Variability and Changes in the Summertime Hydrological Cycle over European regions

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Objectives:

- To investigate and compare summertime interannual variability of the key elements of hydrological cycle in four European regions characterized by the different climate conditions.

- To analize relationships between soil moisture and precipitation and air temperature variations in different European regions.

- To investigate the structure and role of atmospheric moisture transport in interannual variability of regional hydrological cycles.

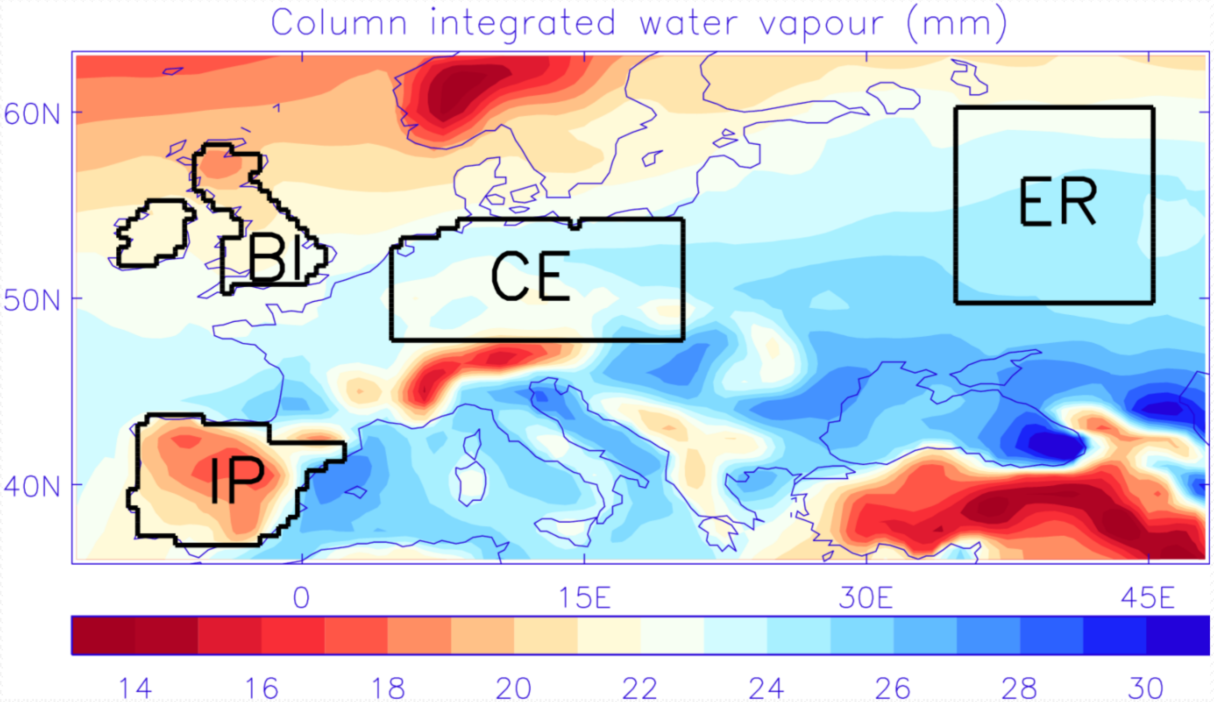
Data sources:

Precipitation and air temperature - the CRU dataset, University of East Anglia (*Mitchell and Jones*, 2005; *Harris et al.*, 2013).

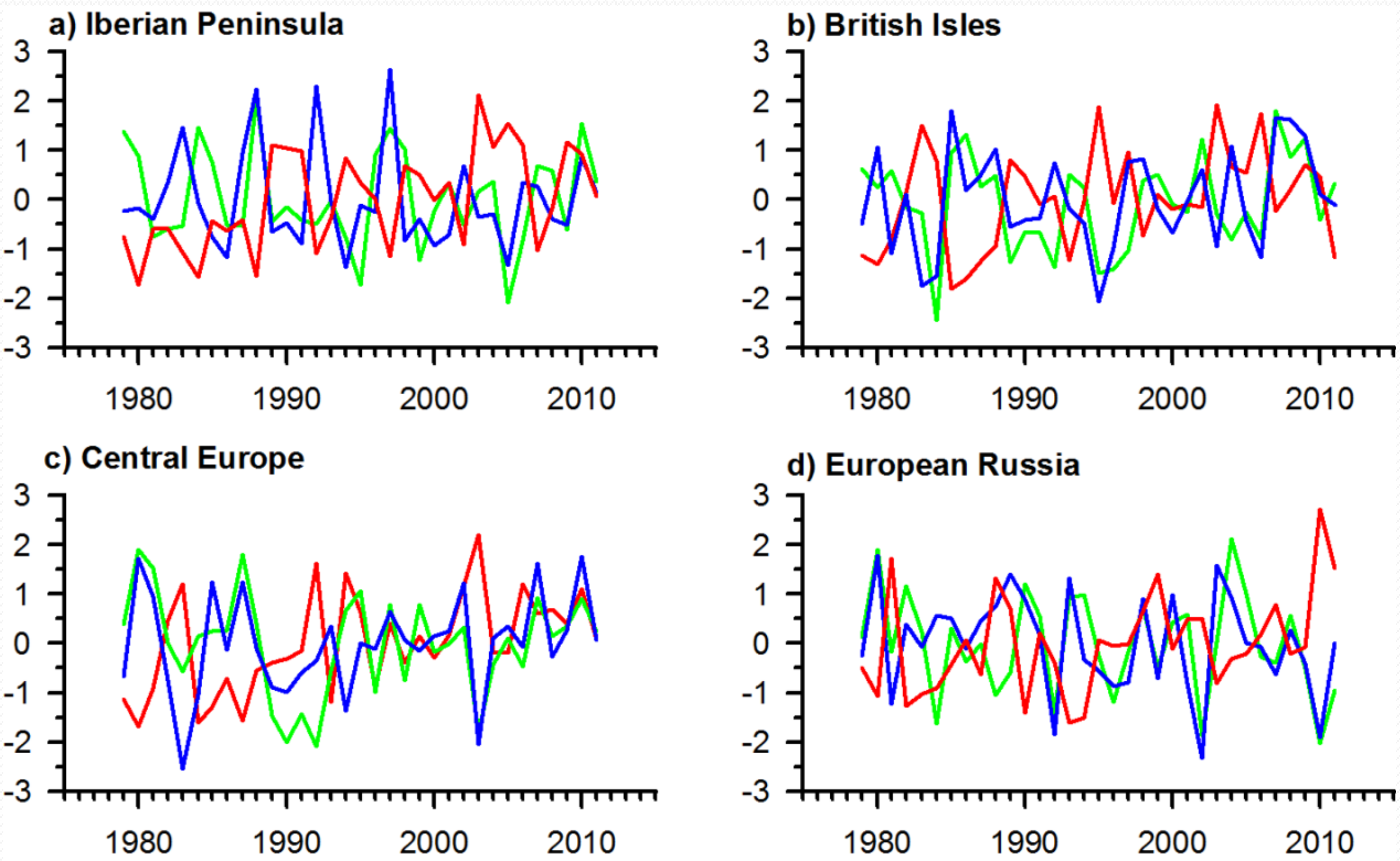
Soil moisture data - NOAA Climate Prediction Center (CPC) dataset (*Fan and van den Dool,* 2004).

Column-integrated water vapour and other data - the ERA Interim reanalysis (*Dee et al.,* 2011) produced by the European Centre for Medium-Range Weather Forecasts (ECMWF).

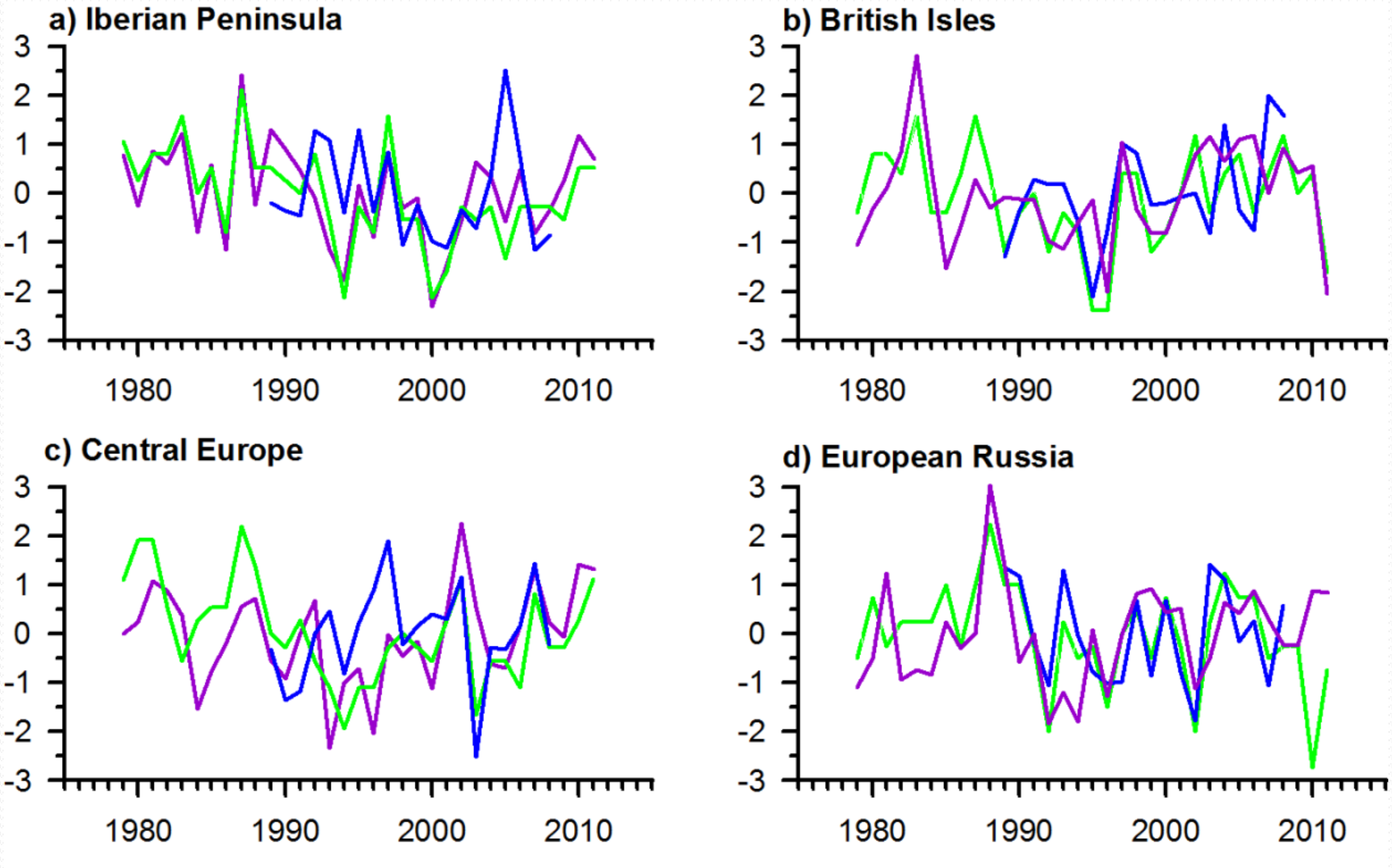
Summer (JJA) mean CWV distribution over Europe. Black curves indicate boundaries of the regions under analysis.



Regional time series of normalized anomalies of summer mean precipitation (blue curve), soil moisture (green curve) and air temperature (red curve).



Regional time series of normalized anomalies of summer mean CWV (violet curve), CWVrat (green curve) and horizontal moisture transport (blue curve).



Correlation coefficients between time series of summer mean precipitation, soil moisture, air temperature, CWV, CWVrat, RH and horizontal moisture transport. Coefficients, shown in color, are statistically significant at the 95% significance level.

IP region	TMP	SM	CWV	MT	CWVr	RH
PRE	-0.53	0.34	0.36	0.30	0.67	0.83
TMP		-0.41	0.11	0.02	-0.42	-0.52
SM			0.06	-0.55	0.25	0.20
CWV				0.22	0.84	0.70
MT					0.25	0.31
CWVr						0.94

BI region	TMP	SM	CWV	MT	CWVr	RH
PRE	-0.48	0.57	-0.15	0.93	0.38	0.86
TMP		-0.56	0.64	-0.46	-0.16	-0.72
SM			-0.11	0.55	0.43	0.65
CWV				0.19	0.64	-0.16
MT					0.70	0.92
CWVr						0.57

Correlation coefficients between time series of summer mean precipitation, soil moisture, air temperature, CWV, CWVrat, RH and horizontal moisture transport. Coefficients, shown in color, are statistically significant at the 95% significance level.

CE region	TMP	SM	CWV	MT	CWVr	RH
PRE	-0.33	0.61	0.28	0.86	0.54	0.56
TMP		-0.31	0.42	-0.24	-0.53	-0.81
SM			0.27	0.59	0.54	0.49
CWV				0.12	0.53	0.16
MT					0.42	0.51
CWVr						0.90

ER region	TMP	SM	CWV	MT	CWVr	RH
PRE	-0.46	0.60	0.16	0.96	0.80	0.80
TMP		-0.55	0.70	-0.46	-0.33	-0.78
SM			-0.09	0.64	0.56	0.62
CWV				0.24	0.43	-0.16
MT					0.79	0.84
CWVr						0.79

Correlation coefficients between time series of monthly mean soil moisture, precipitation and air temperature. Coefficients, shown in bold, are statistically significant at the 95% significance level.

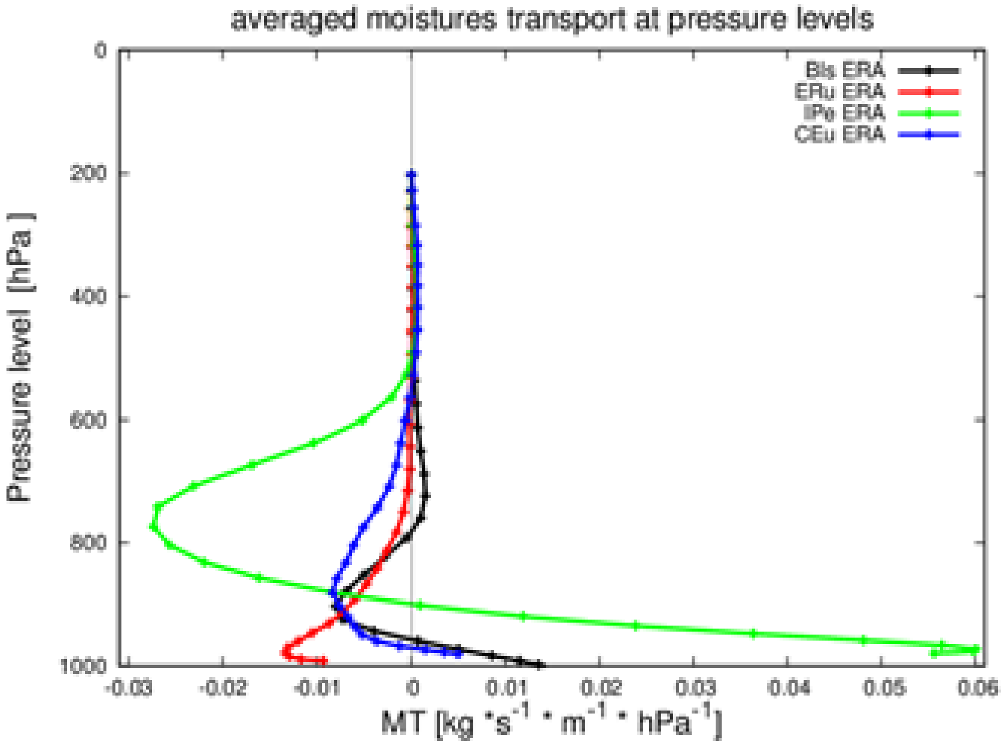
IP	PRECIPITATION			AIR TEMPERATURE		
SM	JUN	JUL	AUG	JUN	JUL	AUG
MAY	0.21	0.02	-0.19	-0.30	-0.29	-0.34
JUN	**0.42**	0.04	-0.15	**-0.49**	-0.35	-0.37
JUL	**0.55**	0.20	-0.09	**-0.58**	**-0.43**	**-0.40**
AUG	**0.55**	0.32	0.11	**-0.57**	**-0.50**	**-0.49**

BI	PRECIPITATION			AIR TEMPERATURE		
SM	JUN	JUL	AUG	JUN	JUL	AUG
MAY	-0.03	-0.14	-0.01	-0.02	0.07	-0.11
JUN	0.33	-0.14	-0.05	-0.18	-0.06	-0.19
JUL	**0.57**	0.34	0.15	-0.20	-0.38	-0.37
AUG	**0.40**	**0.67**	**0.65**	-0.09	**-0.58**	**-0.62**

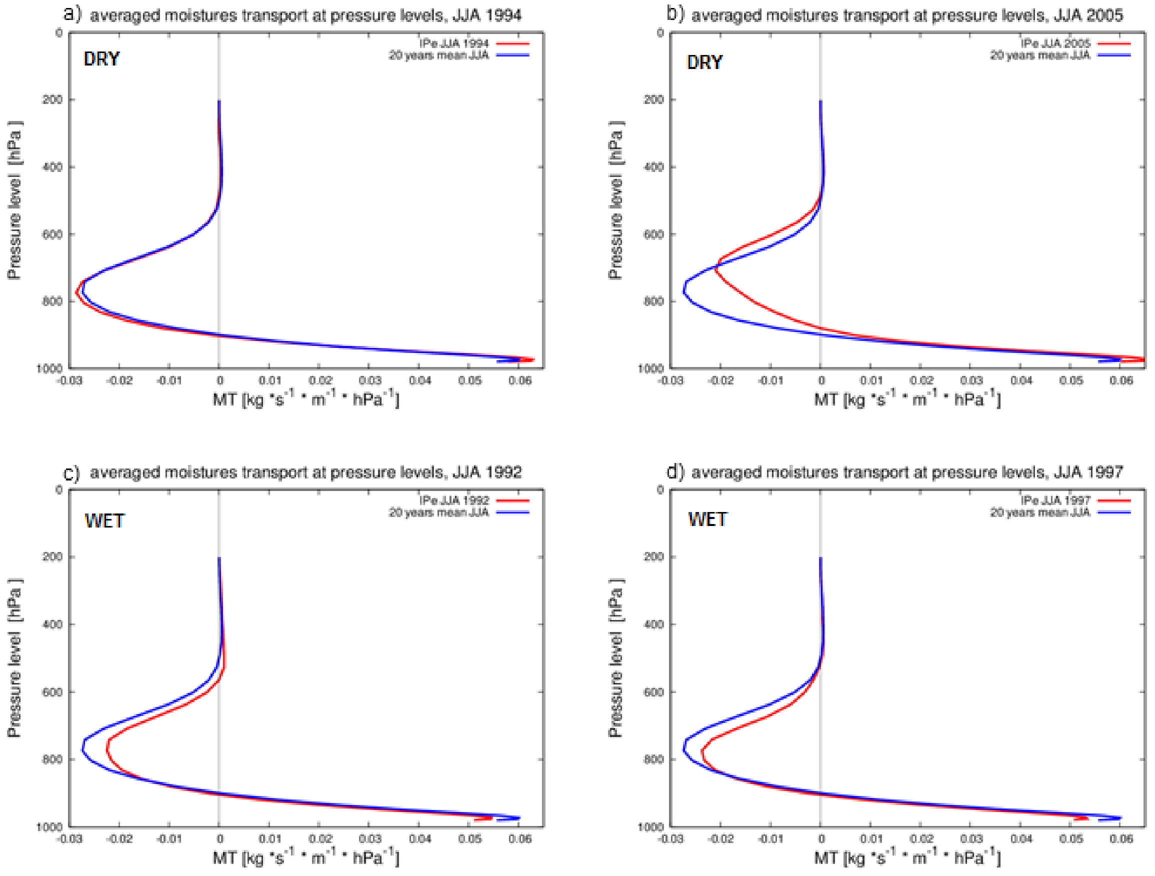
CE	PRECIPITATION			AIR TEMPERATURE		
SM	JUN	JUL	AUG	JUN	JUL	AUG
MAY	0.07	-0.03	0.14	-0.03	0.12	-0.12
JUN	0.34	-0.04	0.17	-0.23	0.04	-0.18
JUL	**0.56**	0.39	0.10	-0.24	-0.26	-0.24
AUG	**0.44**	**0.59**	0.37	-0.07	-0.36	-0.35

ER	PRECIPITATION			AIR TEMPERATURE		
SM	JUN	JUL	AUG	JUN	JUL	AUG
MAY	-0.12	-0.08	-0.01	-0.05	0.09	0.12
JUN	0.28	-0.01	0.04	-0.31	-0.07	-0.07
JUL	**0.53**	0.39	0.09	**-0.52**	-0.36	-0.25
AUG	0.39	**0.61**	**0.47**	-0.39	**-0.52**	**-0.45**

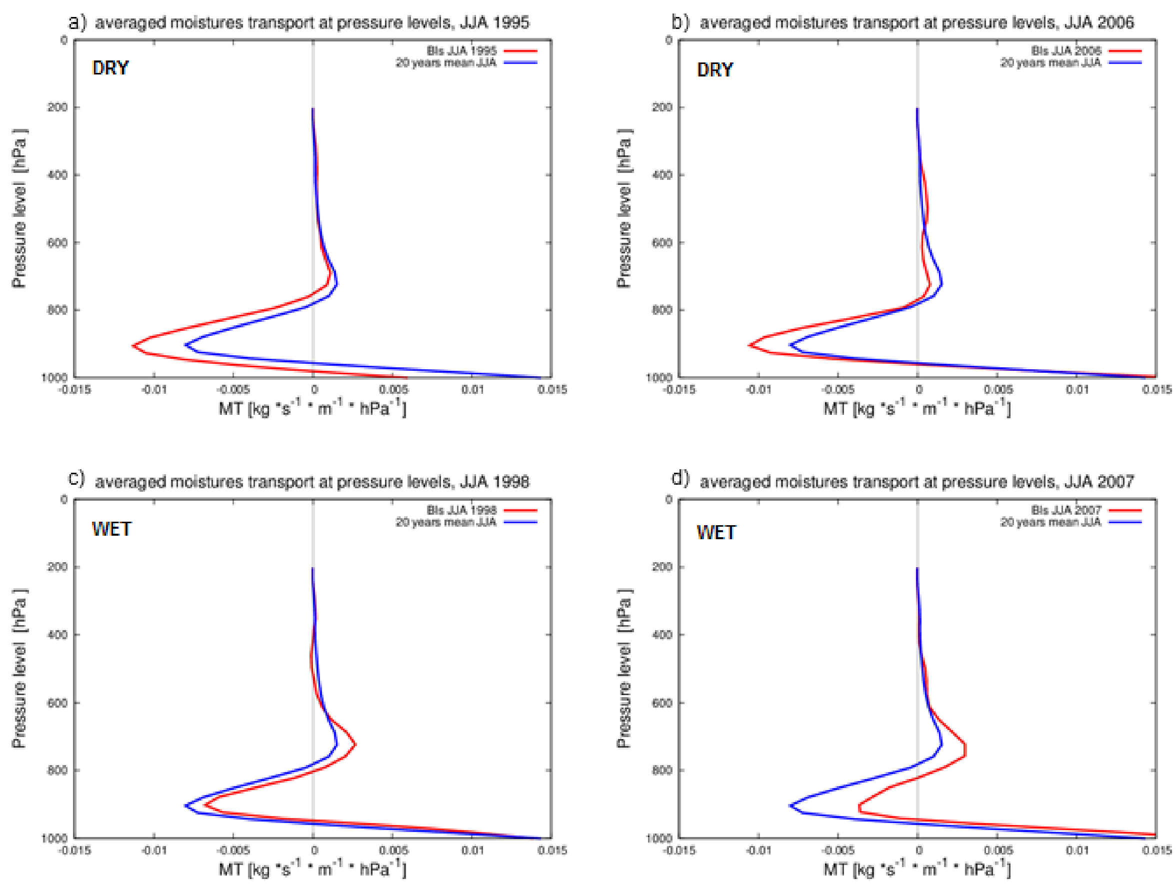
Climatological vertical structure of summertime horizontal moisture transport over four European regions. Positive (negative) values indicate resulting net moisture transport into (out of) the region at particular level.



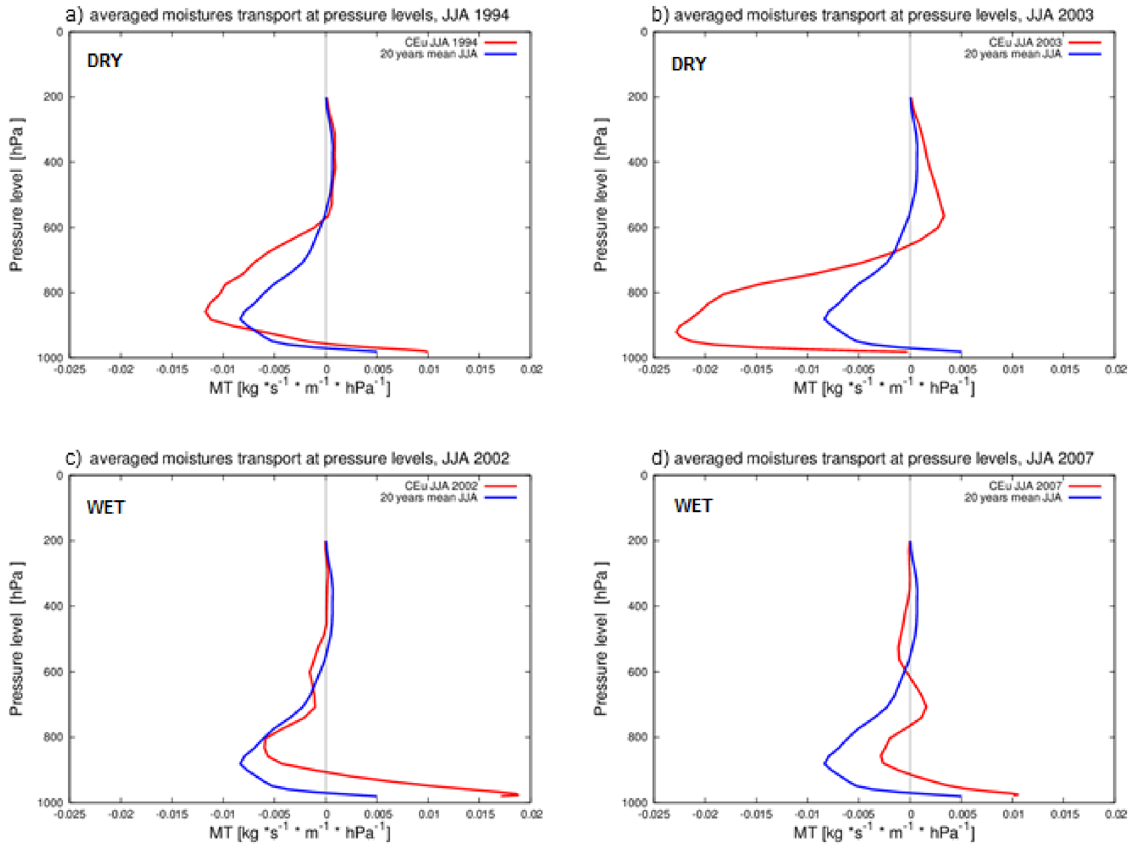
Vertical structure of horizontal moisture transport over IP region during anomalously dry (a, b) and wet (c, d) summers (red) and the JJA mean profile (blue). Positive (negative) values indicate resulting moisture flux into (out of) the region.



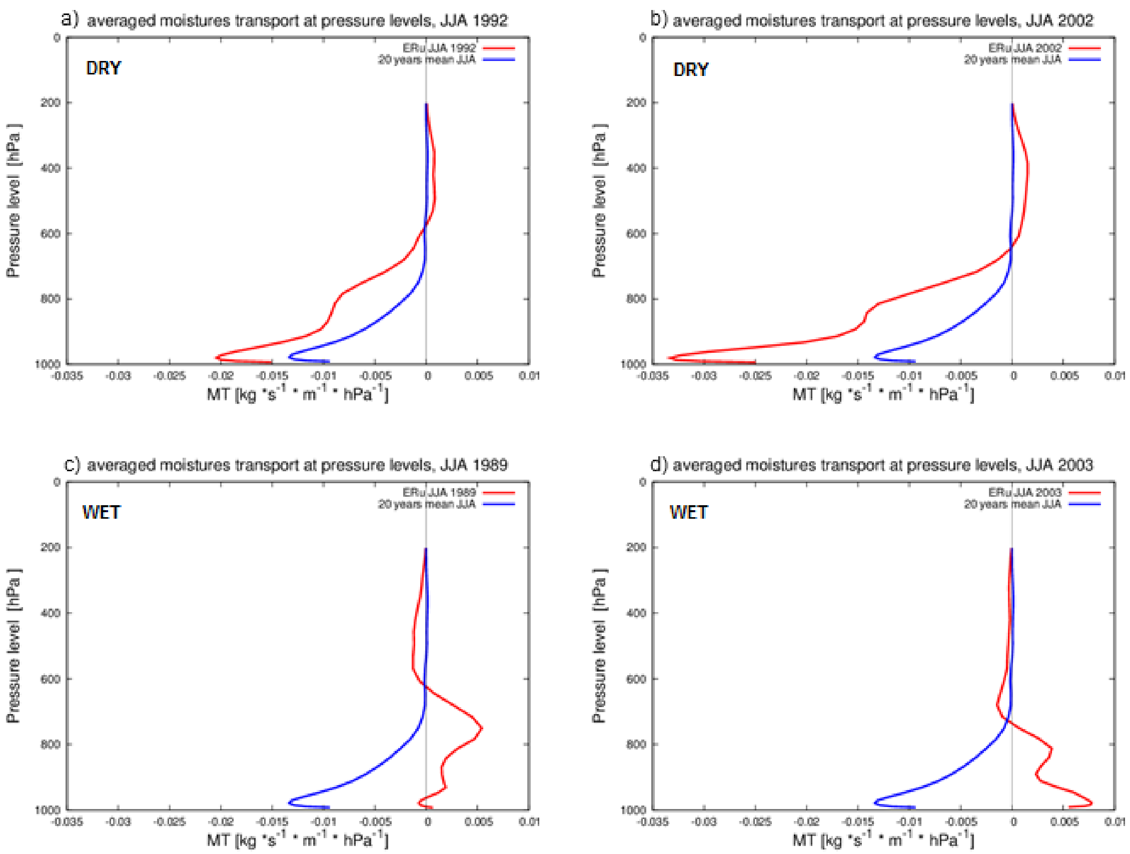
Vertical structure of horizontal moisture transport over BI region during anomalously dry (a, b) and wet (c, d) summers (red) and the JJA mean profile (blue). Positive (negative) values indicate resulting moisture transport into (out of) the region.



Vertical structure of horizontal moisture transport over CE region during anomalously dry (a, b) and wet (c, d) summers (red) and the JJA mean profile (blue). Positive (negative) values indicate resulting moisture transport into (out of) the region.



Vertical structure of horizontal moisture transport over ER region during anomalously dry (a, b) and wet (c, d) summers (red) and the JJA mean profile (blue). Positive (negative) values indicate resulting moisture transport into (out of) the region.



Conclusions:

- SM variability is impacted almost equally by precipitation and air temperature in BI and ER regions. However, stronger links between SM and precipitation are revealed for CE region and between SM and air temperature for IP region.
- In all except IP regions summertime interannual variability of CWV is strongly linked to air temperature consistent with the dominating influence of the Clausius-Clapeyron equation.
- Analysis of the lag-lead links revealed specific regional relationships between different hydrological variables. In particular, it is shown that in some regions interannual variability of SM is linked more strongly to precipitation and air temperature anomalies in the previous month, rather than in the coinciding month.
- Investigation of the vertical structure of regional atmospheric moisture transport has revealed that the more continental the climate of the region is, the larger deviation from the mean profile might be observed during anomalously dry/wet summers.

Detailes of this study can be found in *Zveryaev et al. (JGR-Atmospheres, 2016).*