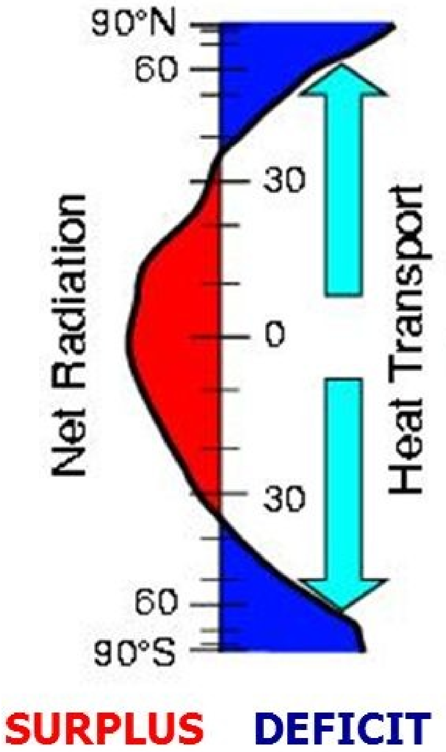
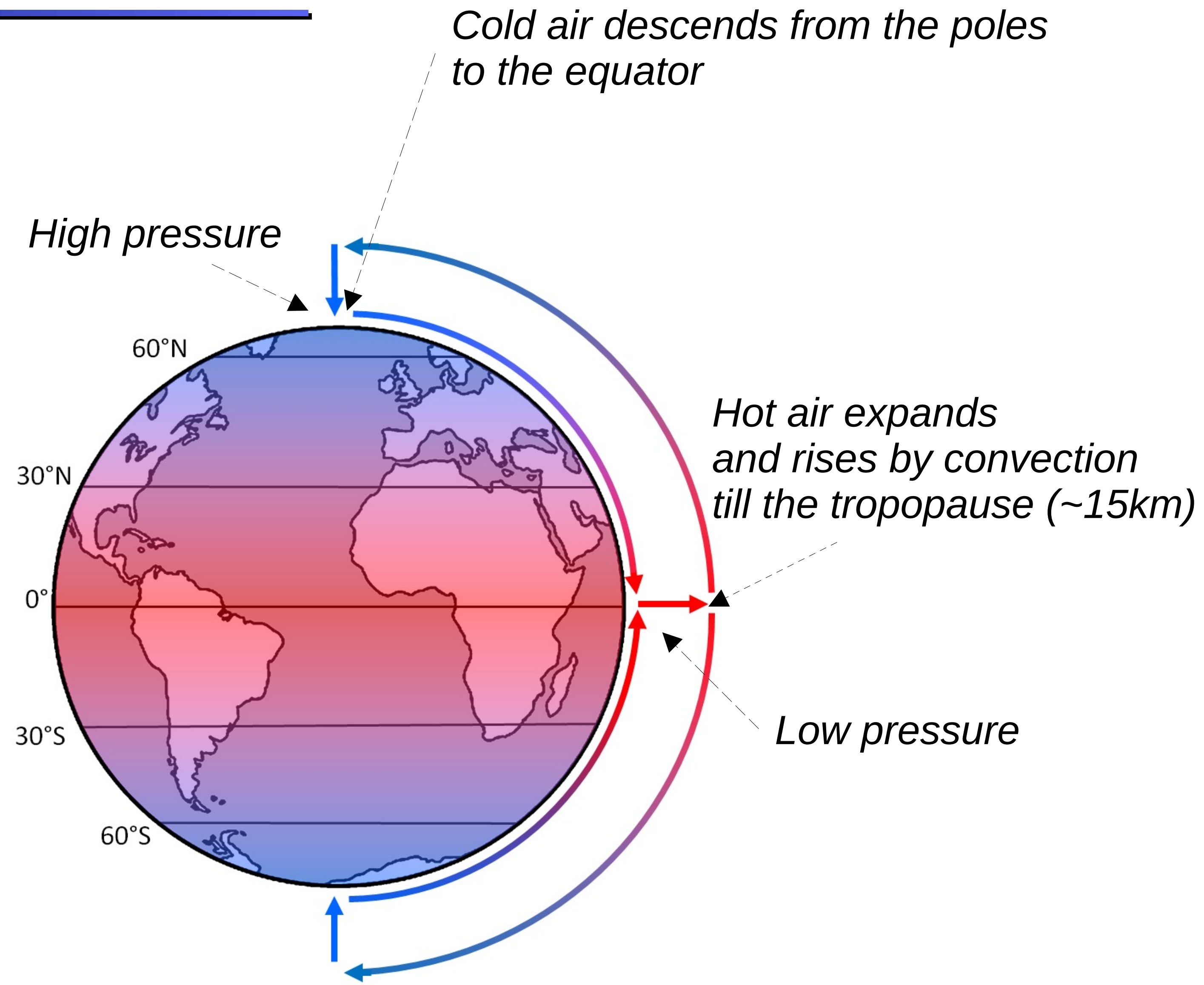
Climate change and renewable energies

Xavier Fettweis

Some Reminders (1/10)

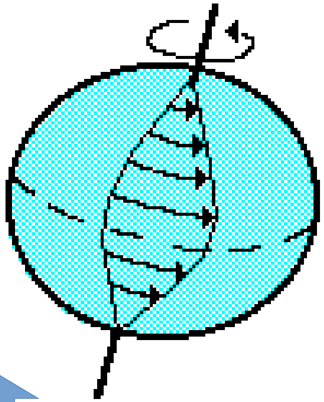
Like an air flow...





The larger the thermal contrast between the poles and the equator, the more dynamic the atmospheric circulation is.

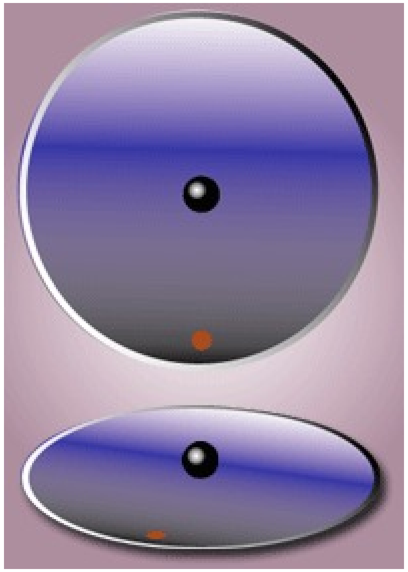
Some Reminders (2/10)

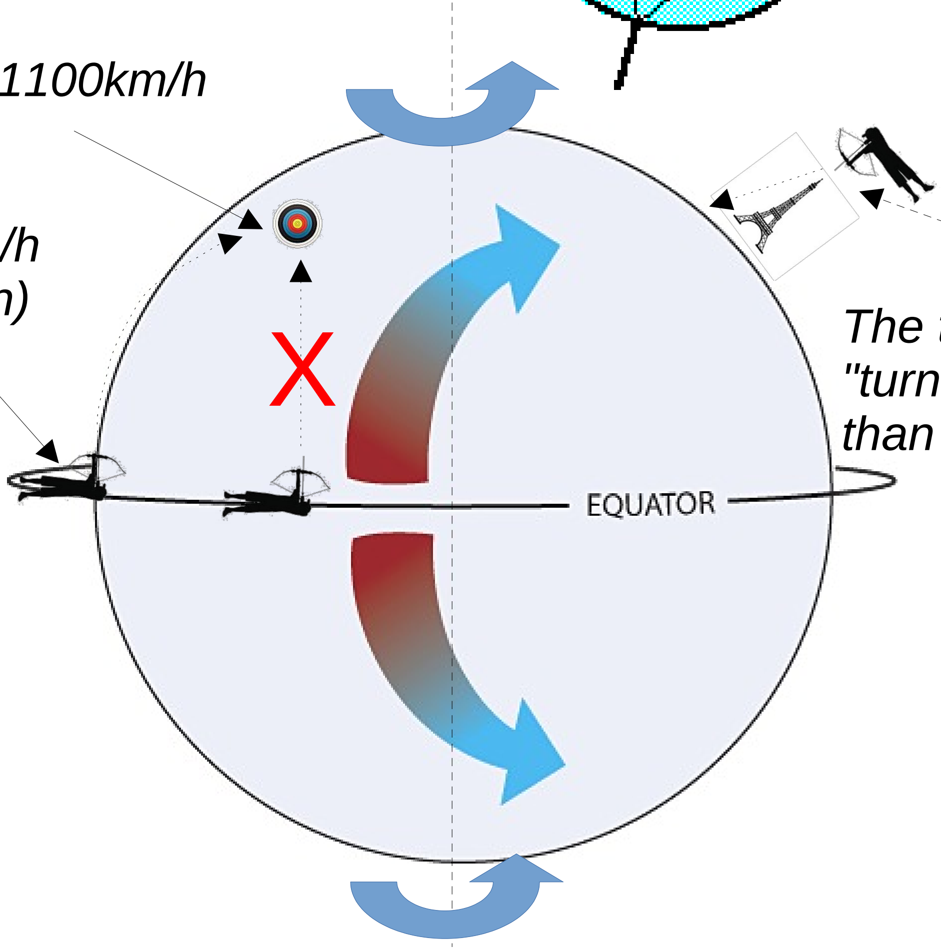


But the Earth is rotating...

Target at 50°N : ~1100km/h

Archer at 0°N : ~1600km/h
(relative velocity 500km/h)



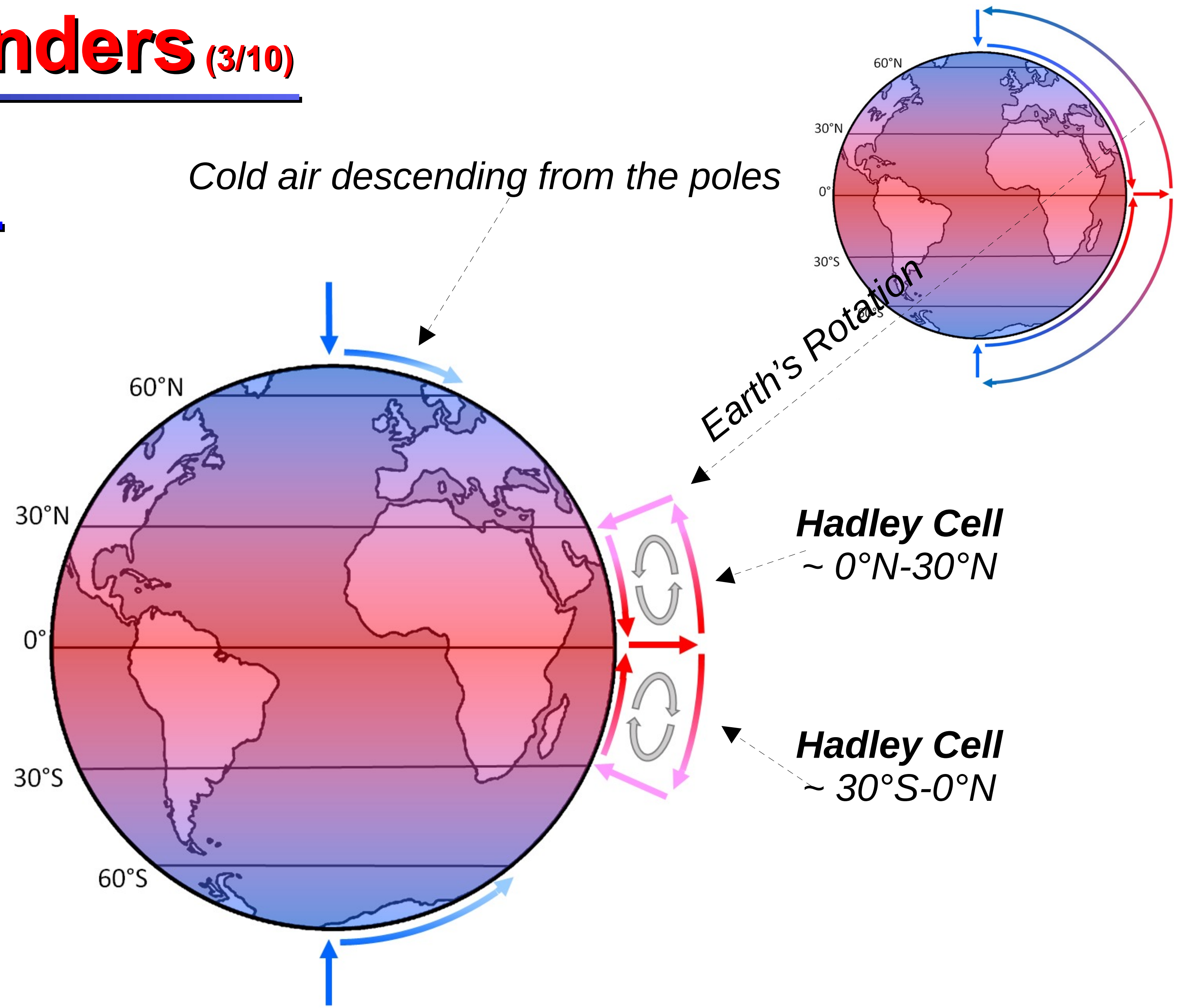


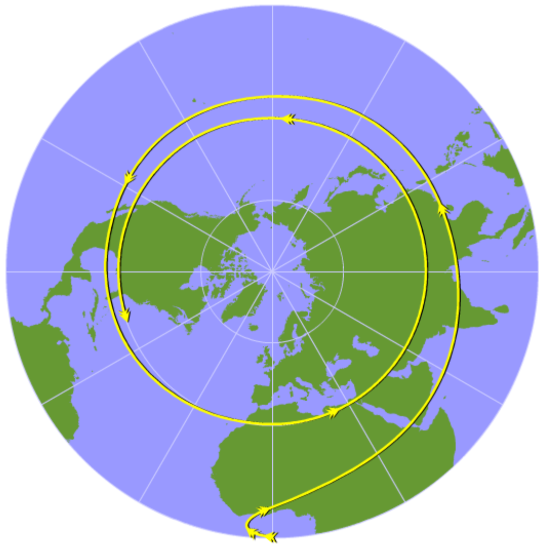
The top of the Eiffel Tower "turns" faster (by 0.05km/h) than its basis

With the Coriolis force...
… the winds are deviated towards the East i.e. the right/left in the Northern/Southern Hemisphere.

Some Reminders (3/10)

Vertical section...

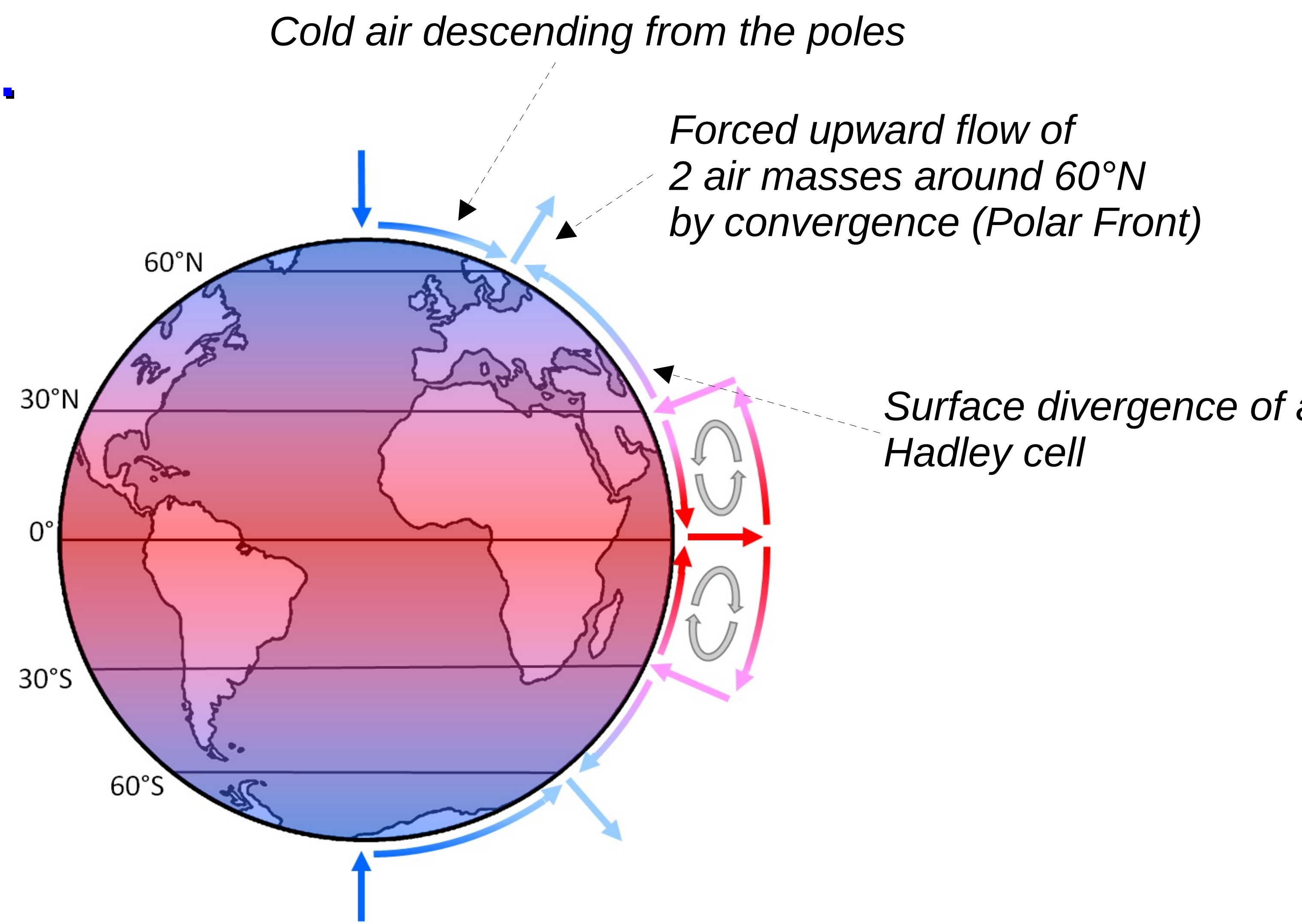




thermal driven

Some Reminders (4/10)

Vertical section...



thermal and dynamics driven

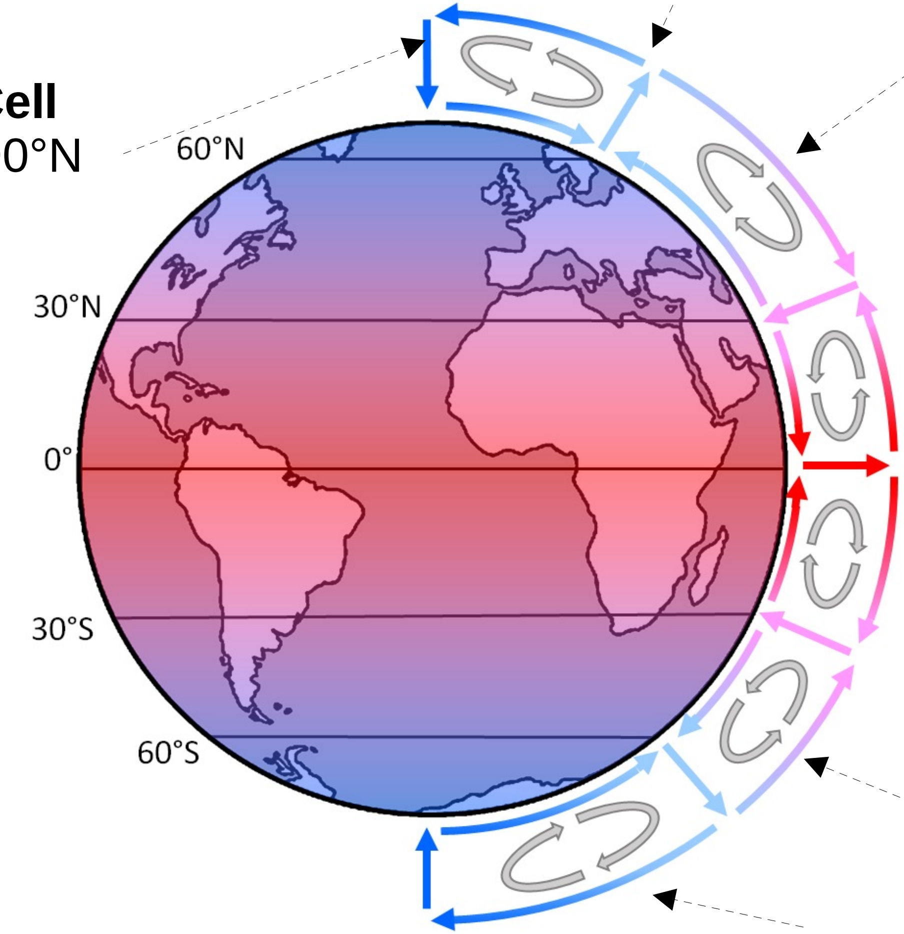
Some Reminders (5/10)

Vertical section...

Divergence at the tropopause (~10km) of the air resulting flow coming from the convergence at the surface

Polar Cell
~ 60°N-90°N

Ferrel Cell
~ 30°N-60°N



Ferrel Cell
~ 30°S-60°S

Polar Cell
~ 90°S-60°S

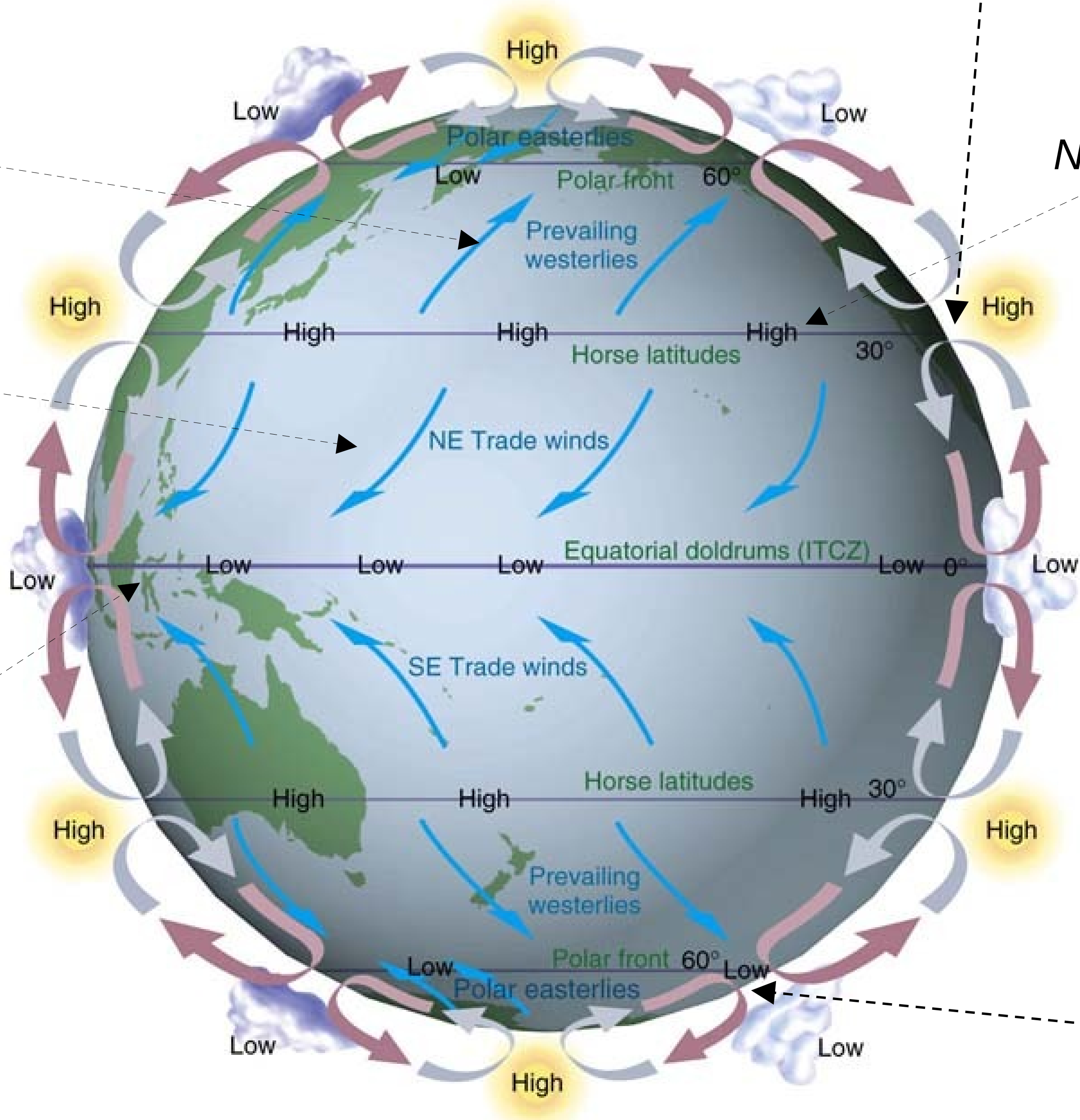
Driver: Thermal (Polar Cell) and Dynamic (Ferrel Cell)

Some Reminders (6/10)

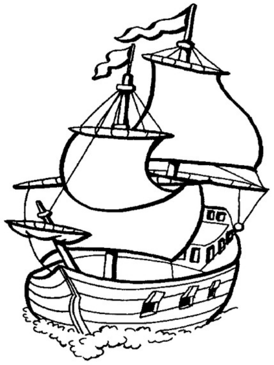
down draft flow +
divergence
=> High Pressure **(H)**

West winds

No wind



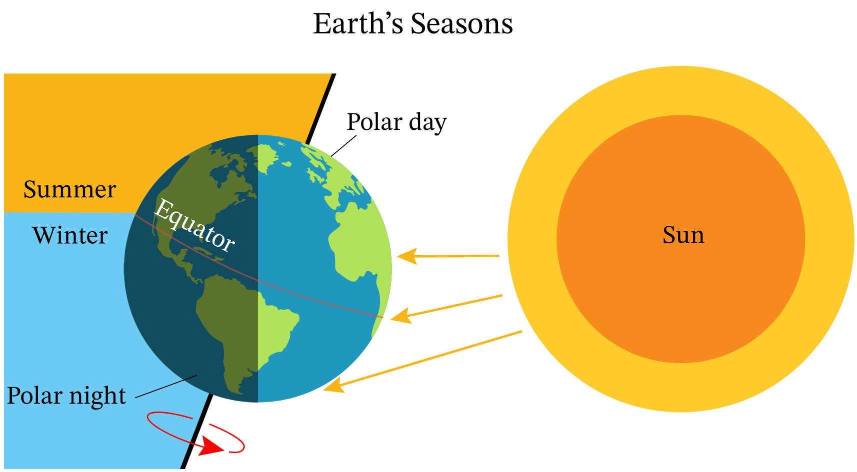
Intertropical Convergence Zone (ITCZ)

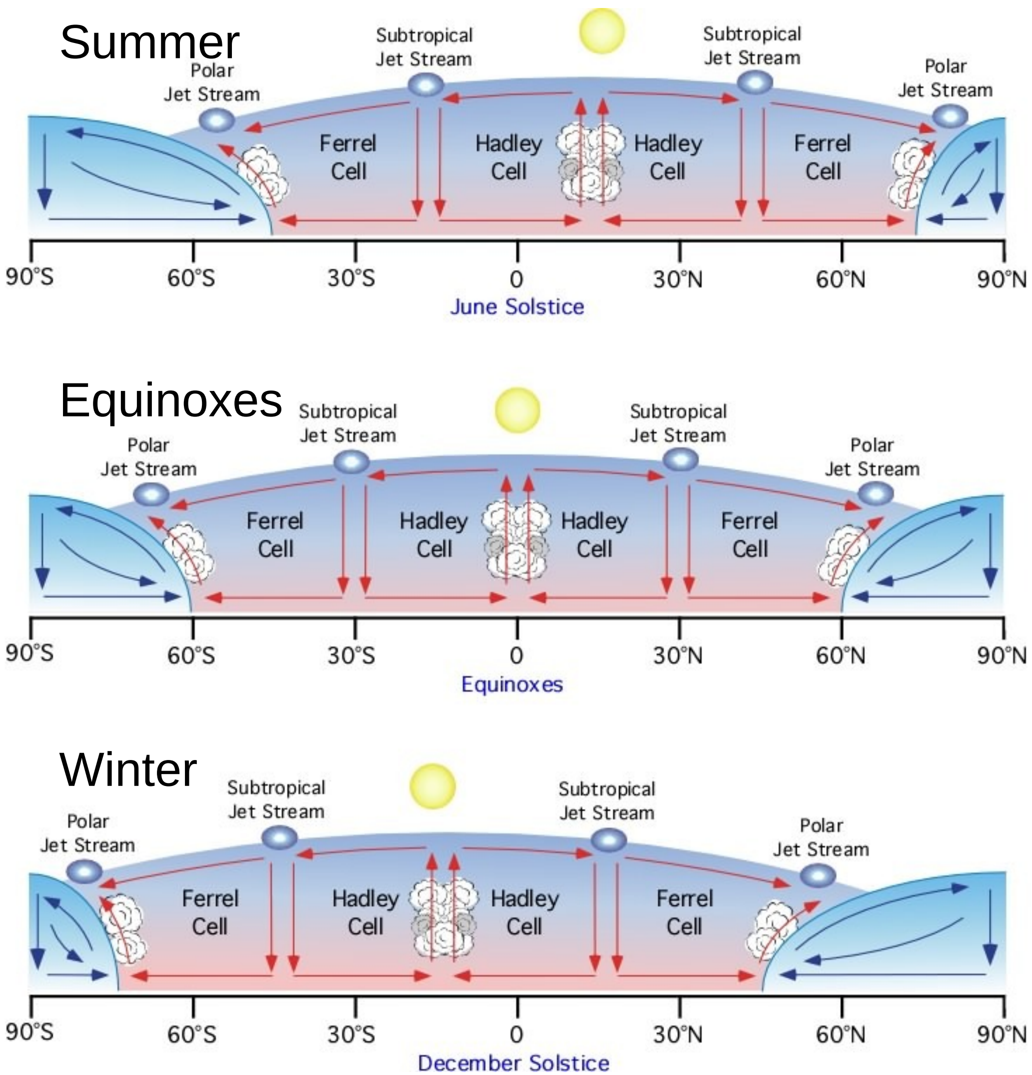


Convergence
+ up draft flow
=> Low Pressure ***(L)***

Some Reminders (7/10)

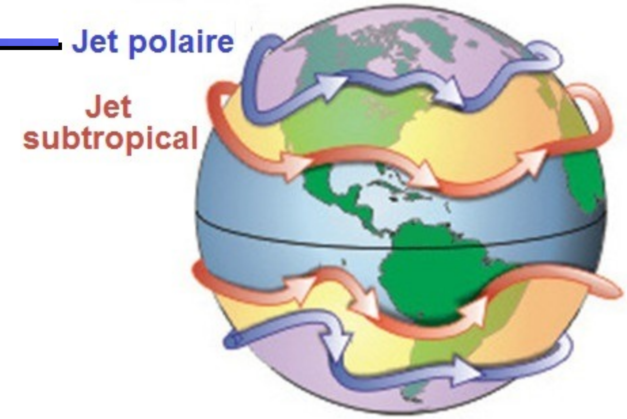
Seasonal variability





- Maximum sunshine in the tropics
- The position of ICTZ seasonally varies.
- The Polar Cell takes up more “space” in winter than in summer

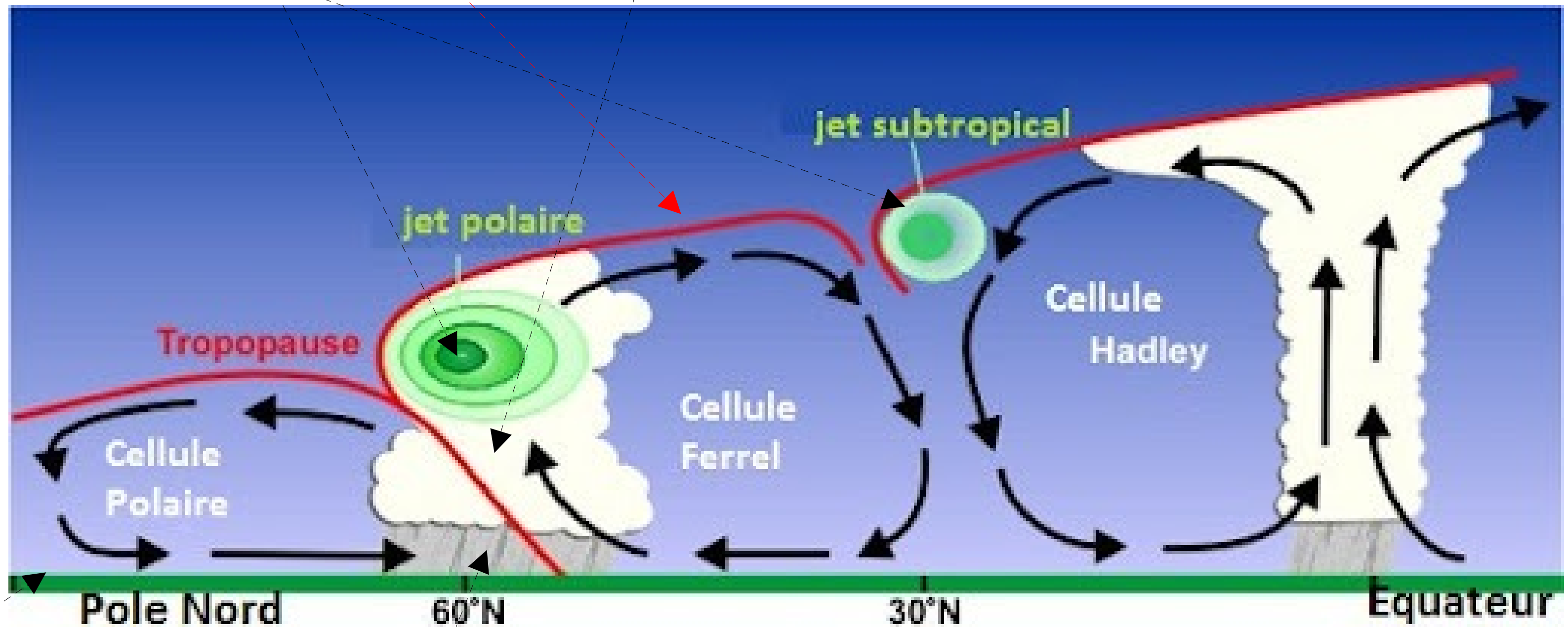
Some Reminders (8/10)



The tropopause altitude decrease with latitude

Thermal wind

Up draft of warm and wet air

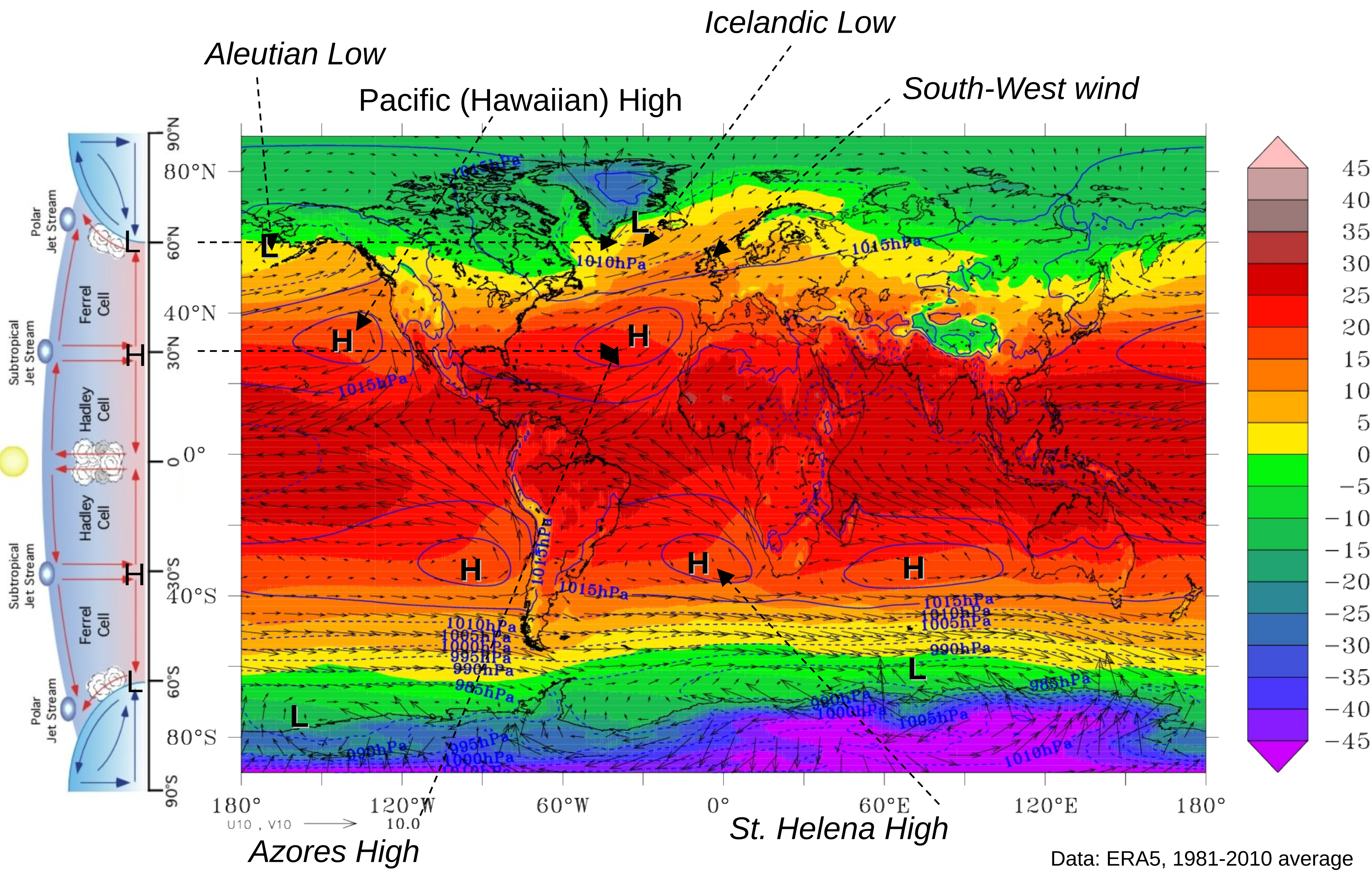


Pole Nord: Cold desert

Precipitation occurs at the Polar Front

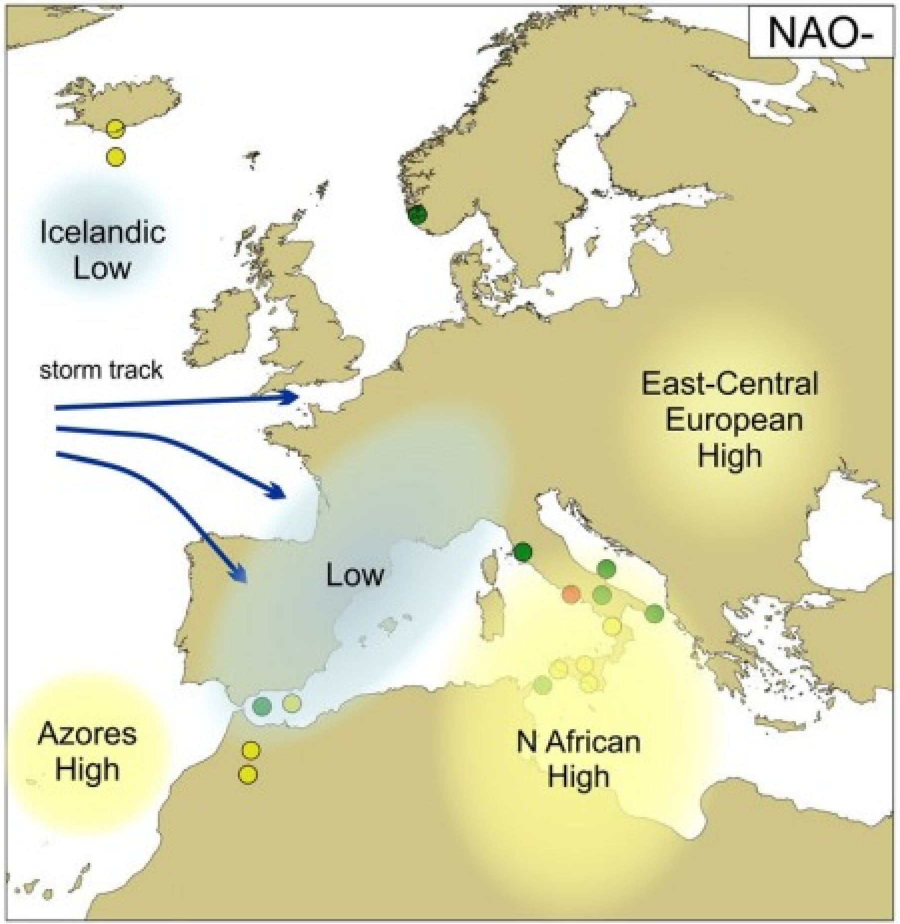
Polar Front oscillation explains the variability of our weather

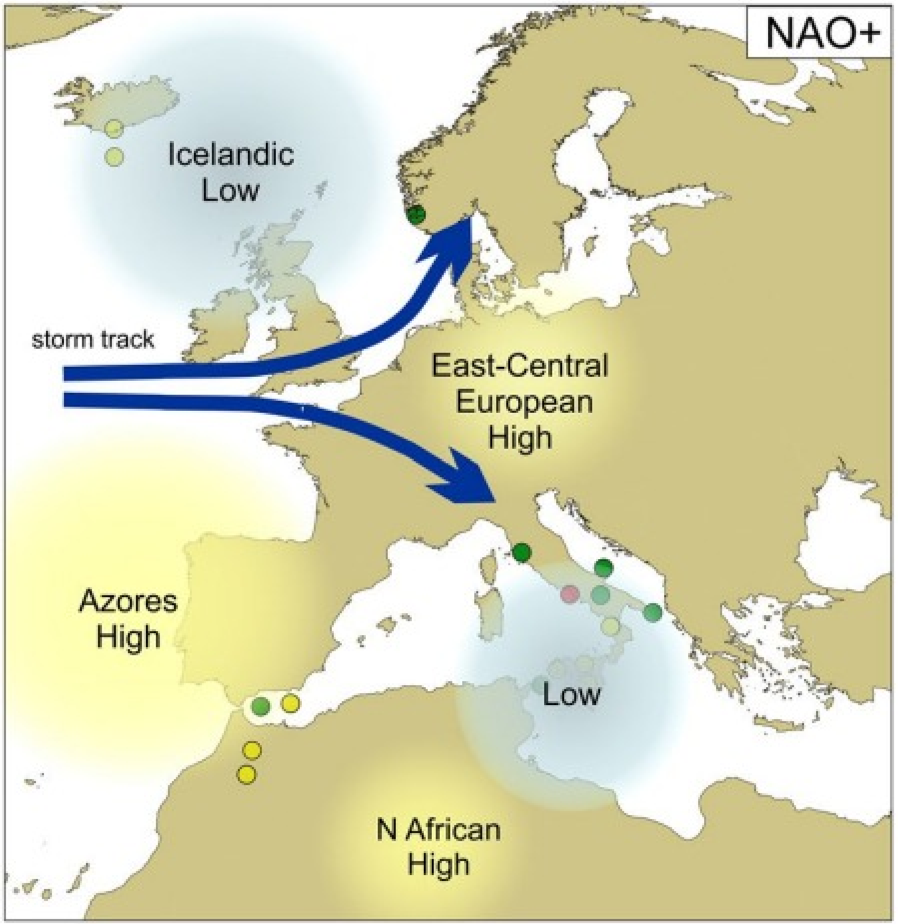
Some Reminders (9/10)



Data: ERA5, 1981-2010 average

Some Reminders (10/10)





North Atlantic Oscillation (NAO)

Normalized pressure difference between the Icelandic Low and the Azores High

Local wind

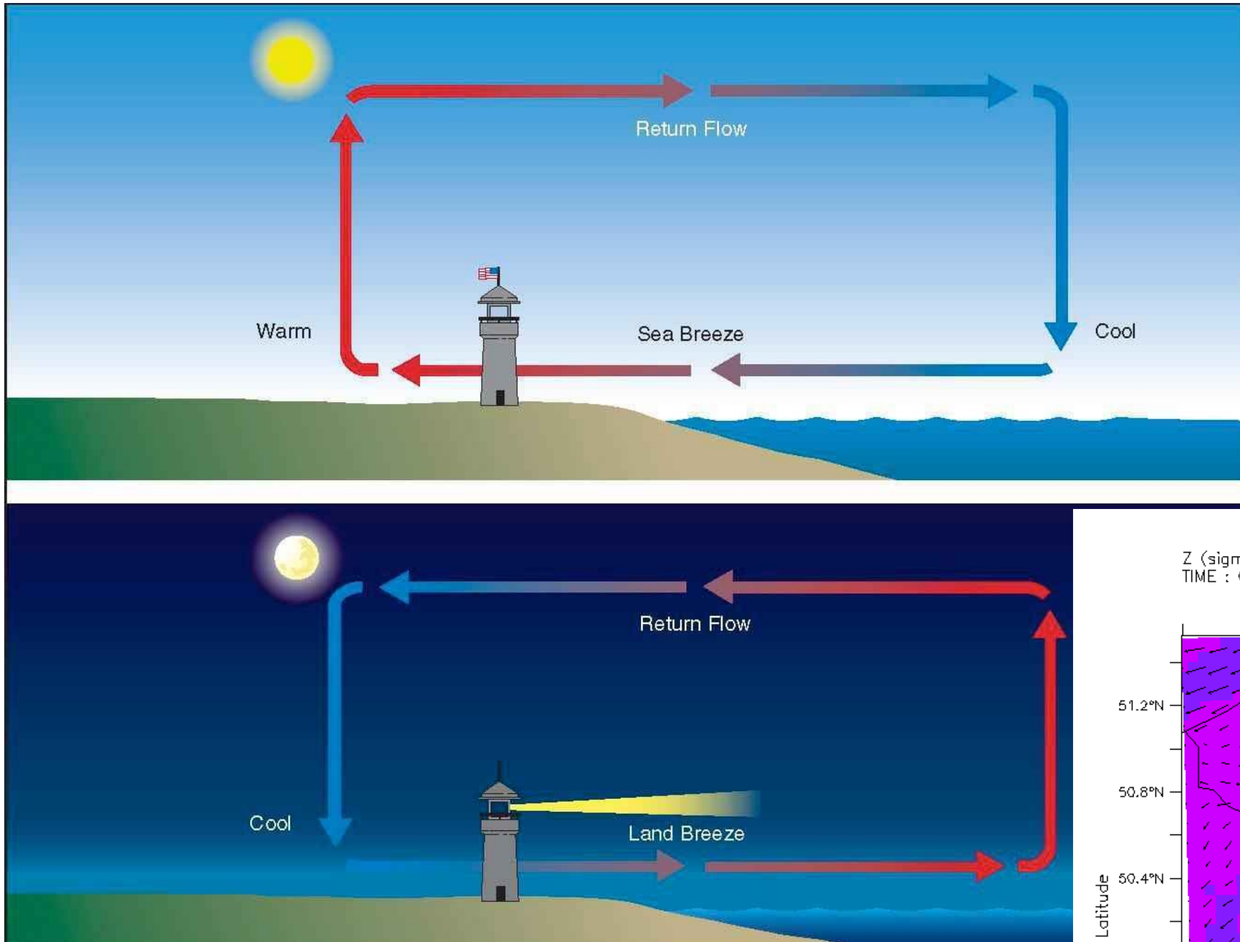
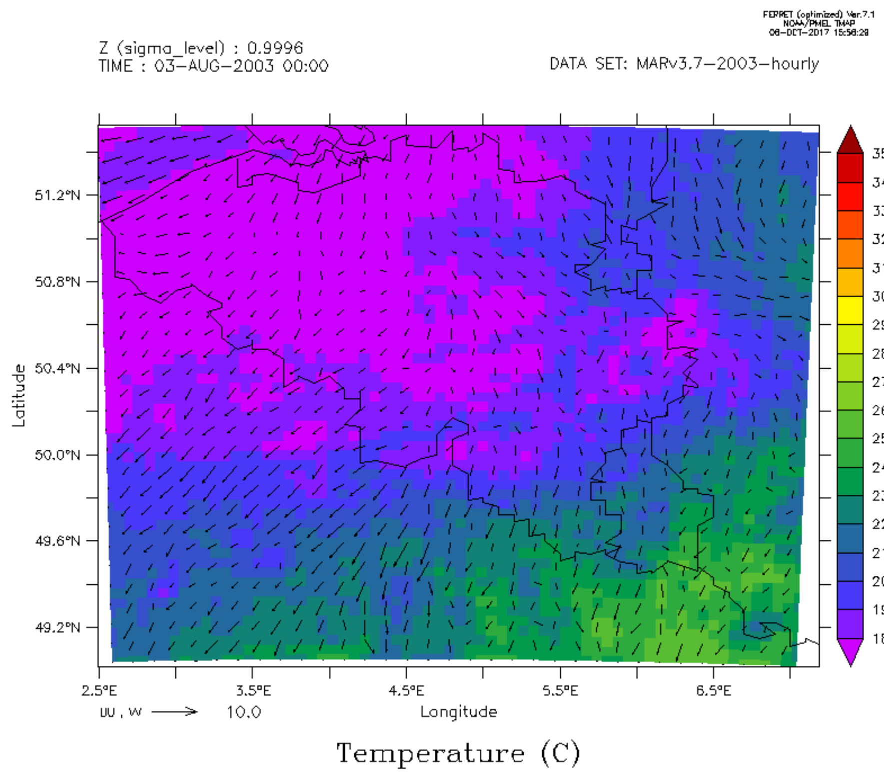


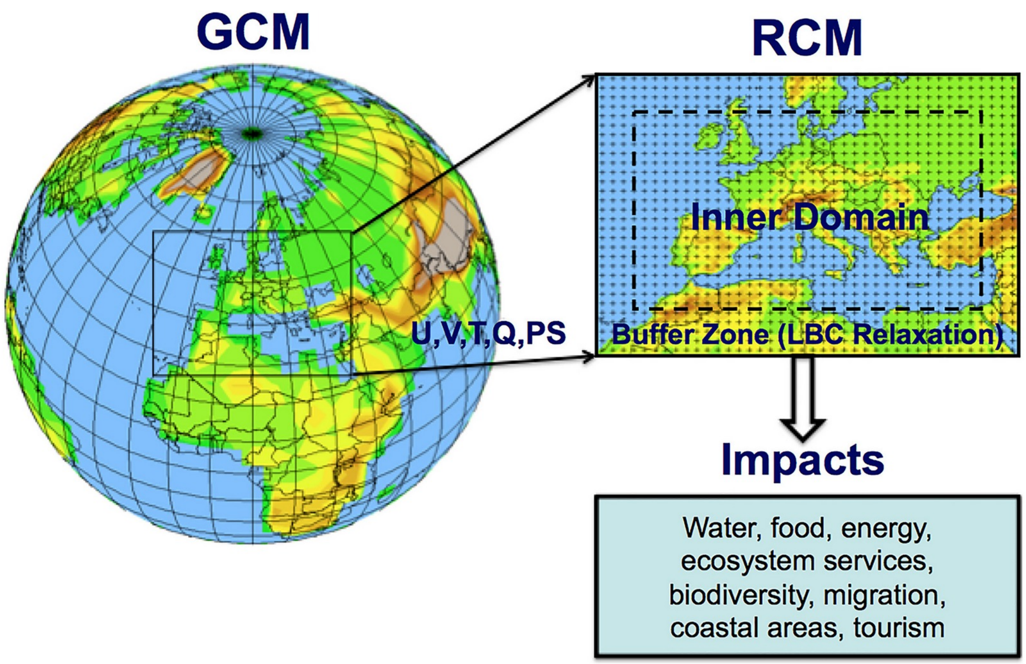
Figure 10-13. Sea breeze and land breeze wind circulation patterns.



Sea and valley breeze

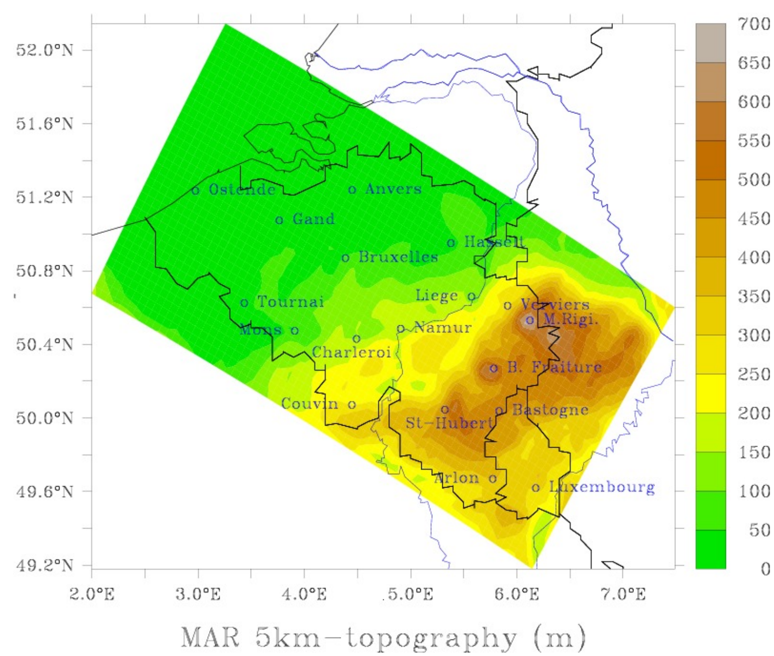
The MAR model

LIÈGE université
Climatologie & Topoclimatologie



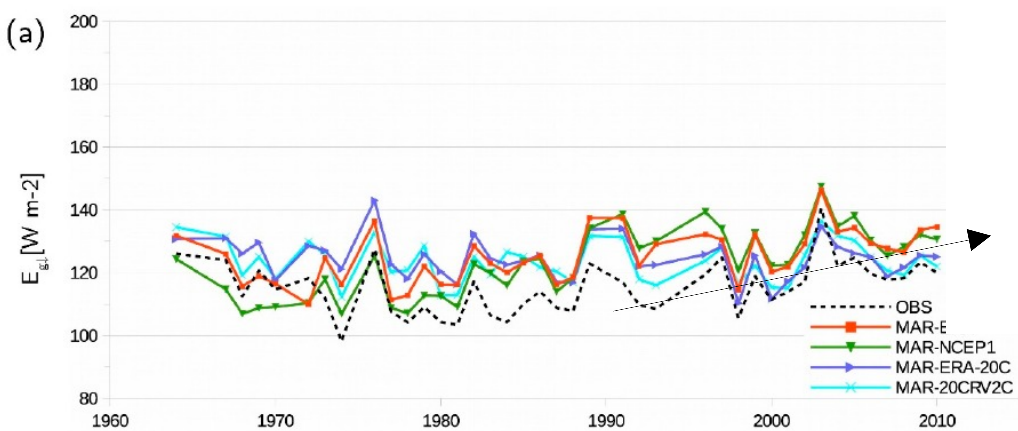
Modèle Atmosphérique Régionale

The MAR model is used to downscale over Belgium large scale future projections

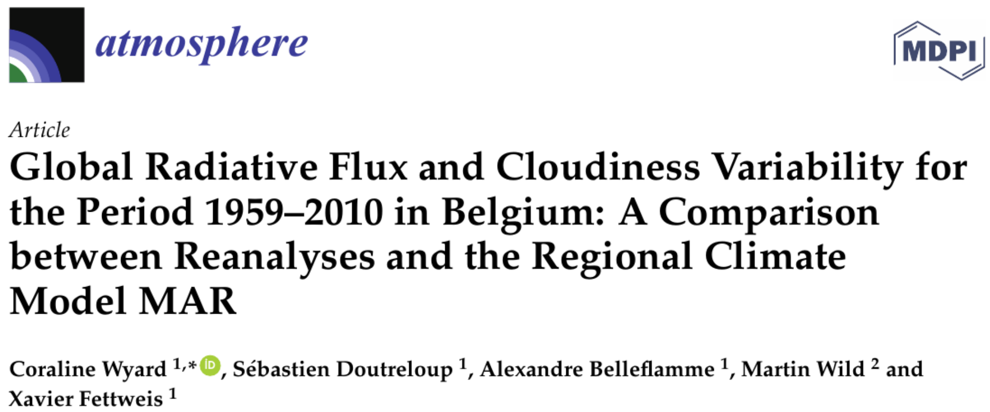


fnrs
LA LIBERTÉ DE CHERCHER

Current evolution : Solar flux (1/2)



Solar flux observed and simulated at Saint-Hubert



atmosphere

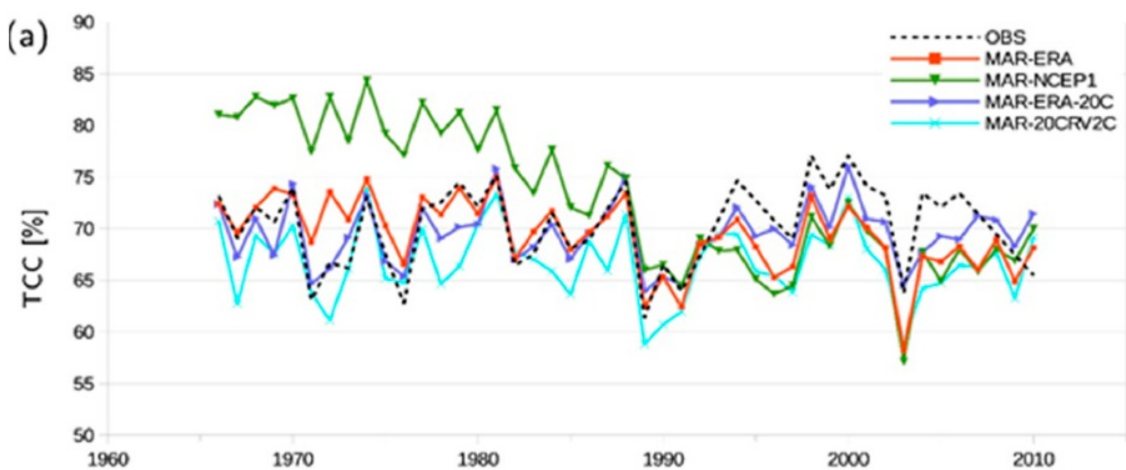
MDPI

Article

Global Radiative Flux and Cloudiness Variability for the Period 1959–2010 in Belgium: A Comparison between Reanalyses and the Regional Climate Model MAR

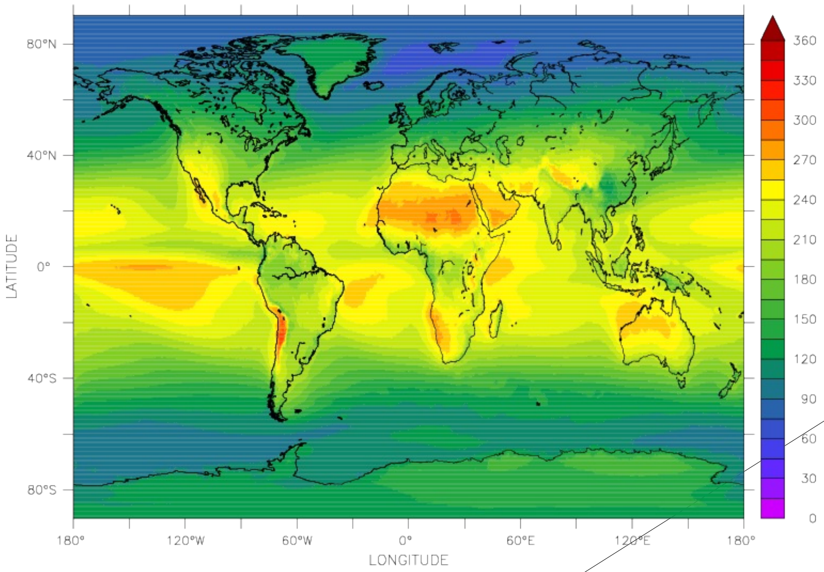
Coraline Wyard [1,*], Sébastien Doutreloup [1], Alexandre Belleflamme [1], Martin Wild [2] and Xavier Fettweis [1]

Cloudiness observed and simulated at Saint-Hubert

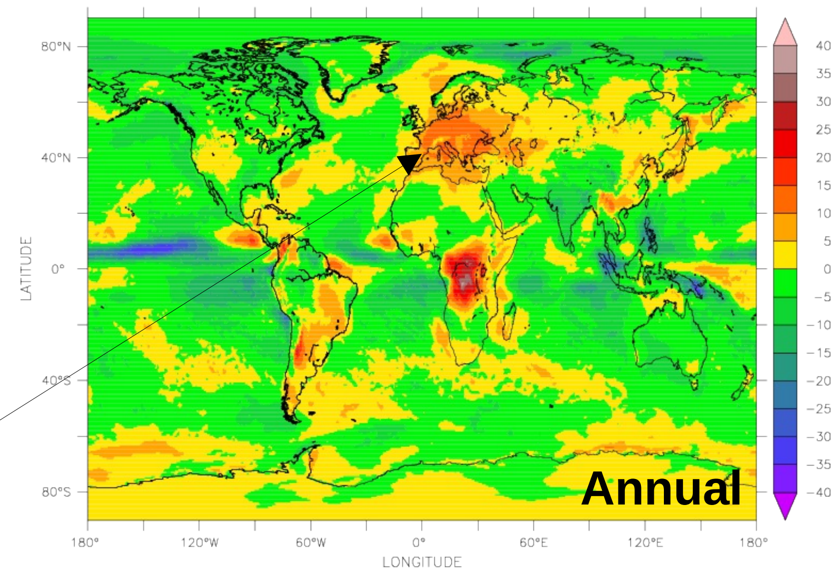


Current evolution : Solar flux (2/2)

Annual solar flux 1960-2021 (w/m2)



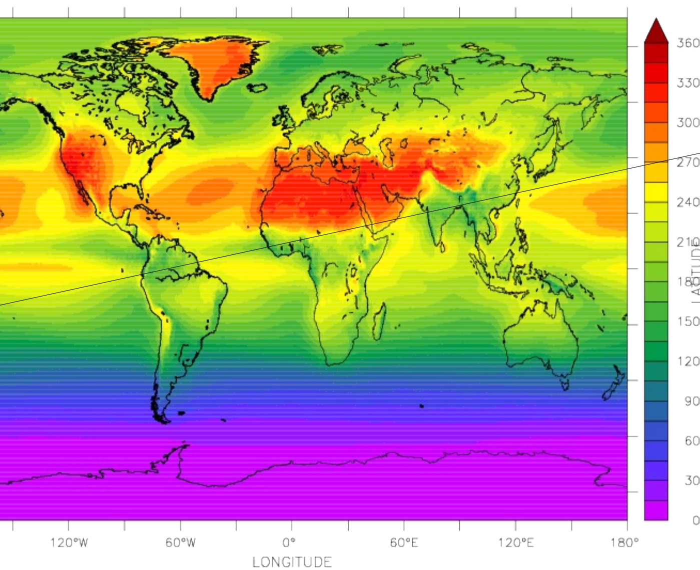
Cumulated change from 1960 (w/m^2/62yrs)

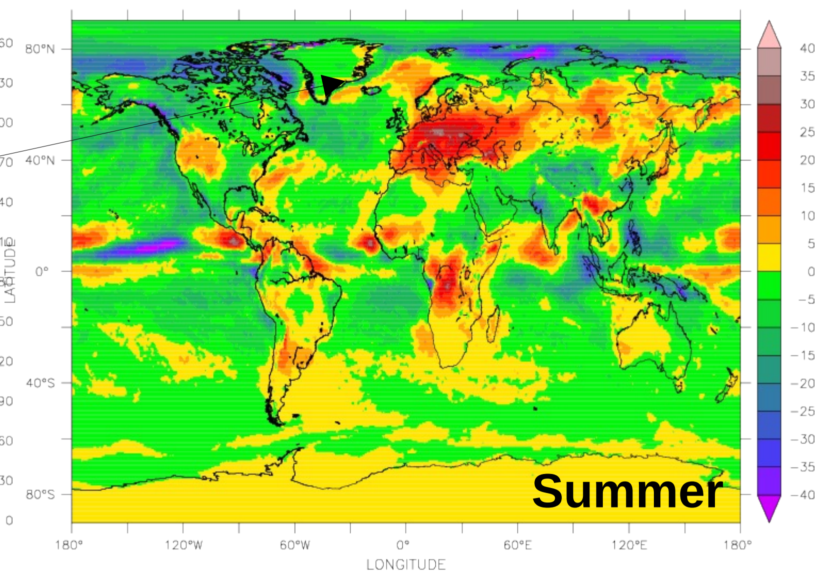


Pollution decreasing

+

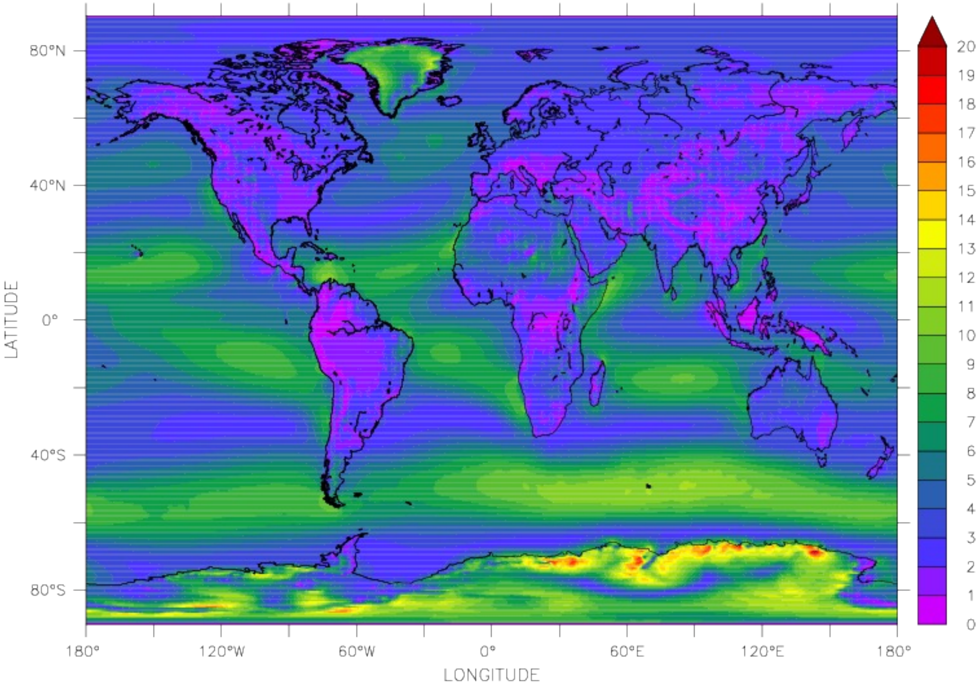
General circulation change
and change in cloudiness



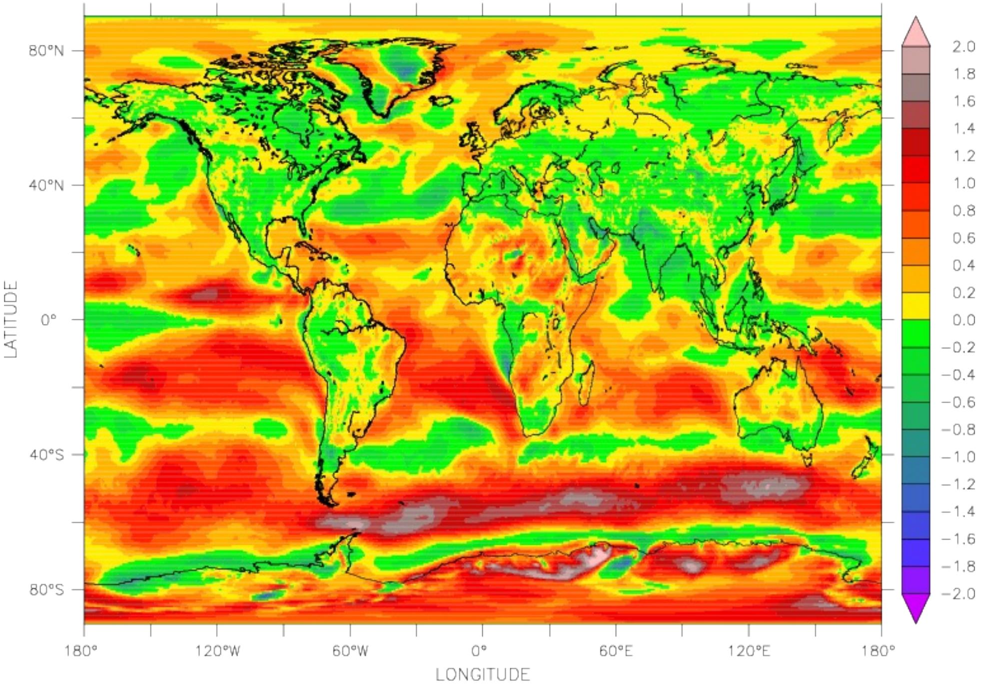


Current evolution : Wind (1/3)

What about wind ?



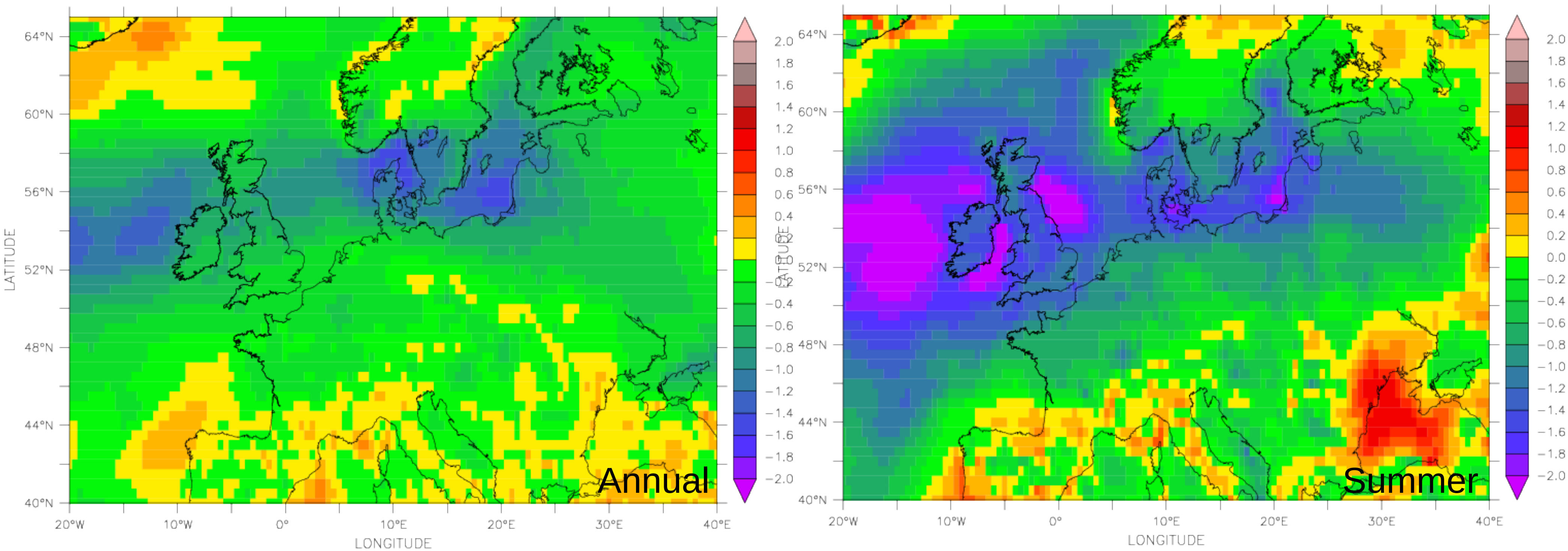
Mean wind speed at 100m
over 1960-2021 (m/s)



Cumulated change (m/s/42yrs)

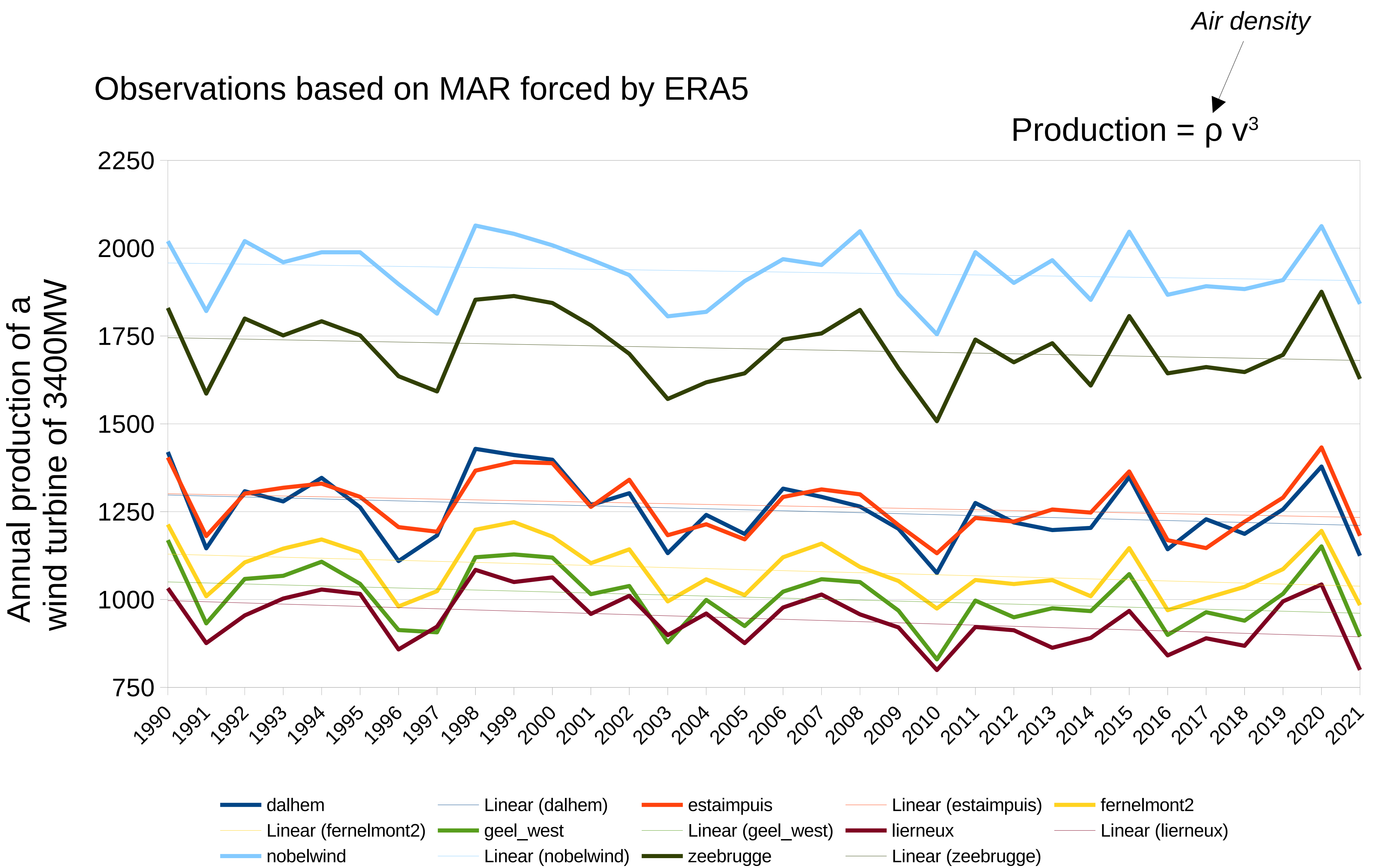
Not very significant change observed but ...

Current evolution : Wind (2/3)



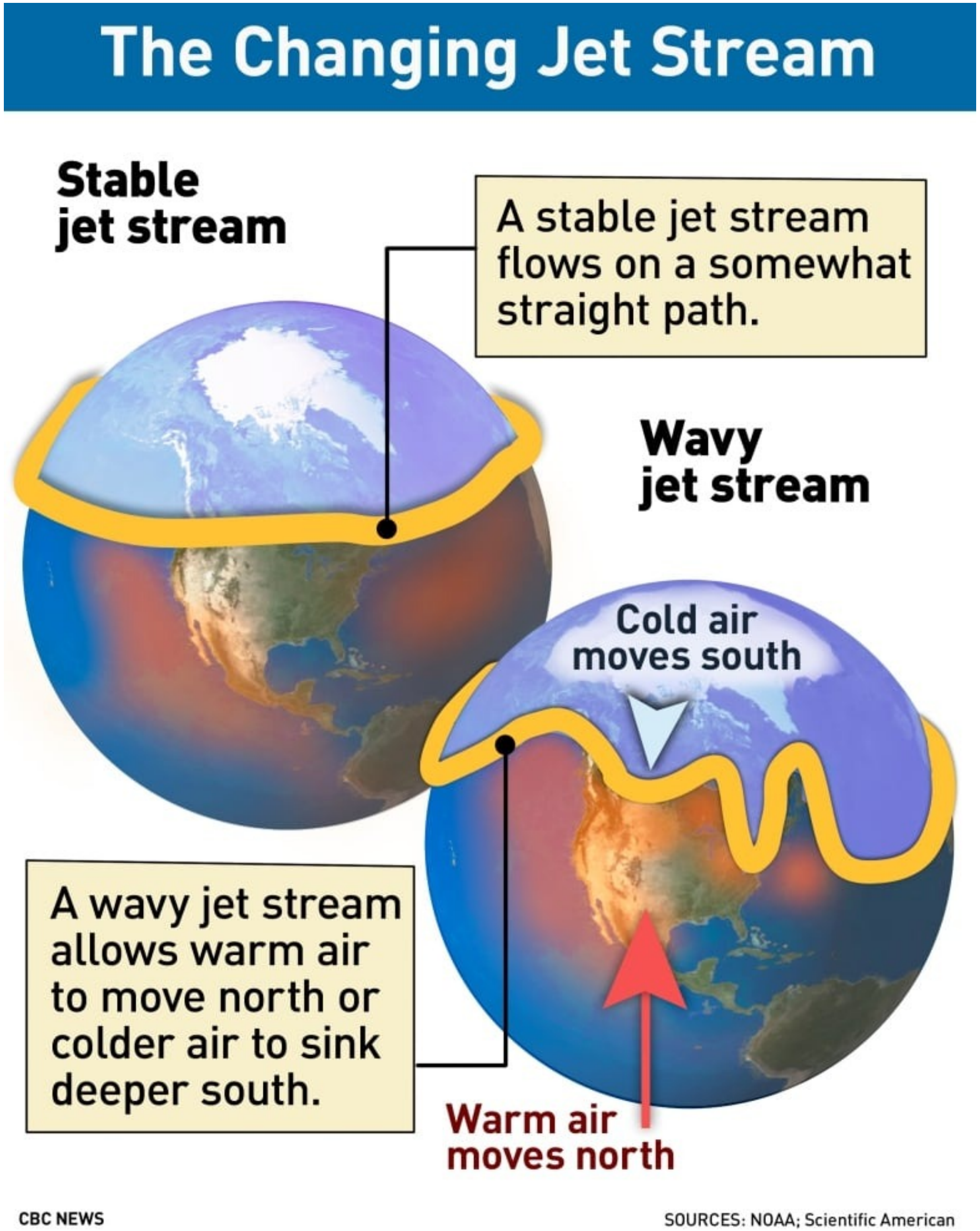
Wind speed anomaly in 2021 (m/s)

Current evolution : Wind (3/3)



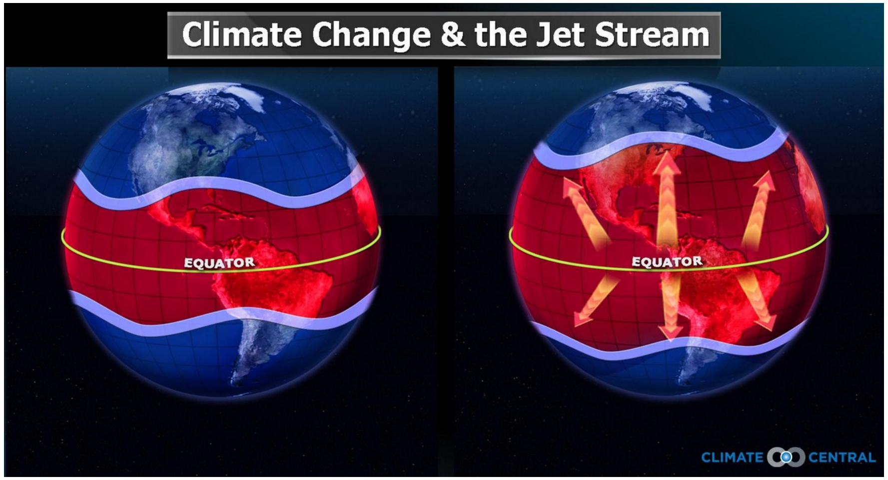
Source : MAR forced by ERA5

Climate change impact (1/4)



=> slow down + oscillation of the jet
- => + meridional wind (N/S)
- => - zonal wind (W/E)
- => + anticyclonic blocking

=> jet toward the Nord (mainly in summer)
- => Azores High should reach our latitude



Climate change impact (2/4)

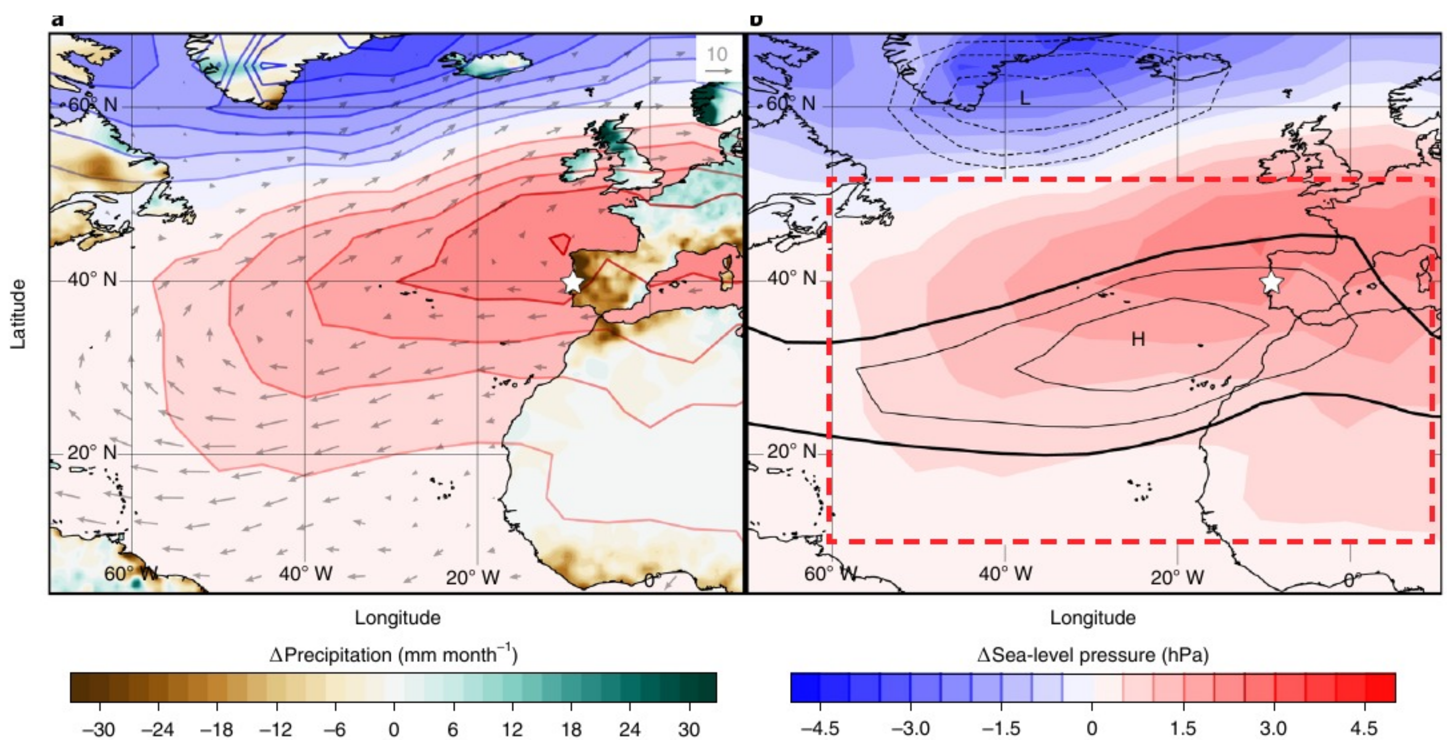
ARTICLES
https://doi.org/10.1038/s41561-022-00971-w
nature geoscience
Check for updates

Twentieth-century Azores High expansion unprecedented in the past 1,200 years

Nathaniel Cresswell-Clay[1], Caroline C. Ummenhofer[1]✉, Diana L. Thatcher[2], Alan D. Wanamaker[2], Rhawn F. Denniston[3], Yemane Asmerom[4] and Victor J. Polyak[4]

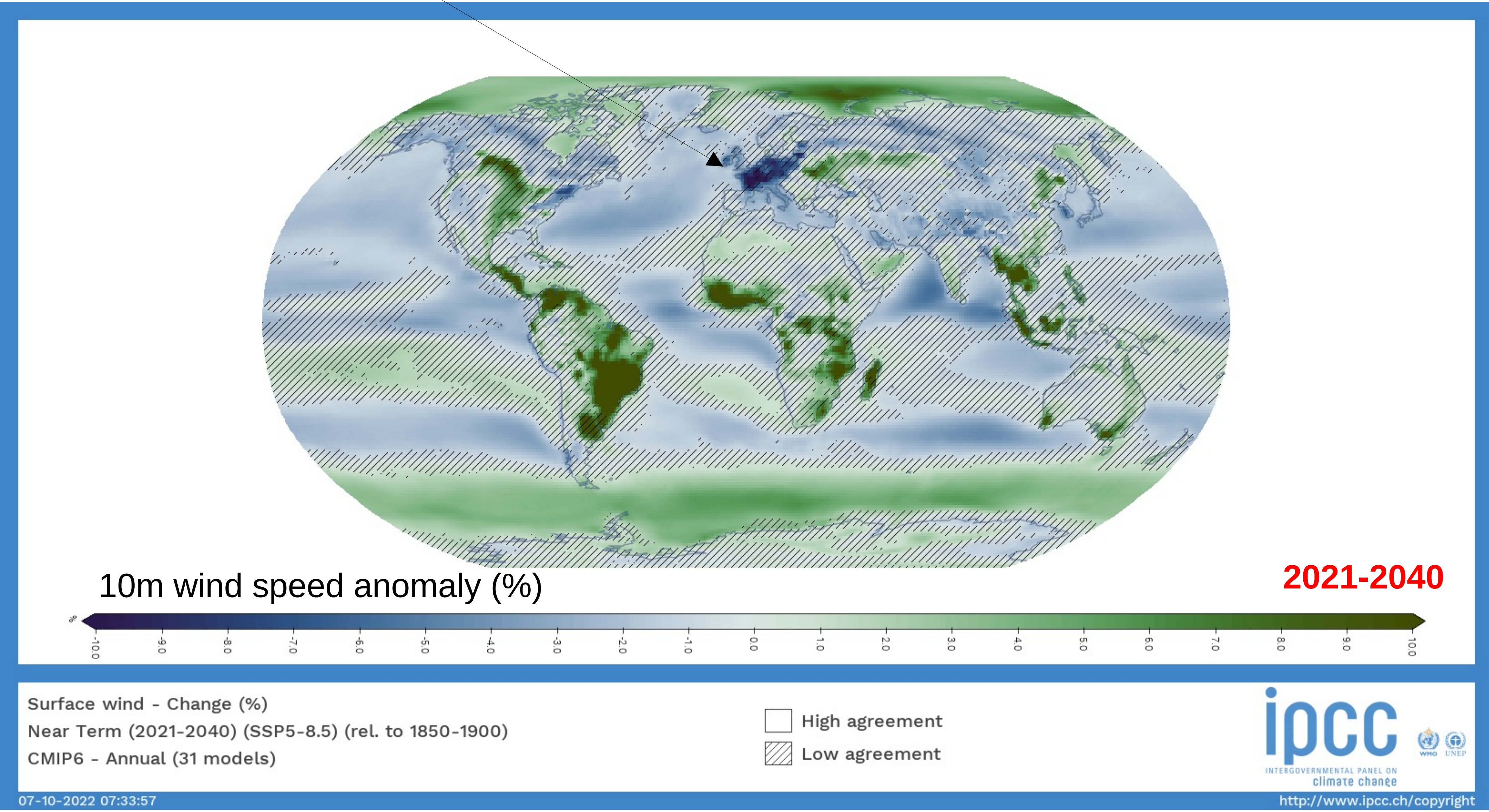
The Azores High is a persistent atmospheric high-pressure ridge over the North Atlantic surrounded by anticyclonic winds that steer rain-bearing weather systems and modulate the oceanic moisture transport to Europe. The areal extent of the Azores High thereby affects precipitation across western Europe, especially during winter. Here we use observations and ensemble climate model simulations to show that winters with an extremely large Azores High are significantly more common in the industrial era (since CE 1850) than in pre-industrial times, resulting in anomalously dry conditions across the western Mediterranean, including the Iberian Peninsula. Simulations of the past millennium indicate that the industrial-era expansion of the Azores High is unprecedented throughout the past millennium (since CE 850), consistent with precipitation proxy evidence from Portugal. Azores High expansion emerges after CE 1850 and strengthens into the twentieth century, consistent with anthropogenically driven warming.

1980-2007 VS 1950-1979



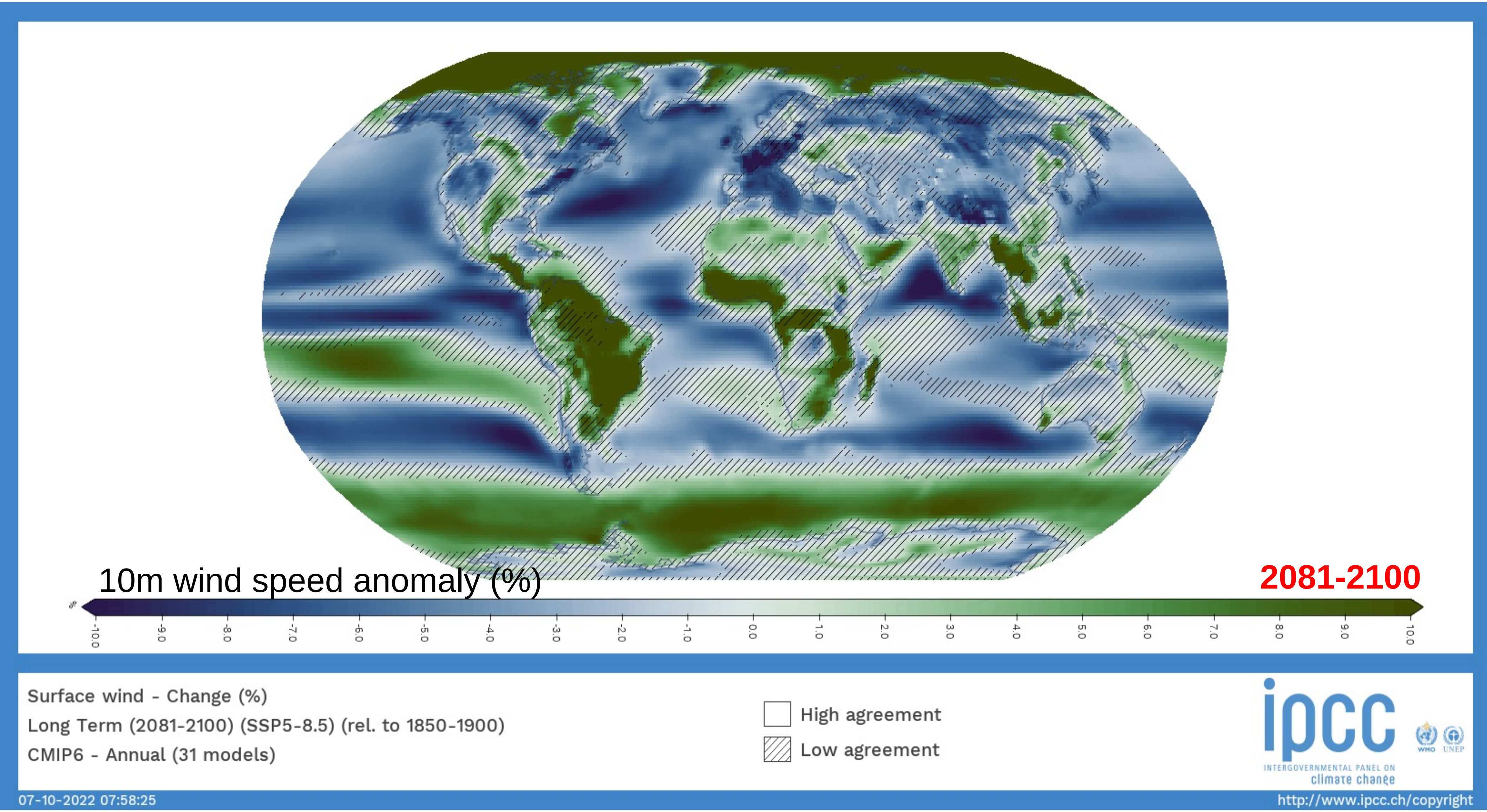
Climate change impact (3/4)

Europe is the most impacted area



Average of 31 global models from IPCC

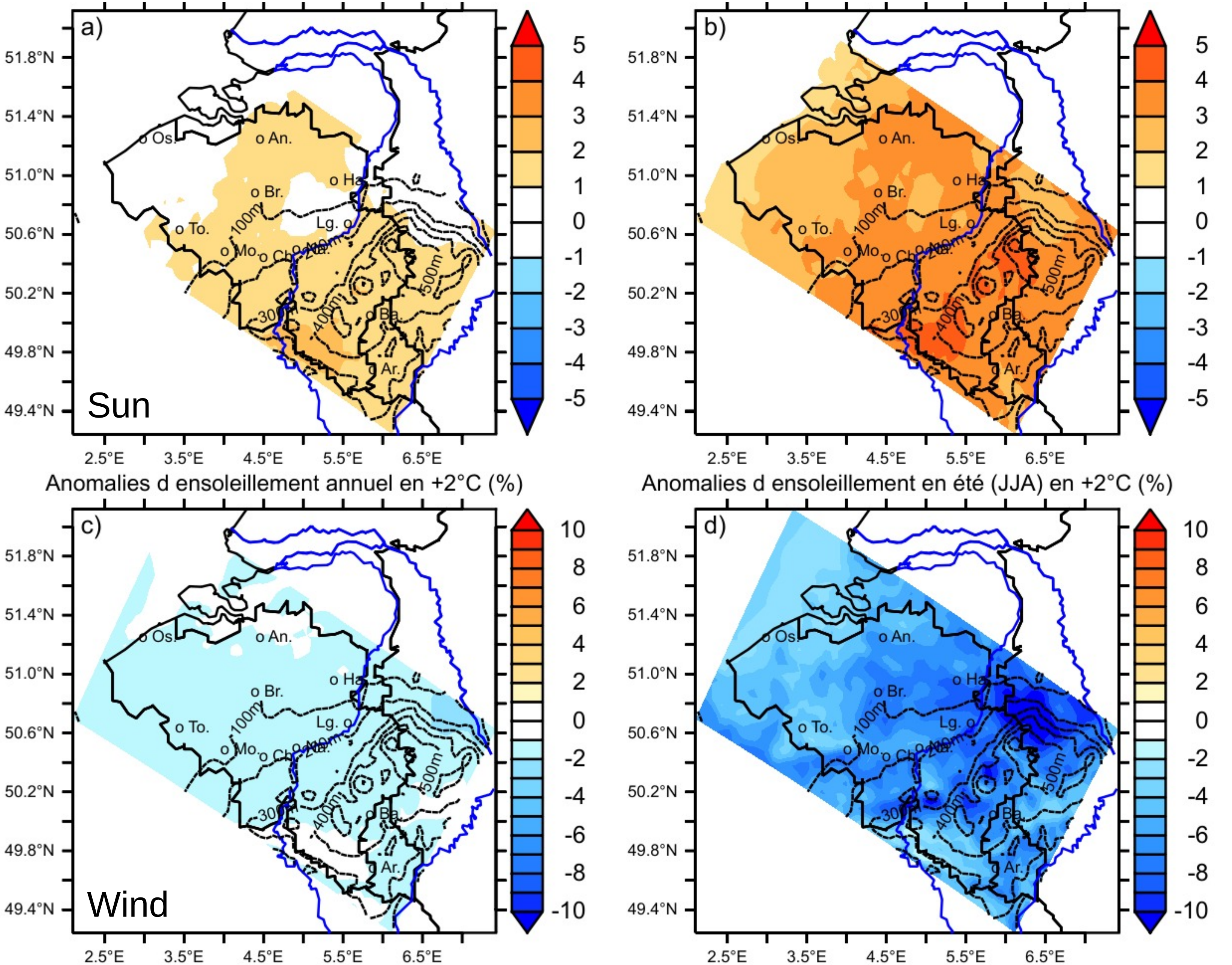
Climate change impact (4/4)



Average of 31 global models from IPCC

Future evolution in Belgium

In a +2°C world
~ 2031-2060



Anomalies d ensoleillement annuel en +2°C (%)

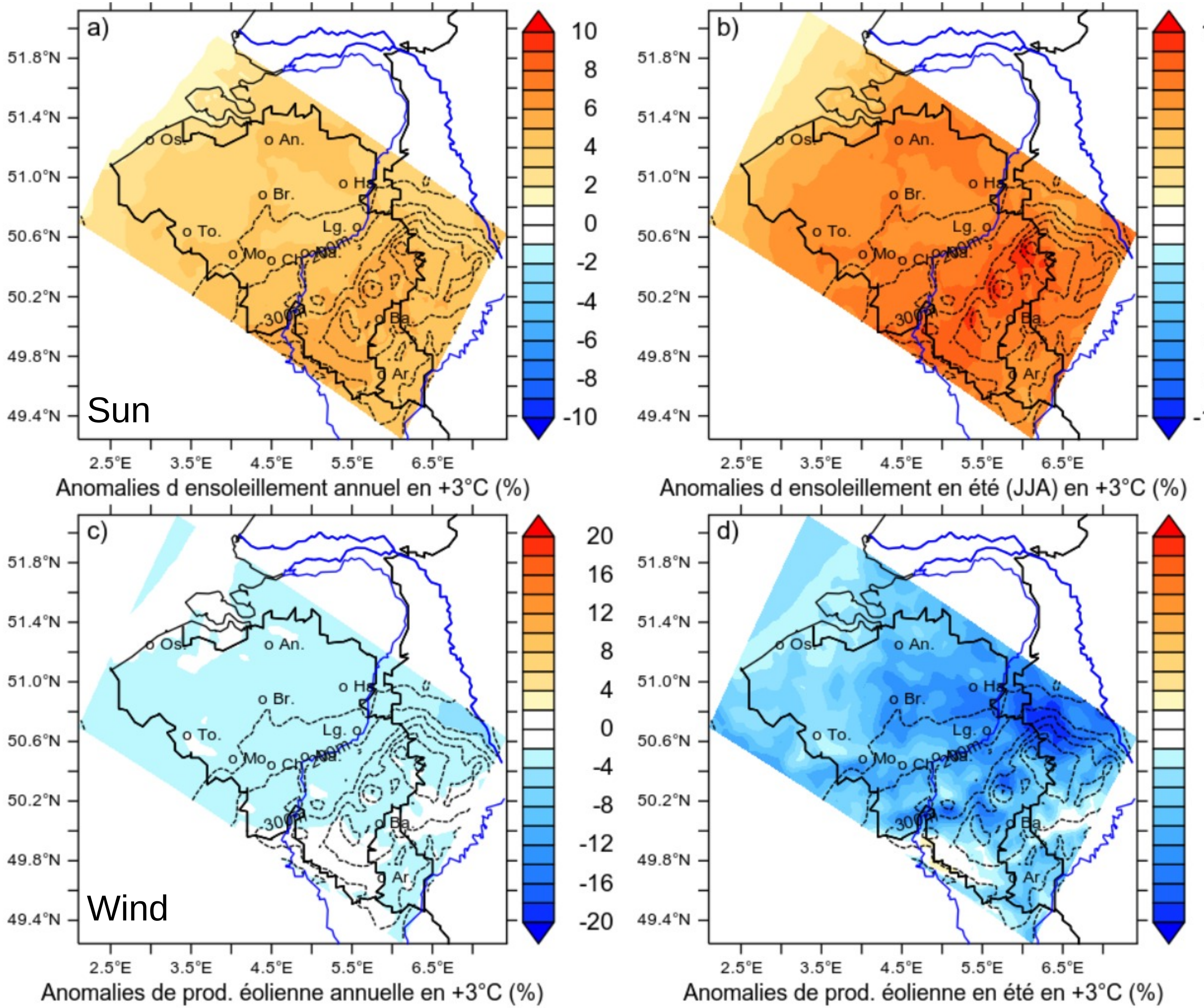
Anomalies d ensoleillement en été (JJA) en +2°C (%)

Anomalies de prod. éolienne annuelle en +2°C (%)

Anomalies de prod. éolienne en été en +2°C (%)

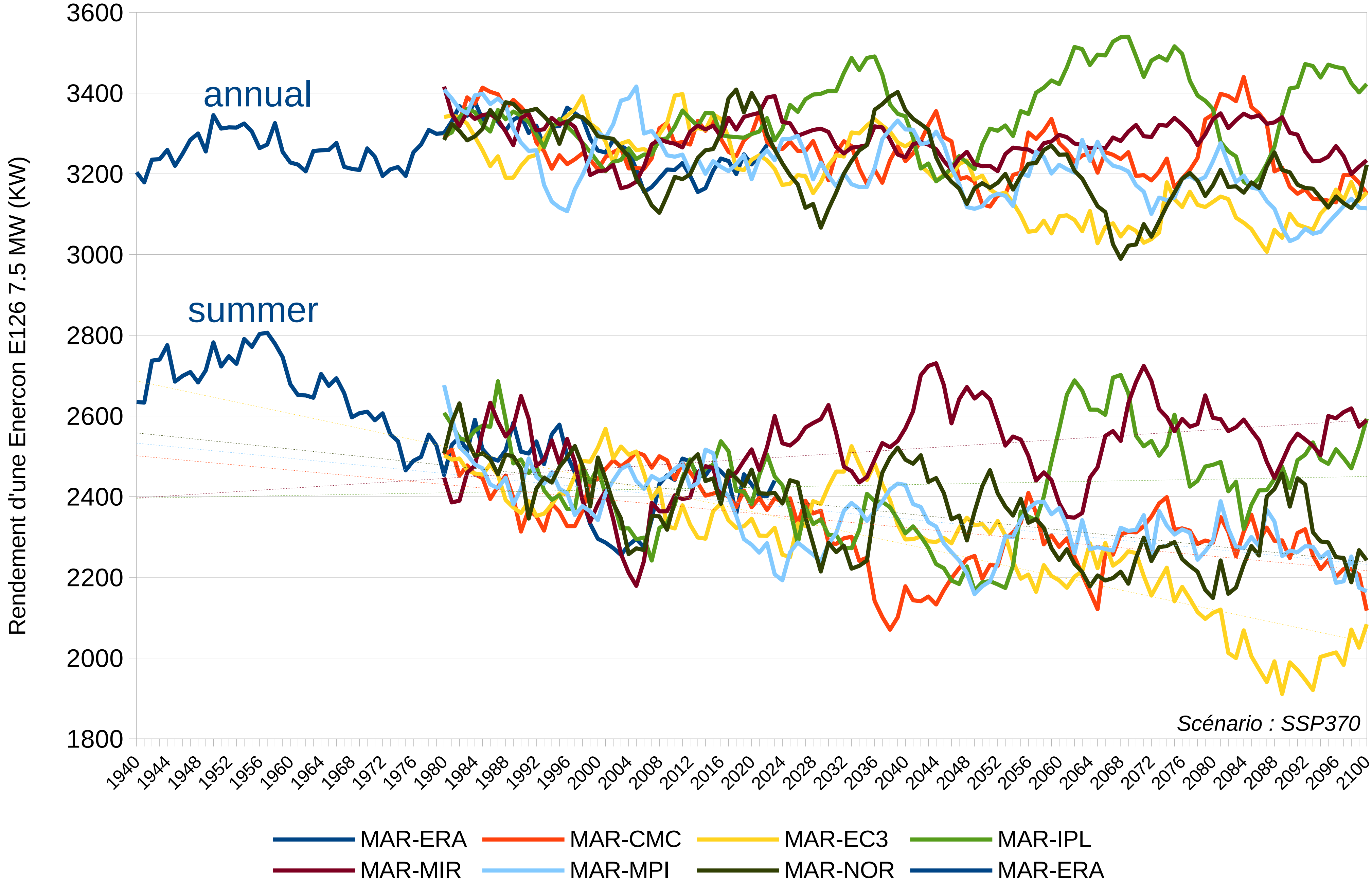
Future evolution in Belgium

In a +3°C world
~ 2061-2090



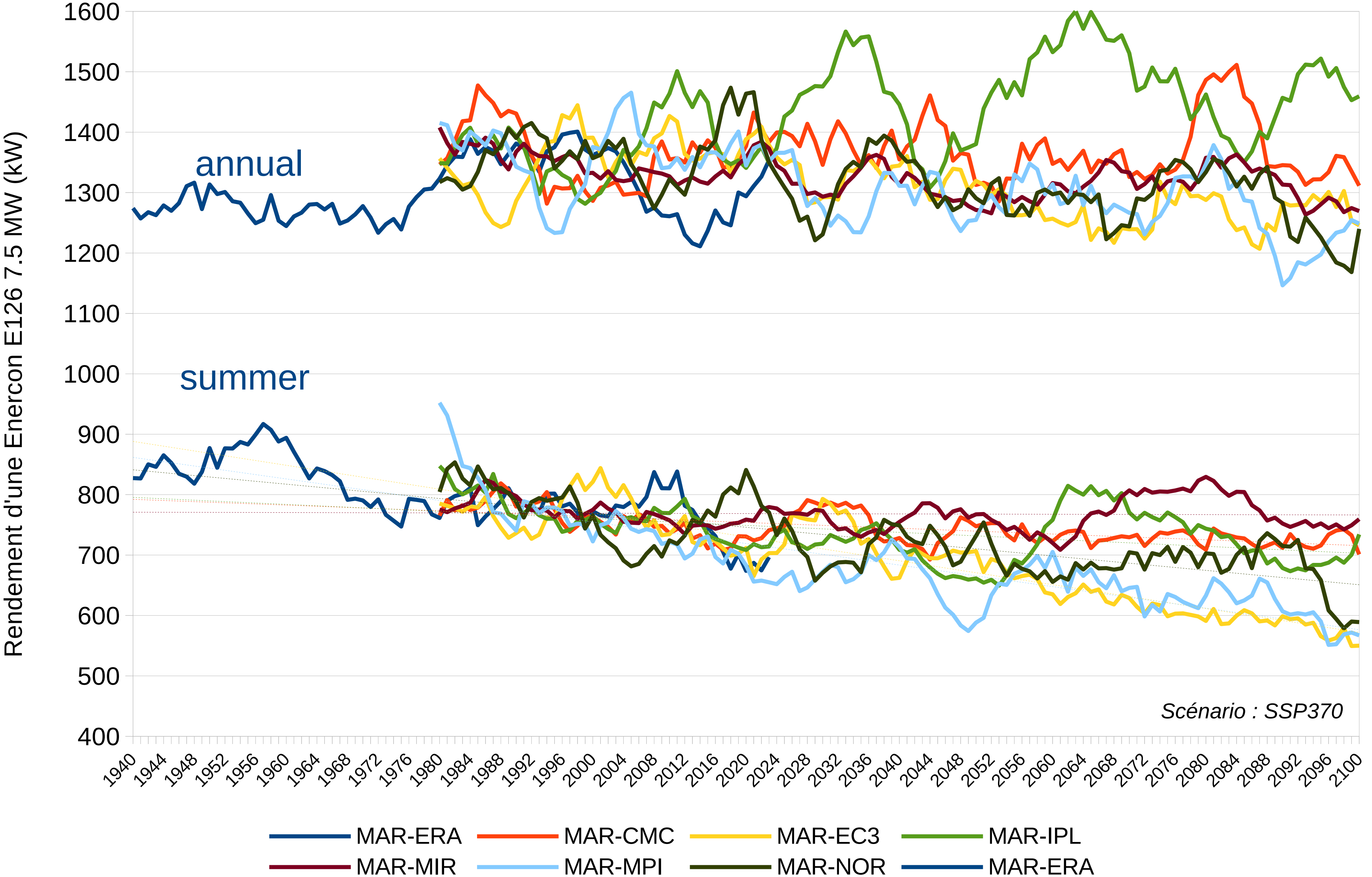
Future evolution in Belgium

North Sea



Future evolution in Belgium

Bastogne



Future evolution : wind turbine (1/2)

Temperature ++
⇒ air density --
⇒ wind speed --
⇒ spatial variability ++
⇒ time variability ++

===> Significant decrease of wind energy over West Europe

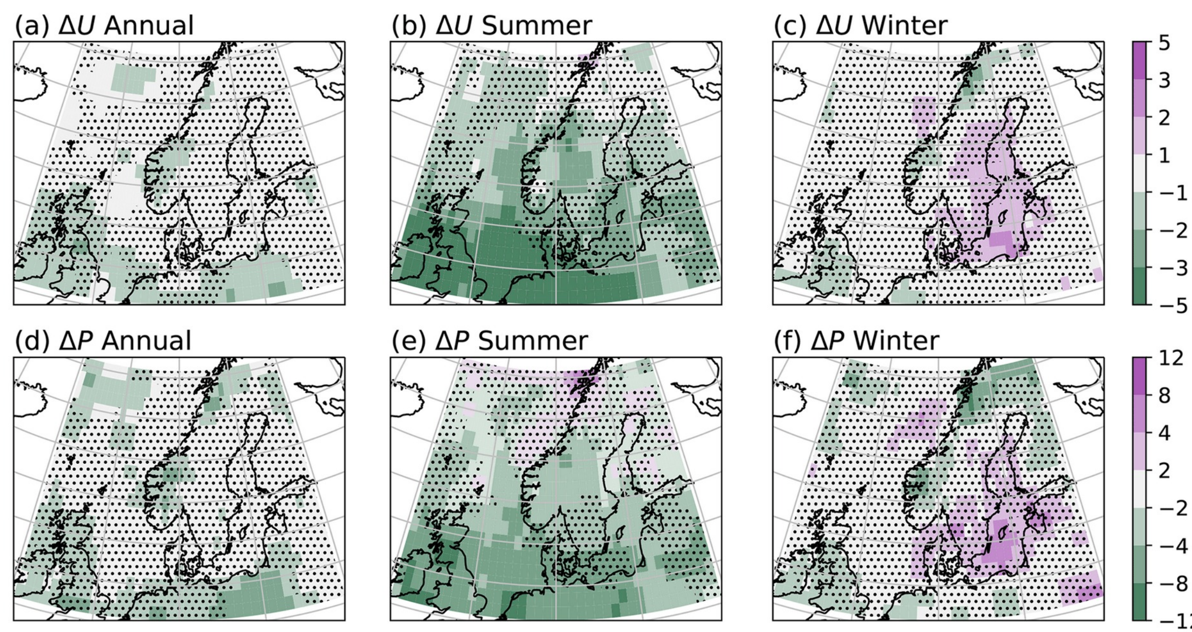
revolution-energetique.com 05/10/22

Bernard Deboyser 5 Oct 2022

Une baisse généralisée des vents en Europe menace-t-elle vraiment l'éolien ?

Current and future wind energy resources in the North Sea according to CMIP6

Andrea N. Hahmann, Oscar García-Santiago, and Alfredo Peña



Median of the ensemble relative change (%) in 100 m a.g.l. wind speed among the CMIP6 models (a)–(c) and wind power density (d)–(f) between the future (2031–2050) and the past (1995–2014). Source

Le réchauffement climatique menace-t-il les éoliennes ?

A l'avenir, le changement climatique pourrait se traduire par une diminution du vent. Une contrainte supplémentaire pour les producteurs d'électricité verte.

Express.fr 13/09/22

ENQUÊTE

Comment la baisse des vents contrarie l'éolien

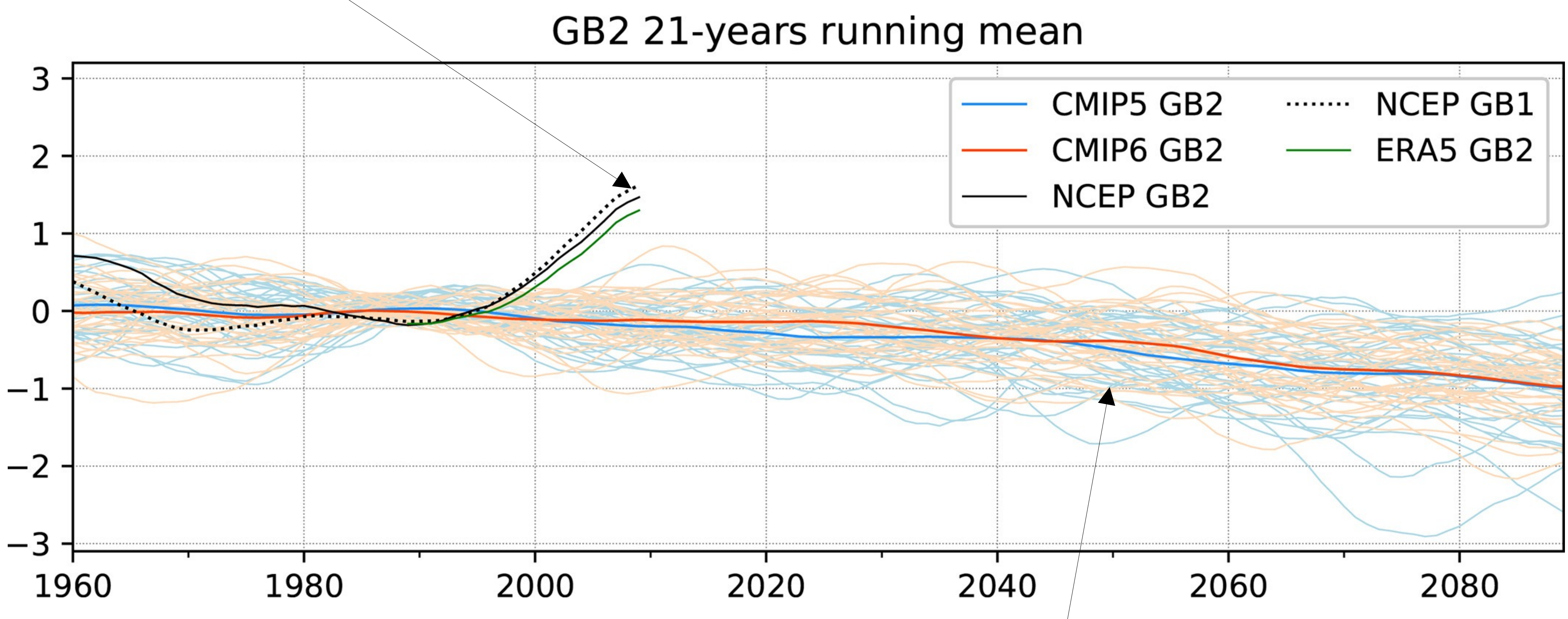
Dans certaines régions d'Europe, les vitesses du vent observées l'an dernier sont les plus faibles jamais enregistrées depuis au moins quarante ans, selon l'observatoire Copernicus. Avec des conséquences sur l'approvisionnement énergétique et la filière éolienne.

Echo.fr 22/09/22

Future evolution : general circulation

It is very likely that GCM underestimates the general circulation change and then the slow down of wind in Europe...

GBI (Greenland Blocking index) ~ - NAO index



~ 50 IPCC models (AR5 and AR6)

Solutions ... (1/7)

Where the dominant wind flows in the same direction than the local wind...

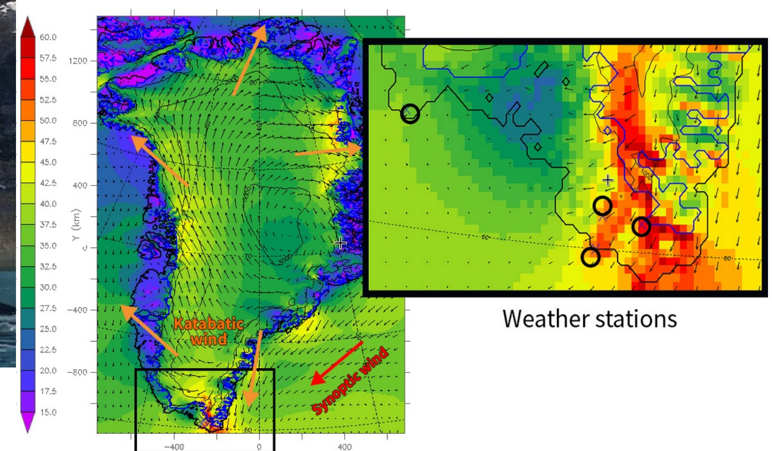
Received: 28 February 2022 | Revised: 15 June 2022 | Accepted: 5 July 2022
DOI: 10.1002/joc.7795

RESEARCH ARTICLE

International Journal of Climatology RMetS

Assessment of future wind speed and wind power changes over South Greenland using the Modèle Atmosphérique Régional regional climate model

Clara Lambin[1] | Xavier Fettweis[1] | Christoph Kittel[1,2] | Michaël Fonder[3] | Damien Ernst[3,4]



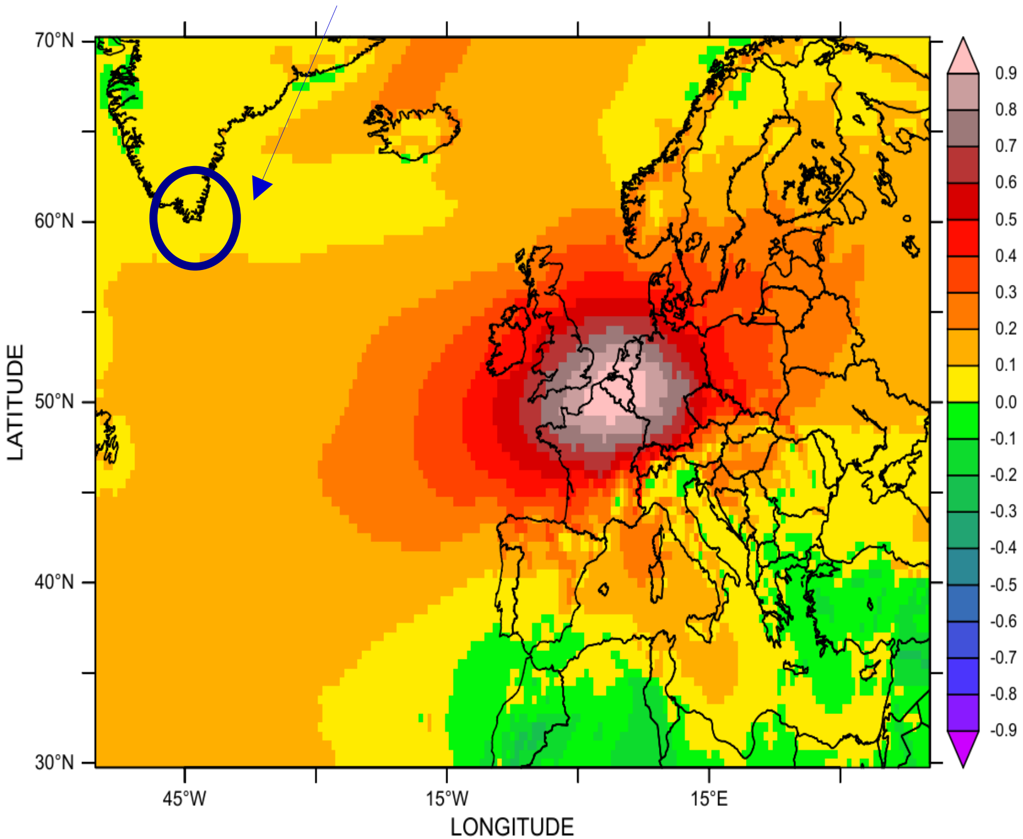
Mean wind speed at 100m (km/h)

Weather stations

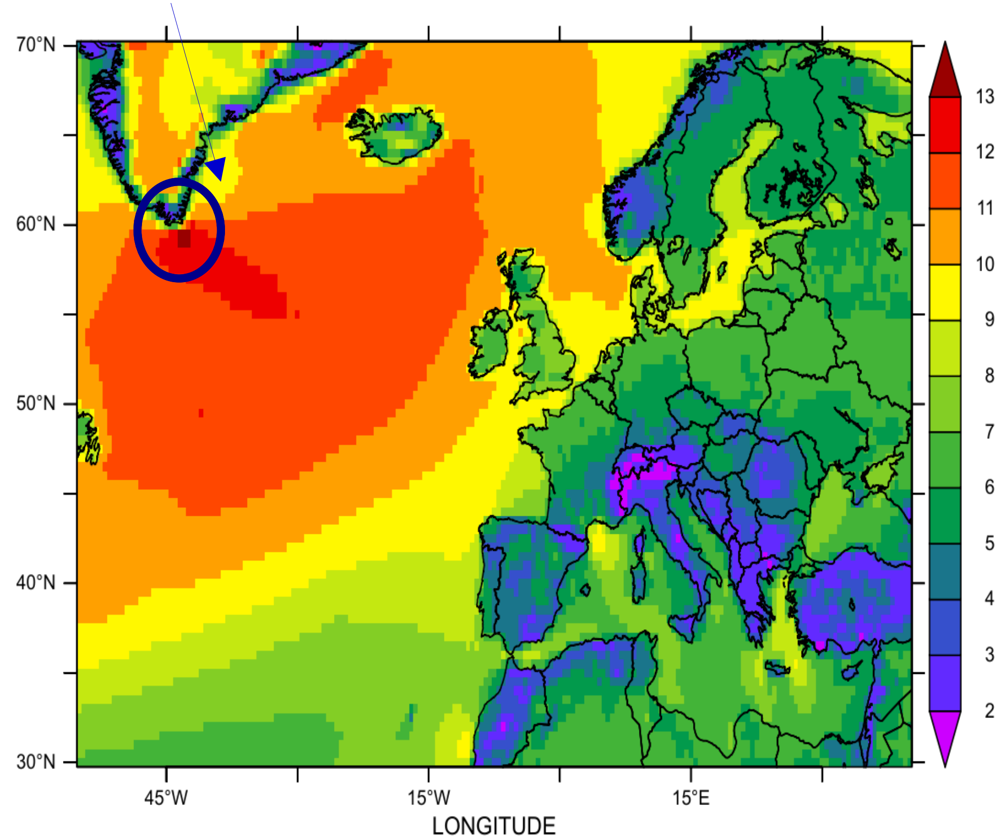
Solutions ... (2/7)

Not correlated

High wind speed



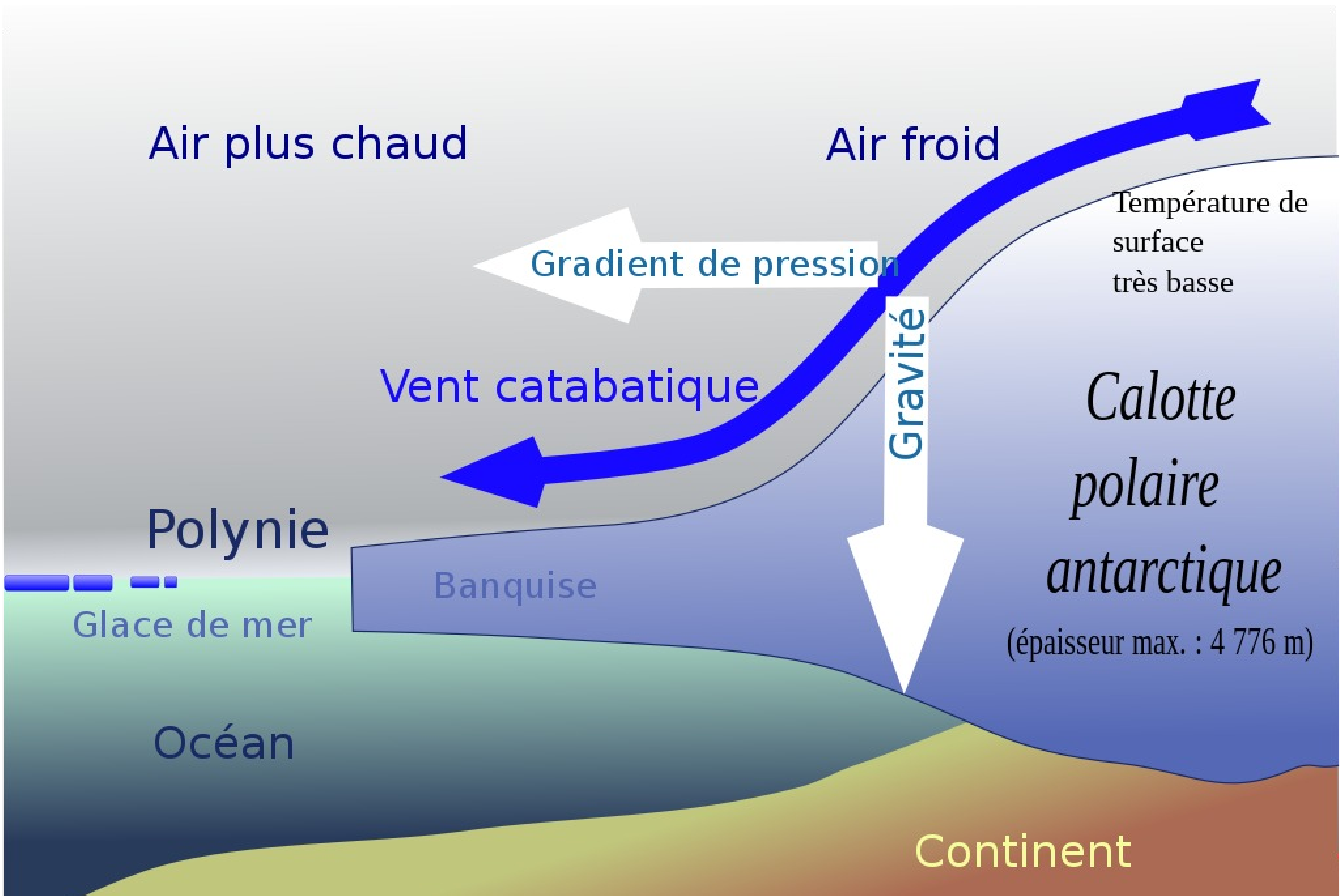
Correlation with the wind in BE



Mean wind speed from ERA5 at 100m (m/s)

Solutions … (3/7)

(local) katabatic wind over the Greenland ice sheet:



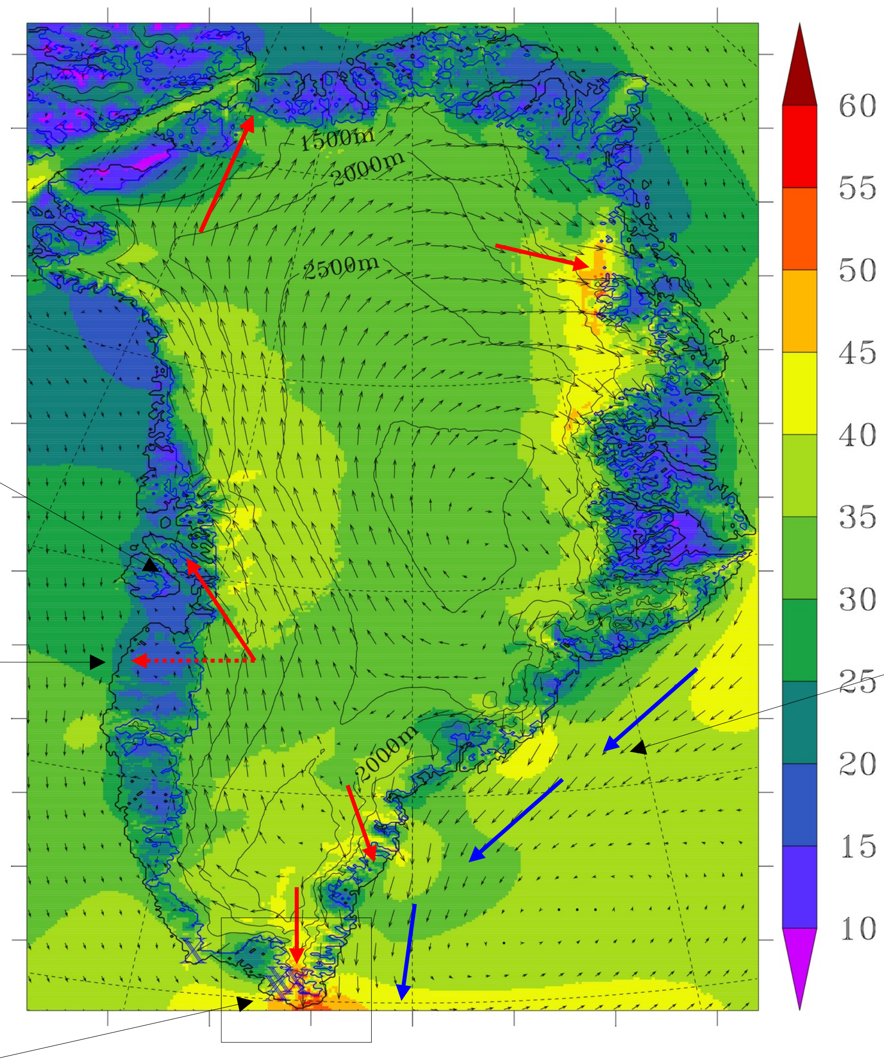
Solutions … (4/7)

1. High wind speeds.
2. Decorrelation with European wind temporal variability.
3. Huge areas.
4. Half-way between Europe and the US.
5. Not impacted by global warming

Real katabatic wind (deviated on its right due to the Coriolis force)

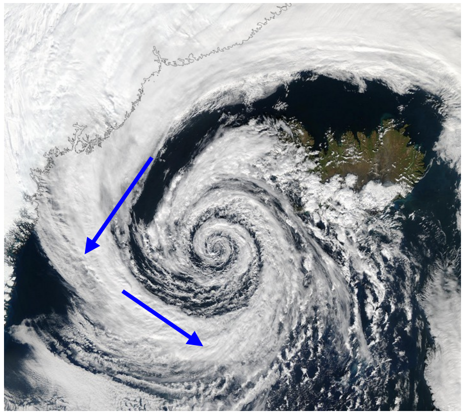
Pure katabatic wind

In this area, combination of both katabatic and synoptic winds

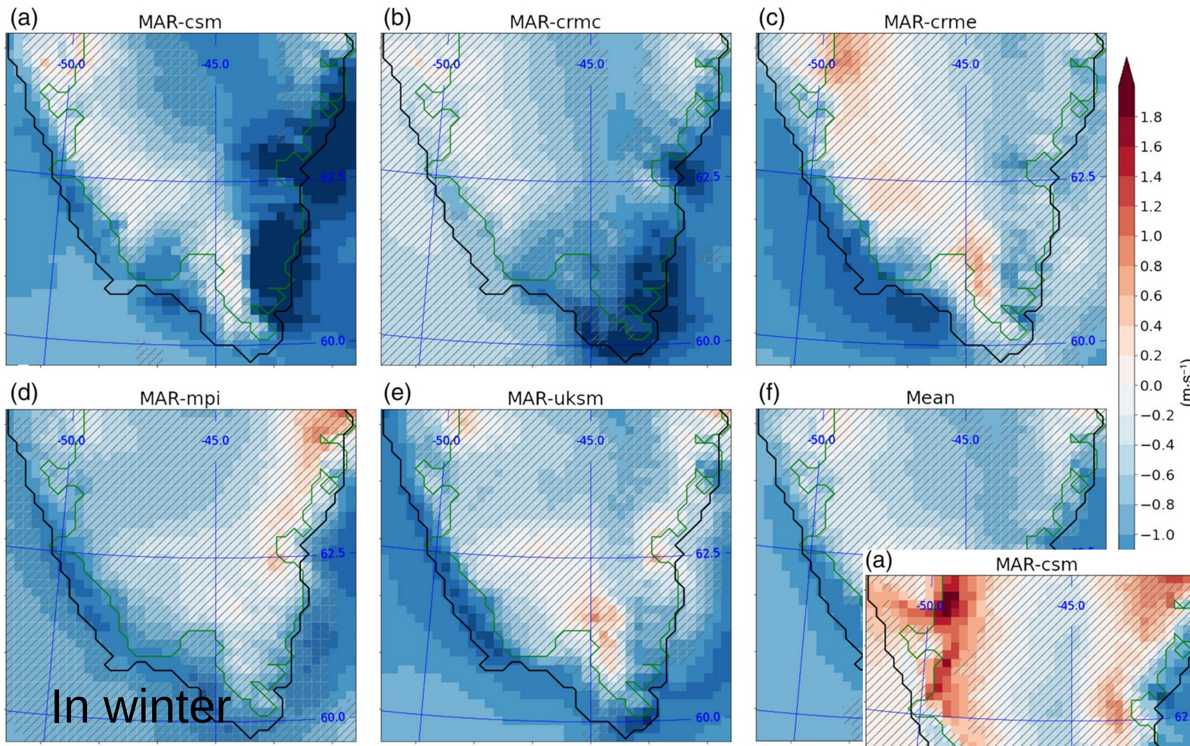


Mean Wind speed at 100m (km/h)

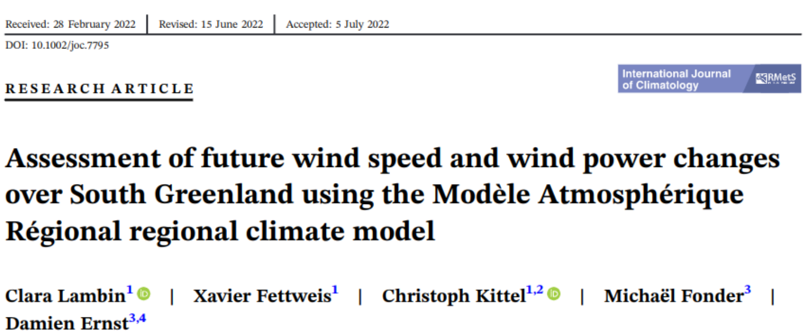
Synoptic wind due to the inland low pressure.



Solutions … (5/7)



wind speed changes from 2071–2100 compared to 1981–2010 (m/s)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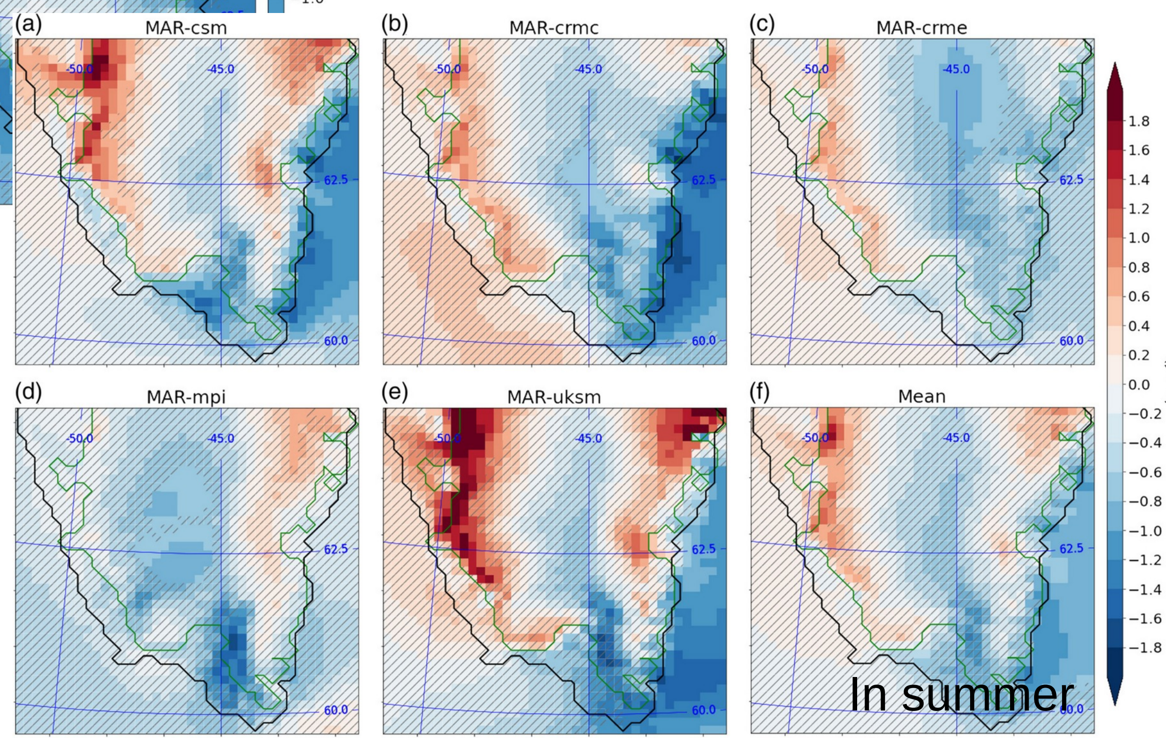
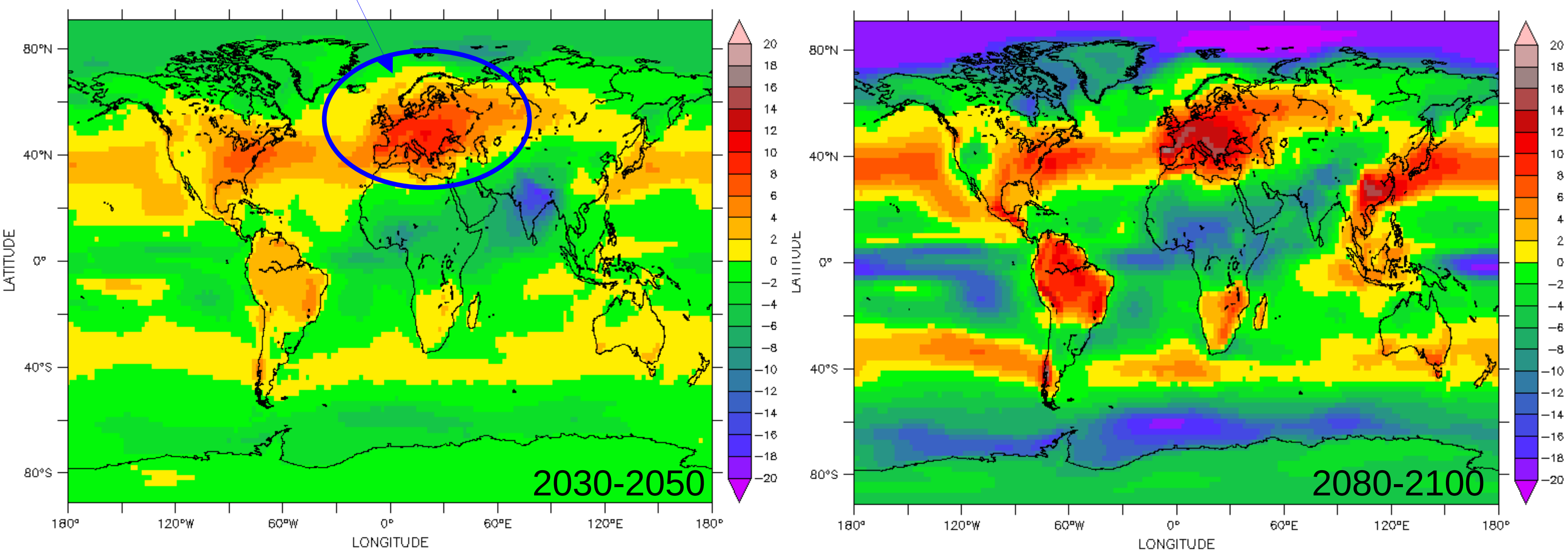


Solutions ... (6/7)

Solar panels ;-)

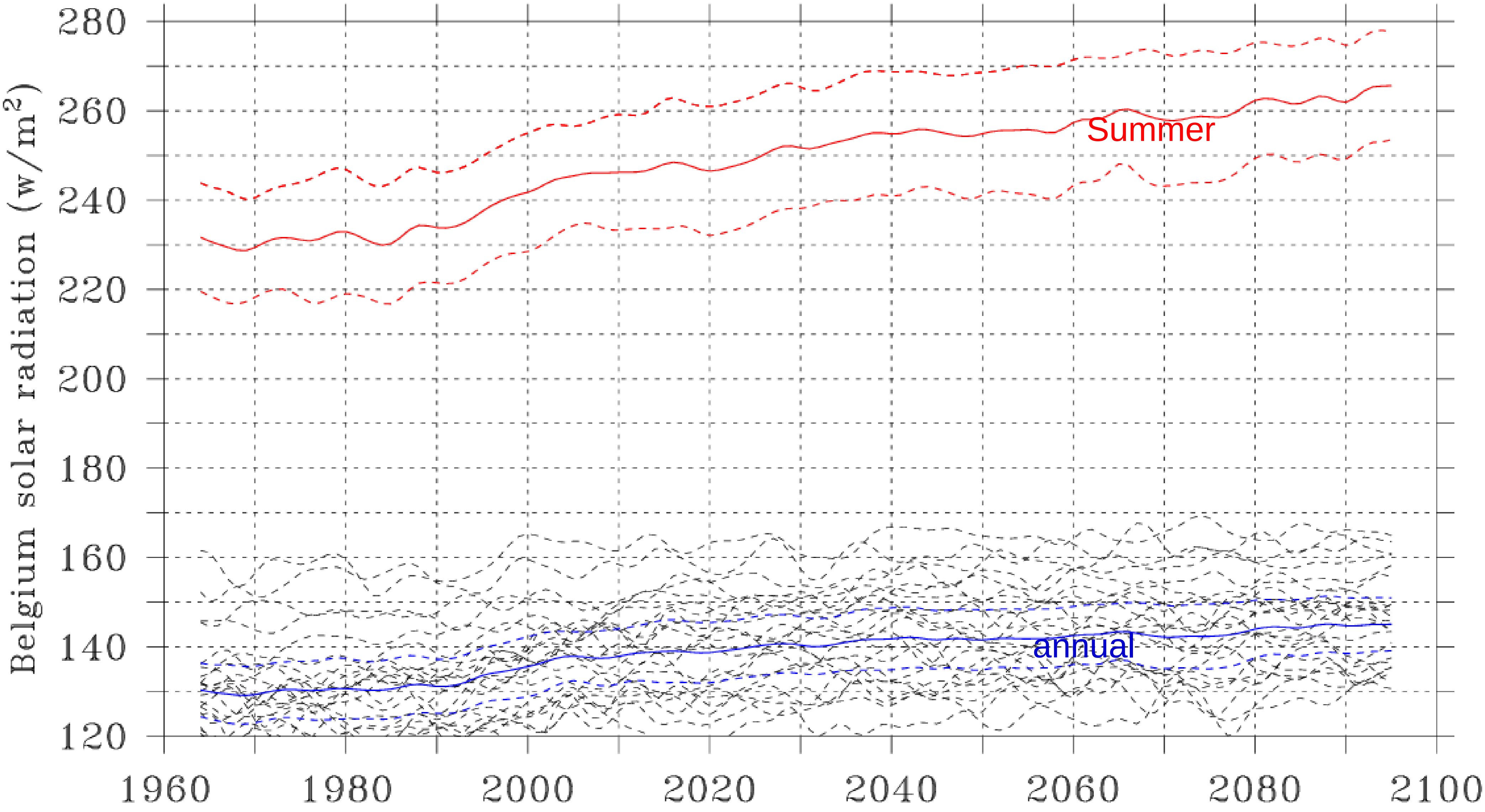


Annual solar radiation anomaly vs 1981-2010 (W/m2)

Source: ensemble mean of 24 GCMs using SSP585

Solutions … (7/7)

Solar panels ;-)



Conclusion

1. Decrease (probably underestimated) of the wind turbines efficiency in Western Europe.

2. Increased efficiency of solar panels as a results of less clouds in Belgium (mainly in summer)