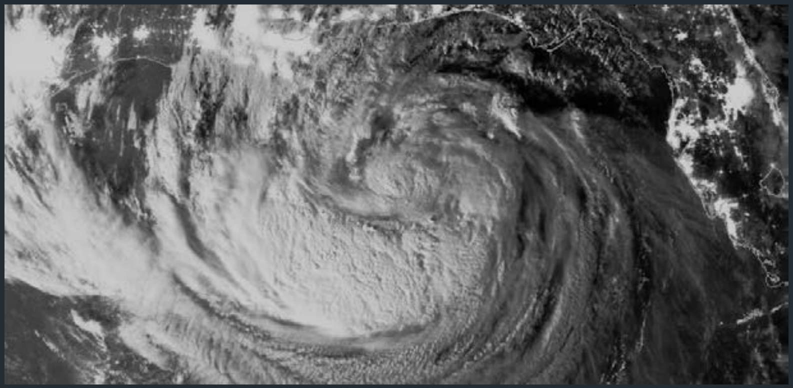

Applications with the VIIRS Day Night Band in CLAVR-x CSPP

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Outlook

- CLAVR-x in CSPP
- Day/Night Band Lunar reflectance model
- Nighttime cloud detection improvements
- Optical properties: The Nighttime Lunar Cloud Optical and Microphysical Properties (NLCOMP)
- Derived atmospheric parameters

Thank you…

- New retrieval work for NLCOMP work is funded by NOAA JPSS Risk reduction project.
- PATMOS-x originally funded by NOAA/NESDIS/STAR and the NOAA PSDI Program.
- VIIRS work funded by the JPSS Cal/Val Program.
- The CSPP team to have CLAVR-x included.
- Users for feedback

CSPP Software Requirements (from Liam's talk in 2013)

CSPP software must:

- Create useful products for the DB community,
- Include up-to-date algorithms,
- Be pre-compiled for 64-bit Linux,
- Be easy to install and operate,
- Include test data for verification,
- Have prompt user support,
- Run efficiently on modest hardware.

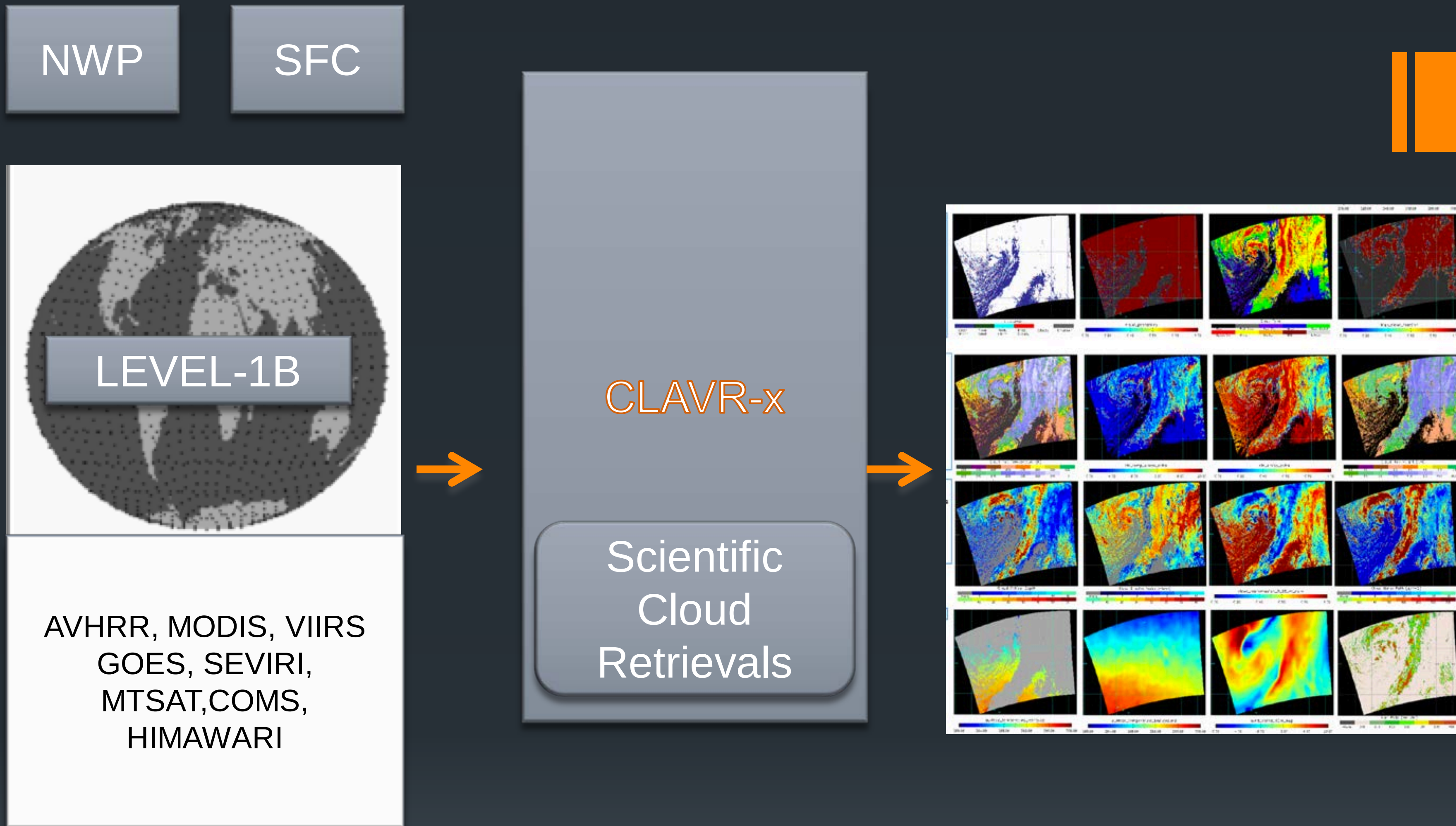
CLAVR-x in CSPP LEO

Current CSPP LEO Software

1. Suomi NPP CrIS, VIIRS and ATMS SDR (geolocation and calibration)
2. Suomi NPP VIIRS EDR (cloud mask, active fires, surface reflectance, NDVI, SST, aerosol optical thickness)
3. CrIS, IASI, and AIRS Dual Regression Retrieval
4. VIIRS SDR GeoTIFF and AWIPS Reprojected Imagery
5. Microwave Integrated Retrieval System (MIRS)
6. Clouds from AVHRR Extended (CLAVR-x)
7. HYDRA2 Multispectral Data Analysis Toolkit
8. Suomi NPP Imagery EDR (projected imagery for AWIPS)

CLAVR-x

- Stands for *Cloud from AVHRR-extended* and is a processing package for cloud retrievals.
- Official operational NOAA retrieval for AVHRR, GOES and JPSS/VIIRS
- PATMOS-x is the climate data set generated by CLAVR-x. Official NCDC cloud climatology.
- CLAVR-x in CSPP: Provides imager cloud products from LEO satellites (AVHRR, VIIRS, MODIS).
- Individual cloud retrievals (ACHA and DCOMP) are also part of CSPP-GEO.

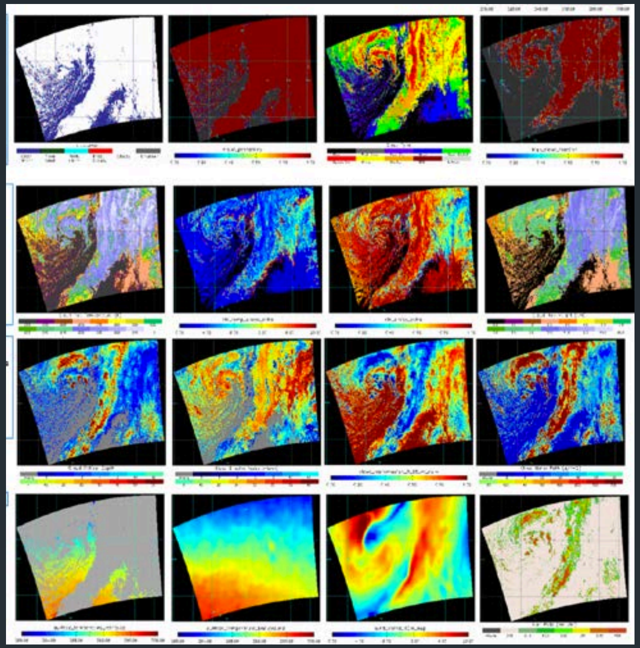

NWP
SFC
LEVEL-1B
AVHRR, MODIS, VIIRS
GOES, SEVIRI,
MTSAT,COMS,
HIMAWARI
CLAVR-x
Scientific
Cloud
Retrievals

Clear-sky estimates

SFC

AVHRR, MODIS, VIIRS
GOES, SEVIRI,
MTSAT,COMS,
HIMAWARI

→ CLAVR-x →



DCOMP

Bayes Mask

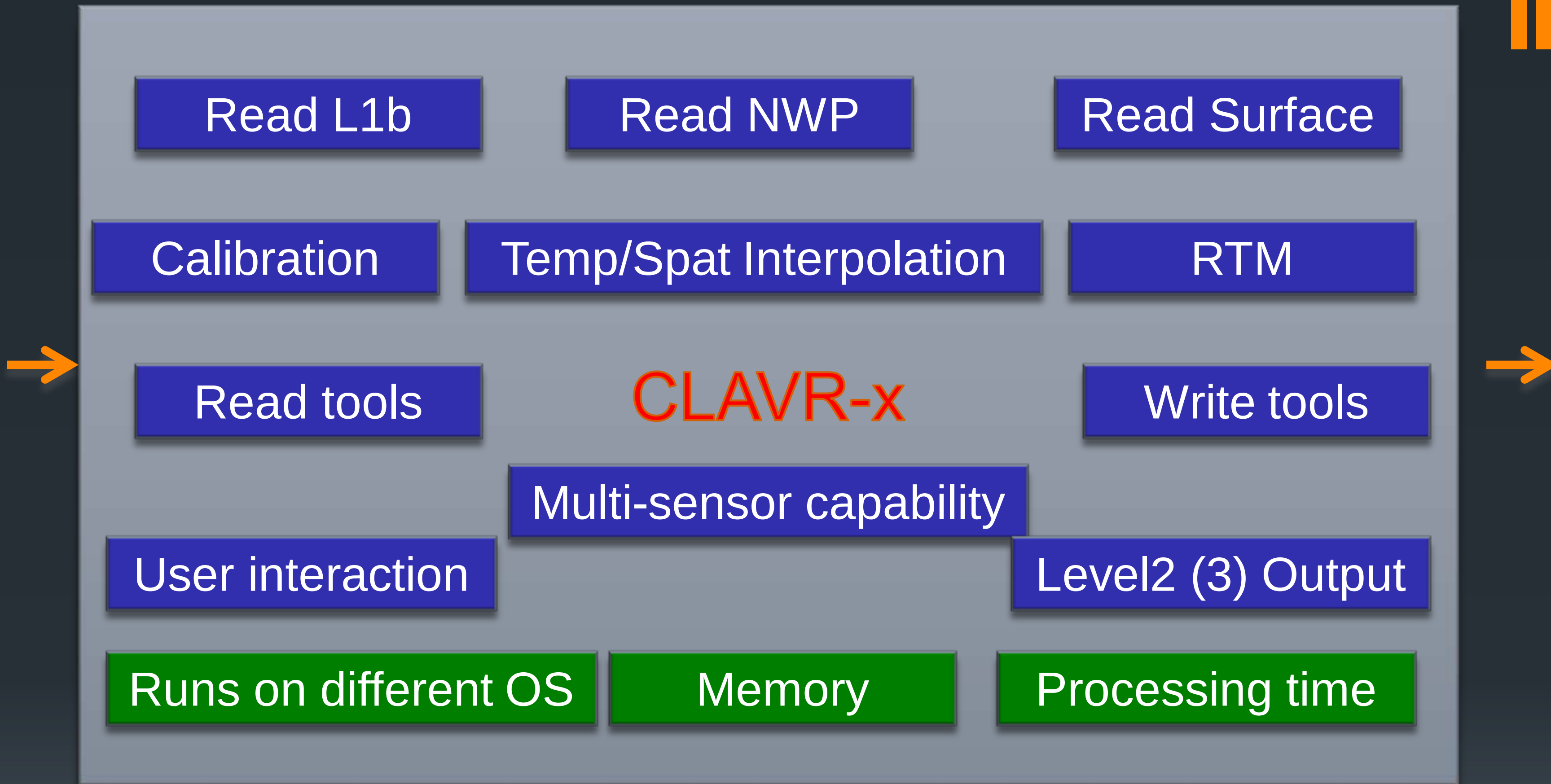
ACHA

Advantage of Decoupling:

- Development
- Testing
- Portability

DCOMP and ACHA are part of CSPP-GEO, NOAA Framework and other processing systems with exact same source code

So what is CLAVR-x then? -- "Service" module..



Many technical and scientific decisions to make! User will want to control the decisions via configuration files.

New Features in the Upcoming CLAVR-x

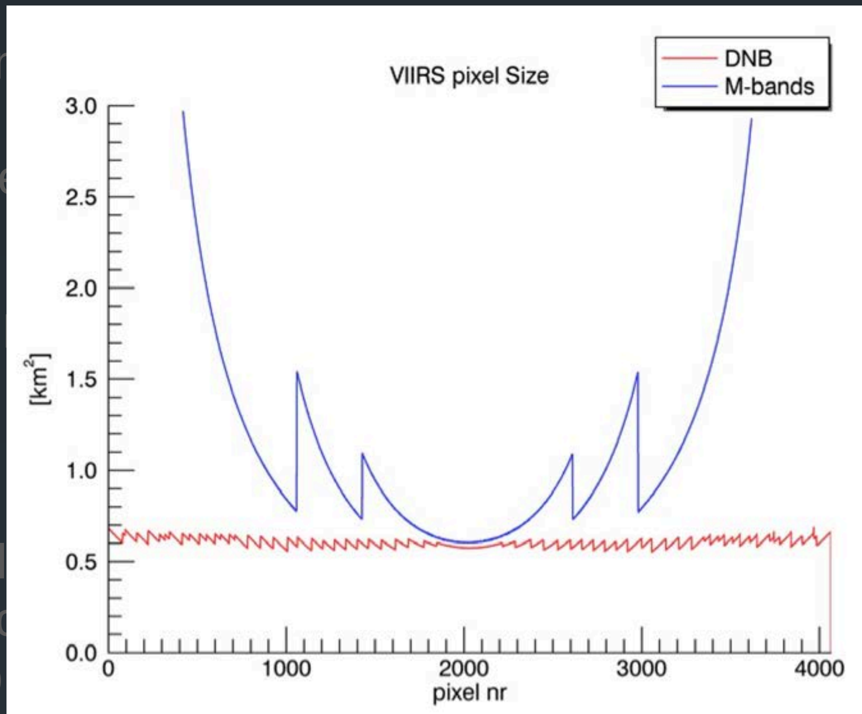
- Many decisions to make inside CLAVR-x. 3 CLAVR-x configuration files are used:
  - Input configuration
  - Processing configuration
  - Output configuration
- These files became messy over decades due to higher complexity. We introduce new **expert level mode**:
  - If you set expert mode = 0, CLAVR-x makes all option decisions for you.
  - User manual describes default values.
  - Higher values of the expert mode setting allow for more user optimization.
- Added channel infrastructures to support HIMAWARI-8/AHI and GOES-R/ABI and also multi-sensor data (e.g. HIRS/AVHRR)
- RTM (PFAAST) routines consolidated into one.
- Improved DNB products…

DNB and moon light for quantitative cloud retrievals in CLAVR-x

- Moon light is about 250 000 dimmer than sun (~10^{-5} W m^{-2} sr^{-1} μm^{-1} at full moon)
- Current sensors (MODIS, AVHRR, etc..) in visible spectrum are only able to detect signals from around 10^{0}-10^{2} W m^{-2} sr^{-1} μm^{-1}
- DMSP-OLS offered low-light images, but the data were not calibrated, with low information depth (6-bit) and low spatial resolution.
- DNB VIIRS onboard NPP-Soumi is the first channel which is both, highly sensitive to low-light in visible spectrum and providing a sufficient data depth (down to 10^{-5}W m^{2} sr^{-1} as a band average with a 14-bit resolution)
- DNB spatial resolution is uniformly 740m along and across the swath from nadir to the edge of the swath.
- DNB has to be collocated with VIIRS M-band channels those pixels grow from nadir to the edge (up to 5 times larger pixels) for retrievals.

DNB and moon light for quantitative cloud retrievals

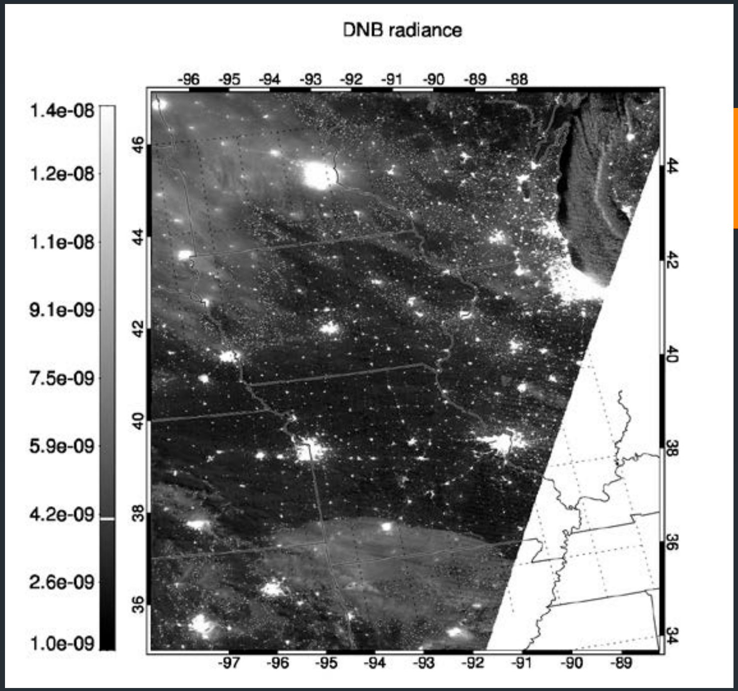
- Moon ... n sun (~10^{-5} W m^{-2} sr^{-1} μm^{-1} at fu...
- Curre... n visible spectrum are only able ... 0^{2} W m^{-2} sr^{-1} μm^{-1}
- DMS... the data were not calibrated, with ... w spatial resolution.
- DNB ... st channel which is both, highl... ectrum and providing a suffic... sr^{-1} as a band average with a 14-b...

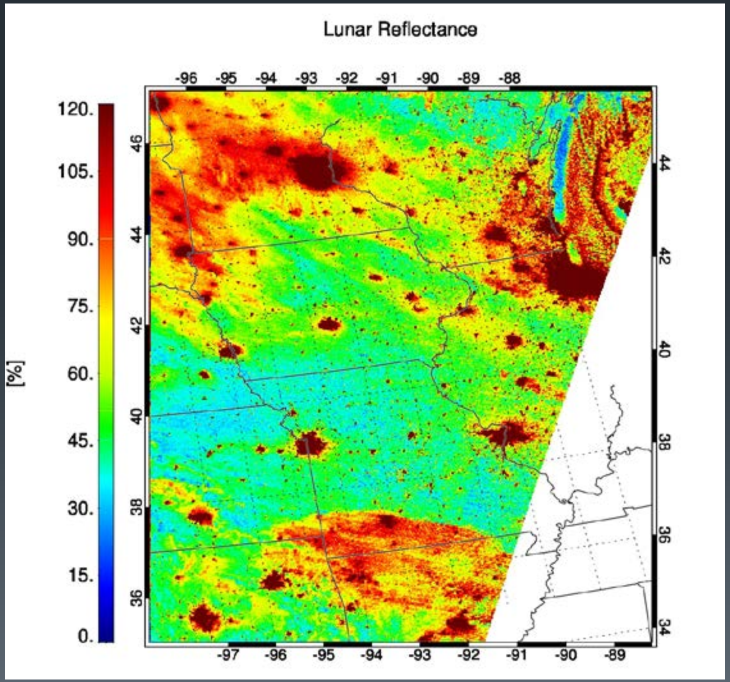


- DNB spatial resolution is uniformly 740m along and across the swath from nadir to the edge of the swath.
- For multi-channel retrievals the DNB has to be collocated with VIIRS M-band channels those pixels grow from nadir to the edge (up to 5 times larger pixel size) for retrievals. (We do a nearest-neighbor , but improved approaches may be possible)

From DNB radiance to lunar reflectance

- The radiance to reflection retrieval was developed by Steven Miller CIRA
- In contrast to solar irradiance the computation of down-welling lunar irradiance is a complex task due to many components which have to be considered:
  - Lunar phase
  - Lunar spectral surface albedo
  - Moon-Earth-Sun orbital geometry
  - Lunar zenith angle



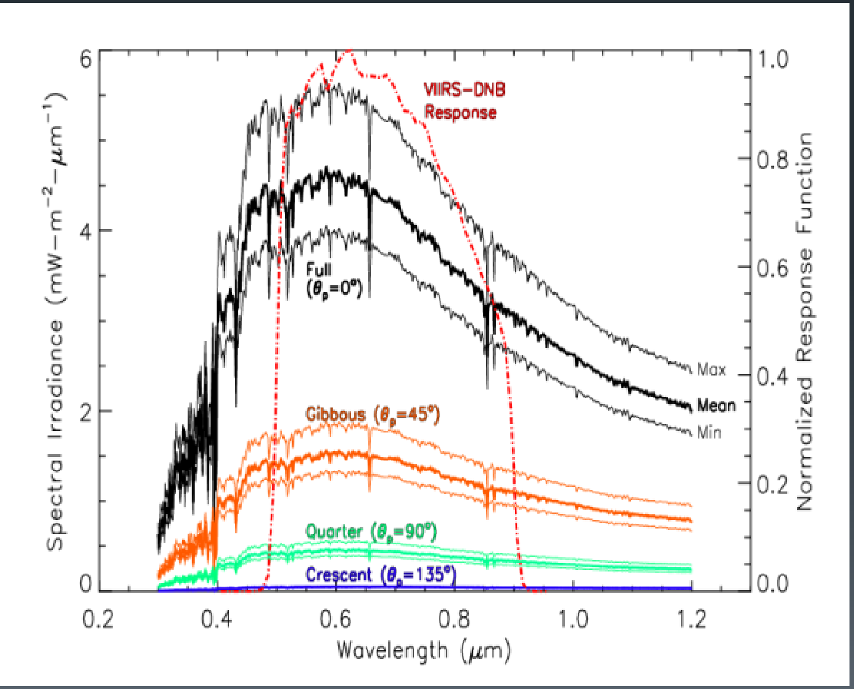


From DNB radiance to moon light reflectance

- The radiance to reflection retrieval was developed by Steven Miller and colleagues at CIRA
- In contrast to solar irradiance the computation of down-welling lunar irradiance is a complex task due to many components which have to be considered:

$$R_{lun} = \pi L / (\mu_M E_M)$$

  - Lunar phase
  - Lunar spectral surface albedo
  - Moon-Earth-Sun orbital geometry
  - Lunar zenith angle
  - ..



From Miller and Turner 2009

From DNB radiance to moon light reflectance

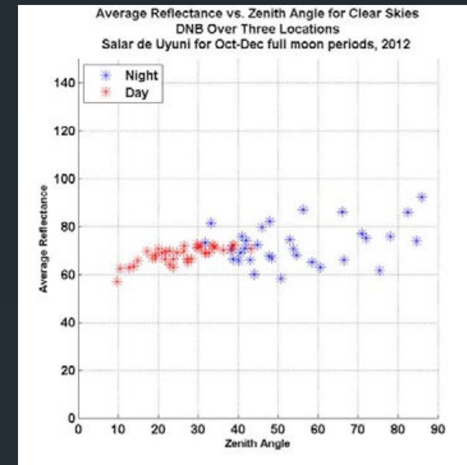
- The radiance to reflection retrieval was developed by Steven Miller and colleagues at CIRA
- In contrast to solar irradiance the computation of down-welling lunar irradiance is a complex task due to many components which have to be considered:
  - Lunar phase
  - Lunar spectral surface albedo
  - Moon-Earth-Sun orbital geometry
  - Lunar zenith angle

We expect an overall uncertainty in lunar reflection from 5% to 12% in respect to moon phase.

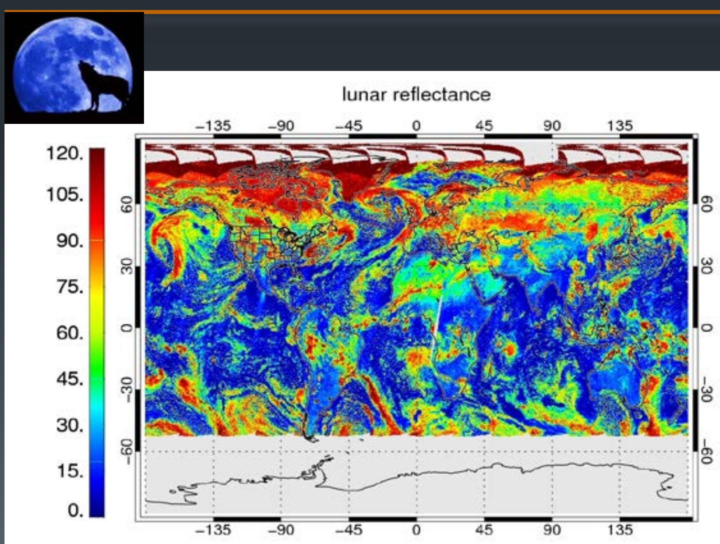
complex moon surface albedo

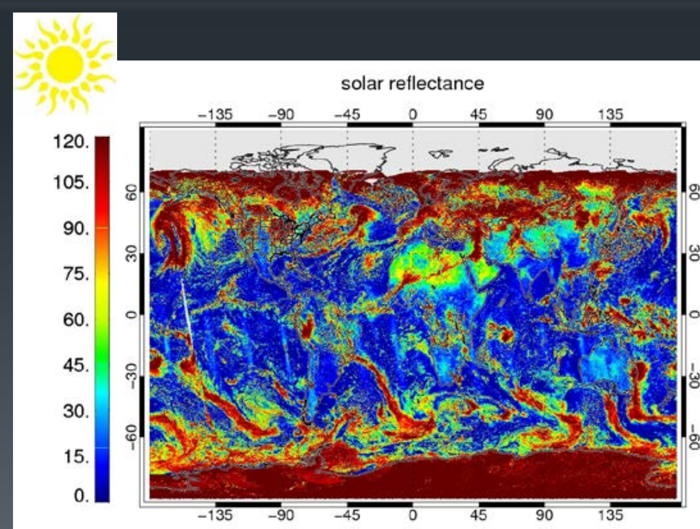
Consistency of lunar and solar reflectance

Lunar and solar reflection results for cloud-free scenes at the Salar de Uyuni salt flat (“Salzpfanne”) in Bolivia.



Results show agreement which is consistent with assumed uncertainties of the lunar model.

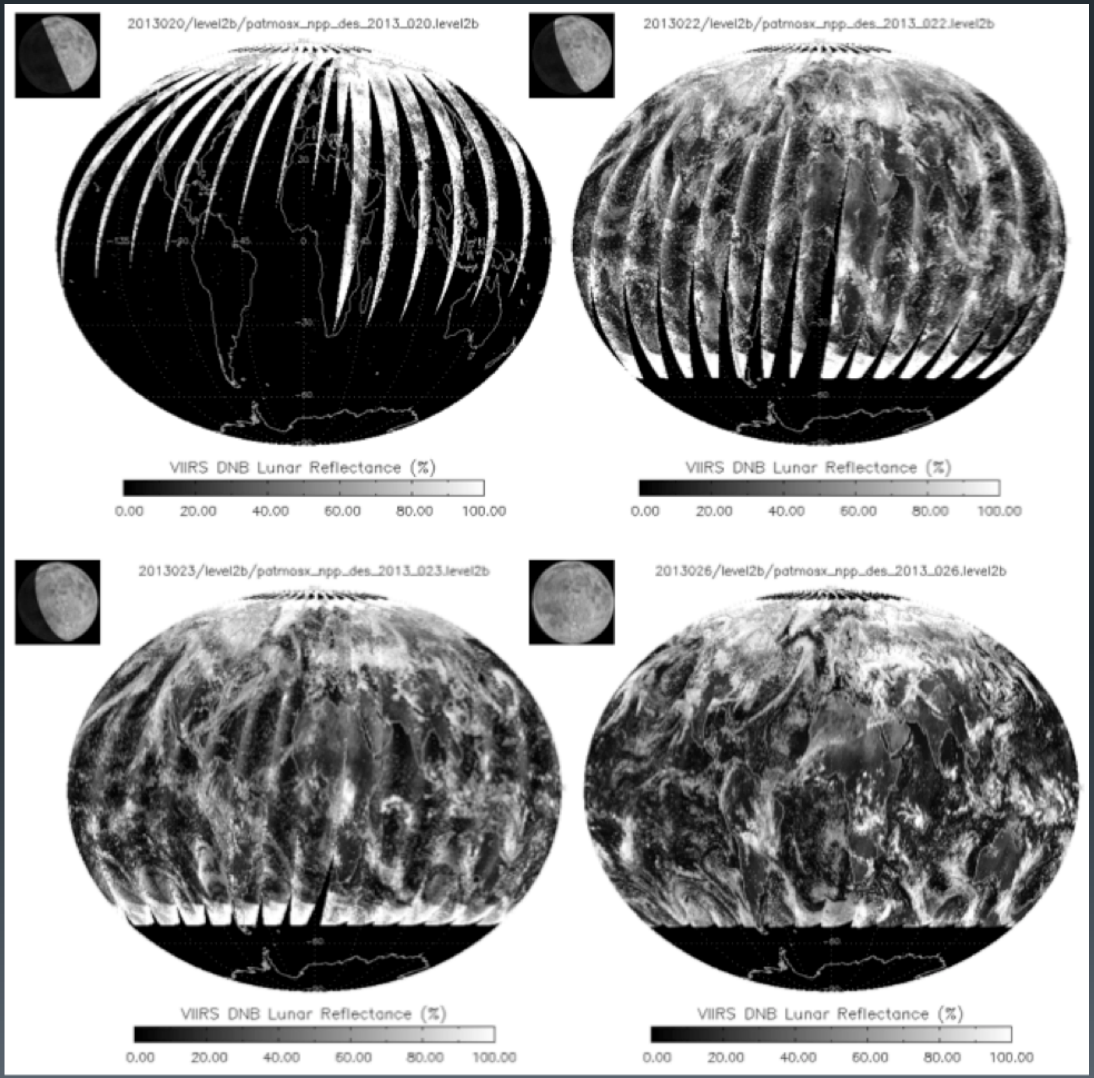




Global daily composites show also good agreement

Global coverage of calibrated lunar reflectance

- Lunar cycle is about 29.5 days
- Lunar reflectance requires filtering of solar zenith (19 below the horizon)
- Sufficient global lunar reflectance coverage is ~70% of nighttime
- Winter poles have coverage most of the time

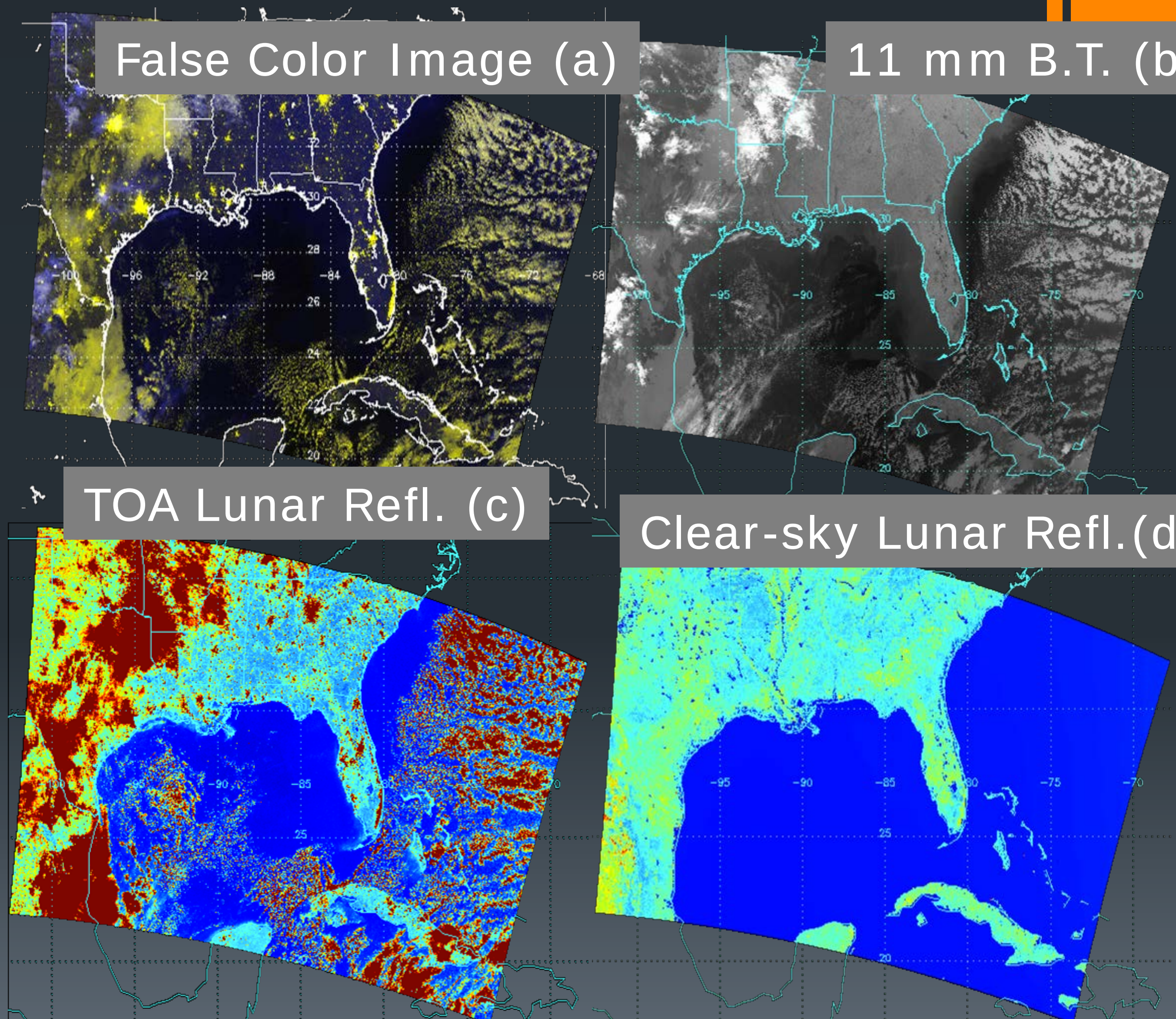


Using VIIRS DNB Lunar Reflectance for Cloud Detection

- CLAVR-x has been modified to use the lunar reflectance in its naïve Bayesian Cloud Detection Algorithm.
- Clear-sky estimate computed using combination of 0.63 and 0.86 μm MODIS surface reflectance.
- Cities detected using DNB radiance threshold. Gas Flare detection still being developed.
- Auroras have not proven to be problematic and no explicit treatment is included yet. Auroras are dimmer than cities and offer no thermal signal.

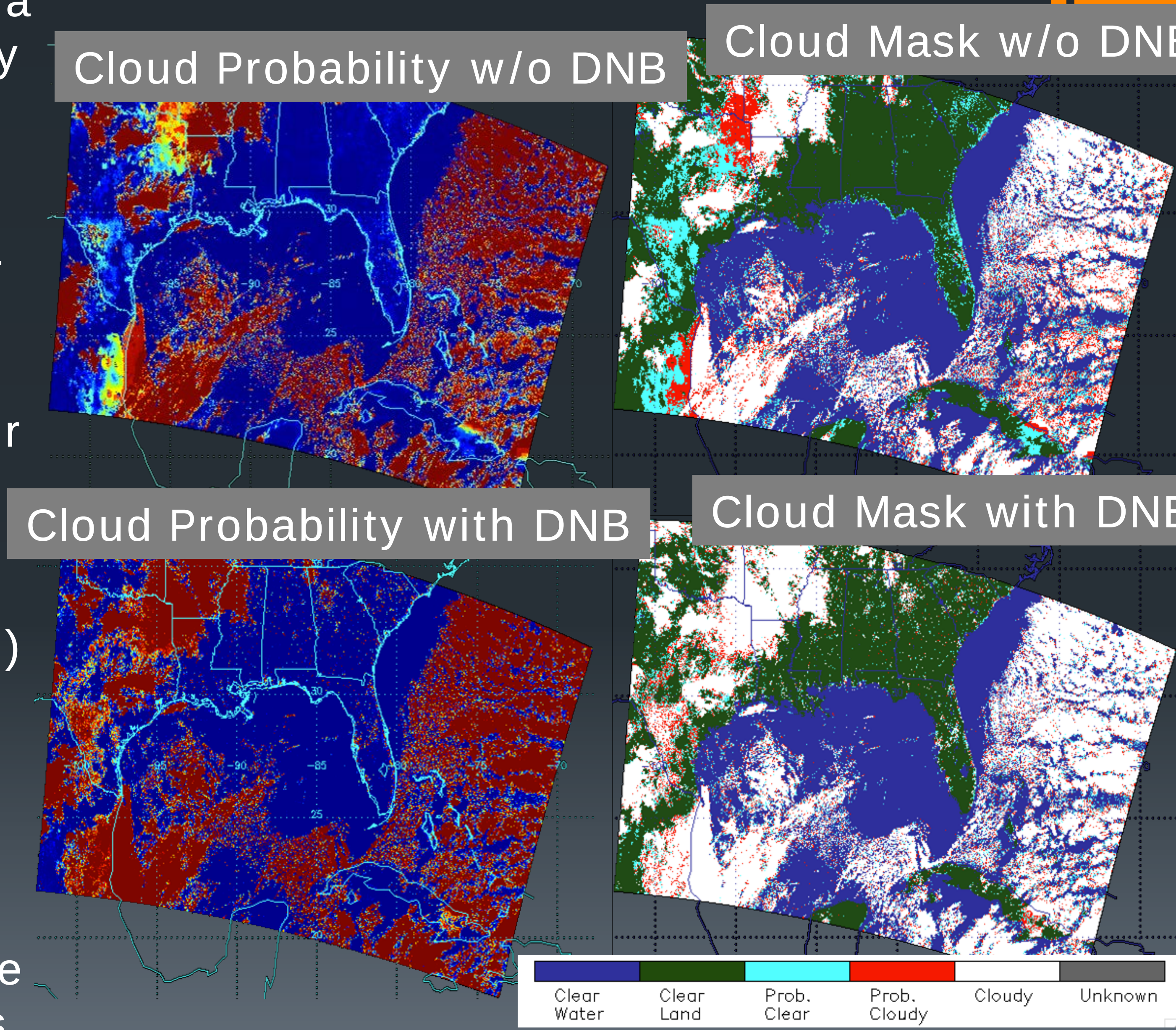
Use of DNB in CLAVR-x Mask

- The data on the right is from the Miami SNPP VIIRS data on March 29, 2013.
- False color image (a) and 11 µm BT (b) shown for reference.
  - Cloud mask uses difference in observed (c) and computed clear-sky (d) lunar reflectance.
- Note fog over Texas which is nearly invisible in 11 µm BT.

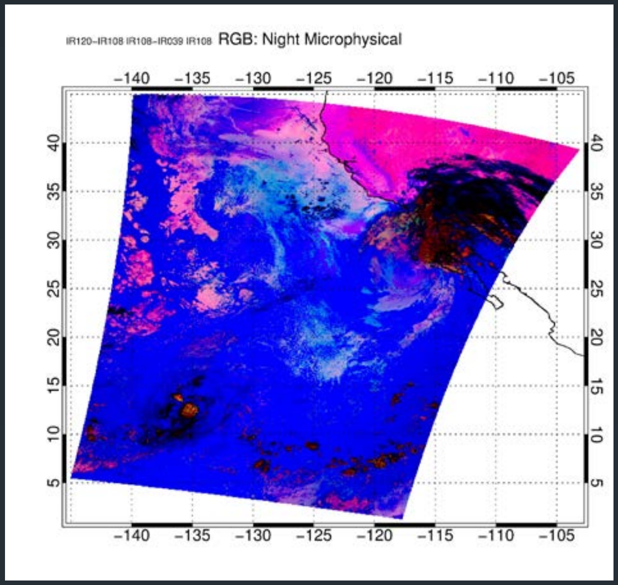


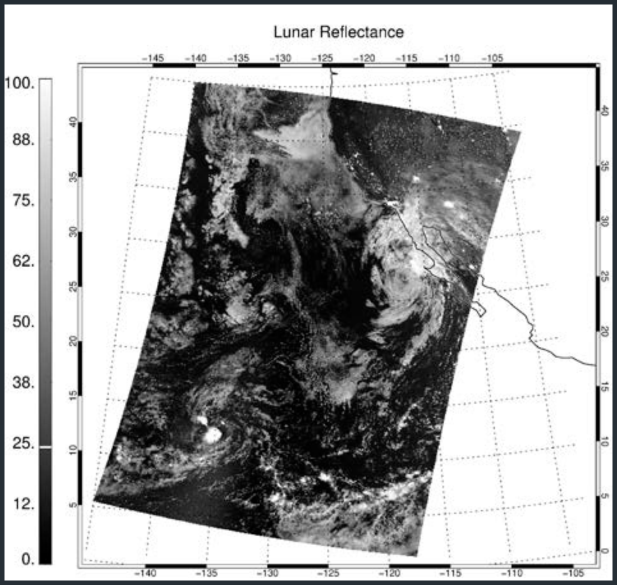
Impact of DNB on CLAVR-x Cloud Mask

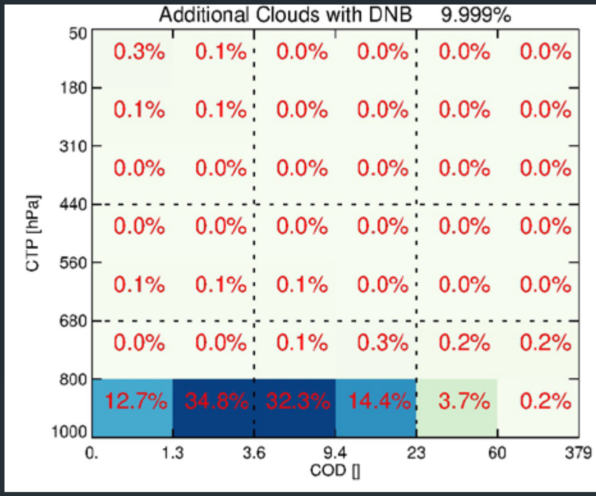
- CLAVR-x makes a cloud probability (0-1) and a 4-level mask.
- DNB has major impact in detecting low level clouds over Texas.
- Impacts over ocean are (here) less but noticeable at cloud edges.
- For the mask, this means more cloudy and less

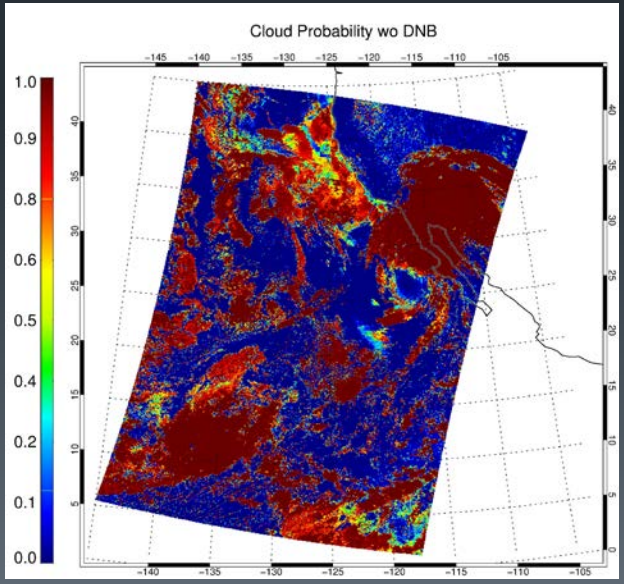


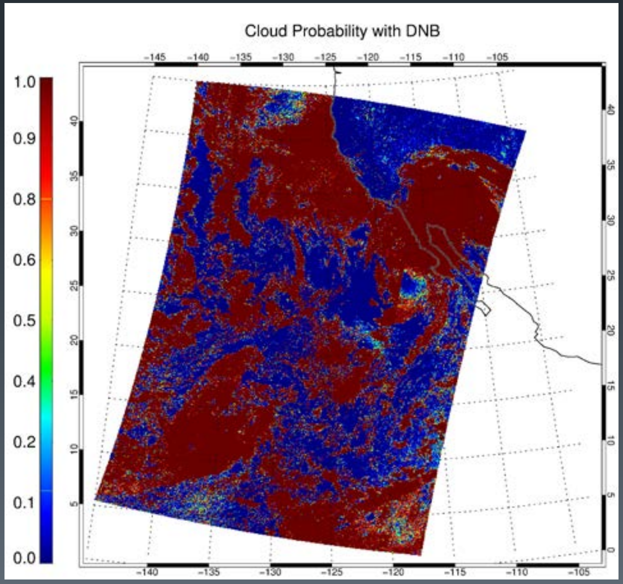
Cloud Mask improvement with DNB

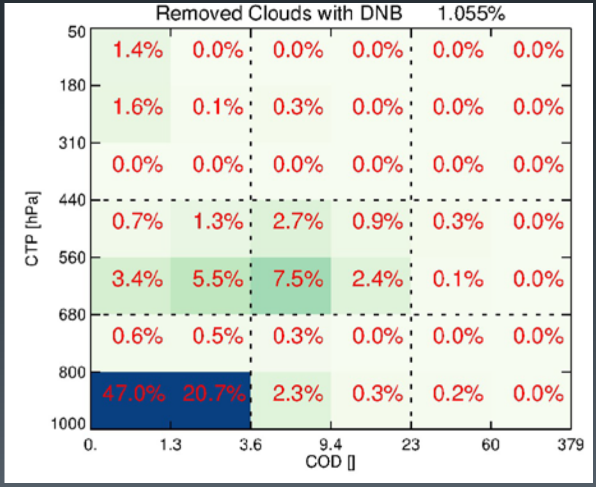












The Nighttime Lunar Cloud Optical and Microphysical Properties (NLCOMP) retrieval

- The new Nighttime Lunar Cloud Optical and Microphysical Properties retrieval (NLCOMP) is an extension of the Daytime COMP (DCOMP) retrieval to use moonlight reflectance for the first satellite-based quantitative cloud properties retrieval during night.
- Retrieves Cloud Optical Thickness and Effective Radius, those can be used to derive cloud water path.
- Input parameter: DNB visible lunar reflectance, M-12,M-15,M-16 brightness temperatures
- NLCOMP products has higher uncertainty than DCOMP due to higher uncertainty of lunar reflectance in contrast to solar reflectance.
- Limitations: City lights, ships, diffuse lights, etc..

Reference: Walther, Miller and Heidinger (2013): The Expected Performance of Cloud Optical and Microphysical Properties derived from Suomi NPP VIIRS Day/Night Band Lunar Reflectance. JGR

Daytime retrieval (DCOMP)

- Standard approach: simultaneous measurements in a visible and in an absorbing N-IR channel
- Use of solar reflectance because solar irradiance is known very exactly
- NIR channel can be in mixed solar/terrestrial region of spectrum around 3.8 micron
- Forward model equation set for a given geometrical constellation:

$$R_{sol,VIS} = R_c(\tau,r_e) + \frac{A_s t_{0c}(\tau,r_e) t_c(\tau,r_e)}{1 - S_c(\tau,r_e) A_s}$$

$$R_{sol,NIR} = R_c(\tau,r_e) + \frac{A_s t_{0c}(\tau,r_e) t_c(\tau,r_e)}{1 - S_c(\tau,r_e) A_s}$$

$$+ (\varepsilon_c(\tau,r_e) B(T_c) + \varepsilon_{sfc} B(T_{sfc}) t_c(\tau,r_e) + ..) / I_{sol}$$

NLCOMP

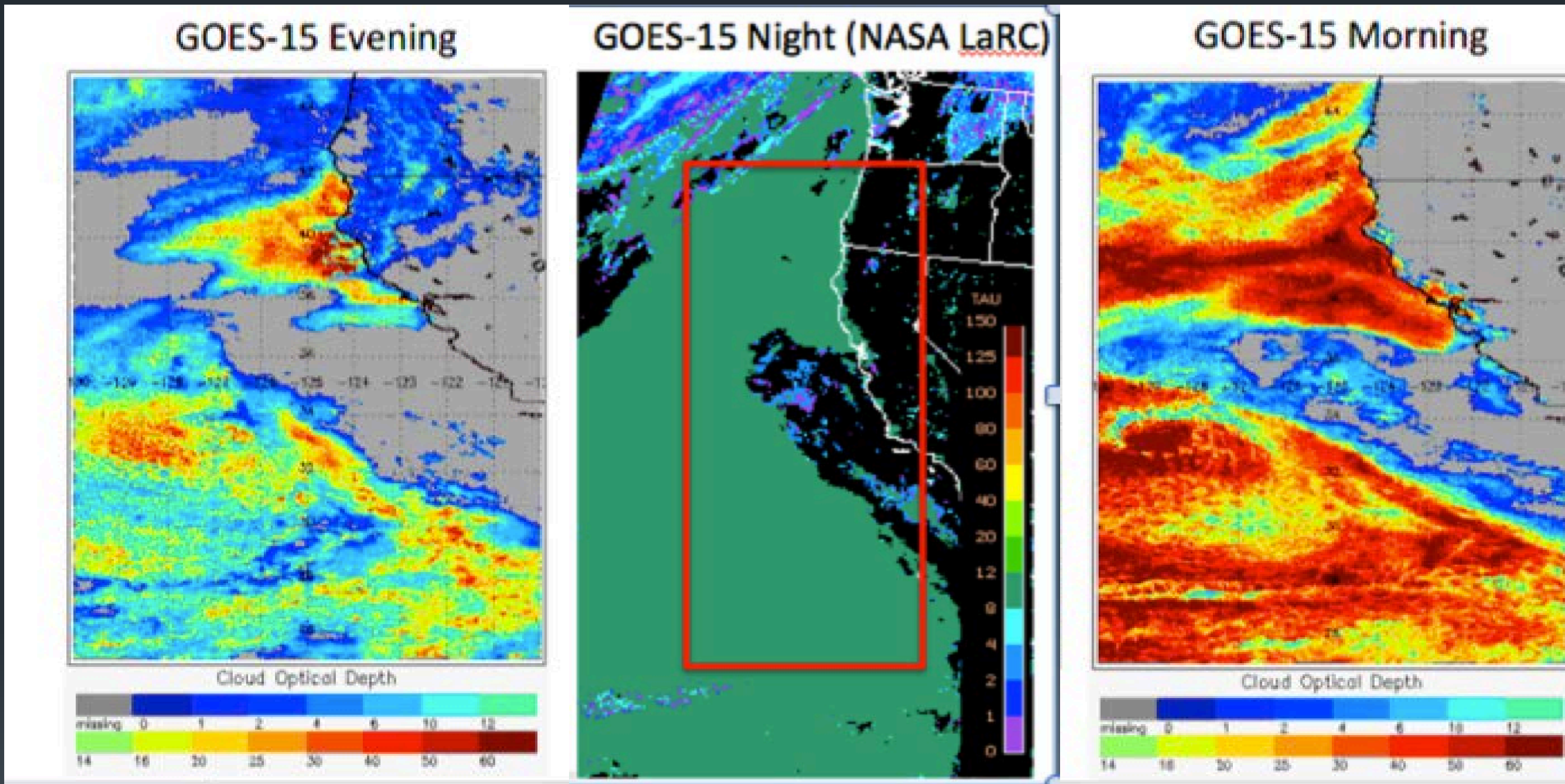
- Standard approach: simultaneous measurements in a visible and in an absorbing N-IR channel
- Use of lunar reflectance but lunar irradiance is not known very exactly
- NIR channel can be in mixed ~~solar/~~terrestrial region of spectrum around 3.8 micron, but no reflection value.
- Forward model equation set for a given geometrical constellation:

$$R_{lun,DNB} = R_c(\tau, r_e) + \frac{A_s t_{0c}(\tau, r_e) t_c(\tau, r_e)}{1 - S_c(\tau, r_e) A_s}$$

$$\Re_{NIR} = 0$$

$$+ \varepsilon_c(\tau, r_e) B(T_c) + \varepsilon_{sfc} B(T_{sfc}) t_c(\tau, r_e)$$

NLCOMP: Filling the nighttime gap: Cloud Optical Thickness



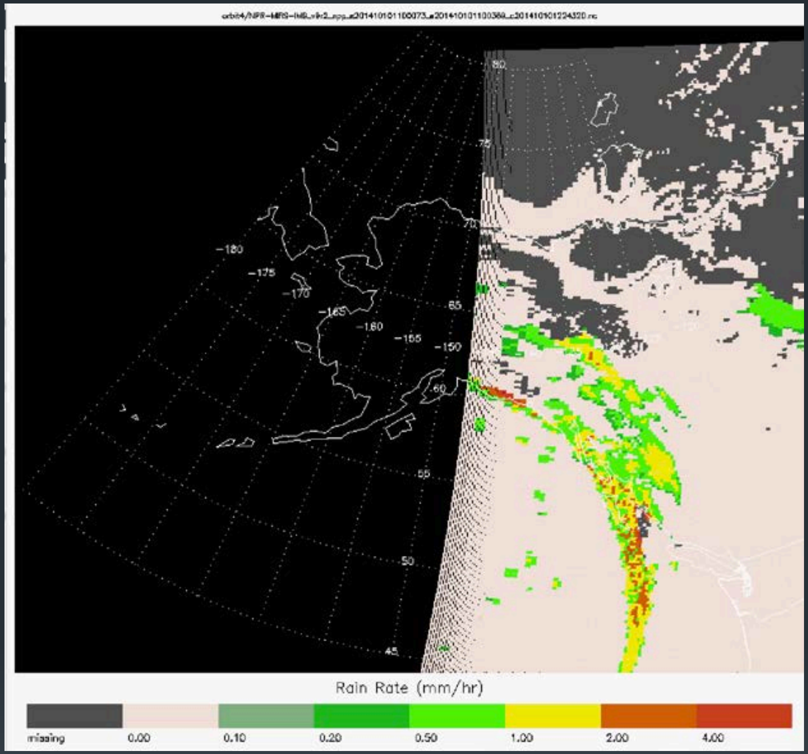
DCOMP
06:30PM

NLCOMP
IR-based
01:30AM

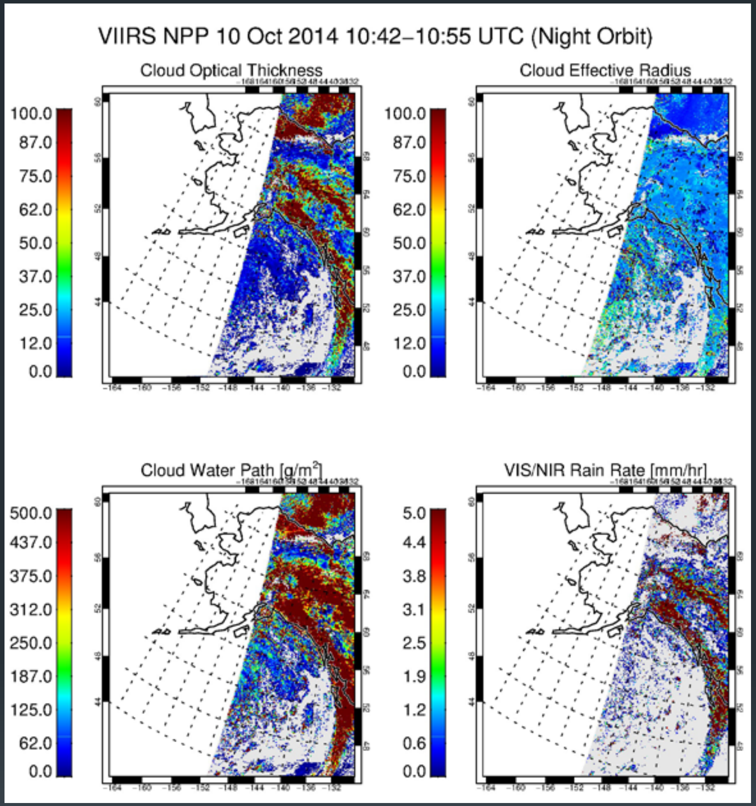
DCOMP
09:30AM

LARC Shortwave Infrared Infrared Split Window Technique (SIST) algorithm (Minnis et al., 1998).

NLCOMP: Filling the Arctic winter gap: Precipitation

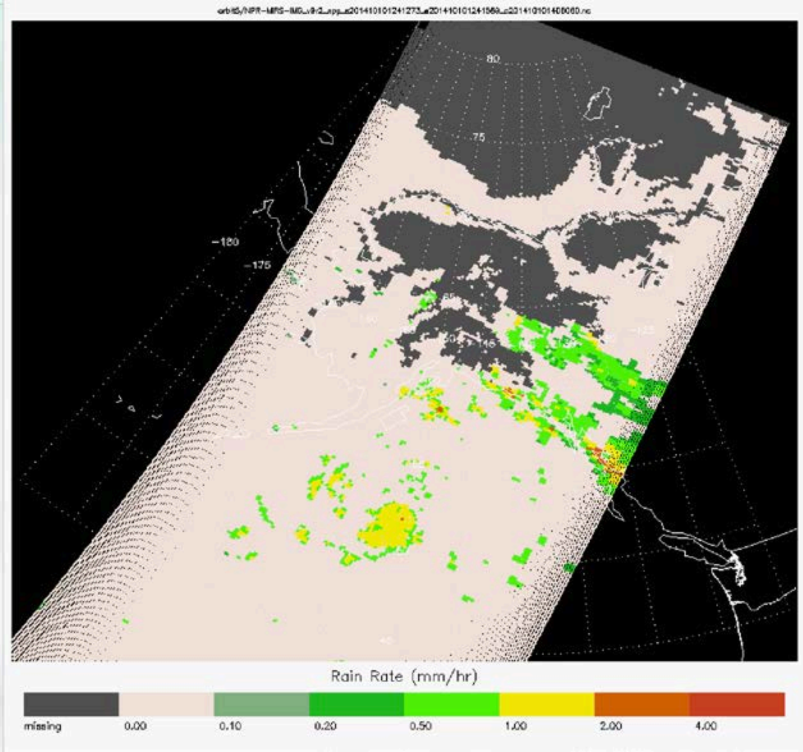


ATMS sensor on NPP provides MW–based rain rate

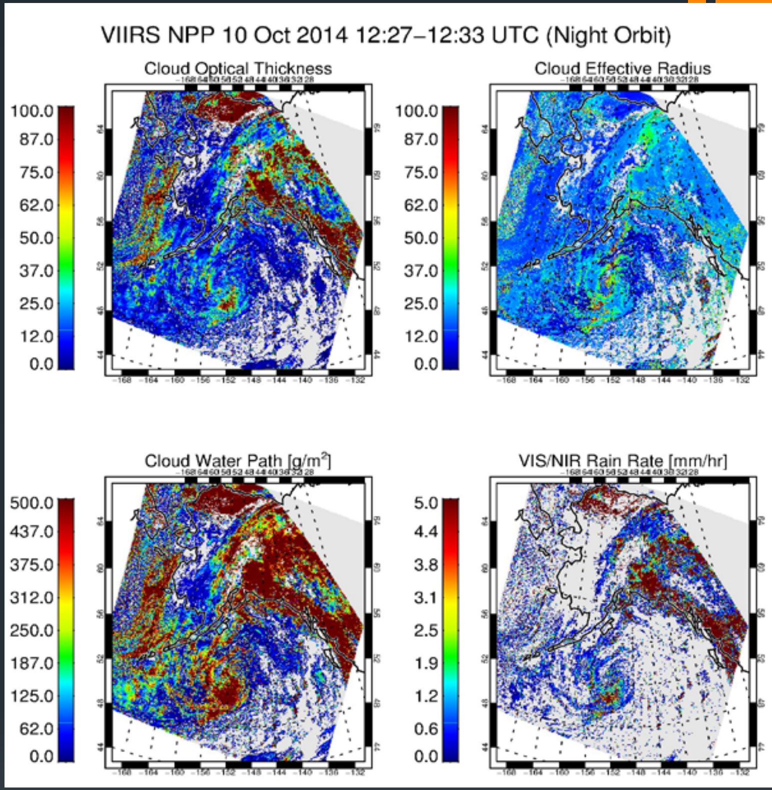


NLCOMP cloud products and rain rate estimates using (Roebeling 2009)

NLCOMP: Filling the Arctic winter gap: Precipitation



ATMS sensor on NPP provides MW–based rain rate

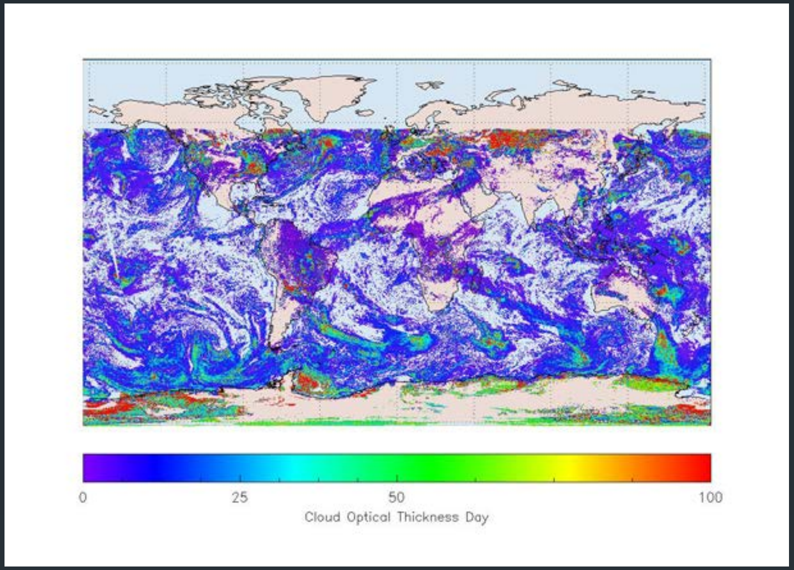


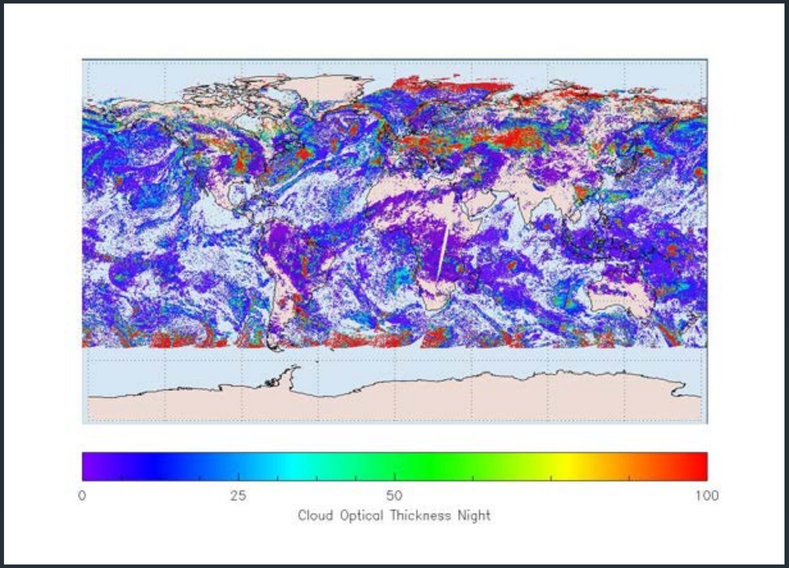
NLCOMP cloud products and rain rate estimates using (Roebeling 2009)

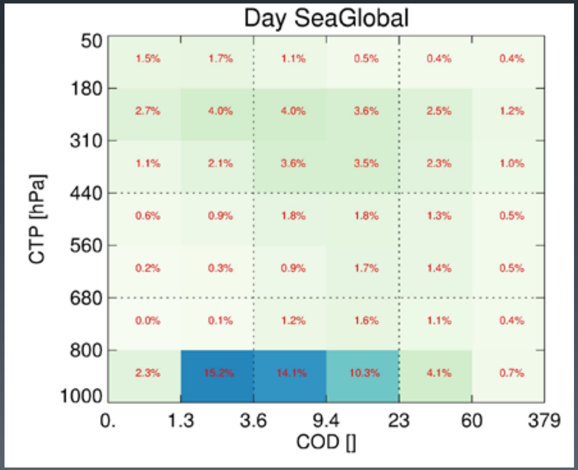
- less physical based retrieval

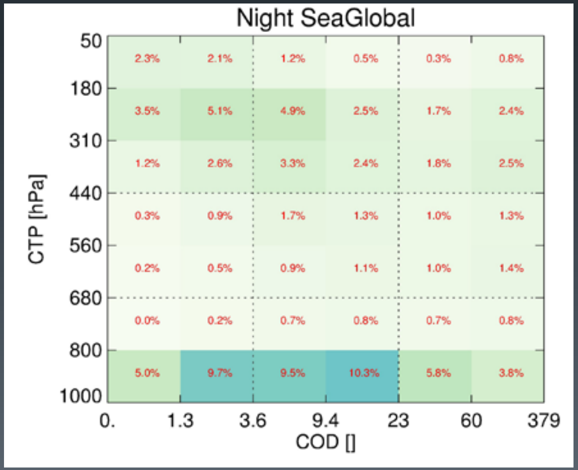
+ much higher spatial resolution (750m vs 35km)

Global daily composite: 27 Jan 2013









Summary

- The new DNB channel of VIIRS offers observations of low-light signals in a visible channel during night.
- A lunar down-welling irradiance predictor was developed which enables us to use DNB lunar reflectance as an input of quantitative cloud retrievals.
- DNB products as a part of CLAVR-x output:
  - DNB radiance on M-Grid
  - Lunar zenith, azimuth, relative-azimuth, scattering and glint angles
  - Lunar reflectance / Solar reflectance on M and DNB-grid
  - Nighttime optical thickness
  - Nighttime effective radius
- Lunar reflectance helps to correct cloud mask for missed low-level clouds.
- Comparisons to daytime results demonstrates consistency between day and nighttime observations of COD.
- NLCOMP will help to close the nighttime observation gap of cloud optical properties. This will be especially valuable in high latitudes winter where cloud observations are missed for longer periods (example: clouds, icing and rain rate for Alaska)