Assessment of SNPP VIIRS CTH Algorithm Performance with Calipso Cloud Layer products – for AMS 2013

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Outline

The talk is focused on the following areas:

- Summary of VIIRS Cloud Top Height Algorithms – 4 algorithms depending on day, night, ice cloud and water cloud conditions, a total of 4 algorithms
- Theoretical considerations of NPP Thermal IR bands used in NPP CTH retrievals
- Presentation of Comparison results for the days in October and November 2012 when near simultaneous nadir overpasses of NPP and Calipso occurred
- Concluding Remarks

SNPP VIIRS Day time Ice Cloud Top Height Algorithm

Input Cloud Effective Diameter (De) from Day Cloud Optical Properties Algorithm based on Reflectance LUT of Visible and Near IR bands

$R_i = (1 - \varepsilon_i)\, R_{ai} + \varepsilon_i\, B_i(T_c)$,

For M14 (8.7 micron) and M16 (12 micron) bands

$$[(R_{16} - B_{16}(T_c))/(R_{a16} - B_{16}(T_c))] - [(R_{14} - B_{14}(T_c))/(R_{a14} - B_{14}(T_c))]^{k_{16}/k_{14}} = 0$$

Where:

R = Measured Radiance
Ra = Clear radiance
B(Tc) = Planck Function at cloud top temperature (Tc)
k16/k14 = Log(1-ε(m16))/Log(1- ε(m14)) and is parameterized as :
k16/k14 = 1.596 – 0.04*De

SNPP VIIRS Night time Ice Cloud Top Height Algorithm

Input VIIRS 3.7(M12), 8.55(M14),10.76(M15) and 12 μm(M16) Radiances for Cloudy Pixels

↓

Compute pixel-level CTT (T_c) using M14 and M16 radiances

Initial $k_{16}/k_{14} = 1.1$

$k_{16}/k_{14} = 1.596 - 0.004 * D_e$

$[(R_{16}-B_{16}(Tc)) / (R_{a16}-B_{16}(T_c))] - [(R_{14}-B_{14}(T_c)) / (R_{a14}-B_{14}(T_c))]^{k_{16}/k_{14}} = 0$

Compute τ, and D_e using M12 and M15 radiances

↓

$R_{15} = (1 - \varepsilon_{15})\, R_{a15} + \varepsilon_{15}\, B_{15}(T_c)$ -- for ε_{15}

$\varepsilon_{15} = 1 - exp(-k_{15}\, \tau / \cos(\theta))$ where $k_{15} = 0.52$ -- for τ

$[(R_{15}-B_{15}(Tc)) / (R_{a15}-B_{15}(T_c))] - [(R_{12}-B_{12}(T_c)) / (R_{a12}-B_{12}(T_c))]^{k_{15}/k_{12}} = 0$

$$k_{15} / k_{12} = \sum_{n=0}^{2} b_n D_{e,k}^{-n}$$

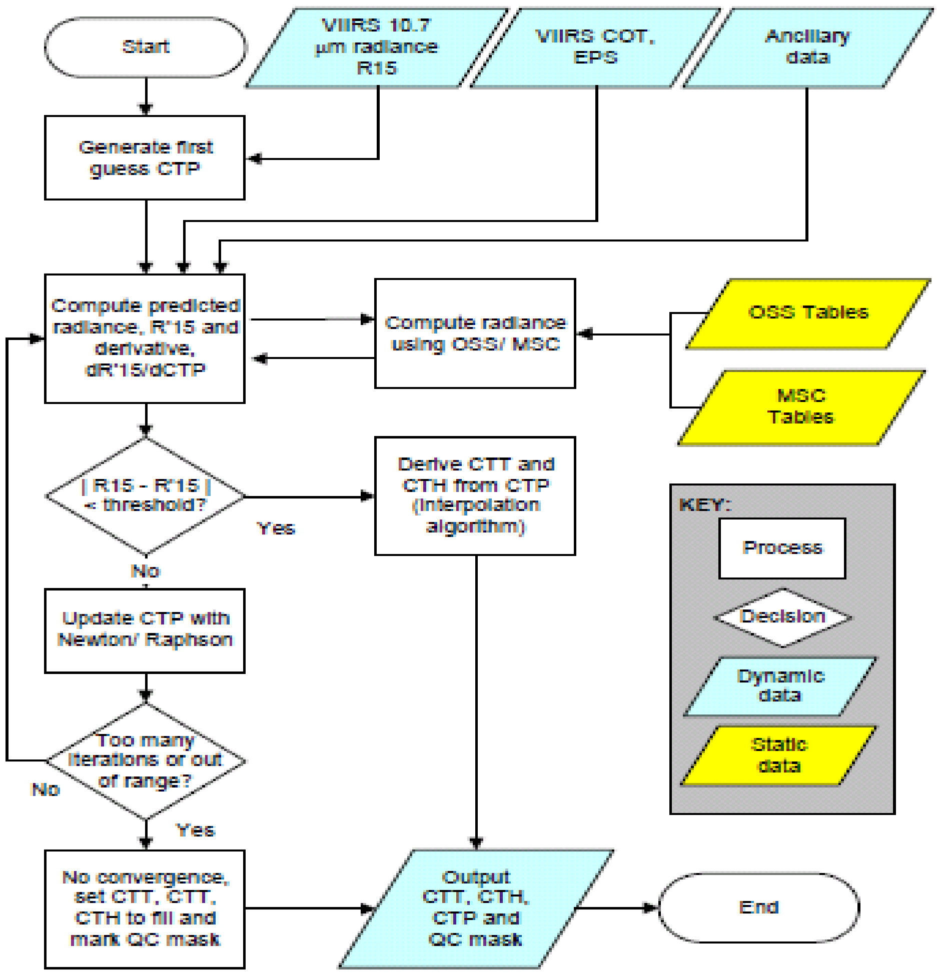
↓

CTT converged ?

No → Update De (return to compute CTT step)

yes ↓

SNPP VIIRS Day time Water Cloud Top Height Algorithm based on AER OSS RTM



SNPP VIIRS Night time Water Cloud Top Height Algorithm

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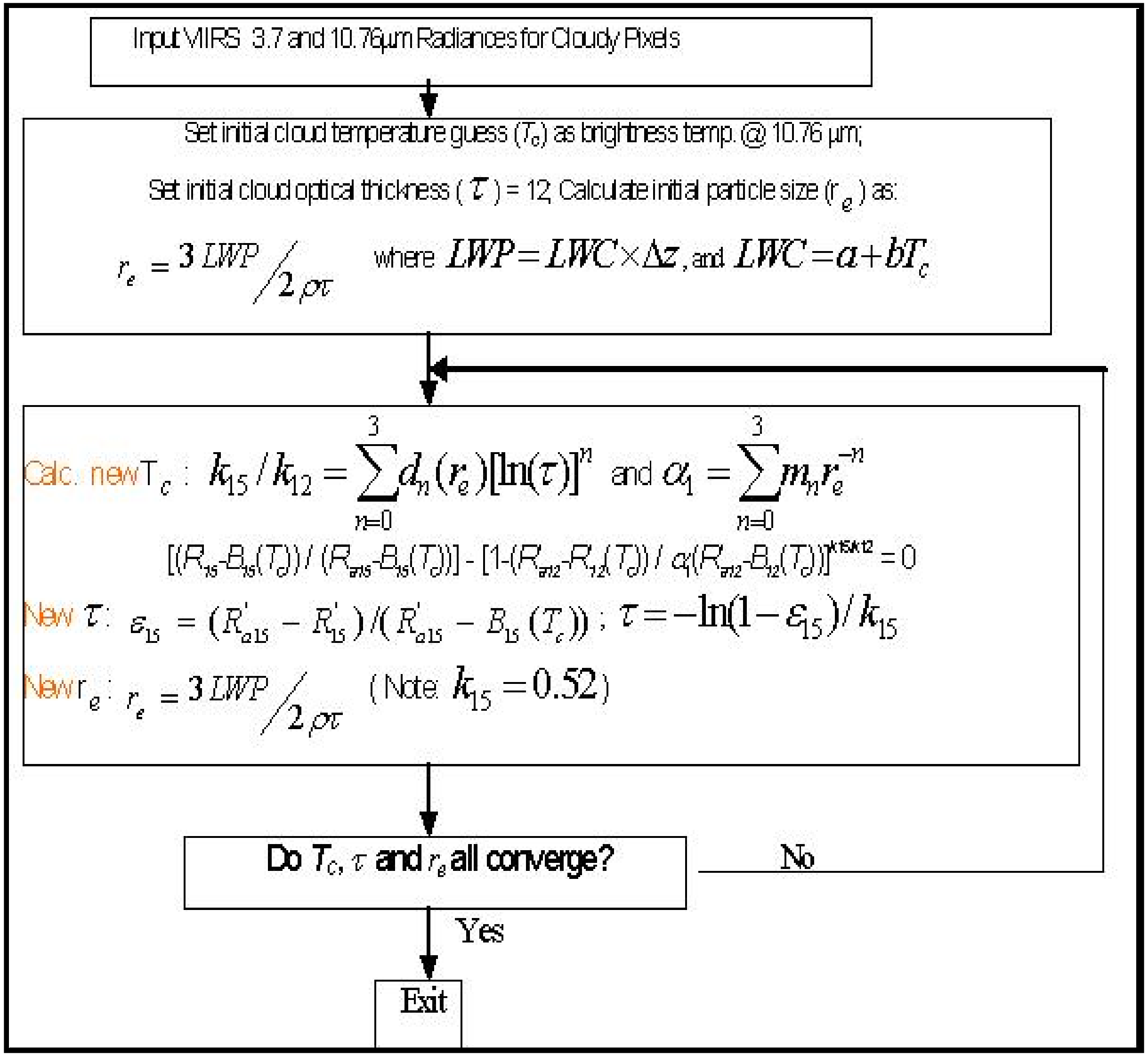

Theoretical Considerations for SNPP VIIRS Thermal IR Algorithms for Cloud Top Height Retrievals

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- In the VIIRS Thermal IR method the key parameter is the k16/k14 or k15/k12 ratios
- These ratios can be directly related to the absorption coefficient ratio if either the scatter effect for both bands are small or similar
  - $k16/k14 = Log(1-\varepsilon_{M16})/Log(1-\varepsilon_{M14}) \approx ß_{M16}/ß_{M14}$
  - Where ß is the absorption coefficient
- From ADA (Anomalous Diffraction Approximation, Mitchell JAS 2000) the absorption efficiency (ß =QA):
  - $Q_{abs} = 1- \exp(-8\pi\eta_i D_e/3\lambda)$
  - Where η_i ,D_e, λ are Imaginary refractive index, effective particle diameter and band wavelength. A=projected area of particle
- Table of Imaginary Refractive Index

Band / cloud phase	3.7 µm(M12)	8.5 µm(M14)	10.7 µm(M15)	12.0 µm(M16)
water	0.0036	0.036	0.0764	0.20
Ice	0.0069	0.0389	0.1376	0.411

Theoretical Considerations for SNPP VIIRS Thermal IR Algorithms for Cloud Top Height Retrievals - continued

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- Due to small values in the M12 and M13 imaginary refractive index for ice and water cloud we expect:
  - $ß_{M12}/ß_{M13} = Q_{M12}/Q_{M13} \approx (\eta i_{M12}/\eta i_{M13})*(\lambda_{M12}/\lambda_{M13})$, independent of De, therefore particle habit
  - This band combination may be exploited in future algorithm enhancement

- Due to relatively larger values in M14 and M16 imaginary refractive index we expect there is dependence of De for $ß_{M16}/ß_{M14}$
  - This is borne out in SNPP VIIRS Parameterization for k16/k14 ratio, however, from ADA considerations, it is believed that De^2 and De^3 terms be included

- To increased sensitivity, however, consideration should be given to M12 and M16 combination (instead of M14 and M16 used by SNPP) in future development for **night time** CTH retrievals

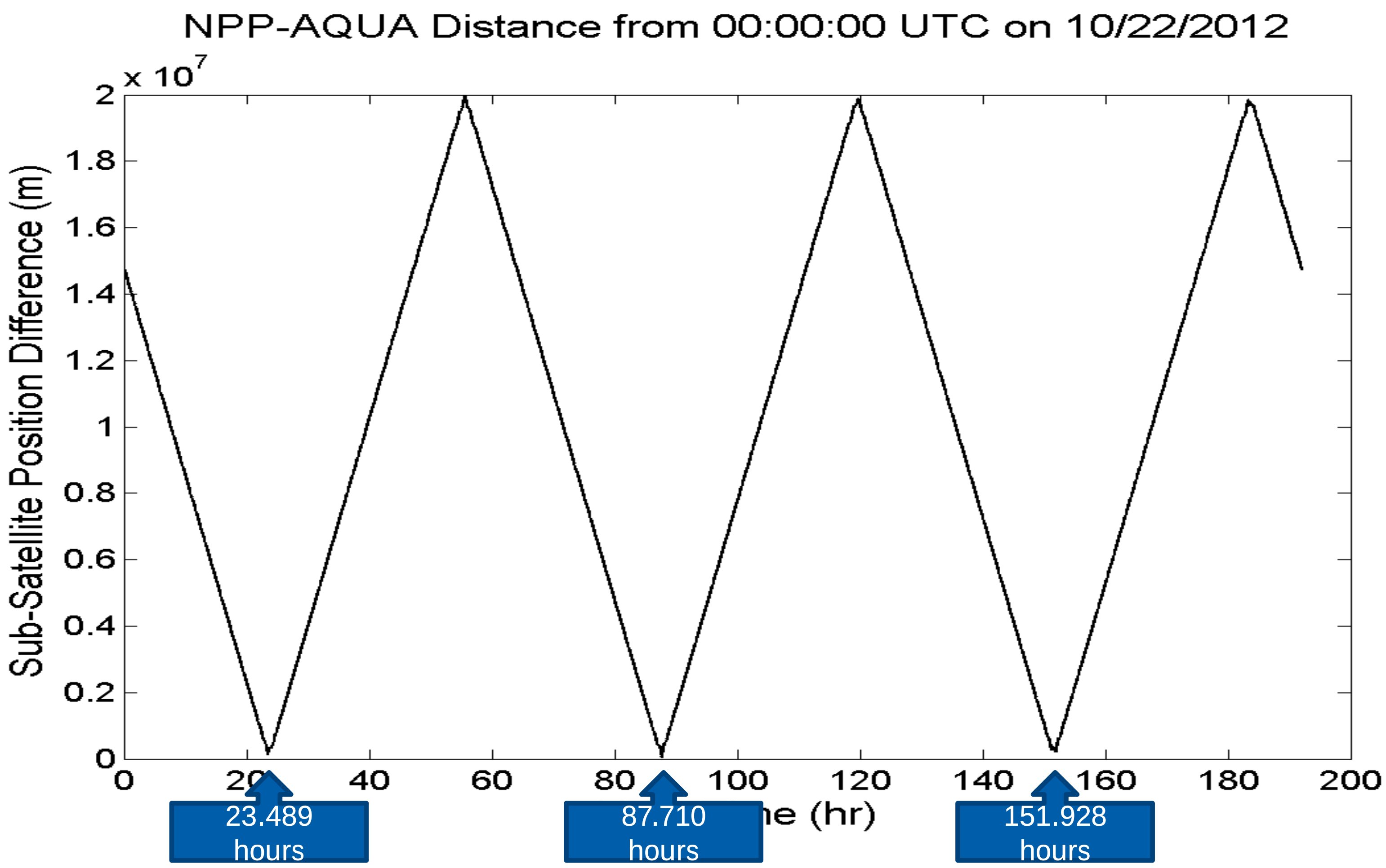
- M13 and M16 combination should be given consideration for **day time** CTH retrievals due to significant solar component in M12 for day conditions

- In addition the use of M15 in the calculation of cloud optical thickness in NPP VIIRS night time may not be optimal. M12 may be a better choice because its emissivity does not saturate as fast as M15 due to significantly smaller refractive index value

Presentation of Comparison results - SNPP and Calipso Data Match up Criteria

- Temporal constraint: ±10 minutes, i.e. SNPP could be ahead or behind Calipso within 10 minutes
- Spatial constraint: Nearest neighbor and pixel separation ≤ 1 km
- Only high quality pixels are selected for comparison, meaning that:
  - On SNPP data - the pixel must have a converged CTH, confidently cloudy, either water or ice cloud, not including mixed phase
  - On Calipso data - must be high confidence in cloudiness and in cloud phase
- To accurately assess SNPP VIIRS CTH algorithm performance matched up pixels not in agreement in cloud confidence and cloud phase between SNPP and Calipso are not considered

Simultaneous Nadir Overpass Matchup Points Between SNPP and EOS-AQUA (and similarly for Calipso) – occur every ~2.4 days



Example of SNPP and Calipso Ground Track where near simultaneous nadir overpass occurs

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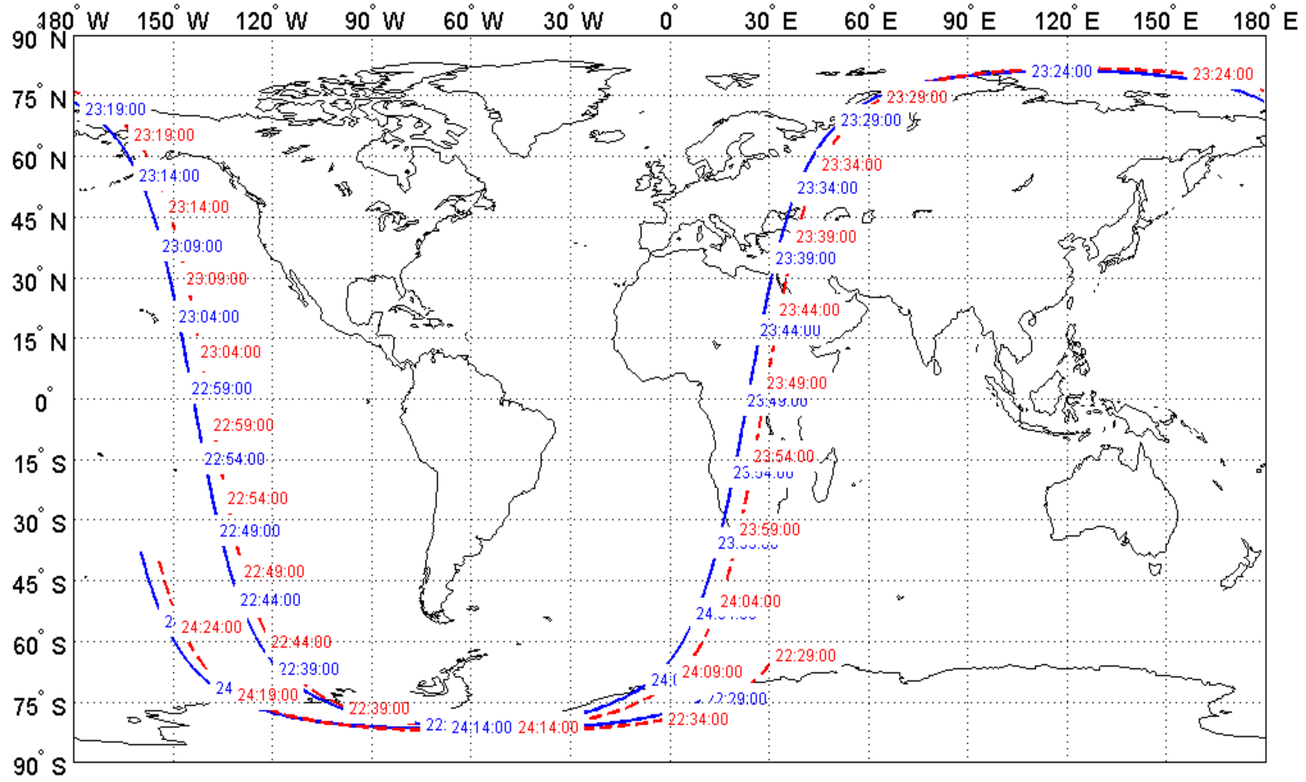
NPP (blue) & CALIPSO (red) Ephemerides from 00:00:00 UTC on 10/22/2012



Template for the presentation of Comparison Results

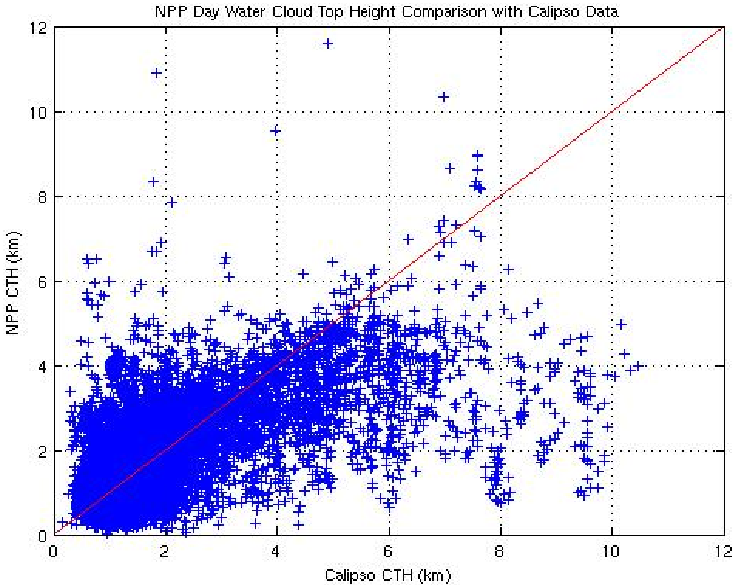
Scatter plot showing Calipso and SNPP CTH correlation

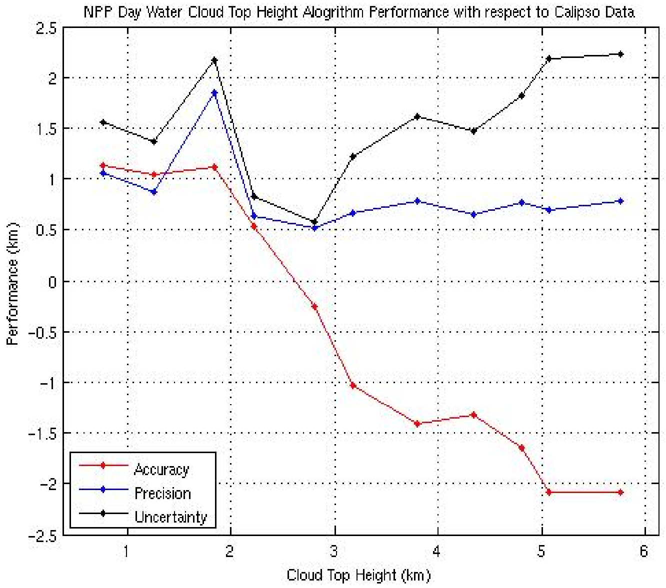
NPP Performance against Calipso data in different CTH bins

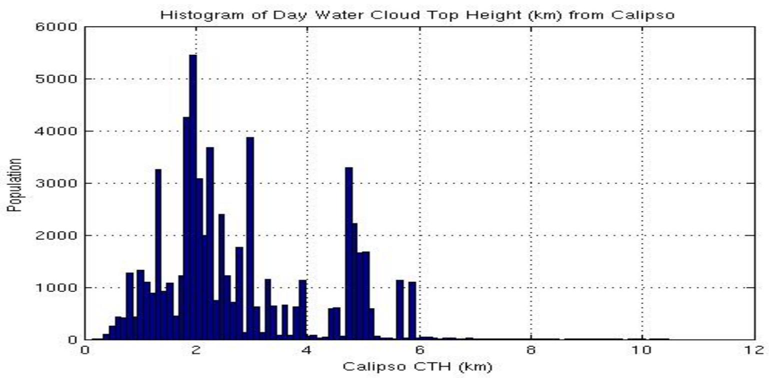
Distribution of Cloud Top Height based on Calipso Data

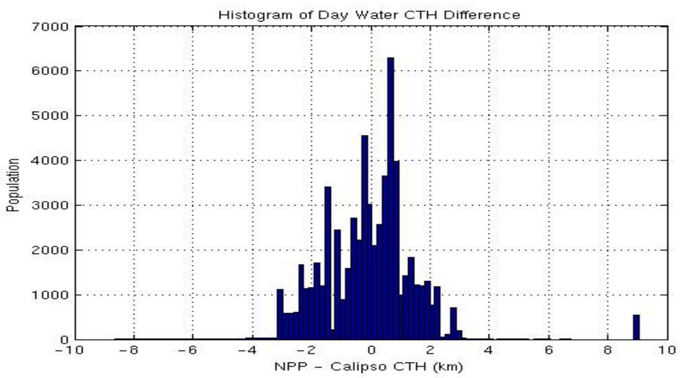
Distribution of CTH difference between NPP and Calipso data

Performance of SNPP VIIRS Day Water Cloud Top Height Algorithm



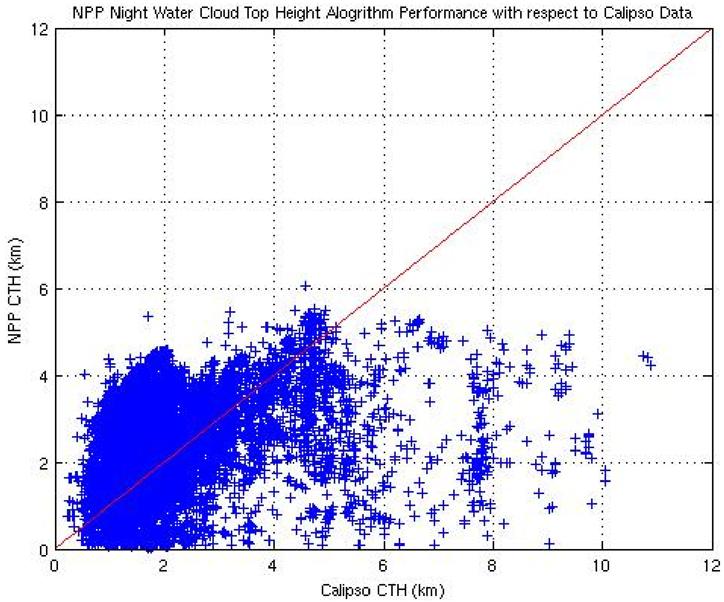


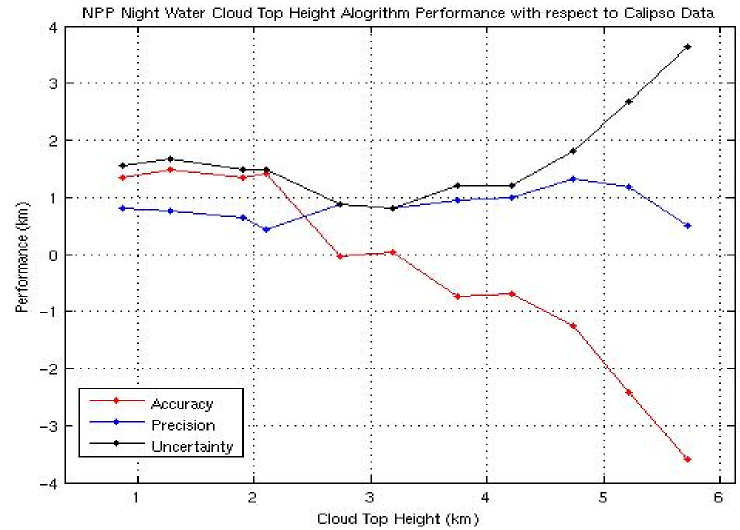


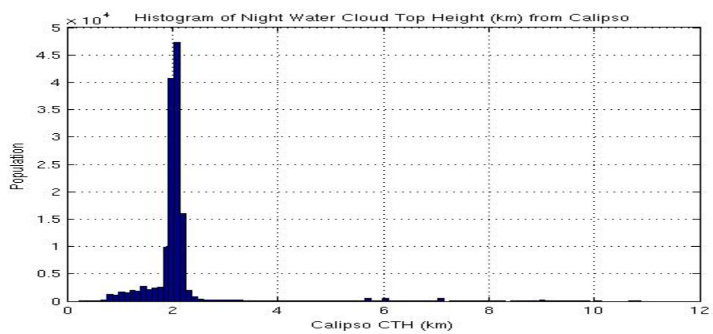


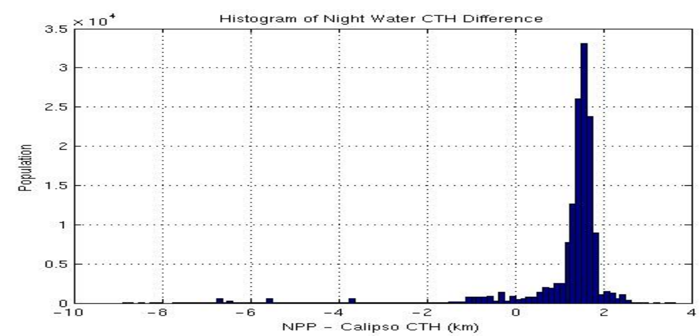
- Mean error = -0.048 km
- Uncertainty in error =1.61 km

Performance of SNPP VIIRS Night Water Cloud Top Height Algorithm



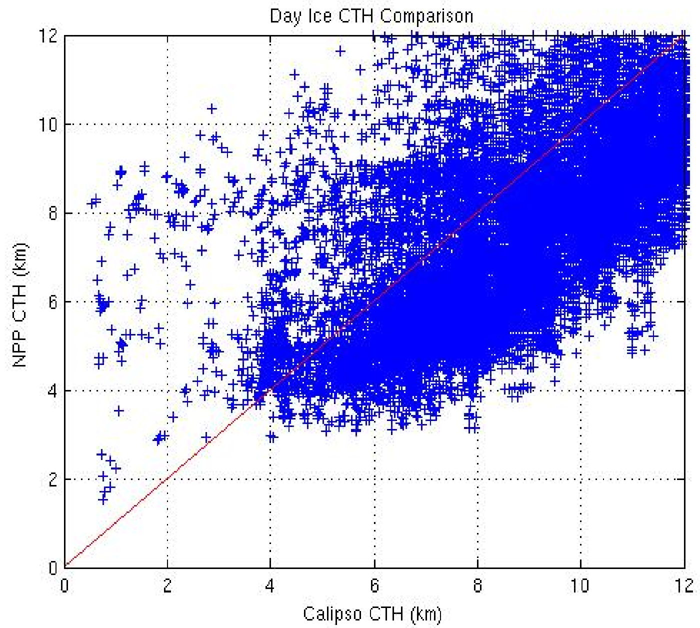


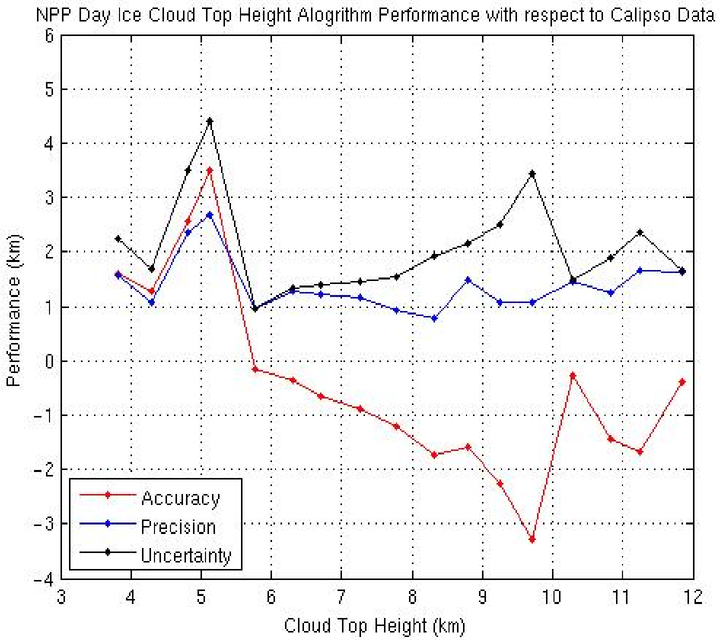


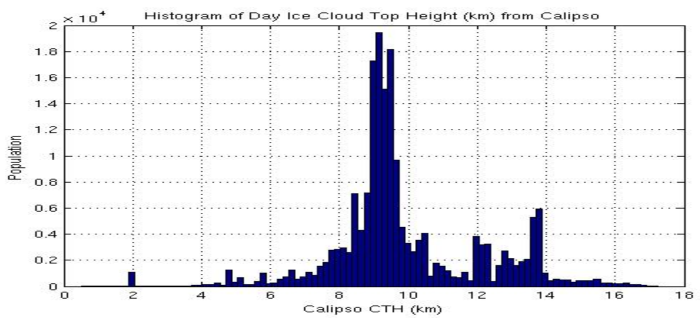


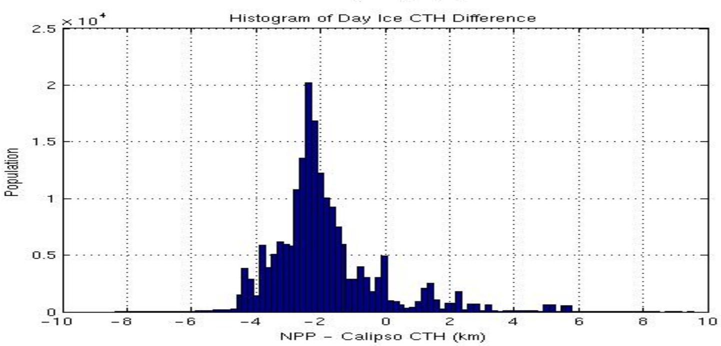
- Mean error = 1.26 km
- Uncertainty of error = 1.042 km

Performance of SNPP VIIRS Day Ice Cloud Top Height Algorithm



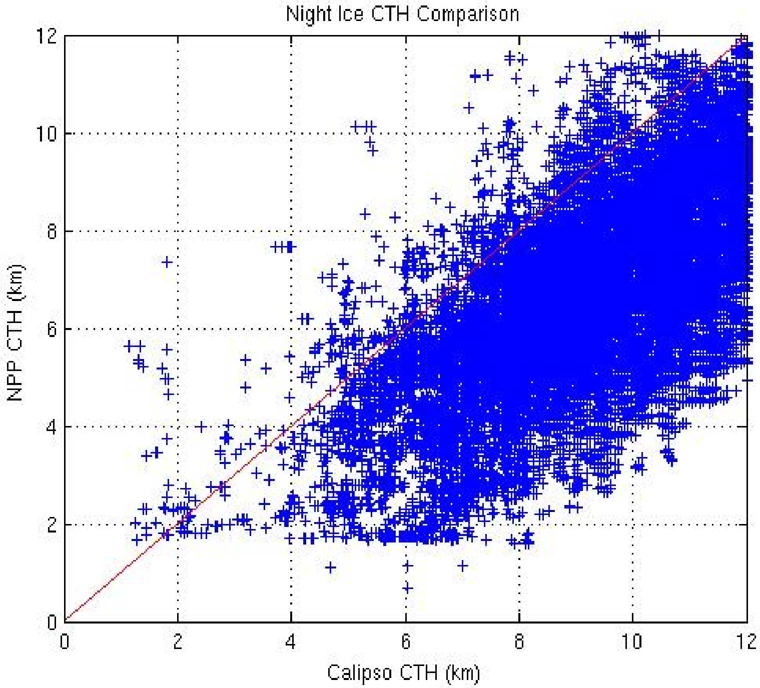


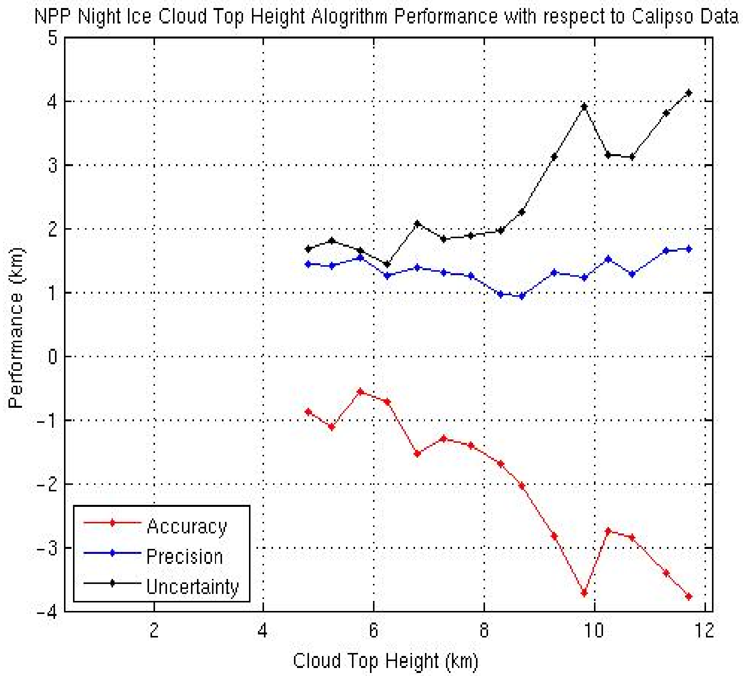


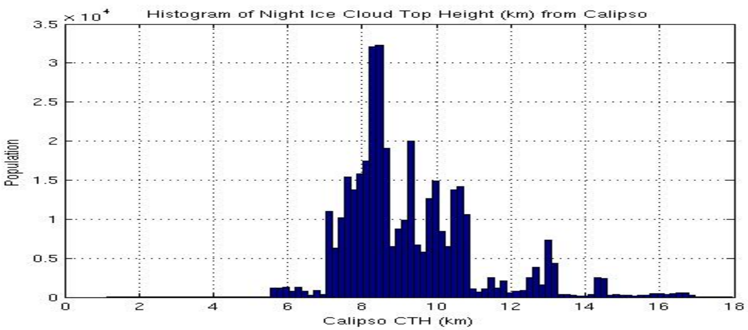


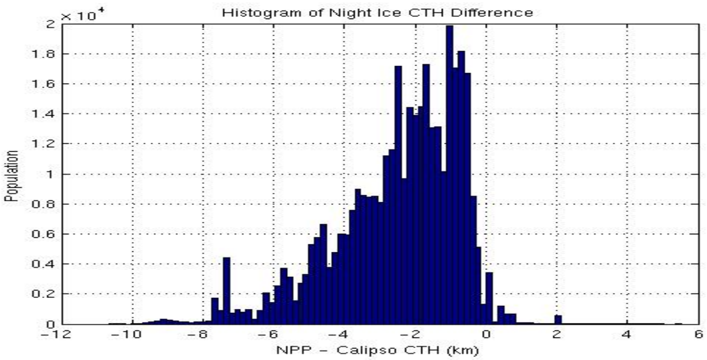
- Mean error=-1.84 km, significant negative bias
- Uncertainty of error =1.73 km

Performance of SNPP VIIRS Night Ice Cloud Top Height Algorithm









- Mean error=-2.49 km, significant negative bias
- Uncertainty of error=1.78 km

Concluding Remarks

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- We have presented the SNPP VIIRS Cloud Top Height Algorithms which contain 4 separate algorithms

- We presented some theoretical considerations in the selection of the 2 thermal IR bands used in the retrieval of Cloud top temperature which along with atmospheric profile leads to the calculation of CTH

- Based on our theoretical considerations SNPP VIIRS CTH may be further enhanced by choosing the more appropriate 2-band combination

- Furthermore our theoretical considerations indicate that choosing of M15 for the retrieval of cloud optical thickness for night condition may be less sensitive than using M12

- The performance of day water cloud performs slightly better than its night time counterpart, nevertheless both are considered to meet the former NPOESS system Spec

Concluding Remarks - continued

- The performance of night ice cloud is slightly better than day ice cloud algorithm. In both cases there is a significant negative bias (-1.84 and -2.64 km respectively) relative to Calipso data.

- In light of the theoretical considerations the parameterization equation for k16/k14 ratio is the likely candidate that contributes to these biases

- Future update of the SNPP VIIRS CTH algorithm is to confirm the source(s) of these biases and new parameterization equation as well as its associated constants may need to be determined

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