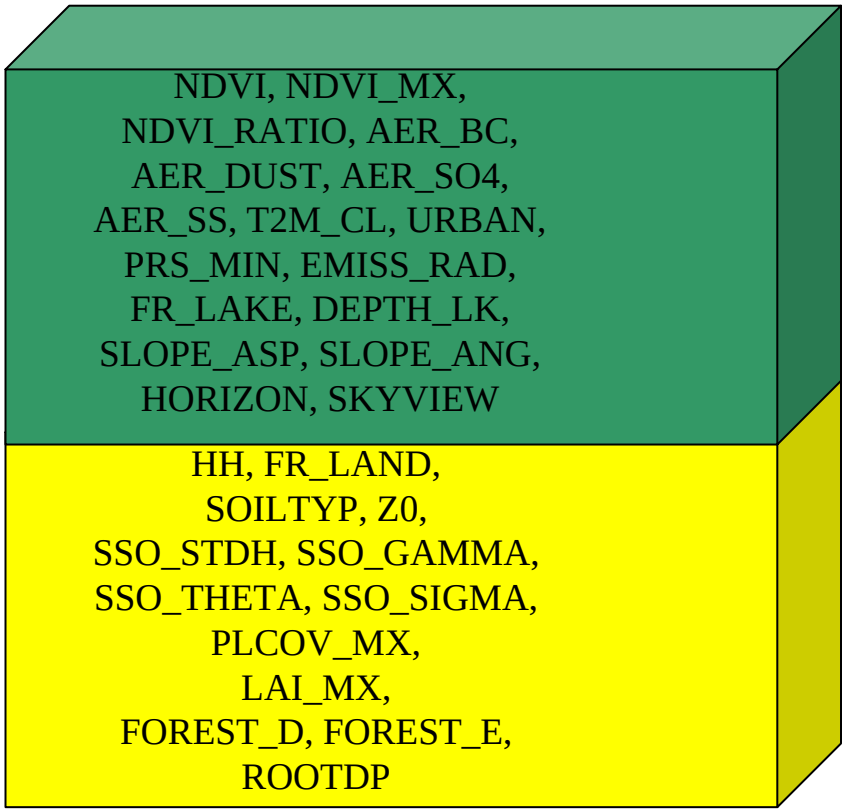


(H. Asensio, DWD)

External parameters (COLOBOC)



- Current external parameter fields for the COSMO model, total 15 fields

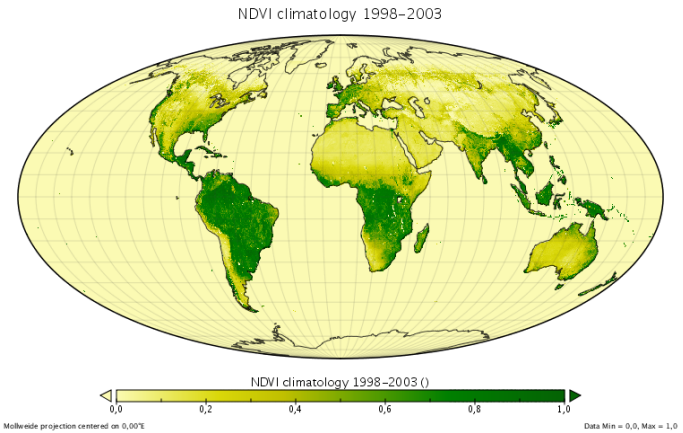


- planned extensions for the COSMO model, total 30 fields

(H. Asensio, DWD)

Additional/Alternative raw datasets

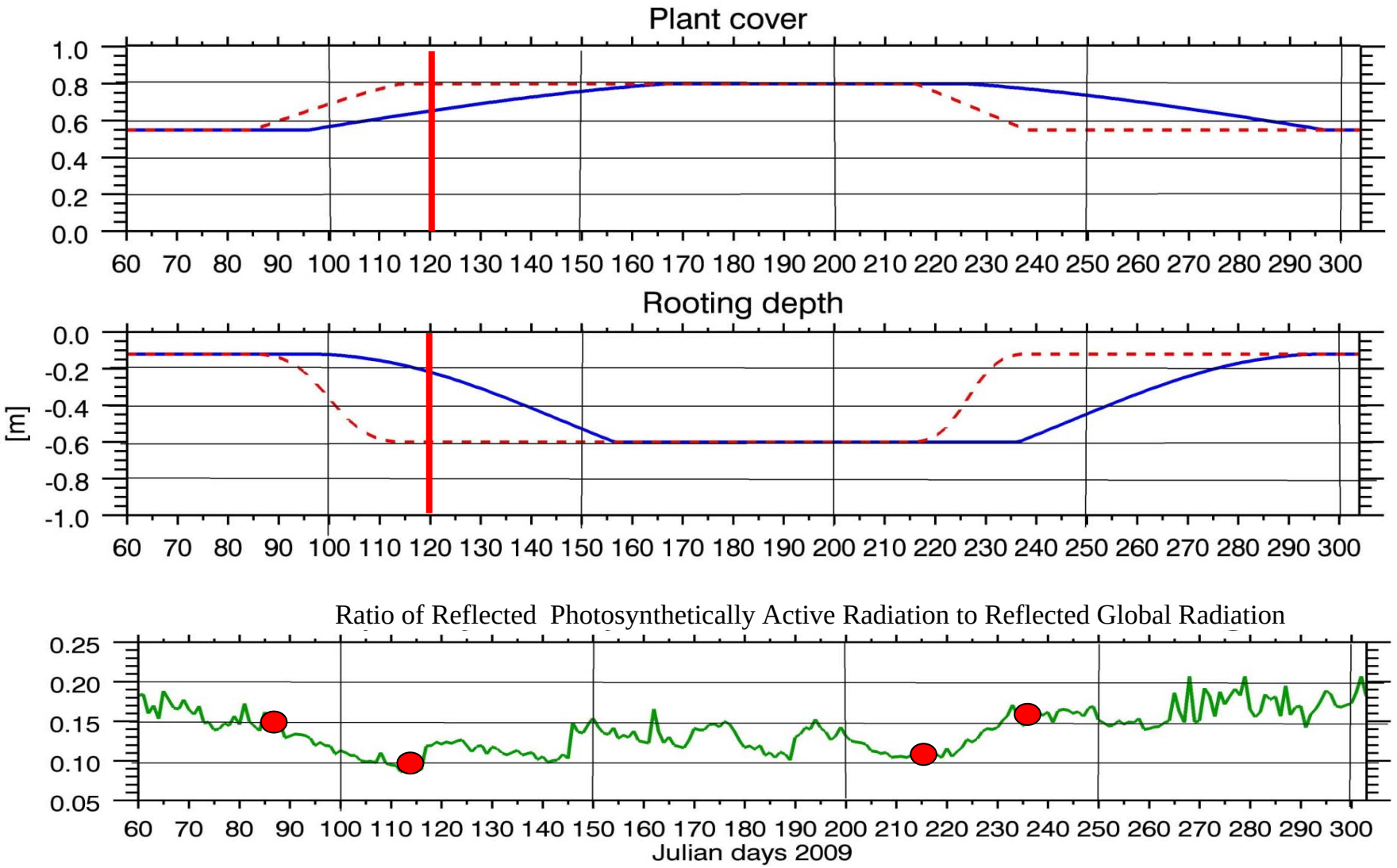
- **SEAWiFS: NDVI**
- Aerosol climatology
- MODIS data for background albedo (?)
- **Harmonized World Soil Database (FAO/IIASA/ISRIC/ISSCAS/JRC); BUEK1000 (Germany only): both datasets include vertical information**
- lake database (DWD); gridded dataset for lake depth from E. Kourzeneva
- (Very) high resolution orography data (SRTM, ASTER)
- Globcover for land use (?)



NDVI
(SEAWiFS)

(H. Asensio, DWD)

Importance of phenology

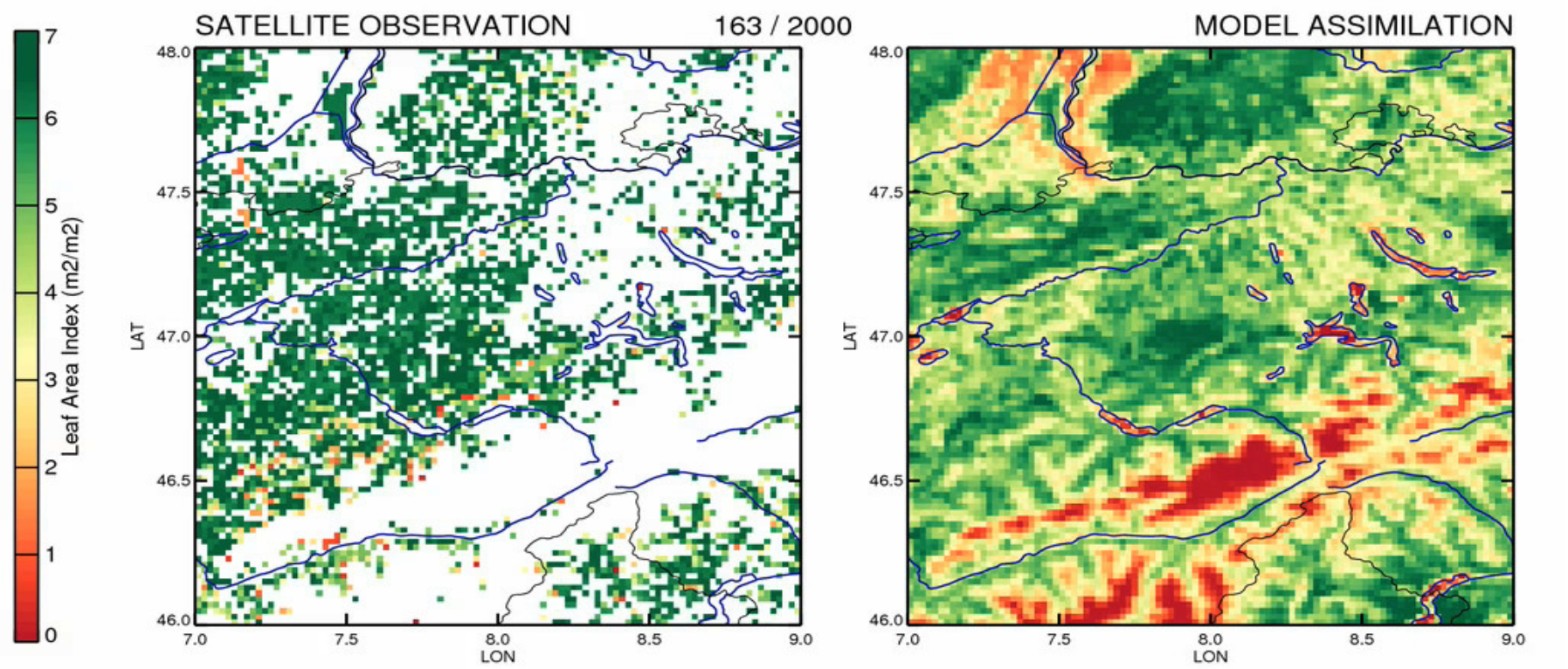


(G. Vogel, DWD)

COLOBOC, Real-time phenology

Prognostic penology model based on minimum daily temperature, mean daily vapor pressure deficit, mean daily global radiation (Growing Season Index, Jolly 2005).

The model derives LAI and FPAR (Fraction of Absorbed Photosynthetically Active Radiation): R. Stöckli, MeteoSwiss



satellite derived LAI

forecast: coupled to NWP model

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Observation datasets for SVAT validation

- **New instruments at Payerne**
  Measurement of turbulence @ 10m, in activity since spring 2009.
  Soil moisture and temperature kept after end of SwissSMEX

- **COLOBOC: Data exchange action within SRNWP**
  Operational data with time lag from:
  Lindenberg (D), Payerne (CH), Toulouse (F), San Pietro (I),
  Sodankylaa (Finland), Cabauw (Netherland).

SwissSMEX project:
ETH Zurich, Agroscope, MeteoSwiss
http://www.iac.ethz.ch/url/research/SwissSMEX

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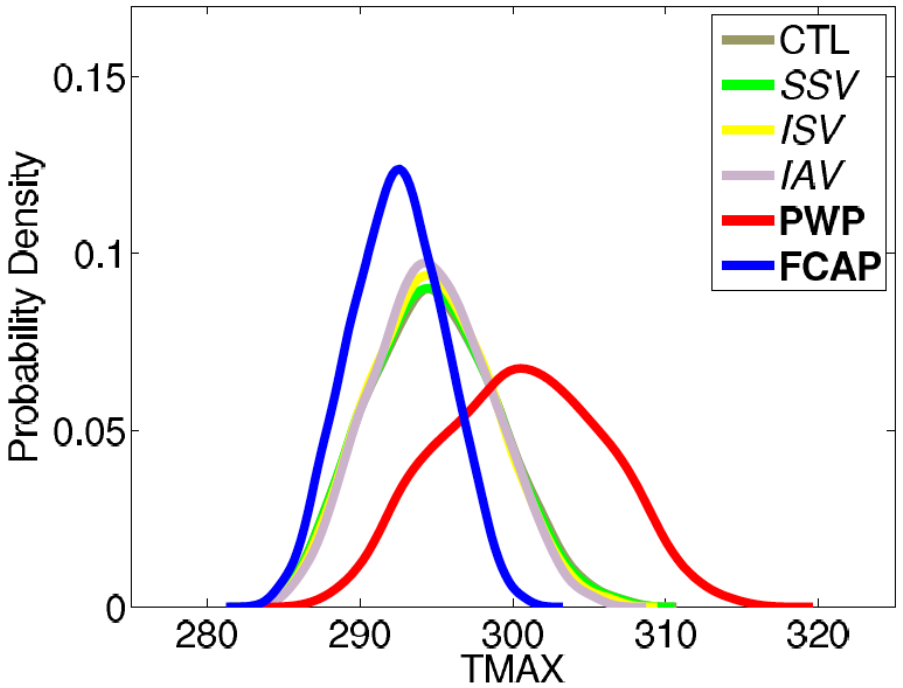
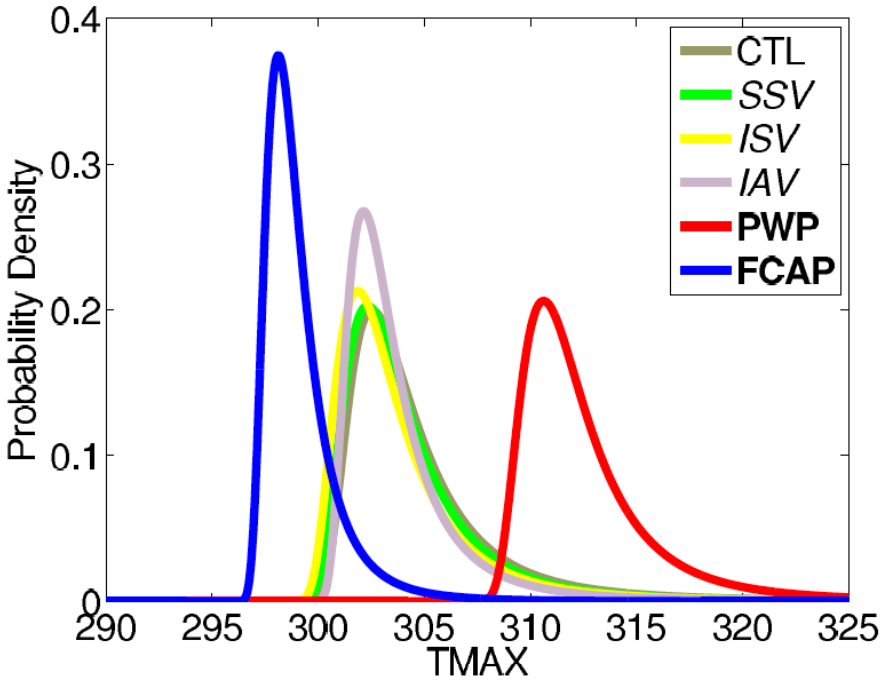
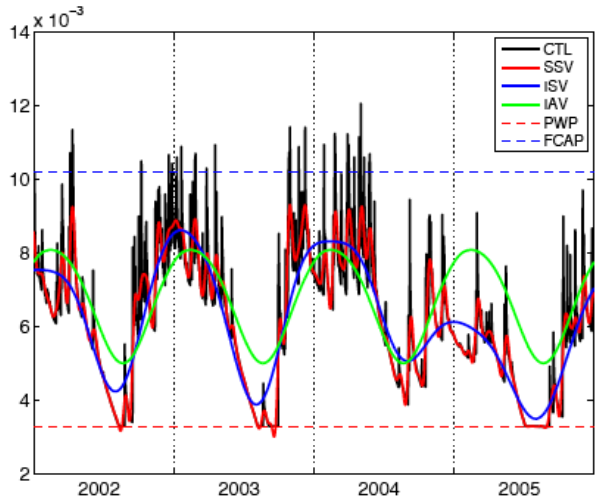
Role of soil moisture for extreme events







Experiments' results for France domain:

- Asymmetric effects of soil moisture
- Hot extremes strongly impacted by soil moisture content
- Also impacts on 20th century trends

(Jaeger and Seneviratne, 2010, Clim. Dyn. In press)

COSMO/CLM: SOILVEG and COLOBOC initiatives

SOILVEG & COLOBOC initiatives: Main activities

- Tests and new implementations in Terra-ML
- Alternative land modules:
  Terra-ML vs Veg3D vs Community Land Model
- External parameters: Soil parameters, vegetation
- Model validation, Validation datasets
- Applications, modeling experiments
- Further developments/submodules: e.g. Urban modelling, snow models

- Future: Current status of SOILVEG and COLOBOC, plans

Schedule, COLOBOC/SOILVEG meeting

COLOBOC/SOILVEG Workshop, Langen (DE), 2010 March 1st, 14h30 - 18h30

14h30 - 15h55 SOILVEG activities
[S. Seneviratne, 10'] SOILVEG Overview
[E. Davin, 20'] Coupling of COSMO/CLM to Community Land Model: COSMO-CLM^2
[R. Lorenz, 10'] Role of soil moisture for persistence of heat waves
[F. Kalinka, B. Ahrens, 15'] Layered soil in TERRA
[A. Will, 15'] Projects at U. Cottbus
[G. Schaedler, 15'] Projects at KIT

15h55 - 16h15 Tea break

16h15 - 17h45 COLOBOC activities
[H. Asensio 15'] Software consolidation and new raw data sets for the COSMO external parameters
[J. Helmert, G. Vogel, H. Asensio 20'] Revision of the COSMO land-surface scheme
[G. Vogel, J. Helmert 15'] Local validation of experiments with COSMO-EU
[E. Kazakova, I. Rozinkina 15'] Snow modelling activities at RHMC
[G. Duniec, A. Mazur 10'] Implementation of tile approach in COSMO
[JM. Bettems 15'] Status of other COLOBOC activities

17h45 - 17h50 Small break

17h50 - 18h30 Discussion
[JM. Bettems] Is there a life after COLOBOC?
[S. Seneviratne] Long-term plans for SOILVEG

Current plans

- COLOBOC will come to an end this summer: Plans for future?
- COLOBOC/SOILVEG meeting established a strong need for increased contact between land modeling communities within COSMO and CLM:
  - Synergies, Critical mass for given projects
  - CLM: mostly new developments (e.g. new model versions, new parameter sets); COSMO community can ensure continuity of successful implementations
  - Suggestion to continue common COSMO/CLM soil/land/veg meetings in the future (1x year)
  - COSMO Activity on land processes?

- SOILVEG: Suggestion for coming 1-2 years:
  - Chair: G. Schaedler (KIT); deputy chair: E. Davin (ETH Zurich)
  - Definition of common projects, also together with COSMO
  - e.g.: ETH Zurich / MeteoSwiss (S. Seneviratne, J.M. Bettems: MSc on implementation of COSMO-CLM^2 in NWP mode @ 7km)

Conclusions

- Land surface processes play a major role for the climate system, also in Europe
- Several new developments within COSMO/CLM community
- Identified needs for strengthened collaboration in this area between COSMO and CLM community

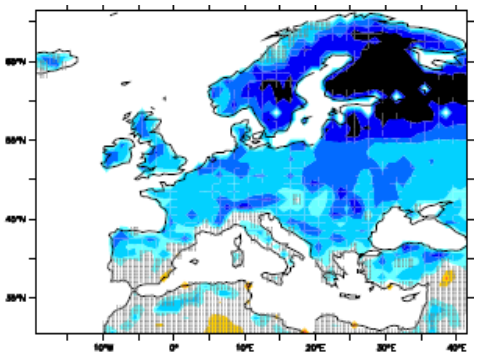
Surface radiation

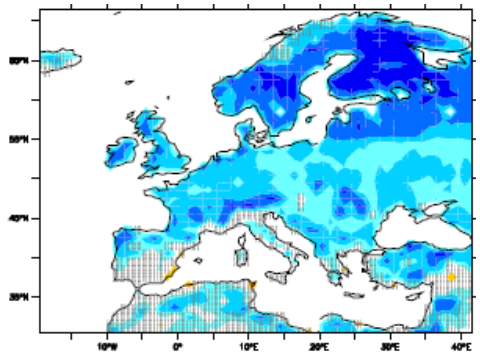
Model minus GSWP-2

COSMO-CLM

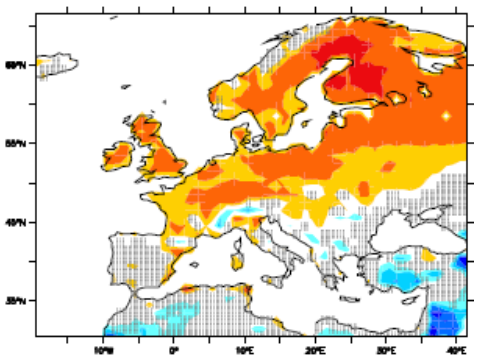
COSMO-CLM^2

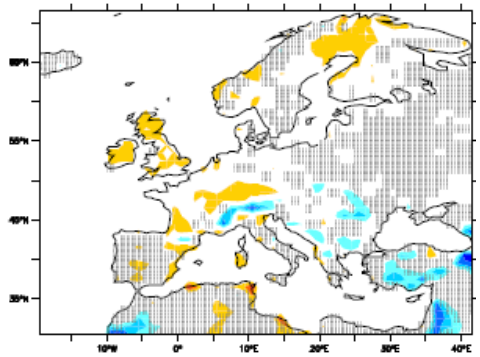
Net radiation



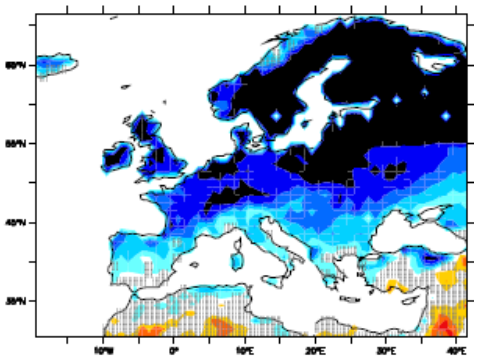


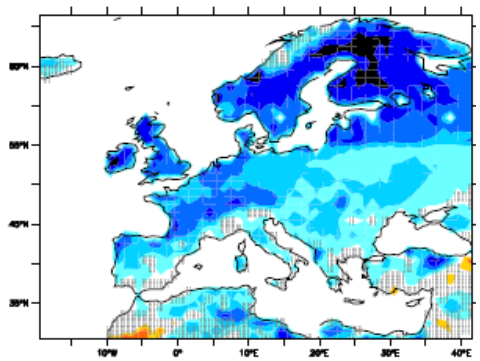
Net longwave

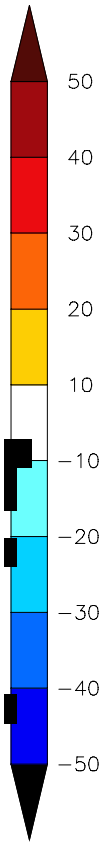




Net shortwave







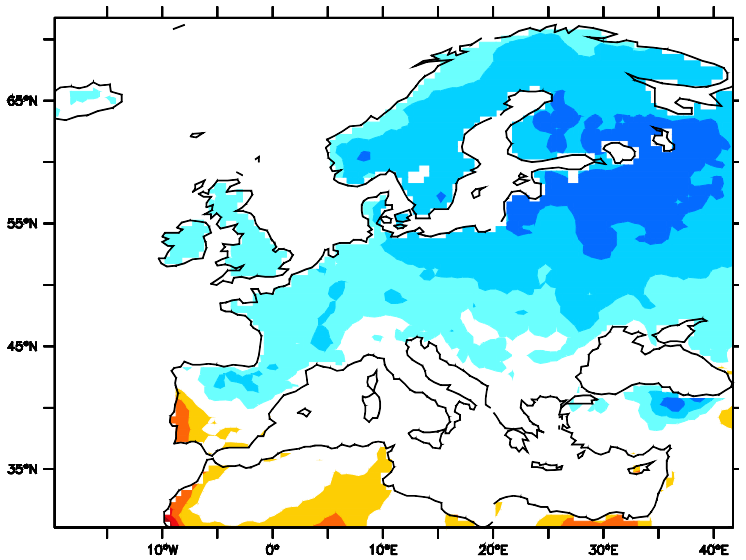
W/m^2

(E. Davin)

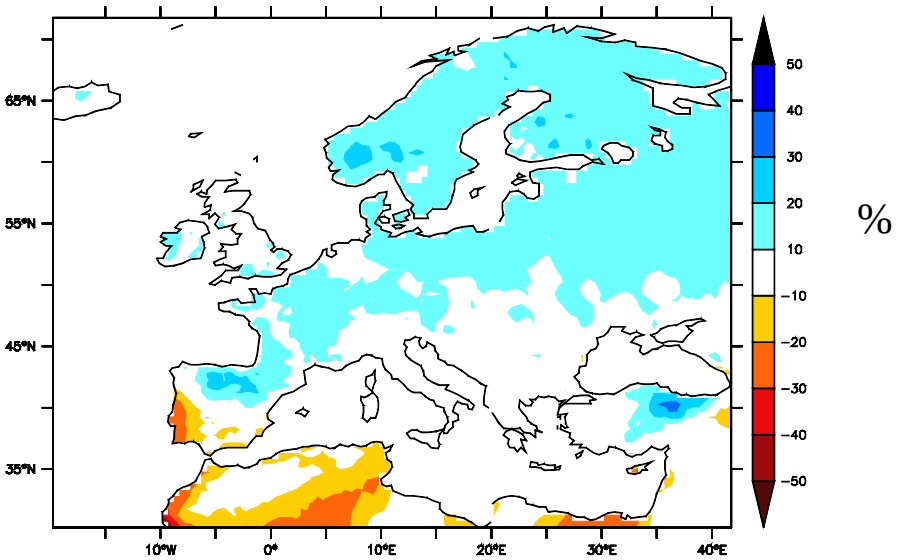
Cloud cover

Model minus CRU

COSMO-CLM



COSMO-CLM^2



Reduction in cloud cover in COSMO-CLM^2 exclusively affects low level clouds

(E. Davin)

Interannual variability

Correlation between model and CRU observations

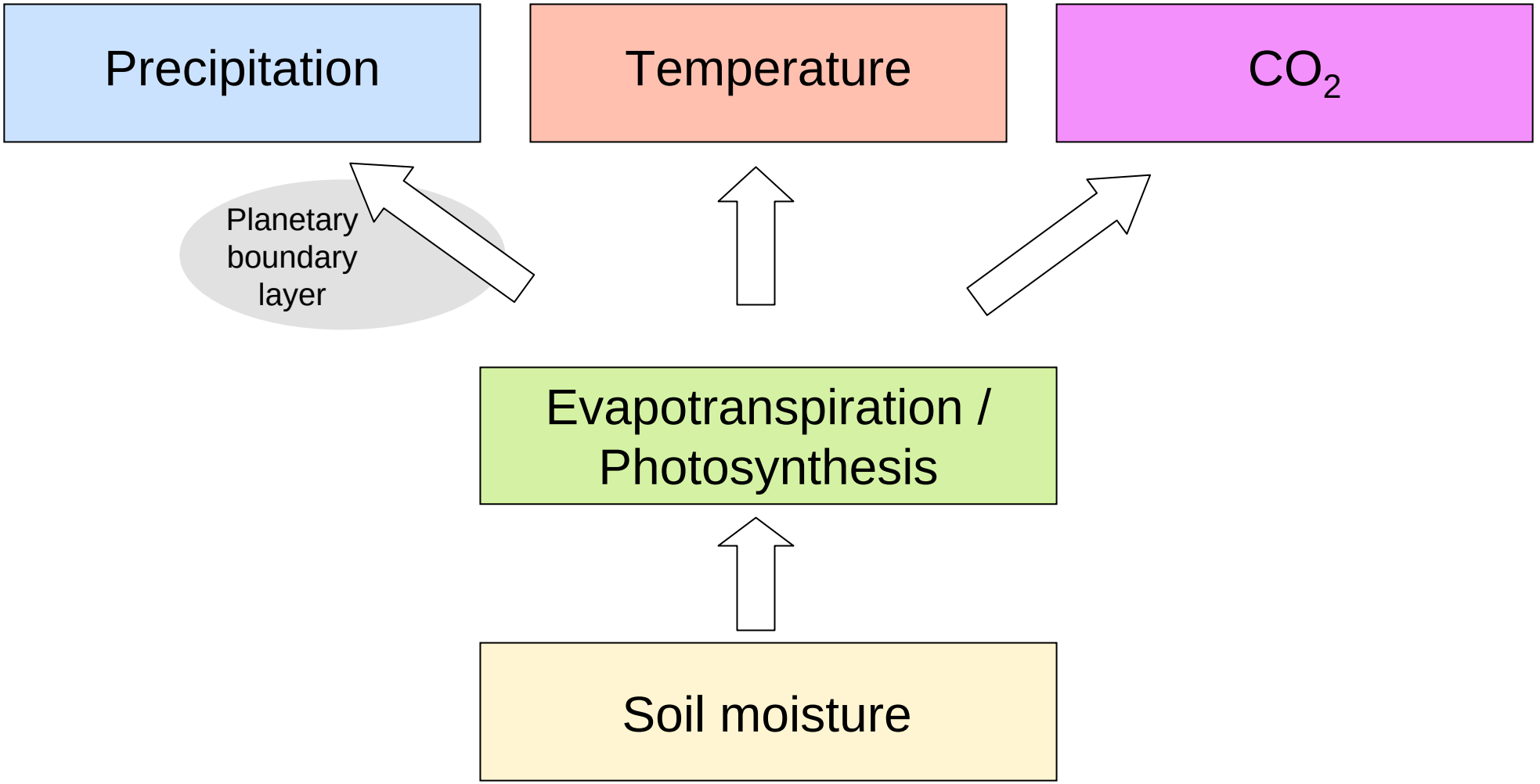
based on summer (JJA) temperature for the period 1986-2006

Domains	COSMO-CLM	COSMO-CLM^2
British Isles	0.97	**0.98**
Iberian Peninsula	0.89	**0.92**
France	0.86	**0.91**
Mid-Europe	0.92	**0.94**
Scandinavia	0.93	**0.94**
Alps	0.91	**0.92**
Mediterranean	0.75	**0.88**
Eastern Europe	0.67	**0.88**

…but no improvements for precipitation…

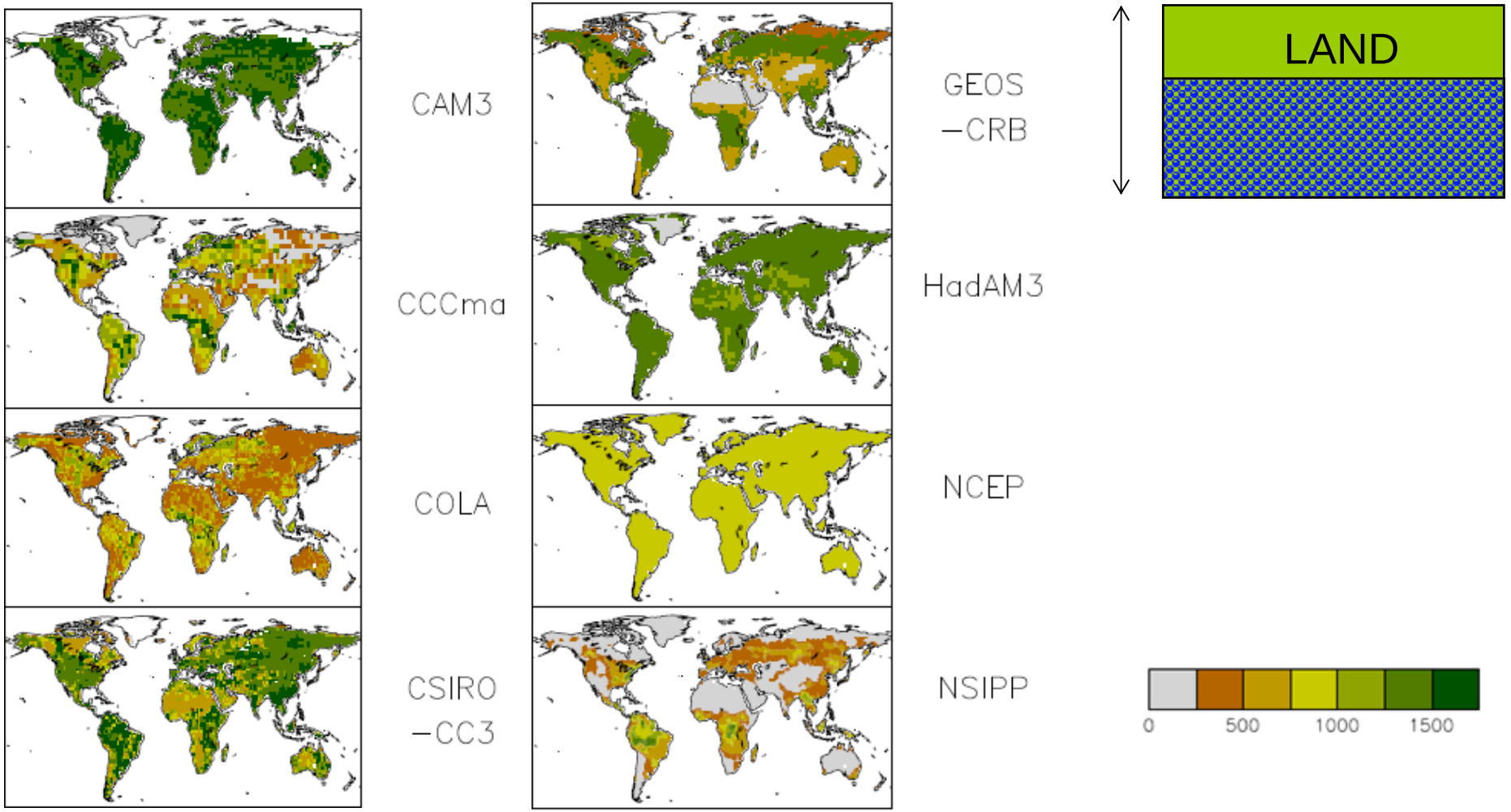
(E. Davin)

Introduction: Overview, soil moisture-climate feedbacks



Specification of soil properties in climate models

Water-holding capacity



(Seneviratne et al. 2006, JHM)

SwissSMEX: Swiss Soil Moisture Experiment (2008-2011; SNF)

ETH Zurich, IAC: S.I. Seneviratne (PI), H. Mittelbach, I. Lehner, A.J. Teuling, K. Schroff
Agroscope ART: J. Fuhrer (co-PI), C. Ammann
MeteoSwiss: M. Rotach (co-PI), Y-A. Roulet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Klimaforschung

Der Bodenfeuchte auf den Grund gehen

Wie feucht ein Boden ist, hat grossen Einfluss auf das Regionalklima. Doch die Klimawissenschaft hat wenig Ahnung, wie gross dieser Beitrag wirklich ist. Ein neues, dichtes Messstellennetz in der Schweiz wird die dazu nötigen Daten liefern.

Doktorandin Heidi Mittelbach richtet eine Messstelle ein zur Erfassung von Bodenfeuchtigkeit und -temperatur. (mehr Bilder)

Das Testfeld vor Oensingen ist topfeben. Ausgedehnte Wiesen bis zum nächsten Hügel am Horizont und zur Autobahn A1, ein paar Gehölzstreifen. Die höchsten Erhebungen im Umkreis von einem halben Kilometer sind mehrere Erdhaufen, die auf der Wiese auf blauen Planen lagern. Drei Tonnen Material, schwerer lehmiger Gley-Boden aus zwei 1,20 Meter tiefen Gruben. Alles von Hand ausgehoben.

Blaue Erde

Irene Lehner, Postdoktorandin am Institut für Atmosphäre und Klima sowie die Doktorandin Heidi Mittelbach stehen in Gruben und stecken in regelmässigen Abständen Messsonden in den lehmigen Boden. Noch am Vorabend haben die Forscherinnen ein 100jähriges Niederschlagsereignis über einem Quadratmeter simuliert, das Wasser blau, mit Lebensmittelfarbe eingefärbt, um bevorzugte Fliesswege zu erkennen Die Schollen sind noch immer blau, die Schuhe, und die Hosensäume von Mittelbach ebenso. Dafür erkennt sie nun im Aushub, wo das Wasser versickert ist, das Bodenprofil sieht aus wie ein Marmorkuchen. Unter Einsatz ihres Körpergewichts lässt Mittelbach die Sonden vor allem in den braunen Stellen verschwinden.
In jeder Grube stecken die Forscherinnen in sechs verschiedenen Tiefen Sonden in den Erdboden, um die Bodentemperatur zu messen oder um den Wassergehalt festzuhalten. Alle zehn Minuten senden die Sonden Daten an ein Aufzeichnungsgerät, den Logger, der in einem Gehäuse über Boden eingebaut ist.

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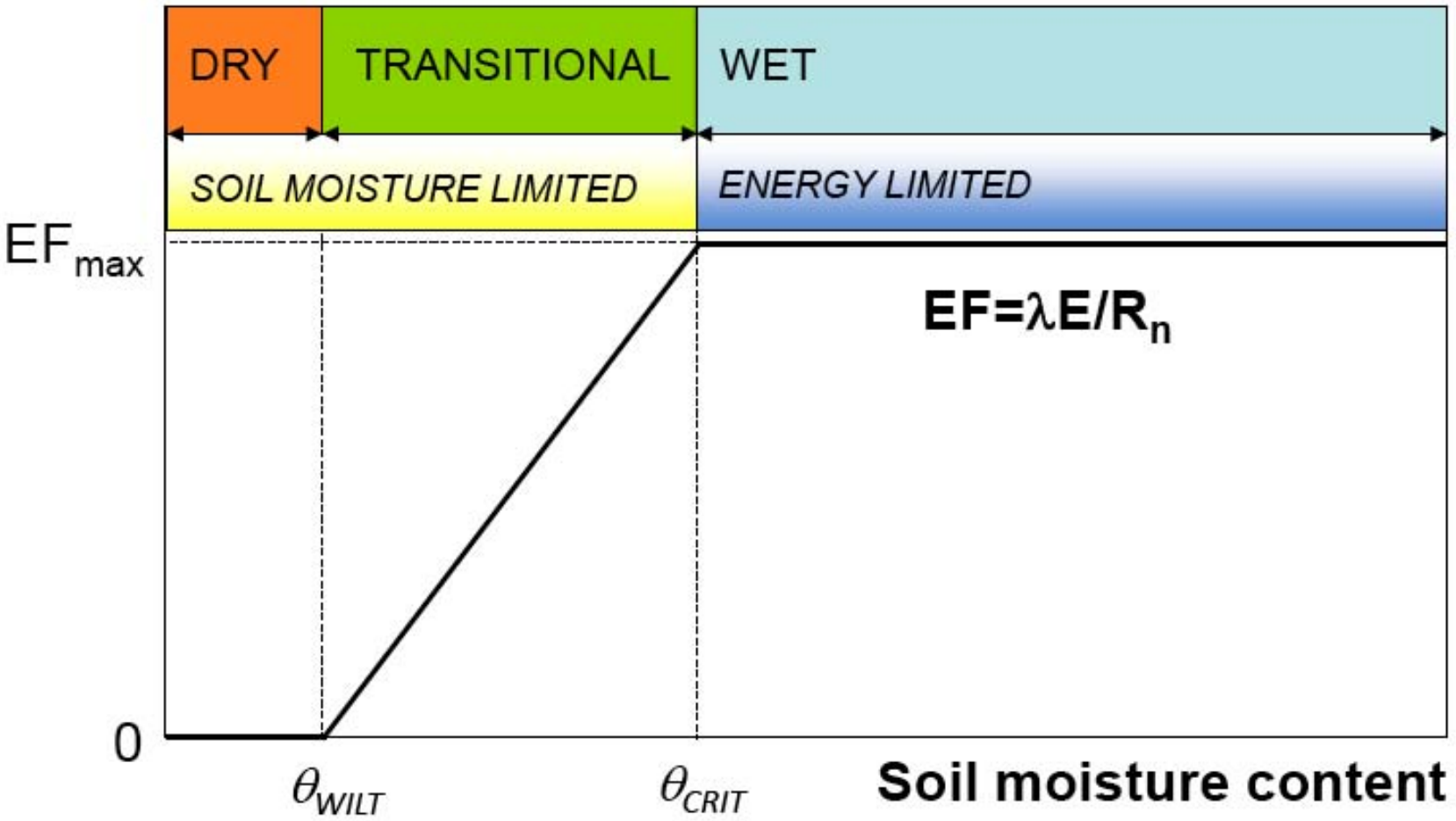
Projektleiter verlässt Science City



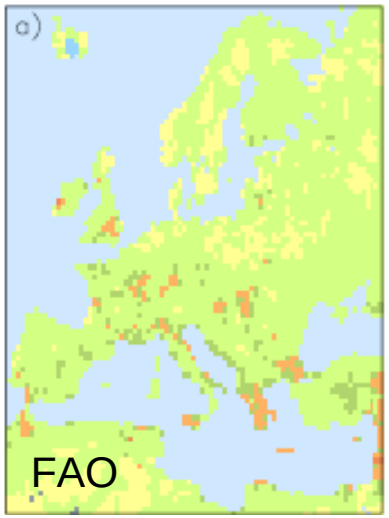


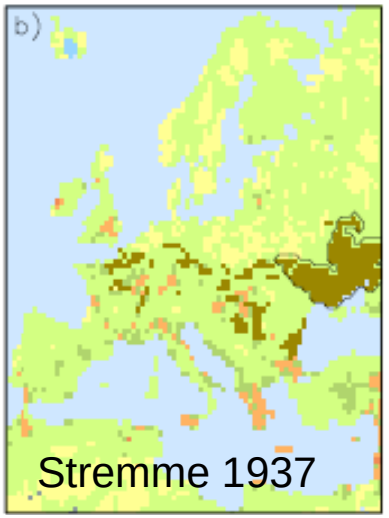

Transitional climate regions



(Seneviratne et al. 2010, Earth-Science-Reviews, in press)

Role of soil datasets

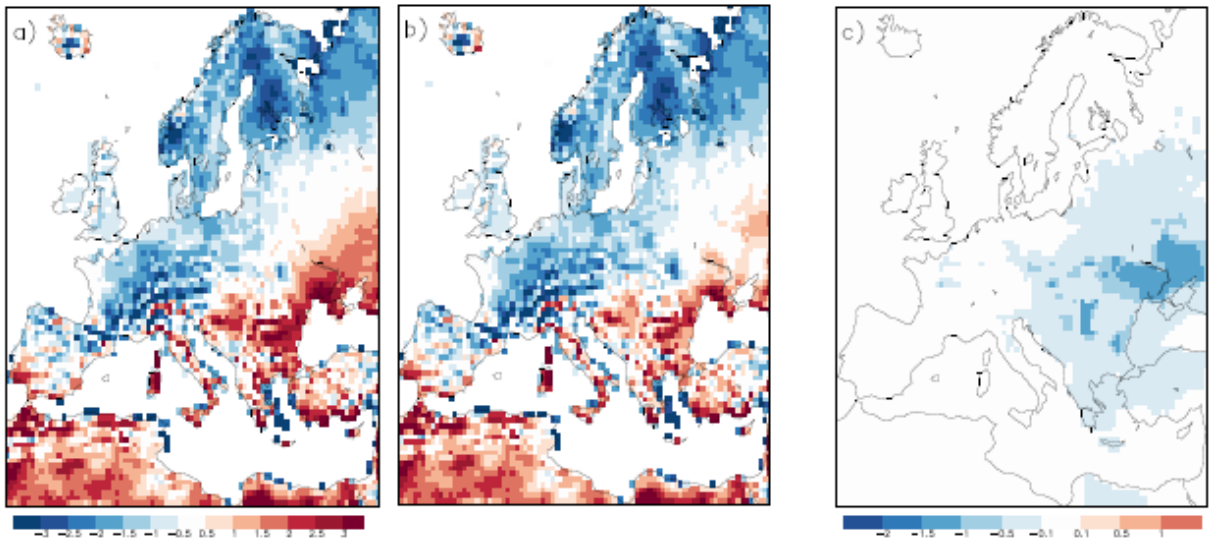




Silt loam

Sandy loam

	sandy loam	silt loam
volume of voids [-]	0.445	0.485
field capacity [-]	0.260	0.360
permanent wilting point [-]	0.100	0.130
heat capacity $[10^6 J/(m^3 K)]$	1.350	1.450
heat conductivity $[W/(Km)]$	1.74	1.25
fraction of sand [%]	65	10
fraction of clay [%]	10	15



Bias of JJA temperature in (a) original simulation, (b) simulation with new specification; (c) difference

(Anders and Rockel, Clim. Dyn. 2009)

SOILVEG Overview

- 21 participants to last working group meeting (Sept. 2009)

- Two streams of development:

  - consolidation of TerraML (coordination with COLOBOC priority project from COSMO consortium)

  - new version coupled to Community Land Model (interested groups - developers, potential users)

COLOBOC Tasks

- Task 0: Observations sets for SVAT-model validation
- Task 1: Consolidate externalized TERRA module
- Task 2: Consolidate software for generating external parameters
- Task 3.1: Document external parameter data set
- Task 3.2: Consolidate external parameter data set
- Task 4: Revision of TERRA and associated look-up tables
- Task 5.1: Verify and consolidate new multi-layer snow model
- Task 5.2: Improved snow analysis
- Task 6: Urban module
- Task 7: Parameterization of land surface heterogeneity by tile/mosaic approach