Origins of the extremely warm European fall of 2006

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**Fall 2006: Exceptional land temperature anomaly**

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

T2M anomaly: +2.6 degC.

Corresponds to $3.5\sigma$ of the distribution.

Impacts on phenology and ecosystems.

See also
- [Luterbacher et al., 2007, *GRL*]
- [Piao et al., 2008, *Nature*]

**How to explain this exceptional anomaly?**

[Cattiaux et al., 2009, *GRL*]
European fall temperatures are strongly linked to a dipole of the geopotential height, i.e. to the meridional flow.
The best correlation is found for the V-Wind at 500mb over this area: $r = 0.72$ (p.value = $8.10^{-11}$).

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

Corresponds to $2.1\sigma$ of the distribution.

Record since 1948.

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

[Cattiaux et al., 2009, GRL]
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.
Scatter plot of daily anomalies: $T_{2M}$ vs. $V$-Wind over SON 1948-2006

The regression lines are parallel.

Red dots appear shifted upward.

$r = 0.62$
$r = 0.74$

[Cattiaux et al., 2009, *GRL*]
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]
Coastal SST anomaly: $+1.6 \text{ degC}$. Corresponds to $3.6\sigma$ of the distribution. Record since 1948. Acts in a warming trend.

Southern anomaly ($+1.5 \text{ degC, } 3.3\sigma$): deficit in the coastal upwelling.

Northern anomaly ($+1.8 \text{ degC, } 3.6\sigma$): consequence of the Southern anomaly.

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

[Cattiaux et al., 2009, GRL]
Reconstruction of fall T2M anomalies from V-Wind and SST anomalies (linear regressions)

SST contribution: seasonal anomalies

Temperature Anomalies in degreesC

-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

Years


SON2006

T2M from NCEP
T2M' = f(VWind)

-2.6C
-1.3C
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.
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%).

[Cattiaux et al., 2009, GRL]
Model details


Non-hydrostatic equations of motion over a predefined domain.
32 vertical levels and 4 active soil layers.
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**: Sensitivity to atmospheric dynamics (3D wind nudged or not).
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**V-Wind difference:**
Pattern comparable to the fall 2006 anomaly, albeit slightly shifted N-E.

[Cattiaux et al., 2009, GRL]
**WNC-WFC difference of V-Wind**

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).
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.
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**T2M difference:**

[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).

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

![SST contribution (MM5)](image)

[Cattiaux et al., 2009, GRL]

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

SST difference:
It is the Fall 2006 actual anomaly.

T2M difference:
Positive and spatially homogeneous.
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**.
Both statistical & dynamical models agree:

The $+2.6\,\text{degC}$ land temperature anomaly of the fall 2006

$= 1.3\,\text{degC}$ due to atmospheric circulation (50%)
$+ 0.7/0.8\,\text{degC}$ due to the SST (30%)
$+ 0.5/0.6\,\text{degC}$ 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:** $+0.4\,\text{degC} - 1.0\,\text{degC}$ (20 – 40%)

$= \text{V-Wind trend contribution: } +0\,\text{degC}$
$+ \text{SST trend contribution: } +0.4\,\text{degC}$
$+ (\text{?}) \text{ unexplained part: } +0.5/0.6\,\text{degC}$.

**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?

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

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).