Changes in Apparent Temperature Over the Ocean during 1950-2023: Addressing Uncertainties of Near-surface Wind Speeds Changes from Reanalyses and Model Data

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1. Introduction

Apparent temperature (APT) changes, the human-perceived temperature, due to global warming significantly impact on human health and society.

Most APT studies focus on changes over land.

If relative humidity and near surface wind speed remain constant, APT would increase at approximately 1.1-1.4 times of the rate of air temperature change.

2. Methods

MAPT calculation

Based on Steadman's APT equation (1984), MAPT (°C) is a function of Marine Air Temperature (MAT, °C), Vapor Pressure (e, hPa) and Near-surface Wind Speeds (NSWS, m/s):

$$MAPT = -2.7 + 1.04 \times MAT + 0.2 \times e - 0.65 \times NSWS$$

where e is ia function of MAT and RH:

$$e = \frac{RH}{100} \times 6.112 \times \exp\left(17.67 \times \frac{MAT}{MAT + 243.5}\right)$$

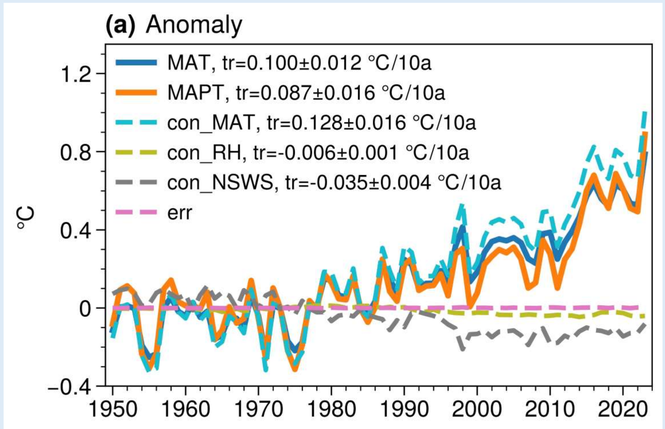
Given that observed ocean surface RH remains relatively constant while global mean temperatures rapidly increases (IPCC, 2021), we take RH as an individual factor in the contribution analysis.

Factor Contribution Quantification

Absolute Sensitivity Coefficient (ASC) of each meteorological factor is defined as the partial derivative of MAPT with respect to that factor

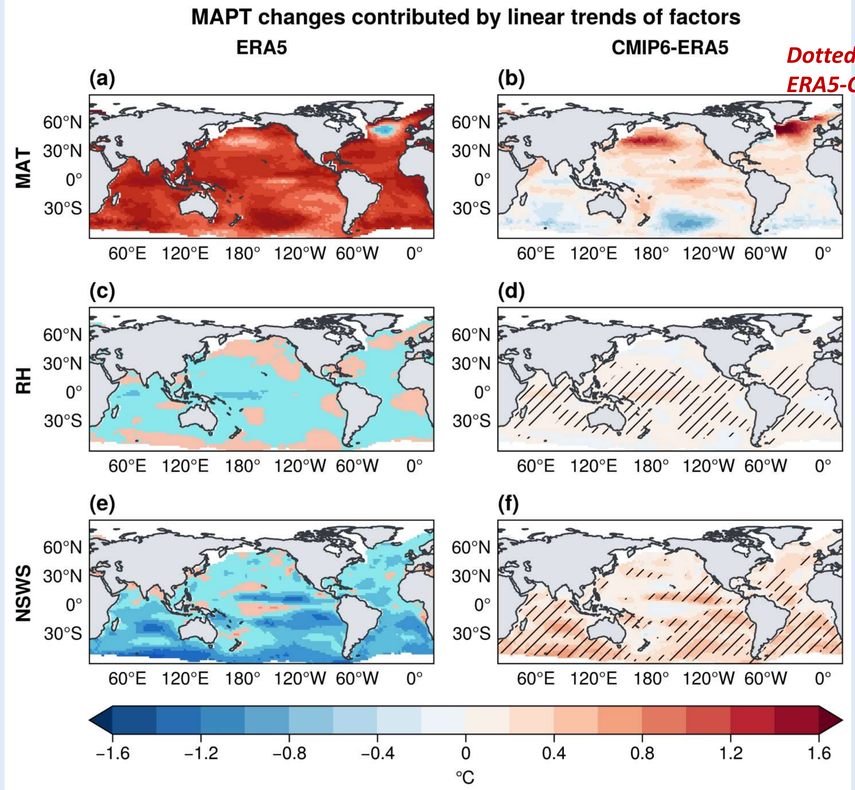
$$Contribution = ASC \times Factor\ Changes$$

3. Factors' Contribution to MAPT changes Based on ERA5 and CMIP6



MAPT has a global-averaged increase during 1950-2023. However, it has increased slower than MAT.

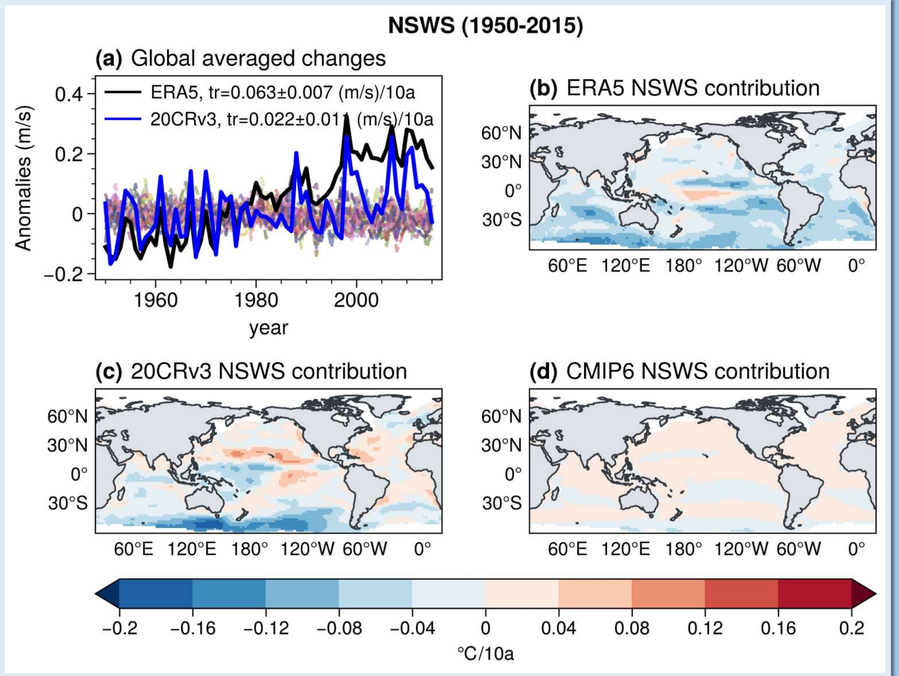
MAT has a warming contribution (about 1.28 times of MAT warming), RH has little influence, and NSWS has a significant cooling effect.



ERA5 and CMIP6 agree that MAT has dominated MAPT changes (warming all over the oceans), RH has very limited influence (basically cooling in low-mid latitudes and warming in high latitudes), and NSWS has widespread negative contribution (especially in southern hemisphere).

ERA5-CMIP6 Difference: NSWS contribution important but could not be explained by natural variability (>3 std of CMIP6 models)

4. NSWS Changes Uncertainty



How to understand NSWS differences?

NSWS from 20CRv3 reanalysis, which only assimilates sea level pressure, has about half increasing rate of that from ERA5 which also assimilates marine wind measurements, while NSWSs from CMIP6 have slight decreasing trends.

ERA5 NSWS has an almost globally cooling effect, while 20CRv3 NSWS has a warming effect in most of the northern hemisphere. Even though CMIP6 NSWS trends are much smaller than those of reanalysis, its pattern is more similar to 20CRv3 rather than ERA5.

5. Summary

MAT has dominated MAPT changes during 1950-2023, RH has limited influence, and NSWS has an important cooling effect on MAPT over some southern regions.

The discrepancies in wind speed trends among different reanalyses and model data mean we should be more critical about how wind changes affect MAPT.