Origins of the extremely warm European fall of 2006

Julien Cattiaux
R. Vautard, P. Yiou

LSCE – IPSL France

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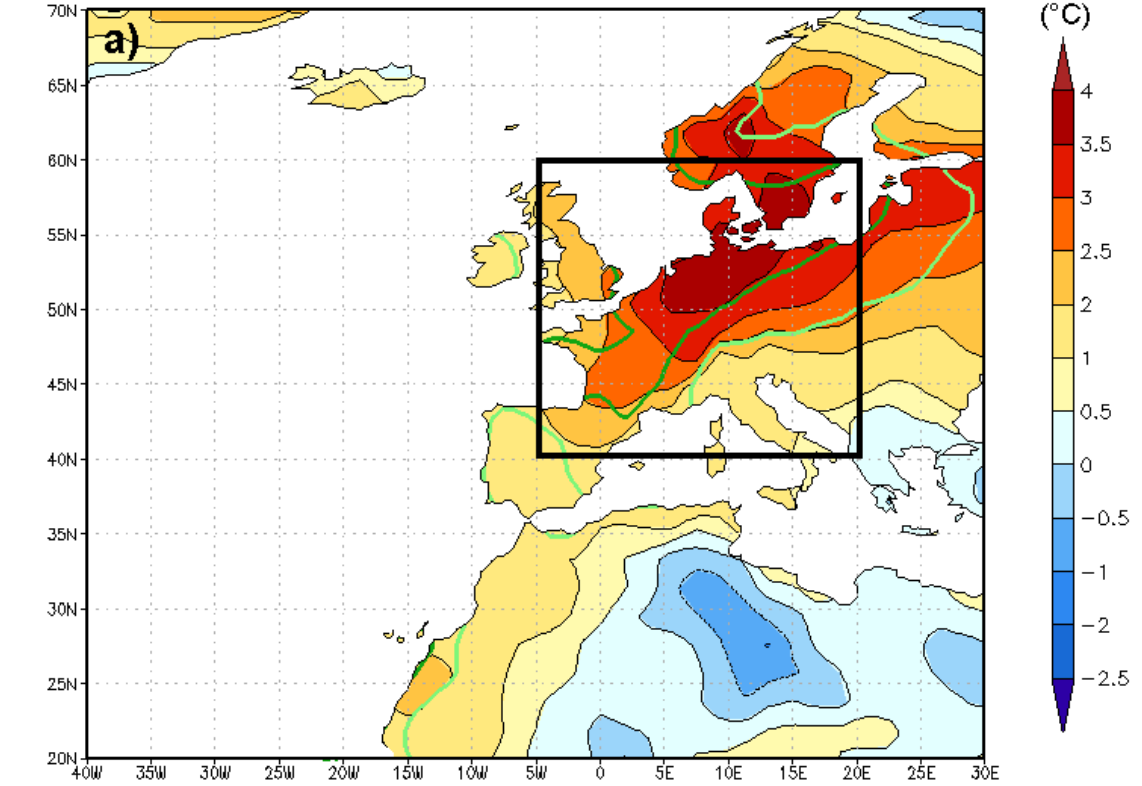
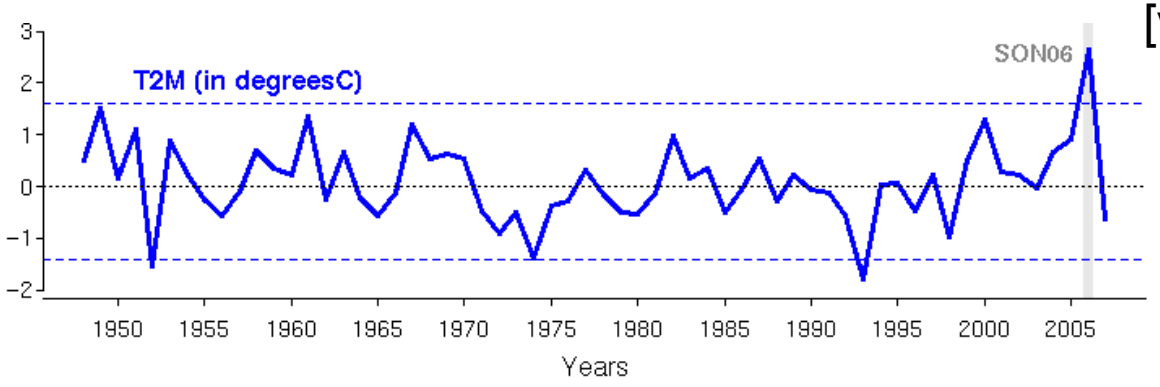
CL1 Session: Climate Extremes and Impacts.

Fall 2006: Exceptional land temperature anomaly

T2M: SON 2006 anomaly & SON 1948-2007 time series





Dataset: 1948-2007 NCEP reanalyses [Kistler et al., 2001, *BAMS*].

T2M anomaly: **+2.6 degC**.

Corresponds to **3.5σ** of the distribution.

Impacts on phenology and ecosystems.

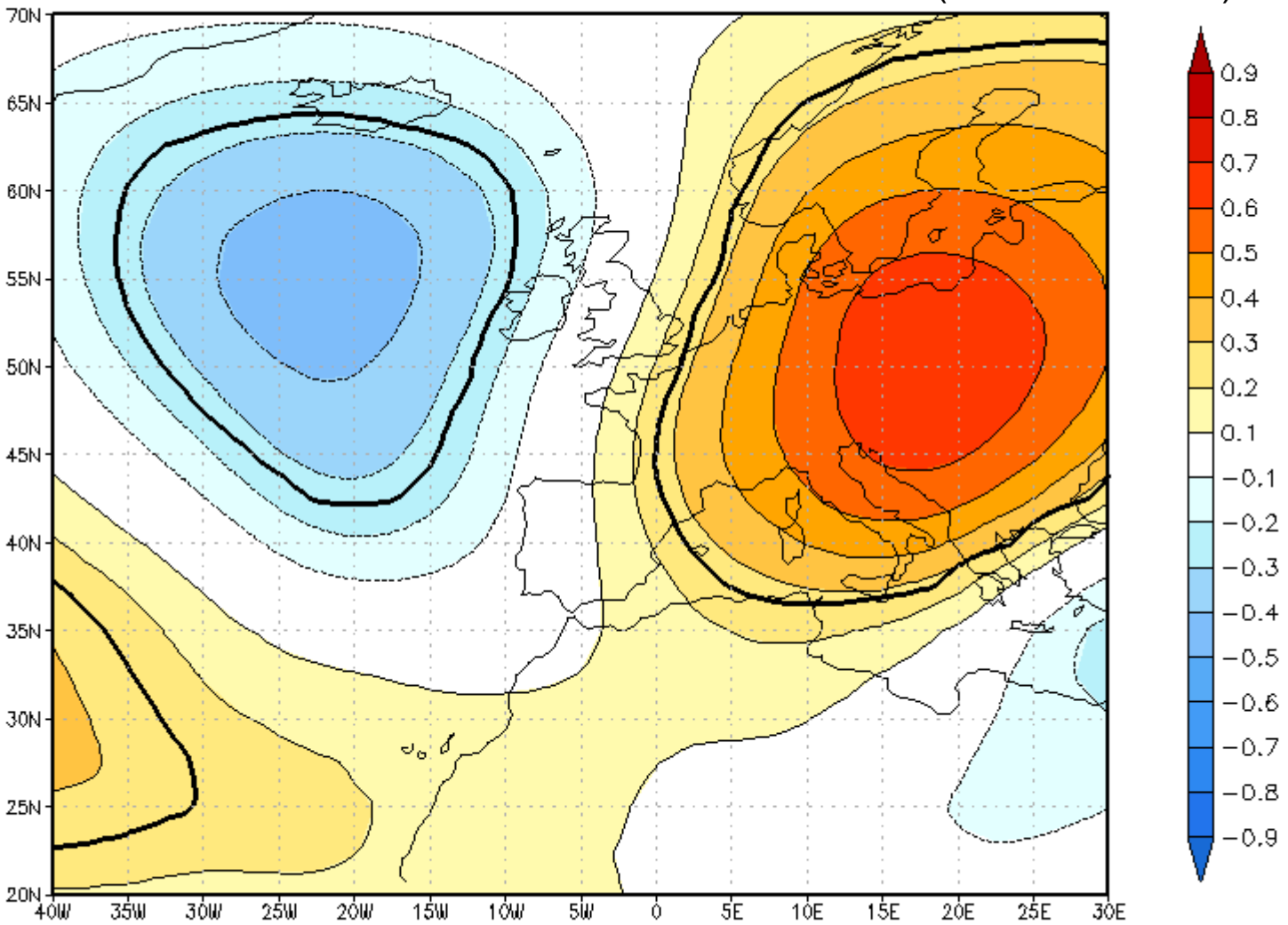
See also
[Luterbacher et al., 2007, *GRL*]
[Piao et al., 2008, *Nature*]
[van Oldenborgh, 2007, *Clim. Past.*]

How to explain this exceptional anomaly?

[Cattiaux et al., 2009, *GRL*]

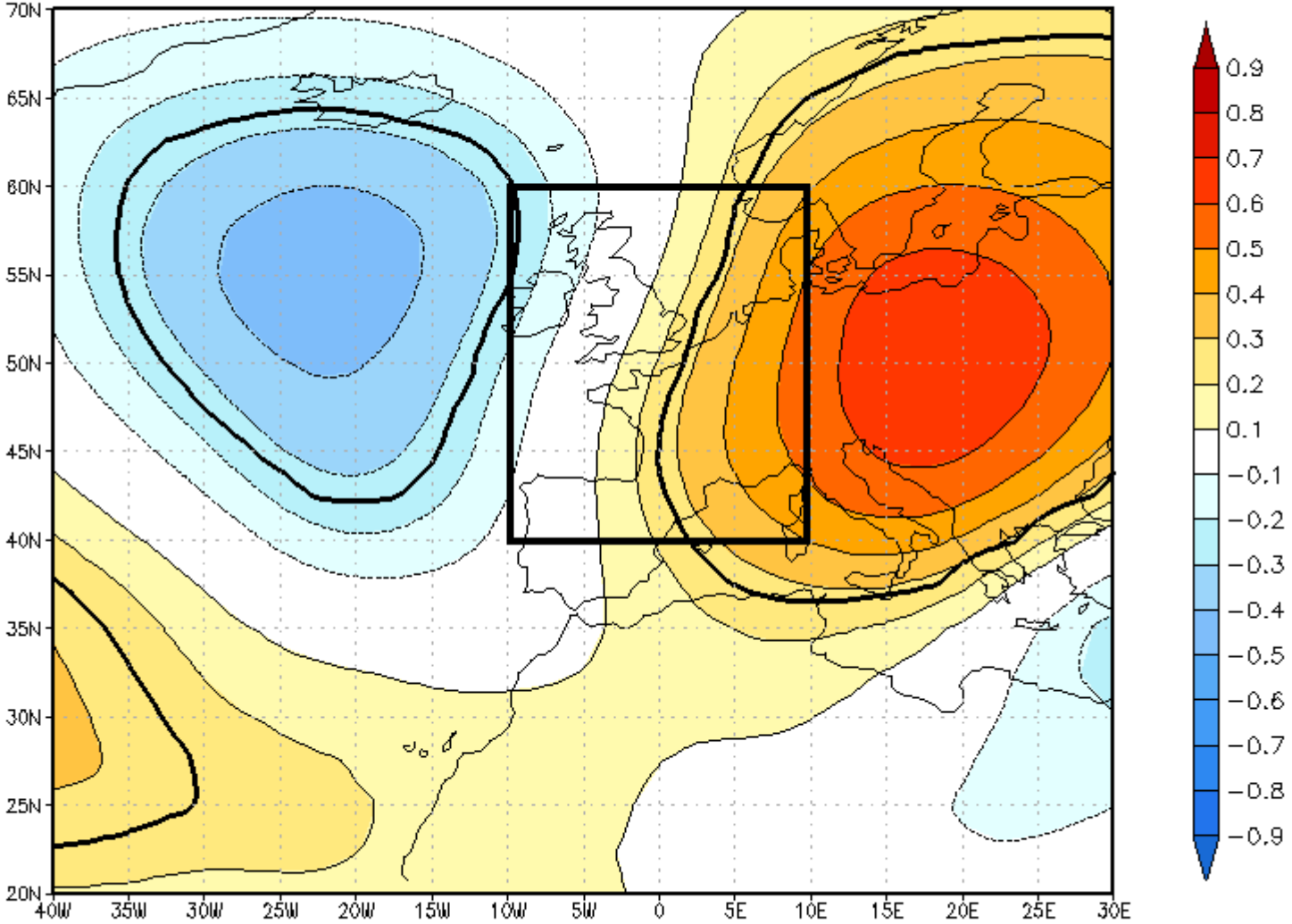
European temperatures and atmospheric circulation

Correlation between Z500 field and T2M time series (SON 1948-2007)



European fall temperatures are **strongly linked** to a dipole of the geopotential height, i.e. to the meridional flow.

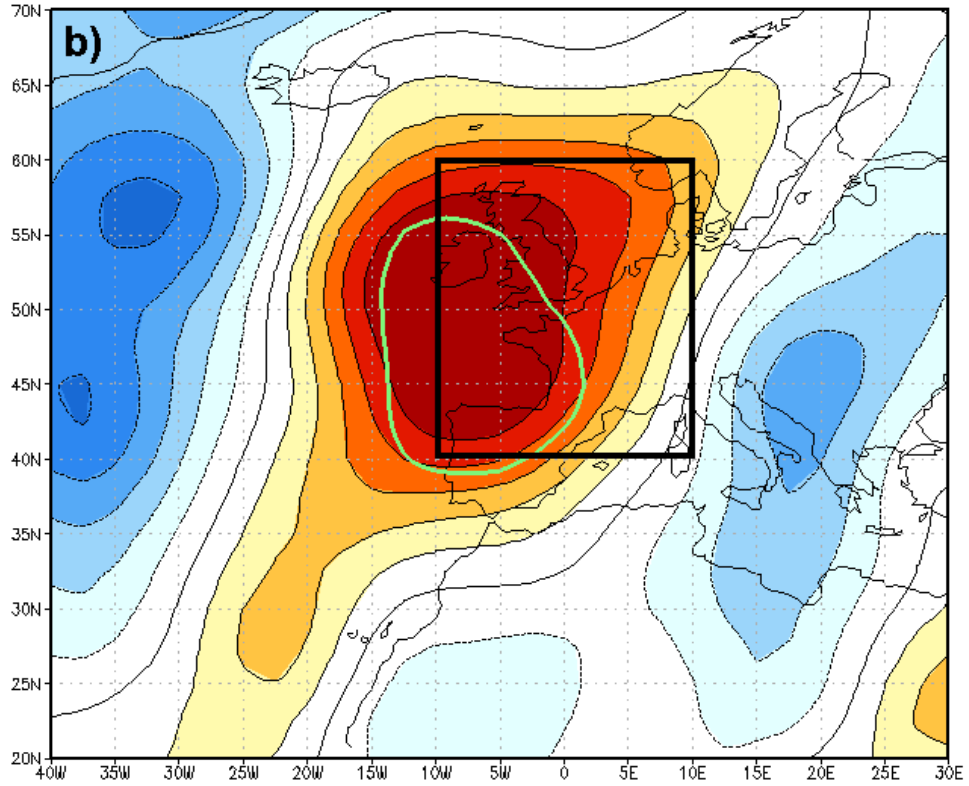
Correlation between Z500 field and T2M time series (SON 1948-2007)

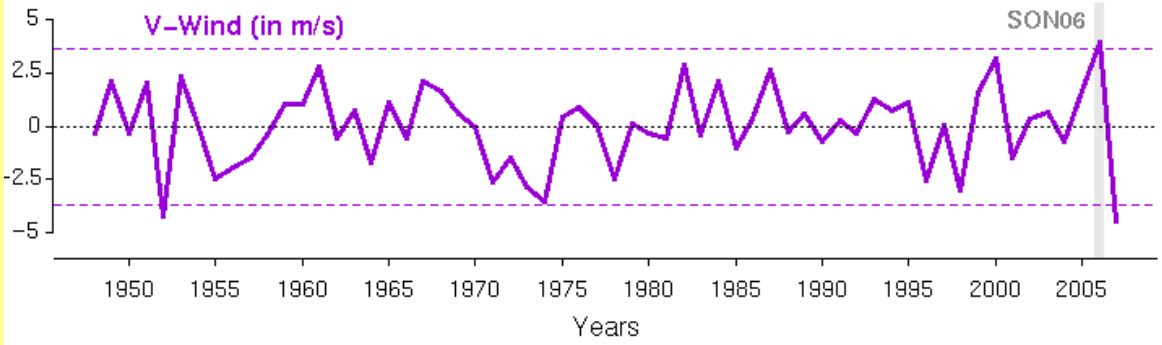


The best correlation is found for the **V-Wind** at 500mb over this area: r = 0.72 (p.value = 8.10^{-11}).

Fall 2006: Exceptional V-Wind anomaly

V-Wind: SON 2006 anomaly & SON 1948-2007 time series





V-Wind (500mb) anomaly: **+3.9 m/s.**

Corresponds to **2.1σ** of the distribution.

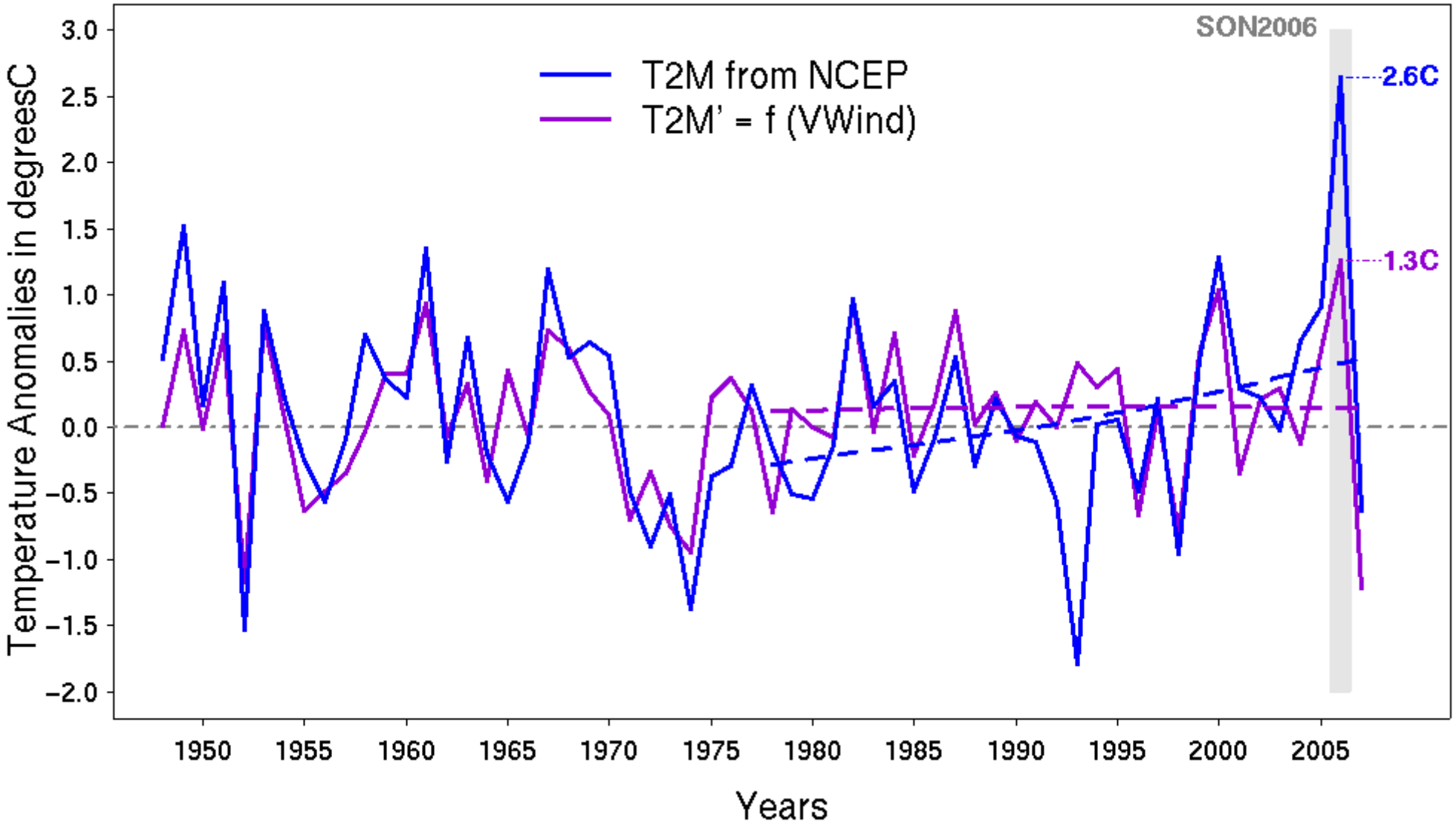
Record since 1948.

Does this anomalous atmospheric flow explain the fall 2006 warm anomaly?

[Cattiaux et al., 2009, *GRL*]

Dynamics contribution: seasonal anomalies

Reconstruction of fall T2M anomalies from V-Wind anomalies (linear regression)



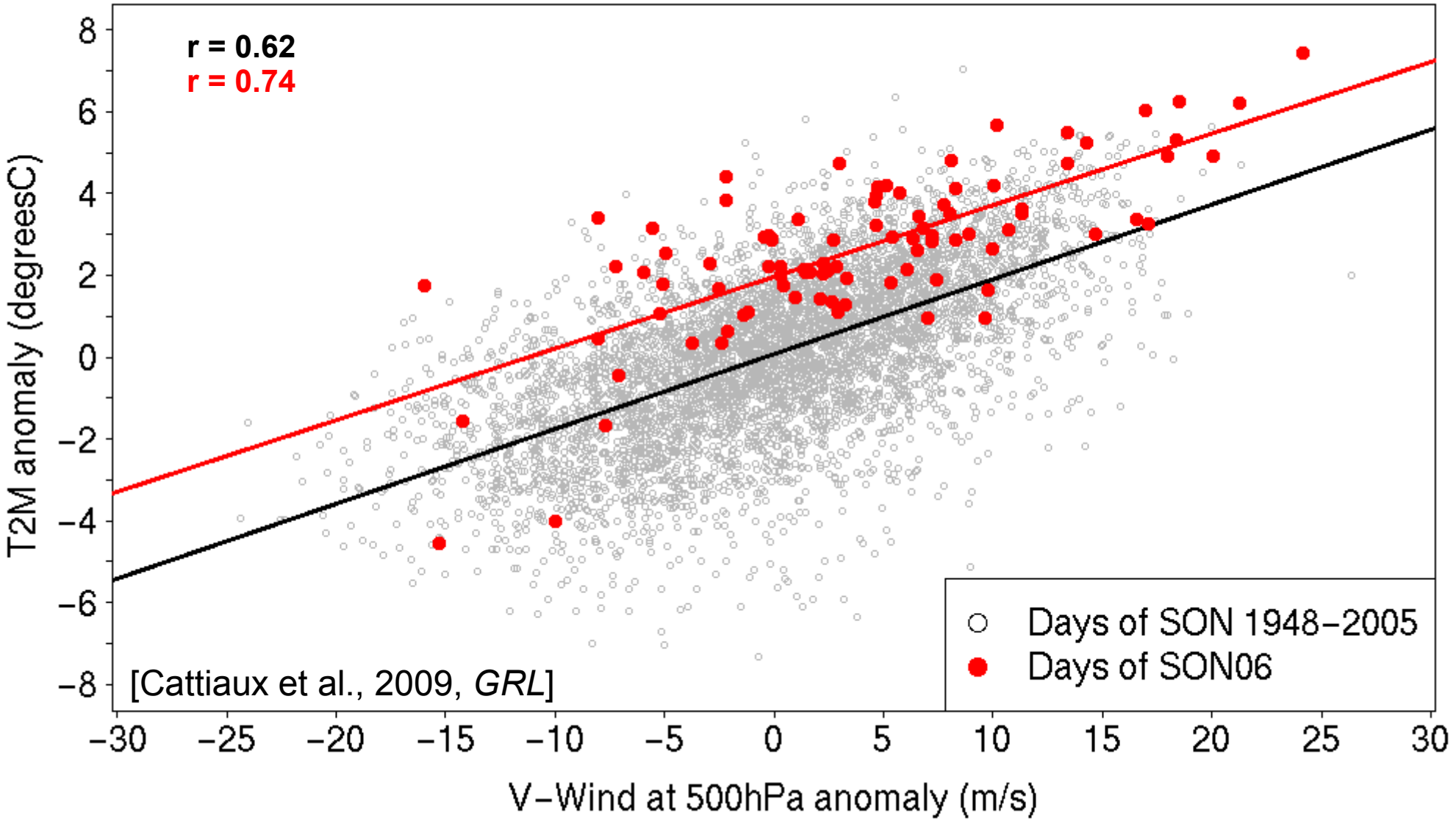
High correlation (r = 0.72).

The fall 2006 anomaly is only « half » reconstructed.

The 1978-2007 warming trend is not represented.

Dynamics contribution: daily anomalies

Scatter plot of daily anomalies: T2M vs. V-Wind over SON 1948-2006

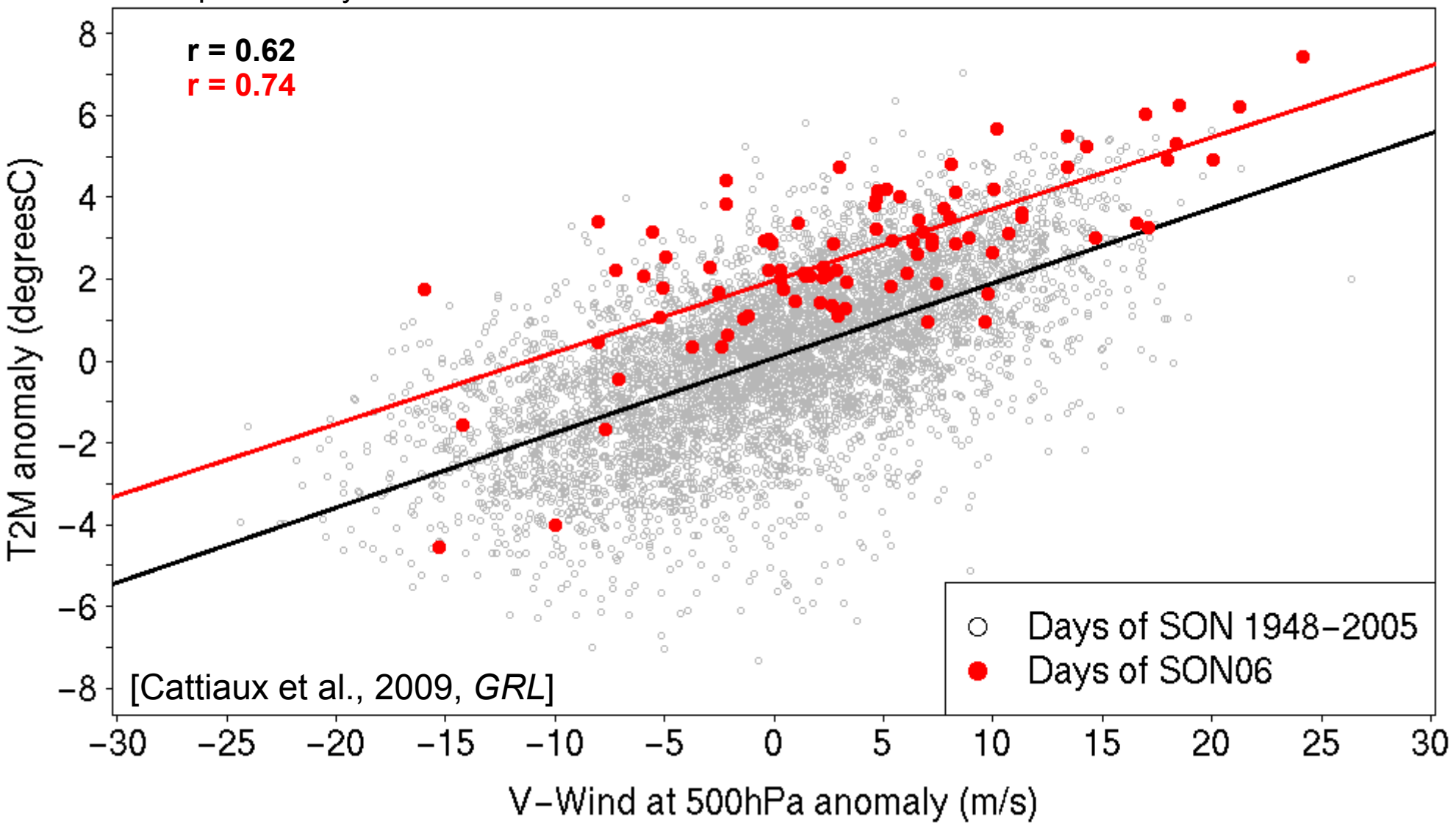


The regression lines are **parallel**.

Red dots appear **shifted upward**.

Dynamics contribution: daily anomalies

Scatter plot of daily anomalies: T2M vs. V-Wind over SON 1948-2006



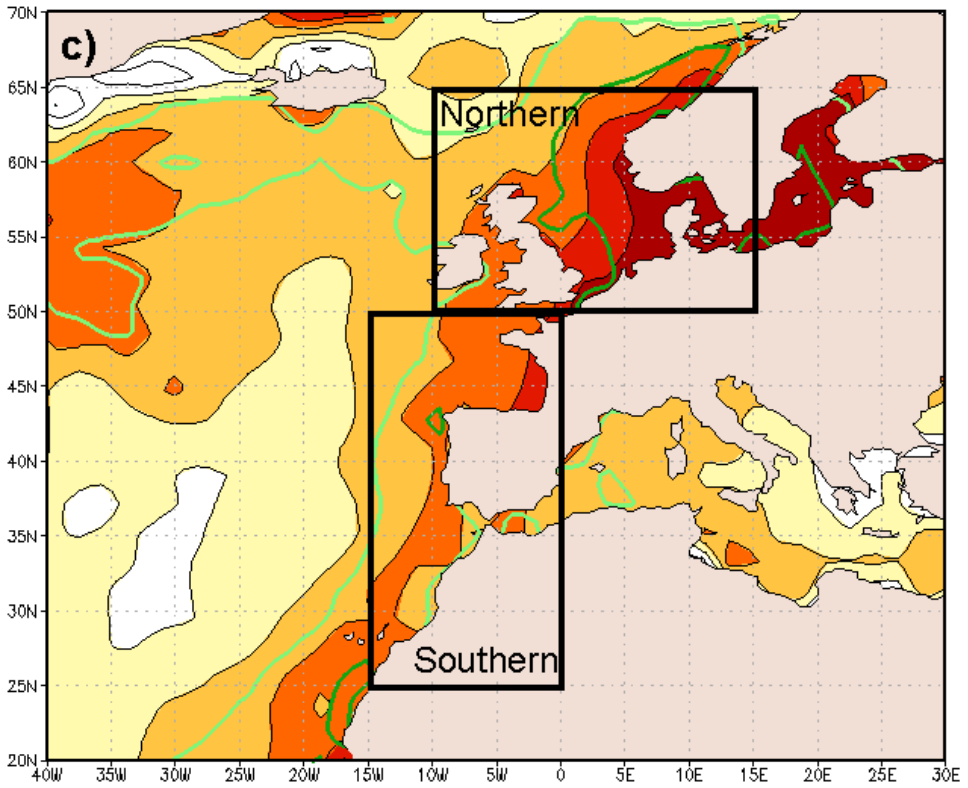
The meridional flow influences the T2M daily variability of fall 2006 in the same way than in the past.

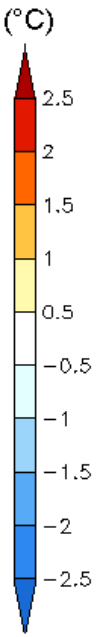
The land temperatures are globally enhanced.

See also
[Yiou et al., 2007, *GRL*]

Fall 2006: Exceptional SST anomaly

SST: SON 2006 anomaly & SON 1948-2007 time series





Coastal SST anomaly: **+1.6 degC.**

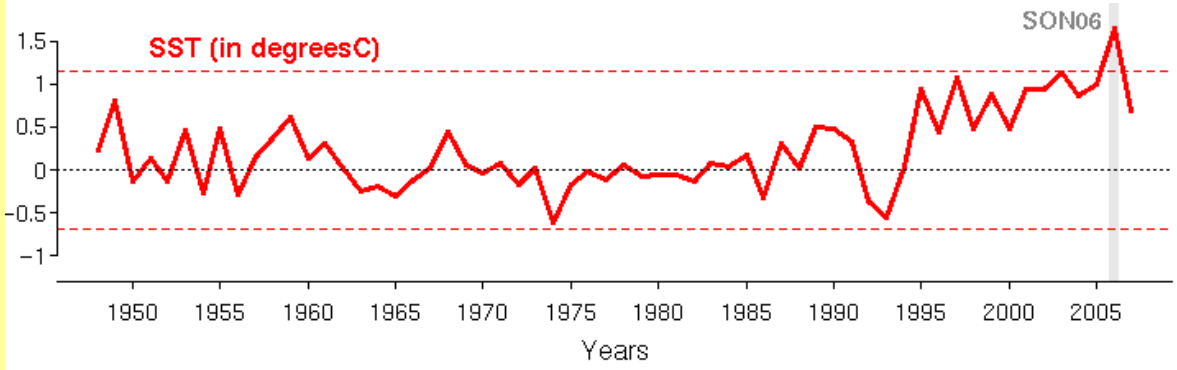
Corresponds to **3.6σ** of the distribution.

Record since 1948.

Acts in a warming trend.

Southern anomaly (+1.5 degC, 3.3σ): deficit in the coastal upwelling.

Northern anomaly (+1.8 degC, 3.6σ): consequence of the *Southern* anomaly.

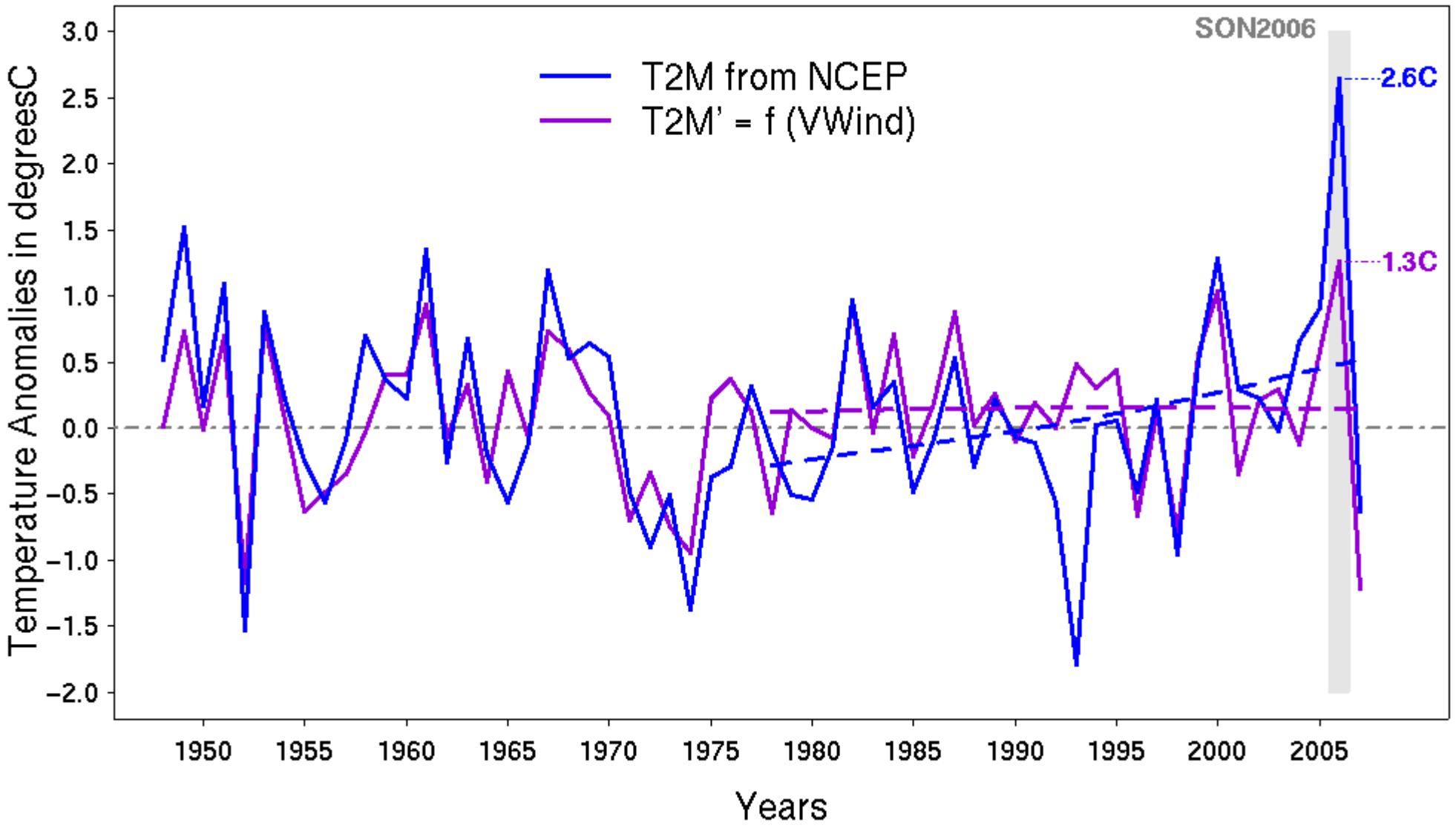


What is the contribution of the SST to the fall 2006 warm anomaly?

[Cattiaux et al., 2009, *GRL*]

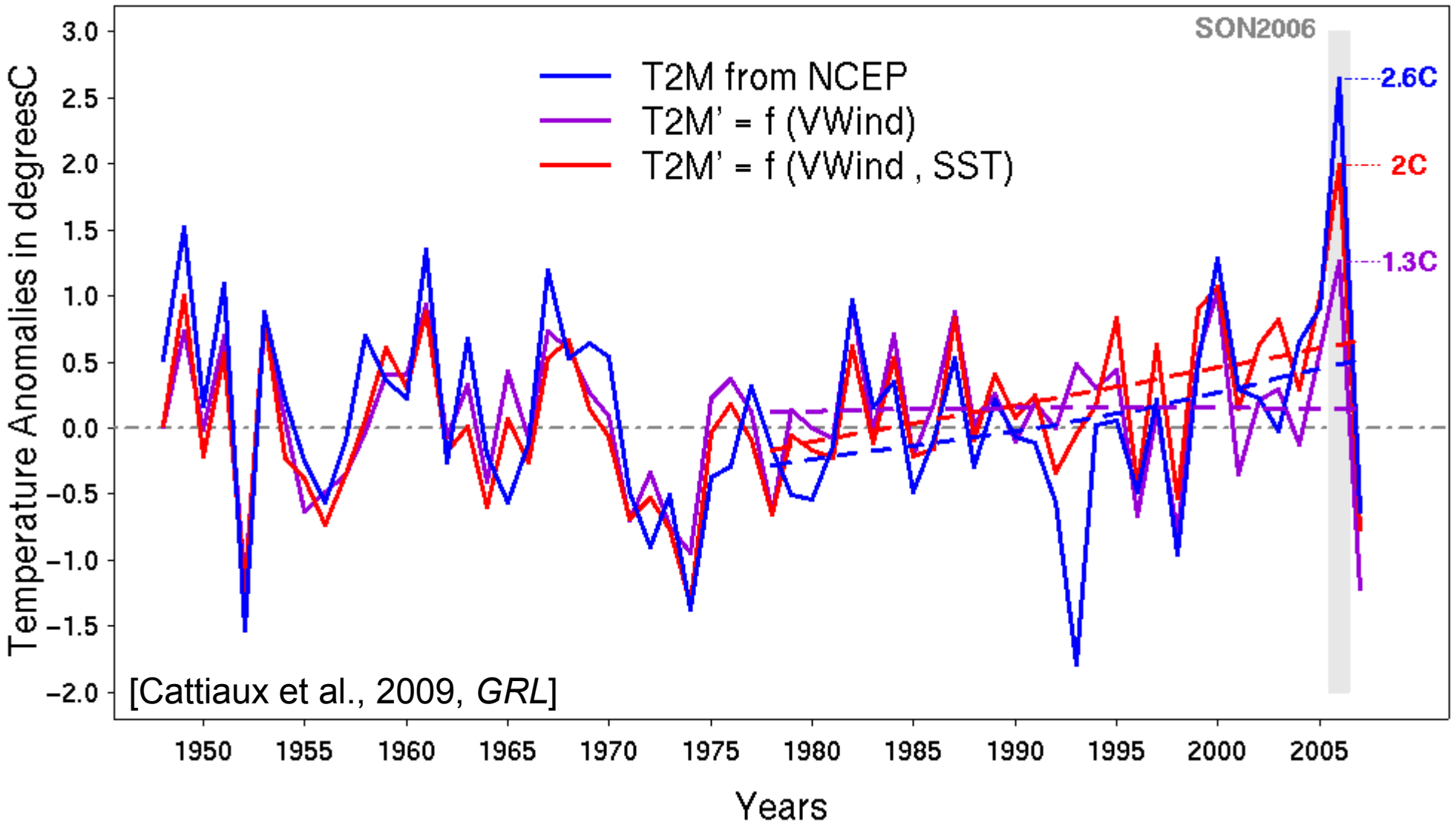
SST contribution: seasonal anomalies

Reconstruction of fall T2M anomalies from V-Wind and SST anomalies (linear regressions)



SST contribution: seasonal anomalies

Reconstruction of fall T2M anomalies from V-Wind and SST anomalies (linear regressions)

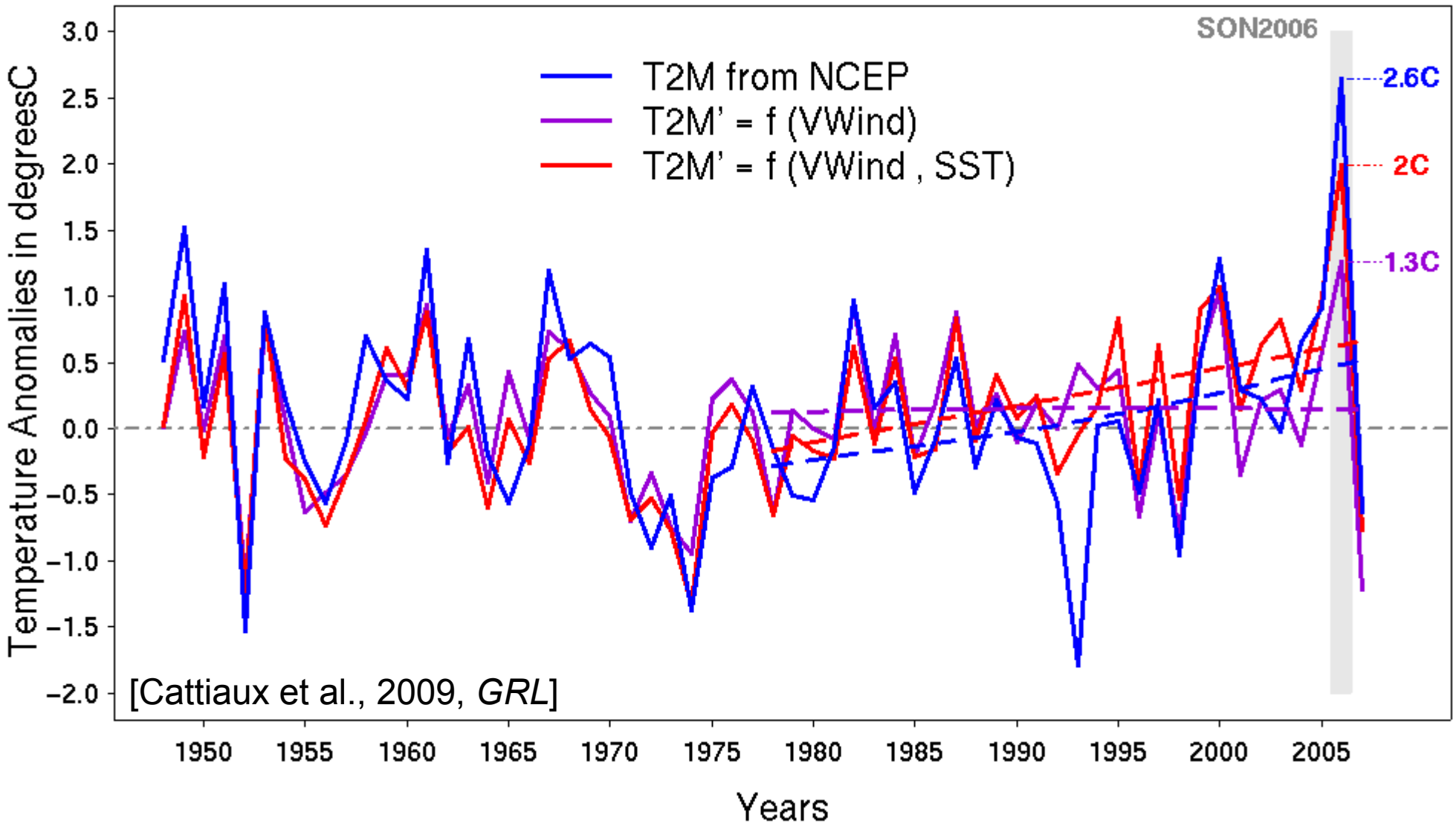


Higher correlation (r = 0.72 to r = 0.81).

The **fall 2006** anomaly and the 1978-2007 **warming trend** are better reconstructed.

SST contribution: seasonal anomalies

Reconstruction of fall T2M anomalies from V-Wind and SST anomalies (linear regressions)



Additivity of forcings: the +2.6 degC temperature anomaly of the fall 2006
= 1.3 degC due to atmospheric circulation (50%)
+ 0.7 degC due to SST (30%)
+ 0.6 degC unexplained so far (20%).

Model details

MM5 = Penn State University / NCAR 5th generation of Mesoscale Model.
See [Duddhia 1993, *Mon. W. Rev* ; Grell et al., 1994, *NCAR Tech. Note*].

Non-hydrostatic equations of motion over a predefined domain.
32 vertical levels and 4 active soil layers.
Domain: Eastern Atlantic – Western Europe [40W-30E ; 20-67N] area.
150x150 grid points, horizontal resolution of ~35km.
Simulations are driven with boundary conditions from ECMWF (4 x daily).

Sensitivity experiments

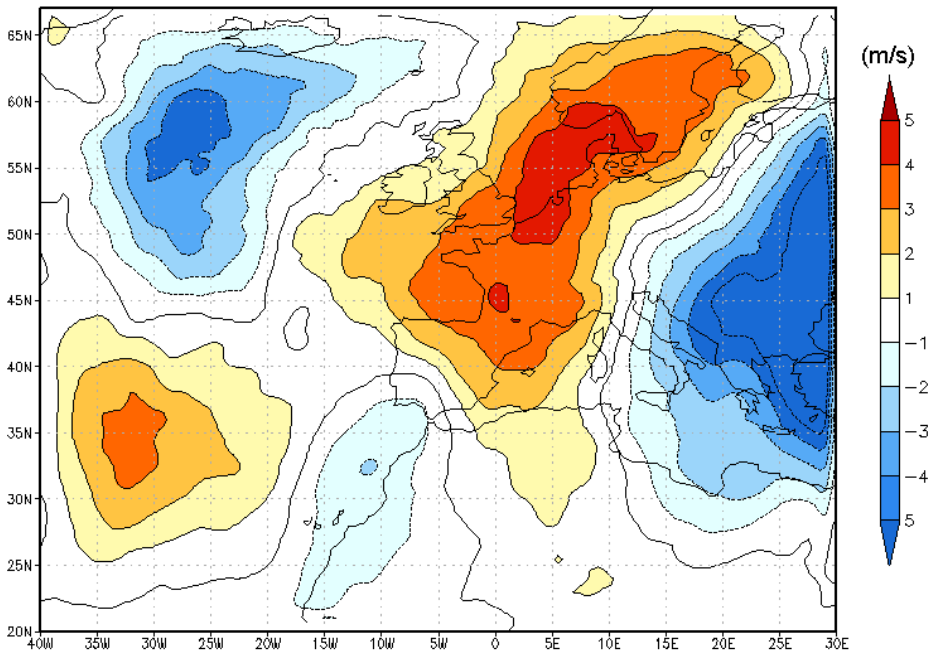
Playing with dynamics and SST forcings to isolate each contribution…

CTL: Wind 3D-field nudged and actual SST.
WNC: Wind 3D-field nudged and climatological (1961-1990) SST.
WFC: Wind 3D-field « free » and climatological (1961-1990) SST.

No nudging is applied to temperature and humidity 3D fields.

>> **WNC-WFC: Dynamics contribution**.
>> **CTL-WNC: SST contribution**.

WNC-WFC difference of V-Wind

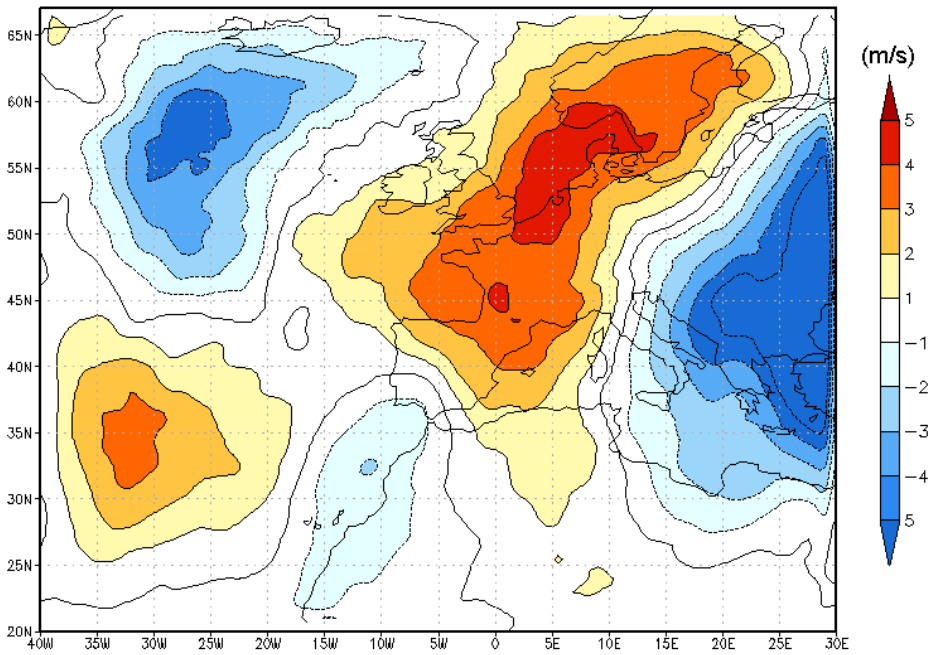


[Cattiaux et al., 2009, *GRL*]

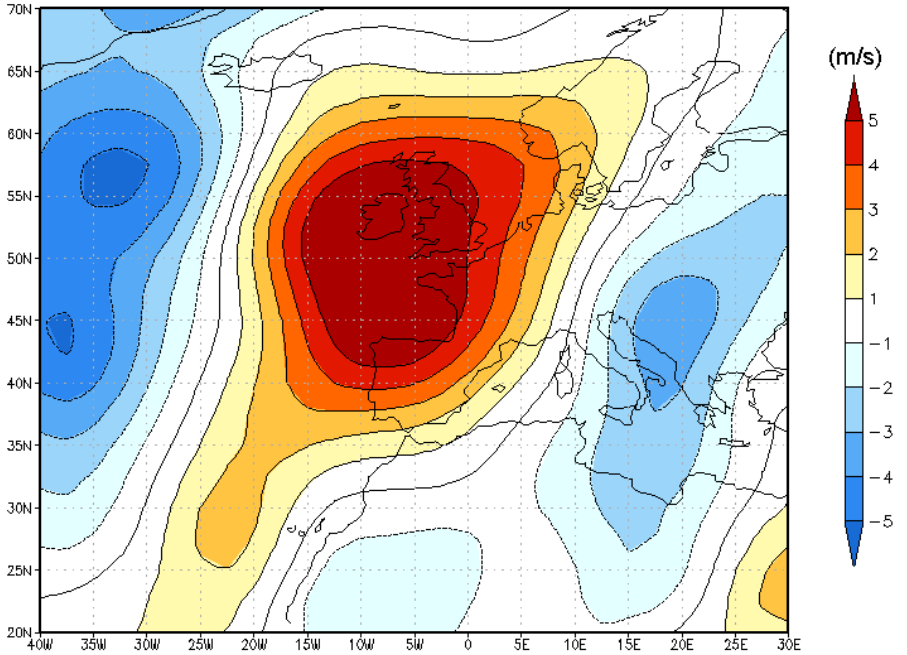
WNC-WFC: Sensitivity to atmospheric dynamics (3D wind nudged or not).

Dynamics contribution (MM5)

WNC-WFC difference of V-Wind



Fall 2006 V-Wind anomaly



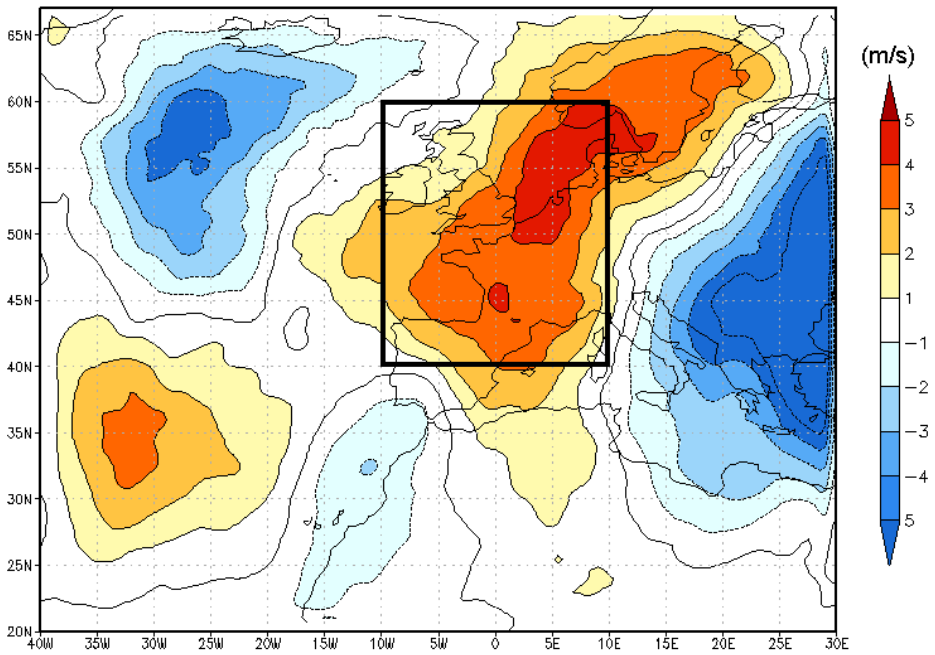
[Cattiaux et al., 2009, *GRL*]

WNC-WFC: Sensitivity to atmospheric dynamics (3D wind nudged or not).

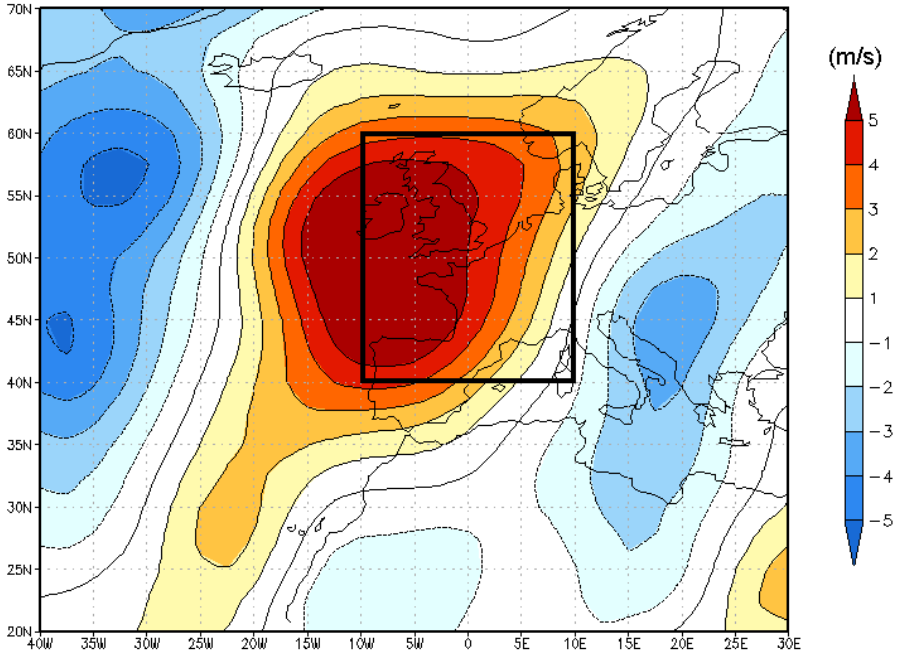
V-Wind difference:
Pattern comparable to the fall 2006 anomaly, albeit slightly shifted N-E.

Dynamics contribution (MM5)

WNC-WFC difference of V-Wind



Fall 2006 V-Wind anomaly



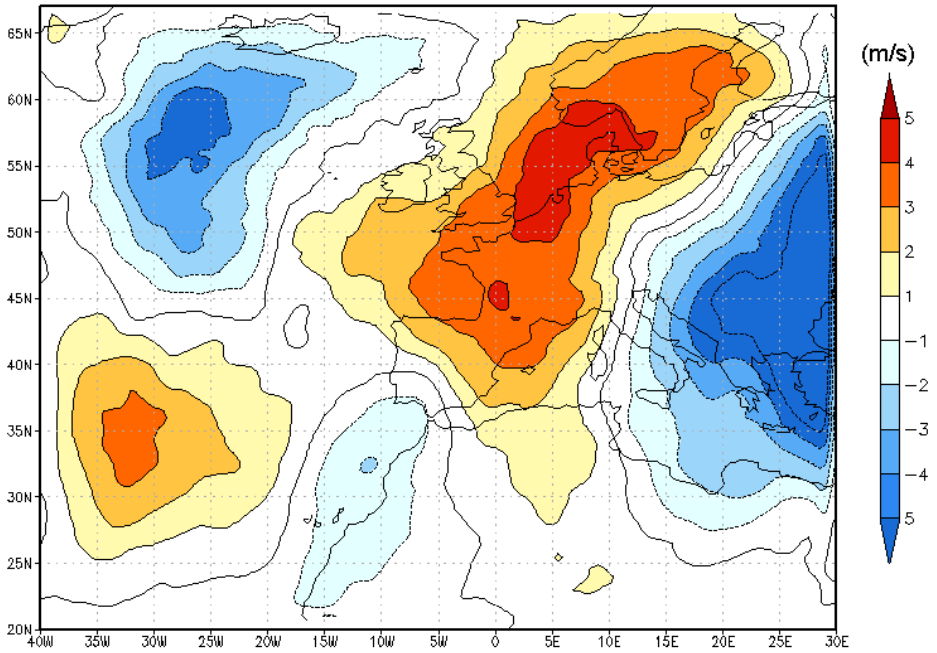
[Cattiaux et al., 2009, *GRL*]

WNC-WFC: Sensitivity to atmospheric dynamics (3D wind nudged or not).

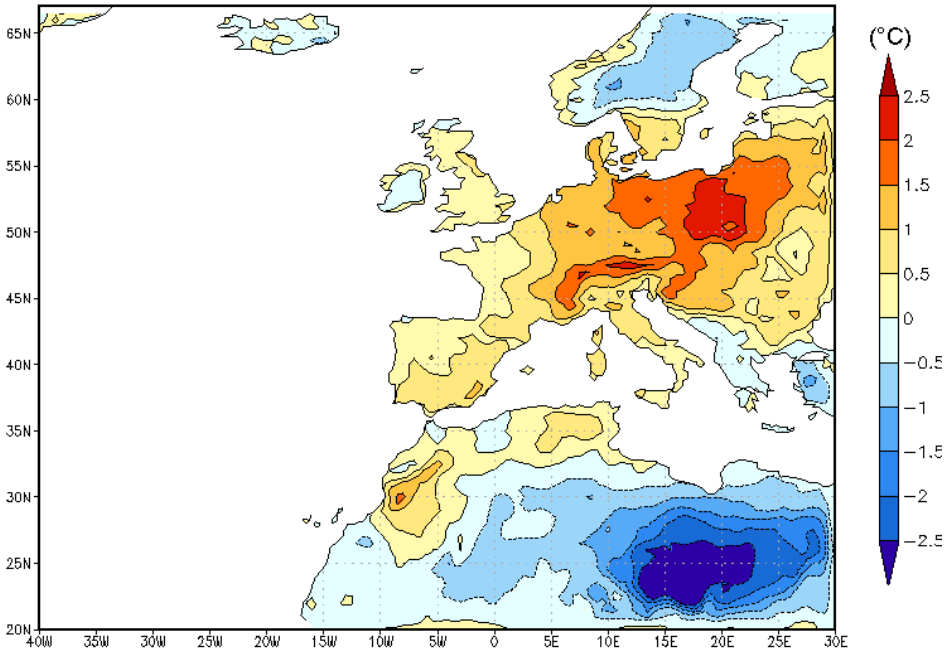
V-Wind difference:
Pattern comparable to the fall 2006 anomaly, albeit slightly shifted N-E.
Over the area: **2.8 m/s** (weaker than the **actual 3.9 m/s** anomaly).

Dynamics contribution (MM5)

WNC-WFC difference of V-Wind



WNC-WFC difference of T2M



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WNC-WFC: Sensitivity to atmospheric dynamics (3D wind nudged or not).

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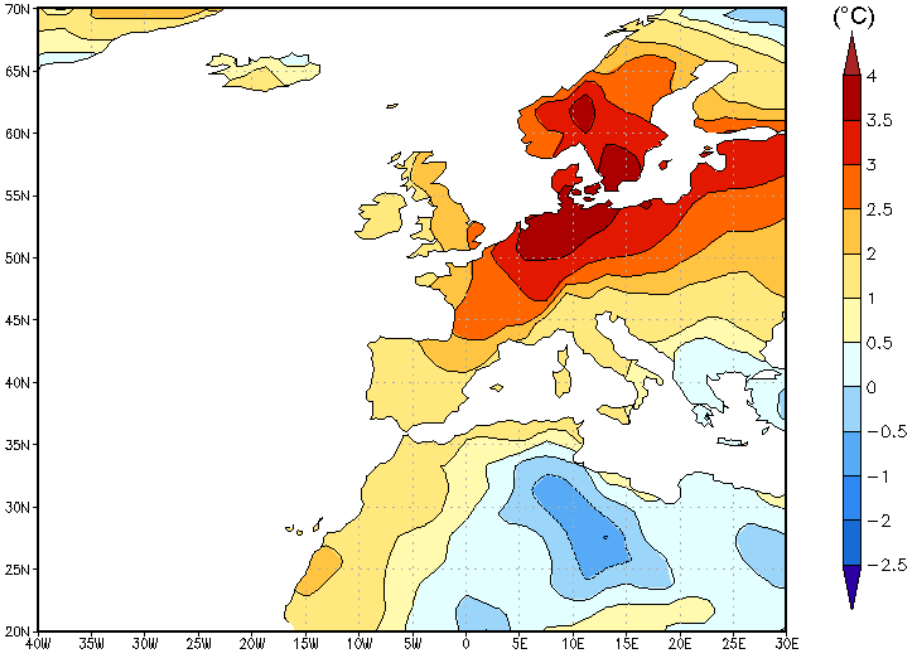
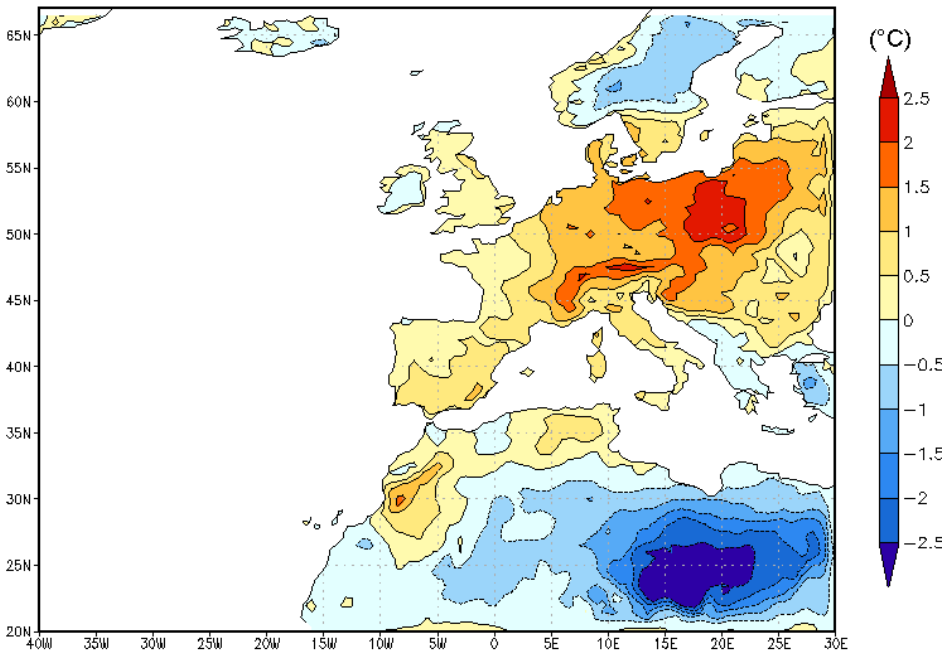
T2M difference:

Dynamics contribution (MM5)

Fall 2006 T2M anomaly



WNC-WFC difference of T2M



[Cattiaux et al., 2009, *GRL*]

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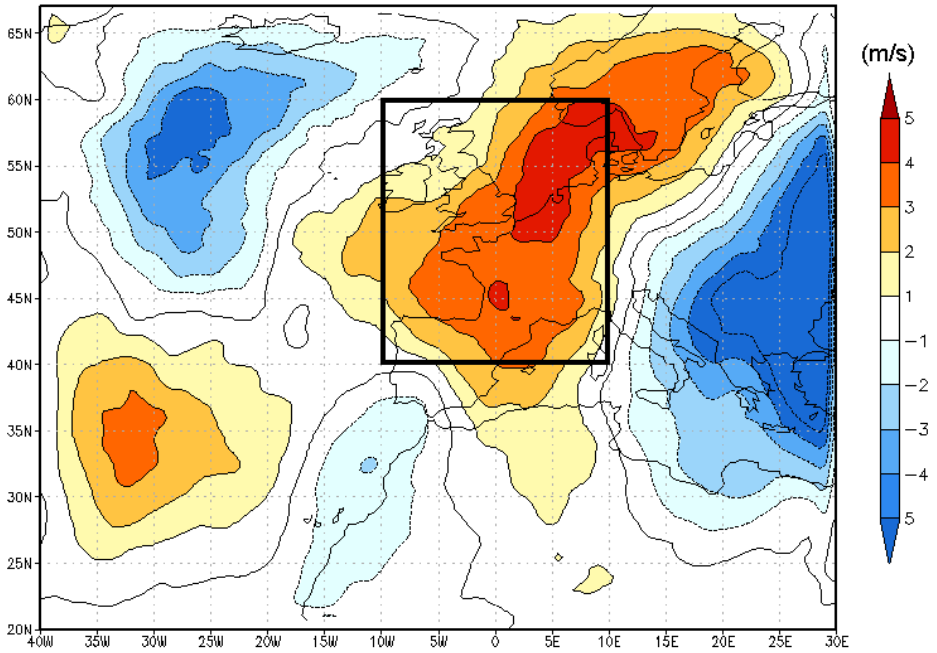
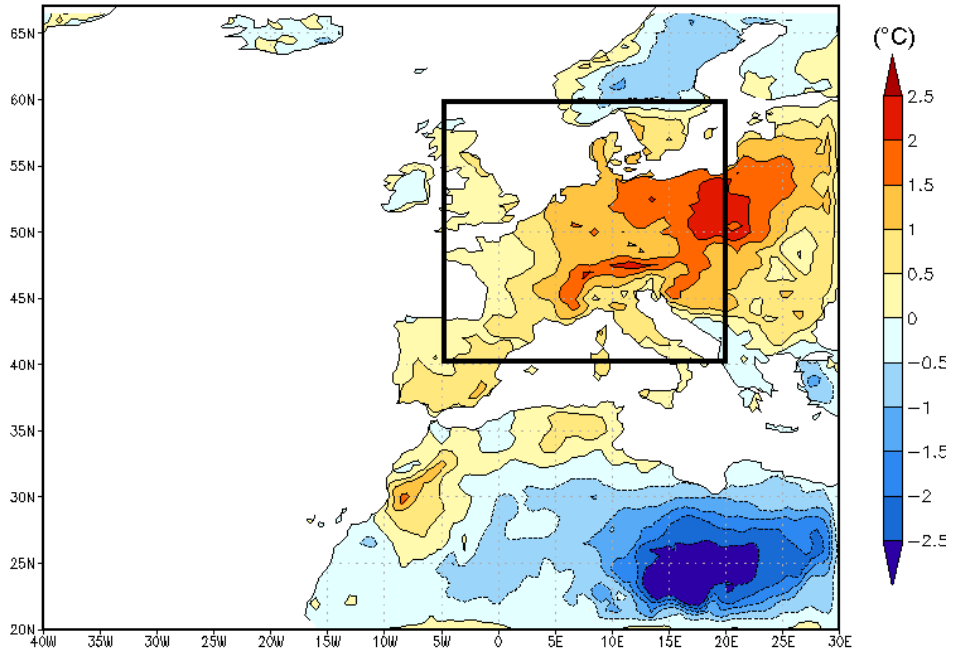
T2M difference:
The pattern of the fall 2006 is roughly reconstructed.

Dynamics contribution (MM5)

WNC-WFC difference of V-Wind



WNC-WFC difference of T2M



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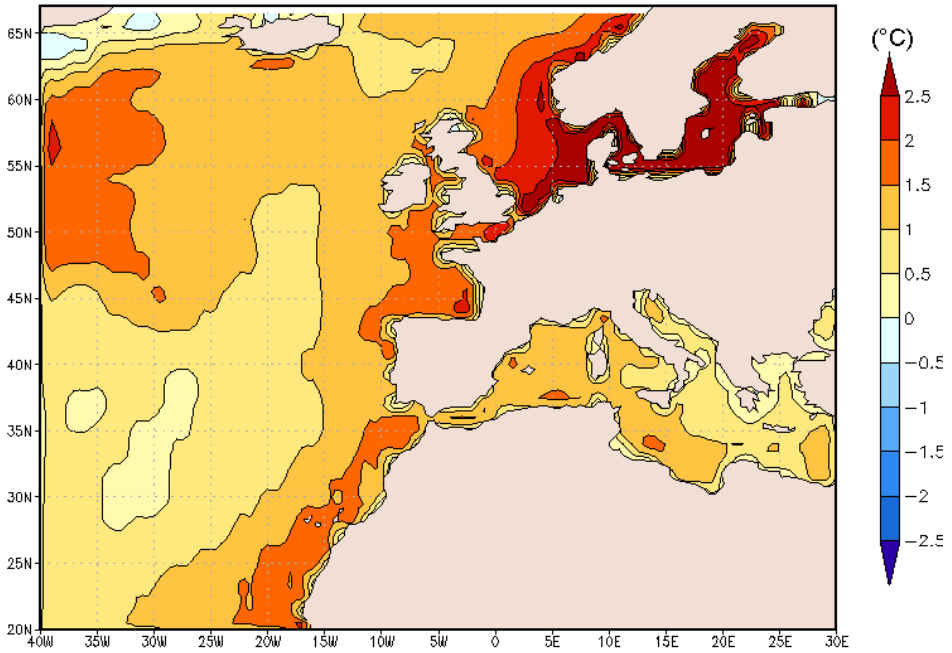
WNC-WFC: Sensitivity to atmospheric dynamics (3D wind nudged or not).

V-Wind difference:
Pattern comparable to the fall 2006 anomaly, albeit slightly shifted N-E.
Over the area: 2.8 m/s (weaker than the actual 3.9 m/s anomaly).

T2M difference:
The pattern of the fall 2006 is roughly reconstructed.
Over the area: **0.9 degC** for a 2.8 m/s V-Wind difference.
Extrapolating.. **1.3 degC** for a 3.9 m/s V-Wind difference.

CTL-WNC difference of SST

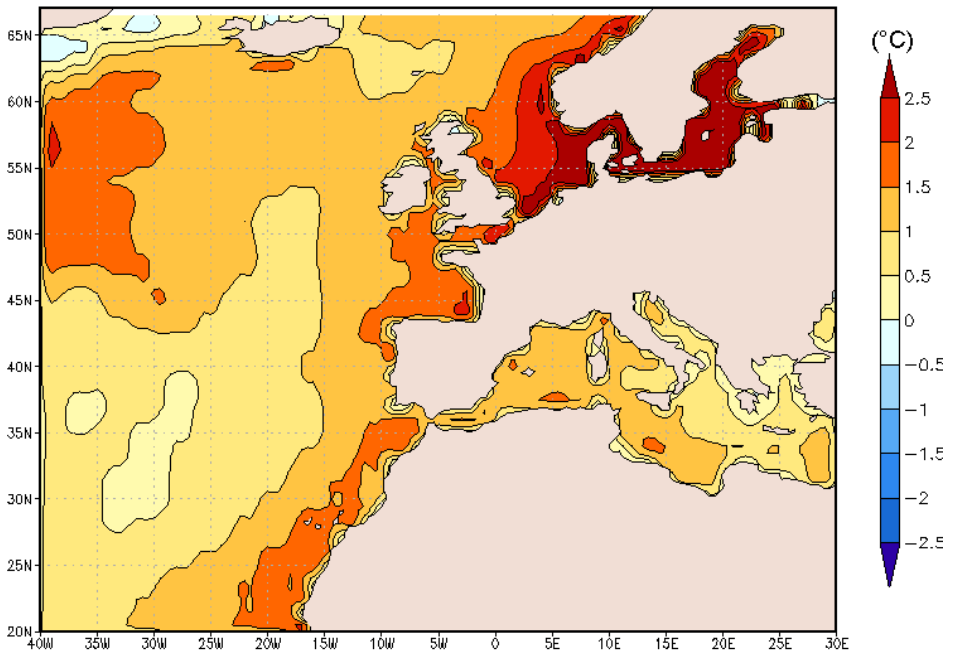


[Cattiaux et al., 2009, *GRL*]

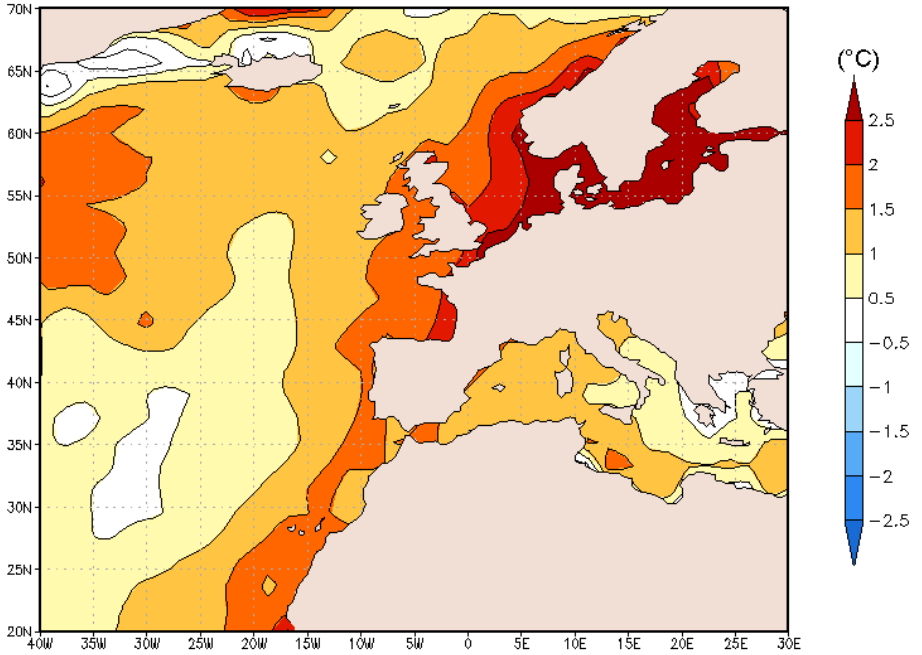
CTL-WNC: Sensitivity to SST forcing (actual or climatological).

SST contribution (MM5)

CTL-WNC difference of SST



Fall 2006 SST anomaly



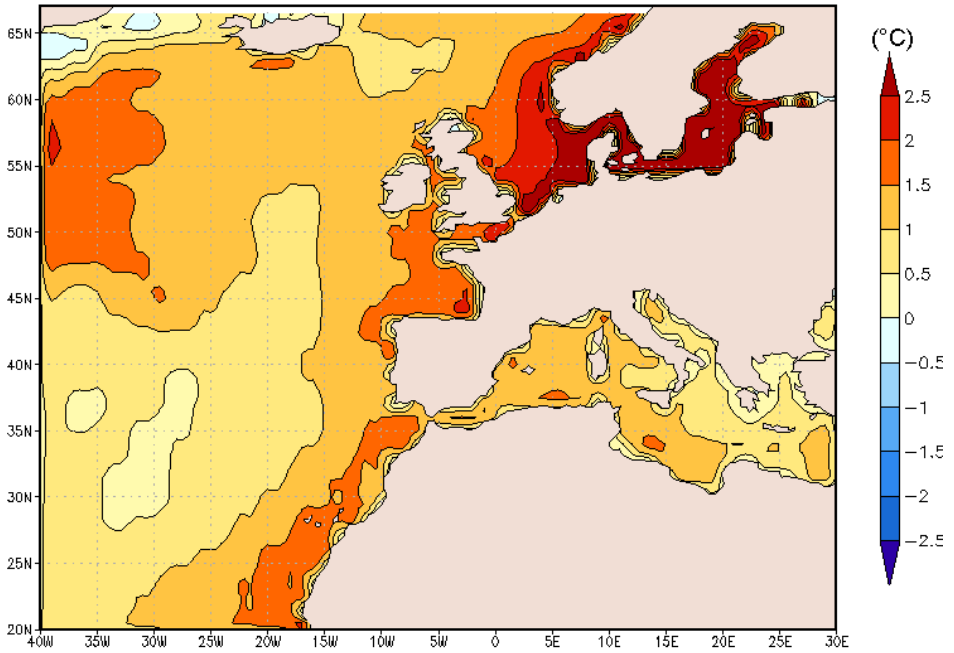
[Cattiaux et al., 2009, *GRL*]

CTL-WNC: Sensitivity to SST forcing (actual or climatological).

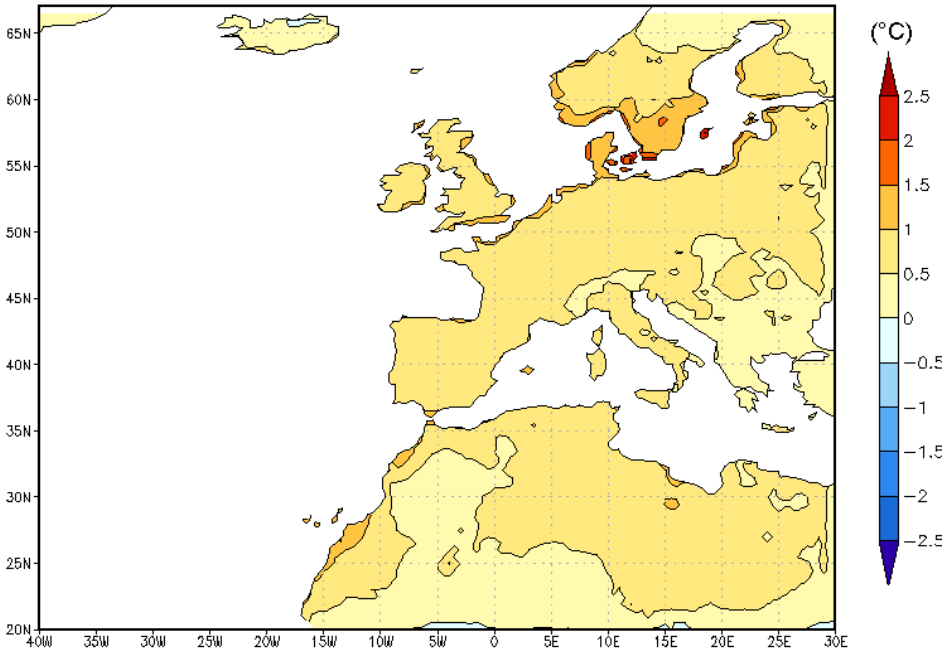
SST difference:
It is the Fall 2006 actual anomaly.

SST contribution (MM5)

CTL-WNC difference of SST



CTL-WNC difference of T2M



[Cattiaux et al., 2009, *GRL*]

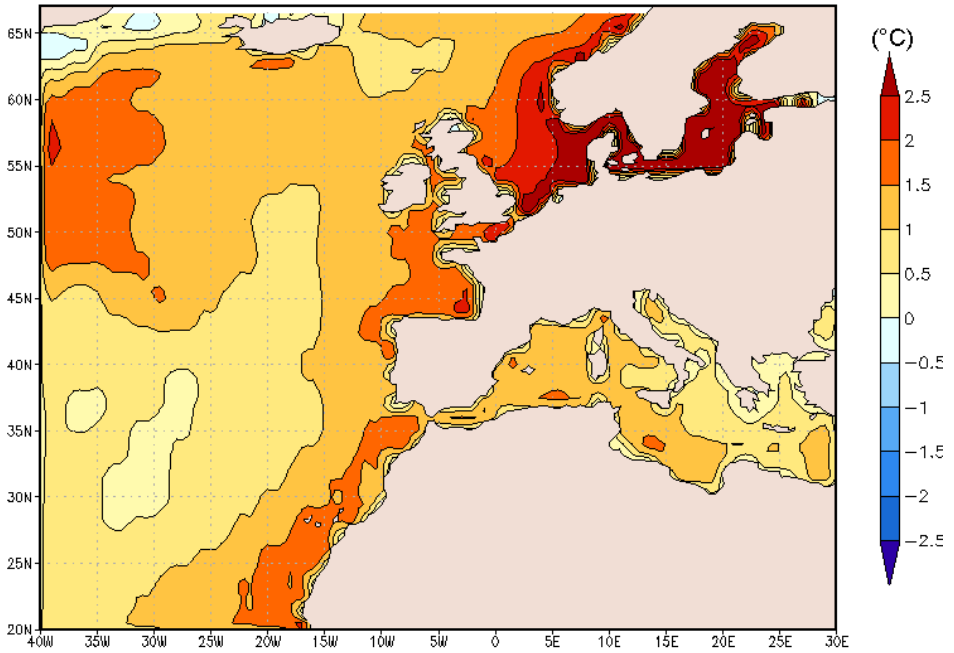
CTL-WNC: Sensitivity to SST forcing (actual or climatological).

SST difference:
It is the Fall 2006 actual anomaly.

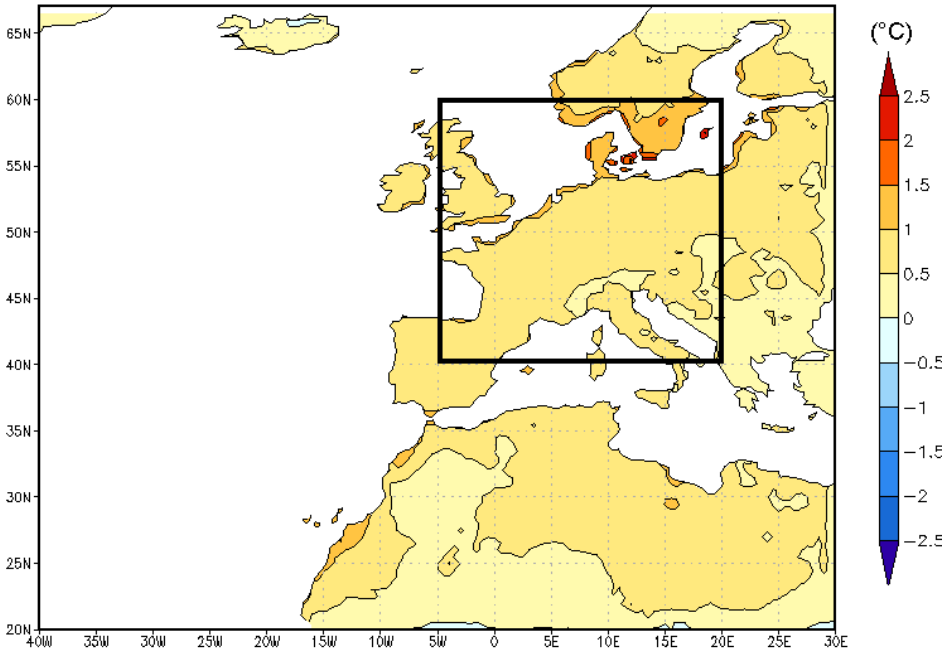
T2M difference:
Positive and spatially homogeneous.

SST contribution (MM5)

CTL-WNC difference of SST



CTL-WNC difference of T2M



[Cattiaux et al., 2009, *GRL*]

CTL-WNC: Sensitivity to SST forcing (actual or climatological).

SST difference:
It is the Fall 2006 actual anomaly.

T2M difference:
Positive and spatially homogeneous.
Over the area: **0.8 degC.**

Conclusions & Discussion

Both statistical & dynamical **models agree**:

The **+2.6 degC** land temperature anomaly of the fall 2006
= **1.3 degC** due to atmospheric circulation (50%)
+ **0.7/0.8 degC** due to the SST (30%)
+ **0.5/0.6 degC** unexplained so far (20%).

Dynamics contribution: temporal and spatial variability.
SST contribution: global shift towards warmer values.

Remaining 20%: other processes, non-linearity, anomalous global configuration?

Man-induced contribution: **+0.4 degC - 1.0 degC (20 – 40%)**
= V-Wind ***trend*** contribution: +0 degC
+ SST ***trend*** contribution: +0.4 degC
+ (?) unexplained part: +0.5/0.6 degC.

Other seasons?
Poster XY149: On the role of the East-Atlantic SST in enhancing the recent European seasonal land temperatures.

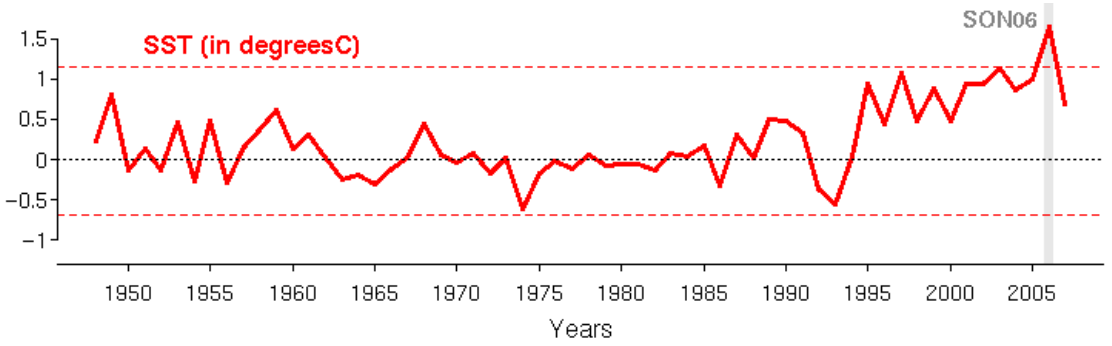
Thank you for your attention

Questions?

Ref: Cattiaux, J., R. Vautard, and P. Yiou (2009), Origins of the extremely warm European fall of 2006, Geophys. Res. Lett., 36, L06713, doi:10.1029/2009GL037339.

SST trend contribution (MM5)

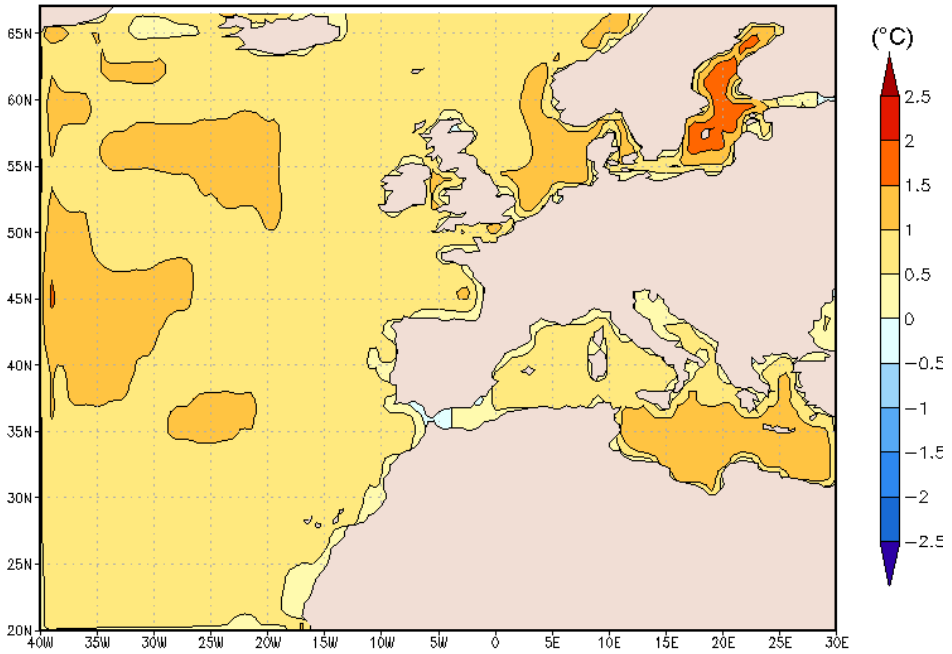
SON 1948-2007 SST anomalies



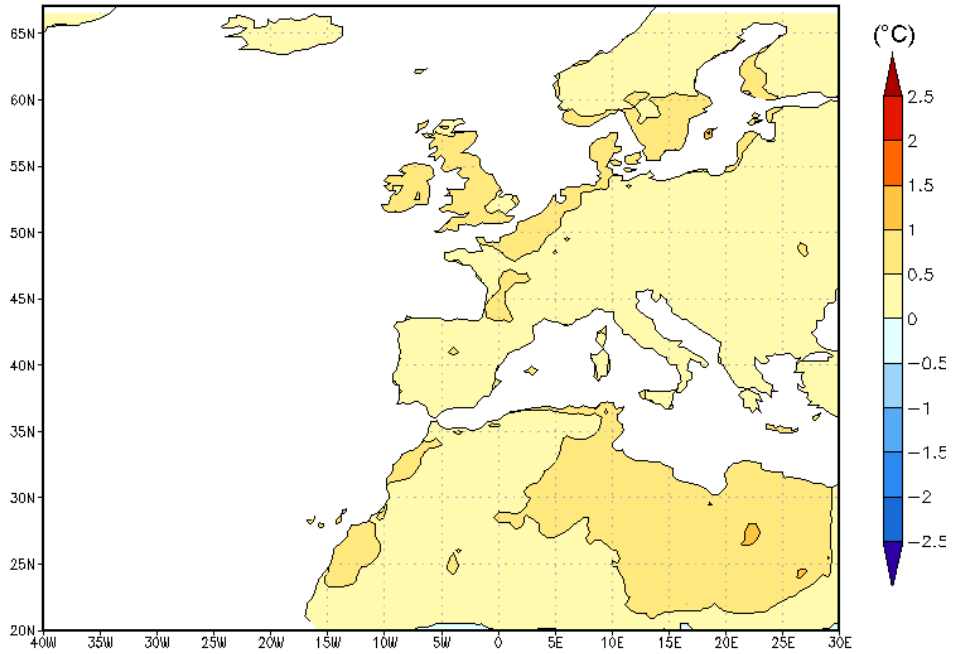
The recent (1996-2005) SST are globally 1 degC warmer than in 1961-1990.

Additional simulation: WNCC: Wind nudged and current climatological (1996-2005) SSTs
>> WNCC-WNC difference: SST trend contribution

WNCC-WNC difference of SST



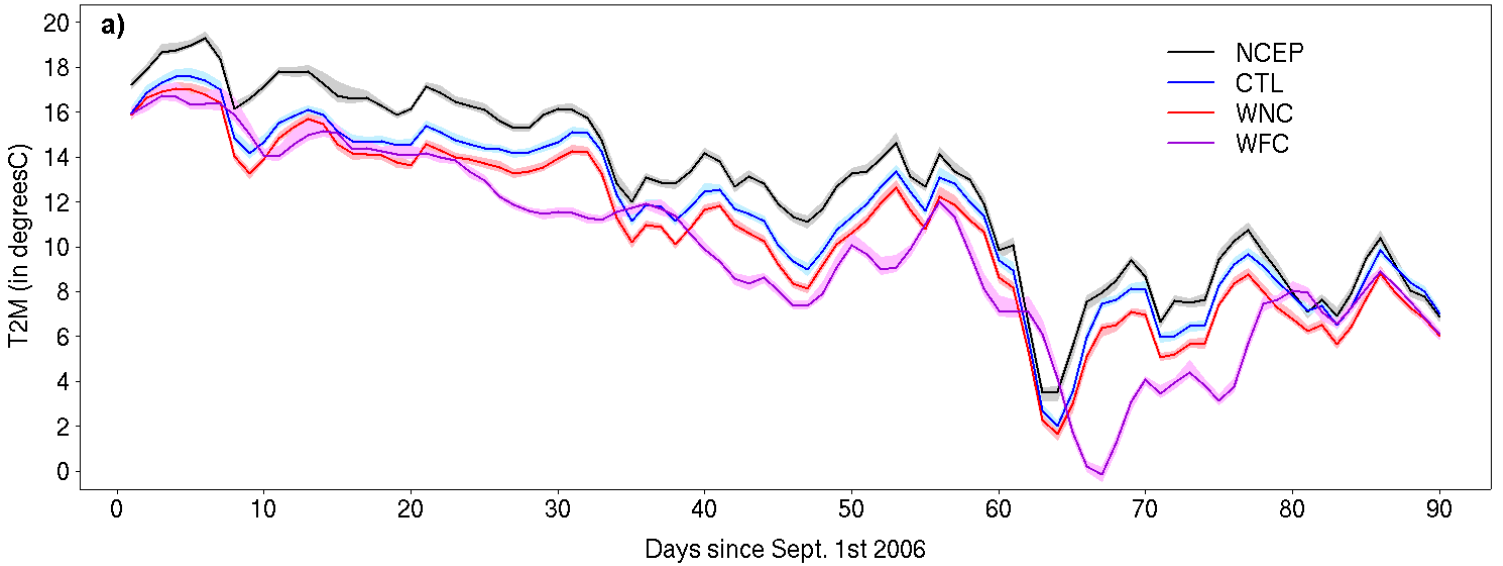
WNCC-WNC difference of T2M

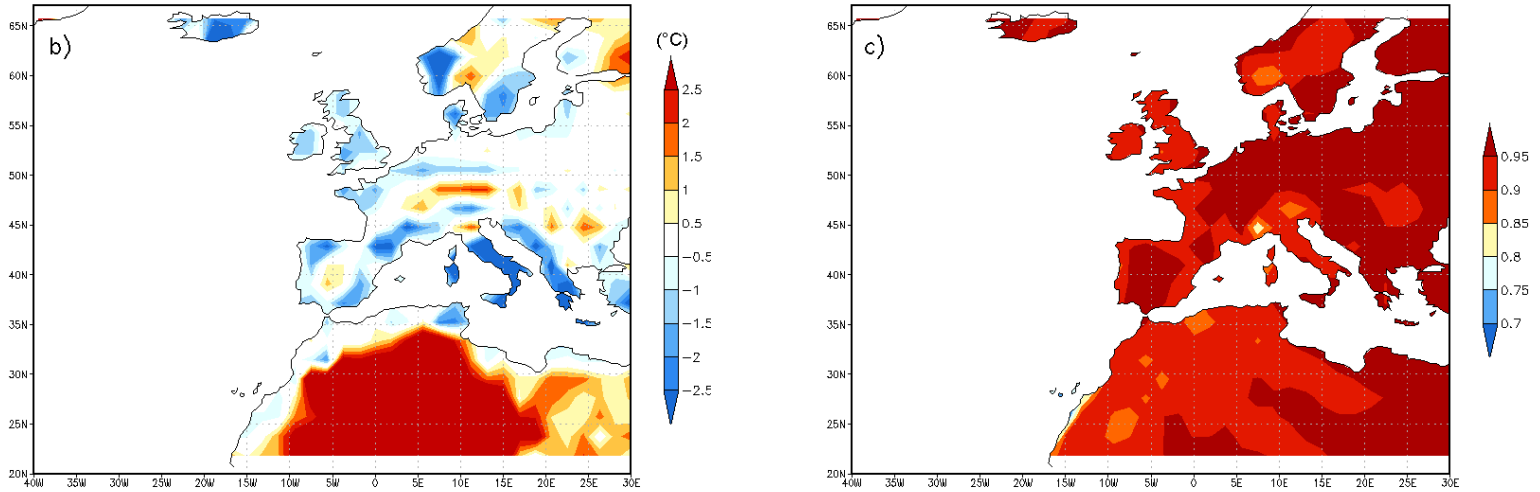


WNCC-WNC T2M difference over the area: 0.4°C

[Cattiaux et al., 2009, *GRL*]

Comparison MM5 simulations and NCEP





[Cattiaux et al., 2009, *GRL*]

NCEP-CTL (a-b-c): MM5 has a cold bias over Europe (a-b), but the daily variability is well represented (a-c).

CTL-WNC (a): WNC is ~0.8 degC cooler than CTL all along the fall 2006. The anomalous SST do not influence the T2M daily variability.

WNC-WFC (a): The daily variability of the T2M changes under a different atmospheric flow. WFC is also globally cooler than WNC (weaker wind).