# The global land surface atmospheric stilling

*Decline in surface wind speed*


Robert Vautard
Julien Cattiaux
Pascal Yiou

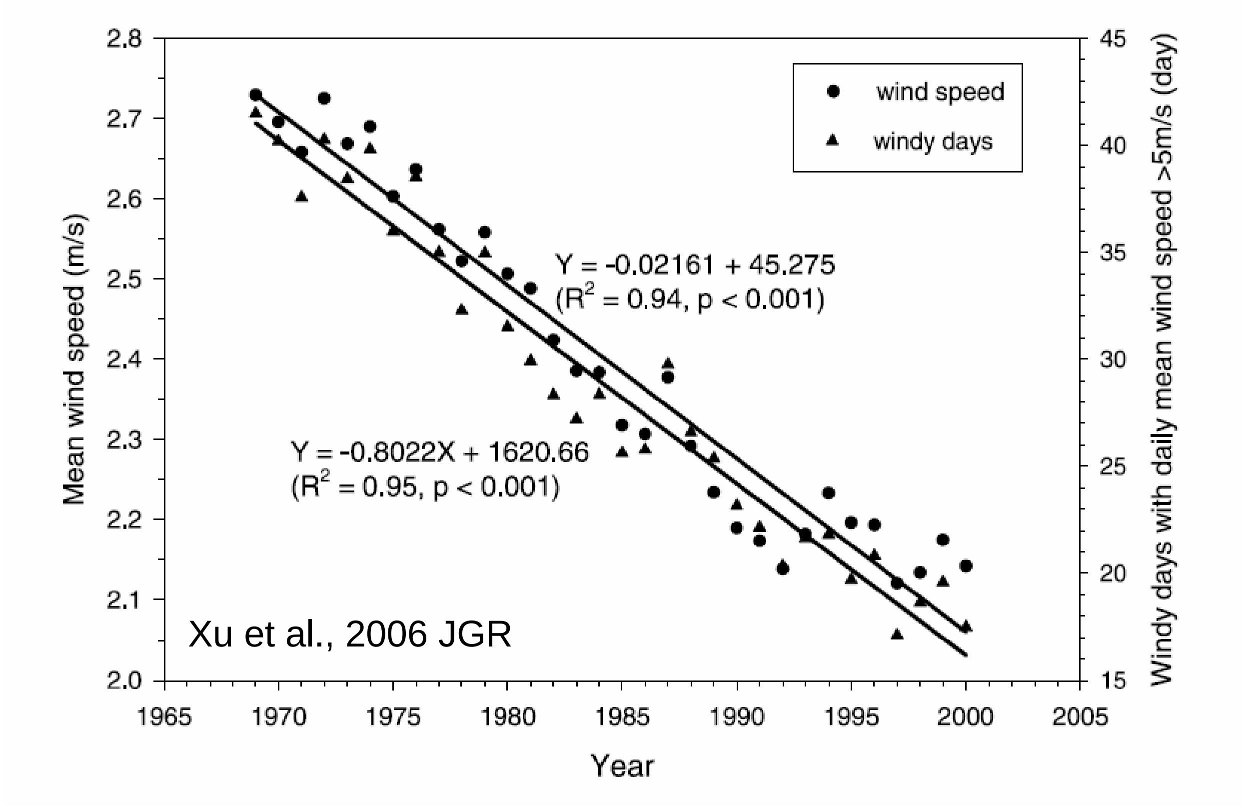

Réunion ESTIMR – 24/09/2009

# Previous studies

- China: Xu et al., 2006; Zhang et al., 2007.

*Significant decrease of monsoon winds in all seasons.*

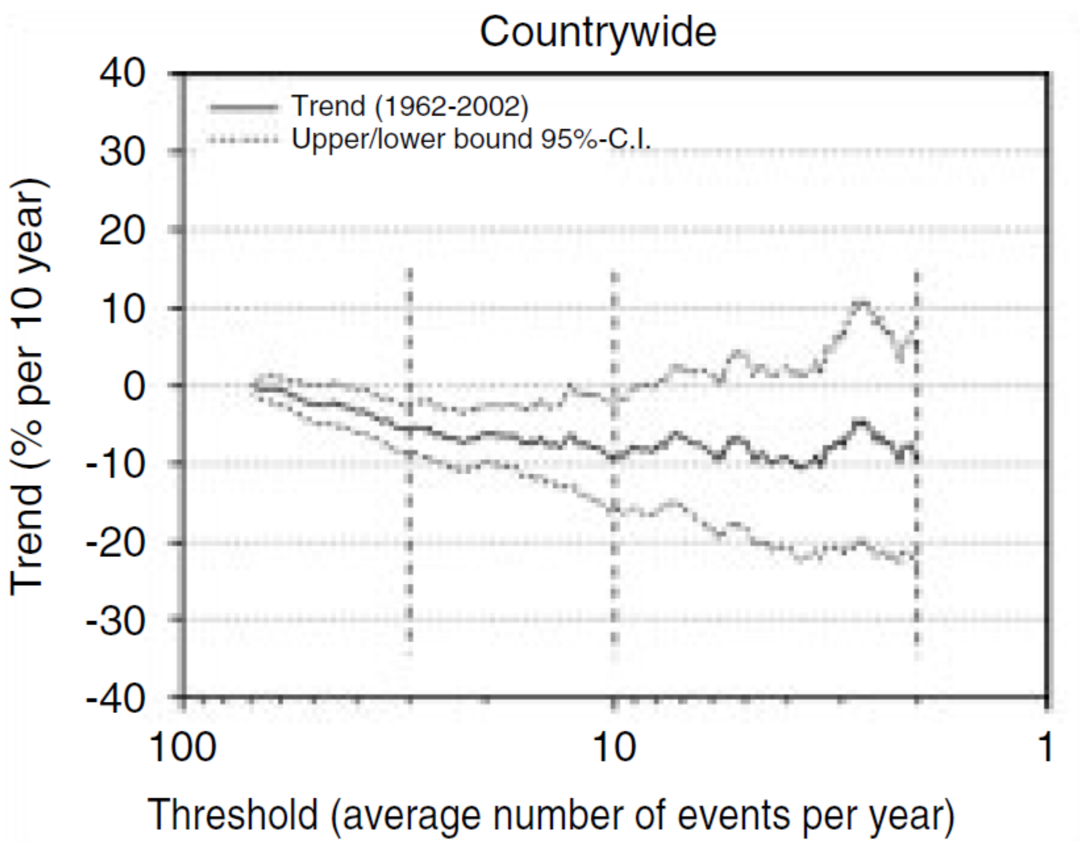
*Why? Winter: N/S gradient in the warming trend. Summer: dimming due to air pollution.*



# Previous studies

- China: Xu et al., 2006; Zhang et al., 2007.
*Significant decrease of monsoon winds in all seasons.*
*Why? Winter: N/S gradient in the warming trend. Summer: dimming due to air pollution.*

- Europe (Netherlands): Smits et al., 2005.
*Decreasing trends, but not present in geostrophic winds.*
*Also not present in NCEP re-analyses (heterogeneities?)*




Smits et al., 2005 JC

# Previous studies

- China: Xu et al., 2006; Zhang et al., 2007.

*Significant decrease of monsoon winds in all seasons.*
*Why? Winter: N/S gradient in the warming trend. Summer: dimming due to air pollution.*

- Europe (Netherlands): Smits et al., 2005.

*Decreasing trends, but not present in geostrophic winds.*
*Also not present in NCEP re-analyses (heterogeneities?)*

- Europe (France): Thèse J. Najac (CERFACS), 2009.

*Decreasing winds in observations and in SRES A1B (from multi-model PMIP3).*
*« Aucune étude de détection / attribution de changement climatique sur les vents de surface n'ayant jamais été réalisée à notre connaissance et une telle étude n'étant pas le sujet de cette thèse, cette question reste donc ouverte. »*

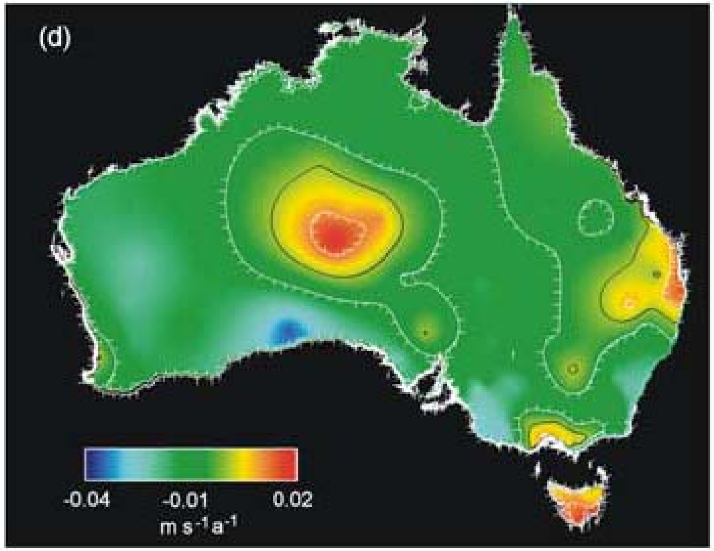
# Previous studies

- China: Xu et al., 2006; Zhang et al., 2007.
*Significant decrease of monsoon winds in all seasons.*
*Why? Winter: N/S gradient in the warming trend. Summer: dimming due to air pollution.*

- Europe (Netherlands): Smits et al., 2005.
*Decreasing trends, but not present in geostrophic winds.*
*Also not present in NCEP re-analyses (heterogeneities?)*

- Europe (France): Thèse J. Najac (CERFACS), 2009.
*Decreasing winds in observations and in SRES A1B (from multi-model PMIP3).*
*« Aucune étude de détection / attribution de changement climatique sur les vents de surface n'ayant jamais été réalisée à notre connaissance et une telle étude n'étant pas le sujet de cette thèse, cette question reste donc ouverte. »*

- Australia: Mc Vicar et al., 2008.
*Again, decline observed but no clear explanation.*




Mc Vicar et al., 2008 GRL

Previous studies

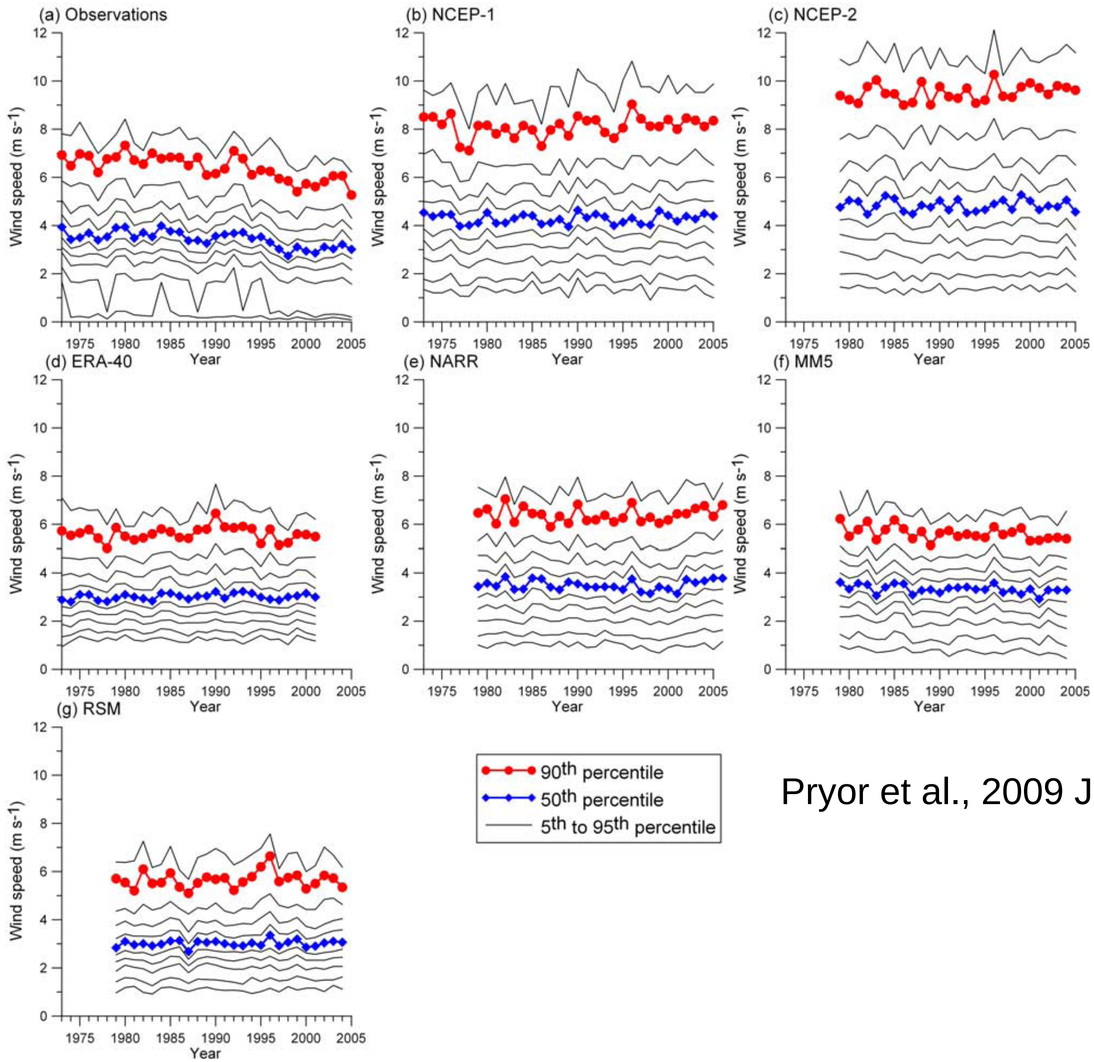
- Ch
*Sign*
*Why*

- Eu
*Decr*
*Also*

- Eu
*Decr*
*« Au*
*n'aya*
*thèse*

*face*
*le cette*

- Au
*Agai*




Pryor et al., 2009 JGR

- USA: Klink, 1999; Pryor et al., 2009:

*50th and 90th percentile wind speeds: significant decrease in 2 observational data sets, in MM5 nested within NCEP, but not in 4 reanalysis data sets and in RSM nudged by NCEP.*
*« further research on wind climate variability and evolution is required »*

# Causes?

- Changes in the global or synoptic atmospheric circulation.

- Increasing local surface roughness [Roderick et al., 2007].

- Changes in the boundary layer structure.

- Northward shift of the Hadley circulation
  [Worden et al., 2007; Lu et al., 2007; Seidel et al., 2008].

- Instrumental issues [De Gaetano, 1998; McKee et al., 2000].

# Causes?

- Changes in the global or synoptic atmospheric circulation.

- Increasing local surface roughness [Roderick et al., 2007].

- Changes in the boundary layer structure.

- Northward shift of the Hadley circulation
  [Worden et al., 2007; Lu et al., 2007; Seidel et al., 2008].
  *Consistent link in obs but not clearly established using model simulations.*

- Instrumental issues [De Gaetano, 1998; McKee et al., 2000].
  *Replacement of anemometers over the past decades & too many areas concerned.*

# Causes?

- Changes in the global or synoptic atmospheric circulation.

- Increasing local surface roughness [Roderick et al., 2007].

- Changes in the boundary layer structure.

- Northward shift of the Hadley circulation
  [Worden et al., 2007; Lu et al., 2007; Seidel et al., 2008].
  *Consistent link in obs but not clearly established using model simulations.*

- Instrumental issues [De Gaetano, 1998; McKee et al., 2000].
  *Replacement of anemometers over the past decades & too many areas concerned.*

# Wind speed and pressure data

## Observational data sets

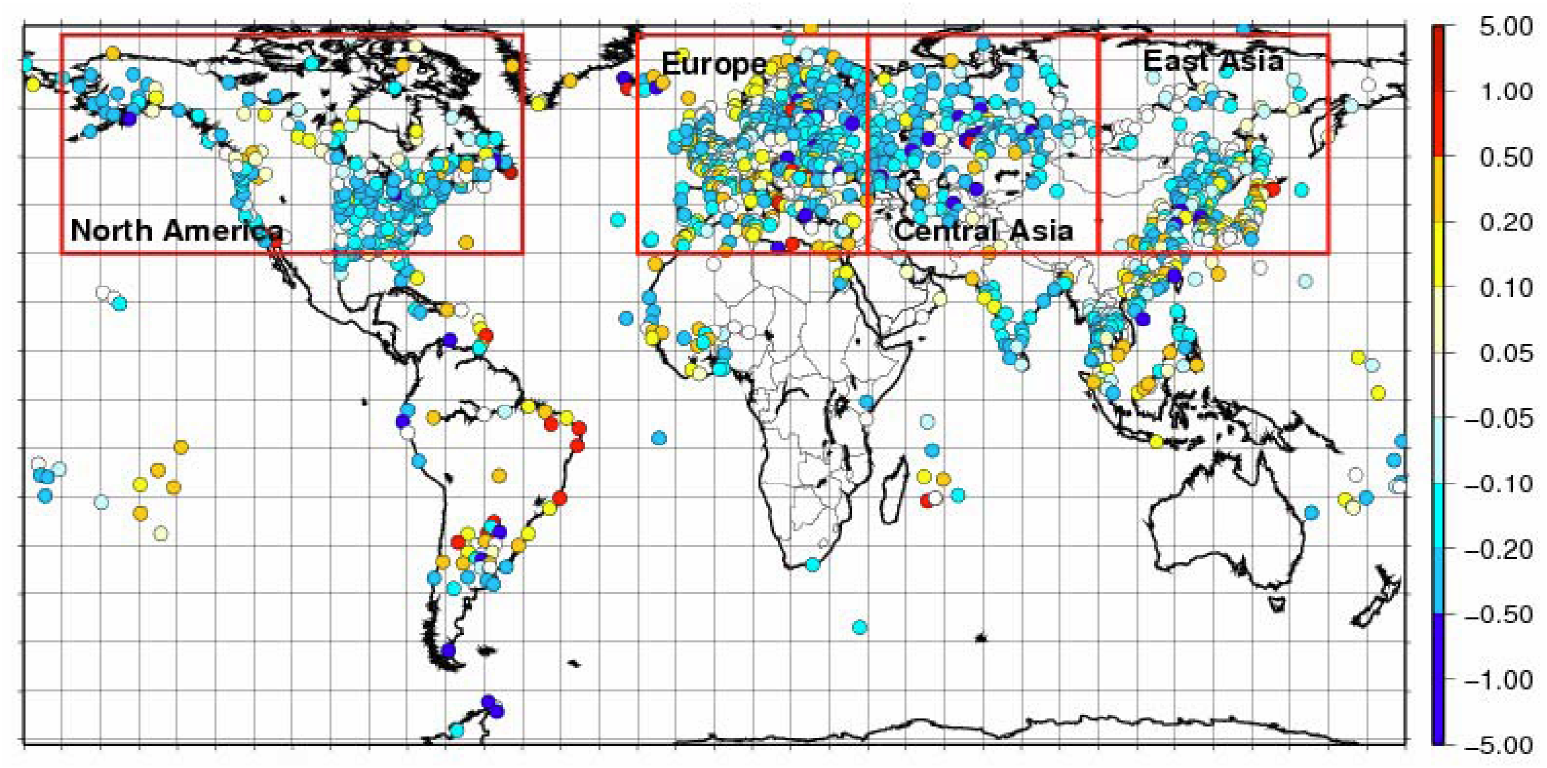
- NCAR surface stations (DS461.0): 1342 worldwide stations (1046 in 30-75°N).
  *hourly / 3-hourly surface wind speed data (aviation or weather services).*

- NCAR rawinsondes (DS435.0): ~600 (?) worldwide stations.
  *2xdaily wind speed data at pressure levels.*

## Reanalyses data set

- NCEP/NCAR reanalyses.
  *193x47 grid points over the Northern Hemisphere.*

# 1979-2008 surface wind speed trend ($m.s^{-1}$/dec)



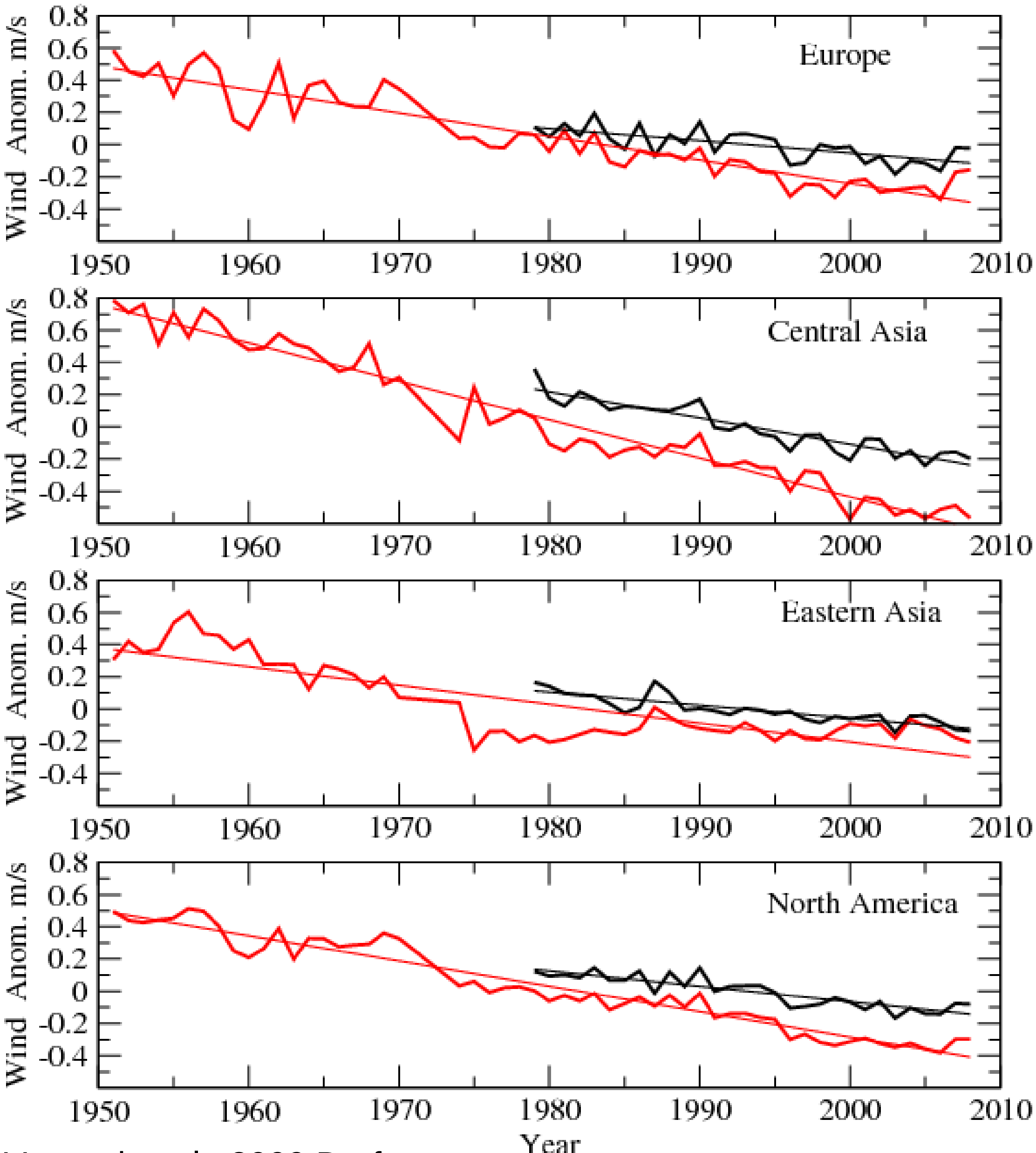

**Observations (aviation stations)**

Vautard et al., 2009 Draft.

68% of stations exhibit a wind speed decline (71% in 30-75°N).
Europe: -0.07; East Asia: -0.18; Central Asia: -0.10 & North America -0.10 $m.s^{-1}$/dec.
Decline of ~10% in 30 years.

Increased surface wind speeds in scattered coastal regions (Med, Japan).

# 1950-2008 surface wind speed evolution



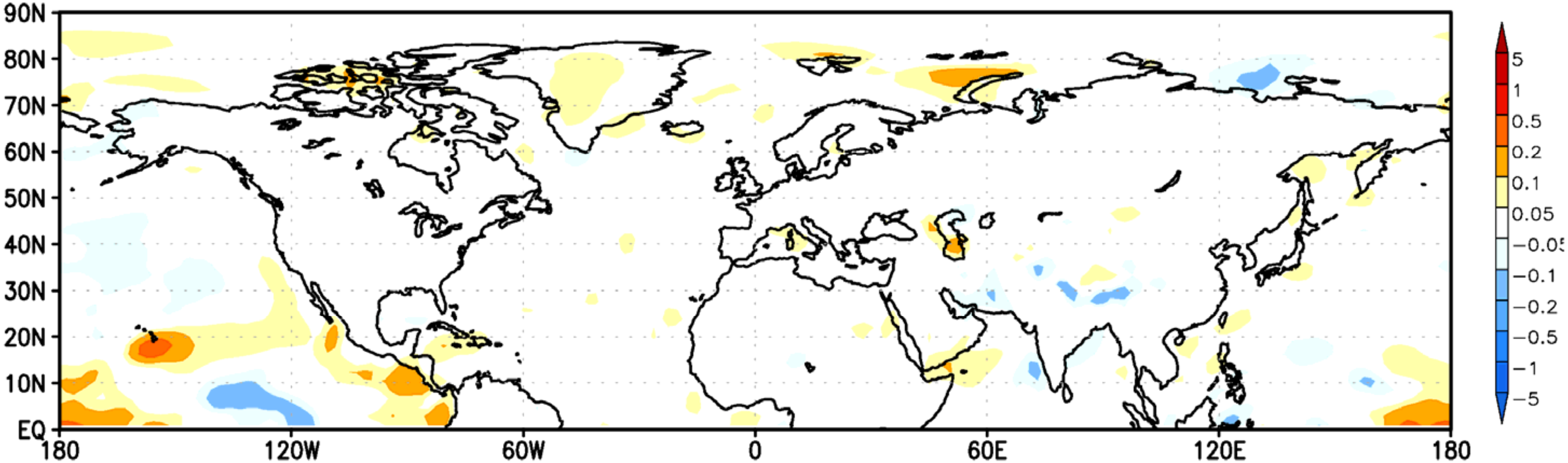

Vautard et al., 2009 Draft.

**Observations (aviation stations)**

*Anomalies wrt. last 60 or 30 yrs*
Red: « old » stations (60 yrs)
Black: « new » stations (30yrs).

>> Stilling actually started
as early as in the fifities.

# 1979-2008 surface wind speed trend (m.s$^{-1}$/dec)




**NCEP Reanalyses**

Vautard et al., 2009 Draft.

No trend. (Values x4 to get something to plot with the same color scale).

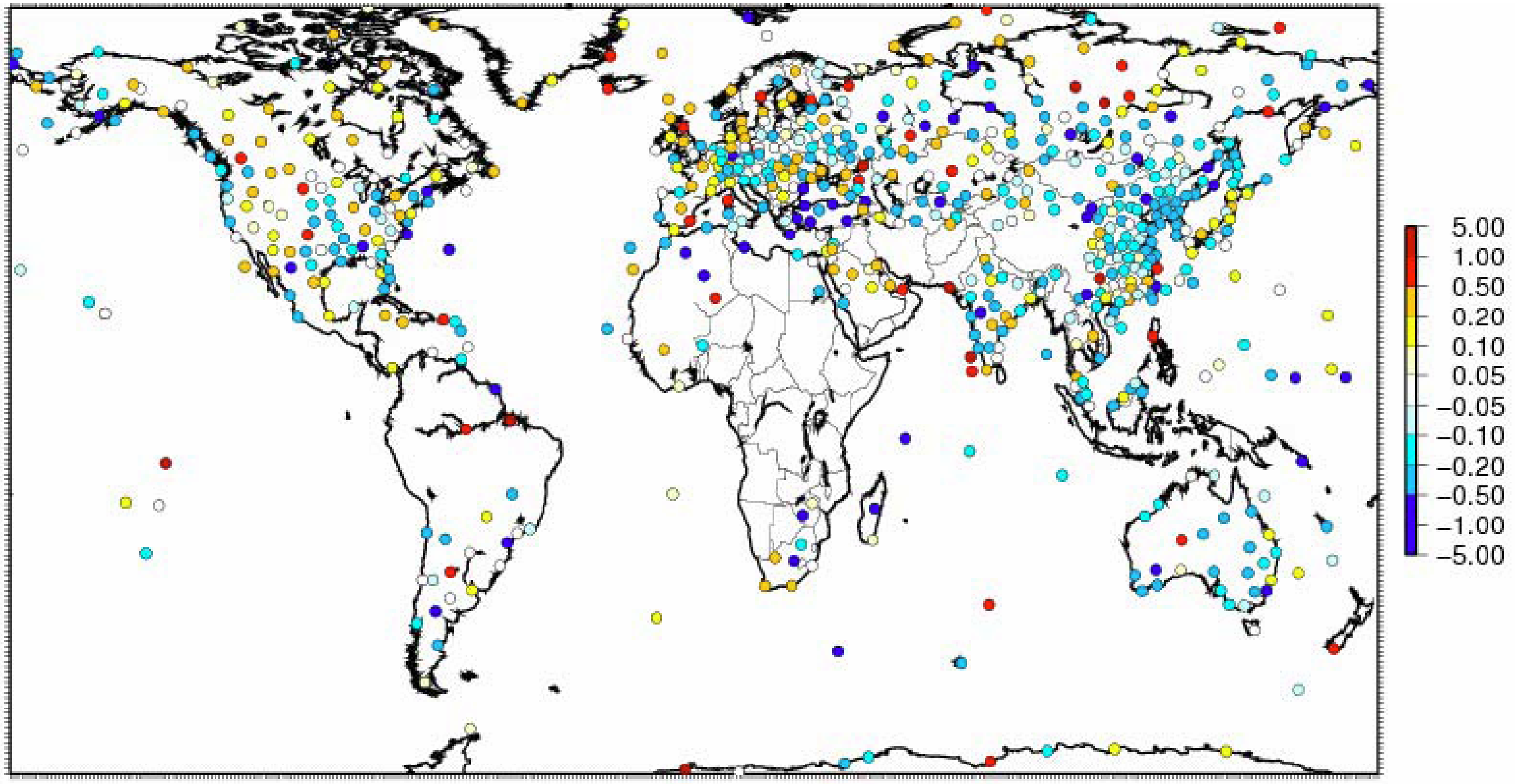
*Cf. Smits et al., 2005; McVicar et al., 2008; Pryor et al., 2009.*

>> Heterogeneities (Smits, Pryor)?

>> Or evidence that large-scale flow is not the driving process of the stilling...

*(10m-winds are not used in reanalysis process, while upper-air winds are).*

1979-1998 850hPa wind speed trend ($m.s^{-1}$/dec)



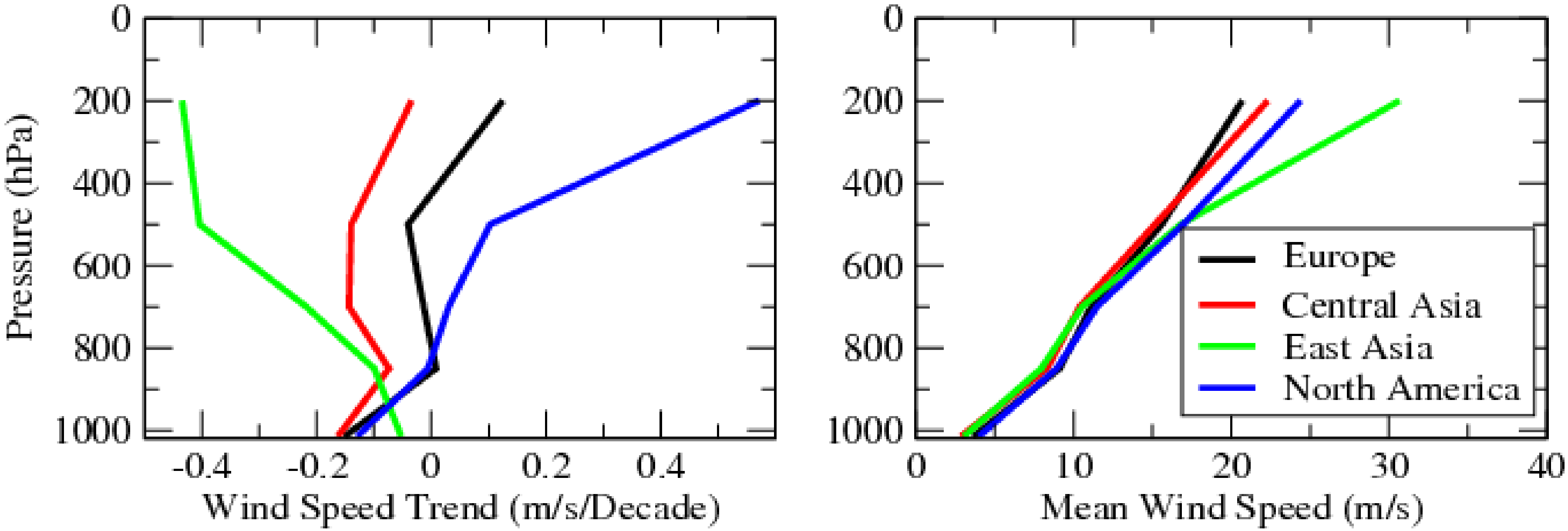

**Observations (rawinsondes)**

Vautard et al., 2009 Draft.

Europe: 56%; East Asia: 72%; Central Asia: 58% & North America 45% of stations show a negative trend.

No spatial coherence with the surface trends...

# 1979-1998 vertical profiles of wind speed trends




Vautard et al., 2009 Draft.

... No spatial coherence with the surface trends (especially North America).
Except in East Asia: strong decline of upper-air wind speeds.

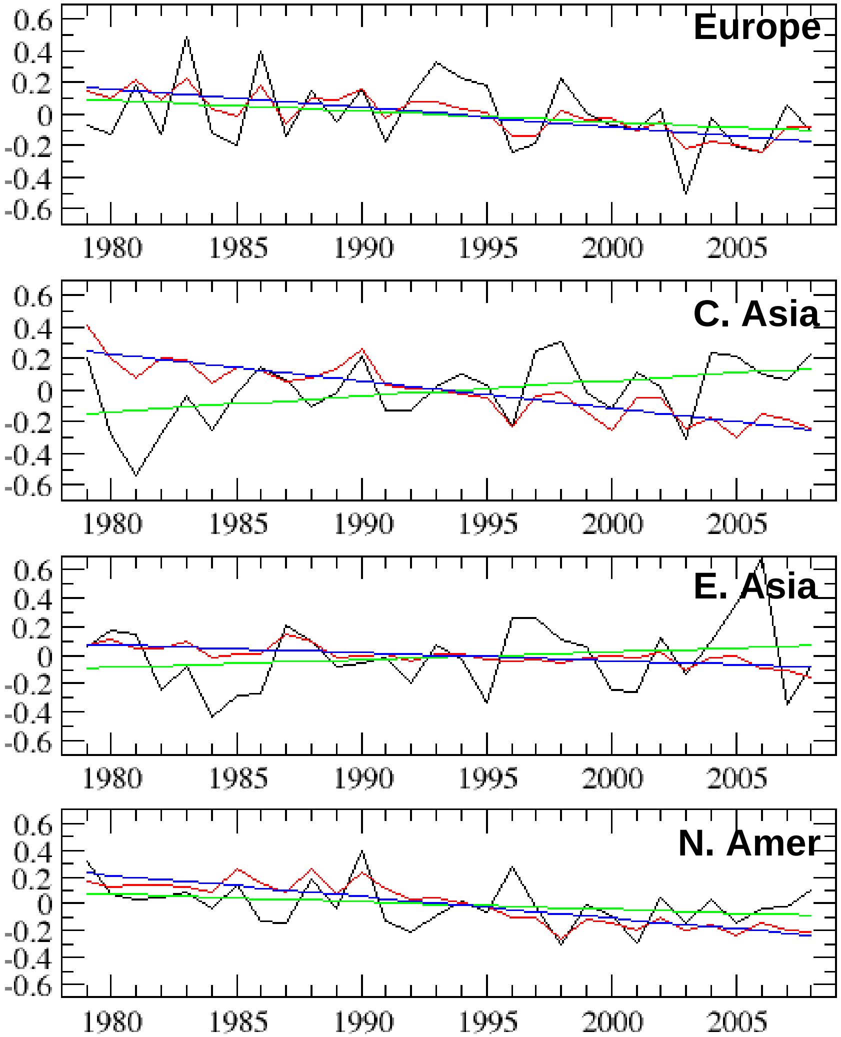
>> Global surface stilling can not be linked to upper-air winds evolution.

>> Regional monsoon changes & air pollution may be responsible in East Asia. [Xu et al., 2006]

# Trends in geostrophic winds?

*>> Geostrophic winds calculated from SLP gradients between pairs of near-by sites.*

$$u_g = -\frac{g}{f}\frac{\partial Z}{\partial y} \qquad v_g = \frac{g}{f}\frac{\partial Z}{\partial x}$$



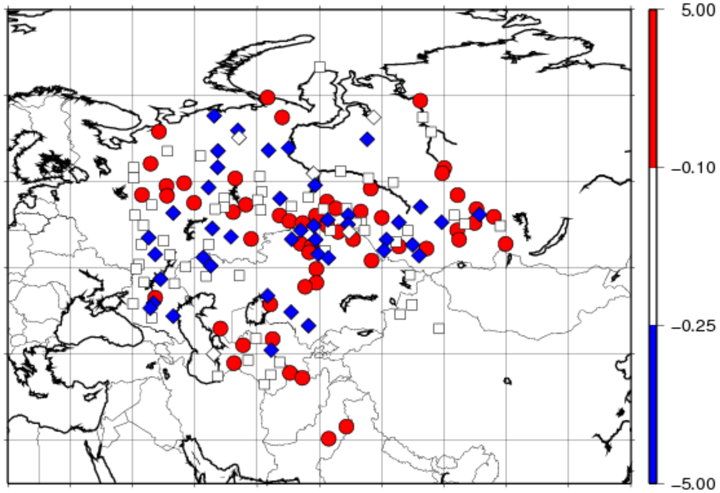

Any change in large-scale synoptic winds should show up in geostrophic winds.

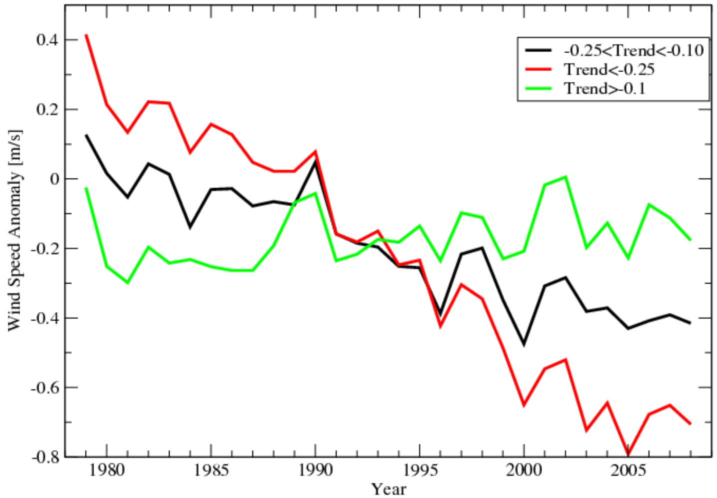
>> Geostrophic winds do not display generalized decreasing trends.

Vautard et al., 2009 Draft.
Black: Geostrophic wind (with green trend).
Red: Surface wind (with blue trend).

# « Stilling » and « non-stilling » stations

*Central Asia - Yearly wind speeds by classes: Trend < -0.25 , > -0.1, in between.*



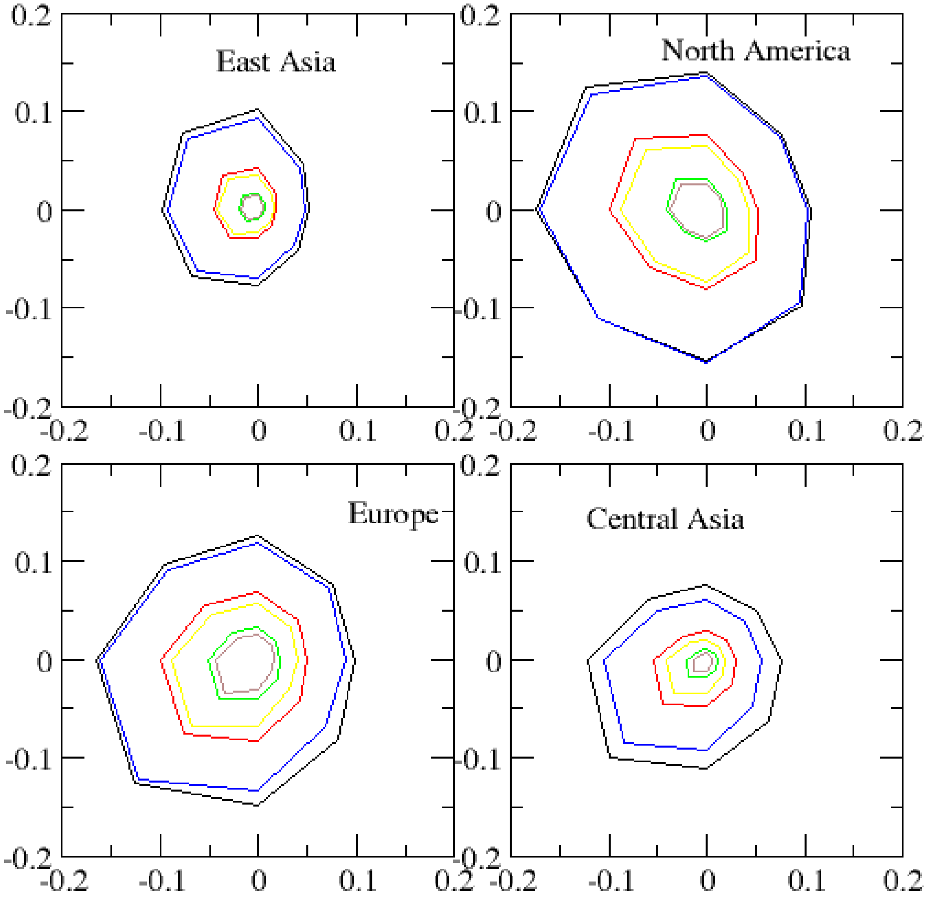




Vautard et al., 2009 Draft.

- Poor intra-regional coherence between wind trend amplitudes.
- Variability fairly similar over the 3 classes of stations.

>> Processes driving trend amplitudes appear unlinked with processes driving the interannual surface wind variability.

# Isotropic behaviour of the surface stilling




Vautard et al., 2009 Draft.

Surface wind decline is nearly isotropic.

Also the trend is fairly independent of the season and time of day (not shown).

>> Uniform behaviour of the stilling.

>> If caused by changes in general circulation, differences should show up between sectors.

# Causes?

- Changes in the global or synoptic atmospheric circulation.

- Increasing local surface roughness [Roderick et al., 2007].

- Changes in the boundary layer structure.

- Northward shift of the Hadley circulation
  [Worden et al., 2007; Lu et al., 2007; Seidel et al., 2008].
  *Consistent link in obs but not clearly established using model simulations.*

- Instrumental issues [De Gaetano, 1998; McKee et al., 2000].
  *Replacement of anemometers over the past decades & too many areas concerned.*

# Causes?

- Changes in the global or synoptic atmospheric circulation.
  *Trends no present in reanalyses, upper-air winds, geostrophic winds.*
  *Variability of stilling stations similar to non-stilling stations.*
  *Stilling uniform and isotropic.*

- Increasing local surface roughness [Roderick et al., 2007].

- Changes in the boundary layer structure.

- Northward shift of the Hadley circulation
  [Worden et al., 2007; Lu et al., 2007; Seidel et al., 2008].
  *Consistent link in obs but not clearly established using model simulations.*

- Instrumental issues [De Gaetano, 1998; McKee et al., 2000].
  *Replacement of anemometers over the past decades & too many areas concerned.*
  *Stilling global and isotropic.*

# Causes?

- Changes in the global or synoptic atmospheric circulation.
  *Trends no present in reanalyses, upper-air winds, geostrophic winds.*
  *Variability of stilling stations similar to non-stilling stations.*
  *Stilling uniform and isotropic.*

- Increasing local surface roughness [Roderick et al., 2007].

- Changes in the boundary layer structure.

- Northward shift of the Hadley circulation
  [Worden et al., 2007; Lu et al., 2007; Seidel et al., 2008].
  *Consistent link in obs but not clearly established using model simulations.*

- Instrumental issues [De Gaetano, 1998; McKee et al., 2000].
  *Replacement of anemometers over the past decades & too many areas concerned.*
  *Stilling global and isotropic.*

## Surface roughness: MM5 sensitivity experiments

**3 simulations of the year 2007 over Eur-Asia**

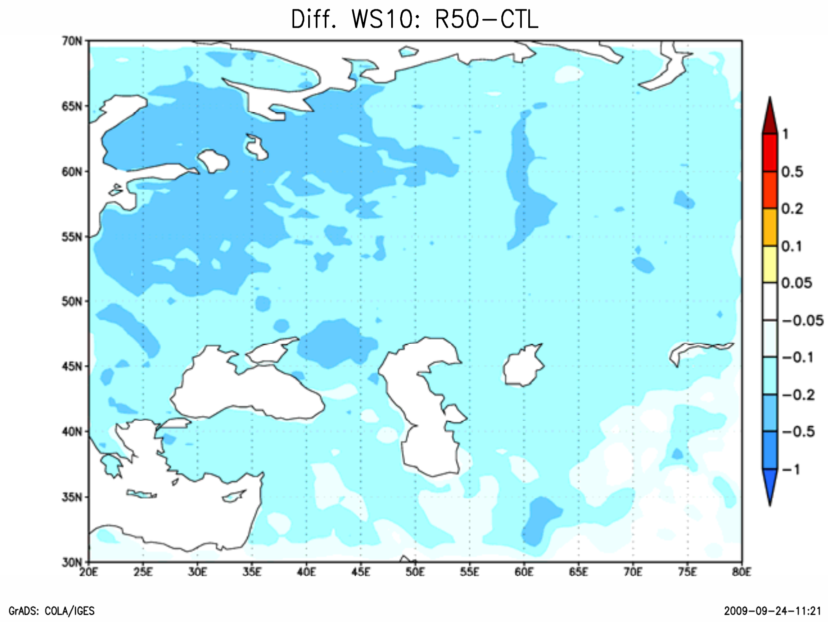
**CTL** *control simulation driven and nudged (3D-wind) by OPERA.*
**R50** *idem CTL but with roughness lengths of all land classes increased by 50%.*
**R100** *... 100%.*

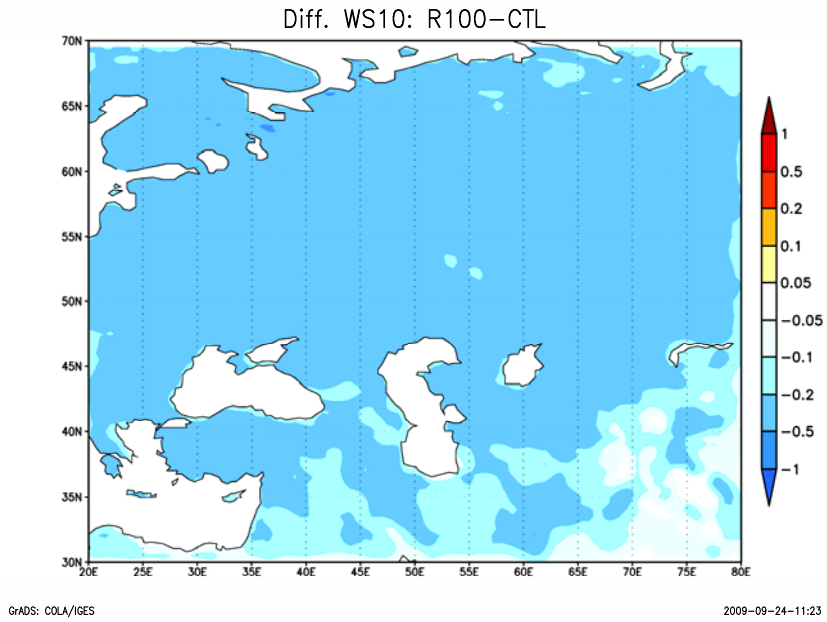
# Surface roughness: MM5 sensitivity experiments

**3 simulations of the year 2007 over Eur-Asia**

**CTL** *control simulation driven and nudged (3D-wind) by OPERA.*
**R50** *idem CTL but with roughness lengths of all land classes increased by 50%.*
**R100** *... 100%.*

Vautard et al.. 2009 Draft.



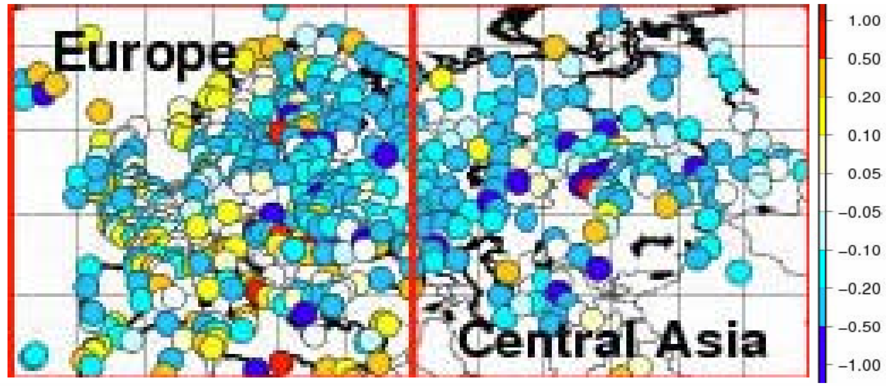




R50-CTL: average surface wind difference of -0.16m/s
R100-CTL: ... -0.26m/s

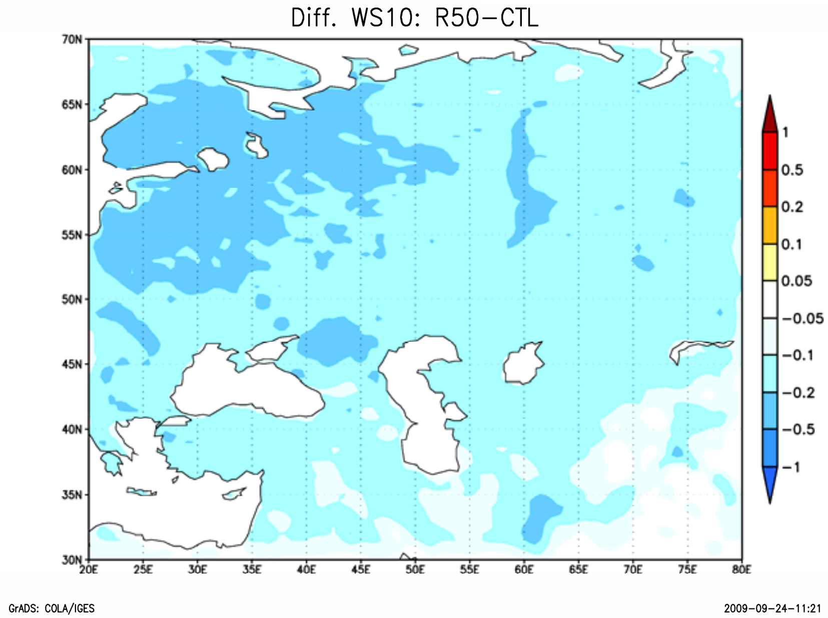
# Surface roughness: MM5 sensitivity experiments

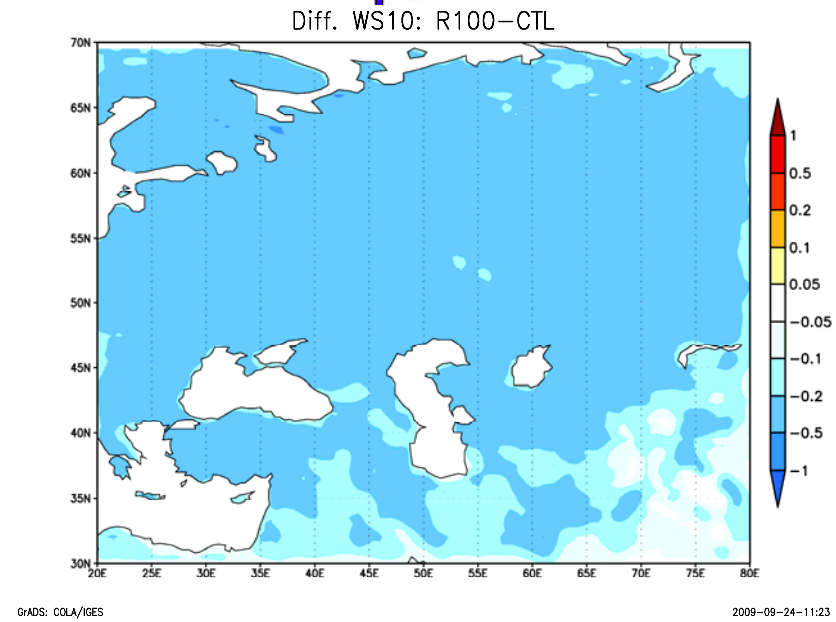
3 simulations of the y

**CTL** *control simulatio*
**R50** *idem CTL but w* *creased by 50%.*
**R100** *... 100%.*




Vautard et al.. 2009 Draft.



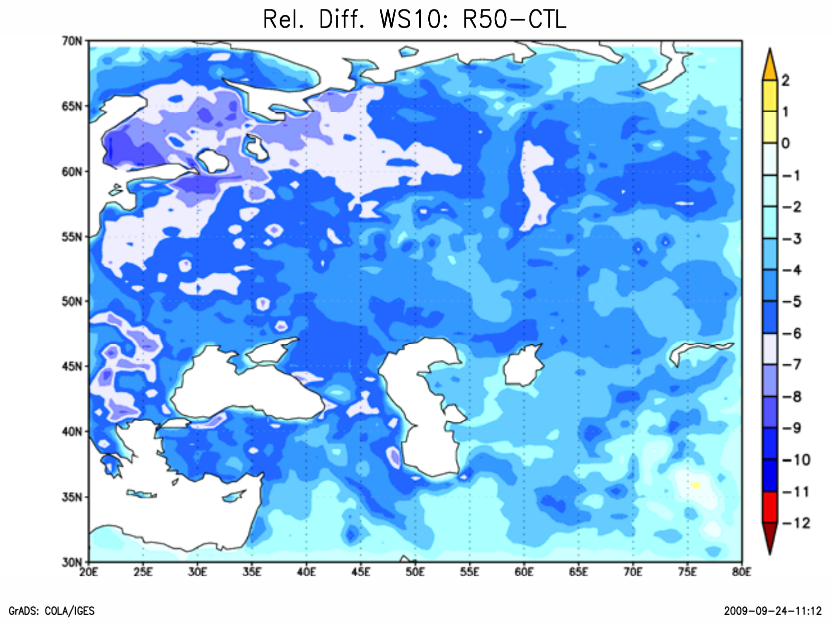

R50-CTL: average surface wind difference of -0.16m/s
R100-CTL: ... -0.26m/s
Observations: Europe -0.21m/s and Central Asia -0.54m/s in 30 years.

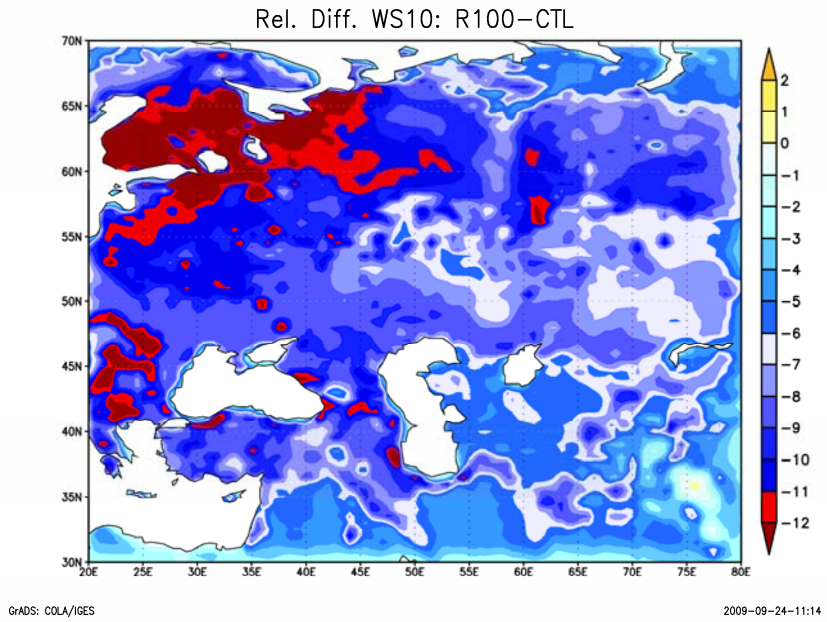
Surface roughness: MM5 sensitivity experiments

**3 simulations of the year 2007 over Eur-Asia**

**CTL** *control simulation driven and nudged (3D-wind) by OPERA.*
**R50** *idem CTL but with roughness lengths of all land classes increased by 50%.*
**R100** *... 100%.*

Vautard et al.. 2009 Draft.




R50-CTL: average surface wind difference of -0.16m/s → -4.5%.
R100-CTL: ... -0.26m/s → -7.5%.
Observations: Europe -0.21m/s and Central Asia -0.54m/s in 30 years → -10%.

# Causes?

- Changes in the global or synoptic atmospheric circulation.
  *Trends no present in reanalyses, upper-air winds, geostrophic winds.*
  *Variability of stilling stations similar to non-stilling stations.*
  *Stilling uniform and isotropic.*

- Increasing local surface roughness [Roderick et al., 2007].
  *Only a partial contribution which still needs to be properly estimated.*

- Changes in the boundary layer structure.
  *Still to be investigated. Changes in momentum fluxes?*

- Northward shift of the Hadley circulation
  [Worden et al., 2007; Lu et al., 2007; Seidel et al., 2008].
  *Consistent link in obs but not clearly established using model simulations.*

- Instrumental issues [De Gaetano, 1998; McKee et al., 2000].
  *Replacement of anemometers over the past decades & too many areas concerned.*
  *Stilling global and isotropic.*

# Concluding remarks

Surface stilling had never been investigated at its global extent so far.

It can not be attributed to changes in global or synoptic circulation.
Over China, the long-distance temperature gradient (due to monsoon changes and air pollution [Xu et al., 2006]) seems to contribute to stilling.

It may mostly result from changes in local or meso-scale processes (surface roughness or boundary layer changes).

Stilling trends are not present in NCEP reanalyses, which should be elucidated.

The wind power energy (varying as the cubic power of wind speed) may be significantly affected in the future.