VIIRS CLOUD OPTICAL AND MICROPHYSICAL PROPERTIES AND THEIR APPLICATIONS

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Overview:
Cloud optical properties and techniques

- Products are Clouds Cloud optical thickness (COD or τ), cloud effective particle size (REF or r_e) and ice and liquid water path (IWP,LWP)

  - Using reflectance measurements in solar spectrum (0.6µm or 0.8µm for COD , and 1.6µm, 2.1µm, 3.7µm bands for r_e) from backscattered sun light during daylight

  - IR imager and sounder retrievals of COD and r_e for thin cirrus clouds

  - Microwave radiometers for water path

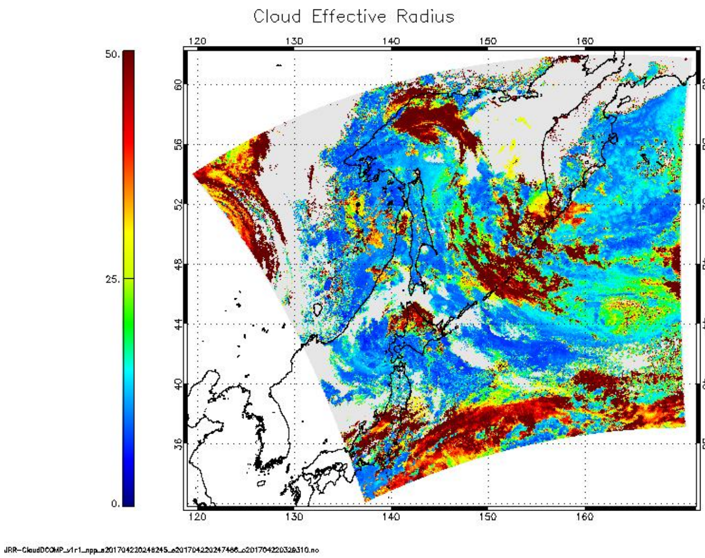
  - Using reflectance measurements in solar spectrum (DNB broad band for COD , and 3.7µm band for r_e) from backscattered moon light during night.

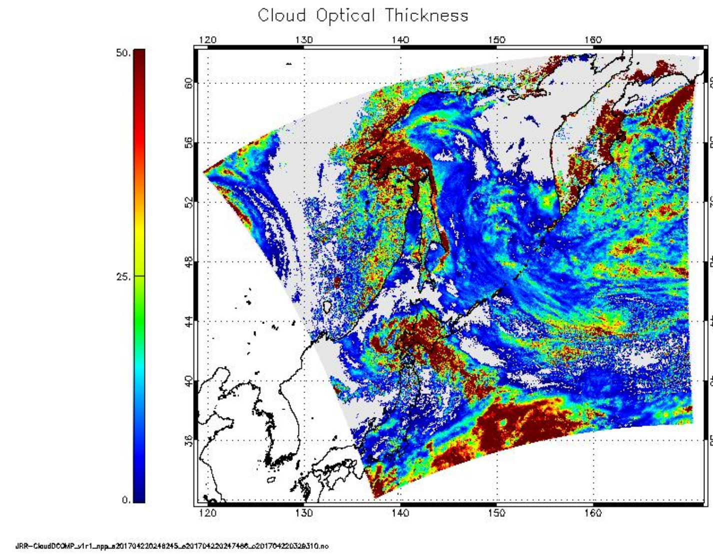
  - Water path are directly computed from COD and REF under adiabatic assumption.

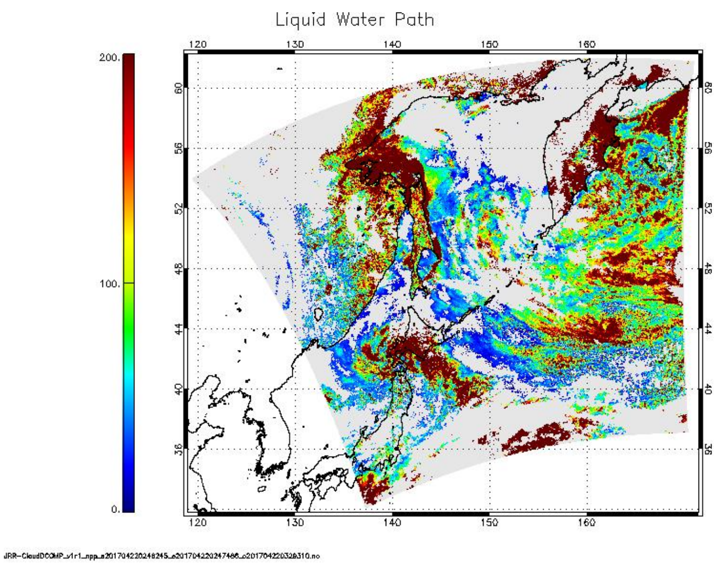
Status of Daytime Cloud Optical and Microphysical Products (DCOMP) retrieval components

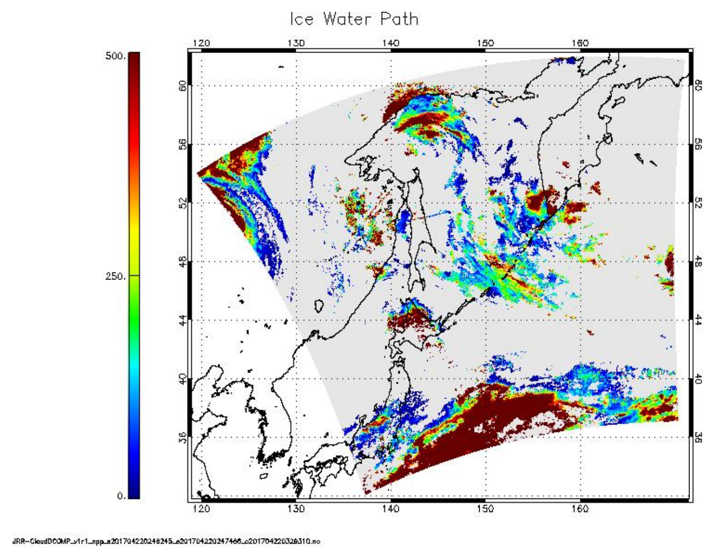
- Scientific data products are COD, REF, LWP and IWP
- Several DCOMP channel configurations possible: 1 (Channels M5/M10) ; **2 (M5/M11);** 3 (M5/M12)
- Cloud mask: Use of VIIRS Bayesian cloud mask, only use cloudy or likely cloudy pixels
- Cloud thermodynamic phase at cloud top (ice or liquid): Use of VIIRs cloud phase algorithm
- One-layer cloud assumption
- Surface spectral albedo: Include ancillary data (MODIS-based multiple year climatology)
- Use of CSFR ancillary data for snow and sea ice extent
- Atmospheric correction: requires CSFR or GFS ancillary information of water vapor and temperature profile and cloud top pressure from ACHA cloud retrieval.
- Optimal estimation inversion technique provides physically-based product uncertainty.
- Large parts of forward model are precomputed and stored in LUTs.
- Ice clouds phase functions: Use of habit “aggregate column” database by Yang and Baum
- Modular design of DCOMP. Identical software runs for all current sensors

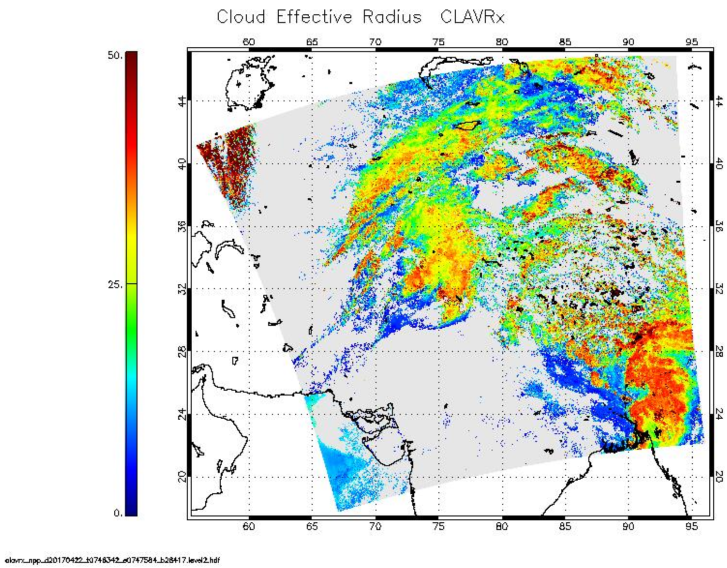
Assessment of current operational data (SAPF)

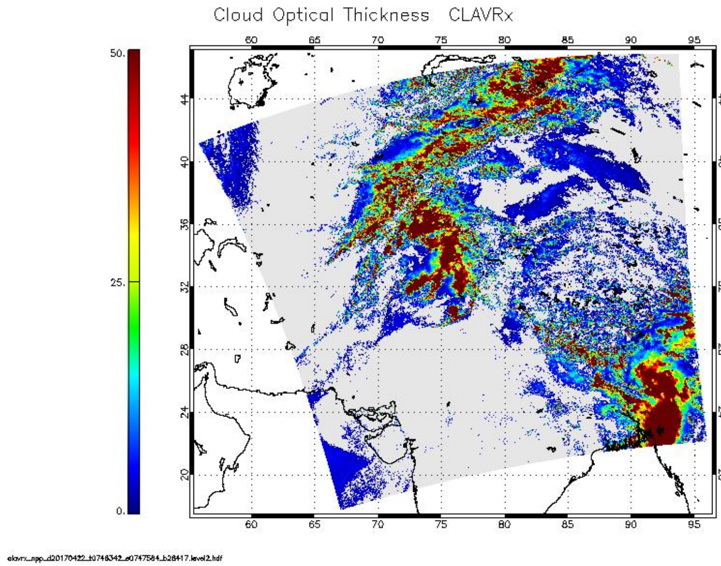




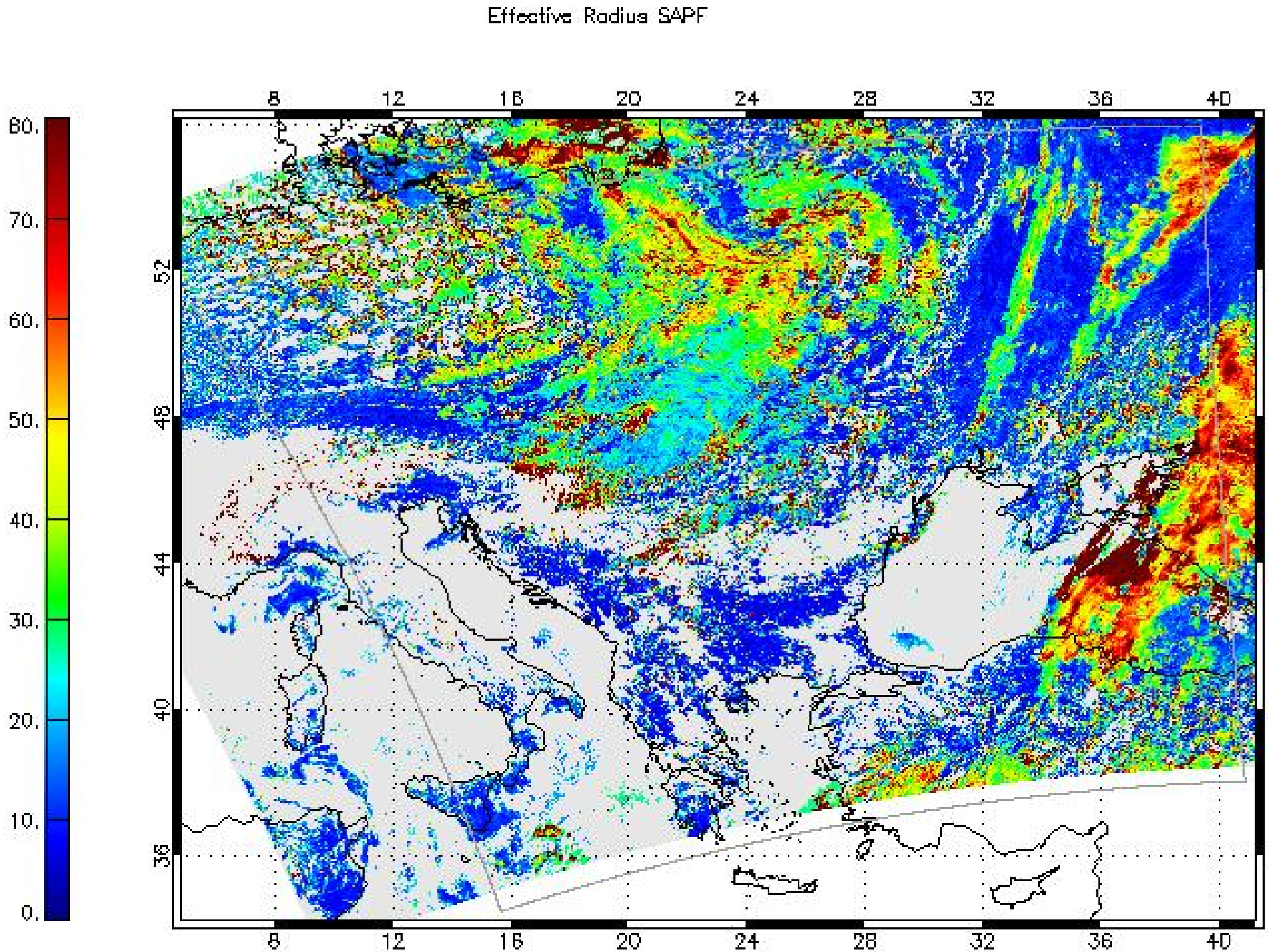








- SAPF DCOMP results show no obvious artefacts (such as “a-priori peaks” or striping etc..) on global scale.
- COD shows good agreement to current CLAVR-x version
- REF shows a bias which needs to investigate.


Effective Radius SAPF
80.
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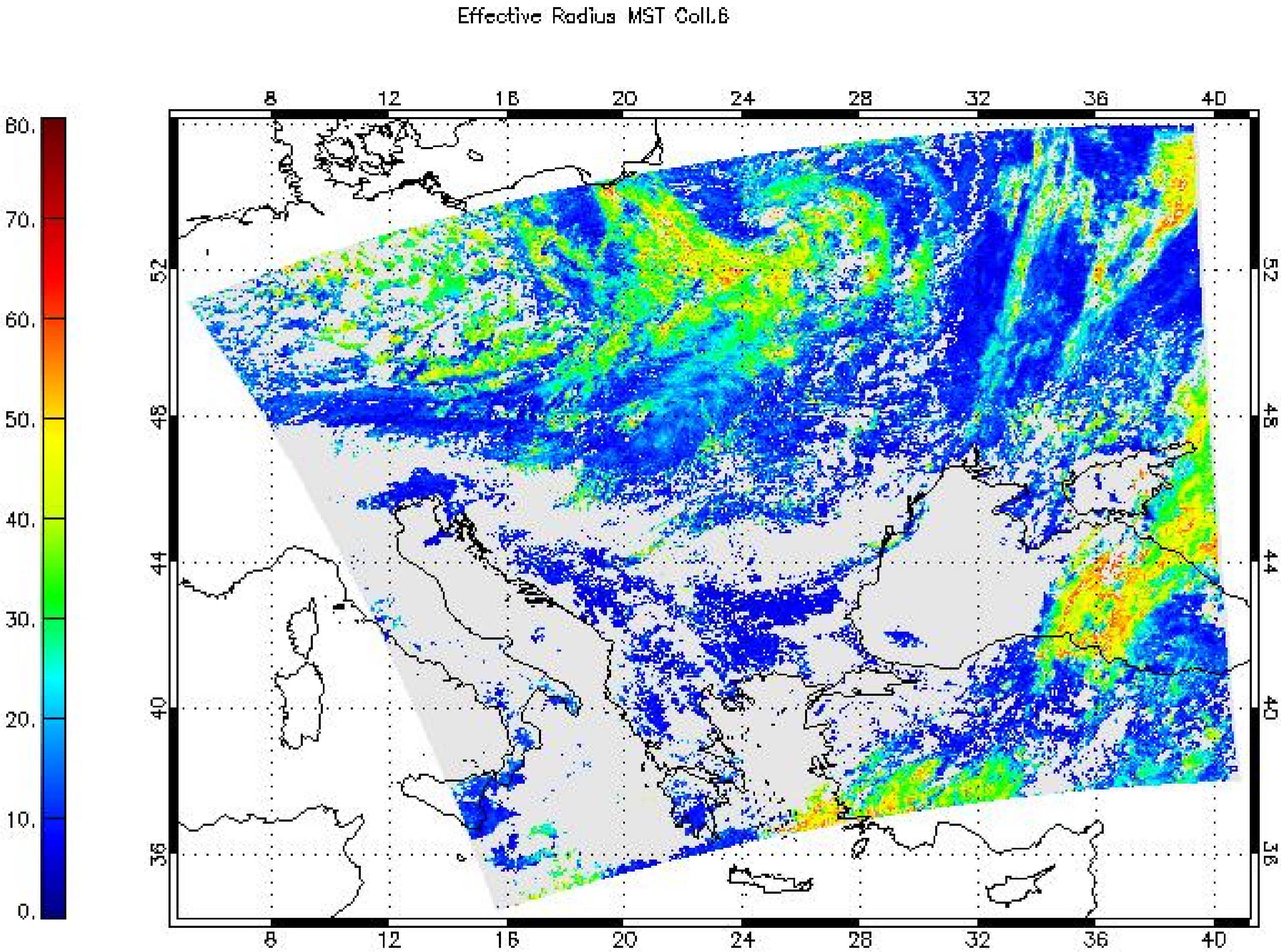
Effective Radius MST Coll.6
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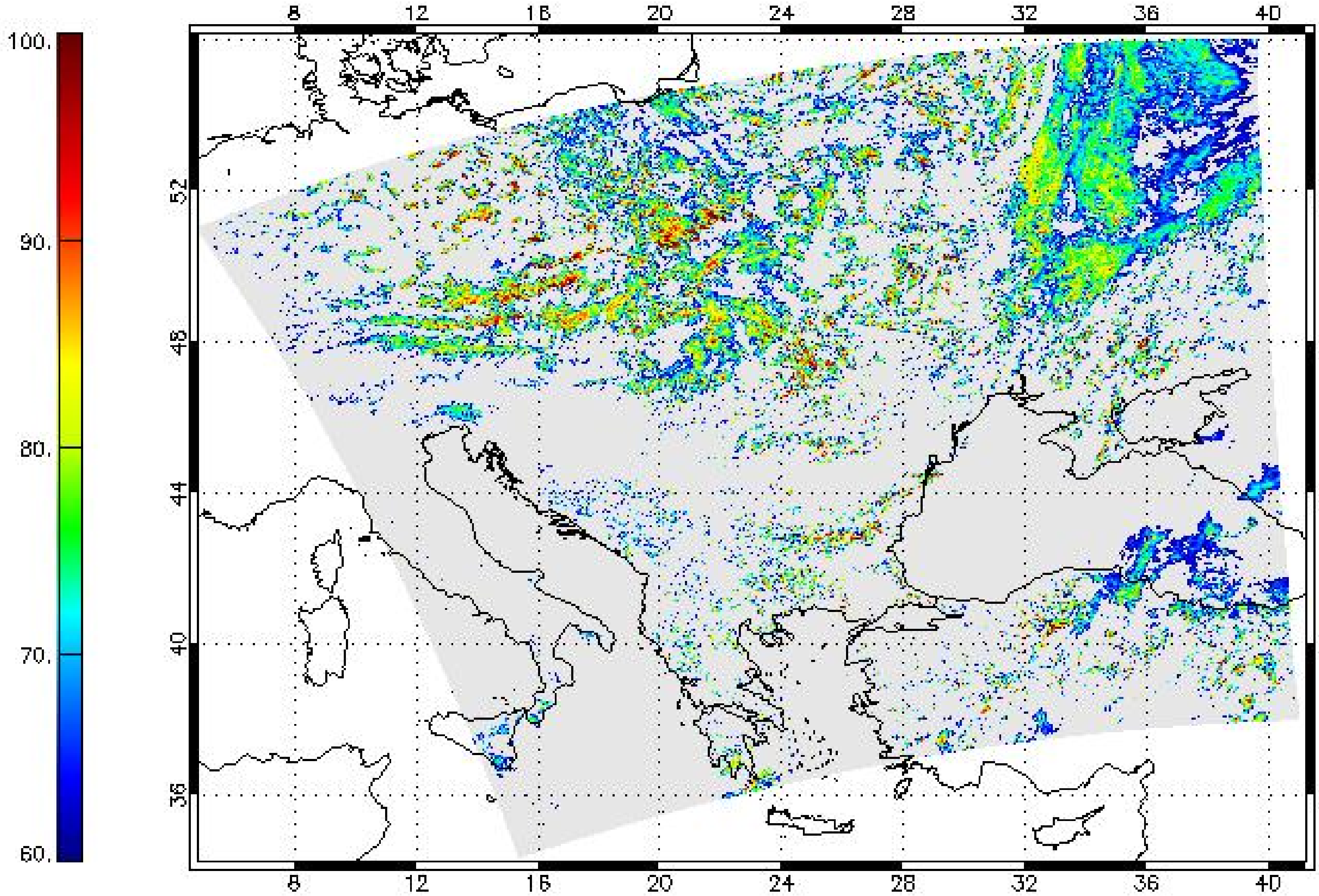
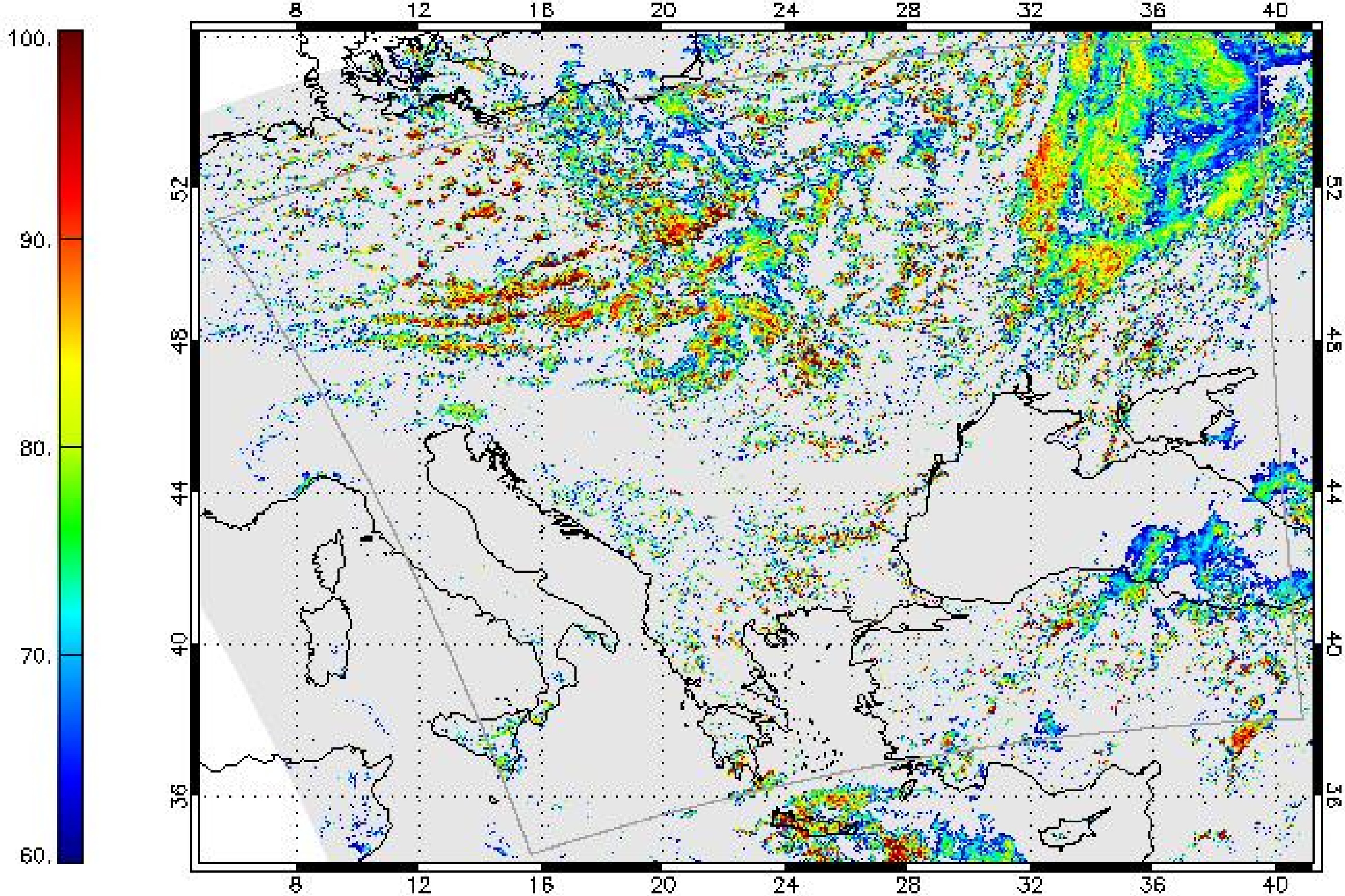
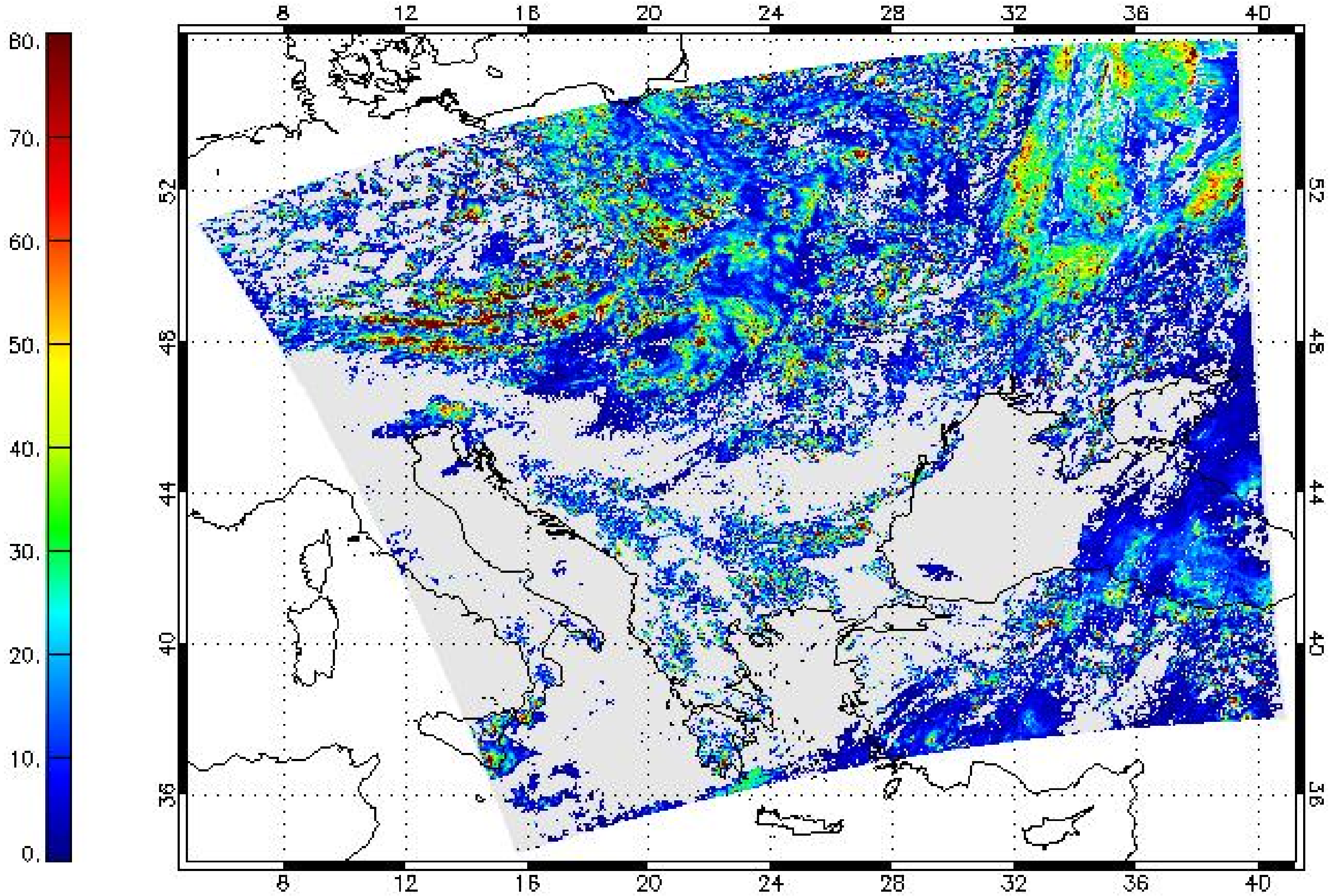
Visible Reflectance MODIS



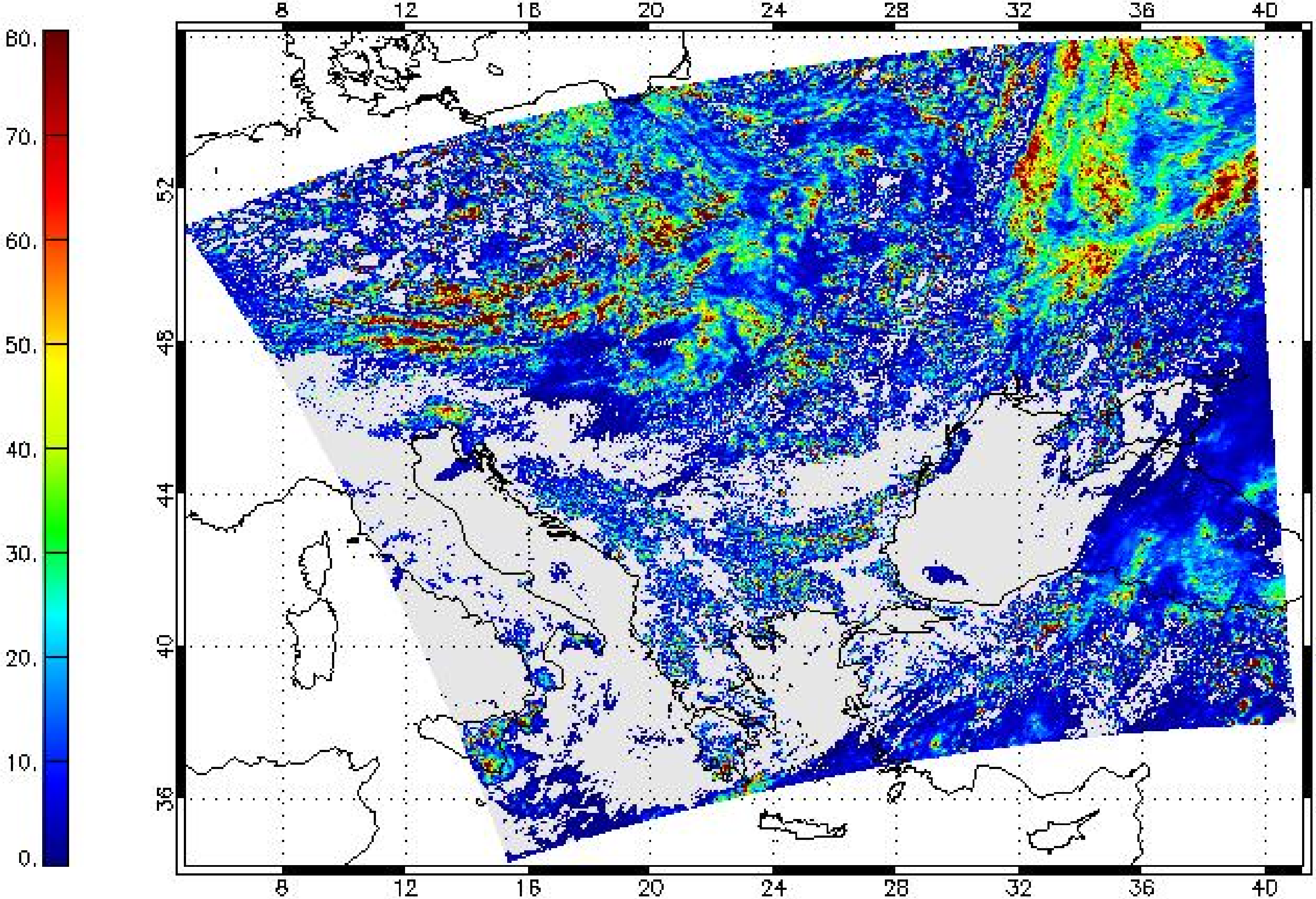
Visible Reflectance VIIRS



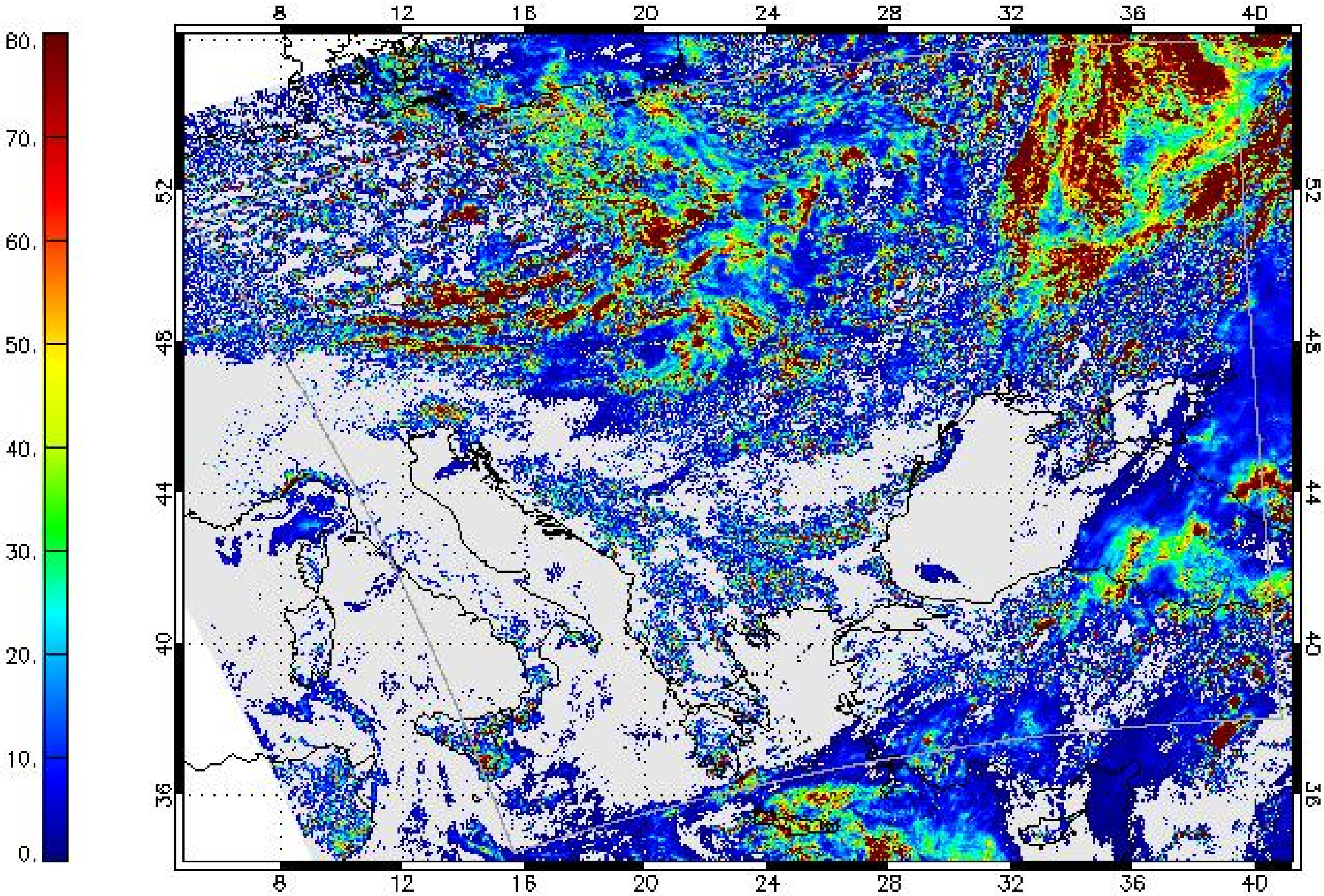
Cloud Optical Thickness MST Coll.6 MODIS



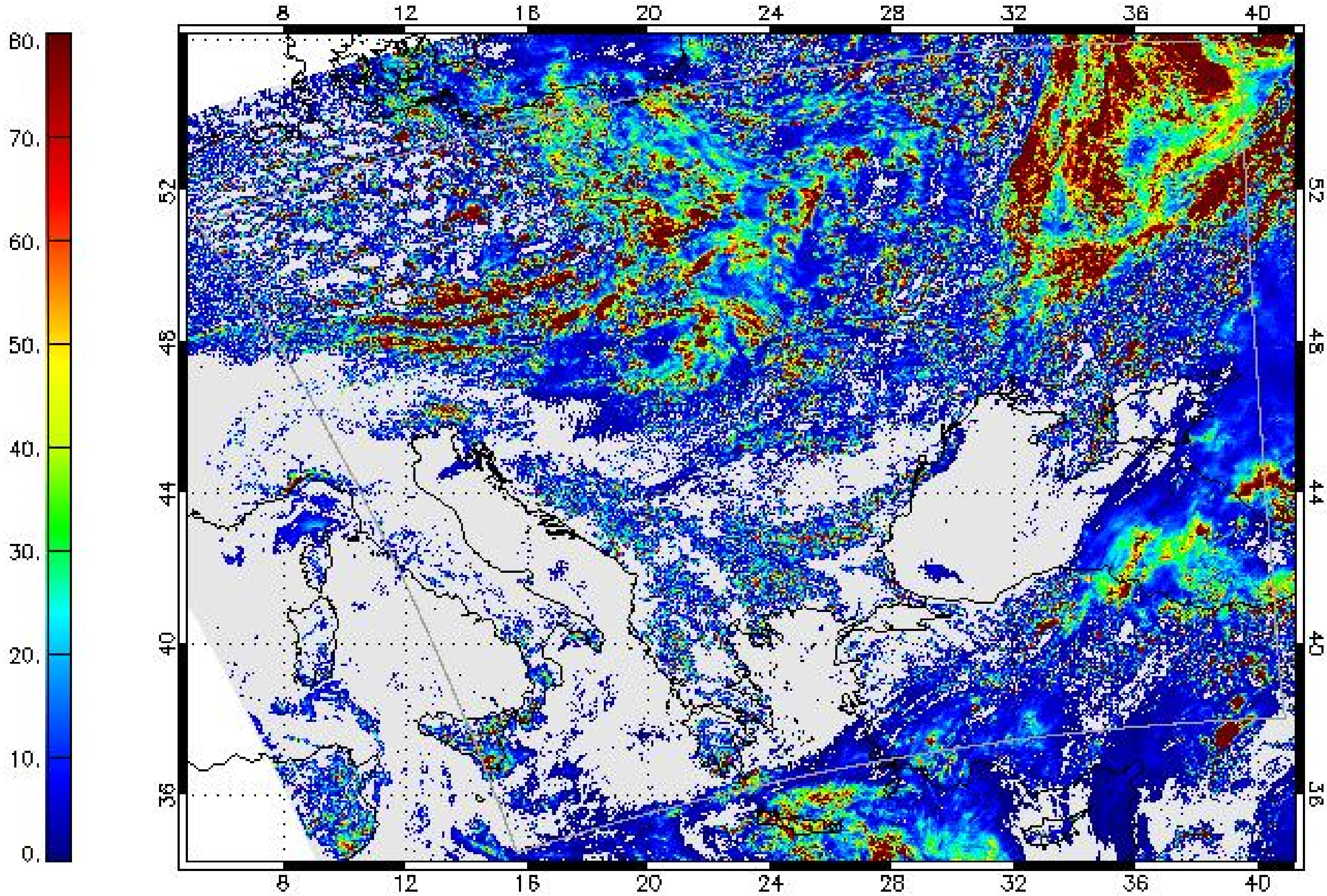
Cloud Optical Thickness CLAVR−x MODIS



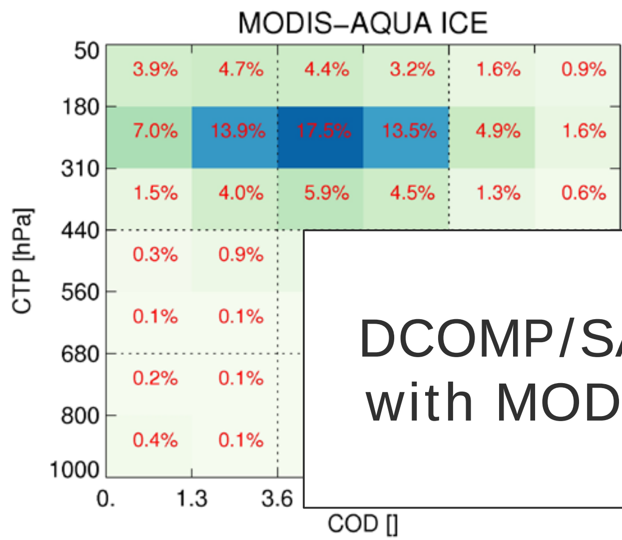
Cloud Optical Thickness CLAVR−x VIIRS

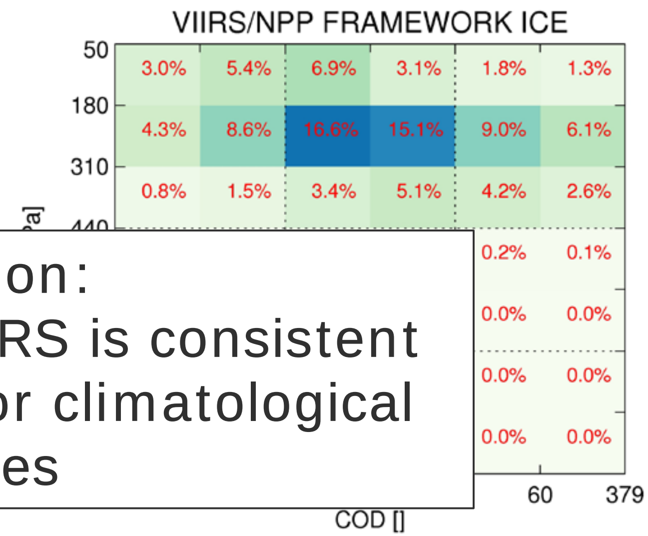


Cloud Optical Thickness SAPF VIIRS

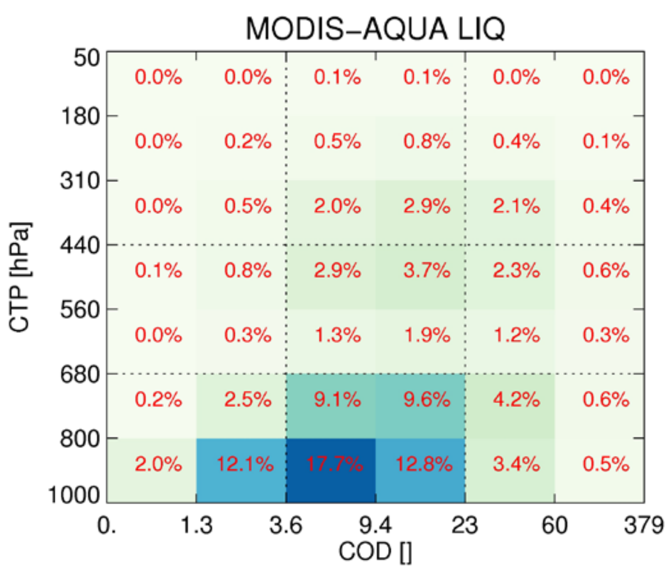


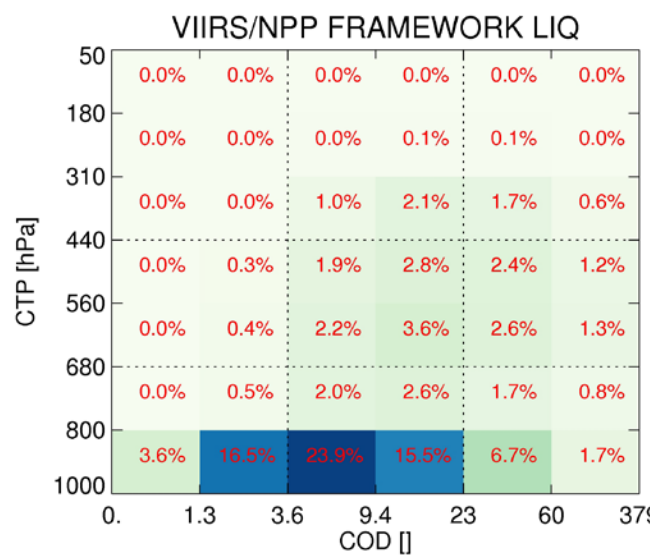
Validation results COD – MODIS: phase separated





Conclusion:
DCOMP/SAPF on VIIRS is consistent with MODIS coll.6 for climatological purposes





What could be in a future operational algorithm?

- **Product retrieval improvements:**
  - Use of higher resolved I-band for COD and REF at daytime
  - Near-IR only retrievals for REF over very bright surfaces (e.g. Greenland)
  - Improvements for regions and periods with highly variable snow extent
  - Optional processing of all pixel processing (no consideration of cloud mask)
  - Include Multi-layer forward model
  - Include NLCOMP, a DNB/M12-based nighttime algorithm

- **Application additions:**
  - Rain probability
  - Rain rate
  - Rain probability Night
  - Rain rate Night
  - Icing threat parameters
  - Cloud transmission

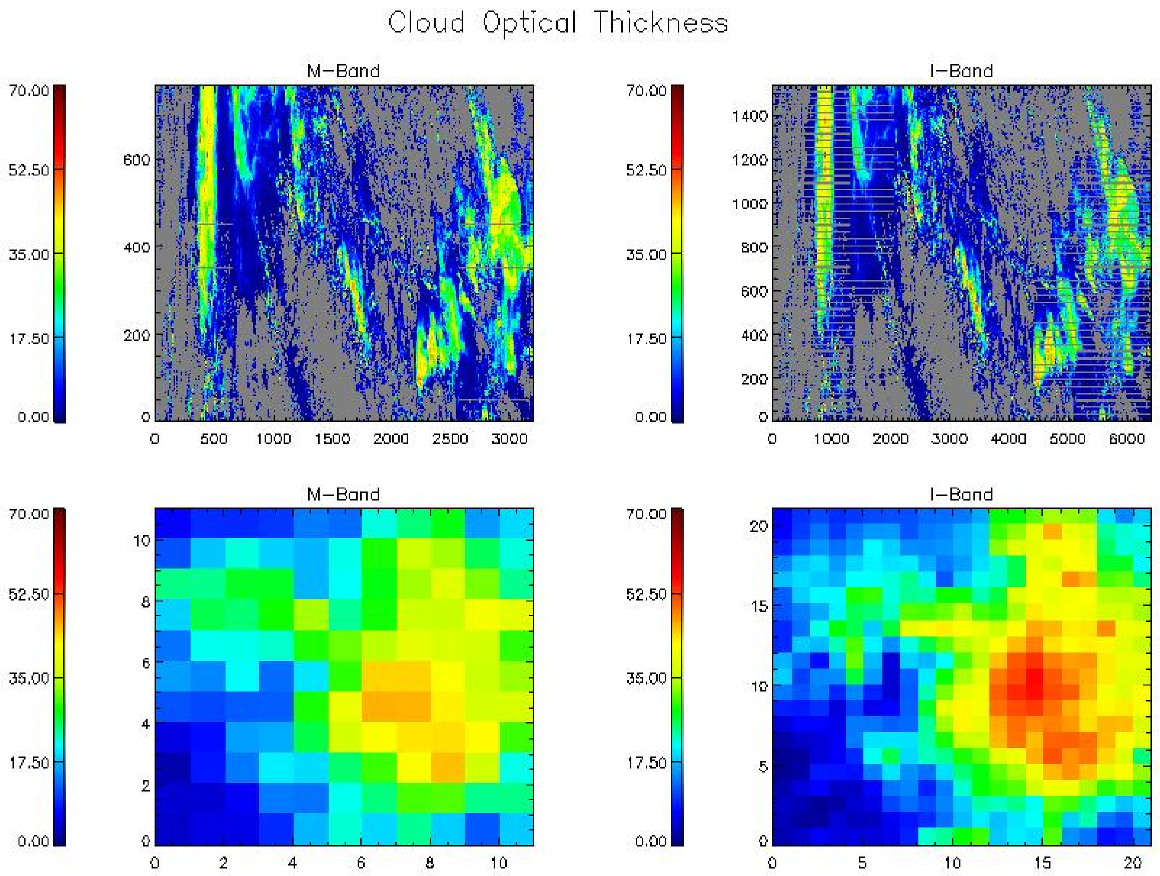
What is planned to include in future operational algorithm

- Current retrieval uses 16 M-bands (750m)
- 5 I-bands with resolution of 375m
- 4 I-band pixels are collocated with one M-band

I1 (B)	0.64	0.08	0.6 - 0.68	Visible/ Reflective	375 m
I2 (G)	0.865	0.039	0.85 - 0.88	Near IR	
I3 (R)	1.61	0.06	1.58 - 1.64	Shortwave IR	
I4	3.74	0.38	3.55 - 3.93	Medium-wave IR	
I5	11.45	1.9	10.5 - 12.4	Longwave IR	

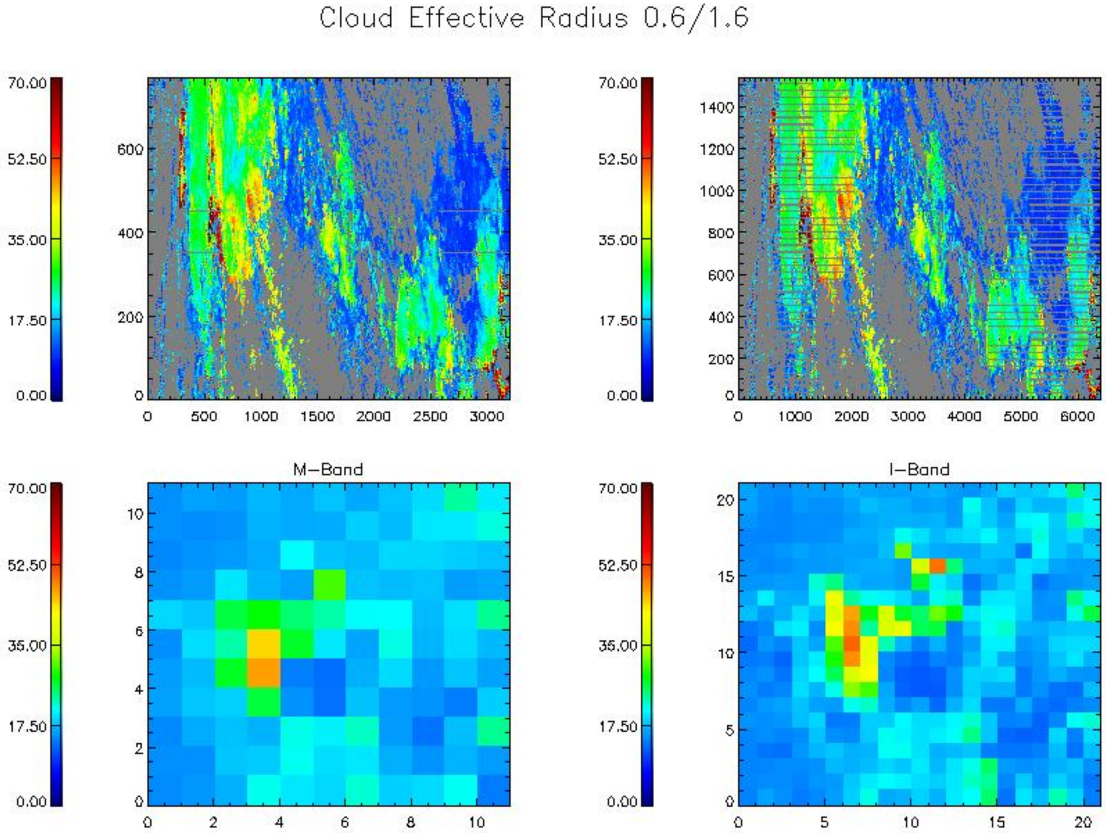
What is planned to include in future operational algorithm

- Use of higher resolved I-band for COD



What is planned to include in future operational algorithm

- Use of higher resolved I-band for REF

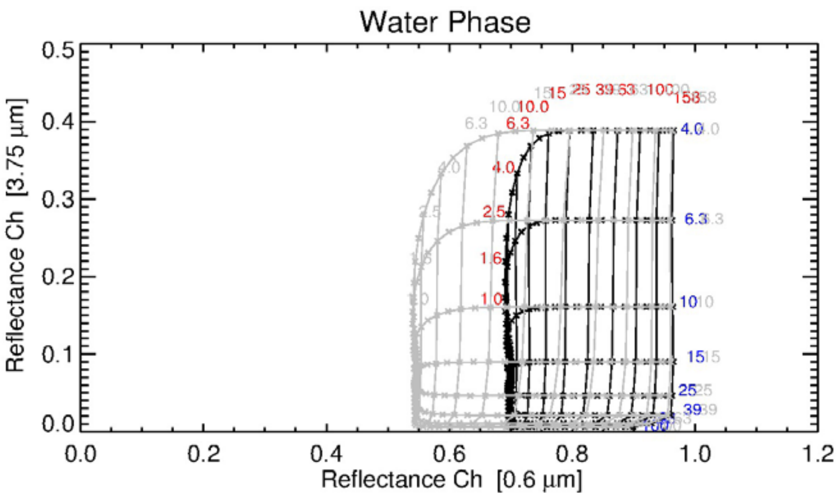


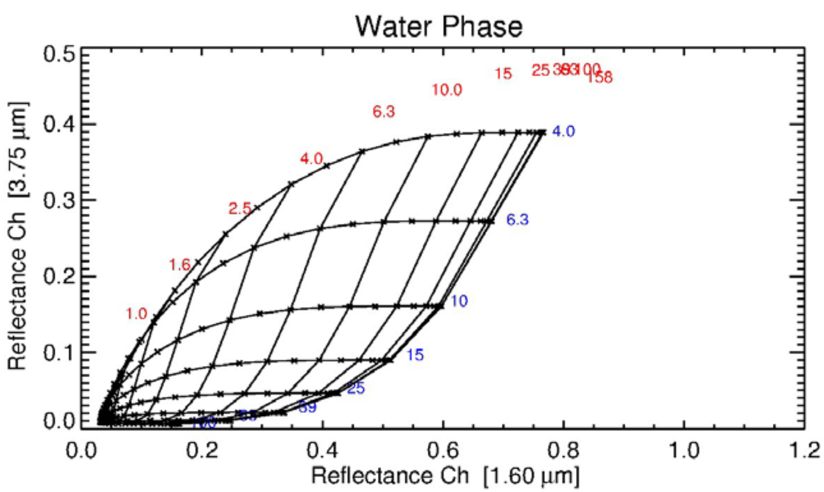
Potential benefit: better detection of small particle signatures at the genesis of severe convective storms

Retrieval over snow and sea ice:

Issues in current approach:

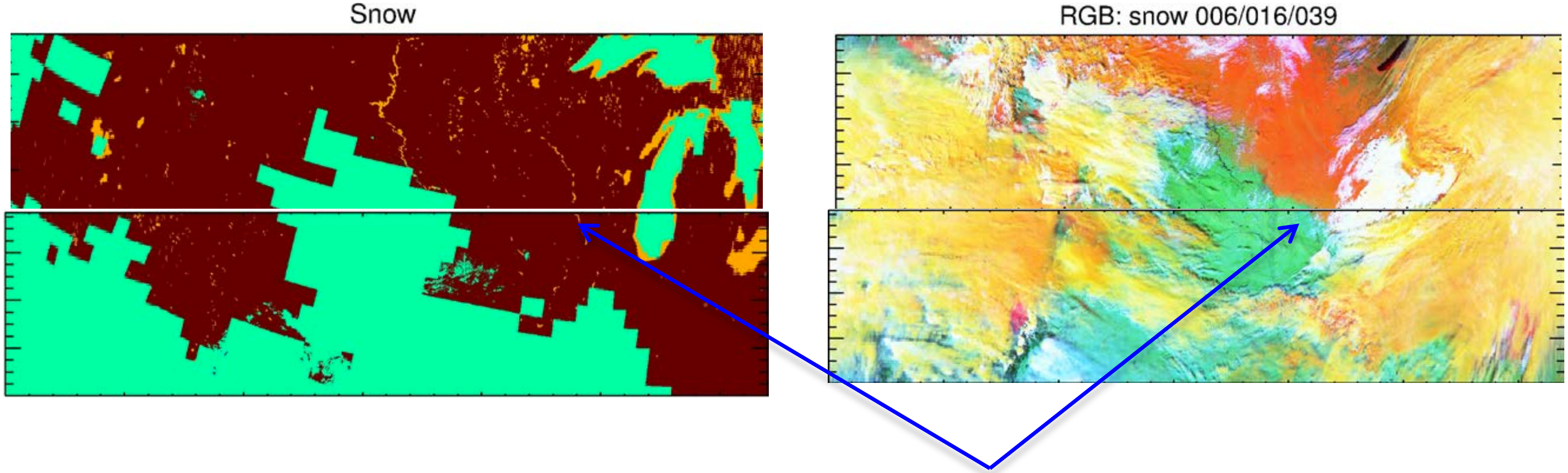
- Snow is very bright at 0.6 and has a high surface reflectivity
- Snow reflectivity assumption is very uncertain
- COD is practically only retrievable for very thick clouds and only with very high solution uncertainty.
- Bi-spectral image suggests to use a one-channel approach for a REF-only retrieval
- Other option to include: Use of 1.6µm /3.75µm approach. (Platnick et al 2001):
  - + low snow albedo at 1.6µm
  - – low cloud reflectance
  - – less orthogonal forward model





Highly variable snow extent

- False snow/snow-free assumption causes retrieval failure for most clouds.
- Current status: CFSR NWP snow depth on 0.5/0.5 lon/lat grid 6-hourly
- Alternative option: GlobSnow Daily on 25km pixel



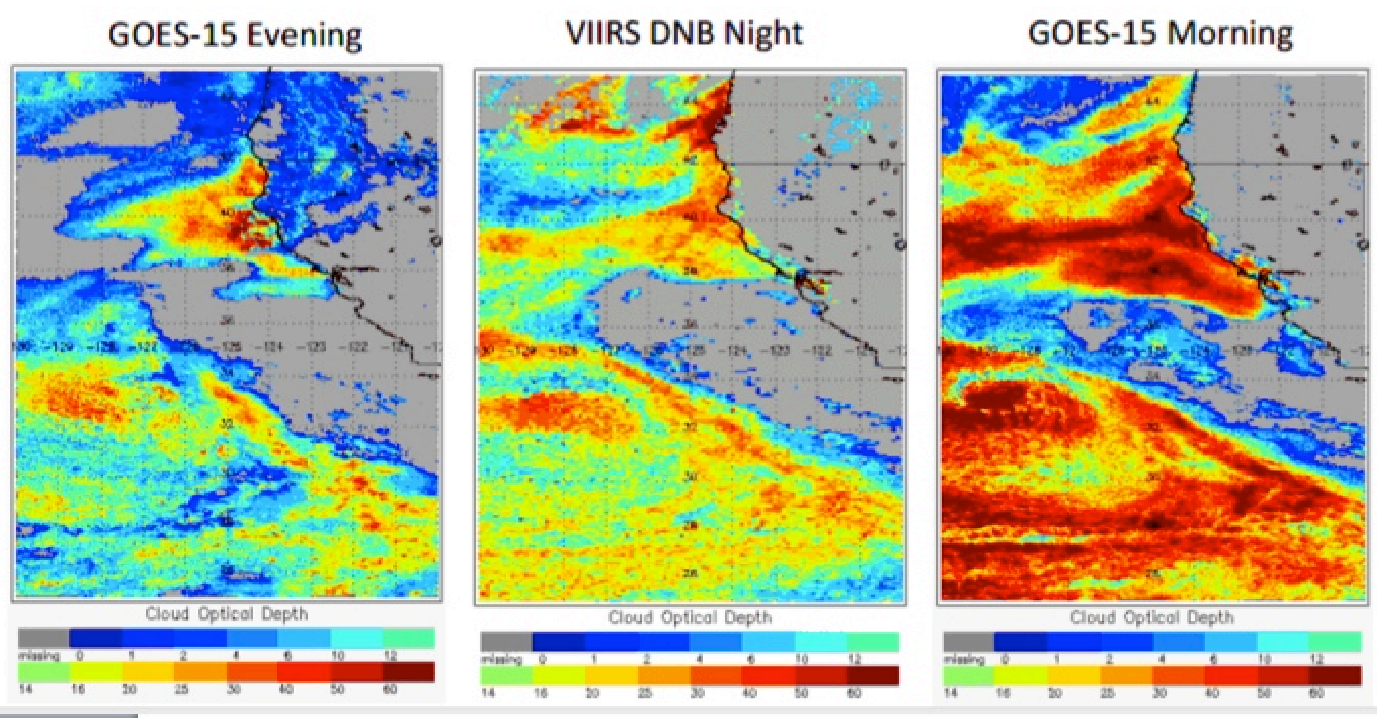
CFSR shows snow, observation snow-free

Idea for next future algorithm:

- Combining highly temporally resolved data with highly spatially resolved information
- Real-time adjustments from clear-sky pixels in neighborhood

Nighttime retrieval of COD and REF

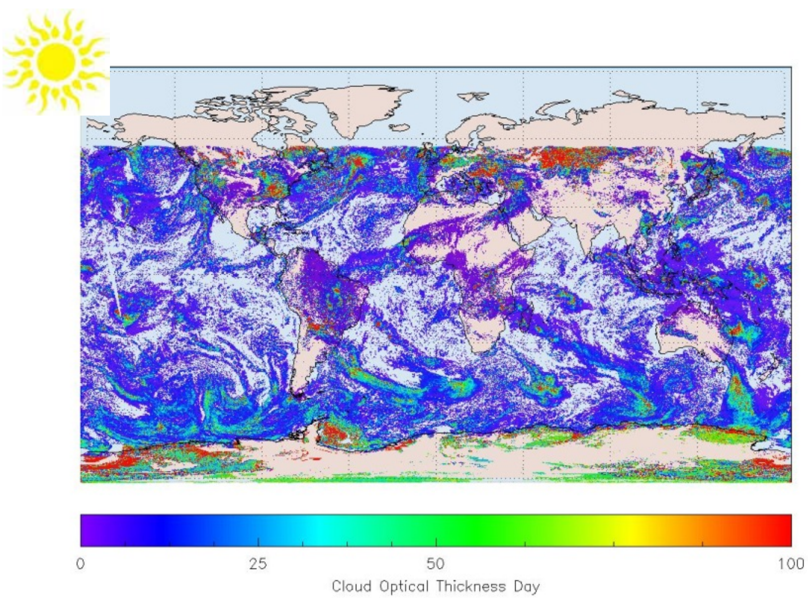
- NLCOMP (Nighttime Lunar Cloud Optical and Microphysical Properties) retrieval uses lunar irradiance calculations to derive visible reflectance in Day/Night band and use it for a DCOMP alike nighttime retrieval.

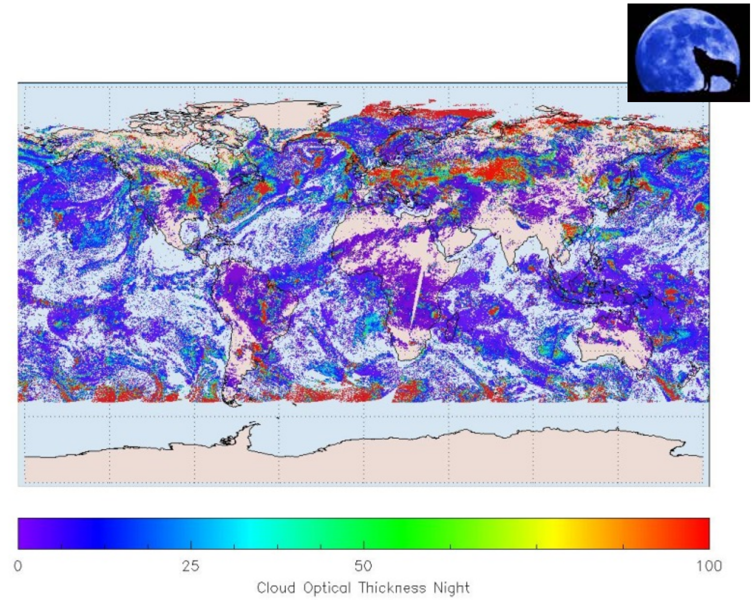


+ NLCOMP shows cloud microphysics structures also at night

Nighttime retrieval of COD and REF

- COD accuracy is slightly lower than for DCOMP due to higher uncertainty of lunar irradiance in contrast to solar irradiance
- REF accuracy is significantly lower due to missing reflectance component in NIR channel (use of emissivity forward model only)
- NLCOMP is limited to non-urban regions
- NLCOMP product coverage and accuracy is dependent on moon phase. (DNB reflectance from moon light is available at about 70% of the time but with varying accuracy)

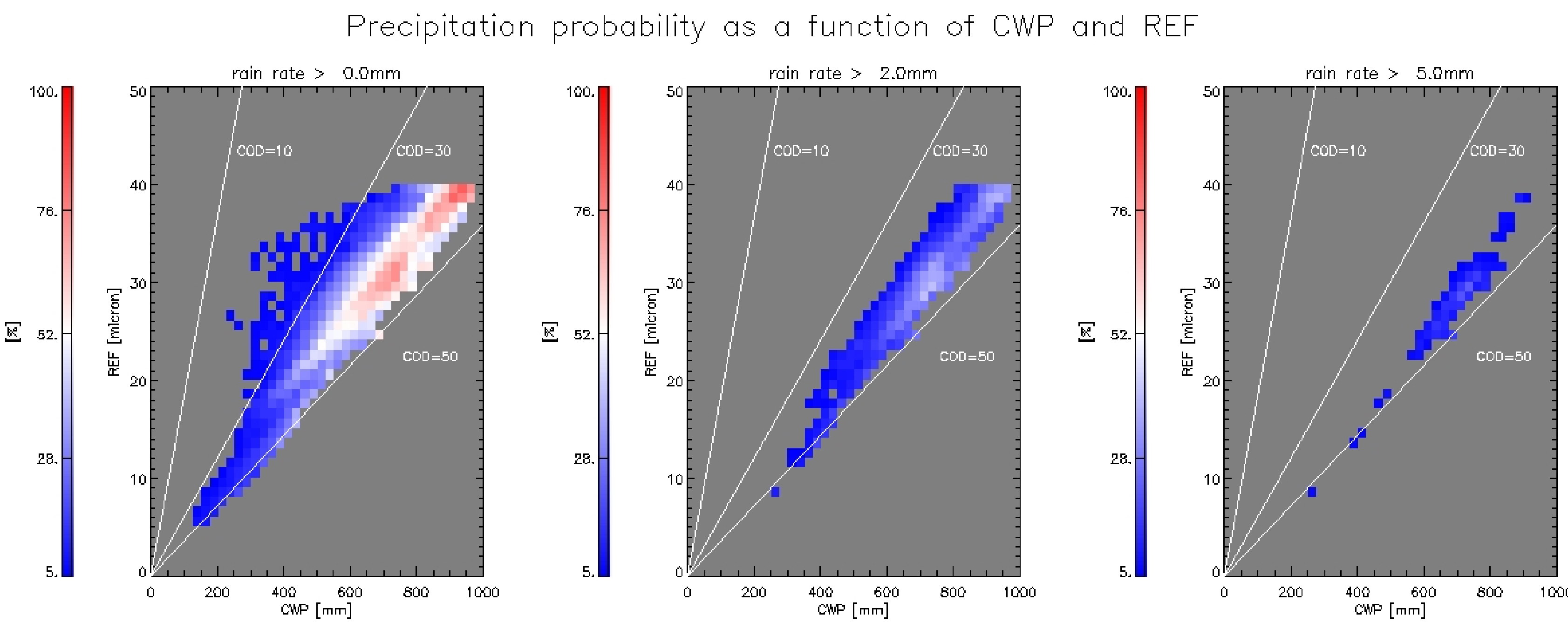




Applications: Rain probability from DCOMP products

Matching 15 days of VIIRS cloud properties with NEXRAD surface precipitation.

Images show NEXRAD precipitation above different thresholds frequency as a function of DCOMP/VIIRS cloud properties



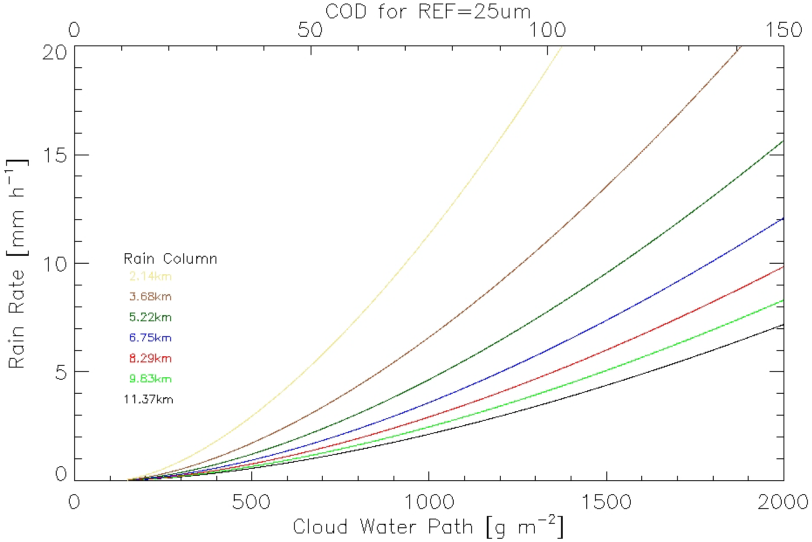
Applications: Precipitation Retrieval from VIS/NIR approach

[Roebeling and Hollemann, 2011] developed a rain detection and rain rate estimate techniques which rely on cloud water path and rain column height estimated by cloud top temperature at daytime

Rain Column:

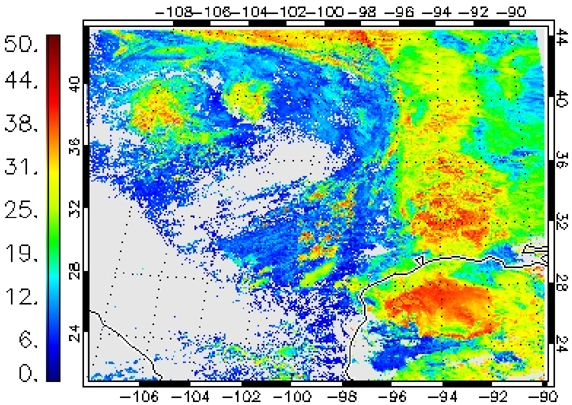
$$H = \frac{(CTT_{\max} - CTT_{pix})}{Lapse\_rate} + dH$$

$$R = \frac{c}{H}\left[\frac{CWP - CWP_0}{CWP_0}\right]^{\alpha}$$

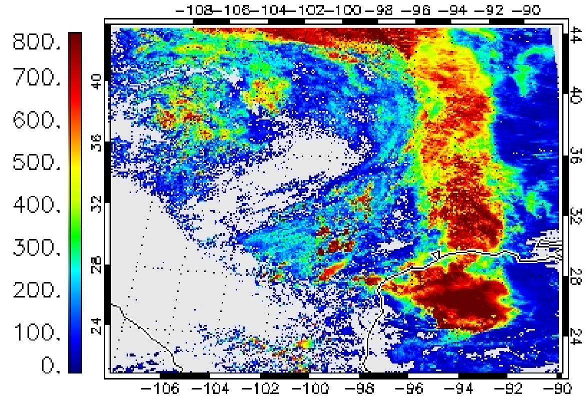


The retrieval is empirical and is based on collocated observations with ground-based measurements.

Applications: Rain rate

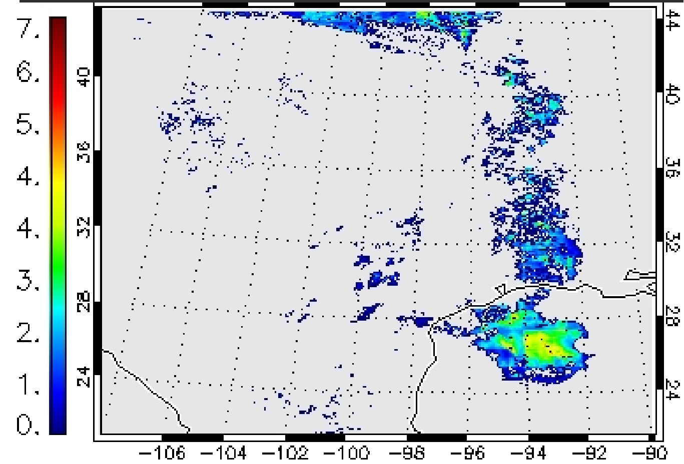


DCOMP Cloud Effective Radius



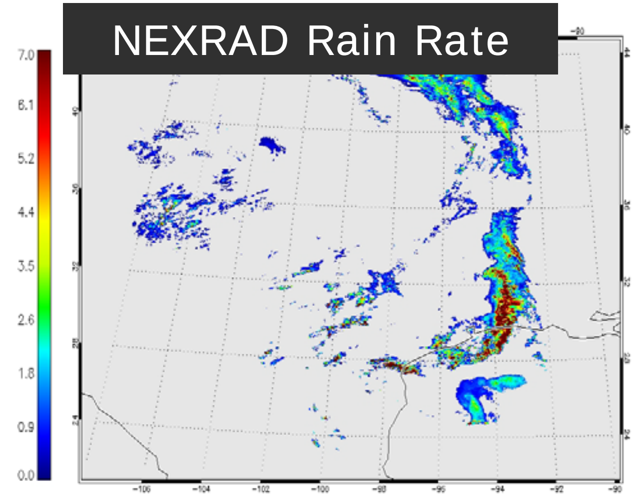
DCOMP Cloud Water Path

DCOMP Rain Rate

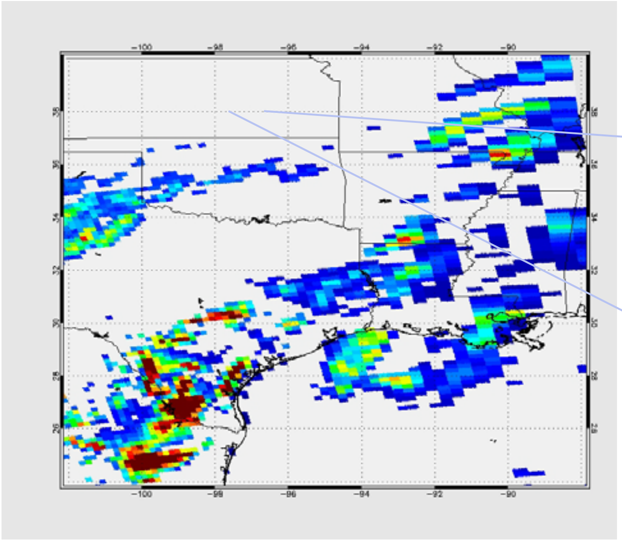


Rai rate retrieval is a DCOMP or NLCOMP based day and night retrieval
Further current developments are hybrid VIIRS/ATMS retrieval which combines the more physical-based MIRS retrieval with the empirical DCOMP retrieval

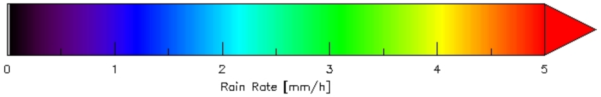
NEXRAD Rain Rate

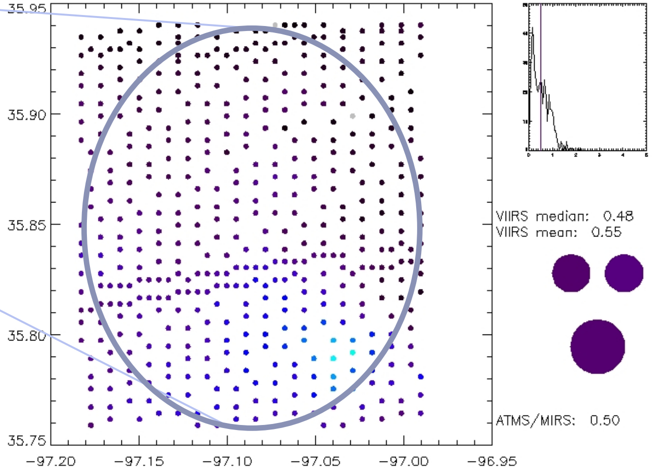


MIRS/ATMS Rain Rate

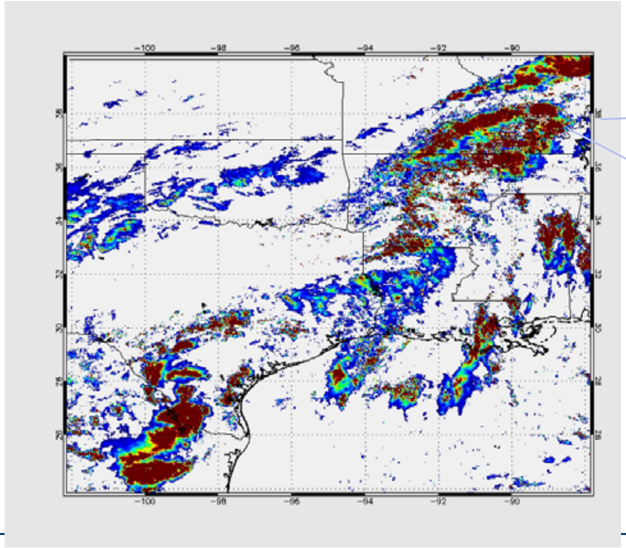


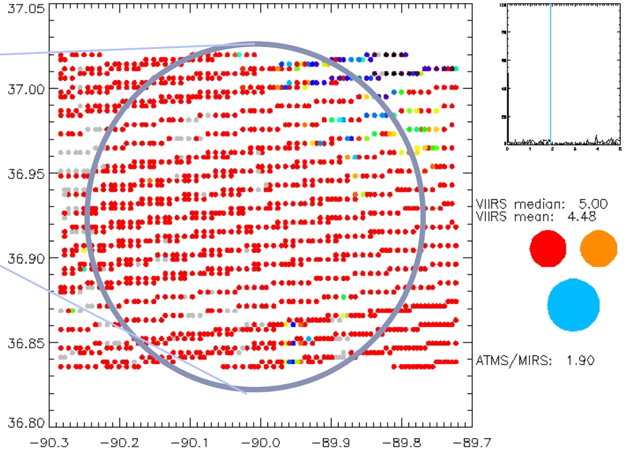
VIIRS/ATMS matching



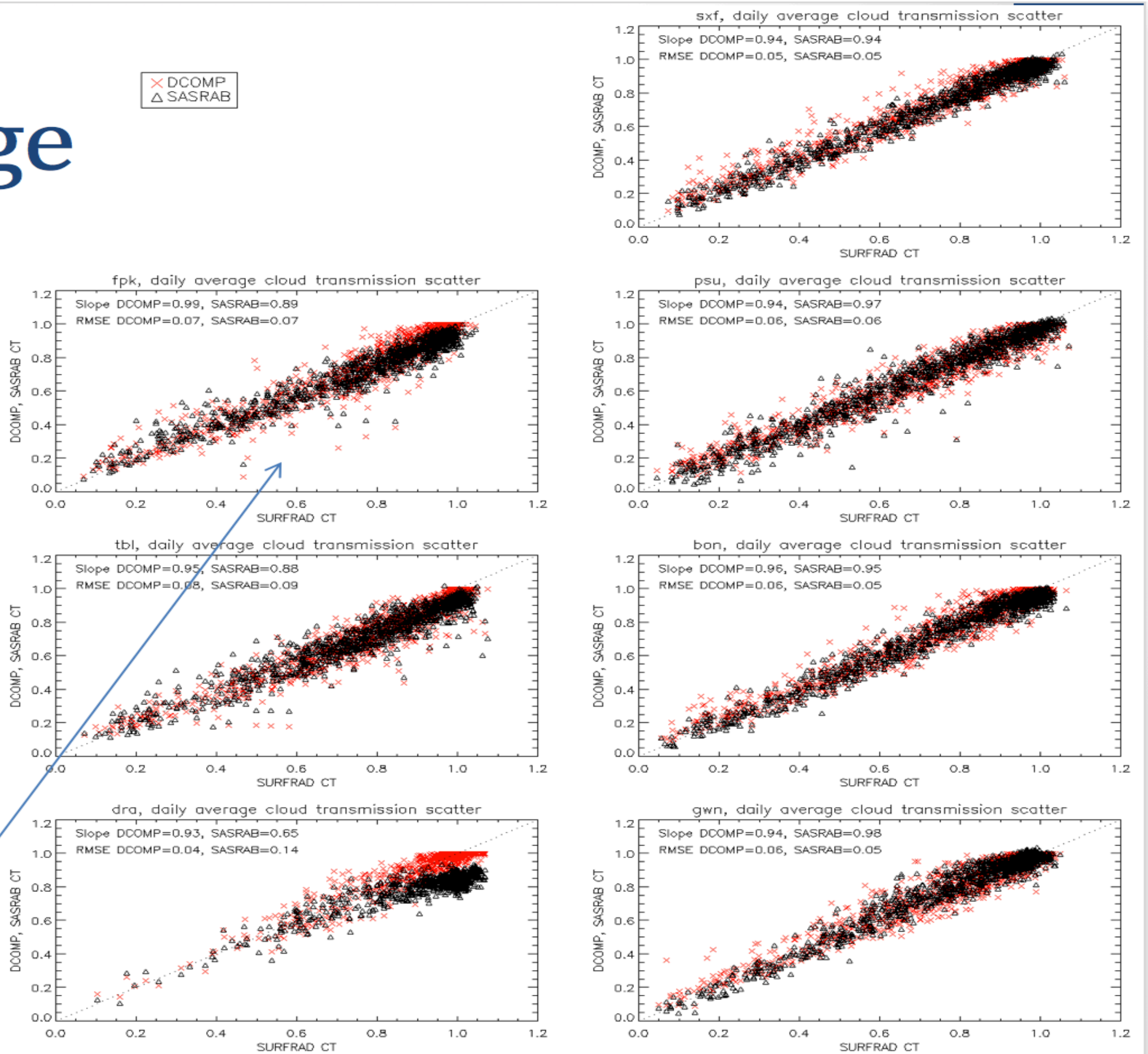


DCOMP/VIIRS Rain Rate





Daily Average CT, 2005-2011



DCOMP – CT direct from DCOMP
SASRAB – CT calculated from SASRAB GHI and B&H CSI
SURFRAD – CT calculated from observed GHI and B&H CSI

Waterfall below 1:1 line goes away if you compare only May-Oct. Probably snow effects. RMSE decreases, too.

SURFRAD/DCOMP cloud comparisons by Christine Molling

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What could be in a future operational algorithm?

- **Product retrieval improvements:**
  - Use of higher resolved I-band for COD and REF at daytime S C
  - NIR-only retrievals for REF over very bright surfaces (e.g. Greenland) S C D
  - Improvements for regions and periods with highly variable snow extent D T
  - Optional processing of all pixel processing (no consideration of cloud mask) S C
  - Include Multi-layer forward model D O
  - Include NLCOMP, a DNB/M12-based nighttime algorithm C O
  - Include lunar reflectance S, C
- **Application additions:**
  - Rain probability SD
  - Rain rate D T
  - Rain probability Night SD O
  - Rain rate Night D T O
  - Icing threat parameters D
  - Cloud transmission C S

S possible in a short time (1 year)
C Already included in CLAVR-x (or development branch)
D more development work needed
O not 100% suitable for operational processing
T technically (software) challenging

Thank you!