Evaluation of Climate Fingerprinting Sounder Product (ClimFiSP) Air Temperature and H_2O Trends

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Abstract

Climate fingerprinting Sounder Product (ClimFiSP) provides gridded (0.5°x0.5°) daily skin temperature, surface emissivity, air temperature, water vapor, trace gases, and cloud properties, which derived from IR hyper-spectral radiance measured by AIRS on Aqua and CrIS on SNPP and JPSS series. In this work, the ClimFiSP daily air temperature and H_2O were retrieved on 98 pressure levels by applying the spectral fingerprint algorithm on 0.5°x0.5° gridded daily mean radiances from Climate Hyperspectral Infrared Radiance Product (CHIRP). CHIRP is a stable climate-quality radiance time series spanning AIRS and CrIS. The air temperature and H_2O monthly data and trends were calculated from the more than two decades long CHIRP AIRS data. Troposphere warming and stratosphere cooling can be seen in both ClimFiSP and ERA5 air temperature data. The ClimFiSP air temperature trends are also compared with the MW sounding air temperature trends to validate the ClimFiSP air temperature results. The H_2O trends on upper troposphere are evaluated by comparing with the ERA5 H_2O trends, and results show a reasonable agreement with two sets of results. The ClimFiSP algorithm provides a unique and fast way to retrieve the spatial-temporal change in climate variables from the corresponding change in radiances, gridded at the same spatial-temporal scale. This greatly facilitates the procession of long-term climate data records.

ClimFiSP Algorithm

$\Delta R = S\Delta X + \varepsilon$

$\Delta X = (S^T\Sigma^{-1}S + \sum_a^{-1})^{-1} S^T\Sigma^{-1}\Delta R$

ΔR - climate spectral radiance anomaly

ΔX - anomaly of climate variables

S - spectral fingerprinting kernel

ε - fingerprinting nonlinearity error term

$\Delta R = R - R_{ref}$ $\quad\quad$ $\Delta X = X - X_{ref}$

R_{ref} and X_{ref} are preconstructed spectral radiance observations and corresponding climate variables of representative states at specified space-time grid (e.g. daily average, 0.5 ° × 0.5 °).

Error Estimation :

$\Sigma_X = (S^T\Sigma^{-1}S + \Sigma_a^{-1})^{-1}$

Σ and Σ_a are error covariance terms for ΔR, and ΔX

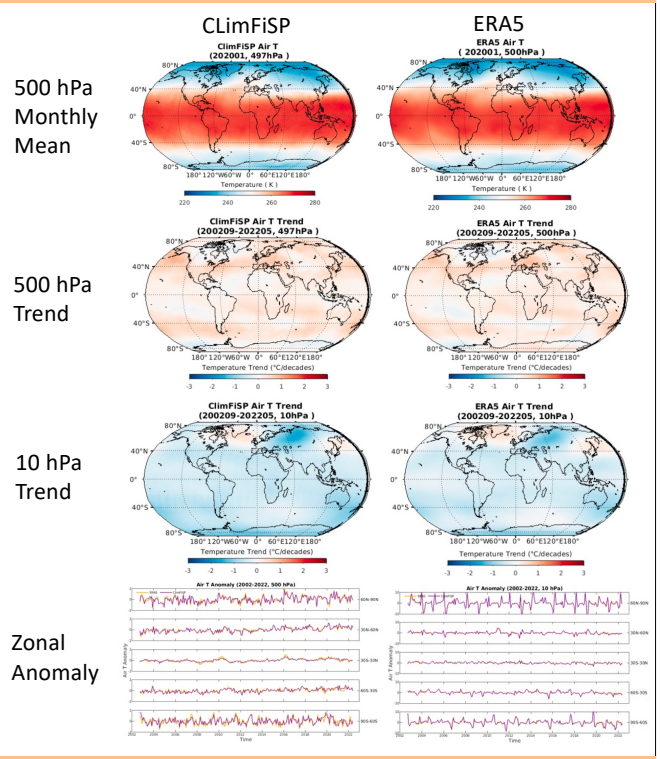
Advantage of ClimFiSP algorithm:

- Derive long-term atmospheric temperature and water vapor anomalies from hyperspectral infrared sounders
- Constructing radiometrically consistent radiative kernels
- Principal component based radiative transfer model (PCRTM) was used to perform multiple scattering calculations of clouds
- Using PCRTM-based physical retrieval algorithm to derive radiometrically consistent radiative kernels from real satellite observations
- Rigorous radiometric fitting to satellite-observed radiances under all-sky conditions
- Solution is directly obtained via an inverse relationship between the atmospheric anomalies and the corresponding spatiotemporally averaged radiance anomalies
- Computationally efficient than the traditional way of producing climate data records because no needs to perform Level 2 retrievals on each individual satellite footprint

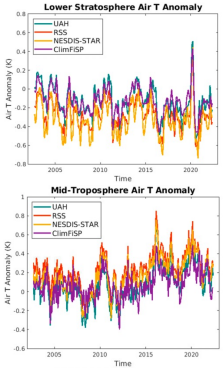
Datasets Used in This Work

- ClimFiSP: skin temperature, surface emissivity, air temperature, H_2O, O_3, CO, and cloud properties on 0.5°x 0.5° grid and 98 pressure level
- ClimFiSP: 2002 to 2022 descending air temperature and specific humidity data was used in this work
- ERA5: 2002 to 2022 air temperature and H_2O data (0.25 ° x 0.25 °)
- Microwave Sounding Units (MSU): Lower Stratosphere (LS) and Mid-Troposphere (MT) air temperature

ClimFiSP Air Temperature Trends



ClimFiSP and MSU Air Temperature Anomaly and Trend



ClimFiSP global air temperature anomaly was calculated for 98 levels and integrated by applying standard atmosphere weighting function for MSU channel for lower stratosphere to get the global lower stratosphere air temperature anomaly results.

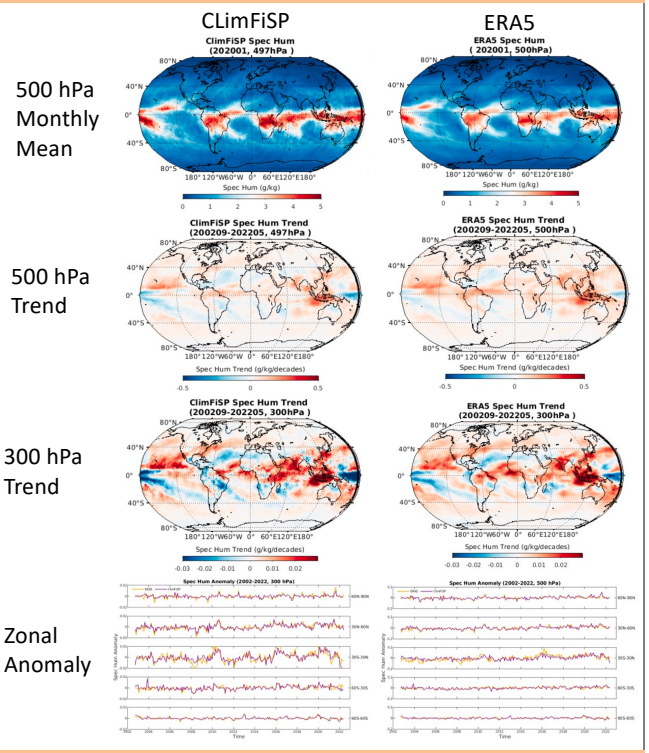
ClimFiSP global air temperature anomaly was calculated for 98 levels for land and ocean. The calculated 98 levels air temperature anomalies were integrated by applying standard atmosphere weighting function for MSU channel for mid-troposphere land/ocean to get a combined mid-troposphere air temperature anomaly.

Trend	ClimFiSP	UAH	RSS	NESDIS STAR
LS	-0.053/decade	-0.080/decade	-0.046/decade	-0.031/decade
MT	0.102 /decade	0.169/decade	0.149/decade	0.0176/decade

* UAH/RSSNESDIS-STAR data: https://www.ncei.noaa.gov/access/monitoring/msu/overview

* Weighting function data: https://data.remss.com/msu/weighting_functions/

ClimFiSP H_2O Trends



Conclusion

- ClimFiSP and ERA5 air temperature trend matches very well for both 497 hPa and 10 hP
- ClimFiSP and ERA5 air temperature zonal anomaly matches very well for both 497 hPa and 10 hPa in five zone
- ClimFiSP air temperature anomaly in LS catches most variation in MSU UAH global LS air temperature anomaly between 2002 to 2022
- ClimFiSP MT air temperature trend is smaller than the MSU UAH/RSS/ NESDIS STAR MT trend
- ClimFiSP H_2O trends on upper troposphere show a reasonable agreement with ERA5 H_2O trend
- ClimFiSP and ERA5 zonal specific humidity anomaly agrees very well in most latitude zone except the tropical region
- The ClimFiSP algorithm provides a unique and fast way to retrieve the spatial-temporal change in climate.

Reference

Wu, W., Liu, X., Yang, Q., Zhou, D. K., & Larar, A. M. (2020). Radiometrically consistent climate fingerprinting using CrIS and AIRS hyperspectral observations. *Remote Sensing*, *12*(8), 1291.