Evidence for global wind stilling in observations and reanalysis

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National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Near-surface wind speed
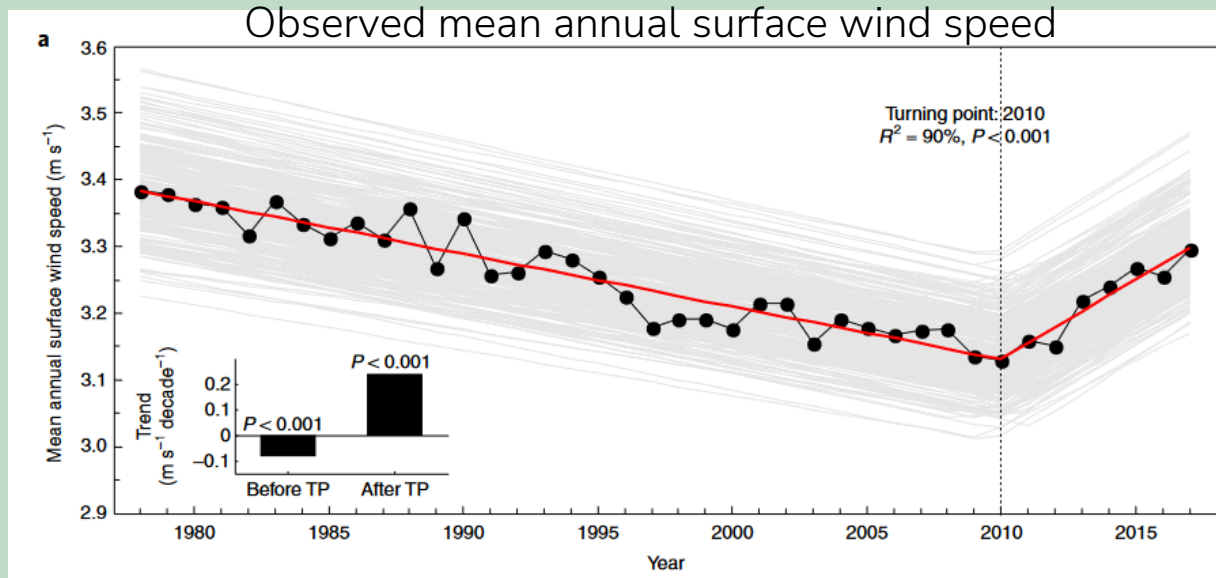
Key meteorological and climate variable

Carries moisture and heat, plant pollen, insects and birds

Affect the hydrological cycle and soils

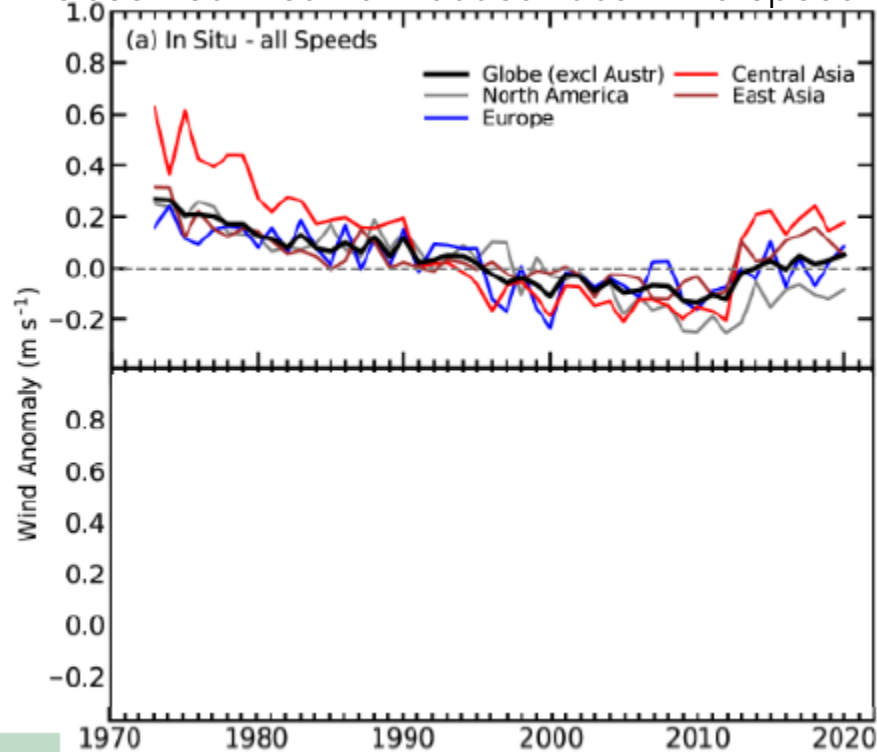Important for producing wind energy

The Global Stilling

Observed mean annual surface wind speed

Turning point: 2010
$R^2 = 90\%$, $P < 0.001$

Global (North America, Europe, Asia) mean annual surface wind speed [m s^{-1}] during 1978-2017 (GSOD data). Zeng et al. 2019.
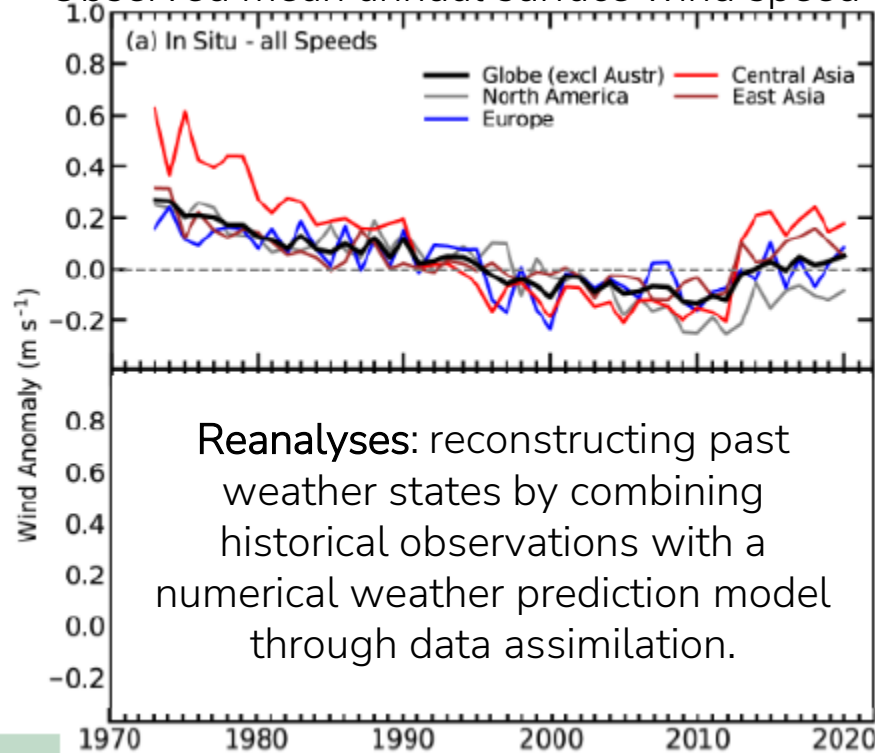
In **observations**:

Decrease in near-surface wind speed between 1970 and 2010

The Global Stilling

Observed mean annual surface wind speed

Dunn et al. 2021 – observations (HadISD) and reanalyses.

In **observations**:

Decrease in near-surface wind speed between 1970 and 2010

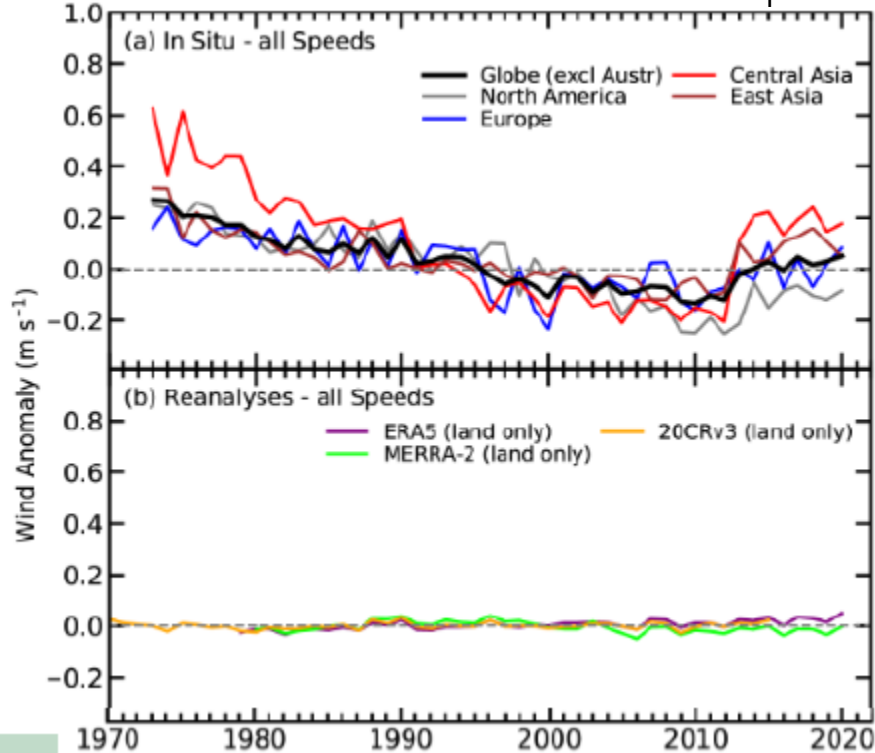# The Global Stilling

Observed mean annual surface wind speed

Reanalyses: reconstructing past weather states by combining historical observations with a numerical weather prediction model through data assimilation.

Dunn et al. 2021 – observations (HadISD) and reanalyses.

In **observations**:

Decrease in near-surface wind speed between 1970 and 2010

The Global Stilling

Observed mean annual surface wind speed

Dunn et al. 2021 – observations (HadISD) and reanalyses.

In **observations**:

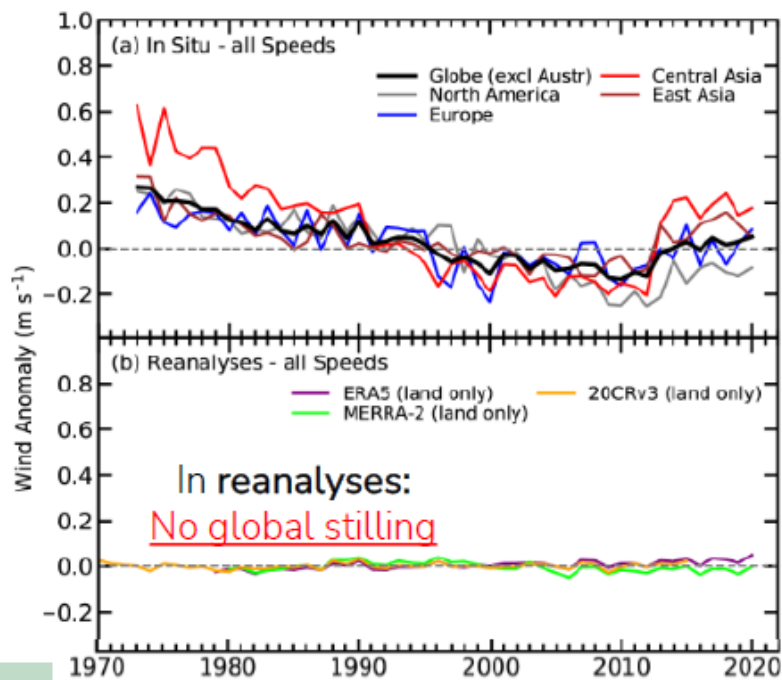Decrease in near-surface wind speed between 1970 and 2010

In the **reanalyses**:
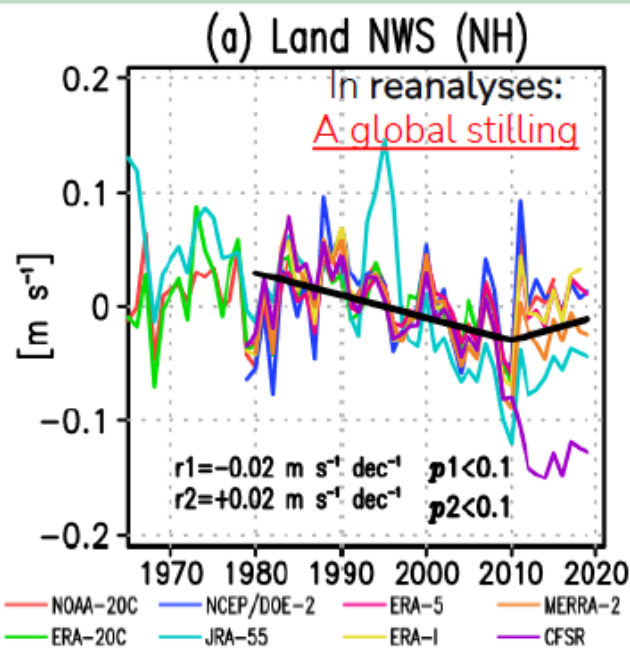
No global stilling!

The Global Stilling

Two contradictory results !

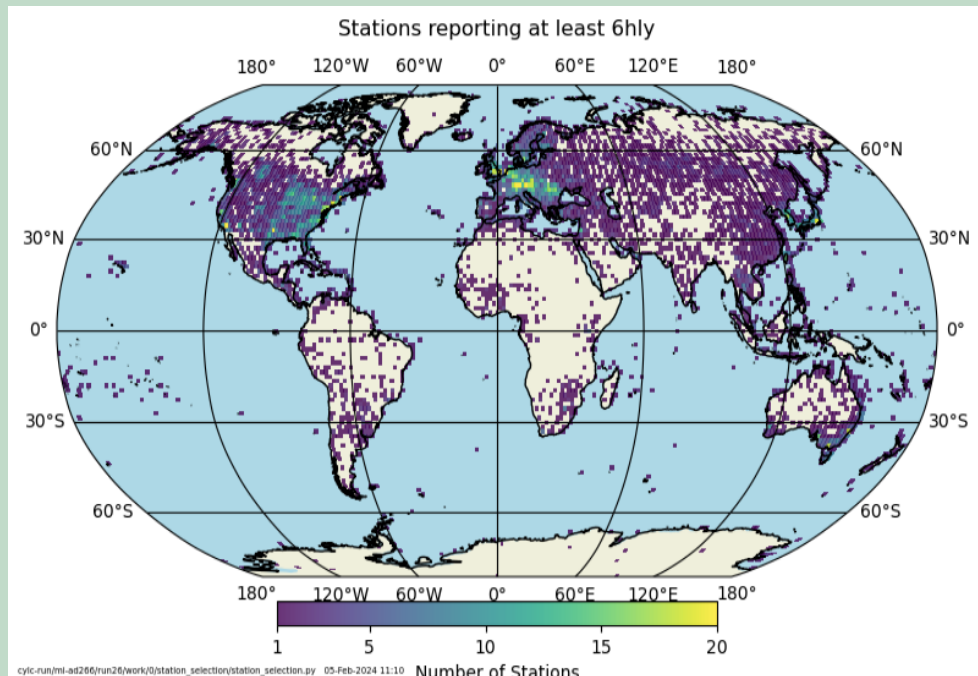Dunn et al. 2021 – observations (HadISD) and reanalyses. Average over the northern Hemisphere

Deng et al. 2021 – Reanalyses. Average over the northern Hemisphere

HadISD3

Met Office Hadley Centre observations datasets (HadISD3) (Dunn et al. 2019) [version 3.4]. A dataset that contains sub-daily 10-m wind speed values for individual stations.
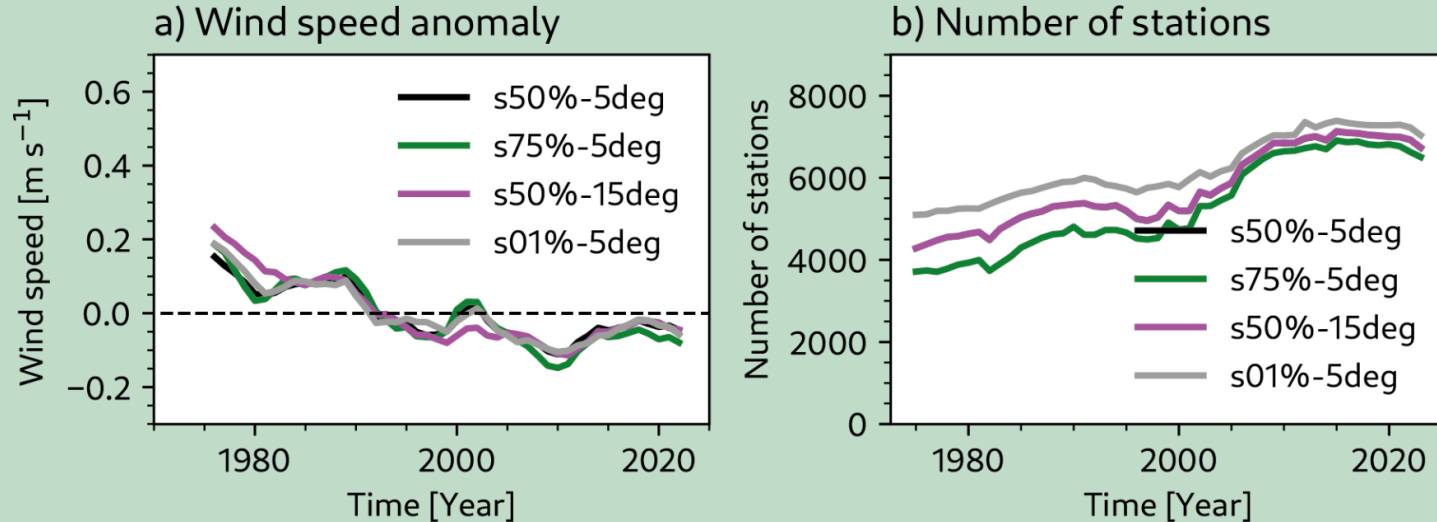

Station density in HadISD3

Pre-processing to account only for stations with 50% of the 30-hourly values for each year and with 90% of the year over 1980-2010.
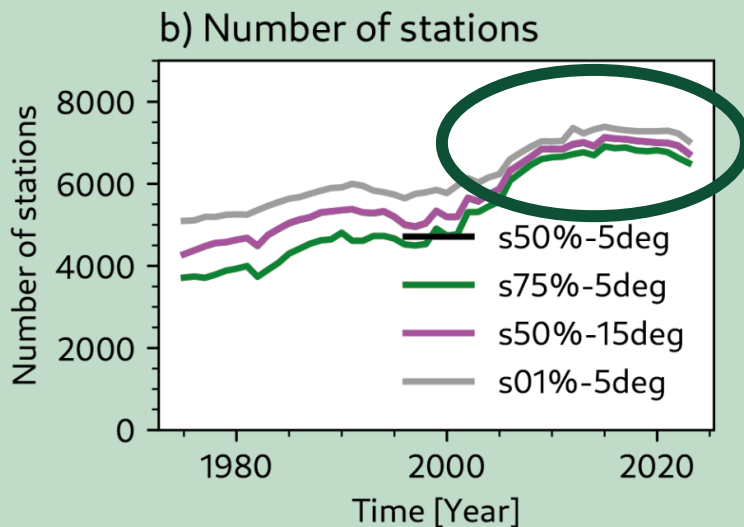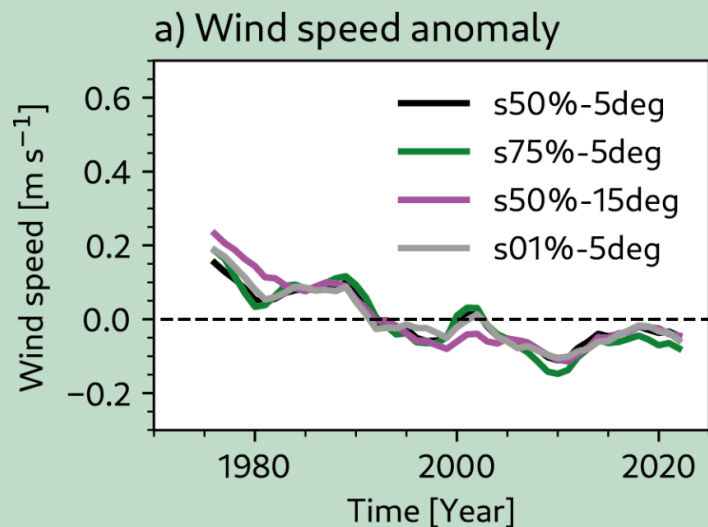
Data is saved onto a 5° x 5° grid.

HadISD3

Observed (HadISD3) annual mean near-surface wind speed anomaly [m s^{-1}] over land and the northern hemisphere [0-70°N], using different thresholds for rejection of stations and when averaged over grid boxes of various horizontal resolutions. (b) The number of stations used to compute the annual mean wind speed for each year and for each threshold and horizontal resolution as used in panel (a). Anomalies are computed relative to the period 1980-2010. A 3-year running mean was applied to reduce high-frequency variability.
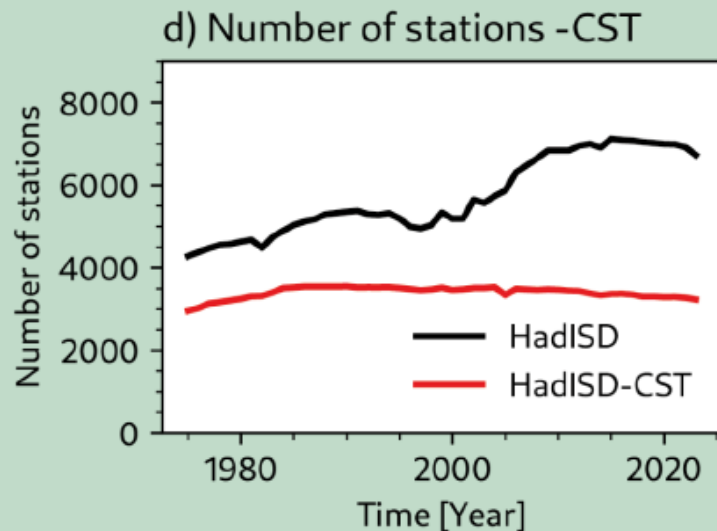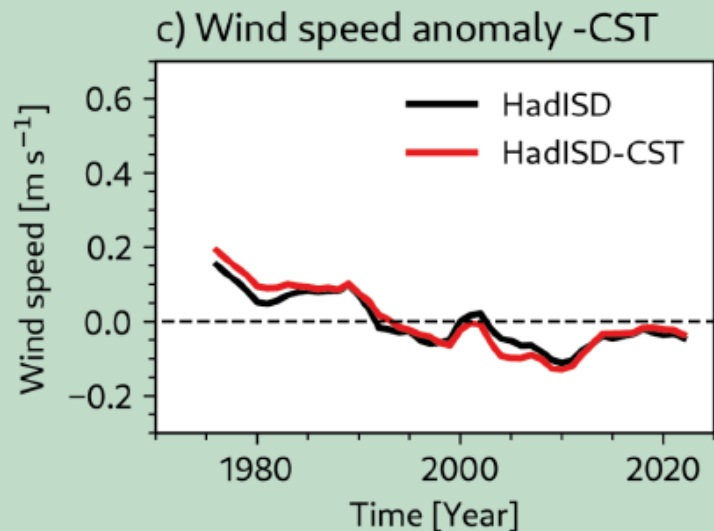
HadISD3

a) Wind speed anomaly

Legend: s50%-5deg, s75%-5deg, s50%-15deg, s01%-5deg

b) Number of stations

Legend: s50%-5deg, s75%-5deg, s50%-15deg, s01%-5deg

Due to the inclusion of new stations?

Observed (HadISD3) annual mean near-surface wind speed anomaly [m s⁻¹] over land and the northern hemisphere [0-70°N], using different thresholds for rejection of stations and when averaged over grid boxes of various horizontal resolutions. (b) The number of stations used to compute the annual mean wind speed for each year and for each threshold and horizontal resolution as used in panel (a). Anomalies are computed relative to the period 1980-2010. A 3-year running mean was applied to reduce high-frequency variability.
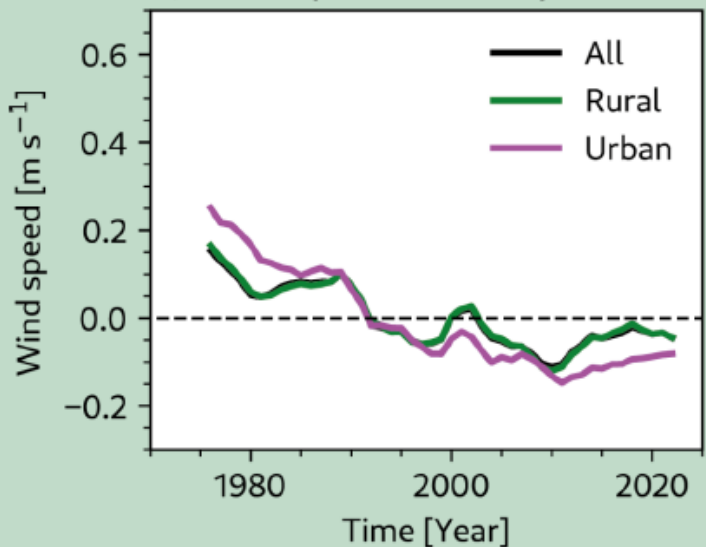
HadISD3

c) Wind speed anomaly -CST

d) Number of stations -CST

Observed (HadISD3) annual mean near-surface wind speed anomaly [m s⁻¹] over land and the northern hemisphere [0-70°N], using all (black) available stations and (red) the same stations over the period 1980-2010. Anomalies are computed relative to the period 1980-2010. A 3-year running mean was applied to reduce high-frequency variability.
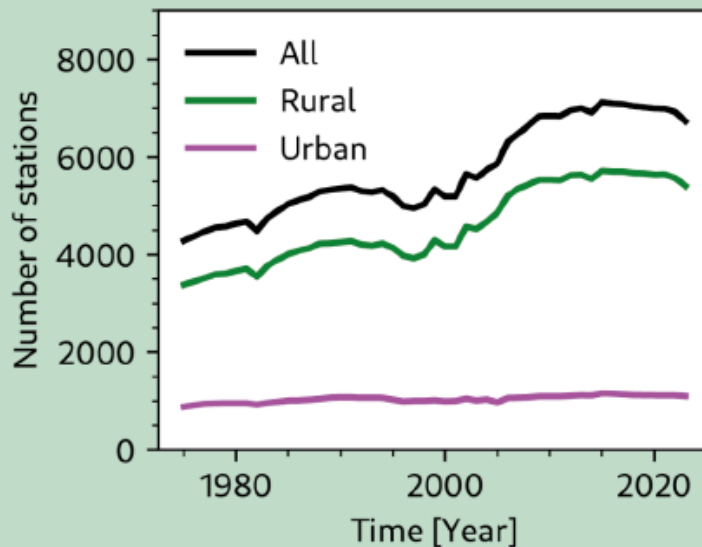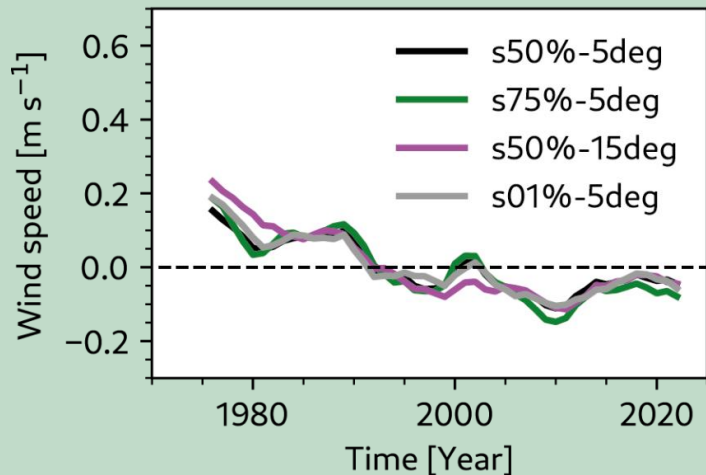
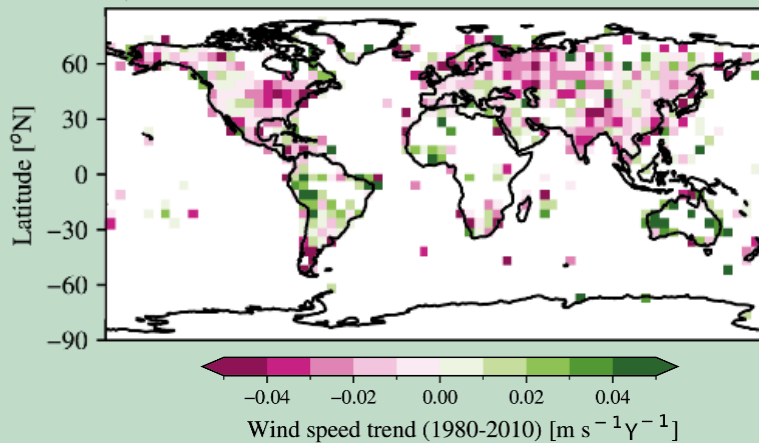The global stilling is not due to the inclusion of new stations

HadISD3

e) Wind speed anomaly

f) Number of stations

Wind stilling over both the rural and urban areas

Observed (HadISD3) annual mean near-surface wind speed anomaly [m s⁻¹] over land and the northern hemisphere [0-70°N], using all (black) available stations and for stations that are in a (green) rural and (purple) urban area. Anomalies are computed relative to the period 1980-2010. A 3-year running mean was applied to reduce high-frequency variability.

HadISD3

Annual men near-surface wind speed anomalies [m s⁻¹]

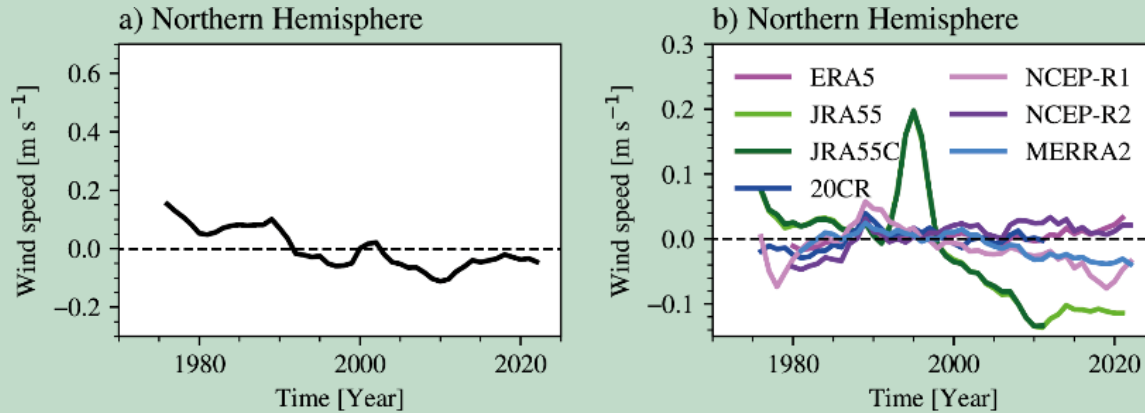*Trend in annual-mean near-surface wind speed [m s⁻¹ Y⁻¹] from 1980 to 2010 in HadISD3. A 3-year running mean was applied to reduce high-frequency variability.*
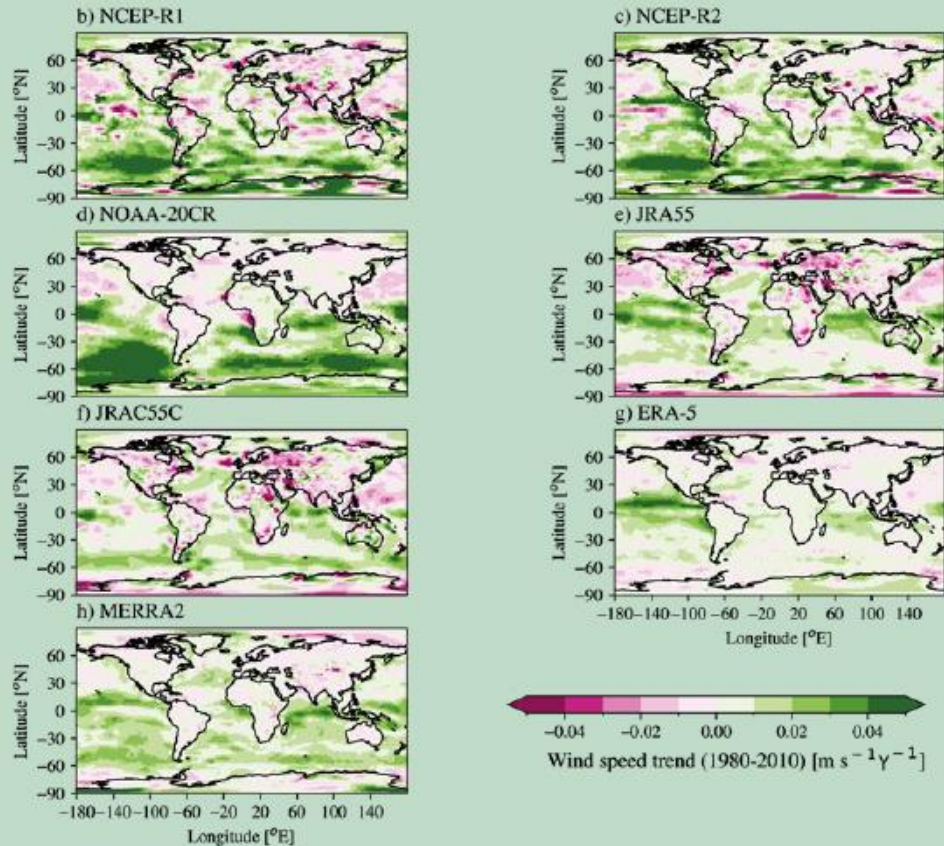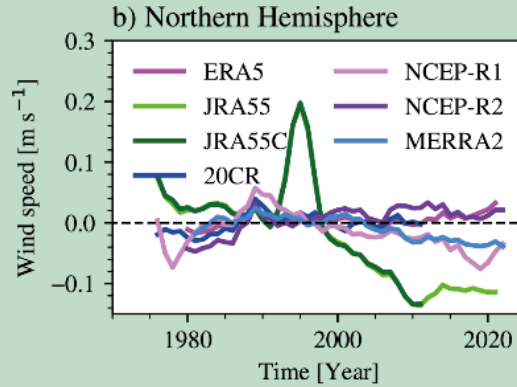
HadISD3 and the Reanalyses

a) Northern Hemisphere

b) Northern Hemisphere

ERA5   NCEP-R1
JRA55   NCEP-R2
JRA55C   MERRA2
20CR

Annual mean wind speed anomaly [m s⁻¹] over land and the northern hemisphere [0-70°N] in (a) observation (HadISD3) and (b) a set of reanalyses. (c), as in (b), but when computing the wind speed using the monthly means of the meridional and zonal component of the wind speed. Anomalies are computed relative to the period 1980-2010. A 3-year running mean was applied to reduce high-frequency variability.
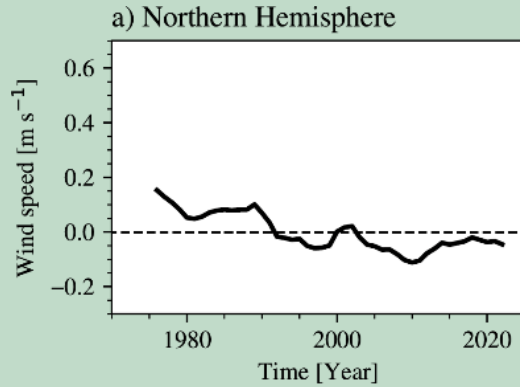
Consistent with Dunn et al. 2021
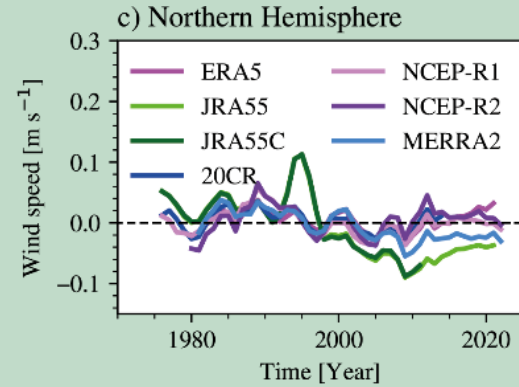
Deng et al. 2021 ??

HadISD3 and the Reanalyses

Trend in annual-mean near-surface wind speed [m s⁻¹ Y⁻¹] from 1980 to 2010 in (a) HadISD3, (b) NCEP-R1, (c) NCEP-R2, (d) NOAA-20CR, (e) JRA55, (f) JRA55C, (g) ERA-5, and (h) MERRA2. A 3-year running mean was applied to reduce high-frequency variability.

A timescale decomposition

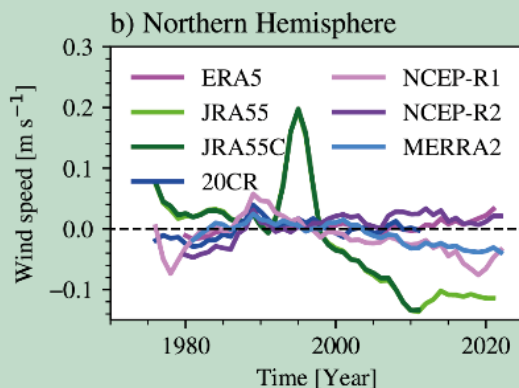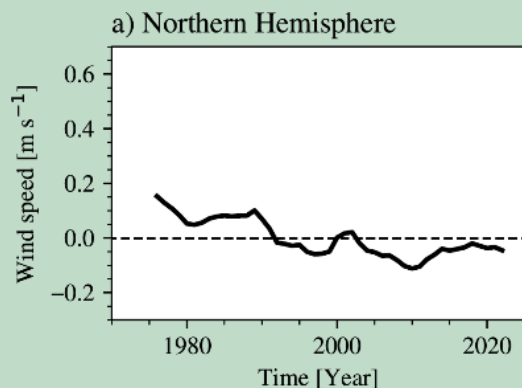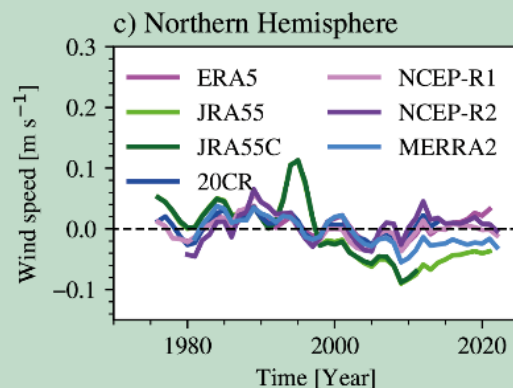a) Northern Hemisphere

b) Northern Hemisphere

c) Northern Hemisphere

Hourly/6-hourly

Monthly means

$$wspd = \sqrt{u^2 + v^2}$$

A timescale decomposition

a) Northern Hemisphere

b) Northern Hemisphere
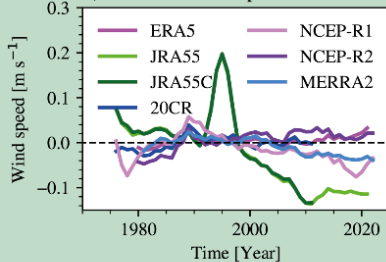
c) Northern Hemisphere

Hourly/6-hourly

Monthly means

$$wspd = \sqrt{u^2 + v^2}$$

Decrease in half of the reanalysis
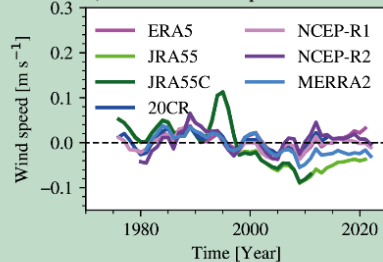
Decrease in all reanalysis

A timescale decomposition

A timescale decomposition

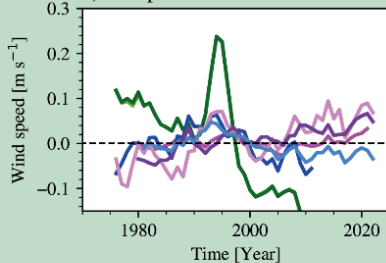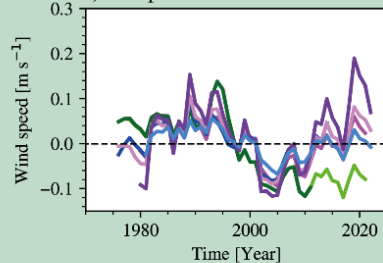$$u = \bar{u} + u' \quad \text{and} \quad v = \boxed{\bar{v}} + \boxed{v'}$$

Monthly mean   Deviation from the monthly mean

$$
\begin{aligned}
u^2 + v^2 &= (u' + \bar{u})^2 + (v' + \bar{v})^2 \\
&= (u'^2 + 2u'\bar{u} + \bar{u}^2) + (v'^2 + 2v'\bar{v} + \bar{v}^2) \\
&= \underbrace{(u'^2 + v'^2)}_{\text{sub monthly}} + \underbrace{(\bar{u}^2 + \bar{v}^2)}_{\text{monthly}} + \underbrace{2(u'\bar{u} + v'\bar{v})}_{\text{cross-term}},
\end{aligned}
$$

A timescale decomposition
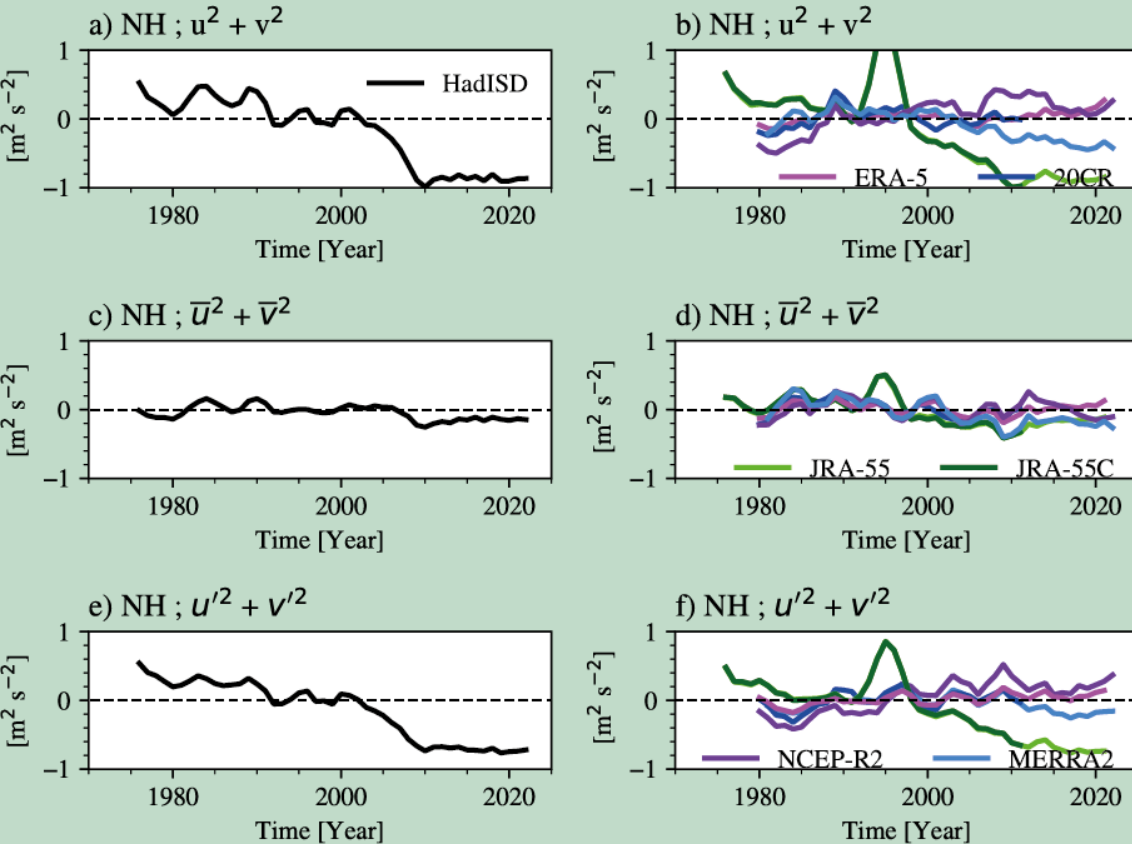

a) NH ; u² + v²

b) NH ; u² + v²

c) NH ; ū² + v̄²

d) NH ; ū² + v̄²

e) NH ; u′² + v′²

f) NH ; u′² + v′²

Annual mean anomaly in $u^2 + v^2$ [$m^2\ s^{-2}$] over land and the northern hemisphere [0-70°N] in (a) observation (HadISD3) and (b) a set of reanalyses. (c) and (d), as in (a) and (b) but for $\bar{u}^2 + \bar{v}^2$. (e) and (f), as in (a) and (b) but for $u'^2 + v'^2$. Anomalies are computed relative to the period 1980-2010. A 3-year running mean was applied to reduce high-frequency variability.
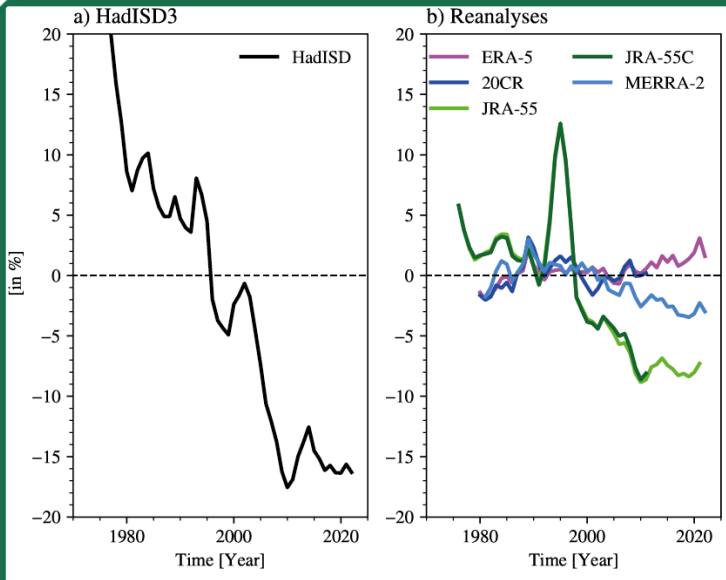
Explains the global stilling, and the differences between the reanalyses

Take home message

There is no global stilling in the reanalyses

The difference between the reanalyses and the observation is due to the representation of the high-frequency variability of the wind speed.

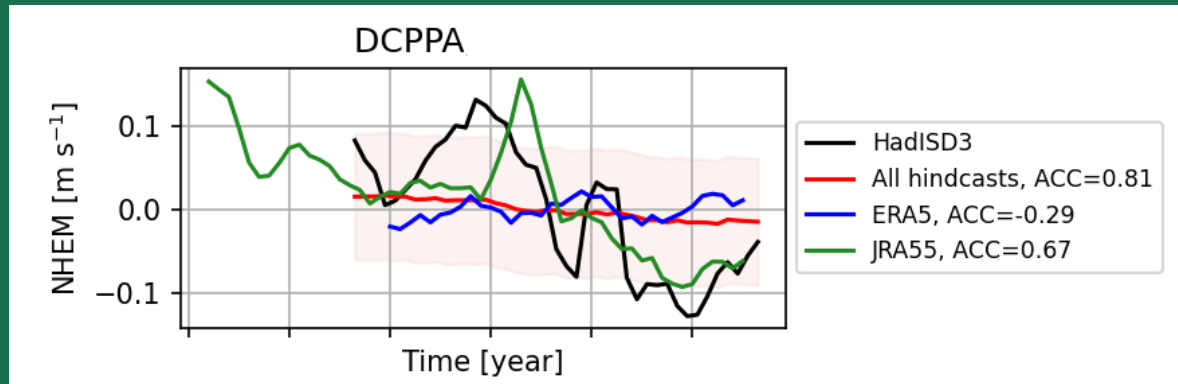Strong effects for the production of wind energy (and forecasts)

$$WPD = \frac{1}{2}\rho\, u_{100}{}^3$$

Annual mean anomaly in wind speed density [in %] over land and the northern hemisphere [0-70°N] in (a) observation (HadISD3) and (b) a set of reanalyses. Anomalies are computed relative to the period 1980-2010. A 3-year running mean was applied to reduce high-frequency variability.

Further work

Decadal predictability of the global stilling; the prediction systems (DCPP-A) can reproduce the direction of the global stilling (ACC=0.81).

Anomalies in 10-m wind speed averaged over the Northern Hemisphere and land, for HadISD (black), ERA5 (blue), JRA55 (green), the DCPPA ensemble mean (red). The red shading shows uncertainty (two times the standard error from all DCPPA ensemble members).

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