A Study on the Use of ARM Measurements for Validation of NPOESS/VIIRS Cloud Product

Eric Wong[1], Steve Ou[2], Paul Lee[1], and Lushalan Liao[1]

1 Northrop Grumman Space Technology, Los Angeles, CA

2 Department of Atmospheric Sciences, University of California, Los Angeles, CA.

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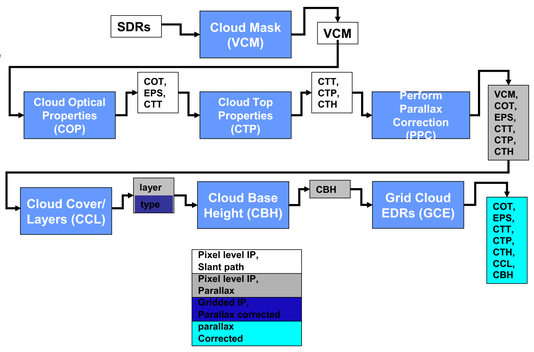
- *NPOESS/VIIRS Cloud Algorithms Processing Chain*
- *General Validation Approach*
- *Uncertainties in Ground-Based Measurements/Products*
- *Example of Cloud Heights Algorithms Testing Using ARM Data*
- *Pre-Launch and Post-Launch Validation Plans*

Cloud Chain Process Flow



VIIRS Cloud EDRs Requirements

EDR Description	System Spec	
	Range	Uncertainty
Cloud Base Height	0-20 km	2 km
Cloud Cover Layers	0 -1.0 HCS coverage/4 layers	0.15 (fraction)
Cloud Effective particle Size	0-50 μm	2.5 μm (day water); 4 μm (day ice); 4 μm (night)
Cloud Optical Thickness	0.1-64 (day water) 0.1-10 (day ice)	0.3 or 10% whichever larger (day water); 0.1 or 10% whichever larger (day ice)
Cloud Top Height	0-20 km	0.5 km (day water); 2 km (ice)
Cloud Top Pressure	50-1050 mb	130 mb (0-3 km cth) for day water; 30 mb (> 7 km CTH)
Cloud Top Temperature	175-310 K	3 K (water); 5 K (ice)

VIIRS Cloud Optical Property Algorithms

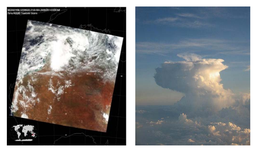
- Solar Algorithm
  - –For Daytime Ice and Water Clouds
  - –Uses M5 (0.672 μm for land), M8 (1.24 μm for snow/ice) and M10 (1.61 μm)
  - –Solve for COT and CPS Based on Look-Up Table Approach
- Infrared Algorithm
  - –For Nighttime Ice and Water Clouds
  - –Uses M12 (3.7 μm), M14 (8.55 μm), M15 (10.76 μm) and M16 (12 μm)
  - –Solve for COT, CPS, and CTT Based on Radiative Transfer and Microphysical Parameterizations

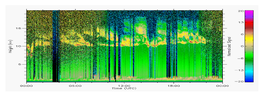
VIIRS Cloud EDR Validation Approach - Use of Ground-Based and limited Airborne Data

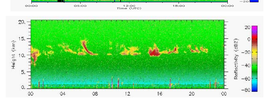
- Qualitative assessment of VIIRS Cloud products against historical record from MODIS and ISCCP etc
- Performance determination using ground based measurements at fixed sites
- Performance determination using limited airborne measurements as the Proteus aircraft (left image) was used in the Tropical Warm Pool International Cloud Experiment

Geographical Locations of ARM Sites

Ground-Based Validation Instrument Considerations







A. For CTT, CTP, CTH, CBH, CCL

Millimeter-Wave Cloud Radar (MMCR) – Measurement Range – 0-20 km ; radar range – mode 1:0.05km, modes2-4, 0.1 km

Micropulse Lidar (MPL) – Measurement Range – 0-20km; lidar range – 0.03 – 0.3 km

Vaisala Ceilometer (VCEIL) – Measurement Range – 0-20 km; Uncertainty – 0.015 km

B. For COT, EPS

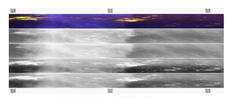
MMCR-AERI

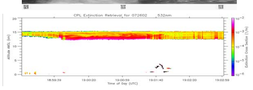
Raman Lidar

MPL-Radiometer

*Sources :
(1) ARM web sites
http://www.arm.gov/instruments/instclass.php?id=cloud
http://www.arm.gov/instruments/instclass.php?id=remprof
(2) Comstock and Sassen (JAOT, 18, 2001) - MPL
(3) Mace et al. (JGR, 103, 1998) - MMCR
(4) Turner (JAM, 44, 2005) - AERI
(5) Wang and Sassen (JAM, 41, 2002) – Raman Lidar
(6) Comstock and Ackerman (JGR, 107, 2002) - MPL
(7) Mace et al. (JGR, 107, 2002) – MMCR-AERI
(8) Ou et al. (JAM, 37, 1998) - Lidar

Airborne Validation Instrument Considerations





A. For CTT, CTP, CTH, CBH, CCL

MAS/ER-2

CPL/ER-2

B. For COT, EPS

CPI/ WB-57

CIN/WB-57

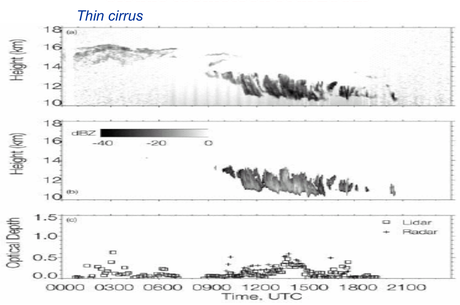
CAPS/WB-57

2D-Probes/UND-Citation

Replicator/Balloon

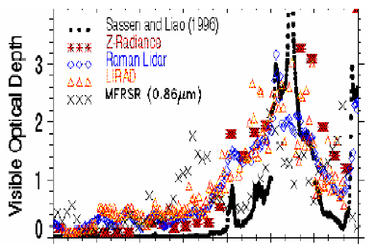
*Sources :
(1) Ou et al. (JAS, 18, 1995) – Balloon replicator (single layer cirrus)
(2) Ou et al. (JAM, 37, 1998) – Balloon replicator (multi-layer cirrus)
(3) Roskovensky and Liou (GRL, 31, 2004) – MAS, CAPS, CIN
(4) Garrett et al. (GRL, 30, 2003) – CIN derived mean particle size
(5) Baumgardner (Atmos. Res., 59-60, 2002) - CAPS
(6) Gerber et al. (JAS, 57, 2000) - CIN
(7) McGill et al. (JAO, 41, 2002) – CPL
(8) Lawson (Proc. *WMO Workshop on Measurement of Cloud Properties for Forecasts of Weather, Air Quality and Climate*, Mexico, 1997) – CPI
(9) Heymsfield et al. (JAS, 59, 2002) – 2D-Probe
(10) Roland et al. (JGR, 105, 2000) – 2D-Probe
(11) Ou et al. (GRL, 26, 1999) – Balloon replicator (Total 3.7 m algorithm)

Assessment of Uncertainties of MPL and MMCR in the Detection of Cirrus Clouds (Comstock et al 2002)



MPL detects thin cirrus while mmCR completely missed it.

Assessment of the Uncertainties in Cloud Optical Thickness Derived from Various Combination of Ground- Based Measurements



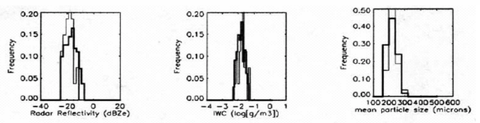
Assessment of the Uncertainty in Cloud Particle Sizes from MMCR-AERI against Aircraft Measurements (Mace 2002)

Table 8. Comparison of Microphysical Parameters Observed by the UND Citation and Derived From the Reflectivity Observations of the NOAA-K Cloud Radar[a]

MMCR-AERI — Aircraft in-situ meas. — MMCR-AERI — Aircraft in-situ meas.

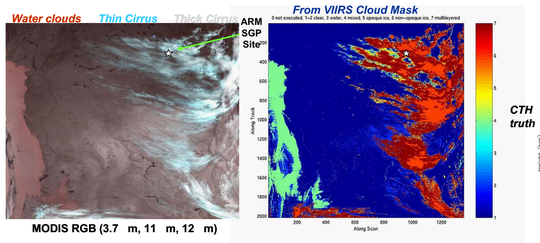
	NOAA-K *IWC* Mean, g m^{-3}	ACFT *IWC* Mean, g m^{-3}	NOAA-K *IWC* SDV, g m^{-3}	ACFT *IWC* SDV, g m^{-3}	NOAA-K L_{MM} Mean, μm	ACFT L_{MM} Mean, μm	NOAA-K L_{MM} SDV, μm	ACFT L_{MM} SDV, μm
Leg 1	0.016	0.020	0.009	0.011	219.	238	31.6	48.1
Leg 2	0.014	0.013	0.009	0.011	211	261	31.5	84.2
Leg 3	0.018	0.012	0.011	0.011	226	280	33.1	84.6
Leg 4	0.022	0.011	0.015	0.010	235	299	36.7	83.5
Leg 5	0.014	0.010	0.007	0.010	214	301	28.0	77.5

[a]See the text for additional information.



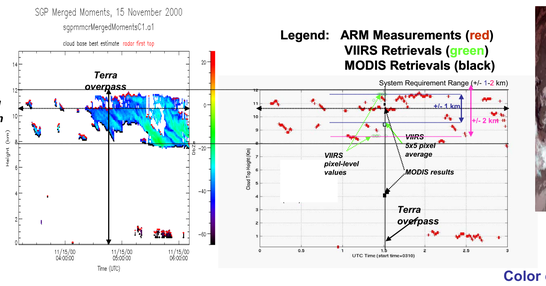
Example of VIIRS Algorithm Testing - CTH vs ARM-SGP Radar CTH

Nighttime Ice Cloud Test Case - Single Layered Cloud

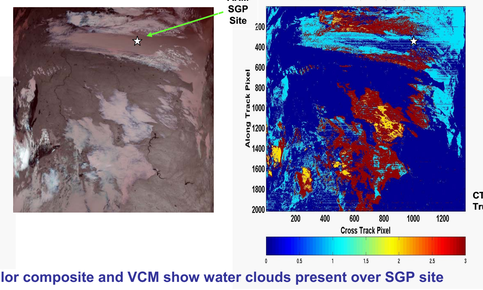


- **Scene Selected – MODIS/Terra Nov 15, 2000, 0440 UTC**
  - A case over ARM site at SGP, Oklahoma
  - -Terra overpass overlapped with Central Facility MMCR site
  - MMCR data indicates the presence of single layer ice cloud
- **Testing Involved:**
  - Compare VIIRS retrieved Cloud Top Height with ARM MMCR data
  - Compare with MODIS derived Cloud Top Height

Testing of VIIRS Nighttime Ice Cloud Algorithms - VIIRS and MODIS Cloud-Top Height Comparisons with ARM-SGP Site Measurements– 15 Nov 2000, 0440 UTC

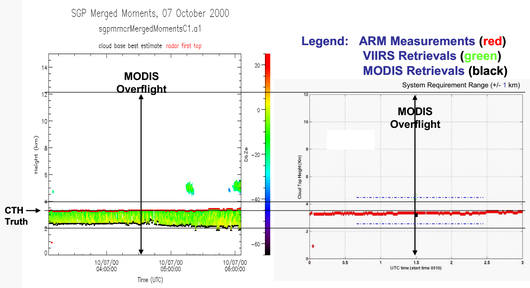


Example of VIIRS Algorithm Testing - Cloud Heights vs ARM-SGP Radar Cloud Heights, UTC 0435 on Oct 7, 2000



Color composite and VCM show water clouds present over SGP site

Testing of VIIRS Nighttime Water cloud Algorithms - VIIRS and MODIS Cloud-Top Height Comparisons with ARM SGP Site Measurements— 7 Oct 2000, UTC 0435



Cloud Type Stratification Based on ISCCP Dataset

- for the estimation of sampling requirement

Single-Layer Cloud Type

P_c		
P_c < 440mb	High Stratiform Cloud(Cirrus /Cirruostratus) < 10	High Convective Cloud (Cirrus Anvil/Cumulus- Nimbus) > 10
440mb < P_c < 680mb	Middle Stratiform Cloud (Altostratus/Altocumulus) < 15	Middle Convective Cloud (Nimbo-stratus) > 15
P_c > 680mb	Low Stratiform Cloud (Stratus/Strato-cumulus) < 20	Low Convective Cloud (Cumulus) > 20

Multi-Layer Cloud Type

P_c < 440mb		
	High Stratiform Cloud /Low Cloud $_{high}$ < 10	High Convective Cloud /Low Cloud $_{high}$ > 10

Mixed-Phase Cloud Type

P_c < 440mb		
	Stratiform $_{high}$ < 15	Convective $_{high}$ > 15

Estimation of ARM Sites Sampling Requirements for VIIRS Cloud Products

- Cloud stratification adopted for the estimation of EDR validation duration:
  - cloud microphysical types: ice (high cloud), water (mid, low, mixed-phase), multi-layer (5)
  - cloud macro-physical (formation/transport) types : convective and stratiform (2)
- Using ISCCP historical cloud cover data, the smallest probability of the 3 ARM sites being covered with one of the above cloud types (10 types) is ~ 5%
- The corresponding minimal cloud data points collected /year/site/type/viewing geometry/solar geometry = revisit time (~ 2/16 days at mid-lat site) x probability of cloudiness (0.05) x 365 days x number of orbits (2) = 4.6 measurement points.
- ARM has 2 sites: SGP and TWP. These 2 sites cover the two major surface types: continental land and ocean, respectively.
- Measurement points needed for statistical analysis per cloud type(~ 10).
- Estimated Long Term Duration required per site per type ~ 2 years (10/4.6 ~ 2)
- The goal with the inclusion of additional ground sites (TBD) is 1 year

Estimation of Airborne In-Situ Sampling Requirement for VIIRS Cloud EDRs

- Because of the inherent uncertainties in COP data from surface instruments, it is necessary to complement the surface validation with airborne in-situ measurements.
- We consider only high cloud - most past field measurements were for high clouds
- The ISCCP annual high cloud covers over the ARM-TWP sites are about 60%.
- The corresponding minimal cloud data points collected per campaign for high cloud = revisit time (~ 2/16 days) x campaign duration (30 days) x probability of cloudiness (0.6) = 2.4 measurement points
- Min. datapoints required for statistical analysis for high clouds (~ 5).
- Estimated number of airborne measurement for High Cloud at ARM TWP site ~ 2

Near- and Long-Term Validation Plan for VIIRS Cloud Products

- Prepare for qualitative assessment of VIIRS CLOUD products.
  - acquire & assess other sensor data products, ISCCP, MODIS, Cloudsat, Calipso etc.
  - develop software to process VIIRS and other sensor data products
- Interact with the selected ground based cloud data networks (e.g. ARM sites, universities etc.).
  - acquire or develop (based on open literature) retrieval algorithms employed for the processing of ground based data.
  - acquire and assess ground site cloud data products (e.g. ARM VAP for cloud products).
  - develop software to analyze VIIRS and fixed site retrieved cloud products.
- Assess the need, the locations and timing of airborne measurements.

Near- and Long-Term Validation Plan for VIIRS Cloud Products

- Interact and coordinate with the fixed site and airborne measurement teams .
  - Acquire or develop softwares to process in-situ measurements.
  - Develop softwares to analyze VIIRS and airborne retrieved cloud products.
- Participate in planned community field campaigns, if any.