Cloud Detection, Height and Optical Properties: MODIS Standard & MODIS/VIIRS Continuity Products

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MODIS/VIIRS Science Team Meeting
College Park, MD
20 November 2019

Topics

- MODIS Standard Cloud Product Status (**MOD35**, **MOD06**)
  - C6.1 trend assessments
  - C7 major activities
- MODIS/VIIRS Continuity Product Status (**CLDMSK**, **CLDPROP**)
  - Continuity paradigm overview
  - Example results (L2 and L3)
  - Ongoing efforts
- New “atmosphere imager” web site, documentation, etc.

Collection/Version History

MODIS Atmosphere Team Products (MOD/MYD 04, 05, 06, 07, 35, 08, ATML2)

Collection	Start of Reprocessing MODIS Terra	Start of Reprocessing MODIS Aqua
6.1	Sept. 2017 (completed Dec. 2017)	Dec. 2017 (completed March 2018)
6.0	2014	2013
5.1	2008	2008
5.0	2005	2005
4	2002	2002
3	2001	2002
1	2000	–

MODIS & VIIRS Cloud Continuity Products (CLDMSK, CLDPROP)

Version	Start of Reprocessing	Public in LAADS
1.1*	Aug. 2019 (completed Sept. 2019)	Nov. 2019 (L2 + L3)
1.0	March 2019 (completed Apr. 2019)	April 2019 (L2)

** improved thermodynamic phase wrt MOD06 heritage*

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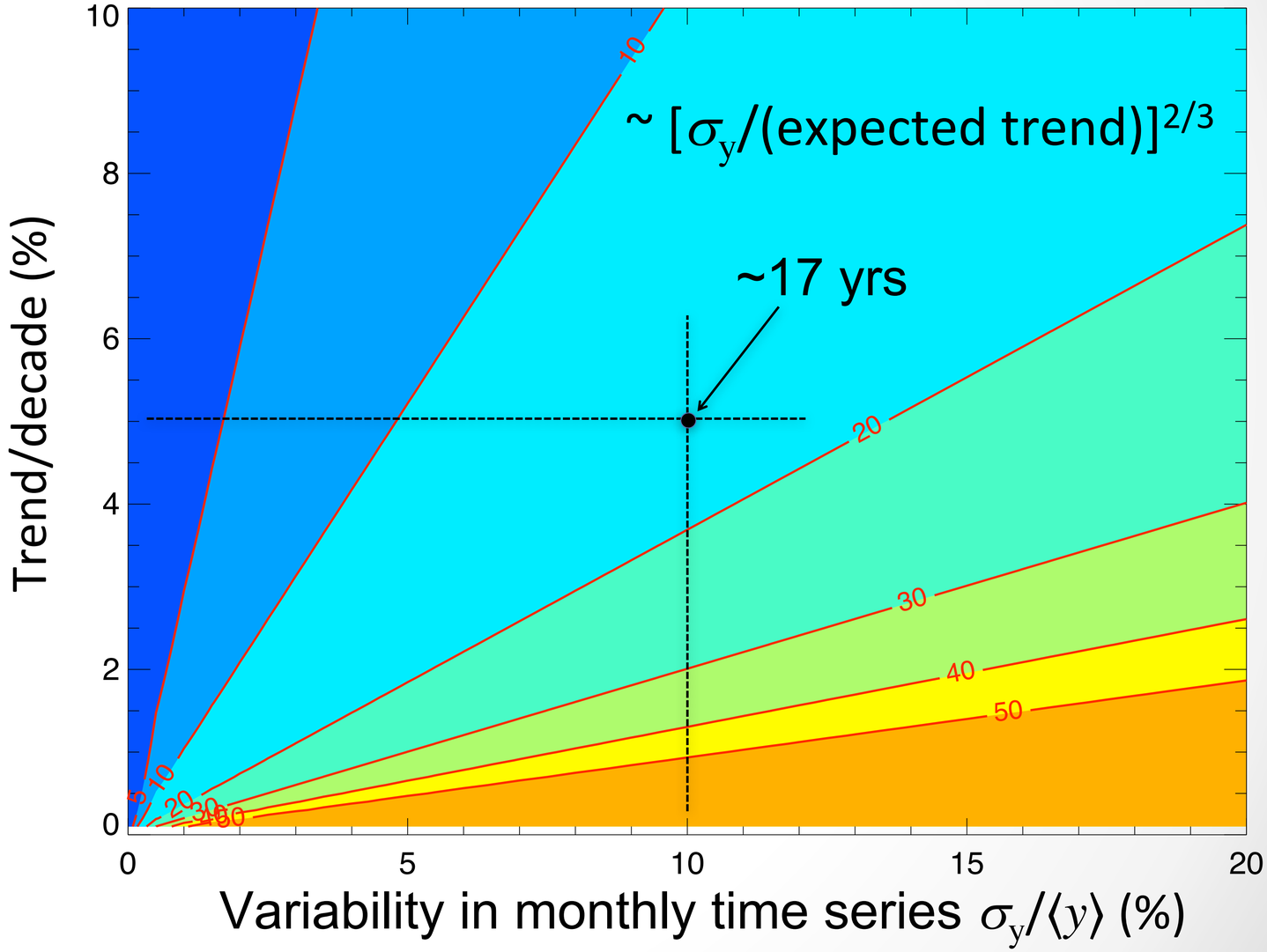
MODIS Radiometric Stability Challenges: Reminder

- L1B
  - C5.1 => C6.0
    - Terra VNIR/SWIR radiometric corrections (RVS), corrected significant Cloud Optical Thickness (COT) trends
    - Aqua VNIR spatial “re-registration”, corrected small cloud scale retrieval issues
  - C6.0 => C6.1
    - Terra IR cross-talk corrections, corrected significant trends in cloud amount and cloud top height trends
    - Further Aqua/Terra RVS corrections (primarily COT trends)

Trend Detection

Number of Years Required to Detect a Trend

(90% prob. of detecting a trend to a 0.05 statistical level, no autocorrelation)

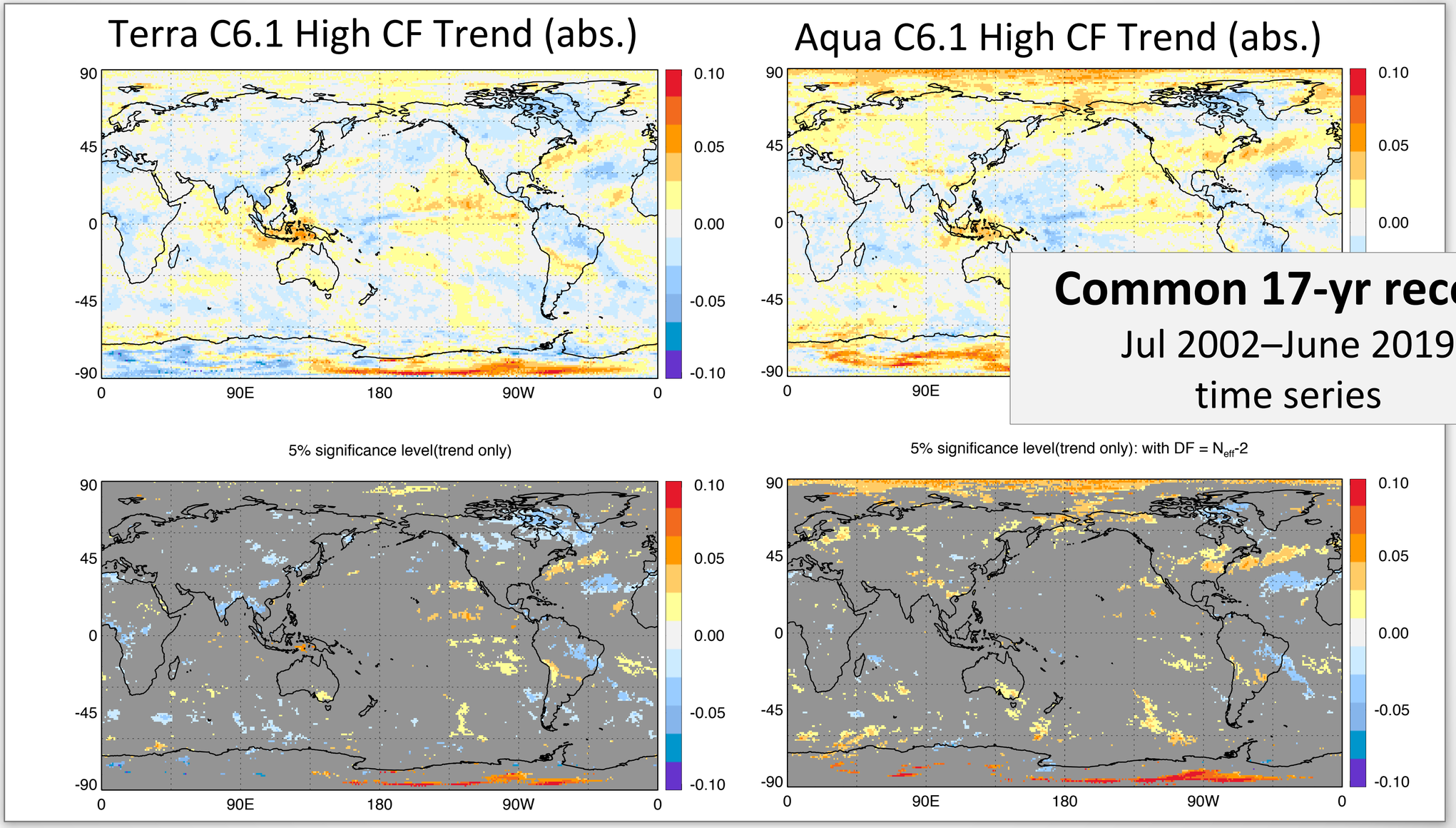


Platnick et al., UMCP, Nov 2019

C6.1 MODIS Terra vs Aqua Trends: High Cloud Fraction

trend per decade

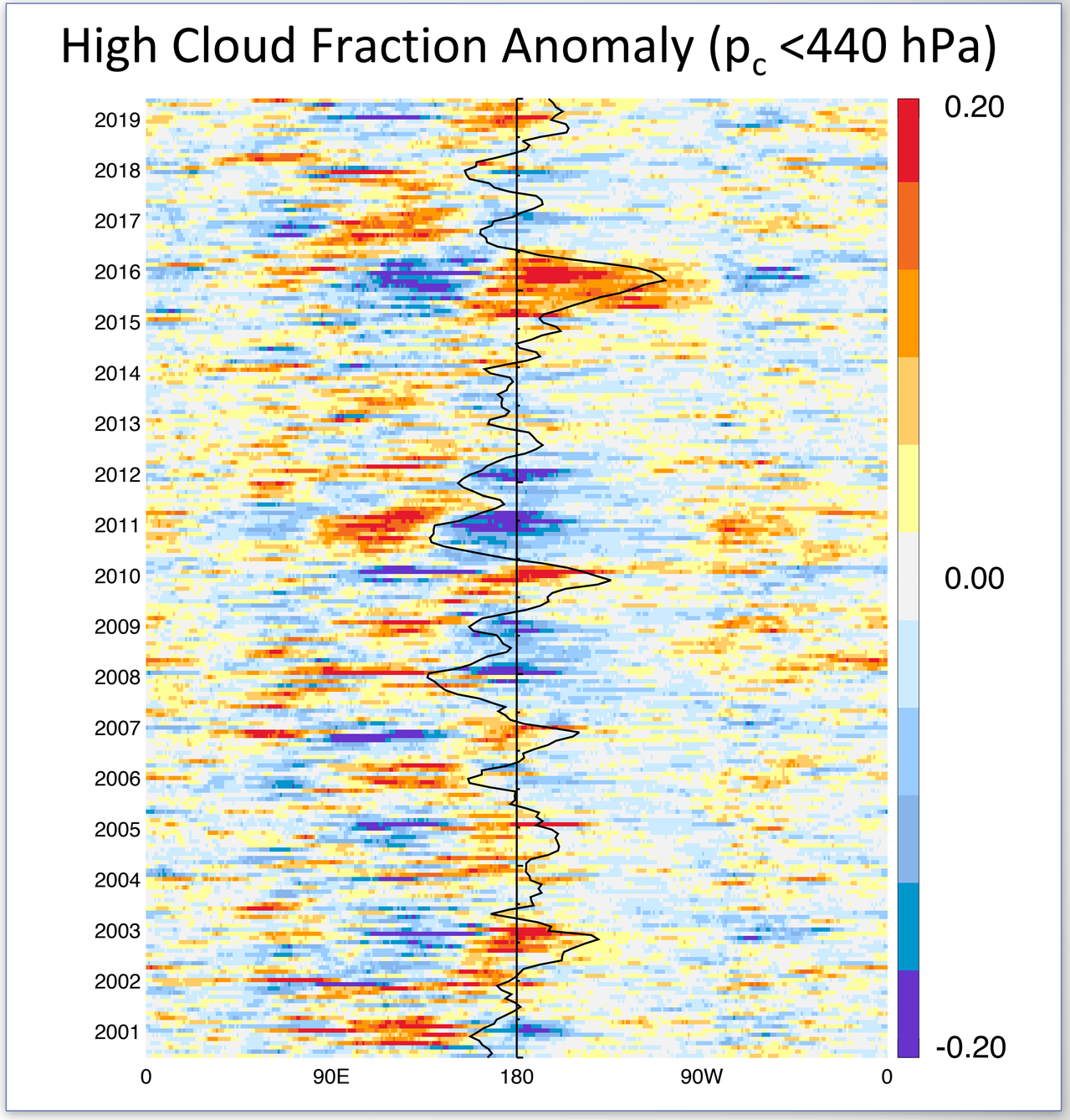
trend masked by **5% sig. level**



Common 17-yr record
Jul 2002–June 2019
time series

C6.1 MODIS Terra High Clouds vs. El Nino Southern Oscillation (ENSO)

Hovmöller plot:
Jul 2000–June 2019, ±15° lat
solid line:
ENSO 3.4 index

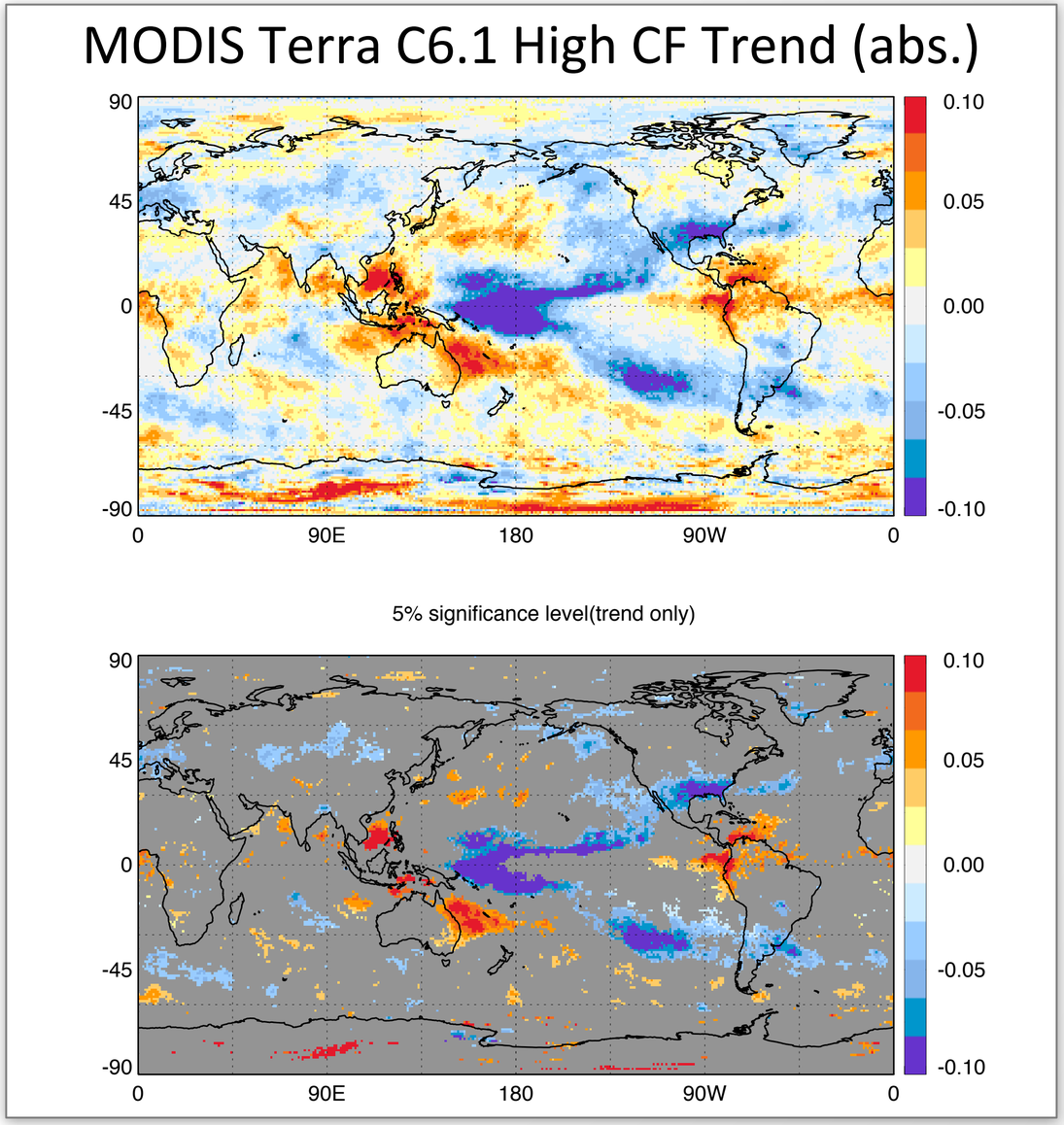


C6.1 MODIS Terra Trends: High Cloud Fraction

trend per decade

12 year record
Jul 2000–June 2012
time series

trend masked by **5% sig. level**

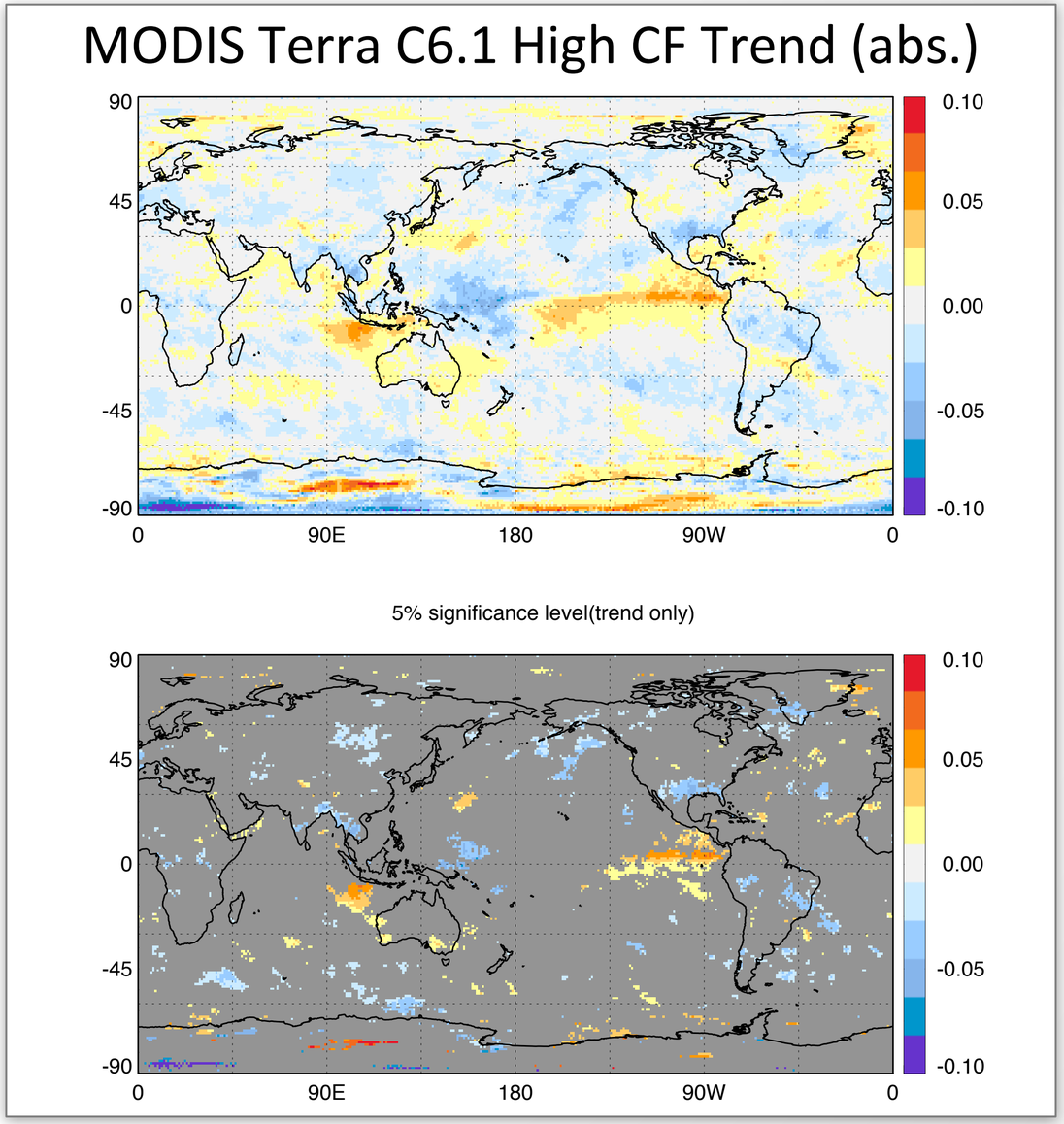


C6.1 MODIS Terra Trends: High Cloud Fraction

trend per decade

17 year record
Jul 2000–June 2012
time series

trend masked by **5% sig. level**

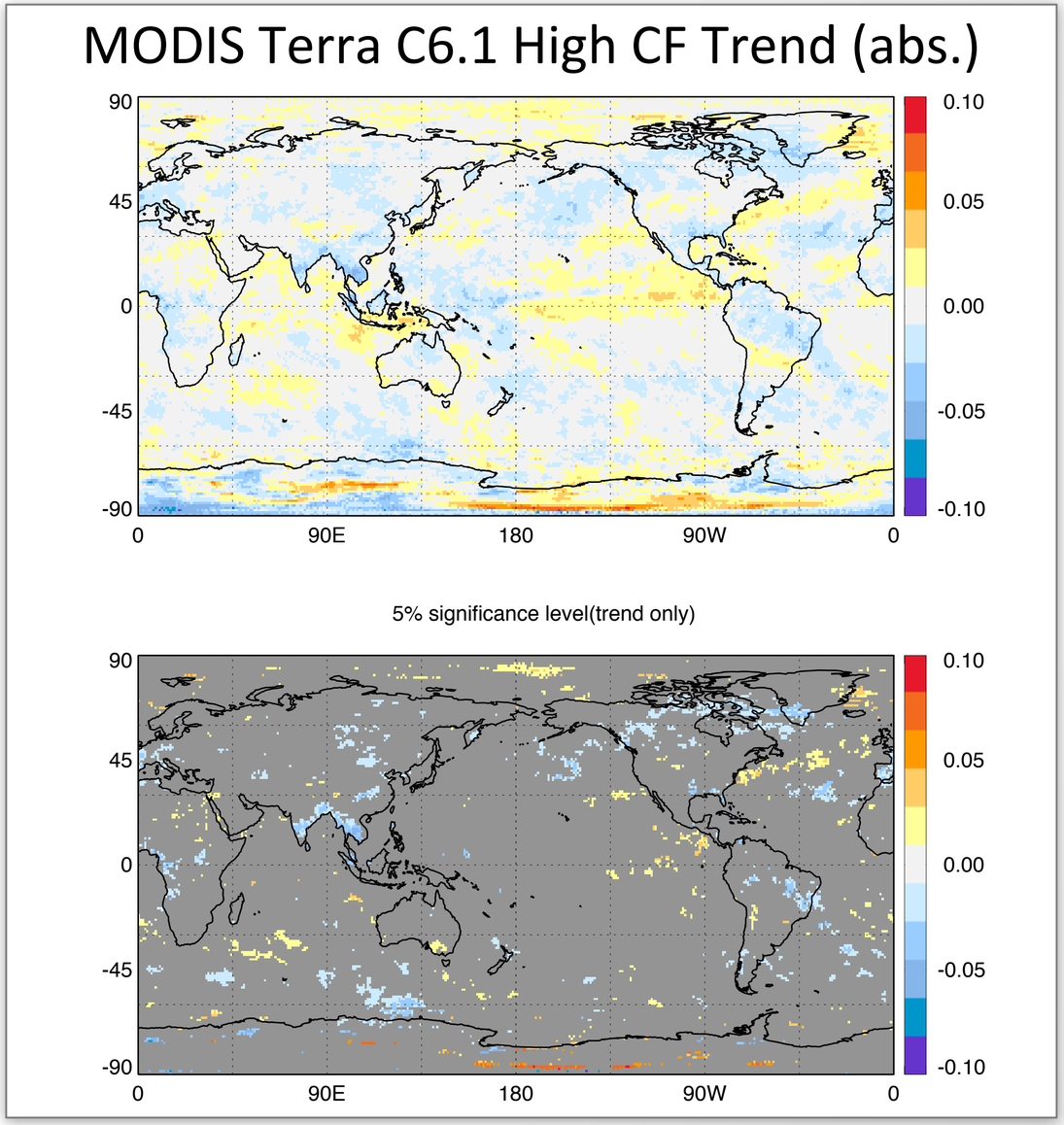


C6.1 MODIS Terra Trends: High Cloud Fraction

trend per decade

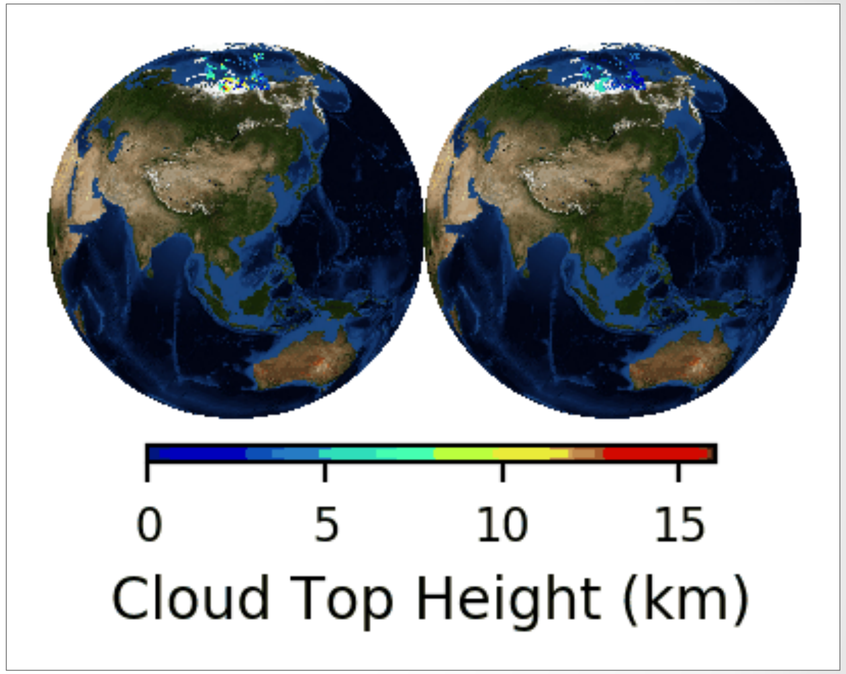
19 year record
Jul 2000–June 2012
time series

trend masked by **5% sig. level**



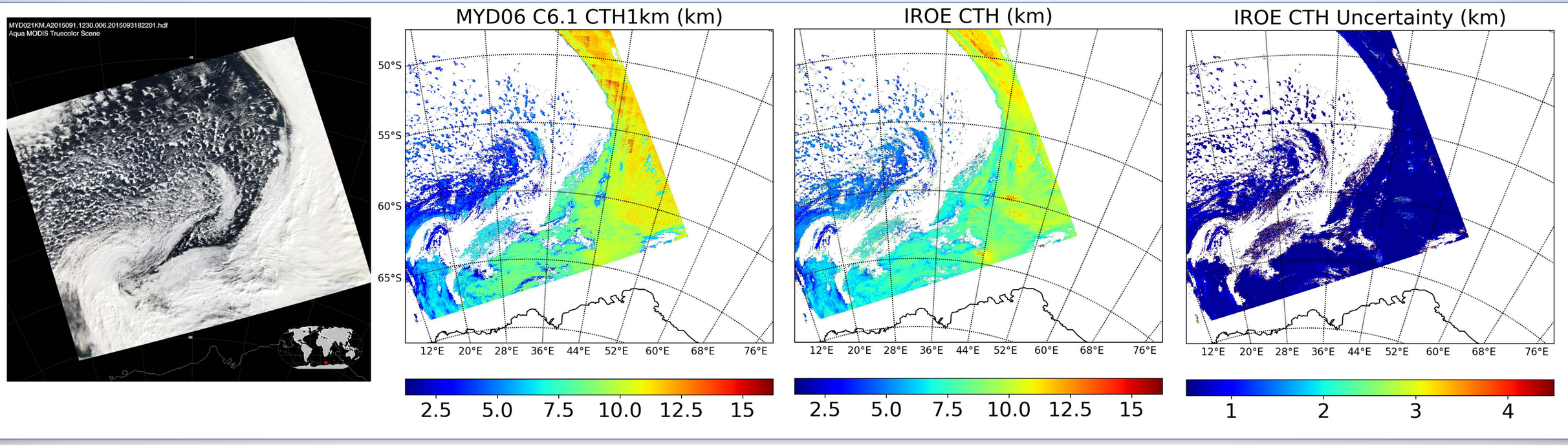
C7 IR Optimal Estimation (IROE) 1km Cloud Top/Optical Properties

- Features
  - Instantaneous 1-km ice cloud optical thickness, effective radius, and cloud-top height retrievals, with uncertainties
  - Consistent day/night optical retrieval algorithm
  - Designed for ice cloud retrievals using MODIS IR bands (3.7-14 μm), but can use other IR band combinations (e.g., VIIRS)
  - Computationally efficient: comparable to current MOD06 COP algorithm
  - Awaiting MODAPS science testing



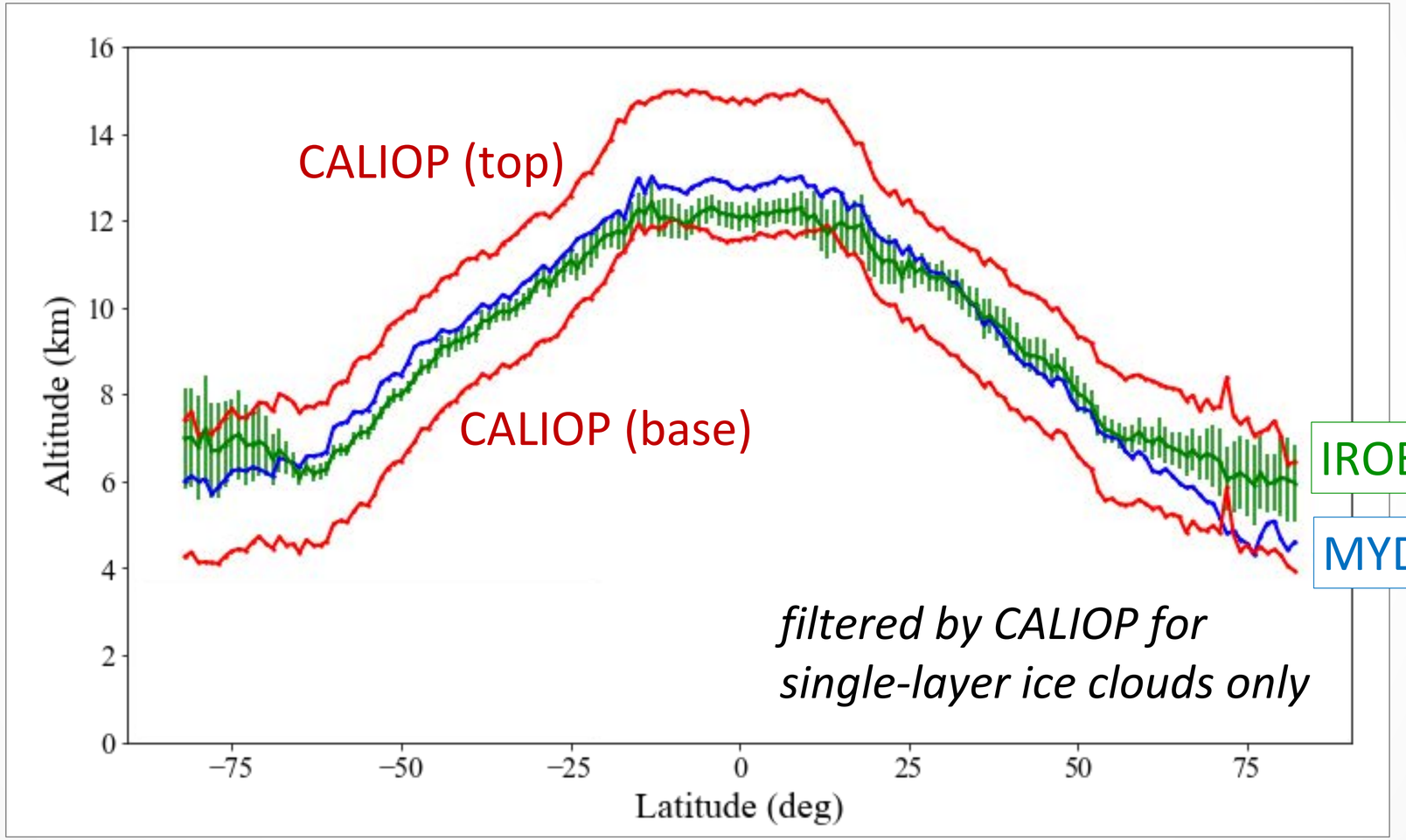
Chenxi Wang et al., JGR, 2016a,b; also see poster

IR Optimal Estimation (IROE) Granule Example

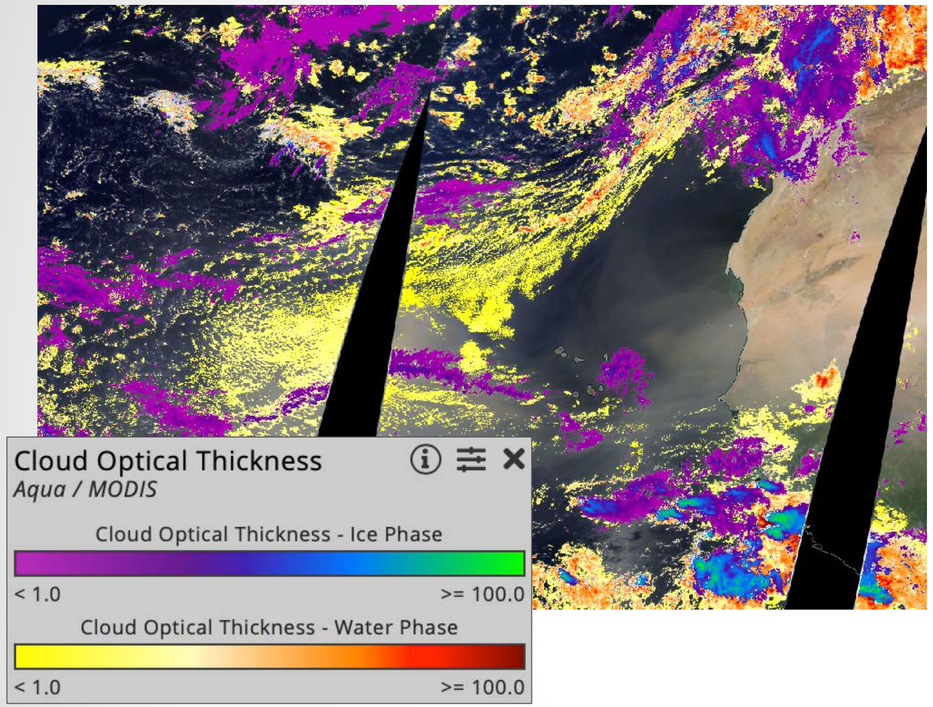


IR Optimal Estimation (IROE) Global Evaluation

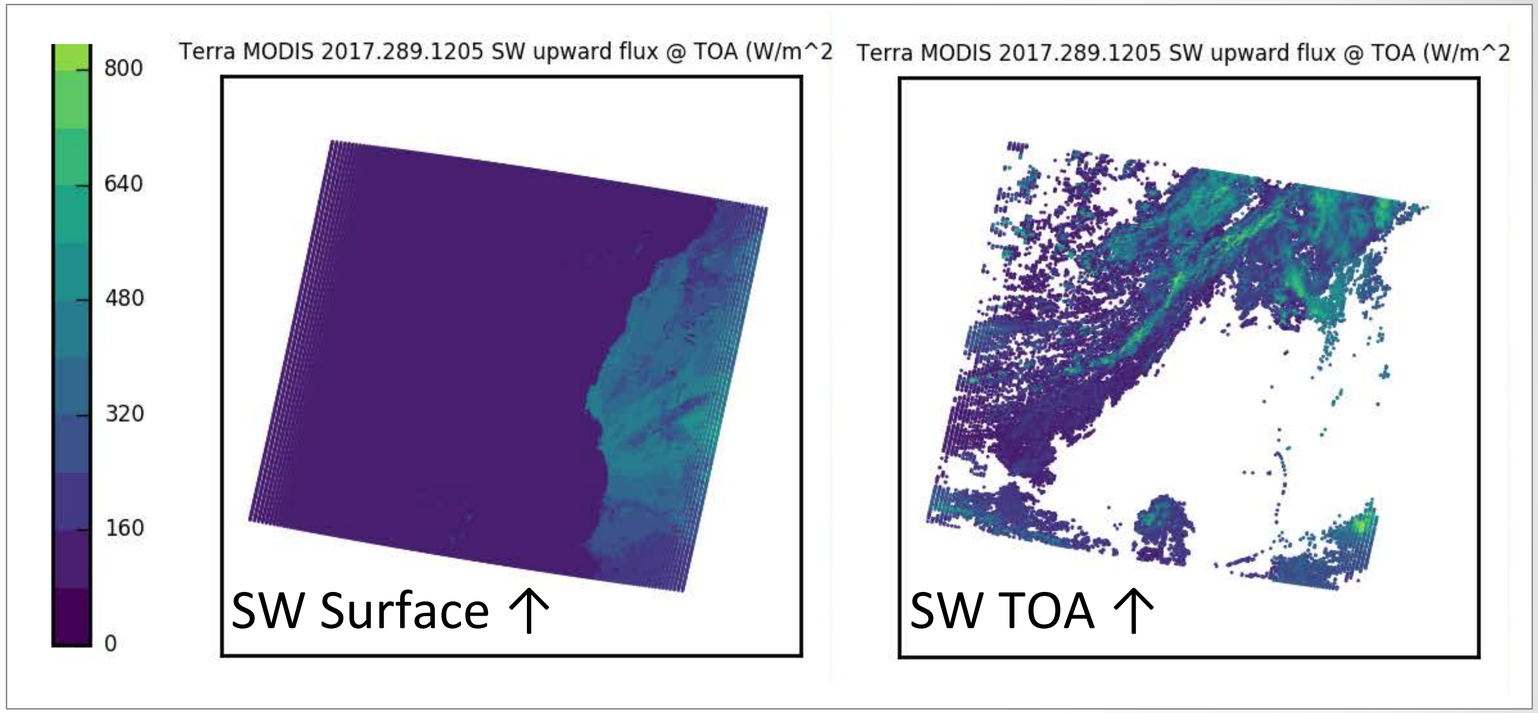
April 2015 Zonal Mean Ice Cloud Top Height (km) comparisons



C7 Radiative Flux Example Calculation



MODIS Terra, 16 Oct. 2017



for liquid water cloud scenes:
TOA SW + LW upwelling "clear" – cloudy TOA ≈ -136 W/m^2

Gala Wind, Dongmin Lee, Lazaros Oreopoulos, Ping Yang, et al.

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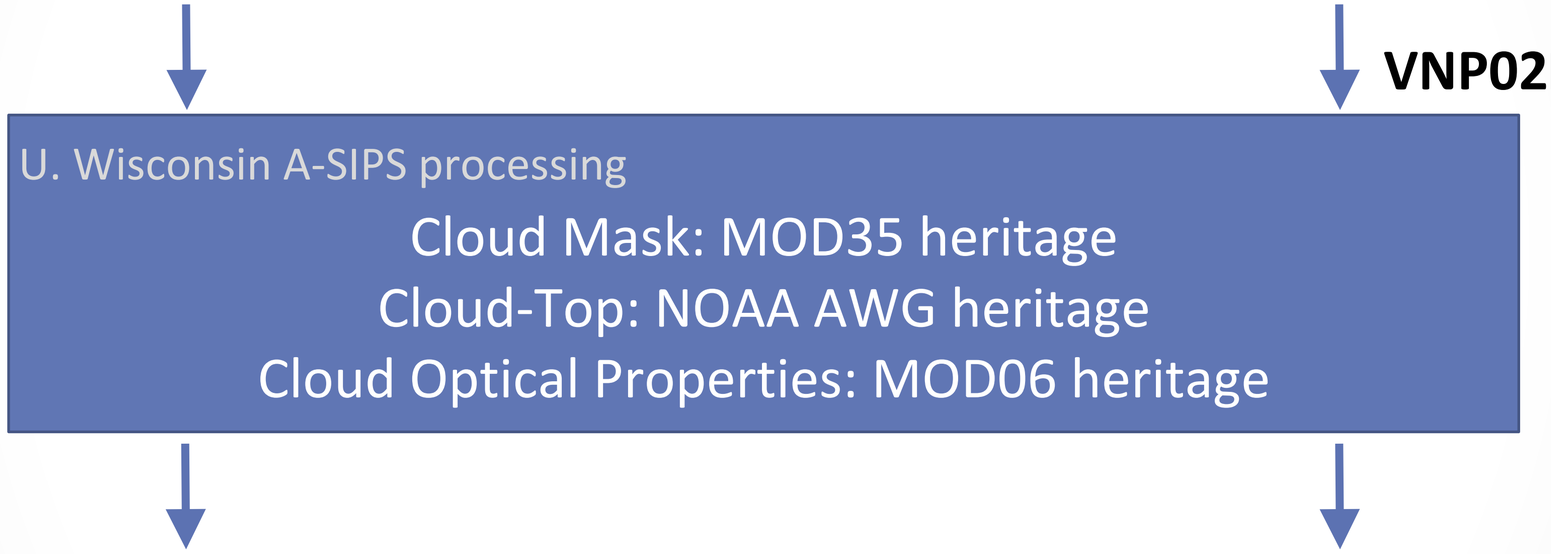
Challenges for MODIS/VIIRS Cloud Product Continuity: Reminder

- Spectral coverage (most direct challenge)
  - 2 μm window channels: VIIRS 2.25 μm vs. MODIS 2.13 μm
  - VIIRS missing MODIS CO_2 and H_2O absorption channels
- Relative radiometric calibration in solar reflectance channels
  - Spectral bias adjustments made to SNPP VIIRS using *homogenous* liquid water clouds (*Meyer et al.* using A-SIPS match files)
- Spatial resolution and spatial/temporal sampling
  - VIIRS (750, 375 m) vs. MODIS (1000 , 500 , 250 m) at nadir
  - VIIRS pixel size DOES NOT increase as substantially with scan angle as MODIS
  - Missing M-band bow-tie pixels “added” by A-SIPS for following results

Strategy for Spectral Differences: Common MODIS & VIIRS Algorithm

MODIS Aqua L1B + Geolocation
MYD02, **MYD03**
(channel subset common w/VIIRS)

NASA VIIRS L1B intermediate product*
(w/restored bow-tie pixel deletions +
VNIR/SWIR radiometric adjustments) +
Geolocation
VNP02MOD, **VGEOM**



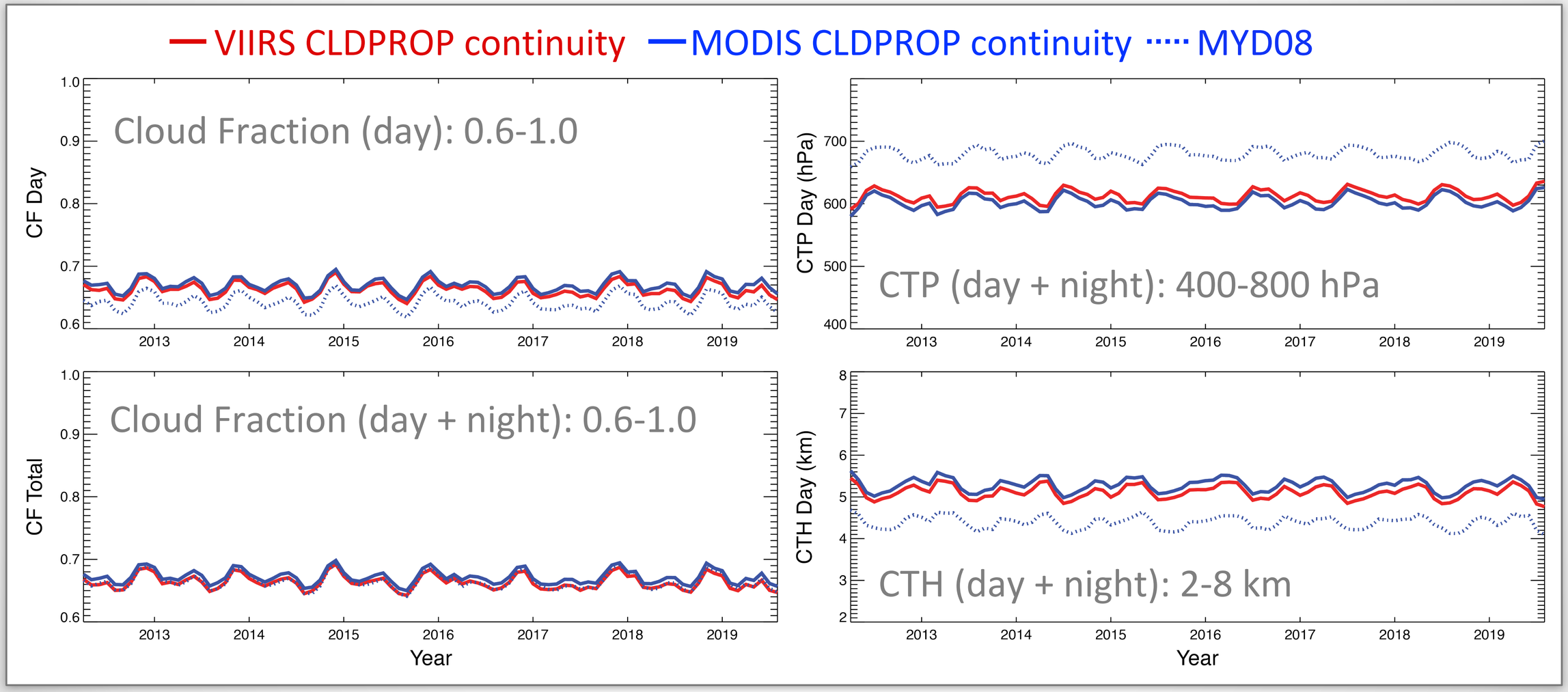
MODIS Continuity Products
CLDMSK_L2_MODIS_Aqua
CLDPROP_L2_MODIS_Aqua

VIIRS Continuity Products
CLDMSK_L2_VIIRS_SNPP
CLDPROP_L2_VIIRS_SNPP

L3 Continuity Products (“Yori”)
CLDPROP_D/M3_VIIRS_SNPP
CLDPROP_D/M3_MODIS_Aqua

* *Atmosphere SIPS*

Cloud Mask and Cloud Top Pressure (CTP)/Height (CTH)

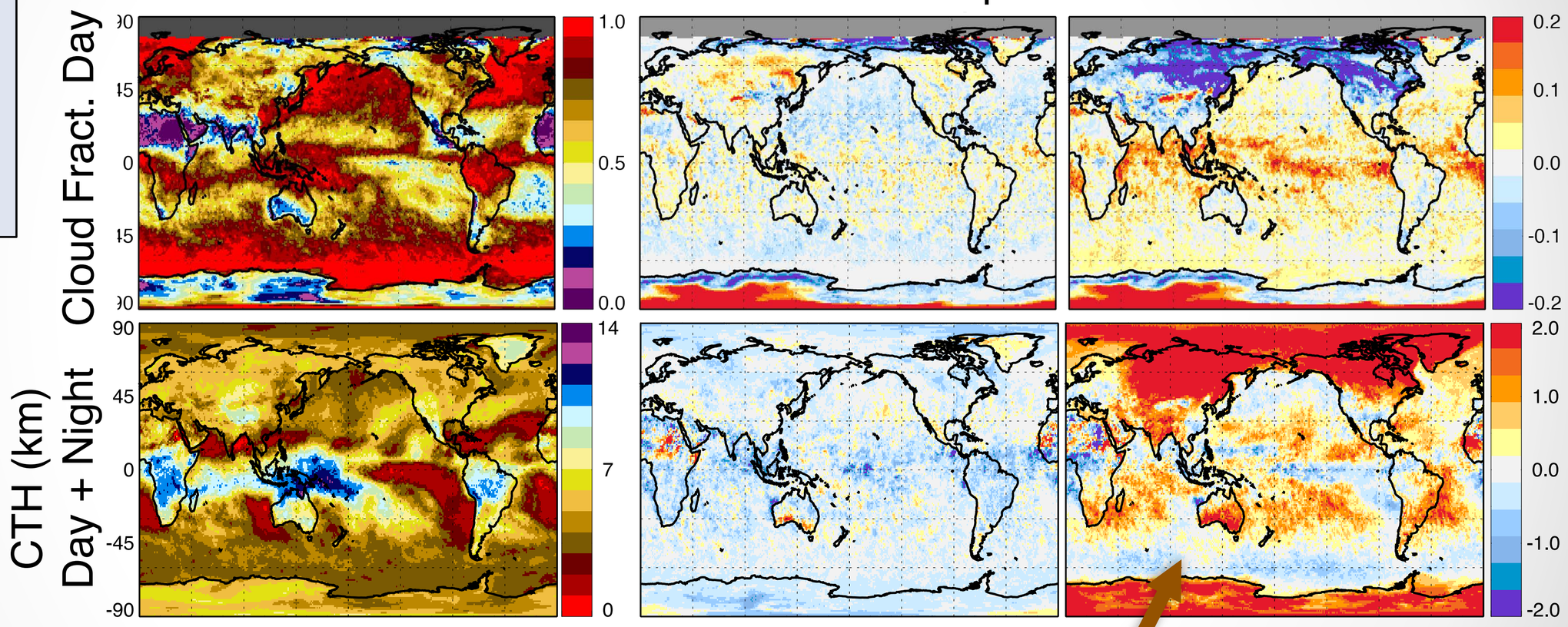


CLDPROP v1.1, ±60° latitude, ocean + land

Monthly Means
Feb 2014 (v1.1)

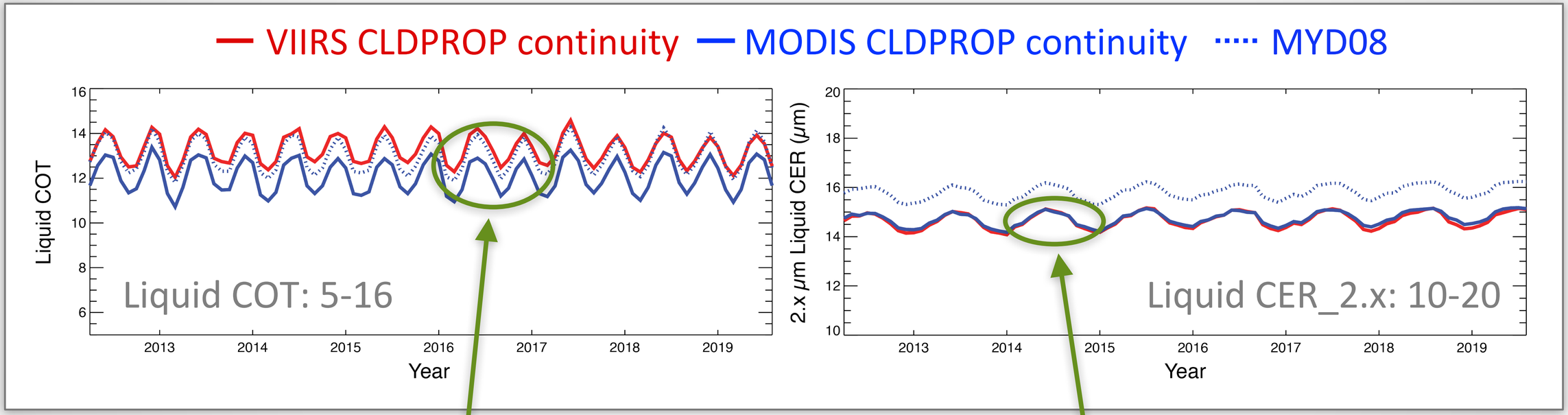
- Production version of common algorithm, includes SW Radiometric Bias Correction
- Pixel-weighted aggregation over common swath

common algorithm



a separate MODIS product run with the common algorithm is required for continuity

Daytime Cloud Optical Properties Liquid Clouds



"overcast" population

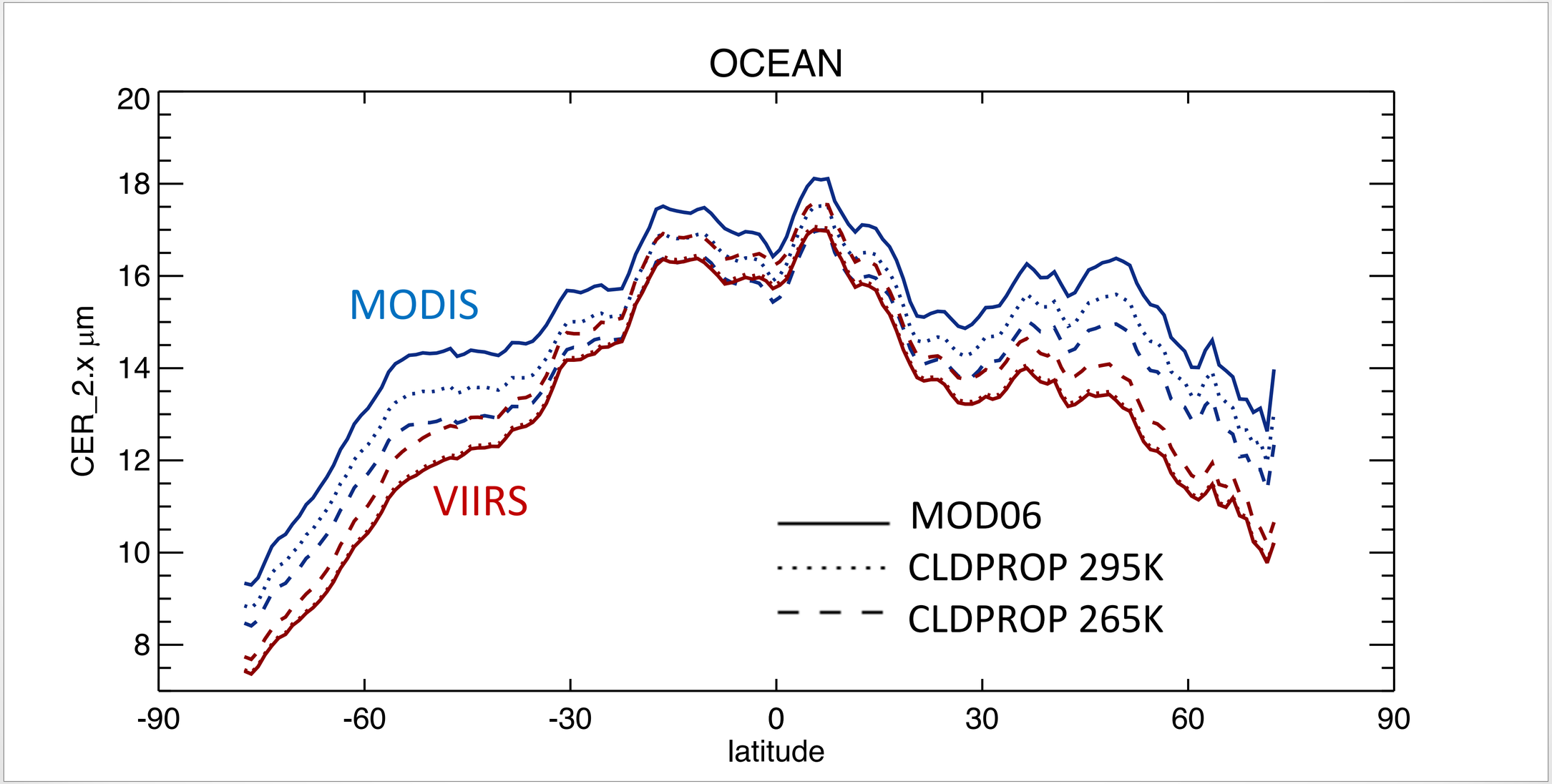
why the sig. difference?!

required updated liquid index of refraction dataset improved biases across the 2 μm window locations

CLDPROP v1.1, ±60° latitude, ocean + land

MODIS Liquid Water CER_2.x µm Comparisons

Feb. 2014 zonal means vs. liquid water index of refraction (LUTs)

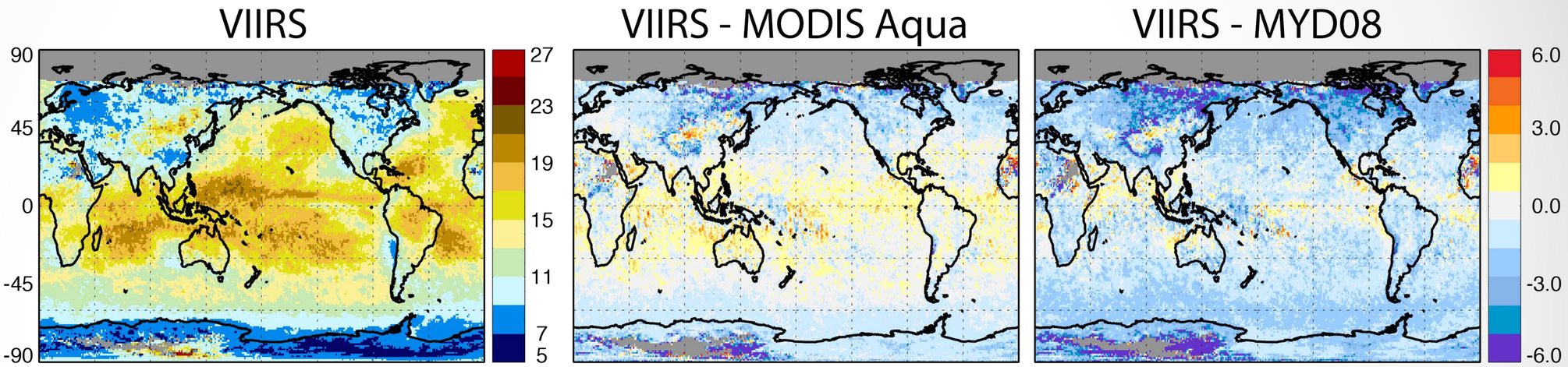


Liquid Water CER_2.x (μm) Comparisons

Monthly Means
Feb 2014 (v1.1)

- Production version of common algorithm, includes SW Radiometric Bias Correction
- Pixel-weighted multi-day aggregation over common MODIS swath
- Daytime only
- Highest Quality (“Overcast” pixels)

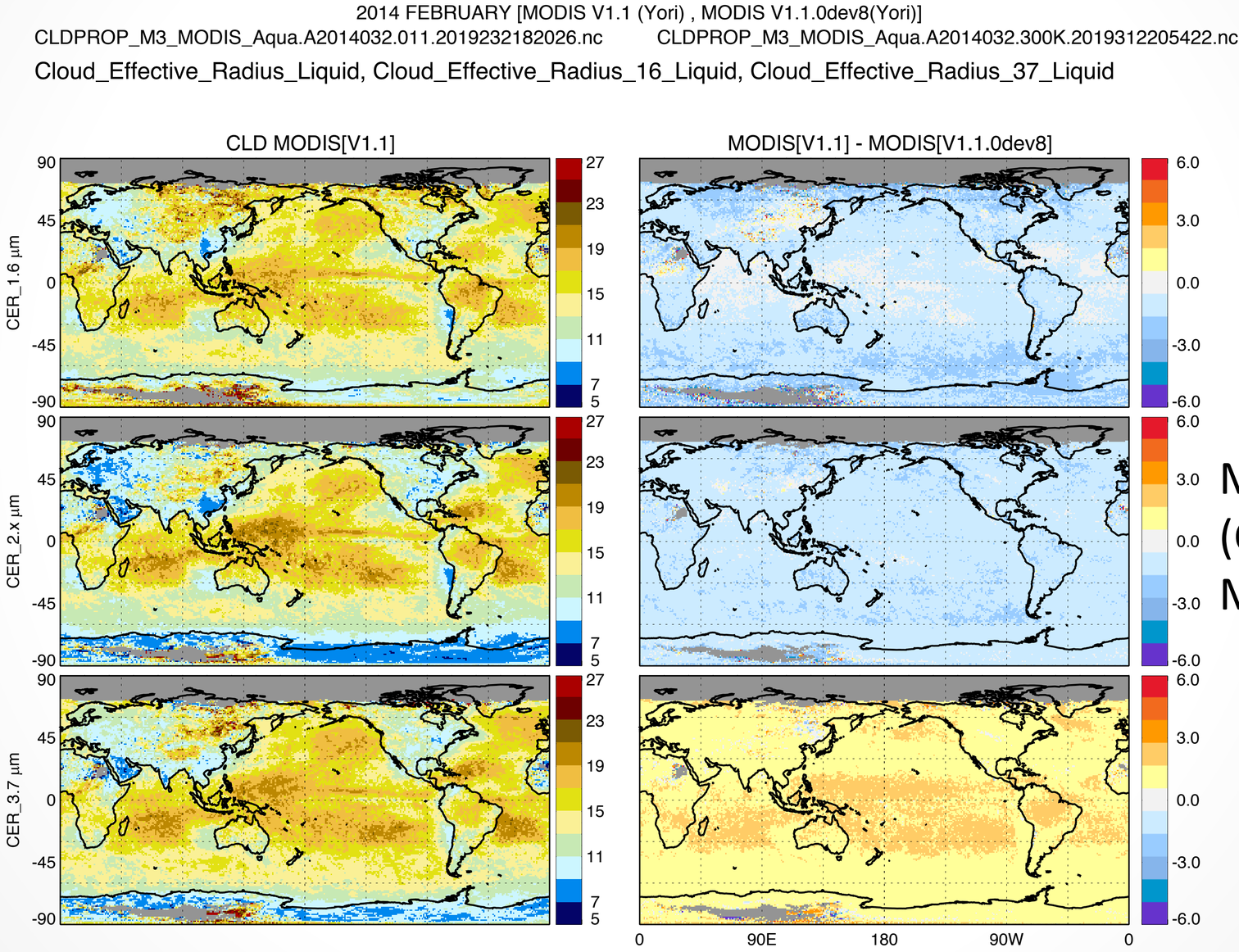
common algorithm



Initial implementation of CLDPROP 2.25 μm (VIIRS) and MYD06 (MODIS) 2.13 μm (MODIS) effective radii revealed large biases, suggesting an inconsistency in the RT forward model.

=> Updated liquid index of refraction dataset improved biases (center panel)

MODIS Liquid Water CER Comparisons



CER 1.6 µm

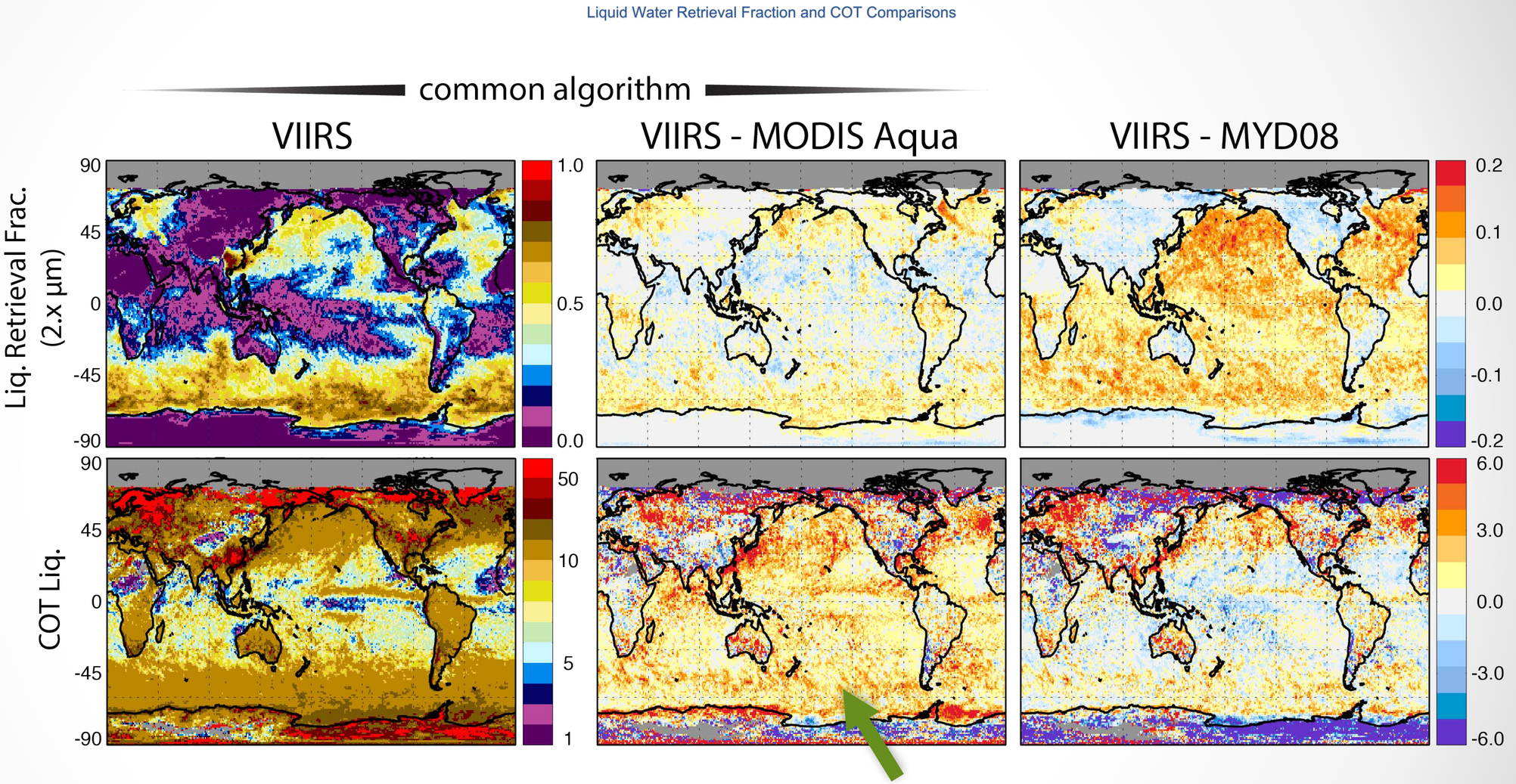
CER 2.x µm

CER 3.7 µm

MODIS ΔCERs (CLDPROP LUTs *minus* MOD06 C6.1 LUTs)

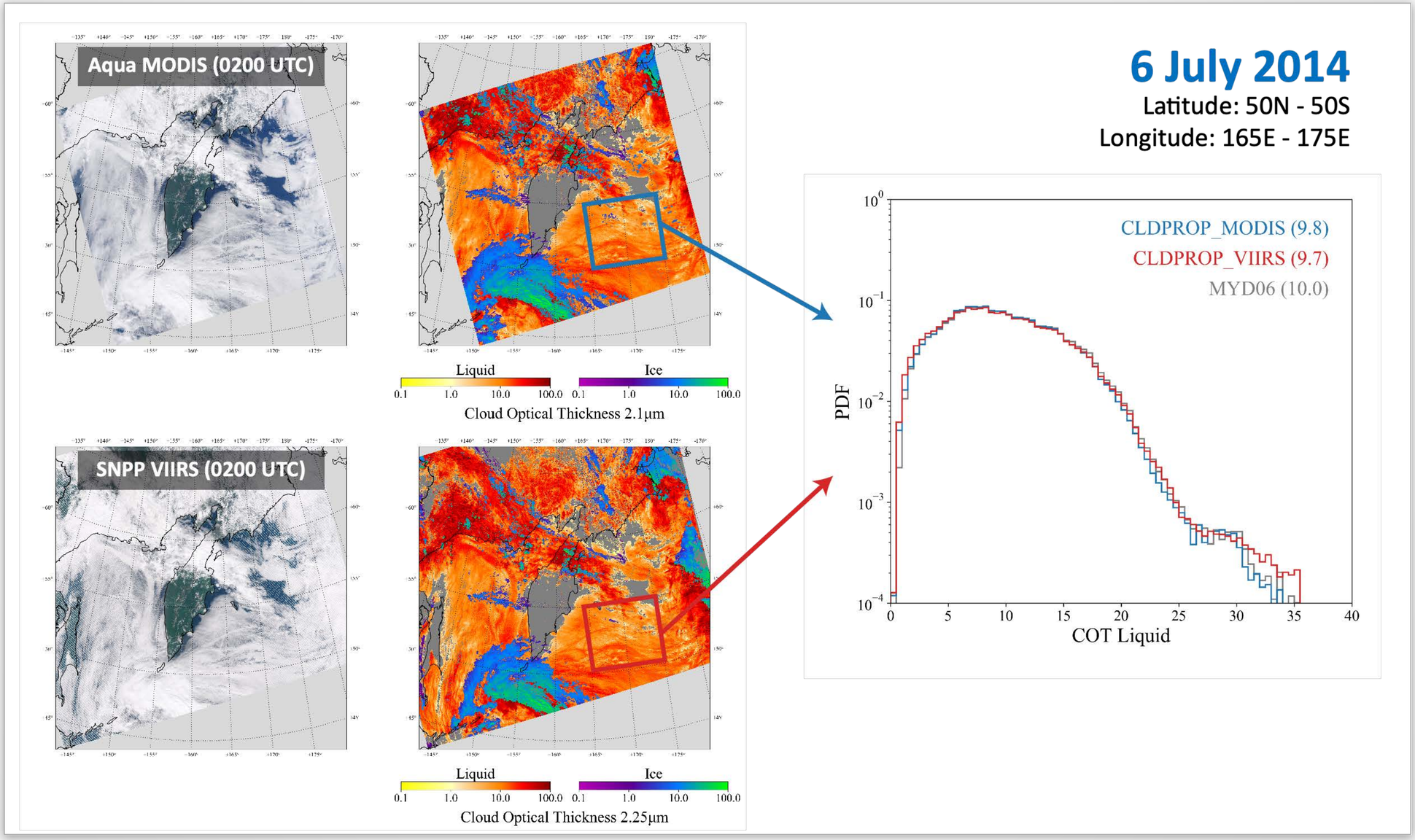
Monthly Means
Feb 2014 (v1.1)

- Production version of common algorithm, includes SW Radiometric Bias Correction
- Pixel-weighted aggregation over common swath
- Daytime only
- Highest Quality (non-“Partly Cloudy” pixels)

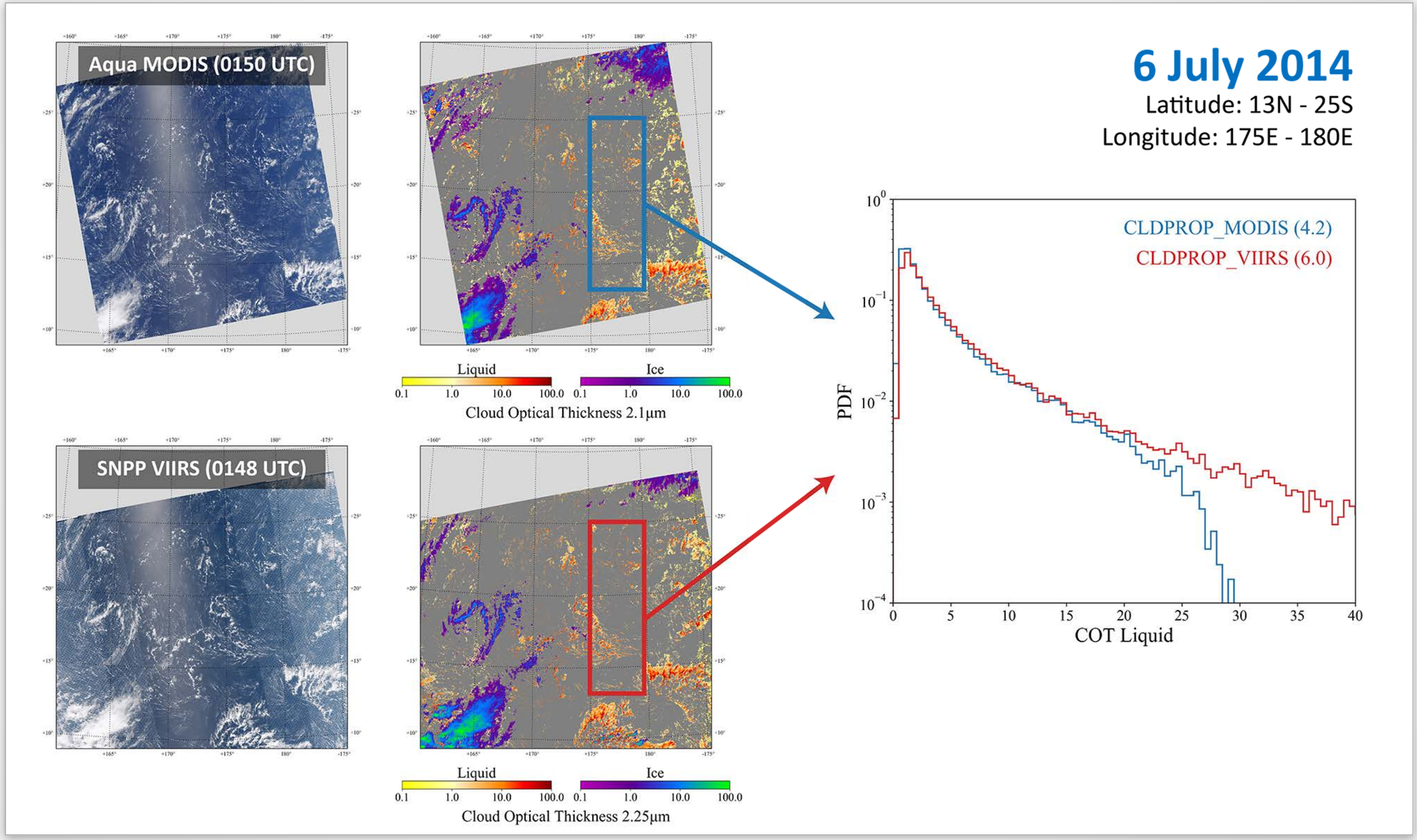


Systematic Liq. COT VIIRS > MODIS over ocean!?

Pixel FOV: horizontally *homogeneous* liquid cloud scene

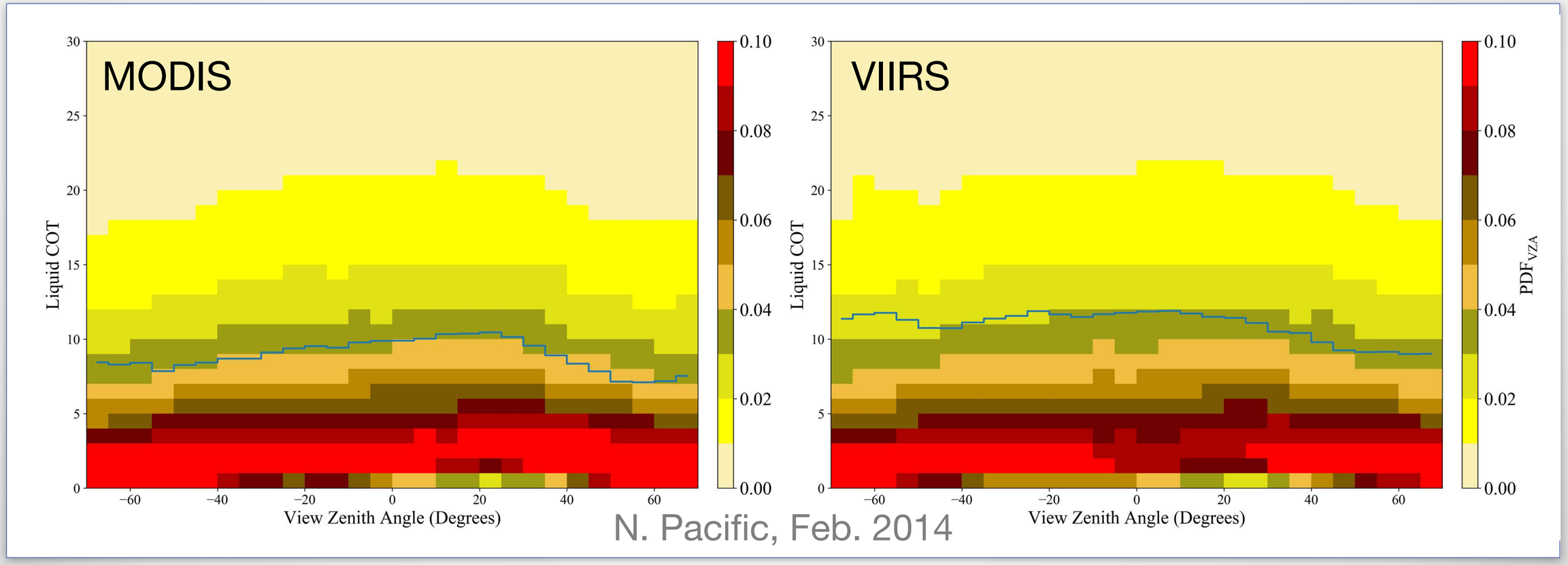


Pixel FOV: horizontally *heterogeneous* liquid cloud scene



Research L3 Product using Yori Infrastructure at A-SIPS

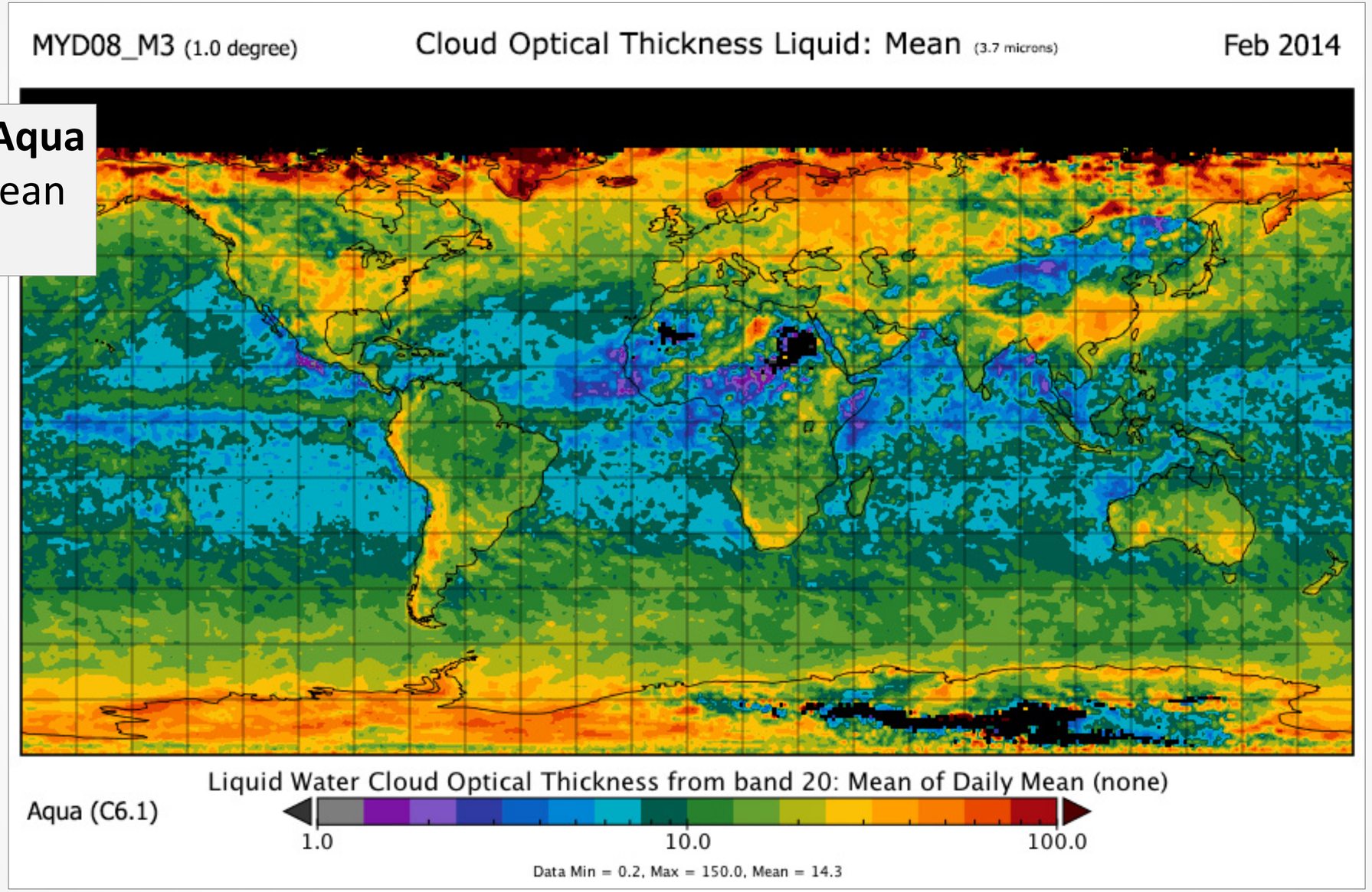
- Developed to understand
  - Temporal sampling differences between Aqua MODIS and SNPP VIIRS aggregations
  - Viewing geometry sensitivities



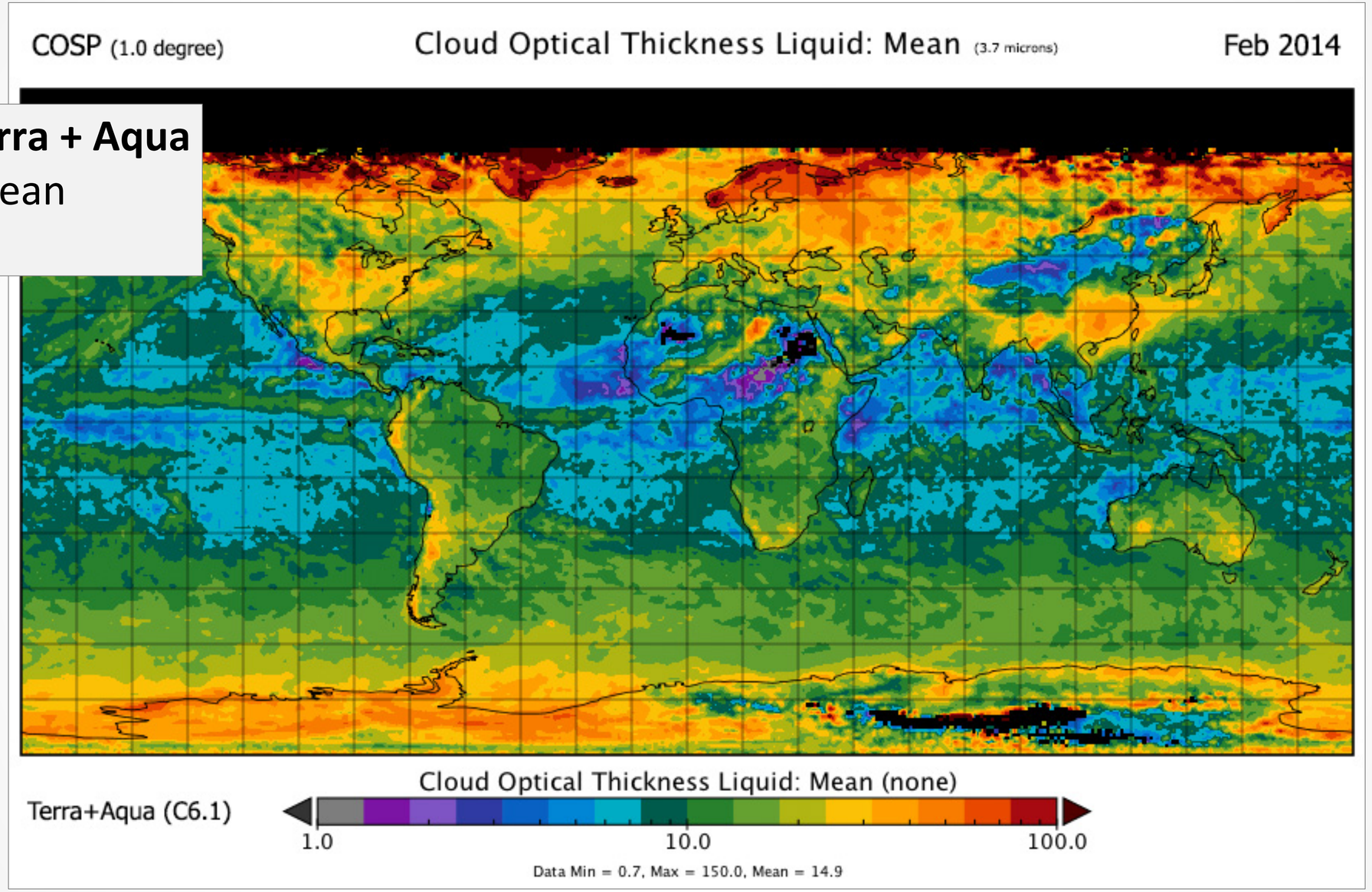
MODIS COSP L3 Products using Yori Infrastructure at A-SIPS

- COSP (CFMIP Observational Simulation Package)
  - MODIS C5 Cloud Simulator was initially developed for COSP as part of IPCC AR5 CFMIP5 climate model evaluation.
  - Simulates core MODIS cloud products from model output and generates L3-like statistics.
  - Separate monthly L3 file produced corresponding to simulator output only and converted to netCDF (CF compliant convention).
- MODIS C6 Cloud Simulator being updated for CFMIP6 (R. Pincus)
- Tested new COSP L3 product using Yori at A-SIPS
  - Special example 0.25° L3 research product produced at request of LLNL/DoE

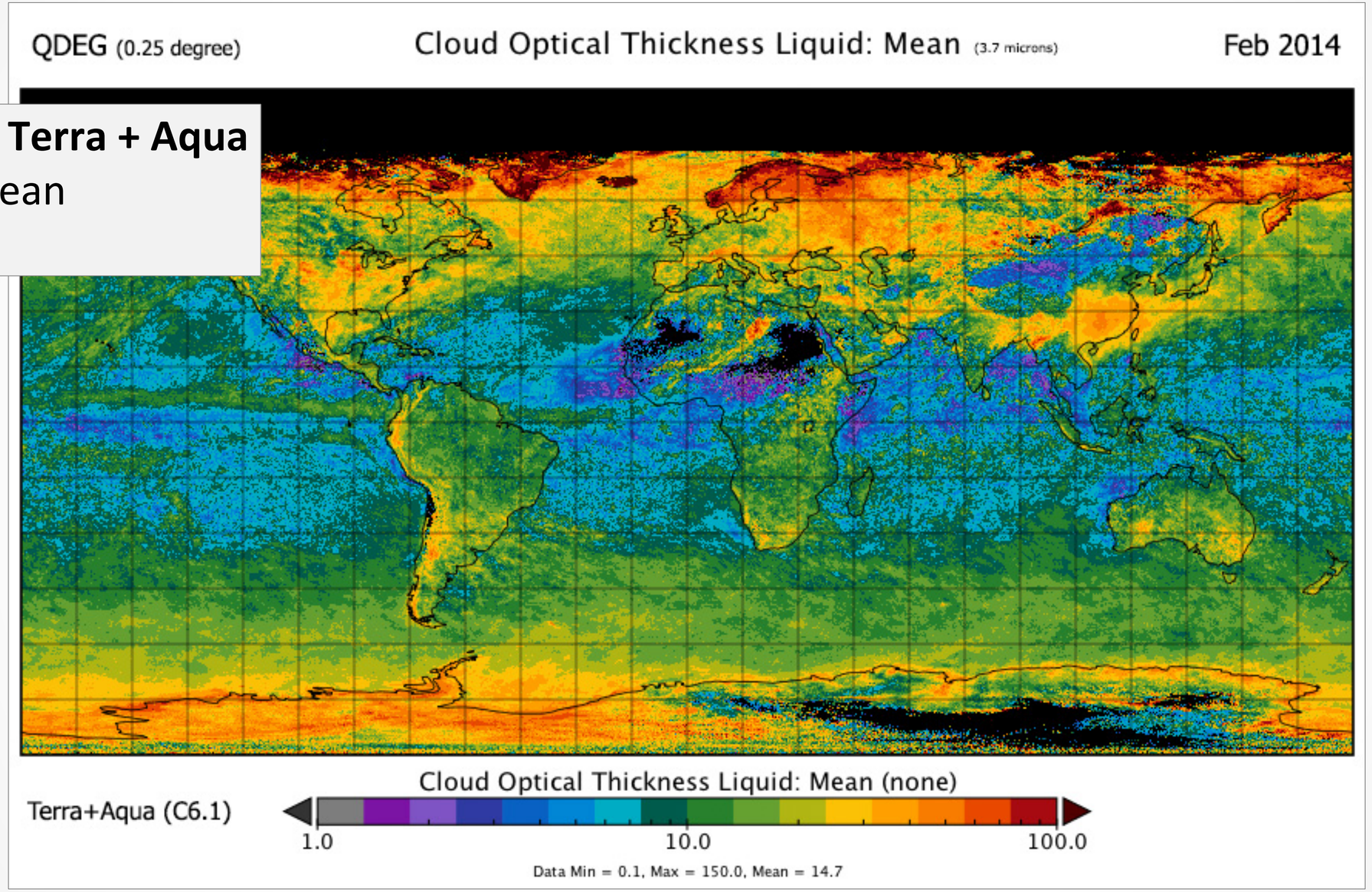
MYD08 (1°) Aqua
COT liquid mean
Feb 2014



COSP (1°) Terra + Aqua
COT liquid mean
Feb 2014



COSP (0.25°) Terra + Aqua
COT liquid mean
Feb 2014



CLDPROP Phase with Machine Learning Random Forest (RF)

- Features
  - Evaluates two RF tree structure for simultaneous VIIRS cloud phase/masking
    - All day (day + night): IR-only (8.6, 11, and 12 μm)
    - Daytime only: IR + VNIR/SWIR (0.86, 1.24, 1.38, 1.64 and 2.24 μm)
  - Trained on 4-yrs of collocated VIIRS & CALIOP data (2013-2016)
  - Evaluated against 1-yr (2017) of collocated VIIRS & CALIOP data

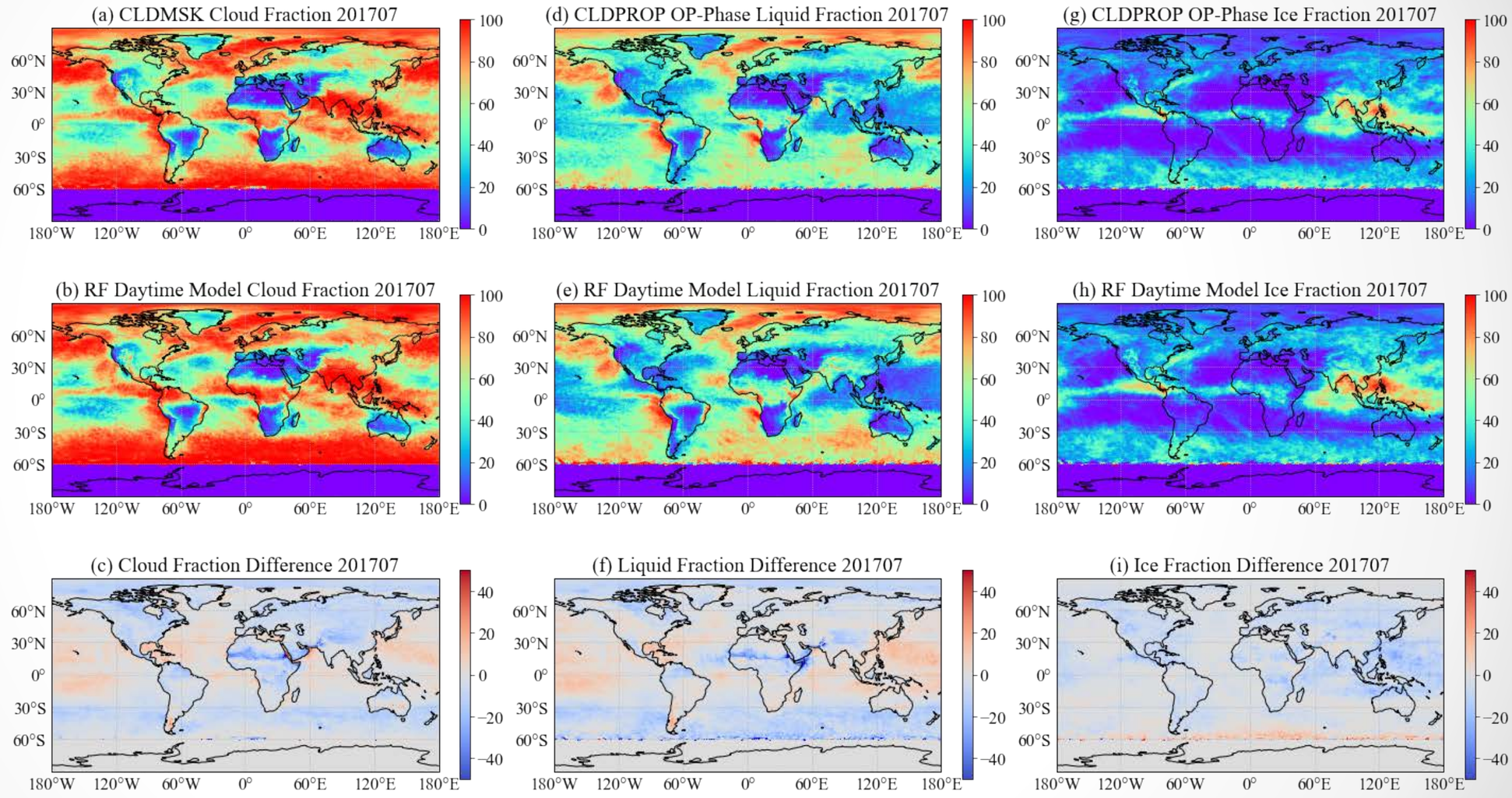
see Chenxi Wang et al. poster, manuscript submitted to *AMT*, Oct. 2019

CLDPROP Phase with Machine Learning Random Forest (RF)

RF

CLDPROP (v1.1)

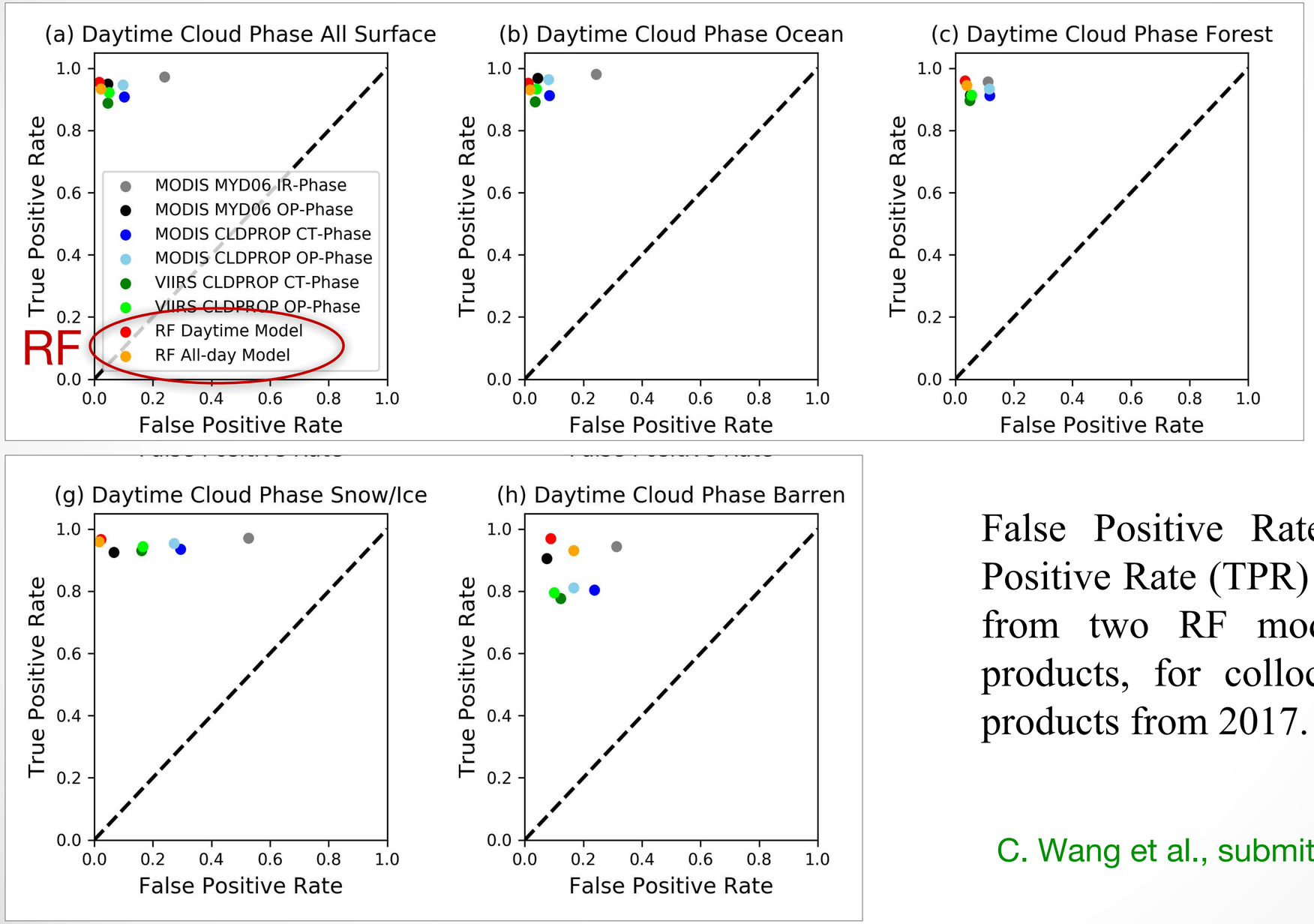
CLDPROP (v1.1) - RF



January 2017

C. Wang et al., submitted to *AMT*, Oct. 2019

CLDPROP Phase with Machine Learning Random Forest (RF)



False Positive Rate (FPR) vs. True Positive Rate (TPR) for daytime results from two RF models and standard products, for collocated CALIOP L2 products from 2017.

C. Wang et al., submitted to *AMT*, Oct. 2019

CLDPROP Phase with Machine Learning (Random Forest)

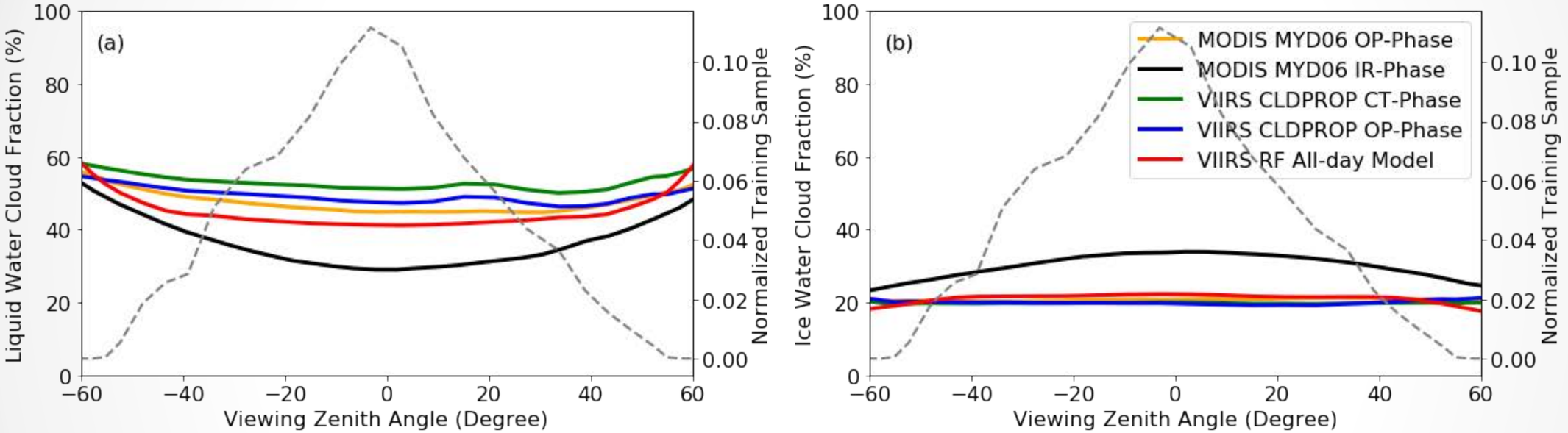


Figure 12. Liquid water (a) and ice (b) cloud fractions as a function of viewing zenith angle from the one-month daytime cloud mask/phase products in January 2017. The gray dashed curve is the probability density function of the 4-year VIIRS/CALIOP training samples (2013-2016).

C. Wang et al., submitted to *AMT*, Oct. 2019

MODIS/VIIRS Cloud Product Continuity Summary

- Shortwave radiometric data record continuity is challenging, even with the same instrument (MODIS Aqua/Terra). More so for different instruments.
- Impact of 2.x μm window channel placement on optical properties (ice as well as liquid) requires understanding spectral imaginary index of refraction.
- Next Steps:
  - Public release: v1.1 L2 & L3 (November 2019)
  - Algorithm: Further investigation of index of refraction sensitivity (ice as well as liquid), FOV/sampling aggregation sensitivities, and use of CrIS to compensate missing VIIRS IR absorption channels (longer term).
  - Science assessment: time series analysis, include “cloud radiative effect” datasets and assess radiative continuity, user community feedback, …

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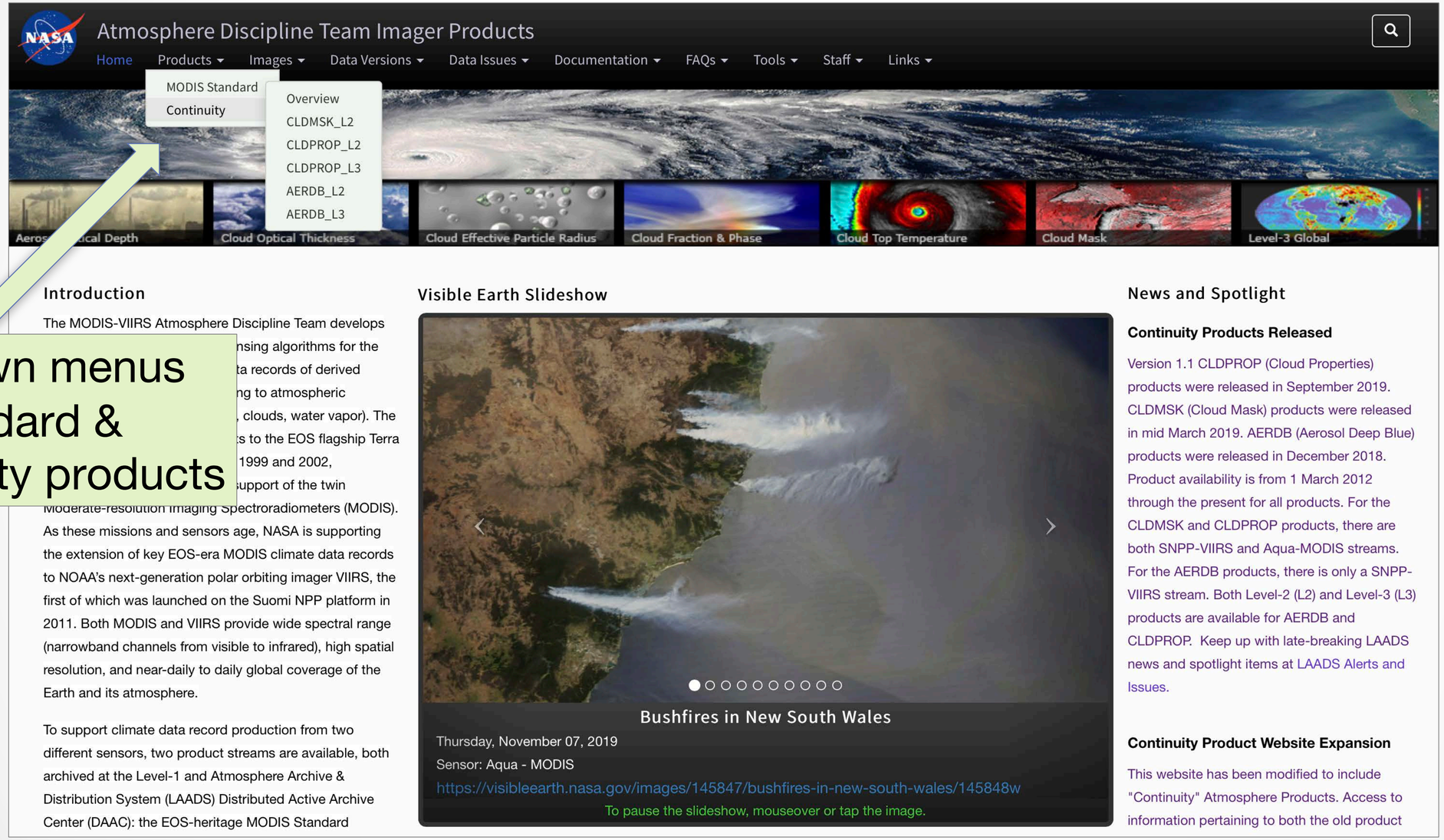
  - Example results (L2 and L3)
  - Ongoing efforts
- New “atmosphere imager” web site, documentation, etc.

New Atmospheres Imager Team Web Site



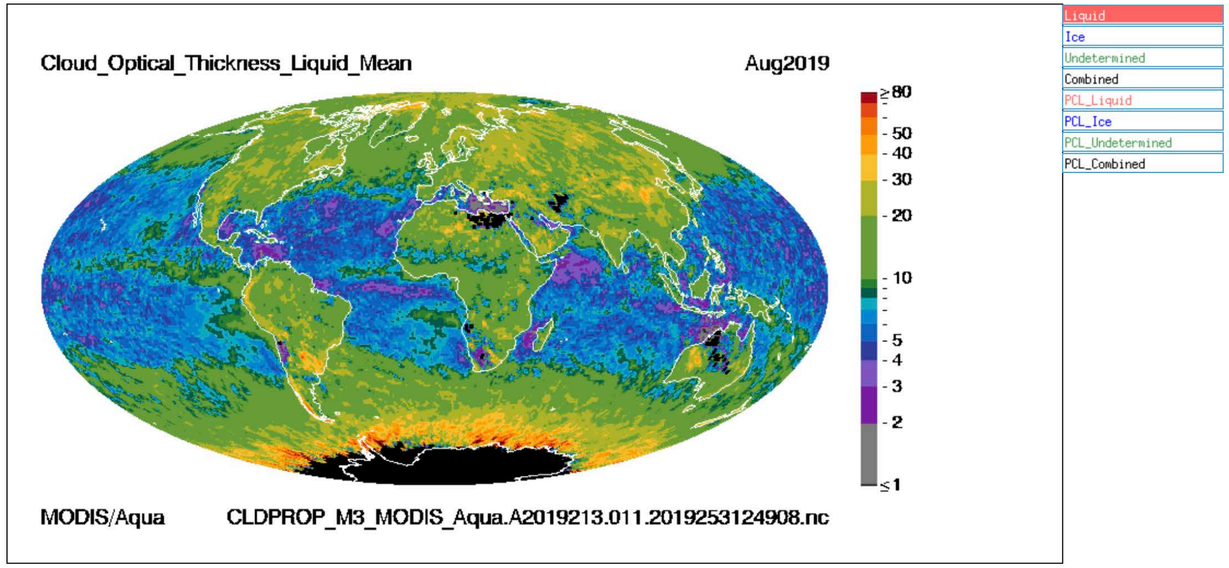
pull-down menus for standard & continuity products

atmosphere-imager.gsfc.nasa.gov

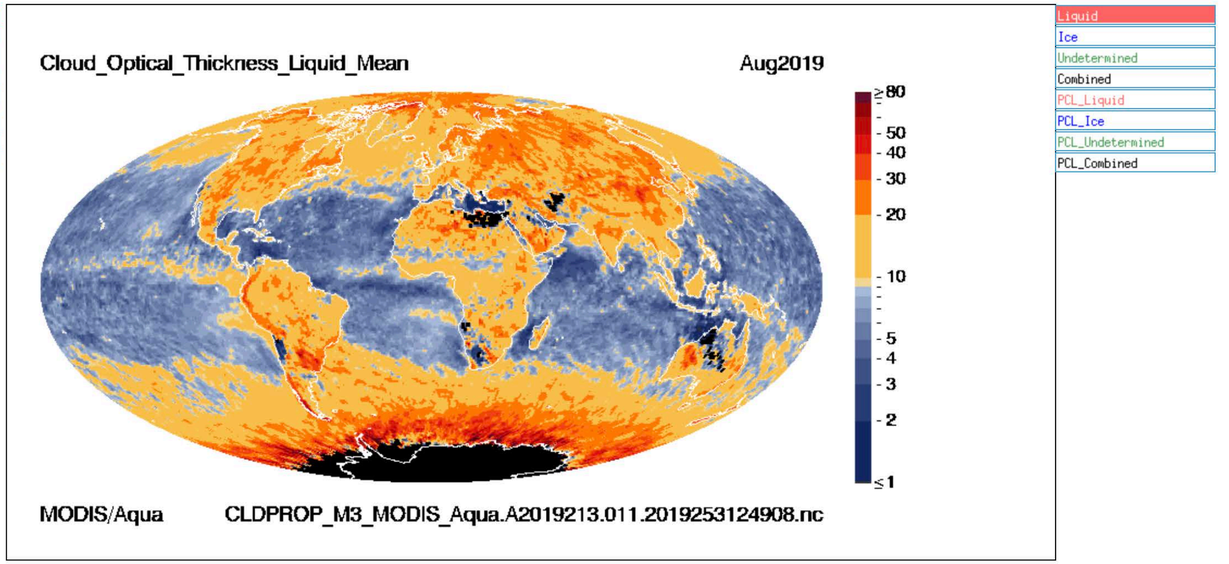
Continuity Product L3 Browse (Currently Cloud Only)

New user interface and color bar choices

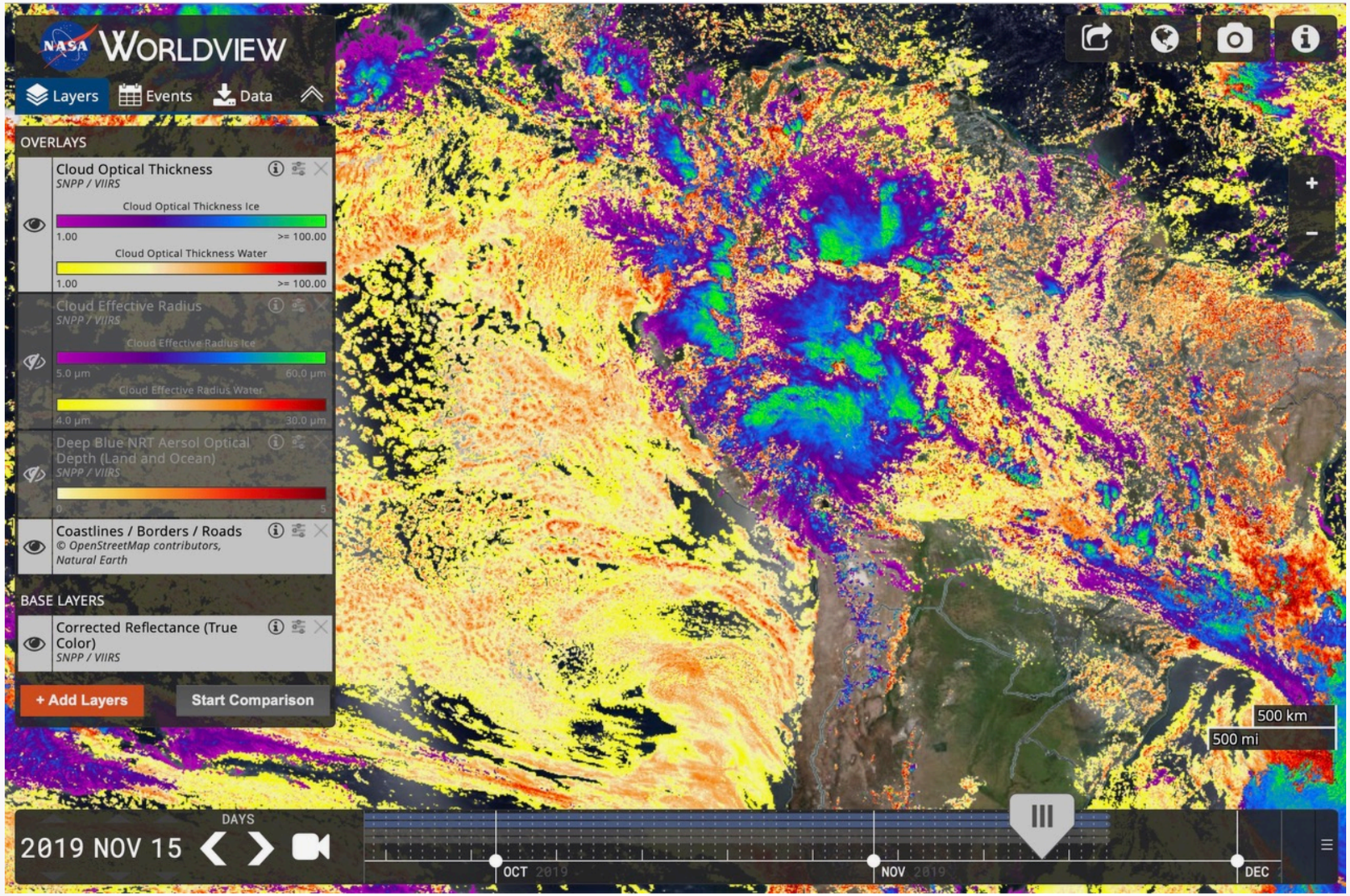
Default color bar



Colorblind friendly



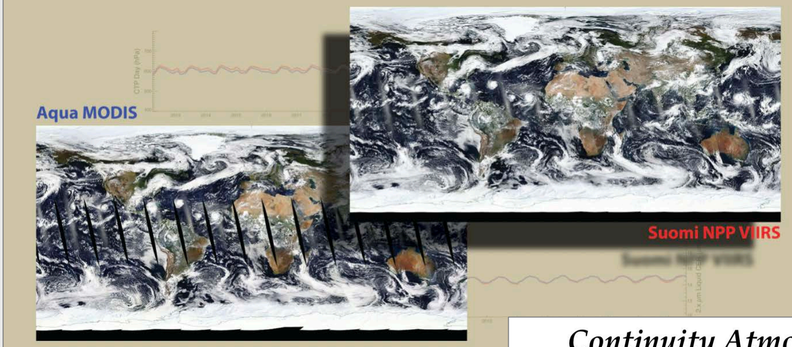
CLDPROP in Worldview Example (VIIRS COT)



MODIS/VIIRS STM, Cloud Products, Nov. 2019

Continuity Product User Guides

EOS MODIS and SNPP VIIRS Cloud Properties:
User Guide for the Climate Data Record Continuity
Level-2 Cloud Top and Optical Properties Product
(CLDPROP)



Version 1.1
October 2019

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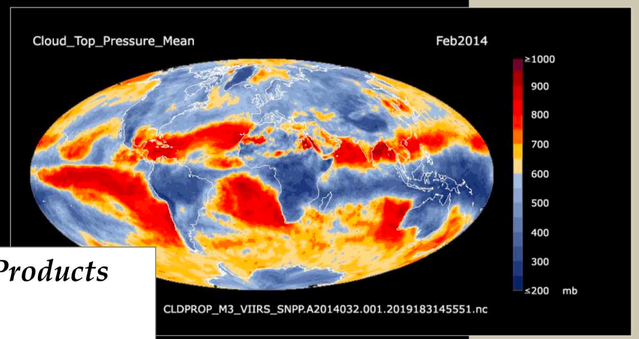
6 Cooperative Institute for Meteorological Satellite Studies, University of V
7 ADNET Systems, Inc., Bethesda, MD

Level-3 Continuity Cloud Properties (CLDPROP_L3)
Global Gridded Product
User Guide



Continuity Atmosphere Products
QA Plan
for CLDPROP, CLDMSK, & AERDB

Version 1.1
2 April 2019

Continuity Atmosphere L3 CLDPROP
(VIIRS SNPP & MODIS Aqua)
l Gridded Products for Daily (D3) and Monthly (M3)
User Guide

User Guide, Version 1.7, 12 Septembe

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The Continuity MODIS-VIIRS Cloud Mask (MVCM) User's Guide

Based on NASA MODIS Cloud Mask (MOD35, MYD35)
Reprocessed Data - Version 1
Product User's Guide Version 1.0

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January 2019

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The Deep Blue aerosol project:

Aerosol retrievals from S-NPP VIIRS

Data product user guide and file specification document

This guide is specific to Version 1 of the VIIRS Deep Blue data products