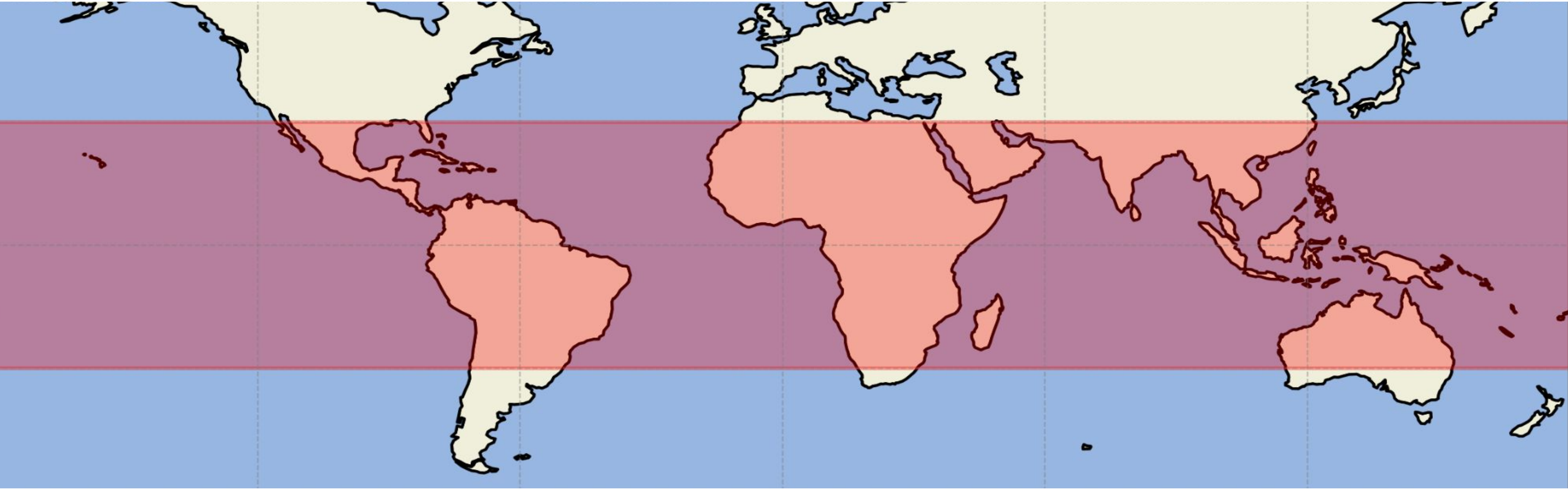
UPPER TROPOSPHERIC HUMIDITY AND CLOUD RADIATIVE FORCING: A TROPICAL PERSPECTIVE

EGU25 - 849



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INTRODUCTION

- **Clouds influence the the Earth's Energy Budget (EEB). The cloud radiative forcing (CRF) quantifies the impact of clouds on the EEB. It is calculated as the difference between actual and cloud-cleared outgoing radiant fluxes at the top of the atmosphere.**
- **CRF consists of two opposing components: longwave cloud radiative forcing (LWCRF) and shortwave cloud radiative forcing (SWCRF).**
- **LWCRF represents the warming effect caused by clouds trapping longwave radiation that would otherwise escape into space.**
- **SWCRF accounts for the cooling effect, as clouds reflect a significant portion of incoming shortwave radiation, known as the Albedo effect.**
- **The variability in relative humidity (RH) can modulate CRF by altering cloud properties, such as cloud cover and optical depth, affecting the absorption and reflection of solar and terrestrial radiation.**
- **Upper tropospheric humidity (UTH) variability impacts the amount of outgoing longwave radiation, affecting the EEB.**

MOTIVATION

- **Understanding the variability in the amount and distribution of clouds in a warming climate is essential as they modulate the shortwave and longwave cloud radiative feedbacks (Harrison et al. (1990); Bony et al. (2006) and, thereby, the Net CRF.**
- **Soden and Fu, 1995, showed that regions of increased UTH strongly correlate with enhanced greenhouse effect by trapping more outgoing longwave radiation, thereby warming the Earth's surface.**
- **Sherwood et al. (2010) studied the changes in RH in climate models and their effects on cloud patterns, which found a robust trend in RH, with variations in amplitude depending on model resolution, particularly in the subtropics and tropical regions.**
- **Bennhold and Sherwood (2008) have documented the mean biases between models and satellite data of upper-tropospheric humidity, precipitable water, and net cloud radiative forcing. They observed that UTH and PW are not strongly connected in the models as in the observations.**
- **Bony et al. (2020) showed that lower-atmospheric stability and convective clustering have complementary and equally significant impact on the radiation budget.**
- **In a recent study Sathyamoorthy (2022) found that the reduction in high-level cloud cover over the South Indian sub-region (SISB) during the peak Indian summer monsoon season leads to increased longwave radiative forcing and net radiative warming.**

DATA AND METHODOLOGY

- **This study uses the satellite Microwave and Infrared measurements of Upper Tropospheric Humidity (MWUTH and IRUTH) from NOAA and MetOp-A (Buehler et al., 2008; Buehler et al., 2007; Devika et al., 2023).**
- **Observed TOA longwave (LW) fluxes monthly means data from the Edition 4.1 CERES SYN1deg Daily data (Wielicki et al., 1996; Doelling et al., 2013; Rutan et al., 2015).**
- **NVAP-M CLIMATE Total Precipitable Water (TPW) data with 1° × 1° grid resolution globally is used in this study (Doi:10.5067/NVAP-M/NVAP_CLIMATE_ Total-Precipitable-Water_L3.001).**
- **This study focuses on the tropical region. Initially, the annual climatology of MWUTH, IRUTH, TPW and LWCRF are analysed. The joint distribution of UTH and TPW was studied with the composite projection of LW. MWUTH, IRUTH and LW data for 2000-2010 are used to reconstruct LWCRF for 2011-2021 by linear regression method. Correlation maps were constructed between the original and reconstructed LWCRF.**

RESULTS

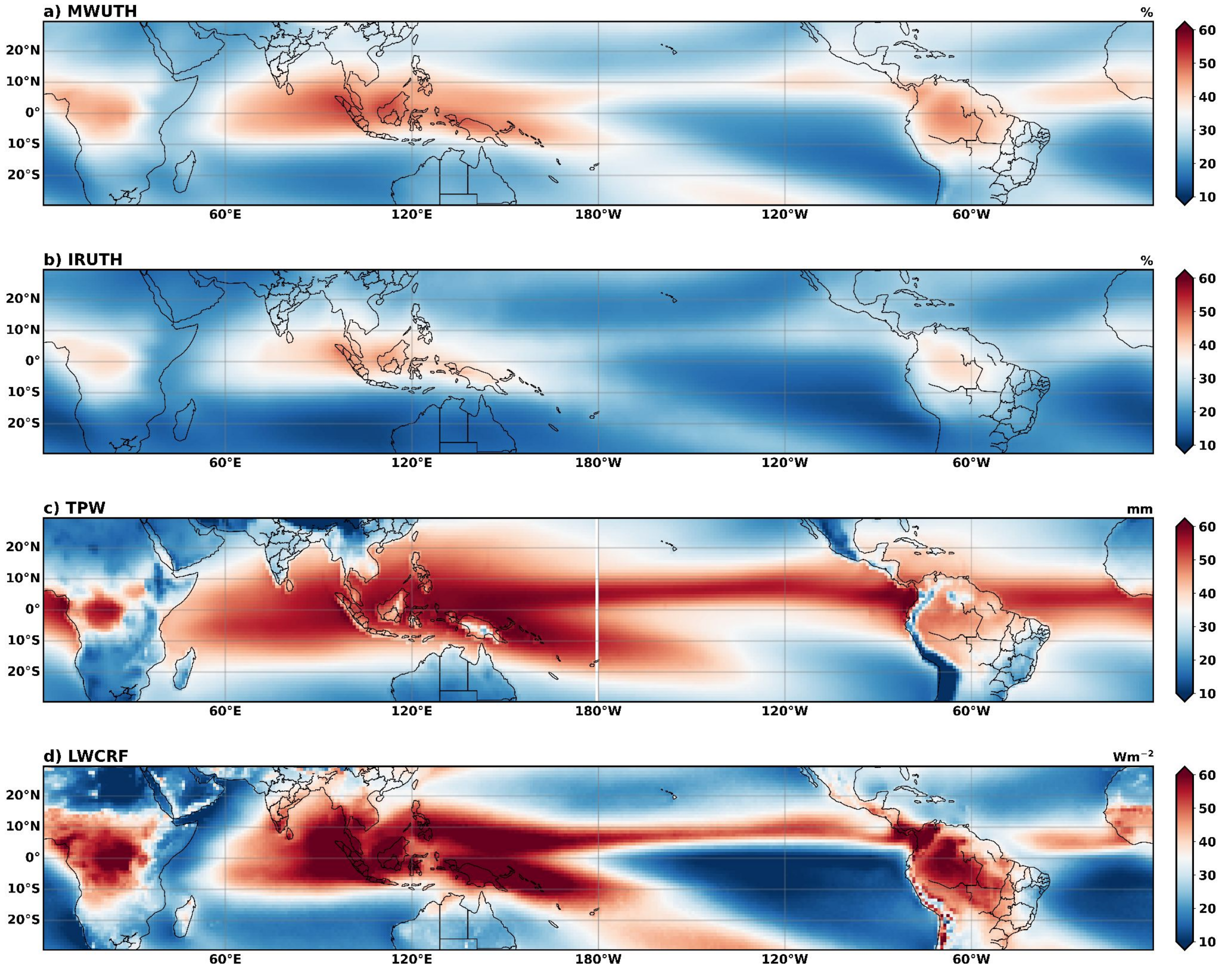

Fig 1. Annual climatology of a) MWUTH, b) IRUTH, c) TPW, and d) LWCRF for the period 2000-2021.

Annual climatology of Microwave UTH, Infrared UTH, Total Precipitable Water, and Longwave Cloud Radiative Forcing shows a similarity in distribution pattern, but with varying intensities. Hence there exist a connection between the variability of theses parameters.

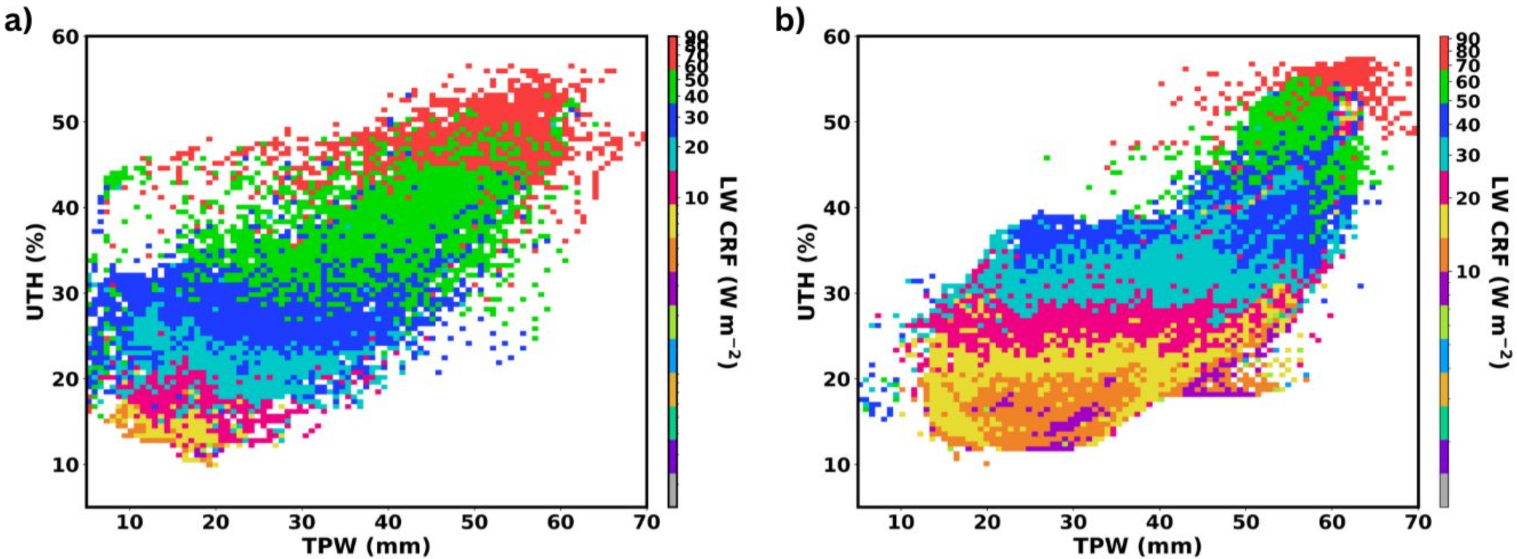

Fig 2. Joint distribution of UTH, TPW and LWCRF over the tropical land (a) and ocean (b) regions

In the joint distribution of Upper Tropospheric Humidity, Total Precipitable Water and Longwave cloud Radiative Forcing over the tropical land and ocean regions, gradients are along the vertical direction only and the pattern is mostly homogeneous along the horizontal direction. This indicates that UTH has more influence than Total Precipitable Water in the variability of Longwave cloud Radiative Forcing over the tropical land and ocean regions. Keeping this relationship in mind we tried to reconstruct Longwave cloud Radiative Forcing using Upper Tropospheric Humidity using linear regression method.

Fig 3 shows the JJAS seasonal climatology of

- a) satellite observed Longwave cloud Radiative Forcing (original LWCRF).
- b) Longwave cloud Radiative Forcing reconstructed from Microwave UTH data.
- c) Longwave cloud Radiative Forcing reconstructed from Infrared UTH data.
- d) Correlation between original LWCRF and that reconstructed from Microwave UTH data.
- e) Correlation between original LWCRF and that reconstructed from Infrared UTH data.
- The hatches represents regions with significance more than 95 percentile.
- From Fig 3.d and e, we can say that, the variability of Longwave cloud Radiative Forcing is better represented by Microwave UTH data than Infrared UTH data over the tropics.

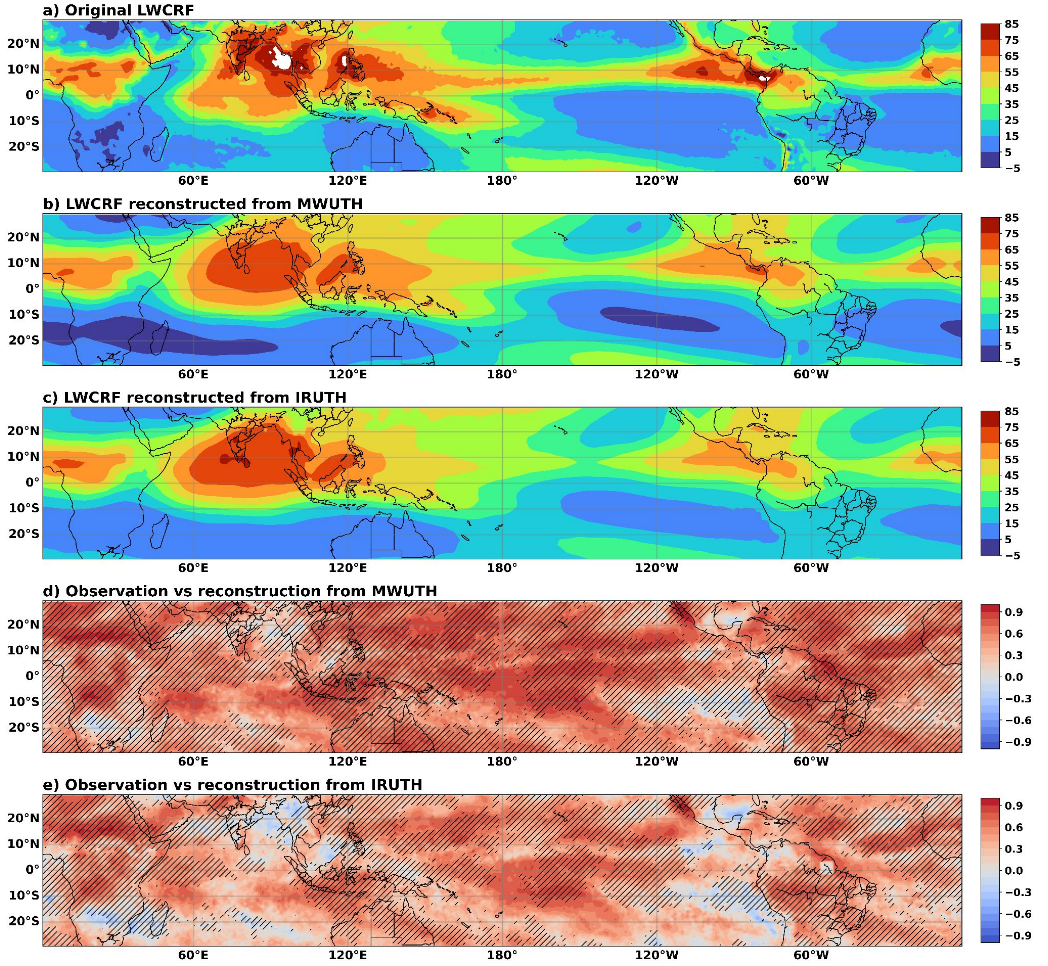

Fig 3. Seasonal climatology of original LWCRF (a), LWCRF reconstructed from MWUTH (b) and from IRUTH (c), correlation between original and reconstructed LWCRF from MWUTH (d) and IRUTH (e) for the period 2011-2021.

	Land		Ocean	
	RMSE	Correlation	RMSE	Correlation
LWCRF and $LWCRF_{MWUTH}$	6.47	0.89	6.99	0.89
LWCRF and $LWCRF_{IRUTH}$	7.36	0.86	7.88	0.86
LWCRF and $LWCRF_{TPW}$	11	0.74	13.69	0.74

Table 1. Statistics of reconstructed LWCRF over land and ocean regions.

Statistics shows that reconstruction from Microwave UTH is better than that from Infrared UTH and Total Precipitable Water. Thus, quantification also suggests that the variability of Longwave cloud Radiative Forcing is better represented by Microwave UTH than other parameters considered.

CONCLUSIONS

- **The spatial patterns of annual climatology of Microwave Upper Tropospheric Humidity (MWUTH), Infrared Upper Tropospheric Humidity (IRUTH), Total Precipitable Water (TPW), and Longwave Cloud Radiative Forcing (LWCRF) are similar with varying intensities.**

- **From the joint distribution of UTH, TPW and LWCRF, it is clear that UTH highly impacts LWCRF than TPW over land and ocean regions.**

- **LWCRF is reconstructed for the period 2011-2021 by linear regression method using the original LWCRF and UTH data for the years 2001-2010.**

- **The variability of LWCRF is better represented by MWUTH than IRUTH.**

Thank you for your attention!

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