Deriving High-quality Climate Data Records from Two Decades of Satellite Hyperspectral Remote Sensors

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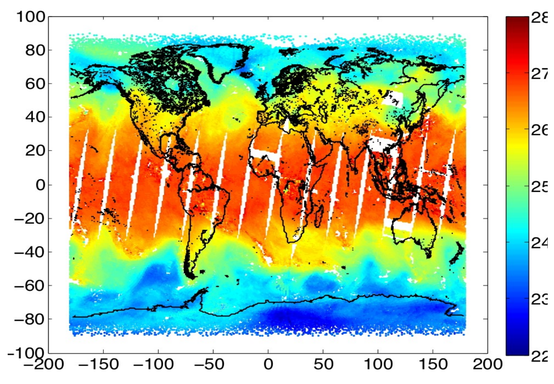
Introduction

- Modern hyperspectral satellite remote sensors provide wealth of information on atmospheric and surface properties
- Two retrieval algorithms have been developed at NASA Langley
  - ***Single Field-of-view Sounder Atmospheric Product (SiFSAP):*** a Level 2 (L2) algorithm and product that can be used for weather, dynamics, and climate studies
  - ***Climate Fingerprinting Sounder Products (ClimFiSP):*** a Level-3 (L3) algorithm and product which can generate high-accuracy climate trends, anomalies etc
- Both products will be available at NASA data center for public access

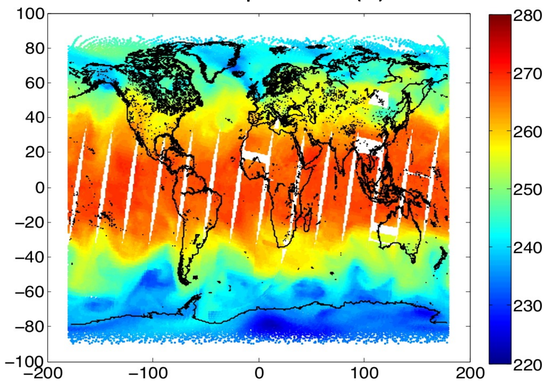
SiFSAP Algorithm and Examples of SiFSAP Products

- Key Components:
  - ➢Performs retrieval for each FOV with the presence of clouds
  - ➢High-quality product by ensuring radiometric closure
  - ➢non-linear optimal estimation physical retrieval algorithm
  - ➢9 times high spatial resolution than current operational CrIS and AIRS products
  - ➢Uses all spectral information instead of selecting only a few hundred channels
  - ➢Fitting observed radiance spectra directly instead of cloud-cleared radiances
- SiFSAP Products:
  - ➢Vertical Profiles of T, H_2O, and trace gases (CO_2, O_3, CO, CH_4, N_2O)
  - ➢Cloud (phase, height, cloud top pressure, particle size, optical depth)
  - ➢Surface temperature and emissivity
  - ➢Averaging kernels and radiative kernels

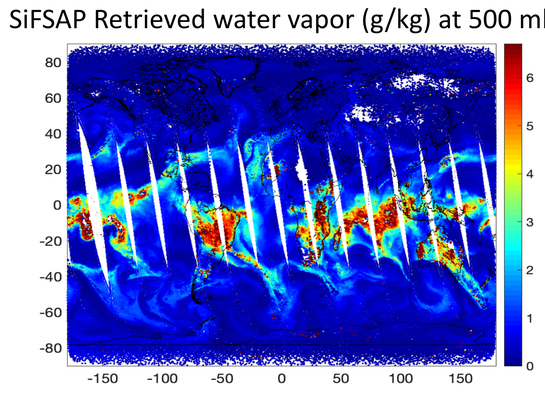
SiFSAP Retrieved Temperature (K) at 500 mb



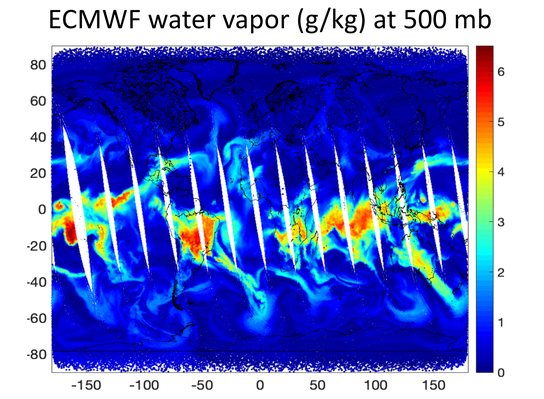
ECMWF Temperature (K) at 500 mb



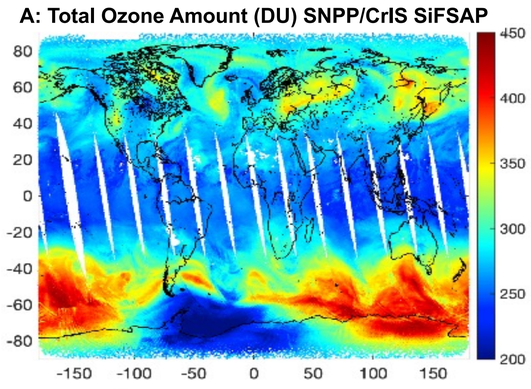
SiFSAP Retrieved water vapor (g/kg) at 500 mb



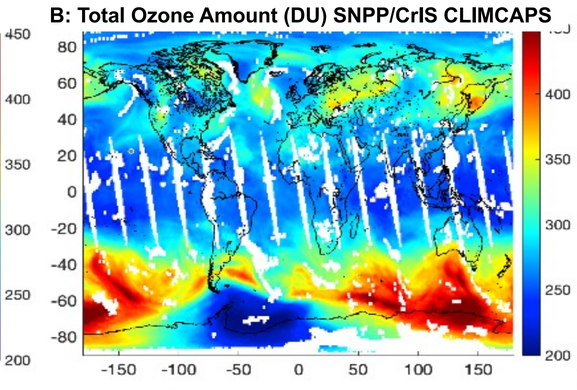
ECMWF water vapor (g/kg) at 500 mb



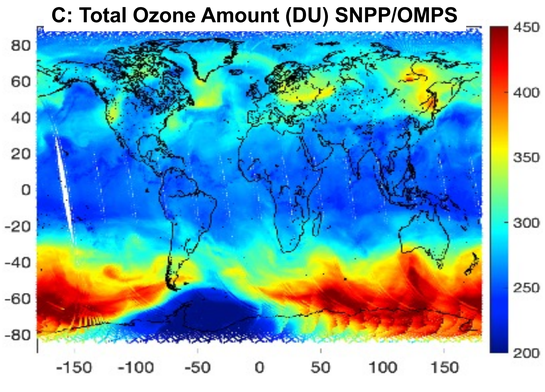
A: Total Ozone Amount (DU) SNPP/CrIS SiFSAP



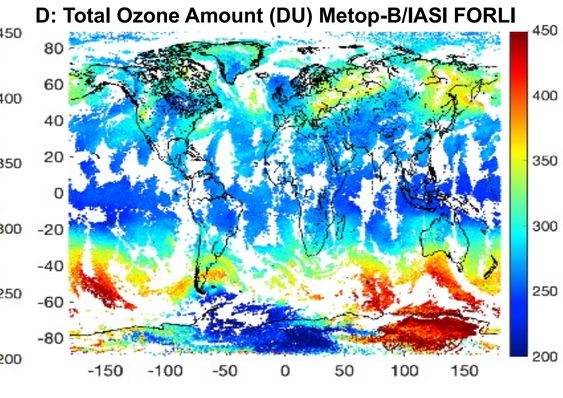
B: Total Ozone Amount (DU) SNPP/CrIS CLIMCAPS



C: Total Ozone Amount (DU) SNPP/OMPS



D: Total Ozone Amount (DU) Metop-B/IASI FORLI

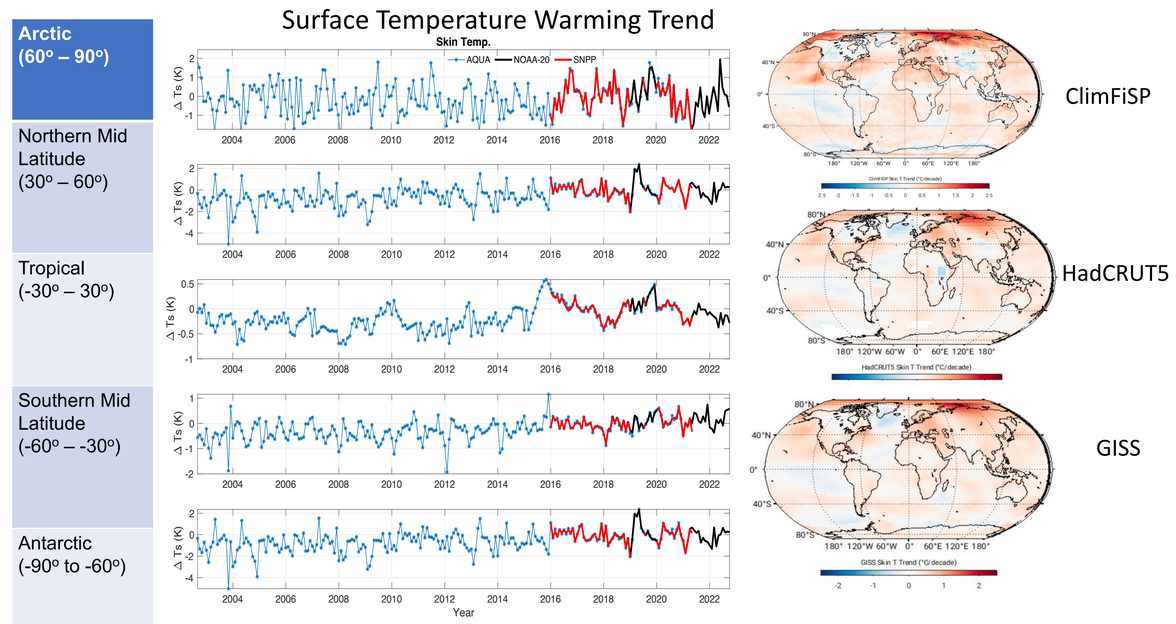


O3 total column amount retrieved from satellite-based observations on September 20th, 2019 (A – SNPP/CrIS SiFSAP; B – SNPP/CrIS CLIMCAPS; C – SNNP-OMPS; D – Metop-B/IASI FORLI).

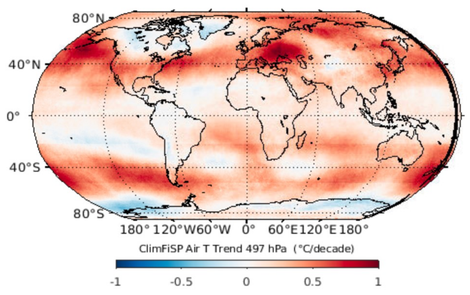
ClimFiSP Algorithm and Examples of ClimFiSP Products

- Issues with traditional L1-L2-L3 climate products
  - ➢L2 algorithm inconsistency for different satellite sensors
  - ➢Lack of radiance closure (e.g cloud-clearing method)
  - ➢L1-L2-L3 algorithm is computational demanding
- ClimFiSP is designed to address the above-mentioned deficiencies
  - ➢Works on gridded L1 products directly using consistent radiative kernels
  - ➢All parameters including clouds retrieved simultaneously
  - ➢More than 5 orders of magnitude faster than traditional L1-L2-L3 method
  - ➢Quick re-generation of climate products when instrument is re-calibrated or L1 algorithm is improved
- ClimFiSP
  - ➢21 years of consistent climate products from AIRS, SNPP CrIS, and JPSS CrIS
  - ➢Harvest decades of hyperspectral sounder measurements for climate studies
  - ➢Provides products attractive to wide range of users

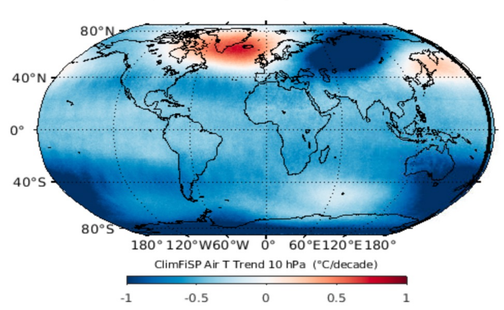
Surface Temperature Warming Trend



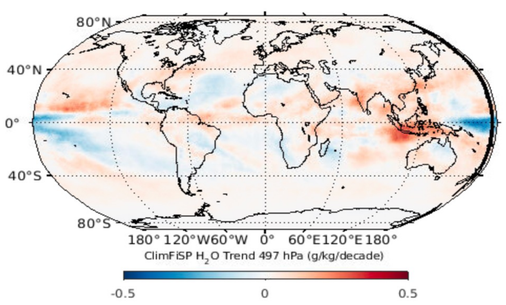
Tropospheric warming (500 hPa)



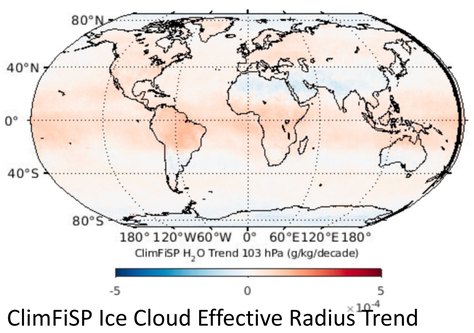
Stratospheric cooling (10 hPa)



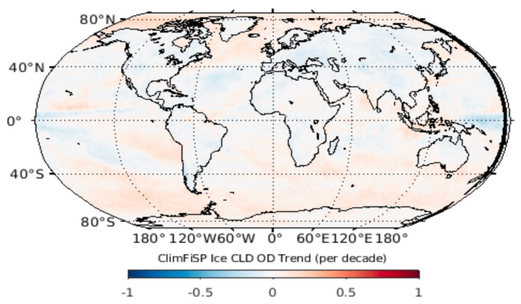
Water Vapor Trend at 500 hPa



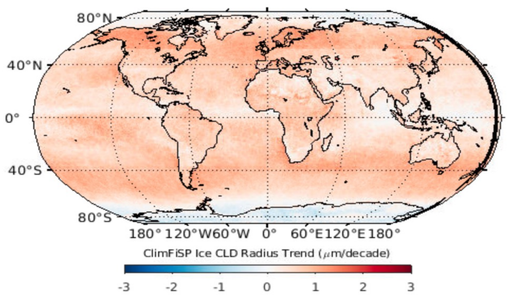
Water Vapor Trend at 100 hPa



ClimFiSP Ice Cloud Optical Depth Trend



ClimFiSP Ice Cloud Effective Radius Trend



Summary and More information on PCRTM

- Two advance retrieval algorithms SiFSAP and ClimFiSP have been developed at NASA Langley
  - ➢ SiFSAP has generated excellent results from AIRS, CrIS, IASI with higher spatial resolution than current NASA and NOAA operational products
  - ➢ ClimFiSP has generated 20 years of high-quality climate data records with consistent fingerprinting method from multiple IR sounders
- More than 200 atmospheric and surface parameters retrieved from hyperspectral IR sounders
  - ➢ High-quality products due to high information content of hyperspectral IR remote sensors and the advanced algorithms
  - ➢ No external information needed
- Consistent retrieval method used for different satellite IR sounders
  - ➢ Minimize errors due to forward model or inversion algorithm differences
- Provide radiative kernel and a complete atmospheric state and surface properties for climate model validations
  - ➢ Radiative kernel can be used to convert GCM output to TOA satellite radiances
  - ➢ Complete atmospheric and surface parameters can be used to calculate OLR, fluxes, heating/cooling rate, and laps rate etc.

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