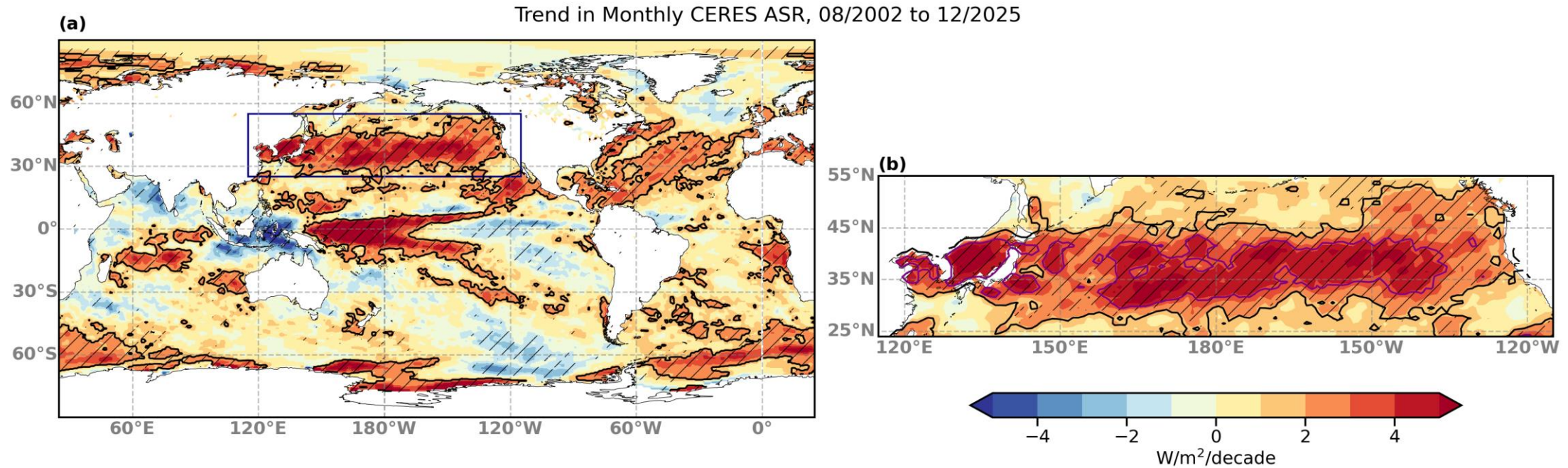


Excessive 21st century solar absorption in the North Pacific attributed to poleward storm track shift and to aerosol emission decreases

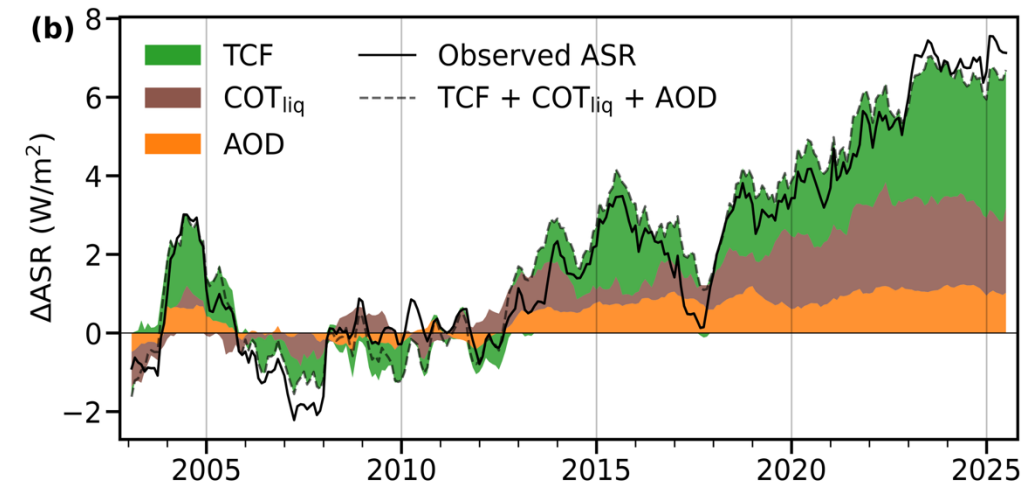
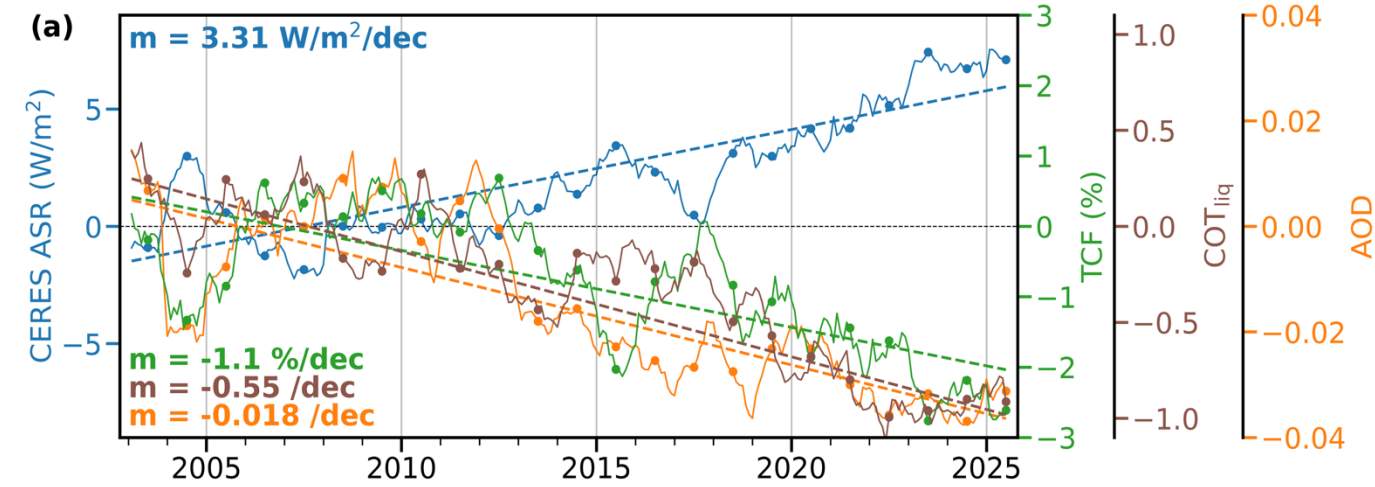
George Tselioudis and Joe Kelly
NASA/GISS, Columbia University



- The N. Pacific Absorbed Shortwave Radiation (ASR) positive trend is a dominant signal explaining 40.3% of the global positive ASR trend
- Here we perform an attribution study to understand and quantify the processes that produce the positive N. Pacific ASR trend, focusing on the region bounded by the 1.75 W/m²/decade ASR isoline

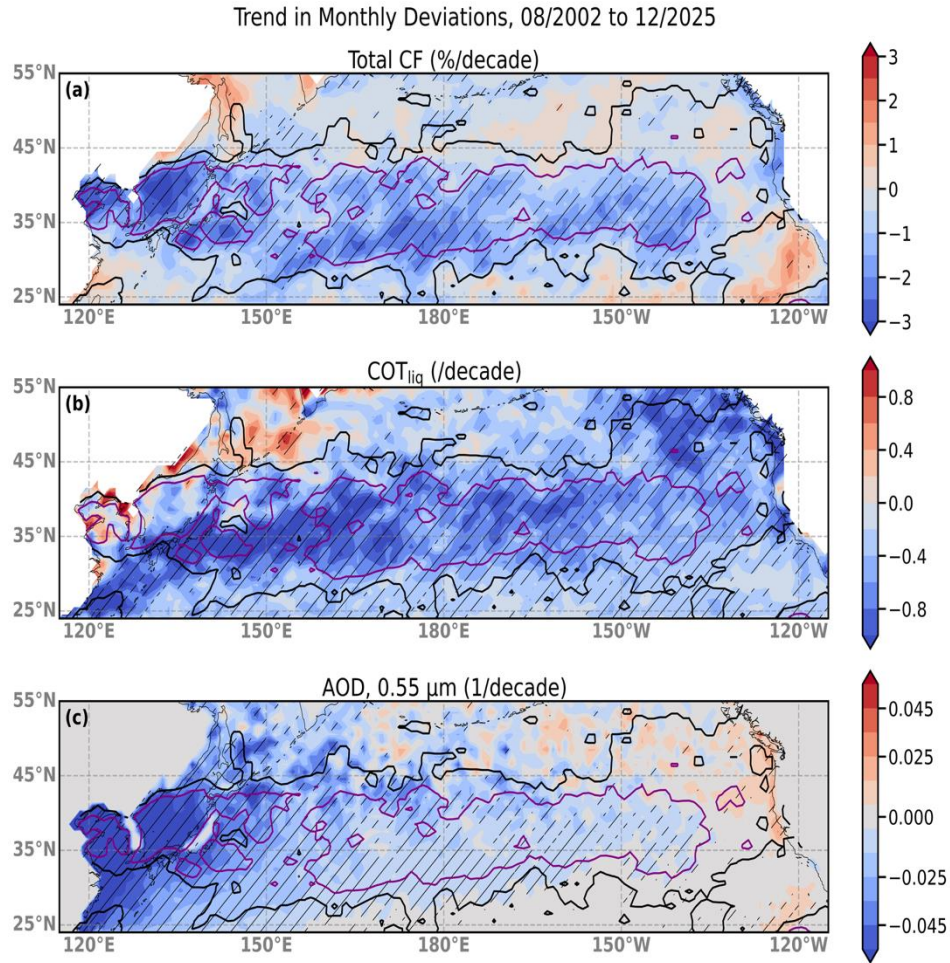
N. Pacific ASR trend attribution

- The positive N. Pacific ASR trend of $3.31 \text{ W/m}^2/\text{dec}$ happens together with statistically significant negative trends in MODIS/VIIRS-derived Total Cloud Fraction (TCF), liquid Cloud Optical Thickness COT_{liq} , and Aerosol Optical Depth (AOD)
- An ASR trend decomposition analysis using those three ‘Radiation Controlling factors’ as predictors, shows that together they contribute close to the totality of the ASR trend almost throughout the length of the 2002-2025 ASR time series.
- In Terms of their individual contributions, cloud fraction contributes 44.5% to the reconstructed N. Pacific ASR trend, liquid cloud optical thickness contributes 38.7% of the trend, and aerosol optical depth 18.3% of the trend.



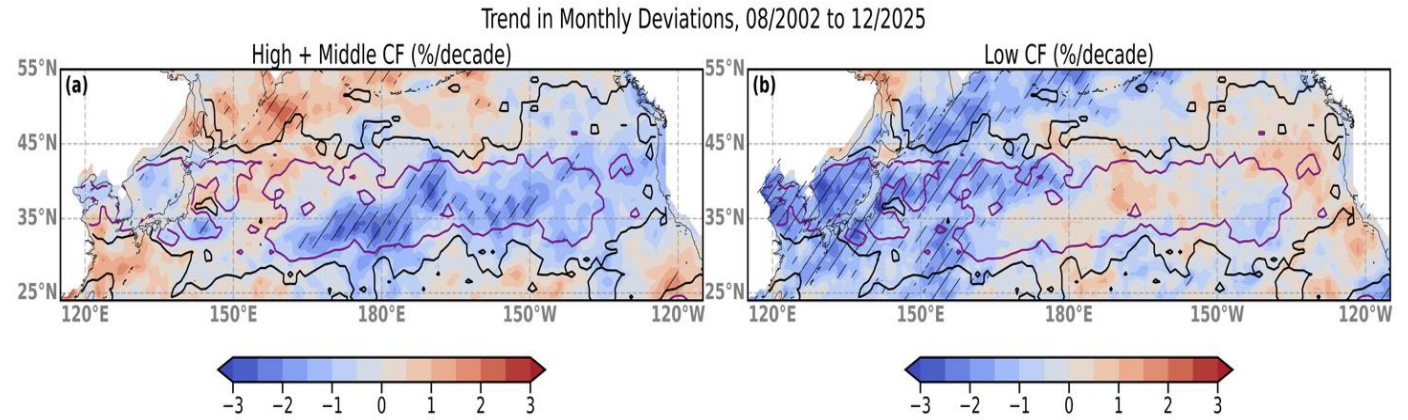
	Trend (W/m^2)	Contribution(%)
Total ASR	3.31 ± 0.29	
TCF	1.47 ± 0.28	44.5 ± 9.2
COT	1.28 ± 0.28	38.7 ± 9.1
AOD	0.61 ± 0.07	18.3 ± 2.6

TCF, COT_{liq} and AOD Spatial Trends

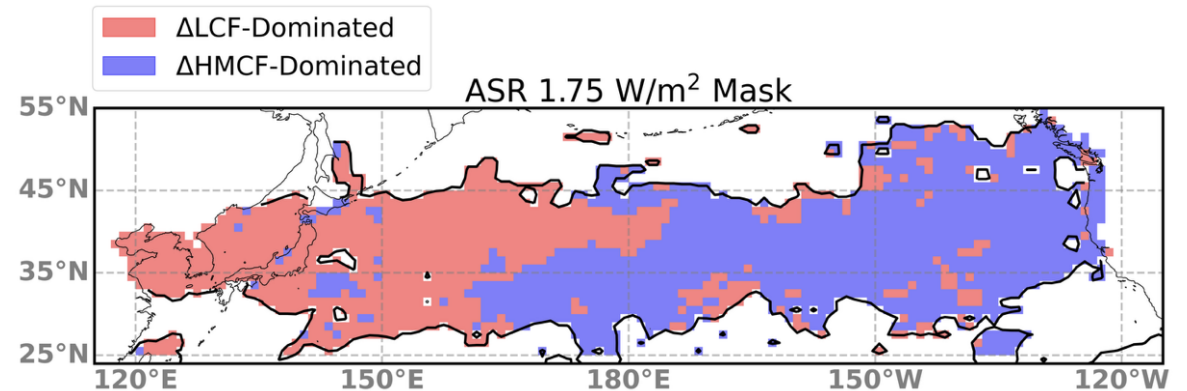


TCF and COT_{liq} show relatively uniform decreasing trends across the N. Pacific basin, while AOD shows an East-West gradient with the strongest decreases in the western part of the basin

High and Middle vs Low CF spatial trends

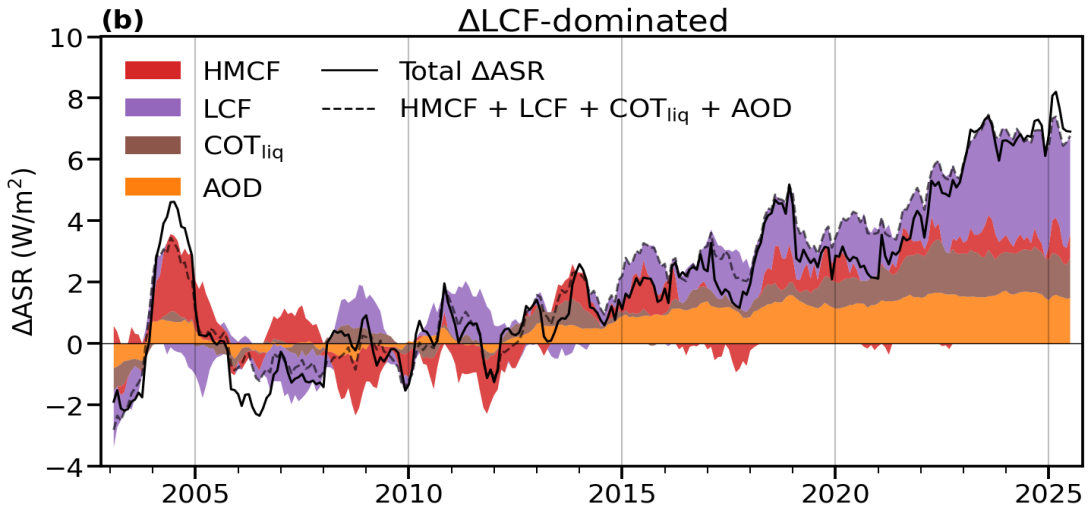
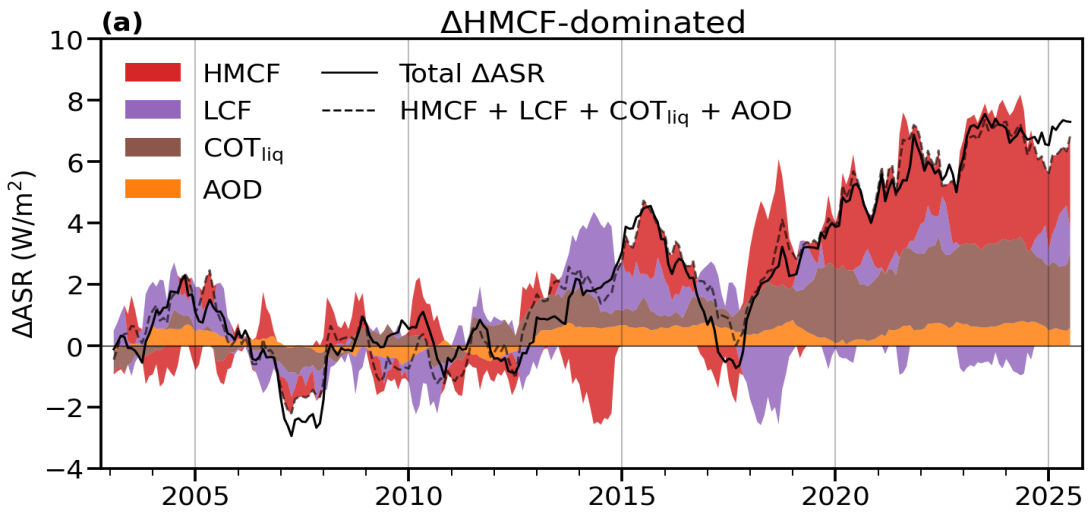


High+Middle and Low CF show contrasting spatial trends, with decreases in HMCF occurring primarily in the eastern part and decreases in LCF occurring primarily in the western part of the basin



To distinguish between CF decreases driven by HMCF changes and those driven by LCF changes, we create a mask that defines locations dominated by ΔHMCF and those dominated by ΔLCF

ASR trend attribution in the Δ HMCF- and Δ LCF-dominated regimes

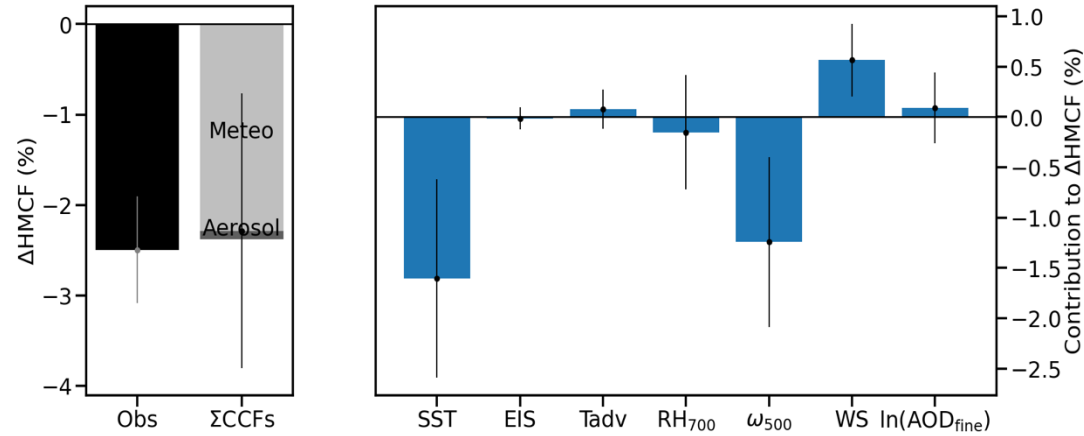


- Predictably, HMCF and LCF changes dominate in their respective regimes, and HMCF changes are the strongest cloud fraction contributor in the regional mean ASR trend
- COT_{liq} is a strong contributor in both regimes, surprisingly more so in the Δ HMCF-dominated regime
- AOD is strongest in the Δ LCF-dominated regime that mostly extends in the western part of the basin

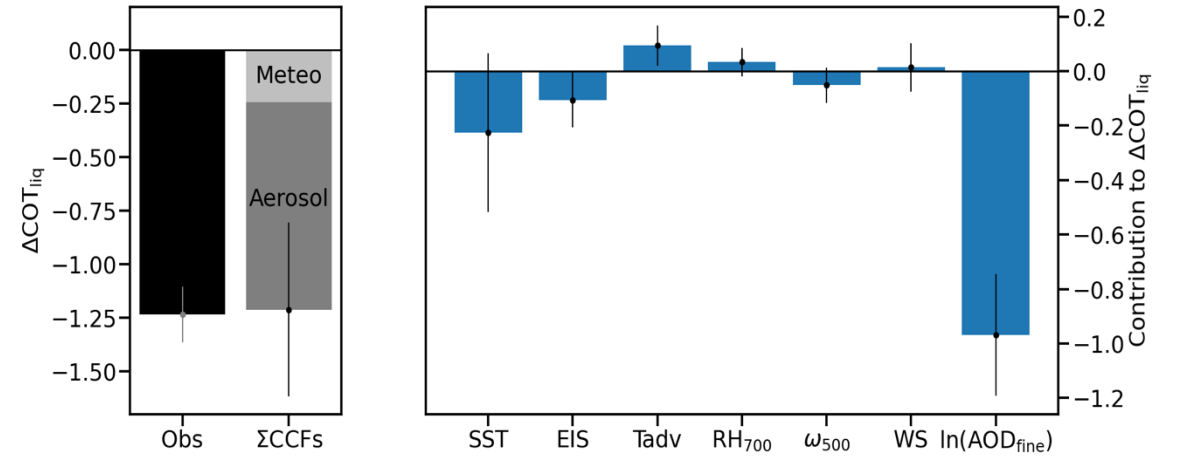
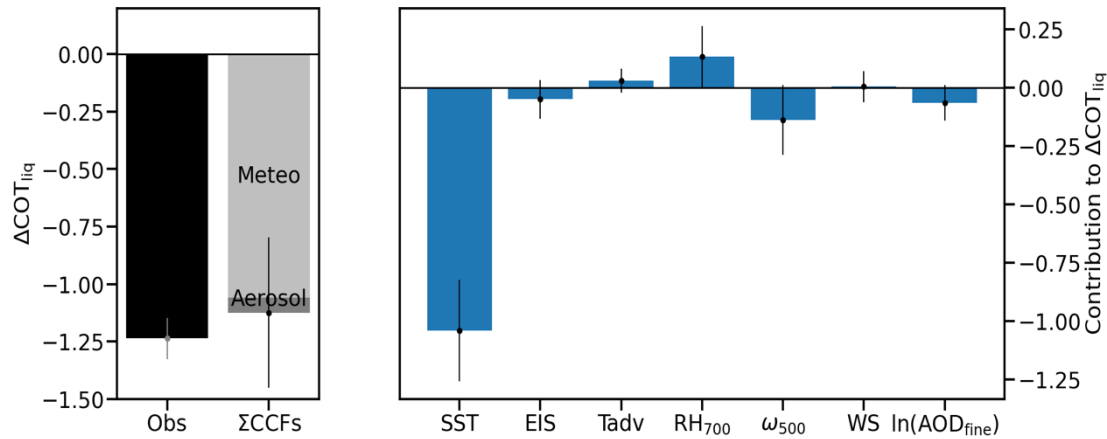
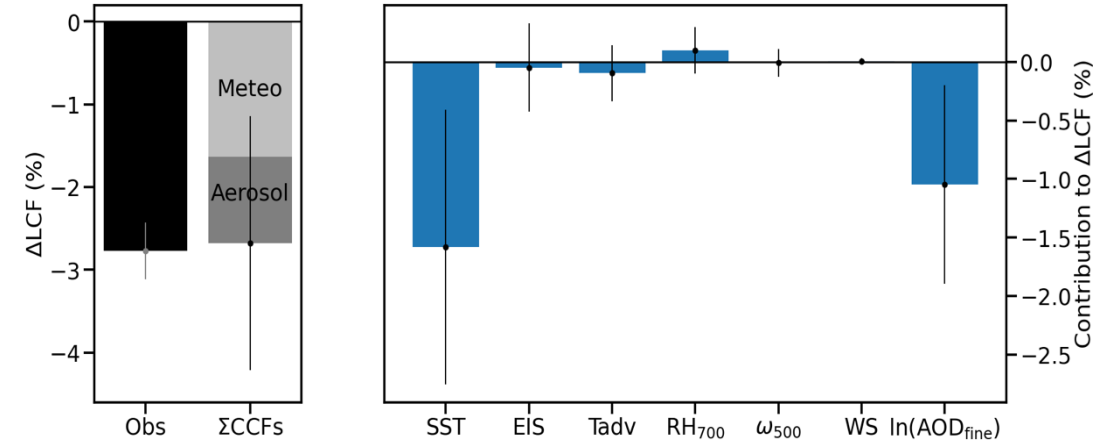
	Total Region	Δ HMCF-Dom	Δ LCF-Dom
Total ASR	3.31 ± 0.29	3.40 ± 0.29	3.21 ± 0.39
HMCF	– 0.87 ± 0.28	1.73 ± 0.46	0.08 ± 0.23
TCF	1.47 ± 0.28	–	–
LCF	– 0.66 ± 0.26	-0.08 ± 0.33	1.65 ± 0.35
COT	1.28 ± 0.28	1.46 ± 0.28	0.77 ± 0.31
AOD	0.61 ± 0.07	0.29 ± 0.06	0.93 ± 0.09

CCF Analysis in the two regimes

Δ HMCF



Δ LCF



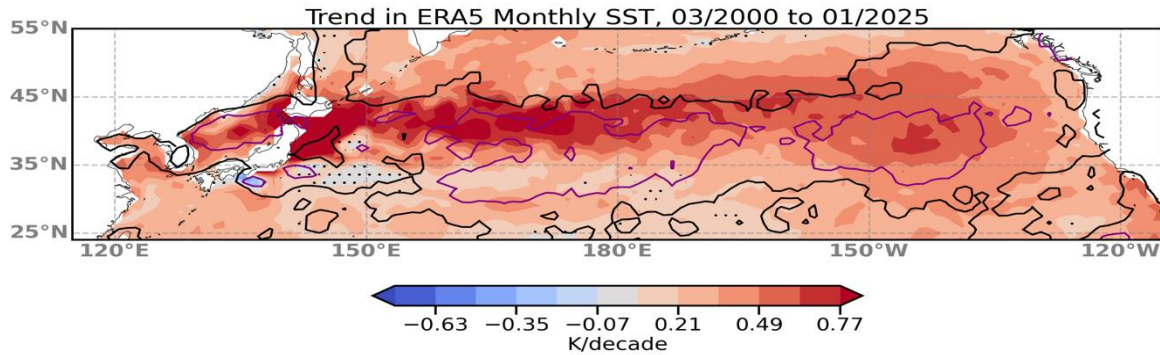
Aerosol effects dominate the trend in COT_{liq} and play a significant role in the trend of LCF

SST is the primary contributor to the LCF trend and together with EIS and temperature advection contribute to the COT_{liq} trend

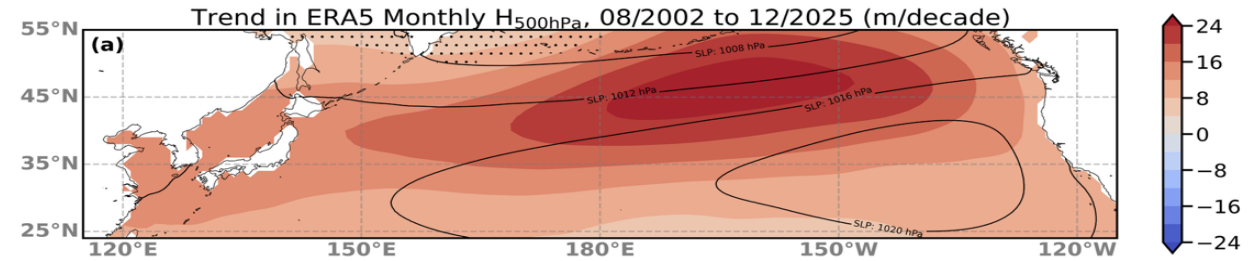
- Meteorological factors dominate both the HMCF and COT_{liq} trends with minimal aerosol contributions
- SST and vertical velocity contribute to the HMCF trend while SST dominates the COT_{liq} trend

A positive cloud-dynamics feedback loop

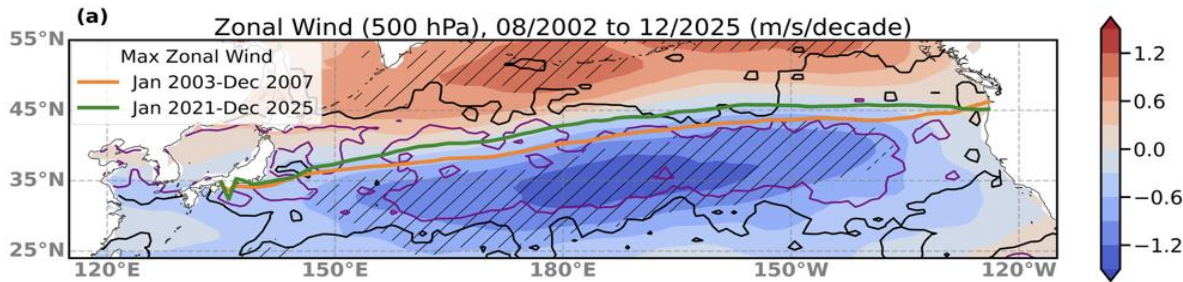
An increase in SST across the N. Pacific basin....



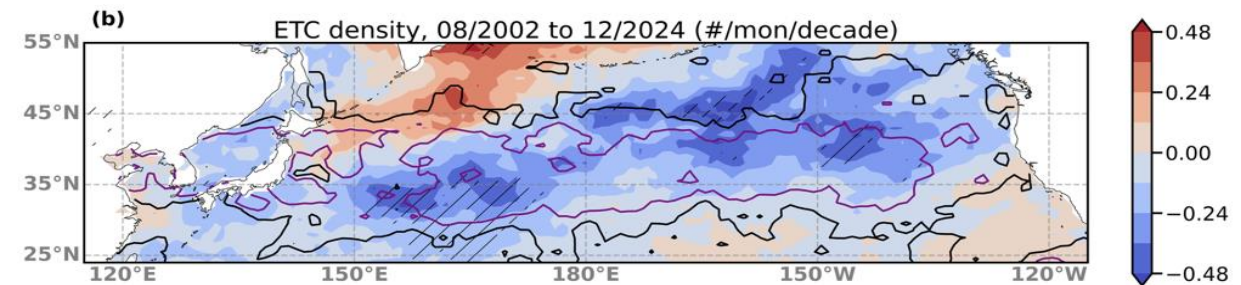
increases geopotential height and strengthens the high-pressure ridge..



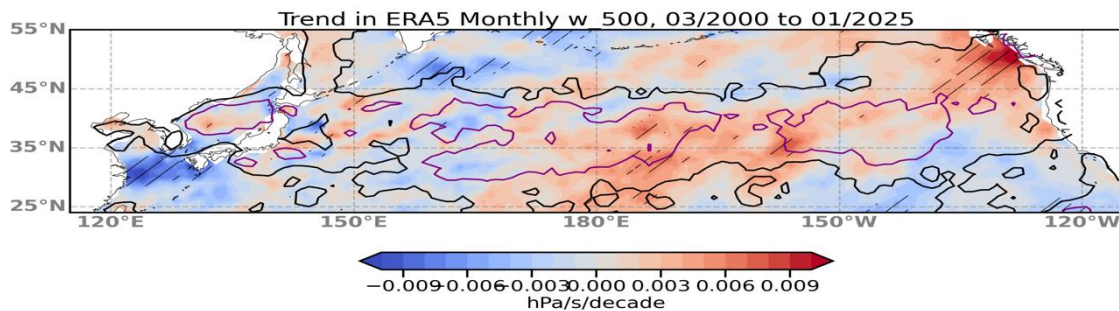
which shifts the midlatitude jet stream poleward....



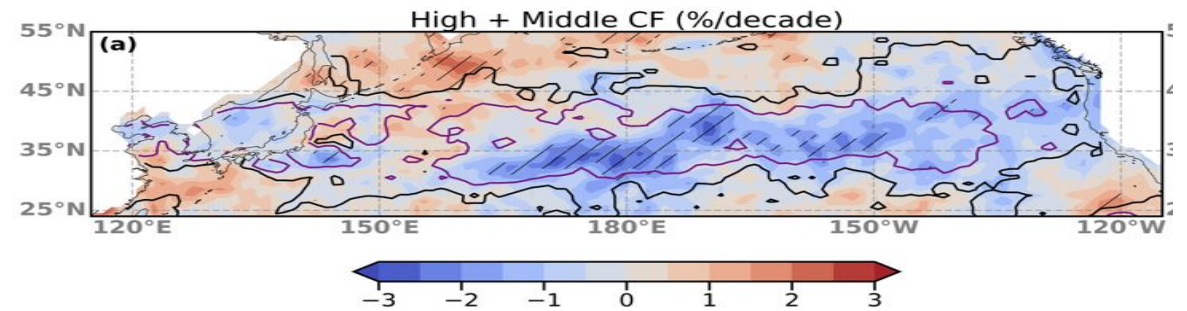
along with the midlatitude storm track....



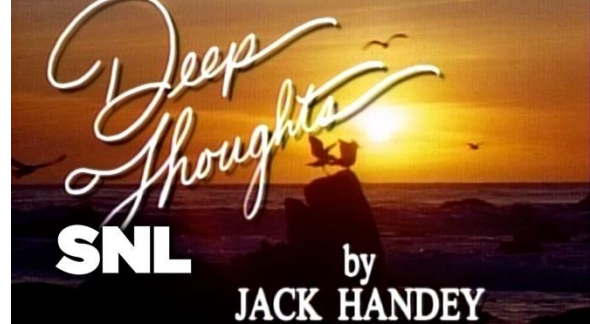
increasing large scale subsidence....



thus decreasing HMCF and increasing ASR and therefore SST.



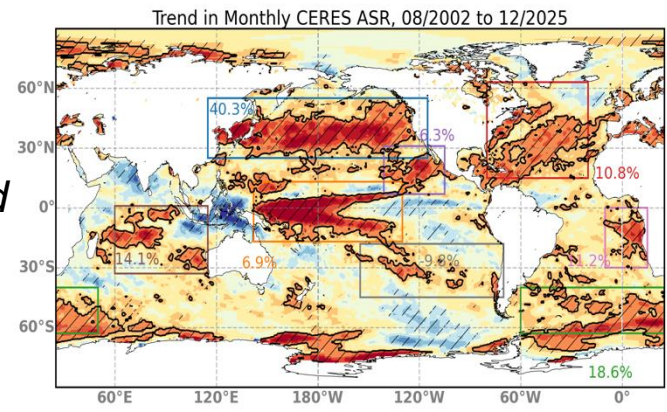
In other words, 'The jet stream is real, and it is shifting poleward' 'Pressure'



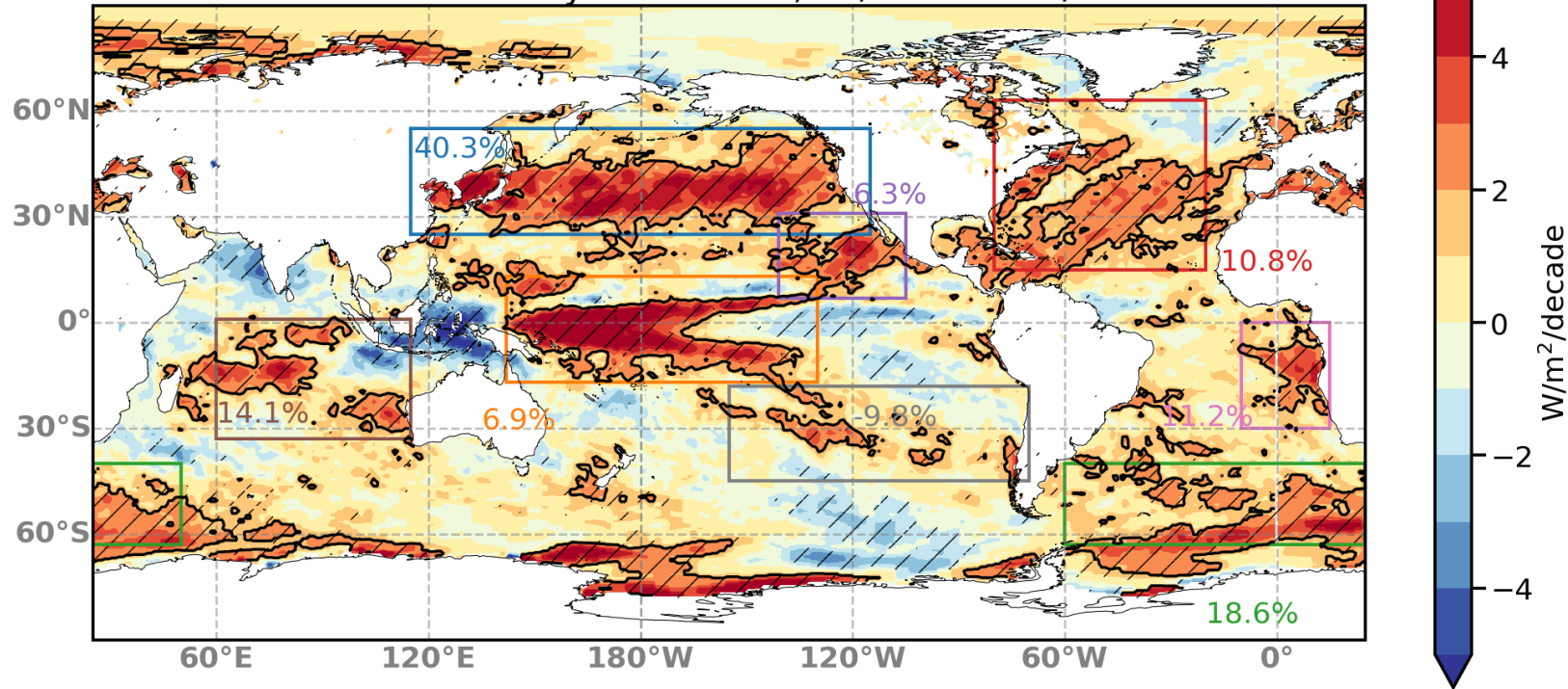
The globally dominant North Pacific ASR trend of $3.31 \text{ W/m}^2/\text{dec}$ occurs due to the confluence in the basin of four processes:

- A decrease in high and middle cloud fraction that contributes 26% to the trend, occurs in the central and eastern parts of the basin, and can be attributed to a poleward shift of the N. Pacific storm track that can be part of a positive cloud-dynamics feedback loop.
- A decrease in low-cloud fraction that contributes 20% to the trend, occurs in the western part of the basin, and can be attributed in part to thermodynamic, SST-driven influences and in part to aerosol influences related to the Albrecht effect.
- A decrease in low-cloud reflectivity that contributes 38% to the trend, occurs throughout the basin, and can be attributed in the eastern part to thermodynamic effects and in the western part to aerosol influences related to the Twomey effect.
- A decrease in aerosol optical depth that contributes 17% to the trend, occurs primarily in the western part of the basin, and can be attributed to decreases in aerosol emissions.

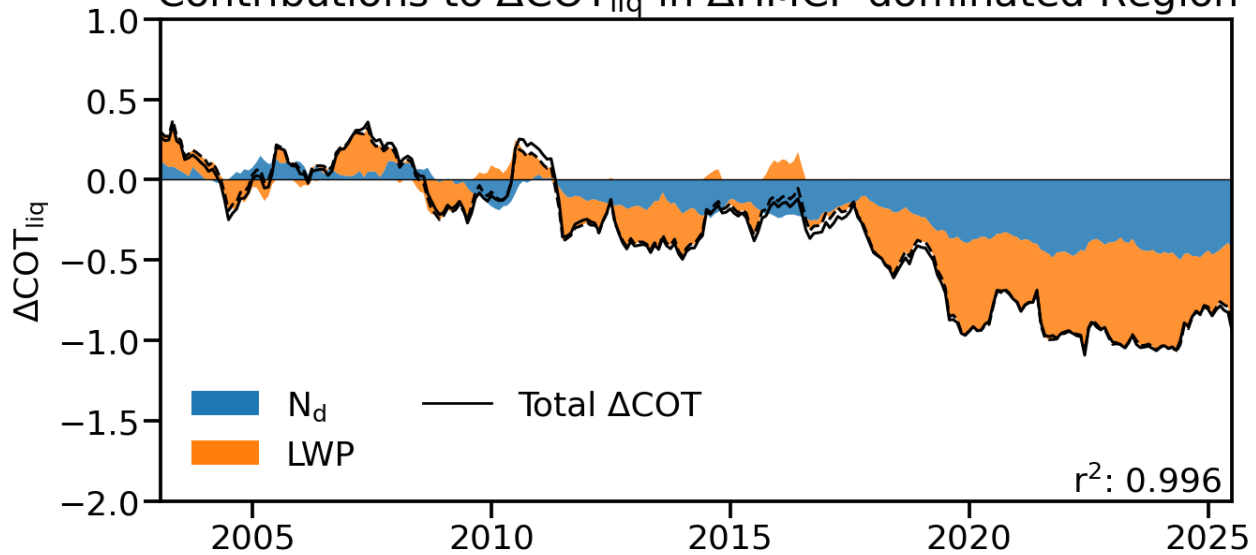
It is almost certain that a similar analysis of the other regions of strong ASR increases will produce different dependencies of the ASR trend on radiation controlling properties and processes, and that globally valid conclusions for the mechanisms causing the strong 21st century ASR trend can be structured only as a synthesis of the mechanisms operating in the different regions and climate regimes.



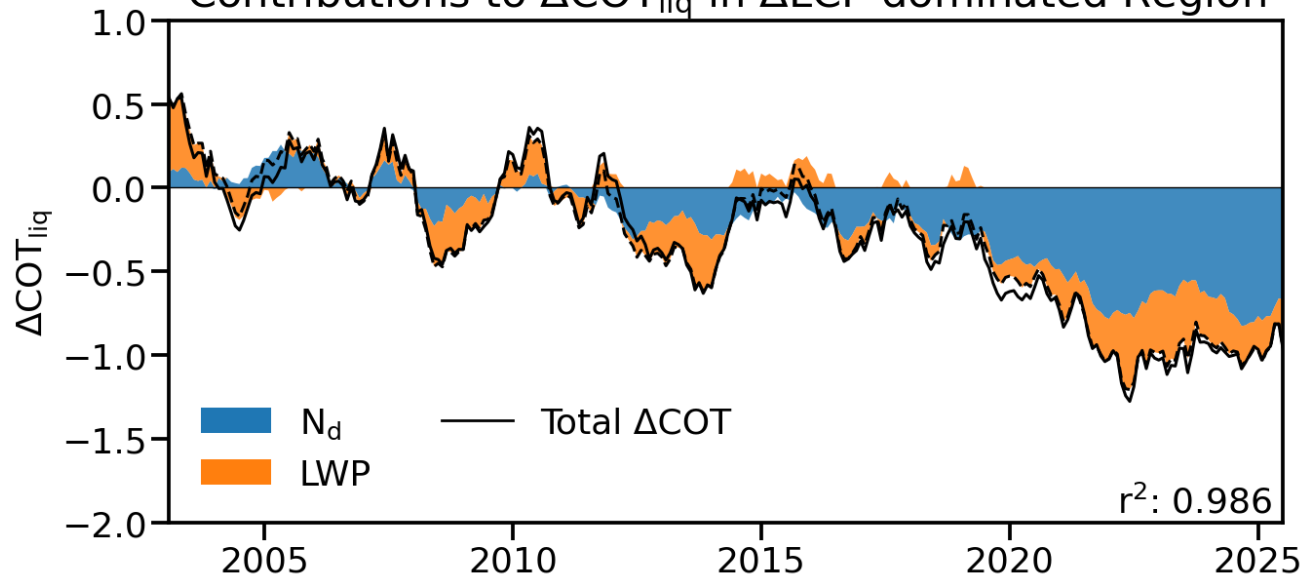
Trend in Monthly CERES ASR, 08/2002 to 12/2025



Contributions to $\Delta\text{COT}_{\text{liq}}$ in ΔHMCF -dominated Region

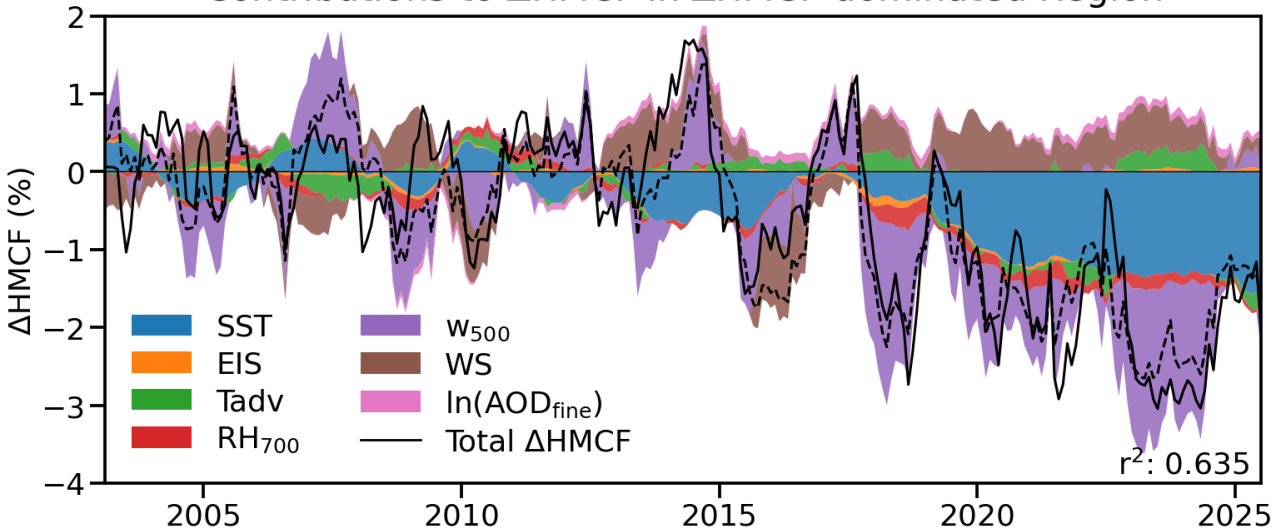


Contributions to $\Delta\text{COT}_{\text{liq}}$ in ΔLCF -dominated Region



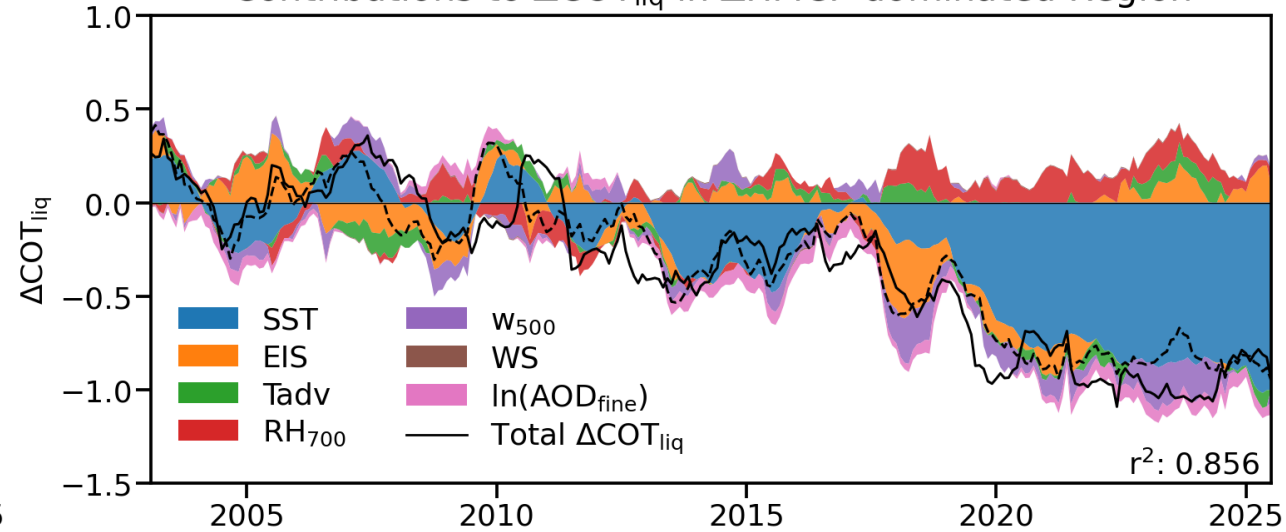
Not Detrended, Annual Means

Contributions to ΔHMCF in ΔHMCF -dominated Region



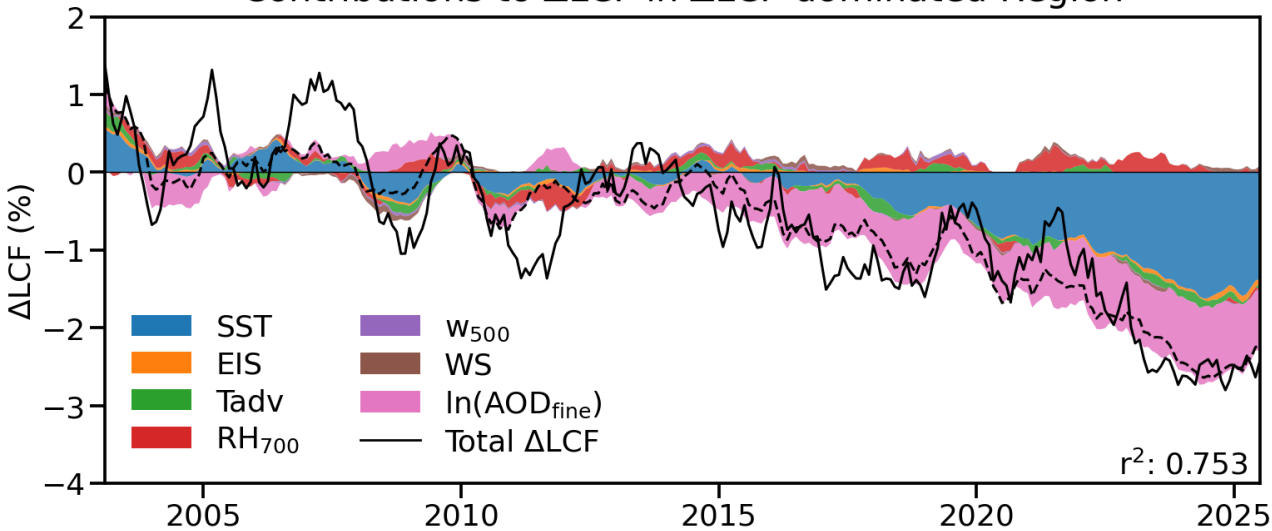
Not Detrended, Annual Means

Contributions to $\Delta\text{COT}_{\text{liq}}$ in ΔHMCF -dominated Region



Not Detrended, Annual Means

Contributions to ΔLCF in ΔLCF -dominated Region



Not Detrended, Annual Means

Contributions to $\Delta\text{COT}_{\text{liq}}$ in ΔLCF -dominated Region

