Deriving a Suite of Climate Data Records from 21-years of Sounder Observations

Xu Liu

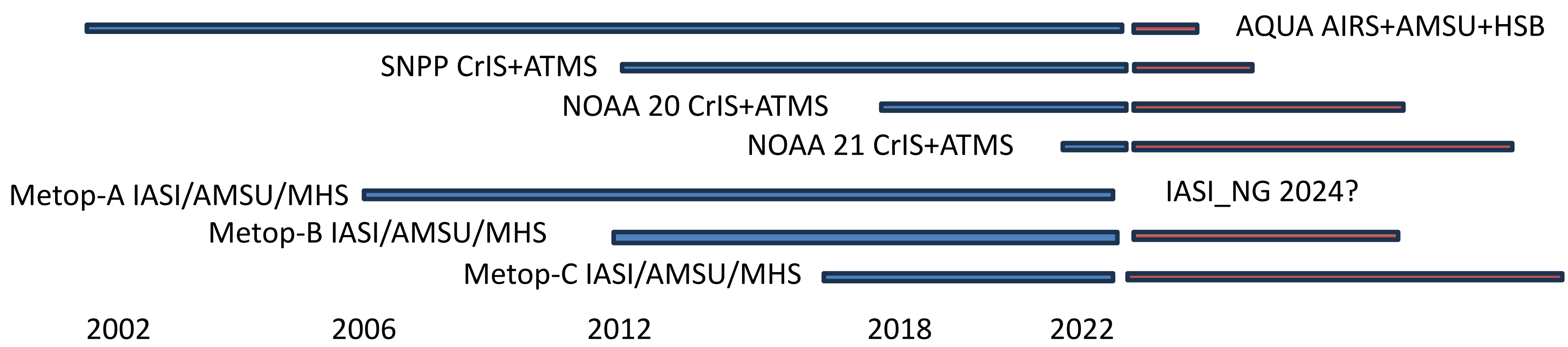
[1]W. Wu, [1]L. Lei, [1]X. Xiong, [1]Q. Yang, [2]Q. Yue, [1]D. K. Zhou, [1]A. L. Larar, [3]L. Strow, [4]P. Yang, [5]L. Zhou et. al.

[1] NASA Langley Research Center, Hampton, VA, USA
[2] Jet Propulsion Laboratory, California Institute of Technology, CA, USA
[3] Department of Physics, UMBC, MD, USA
[4] Texas A&M University, College Station, TX, USA
[5] NOAA STAR andJPSS Office, MD, USA

Acknowledgement for NASA funding, Sounder SIPS, and computer supports

Introduction

- Hyperspectral IR sounders provide high quality observations on
  - Atmospheric temperature, water vapor and trace gas vertical profiles
  - Cloud and aerosol properties
  - Surface properties (temperature, emissivity, reflectivity …)

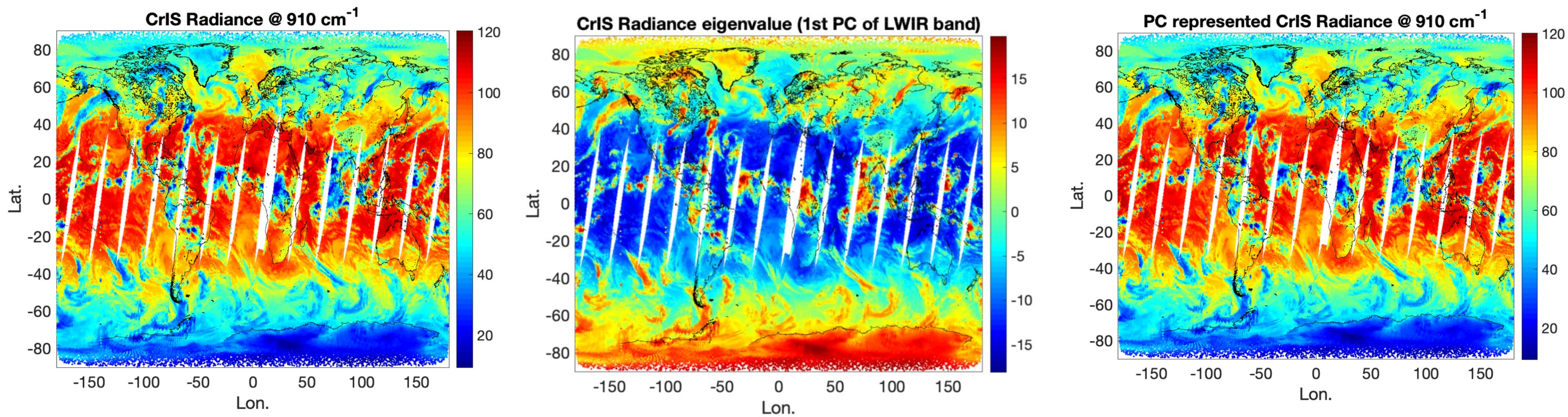


- Challenges in producing Climate Data Records (CDRs) from all these IR sounders
  - L2 algorithms may be different for all these sounders which may introduce algorithm-related errors in deriving long-term trend or time series
  - Time consuming to process or re-process 20-years CDR from these IR sounders
- Climate Fingerprinting Sounder Product (ClimFiSP) is a L3 algorithm developed at NASA Langley is designed to address these challenges

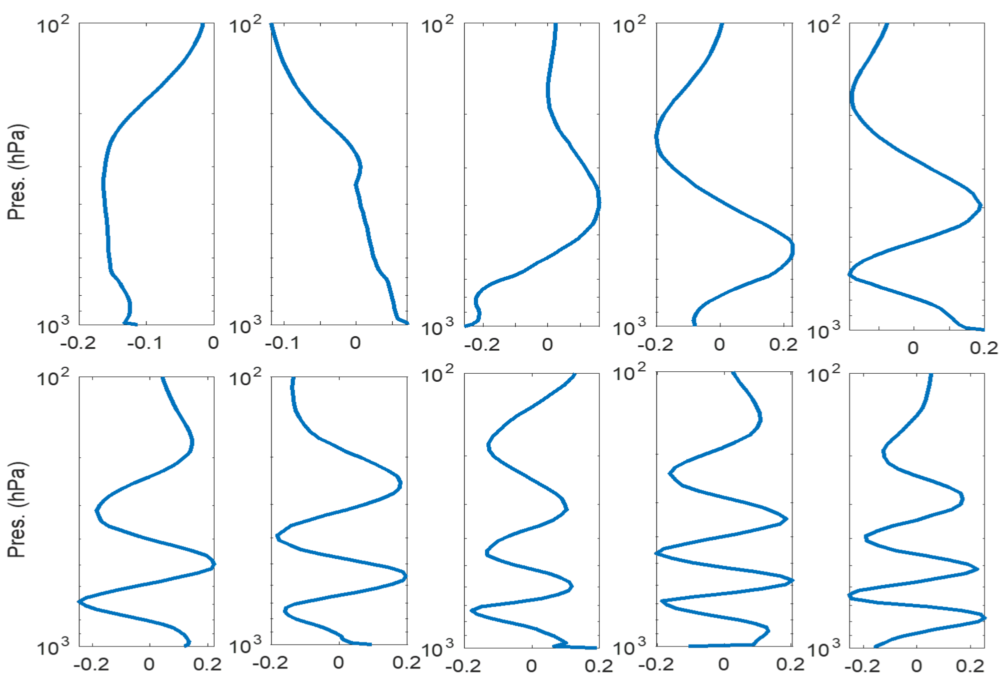
Special Features of the ClimFiSP Algorithm

- ClimFiSP performs spectral fingerprinting retrievals on gridded L1 directly
  - 3-4 orders of magnitude faster than L1-L2-L2 approach
  - Uses consistent radiative kernels for all IR sounders
  - Fit all-sky cloudy radiance spectra directly to ensure radiometric closure
  - All sounder spectral channels (thousands) used in ClimFiSP L3 algorithm
- Principal Component-based Radiative Transfer Model (PCRTM) is used to
  - Compress thousands of hyperspectral channels into less than 200 Principal Components (PCs)
  - Capture all information content of the hyperspectral sounders
- Retrieved atmospheric and surface properties are compressed into PC-domain
  - Reduce the ill-condition of the inversion
  - Efficiently keep error covariance and averaging kernels into smaller dimension
- Radiative Kernels derived from a Single Field-of-view Sounding Atmospheric Product (SiFSAP) (Liu et al. 2009, Wan et al. 2020, 2023, Xiong et al. 2022, 2023)
  - PCRTM-based all-sky retrievals (radiance closure)
  - Uses all spectral channels
- Supported by NASA NNH17ZDA001N-TASNPP and NNH20ZDA001N-SNPPSP
  - Consistent climate products from AIRS, SNPP CrIS, and NOAA20 CrIS
  - Harvest decades of hyperspectral sounder measurements for climate studies
  - Soon will be available at NASA GES DISC for public access

PC-compression of both Radiance Spectra and State Vector



Example of PCs representing H2O vertical profiles

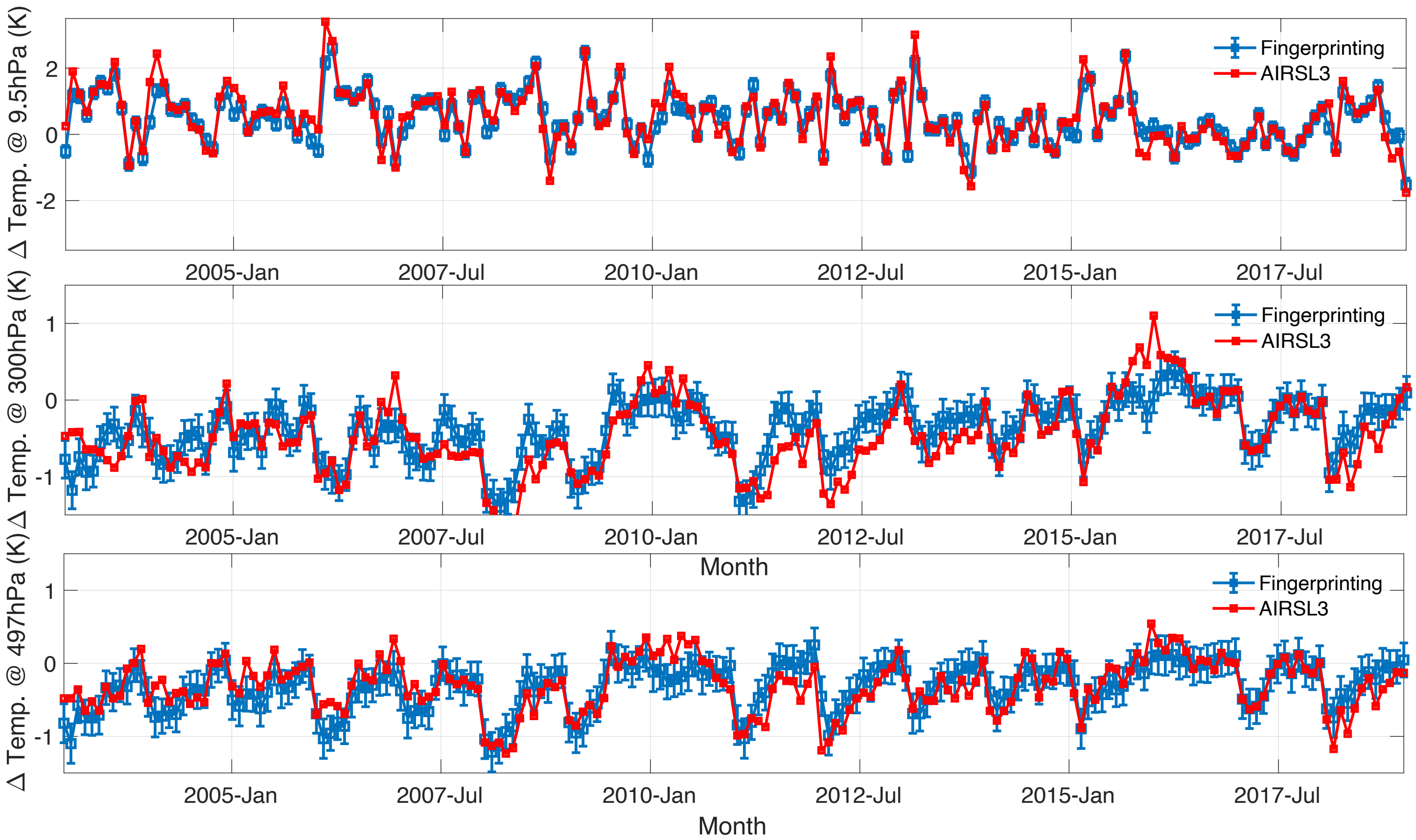


Satellite Sensors	Original Dim	PC-compressed Dim
CrIS	2211	124
AIRS	2378	120
IASI	8461	190

Geophysical Parameters	Original Dimension	PC-compressed Dimension
Temperature	101	20
H2O	101	15
CO2	101	1
O3	101	10
CO	101	4
CH4	101	2
N2O	101	2
IR Surface Emissivity	Hundreds - thousands	8
MW Surface Emissivity	15-22	5

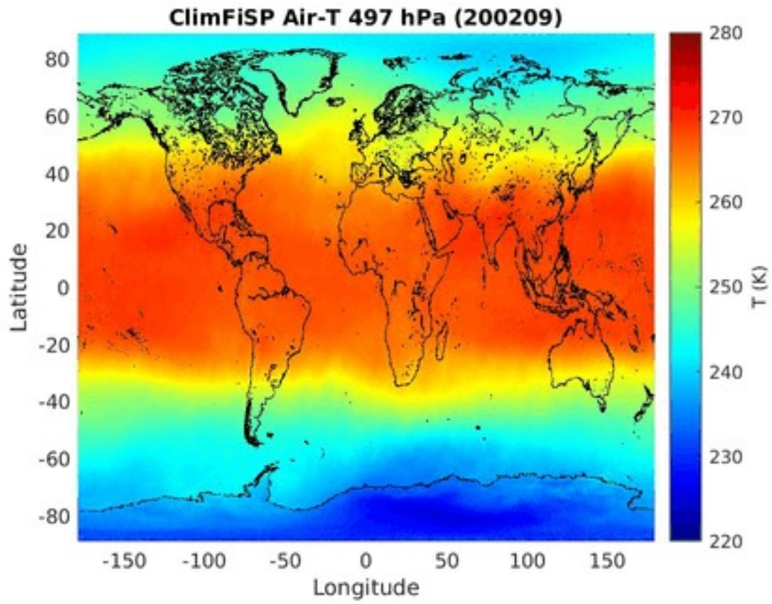
Examples of ClimFiSP Product Published in 2020

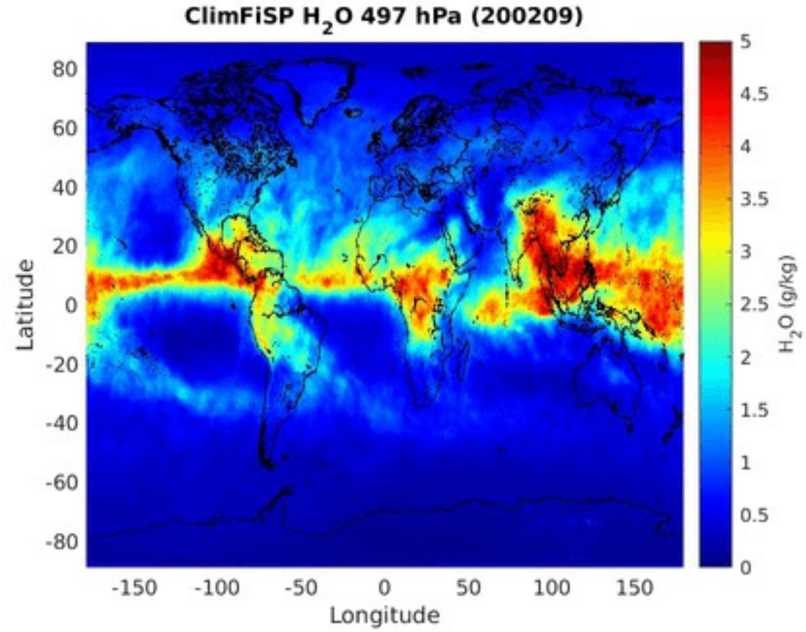
- ClimFiSP enables of the fusion of AIRS and CrIS data into a consistent temperature anomalies at different atmospheric pressure levels
- ClimFiSP and AIRS L3 temperature anomalies from 2003 to 2018 show general agreement

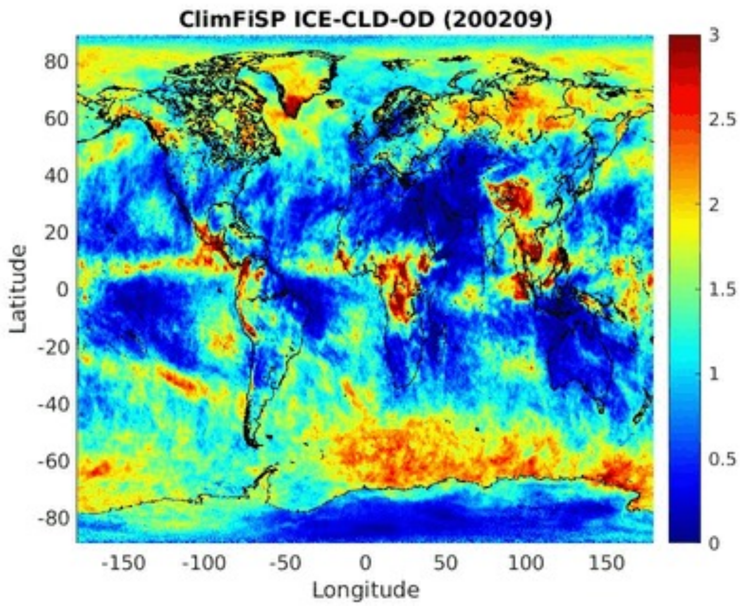


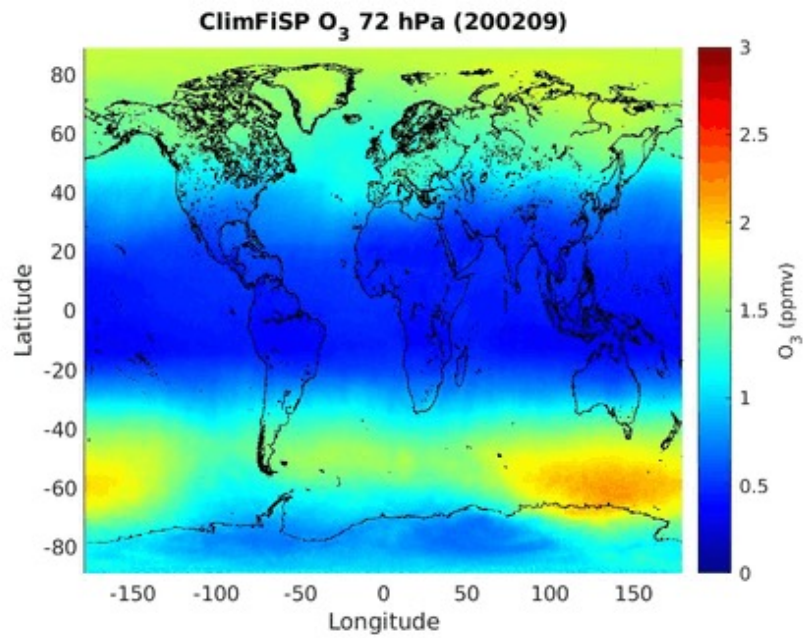
Wu et. al. (2020) "Radiometrically Consistent Climate Fingerprinting Using CrIS and AIRS Hyperspectral Observations" Remote Sensing. https://doi.org/10.3390/rs12081291

Examples of Temporal and Spatial Variations of ClimFiSP









ClimFiSP Surface Temperature from AIRS and CrIS (SNPP/NOAA20) Sep. 2002 – June 2022

Zonally Surface Temperature Anomalies

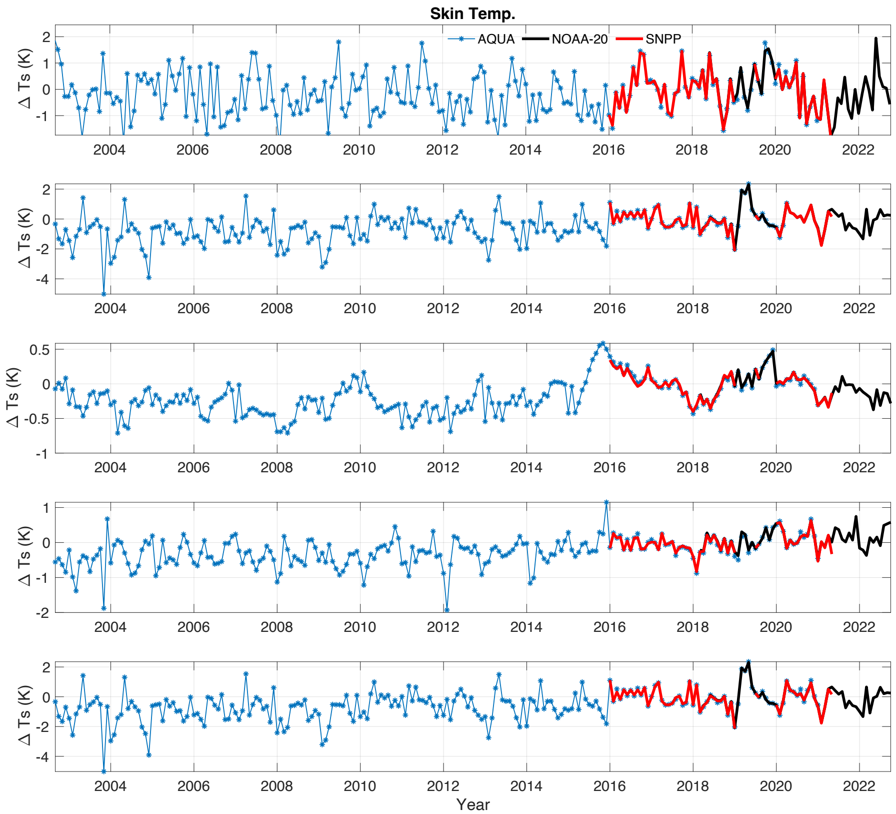
(-60º – -90º)

(-60º – -30º)

(-30º – 30º)

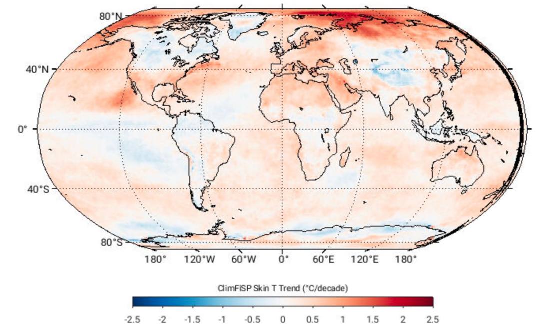
(30º – 60º)

(-90º – -60º)

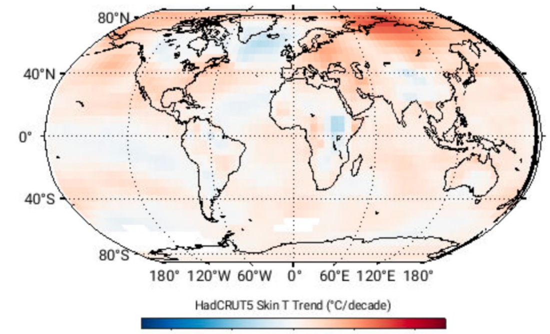


PCRTM-based SiFSAP and ClimFiSP sounder products will be generated at NASA GES DISC for public access

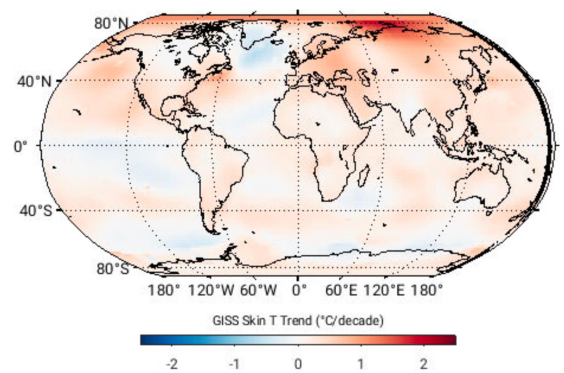
Surface Temperature Warming Trend



ClimFiSP

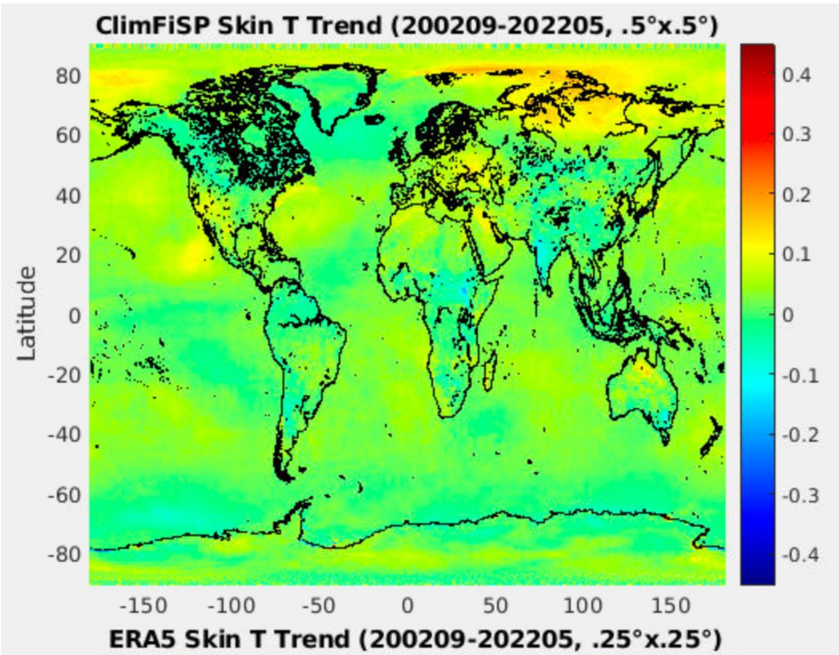


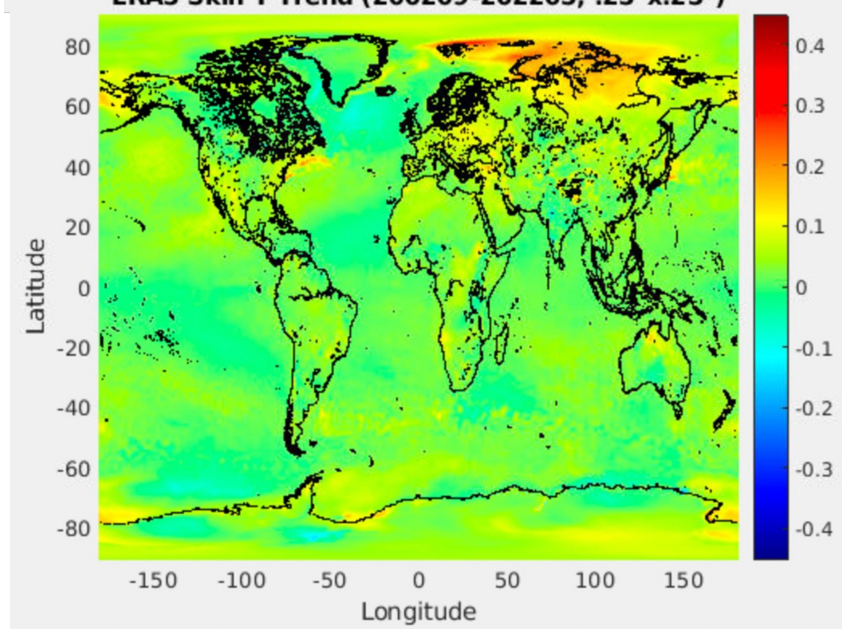
HadCRUT5

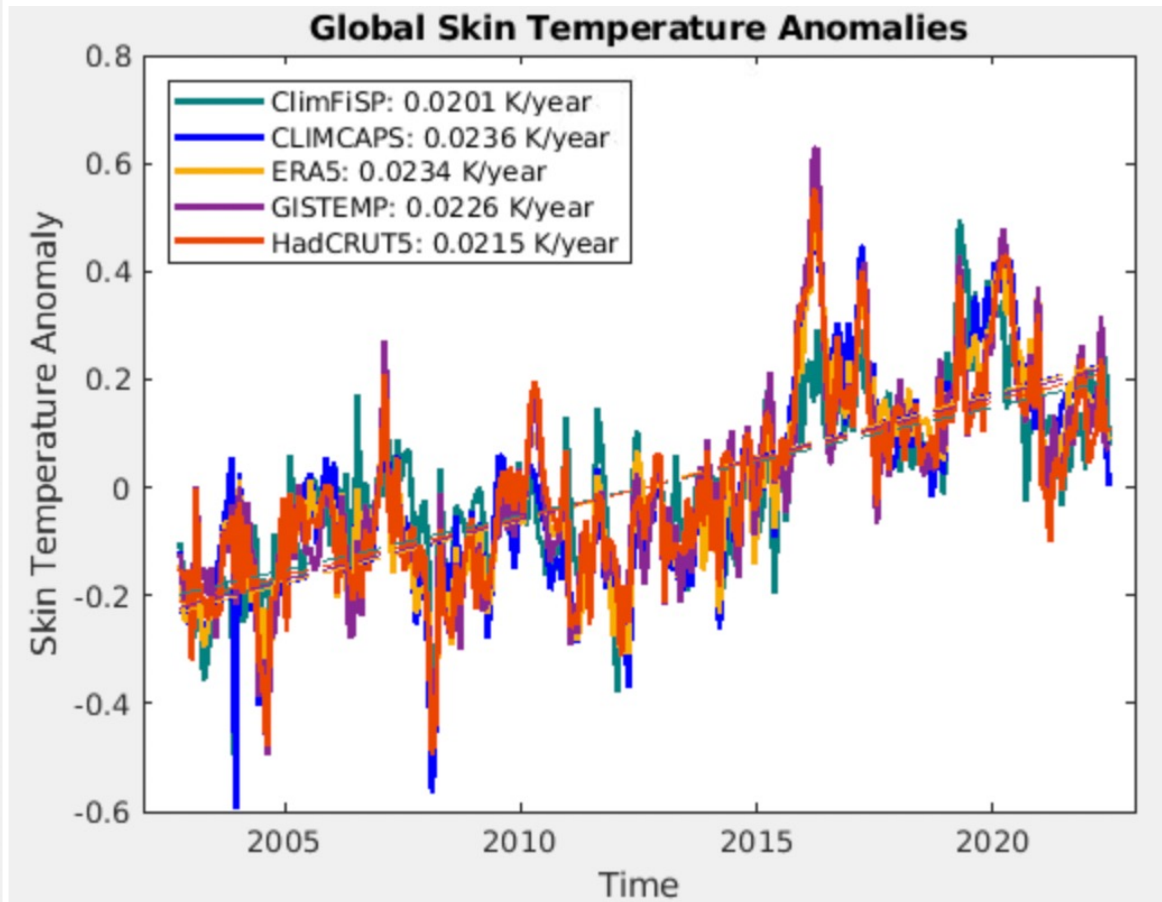


GISS

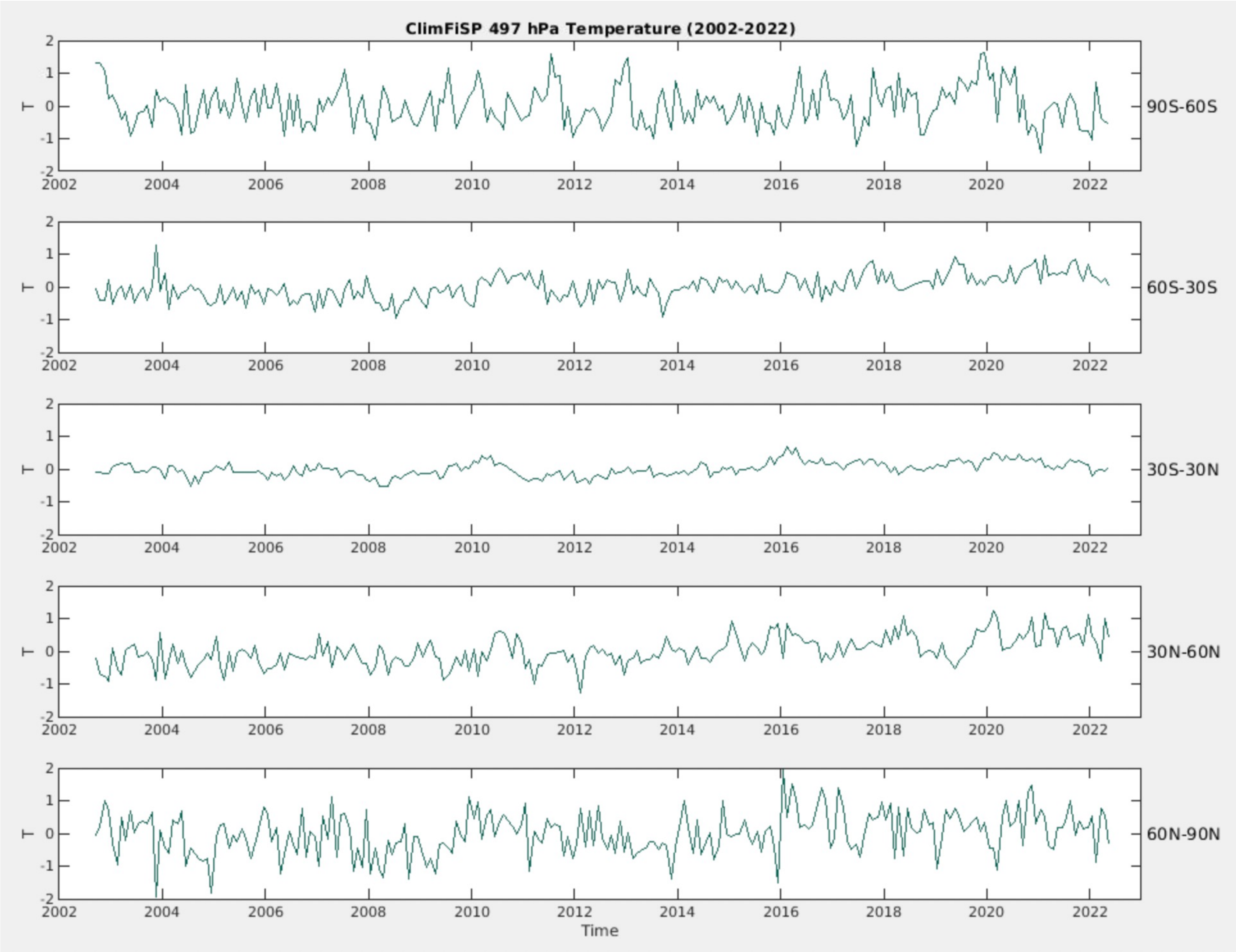
Surface Temperature Trends Comparisons



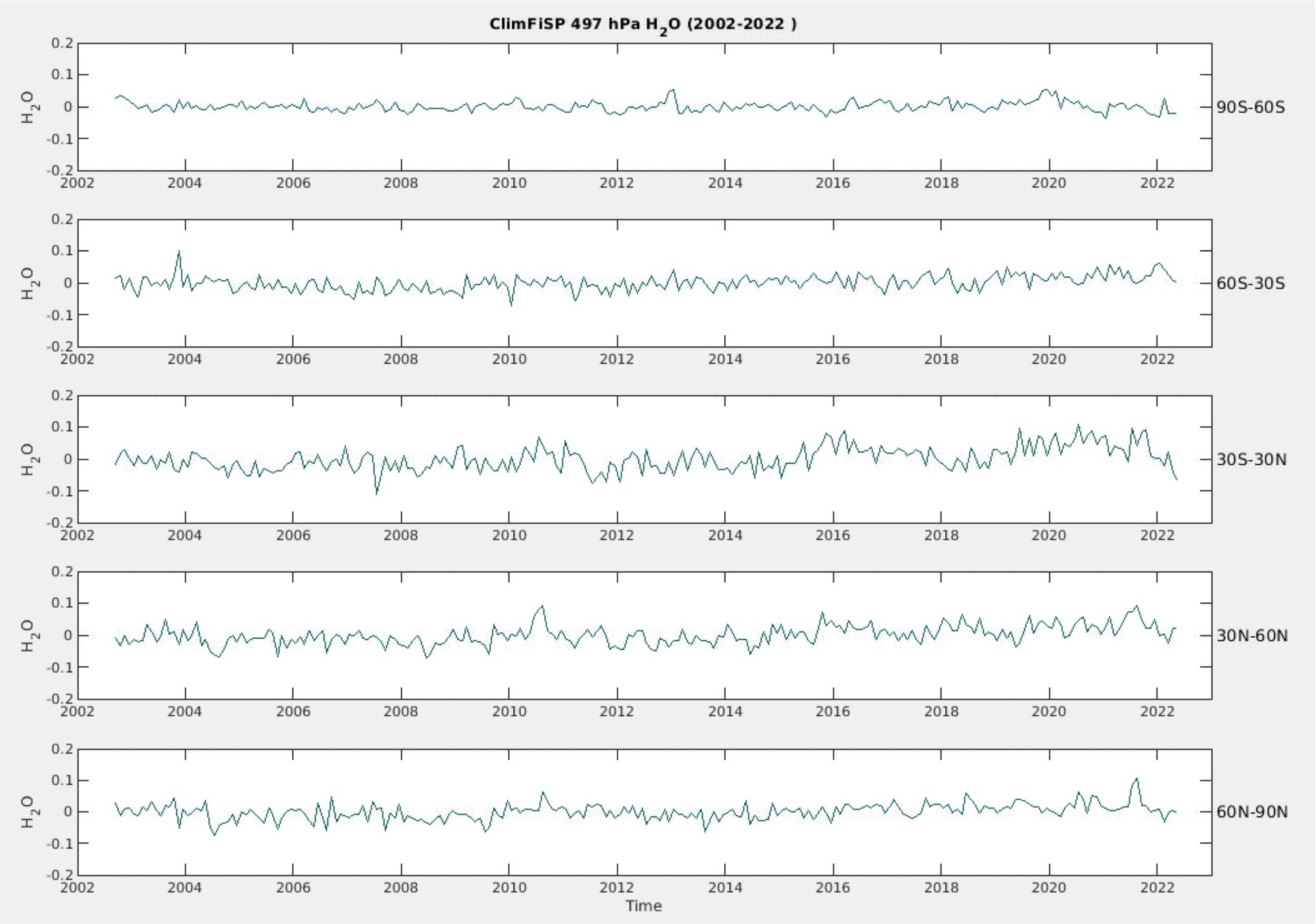




ClimFiSP Zonal Temperature Anomaly at 500 hPa

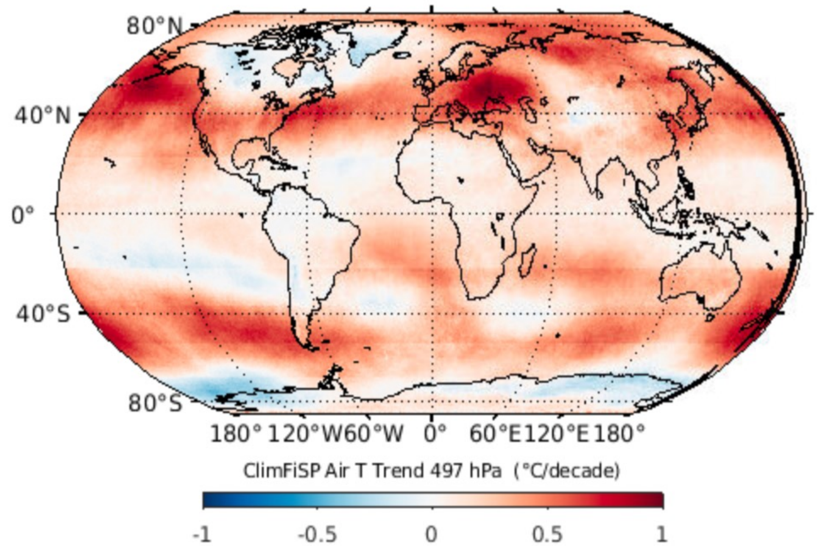


ClimFiSP Zonal H_2O Anomaly at 497 hPa

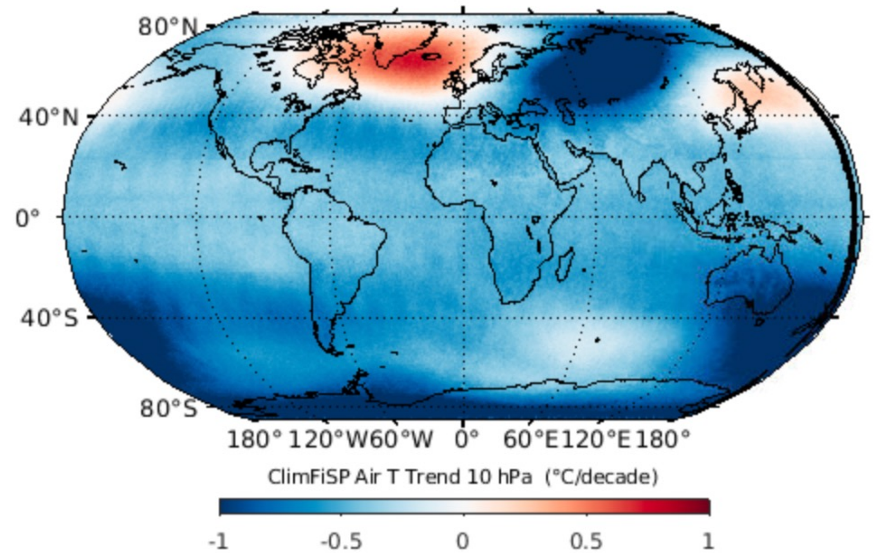


Atmospheric Temperature and Water Vapor Trends (September 2002 to June 2022)

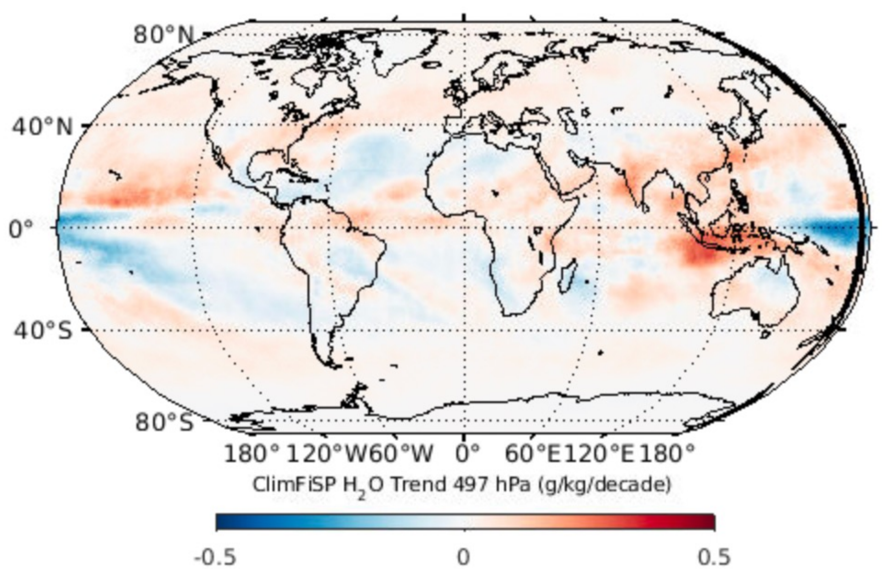
Tropospheric warming (500 hPa)



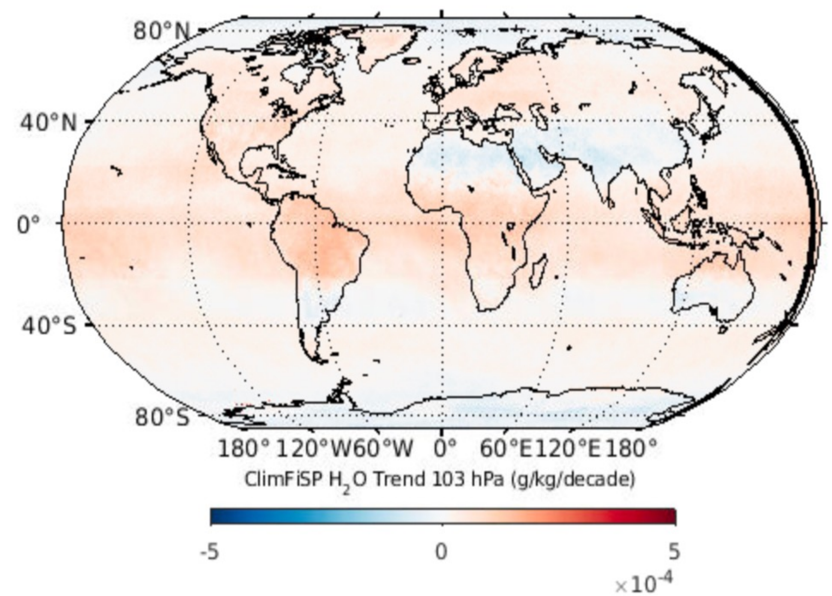
Stratospheric cooling (10 hPa)



Water Vapor Trend at 500 hPa



Water Vapor Trend at 100 hPa



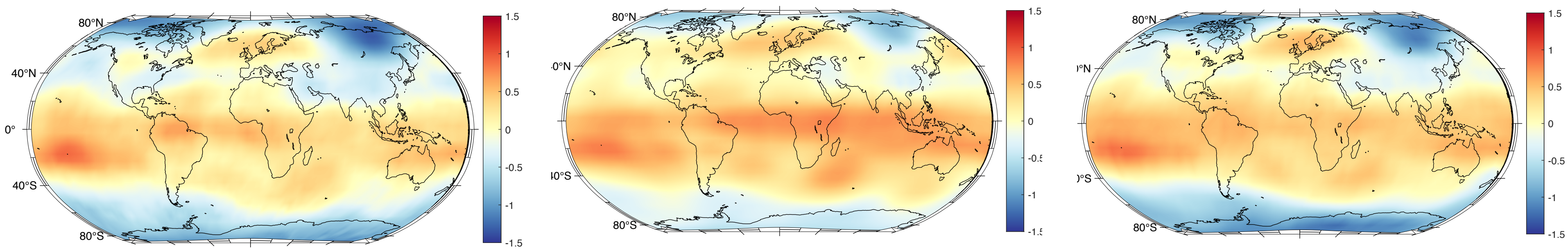
ClimFiSP air temperature trends (K/decade) Sep. 2002 – June 2022 AIRS

CLIMCAPS (L1->L2->L3) cloud clearing

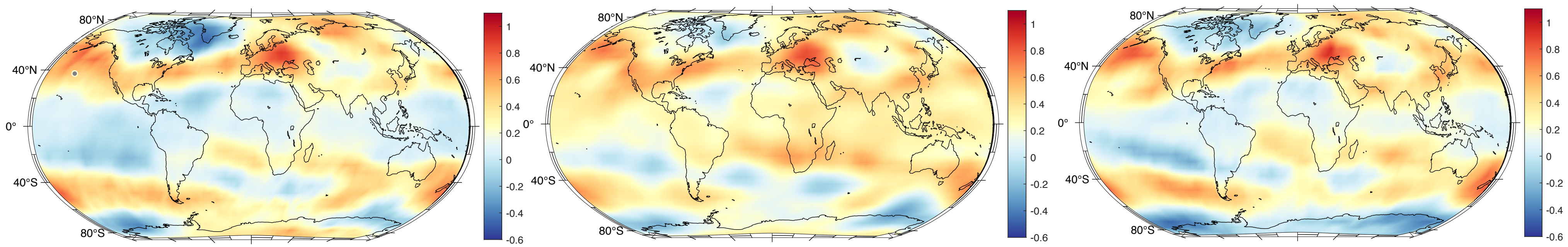
ERA5

ClimFiSP L1-> L3

70 hPa

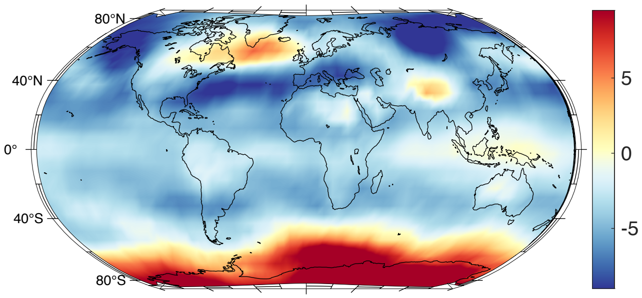


400 hPa

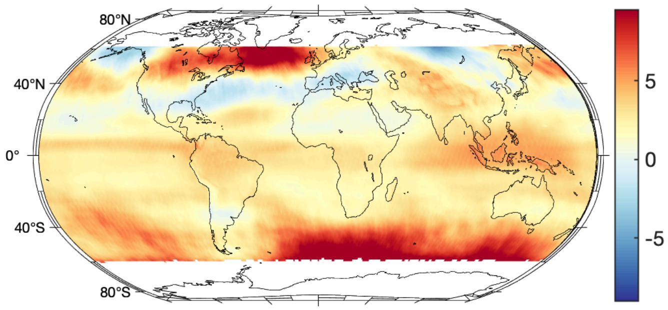


More Examples of ClimFiSP Trends (Total Ozone and Cloud Optical Depth)

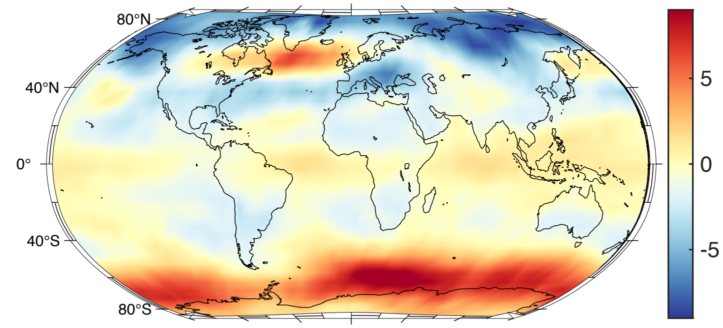
CLIMCAPS (L1->L2->L3) cloud clearing



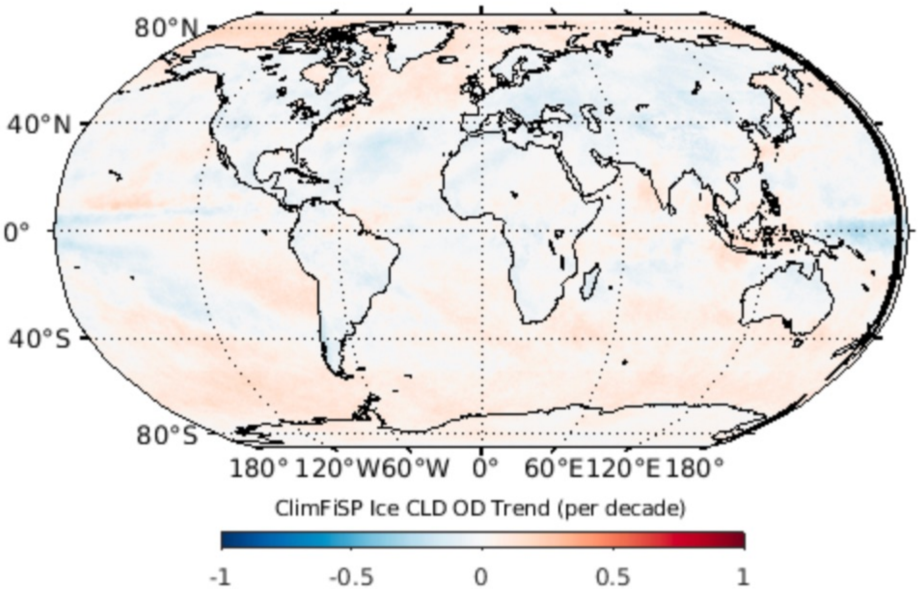
OMI (DU/decade)
Oct. 2004 –Dec. 2020)



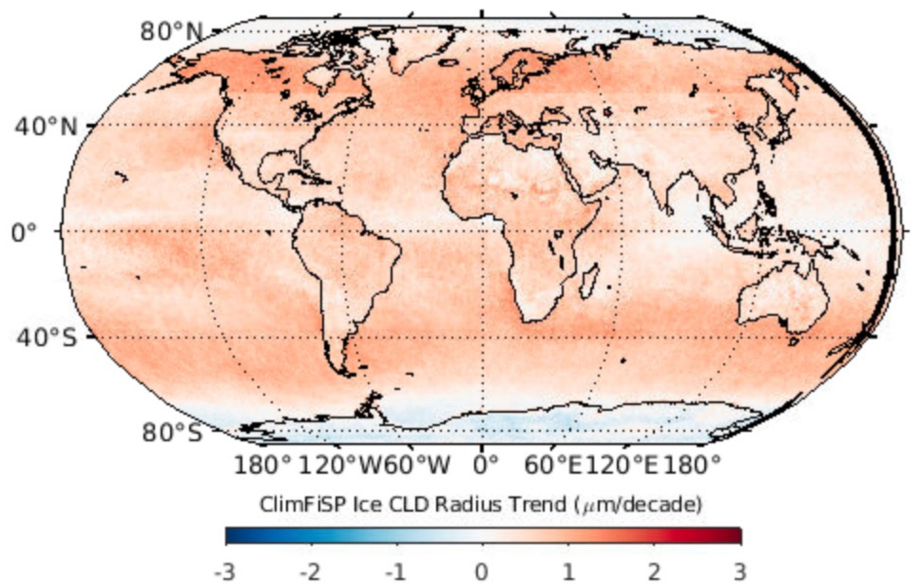
ClimFiSP L1-> L3



ClimFiSP Ice Cloud Optical Depth Trend
(Sept. 2002-June 2022)



ClimFiSP Ice Cloud Effective Radius Trend



Summary and Conclusions

- Consistent CDRs from 20-years of IR hyperspectral Sounders has been derived using NASA Langley's ClimFiSP L1-L3 algorithm
  - Temperature, water vapor, and trace gas atmospheric profiles
  - Cloud temperature, pressure, optical depth, phase, and effective size
  - Surface skin temperature and surface emissivity spectra
- The advantages of ClimFiSP (L3) include
  - Observation-based radiative kernels derived from our PCRTM-based L2 algorithm SiFSAP
  - 3-4 orders of magnitude faster than traditional L1-L2-L3 algorithms
  - Consistent CDRs using the same radiative kernels for all IR sounders
  - Radiance closure by fitting observed radiance spectra (all channels)directly
- SiFSAP (L2) products are being produced at NASA GES DICS
  - Available to public soon
- ClimFiSP product will be delivered to NASA SIPS and GES DISC
  - Aqua AIRS, SNPP and NOAA-20 ClimFiSP will be available soon
  - Will continue to process NOAA-21 CrIS and future JPSS IR sounder data
  - ClimFiSP Algorithm can also be applied to Metop IASI data