Hemispheric and seasonal discrepancies of near-surface extreme wind trends between reanalysis data and climate models

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Motivation

- Near-surface extreme winds are connected to severe weather and affect wind energy generation.
- The frequency of extreme near-surface zonal wind is projected to increase by the end of the 21st century in the midlatitudes.[1]

Questions

- Are there trends in mid-latitudinal near-surface extreme winds?
- If there are trends in the reanalyses, do models capture the signal?
- If there are discrepancies, do they occur in any specific season or hemisphere?

Data

To answer the questions, we focus on the trends in the satellite era (1980 ~ 2020). We compare 850 hPa daily zonal wind in:

Reanalyses
- 3 reanalysis datasets (ERA5, MERRA2, and JRA55)

and

CMIP6 models
- 25 CMIP6 models
- Historical (1980 ~ 2014) and SSP585 (2015 ~ 2020)

AMIP6 models
- 21 AMIP6 models
- Only historical periods

Additionally, the contribution of individual anthropogenic forcing is examined by DAMIP models [2]
- 3 single forcing experiment (hist-GHG, hist-aer, hist-nat)
- 35 ensemble members from 9 models
- Historical (1980 ~ 2014) and SSP245 (2015 ~ 2020)

All the data are interpolated to 1.5° lat x 1.5° lon grids.

Recent trends in the reanalyses

- **Positive** trends in the **southern hemispheric** (SH) climatological jet position, especially for the slowest wind.
- **Negative** trends in the fastest winds (higher percentiles) in the **northern hemispheric** (NH) high latitudes.

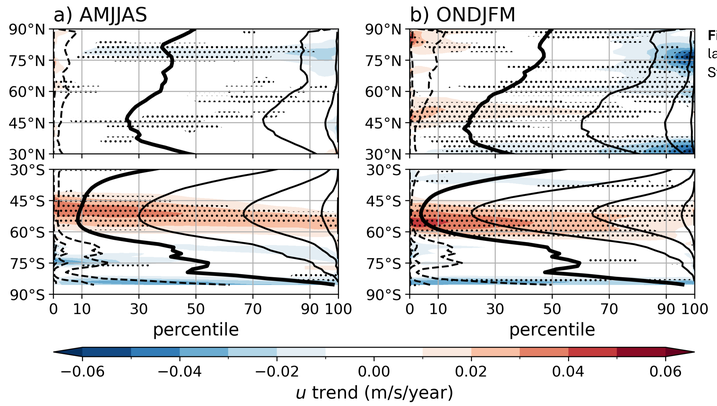

Fig. 1 Multi-Reanalyses mean trends in 850 hPa zonal wind across percentiles in the mid-latitudes in (a) AMJJAS and (b) ONDJFM. Contours are 1980 ~ 2000 climatology (CI: 8 m/s). Statistically significant ($\alpha = 0.05$) trends are stippled.

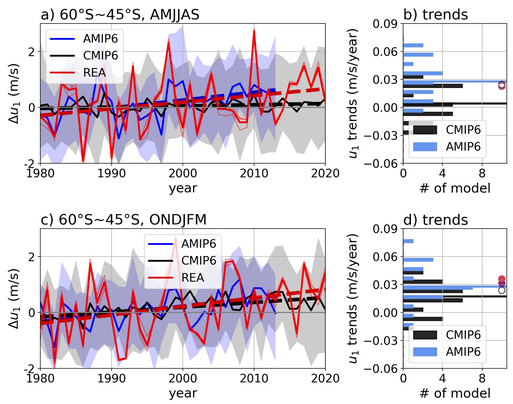

Fig. 2 **(a), (c)** Time series of the southern hemispheric mid-latitudinal averaged u_{pr1} anomalies in reanalyses (red), CMIP6 models (black), and AMIP6 models (blue). Dashed lines are the linear regression. Shading denotes the 10th and 90th percentiles across models. **(b), (d)** Distribution of the linear trends in reanalyses, CMIP6, and AMIP6 models. Filled (unfilled) circles are statistically (in)significant trend. Horizontal lines are multi-model mean. Unfilled bars denote that the trends in the models statistically significantly deviate from the trends in the reanalyses.

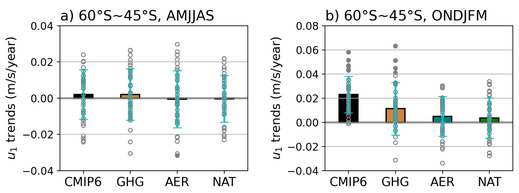

Fig. 3 Linear trends of the southern hemispheric mid-latitudinal averaged u_{pr1} in CMIP6 and DAMIP single forcing experiments. Grey circles are the trends of individual ensembles. Filled (unfilled) circles denote statistically (in)significant. Cyan bars are one standard deviation across the ensembles.

Positive trends in the SH mid-latitudes

- The trends in the reanalyses are statistically indistinguishable from both the AMIP and CMIP models.
- CMIP models capture the trends in **summer** (ONDJFM).

Contribution from the GHG forcing

- The positive trends during SH ONDJFM are mostly attributed to the **greenhouse gas** forcing.

Negative trends in the NH high latitudes

- Models **cannot capture** the negative trends of the fastest winds in the reanalyses.

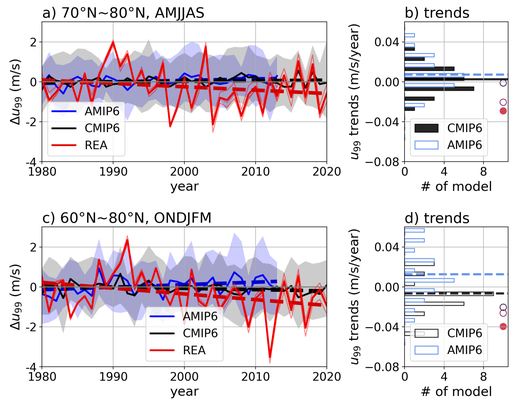

Fig. 4 Similar to Fig. 2, but for u_{pr99} in the northern hemispheric extratropics.

Longitudinal sectors for the discrepancies

- During summer the discrepancy is mostly in the **Pacific-North America** sector.
- During winter the discrepancy is mostly from the **Atlantic-Eurasia** sector.

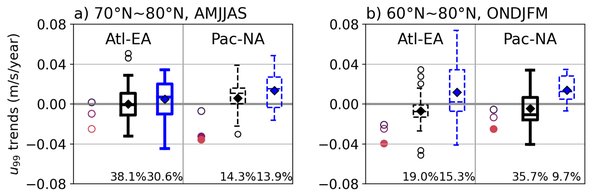

Fig. 5 The trends in the northern hemispheric extratropics in 2 longitudinal sectors, Atlantic-Eurasia (Atl-EA, 60°W~120°E) and Pacific-North America (Pac-NA, 120°E~60°W) sectors. Filled circles are the statistically significant trends in the reanalyses. Boxes are the trends in CMIP6 (black) and AMIP6 (blue) models. Dashed (solid) boxes denote that the trends in models are (not) statistically significantly discrepant from the reanalyses. The numbers are the rank of the reanalyses mean in the model distribution.

Take-Aways

1. A positive trend in the SH mid-latitudes across all percentiles and seasons is observed in the satellite era in the reanalyses. In contrast, the recent trend in the NH high latitudes is negative and concentrated in the fastest wind in winter.
2. Models agree with the trends in the reanalyses in the SH mid-latitudes, especially in summer, which is mostly attributed to the GHG forcing. In contrast, models fail to capture the trends in the reanalyses in the NH high latitudes.
3. The discrepancies in the NH high latitudes are mostly from the Pacific-American sector in summer and the Atlantic-Eurasian sector in winter.

References

1. Gastineau, G., & Soden, B. J. (2009). Model projected changes of extreme wind events in response to global warming. *Geophysical Research Letters*, *36*(10).
2. Gillett, N. P., Shiogama, H., Funke, B., Hegerl, G., Knutti, R., Matthes, K., ... & Tebaldi, C. (2016). The detection and attribution model intercomparison project (DAMIP v1. 0) contribution to CMIP6. *Geoscientific Model Development*, *9*(10), 3685-3697.