

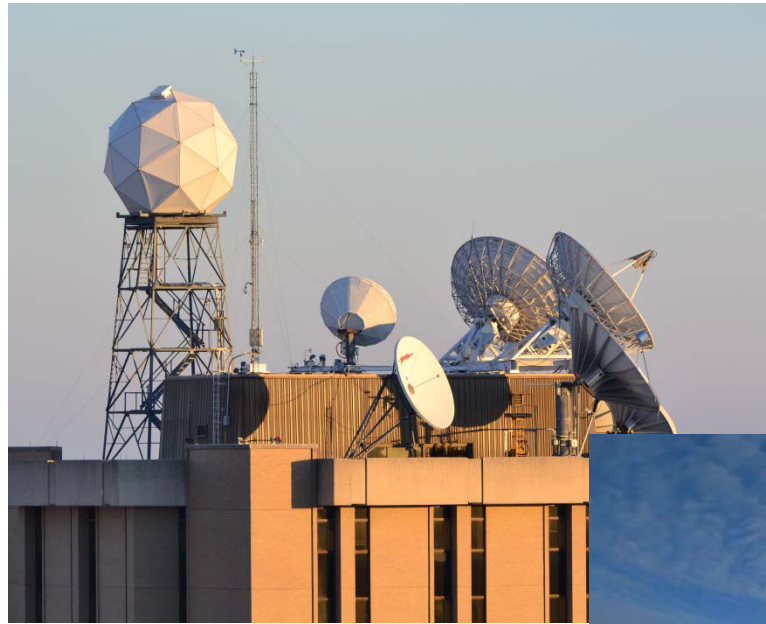
The Advancement of Community Based LEO and GEO Satellite Processing and Application Packages

Allen Huang, Liam Gumley, Kathy Strabala, Scott Mindock, Graeme Martin, Ray Garcia, Geoff Cureton, Jim Davies, Nick Bearson, Elisabeth Weisz, Nadia Smith, Bill Smith Sr. & many others

The Sixth Asia/Oceania
Meteorological Satellite Users'
Conference

Tokyo, Japan

11 November, 2015



The Advancement of Community Based LEO and GEO Satellite Processing and Application Packages

Outline:

1. CIMSS Processing Packages: ITPP, IAPP, IMAPP, CSPP-LEO, CSPP-Geo

2. IMAPP (2014/2015) Overview

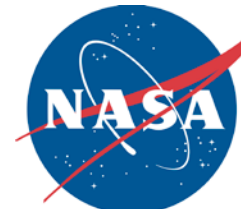
3. CSPP Overview

4. Innovations with new sponsors:

4.1 ISEE (Innovative Satellite Enhanced Exploration)

4.2 Technology Innovation for real-time Wx Forecasting

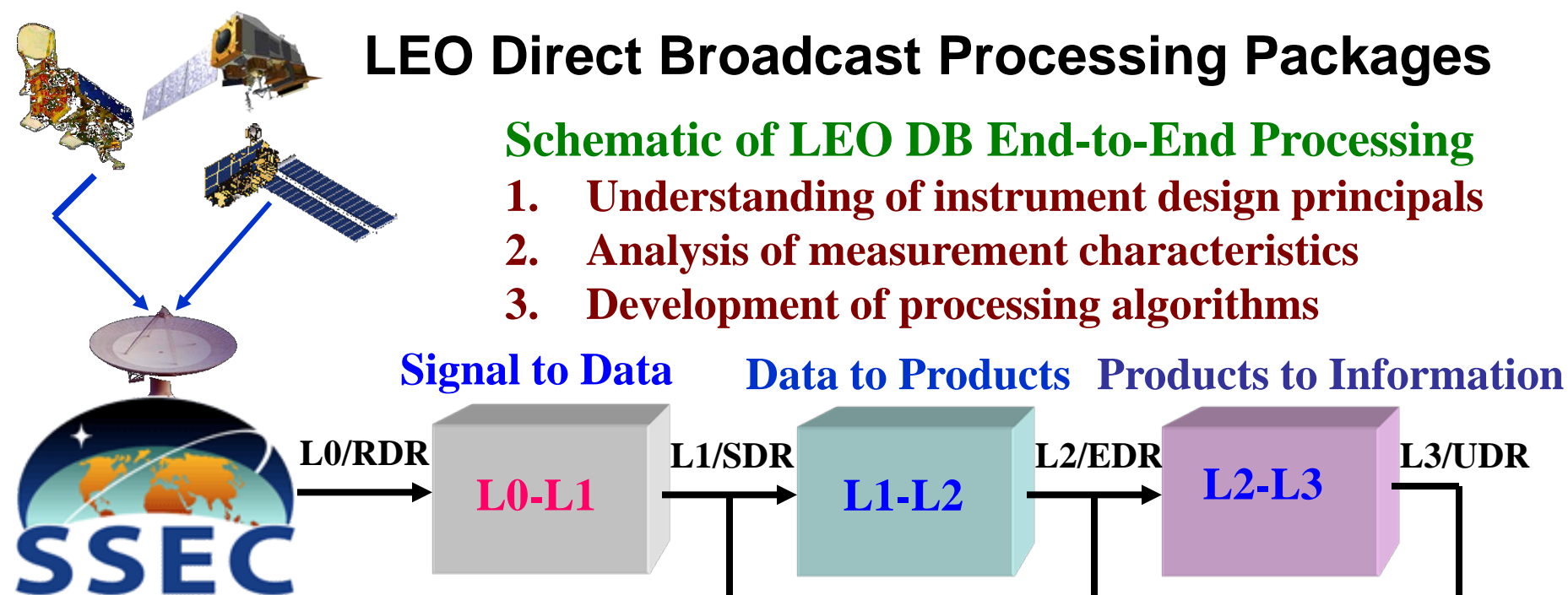
5. Summary



LEO Direct Broadcast Processing Packages

Schematic of LEO DB End-to-End Processing

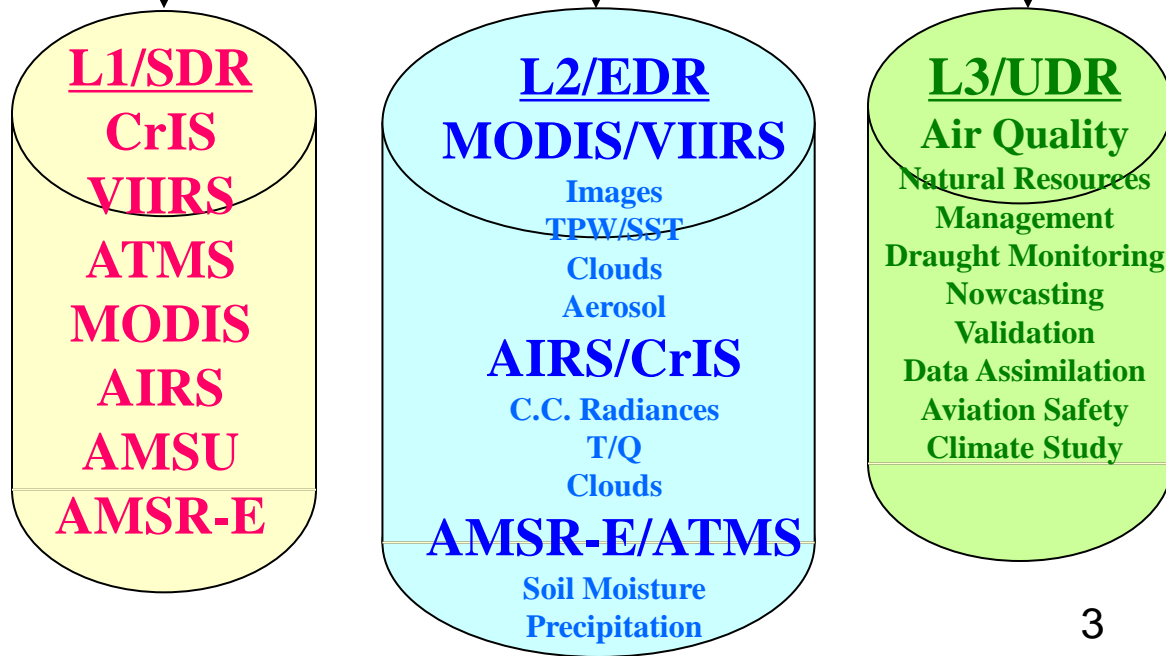
1. Understanding of instrument design principals
2. Analysis of measurement characteristics
3. Development of processing algorithms



Schematic of LEO DB End-to-End Processing

-continue

4. Use of processing S/W System
5. Linkage to meteorological & environmental modeling & applications



From ITPP, IAPP, IMAPP to CSPP 1992 to 2015

(1/2)

- 1992: TOVS (TIROS-N) export package started
- 1993: 1st release of ITPP for NOAA-8
- 1999: 1st release of IAPP for NOAA-15
- 2000: 1st release of IMAPP for Terra MODIS
- 2002: 1st IMAPP science products released for Terra MODIS & 1st release for both Terra & Aqua MODIS
- 2004: 1st IMAPP training workshop at Nanjing, China
- 2005: 2nd & 3rd IMAPP training workshops & IAPP V2.1 released. 1st release of IMAPP AIRS/AMSU/HSB sounding rtv.

IMAPP: 61 releases since May 2000

CSPP: 29 releases since March 2012

From ITPP, IAPP, IMAPP to CSPP 1992 to 2015

(2/2)

- 2006: 1st IMAPP AMSR-E soil moisture & workshops in Norway & S. Africa
- 2007: IMAPP AMSR-E Snow Water Equivalent & workshop in Brazil
- 2008: 1st release of IMAPP DB-CRAS NWP model
- 2009: 1st release of Google Earth
- 2010: IMAPP Virtual Appliance
- 2012: CSPP 1st release for Suomi NPP & IDEA-I 1st release
- 2015: CSPP-IAPP for NOAA 15/16/18/19 & Metop A/B release
- 2015: CSPP-GEO for GOES GRB & GVAR

IMAPP: 61 releases since May 2000

CSPP: 29 releases since March 2012



International MODIS/AIRS Processing Package



IMAPP - Funded by NASA since 2000

<http://cimss.ssec.wisc.edu/imapp/>

- 61 software packages released in 15 years
- More than 3000 registrants from 76 different countries
- 12 direct broadcast workshops held on 6 continents serving students from more than 60 countries
- 15 MODIS related software packages
- 6 AIRS related software packages
- 4 AMSR-E software packages

Indonesia Workshop Sep. 2011



Shanghai Workshop June 2011



CSPP Software Suites

CSPP Software	Product Description
1. SDR	VIIRS, CrIS, and ATMS geolocated and calibrated earth observations.
2. VIIRS EDR	VIIRS imager cloud mask, active fires, surface reflectance, vegetation indices, sea surface temperature, land surface temperature, and aerosol optical depth.
3. HSRTV	Hyperspectral infrared sounder retrievals of temperature and moisture profiles, cloud properties, total ozone, and surface properties.
4. Polar2grid	Reprojected imagery (single and multi-band) in GeoTIFF and AWIPS formats.
5. Hydra	Interactive visualization and interrogation of multispectral imagery and hyper spectral soundings.
6. MIRS	Microwave sounder retrievals of temperature and moisture profiles; surface properties; snow and ice cover; rain rate; and cloud/rain water paths.
7. CLAVR-x	Multispectral imager retrievals of cloud properties; aerosol optical depth; surface properties; ocean properties.
8. NUCAPS	Combined hyperspectral infrared sounder and microwave sounder retrievals of temperature and moisture profiles, cloud cleared radiances, and trace gases.
9. IAPP	Combined infrared sounder and microwave sounder retrievals of temperature and moisture profiles, water vapor, total ozone, and cloud properties.
10. ACSPO	Multispectral imager retrievals of sea surface temperature.

CSPP LEO covers multi sensors on board International Satellite Systems

Satellite	Multispectral Imager	Infrared Sounder	Microwave Sounder
Suomi NPP	VIIRS <i>SDRs (Level 1B), Images, Visualization, Clouds, Aerosols, Land, Ocean</i>	CrIS <i>SDRs (Level 1B) Atmospheric Profiles, Clouds, Visualization</i>	ATMS <i>SDRs (Level 1B), Atmospheric Profiles, Precipitation, Visualization</i>
NOAA-18/19	AVHRR <i>Clouds, Aerosols, Land Surface, SST, Visualization</i>	HIRS <i>Atmospheric Profiles</i>	AMSU, MHS <i>Atmospheric Profiles, Precipitation</i>
Metop-A/B	AVHRR <i>Clouds, Aerosols, Land Surface, SST, Visualization</i>	IASI, HIRS <i>Atmospheric Profiles, Clouds, Visualization</i>	AMSU, MHS <i>Atmospheric Profiles, Precipitation</i>
Terra	MODIS <i>Images, Visualization</i>	N/A	N/A
Aqua	MODIS <i>Images, Visualization</i>	AIRS <i>Atmospheric Profiles, Clouds, Visualization</i>	AMSU <i>Atmospheric Profiles, Precipitation, Visualization</i>

CSPP S/W Suite produces Imager/Sounder (VIS, IR, & MW) products and provides supporting tools

CSPP Software	Suomi NPP	NOAA-18/19	Metop-A/B	Terra	Aqua
1. SDR	VIIRS, CrIS, ATMS	Provided by AAPP	Provided by AAPP	Provided by SeaDAS	Provided by SeaDAS
2. VIIRS EDR	VIIRS	N/A	N/A	N/A	N/A
3. HSRTV	CrIS	N/A	IASI	N/A	AIRS
4. Polar2Grid	VIIRS, CrIS, IASI	Future version	Future version	MODIS	MODIS, AIRS
5. Hydra	VIIRS, CrIS, ATMS	AVHRR	AVHRR, IASI	MODIS	MODIS, AIRS
6. MIRS	ATMS	AMSU, MHS	AMSU, MHS	N/A	N/A
7. CLAVR-x	VIIRS	AVHRR	AVHRR	MODIS	MODIS
8. NUCAPS	CrIS, ATMS	N/A	Future version	N/A	Future version
9. IAPP	N/A	HIRS, AMSU, MHS	HIRS, AMSU, MHS	N/A	N/A
10. ACSPO	VIIRS	AVHRR	AVHRR	MODIS	MODIS

CSPP LEO S/W Suite provided by NOAA (1/4)

ACSPPO (Advanced Clear-Sky Processor for Oceans) retrieves sea surface temperature from multispectral imager observations

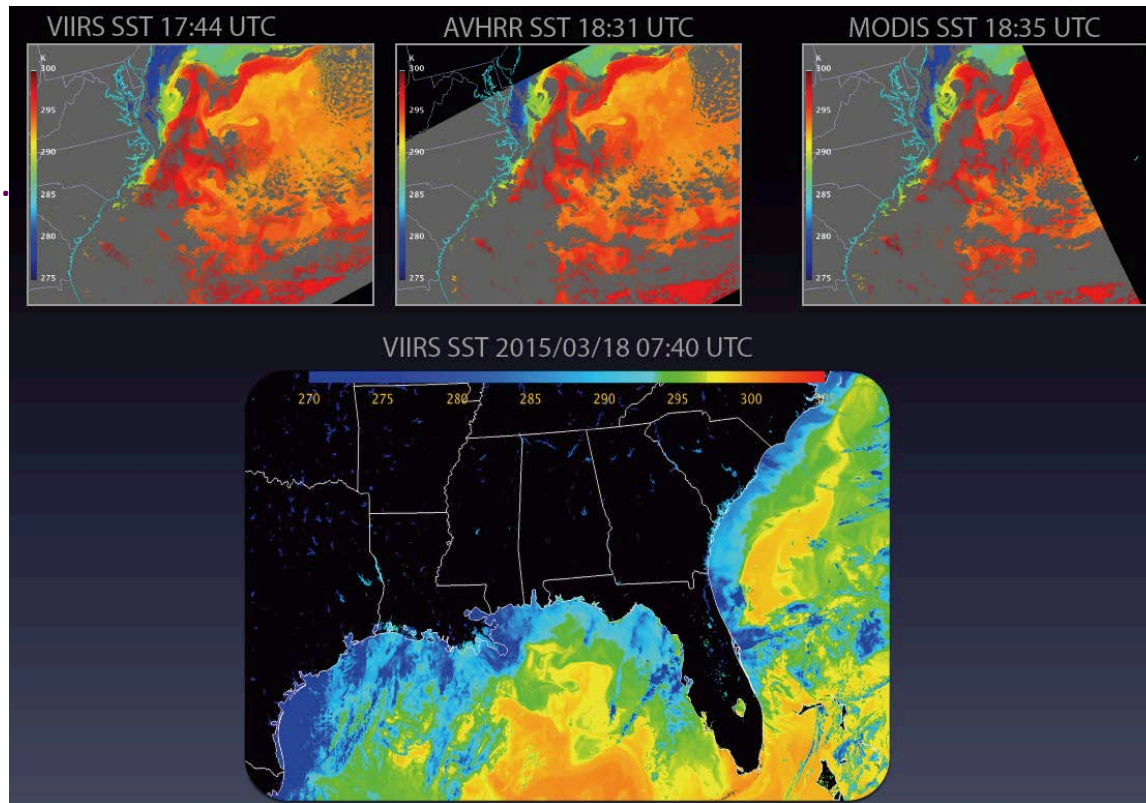
Heritage: Developed at NOAA/NESDIS/STAR by Alex Ignatov, John Sapper, John Stroup, and Yury Kihai.

Satellites/Sensors: Suomi NPP VIIRS; NOAA-18/19 AVHRR; Metop-A/B AVHRR; Terra/Aqua MODIS.

Products: Sea surface temperature, aerosol optical thickness; and clear-sky radiances.

Features:

- Multi-sensor common algorithm.
- ACSPPO is the official JPSS algorithm for SST.



CSPP LEO S/W Suite provided by NOAA (2/4)

MIRS (Microwave Integrated Retrieval System) creates atmospheric profile, precipitation, and surface products from microwave sounder data -

Heritage: Developed at NOAA/NESDIS by Sid Boukabara, Chris Grassotti, et al.

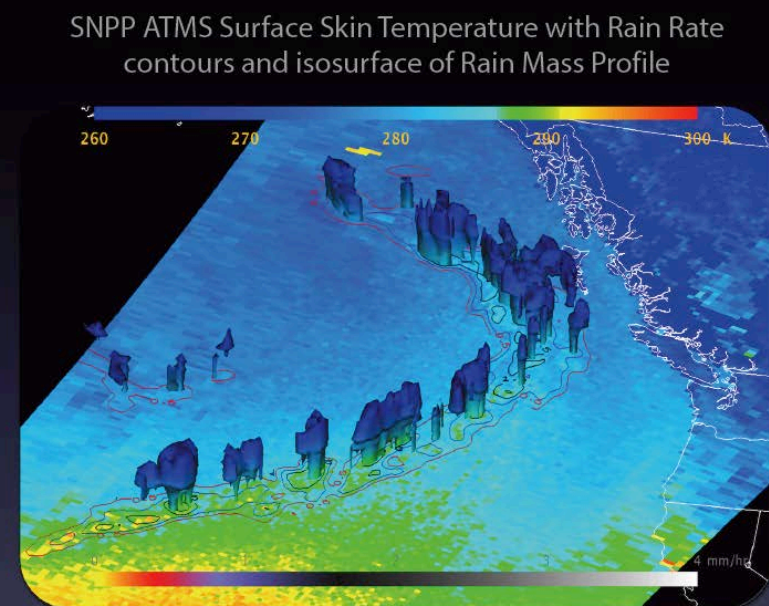
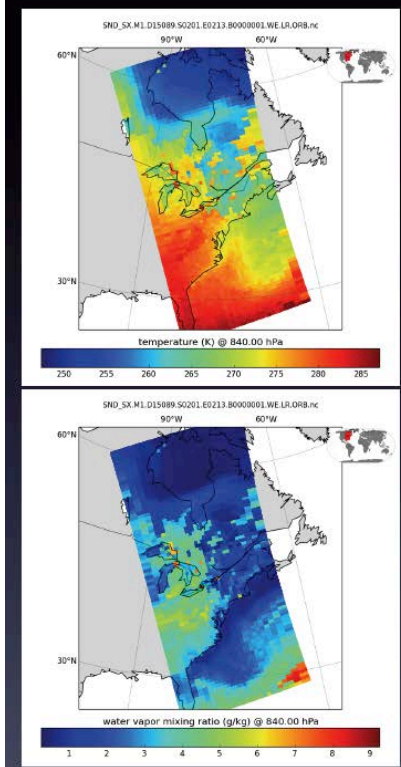
Satellites/Sensors: Suomi NPP ATMS; Metop-A/B AMSU, MHS; NOAA-18/19 AMSU, MHS.

Products: Temperature and moisture profiles, total precipitable water, surface skin temperature and emissivity, rain rate, cloud liquid water, rain water path, ice water path, liquid water path, sea ice concentration, snow water equivalent, and snow cover.

Features:

- Multi-sensor common algorithm.
- Physics-based retrieval.
- Retrieves land and ocean products in all sky conditions.
- Extensively validated and documented

Metop-B AMSU/MHS 840 hPa temperature and water vapor



CSPP LEO S/W Suite provided by NOAA (3/4)

NUCAPS (NOAA Unique CrIS/ATMS Processing System) retrieves atmospheric temperature, moisture, and trace gases from combined infrared and microwave observations.

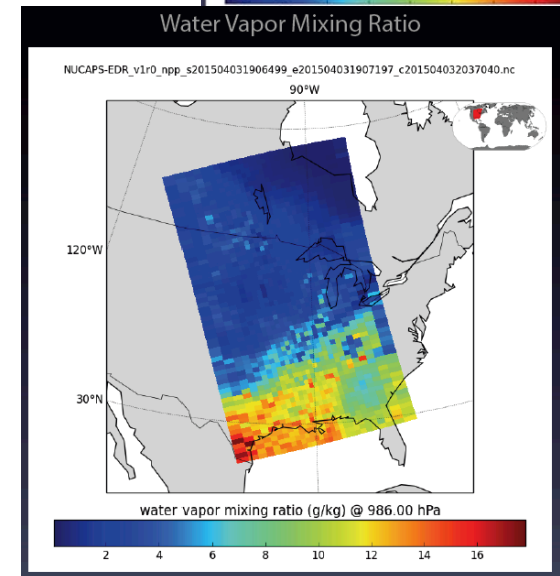
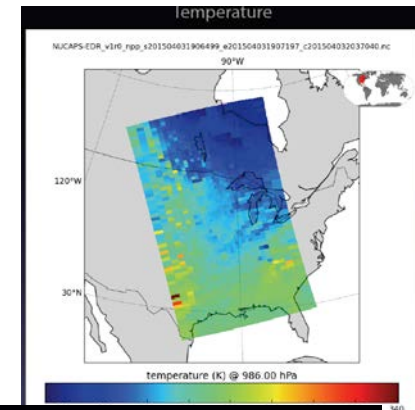
Heritage: Developed at NOAA/NESDIS/STAR by Chris Barnet, Antonia Gambacorta, Walter Wolf, Mark Liu et al.

Satellites/Sensors: Suomi NPP CrIS/ATMS

Products: Temperature, water vapor, and ozone profiles; trace gas profiles including ozone, carbon monoxide, methane, carbon dioxide, nitrous oxide, sulphur dioxide; infrared and microwave surface emissivity; cloud cleared radiances.

Features:

- Multi-sensor common physical retrieval algorithm.
- Future versions will support Metop-A/B IASI/AMSU/MHS and Aqua AIRS/AMSU.
- NUCAPS is the official NOAA sounding product for JPSS.



CSPP LEO S/W Suite provided by NOAA (4/4)

CLAVR-x (Clouds from AVHRR Extended) creates quantitative cloud, aerosol, and surface products from imager data

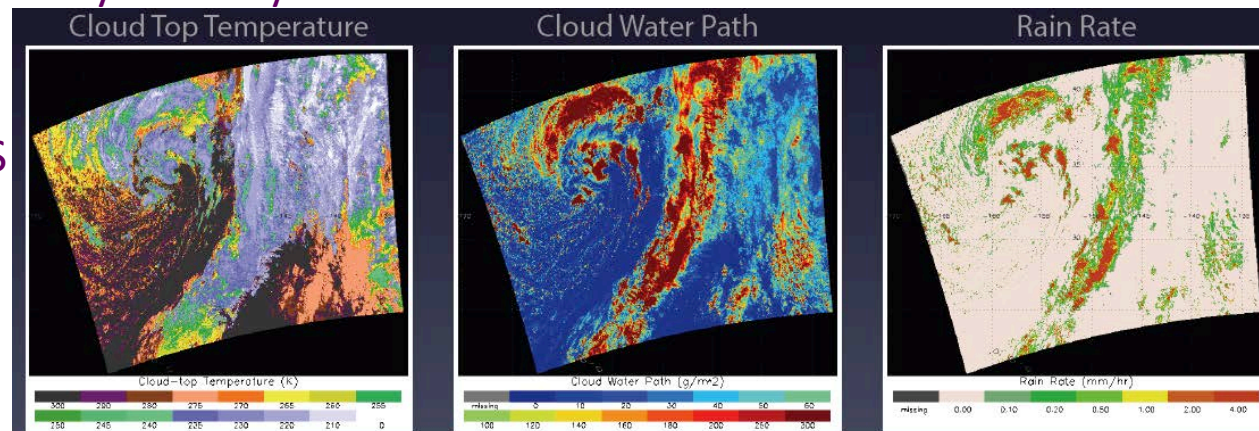
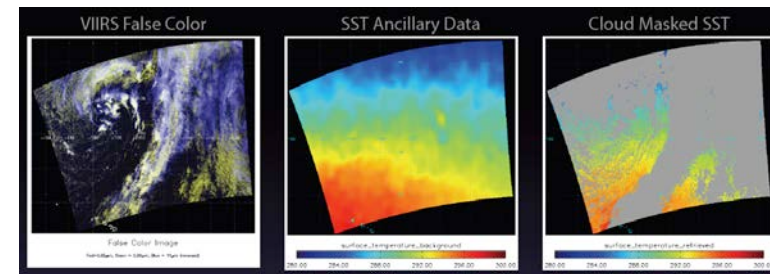
Heritage: Developed at NOAA/NESDIS/STAR and CIMSS/SSEC by Andy Heidinger, Andi Walther, Denis Botambekov, et al.

Satellites/Sensors: Suomi NPP VIIRS; Terra/Aqua MODIS; Metop-A/B AVHRR; NOAA-18/19 AVHRR.

Products: Cloud mask, type, fraction, and phase; cloud top height, pressure, temperature, and emissivity; cloud optical depth and effective radius; aerosol optical thickness; normalized difference vegetation index; sea surface temperature; all in HDF4 format.

Features:

- Multi-sensor common algorithm.
- Product files include cloud and surface products, calibrated observations, and many ancillary data fields (user controlled).
- CLAVR-x is the official NOAA cloud product for JPSS



CSPP Software Release: Microwave Integrated Retrieval System for ATMS, AMSU-A, and MHS Version 2.0 – 12 October, 2015

The Community Satellite Processing Package (CSPP) project is pleased to announce an updated release of the NOAA/NESDIS/STAR Microwave Integrated Retrieval System (MIRS)

What is New in CSPP MIRS Version 2.0:

- * Base NOAA software has been upgraded from v9.2 to v11.1.
- * NOAA-18, NOAA-19, Metop-A and Metop-B retrievals are now produced by default at the resolution of the MHS instrument, with AMSU-A data interpolated to match.
- * Product arrays stored as scaled integers now have different scaling attributes. The "scale" divisor (100) attribute has changed to a multiplier (0.01) named "scale_factor". This was to bring the product into Climate and Forecast (CF) standards compliance. The stored integer values have not changed, so that a brightness temperature of 273.15K, for example, is still represented by an integer value 27315.

Supported satellites, sensors, and data include:

- * Suomi NPP ATMS SDR (from CSPP or CLASS)
- * NOAA 18 and 19 AMSU-A and MHS Level 1B (from AAPP)
- * Metop-A and Metop-B AMSU-A and MHS Level 1B (from AAPP)

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.....

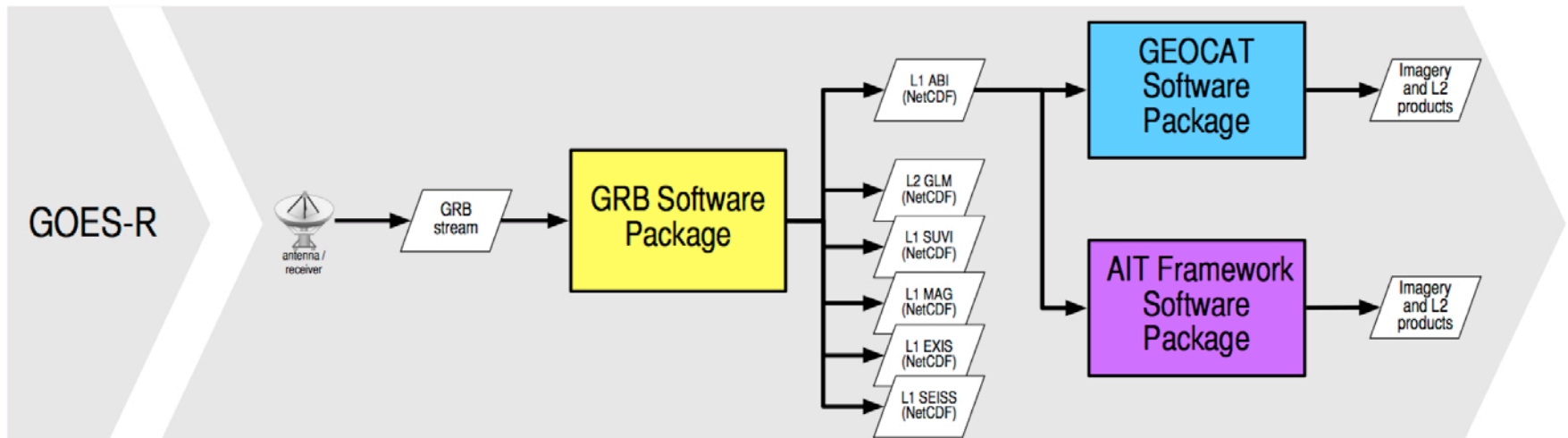
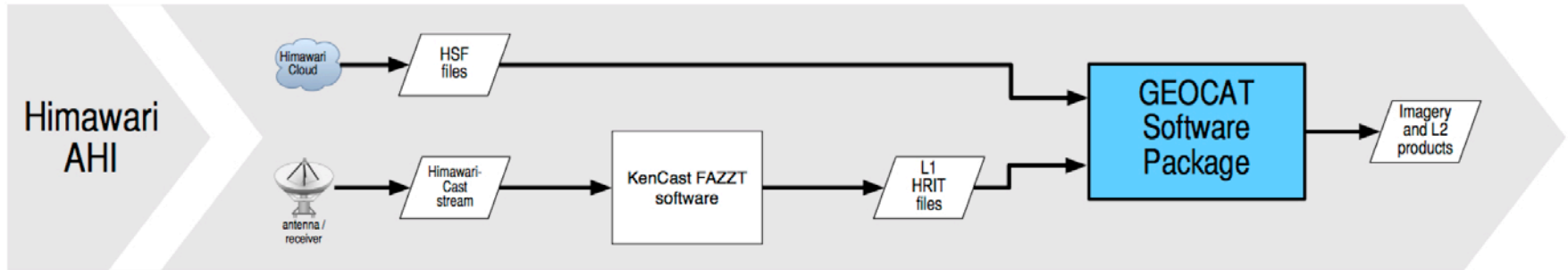
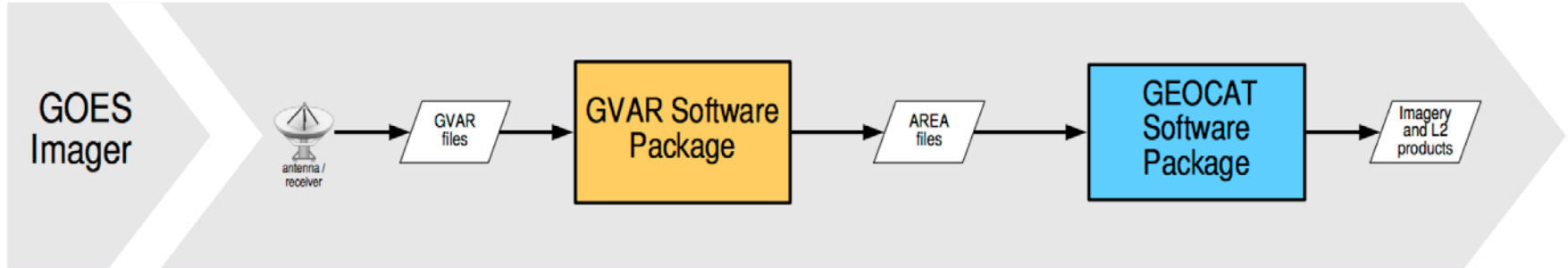
Experimental Products (not fully validated) created by MIRS include:

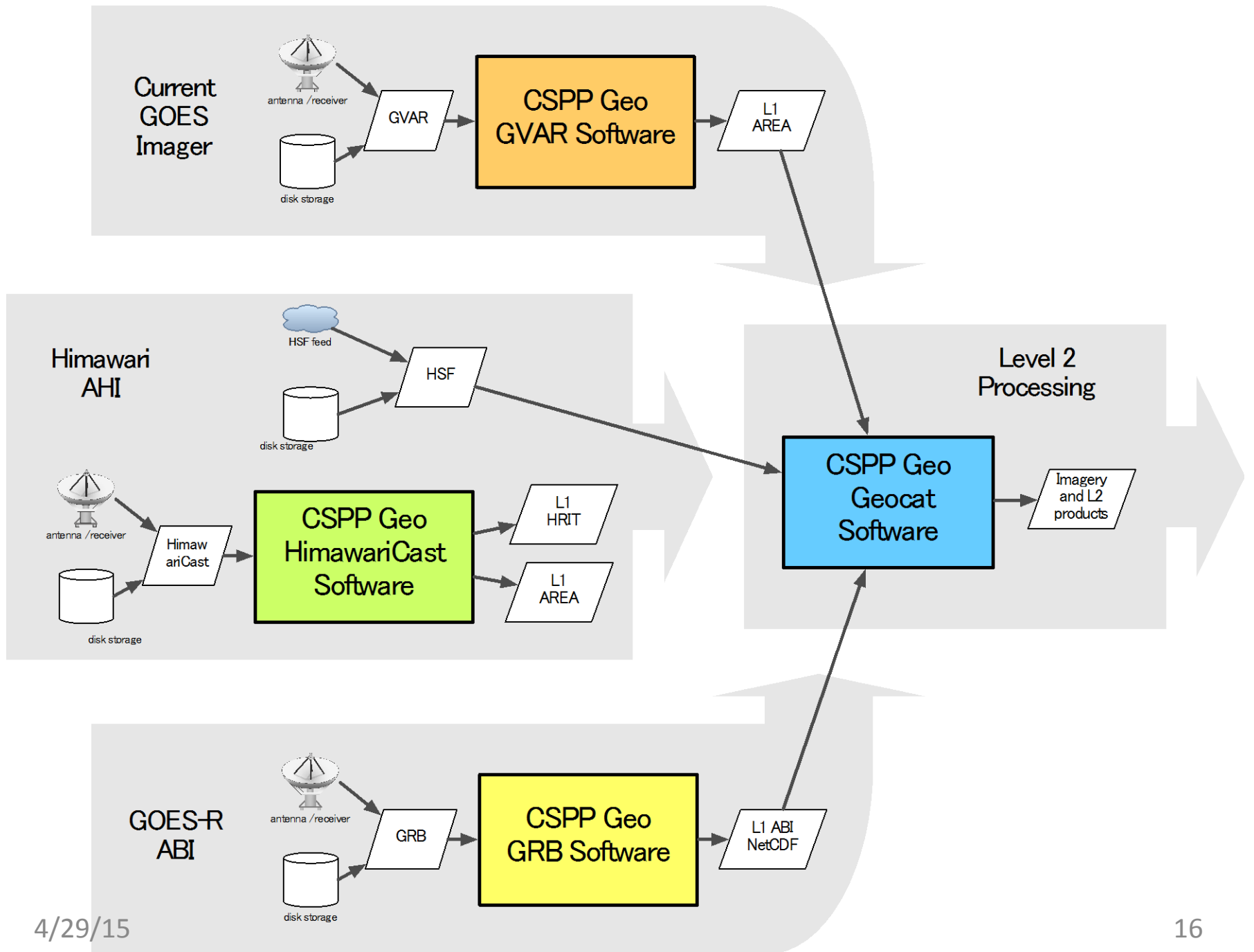
- * Cloud Liquid Water Profile (CLWP) over ocean.....

System requirements for the CSPP_MIRS v2.0 software are as follows:

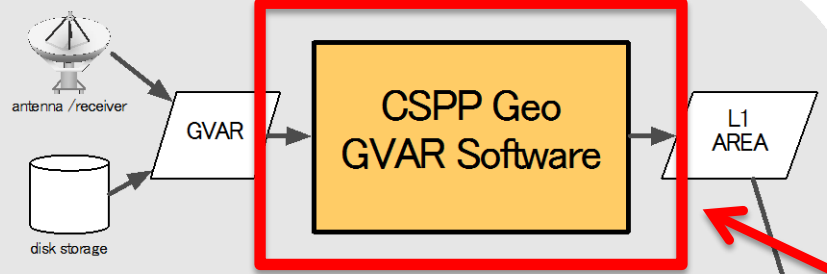
- * Intel or AMD CPU with 64-bit instruction support,
- * 1 GB RAM
- * CentOS-6 64-bit Linux (or other compatible 64-bit Linux distribution),
- * 1 GB of disk space (plus space for your own DB data and CSPP_MIRS products).

CSPP-GEO GOES-GVAR, ABI-GRB & AHI Processing S/W



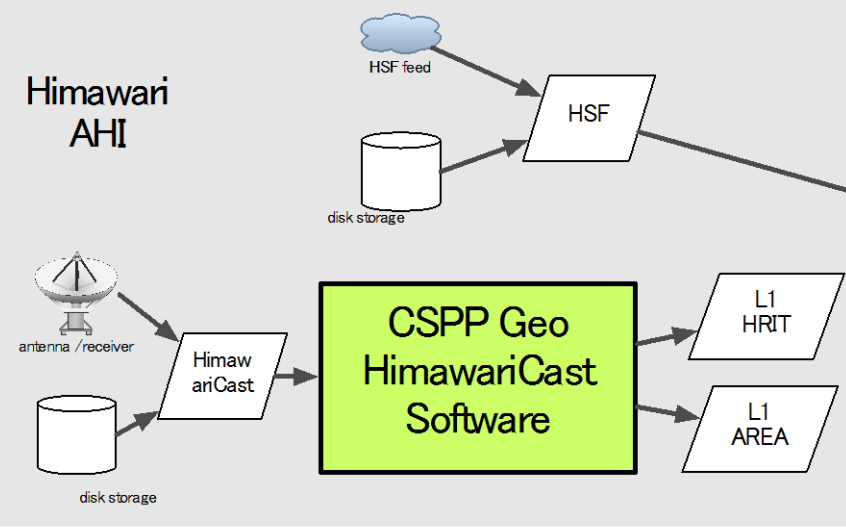


Current
GOES
Imager

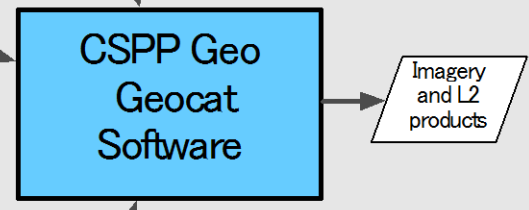


**Version 1.0
released**

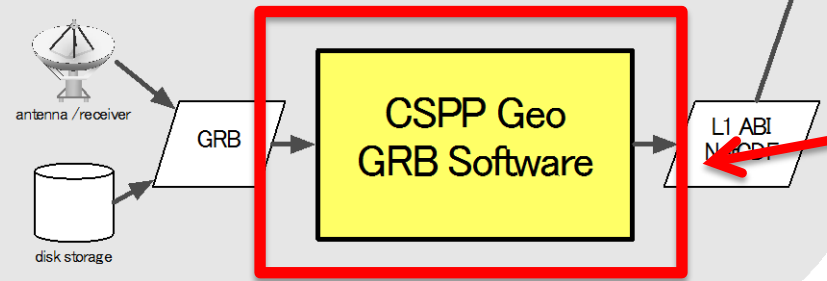
Himawari
AHI



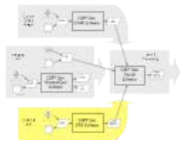
Level 2
Processing



GOES-R
ABI



**Version 0.1
released**



CSPP Geo GRB software

- Ingests raw GRB stream, extracts payloads from packets and constructs datasets
- Primarily new Python code, NASA RT-STPS used for ingest
- Tested with Harris GRB simulator, DOE data
- High data rate drives software design and hardware spec
- GRB V0.1 prototype released March 2015
 - Creates **ABI Level 1** and **GLM Level 2** datasets
 - Writes output to NetCDF4 files
 - Test dataset provided
- Software and documentation available from website:
<http://cimss.ssec.wisc.edu/csppgeo/>
 - Includes ICD describing planned upstream data interface
- Planning new releases ~every 3 months, eventually support **all GOES-R instruments**

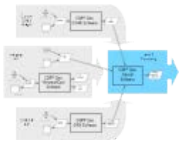
GRB minimum hardware requirements

12 core, 2.4 GHz CPU with 64-bit instruction support

32GB RAM

CentOS 6 64-bit Linux (or other compatible 64-bit Linux distribution)

100 GB disk space



CSPP Geo GEOCAT software

- Initial version will support **GOES Imager** and produce
 - cloud products (Andrew Heidinger, NOAA/STAR)
 - fog / low stratus (Mike Pavolonis, NOAA/STAR)
- Later versions will add support for **AHI** and **ABI**, add other L2 products and algorithm updates
- Ancillary data will be served from SSEC / CIMSS via the internet
- Design challenges:
 - Some L2 algorithms use data from previous timesteps; so all images must be mapped to same projection
 - High data rate will require parallelization and substantial hardware
- Initial release summer 2015

Estimated system requirements*

CPU: Intel Xeon E5 v2 “Ivy Bridge”, 20-core (2 x 10-core), 2.8GHz

RAM: 192GB

Disk: 14TB (does not include long-term storage)

* includes imagery, clouds, fog, winds and hurricane intensity estimation

CSPP Geo software release: GRB v0.3 Prototype

6 October, 2015

The CSPP Geo GRB Version 0.3 Prototype software package is now available for download. This is the final planned prototype release of software that will allow direct broadcast users to process data received from the GOES-R satellite after it is launched in 2016. The software is publicly available and free to use.

The main new capabilities included in this release are:

- Creates Level 1 products from the two remaining instruments, EXIS and SUVI. All six GOES-R instruments are now supported.
- Added options for improved configurability

Output is written to mission-standard NetCDF-4 files. Optionally, quicklooks can be generated from the ABI radiance product.

The minimum system requirements for the CSPP Geo GRB software are (same as previous releases):

- 12 core, 2.4 GHz CPU with 64-bit instruction support,
- 32GB RAM,
- CentOS 6 64-bit Linux (or other compatible 64-bit Linux distribution),
- 100 GB disk space

Root access may be needed on the target machine to configure network buffer settings to the recommended sizes.

A test data package is provided, including scripts that simulate the GRB data stream by sending artificial data for each of the supported instruments over two sockets. In our internal testing, the software was able to keep up with the expected GRB data rate without packet loss when running on the recommended hardware.

The future version 1.0 release will include performance optimizations, and any changes that are needed to process mission data. We plan to release version 1.0 beta before launch, and the final version 1.0 after any issues have been resolved and correct processing of mission data has been verified.

The CSPP Geo GRB software and documentation can be downloaded from:

<http://cimss.ssec.wisc.edu/csppgeo/>

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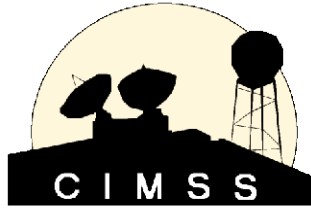
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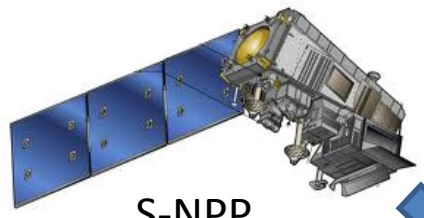


ISEE Scenario



1. Event is **seen, investigated & understood** with ISEE
2. Event on Earth: **fire, flood, volcano, algal bloom, pollution, fog, severe wx, & unusual phenomenon**
3. **S-NPP/JSPP** Satellite Observation – Primary
4. **Integrated with** other Data/Information
5. Direct Broadcast to SSEC & expand to NOAA DBRTN (Direct Broadcast Real-Time Network) – **Real Time**
6. **Processing** into **ISEE servers**
7. **Notification** pushed **to subscribers' cell phones**
8. **Sharing** of event: Web, App, Facebook, Twitter, email, blog

ISEE Synopsis 1st Gen

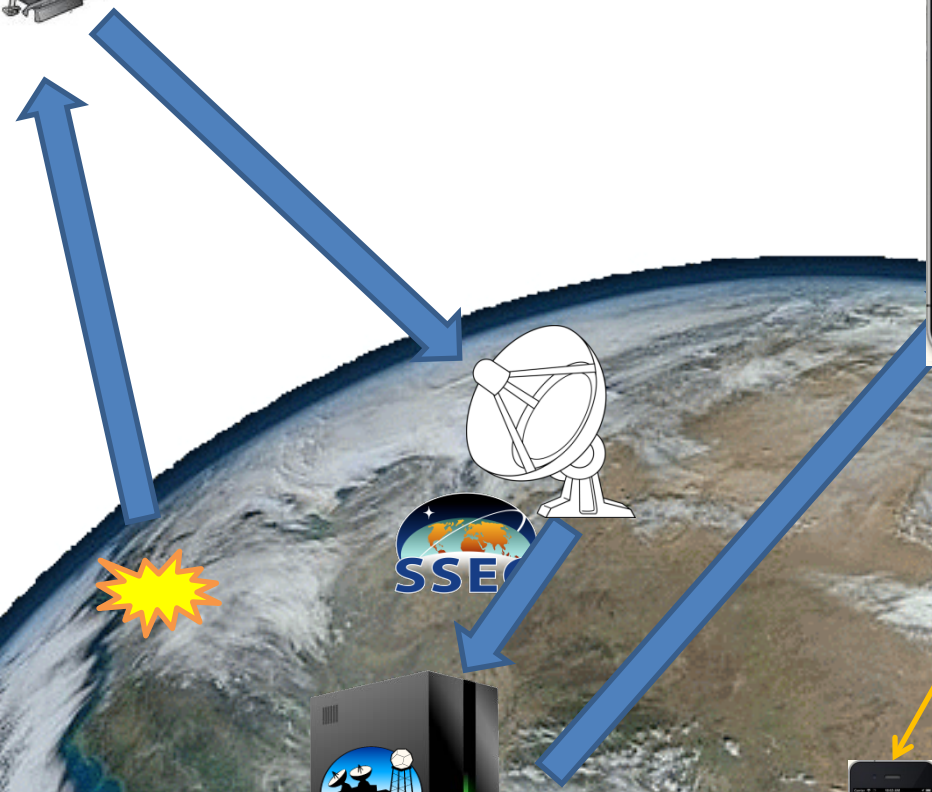
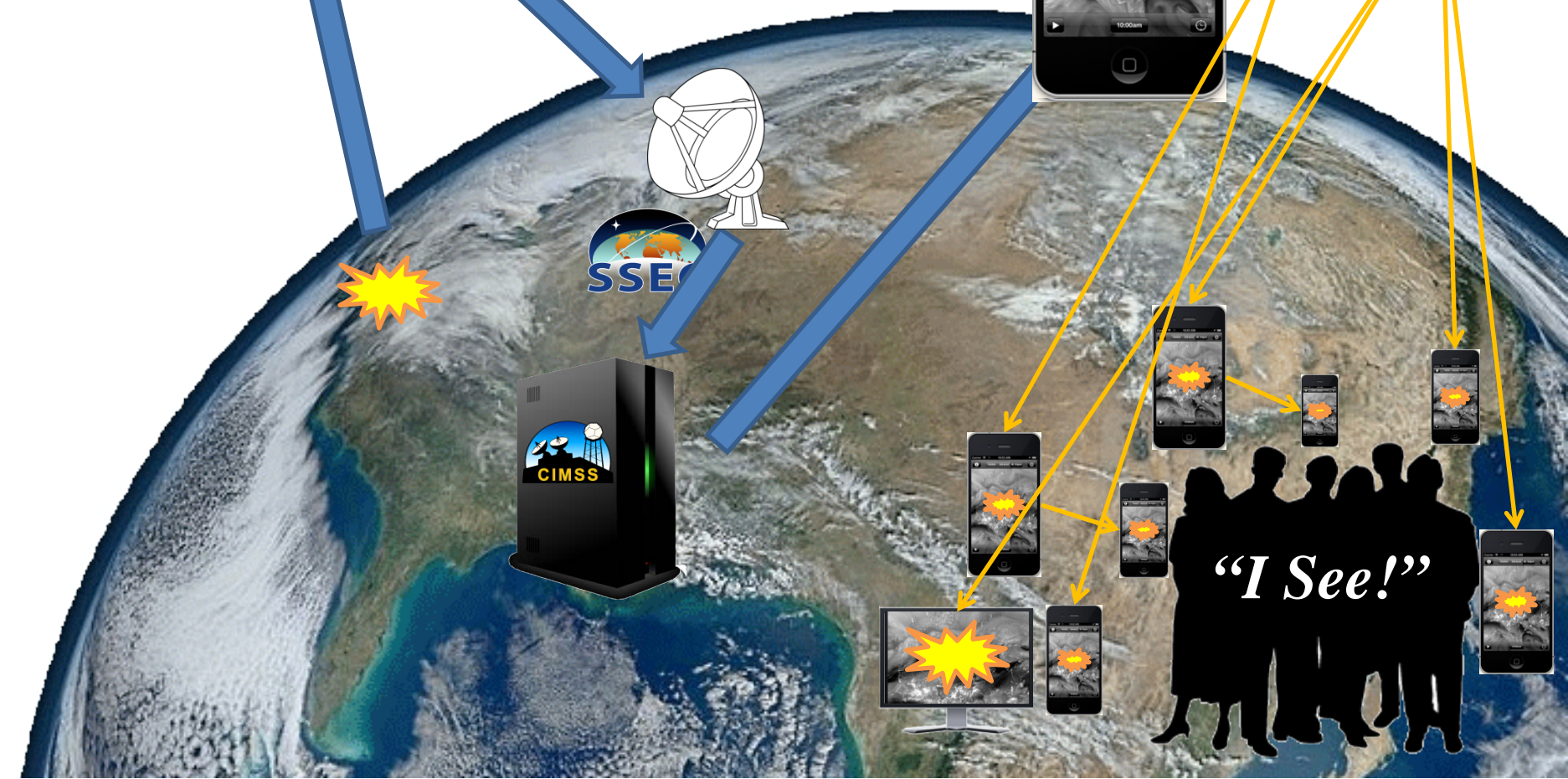


S-NPP

"I See!"

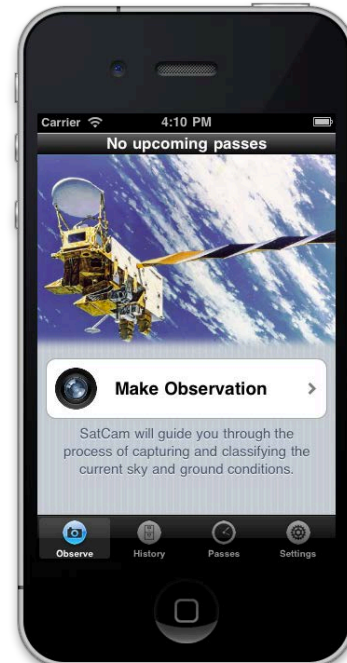


"I See!"

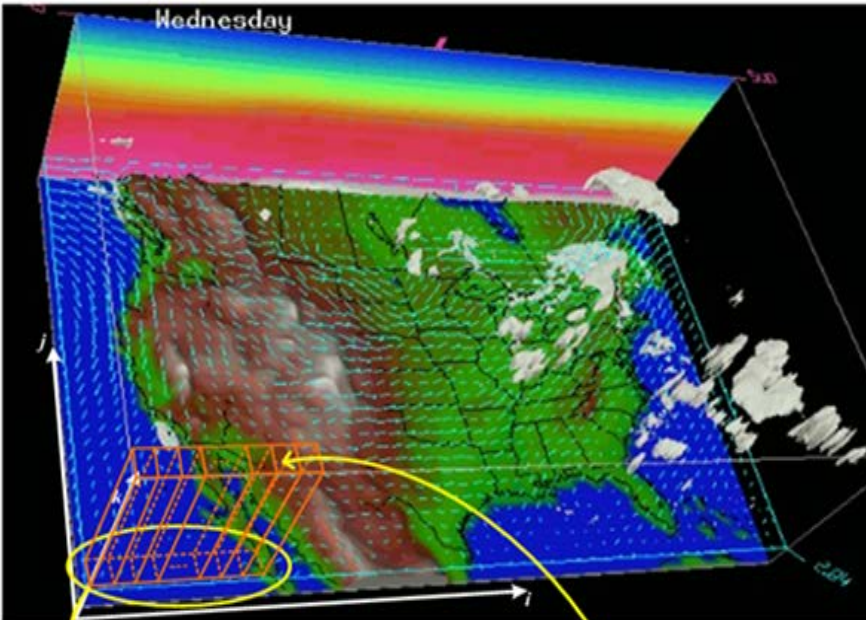


ISEE: Greater than the sum of its parts

- **Data** processing – DB, Data Center, and RealEarth Servers
- Social Media **Sharing** – CIMSS Blog, Twitter, via RealEarth Browser
- **Mobile** display of data – WxSat
- **Notifications** – SatCam
- **Simplification** – (all the above)

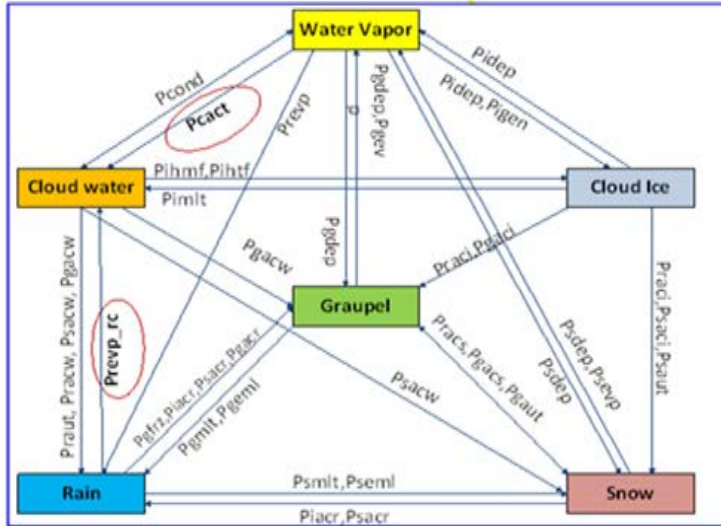


CUDA-based GPU accelerated WRF modules



Blockdim(64, 1, 1);

i dim = 433
j dim = 308
k dim = 35



WRF Module name	Speedup vs. one thread on 1.8Ghz Sandy Bridge (gfortran v.4.6.2)
Single moment 6-class microphysics	500x
Eta microphysics	272x
Purdue Lin microphysics	692x
Stony-Brook University 5-class microphysics	896x
Betts-Miller-Janjic convection	105x
Kessler microphysics	816x
New Goddard shortwave radiance	134x
Single moment 3-class microphysics	331x
New Thompson microphysics	153x
Double moment 6-class microphysics	206x
Dudhia shortwave radiance	409x
Goddard microphysics	1311x
Double moment 5-class microphysics	206x
Total Energy Mass Flux surface layer	214x
Mellor-Yamada Nakanishi Niino surface layer	113x
Single moment 5-class microphysics	350x
Pleim-Xiu surface layer	665x ²⁵

Accelerator-based (GPU/MIC) WRF model development at SSEC/CIMSS UW-Madison

- Will greatly benefit high resolution regional forecasting real-time capability
- Intel awarded SSEC a two-year grant to develop Intel MIC Xeon Phi Coprocessor based WRF using open ACC common architecture
 - SSEC becomes one of the Intel Parallel Computing Center (IPCC)
 - Open Source with minimum changes to WRF existing code structure
 - Less time consumption to adopt/adapt
 - Projected speedup is about <10
- NVIDIA, world largest GPU chip maker, is considering funding SSEC to develop a GPU-CPU Hybrid WRF prototype using CUDA architecture
 - CUDA based unique architecture
 - Need time consuming code porting & optimization
 - Projected speedup is about ~100
- IBM Power architect, WRF experiment with POWER CPU+ NVIDIA GPU
- TQI, GPU/CUDA based WRF for Low Latency Wx Forecast applications

The Advancement of Community Based LEO and GEO Satellite Processing and Application Packages

Summary

With strong support from NASA & NOAA support, SSEC/UW **is committed to fully support NASA & NOAA Direct Readout/Broadcast activities to:**

- Maintain existing DB Processing Packages (i.e. IMAPP) for MODIS and AIRS and to develop new capabilities/applications and package for NPP/JPSS (CSPP, LEO/GEO), & METOP (L1-L2 PP) systems.
- Upgrade DB real-time processing system efficiency, functions, and effort in enhancing Numerical Weather Prediction (DBCAS->GPU-WRF) and air quality model (IDEA-I) and other applications to directly assimilate real time products (i.e. clouds, water vapor, and aerosol) to optimize broad use of DB products.
- Support NOAA NNWS offices & Real-Time DB users in the efficient and broad use of the current and future polar orbiting satellite data/information.
- Offer DB users training workshops in processing algorithms, S/W package operations and real-time applications
- Organize CSPP/IMAPP Users' Group meeting as often as needed
- Innovate to support JPSS/GOES-R program goal and program Scientists' vision

The Advancement of Community Based LEO and GEO Satellite Processing and Application Packages

Thank you for your attention
Questions are welcomed

CSPP Team

CSPP LEO:

**Allen Huang, Liam Gumley, Kathy Strabala, Scott Mindock,
Ray Garcia, Graeme Martin, Geoff Cureton, Elisabeth Weisz,
Nadia Smith, Nick Bearson, James Davies, Jessica Braun**

CSPP GEO:

**Liam Gumley, Graeme Martin, Kathy Strabala, Scott
Mindock, Geoff Cureton, Jessica Braun, Nick Bearson, Ray
Garcia, Tommy Jasmin**