Land-atmosphere coupling

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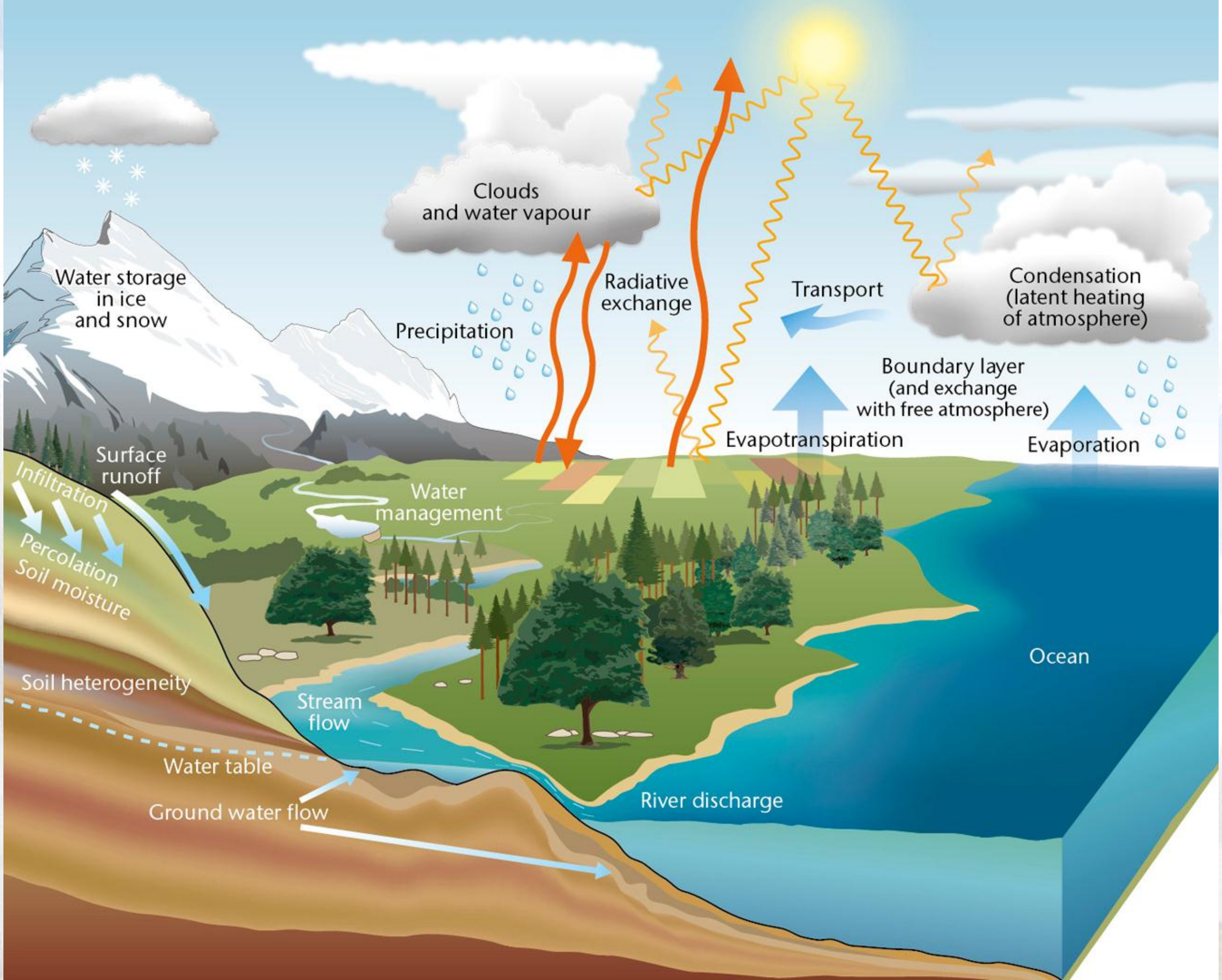
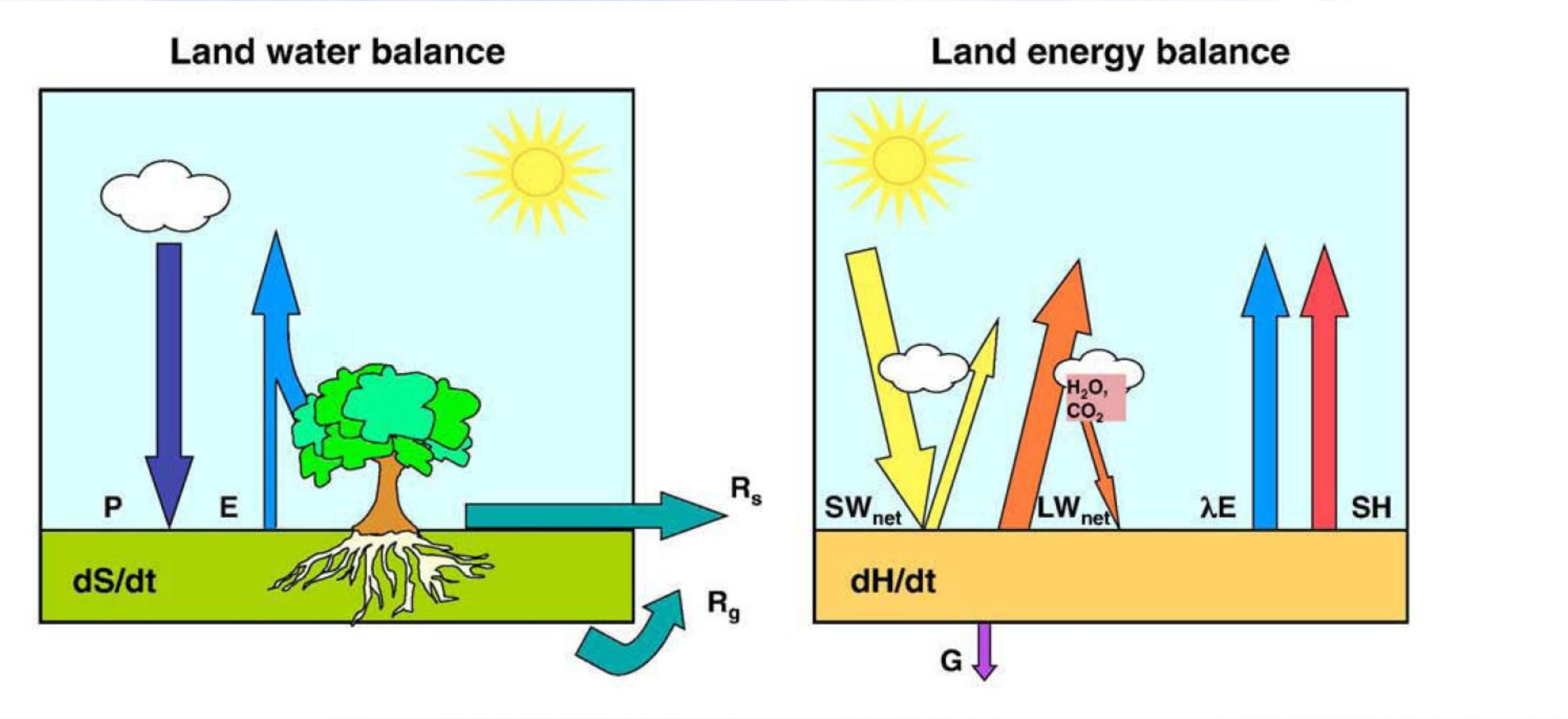
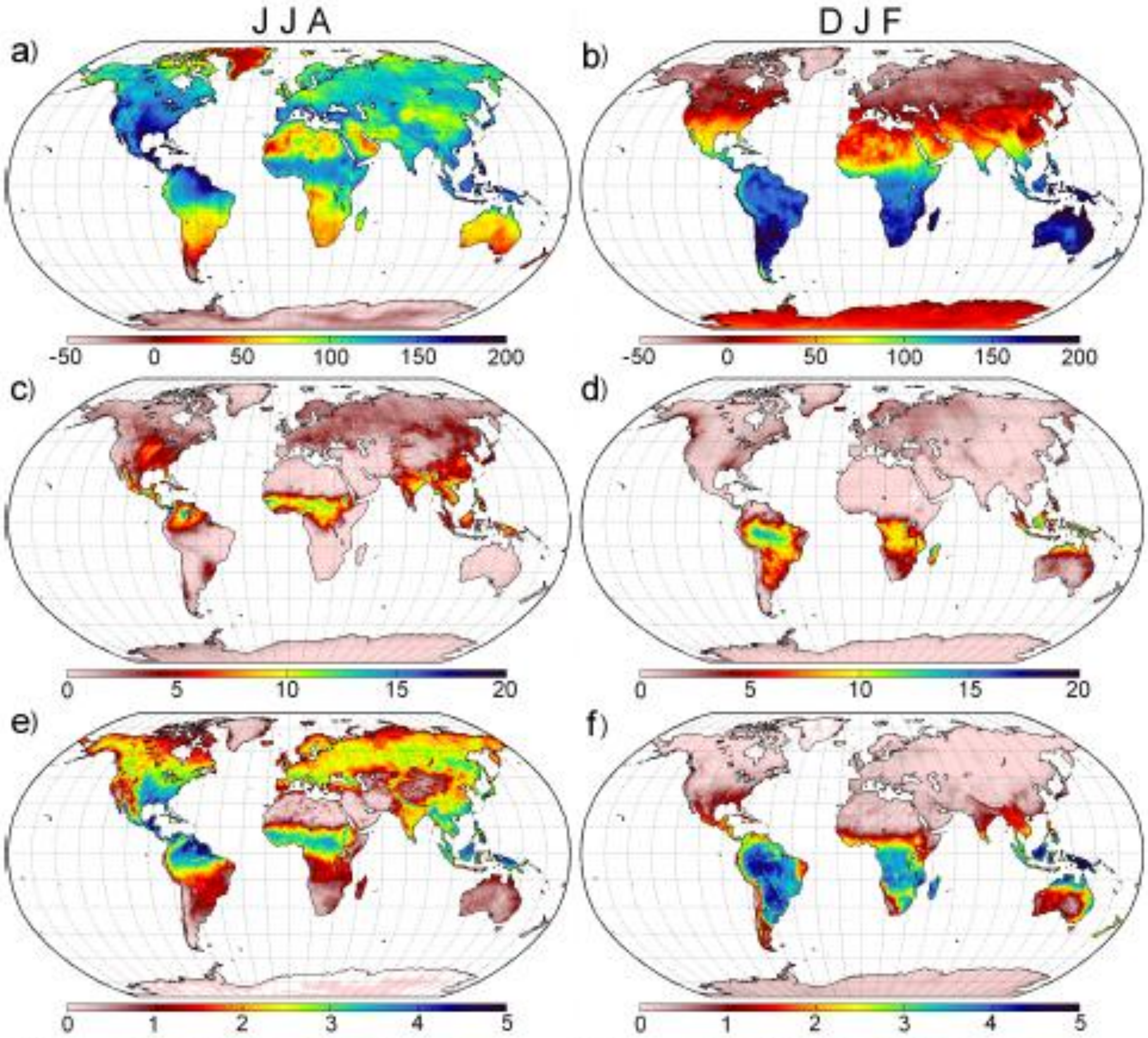

Clouds and water vapour
Water storage in ice and snow
Precipitation
Radiative exchange
Transport
Condensation (latent heating of atmosphere)
Boundary layer (and exchange with free atmosphere)
Evapotranspiration
Evaporation
Surface runoff
Infiltration
Percolation
Soil moisture
Water management
Soil heterogeneity
Stream flow
Water table
Ground water flow
River discharge
Ocean



$$\frac{dS}{dt} = P - E - R_s - R_g$$

$$\frac{dH}{dt} = R_n - LE - SH - G$$

$$R_n = SW_{in} - SW_{out} + LW_{in} - LW_{out}$$



Average fluxes for the period 2003–2007, JJA and DJF

(a), (b) Rn (Wm-2)

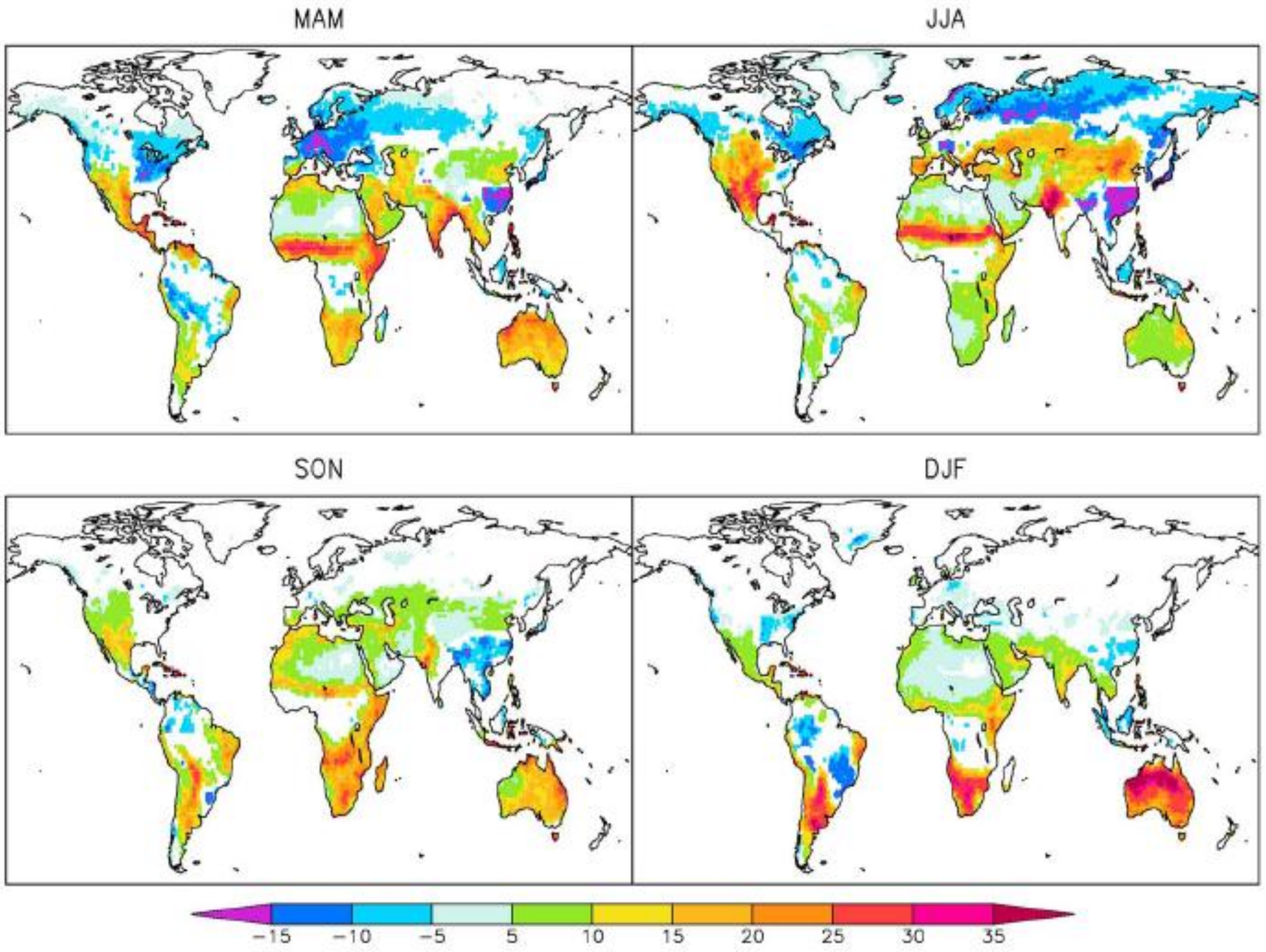
(c) ,(d) P (mmday−1)

(e) , (f) E (mmday−1)

Miralles et al. - 2011 - Magnitude and variability of land evaporation and its components at the global scale doi:10.5194/hess-15-967-2011

$$I = \sigma_w \frac{\Delta LH}{\Delta w}$$

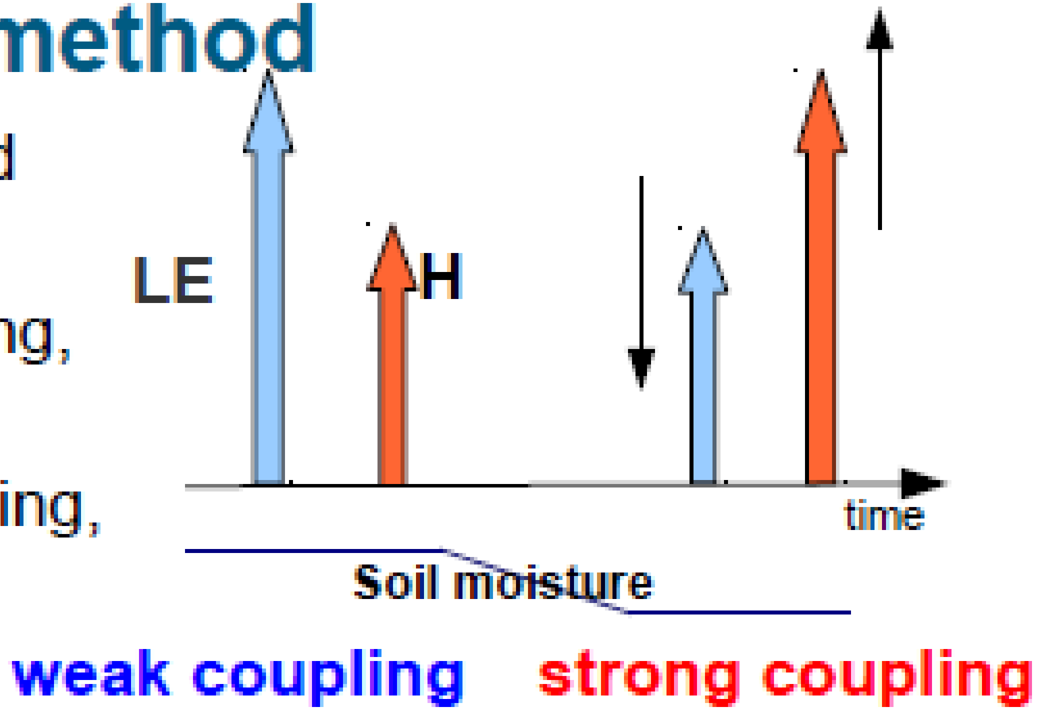
w – soil moisture
LH – Latent Heat



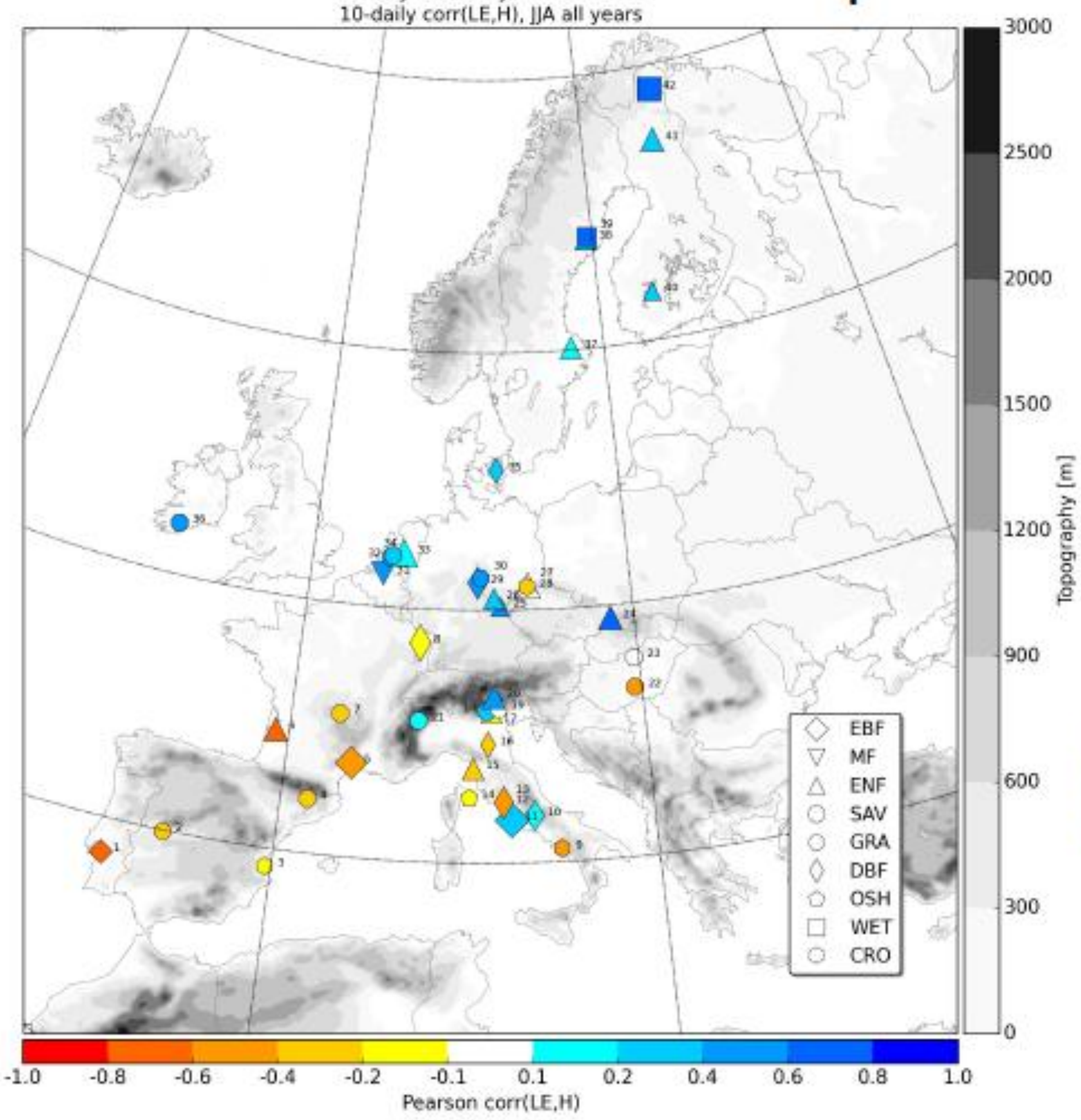
Dirmeyer - 2011 - The terrestrial segment of soil moisture–climate coupling. Geophysical Research Letters, vol. 38, L16702, doi:10.1029/2011GL048268

Coupling strength method

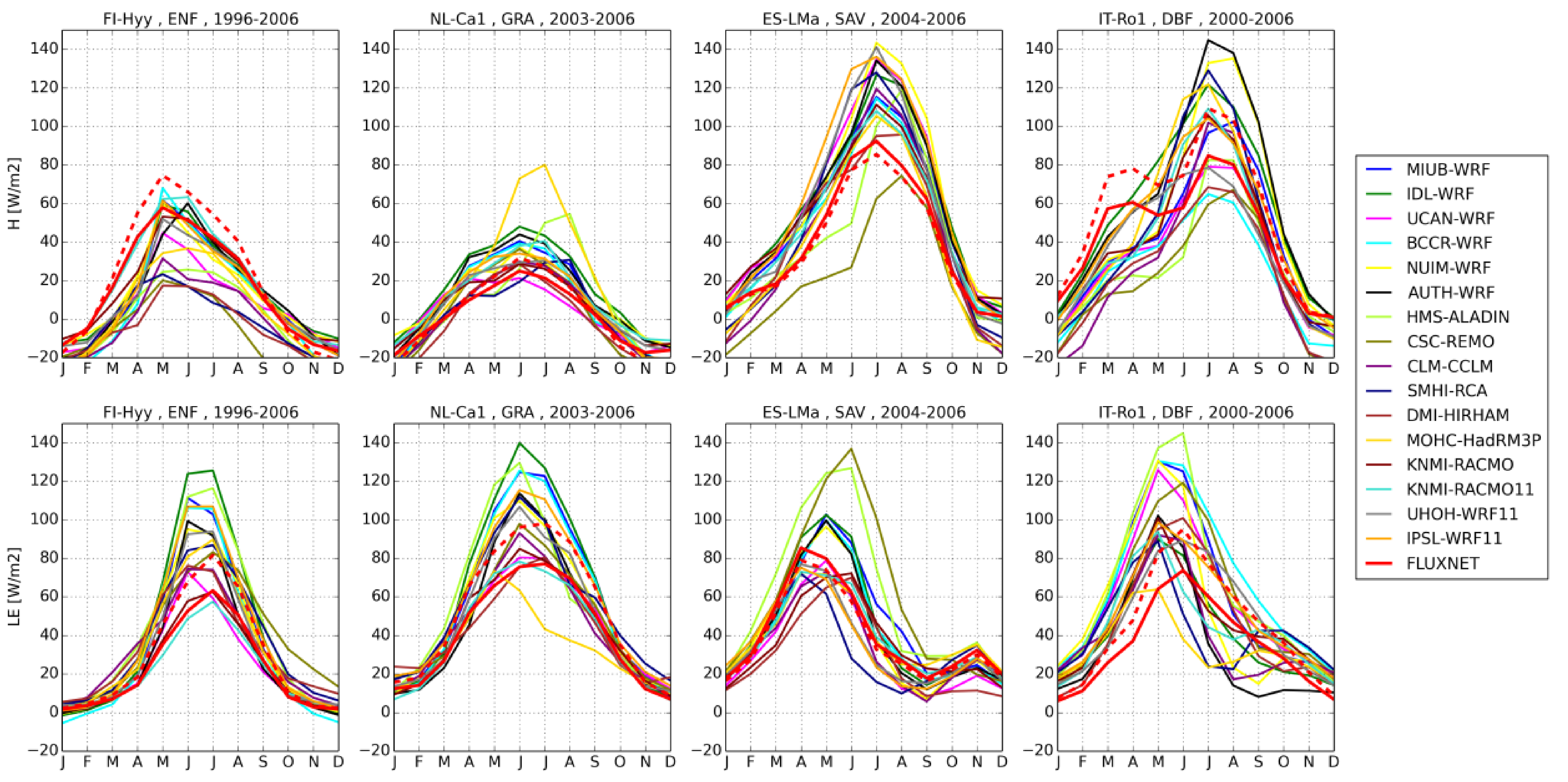
- Correlation of latent (LE) and sensible (H) heat flux
- Corr(H,LE) > 0: weak coupling, energy limited system
- Corr(H,LE) < 0: strong coupling, moisture limited system



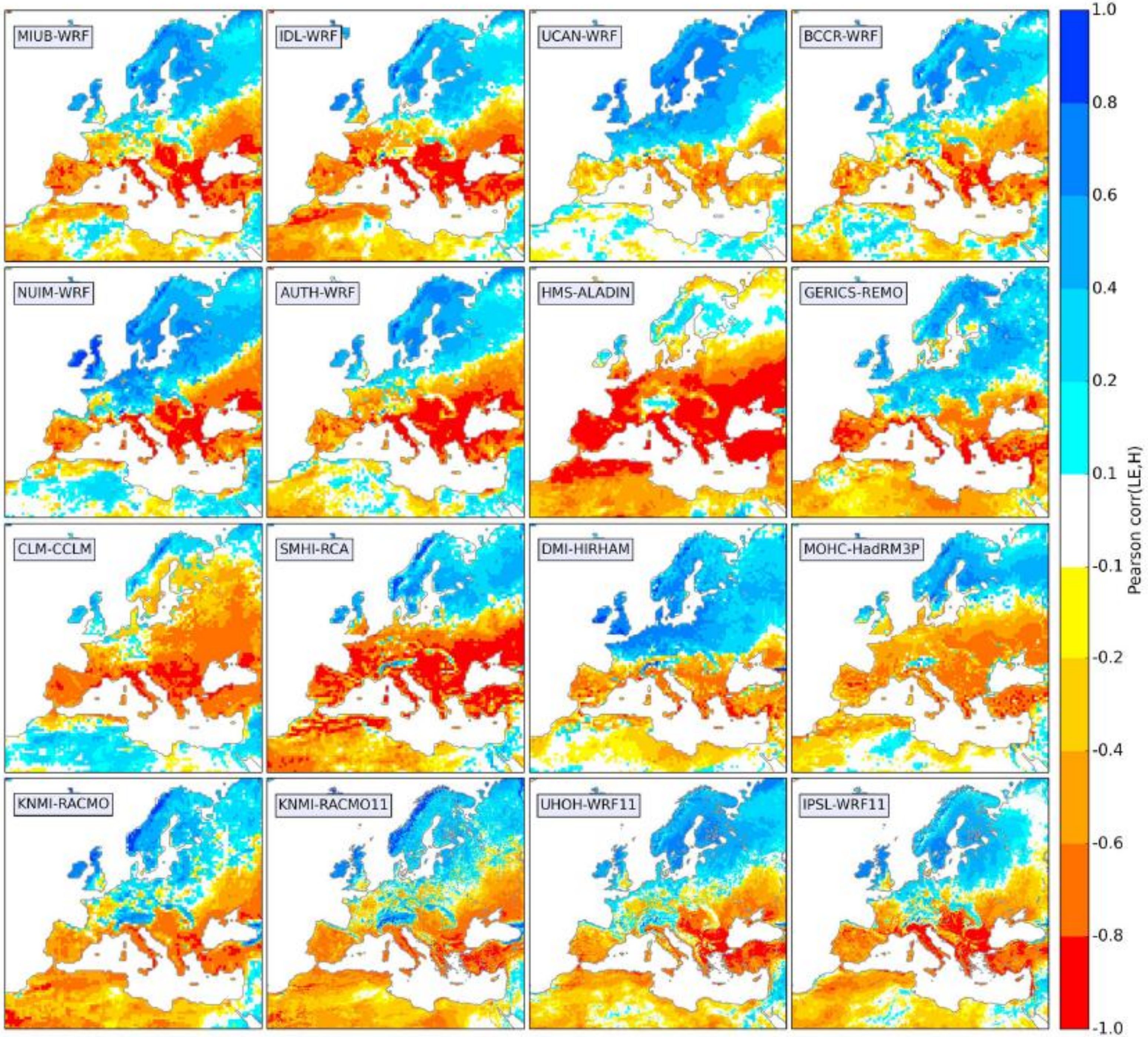
FLUXNET stations, JJA, individual time spans



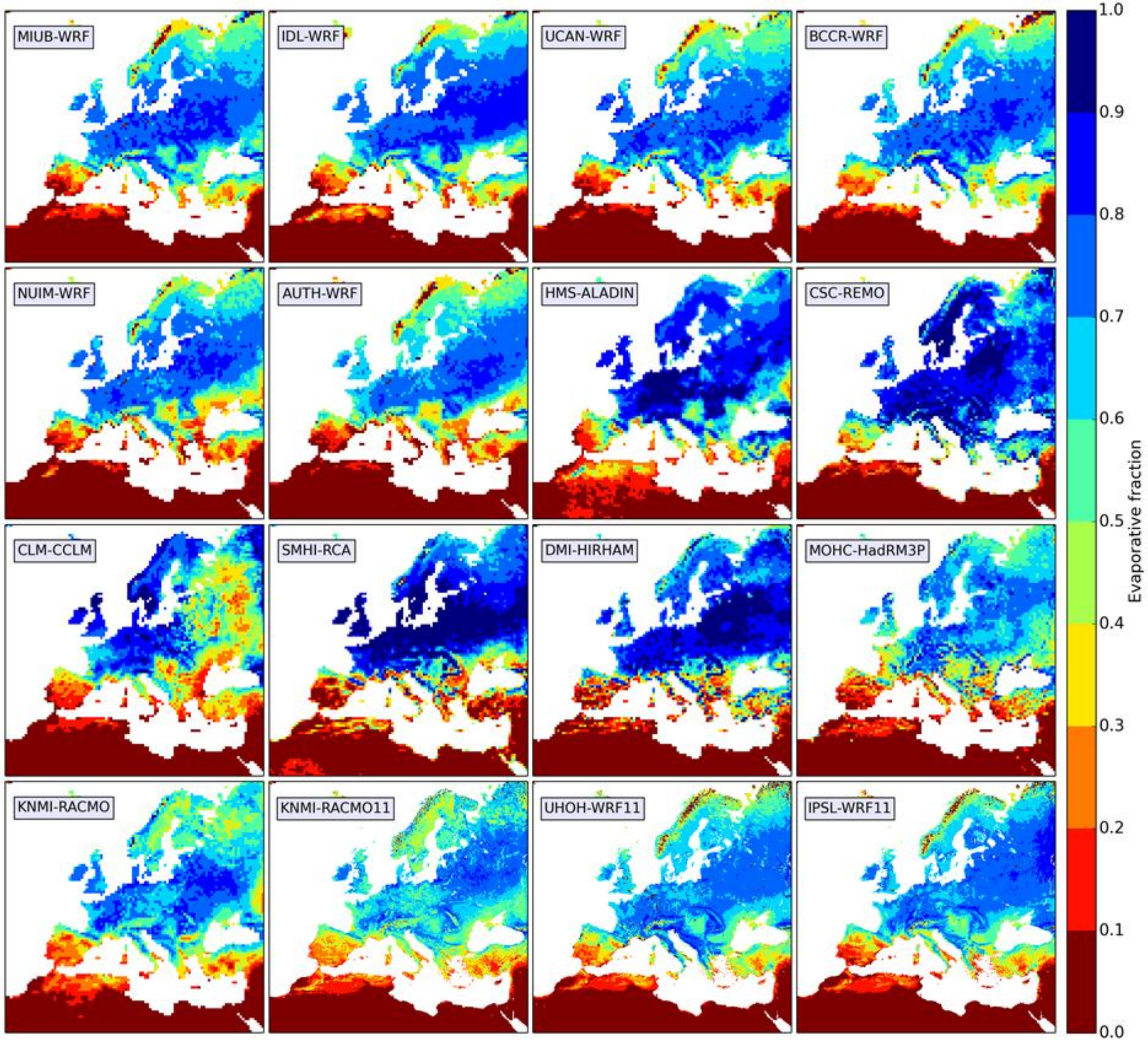
Mean annual cycles of monthly mean of sensible (top) and latent (bottom) heat flux at four representative FLUXNET stations (thick red line)



Knist, S. et al. (2016) Validation of soil moisture and surface fluxes in EURO-CORDEX simulations as part of land-atmosphere coupling analysis. *JGR Atmospheres 122 79-123 DOI:10.1002/2016JD025476*



Correlation of summer (JJA) 10 day averages of latent and sensible heat flux for the years 1990 to 2008.

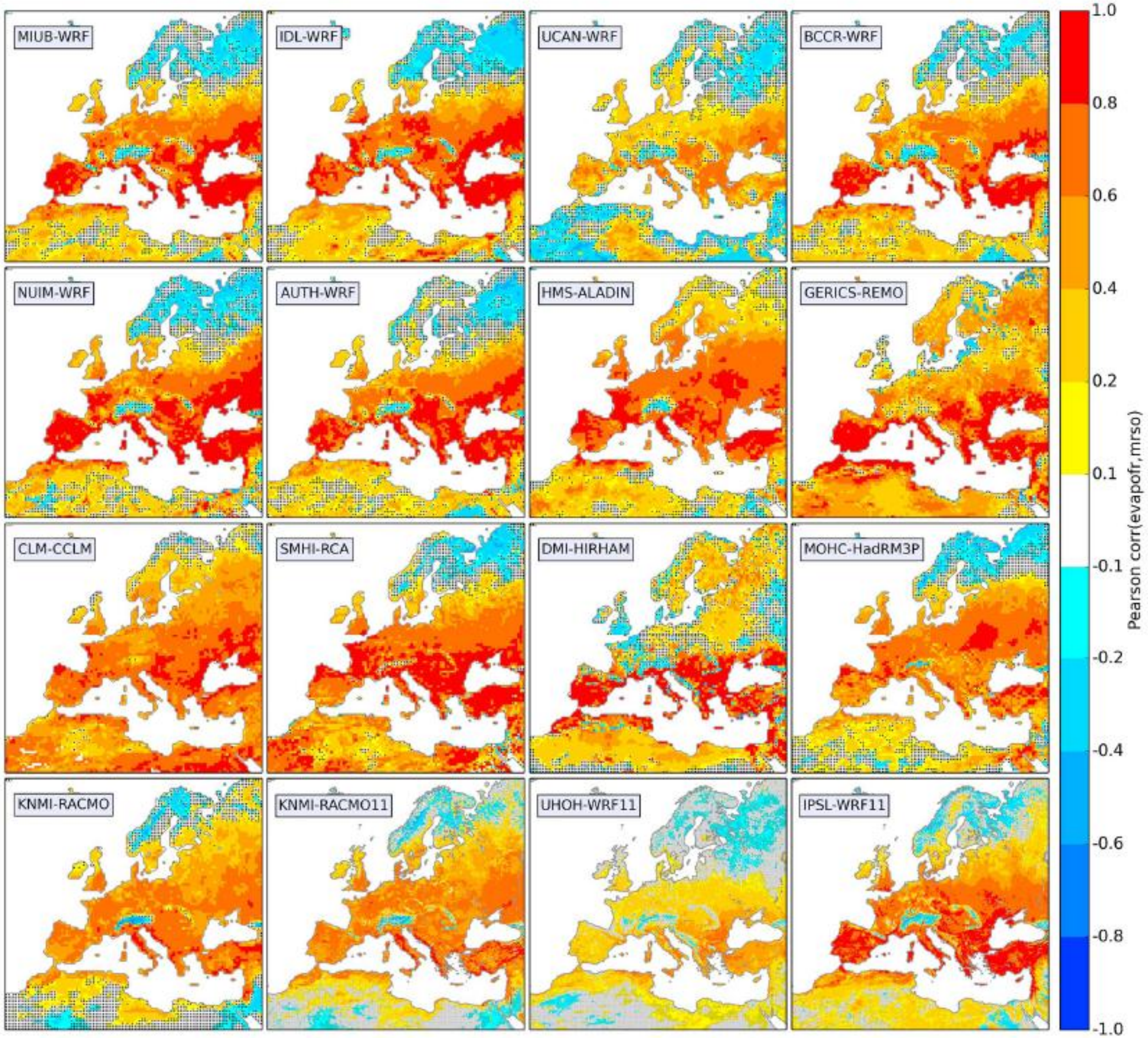


ERA-Interim (1990-2008)

Evaporative fraction

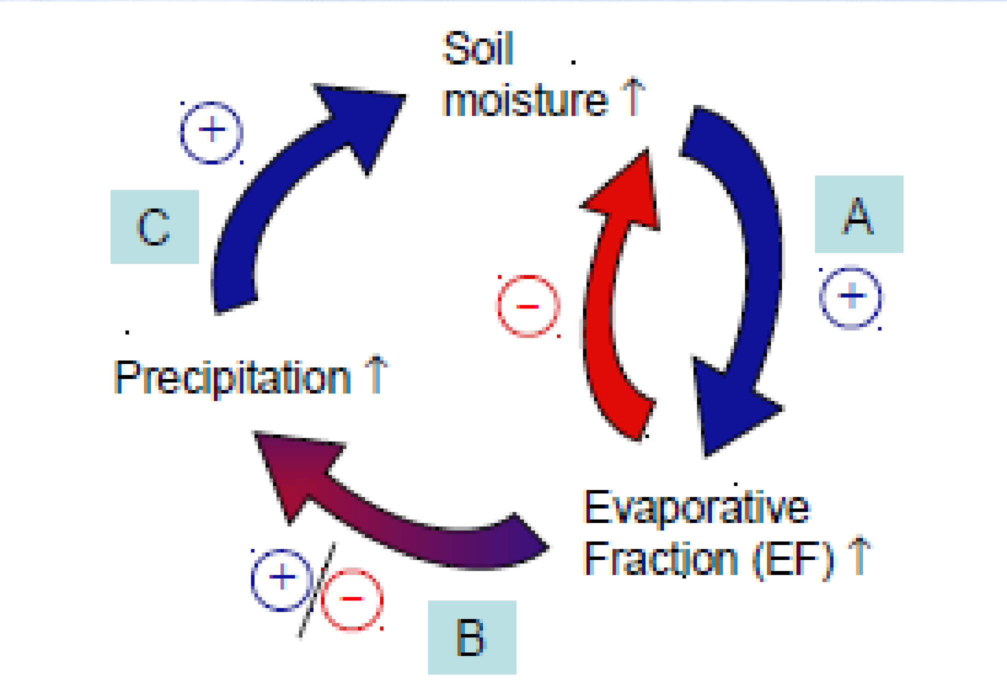
$$EF = \frac{LE}{H+LE}$$

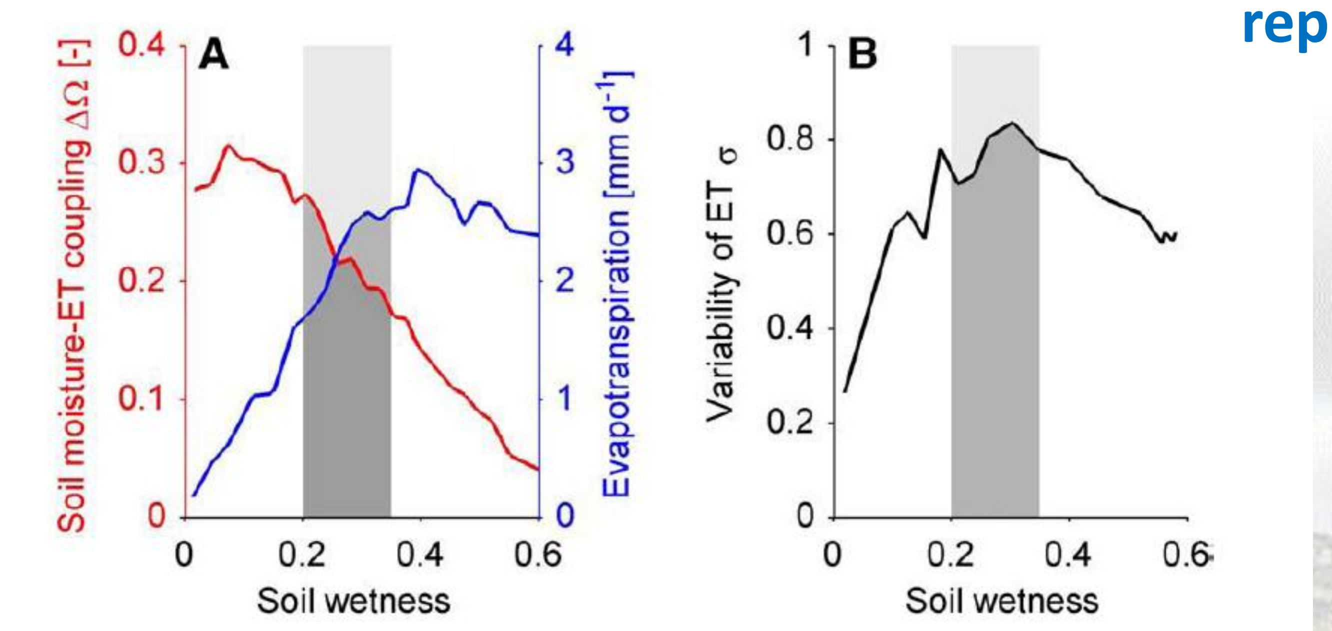
EF ~0 -> Arid Regions
0 <EF <1 -> Transition Regions
EF ~1 -> Humid Regions



Correlation between 10 day averages of total soil moisture and the evaporative fraction computed for the summers between 1990 and 2008

Soil Moisture and precipitation coupling

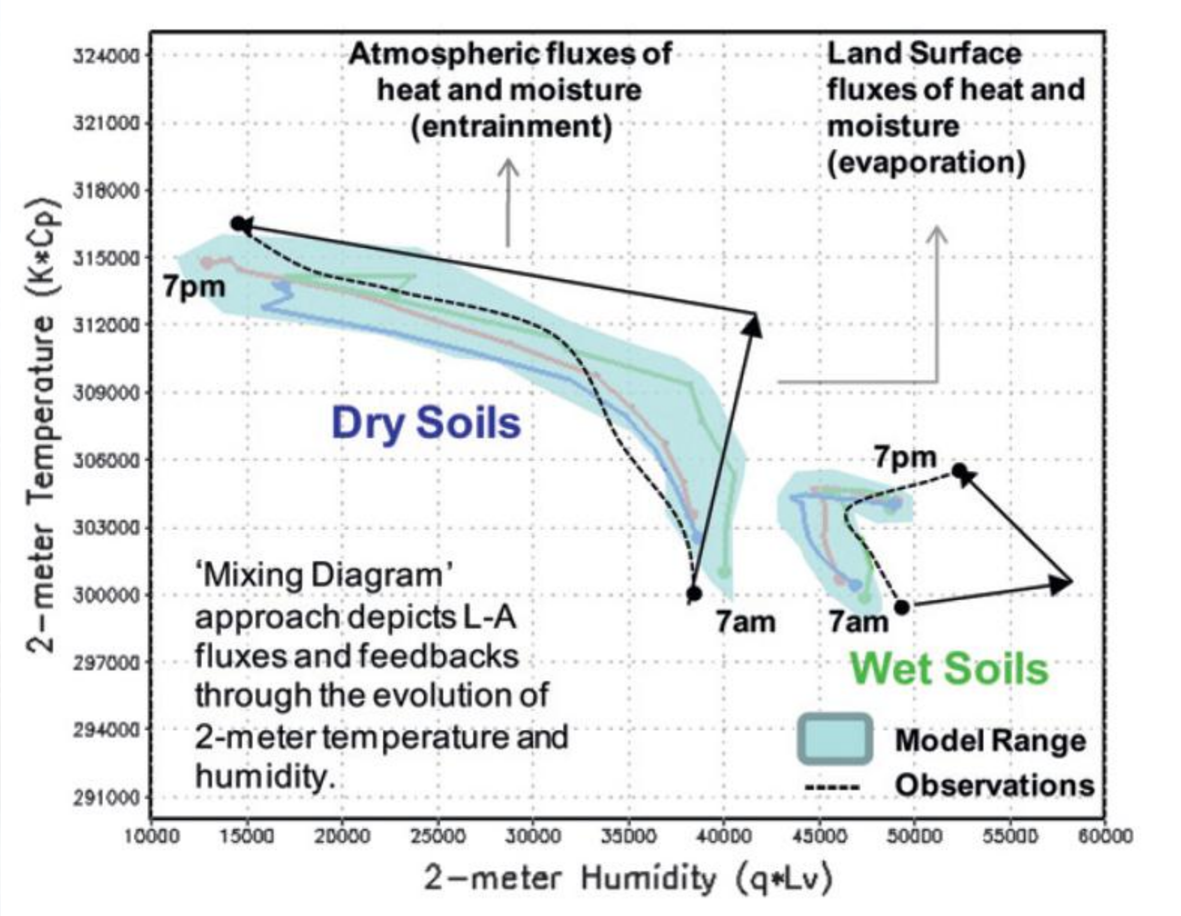


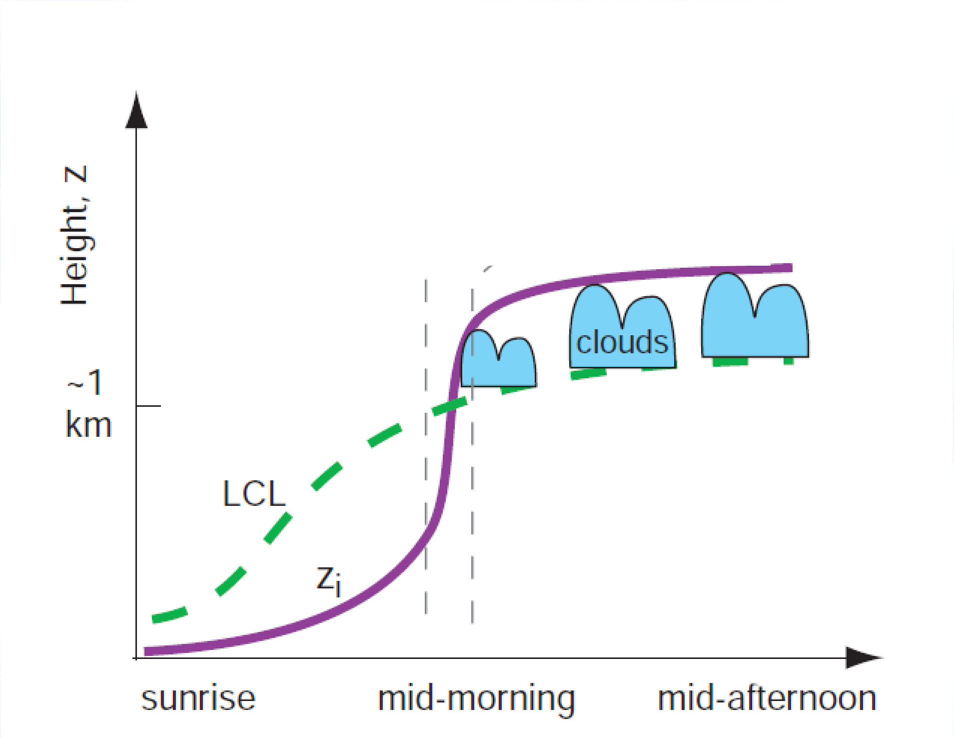


A. Soil moisture impacts the partitioning of energy at the land surface into sensible and latent heat flux (H and LE, respectively), which can be quantified by the evaporative fraction $LE/(H+LE)$

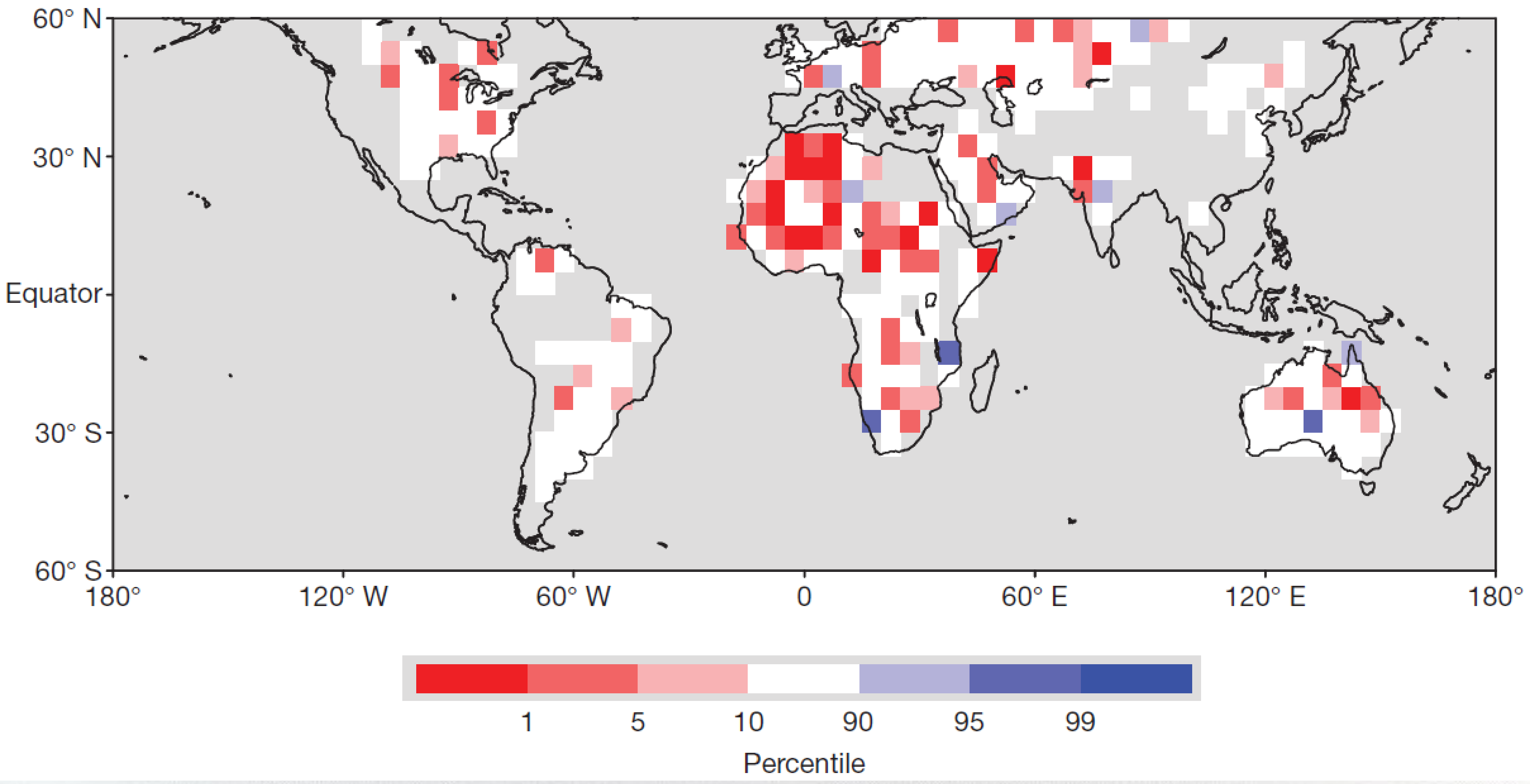
B. The moisture and heat input to the atmosphere corresponding to changes in EF impacts subsequent precipitation.

C. Precipitation impacts soil moisture by replenishing the soil moisture reservoir





Santanello, J. A., C. D. Peters-Lidard, and S. V. Kumar (2011), Diagnosing the sensitivity of local land-atmosphere coupling via the soil moisture-boundary layer interaction, J. Hydrometeorol., 12, 766–786.



Low percentiles - rainfall maxima occurs over locally dry soil more frequently than expected

High percentiles - rainfall maxima occur over locally wet soil more frequently than expected

Afternoon rain falls preferentially over soils that are relatively dry compared to the surrounding area.

Stronger signal over semi-arid regions, where surface fluxes are sensitive to soil moisture, and convective events are frequent. Afternoon moist convection is enhanced and driven by increased sensible heat flux over drier soils, and/or mesoscale variability in soil moisture.

No evidence of a positive feedback, i.e. preference for rain over wetter soils

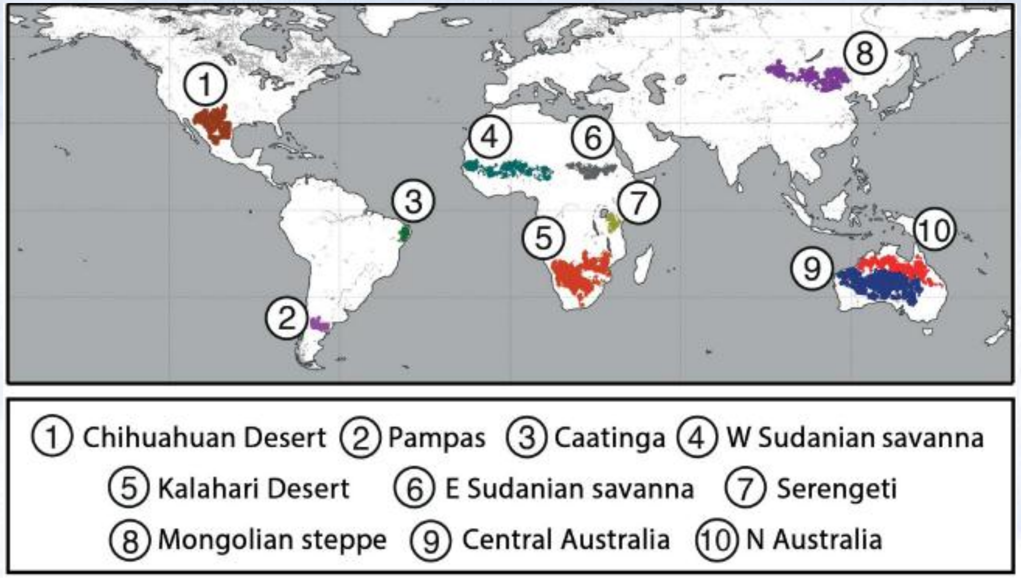
Taylor et al. (2012) - Afternoon rain more likely over drier soils. doi:10.1038/nature11377

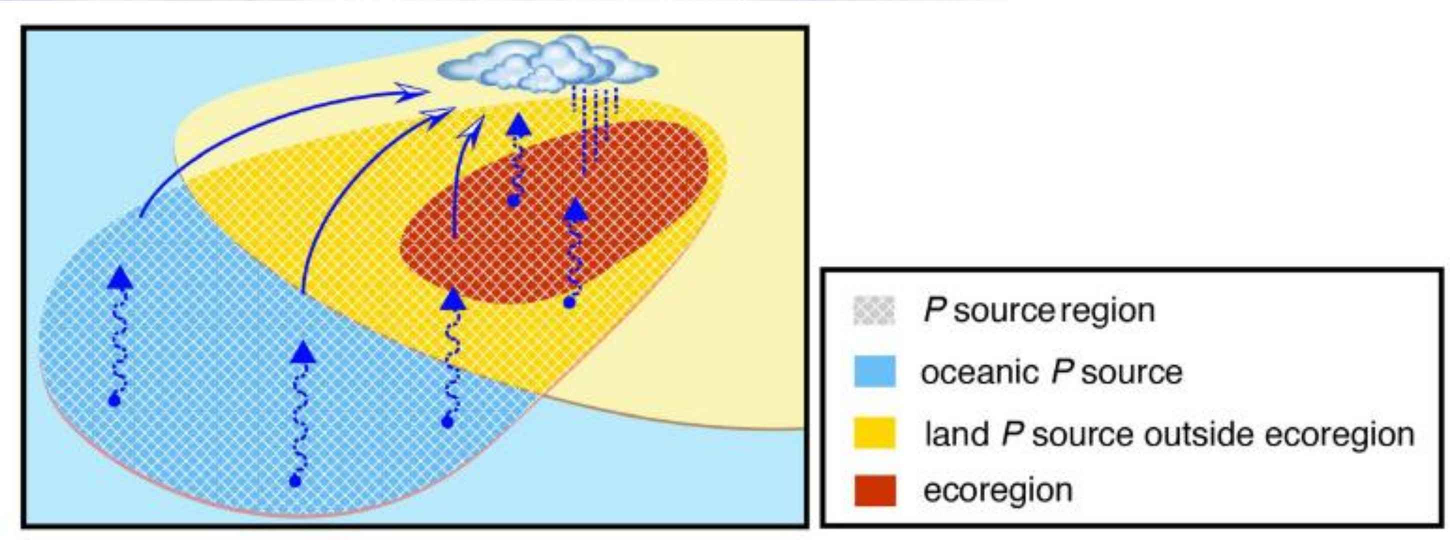
Moisture recycling

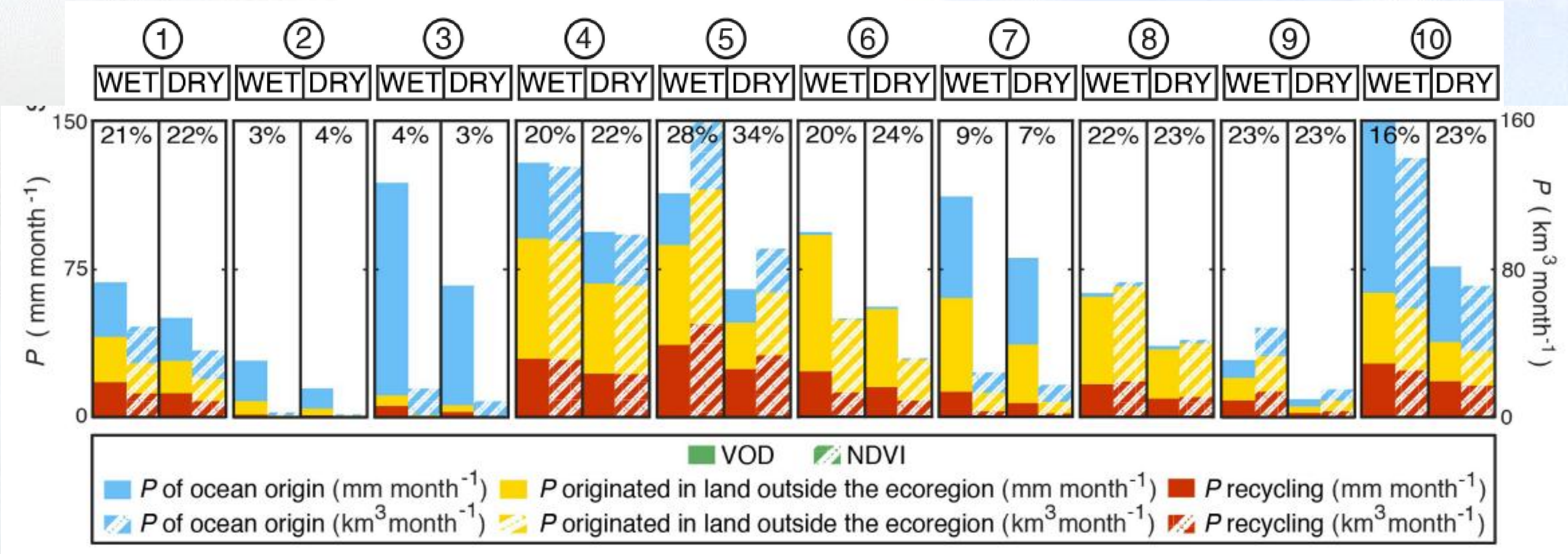
Moisture recycling refers to the contribution of local evapotranspiration fluxes to precipitation.

The recycling ratio ρ is the fraction of precipitation coming from ET.

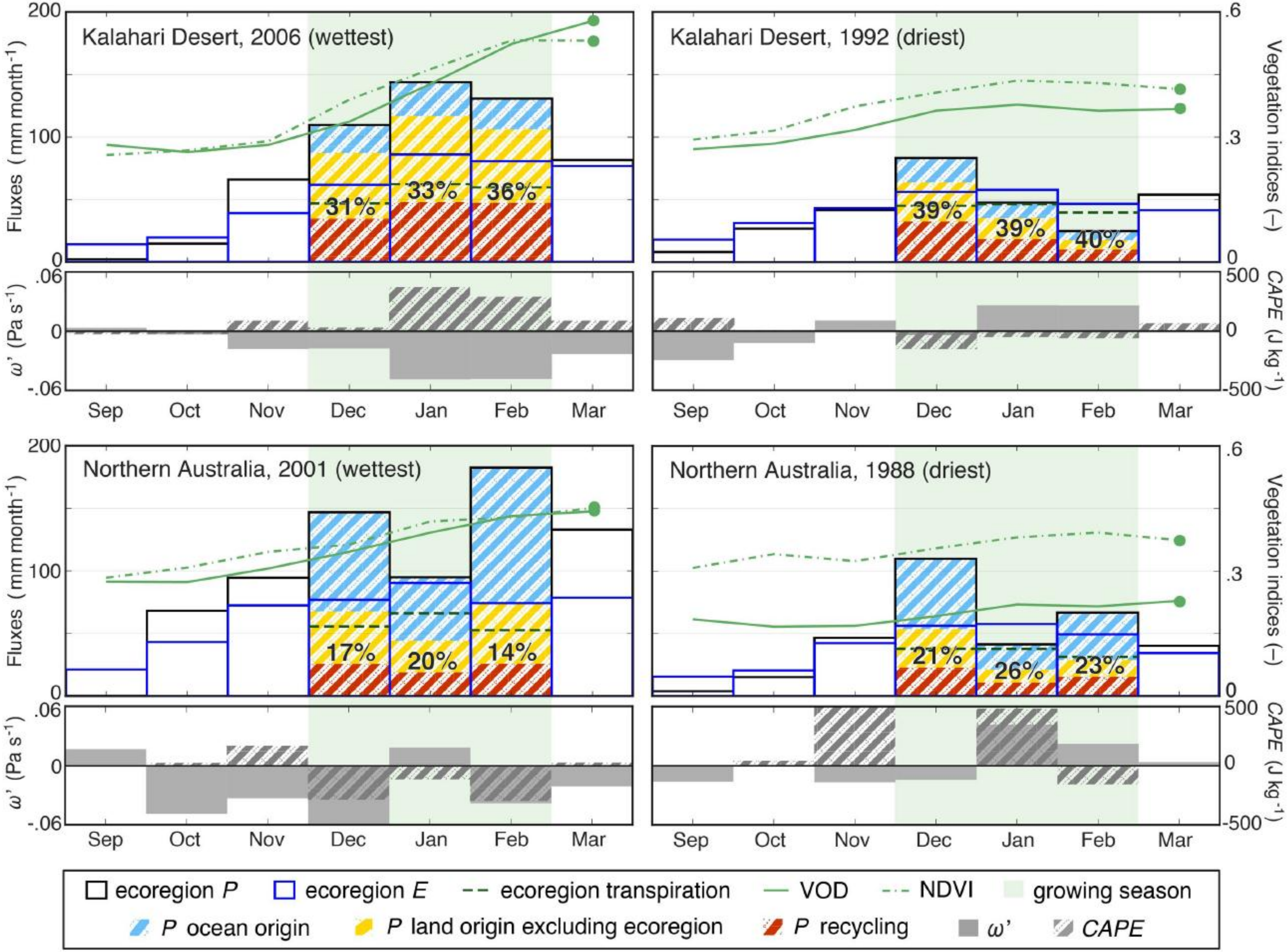
It can be an indication of the degree of control of local processes on precipitation dynamics in a region.



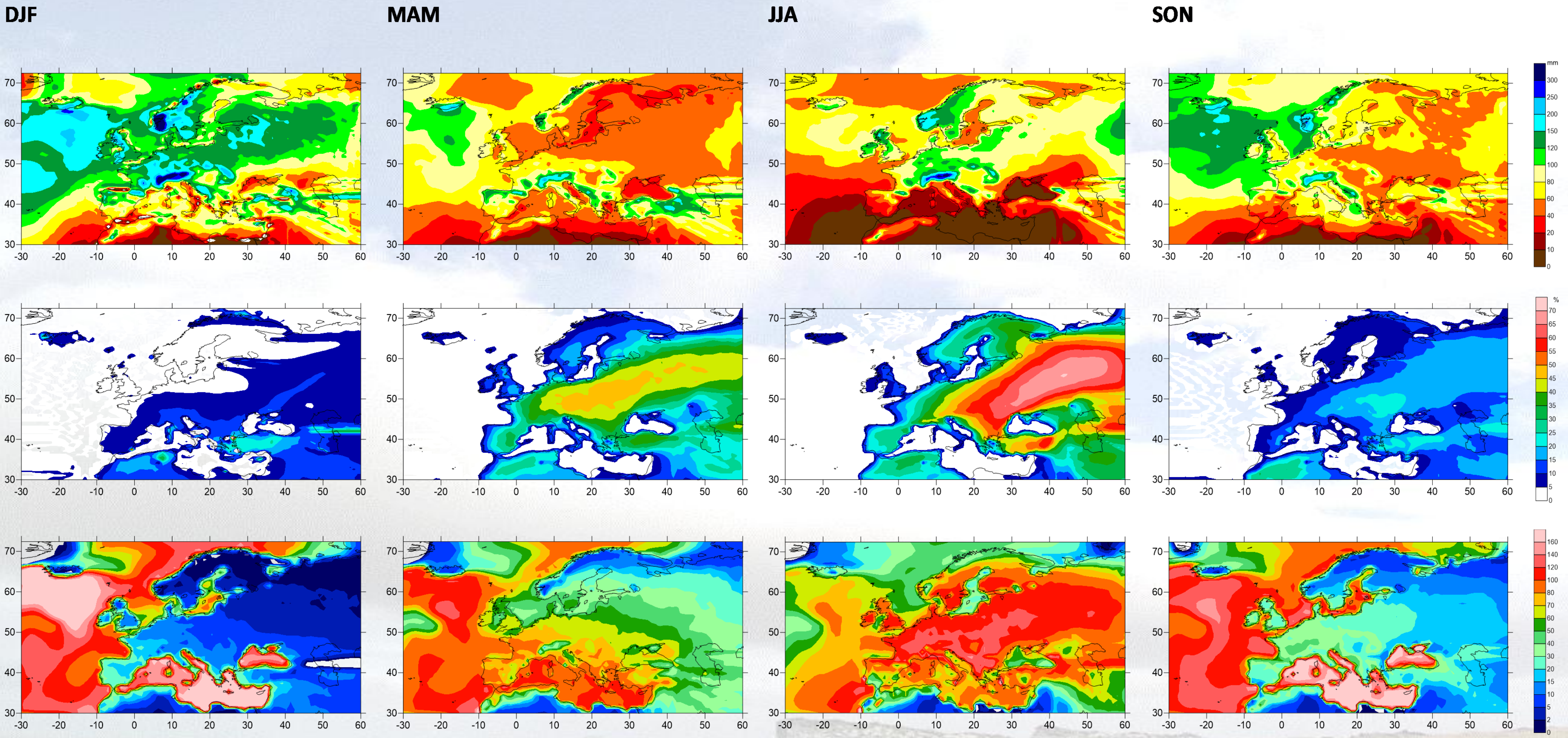




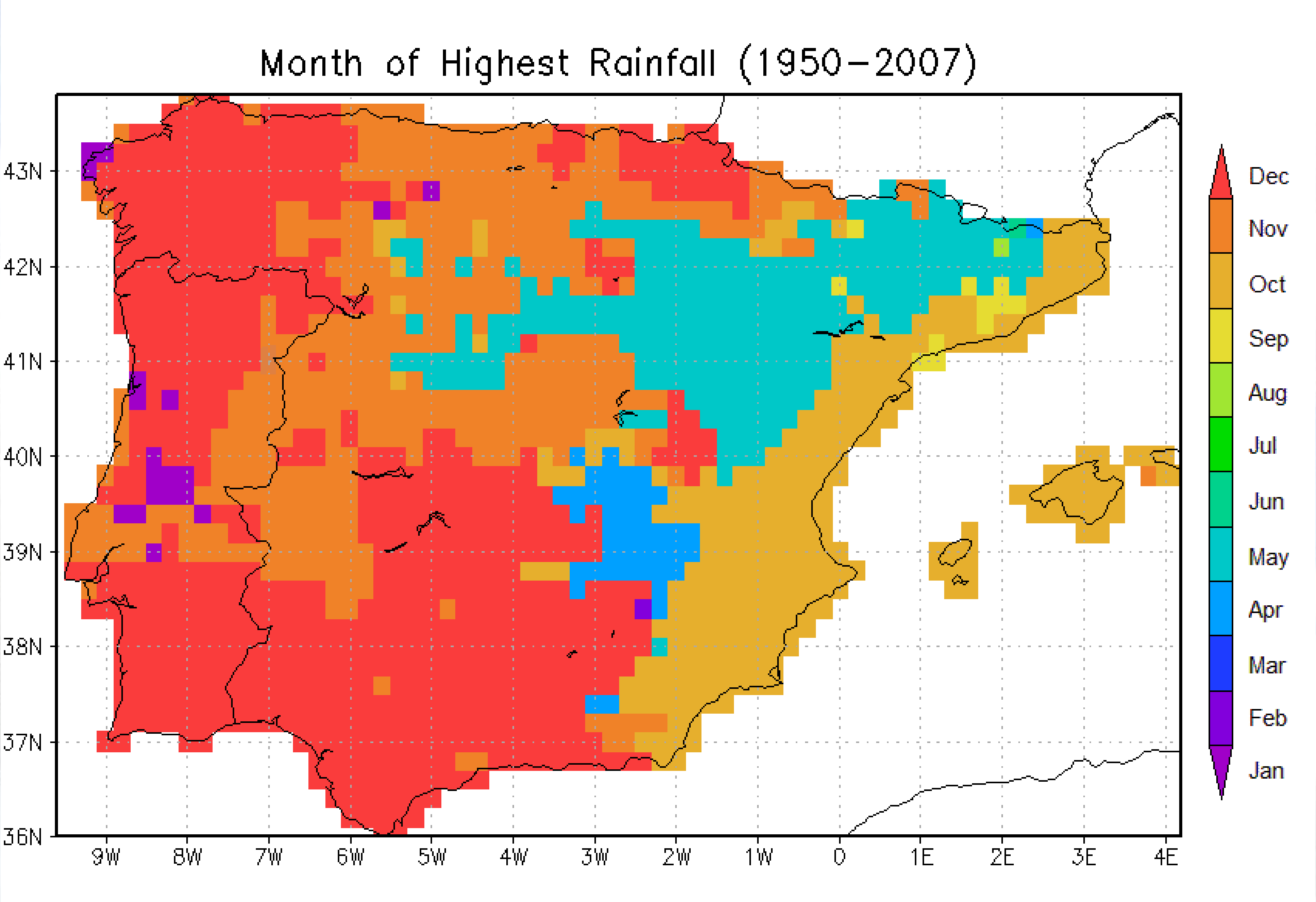
Miralles et al. - 2016 - Contribution of water-limited ecoregions to their own supply of rainfall. doi:10.1088/1748-9326/11/12/124007



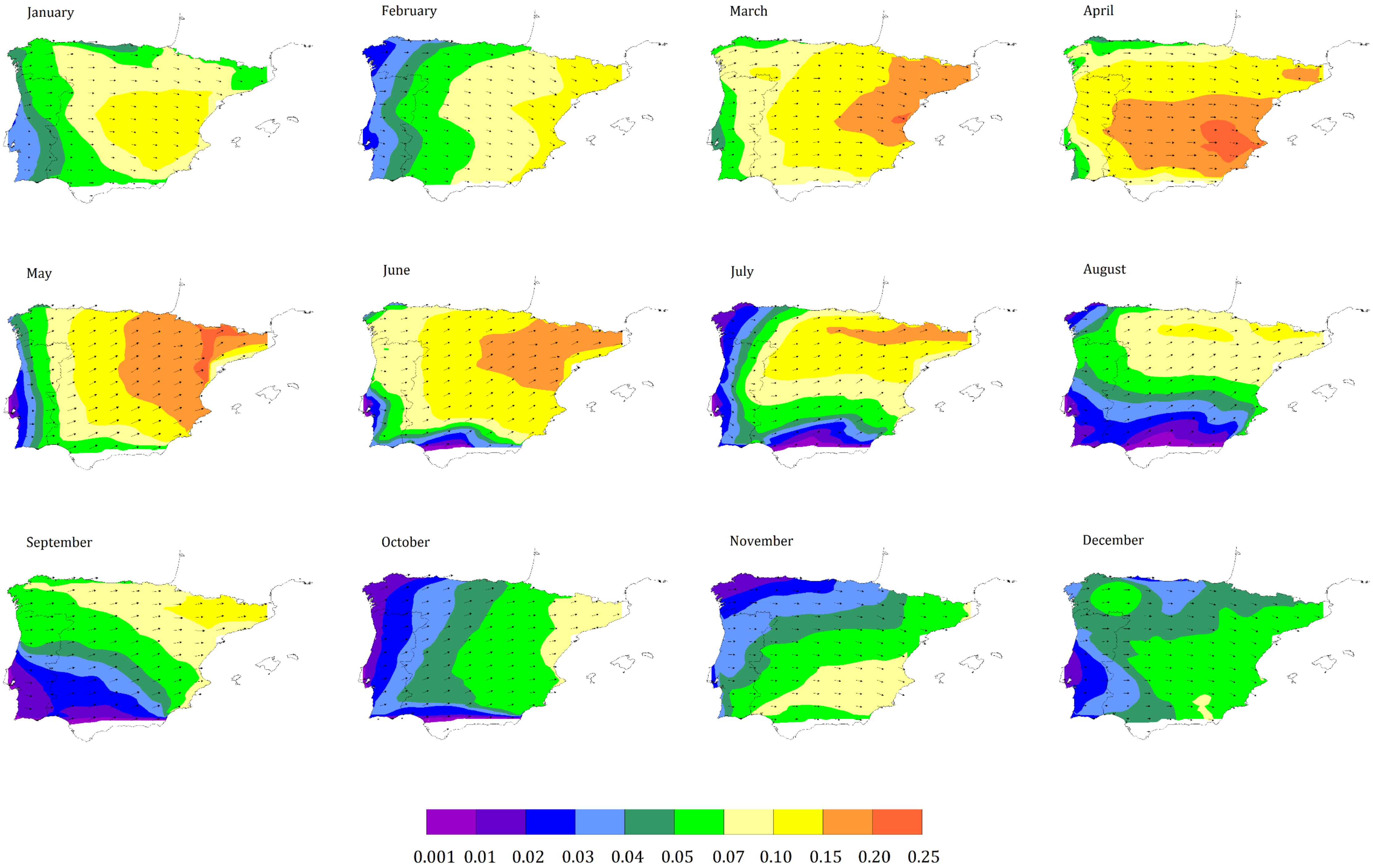
Kalahari Desert, 2006 (wettest)
Kalahari Desert, 1992 (driest)
Northern Australia, 2001 (wettest)
Northern Australia, 1988 (driest)
Fluxes (mm month-1)
Vegetation indices (–)
ω' (Pa s-1)
CAPE (J kg-1)
200
100
0
.6
.3
.06
-.06
500
-500
31%
33%
36%
39%
39%
40%
17%
20%
14%
21%
26%
23%
Sep
Oct
Nov
Dec
Jan
Feb
Mar
ecoregion P
ecoregion E
ecoregion transpiration
VOD
NDVI
growing season
P ocean origin
P land origin excluding ecoregion
P recycling
ω'
CAPE



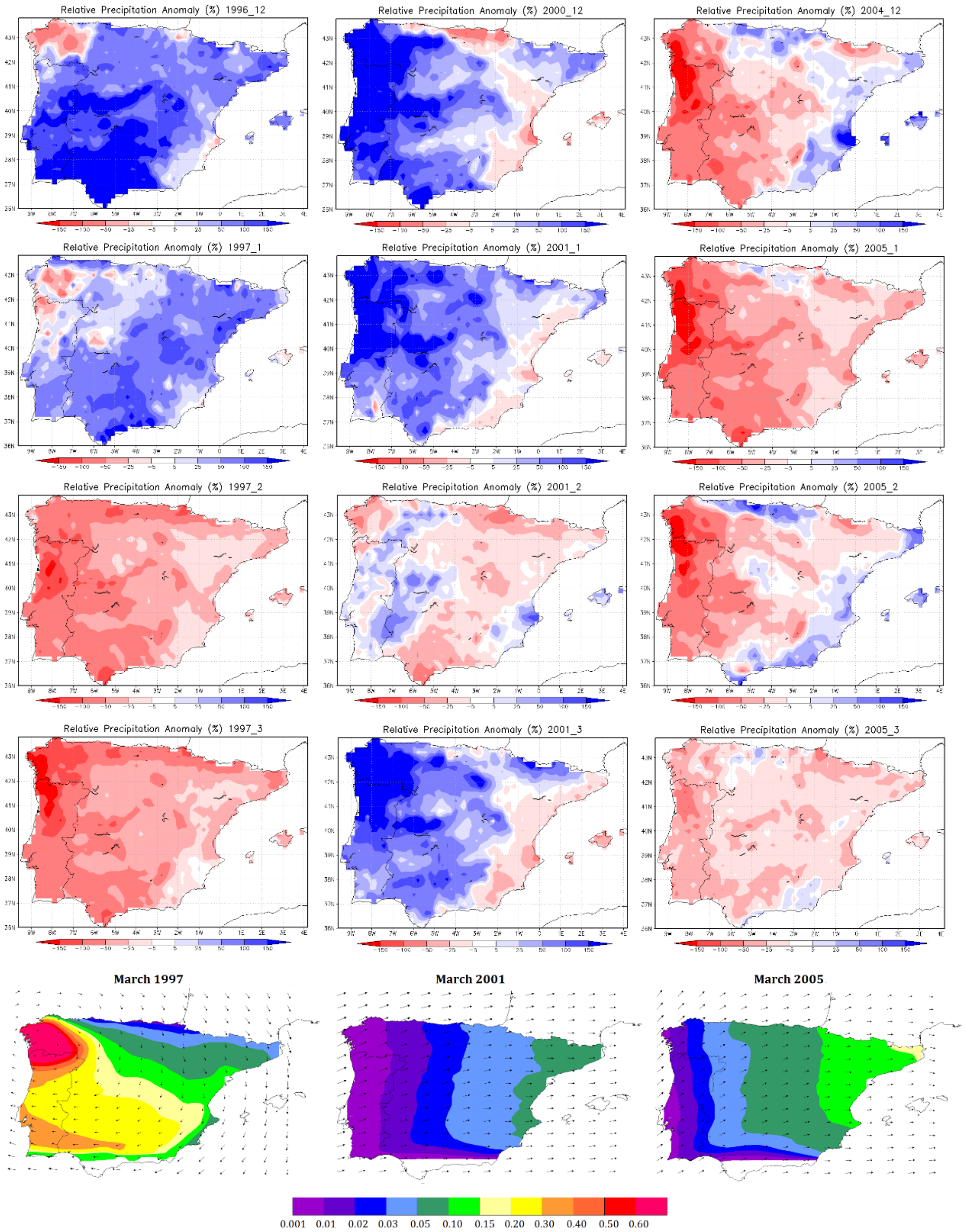
Seasonal mean precipitation (top row), recycling ratio (center), potential evapotranspiration (third row) for the period 1971-2000



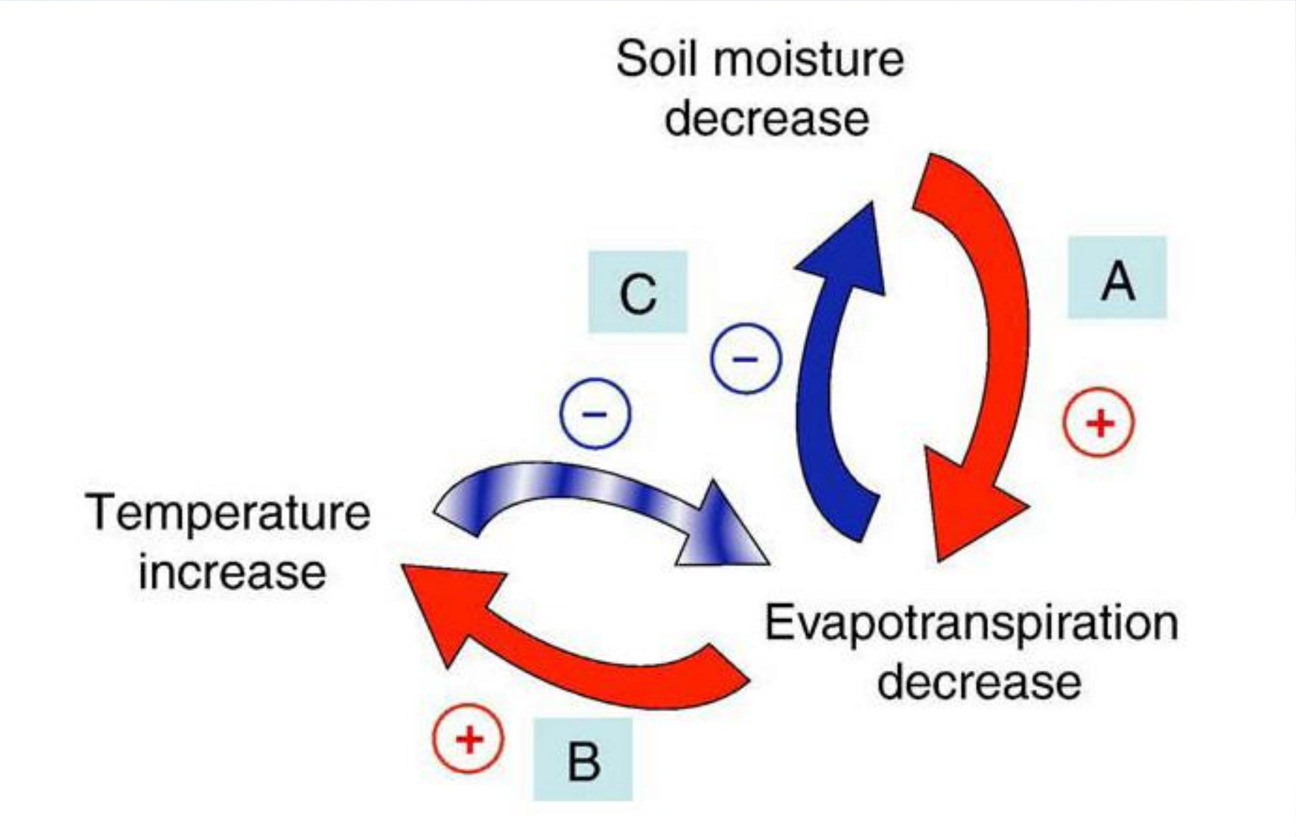
Rios-Entenza et al. (2014) Moisture recycling in the Iberian Peninsula from a regional climate simulation: Spatiotemporal analysis and impact on the precipitation regime. J. Geophys. Res. Atmos., 119, 5895–5912. doi:10.1002/2013JD021274



January
February
March
April
May
June
July
August
September
October
November
December
0.001 0.01 0.02 0.03 0.04 0.05 0.07 0.10 0.15 0.20 0.25

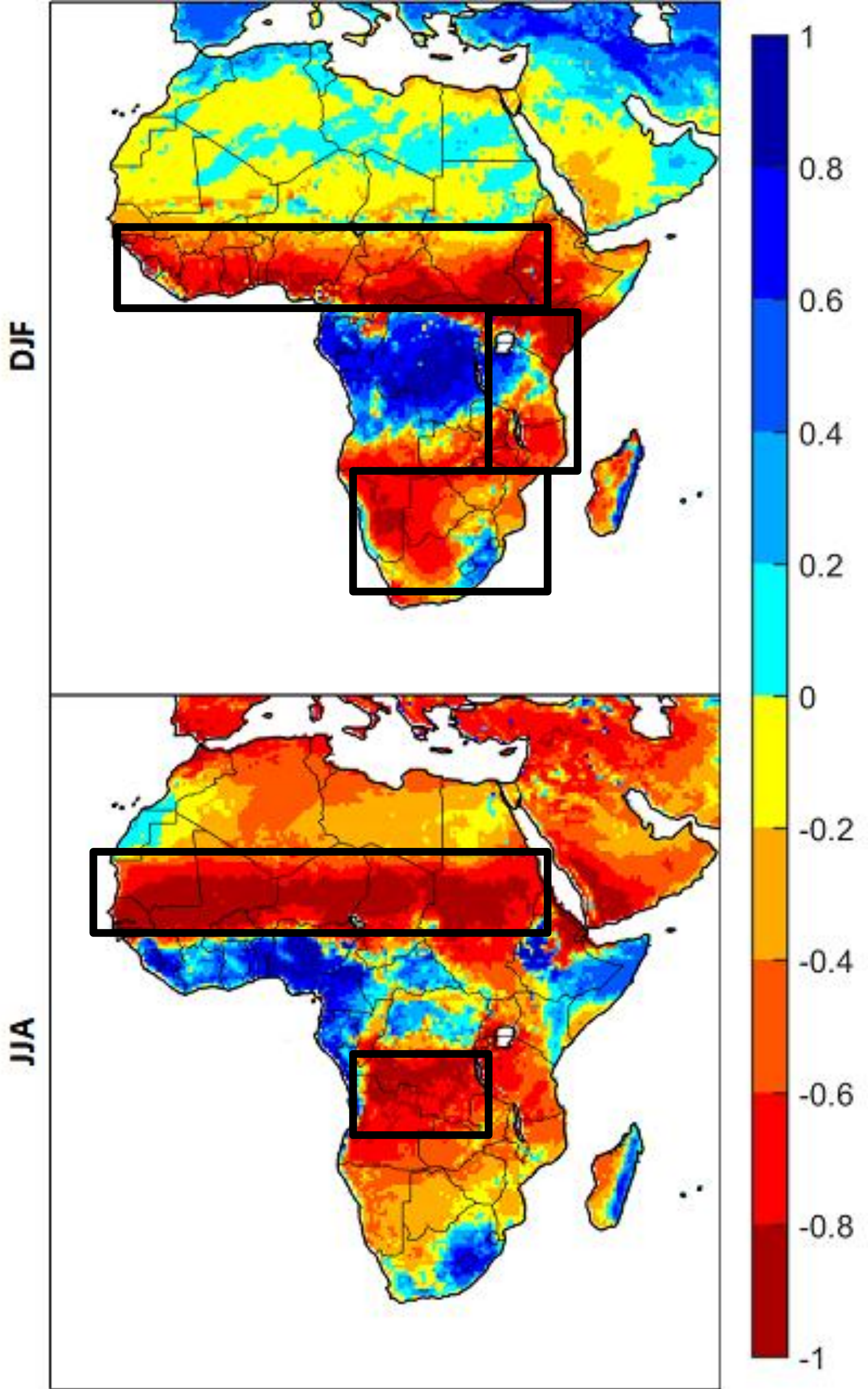

Relative Precipitation Anomaly (%) 1996_12
Relative Precipitation Anomaly (%) 2000_12
Relative Precipitation Anomaly (%) 2004_12
Relative Precipitation Anomaly (%) 1997_1
Relative Precipitation Anomaly (%) 2001_1
Relative Precipitation Anomaly (%) 2005_1
Relative Precipitation Anomaly (%) 1997_2
Relative Precipitation Anomaly (%) 2001_2
Relative Precipitation Anomaly (%) 2005_2
Relative Precipitation Anomaly (%) 1997_3
Relative Precipitation Anomaly (%) 2001_3
Relative Precipitation Anomaly (%) 2005_3
March 1997
March 2001
March 2005
0.001 0.01 0.02 0.03 0.05 0.10 0.15 0.20 0.30 0.40 0.50 0.60

Soil Moisture and temperature coupling



Whenever soil moisture limits the total energy used by latent heat flux, more energy is available for sensible heating, inducing an increase of near-surface air temperature.

10 days of nonoverlapping means correlation between maximum temperature and latent heat flux



Arid areas:

- Lower correlations
- No coupling

Humid areas:

- Positive correlations
- Weak Coupling Regions

Transition areas:

- Negative Correlations
- Strong Coupling Regions

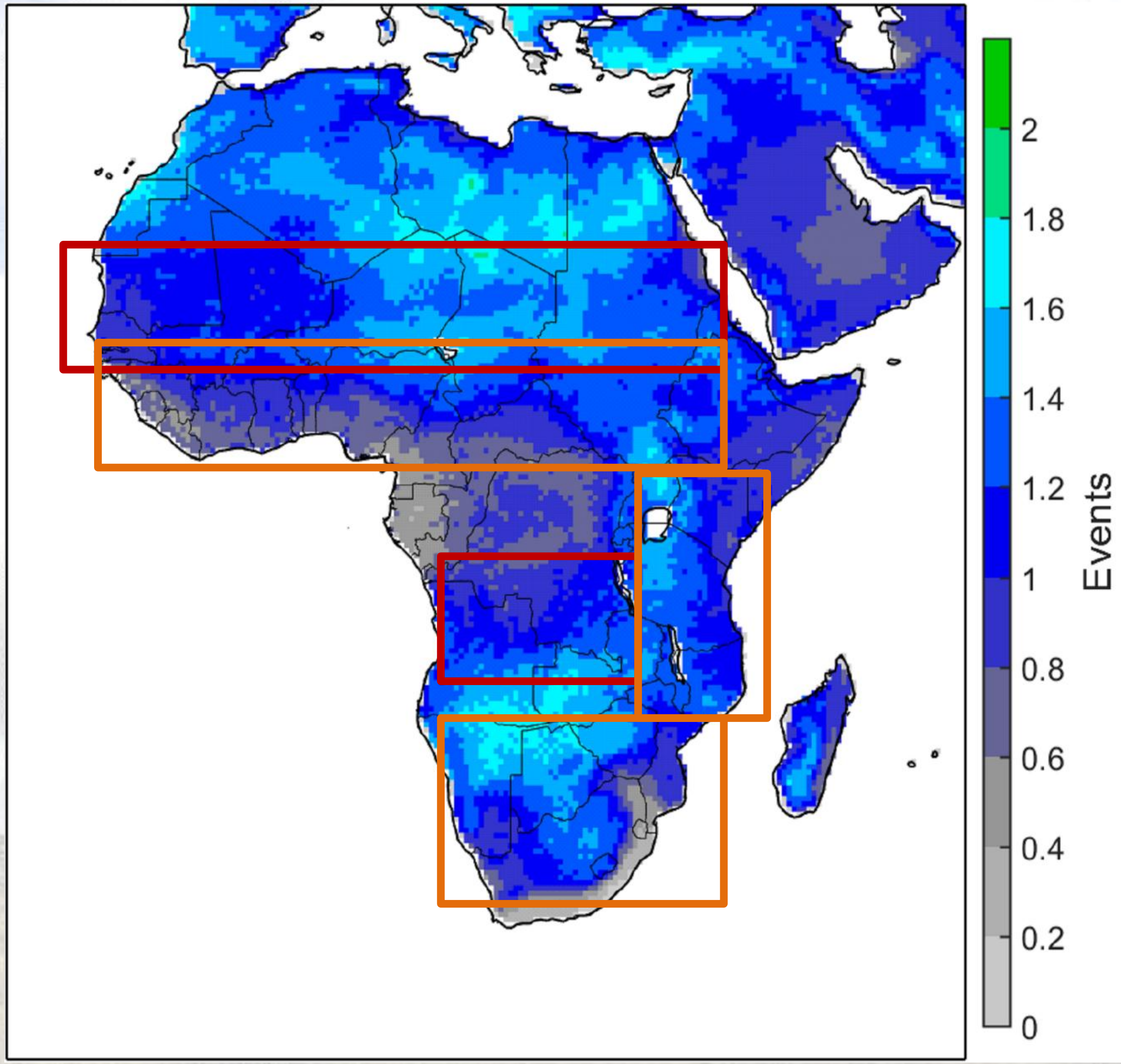
Seneviratne et al., 2006; 2010; Knist et al., 2017

Yearly average number of heat waves

5 or more days with maximum temperature above the 90^{th} percentile set of maximum temperature

More Heat waves over the strong Coupling areas

Historical Ensemble



Heat wave

5 or more days with temperature > P_{90}

P_{90} -> 90^{th} percentile centred on a 31 day window

Maximum Temperature Magnitude

$$MT_d = \frac{T_d - Pt_{25}}{Pt_{75} - Pt_{25}}$$

- Pt_{75} -> 75^{th} percentile
- Pt_{25} -> 25^{th} percentile

Latent Heat Flux Magnitude

$$MH_d = -\frac{LE - Pl_{75}}{Pl_{75} - Pl_{25}}$$

- Pl_{75} -> 75^{th} percentile
- Pl_{25} -> 25^{th} percentile

$$LETCM = \sum_{j=i}^{j=j+30} (MT_d)_j * (MH_d)_j$$

Russo, S. et al. (2015) and . Russo, S. et al. (2016) Environmental Research Letters

Careto et al., 2018

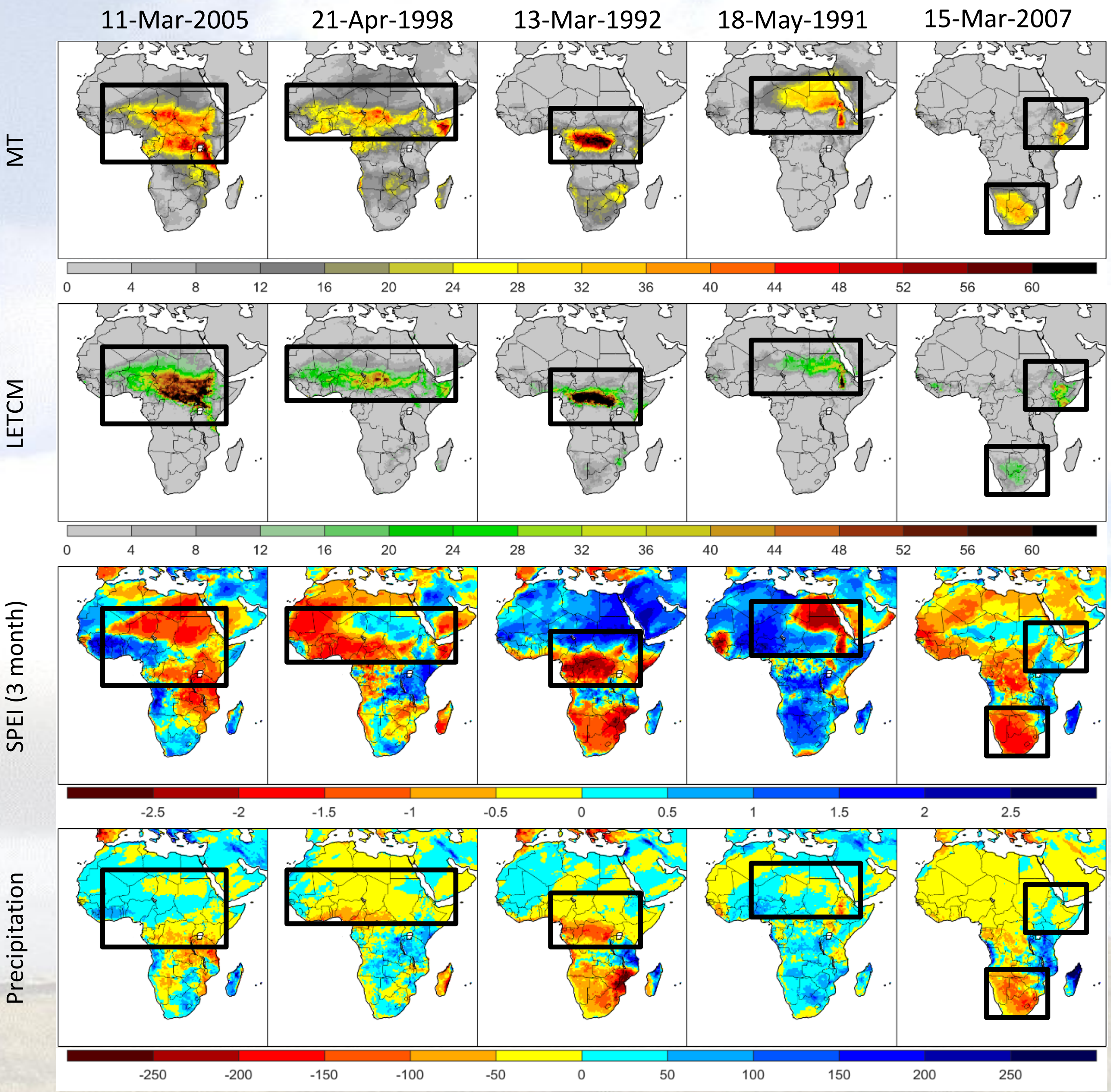
LETCM (Hindcast)

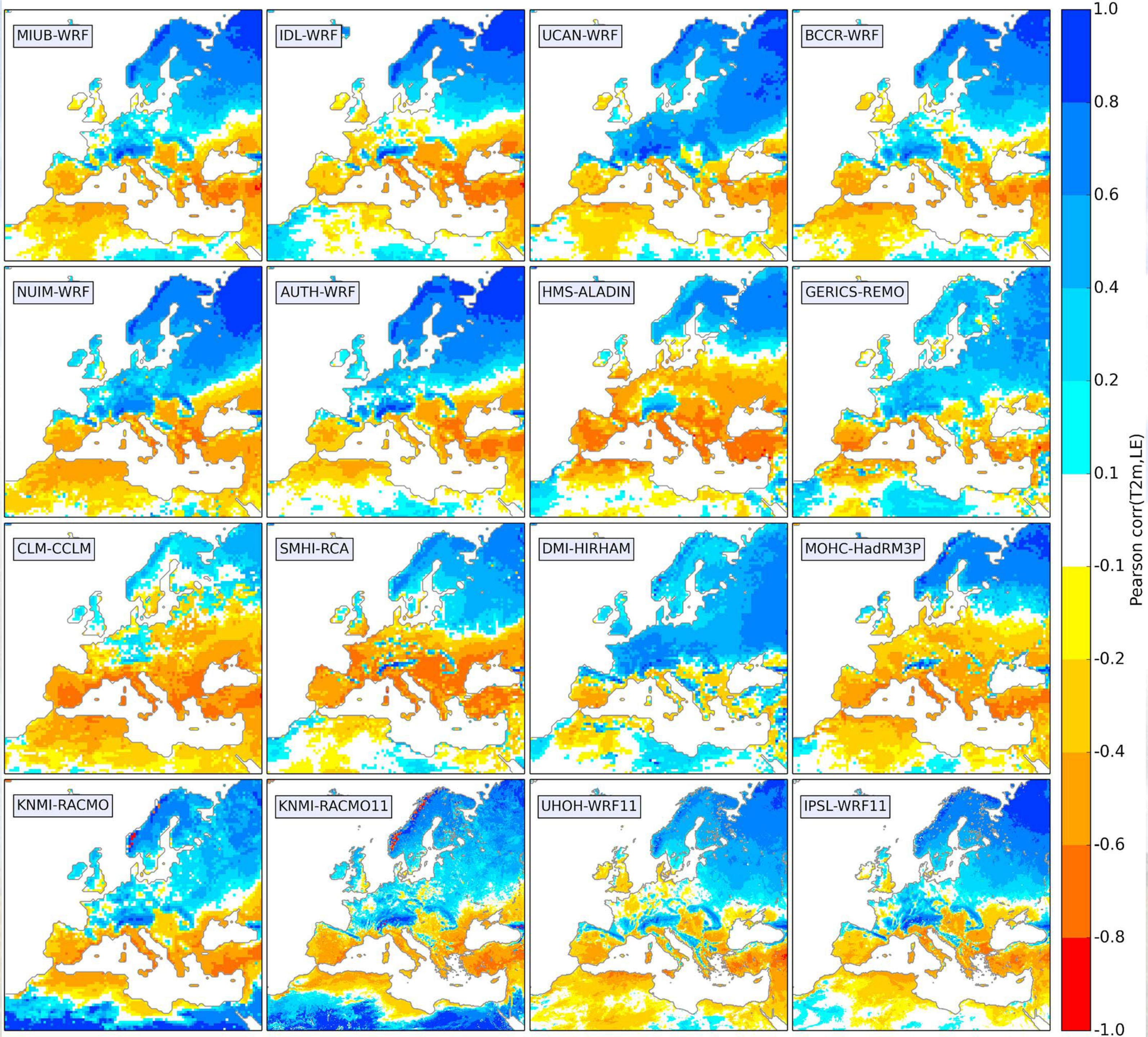
Final Day	% Land area above magnitude of 30
11-Mar-2005	16.3
21-APR-1998	6.2
13-Mar-1992	4.6
18-May-1991	4.2
15-Mar-2007	3.9

Precipitation-Potential Evapotranspiration -> SPEI

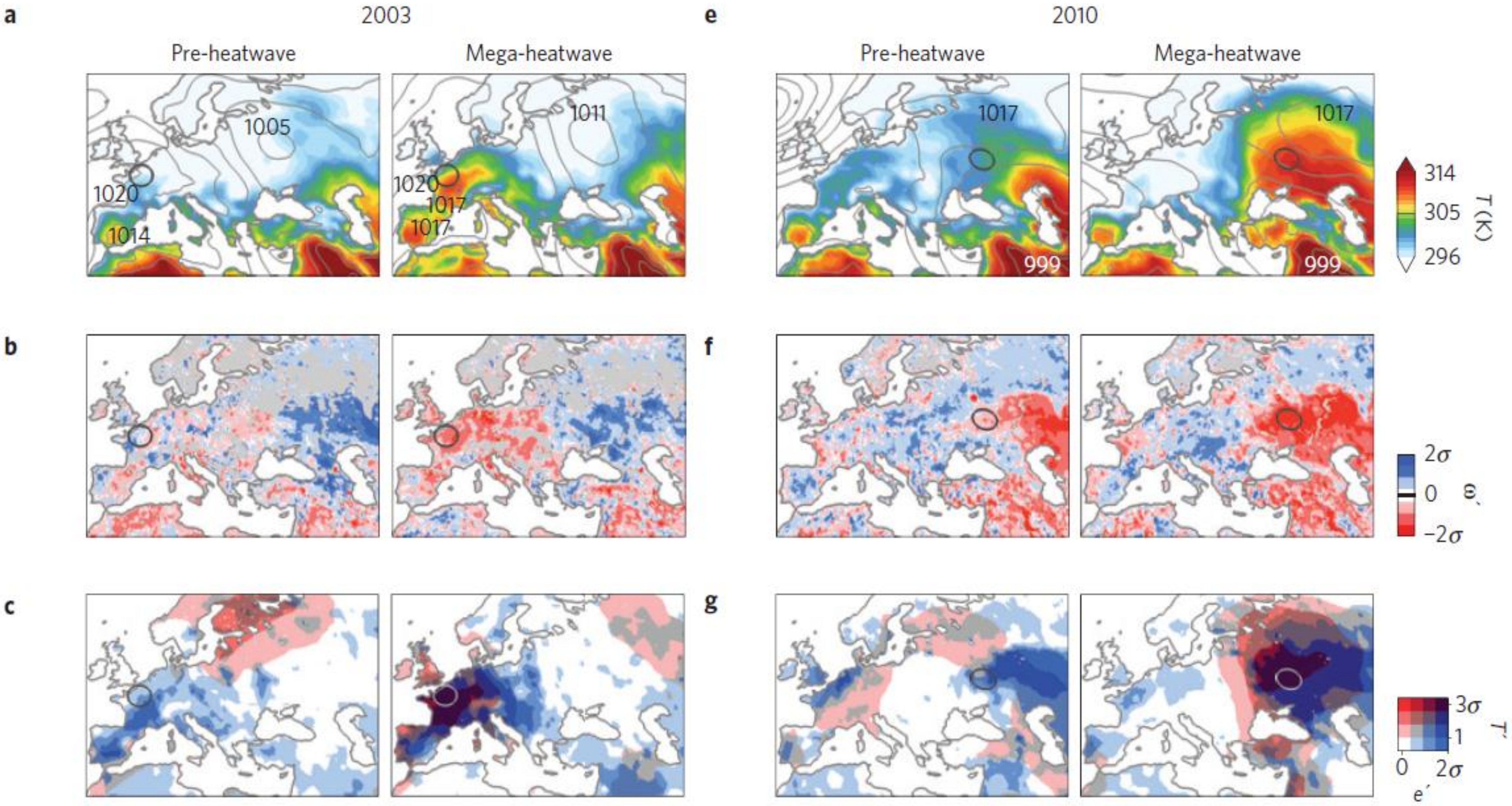
Precipitation:

90 days of accumulated rainfall anomalies relatively to the mean value of all years for the same period

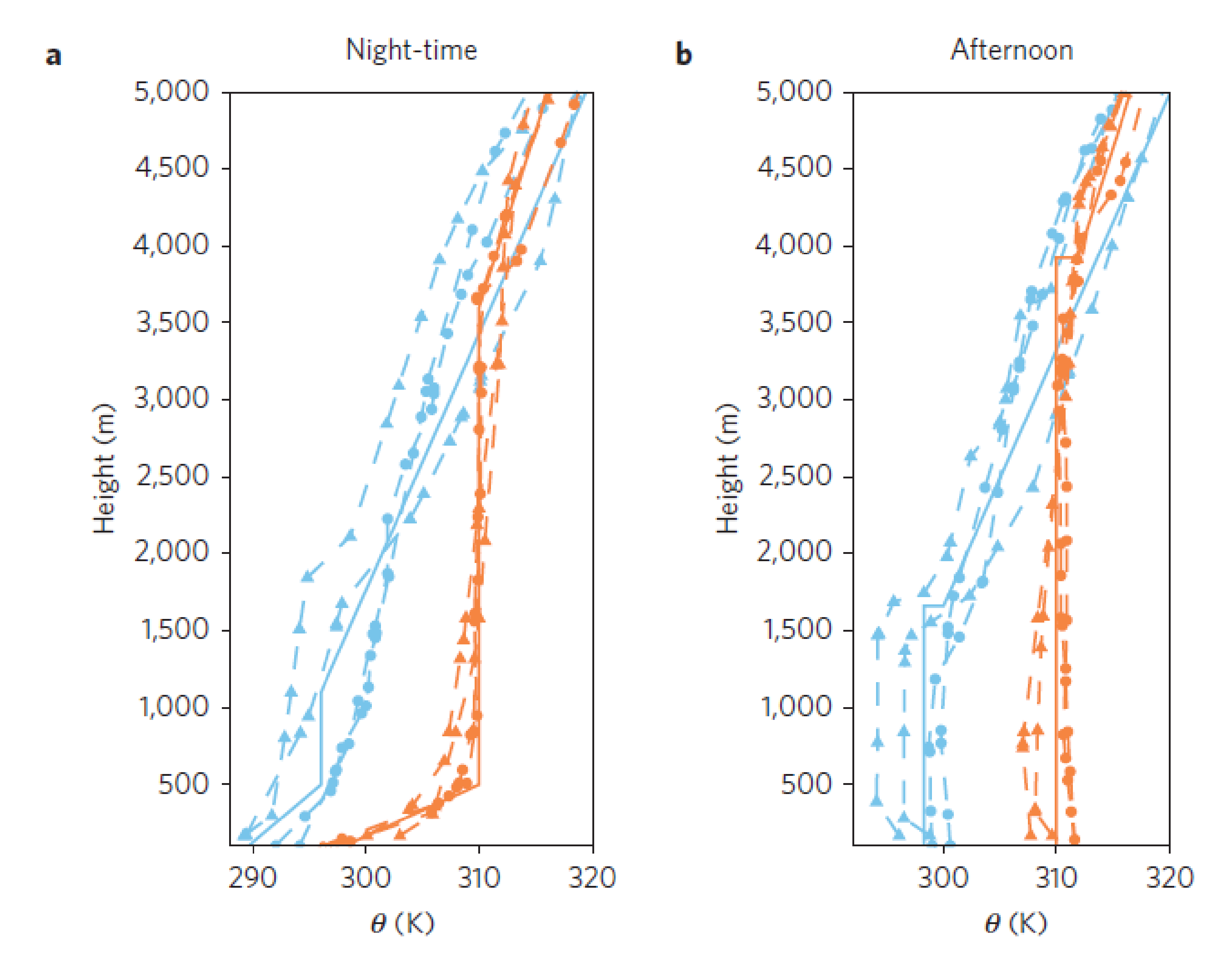


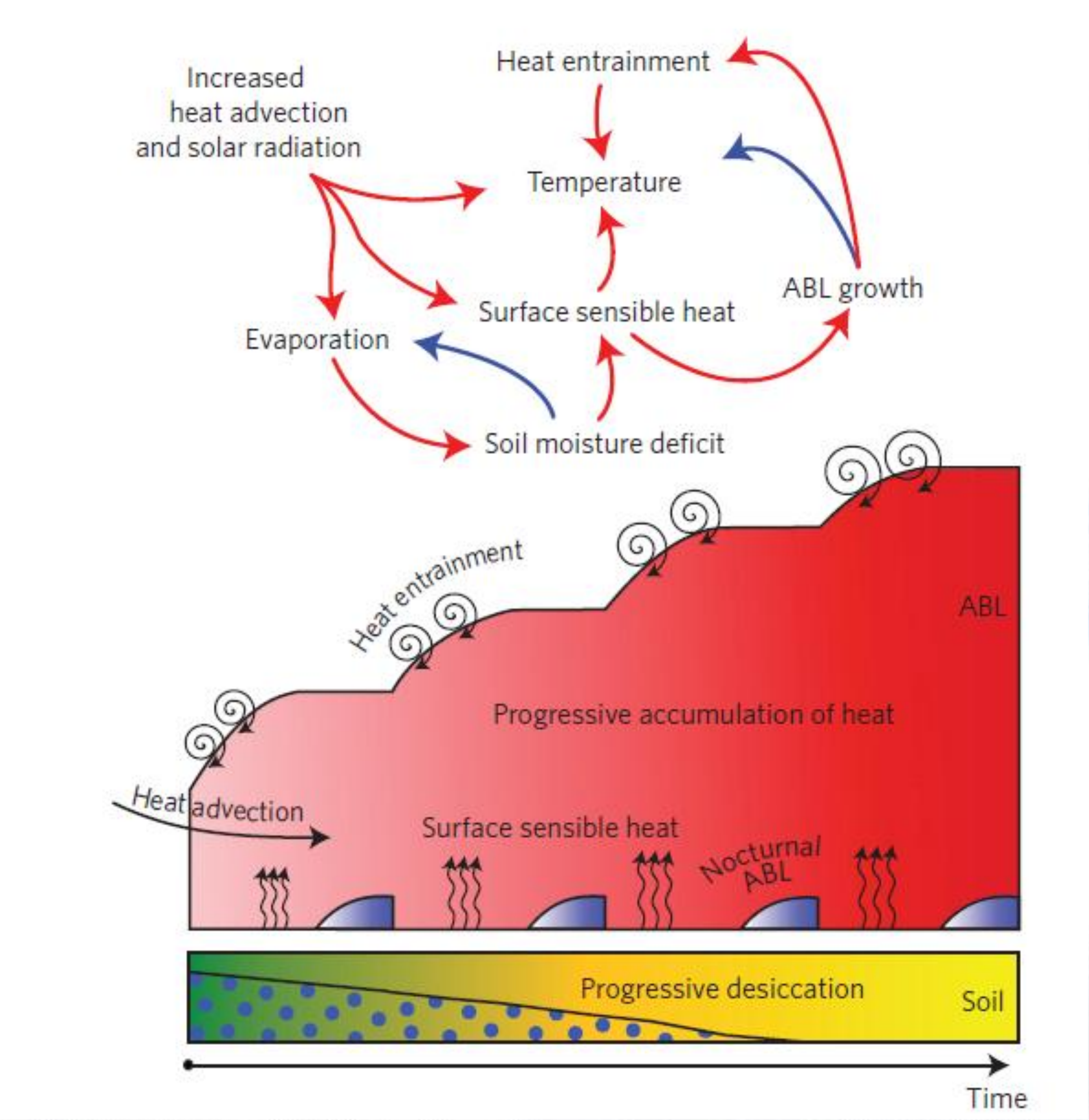


Correlation of summer (JJA) 10 day averages of latent heat flux and air temperature (2 m) for the years 1990 to 2008



Miralles et al. (2014) Mega-heatwave temperatures due to combined soil desiccation and atmospheric heat accumulation. Nature Geoscience. DOI: 10.1038/NGEO2141





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Thank you