# Decadal climate variability and change in the Mediterranean region

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Acknowledgments

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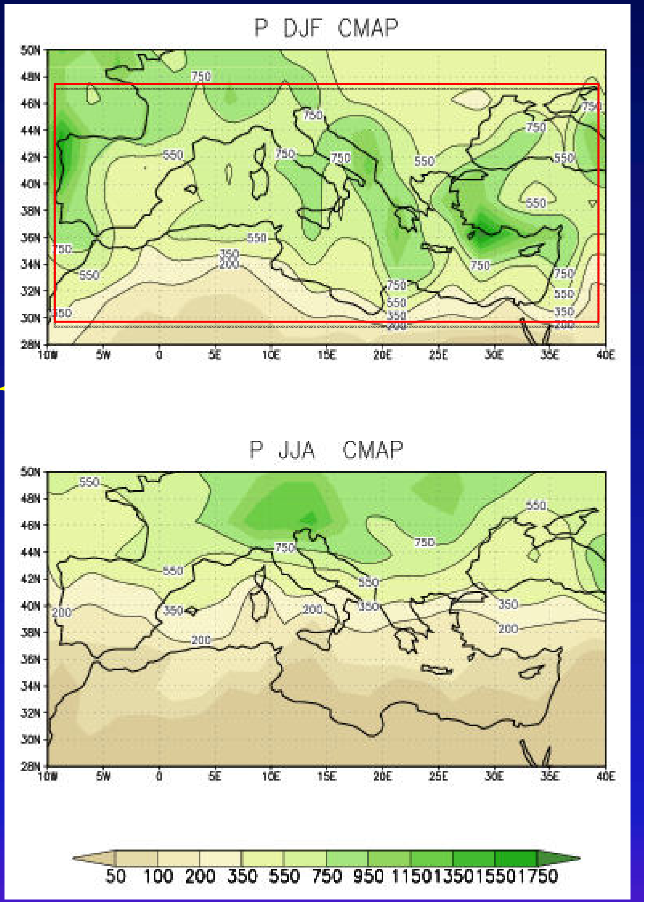
# Motivation

- Mediterranean is climatologically dry and vulnerable to increases in drought.

- Future projections suggest significant climat changes over the Mediterranean.

- Better understand the role of decadal variability in future climate outlooks for the Mediterranean.




More Broadly: the Mediterranean represents a interesting case to further understand decadal variability, predictability and evaluate decadal predictions.

# Outline

- Observed decadal climate variability.

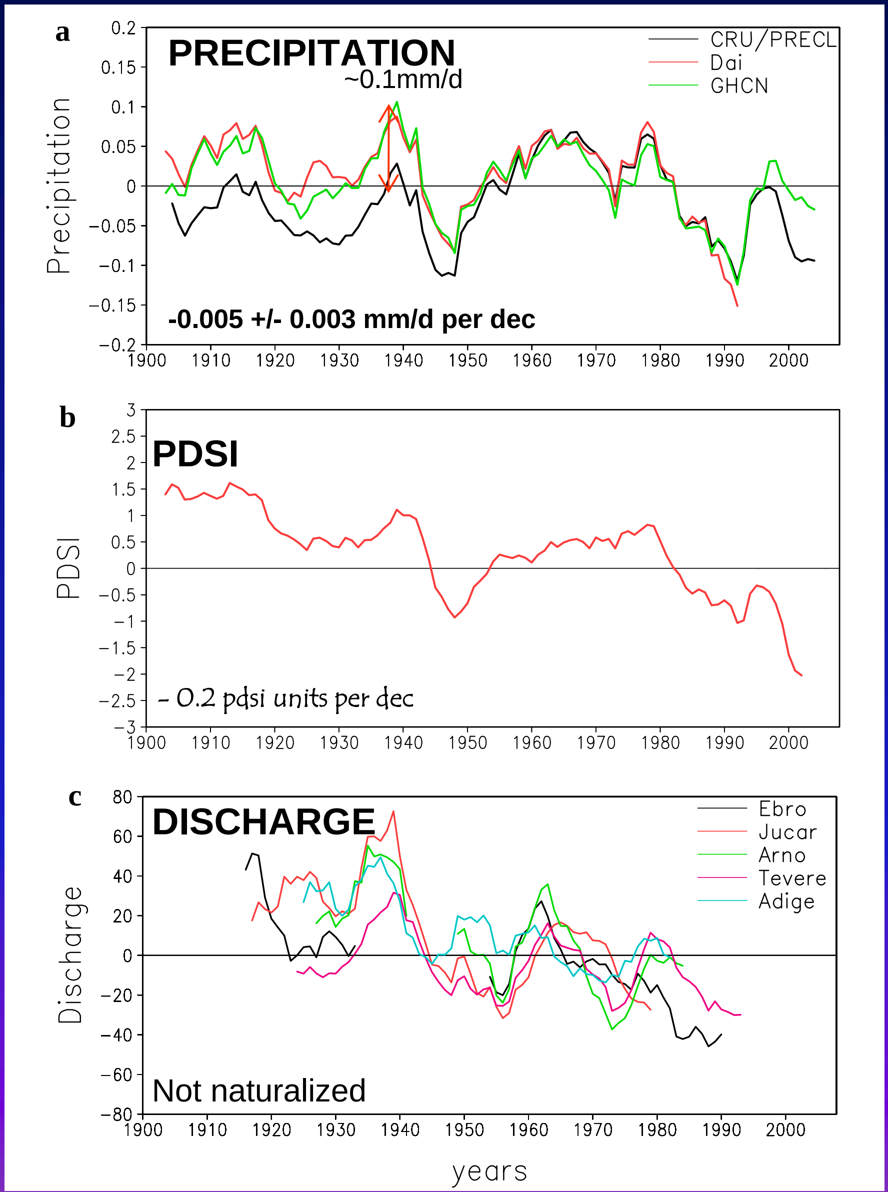
- Forced 20th century changes and 21st century projections.

- Prospects for decadal predictability.

# PART I: Observed* decadal variations

*No assumption regarding the "natural" origin of the anomalies

# Observed Long-term Regional Drought variability




6-years running means of area-averaged anomalies wrt 1950-2000 (1960-1980 for discharge).

- Multi-decadal variations in regional precipitation (~0.1 mm/d).

-Related PDSI and river discharge anomalies.

- Long-term trends in PDSI and river discharge suggest an increase in land-surface aridity due to surface air temperature increase.

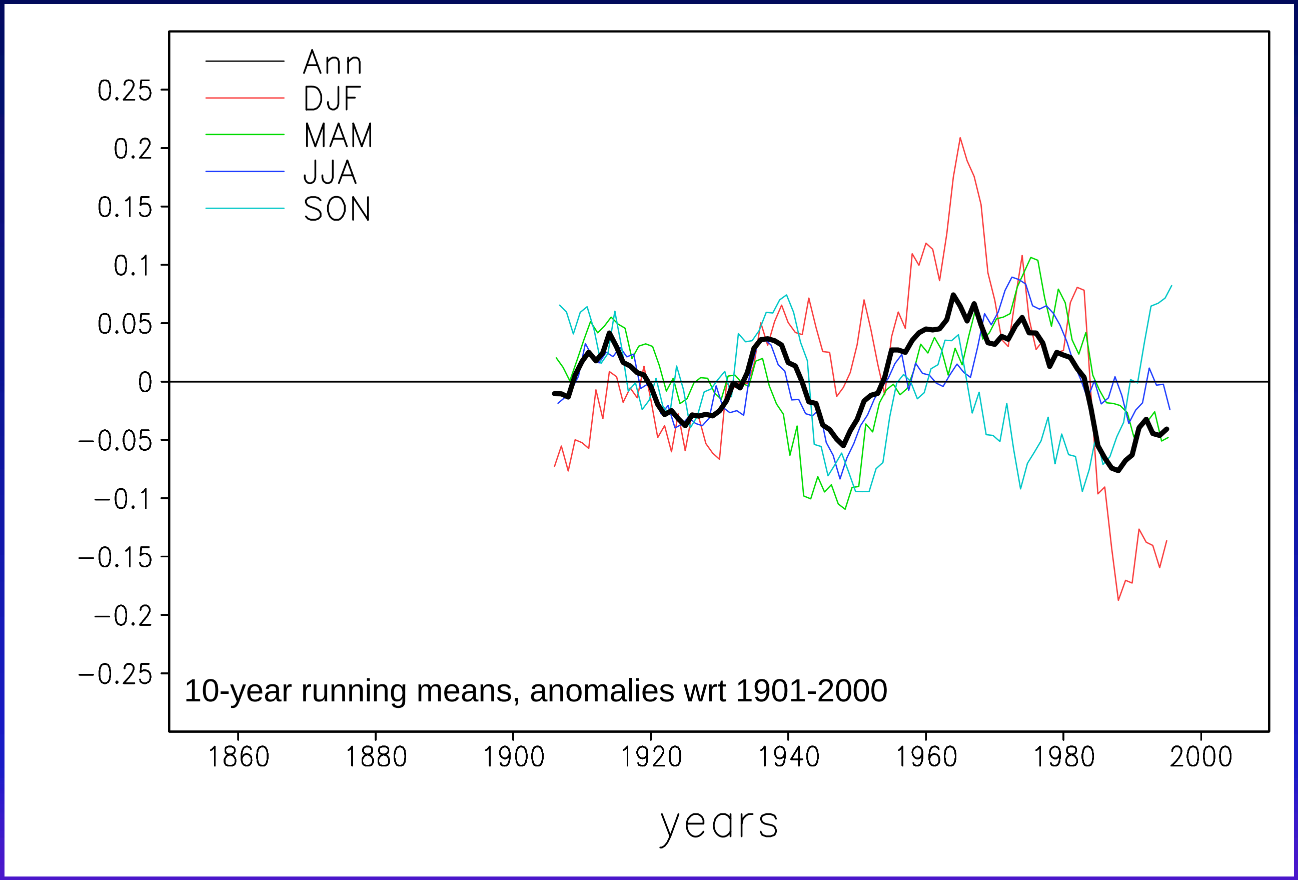
-> Precipitation has affected decadal drought variability, with temperature affecting long-term trends through increased evapotranspiration?

Mariotti et al., ERL, 2008

# Precipitation

Precipitation

D

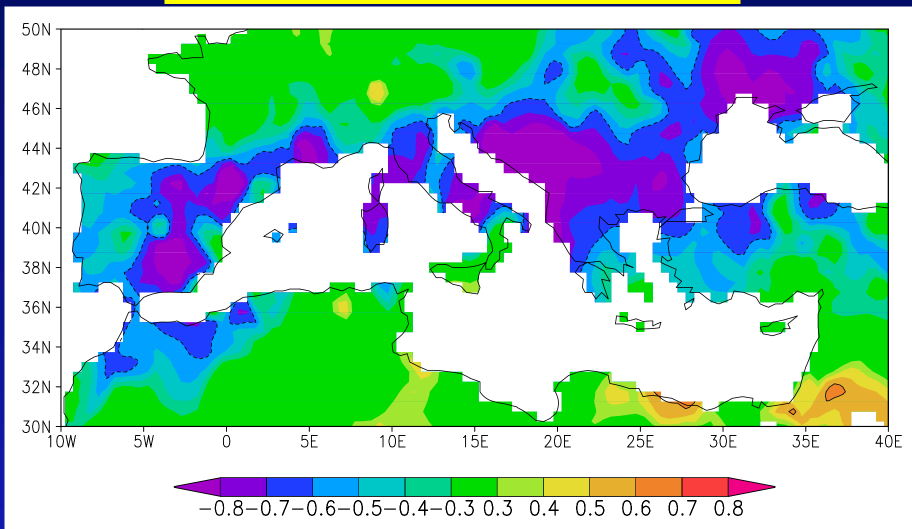



- DJF is a major contributor to annual precipitation anomalies.
- Since the 1970s, a remarkable decrease in DJF prec.
- Note, an increase in SON prec. Since the 1970s.

Mariotti and Dell'Aquila, Clim Dyn, 2011

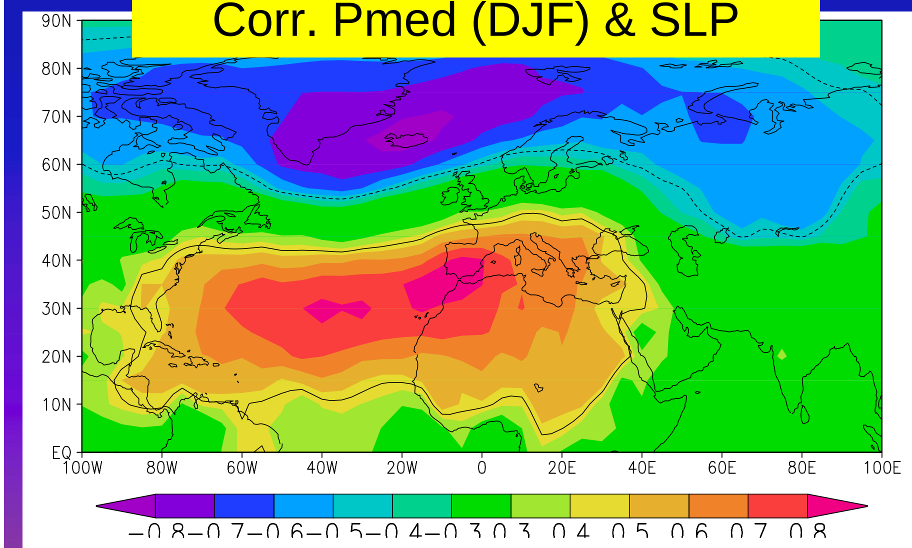
# North Atlantic Oscillation: winter influence

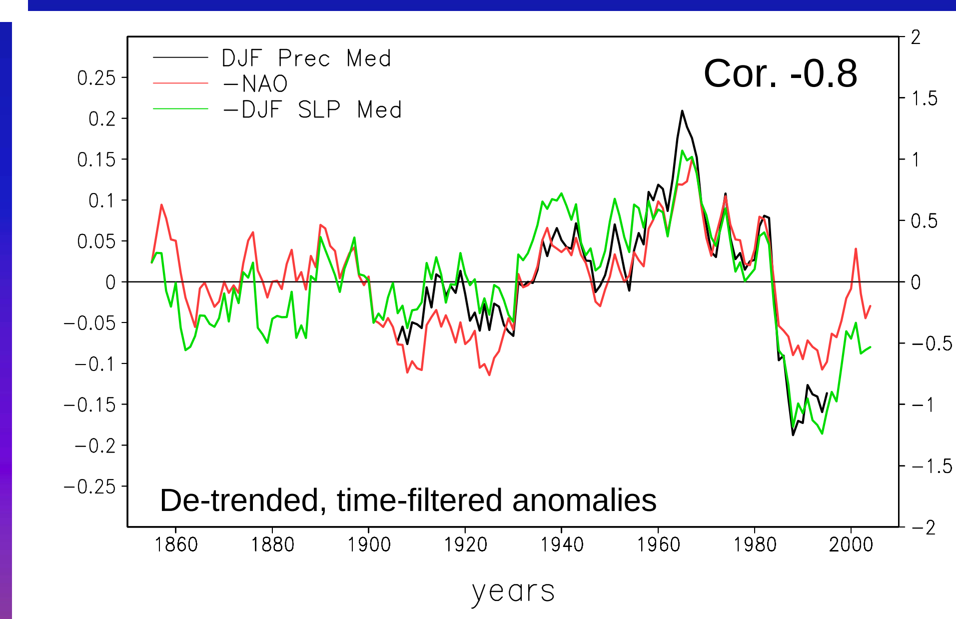
Corr. NAO & P (DJF)




- The NAO explains over 30% of decadal DJF precipitation in the Med. (negative corr.).
- E.g. the striking 25% decrease in DJF precipitation 1960s-1990s.
- It is unclear whether the ’60s-’90s NAO change was “forced”.

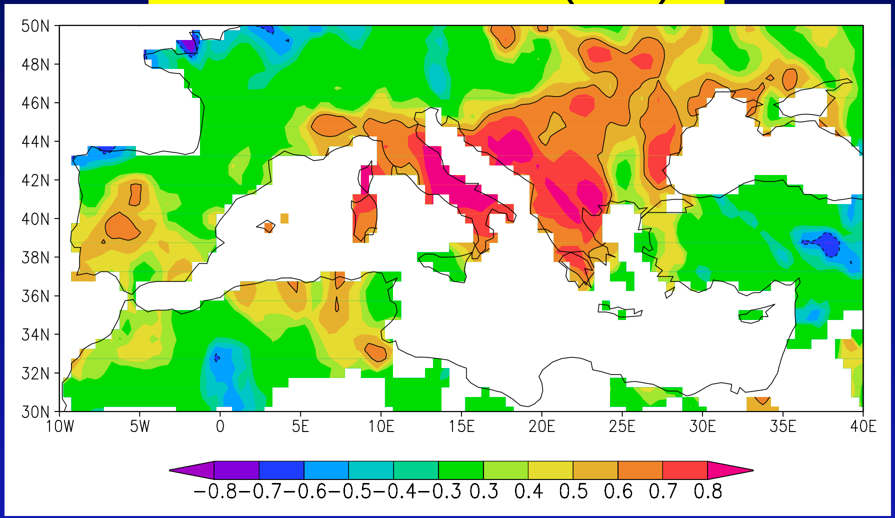
Corr. Pmed (DJF) & SLP



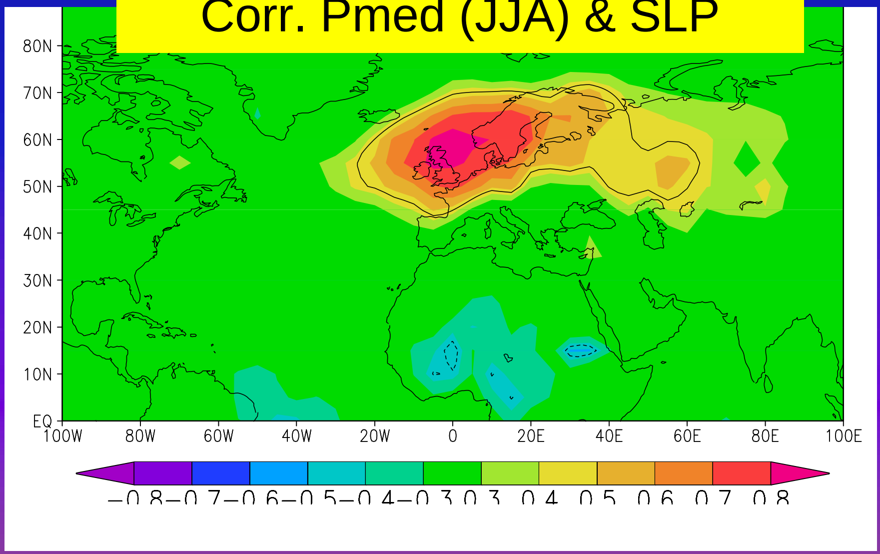
# North Atlantic Oscillation: summer influence

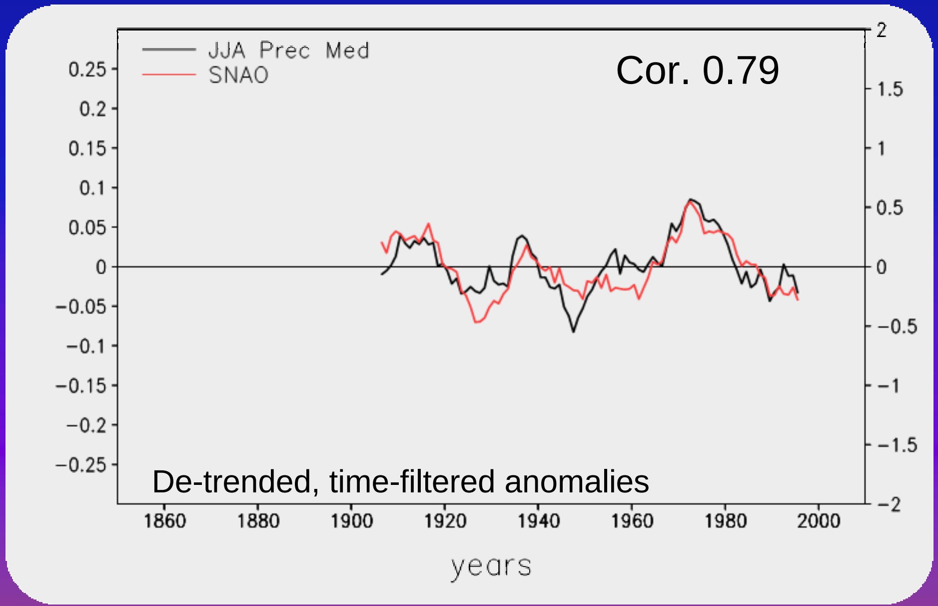
Corr. SNAO & P (JJA)




- The SNAO influence is confined to Central/Eastern Med. (positive corr.)
- Anomalous SLP center over northern Europe.
- Absolute prec. SNAO anomalies are smaller than those of the winter NAO.

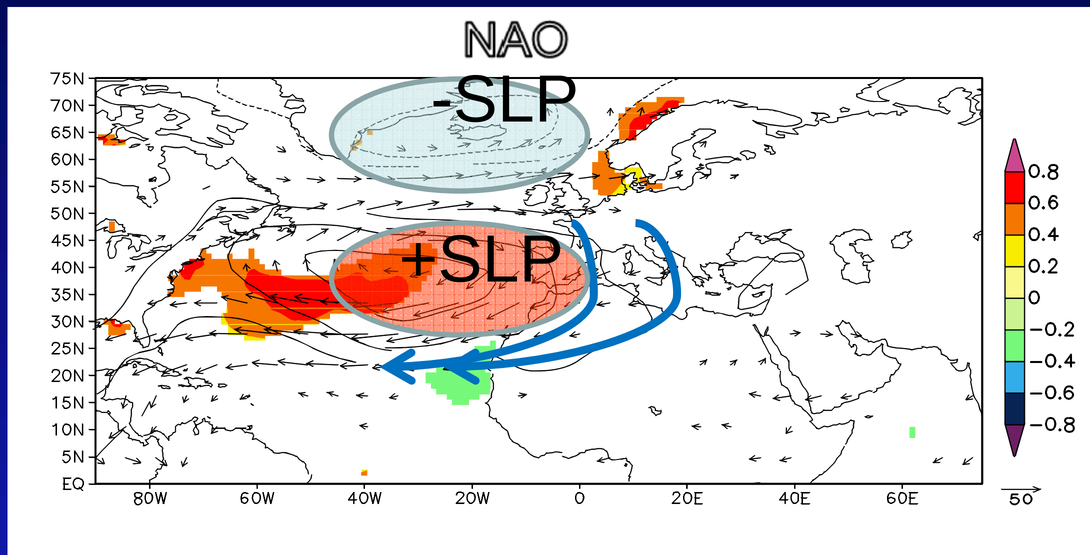
Corr. Pmed (JJA) & SLP



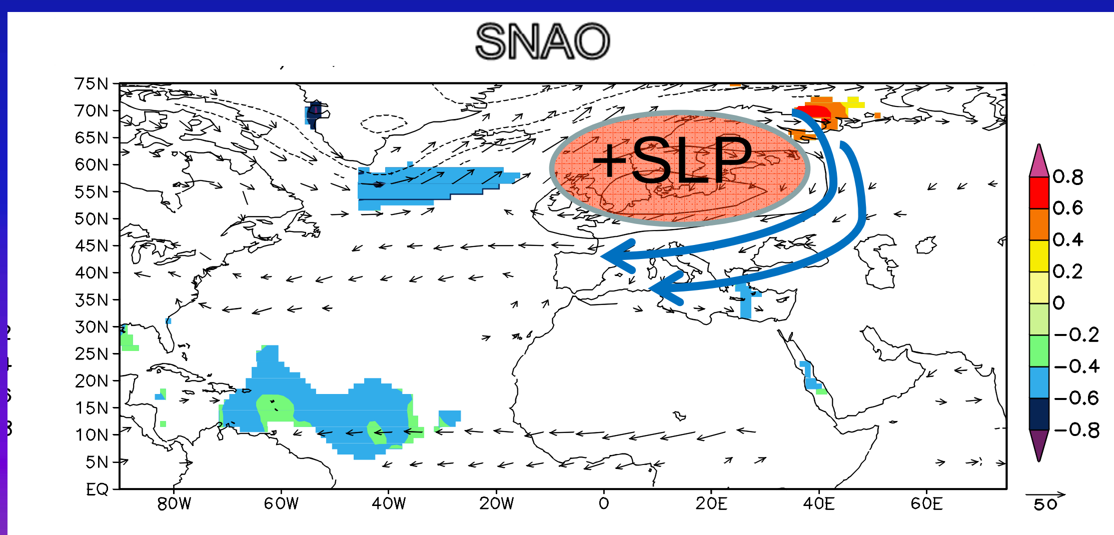
# Seasonal North Atlantic Oscillation patterns

[Positive Phase]




**Winter NAO**

Precip. suppression by regional SLP increase & moisture redirection




**Summer NAO**

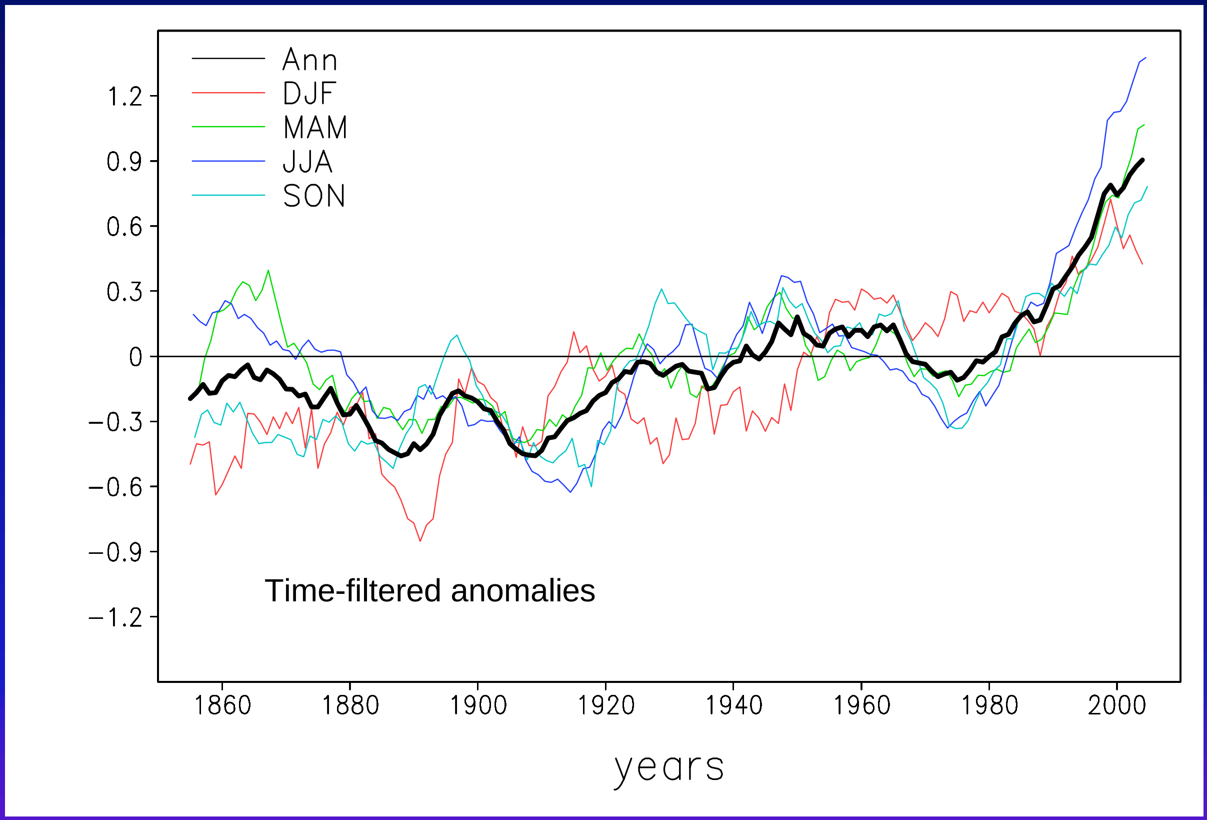
Moisture redirection by the SLP center over N Europe (also Folland et al., 2009)



Mariotti and Arkin, Clim Dyn, 2007

# Surface Air Temperature

Precipitation

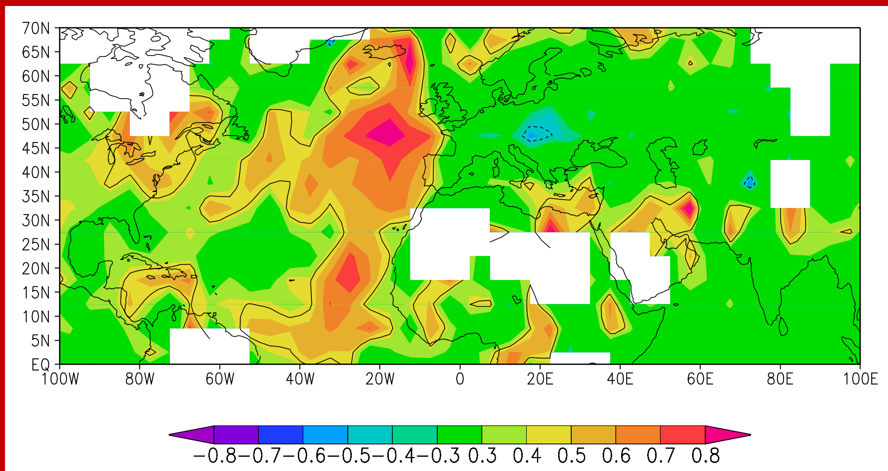


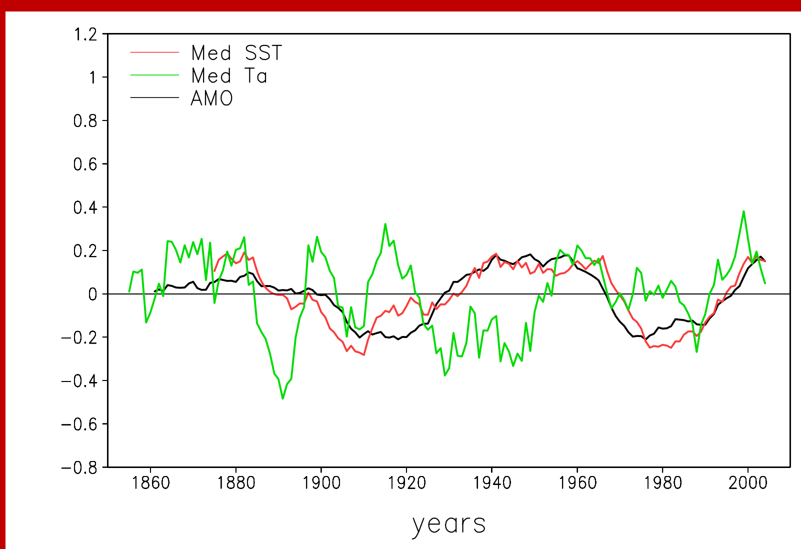

**-Air temperature**: decadal to multi-decadal variations (~ 0.5 K) varying with season; long term positive increase (0.04K/decade) particularly in JJA

Mariotti and Dell'Aquila, Clim Dyn, 2011

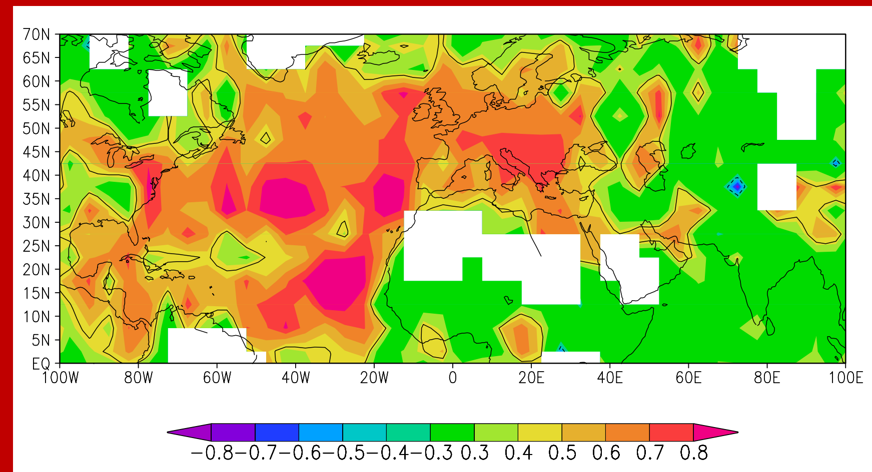
# AMO Influence on air temperature and SST

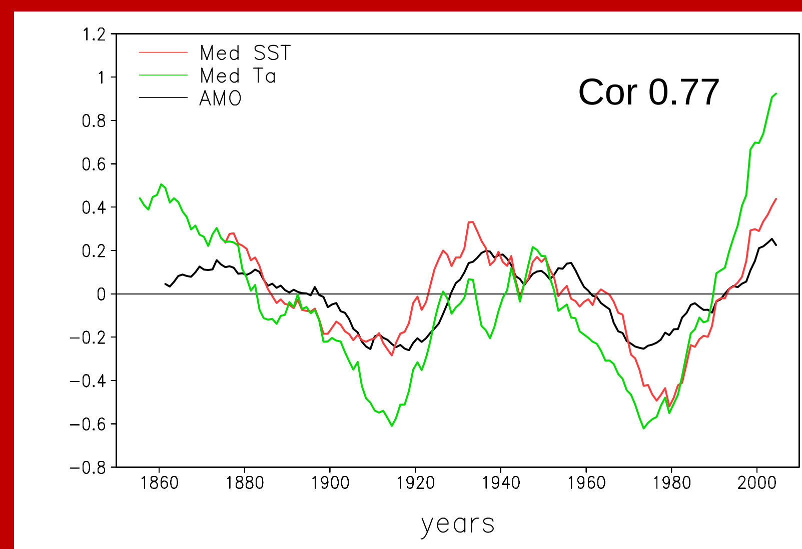
## DJF



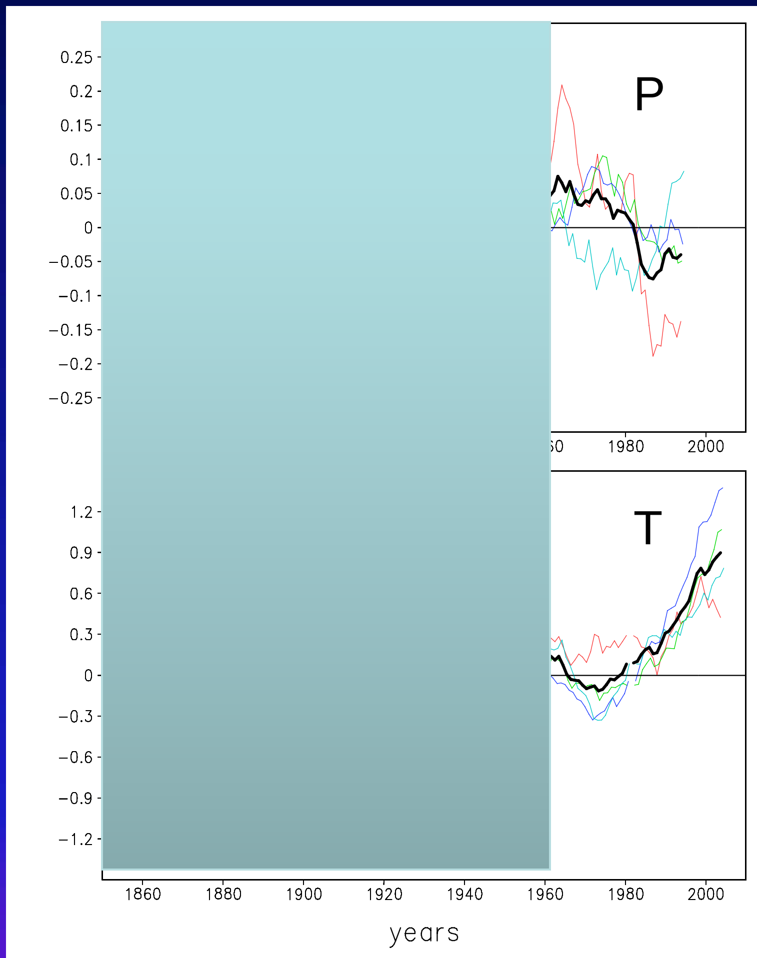

## JJA



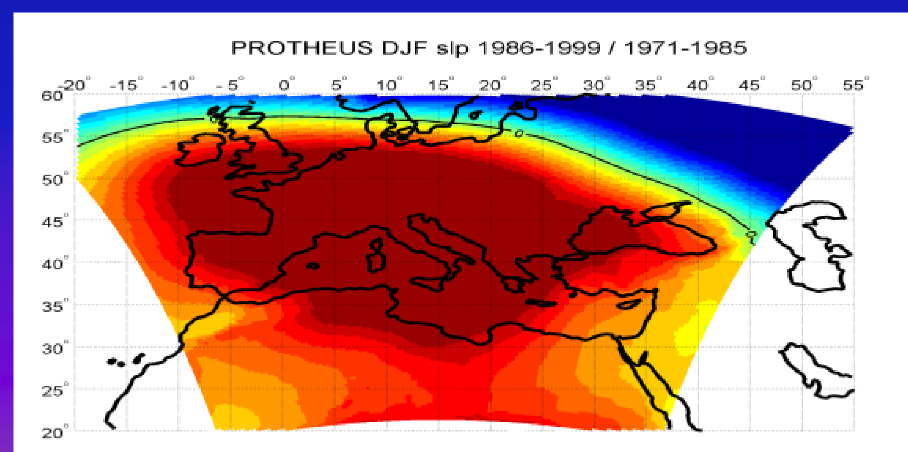

De-trended, time-filtered anomalies

# Mechanisms: A regional climate model study



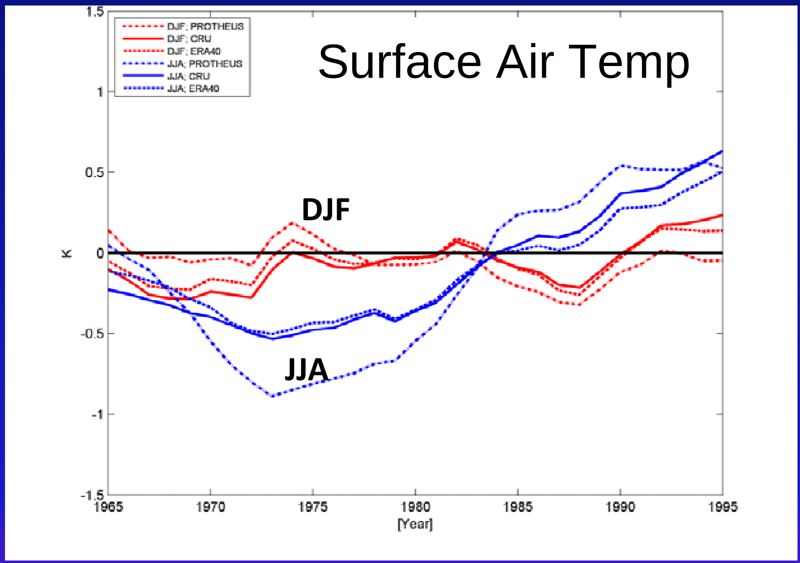

Investigate 1960-2000 variability, specifically the drier and warmer 1986-2000 conditions vs the wetter and cooler 1960-1985 conditions.

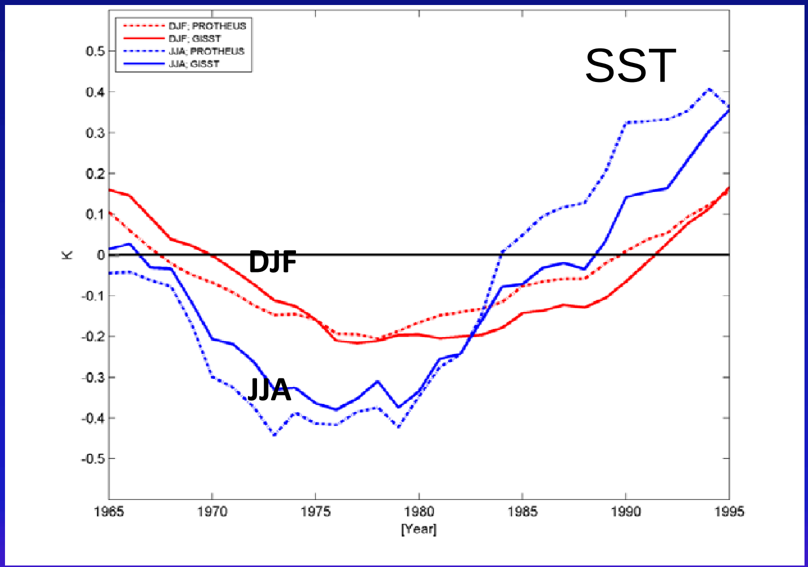
Model Set-up: Fully coupled ocean-atmosphere regional climate model (Protheus) for the Mediterranean region forced by ERA40 re-analyses (30km res); climatological conditions at Gibraltar BC; no aerosols.



# Main Results

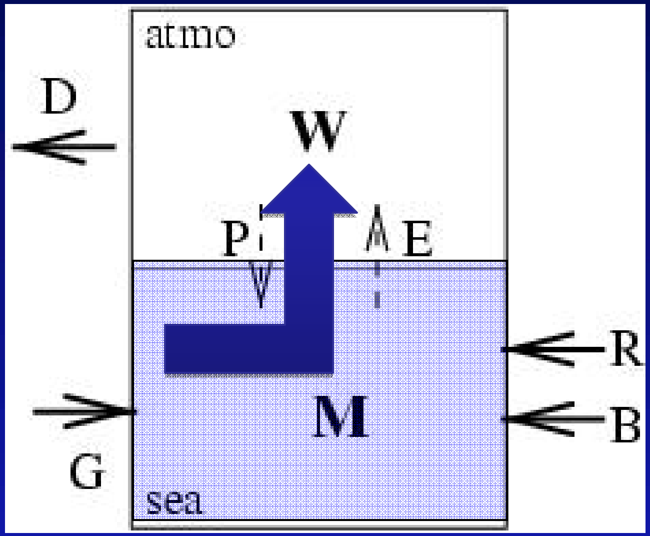
- Model captures observed decadal variability reasonably well.
- In particular, the differing surface air temperature/SST DJF/JJA behaviors

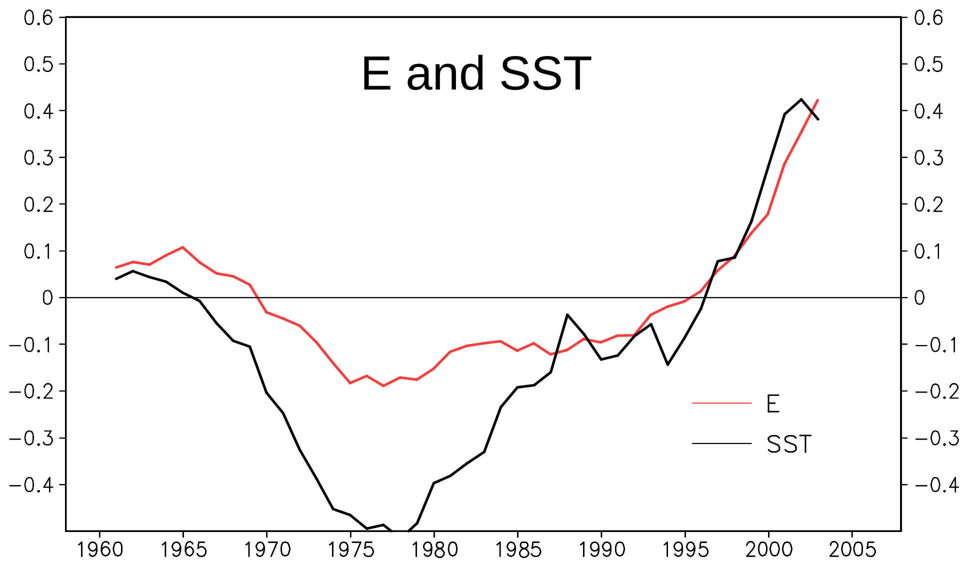


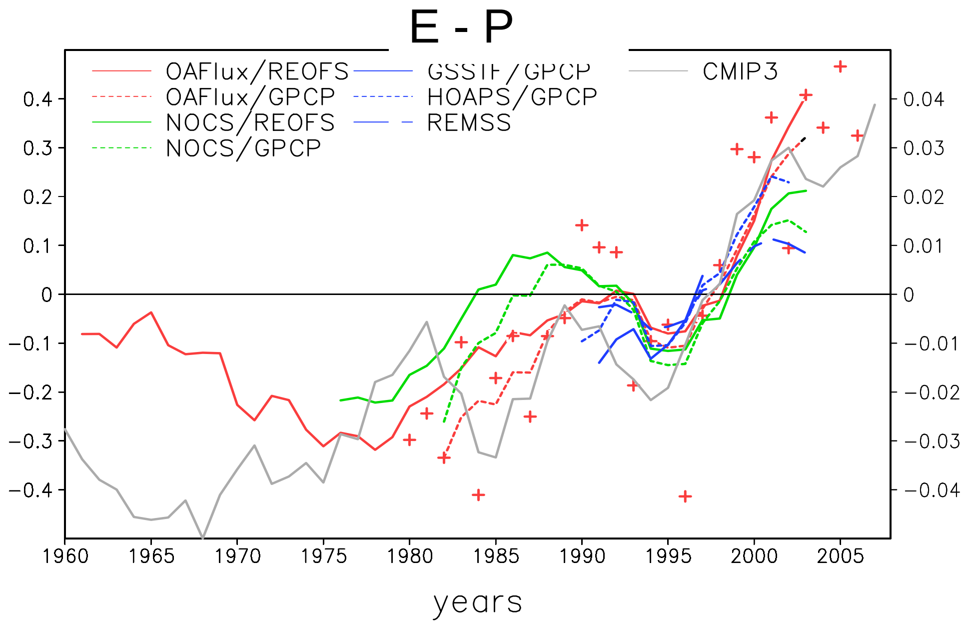




Model set-up suggests AMO signal seems transmitted to the Mediterranean through the atmosphere mostly during the warm/transition seasons and forces AMO-like Mediterranean Sea SST variability.

# AMO influence on Med Sea Water budget?




- Observed E increase largely related to SST changes, i.e. AMO related?

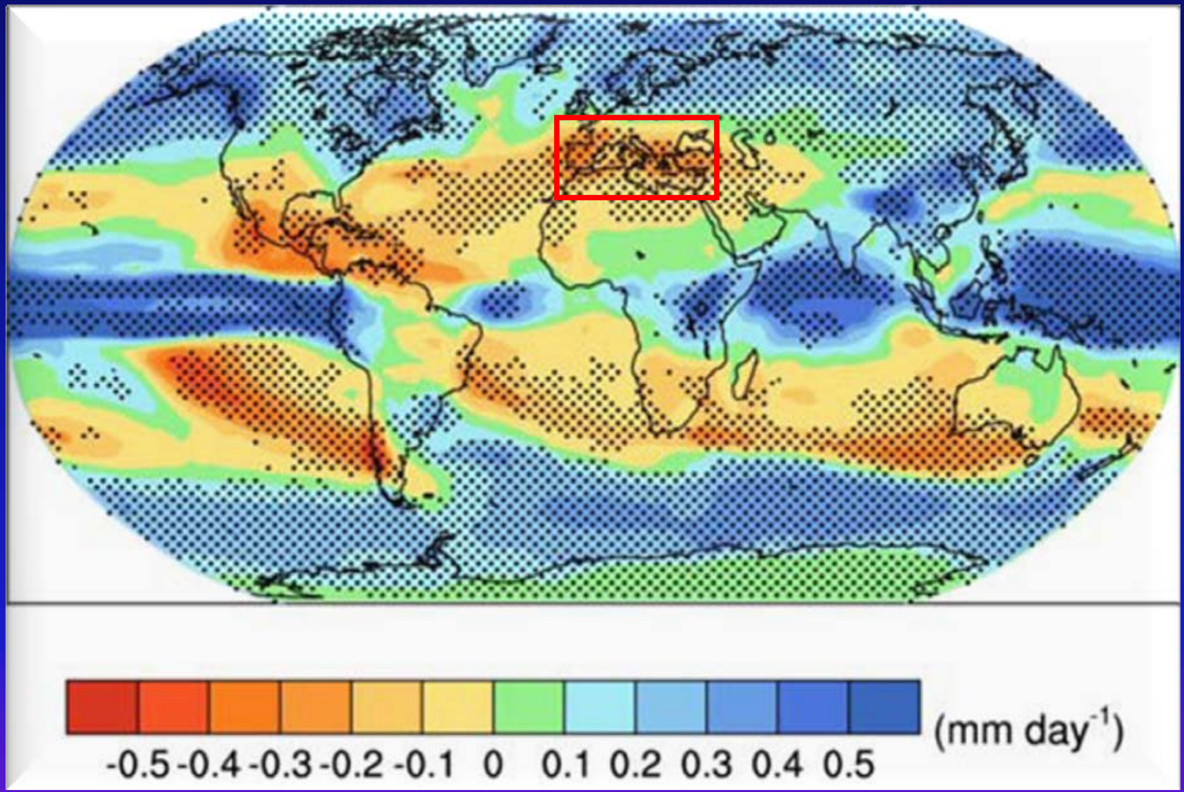
- 30% increase in E-P, largely related to the E increase.

Mariotti, J Clim 2010.

# PART II: GHG "forced" changes

# The Mediterranean Climate Change "Hot-Spot"

Precipitation changes by 2080-2099

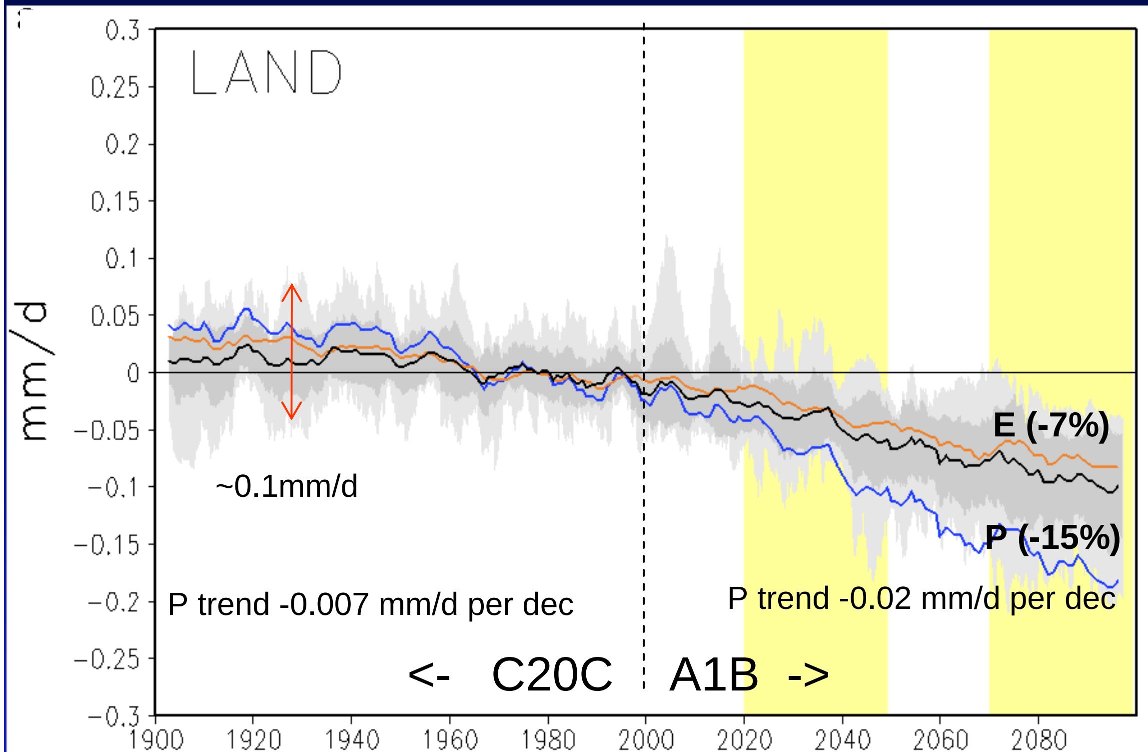



**AR4 projections (A1B)**

High-level of consensus on Mediterranean precipitation decrease resulting from increased GHG concentrations

Stippled regions is where at least 80% of CMIP3 models agree on the sign of the annual mean precipitation change. SRES A1B scenario; 2080-2099 means relative to 1980-1999. *[IPCC, 2007]*

# "Forced" changes in Med. land water cycle

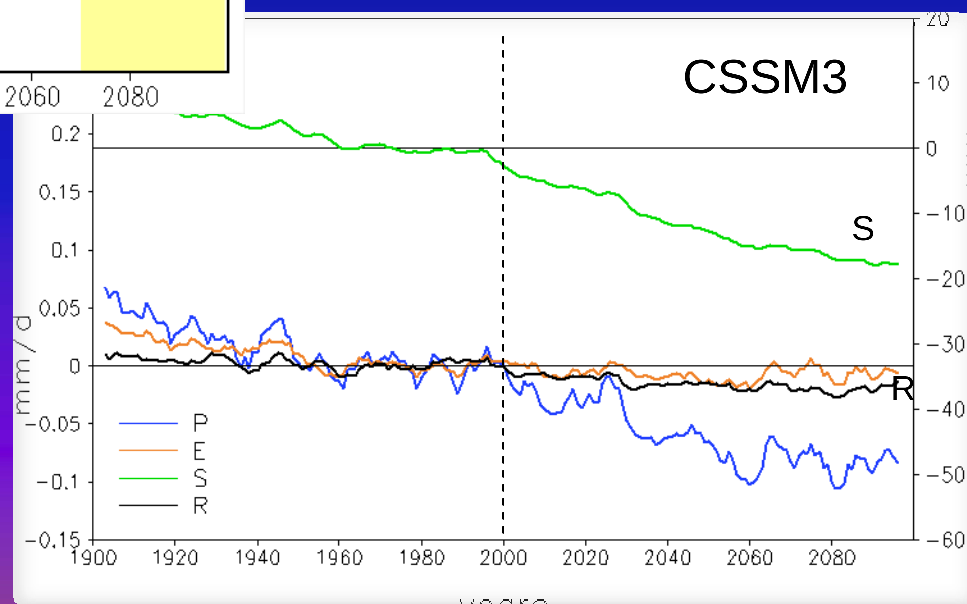



- Ensembles of coupled simulations from 15 CMIP3 models.
- 20th C EXP and A1B scenario projections (P, E and P-E).
- Ensemble mean as a proxy for forced change.

Progressive decrease in P, E and P-E starting late in the 20th C

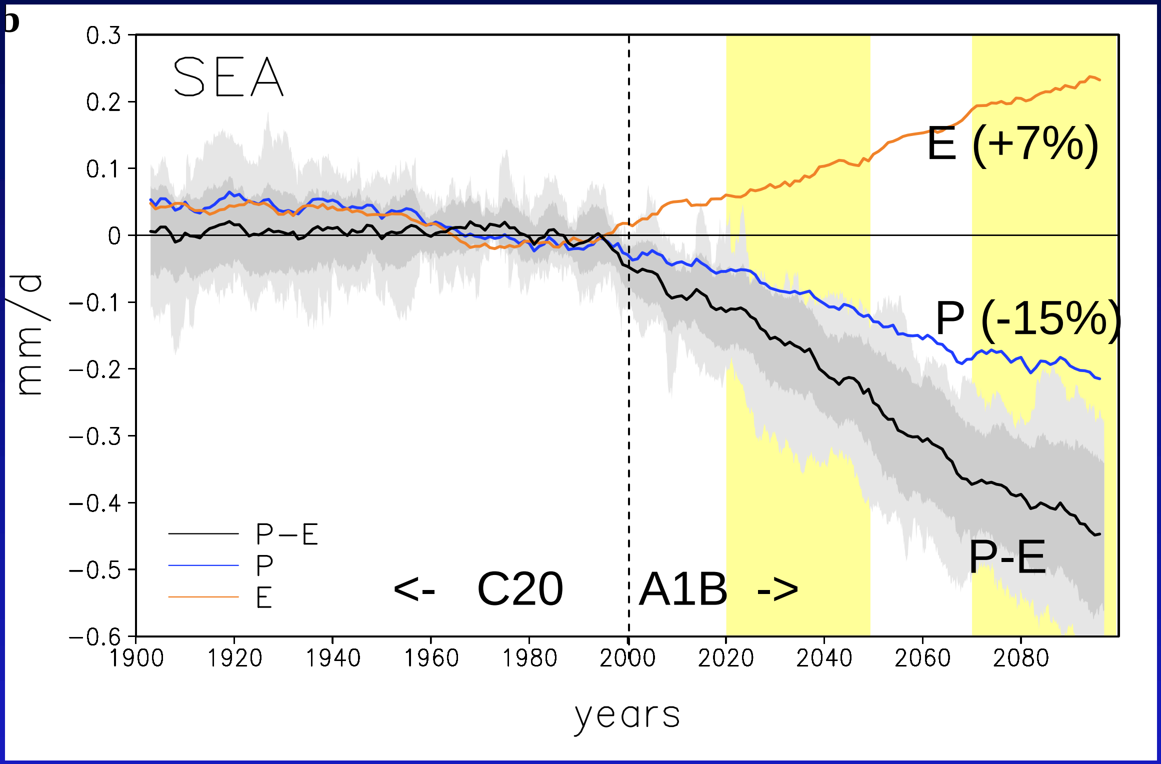
Soil moisture and runoff decreases accompany P-E decrease

P-E ~ R+dS/dt



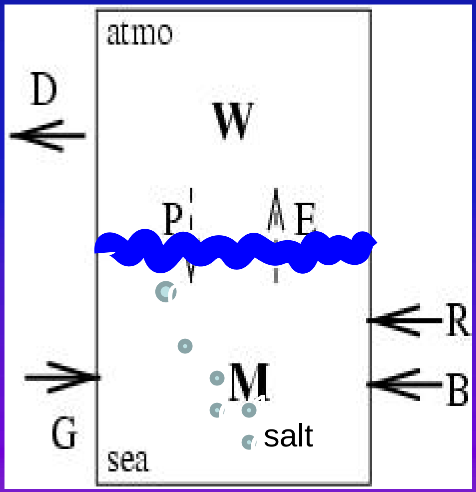

(Mariotti et al., ERL 2008)

# "Forced" Medit. Sea water budget changes




Evaporation increases accompany precipitation decreases → Significant increase in Mediterranean Sea fresh water deficit

Mediterranean Sea

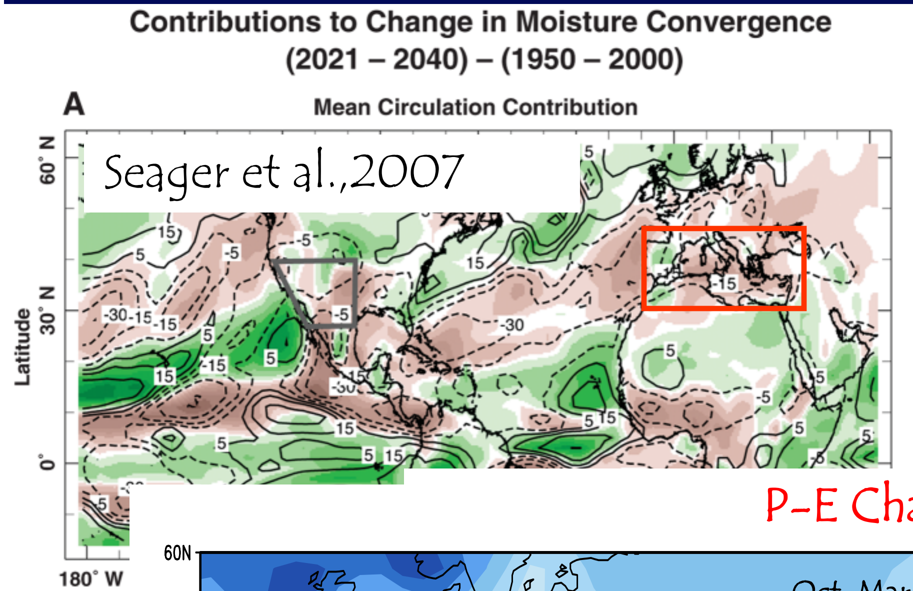



E-P~G+R+B

-Potential important implications for Mediterranean Sea salinity, circulation and sea-level

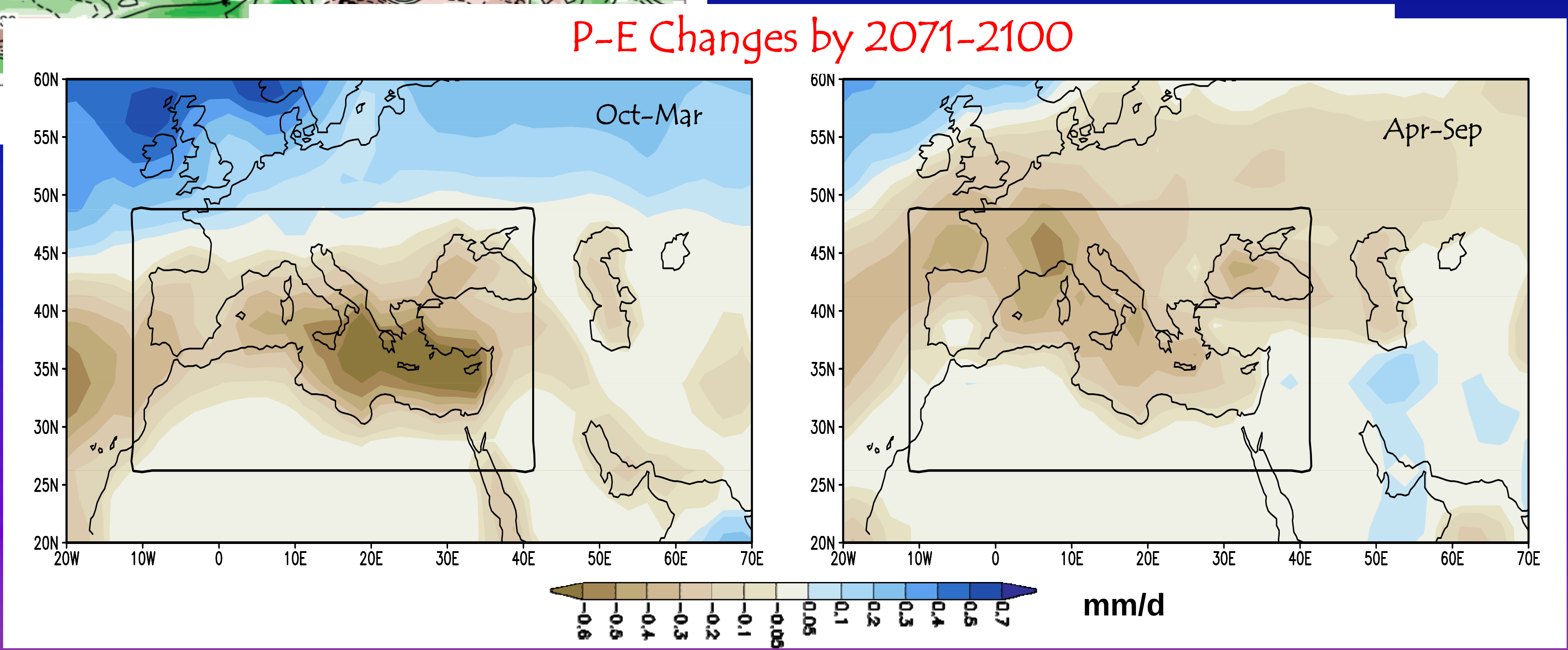
- Potential impacts on the Atlantic via exchanges at Gibraltar

# Spatial characteristics of regional water cycle changes

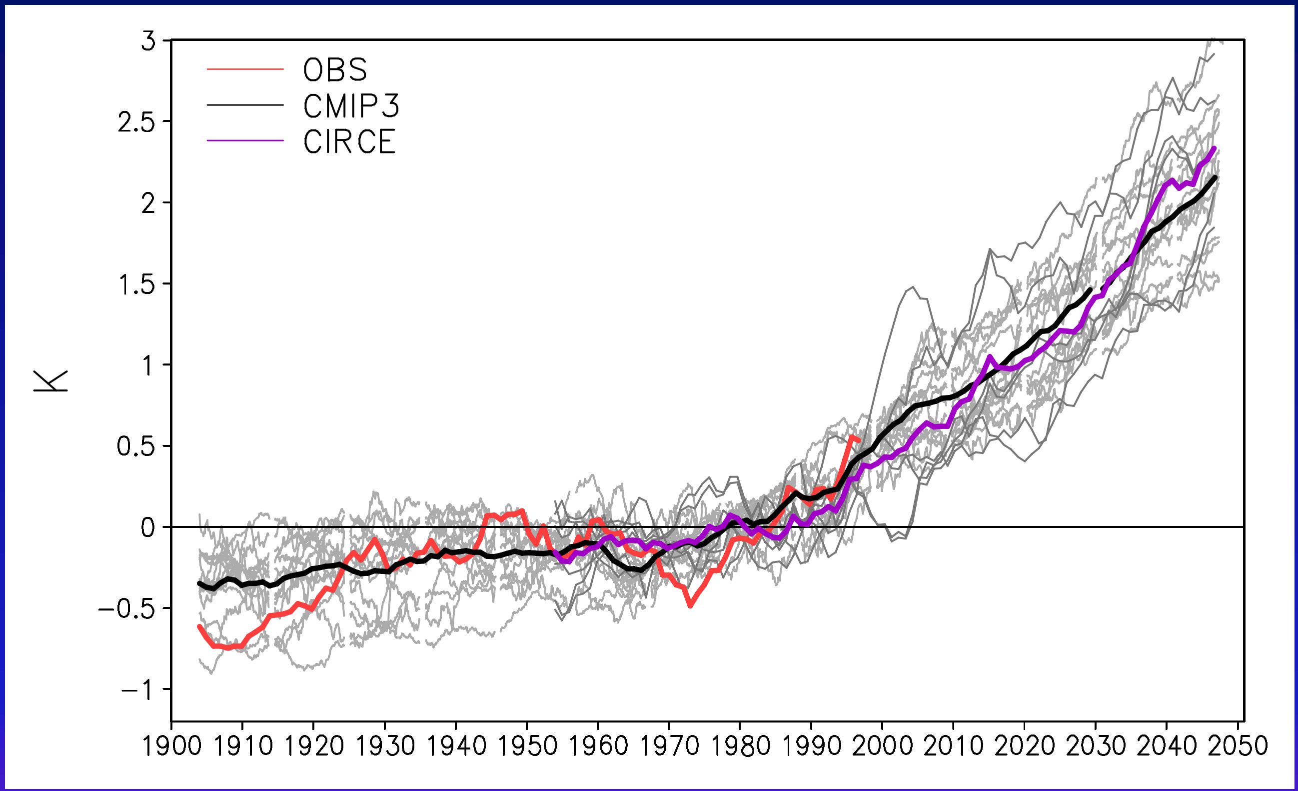



## Med Changes as part of a large-scale pattern of drying

- Northward expansion of the Hadley Cell subsidence zones
- Increased humidity which, in areas of mean moisture divergence, leads to increased mean moisture divergence and reduced P – E.



# Observed and "forced" temperature changes over Mediterranean land

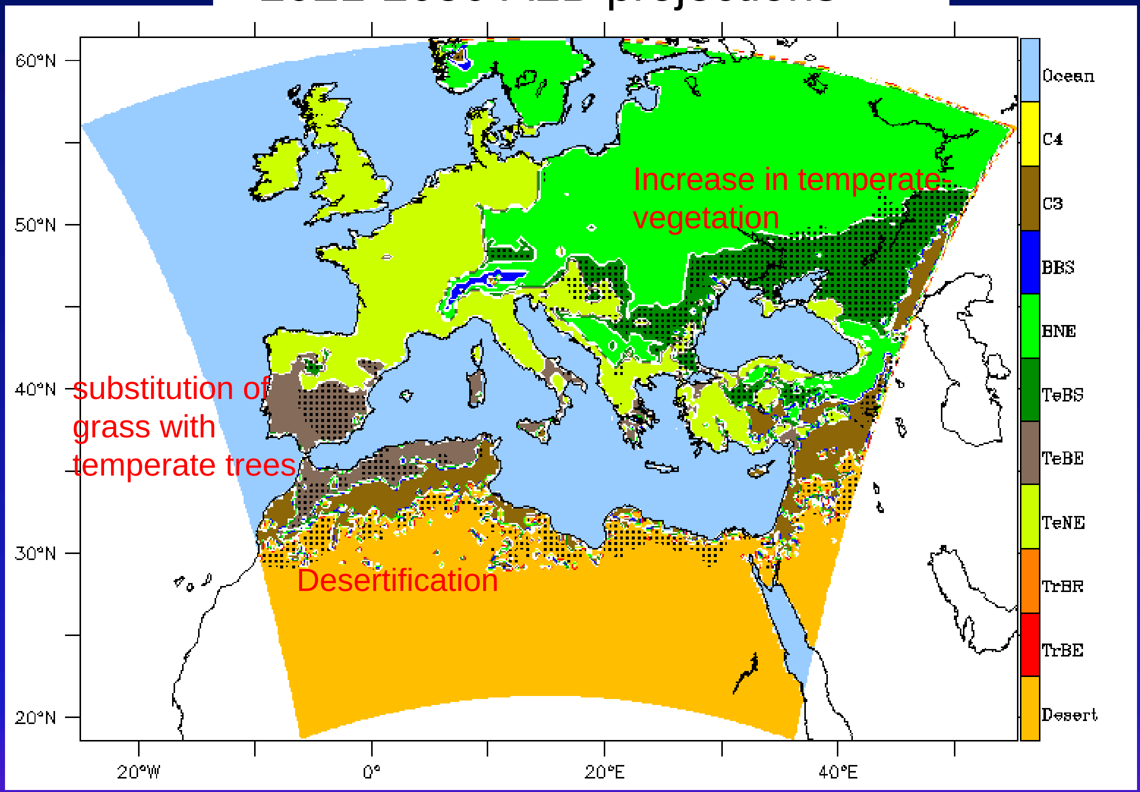



Projected (A1B) Mediterranean land warming by 2050 is about 2 K (simulated trend is ~ 0.3 K per dec during 2000 – 2050, observed trend over 1850-2007 is 0.045 K per dec).

*Mariotti et al., 2011 In preparation*

# Sensitivity of natural vegetation cover to projected increases in drought

2021-2050 A1B projections

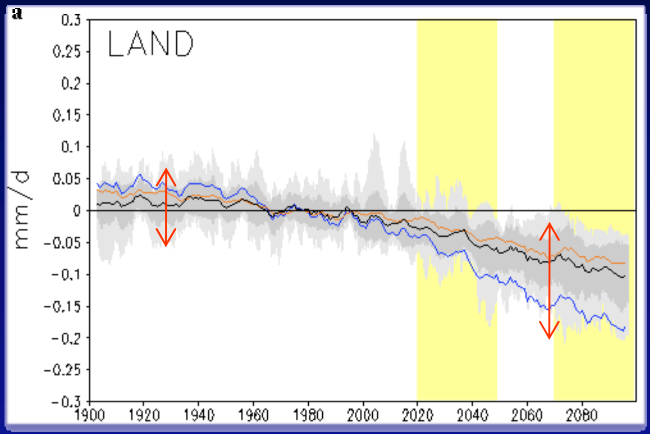



Warming, water-stress and fires → natural vegetation changes

Areas with vegetation changes are stippled. Projections are obtained using a dynamic vegetation model (LPJ) forced by fully coupled high resolution (30Km) regional ocean-atmosphere model simulations. Boundary conditions are from ECHAM5 A1B scenario simulations.

Anav and Mariotti, Clim Res, 2011

# Projections Caveats and Uncertainties



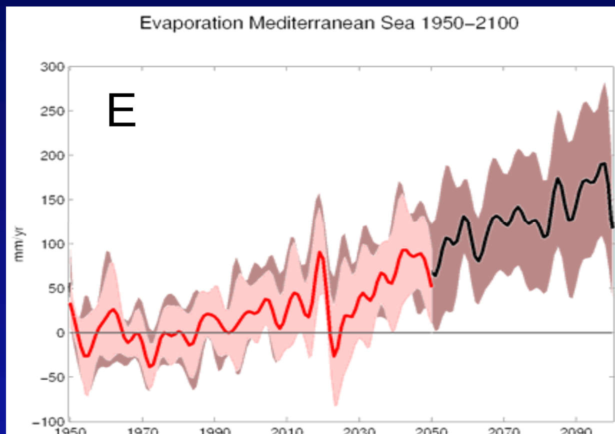

-General uncertainties associated with global climate projections (model errors, natural climate variability and forcing uncertainties)…

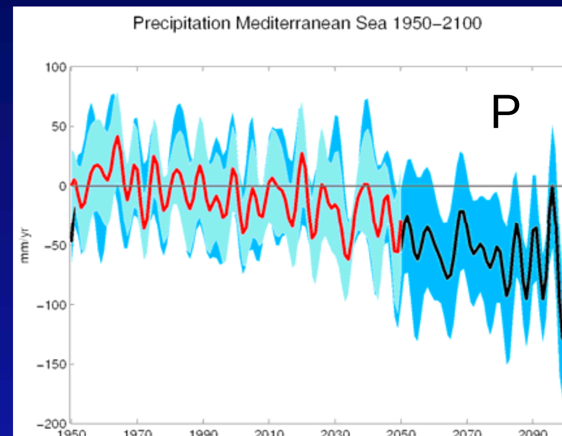
- Inter-model consistency for climate projections in this region is high, however models could all be making similar errors..

-Regionally specific uncertainties, e.g. representation of:

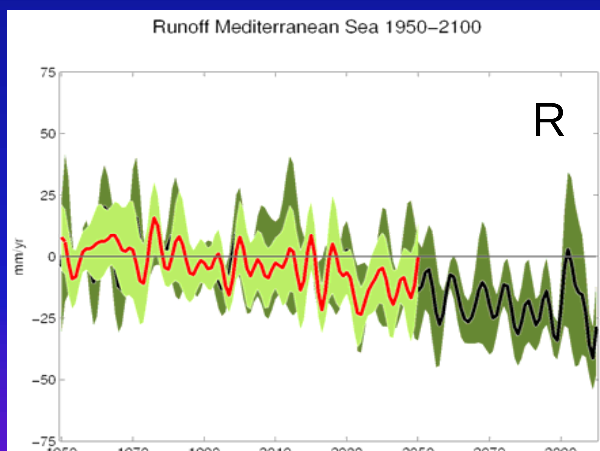
- large-scale influences on regional climate?
- processes associated to the complex regional topography (e.g. Alps)?
- the Mediterranean Sea and exchanges at Gibraltar?

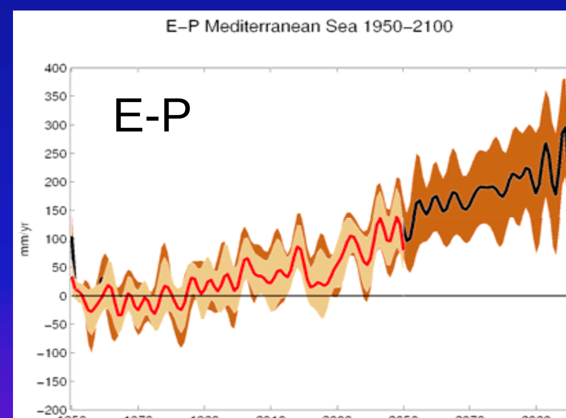
# ENSEMBLES – regional climate model projections over the Mediterranean




12 RCMs (25km res) with BCs (surface & lateral) given by various GCMs' A1B scenarios



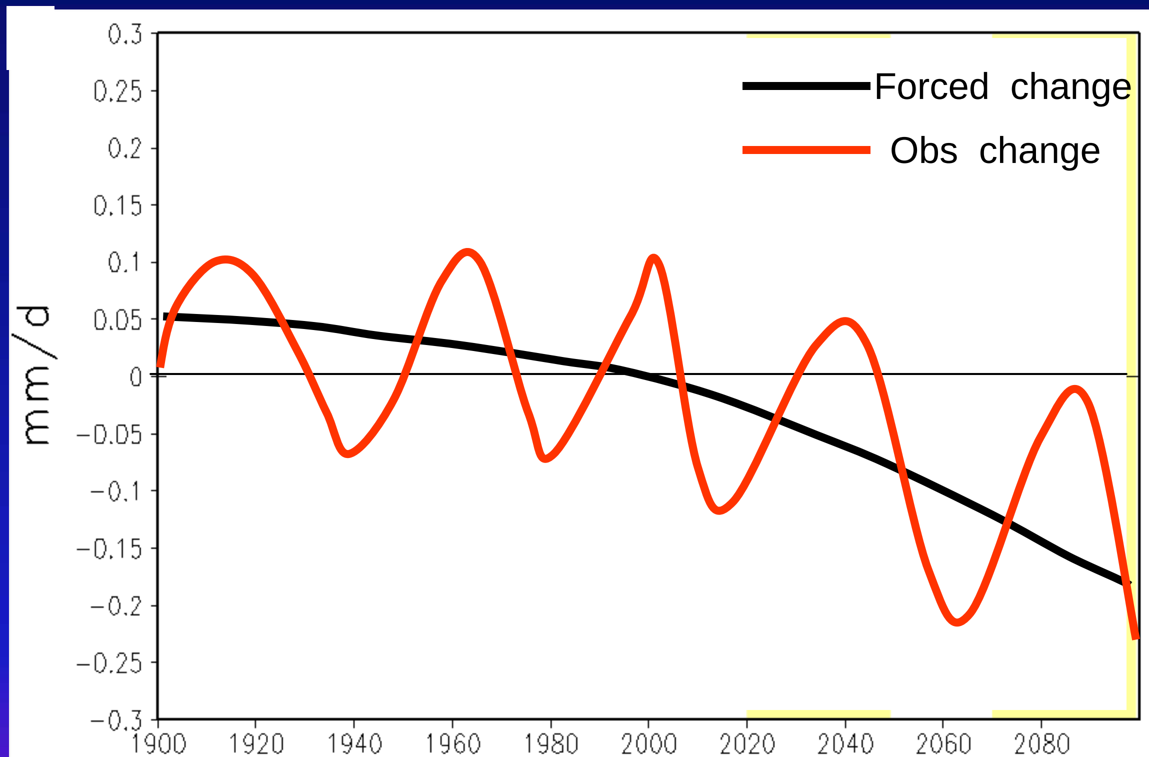

uncertainties are larger for RCMs than for GCMs as RCM uncertainty is a combination of RCM and GCM uncertainty

"Bottom line" from the ENSEMBLES RCMs is basically the same as from CMIP3 GCMs

(Sanchez, Somot, Mariotti, GRL 2009)

# Summary: Prospects for decadal predictability

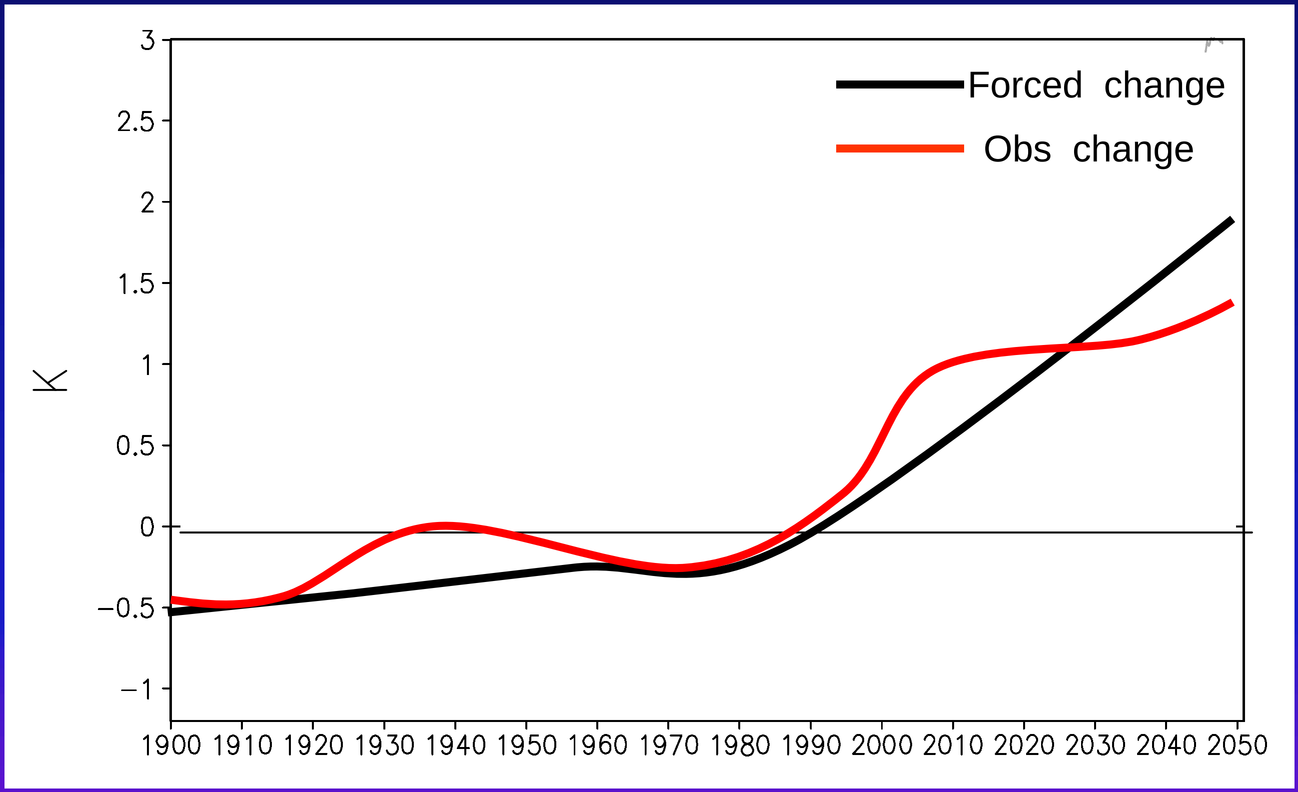
# Conceptual Thinking: Mediterranean Precipitation




-Observed decadal variations are about 0.1 mm/d in amplitude

-Projected forced change is about 0.02 mm/d per decade.

# Conceptual Thinking: Mediterranean Air Temperature




-Observed decadal variations are about 0.5 K in amplitude
-Projected forced changes is about 0.3 K per decade.

# Summary: Decadal Predictability Prospects in the Mediterranean

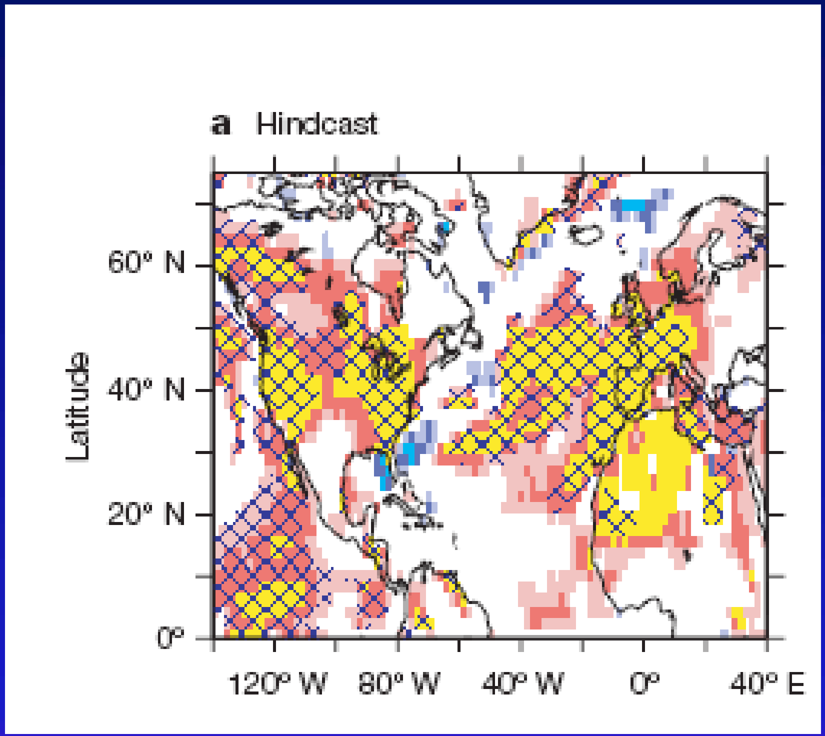
-For centennial time-scales, externally "forced" climate variability is likely a source of predictability for the Mediterranean region (if one knows the forcing, it is a BC problem..).

-In the short-term (10-30 yrs out), "internal" variability is still going to be an important factor especially for precipitation (for annual mean precipitation and surface air temperature, past decadal variations are about one order of magnitude larger than the trends).

-Decadal precipitation variations in the Med. are influenced by the NAO, especially in DJF. At this point, NAO variability is still unpredictable (?).

-Med temperature variations (both air temperature and SST) show linkages with the AMO. So there is potential for predictability of temperature and associated changes to the extent that the AMO may be predictable (?).

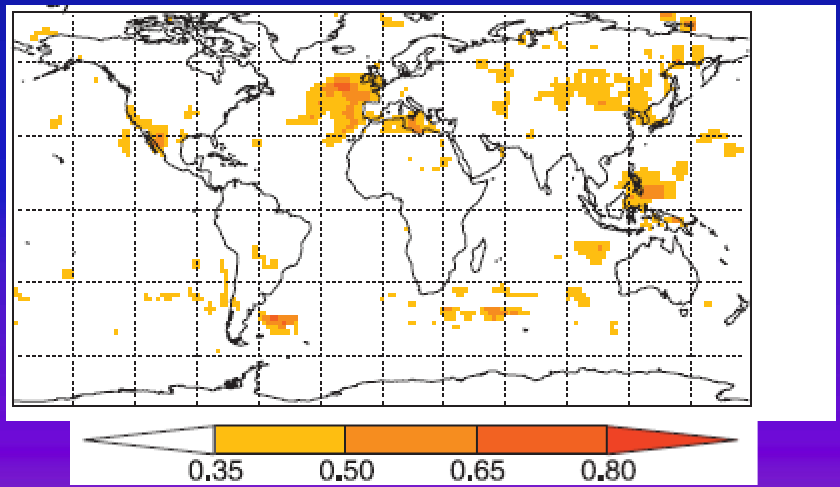
# Regional decadal prediction skill from emerging decadal prediction systems




**Keenlyside, 2008**. Correlation skill in predicting observed ten-year mean Ts anomalies a decade in advance. [9 ten-year-long predictions over the period 1955–2005, made with a climate model initialized using ocean (SST) observations and run with projected changes in radiative forcing].

**Initialized coupled model decadal hindcast experiments**

**The AMO-linkage is likely contributing to the decadal prediction skill for surface air temperature found in parts of the Mediterranean.**




**Pohlmannn et al., 2009**: Prediction skill for Ts of the 10yr hindcasts. Initialization by assimilation of ocean reanalyses products (GECCO temperature and salinity).

# Thank you!

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