COMMUNITY SATELLITE PROCESSING PACKAGE (CSPP)
Past, Current, and Future

Continuing NOAA's goal of sharing meteorological satellite data processing S/W & actively supporting the community who using it……
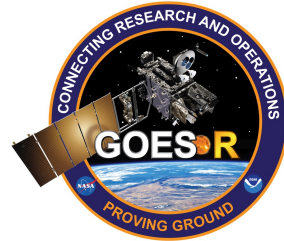CSPP-LEO:

http://cimss.ssec.wisc.edu/cspp/
CSPP-GEO:
http://cimss.ssec.wisc.edu/csppgeo/

CSPP UGM 2022
Madison, WI
**22 June 2022**

40 *years (1982-2022)* *Sharing of Meteorological Satellite Data Processing S/W*

➢ **1982:** International TOVS Processing Package – ITPP
  ❑ Father of processing package – Prof. William L. Smith
  ❑ 1st NOAA infrared/microwave sounding retrieval S/W for global users (HIRS/MSU)

➢ **1999:** International ATOVS Processing Package (IAPP)
  ❑ 2nd generation of NOAA sounding retrieval package (HIRS-2/AMSU)

➢ **2000:** International MODIS/AIRS Processing Package (IMAPP)
  ❑ 1st NASA hyperspectral sounding and imaging processing package (AIRS/AMSU/MODIS)

➢ **2012-2022:** Community Satellite Processing Package (CSPP)
  ❑ 1st NOAA JPSS program critical processing package to include multi-satellites and multi-sensors (VIIRS/CrIS/ATMS/IASI/MERSI/ABI/AHI/AVHRR….)
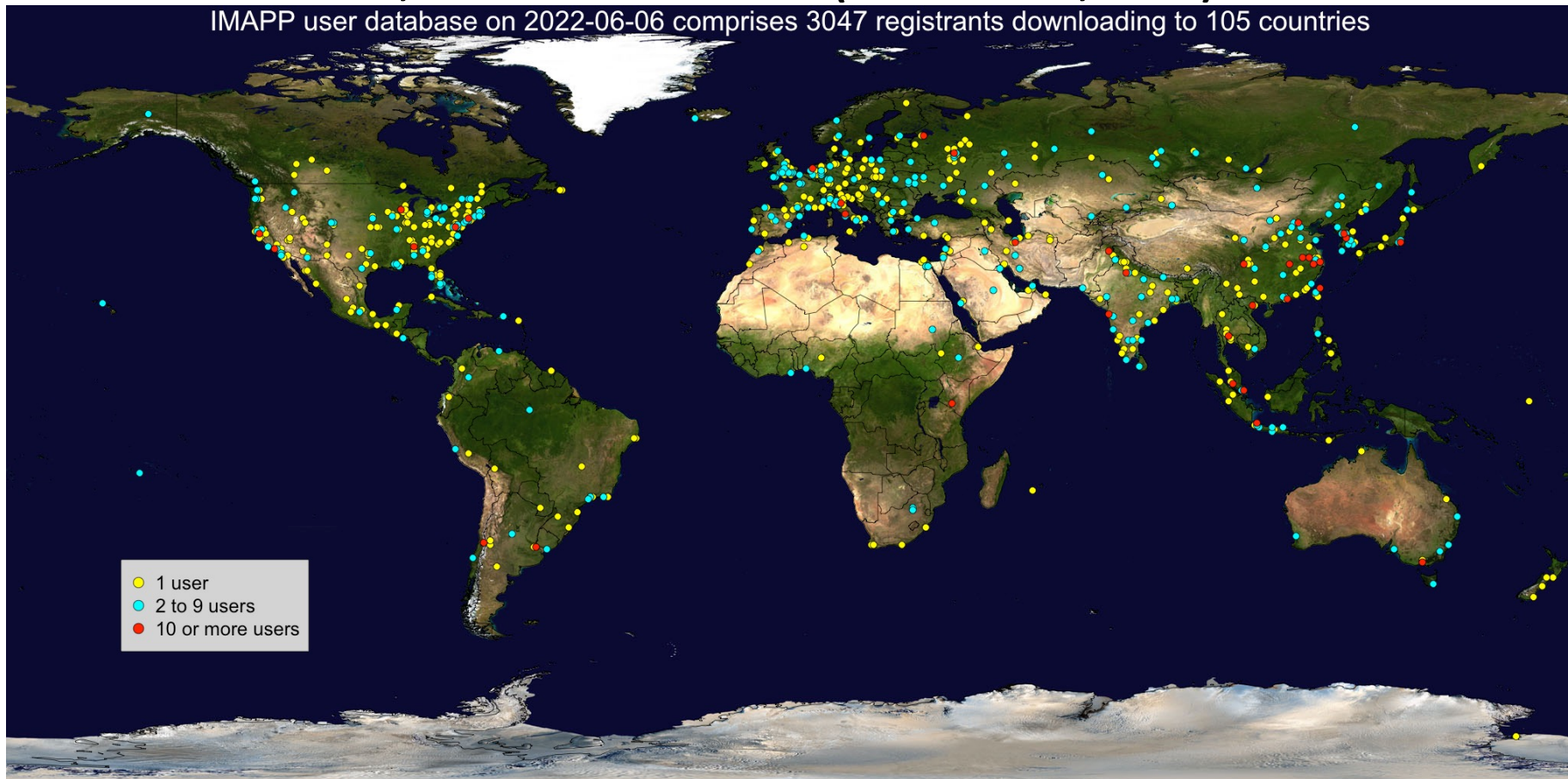
IAPP World-wide users:
154 in 26 Countries (as of June 6, 2022)

IAPP package on 2022-06-06 comprises 154 registrants downloading to 26 countries

- 1 user
- 2 to 9 users
- 10 or more users
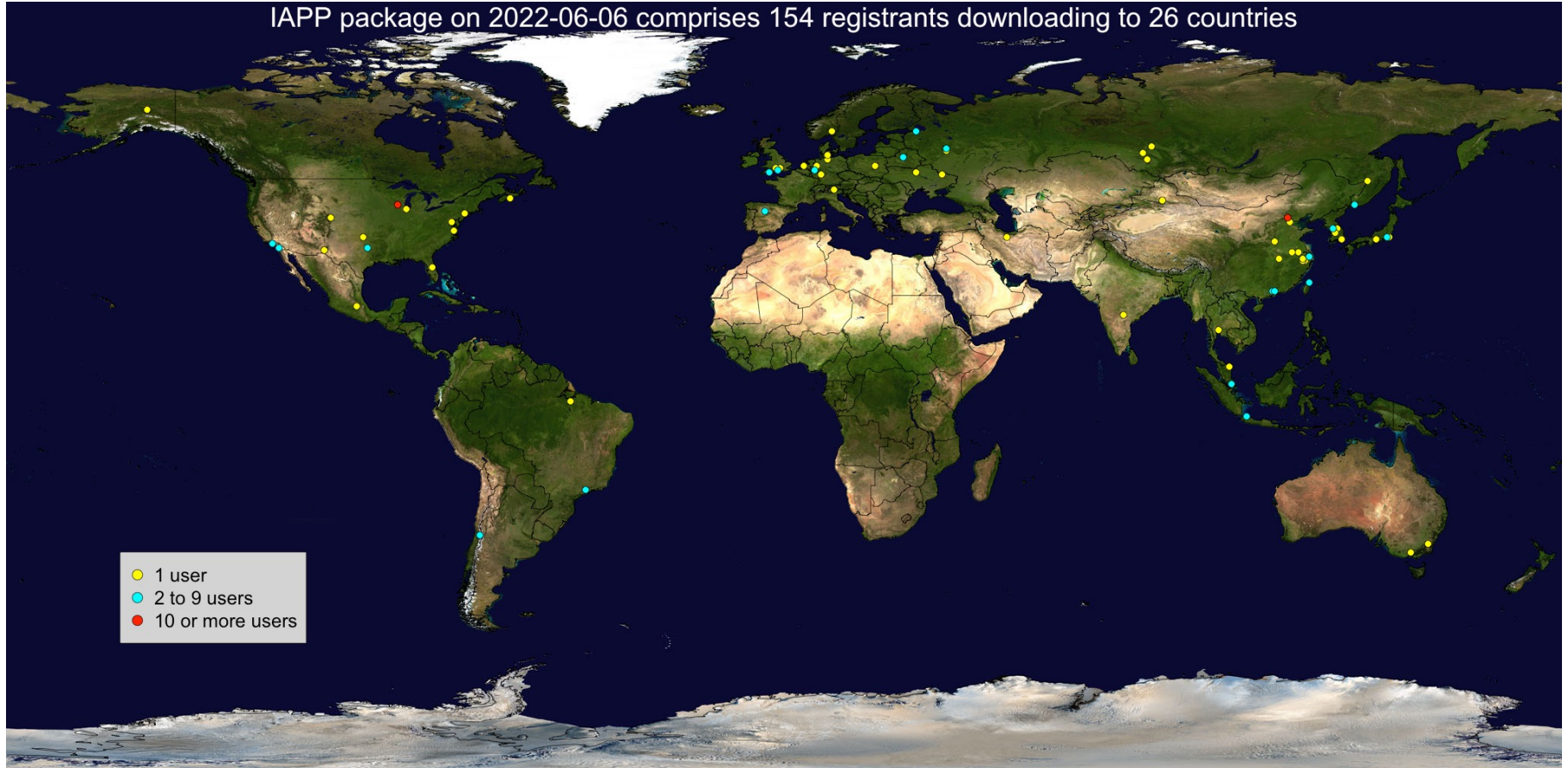
IMAPP World-wide users:
3,047 in 105 Countries (as of June 6, 2022)

IMAPP user database on 2022-06-06 comprises 3047 registrants downloading to 105 countries

- 🟡 1 user
- 🔵 2 to 9 users
- 🔴 10 or more users

CSPP LEO World-wide users:
2,990 in 107 Countries (as of June 6, 2022)

CSPP user database on 2022-06-06 comprises 2990 registrants downloading to 107 countries

- 1 user
- 2 to 9 users
- 10 or more users
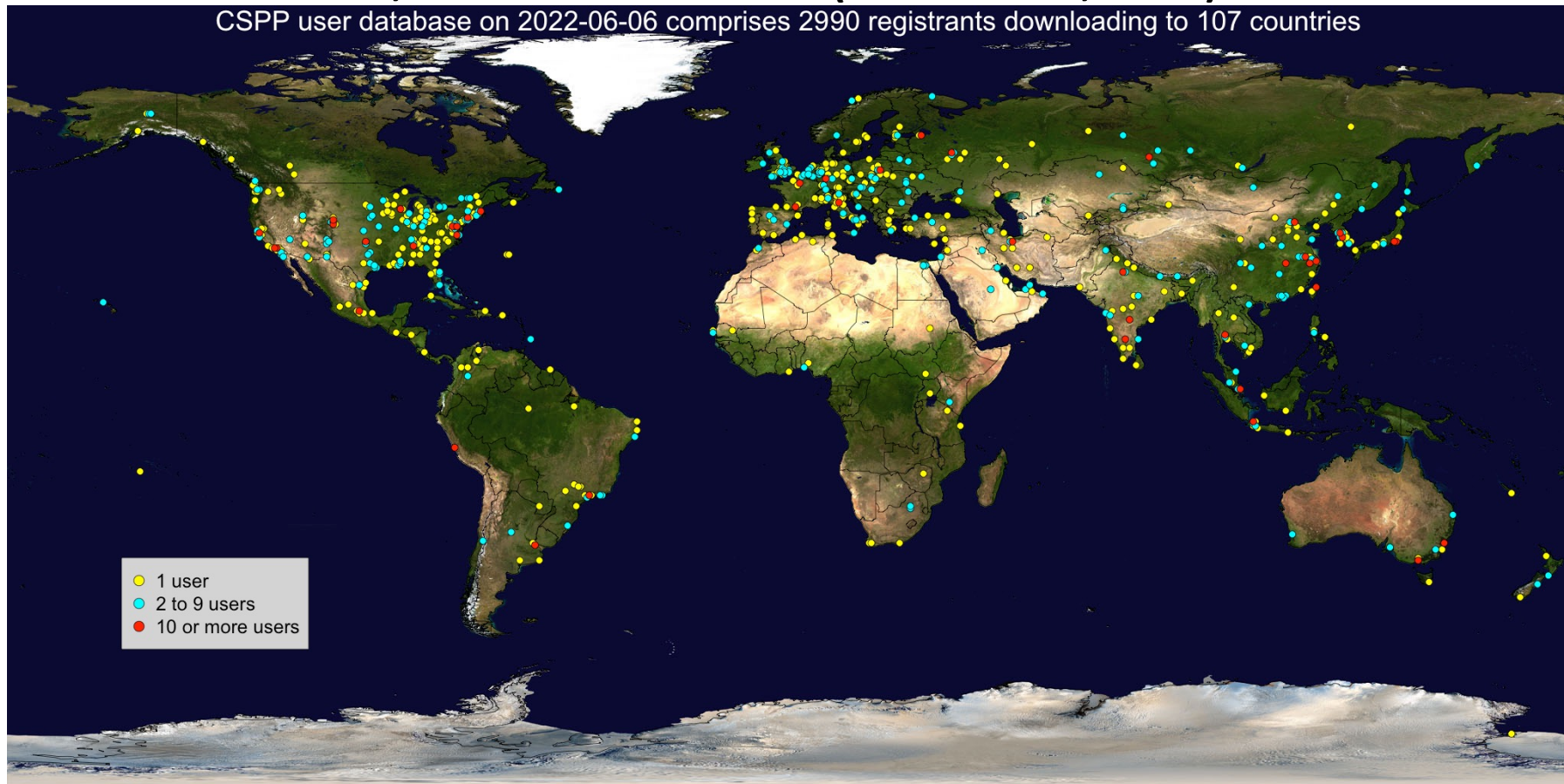
The Development of a Community Satellite Processing Package (CSPP) in support of Suomi NPP/JPSS Real Time Regional (RTR) Applications

A Proposal submitted to JPSS Program Scientist and the
The National Oceanic and Atmospheric Administration
National Environmental Satellite Data and Information Service
Center for SaTellite Applications and Research (STAR)
For the Period
1 July 2012 to 31 March 2013

CSPP to be developed emulates the successful **Community** Radiative Transfer Model (CRTM) to develop a cross-cutting processing software that can support RTR users **in both polar orbiting and geostationary satellite** data processing and applications. CSPP would be supported by JPSS and GOES-R and expanded to include all satellite data from international meteorological and environmental satellite agencies that provide **real time** direct broadcast data down link to **all users** who are capable of receiving such data stream through either X-band or L-band receiving systems.

CSPP-NPP/JPSS will have the following features   (July 2012):

- Ingest CCSDS packet files from VIIRS, CrIS, ATMS and NPP spacecraft diary;
- Create SDR and EDR products for VIIRS, CrIS, and ATMS using the current operational versions of the IDPS PRO algorithms and lookup tables;
- Produce all output files in the HDF5 formats defined by the JPSS Common Data Format Control Books;
- Retrieve all required dynamic non-spacecraft ancillary data <u>automatically</u>;
- Run natively on 64-bit Intel Linux host platforms;
- Run on <u>Microsoft Windows and Apple OS X </u>platforms via a Virtual Appliance;
- Allow the end user to customize which EDR products are created;
- Provide a <u>simple algorithm chaining </u>capability to run algorithms in sequence;
- Provide detailed logs of all processing operations and give clear indications of where and when failures occur;
- Allow the end user to add customer user-developed algorithms;
- <u>Provide products optimized for NWS which are AWIPS and/or NOAA NextGen compatible;</u>
- Provide value-added products for end users that are not part of the JPSS operational suite, such as images in KML format for Google Earth; Night Fog Detection; Volcanic Ash; and Aviation Safety products;
- Utilize GPU-based High-Performance Computing (HPC) technology to reduce the latency of CSPP-NPP/JPSS product generation for time-critical regional applications.

Community Satellite Processing Package (CSPP)
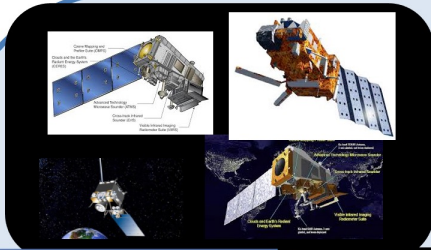## Empowering the weather satellite remote sensing users

March 14, 2012 (CSPP Suomi NPP VIIRS and ATMS SDR Software Version 1.0)

•**First public release** of CSPP for transforming direct broadcast Visible Infrared Imaging Radiometer Suite (VIIRS) and Advanced Technology Microwave Sounder (ATMS) Suomi NPP Raw Data Records (RDRs) to calibrated and geolocated Sensor Data Records (SDRs) in HDF5 format. Documentation, calling scripts and test data are included in the distribution.

•**88 S/W releases so far (CSPP-LEO)**

http://cimss.ssec.wisc.edu/cspp/

SATELLITES:
- S-NPP
- NOAA-20
- TERRA/AQUA
- METOP-A/-B/-C
- FY-3C/3D
- GOES-15/16/17
- HIMAWARI

CSPP S/W Tool Packages:
- Map Projection --Polar2Grid & Geo2Grid
- Visualization – HYDRA & RealEarth

SDR/LEV 1 Preprocessing:
Calibration/NAVIGATION

SENSORS:
- AVHRR
- VIIRS
- MODIS
- AIRS/AMSU
- ATMS
- CrIS
- IASI
- MERSI
- ABI & GLM
- AHI

CSPP S/W Product Packages:
- Clouds - CLAVR$_X$
- Profiles & Trace Gases: NUCAPS
- Profiles: HSRTV
- Profiles & Clouds: MIRS
- SST: ACSPO
- Flood Detection: Flood
- Active Fire: Fire
- ATOVS: IAPP
- Clouds & Profile: GeoAIT/GRB/GVAR
- Imagery clouds, aerosol & LST - AITF
- Clouds, Fog - GEOCAT
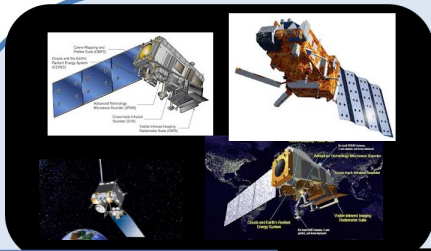
EDR/LEV 2
Atmospheric/Land/Oceanic PRODUCTS

IDR/LEV 3
Applications

PRODUCTS:
- RGB images
- Clouds
- Profiles
- Trace gases
- LST/SST
- Aerosol/Dust
- Fire
- Flood
- Others

Applications:
- Weather forecast
- Fire & Flood
- Air Quality
- Aviation Safety
- Severe Storm

CSPP

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CSPP

SATELLITES:
- S-NPP
- NOAA-20, others
- TERRA/AQUA
- METOP-A/-B/-C
- FY-3C/3D
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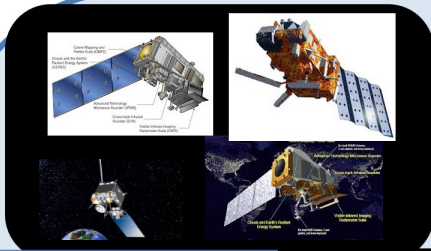- LST/SST
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CSPP

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CSPP

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CSPP

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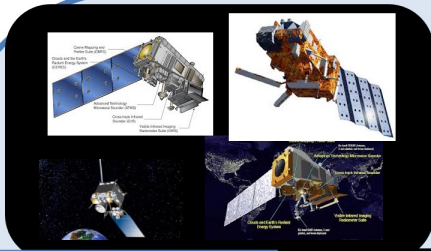**SDR/LEV 1**
Preprocessing:
Calibration/NAVIGATION

EDR/LEV 2
Atmospheric/Land/Oceanic PRODUCTS

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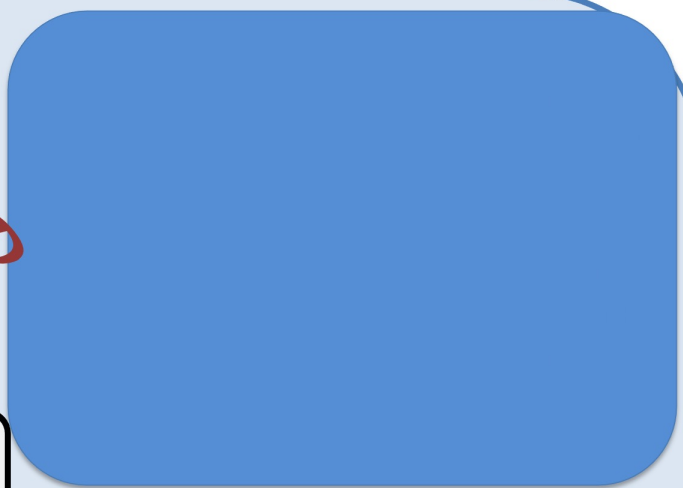**PRODUCTS:**
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CSPP

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CSPP

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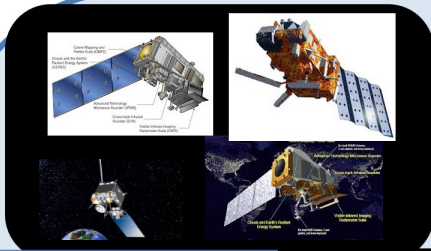Atmospheric/Land/Oceanic PRODUCTS

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CSPP

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CSPP

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CSPP

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CSPP

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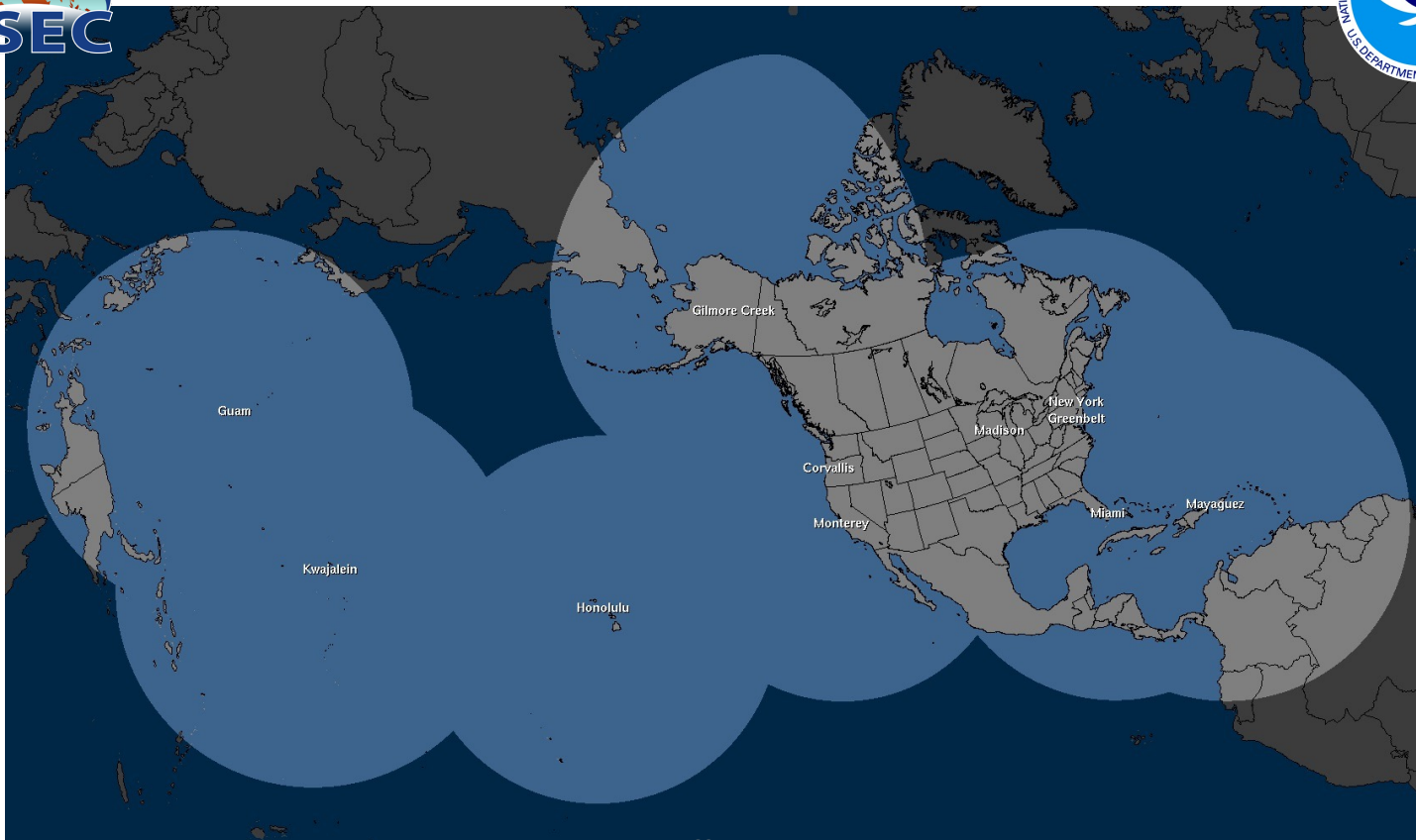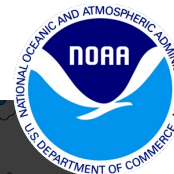- Map Projection --Polar2Grid & Geo2Grid
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CSPP

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NOAA Direct Broadcast Network (DBNet)

Polar2Grid
User friendly visualization tool

- Allows users to easily make high quality Polar Orbiter Satellite imagery, such as true and false color full resolution images.

- Originally designed as a tool that can run at polar orbiter direct broadcast antenna sites to create AWIPS Compatible NetCDF files from S-NPP VIIRS SDR files – funding through JPSS project.

- Extended the use cases to include more instruments, spectral bands and output data formats.

- Simple bash shell script execution with underlying open source Python code base called Satpy.

- Output format options include GeoTIFF, AWIPS, Binary and HDF5

Polar2Grid Supported Products

**Polar Level 1**

➢ VIIRS - S-NPP and NOAA-20

➢ MODIS - Aqua and Terra

➢ AVHRR - NOAA-18, 19 Metop-A,B,C

➢ ATMS – NOAA-20 and Limb Corrected S-NPP

➢ AMSR-2 – GCOMW-1

Polar CSPP Science Products

➢ ACSPO SSTs from VIIRS, MODIS, AVHRR

➢ MIRS Microwave Retrievals from ATMS, AMSU, and MHS

➢ NUCAPS Retrievals from CrIS/ATMS, IASI/AMSU

➢ CLAVRx Cloud Retrievals from VIIRS, MODIS and AVHRR

S-NPP composite VIIRS
Day/Night Band
ACSPO SSTs
15 March 2022

Images created using
Polar2grid using direct
Broadcast overpasses
acquired at the
University of Wisconsin -
Madison

realearth.ssec.wisc.edu
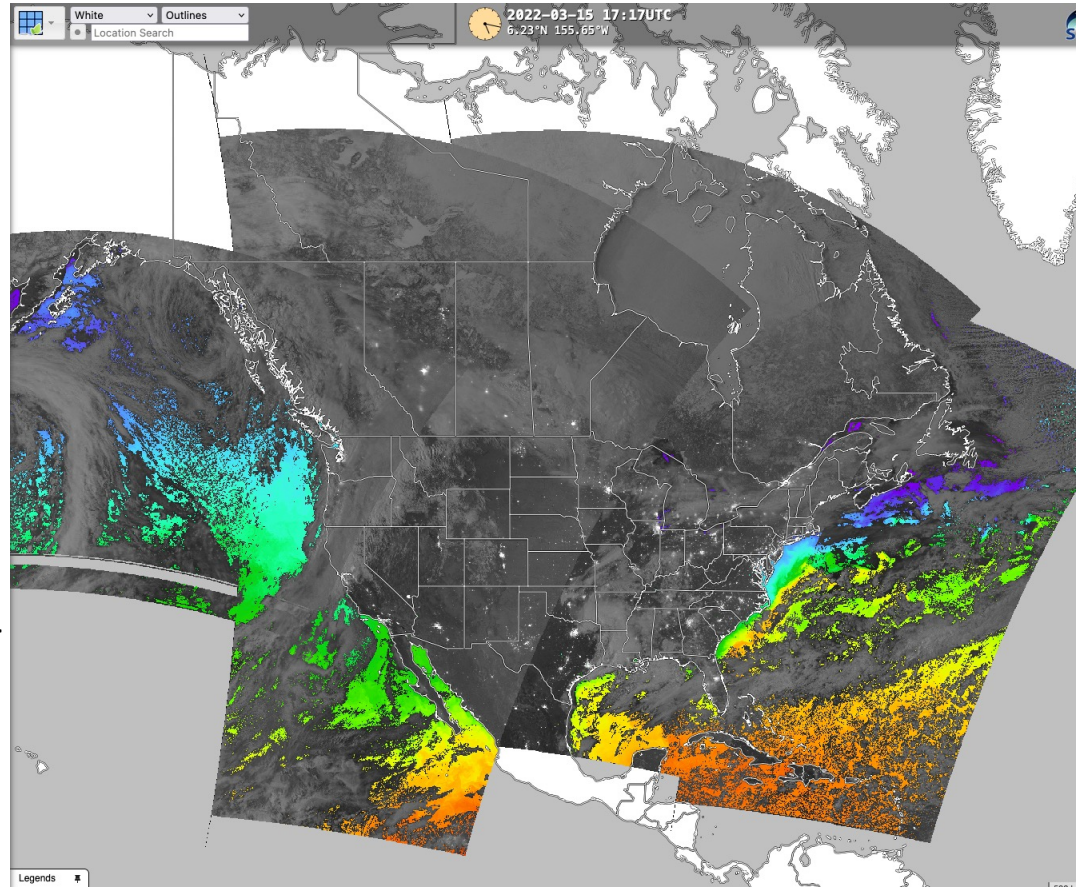
Global Direct Broadcast Application Workshops

- **Promote the local use of satellite data**
  - Lectures and hands-on labs determined by student interest/needs
  - Lectures, labs, data and software freely distributed

    http://cimss.ssec.wisc.edu/dbs
- **How can the data inform decision making?**
  - Remote sensing complemented by local knowledge
- **Encourages international collaborations between the global environmental science community**
- **Teach the principles of remote sensing to foster the next generation of scientists**
- **To date 20 workshops have been taught on 6 continents reaching students from more than 60 countries**

Direct Broadcast Applications Workshops (subset)

2004 - Nanjing, China - Nanjing Institute of Technology

2006 - Andenes, Norway

2006 - South Africa

2007 - Cachoeira Paulista, Brazil as part of **GEOSS**

2009 - Stellenbosch University, South Africa **IGARSS Short Course**

2011 - Indonesia – **WMO Region V Training**

2013, 2015, 2016, 2018 – NWS Training courses in support of users of X/L band antennas installed in Honolulu, Miami, Puerto Rico and Guam.

2017 – Hampton University

2020 - National Laboratory for Earth Observation (LANOT),

   Universidad Nacional Autonoma de Mexico (UNAM)

Direct Broadcast / Remote Sensing Applications Workshops

October 2018 Bogor, Indonesia

Guam National Weather Service Forecast Office April 2018

National Laboratory for Earth Observation (LANOT), Universidad Nacional Autonoma de Mexico (UNAM) February 2020

CSPP Users' Group Meetings (Biennial)

- The meeting brings together the worldwide community of CSPP LEO/GEO meteorological/environmental satellite users to discuss issues relevant to 1) reception, 2) processing, 3) applications, and 4) innovations of satellite data acquired by direct broadcast.
- **Biennial meeting beginning in 2013** (2021 meeting postponed)
  - Host locations include Madison, Wisconsin, EUMETSAT/EU and Chengdu/China

Chengdu

Madison

EUMETSAT

CSPP Sounder Algorithm S/W (1/3)

Hyper-Spectral Enterprise Algorithm Package (HEAP)

Software for retrieving atmospheric profiles of temperature, moisture, trace gases and cloud-cleared radiances from direct broadcast (DB) CrIS+ATMS Sensor Data Records (SDRs) for S-NPP and NOAA-20 and IASI+AMSUA/MHS Level1-b files for Metop-A, B, and C.

HEAP runs the NUCAPS (NOAA Unique Combined Atmospheric Processing System) algorithm. This CSPP release provides NOAA HEAP version 3.1, adapted and tested for operation in a real-time direct broadcast environment.

NUCAPS NetCDF output files containing:
- **Cloud-cleared Radiances (NUCAPS-CCR-AR_v3r0_*.nc files),**
- **Outgoing Longwave Radiation (NUCAPS-OLR_v3r0_*.nc files),**
- **and Environmental Data Record (EDR) vertical profiles of temperature, moisture and trace gasses (NUCAPS-EDR_v3r0_*.nc files) including:**
  - Atmospheric temperature [K] at 100 pressure levels
  - Atmospheric moisture [g/g] at 100 pressure levels
  - Atmospheric ozone [ppb] at 100 pressure levels
  - Atmospheric liquid water [g/g] at 100 pressure levels
  - Carbon dioxide dry mixing ratio [ppm] at 100 pressure levels
  - Trace gas mixing ratios CO, CH4, HNO3, N2O, SO2* [ppb] at 100 pressure levels
  - Surface skin temperature [K]
  - Microwave surface emissivity
  - Column averaged CO2 per ATMS or AMSU Field-Of-View (FOV) [ppm]
  - Cloud top pressure for up to two cloud layers [hPa]
  - Cloud top fractional coverage for up to two cloud layers
  - 10 Stability parameters including CAPE, Lifted Index (LI) and Convective Inhibition (CIN)
  - Quality flags

CSPP Sounder Algorithm S/W (2/3)

University of Wisconsin-Madison **CrIS, AIRS and IASI** Hyperspectral Retrieval Software (**HSRTV**):

HDF5 output files containing these arrays at single Field-Of-View (FOV) resolution:

- Atmospheric temperature [K] at 101 pressure levels
- Atmospheric moisture [g/kg] at 101 pressure levels
- Atmospheric ozone [ppmv] at 101 pressure levels
- Atmospheric relative humidity [%] at 101 pressure levels
- Atmospheric dew point temperature [K] at 101 pressure levels
- Surface skin temperature [K]
- Surface emissivity at instrument spectral resolution [cm-1] (under clear conditions only)
- Total precipitable water (vertically integrated from 100 hPa to surface) [cm]
- Precipitable water 1 (vertically integrated from 900 hPa to surface) [cm]
- Precipitable water 2 (vertically integrated from 700 to 900 hPa) [cm]
- Precipitable water 3 (vertically integrated from 300 to 700 hPa) [cm]
- Total ozone amount (vertically integrated) [dobson units]
- Lifted index [Degrees Celsius]
- Convective available potential energy [J/kg]
- CO_2 amount [ppmv]
- Cloud top pressure 1 [hPa]
- Cloud top temperature 1 [K]
- Cloud optical thickness
- Effective cloud emissivity
- Cloud mask (values: 0 clear, 1 cloud)

CSPP Sounder Algorithm S/W (3/3)

Microwave integrated Retrieval System (MiRS)

NOAA/NESDIS/STAR Microwave integrated Retrieval System (MiRS) software for retrieval of atmospheric profiles, cloud and surface properties from NOAA-20 and S-NPP ATMS, and NOAA-18,-19, Metop-A,-B,-C AMSU-A and MHS microwave sensor data.

Official Validated Products created by MiRS include:

- Temperature profile over open water ocean
- Humidity profile over open water ocean
- Humidity profile over non-coastal Land
- Total Precipitable Water (TPW) over open water ocean
- Total Precipitable Water over non-coastal land
- Land surface temperature
- Surface Emissivity over land and snow
- Snow Water Equivalent (SWE)
- Sea Ice Concentration (SIC)
- Snow Cover Extent (SCE), based on the SWE
- Vertically-Integrated Non-precipitating Cloud Liquid Water (CLW) over open water ocean
- Vertically-Integrated Ice Water Path (IWP)
- Vertically-Integrated Rain Water Path (RWP)
- Rainfall Rate (RR) over open water ocean and non-coastal, non-snow-covered land surface types
- Effective grain size of snow (over snow-covered land surface)*
- Multi-Year (MY) Type Sea Ice Concentration*
- First-Year (FY) Type Sea Ice Concentration*
- Snow Fall Rate (SFR)**
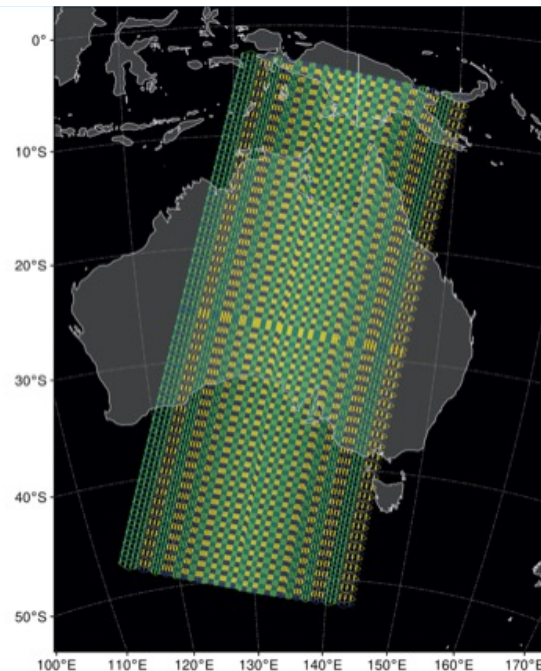- Probability of Falling Snow (Prob_SF)**

Coming CSPP Sounder Algorithm S/W
for 5:30 am Orbit

NUCAPS for HIRAS/MWTS-2/MWHS-2 Hyperspectral IR & Microwave sounding retrieval
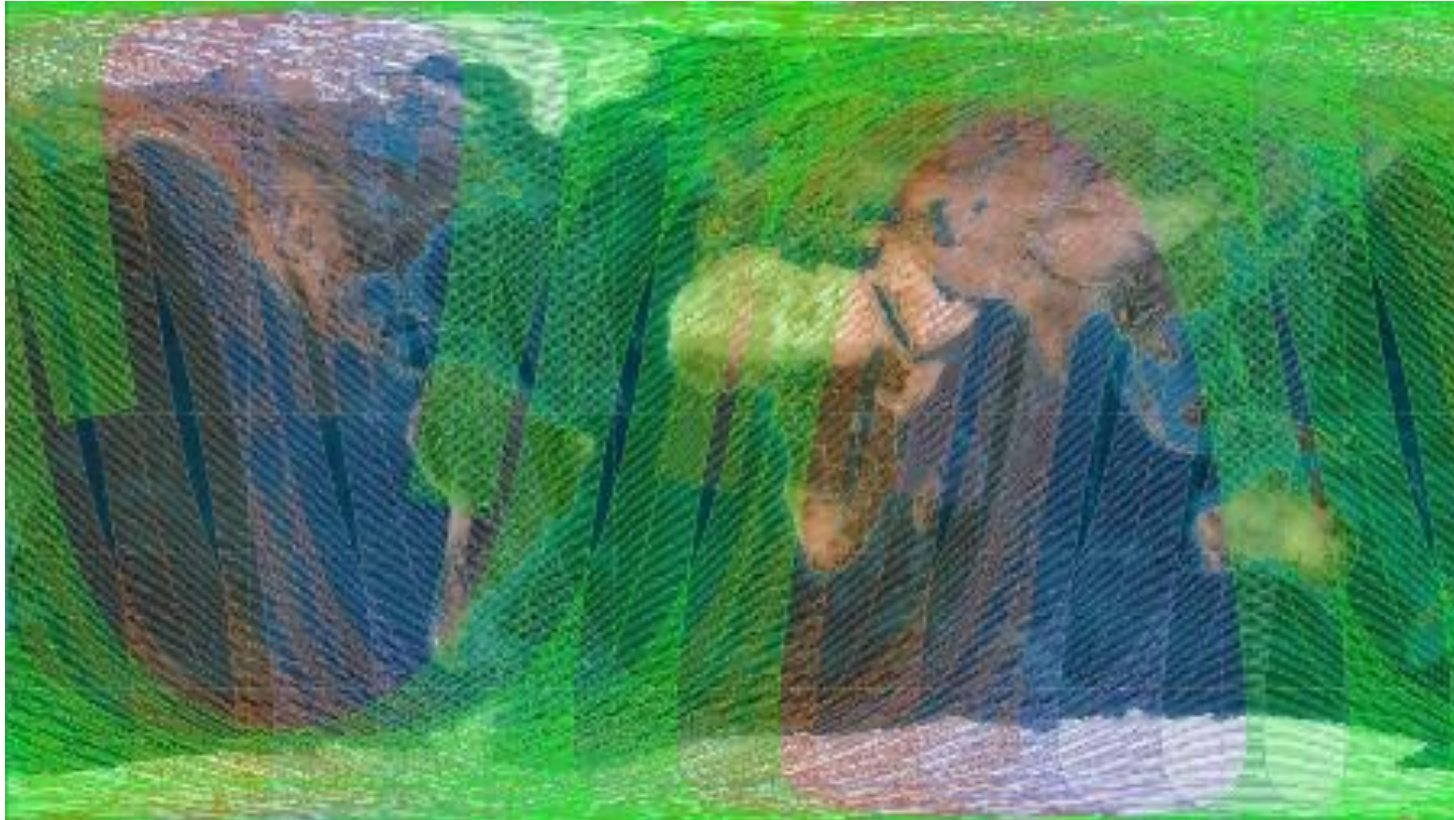
Software for retrieving atmospheric profiles of temperature, moisture, trace gases and cloud-cleared radiances from direct broadcast (DB) HIRAS/MWTS/MWHS Sensor Data Records (SDRs) for FY3D/3E and beyond
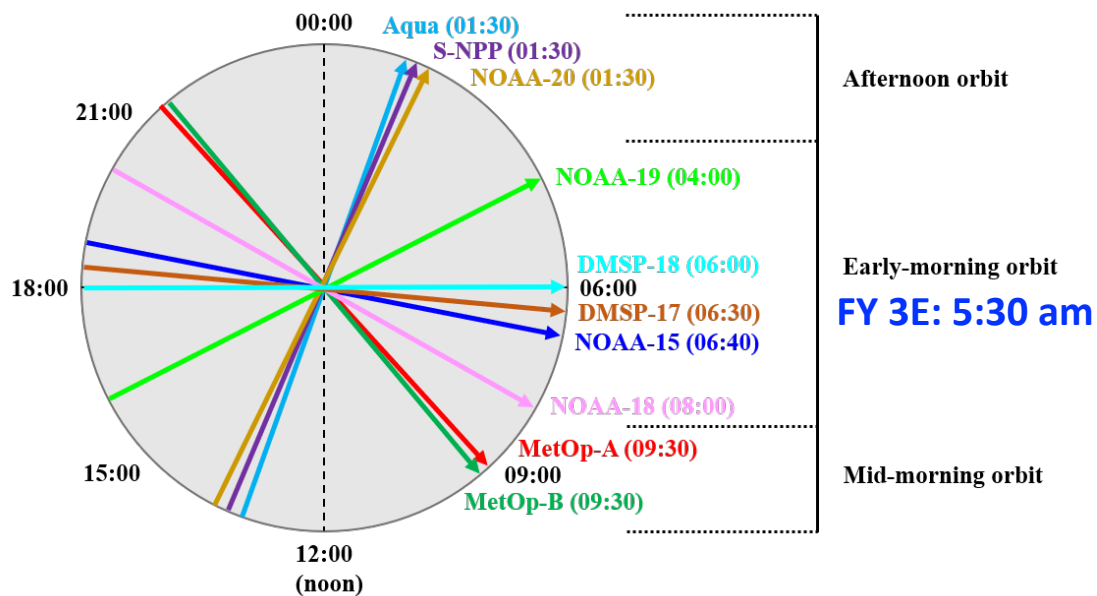
FY-3E is the first meteorological satellite in early morning orbit for civil service, filling in the observing gap in the early morning.

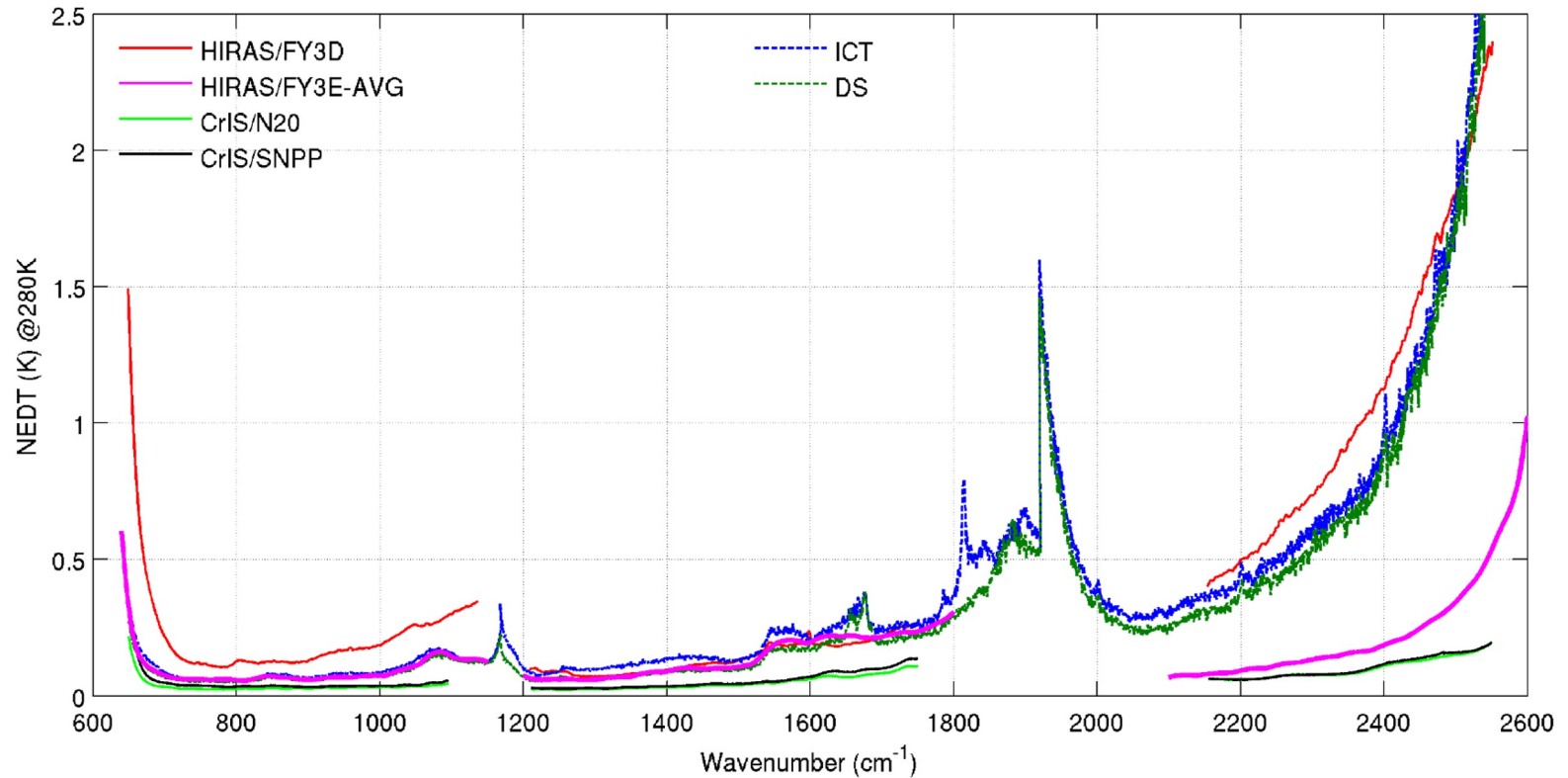Metop-A **9:30 AM**

NPP **13:30 PM**

FY-3 Early Morning **5:30 AM**

After PengZ/CMA

HIRAS (FY3D/3E) & CrIS (SNPP/N20) NEDT Comparison

Coming CSPP Sounder Algorithm S/W
for 5:30 am Orbit

NUCAPS for HIRAS/MWTS-2/MWHS-2 Hyperspectral IR & Microwave sounding retrieval

Software for retrieving atmospheric profiles of temperature, moisture, trace gases and cloud-cleared radiances from direct broadcast (DB) HIRAS/MWTS/MWHS Sensor Data Records (SDRs) for FY3D/3E and beyond

FY 3E: 5:30 am

Spectral range (μm)	Spectral range (cm^{-1})	Spectral resolution (unapodised)	NEΔT @ specified scene temperature
8.56-15.38 μm	650-1168 cm^{-1}	0.625 cm^{-1}	0.2-0.8 K @ 250 K
5.21-8.56 μm	1168-1920 cm^{-1}	0.625 cm^{-1}	0.2-0.3 K @ 250 K
3.92-5.21 μm	1920-2550 cm^{-1}	0.625 cm^{-1}	0.3-0.5 K @ 250 K

Disk usage for 1 global day of FY3E:
- HIRAS: 112G
- MWT/H: 1G
- GFS grib: 1G
- hiras/mwtsx/mwhsx.bin: 31G
- avn.bin: 2G

SUB TOTAL: ~150G

COMMUNITY SATELLITE PROCESSING PACKAGE (CSPP)
Past, Current, and Future
Summary

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CSPP users like you can be sure that now and in the future,

your investments will be long-lasting and rewarding

CSPP
Questions are welcomed!

CSPP Leo: http://cimss.ssec.wisc.edu/cspp/

CSPP Geo: http://cimss.ssec.wisc.edu/csppgeo/

ISEE/RealEarth: http://isee.ssec.wisc.edu/

CSPP users' Group Meeting:
https://www.ssec.wisc.edu/meetings/cspp/

Direct Broadcast Workshop:
http://cimss.ssec.wisc.edu/dbs/