Inter-comparison of MERIS, MODIS and MISR cloud top heights
ENVISAT Project ID:796 (CLOUDMAP3)

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Overview

- Introduction to the EU-CLOUDMAP2 Project
- Intercomparisons of cloud-top heights over ARM-SGP site
  - Low, mid-level clouds
  - High clouds
- Intercomparisons of cloud-top heights over Chilbolton (CFARR) site
  - Low, mid-level clouds
  - High clouds
- Conclusions
EU-CLOUDMAP2 project: objectives

- Production and testing of cloud microphysical and macrophysical properties from new EO instruments: MODIS & MISR (TERRA), MERIS & AATSR (ENVISAT), ATSR2 (ERS2), SEVIRI (MSG)

- Assessment of cloud top height accuracy through inter-comparison and comparison with ground based measurements: active with radar/lidar at ARM sites, Chilbolton, SIRTA; radiosondes for various sites in UK and US

- Inter-comparisons of cloud top heights:
  - MERIS cloud top pressures (O$_2$ A-band)
  - MODIS cloud top pressure (CO$_2$-slicing)
  - MISR stereo cloud top heights
  - 35GHz and 94GHz radars at SGP (ARM) and CFARR (Chilbolton, UK) respectively

- Partners: UCL, Free University Berlin, DLR, RAL, KNMI, SMHI, MCH, ETH
Data-sets and locations

- Comparison between MERIS, MISR, and MODIS CTH vs. radar over SGP in 2003: 11 cloudy cases from 14/01 to 28/08 over SGP radar with MISR/MODIS coincidence (within 30 minutes)
  - 5 cases with MERIS CTP retrieval: 1 low (15/02), 2 mid-level (07/06 and 09/06) and 2 multi-layer (15/05 and 31/05)
  - 6 cases with optical depth less than 5 and no MERIS CTP

- Comparison between MERIS, MISR, and MODIS CTH vs. radar over CFARR in 2003:
  - 7 cloudy cases in May to July, with coincident radar and MERIS: 4 low (20/05, 05/06, 12/06, 04/07), 1 high (01/07), 2 multi-layer (27/05 and 18/06)
  - 2 cases with MISR and MODIS within 30 minutes
SGP 2003 (1)
MERIS, MISR, MODIS vs 35GHz radar CTHs

- Low single cloud: MERIS & MISR in good agreement with radar: (radar CTH continuous from 17:00UT to 17:30UT)
  Radar CTH: 2km – MISR CTH=1.8km (no wind correction) –
  MERIS CTH=1.9km – MODIS CTH=0.8km (too low)

- Mid-level single clouds:
  - 2003-06-07: MERIS & MISR in good agreement with radar
    Radar=4.6km - MERIS=4.3km – MISR CTH=4.5km – MODIS CTH= 6.1km (too high)
  - 2003-06-09: MERIS & MISR below radar cloud layer
    Radar: CBH=5.8km and CTH=6.2km
    MERIS=4.9km– MISR CTH=5.4km – MODIS CTH=7.1km
      (higher than radar CTH), optical depth~5.5 for 2 large areas but 2.3 for smaller areas
SGP 2003 (2)
2003-06-09, MERIS MISR/MODIS overpass at 17:15UT

Edge of cloud at time of overpass + scattered clouds + CTH and CBH highly variable

MERIS CTH=4.9km (top left)
MISR CTH=5.4km (lower left)
MODIS CTH=7.1km (low right)
Radar CTH=6.2km (top right)

MERIS not fully detecting clouds: small optical depth (2-5)
MISR without wind correction=6.3km, maybe problem with wind retrieval
**SGP 2003 (3)**

**MERIS/MISR/MODIS vs radar**

- **Thick high cloud (2003-05-15):**
  - 1 mid-level & 1 high cloud at 17:01UT
  - Radar layers: (1) 0.6-6.3km (2) 7.0-11.7
  - MERIS CTH= 5km at top of lowest layer
  - 1 thick high cloud radar at 17:25UT: CBH=0.4km CTH=11.5km
  - MODIS CTH=10.6km – MISR CTH=8.1km (no wind correction)

- **1 high cloud with 2-3 broken lower layers (2003-05-31):**
  - Radar high layer: CBH=10.0km CTH=11.5km (11.8km at 17:25UT)
  - Radar CBH of lowest layer at 5.2km
  - MERIS CTH=5.5km close to lowest scattered layer
  - MISR CTH=9.3km (0.2° window) & 5.3km (other windows)
  - MODIS CTH=10.6km – Optical depth~2.3
  - MERIS agrees with MISR small windows, highest layer too thin for MERIS and lowest layer too bright for MISR
High cloud deck moved from West to East between ENVISAT and TERRA overpasses. Two layers for MERIS (radar cloud occurrence on left above), one only (top right) for MISR/MODIS. Top layer too thin for MERIS to detect it. MISR does not fully detect high cloud area.
1 high cloud with broken lower layers
Radar high layer CTH=11.5/11.8km
MERIS CTH=5.5km (top left)
MISR CTH=9.3km (0.2° box) &
5.3km (other boxes) (lower left)
MODIS CTH=10.6km – Optical
depth~2.3 (lower right)
MERIS at limit of optical depth
MISR CTH jumps from low to high
layer depending on contrast.
CFARR 2003 (1)
MERIS versus 94GHz radar CTHs

- Low single clouds in good agreement:
  - 2003-05-20: MERIS=1.9km – Radar=2.3km
  - 2003-06-05: MERIS=2.0km – Radar=2.1km
  - 2003-06-12: MERIS=1.7km – Radar=1.6km
  - 2003-07-04: MERIS=1.8km – Radar=1.6km

- High single cloud with MERIS below cloud base (2003-07-01):
  Radar layer CBH=6.0km and CTH=8.5km
  MERIS CTH=4.7km – Optical depth maybe <5

- 2 low cloud layers (2003-05-27): MERIS at top of lowest cloud
  Radar layers: (1) CTH=1.3-1.6km (2) CTH=2.5km
  MERIS CTH=1.2km

- 2 layers, 1 low & 1 mid-level (2003-06-18): MERIS below base of highest
  Radar layers: (1) CTH=1.3-1.8km (2) CBH=3.4km, CTH=4.2km
  MERIS CTH=2.5km
CFARR 2003 (2)
2003-06-18, MERIS overpass at 10:46UT

mid-level broken cloud, so probably reason why no cloud detected by MERIS CTH
Broken cloud situation causes problems for space/time comparison.
CFARR 2003 (4)
MERIS with MISR/MODIS vs Radar

2 dates with TERRA at 11:10UT and ENVISAT at 10:35UT

  - radar: (1) CTH=1.3/1.5km (2) CTH=2.4/2.5km
  - MERIS CTH=1.2km – MISR CTH=1.2km – MODIS CTH=2.3km
  - MERIS & MISR at top of layer (1) and MODIS at top of layer (2)

- 1 low cloud at 10:35UT and 11:10UT (2003-06-12):
  - radar: 1.6km at 10:35UT and 2.0km at 11:10UT
  - MERIS CTH=1.7km – MISR CTH=1.5km – MODIS CTH= 0.9km
  - MERIS CTH at top of low cloud, MISR CTH at cloud base,
    MODIS CTH below cloud with optical depth≈7
CFARR 2003 (5)
2003-05-27
TERRA orbit 18292, 11:10UT - ENVISAT orbit 6475, 10:37UT

MERIS CTH 1.2km (left) – MISR CTH 1.2km (centre) – MODIS CTH 2.3km (right)
Radar CTH (below right):
layer (1)=1.3/1.5km
layer (2)=2.4km
Conclusions (1)

- Low clouds:
  - Single clouds:
    Good agreement between MERIS and radar CTHs.
    MODIS CTH too low on 2 occasions (due to use of 11µm BT)
    MISR in agreement on one occasion, close to CBH on the other.
  - Multi-layer clouds: MERIS and MISR at top of lowest layer, MODIS in good agreement with radar

- Mid-level clouds:
  - Single clouds:
    MERIS in agreement with radar in one case, below cloud base in the other as low optical depth
    MISR in agreement with radar in one case, below base in the other
    MODIS slightly too high but within 1.5km
  - Multi-layer clouds: MERIS below base of highest cloud (broken cloud situation)
Conclusions (2)

- High clouds:
  - Single clouds: MERIS below base of cloud, maybe optical depth too low
  - Multi-layer clouds:
    MERIS at top of lowest layer for both cases, one of them shows small optical depth
    MISR at top of lowest layer layer on one occasion, and on the other overpass later than MERIS so one single layer, but no wind correction so MISR too low
    MODIS indicates CTH high but 0.9 and 1.2km too low

- MERIS CTH very accurate for opaque clouds, all cases when disagreement with radar: optical depth $\leq 5$

- MODIS CTH too low for low clouds, slightly too high for mid-level clouds, and too low for high clouds

- MISR CTH in good agreement for all levels if single cloud. Some problems noticed with lack of wind correction