Rapid Revisit Optical Cloud Imager (RROCI) Status

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RROCI Design Reference Mission (DRM)

S. Jensen

- Launch Vandenburg no earlier than March 1st, 2022
- Current Orbit point of departure for design:
  - 550 km altitude, Sun-Synchronous, LTAN 1030 (Preference) 940-11:30 1230-1400
- Nominal Operations
  - Nadir and RAM directions fixed, no rotations
- Decommissioning
  - Electric propulsion thrusters used to reduce orbital altitude to sub 600 km, then allow for natural decay over the 25 year goal.
- Note: RROCI was described in the ASTRA's team NOAA Geo BAA study titled **GEO utilization of Common LEO Architecture for Weather (G-CLAW)**

EWS-RROCI Top Level Mission Specification

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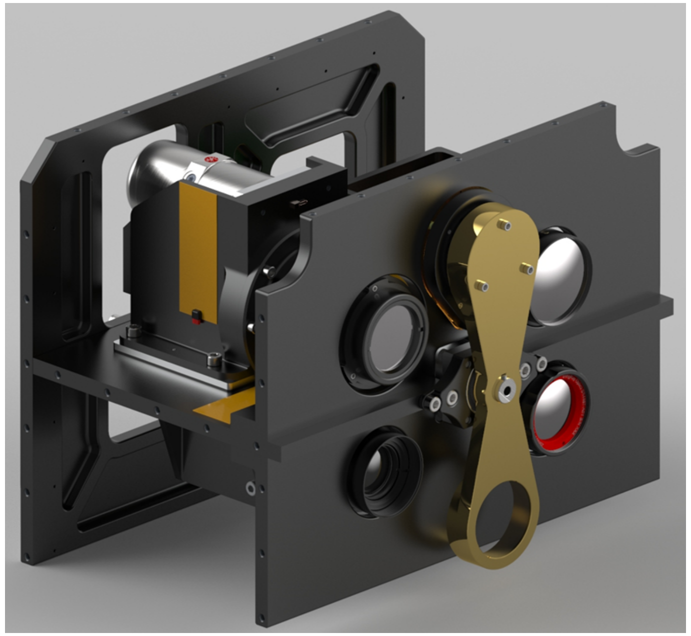
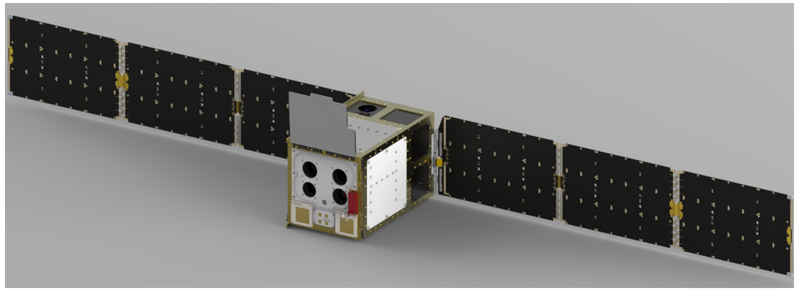
RROCI Payload



Pumpkin SuperNOVA Bus



RROCI Mission Specifications	Predicted Value			
S/V Mass				
S/V Power (EOL Orbit Average)				
Payload Volume	6000 cm^3			
Payload Swath Width (550 km orbit)	200 km (20.6 degree FOV)			
S/V Data Volume (Mbits / Orbit)				
Spectral channels (µm)	VIS 0.67/0.87	SWIR 1.38/1.61	MWIR 3.74	LWIR 8.5/10.7/13.3
Camera's (ImperX, FLIR)				
HSR by band @ 800km	0.448/0.485 km	0.743/0.792 km	0.677 km	0.738/0.828/0.939 km
Operational Availability Post On-Orbit Cal/Val	95.3%			
Guidance, Navigation and Control				
GPS Position Knowledge				
Design Life	> 12 months			
Launch	Q1 2022			

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RROCI Design Reference Mission (DRM)

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- RROCI has several key modes it operates in:

Mode	Description
Safe	Initial mode after DMS processor power-on. Also entered by command or transitioned from idle mode if the idle mode cannot be supported
Idle	All mode transitions pass through the idle mode
Science	Collecting, processing, and storing science data
Overpass	Handling ground commands and transfer of bus and payload telemetry and science data
Calibration	Collecting, processing, and storing calibration data
WFDL/Overpass	Handling transfer of payload telemetry and science data via the alternative WFDL RF path

- Calibration Maneuvers/Operations
  - Spacecraft will point at: (1) Internal IFC Source (2) Ground Targets, (3) Deep Space, (4) Star Fields, (5) Moon(Backup)
- Data Downlink over Ground Station
  - Spacecraft will point and track a ground station to downlink mission data
- After Deployment from Rocket, RROCI camera cover should remain closed for 2-3 weeks during initial outgassing and commissioning to protect cameras

Co-registration of Image Data During Post Processing

- Applies the following corrections:
  - Boresight offsets
  - Image rotations
  - Optical distortion
- Processing software can use spatial calibrations from the ground calibration to correct the data
- Spatial calibration coefficients are updated during star calibrations on-orbit
- These corrections can co-register the data to a common reference grid
  - Any one of the RROCI focal planes
  - Or an external grid of choice
- The resulting data, co-registered to a common reference grid, can then be further processed

MDM – Processing

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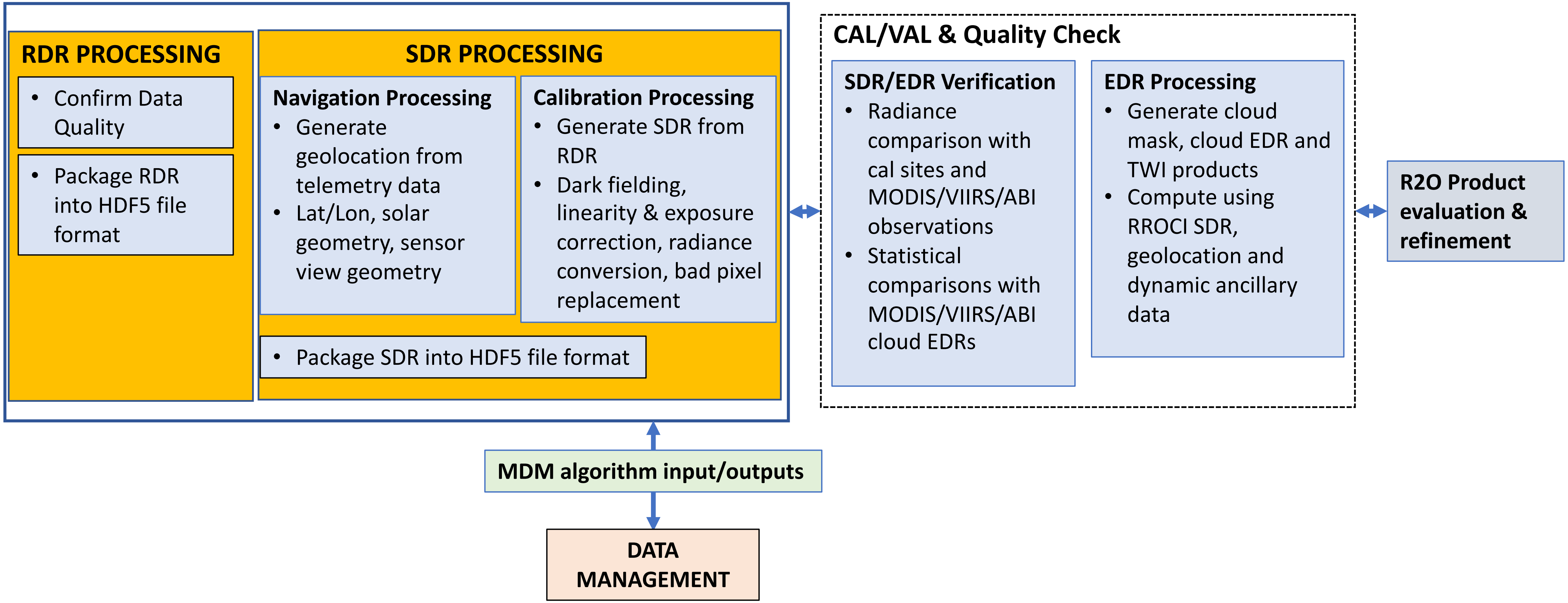

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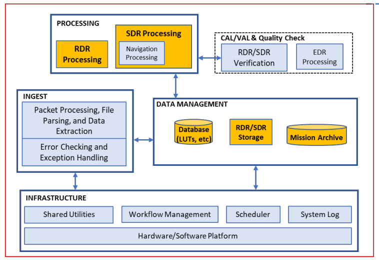
MDM Subsystem– Cloud Implementation Approach



- ❑ **Cloud Platform : AWS**
  - ❑ Primary MDM : US West Region
  - ❑ Backup MDM : US East Region
- ❑ **VPC**
  - ❑ Single VPC per MDM instance
- ❑ **SDLC**
  - ❑ Agile Methodology

AWS Services – Candidate List

- ❑ Infrastructure Implementation and Management
  - CloudFormation
  - CloudWatch
  - CodeStar
- ❑ Computing/Servers/ Storage
  - EC2
  - EBS
  - S3 Standard
- ❑ Archiving
  - S3 Glacier
- ❑ Security
  - IAM
  - KMS
  - ACM
  - WAF
- ❑ Communication/Outreach
  - SNS
  - SES
- ❑ Development
  - CodeCommit
  - CodeBuild
  - CodeDeploy

Data Products Performance Verification Process

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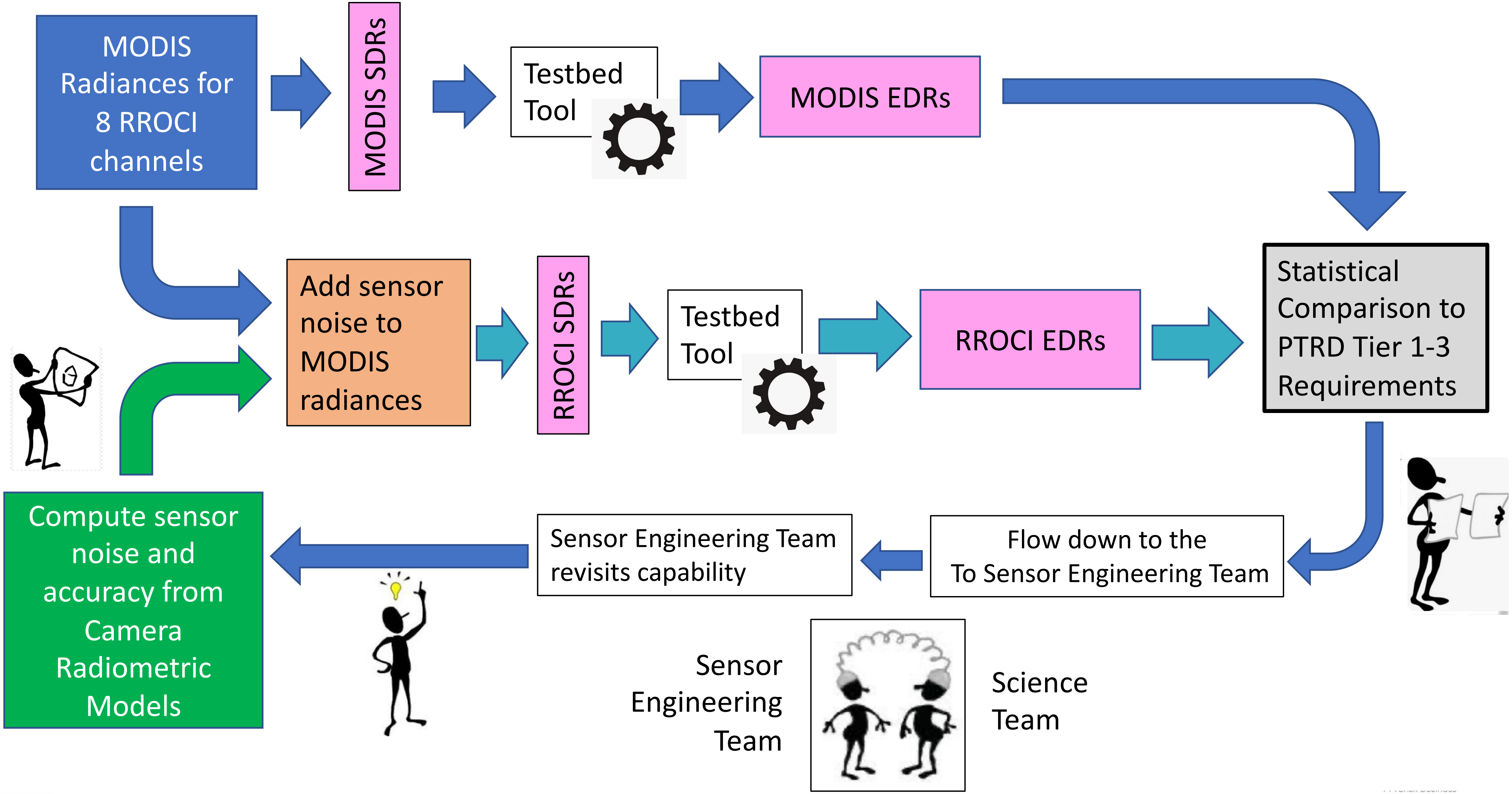


Trade Studies

- Impact of not including the 6.7µm MWIR band and adding 13.3µm band
- Switching 0.55µ to 0.67µ

6.7 µm band removed and add 13.3 µm band added

Background

Both MWIR water vapor channels and LWIR 13-15µm CO_2 channels have long heritage on HIRS and MODIS sensors

Generally, the MWIR channels are employed to infer total precipitable water (TPW)

For cloud retrieval purposes, MWIR water vapor channels are used to infer the presence of low-level temperature inversions and to some degree in cloud phase (high vs low clouds, but the channel has no inherent phase information)

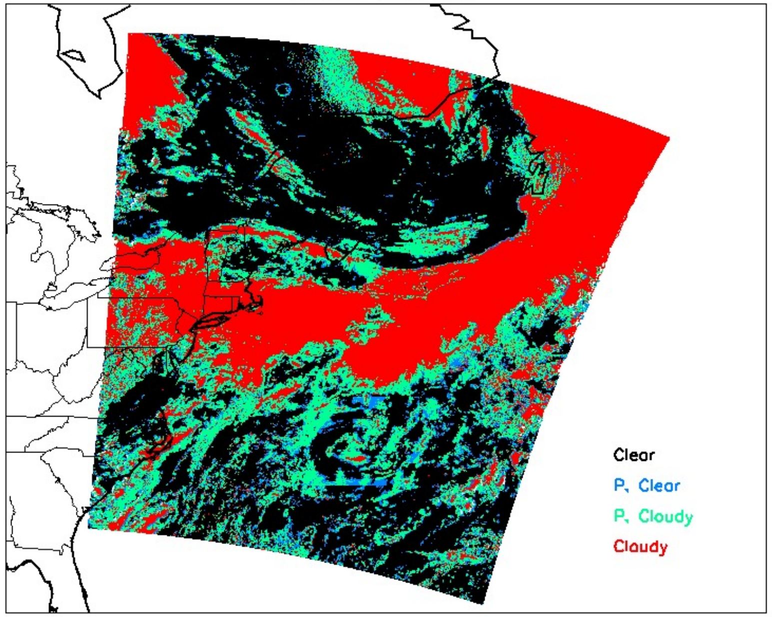
13-15µm CO_2 channels primarily used to infer cloud top height/temperature/pressure and cloud phase, as well as cirrus optical depth.

In the following discussion, use is made of a “weighting function”, that describes the change in transmission with ln(pressure), and indicates where most of the signal is derived in the atmosphere

Does removing the 6.7µm band make a difference?

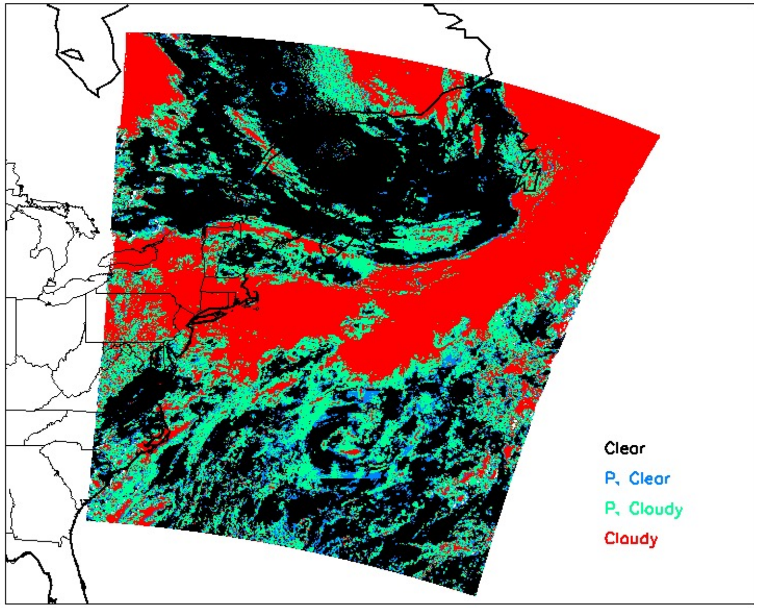
In this experiment we look at cloud cover changes if the 6.7µm band is added back into the RROCI channel set.

RROCI with 6.7 µ band added



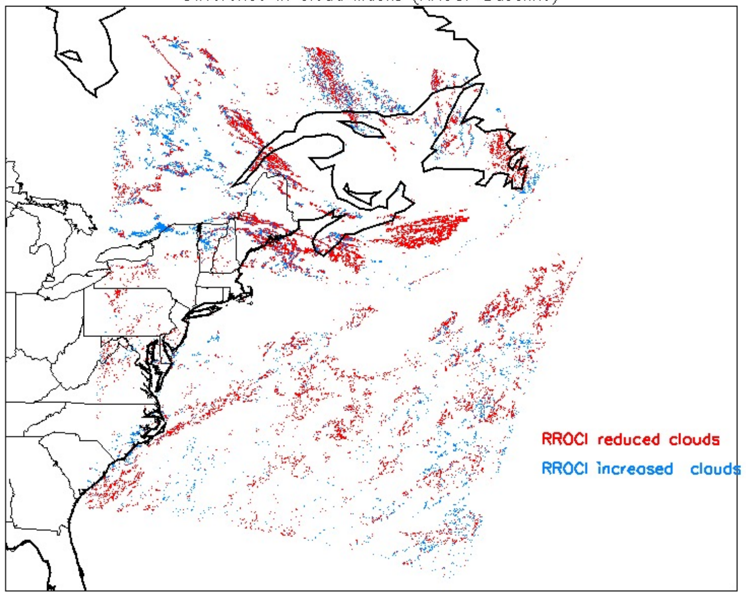
Cloud fraction = 40.57%

RROCI



Cloud fraction = 40.54%

RROCI – (RROCI+6.7)



Cloud fraction changes are negligible
Cloud temperature changes are < 1.5K
Cloud height differences are 0.12 km

We can easily meet Tier 1 and Tier 2 requirements without 6.7µ

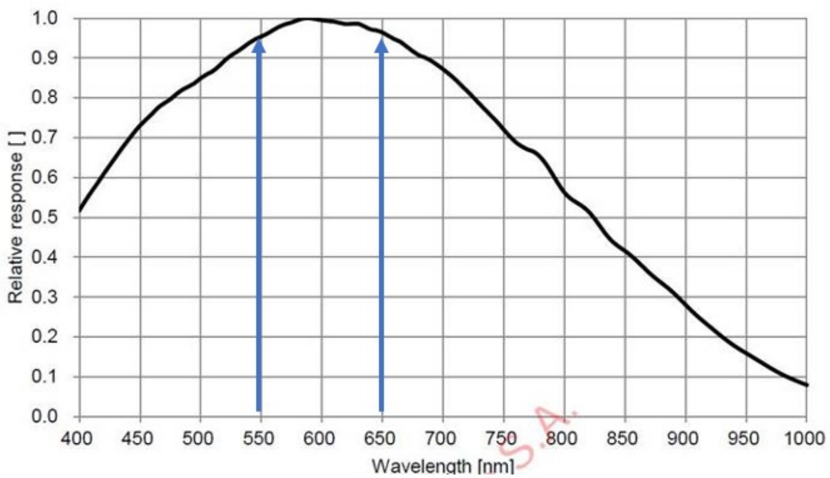
Summary of 6.7 µm band results

- While the 6.7µm channel has some benefits, the 13.3-µm channel is the better choice for global cloud retrievals of height, temperature, and phase.
- When we add 6.7µm into the RROCI payload, the improvement is negligible.
- If there was an opportunity to add one additional LWIR channel, we would suggest the 12 µm with an additional LWIR filter or camera.

Changing the 0.55µm channel to 0.67µm

- Historically, cloud imaging sensors have used ~0.67-µm band
  - 0.63 (AVHRR), 0.64 (ABI), 0.65 (MODIS), 0.7 (DMSP), 0.67 (VIIRS)
- CLAVR-x EDR software uses the 0.65-7 µm channel, as do other software packages
- Both Rayleigh scattering and aerosols are wavelength dependent; both increase as wavelength decreases (e.g., Rayleigh scattering doubles at 0.55 µm from 0.65 µm)
- The optical depth/particle size retrieval process generally follows this path:
  a. Determine whether cloudy pixel is ice or liquid water phase
  b. Determine cloud height, for Rayleigh scattering correction above cloud (basically an atmospheric correction step)
  c. Read cloud transmission/reflectivity properties from look-up table based on viewing angles (solar zenith θ_0, viewing zenith θ, and relative azimuth φ).
  d. Determine land type, use ancillary product to determine bidirectional reflectance function from surface albedo based on viewing angles (solar zenith θ_0, viewing zenith θ, and relative azimuth φ) and time of observation.
  e. Perform radiative transfer calculation.

What changes between the 0.55 µm and 0.65 µm channels?



Wavelength dependence of VIS camera

The camera will not be less sensitive to the longer wavelength

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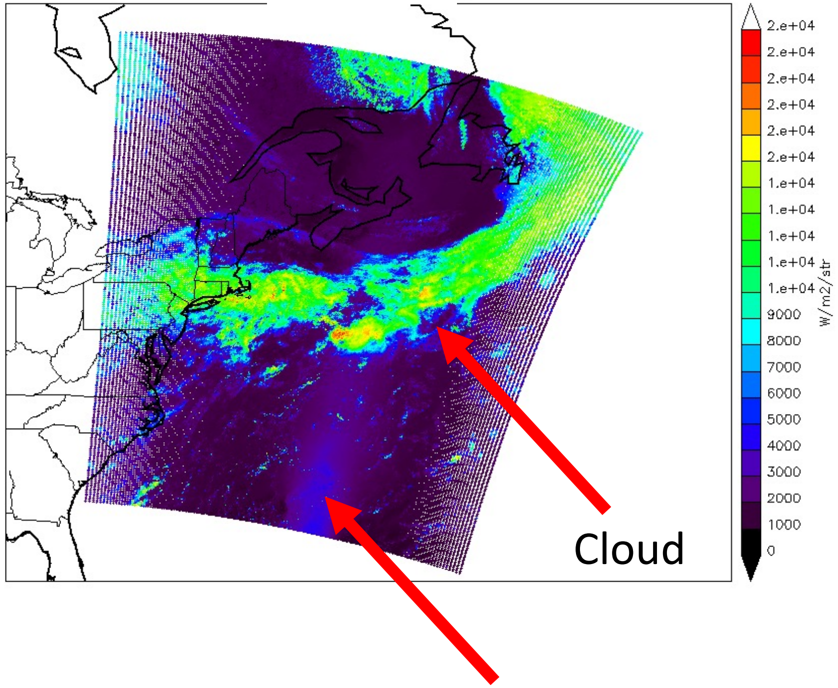
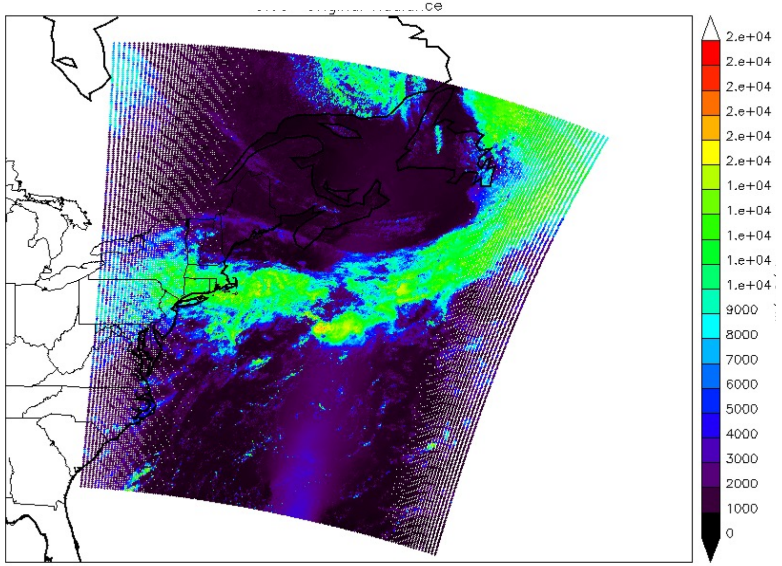
Radiance at 0.55 and 0.65 from MODIS

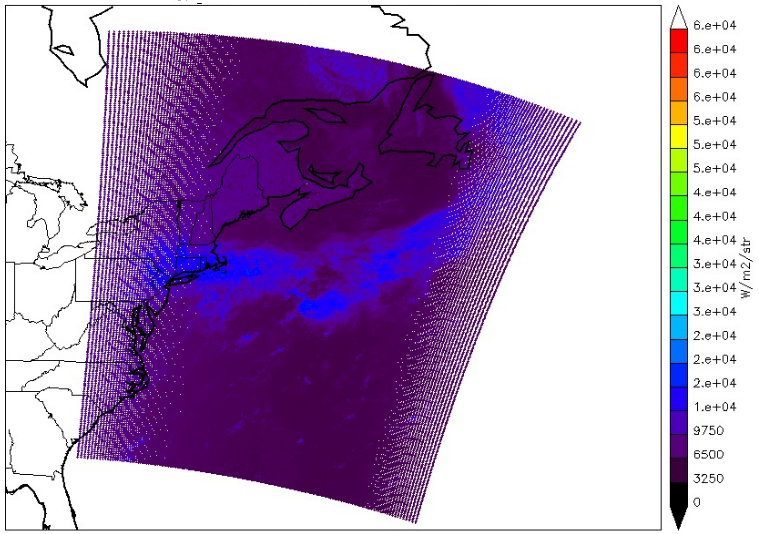
0.55µm



0.65µm



0.55 - 0.65µm



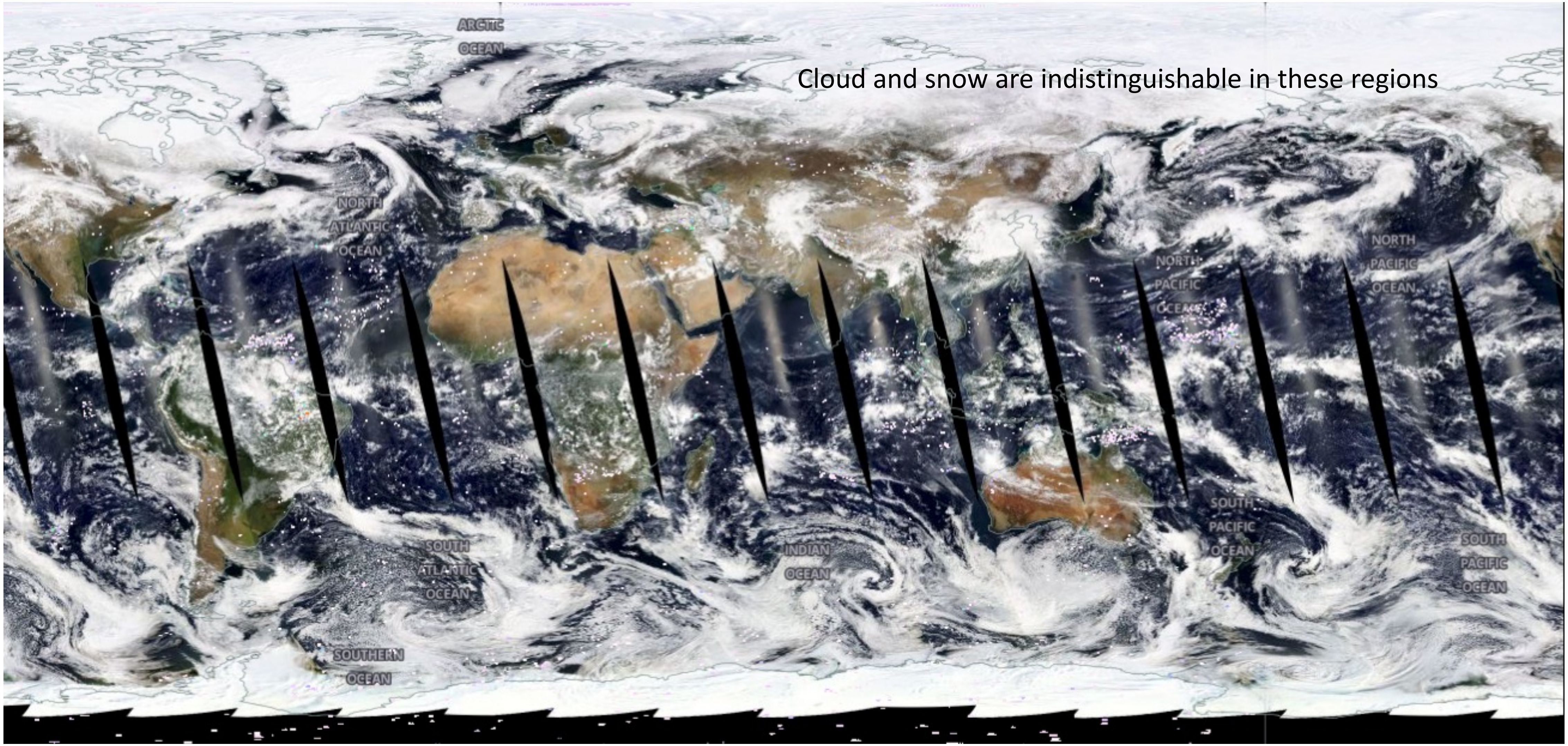
0.55 is brighter for highest clouds

Summary Results of using 0.55µ instead of 0.65µ Experiment

- Using 0.55µ instead of 0.65µ will lead to EDR biases
  - Simple substitution of that band with heuristic correction creates problems with all cloud products
    - Clouds are warmer
    - Clouds are lower
    - Ice OD is lower, ice particles are larger
- To use 0.55µ will require extensive ground processing modifications including computing and deploying additional look up tables
  - This will significantly impact cost and schedule
- RROCI originally proposed 0.55µ, but the Science Team is strongly advocating for a switch based upon the results shown here, and the potential cost of ground software modification.

- **There is no cost or engineering impact to switching filter wavelengths**

Golden Day April 9, 2019 Aqua MODIS RGB Imag



The Opportunity & Benefits

Product	PTRD	Tier	Req / Obj.
CTT thick clouds uncertainty	6a	1	6 K/ 3 K
CTT thin clouds uncertainty	6b	1	12 K
Cloud Probability of Detection day (night)	7	1	93% /98% (86% /95%)
Phase Accuracy	9	2	80%/90%
COD Accuracy day (night)	10a	2	20% (30%)
COD Precision day (night)	10b	2	20% (30%)
CTH Thick Clouds Uncertainty	11a	2	1 km/ 0.5 km
CTH Thin Clouds Uncertainty	11b	2	2 km
CBH Thick Clouds Unc. AGL < 4 km	12a	2	1 km
CBH Thick Clouds Unc. AGL > 4 km	12b	2	2 km
CBH Thin Clouds Unc. AGL > 4 km	12c	2	3 km
Liquid Water Path Uncertainty	13	2	25%
Part. Size Accuracy	15a	3	20%
Part. Size Precision	15b	3	10%

"These parameters are in the trade space for improved performance."

D = day, N = night, AGL= above ground level
Accuracy = average (RROCI- MODIS)
Precision= standard deviation (RROCI-MODIS)
Uncertainty =√ (accuracy^2 + precision^2)|

EDR Results including Using all MODIS Channels

Product	PTRD	Tier	Req / Obj.	Day FDR AM	VIIRS
CTT thick clouds uncertainty	6a	1	6 K/ 3 K		6.6
CTT thin clouds uncertainty	6b	1	12 K		8.6
Cloud Probability of Detection day (night)	7	1	93% /98% (86%/95%)		98
Phase Accuracy	9	2	80%/90%		
COD Accuracy day (night)	10a	2	20% (30%)		15
CTH Thick Clouds Uncertainty	11a	2	1 km/ 0.5 km		1
CTH Thin Clouds Uncertainty	11b	2	2 km		1.4
CBH Thick Clouds Unc. AGL < 4 km	12a	2	1 km		DNC
CBH Thin Clouds Unc. AGL > 4 km	12c	2	3 km		DNC
Part. Size Accuracy	15a	3	20%		7
Part. Size Precision	15b	3	10%		22
Meets Objectives					
Meets Requirements					
Does not meet requirements			.		

Comparison Against all MODIS 36 Channels Still Meets the T1 requirements and compares Well against VIIRS

B8- Our Baseline 8 MODIS Channels

AM- All MODIS Channels

VIIRS- VIIRS Against MODIS L3

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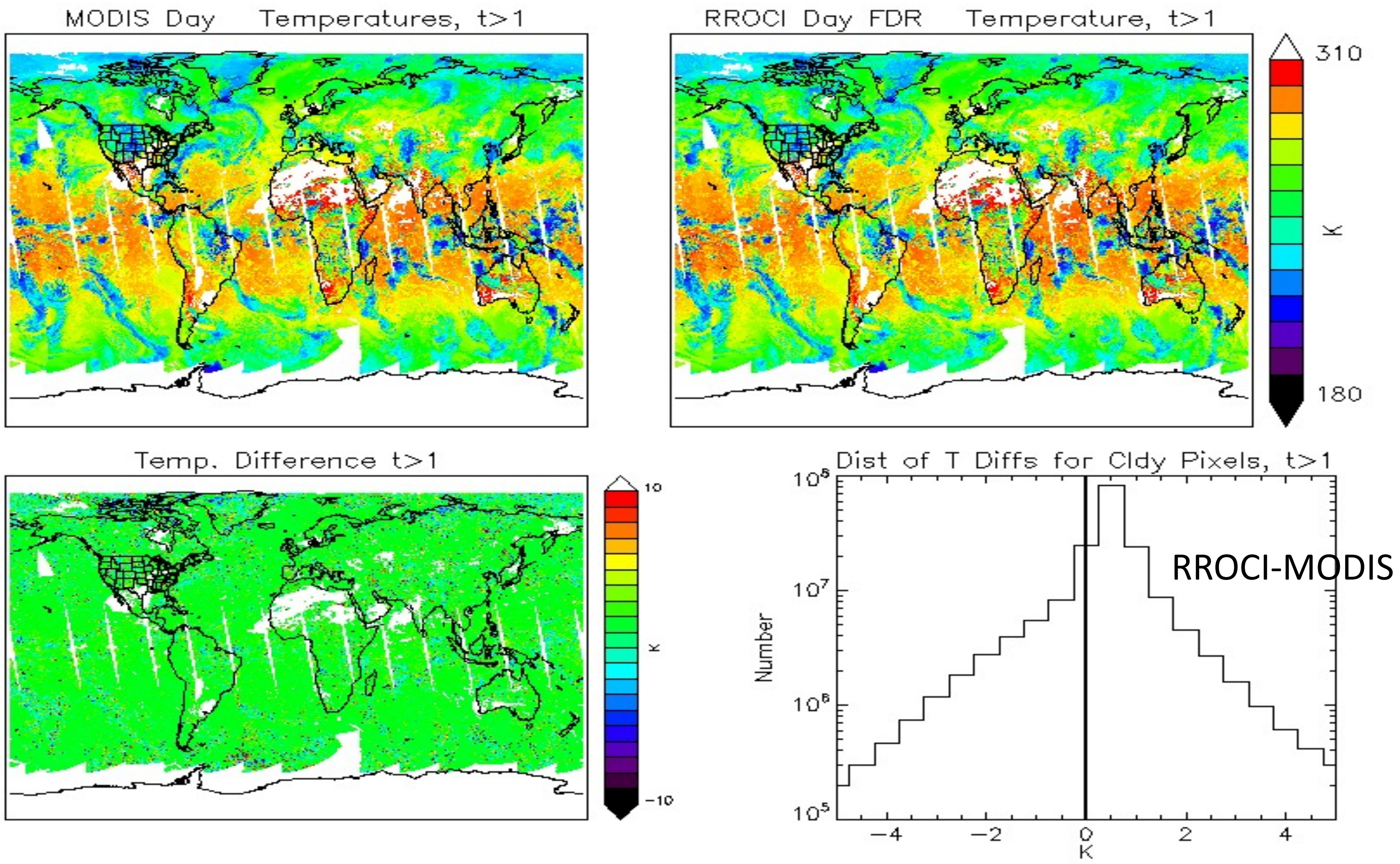
PTRD 6 Cloud Top Temperature (τ >1) (day)



3.0K Unc.
Objective is 3K
Req is 6K

Summary , Questions

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- New Data Products similar to those on VIIRS will be available as early as April 2022.
- There is an opportunity for data evaluation of this data for NOAA
  - This reduces risk for future NOAA satellite architectures, provides additional synergy /partnership with the Air Force, and Possibly allows for a 3-way collaboration during RROCI Cal/val (April –July 22)

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