Land evapotranspiration in reanalyses

Comparisons to observations-based datasets, land-surface models and IPCC simulations

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With contributions from the LandFlux-EVAL team

Outline

1. Evapotranspiration in reanalyses

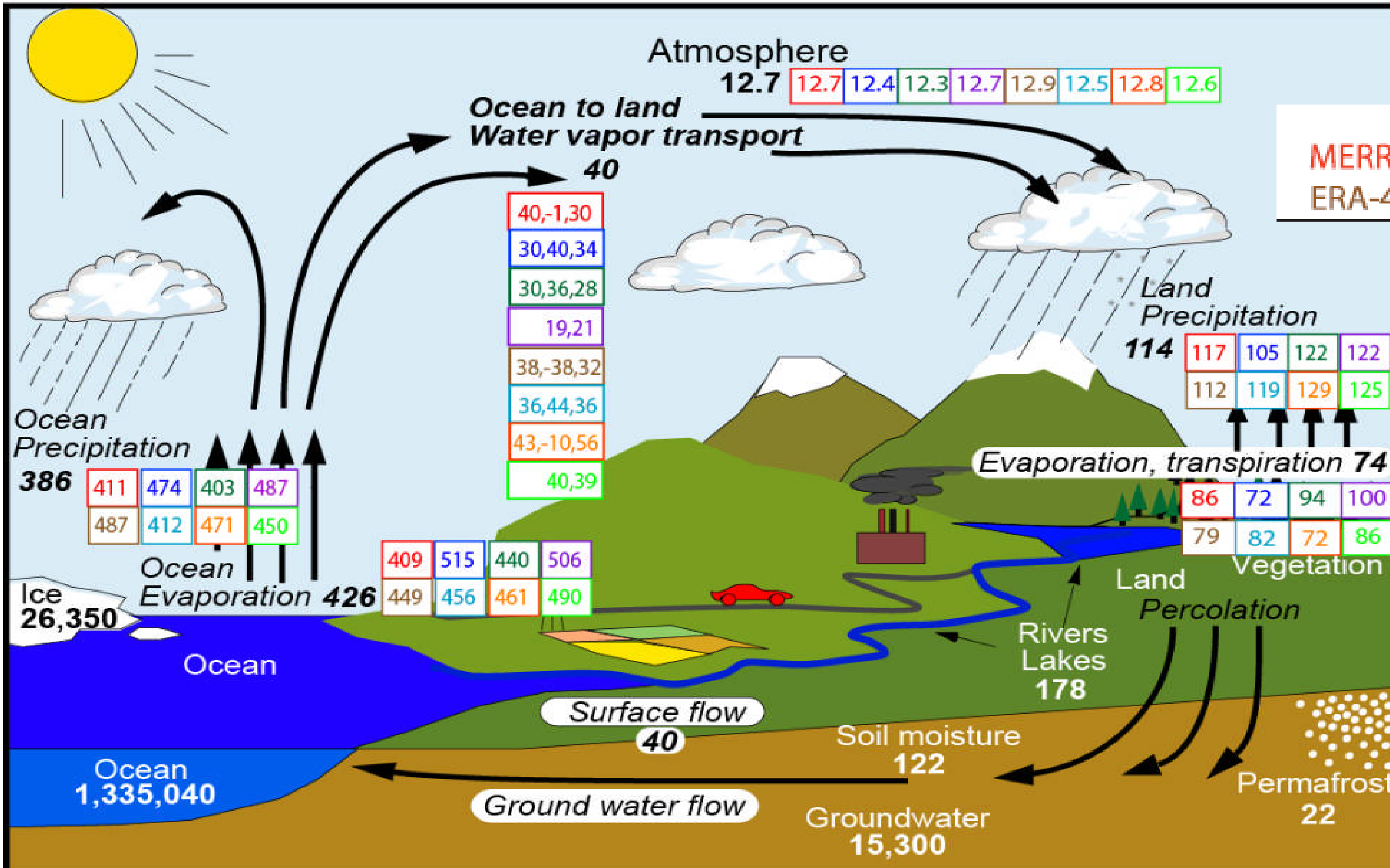
2. Global analysis of land-atmosphere coupling (2m-air temperature from reanalyses)

Motivation

Evapotranspiration (ET) important because of:

- Hydrology and water resources
- Link to other variables of the hydrological cycle (soil moisture, precipitation...) and carbon cycle
- Land-atmosphere feedback and seasonal prediction
- Large uncertainties

The hydrological cycle



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges *1990s

MERRA JRA R1 R2
ERA-40* ERA-I CFSR C20R

Large uncertainties

Trenberth *et al. J. Climate, 2011*

ET in reanalyses

	Land-surface scheme	Characteristics
ERA-Interim	TESSEL	
MERRA	GEOS-5 Catchment LSM	
MERRA-Land	See MERRA, with changes in interception and snow parameters	Off-line replay of MERRA Precipitation forcing corrected with GPCP (newer version with CPC-un)
CFSR-NCEP	NOAH	Observed precipitation (GLDAS)
NCEP (NCAR)	OSU LSM	
JRA-25	Simple Biosphere (SiB) model	

ET dataset categories

- **Diagnostic datasets:**
  Based on observations (satellite, Fluxnet etc.)
- **Land-surface models:**
  Models driven with observation-based forcing
- **Reanalysis products:**
  Models with assimilation of observations
- **Climate models:**
  IPCC CMIP3 and CMIP5 global climate model simulation

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Reference datasets

- **Climate models:**
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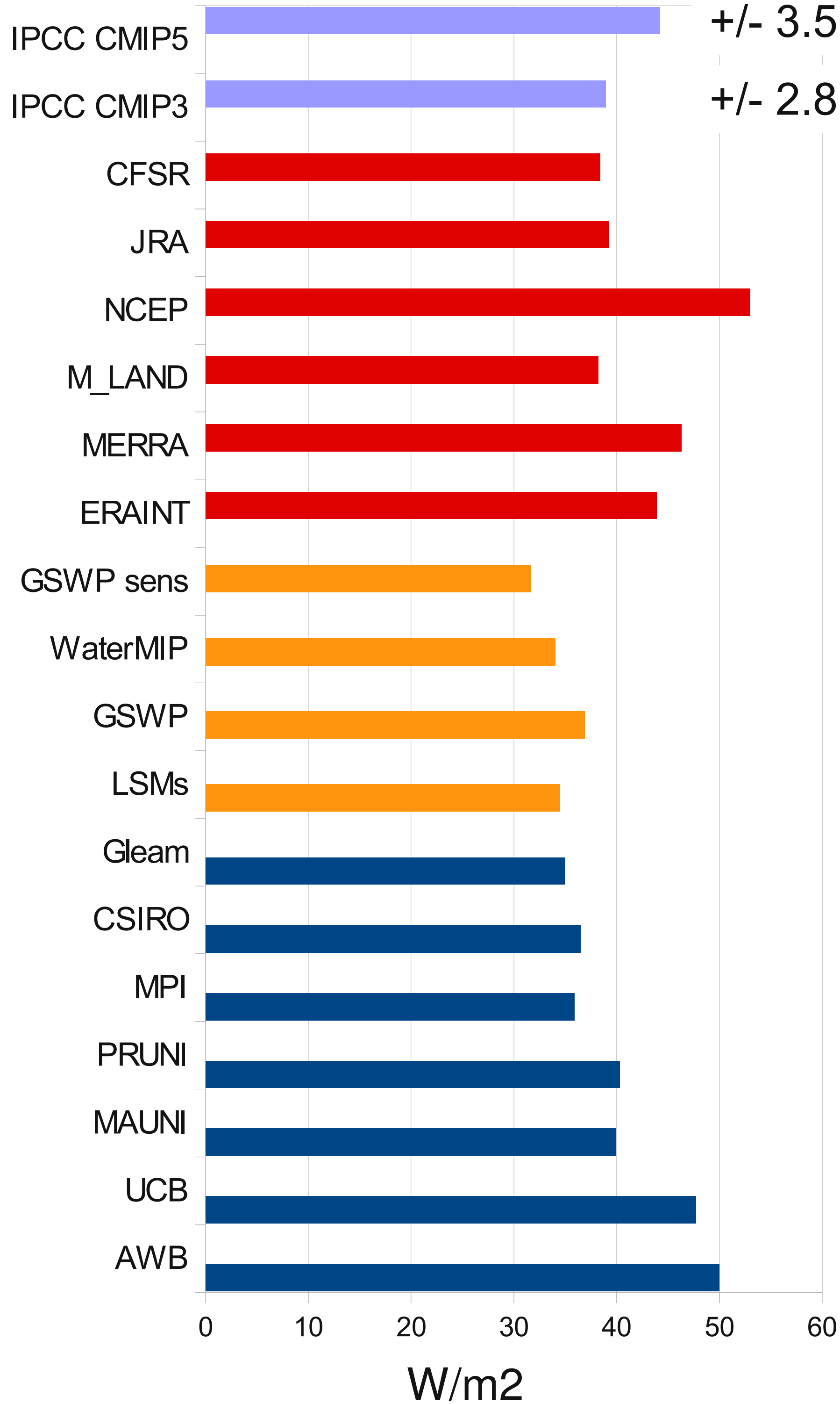
ET evaluation: Research questions

- How well do the reanalyses perform compared to other datasets?
- Are there large differences between IPCC CMIP3 and CMIP5 models?
- What is the influence of forcing on ET?
- Trends in ET?

Global land ET means

1989-1995



9 IPCC simulations

Reanalyses +/- 5.8

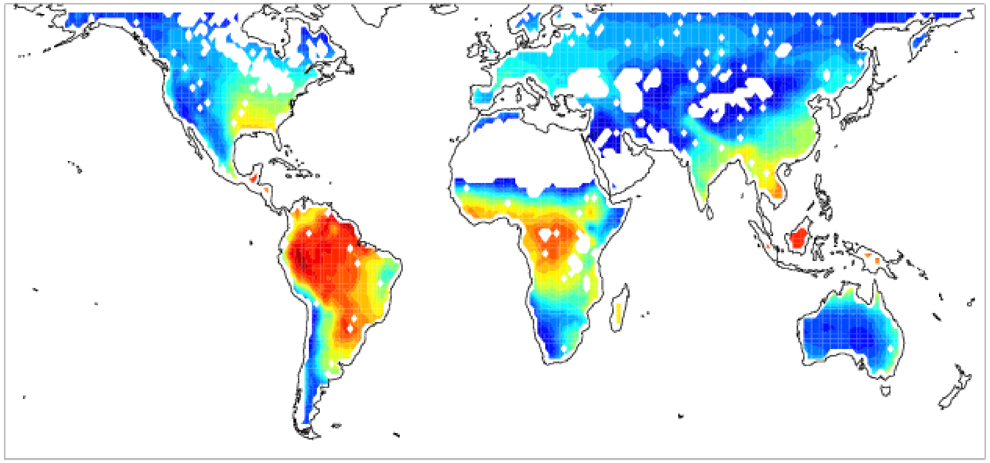
LSMs +/- 4.2

Diagnostic datasets +/- 5.9

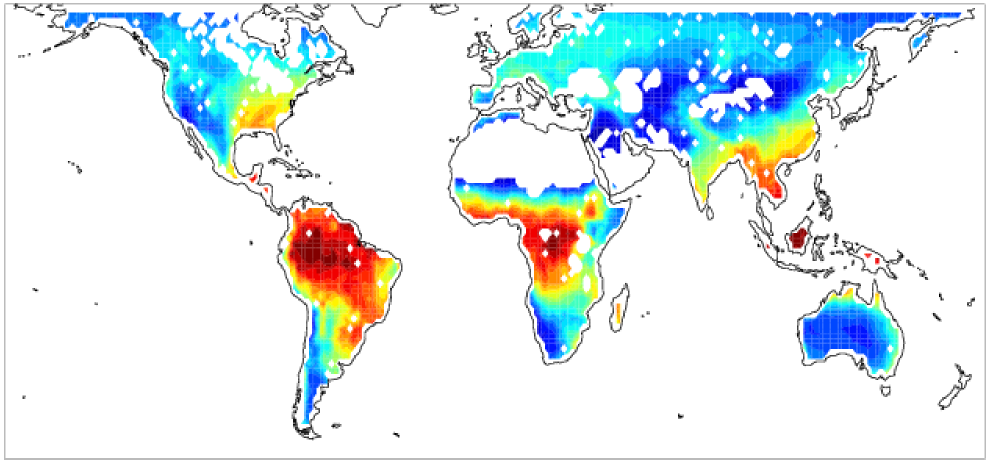
Only common land pixels considered.

Median ET 1989-1995

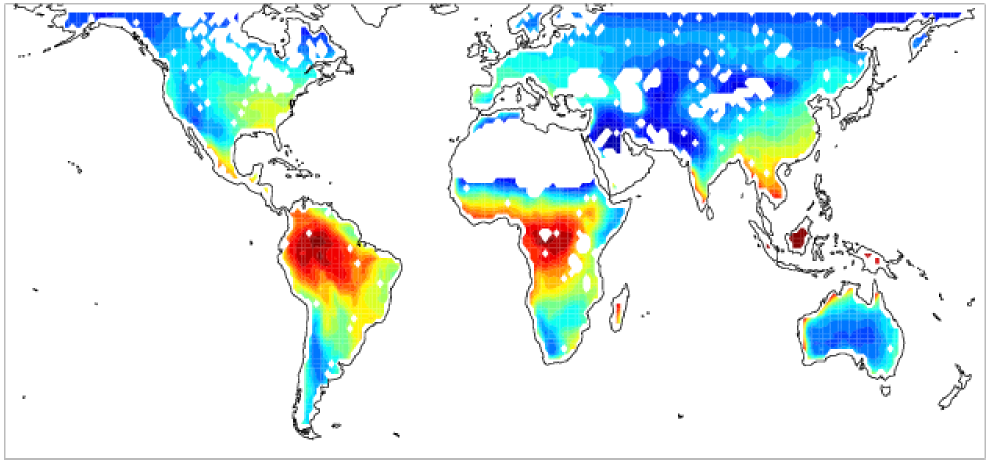
Reference datasets



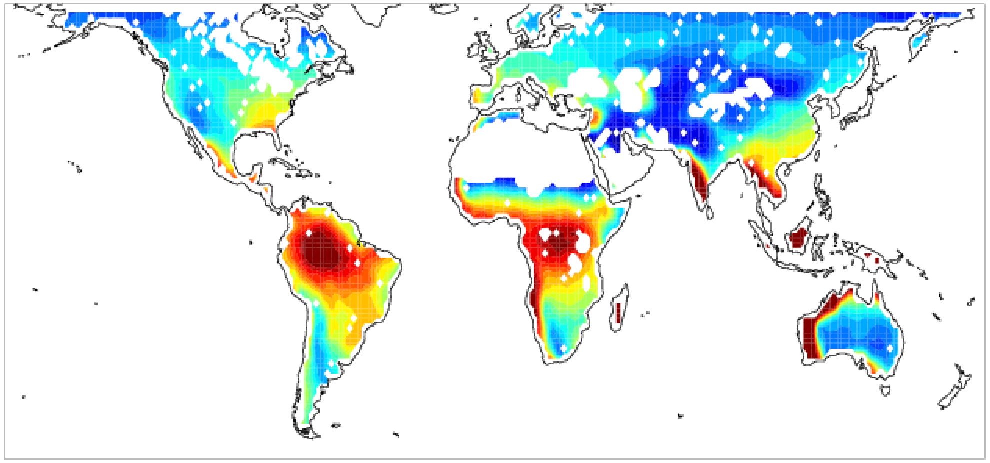
Reanalyses

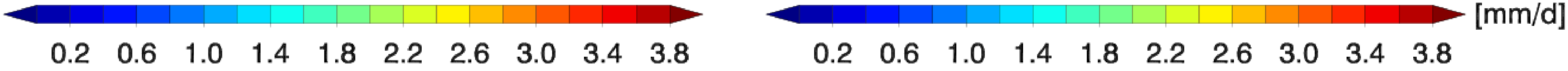


IPCC CMIP3



IPCC CMIP5

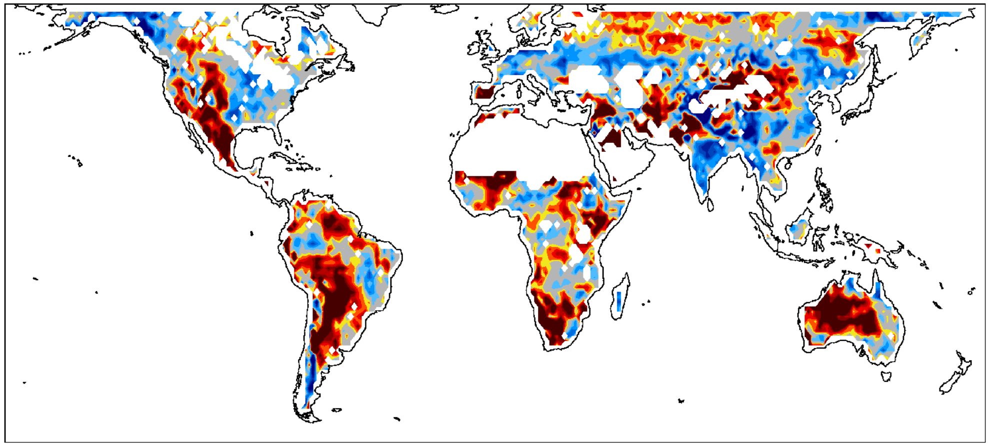




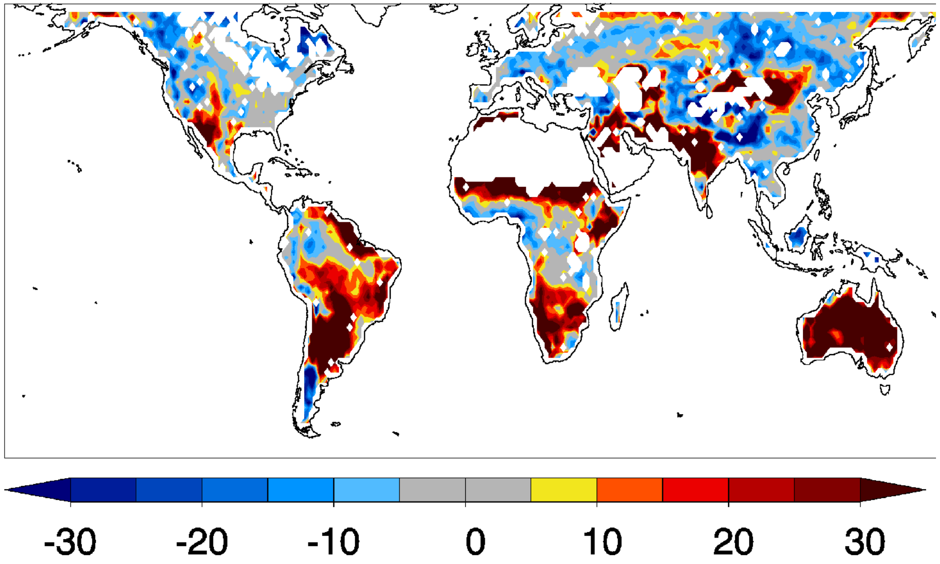
Relative interquartile range of ET

Differences to reference datasets

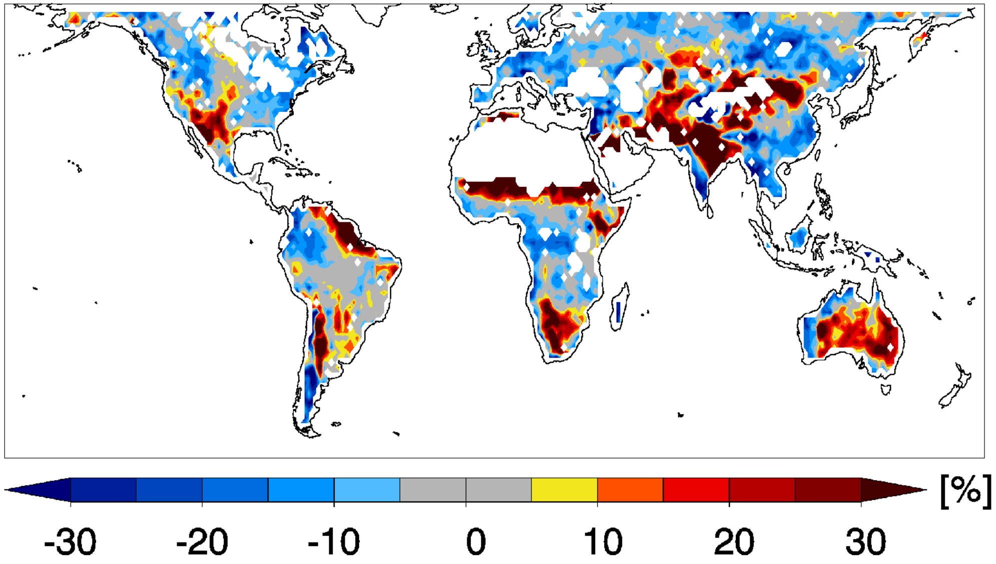
Reanalyses - Reference



IPCC CMIP3 - Reference



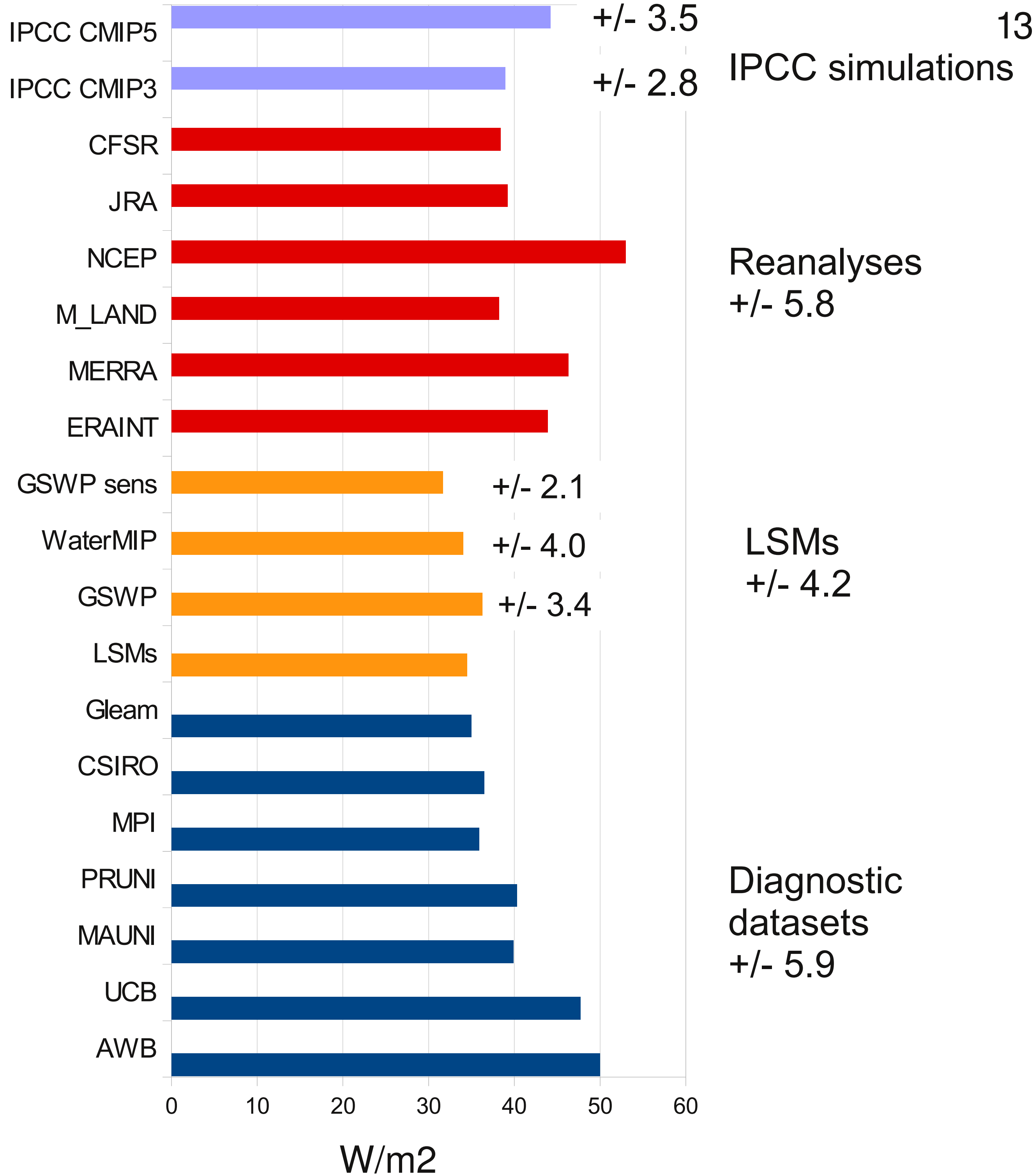
IPCC CMIP5 - Reference



Main findings 1

- Globally, range between reanalyses similar (+/- 5.8 W/m^2) to diagnostic datasets (+/- 5.9 W/m^2)
- LSMs and IPCC simulations smaller range
- Arid regions: Reanalyses and IPCC models high range between datasets (within category)

Global land ET means



Only common land pixels considered.

③ **GSWP Sensitivity runs**

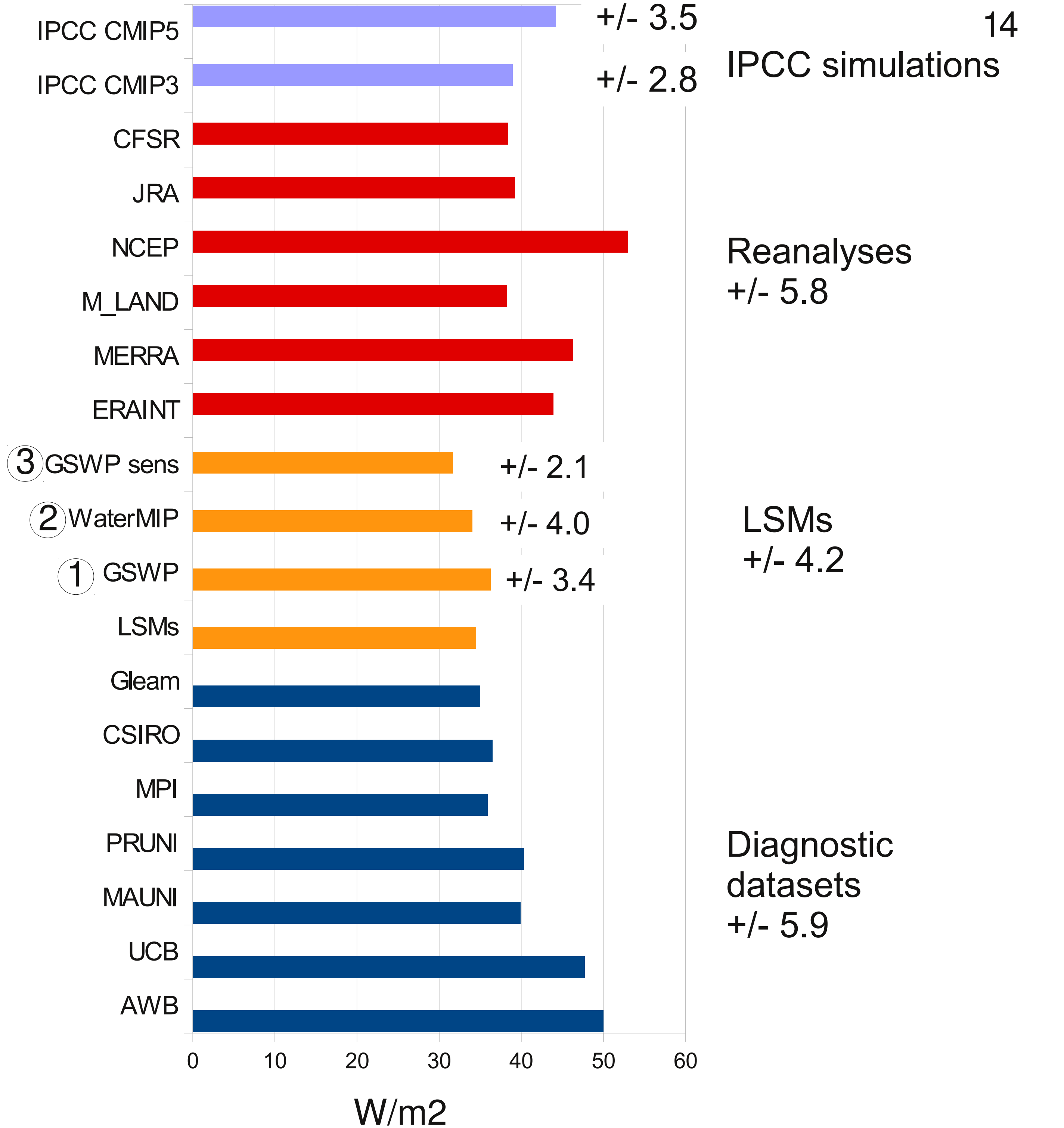
COLA with different precipitation forcings

② **WaterMIP**

LSMs and global hydrological models, same forcing data

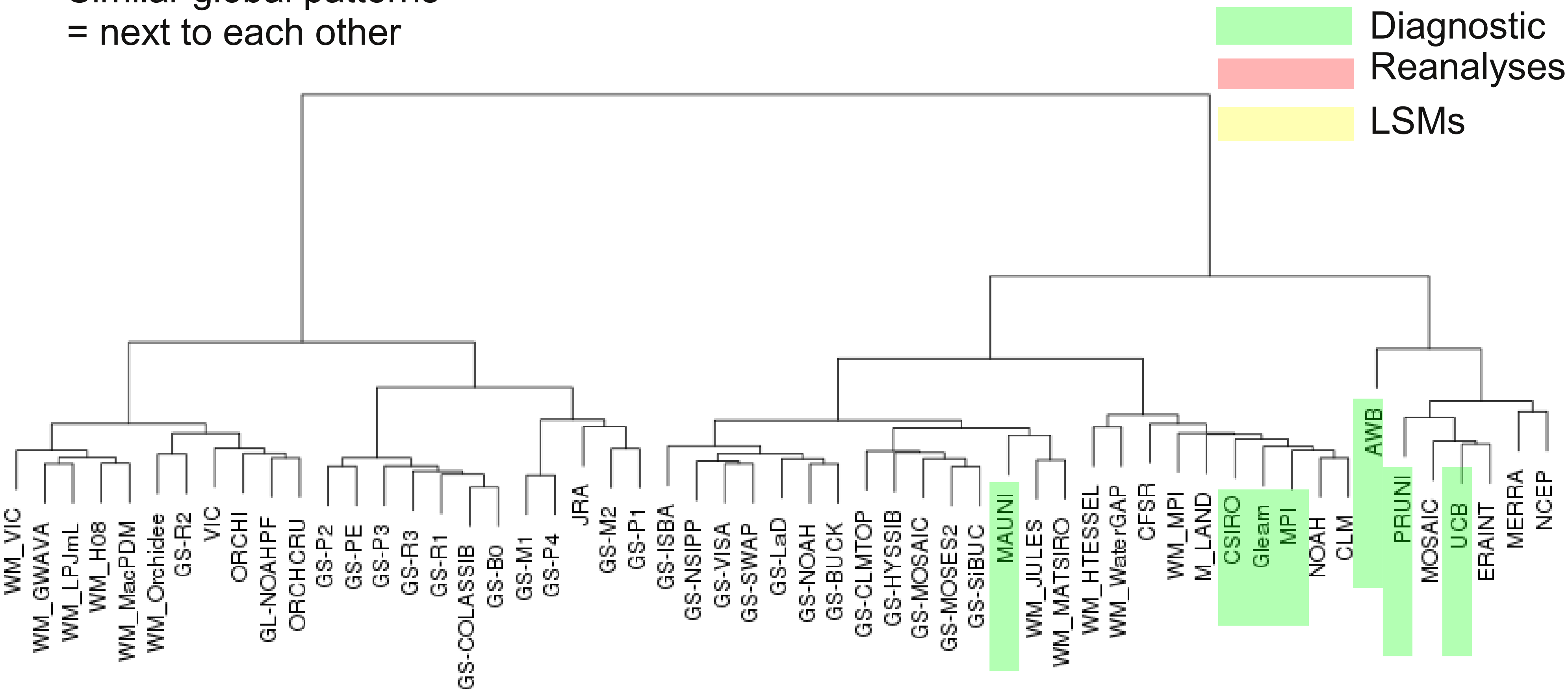
① **GSWP-LSMs**

Several LSMs driven with same forcing data



Cluster of multi-year mean ET

Similar global patterns
= next to each other



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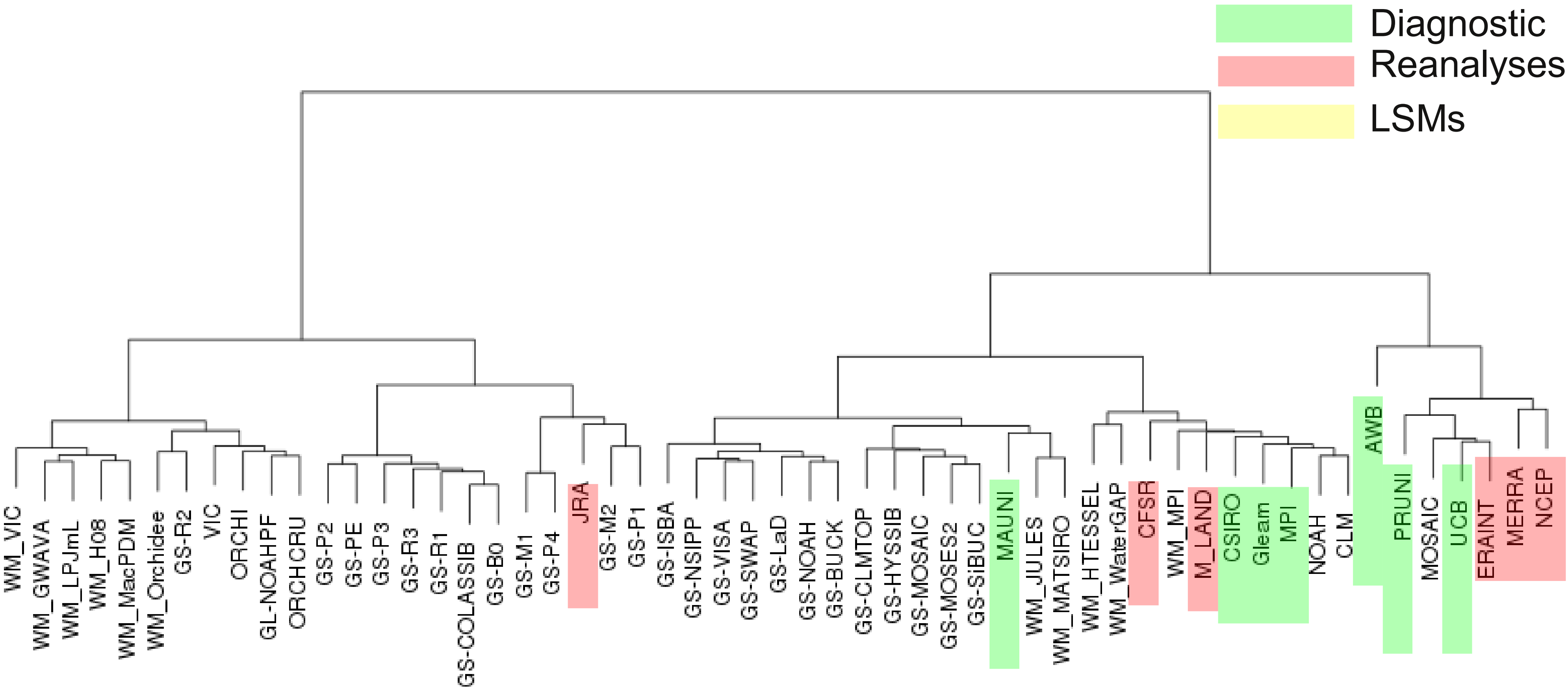

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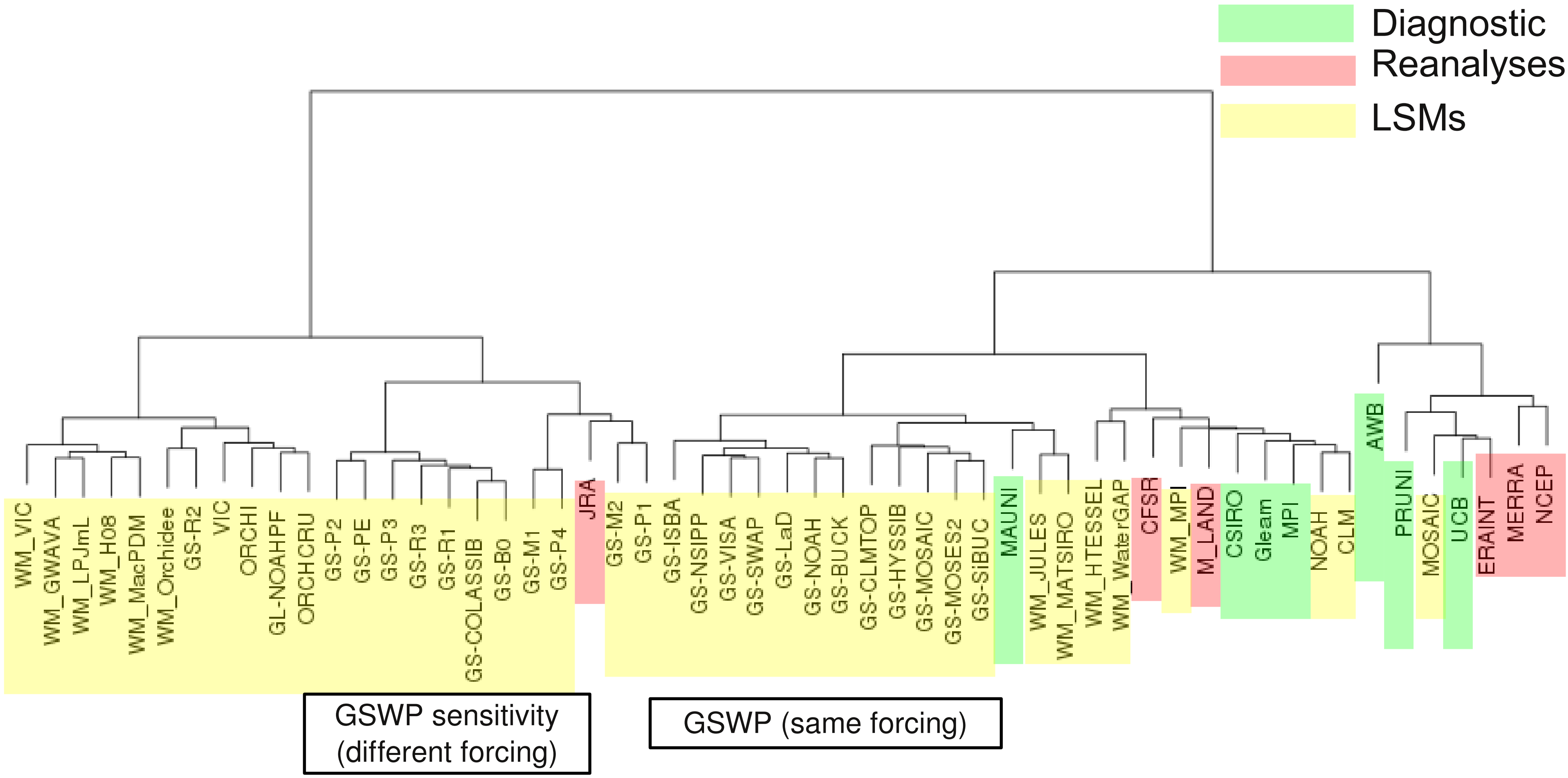
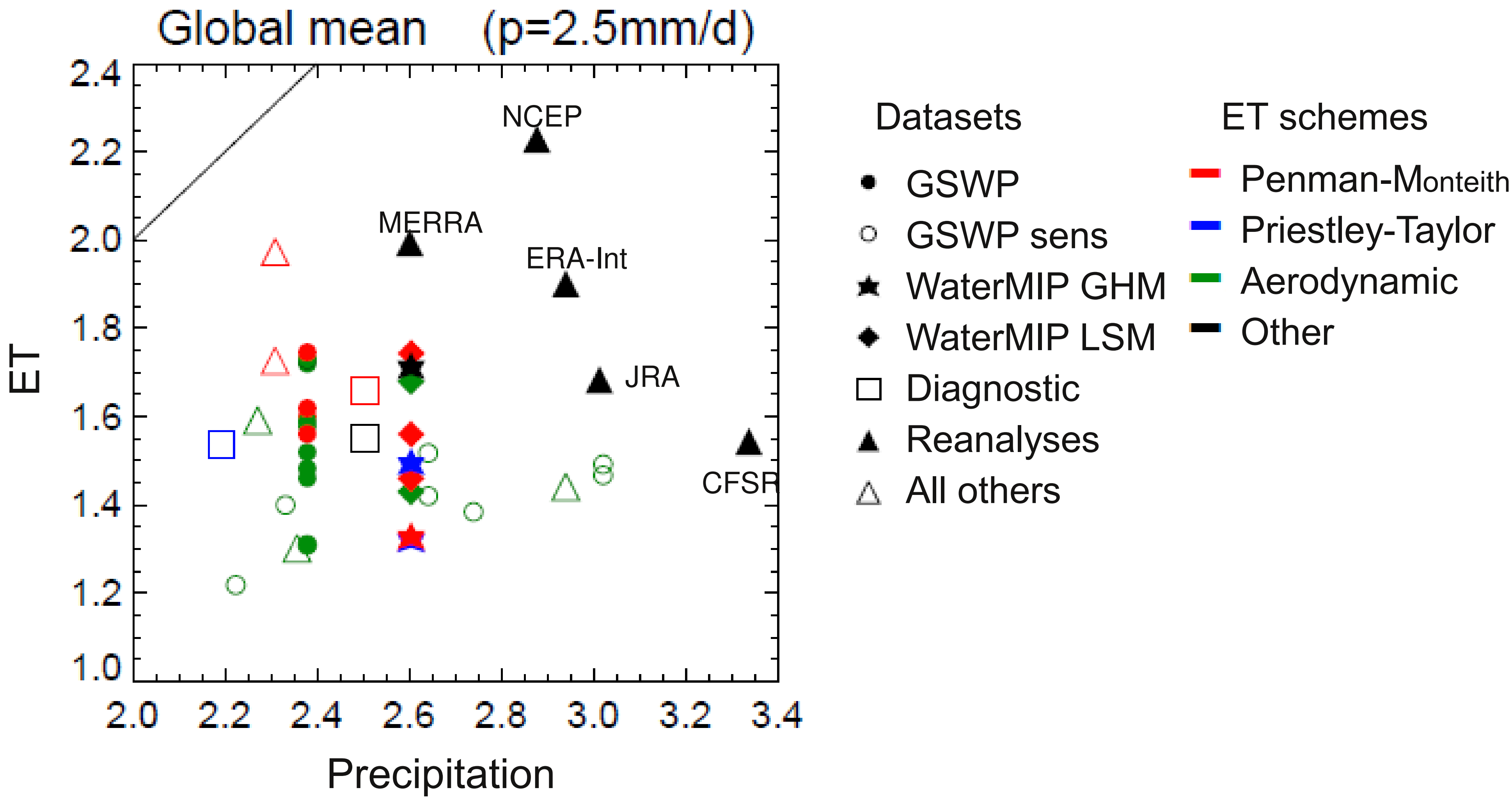
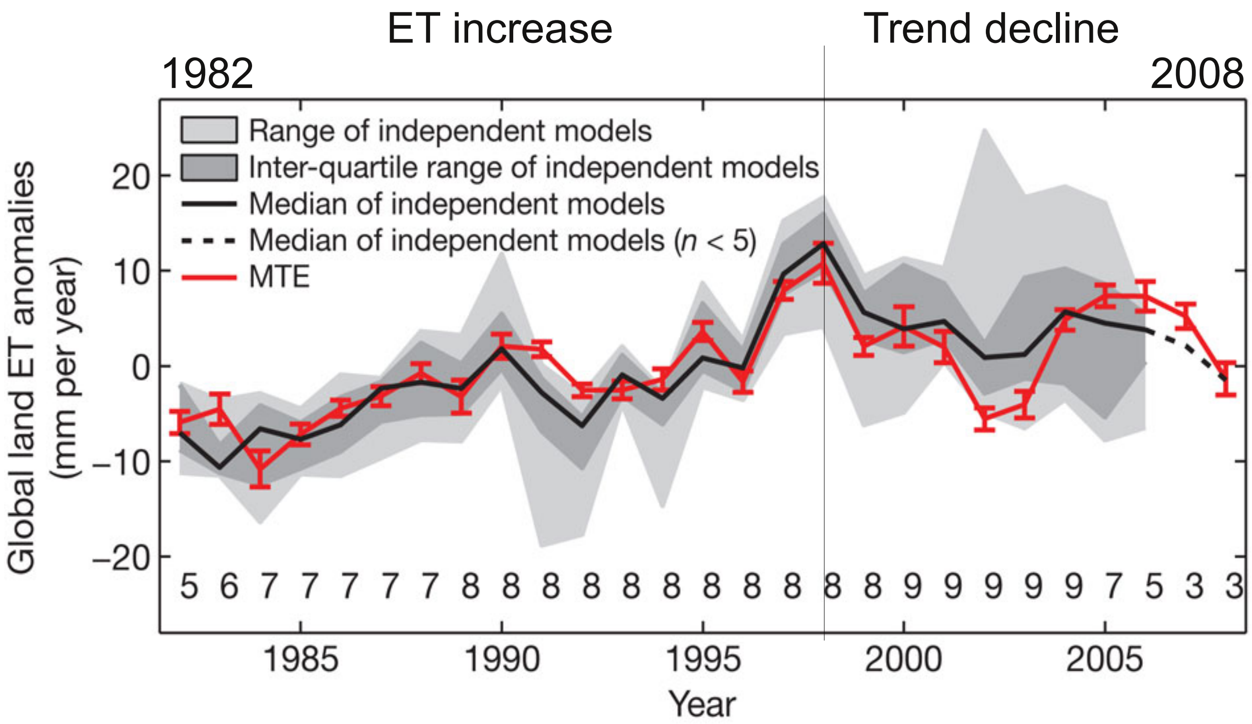


Global mean values – ET vs P



1989-1995 averaged values in mm/d

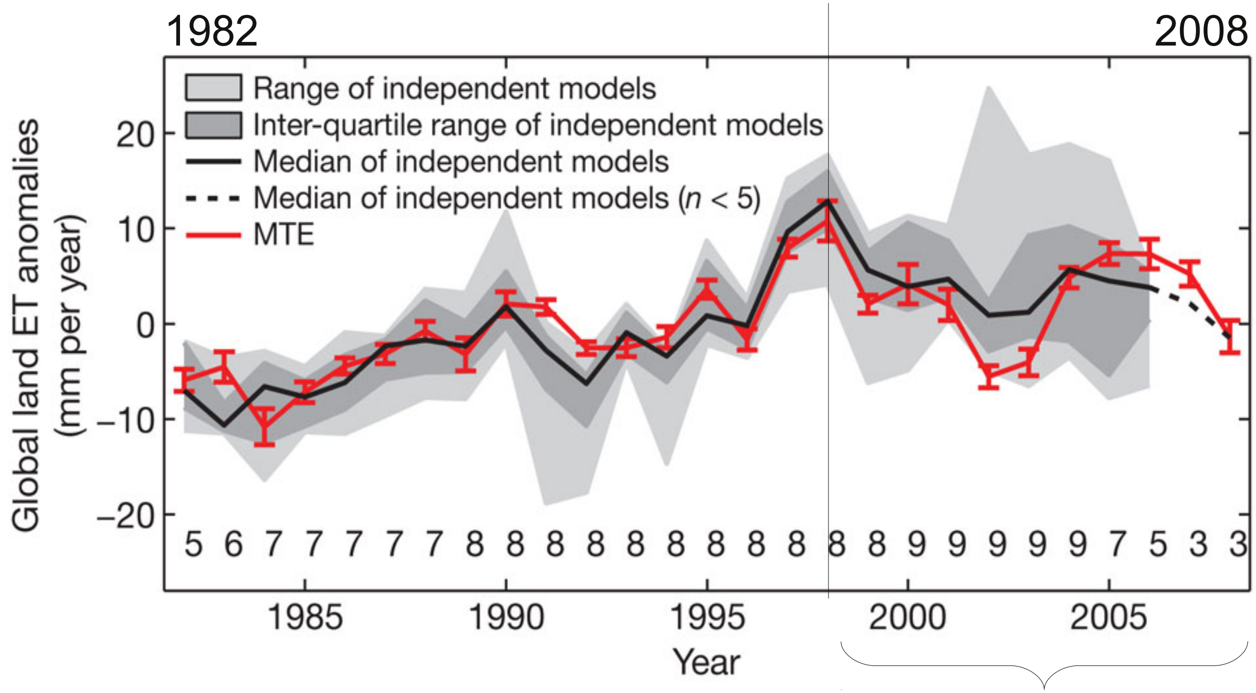
Trend change



Global land-ET variability according to MTE and independent models.

Jung *et al*. *Nature*, 2010

Trend change



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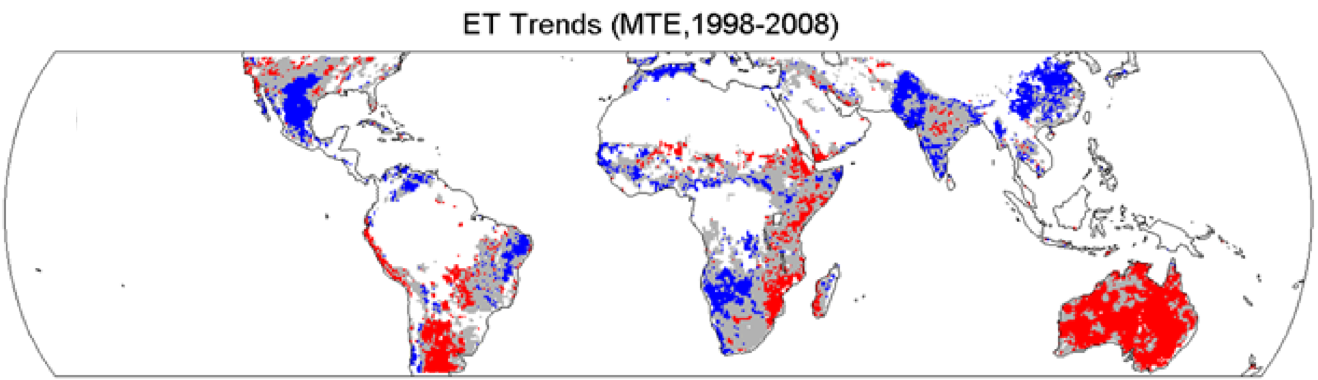


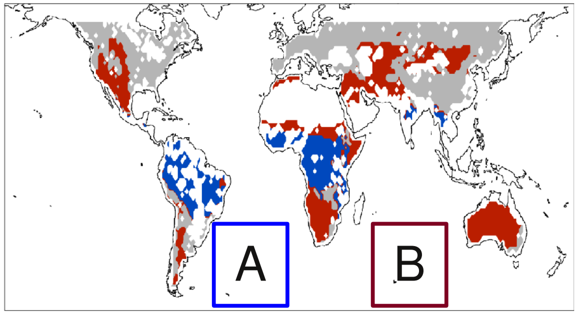
1998-2008

ET decrease

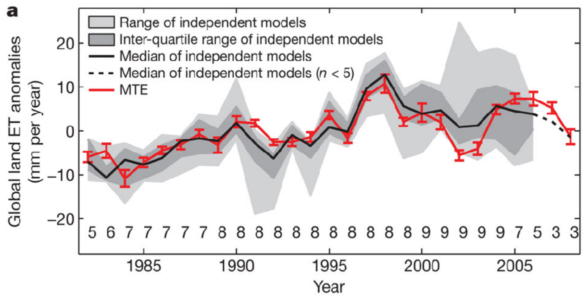
ET increase

Jung *et al*. *Nature*, 2010

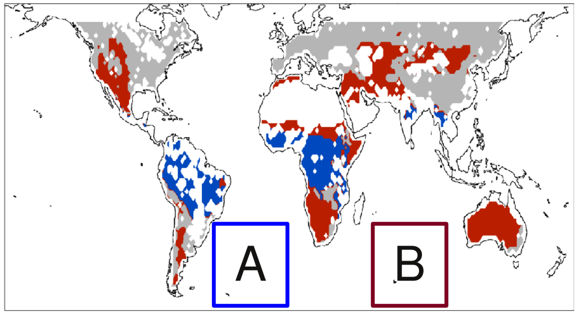
Trend change



Mean yearly precipitation:
4.6 mm/d 0.9 mm/d

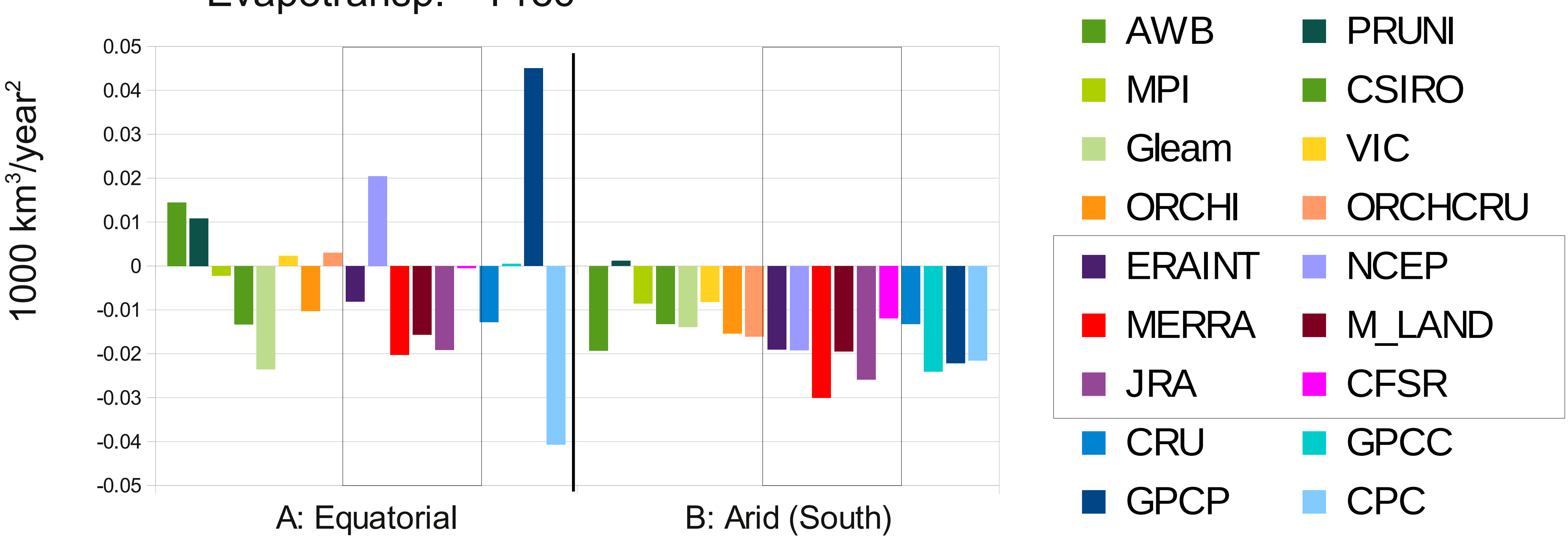


Trend change



Trend change 1998-2005 versus 1989-1997

Evapotransp. Prec



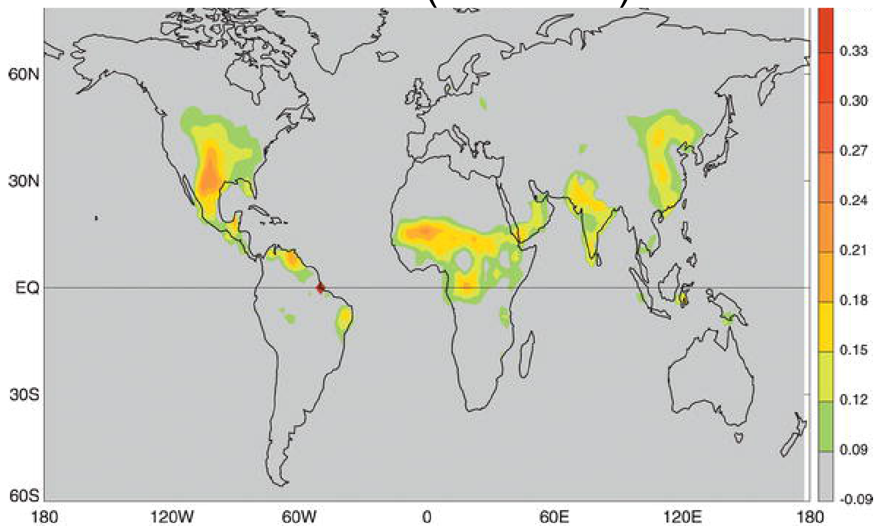
Main findings 2

- Critical role of forcing data – not clear
- Reanalyses relatively high ET and precipitation globally
- Decline of trend in Southern Hemisphere arid regions supported
- Trend change in tropical regions uncertain

Part II: Land-atmosphere coupling

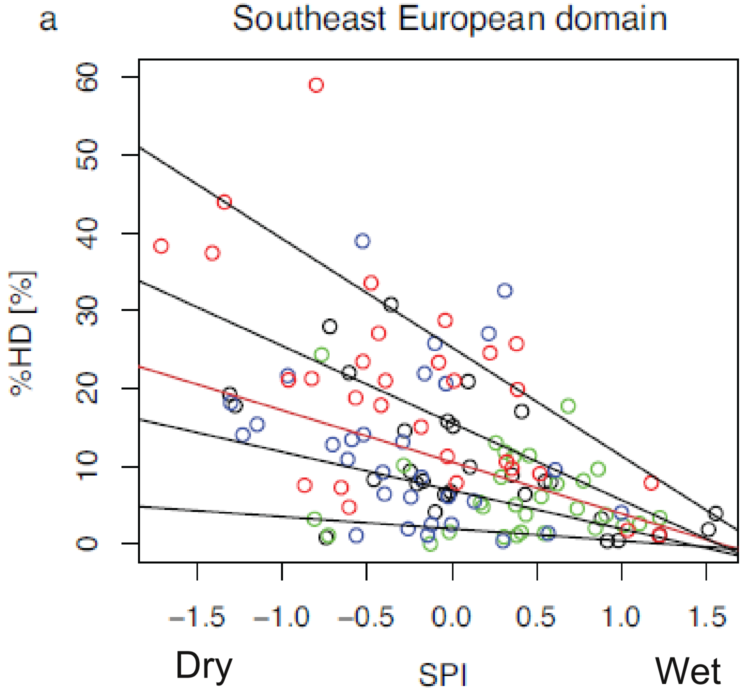
GLACE-I study

Soil moisture - temperature coupling strength
JJA 1994 (12 GCMs)



Koster *et al. J. Hydromet., 2006*

SPI – hot day study



Hirschi *et al. Nat. Geosc., 2011*

Our study:

- Relation of hot temperature extremes and preceding drought conditions
- at the hottest month of each year
- over 1979-2010 period

Hot extremes and drought conditions

Number of Hot Days = NHD

Days with temperature above 90th-percentile of 1979-2010 reference period
Maximum 2-m air temperature from:
ERA-Interim, MERRA, CFSR-NCEP

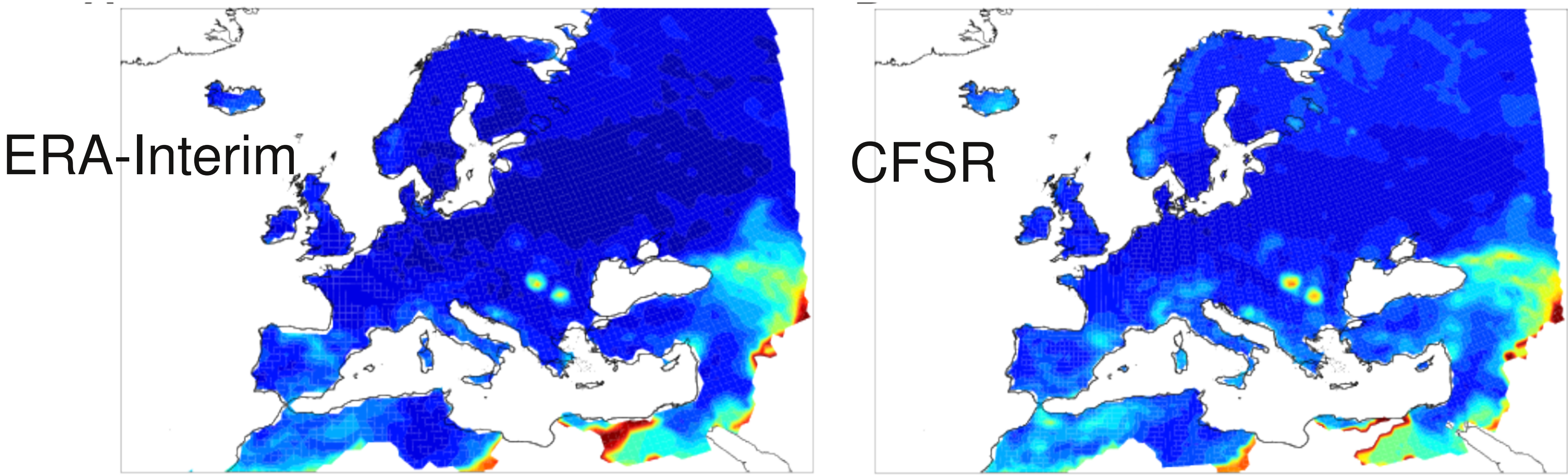
Standardized precipitation index = SPI

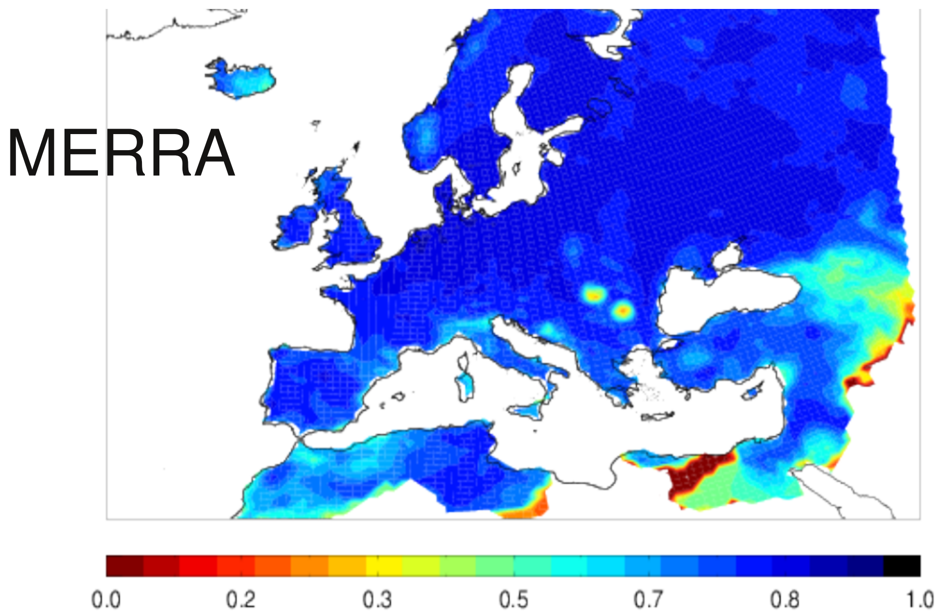
'Observed' precipitation deficits accumulated in previous 3 months from:
CRU, GPCP, CPC

Coupling: Research questions

- How useful is temperature from reanalyses for hot extreme studies?
- In which regions is there a strong relation between hot day occurrence and moisture deficits?

NHD reanalyses versus observations





Correlation of monthly NHD 1979-2010

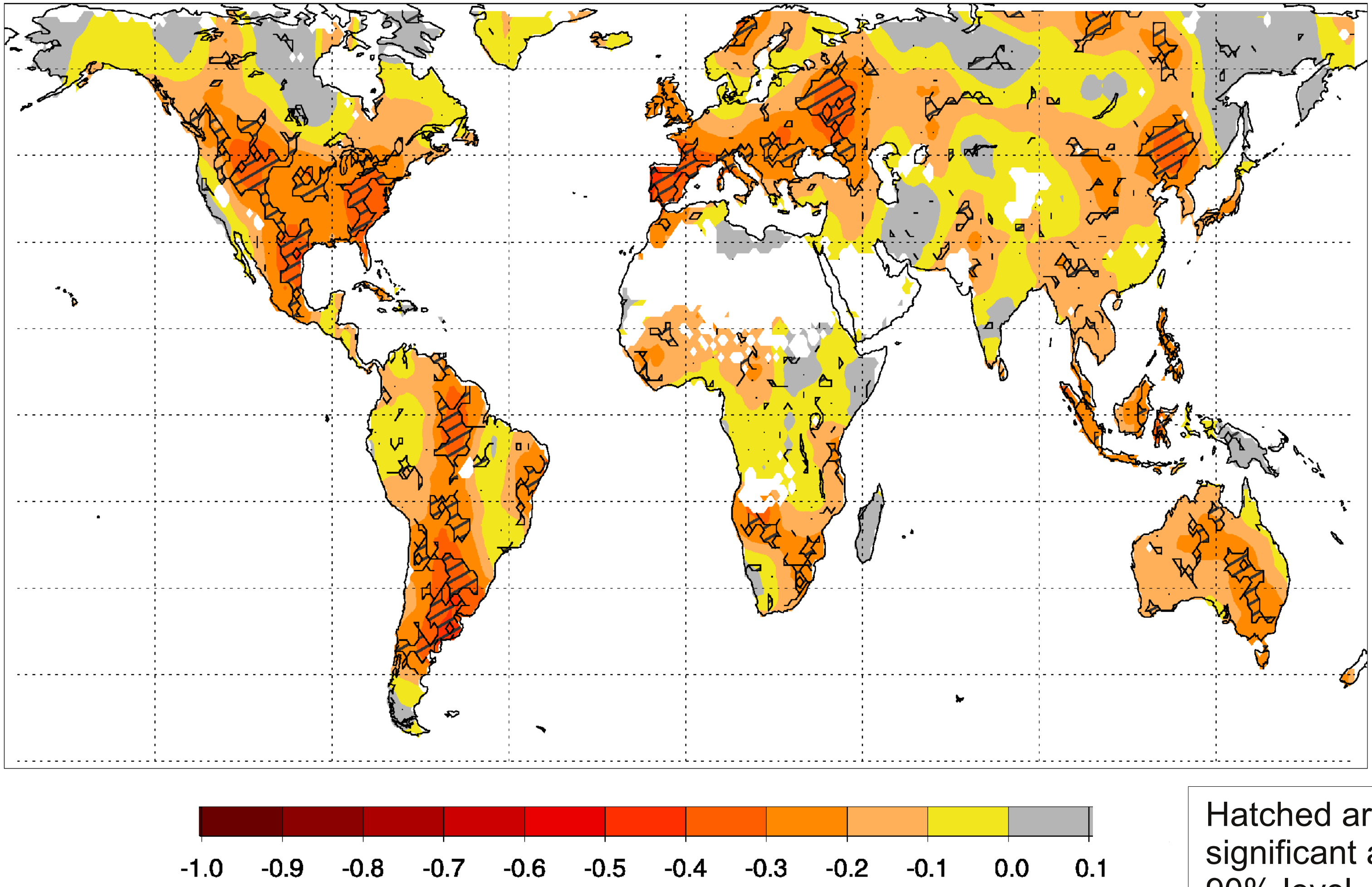
Observations = E-OBS dataset from the EU-FP6 project ENSEMBLES

Land-atmosphere coupling

Hot days at hottest month of each year ERA-Interim

Drought index before that month CRU precip

Correlation number of hot days and preceding drought index (SPI)

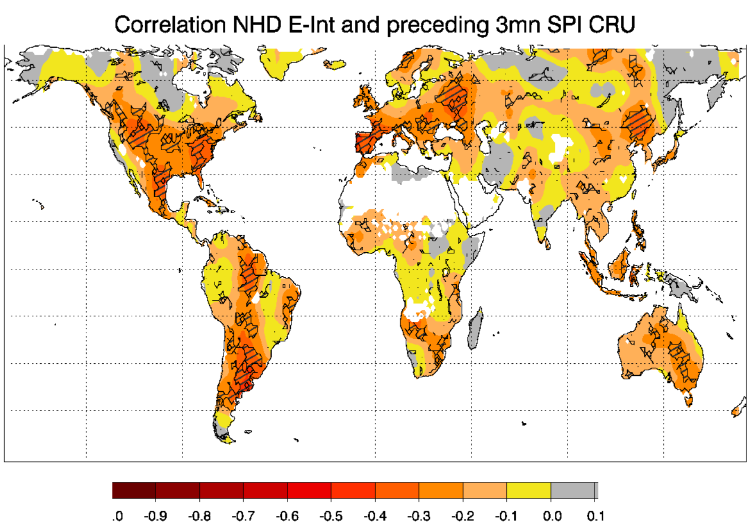


Hatched areas significant at 90% level

Mueller and Seneviratne (in review)

Difference to GLACE-study

- More hot spots
- Hot spots in Southern hemisphere
- 'Truly global'
- Several years
- Based on observational data



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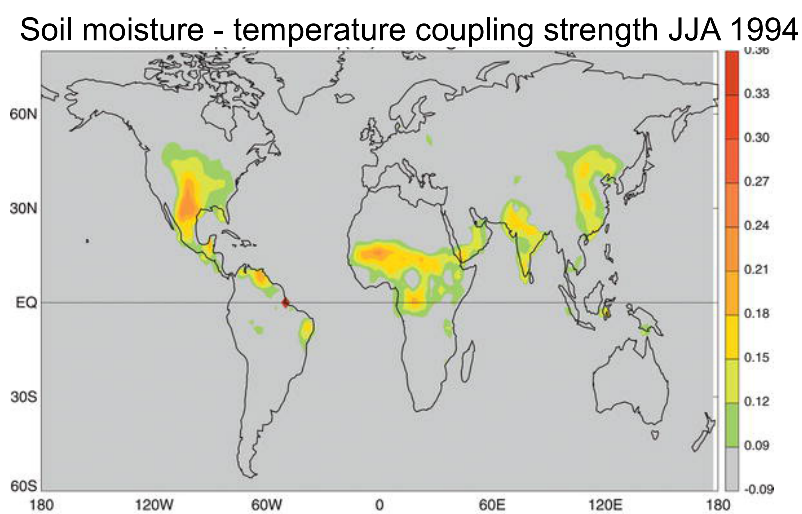
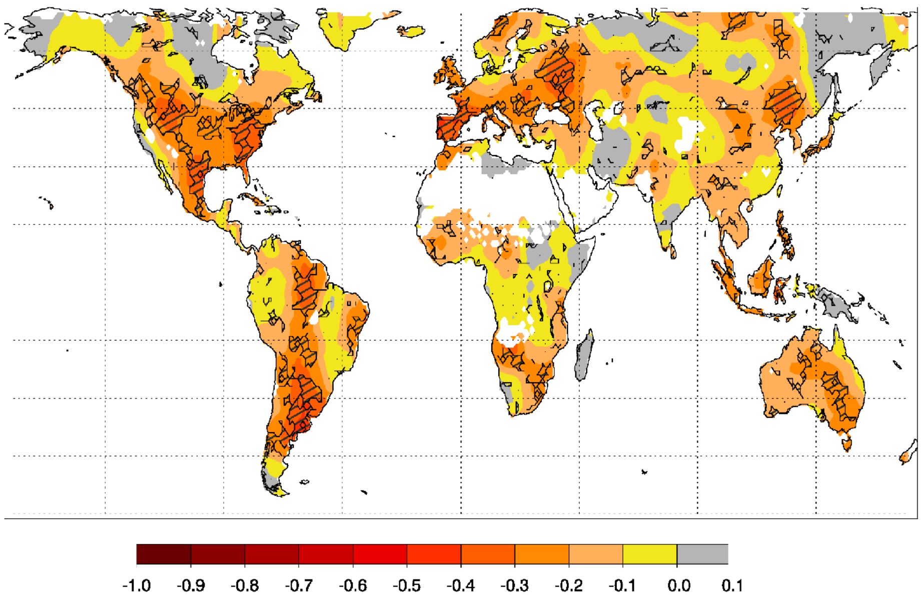


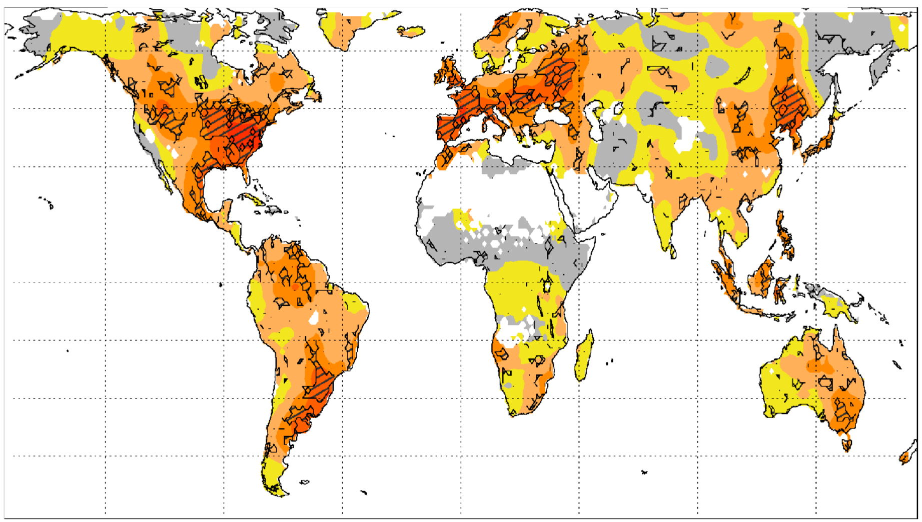
Koster *et al. J. Hydromet., 2006*

ERA-Interim, CFSR and MERRA

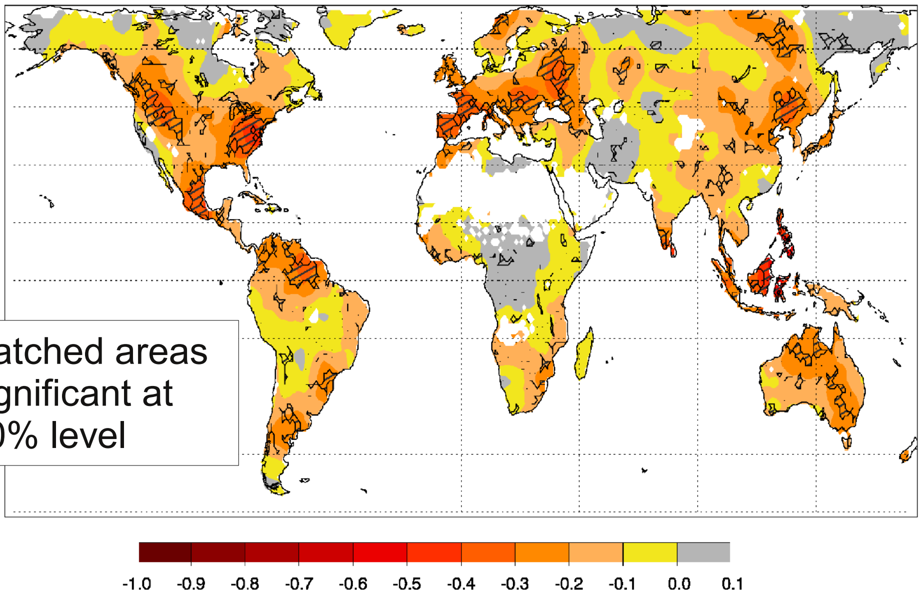
ERA-Interim NHD with CRU SPI



CFSR-NCEP NHD with CRU SPI



MERRA NHD with CRU SPI



Hatched areas significant at 90% level

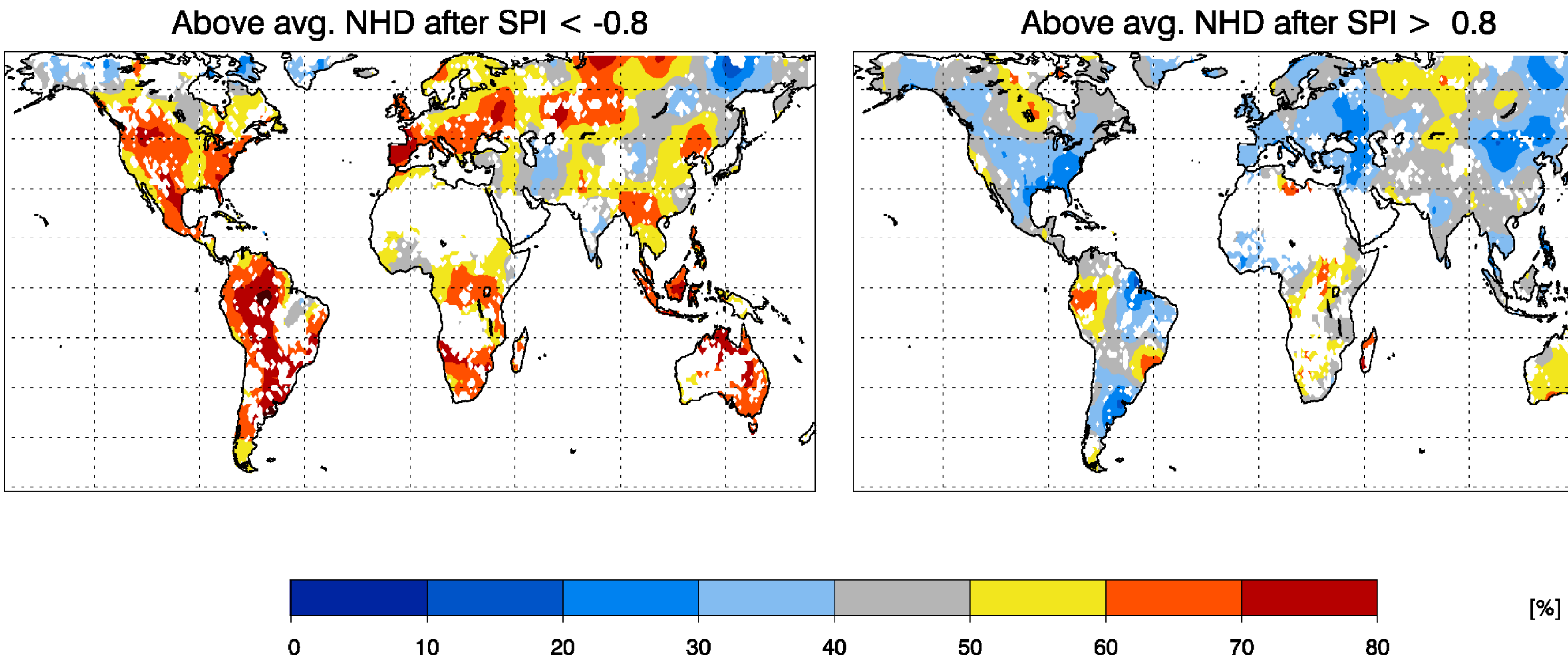
Number of hot days correlated to drought index SPI

Mueller and Seneviratne (in review)

Hot day occurrence probability

After dry conditions

After wet conditions



Occurrence probability in % of years for above-average hot day numbers

Datasets:
Number of hot days: ERA-Interim
3-month SPI: CRU

Mueller and Seneviratne (in review)

Summary

2
- Reanalyses useful for **land-atmosphere interaction** studies
- Only small differences between reanalyses in 2m-air temperature (for such studies)
- Land-surface - atmosphere **coupling** important in wide areas of the globe

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1
- **Uncertainties in ET** in all analyzed datasets comparable
- Large ET uncertainties in **tropical** regions (changes in hydrological cycle unknown)
- **ET trend** decreased after 1998 in arid Southern Hemispheric regions

Thanks to the WCRP for the travel support

and the LandFlux-EVAL team
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IPCC CMIP5 data were provided by Jan Sedlacek (IAC ETH)

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Supplementary material

	NCEP	ECMWF	NASA	NASA
	CFSR	**ERA-Interim**	**MERRA**	**MERRA-LAND**
	Coupled Forecast System Reanalysis	ECMWF Reanalysis	Modern Era Retrospective-analysis for Research and Applications	see MERRA
Time covered	1979/1948 - present	1979-present (soon)	1979-present	see MERRA
Forecast	9h / ocean-coupled 30min, land analysis 24h	12h	6h	see MERRA
Resolution	T382 (38km)	T255 (79 km)	30 km	see MERRA
ET param	Penman-Monteith	similar to Penman-Monteith, feedback of skin temp on R, G	Penman-Monteith	see MERRA
LSM	NOAH	TESSEL	Catchment LSM	see MERRA
Advantage	Fully coupled, GFS as background assimilation model, and recently av. Observations	**Good precip, observ. of temp and humidity**	LSM: Topographic statistics, dynamical update of 3 SM-regimes in each land tile and fluxes computed separately for the 3 regimes	**Precip consistent with GPCP, Catchment model parameters improved**
Problems		Snow analysis, SM optimised for atmospheric fluxes rather than accuracy	No assimilation of land surface obs., precip errors as for other reanalyses (regional biases, intensity, diurnal cyc)	less precipitation errors than MERRA
Radiation	satellite, GSI	None	**Excessive ET caused by overest. surf. Radiation under cloudy conditions**	**Revised Cathment model parameters ameliorate excessive canopy ET**
Surface Temp	different, including other reanalyses	**T2m, rh2m for soil moisture state**		
Precip	Not assimilated, but SM/snow from GLDAS driven with observed precip	None	None	Precip corrected to match GPCP
Development plans	**LSM: Co2-based canopy conductance, multi-layer snowpack, ground water, river-routing scheme**	**Use of land-surface photosynth. based ET and natural carbon dioxide schemes**	**Improved and dynamic vegetation model component, Land data assimilation included in next rean.**	

Catergory	Subgroup	Name	Reference	Information	Avail. yrs	Grid/Resolutio
Diagnostic datasets		UCB	Fisher et al. (2008)	Priestley-Taylor, ISLSCP-II (SRB, CRU, AVHRR)	1986-1995	0.5°
		MAUNI	Wang and Liang (2008)	Empirical, calibrated with Ameriflux, ISLSCP-II (SRB, CRU, AVHRR)	1986-1995	1°
		PRUNI	Sheffield et al. (2010)	Penman-Monteith ET,ISCCP,AVHRR	1984-2006	0.25°
		MPI	Jung et al. (2009)	Empirical, global upscaling of FLUXNET data, CRU etc.	1982-2008	0.5°
		GLEAM	Miralles et al.			
		CSIRO	Zhang et al. (2010)	Penman-Monteith-Leuning ET	1984-2009	
		AWB	Mueller et al. (2010)	Atmospheric water balance (GPCP, ERA-Interim)	1989-2008	2.5°
LSMs	GSWP	GS-COLA, GS-NOAH, GS-NSIPP, GS-VISA, GS-ISBA, GS-BUCK, GS-CLMTOP, GS-HYSSIB, GS-LAD, GS-MOSAIC, GS-MOSES2, GS-SIBUC, GS-SWAP	Dirmeyer et al. (2006)	13 GSWP LSM simulations, forced with ISLSCP-II and/or reanalysis data:	1986-1995	1°
	GSWP	Sensitivity runs from COLA model			1986-1995	
	GLDAS	GL-NOAH, GL-CLM, GL-MOSAIC	Rodell et al. (2004)	GLDAS LSM simulations	1979-2009	1°
	ORCH	EI-ORCH	Krinner et al. (2005)	ORCHIDEE LSM with ERA-Interim forcing	1989-2008	0.7°
		CRU-ORCH		ORCHIDEE LSM with CRU-NCEP forcing	1989-2008	0.7°
	WaterMIP	WM-GWAVA,WM-H08,WM-HTESSEL,WM-JULES,WM-LPJmL,WM-MacPDM,WM-MATSIR,WM-MPI,WM-VIC,WM-WaterG,WM-ORCHI				
	VIC	VIC	Sheffield and Wood (20	LSM with combined model/observation dataset of meteorological forcing	1948-2008	
Reanalyses		ERA-INT	Dee and Uppala (2008)	ERA-Interim Reanalysis	1989-2008	0.5°
		MERRA	Bosilovich (2008)	Reanalysis	1979-2009	0.5°x0.6°
		M-LAND		MERRA-Land Reanalysis	1979-2007	0.5°x0.6°
		NCEP	Kalnay et al. (1996)	Reanalysis	1948-2010	0.5°x0.6°
		CFSR				
		JRA-25	Onogi et al. (2007)	Reanalysis	1979-2007	2.5°

CMIP3 and CMIP5 models considered

CMIP3:

ECHAM5
INMSM
IPSL
HadGEM
NCAR
HacCM
MRI
GISS
Miroc-med
CCCMA
GFDL

CMIP5:

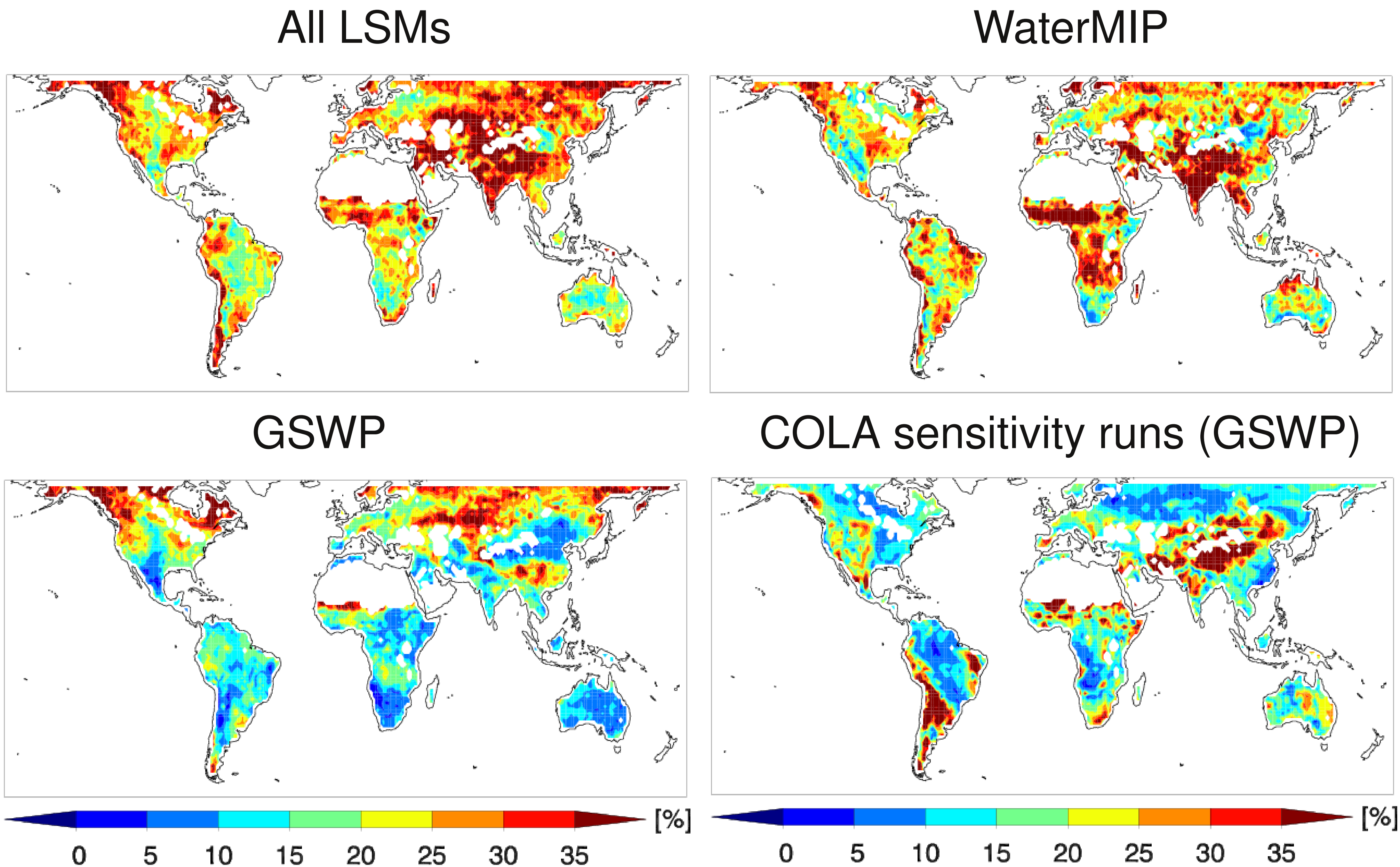
BCC_CSM
CanESM2
CNRM_CM5
CSIRO_Mk3
GFDL_CM3
GISS_E2H
HadCM3
HadGEM2
Inmcm4
IPSL_CM5A_LR
MIROC_ESM
MPI_ESM_LR
MRI_CGCM3
NorESM1

All simulations:
20 century (historical)

Sensitivity experiments GSWP

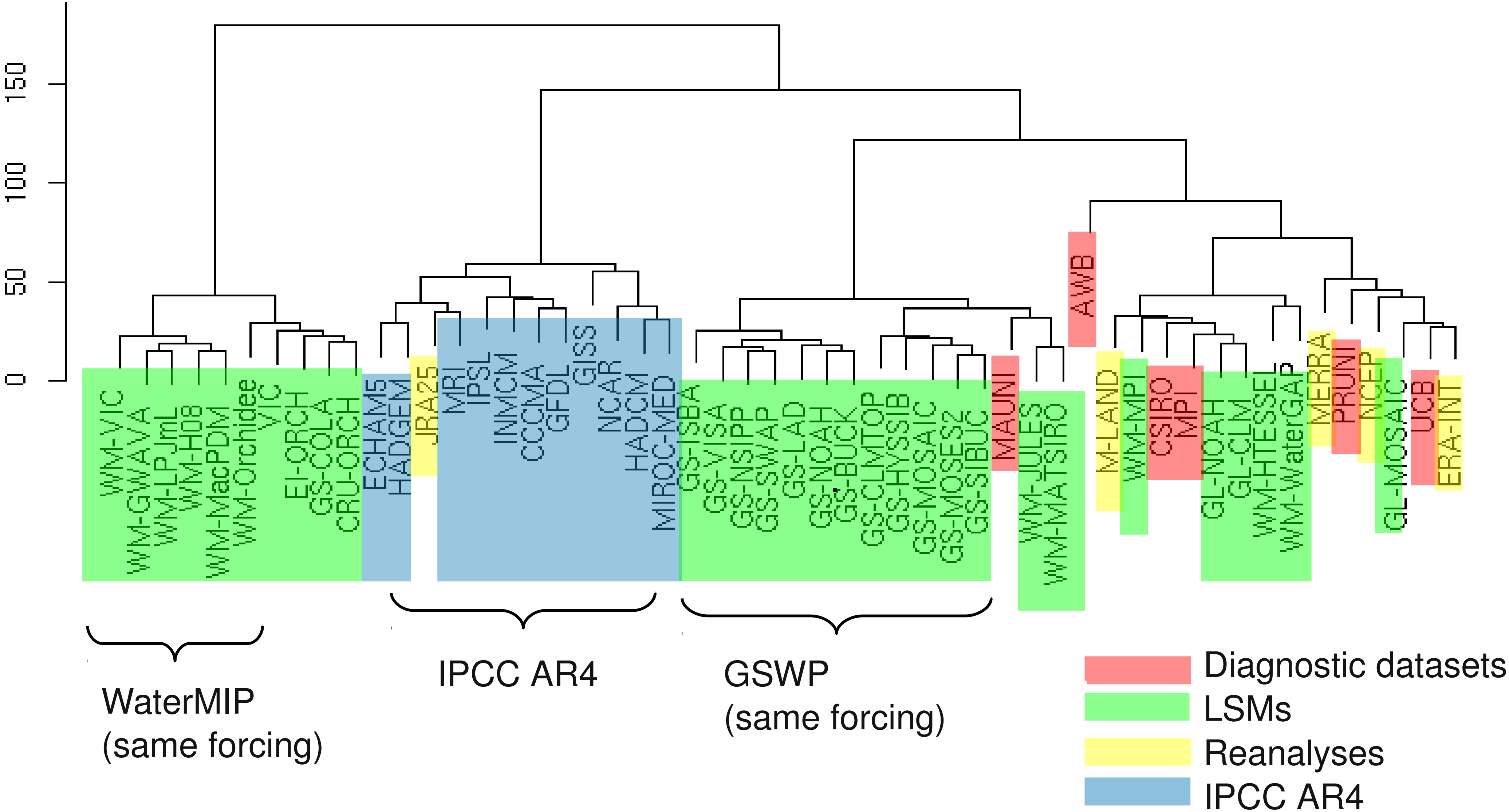
	B0	Standard forcing data: NCEP Precipitation hybrid. with GPCP, corrected for gauge undercatch & blended with GPCC Radiation from SRB
All variables	**M1**	All original NCEP meteorological data (no hybridization with observational data)
	M2	All original ERA-40 meteorological data (no hybridization with observational data)
Precipitation	**P1**	ERA-40 precipitation (no hybridization with observational data)
	P2	NCEP-DOE hybrid. with GPCC corrected for gauge undercatch
	P3	NCEP-DOE hybrid. with GPCC (no undercatch correction)
	P4	NCEP-DOE precipitation (no hybrid. with observational data)
	PE	ERA-40 precipitation hybrid. with GPCC, and blended with GPCP where gauge density is low
Radiation	**R1**	NCEP-DOE radiation
	R2	ERA-40 radiation
	R3	ISCCP radiation

Uncertainty - relative IQR of ET



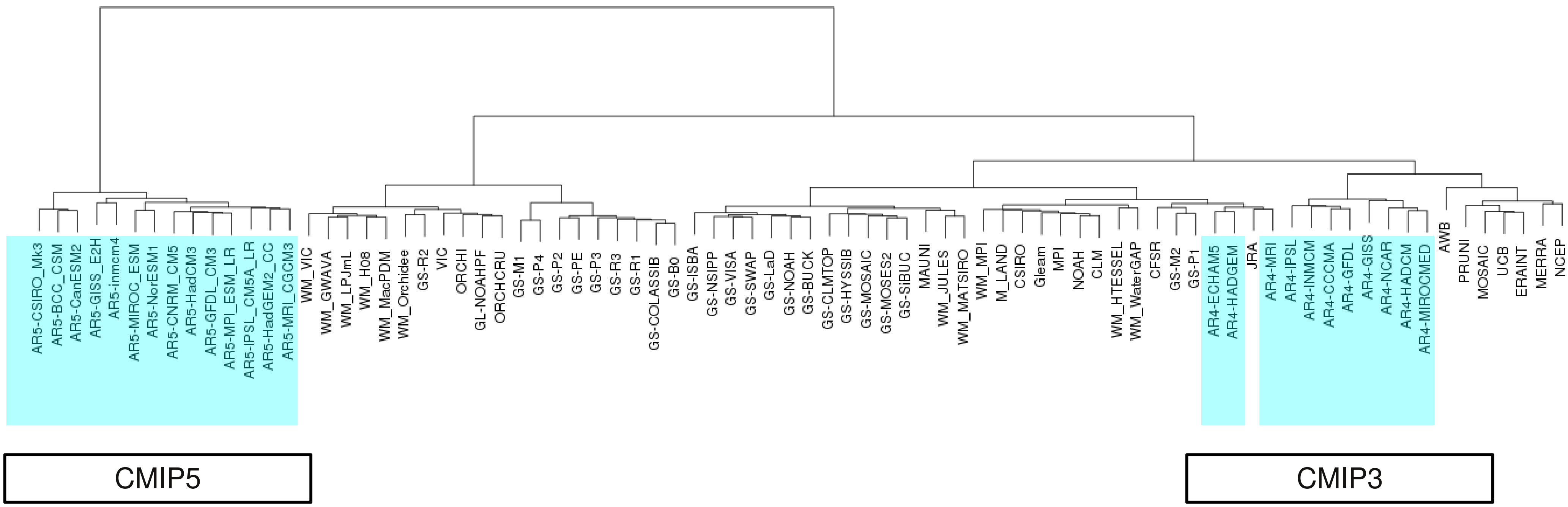
Cluster analysis

Multi-year means 1989-1995, euclidean distance



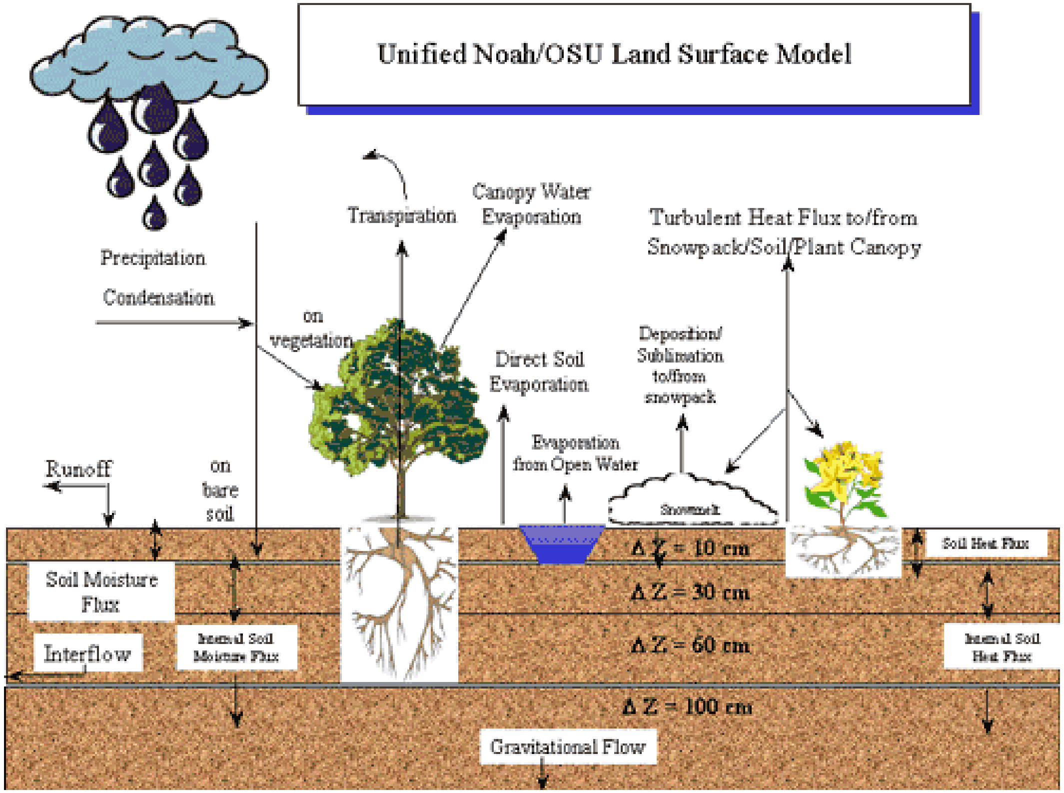
Cluster of multi-year mean ET

IPCC simulations in the cluster tree

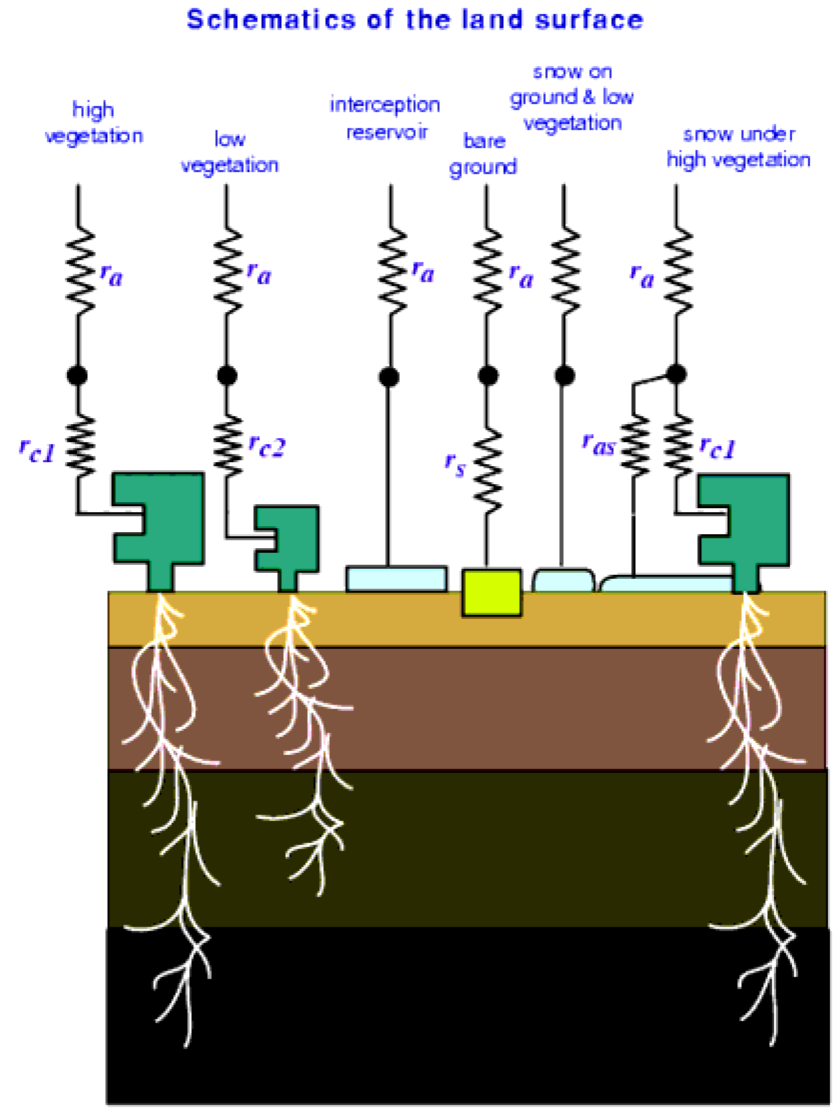


ET in reanalyses

Land-surface model: Model land interactions with the atmosphere (partitioning of net radiation into latent and sensible heat)



NOAH/OSU (NCAR)



TESSEL (ECMWF)