Retrieval of nighttime cloud optical and microphysical properties for GOES-R

Patrick W. Heck
Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin-Madison, Madison, Wisconsin

Patrick Minnis
Science Directorate, Climate Science Branch
NASA Langley Research Center, Hampton, Virginia

Sarah T. Bedka **Christopher R. Yost** **J. Kirk Ayers** **Gang Hong**
<-------- *Science Systems and Applications, Inc.* ------->
Hampton, Virginia

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Introduction

Presented are results from NASA Langley's Nighttime Cloud Optical and Microphysical Properties (NCOMP) algorithm, a thermal wavelength-only retrieval algorithm that can be applied both day and night, but is used primarily at night due to the advantages of using visible wavelengths during sunlit portions of the day. NCOMP is one of the suite of techniques being used to retrieve cloud properties from the GOES-R Advanced Baseline Imager (ABI) proxy data set, SEVIRI imagery.

NCOMP is a variation of NASA Langley's Solar-infrared Infrared Split-window Technique (SIST), which is being applied at LaRC to SEVIRI, GOES, MODIS, AVHRR, FY-2C and MTSAT data in near real-time in support of a variety of projects. SIST-derived nighttime cloud properties derived from MODIS data also form one of the underpinnings of Clouds and the Earth's Radiant Energy System (CERES) radiation budget products.

Using wavelengths in the window region, as well as the emitted portion of 3.9 µm, NCOMP yields cloud macro-physical and microphysical properties that have been validated (results included here) but the insensitivity of the window channel wavelengths in optically thick clouds (τ > ~6) has limited its ability to fully characterize these clouds.

The usage of additional wavelengths outside the window region is being explored and is expected to increase NCOMP's and SIST's robustness. An example of this technique's application to MODIS data is also presented.

NCOMP retrievals of cloud optical depth, particle size and Liquid Water Path (LWP) and Ice Water Path (IWP) have been validated with results for COD and LWP shown.

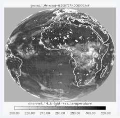
For these validation studies, both NCOMP retrievals are conducted on 3.9-, 11.2- and 12.3-µm SEVIRI nighttime imagery that is being used as a proxy for GOES-R ABI data.

NCOMP Algorithm

Technique:

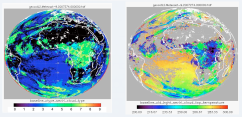
NCOMP determines the **C**loud **O**ptical **D**epth, **COD**, and **C**loud **P**article **S**ize, **CPS**, that produce modeled brightness temperatures closest to the observed brightness temperatures for each ABI proxy pixel. Observed BTDs are compared to BTDs simulated using emittance parameterizations and cloud physical parameters are inverted. The **COD** and **CPS** that produce the minimum difference between observed and modeled BTDs are assumed to describe the cloud. The phase-appropriate water path, either **LWP** or **IWP**, is calculated based on the retrieved **COD** and **CPS**.

1 Oct 2006, 00:00 UTC



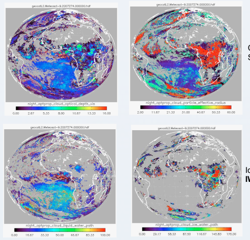
Inputs:

- ABI Channels 7, 14, 15 (3.9, 11.2, 12.3 µm)
- **GOES-R Cloud Temperature: T_{cld}** from Heidinger et al.
- **GOES-R Cloud Type** from Pavalonis et al.
- RTM, NWP
- Surface information
- Algorithm coefficients for determining cloud emissivity and calibration (when needed)



Output Products:

- **C**loud **O**ptical **D**epth, **COD**
- **C**loud **P**article **S**ize, **CPS**
- **L**iquid **W**ater **P**ath, **LWP**
- **I**ce **W**ater **P**ath, **IWP**



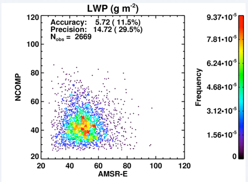
Validation

NCOMP products have undergone extensive validation and meet the GOES-R program's required specifications. During nighttime hours, the availability of validation sources is somewhat limited, particularly in comparison to daytime sources. The primary limitation to nighttime validation, however, is the inability of some sensors to retrieve accurate microphysical and some macrophysical descriptors for optically thin clouds. Despite those limitations, NCOMP compares well to the available sources.

GOES-R NCOMP LWP Compared to AMSR-E

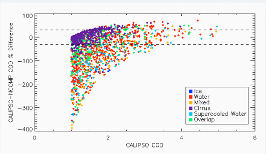
- AMSR-E retrievals of LWP are matched in space and time to NCOMP retrievals from SEVIRI imagery. AMSR-E LWP are obtained from passive microwave measurements aboard Aqua.
- Although AMSR-E performance is degraded for optically thin clouds, NCOMP meets GOES-R performance specifications.
- Studies are underway to extend NCOMP and SIST to optically thick clouds (see right).
- Results are for single layer water clouds only, but hope to extend this performance to mixed clouds, supercooled clouds, etc.

LWP from NCOMP and AMSR-E
1 < tau < 5 only



Despite the limitation of focusing on optically think clouds, AMSR-E LWP provides the best and most direct validation source for NCOMP. Other NCOMP products prove trickier…

GOES-R NCOMP COD Compared to CALIPSO



- CALIPSO comparison meets specs for ice clouds
- Results are highly dependent on GOES-R Cloud Type, a subset of which is shown.
- As expected, cirrus clouds provide the best comparisons as they are one of CALIPSO's strong points.
- TBD: is CALIPSO a feasible validation source for other cloud types?
- TBD: Can CloudSat be used for optically thin clouds, whether ice or water?

NCOMP Performance

- ✓ LWP is meeting F&PS requirements
- ✓ COD is meeting F&PS requirements for ice clouds
- ✓ CPS is meeting F&PS requirements for ice clouds
- ✓ IWP for thin ice clouds is TBD, as are COD and CPS for water clouds. Investigation of routine sources continues as does expansion of deep-dive datasets to meet routine validation needs.

* no direct comparison indicates that direct validation sources for large data sets are currently not available or at a level of maturity that lend themselves to routine validation.

Product	*Measurement Range*	*Measurement Accuracy*	*Measurement Precision*
COD	1.0 – 5.0 1.0 – 5.0	30% 2.3%	max of 0.8 or 30% 0.47 or 28.2%
CPS	liquid: 2 < CPS < 32µm 2 < CPS < 32µm ice: 2 < CPS < 50µm 2 < CPS < 50µm	liquid: max of 4µm or 30% *no direct comparison ice: 10µm 1.3 µm	liquid: max of 4µm or 25% *no direct comparison ice: max of 10µm or 25% *8.4 µm or 17.9%
LWP	25 < LWP < 100 gm^{-2} 25 < LWP < 100 gm^{-2}	greater of 25 gm^{-2} or 15% 5.7 gm^{-2} or 11.5%	greater of 25 gm^{-2} or 40% 14.7 gm^{-2} or 29.5%
IWP	25 < IWP < 175 gm^{-2} 25 < IWP < 175 gm^{-2}	greater of 25 gm^{-2} or 30% *no direct comparison	greater of 25 gm^{-2} or 40% *no direct comparison

Black = F&PS requirements Red = Validation results

New Thermal Retrievals Compared to CloudSat/CALIPSO

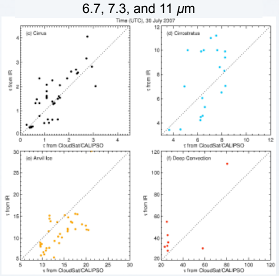
This new thermal-only method is compared to CloudSat/CALIPSO data for a nighttime case study with larger COD.

Example here uses data taken over ocean using Aqua MODIS data.

- The correlations are reasonable for τ < ~23, not as good for thicker clouds, though little data involved.
- Much additional data are need to refine this method. 3.7-μm data can also be used instead of 7.3 μm.
- Usage of 6.7 and 7.3 μm extends τ range significantly.

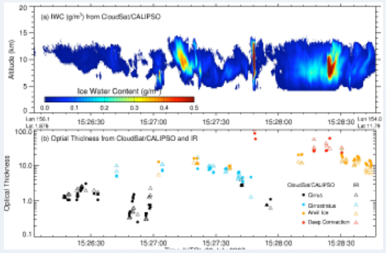
Based on work from Gang Hong.

Comparison of retrieved τ using 6.7, 7.3, and 11 μm



Ice water content (top) and τ from CloudSat/CALIPSO

(Cloud type classification is from CloudSat/CALIPSO)



Conclusions & Future Plans

- Comparisons of NCOMP LWP with AMSR-E LWP provide the richest validation source for NCOMP. Other space-borne passive microwave instruments should provide similar opportunities in the GOES-R era.
- NCOMP COD compared to CloudSat/CALIPSO COD for optically thin ice clouds also proves to be a valid source for assessing NCOMP's performance.
- Selectivity of validation data sets need to be increased so that multi-layer clouds do not unduly bias the comparisons.
- Usage of thermal channels outside the window channel areas show good possibilities for extending NCOMP's applicability to much thicker clouds, a first for nighttime analyses.
- Initial comparisons of particle size for both water and ice (not shown) indicate some skill but the particulars of various retrieval schemes involved in validation sources, e.g. cutoffs, size definitions, etc., need to be well-understood.
- NCOMP will be performed during daylight hours with channel selections varying. These results will be compared directly to NCOMP nighttime results to determine continuity between day and night retrievals, as well as to daytime results which are more robust due to its ability to retrieve a superior range of cloud optical depth using visible wavelengths.
- More case-studies and application to GOES, MODIS and SEVIRI.