KNMI

Soil drying in Europe and its impact on atmosperic circulations

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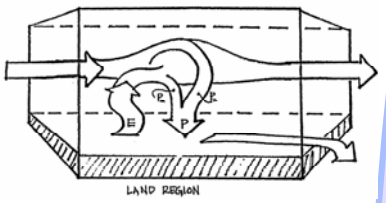
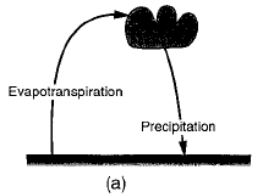
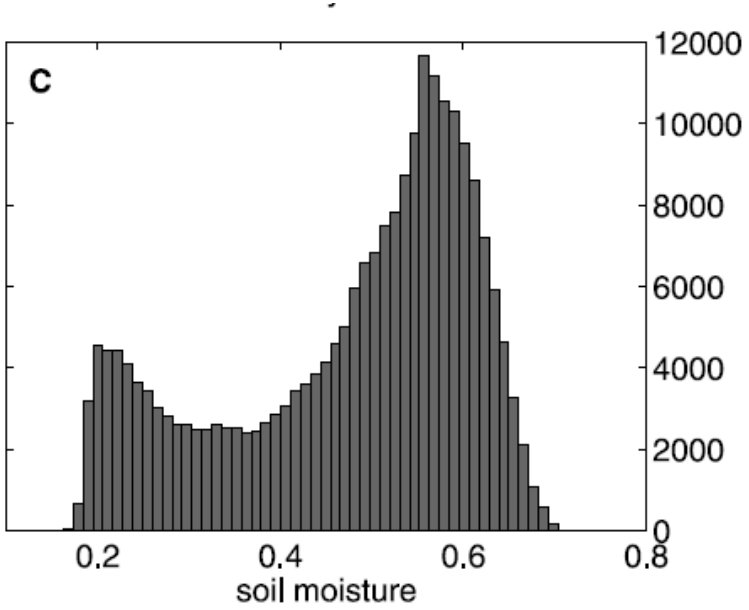
How does the land change the hydroclimate?

- It is part of the hydrological cycle
  - It may buffer precipitation anomalies



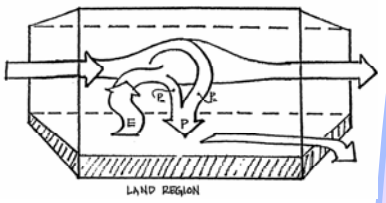


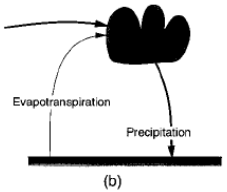


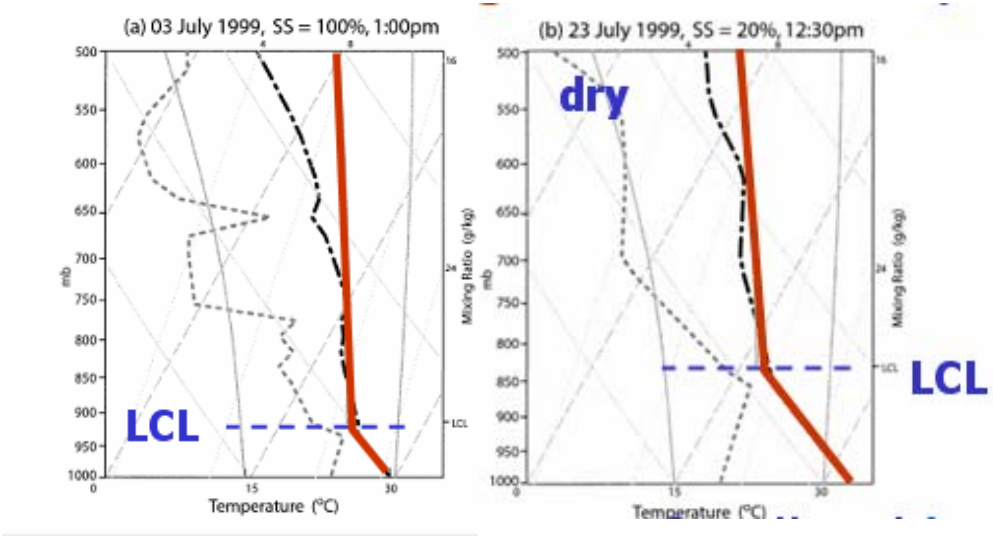
d'Andrea et al (2006): in regions of weak advection positive feedback may lead to 'locking in' on **dry or wet** regimes

How does the land change the hydroclimate?

- It is part of the hydrological cycle
  - It may buffer precipitation anomalies
  - It may change the atmospheric ability to form precipitation



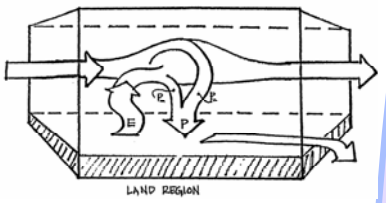




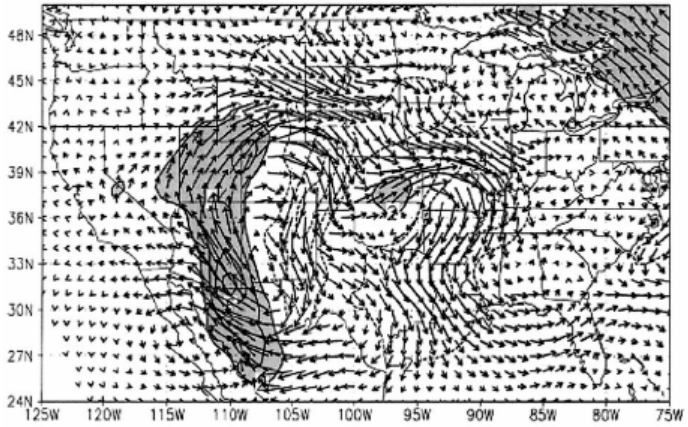
Findell and Eltahir (2003): this feedback can be **positive** (wet soils favouring convection when MSE build up is required) **or negative** (dry soils leading to PBL reacing LCL)

How does the land change the hydroclimate?

- It is part of the hydrological cycle
  - It may buffer precipitation anomalies
  - It may change the atmospheric ability to form precipitation
- It may change the atmospheric circulation



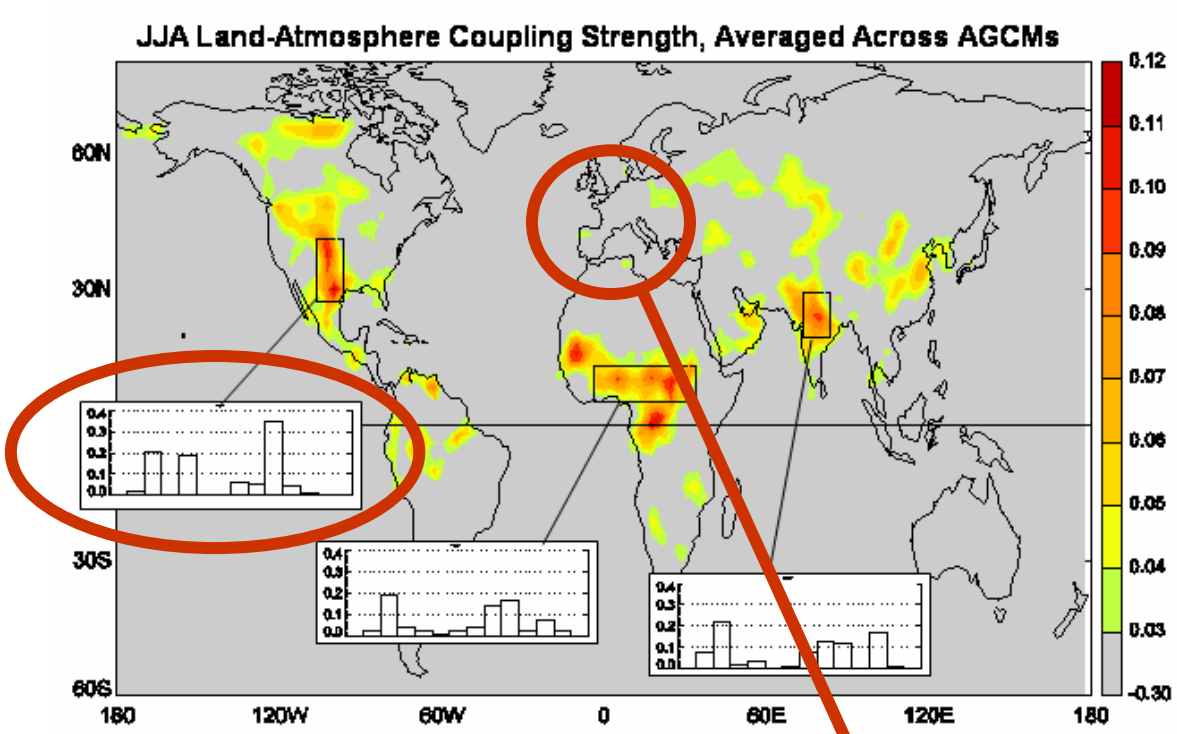
- e.g. Kanamitsu et al (2003) looked at SW US
- Cook et al (2006) looked at Southern Africa
- Van Ulden et al (2006) speculated about impact of drying on European circulation in AR4 GCMs



A famous plot on land-atmosphere interaction

- Areas where changing soil moisture variability affects local daily precipitation variability

varies widely between models



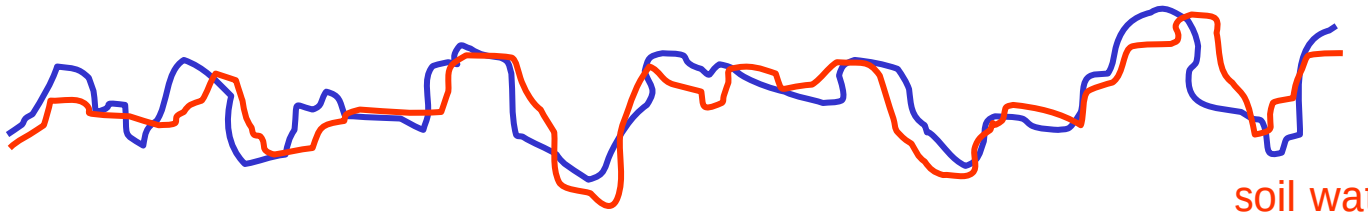
Probably dominated by local feedback

No strong feedback in Europe

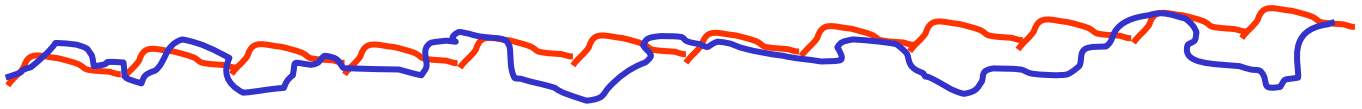
Koster et al, Science 2004

How to ‘measure’ land-atmosphere coupling?

- Compare two multi-year simulations:
  - One normal (‘coupled’) simulation



  - One ‘uncoupled’ simulation with fixed land cond’s



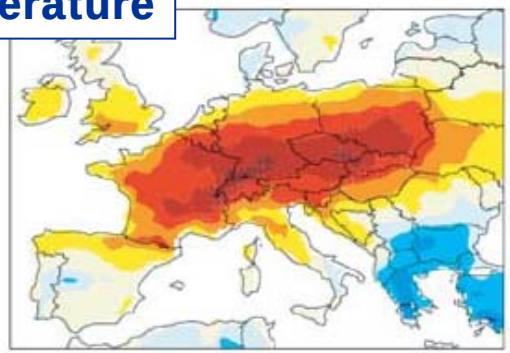
- See what is the effect on variability of *T, P*

Change in interannual variability for future conditions

- Land-atmosphere interaction influences this variability!
- Northward shift of areas with strong variability

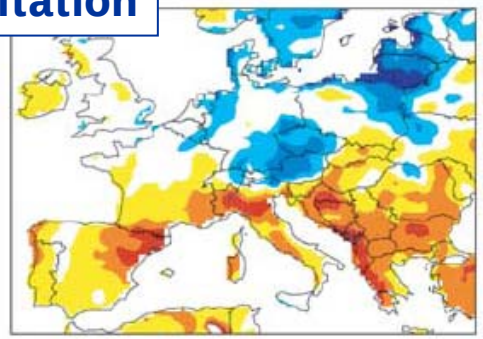
Temperature

SCEN – CTL



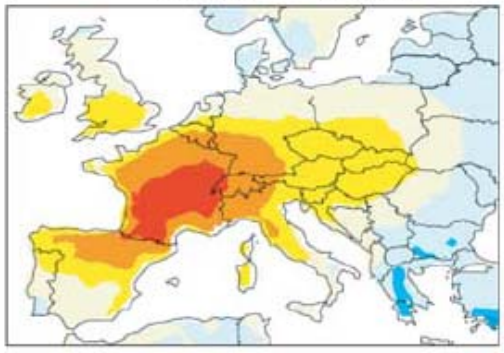
Precipitation

SCEN – CTL

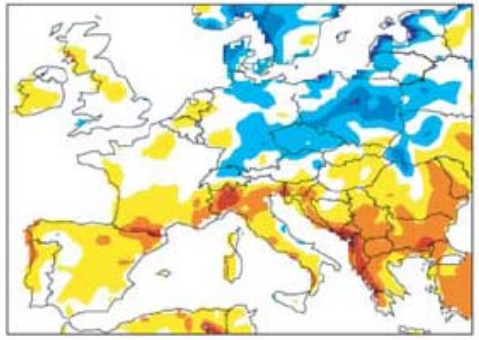


Coupled

g $SCEN_{uncoupled} - CTL_{uncoupled}$



c $SCEN_{uncoupled} - CTL_{uncoupled}$



Uncoupled

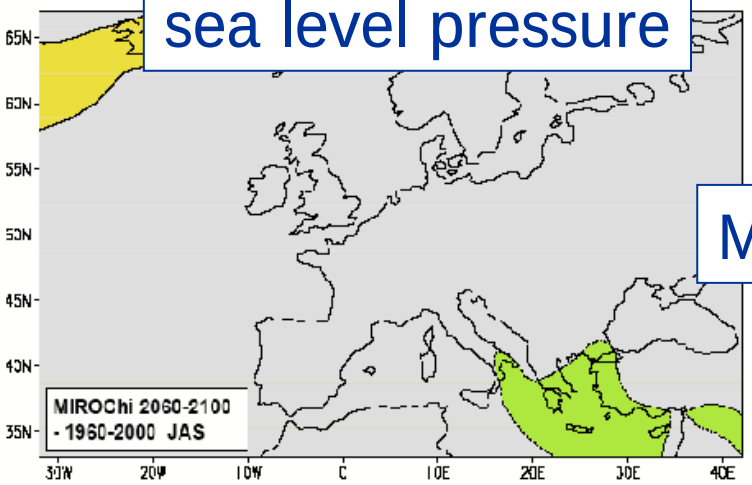
Seneviratne et al, 2006

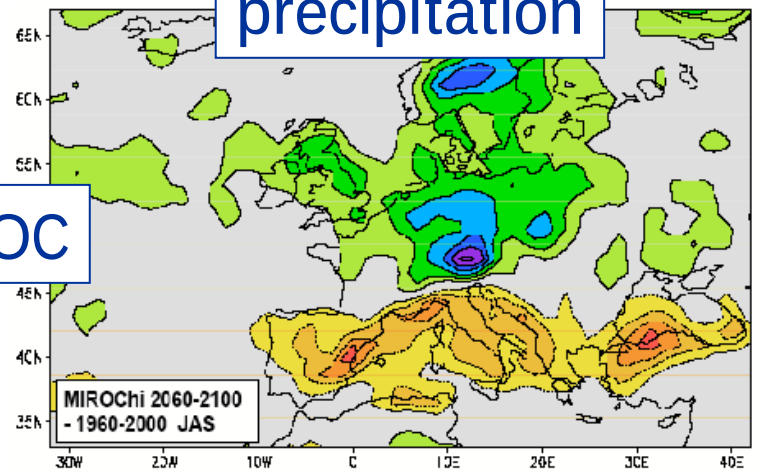
Change of circulation and precipitation in summer

sea level pressure

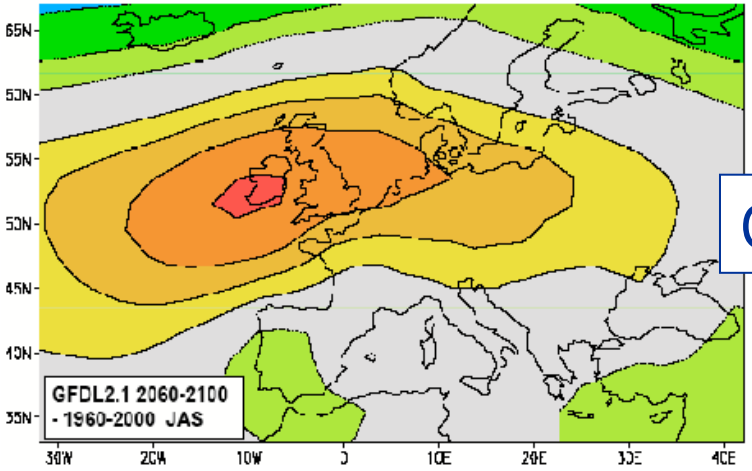
precipitation

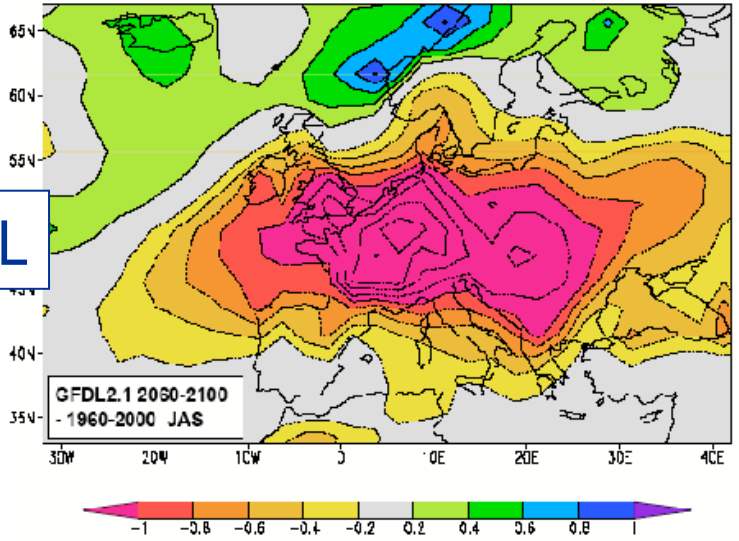
MIROC





GFDL





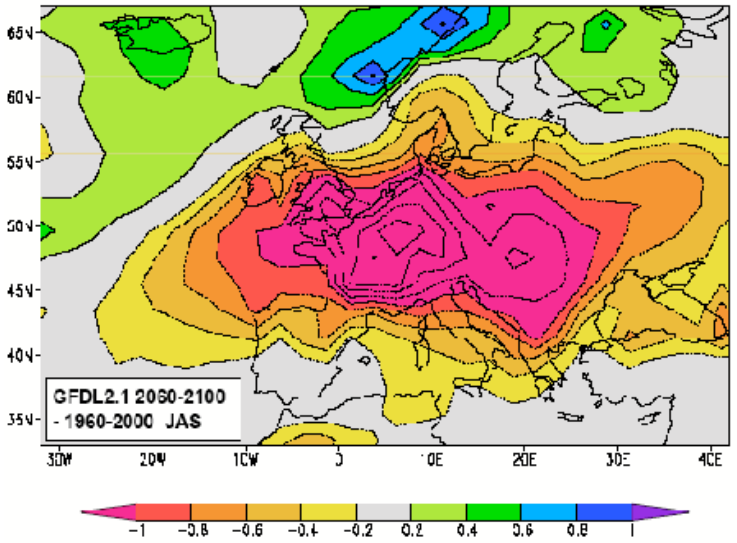
Van Ulden and Van Oldenborgh, 2006

Feedback hypothesis

Soil water stress

⇩

Relatively high land temperature



Van Ulden and Van Oldenborgh, 2006

Feedback hypothesis

Soil water stress

⇩

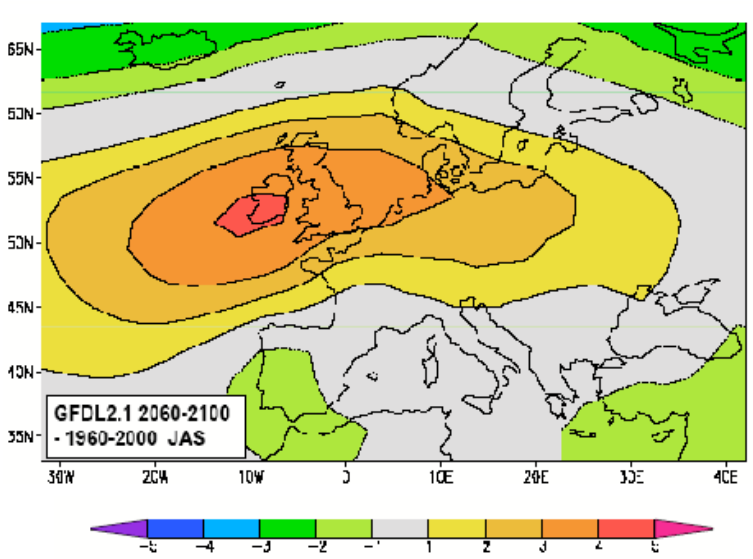
Relatively high land temperature

⇩

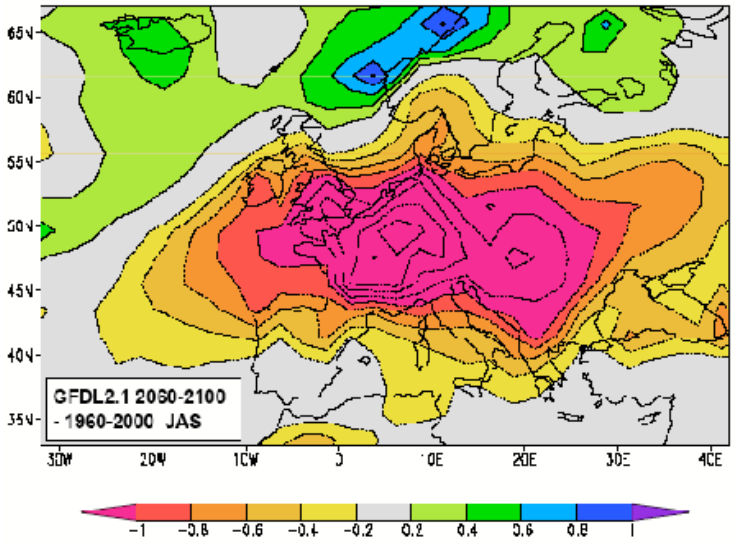
High land-sea temperature contrast

⇦

Thermal low above land, high above sea

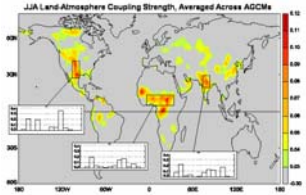


Van Ulden and Van Oldenborgh, 2006

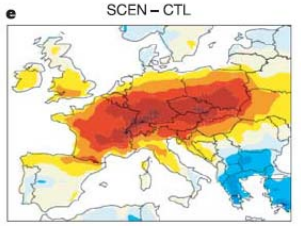


Summary so far

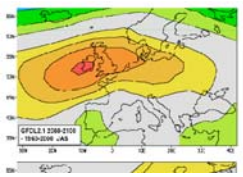
- Land-atmosphere interaction has impact on regional hydroclimate
  - local feedback and/or change in circulation ?
- Over Europe signal within a season is not strong
  - local or remote?

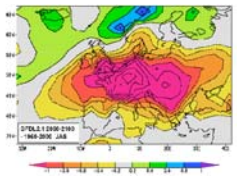


- In Europe year-to-year variability is a function of land-atmosphere interaction
  - and changes with climate change



- Can we find a circulation response over Europe?



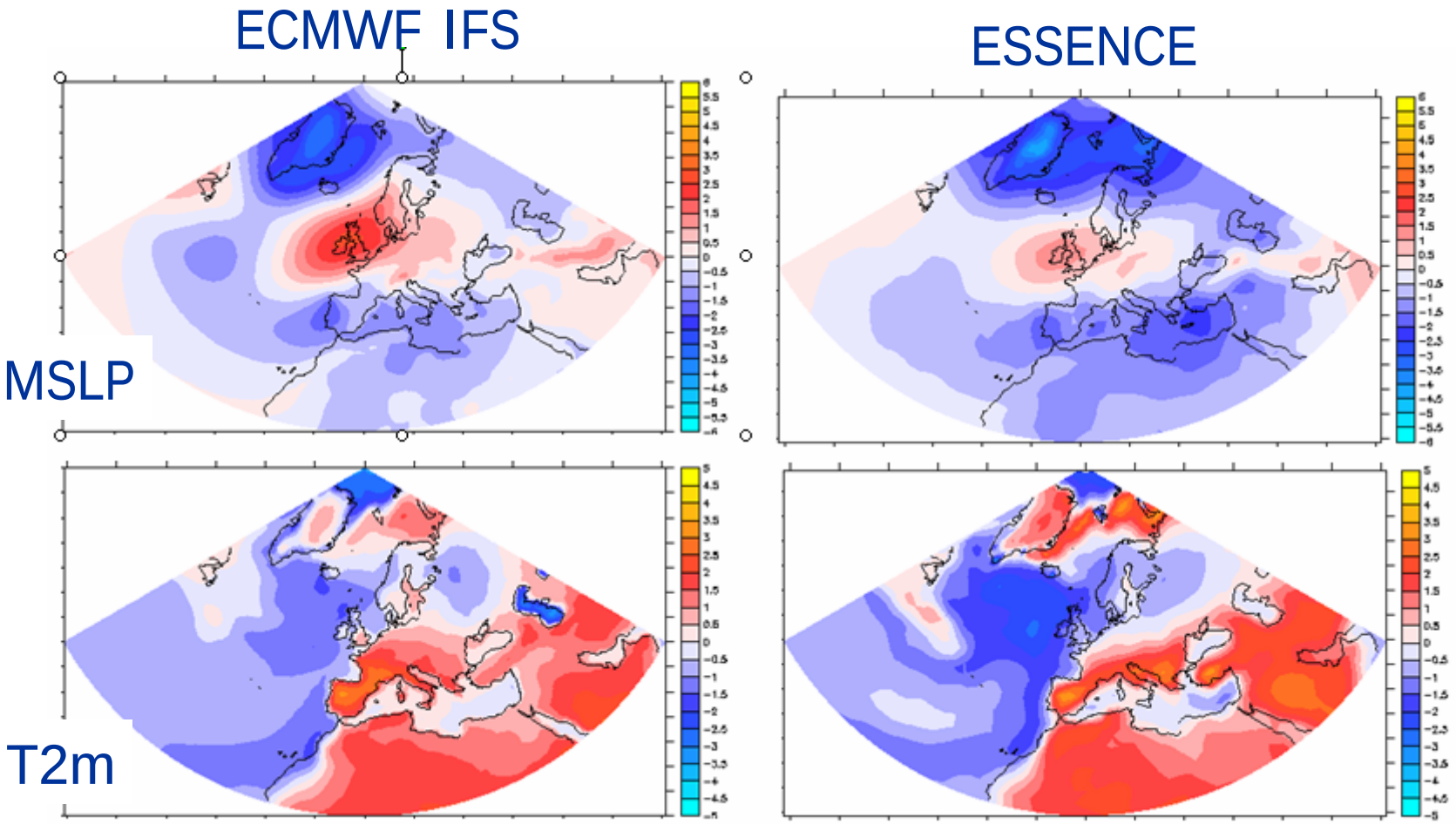


2 studies concerning Europe

- Do we see effect of land-atmosphere interaction on **summertime blocking**?
- Can we explain changes in atmospheric circulation from **land drying**?

- 2 sets of model runs (1950 – 2100)
  - ESSENCE
    - ensemble of ECHAM/OM1
    - plus one member with daily climatological soil
  - IFS
    - ECMWF atmosphere-only model with prescribes SSTs
    - plus one simulation with altered regional surface condition

Analysis of JJA ESSENCE and ECMWF time slice runs



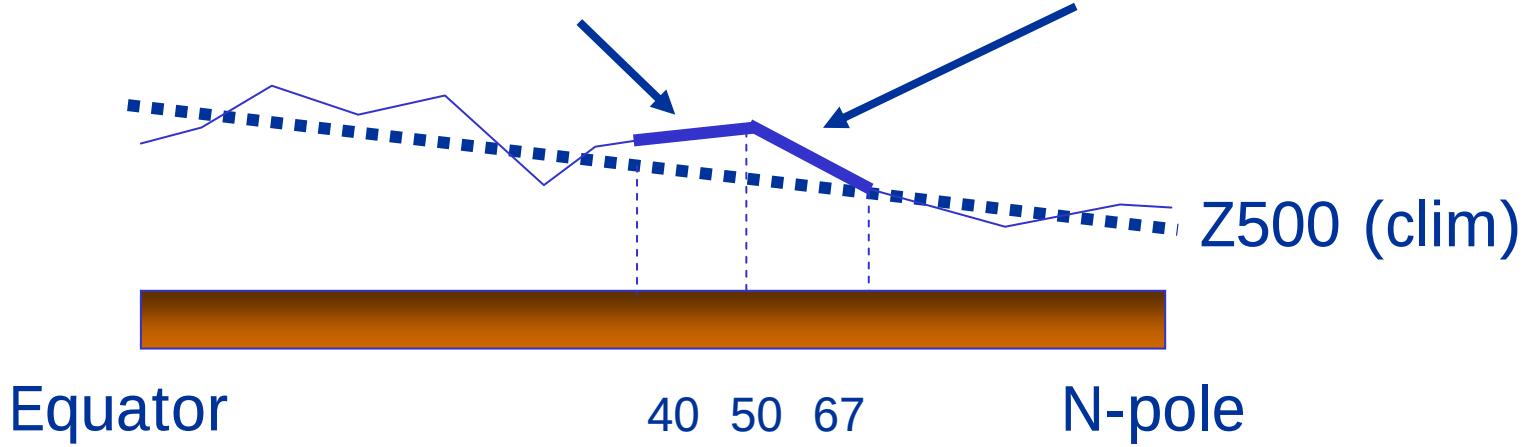
Difference future (A1b 2070-2100) – control (1970-2000)

Haarsma et al, submitted

A first diagnostic exploration in ESSENCE

- Basic question: is it true that soil-atm interaction has impact on blocking circulation?
  - Persistence of blockings
  - Frequency of blocked conditions

- Start with summer blockings
  - blocked if $\partial Z/\partial y_{40\text{-}50} > 0$ and $\partial Z/\partial y_{50\text{-}67} < -10$ m/°



Tibaldi & Monteni, 1990

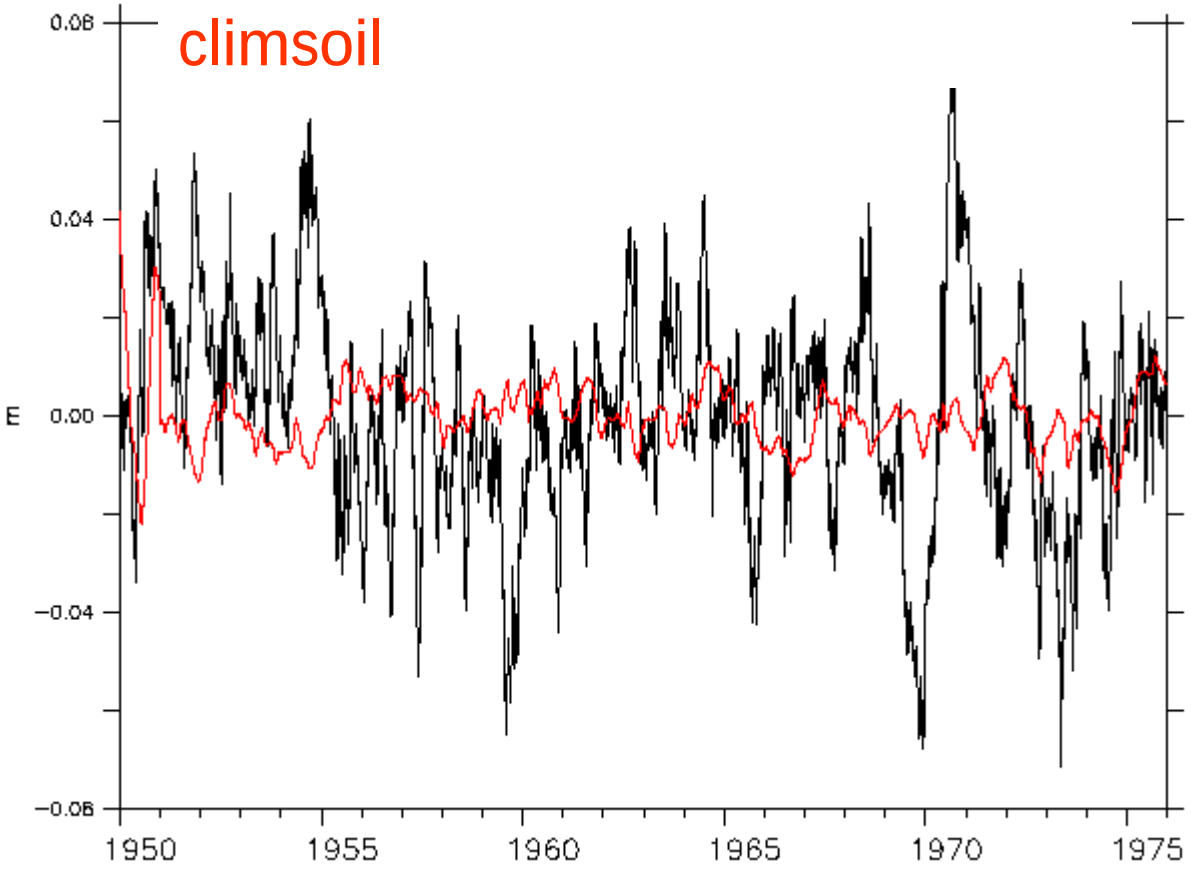
The ESSENCE experiments

- Baseline experiment (17 members; 5 analysed)
  - # 1-16: only monthly soil fields stored
  - **fixed** daily soil moisture (and snow): stored from #17
  - **climatological** surface fields: monthly soil moisture/snow from #1 – 16 averaged and interpolated to daily fields
- CLIM experiment (1 member)
  - using **climatological** surface fields
- 'GLACE' experiment (5 members)
  - each using **fixed** soil moisture
  - failed ☹

The CLIMSOIL run

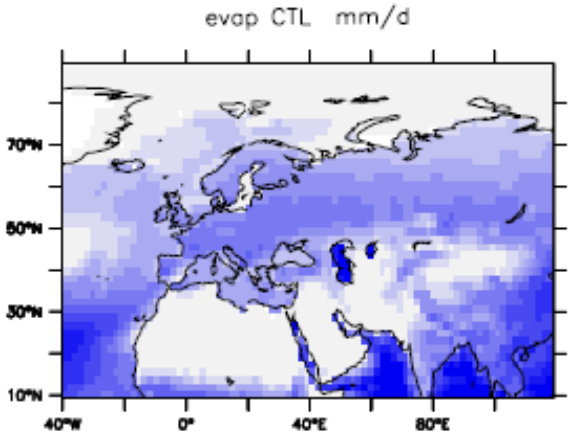
one member of control ensemble

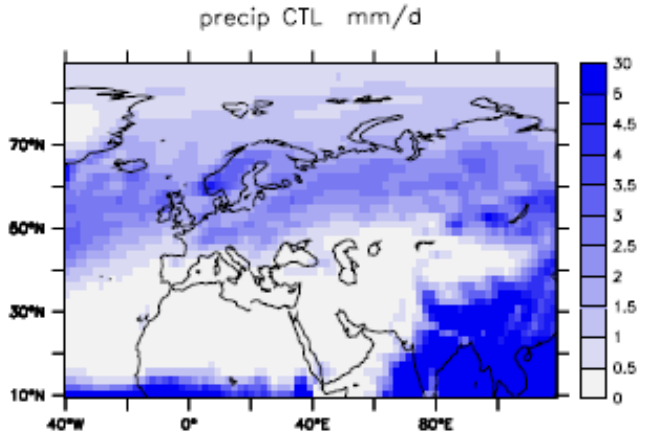
climsoil



Impact of prescribing soil moisture

CTL



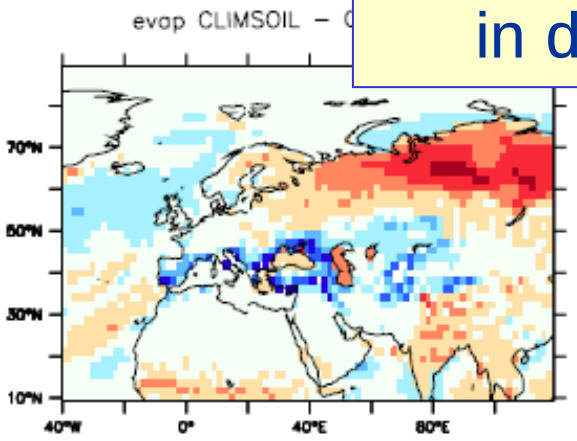


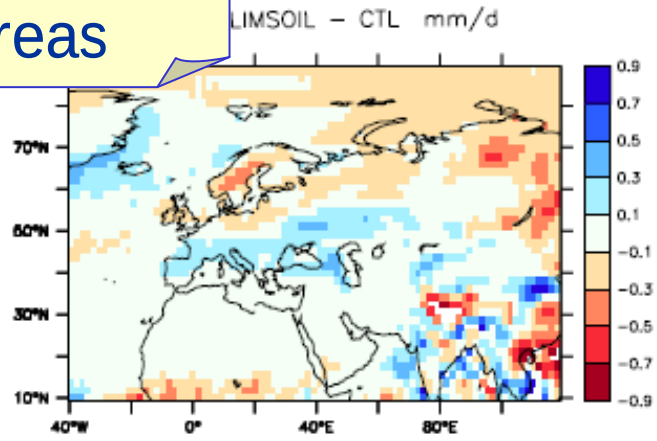
evaporation

more evap
(and precip)
in dry areas

precipitation

CLIMSOIL
minus
CTL

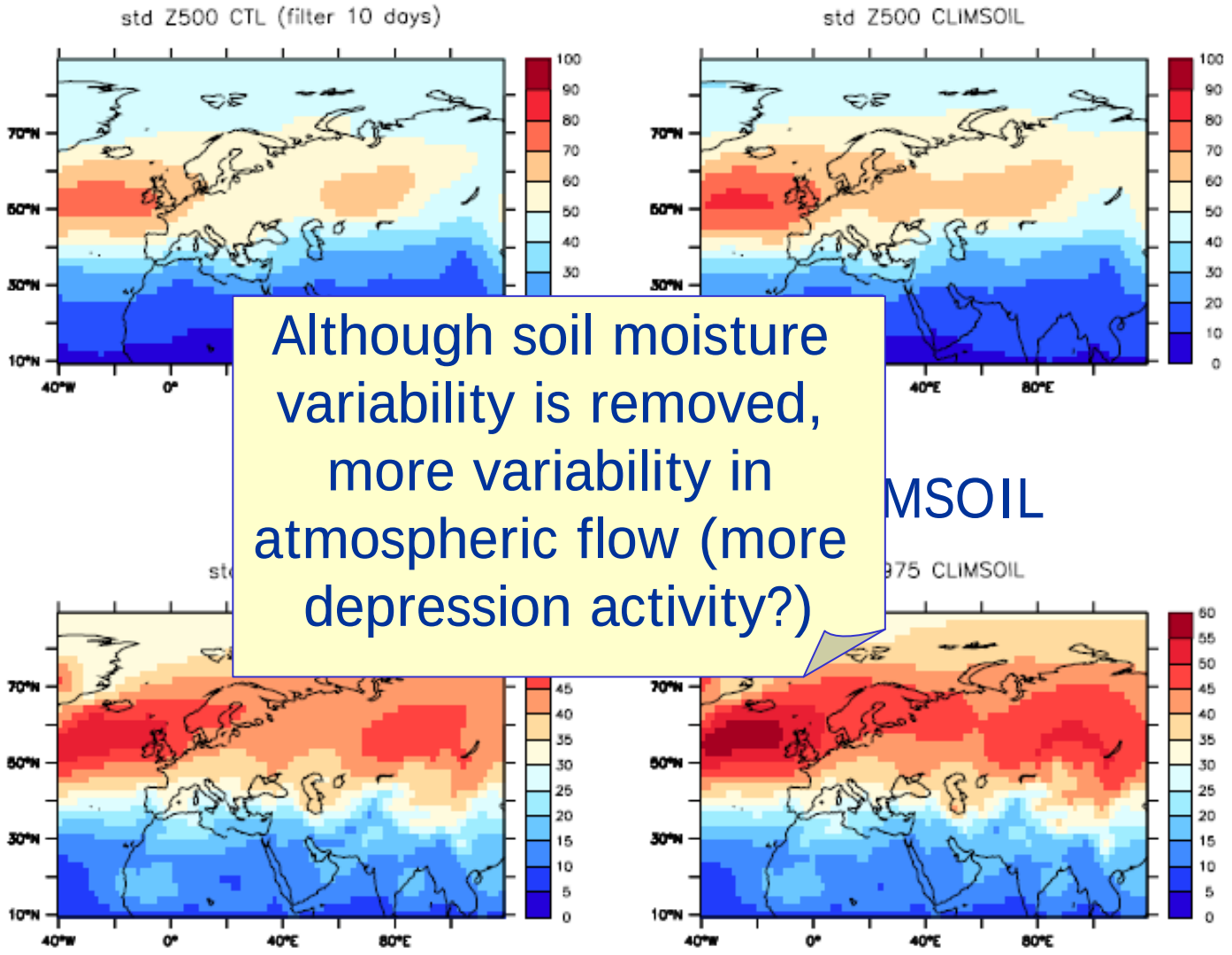




Variability of pressure levels

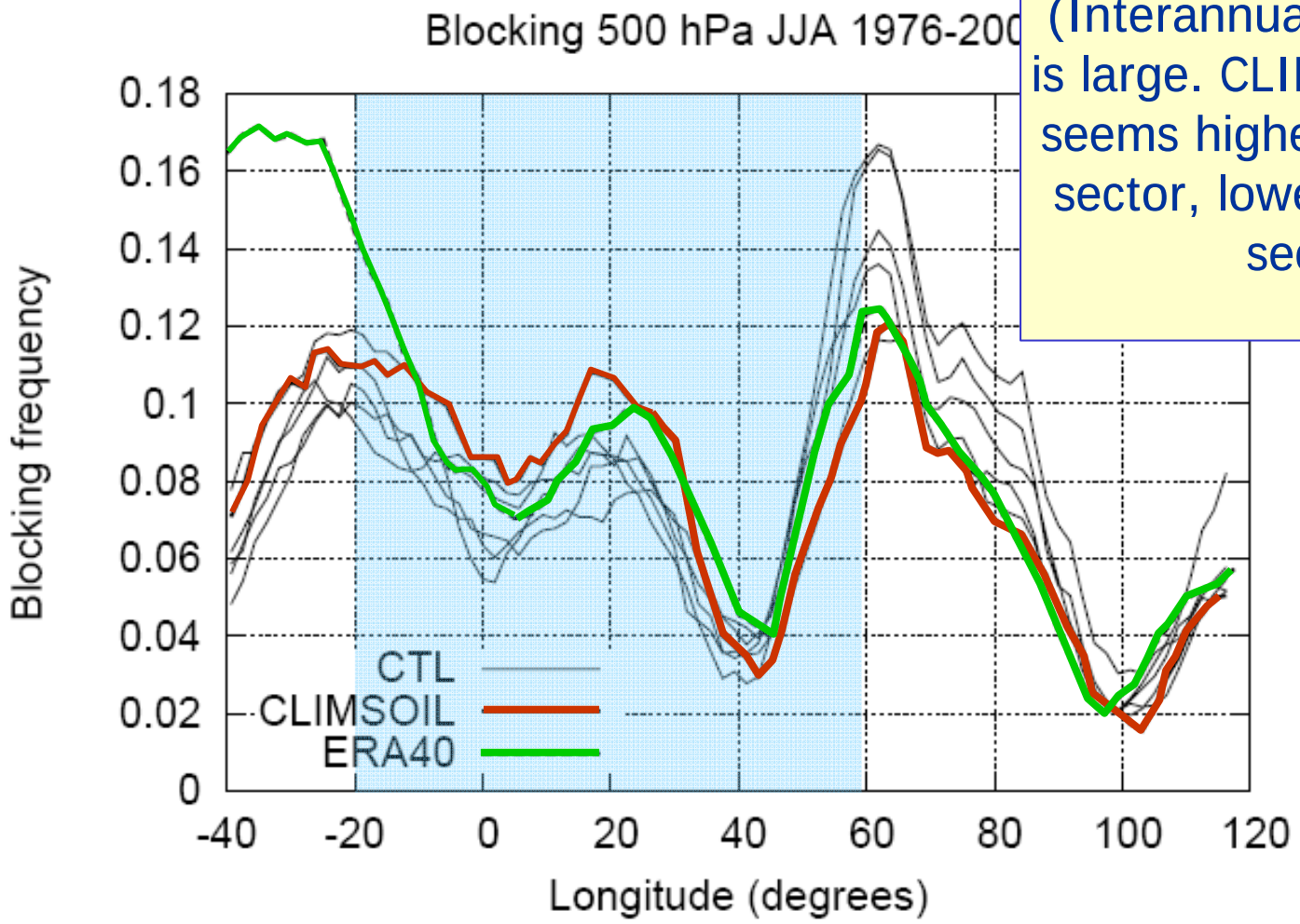
z500

z975



Although soil moisture variability is removed, more variability in atmospheric flow (more depression activity?)

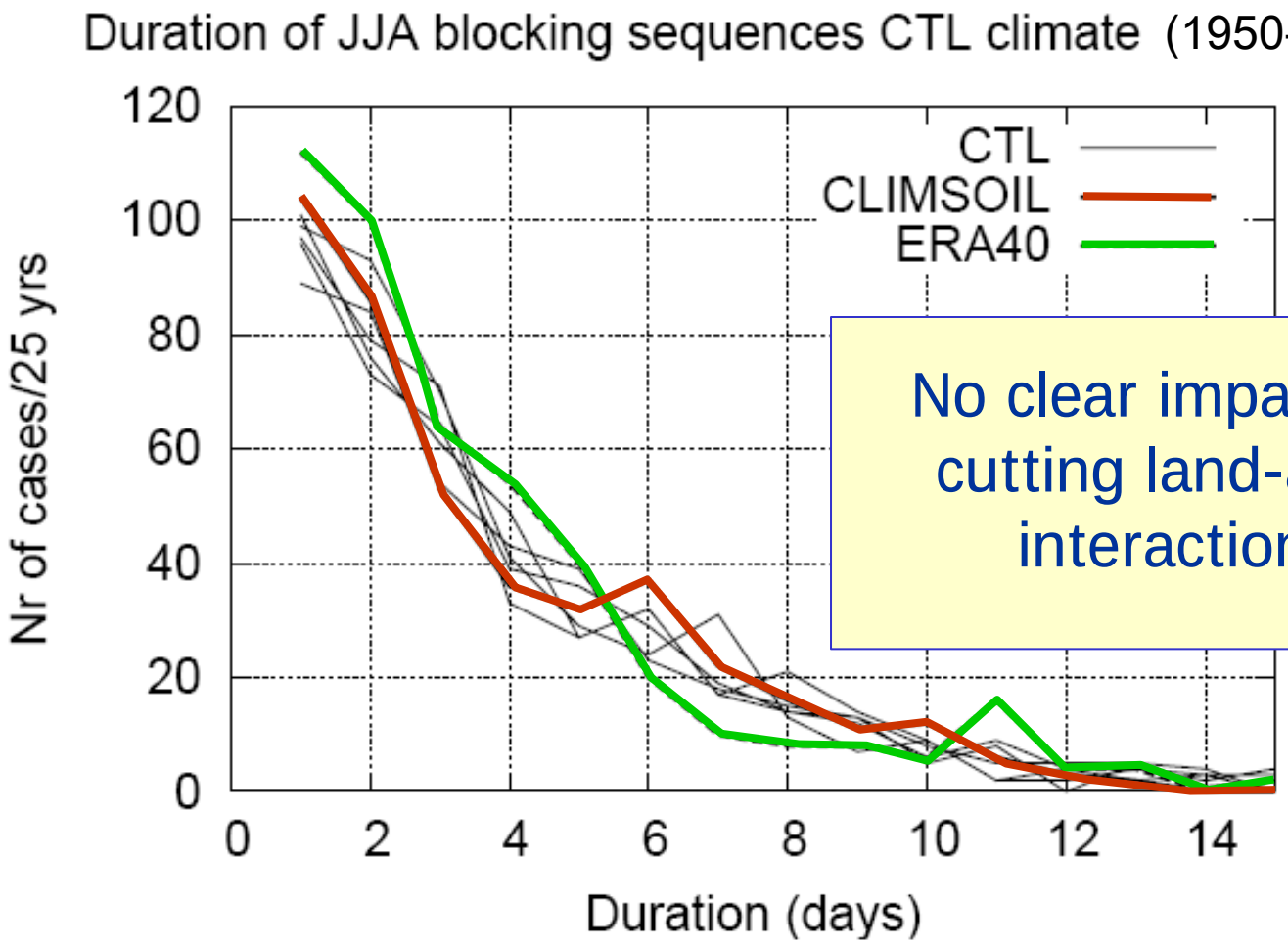
The blocking index in JJA



(Interannual) variability is large. CLIMSOIL signal seems higher in Western sector, lower in Eastern sector

European sector is blocked when at least 3 consecutive longitudes pass the criterion

Persistence of blockings



No clear impact of cutting land-atm interaction

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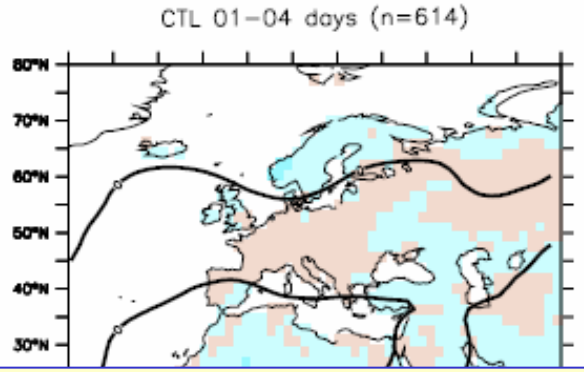
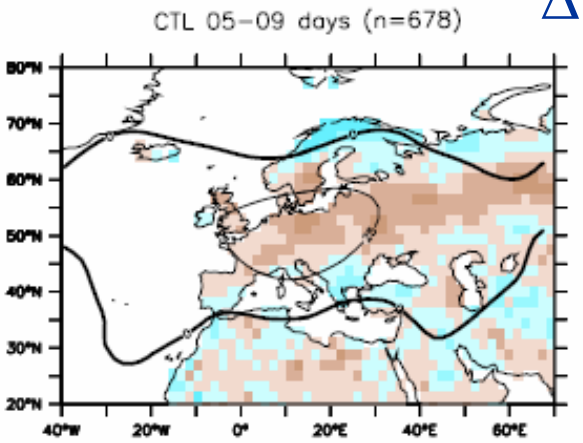
Composite of Z500-anomaly

$\Delta W/\sigma_{W,daily}$

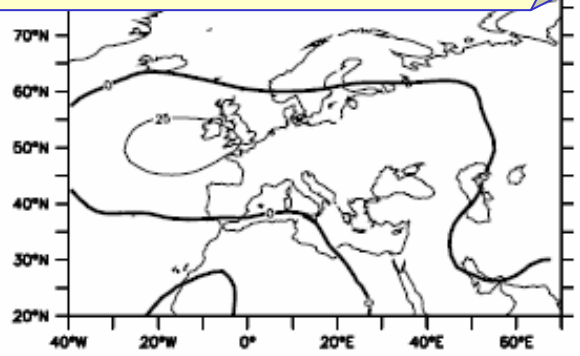


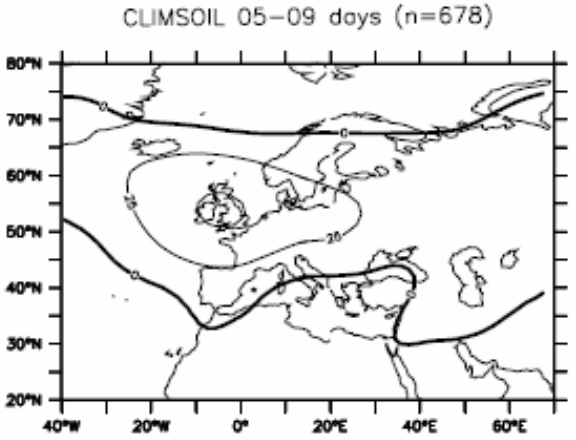


CTL

High pressure pattern shows preference for more westward position

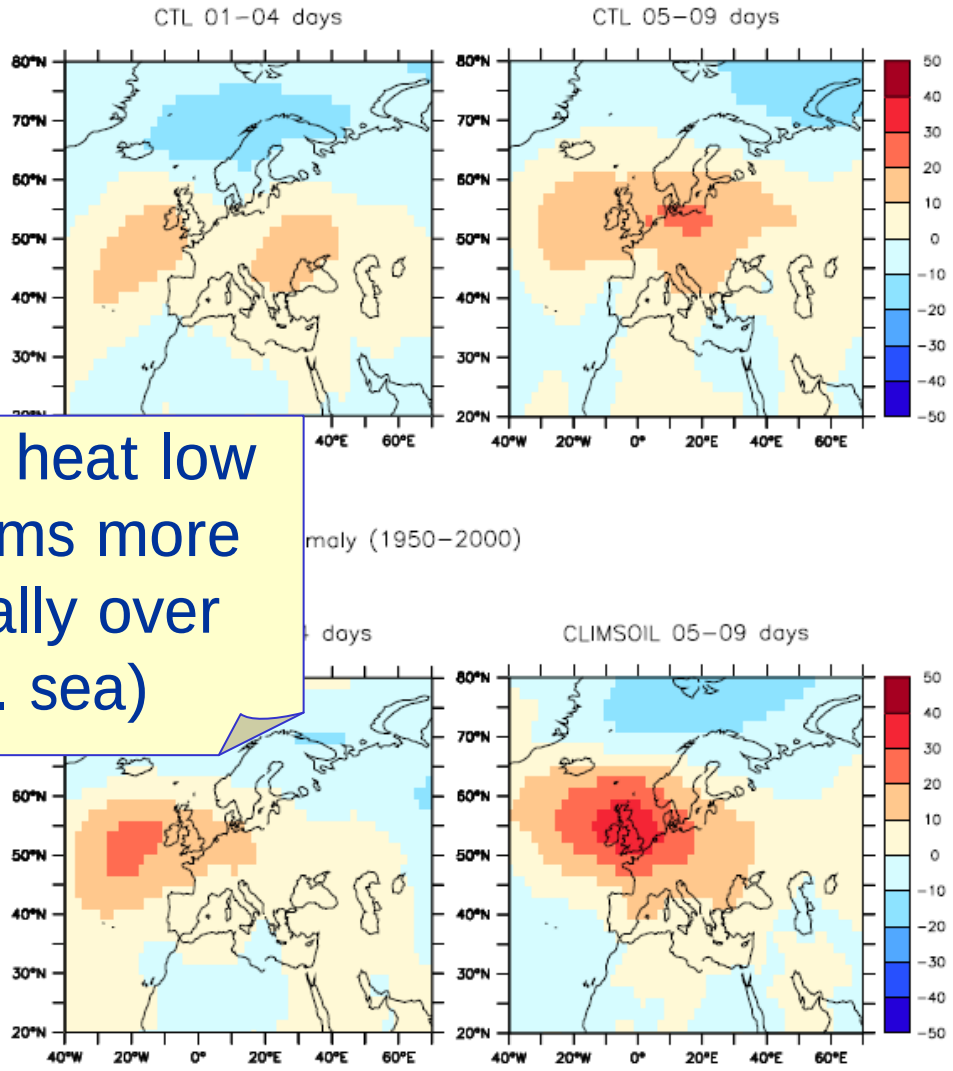
ys) ^{Z5} longer episodes (5-9 days)





CLIMSOIL

Patterns of Z975-anomaly



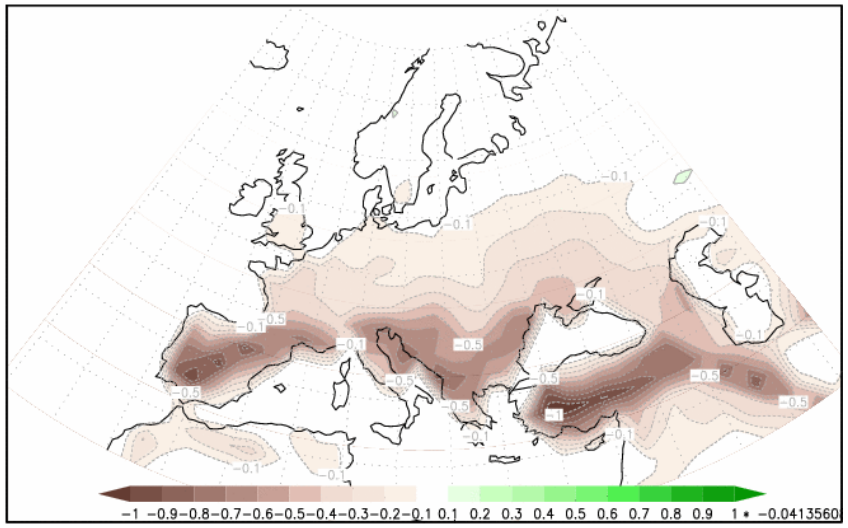
Not surface heat low (here it forms more preferentially over high lat. sea)

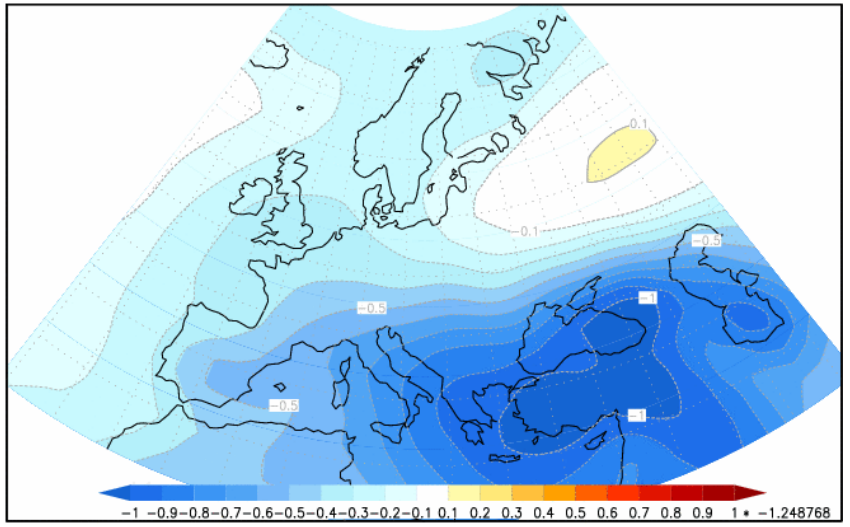
2 studies concerning Europe

- Do we see effect of land-atmosphere interaction on summertime blocking? Not a lot.
  - no change in blocking persistence or frequency
  - with interaction: less Z500 variability over land
  - high pressure anomaly in blocked conditions a bit more off the continent (shift to the West)
- Can we explain changes in atmospheric circulation from land drying?

Matching patterns soil m. (June) – MSLP (Jul-Aug)

- SVD analysis (patterns giving maximum correlation)
- Monthly mean ESSENCE (17 members, 1950–2000)





dry Medit. soil in June

low ... august

Note: no clear correlation exists in N-Europe

Haarsma et al, submitted

Sep 2008

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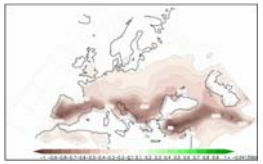
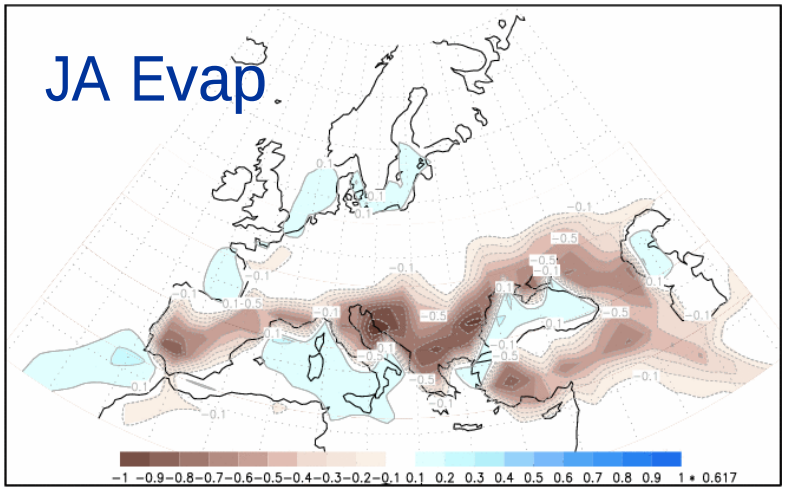
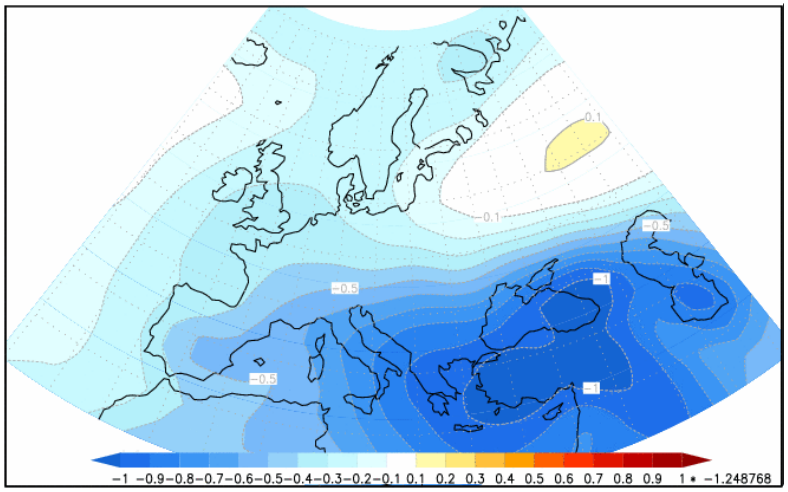
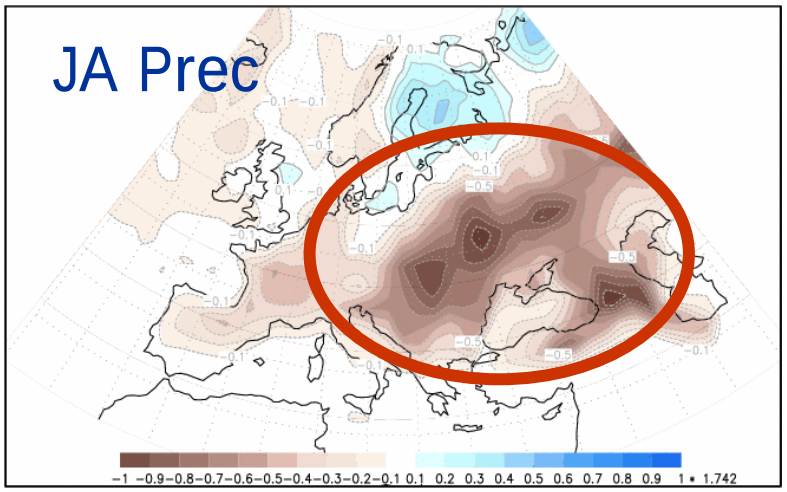


Likewise matching...



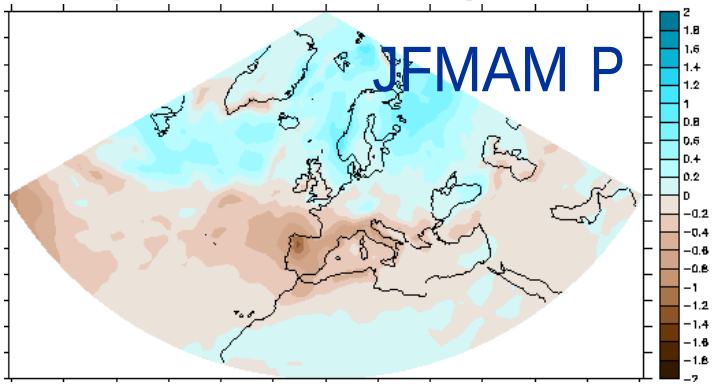




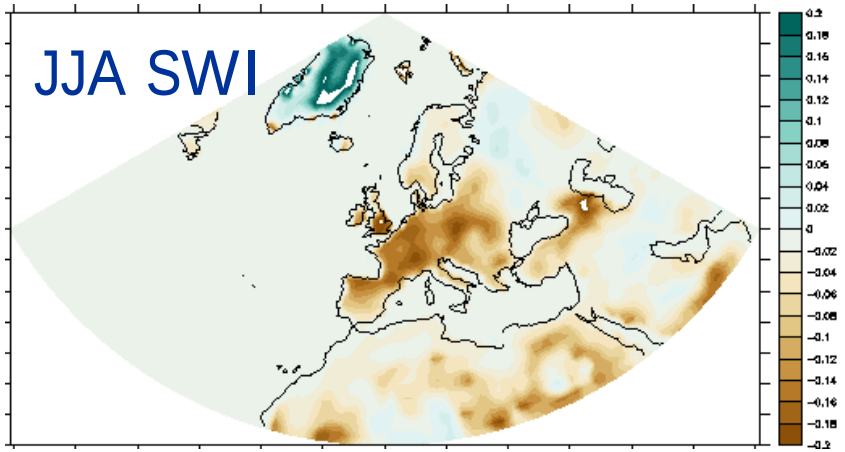
Subsequent precipitation response in area with largest MSLP-gradient

Future – control ECMWF run

- Low precipitation/high evaporation in spring in S.Europe

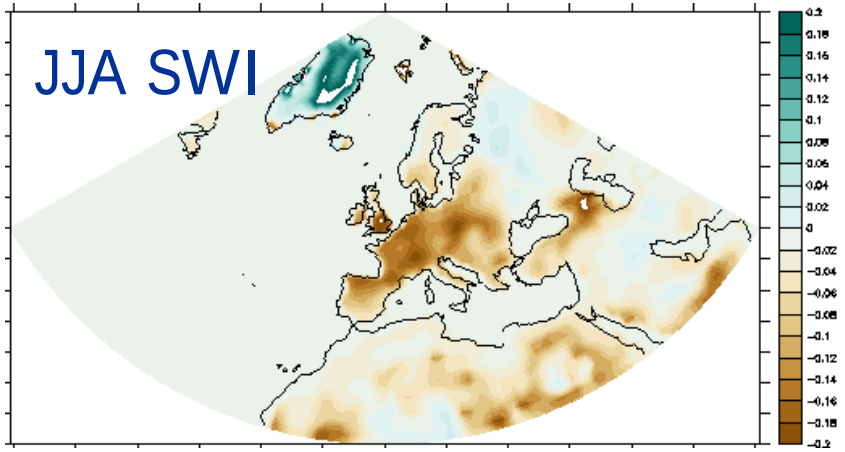


- Dry summer soil in S. and C.Europe

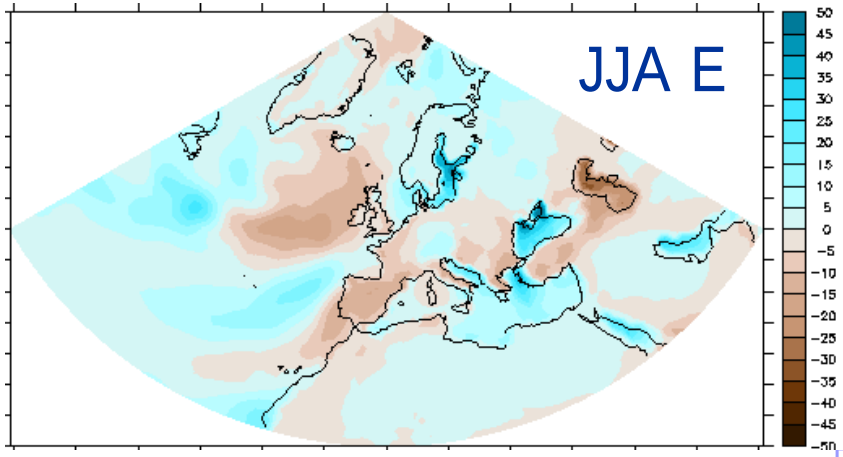


Future – control ECMWF run

- Dry summer soil in S. and C.Europe

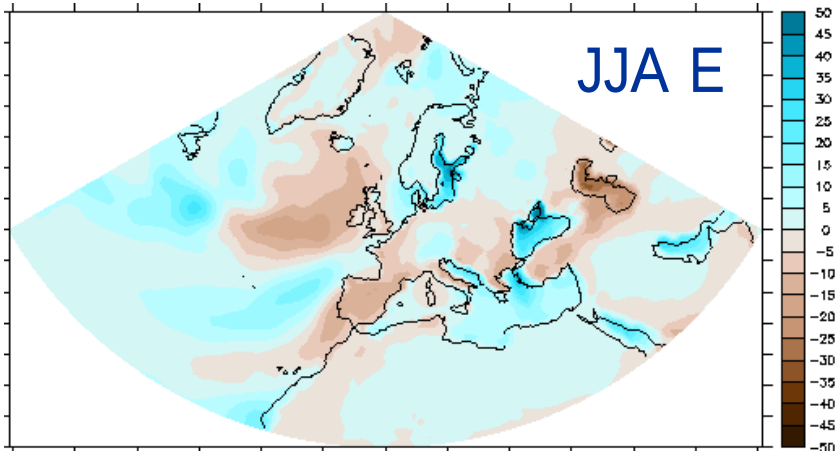


- Reduced evaporation and enhanced heating mainly in S.Europe (where evap is moisture limited)

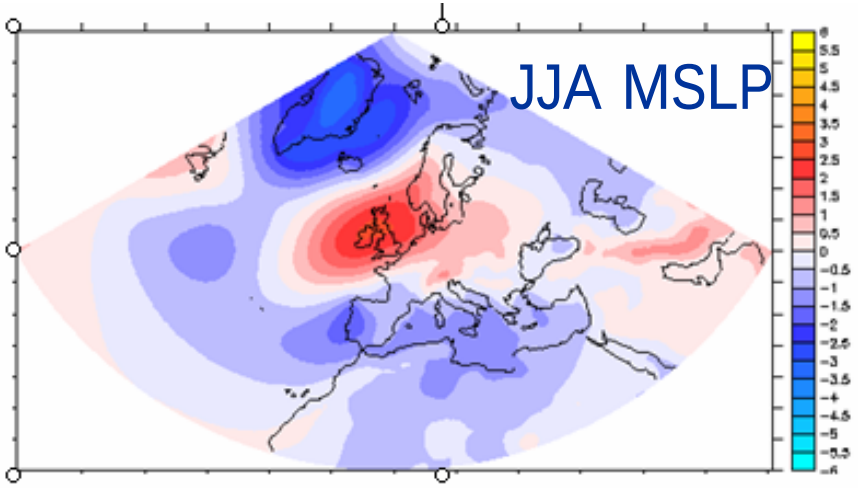


Future – control ECMWF run

- Reduced evaporation and enhanced heating mainly in S.Europe



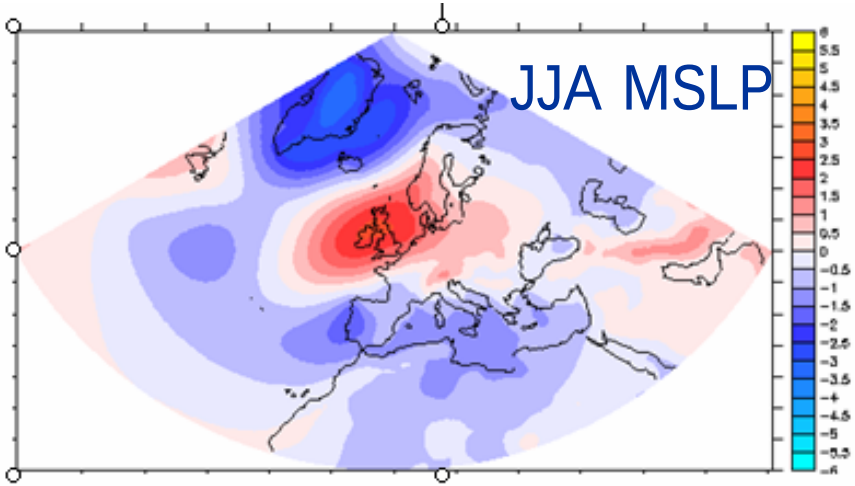
- S.European heat low



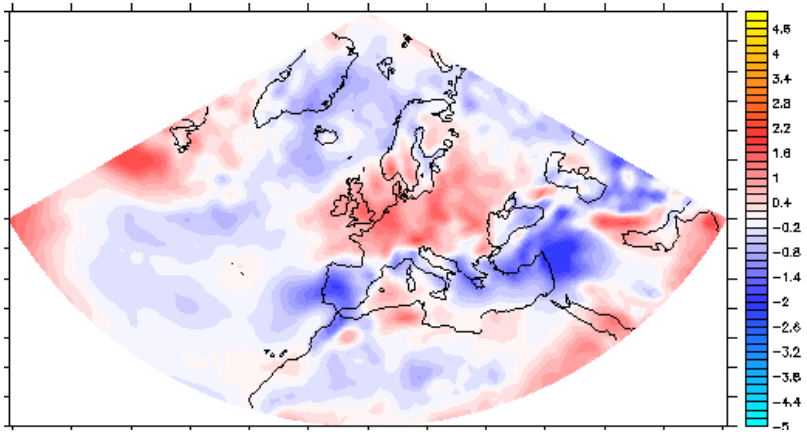
(confirmed with experiment with extra heating in only S.Europe)

Future – control ECMWF run

- S. European heat low



- More subsidence in C.Europe

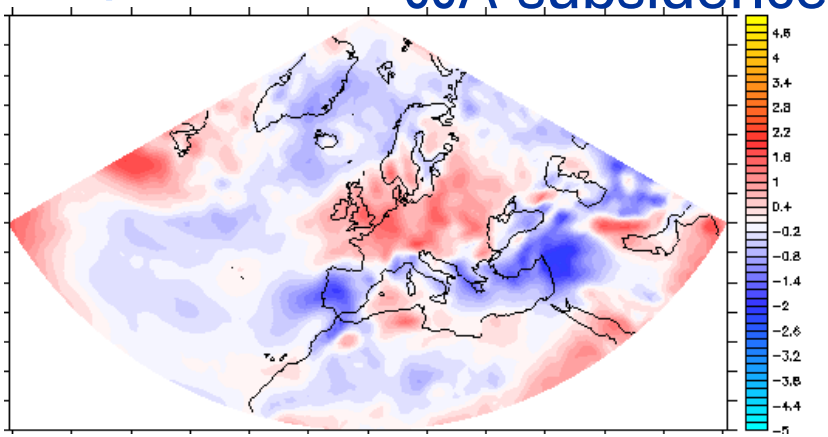


JJA subsidence

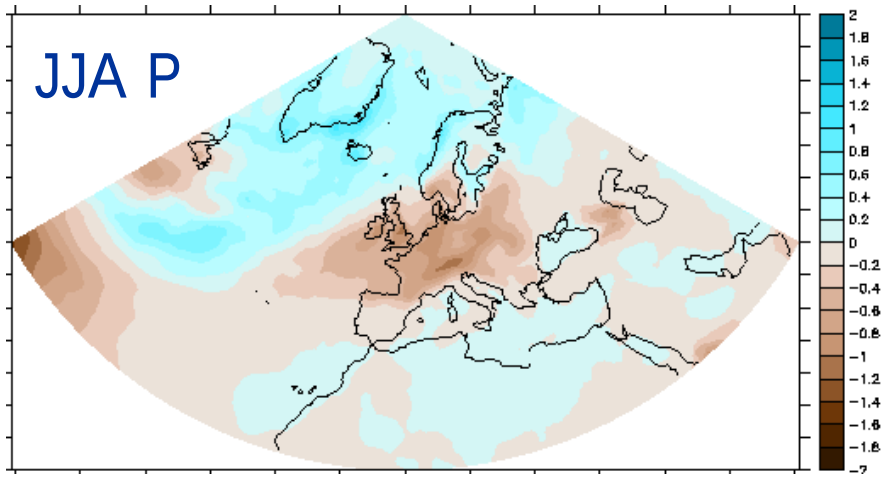
Future – control ECMWF run

- More subsidence in C.Europe

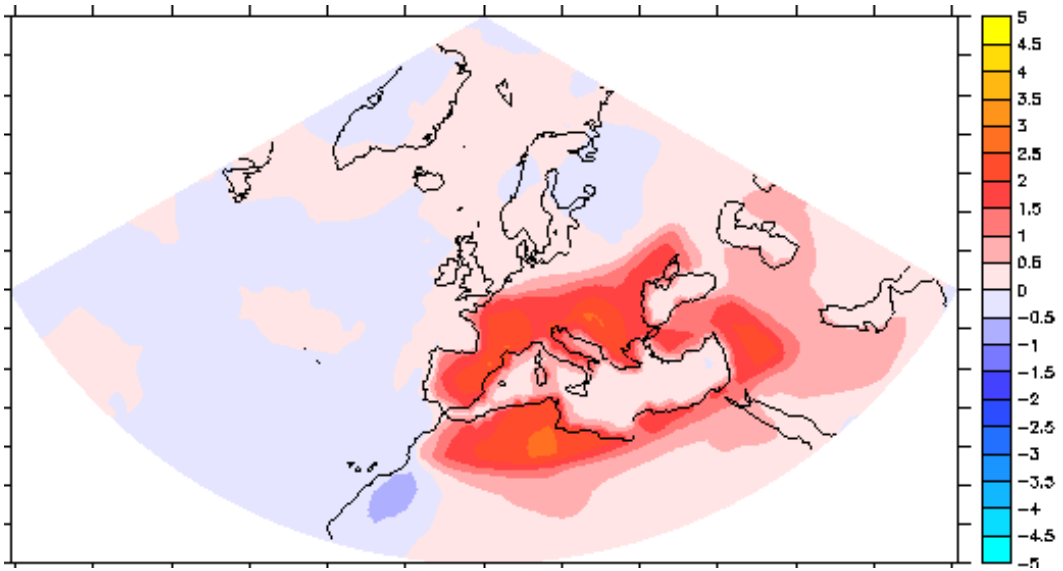
JJA subsidence



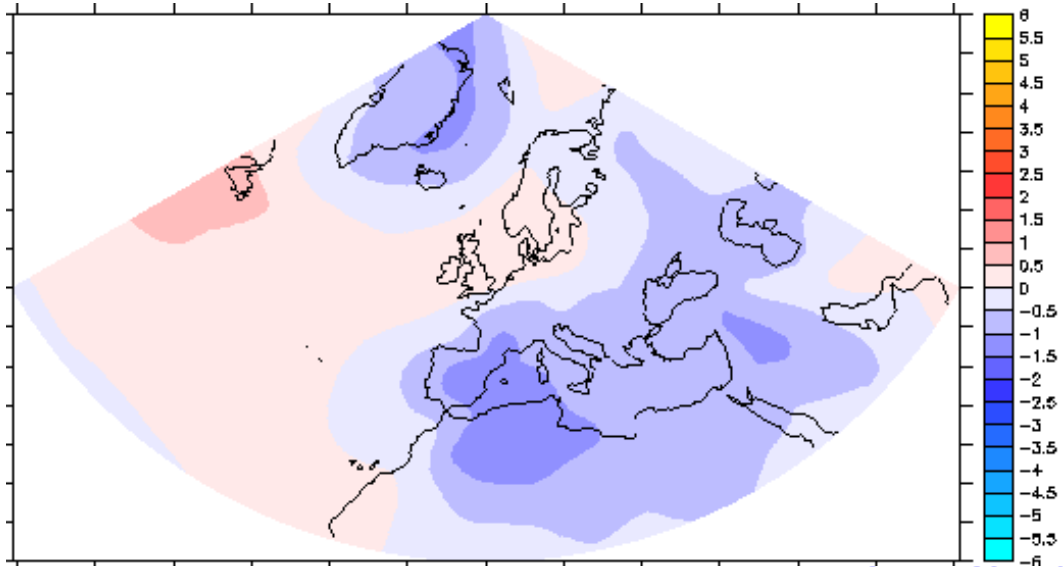
- Less cloud & precipitation, more heating in C.Europe



MEDFLUX exp
(20 W/m2 extra heating)



JJA T2m



JJA MSLP

What did we learn?

- Blockings do not seem less persistent when land-atm interaction is reduced
- Z500 and surface patterns tend to shift westward
- Mediterranean heat lows and their effect on European circulation play a role