CERES MODIS & VIIRS Cloud Properties: Update Fall 2016

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G. Hong (models, night tau), R. Brown (QC), E. Heckert (web),
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P. Yang, S. Hioki (ice models)

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Thanks to Dave Doelling and his calibration team!

CERES Science Team Mtg., Reading, UK, 18-21 October 2016
Topics

- Publications
- Status
- MODIS Collection 6 vs 5
- Changes for Ed5
  - new ice models
  - multilayer
  - clouds over snow
- VIIRS: use CrIS?

Bill Smith
- GEO clouds
Edition-4 related


Edition-5 related


CERES MODIS Status (Collection 5 Data)

- Ed2 processing
  - Aqua: through May 2016, will continue until January 2017 (?)
  - Terra: through May 2016, will continue until January 2017 (?)
- Ed4 Beta-2 processing
  - Aqua: through April 2016 (~14 y)
  - Terra: through April 2016 (~16 y)

CERES VIIRS Ed 1 Status

- Ed1 delivered, 4 years completed
  - Jan 2012 – Dec 2015
CERES Data Quality Summaries

• DQS clouds validation for Ed4 available
  - Full DQS available


• DQS Validation started for VIIRS Ed1

• DQS validation for GEOSat analyses next
Intersatellite Consistency

• VIIRS vs. Aqua MODIS: 2015
• VIIRS & MODIS very similar in daytime
• Largest differences at night (tropics & polar regions)
  - MODIS uses 6.7 and 13.4 µm channels not on VIIRS
VIIRS – MODIS Consistency Summary

- 2015 VIIRS mostly as consistent as it was for 2013
  - mean cloud fractions very close
  - water cloud heights tend to be higher for VIIRS
  - VIIRS optical depths larger, greatest for liquid
    - resolution effect larger for water clouds
  - VIIRS water droplet radius 1 µm smaller
    - different reflectance model

- Nocturnal cloud amounts differ regionally
  - bring in CrIS information?

- VIIRS tau over snow > MODIS, 1.24-µm calibration?

- All VIIRS channels should be normalized to MODIS
Toward MODIS Edition 5 / VIIRS Edition 2

• Use MODIS Collection 6 calibrations
  - additional results shown here

• Merge SNPP CrIS and VIIRS footprints to recover WV and CO2 channels
  - will improve consistency with MODIS record

• Revised algorithms for 1.24, 1.6, and 2.1 µm retrievals
  - optimal multi-channel algorithm for cloud/snow retrievals

• Employ new 2-Habit model from P. Yang for ice clouds
  - testing still underway

• Nighttime ice cloud optical depths from neural network
  - discussed previous STM
  - use same water reflectance model as VIIRS Ed1

• Improving multi-layer algorithms
  - will discuss in later presentation

• Surface skin temperature
  - discussed previous STM
MODIS Collection 5 (C5) vs Collection 6 (C6)

C5 processing ends January 2017, what do we do?
- Continue processing Ed4? Expedite Ed5 code development?
- Either choice will require some adjustments

CERES Ed4 attempted to normalize all C5 Terra channels to Aqua
- No change in Aqua, degradation seen after 2008
- 3 segments for 0.65 µm
  - no change in Terra prior to June 2002 😔
- 3.8 µm: 0.5 K decrease in daytime, nonlinear change in low end at night
- Slight changes for 2.13 and 1.24 µm
- No changes for 11 and 12 µm

MODIS C6 calibration changes; no overt attempts to reconcile Aqua & Terra
- Minimal changes in Aqua, post-2008 degradation not taken into account
- Terra 3.8-µm low end corrected
- Terra 0.65-µm still < Aqua
- Some small changes in 1.24 and 2.13 µm
- < 0.2 K changes for low ends of 11 and 12 µm
Analysis of C5 vs C6 issues for CERES

Examine changes in reflectance/temperature differences
  • Compute differences relative to Aqua C6
  • Compute slope of forced linear regression (zero offset)
  • Examine seasonal and annual variability: 9 days/ mo for 2003, 2008, 2013

Examine changes in cloud parameters from October
  • Trends provided in Spring STM presentation
  • Regional changes provided here
Scatterplots of C5 vs C6 for 0.65 μm reflectance

July 08

Ed2

C6

Ed4

Nov 08

Slope: 0.996980
Mean PY-PX: -0.017
Stdev PY-PX: 0.057
Total Counts: 61123

Slope: 0.984916
Mean PY-PX: -0.0083
Stdev PY-PX: 0.056
Total Counts: 60978

Slope: 0.999783
Mean PY-PX: -0.0034
Stdev PY-PX: 0.068
Total Counts: 65425
C5 vs C6 for 3.78-µm Brightness Temperatures (K), June 2008

Day

Night
Visible channel (0.65 µm) C5-C6 changes

mean difference

- Terra C5 and Aqua C6 differences:
  - Ref0063 Day Time

slope of regression

- Terra C5 and Aqua C6 ratios:
  - Ref0063 Day Time

Oct, Nov, Dec are oddball months: Antarctic is target, all bright, no balance of darker scenes

Aqua C6 rises by 0.4% in 2008, then drops

Terra C5 and C6 reverse after 2008

- Terra C5 closer (0.5% vs 1.5% differences) to Aqua, < 2008
- Aqua degradation brings Terra C6 closer in 2013
• 0.65 µm: C5 Terra 0.2% < Aqua
  C6 0.3% > Aqua

• 1.24 µm: C5 Terra 0.2% < Aqua
  C6 3% > Aqua

• 1.38 µm: C5 Terra 5% < Aqua
  C6 10% < Aqua

• 2.13 µm: C5 Terra 2% < Aqua
  C6 1% < Aqua

• 3.78 µm: day: C5 ± 0.05 K  night: C5 ± 0.05 K
  C6 + 0.25 K  C6 + 0.20 K

• 6.7 µm: C5 Terra differs by -1 K after 2008
  C6 -0.5 K in 2003, -3.5 K in 2013

* 11 µm: C5 ± 0.1 K
  C6 ± 0.03 K

• 12 µm: C5 ± 0.1 K
  C6 ± 0.03 K
Cloud Fraction Using Terra C5 vs C6 Using Ed4 Code

Oct, 2005 Daytime

- C5 adjusted with LaRC calibrations, C6 nominal calibrations used

- Cloud amount changes mostly < 0.04
- C6 yields average increase of ~ 0.02 in polar, ~0.005 in tropics
C5-C6 Summary & Future

• Changes caused by C6 calibrations not enormous, but significant
• Most impactful problem is degradation of Aqua calibration
  - induces artificial trends in C5 Aqua and Terra

For Ed5, using C6, we will need to

• Rely on C6 infrared channel calibrations
  - apply daytime Aqua normalization for Reff for Terra
• Account for Aqua VIS channel degradation after 2008?
  - apply constant normalization to Terra to insure Aqua/Terra consistency

• Utilize Aqua C6 calibrations for NIR channels
  - normalize Terra to Aqua
  - adjust clear-sky maps based on C5 calibrations

Do we do something similar continuing Ed4 with C6?

• Accounting for trend in Aqua will cause discontinuity
  - Terra will be an issue regardless
Restoring MODIS Complement to VIIRS: CrIS

• VIIRS lacks water vapor & CO2 channels used in CERES MODIS clouds
  - working resolution: 750 m with VZA resolution enhancement

• CrIS: interferometer on NPP & JPSS: 14 km resolution
  - 9.13 - 15.38 µm
  - 5.71 - 8.26 µm
  - 3.92 - 4.64 µm

• MODIS channels can be created from CrIS wavelengths
  - integrate over spectral response functions
  - 6.7 & 7.3 µm bands
  - four CO2 bands
Procedures for Mapping CrIS to VIIRS at Subsetted Resolution

VIIRS Subset VZA

Original software:
NWP-SAF, a software developed by NWP SAF for mapping VIIRS to CrIS.

Work done at Langley:
• Used subsetted resolution VIIRS (product VNP0203IMD received at Langley) instead of full resolution NOAA CLASS VIIRS (product GMODO-SVM16_npp) used in the original software.

• Kept NOAA CLASS CrIS inputs unchanged, requiring two products: GCRSO_npp (Geolocation) and SCRIS_npp (SDR).

• Reversed the mapping instruments: merging CrIS to VIIRS, instead of VIIRS to CrIS. Finding VIIRS pixel indices inside CrIS footprints and transferring CrIS SDR at the specified band to VIIRS at the subsetted resolution.
September 19, 2015, Hour: 15, Min: 54-60

VIIRS Satellite View Zenith Angle

CrIS Radiance at 735 cm$^{-1}$

Merged Rad From CrIS to VIIRS at 735 cm$^{-1}$
Using CrIS with VIIRS

- having CrIS would allow consistency with MODIS mask/retrievals
  - polar regions would benefit, especially at night
  - CO2-slicing could be used for cirrus cloud heights
  - nocturnal neural net tau algorithm could be used
  - NN ML algorithm could be employed

- Challenges
  - CrIS does not cover full VIIRS swath width
  - CrIS resolution is 19 x VIIRS
    - deconvolve the fat pixels?

- will the gain from the effort be worth it?
  - TBD
  - process has begun
Optimal Retrievals over Ice and Snow

• 1.24 µm used in place of 0.65 µm over ice and snow surfaces
  - yields reasonable optical depths (COD) for thick stratus
    Dong et al. (JGR, 2016)
  - other validation minimal
  - suspect overestimates for thinner clouds
    - possible impact of surface albedo uncertainty

• 1.6 and 2.13 µm channels have potential over snow
  - yields reasonable optical depths up to a limit
    Minnis et al. (2011)
  - minimal surface albedo impact, may be better for optically thin clouds

• Infrared approach may be needed for thinnest clouds
  - use 11 and 12 µm channels only

• Perform validations for each
  - develop logic based on optimal criteria for each channel

• Initial runs using 1.6 and 1.24 µm during ARISE period (some in situ data)
Diffuse Liquid Cloud Albedos from Adding-Doubling Computations

Cloud model
• modified $\Gamma$ dist
• $\sigma = 0.10$
• Mie scattering
• sfc albedo = 0

Minnis et al. JAS, 1998

$\lambda$ (µm)  $\tau$ Limits
0.65  > 128
1.24  64 - 96
1.62  10 - 30
2.13  6 - 10

Actual limits depend on viewing & illumination angles & sfc albedo

1.24 µm channel has promise for getting most of full range of $\tau$
Diffuse Ice Cloud Albedos from Adding-Doubling Computations

Ice model based on hex column dist

Minnis et al. JAS, 1998

<table>
<thead>
<tr>
<th>λ (μm)</th>
<th>τ Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.65</td>
<td>&gt; 128</td>
</tr>
<tr>
<td>1.24</td>
<td>32 - 60</td>
</tr>
<tr>
<td>1.62</td>
<td>2 - 8</td>
</tr>
<tr>
<td>2.13</td>
<td>1 - 3</td>
</tr>
</tbody>
</table>

Actual limits depend on viewing & illumination angles & sfc albedo

1.24 μm channel has more promise for getting most of full range of τ
Ex: Optical Depth Retrievals Using Terra 1.2 and 1.6 µm data

- Snow-free areas use 0.65 µm, COD(1.6) < COD(1.2)
**Terra-MODIS, September 2014, all ARISE Overpasses**

Condition to run snow tau retrieval is either permanent snow or snow map says snow or Ice map % > 20 %

<table>
<thead>
<tr>
<th>1.24 Snow Retrieval</th>
<th>Ice</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>$25.5 \times 10^6$</td>
<td>$1.5 \times 10^6$</td>
</tr>
<tr>
<td></td>
<td>37.0 %</td>
<td>2.15 %</td>
</tr>
<tr>
<td>Water</td>
<td>$2.1 \times 10^6$</td>
<td>$39.8 \times 10^6$</td>
</tr>
<tr>
<td></td>
<td>2.98 %</td>
<td>57.87 %</td>
</tr>
</tbody>
</table>

Cloud phase agreement = 37.0 % + 57.87 % ~ 95 %
1.24 vs 1.6 μm optical depth comparison, September 2014: both ice

- COD(1.6) < 10
  - most < 7, mean = 2
  - hides low clouds

- COD(1.2) much higher
  - gets reflective effect from low clouds
  - some impact from surface albedo uncertainty

- need to separate overlap from bad surface albedo
  - combination of neural net and COD(1.6)?
1.24 vs 1.6 $\mu$m optical depth comparison, September 2014: both liquid

- COD(1.6) < 20
  - most < 15
  - hides low clouds

- COD(1.2) much higher
  - more sensitive to surface albedo uncertainty

- need to determine when to use 1.6 $\mu$m
  - use 1.6 asymptote as guide

N=39844102.

<table>
<thead>
<tr>
<th></th>
<th>Mean (StdDev)</th>
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<tr>
<td>Tau0124</td>
<td>13.51(12.79)</td>
</tr>
<tr>
<td>Tau0160</td>
<td>6.97(4.76)</td>
</tr>
<tr>
<td>Y-X</td>
<td>-6.54(10.43)</td>
</tr>
<tr>
<td>RMS</td>
<td>12.31..........</td>
</tr>
</tbody>
</table>
1.24 vs 1.6 μm optical depth comparison, September 2014:
1.6 μm ice, 1.2 μm liquid

- COD(1.6) < 8
  - most < 4, mean = 1.5
  - may hide low clouds

- COD(1.2) much higher
  - gets reflective effect from low clouds
  - some impact from surface albedo uncertainty
  - probably chooses liquid because ice cloud very thin

- need to separate overlap from bad surface albedo
  - combination of neural net and COD(1.6)
1.24 vs 1.6 µm optical depth comparison, September 2014:
1.6 µm liquid, 1.2 µm ice

- COD(1.6) < 20
  - most < 12
  - some values > 15

- COD(1.2) much lower for most
  - phase error makes it lower than COD(1.6) in most cases
  - > COD(1.6), it exceeds ~10
  - means equal

- need further analysis of phase algorithm

N= 1474031.

<table>
<thead>
<tr>
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<th>Mean (StdDev)</th>
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<tr>
<td>Tau0124</td>
<td>5.53(10.08)</td>
</tr>
<tr>
<td>Tau0160</td>
<td>5.04(3.46)</td>
</tr>
<tr>
<td>Y-X</td>
<td>-0.494(9.75)</td>
</tr>
<tr>
<td>RMS</td>
<td>9.76</td>
</tr>
</tbody>
</table>
Clouds over snow algorithms remarks

• 1.6 and 2.1 µm channels can be useful for water cloud optical depth retrievals, but need to be used carefully
  - only use for non-asymptotic conditions
  - replace 1.24 µm value
  - perform validations for a variety of conditions

• 1.6 and 2.1 µm channels might be useful for thin cirrus retrievals
  - need other indicators that no lower clouds are present

• 1.6 and 2.1 µm channels may be helpful for multilayered cloud detection/retrieval
  - used in conjunction with 0.65, 1.24, 11, 12, and 6.7 µm

• which to use?
  - 2.1 on both Terra & Aqua, not VIIRS
  - 1.6 on VIIRS & Terra, bad on Aqua
    - recovery possible on Aqua, only at full 0.5 km res

• need to be determined from multiple validation studies
Ice Particle Models

- Current 1-habit (1-H) model yields COD \sim 2 \text{ COD(CALIPSO)}
  - causes \sim 2\text{-km underestimate of height relative to CALIPSO}

- New 2-habit model delivered recently from Yang group
  - initial tests performed

Compact particles, smaller \(g\)
hollow to solid, smaller \(g\)

hence smaller \(\tau\)

From Ping Yang, 2016

Two-habit model (THM)

Habit-1:

Habit-2:

Single column, \(D=L=2a, \sigma^2=0.5, V=0.65D^4\)

20-ensemble of 20-irregular aggregates, randomly tilted surface, \(\sigma^2=0.5, V=0.053D^3\)

Theory indicates 15% decrease at nadir in COD produces 2 km rise \(Z_{eff}\) for this configuration (\(T_s = 290\text{K}, T_c = 220\text{K}\)
Comparisons Between 1HM and THM

**1HM**: One Habit Model with Rough Single Hexagonal Column used for CERES Ed4 (CERES4)

**THM**: Two Habit Model with 20 Irregular Aggregates Randomly Tilted

- Initial run: All Aqua data for March 2008
  - over snow/ice areas: 1.24 μm for tau
  - over snow-free areas: 0.65 μm for tau
Testing Data

NPP-VIIRS: April 30, 2016. Hour 15, 4 Granules
Aqua MODIS, March 2008
Optical Depth, Ice Phase, Day Time
Aqua MODIS, March 2008
Ice Effective Radius, Day Time
Aqua MODIS, March 2008
Eff Height, Ice Phase, Day Time
CERES4

THM

Aqua MODIS, March 2008
Cloud Temp, Ice Phase, Day Time
### Cloud Phase Agreement for THM & 1HM Results
Aqua-MODIS, March 2008

<table>
<thead>
<tr>
<th>CERES4</th>
<th>THM</th>
<th>Ice</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>$0.91 \times 10^9$</td>
<td>$7.9 \times 10^6$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>46.0 %</td>
<td>0.4 %</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>$3.3 \times 10^6$</td>
<td>$1.06 \times 10^9$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.2 %</td>
<td>53.4 %</td>
<td></td>
</tr>
</tbody>
</table>

- Overall agreement: 46.0% + 53.4% ~ 99%
Optical Depth Comparisons, Snow Free

Y-axis: THM; X-axis: 1-H-Rough

- 13% decrease for COD < 2; 18% overall
- Odd artifacts being examined
Optical Depth Comparisons, Snow Cover

- 15% decrease for COD < 2; nearly 50% overall
- Odd artifacts being examined

- 15% decrease for COD < 2; nearly 50% overall
- Odd artifacts being examined
Cloud Particle Size (Re, µm), Both Ice Phase

Snow Free

200803 Ice_Cld_Radius Ice

\[ R = 0.78 \]

Log10(Population)

\[ N = 22789560. \text{ Mean ( StdDev) } \]

- CERES4: 30.85( 13.41)
- THM: 25.35( 12.61)
- Y-X: -5.50( 8.15)
- RMS( 9.83)

Snow Cover

200803 Ice_Cld_Radius Ice

\[ R = 0.93 \]

Log10(Population)

\[ N = 78930889. \text{ Mean ( StdDev) } \]

- CERES4: 40.60( 11.39)
- THM: 35.02( 14.18)
- Y-X: -5.58( 5.82)
- RMS( 8.06)

• Mean Re will go down by ~18% with THM
Cloud Eff Height, Both Ice Phase, Snow Free

For All Tau

200803 Eff_Cld_Height Ice

\[ R = 0.96 \]

<table>
<thead>
<tr>
<th>THM</th>
<th>0.00</th>
<th>1.32</th>
<th>2.64</th>
<th>3.96</th>
<th>5.28</th>
<th>6.60</th>
</tr>
</thead>
<tbody>
<tr>
<td>CERES4</td>
<td>8.51 (2.80)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>THM</td>
<td>8.84 (2.83)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y-X</td>
<td>0.330 (0.768)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMS</td>
<td>0.836</td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

N=224171112.

Mean ( StdDev)

CERES4 | 8.61 (2.80)
THM | 9.28 (2.83)
Y-X | 0.330 (0.768)
RMS | 0.836

For Tau < 2

200803 Eff_Cld_Height 0-2TauIce

\[ R = 0.91 \]

<table>
<thead>
<tr>
<th>THM</th>
<th>0.00</th>
<th>1.32</th>
<th>2.63</th>
<th>3.95</th>
<th>5.27</th>
<th>6.58</th>
</tr>
</thead>
<tbody>
<tr>
<td>CERES4</td>
<td>9.03 (2.86)</td>
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<tr>
<td>THM</td>
<td>9.72 (2.79)</td>
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<tr>
<td>Y-X</td>
<td>0.688 (1.18)</td>
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<tr>
<td>RMS</td>
<td>1.37</td>
<td></td>
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</tr>
</tbody>
</table>

N=72004415.

Mean ( StdDev)

CERES4 | 9.03 (2.86)
THM | 9.72 (2.79)
Y-X | 0.688 (1.18)
RMS | 1.37

• 0.3 km increase overall, 0.7 km increase for thin clouds
Cloud Eff Height, Both Ice Phase, Snow Cover

**All Tau**

200803 Eff_Cld_Height Ice

R = 0.99

N = 78930761. Mean ( StdDev)

- CERES4: 4.91 (2.32)
- THM: 5.08 (2.35)
- Y-X: 0.170 (0.354)
- RMS: 0.393

**Tau < 2**

200803 Eff_Cld_Height 0-2TauIce

R = 0.99

N = 25028605. Mean ( StdDev)

- CERES4: 4.63 (2.37)
- THM: 4.83 (2.44)
- Y-X: 0.203 (0.397)
- RMS: 0.446
Remarks on Initial THM Retrievals

- THM reduces ice cloud optical depth by
  - snow-free: 18% for all; 15% for thin (< 2) ice clouds
  - snow: 48% for all; 15% for thin (< 2) ice clouds

- On average, THM reduces ice Re by 18%
  - IWP will drop
    - need Re profile to obtain accurate IWP

- THM ice cloud Zeff increased by
  - snow-free: 0.33 km for all; 0.69 km for thin (< 2) ice clouds
  - snow: 0.17 km for all; 0.23 for thin (< 2) ice clouds

- THM will bring CERES IR and VIS ice cloud retrievals closer

- CALIPSO: Version 4 out soon with reduced tau, so CERES and CALIPSO optical depths should have better agreement
Multilayer Clouds

• Many single layer ice or ice/water clouds being classified as multilayer
  - new approach uses neural network
  - talk on Thursday morning

Addressing thick ice cloud systems

• NN provides information about ice cloud COD

• Develop a different NN system to separately identify thick cloud systems
  - examine signals from various channels
    - use C3M CC profiles of COD and layering
Welcome Bill Smith
Accounting for LST anisotropy

• Developed approach to account for VZA dependence

• A variant of Vinnikov model could help account for all angle dependencies
  - use multiple matched data with terrain & vegetation information

LST(GOES-E) – LST(GOES-W) over N. America, 2013, 1° regional means

- Mean biases up to 3.5° (day), 1.2° (night) with no correction
- Single VZA correction reduces day to 3° and night to 0.5°
- Universal Vinnikov model reduces night to 1° and day to 2.5°
Shortwave-IR channel (2.13 µm) C5-C6 changes, day

- **Mean difference**
- **Slope of regression**

**Oct - Feb oddball months**

0.02 K rise in Aqua after 2008

Terra C5 and C6 reverse after 2008

- Terra C5 (-0.10 to -0.02 K vs 0.14 to 0.25) closer to Aqua
- Terra C5 within 0.1% and C6 within 0.4% of Aqua
Near-IR channel (1.24 µm) C5-C6 changes

- Mean difference
- Slope of regression

Nov-Feb oddball months

0.02 K rise in Aqua after 2008
Terra C5 and C6 reverse after 2008

- Terra C5 (-0.10 to -0.02 K vs 0.14 to 0.25) closer to Aqua
- Terra C5 within 0.1% and C6 3.0% > Aqua
Near-IR channel (1.38 µm) C5-C6 changes

- **Mean difference**
  - Seasonal
    - Terra C5 (-0.10 to -0.02 K vs 0.14 to 0.25) closer to Aqua
    - Terra C5 within 0.1% and C6 3.0% > Aqua

- **Slope of regression**
  - Nov-Feb oddball months
  - 0.02 K rise in Aqua after 2008
  - Terra C5 and C6 reverse after 2008
Water-vapor channel (6.7 µm) C5-C6 changes

- Mean difference
- Slope of regression

Seasonal changes:
- Nov-Feb oddball months
- 0.02 K rise in Aqua after 2008
- Terra C5 and C6 reverse after 2008

Annual changes:
- Terra C5 (-0.10 to -0.02 K vs 0.14 to 0.25) closer to Aqua
- Terra C5 within 0.1% and C6 3.0% > Aqua
Aqua & VIIRS Mean Cloud Effective Heights (km), 2015

- VIIRS slightly higher than MODIS during the daytime

<table>
<thead>
<tr>
<th></th>
<th>Aqua</th>
<th>SNPP</th>
<th>Aqua</th>
<th>SNPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>2.68</td>
<td>2.86</td>
<td>8.85</td>
<td>9.19</td>
</tr>
<tr>
<td>Night</td>
<td>2.94</td>
<td>3.03</td>
<td>9.48</td>
<td>9.50</td>
</tr>
</tbody>
</table>
Aqua & VIIRS Mean Cloud Optical Depths, Day 2015

- VIIRS larger for water:
  - Aqua degradation, resolution effect?
- VIIRS ice both smaller & larger, 9% less in mean
  - polar regions biggest difference, calibration?

<table>
<thead>
<tr>
<th></th>
<th>Aqua</th>
<th>SNPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>10.8</td>
<td>11.3</td>
</tr>
<tr>
<td>Ice</td>
<td>12.7</td>
<td>11.5</td>
</tr>
</tbody>
</table>
C5 vs C6 for 3.78-µm Brightness Temperatures (K), Day 2008

**June**

- **Ed2**
  - Intercept: 0.00000
  - Slope: 1.00398
  - Mean PY-PX: 0.455266
  - Stdev PY-PX: 2.84567
  - Total Counts: 158335

- **C6**
  - Intercept: 0.00000
  - Slope: 1.00388
  - Mean PY-PX: 0.436115
  - Stdev PY-PX: 2.78904
  - Total Counts: 155028

- **Ed4**
  - Intercept: 0.00000
  - Slope: 0.998707
  - Mean PY-PX: -0.0822198
  - Stdev PY-PX: 2.80749
  - Total Counts: 157012

**November**

- **Ed2**
  - Intercept: 0.00000
  - Slope: 0.996310
  - Mean PY-PX: -0.131067
  - Stdev PY-PX: 2.96505
  - Total Counts: 54495

- **C6**
  - Intercept: 0.00000
  - Slope: 0.991419
  - Mean PY-PX: -0.622196
  - Stdev PY-PX: 2.94861
  - Total Counts: 54392

- **Ed4**
  - Intercept: 0.00000
  - Slope: 0.989362
  - Mean PY-PX: -0.706288
  - Stdev PY-PX: 2.96660
  - Total Counts: 54419