# Assessing Radiative Feedbacks and their Contribution to the Arctic Amplification Measured by Various Metrics

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## 1. Introduction

- Arctic amplification (AA): a more rapid surface air temperature (SAT) change in the Arctic than the global average.
- Various metrics have been used to quantify AA based on SAT anomalies, trends or variability, and can yield quite different conclusions regarding the AA magnitude & temporal patterns.
- Goals of this study:
  - Examine and compare established AA metrics for their temporal consistency in the region north of 70°N from the mid-20th - the early 21st century using observational and reanalysis data.
  - Quantify contributions of different radiative feedbacks to AA based on short-term climate variability in reanalysis and model data using the Kernel-Gregory approach.

## 2. AA metrics

| Metric | Definition | Reference |
|---|---|---|
| $A_1$ | Difference between Arctic SAT anomaly and global SAT anomaly | Francis and Vavrus (2015) |
| $A_2$ | Ratio of the absolute value of Arctic SAT linear trend to the absolute value of global SAT linear trend | Johannessen et al. (2016) |
| $A_3$ | Ratio of the Arctic SAT interannual variability, measured by standard deviation of yearly/seasonal anomalies, to the global SAT interannual variability | Kobashi et al. (2013) |
| $A_4$ | Coefficient of linear regression between Arctic and global SAT yearly/seasonal anomalies | Bekryaev et al. (2010) |
| $A_5$ | Ratio of the Arctic-mean to the global-mean SAT anomalies | Ono et al. (2022) |
| $A_6$ | Ratio of the Arctic standardized SAT anomaly to the global standardized SAT anomaly | Przybylak and Wyszyński (2020) |
| $A_7$ | Ratio of the Arctic trends of standardized SAT yearly/seasonal anomaly to the global trends of standardized SAT yearly/seasonal anomaly | Przybylak and Wyszyński (2020) |

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## 3. AA quantification using various datasets

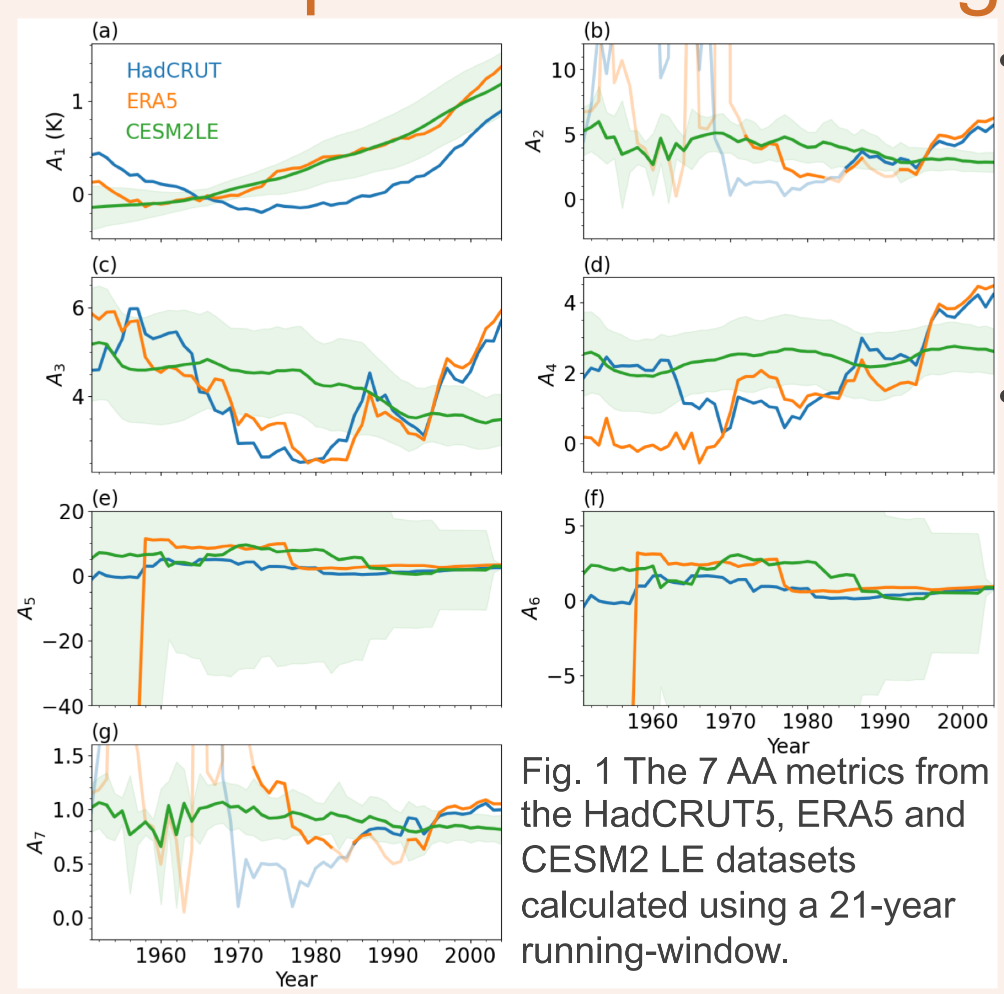
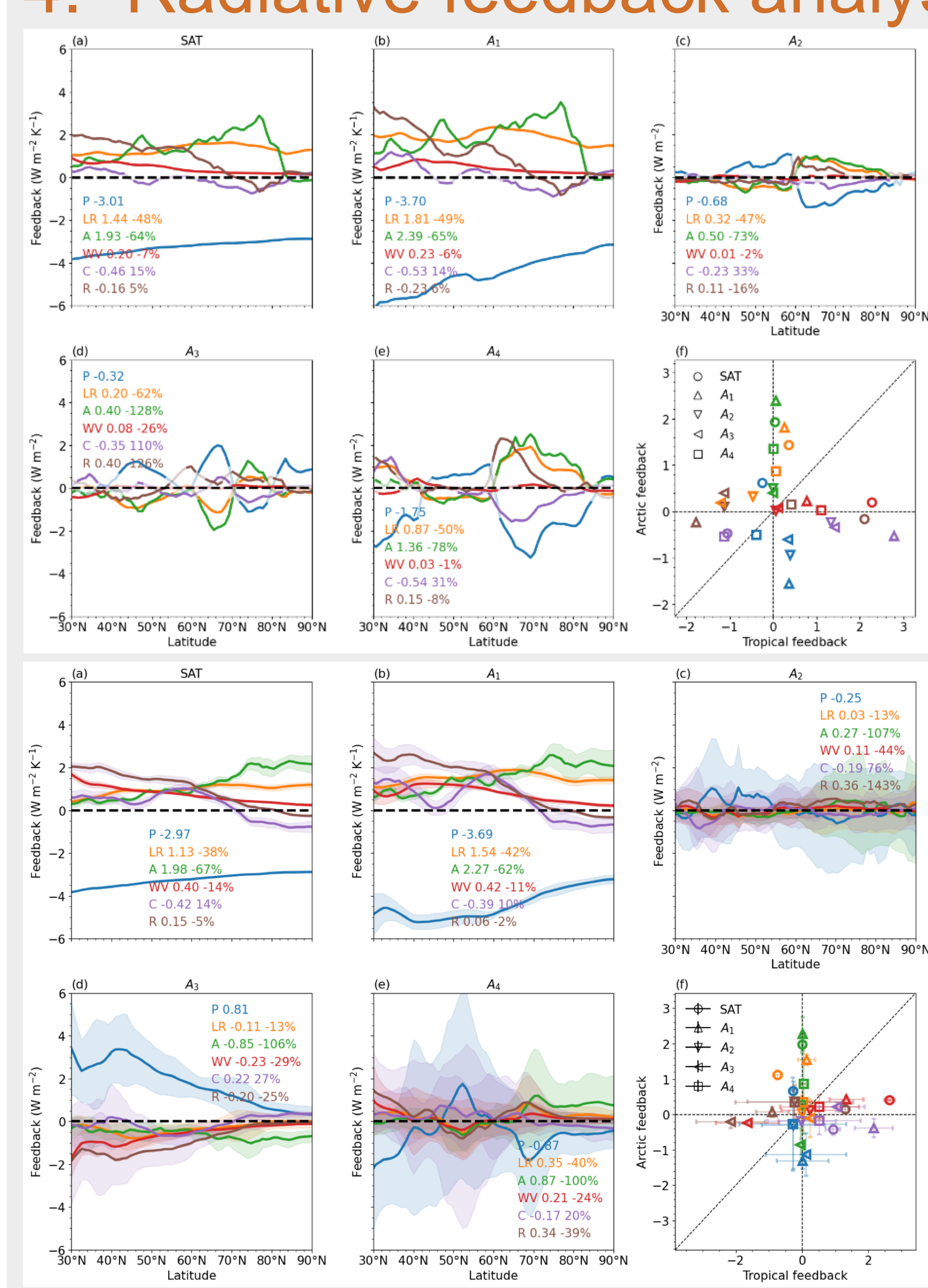



Fig. 1 The 7 AA metrics from the HadCRUT5, ERA5 and CESM2 LE datasets calculated using a 21-year running-window.

- A rapid increase in observed AA from the mid-20th century to the early 21st century in various AA metrics.
- ERA5: good agreement with the HadCRUT5 observations; CESM2 LE: underestimate the recent AA increase (likely linked to model bias or deficiency in capturing natural variability appeared in the observations).

## 4. Radiative feedback analysis




- Qualitative agreement between ERA5 and CESM2 LE: albedo & LR feedback are the top two main contributors to Arctic SAT/AA increase.
- Cloud and WV feedback: relatively weaker effects; less agreement between datasets; greater susceptibility to internal variability.

Fig. 2 ERA5 (up) & CESM2 (down) Planck (P), lapse rate (LR), water vapor (WV), albedo (A) & cloud (C) radiative feedbacks.

## 5. Energy balance model (EBM)

- $MSE = Cp * SAT + Lv * q$ ($Cp$: air specific heat, $Lv$: latent heat of vaporization; $q$: surface air specific humidity from ERA5).
- Suppressing surface albedo feedback → the greatest reduction in SAT difference between the Arctic and global average.

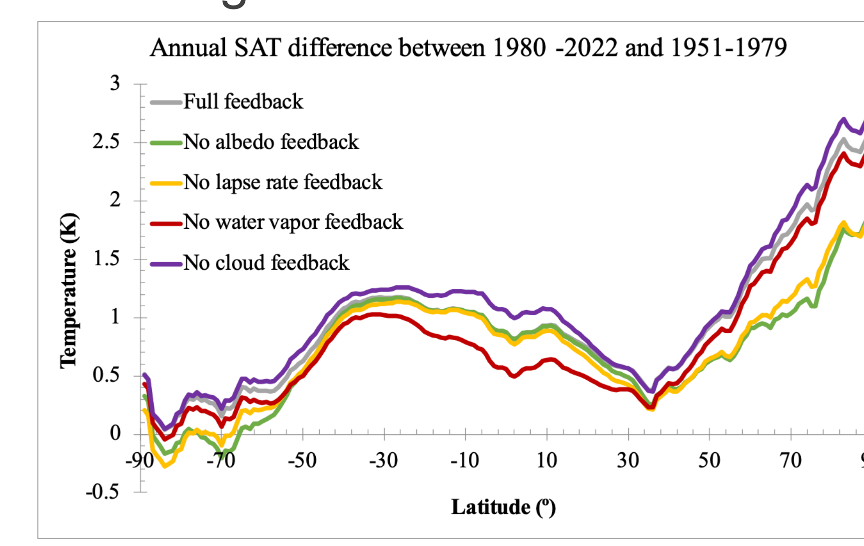



Fig. 3 SAT changes in the EBM with total feedback and individual feedbacks suppressed one at a time.

## 6. Summary

- Albedo and lapse rate feedbacks: positive and comparable (albedo feedback is the dominant contributor for all AA metrics).
- Cloud feedback has large uncertainties (strongly depends on the data used, the time periods considered and the AA metrics used).
- WV and cloud feedbacks are most heavily influenced by internal variability.
- An EBM, incorporating regional feedbacks & diffusivity from ERA5, is employed to establish a robust connection between the estimated regional feedbacks and their contribution to AA.