Aircraft observations and reanalysis depictions of North Atlantic polar front jet stream winds

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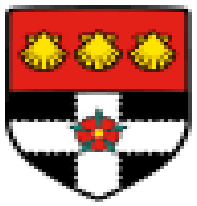

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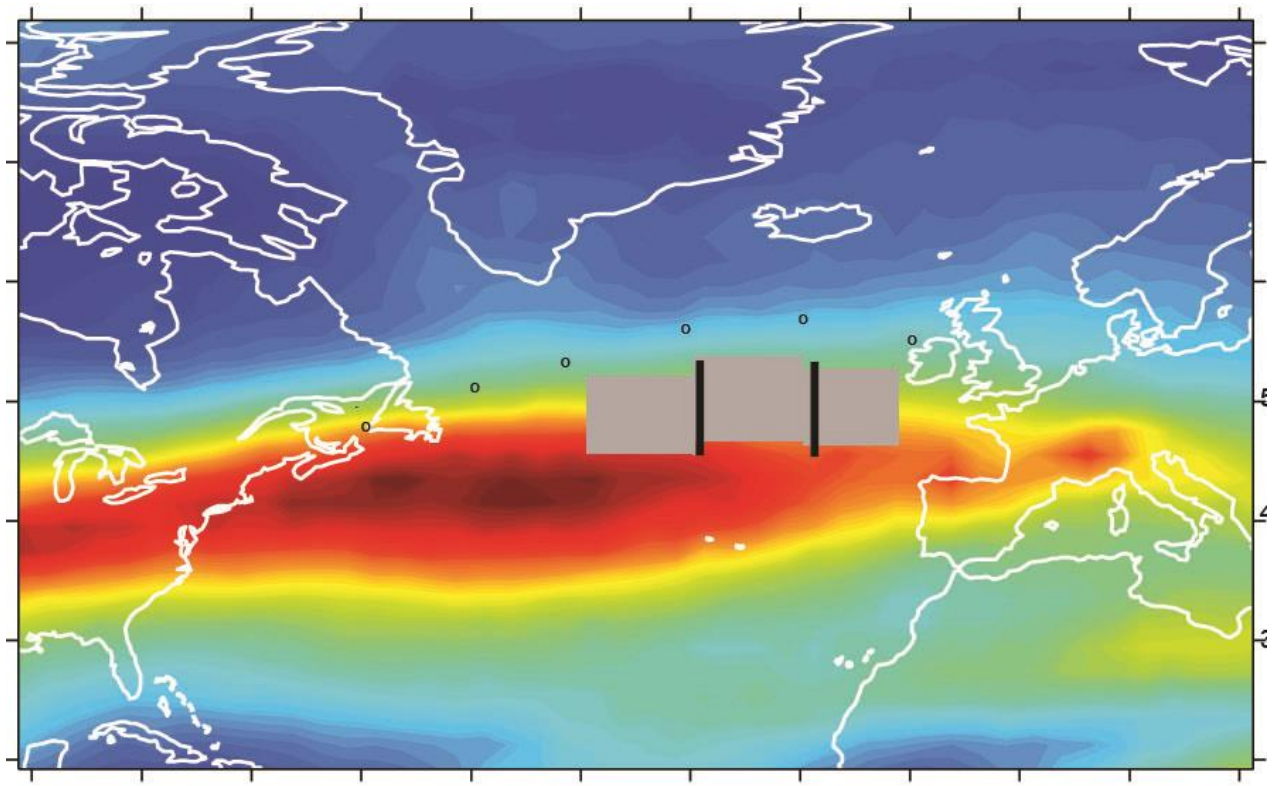
Questions

- Will there be a secular increase in the strength and turbulence of the North Atlantic jet due to doubled CO_2?
- Can it be seen yet?
- Can it be seen independent of computer models?



How can we answer those three questions?

- Three sources: reanalyses, AMDAR/ACARS, GADS
- Reanalyses
  - NCEP-NCAR 50 year reanalysis
  - ERA5 (soon)
- AMDAR archive
  - Contains all aircraft observations transmitted in real time
  - Available online back to ~2002

GADS (Global Aircraft Data Set) archive

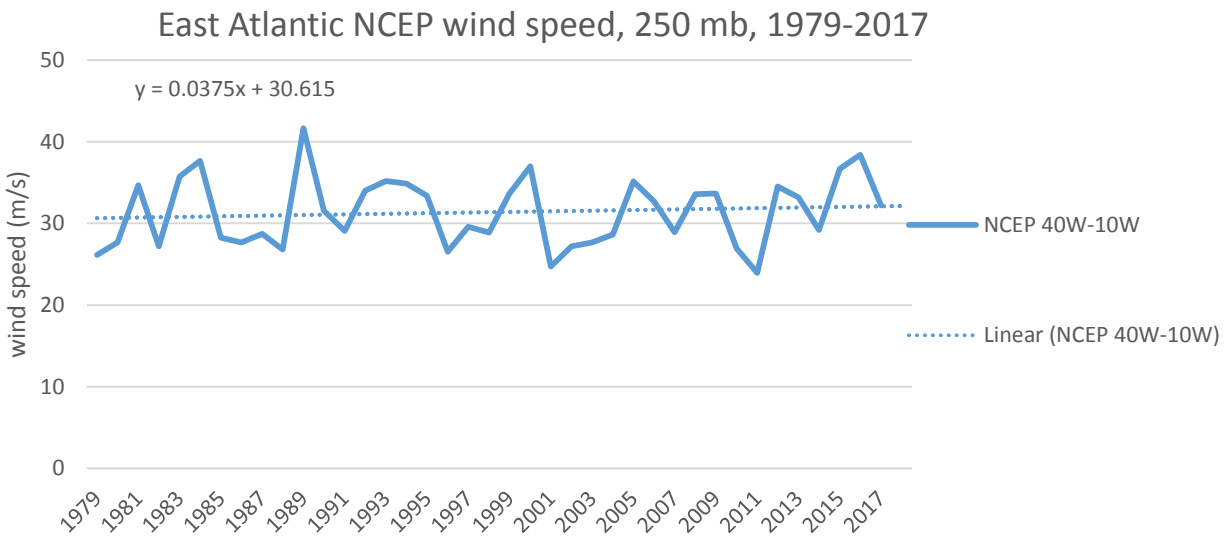
- Started in 1989 and in modern form, 1998 (Tenenbaum, 1991)
- Flight Data Recorder meteorological observations every 4 sec (~1 km)
- 3 billion observations (100 million over North Atlantic for 2002-2017)
- Includes position, time, wind speed, and proxy for turbulence
- Key property: **does not depend on any computer model**
- Independent of real-time AMDAR observations but same sources
- AMDAR and GADS not subject to AIREP voice transmission errors

North Atlantic polar jet stream modeling

- CMIP3: comparisons of more than 17 climate models
- Delcambre et al. (2013): 20th and 21st century doubled CO_2
- Summary: “predict … an overall expansion of the Atlantic jet … [and that] zonal winds … decrease in the core of the … Atlantic jets, with increasing zonal winds located primarily in the jet exit regions and the meridional flanks of the jets.”
- Williams and Joshi (2013), Williams (2017), GFDL CM2.1 model
- Summary: changed jets do not cancel to second order
- Result: longer flight times and more turbulence

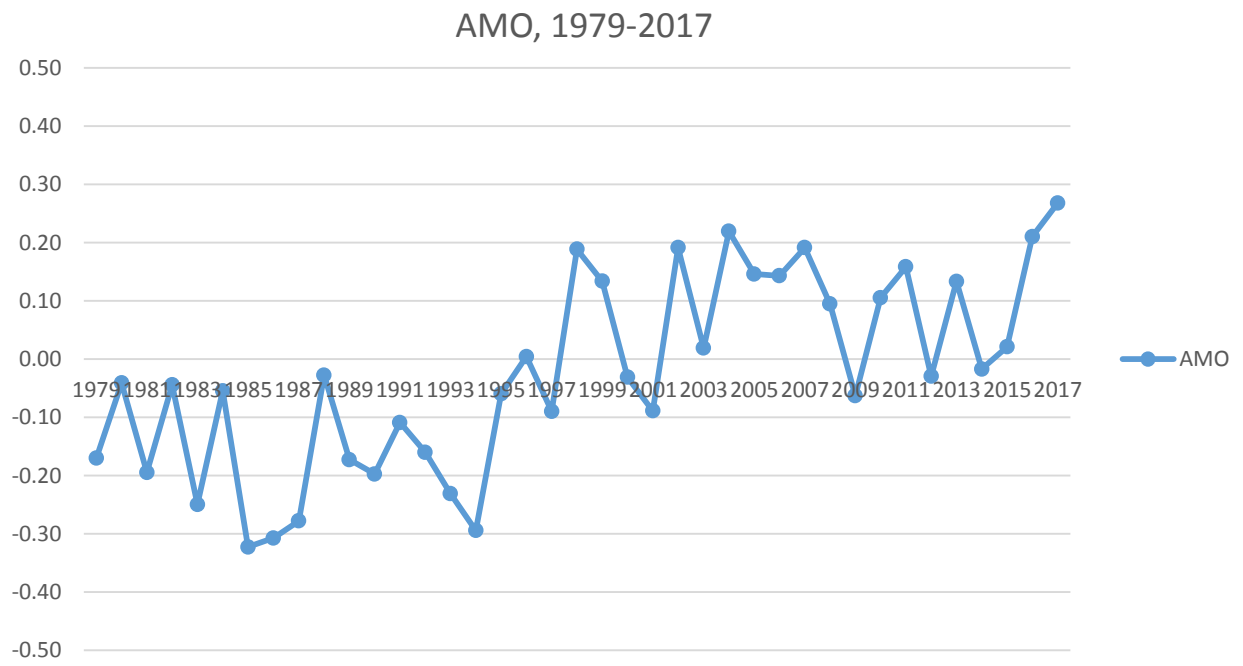
NCEP, 1979-2017

- Longest “modern” winter interval available (DJF; labeled by January)
- Tiny secular increase in wind speed, not statistically significant
- Translate fit, y = 0.0375x + 30.615, to annual percent increase of 0.1%
- Delcambre et al., for a longer time interval and a wider longitudinal interval, also show an annual increase of 0.1%
- Will present annual percent increases in the subsequent graphs as well



Problem: Atlantic Multidecadal Oscillation (AMO)

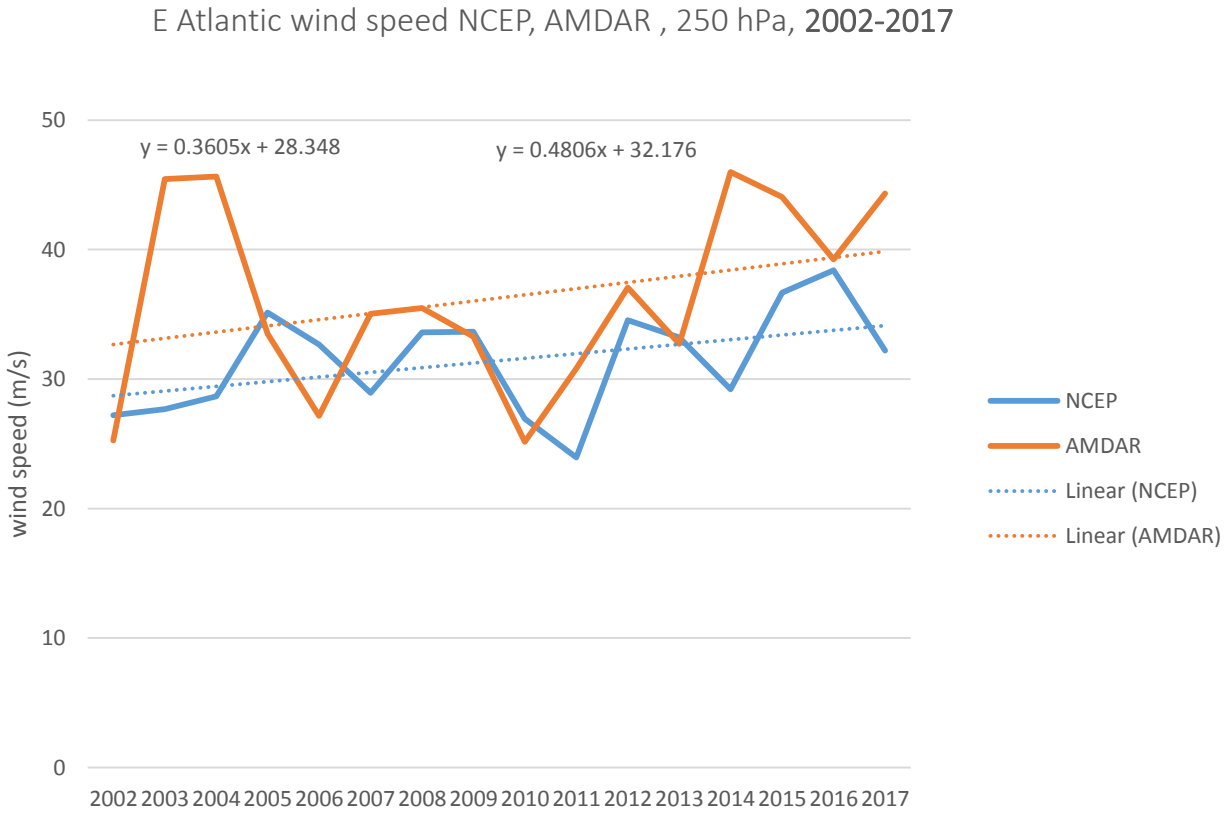
- Long studied phenomena of Atlantic SST that flips every 30-40 years
- Currently in the warm phase with the latest flip just about when AMDAR and GADS started
- Confounds any attempt at studying secular changes over 1979-2017 period
- North Atlantic Oscillation (NAO; period of a few years) seems less relevant



Results: NCEP, AMDAR 2002-2017

- Steady positive portion of the AMO
- Does show statistically significant positive secular slope
- Shading indicate statistically significant result at the 5% level

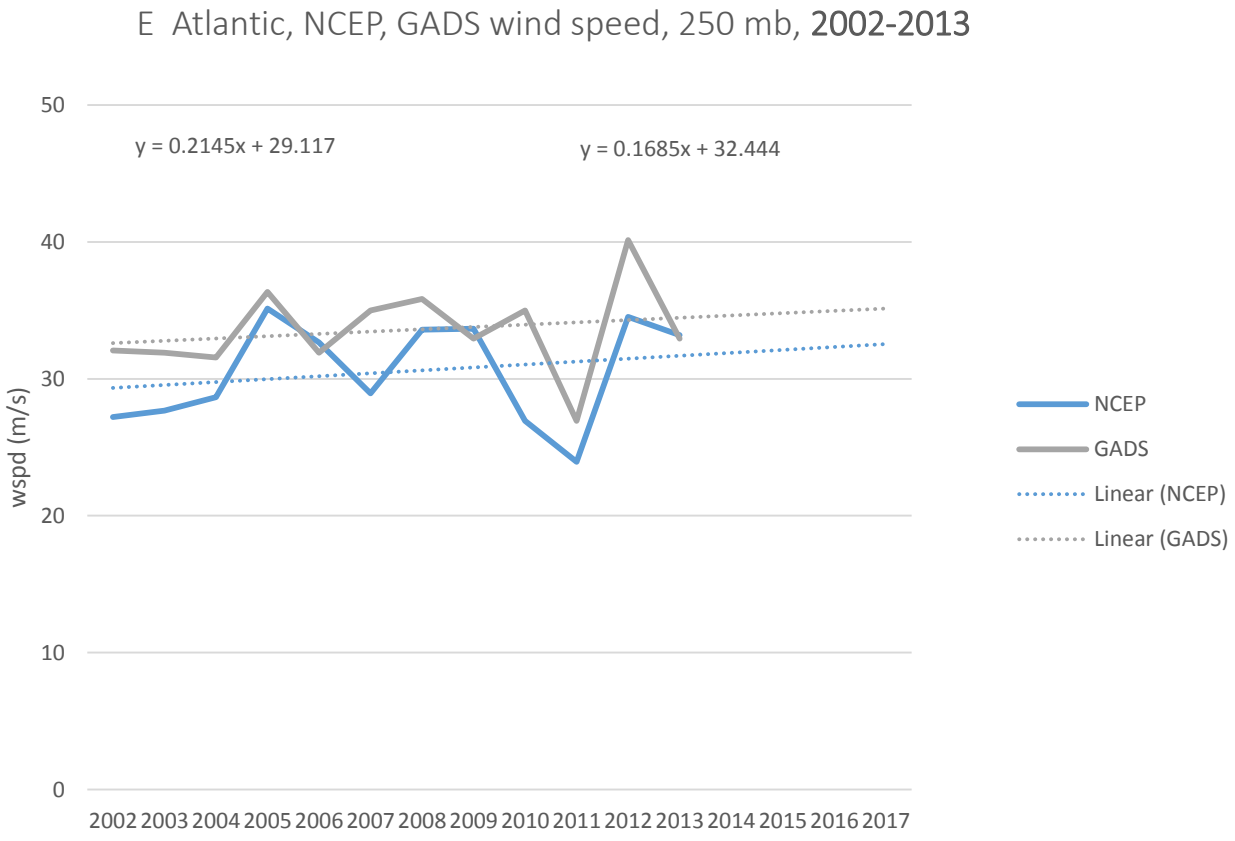
source	annual % increase	F value	dof
NCEP	1.3	3.13	14
AMDAR	1.5	1.54	14



Results: NCEP, GADS
2002-2013

- Check NCEP against independent GADS aircraft observations
- Steady positive portion of the AMO
- Show positive secular slope which is not yet statistically significant
- Awaiting 2014-2017 GADS observations

source	annual % increase	F value	dof
NCEP	0.7	0.46	10
GADS	0.5	0.36	10



Conclusions

- When limited to a fixed AMO phase (2002-2017) see annual increases in jet stream exit regions of NCEP (1.3%), AMDAR (1.5%) versus Delcambre (0.1%, over a longer but longitudinally wider interval)
- Results for NCEP already statistically significant at 5% level
- For 2002-2013, NCEP (0.7%), GADS (0.5%) also show annual increases
- Await 4 more years (2014-2017) to see if GADS result will be statistically significant
- Observations of a secular increase qualitatively consistent with Delcambre but too short an interval to definitively prove at this time