Sinuosity of mid-latitude atmospheric flow in a warming world

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Context

The mid-latitude flow is driven by the equator-to-pole T gradient, which is affected by climate change differently at surface (↘) and aloft (↗).

How does the mid-latitude dynamics respond?
Does the jet stream become wavier?

Method

- Using isohypses (iso-Z500) to characterize the flow trajectory.

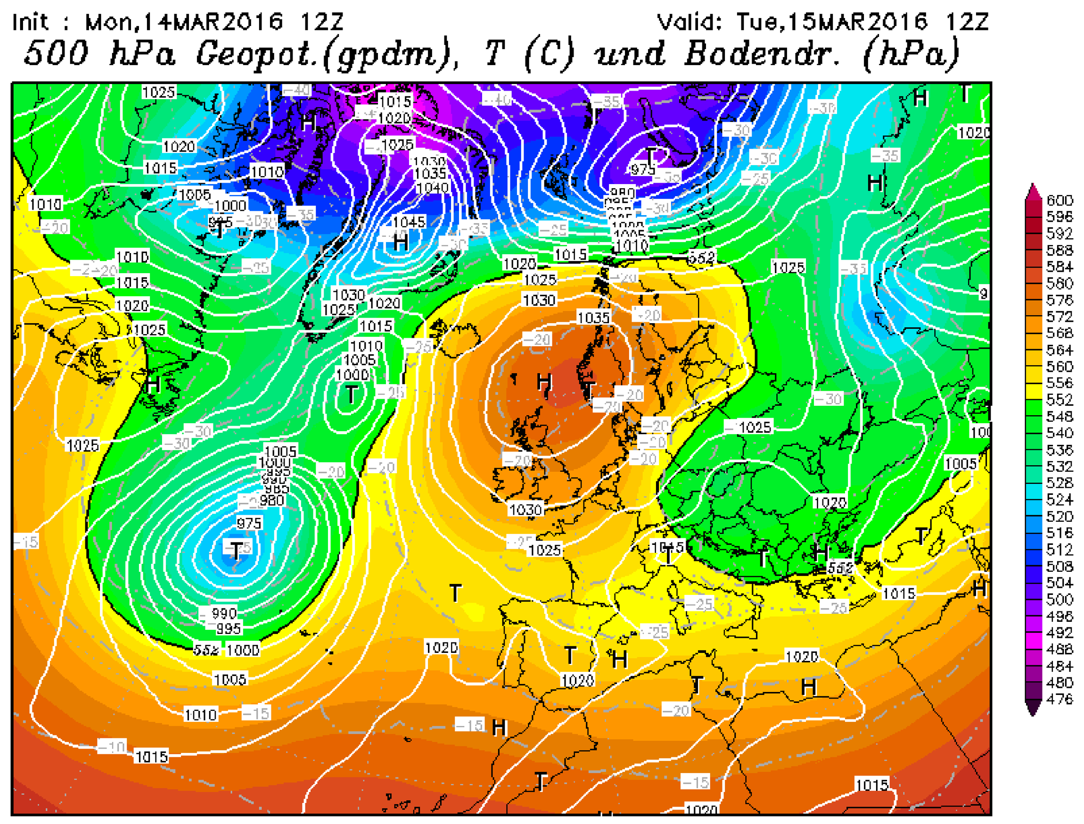

Fig. 1. Daily Z500 for March 15, 2016, © Wetterzentrale.

- For each day, selecting the isohypse located at ∼50°N to account for both the seasonal migration and long-term thermal rise of Z500.
Isohypse value ∼5400 m in winter & ∼5800 m in summer.

- Using a **sinuosity** index to characterize the waviness.
SIN = length of the trajectory divided by the length of the straight line.

Fig. 2. Illustrations from Wikipedia.org/Sinuosity.

- Data : ERA-Interim, 24 CMIP5 models & 40 CESM-LENS members.

Validation of the sinuosity metric

- Isolates meanders responsible for mid-latitude cold spells.

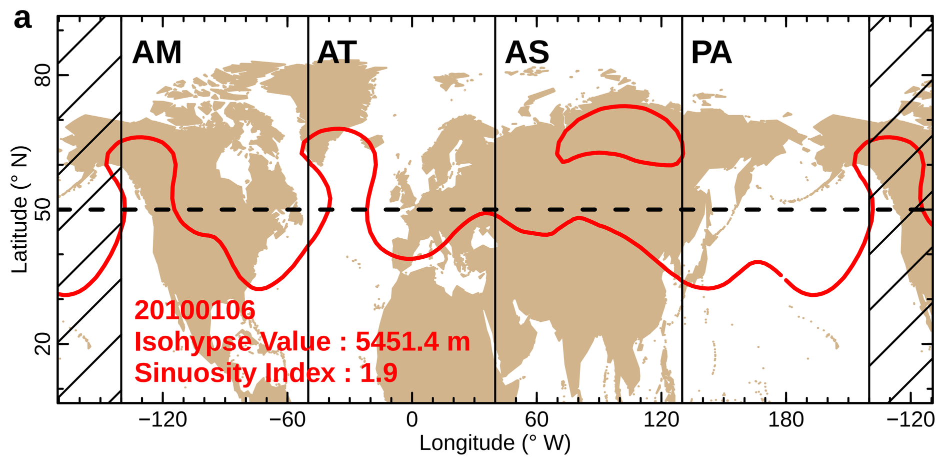

Fig. 3. Selected isohypse for Jan 6, 2010 (cold spell over Eastern U.S. and Europe).

- In the N-Atl in winter, SIN correlated with more classical metrics.

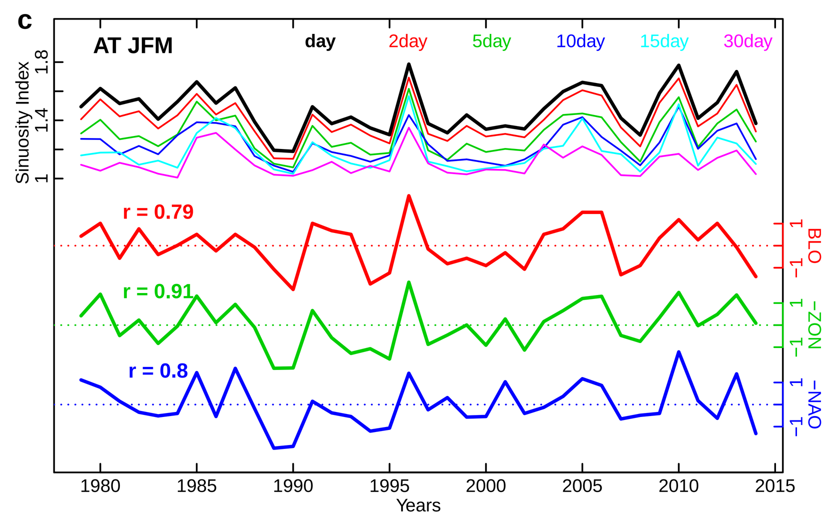

Fig. 4. SIN vs. blocking[1], zonal[2] and NAO[3] indices for AT JFM 1979-2014.

Recent trends

- Only a few significant trends across sectors and seasons. All positive.

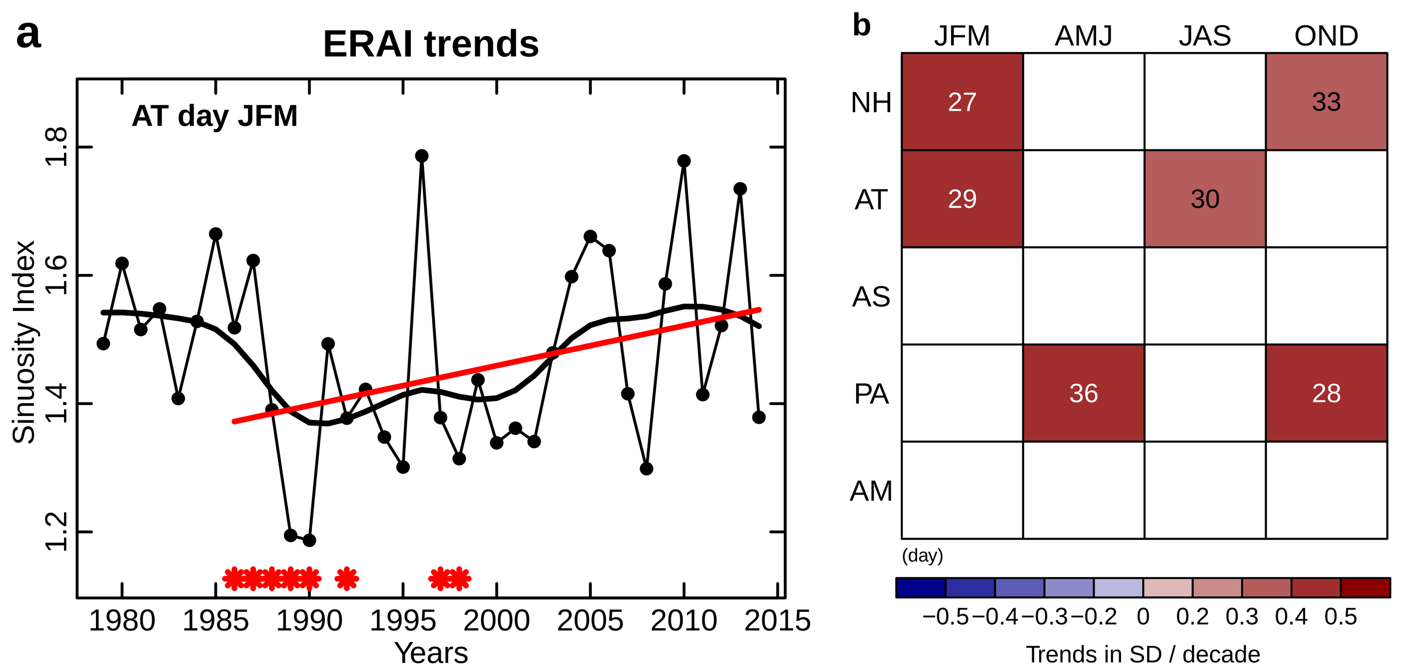

Fig. 5. **a.** SIN for AT JFM 1979–2014. Red (blue) asterisks at year *y* indicate a 90%-level significant positive (negative) trend over *y*–2014. **b.** Longest significant trends for all sectors & seasons. Values = nb of years (e.g. AT JFM has a 29-year positive trend, see **a**).

Projected changes

- Except for N-Am in winter, climate models project a generalized decrease in sinuosity in the RCP8.5.

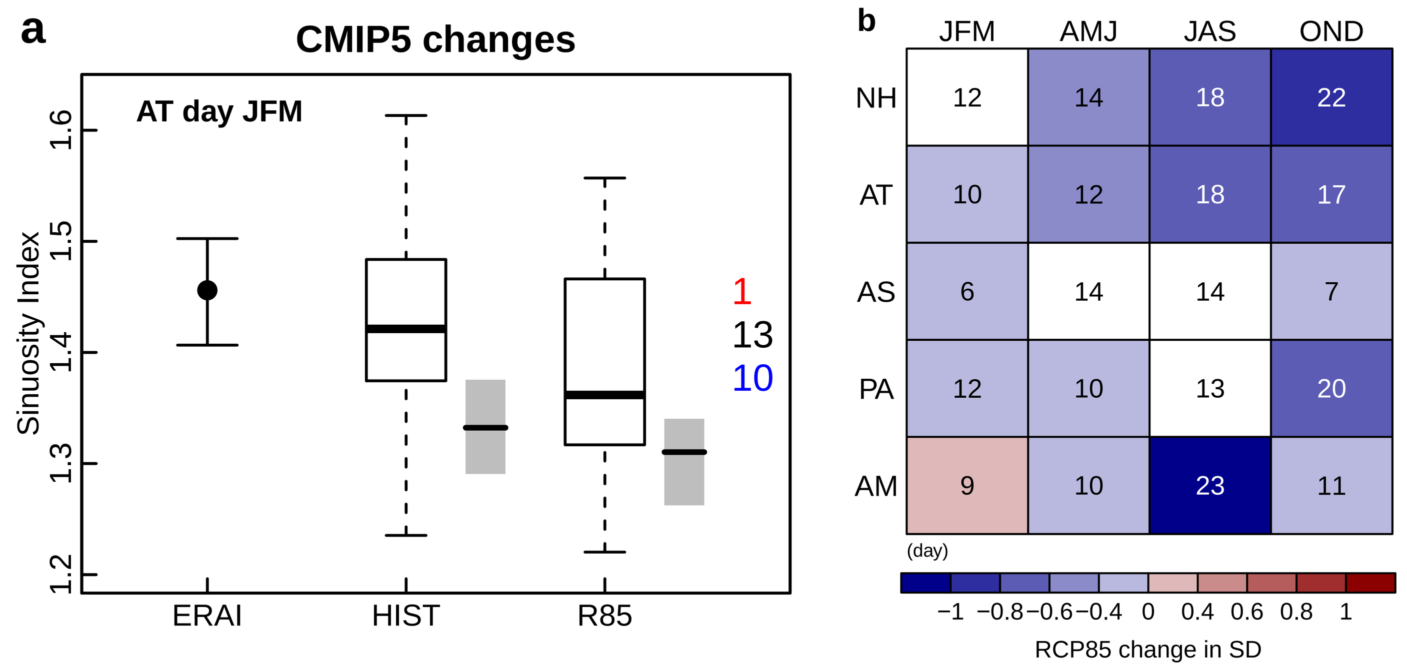

Fig. 6. **a.** Mean SIN for AT JFM: ERAI vs. CMIP5 (white) & CESM (gray) 1979–2008 & 2070–2099. Nb of models with positive / non-significant / negative changes. **b.** CMIP5 ensemble-mean projected changes for all sectors & seasons. Values = nb of models agreeing with the ens. mean (e.g. AT JFM has 10 models with a negative change, see **a**).

Focus on winter NH changes

- High SIN decrease ⇔ strong high-tropospheric tropical warming, strong low-stratospheric polar cooling, & weak Arctic Amplification.

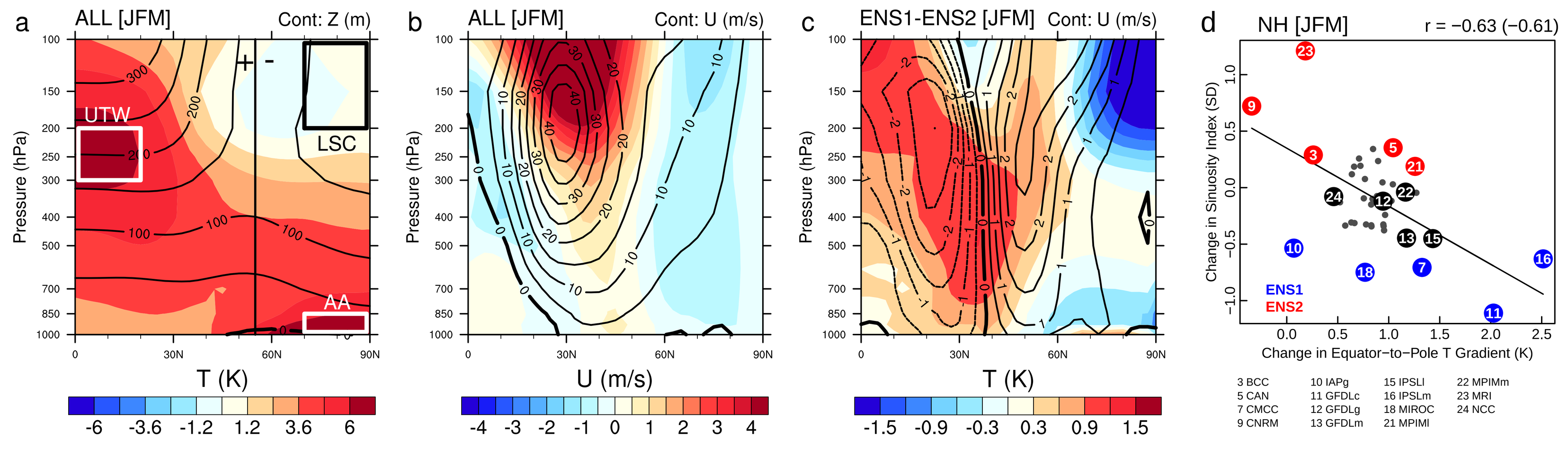

Fig. 7. **a.** Ensemble mean of ΔT (colors) and ΔZ (contours). **b.** Ensemble mean of ΔU (colors) and U (contours). **c.** Difference of ΔT (colors) and ΔU (contours) between models with SIN increase (ENS1) and high SIN decrease (ENS2). **d.** Scatter plot ΔSIN vs. Δ Equator-to-pole T gradient (= T[0–55N] − T[55–90N]).

- SIN decrease ⇔ increase in zonal index and decrease in blockings.

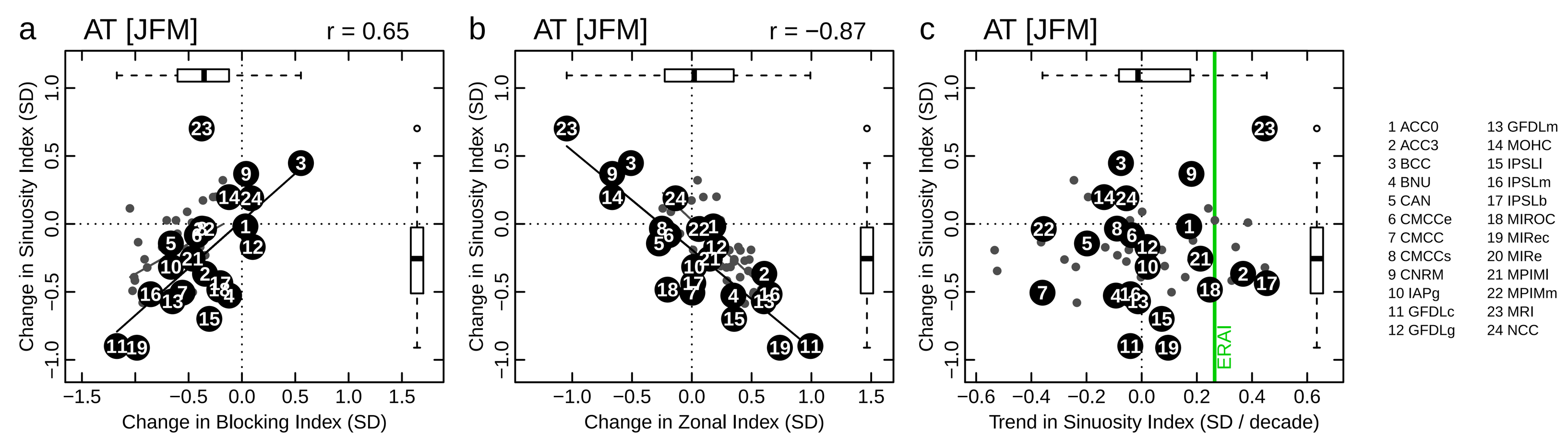

Fig. 8. ΔSIN vs **a.** ΔBLO, **b.** ΔZON and **c.** SIN recent trend (obs in green).

- No link between recent trends and projected changes in SIN.
Recent SIN increase likely due to internal variability.

Conclusions

- The sinuosity is an interesting metric, complementary to more classical indices.
- Recent trends support a wavier flow, but the simulated response to climate change is opposite. Recent trends are likely due to internal variability.
- The model dispersion in the sinuosity response is partially explained by the model-dependent response of the equator-to-pole T gradient.

Cattiaux et al. (2016), Sinuosity of mid-latitude atmospheric flow in a warming world, *Geophysical Research Letters*, 43, 8259–8268, doi=10.1002/2016GL070309.