Multiangle cloud remote sensing from POLDER3/PARASOL

Cloud detection and altitude information


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Instrumental Background

- CNES/LOA instrument, Parasol launched Dec. 2004
  • ~ 705 km polar orbits, ascending (13:30 a.m.)

Data available from March 2005 to Jan 2010 within A-TRAIN and more

- Sensor Characteristics
  • 10 spectral bands ranging from 0.443 to 1.020 µm
  • 3 polarised channels
  • Wide FOV CCD Camera with 1800 km swath width
  • +/- 43 degrees cross track
  • +/- 51 degrees along track
  • Multidirectionnal observations (up to 16 directions)
  • Spatial resolution: 6x7 km
  • No onboard calibration system - Inflight vicarious calibration:
    - 2-3% absolute calibration accuracy
    - 1% interband – 0.1% interpixel over clouds
ERB, WV and Clouds Level 2 processing scheme

Level 1 georeferenced data – Int. Sinusoidal grid 6km x 6km

- Gazeous absorption correction
- Apparent pressure determination

Cloud detection

Clear sky only

- Water vapor content
- Cloud Optical Thickness and spectral albedo
- SW albedo integration

Cloud phase

Ice only

- Microphysical index from polarisation
- Rayleigh and Oxygen cloud pressure

Level 2 gridded product

Int. Sinusoidal 20km x 20km
Multiangle measurements and Cloud detection

**POLDER L1**
- Test “apparent pressure”
- Test “low polarisation at 865nm”
  - Potential sunglint ?
    - yes
    - no
  - Test “high reflectance”
  - Test “polarisation at 443nm”
  - Test “polarisation at 865nm”
  - Test “low reflectance”
  - Test “spectral variability”
- Test “high reflectance and pressure”

All tests are performed (outside sun glint)

Cloud detection uses surface BRDF maps (15 days composite) from the POLDER land surface processing output and ancillary data from ECMWF.

Cloud fraction is computed for 3x3 pixels boxes from results obtained over directions and individual L1 pixels. QA index is computed from proportion of tests giving opposite information and number of tests actually used.

Specific to snow/ice surface (snow index from ECMWF)
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GEWEX – Berlin, June 2010

Multiangle measurements and Cloud detection

Cloud fraction at 20x20 km resolution
Multiangle measurements and Cloud detection

Cloud Cover Quality Index

September 24, 2005

Cloud fraction quality index at 20x20 km resolution
Dash line: Dataset used in this study
Solid line: Official level 3 dataset

MODIS CFD:
« official »
MOD35

MODIS CFC:
« opt. Properties »
MOD06

POLDER:
Bars: min/max before multiangle reclassification

Zeng et al, 2010 (submitted)
MODIS cloud fraction for total swath 2% higher than if limited to POLDER swath

Figure 2. Latitudinal variations of CFC cloud fraction from wide swath (MODIS swath), narrow swath (POLDER swath) and edge of the large swath (POLDER swath subtracted from MODIS swath), and the differences of cloud fraction between MODIS and POLDER swath.

Zeng et al, 2010 (submitted)
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(a) Ocean

(b) Land

(c) Snow over land

(d) Ocean

(e) Land

(f) Snow over land

Mean dif.: 10.2 (%)  
RMS dif.: 24.4 (%)

Mean dif.: 10.4 (%)  
RMS dif.: 25.5 (%)

Mean dif.: -11.9 (%)  
RMS dif.: 36.8 (%)
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Zeng et al, 2010 (submitted)
Sensitivity to thin cirrus

Frequency of « missed cirrus » for POLDER and MODIS (MOD35) as a function of CALIOP optical thickness.
Cloud altitude information

[1] Cloud top Rayleigh pressure

[2] Oxygen A-Band apparent pressure (reported in GEWEX netcdf)

!! Official product reports CP for cloud albedo > 0.3 !!
Basis for the Rayleigh scattering technique:

Single scattering by molecules highly polarizes the signal in the side scattering direction where clouds introduce very little polarization.

Differences between polarized reflectance in the blue (490nm) and the red (865nm) can be related to the Rayleigh optical thickness above the cloud, from which we can infer an apparent cloud top pressure.

Approximation is good as long as:
- cloud is spectrally neutral in polarized reflectance
- cloud is thick enough to block contribution from Rayleigh scattering below it
Multiangle multispectral measurements

Polarised reflectances at 490 nm and 865 nm are used to infer cloud top pressure via determination of rayleigh optical thickness above cloud.
Altitude from Rayleigh pressure Vs Caliop altitude

OLD VERSION: Way too much middle clouds
Altitude from Rayleigh pressure Vs Caliop altitude

NEW VERSION:
Higher high clouds
Lower low clouds

Pray modif (Classe 1)
Maximal distance to Caliop shoot is less than 7.5km

Number of coincidences: 65500

Curve number: 01
Standard deviation: 1.98469
Correlation: 0.838061

\[ a = 0.653644 \quad b = 1.12366 \]
Basis for O2 A-band technique:

Ratio of the reflectance in 2 two channels (an absorbing and a non-absorbing) is approximately equal to the ratio of O2 transmission (two ways) for the two channels. O2 transmission (a measure of the mean photon path length) can then be related to a pressure level (Vanbauce et al).

Pressure level would correspond to target top only for purely reflective bright target such as bright surfaces, sun glint but NOT clouds.

Approximation is good as long as:
- photon penetration is small (almost never the case)
- target reflectance is much larger than atmospheric reflectance
Multiangle multispectral measurements

Differential absorption is used to infer cloud apparent pressure - 763 nm and 765 nm
Directional product – Retrieval is performed in up to 16 directions
Difference between O2 apparent pressure and mid-cloud pressure derived from Combined Cloudsat/Calipso GEOPROF product (hPa).

(a) Before correction

(b) Before correction

Ferlay et al., 2010 (submitted)

Liquid clouds – single layers – uncorrected pressure
Difference between O2 apparent pressure and mid-cloud pressure derived from Combined Cloudsat/Calipso GEOPROF product (hPa).

(c) After the COT-based correction

(d) After the COT-based correction

Ferlay et al, 2010 (submitted)

Liquid clouds – single layers – corrected pressure
Difference between O2 apparent pressure and mid-cloud pressure derived from Combined Cloudsat/Calipso GEOPROF product (hPa).

(a) Before correction

Ice clouds – single layers – uncorrected pressure
Ice clouds – single layers – corrected pressure
Use O2 as midlevel and Pray as top level and estimate a vertical extent of cloud layers.
Cloud top altitude in presence of aerosols

Waquet et al., 2009 (JAS)
Cloud top altitude in polar regions

Tietze et al., 2009 (presented at IAMAS)
Summary (1/2)

Cloud detection skills of POLDER algorithm are limited for
- thin (high) clouds due to limited spectral range (no IR channels)
- small broken clouds due to relatively coarse resolution
- Clouds over snow/ice except liquid clouds when rainbow can be observed.

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- Multiangle measurements allow easier cloud/clear sky discrimination under sun glint condition.
- Quality index (confidence) of cloud detection is provided by the multiple viewing geometries
- Polarisation is very useful for aerosol/cloud discrimination
Summary (2/2)

• O2 A-Band apparent pressure derived from POLDER observation DOES NOT correspond to cloud top
• Rayleigh derived pressure from polarization is much closer to cloud top but can be biased by presence of aerosols above clouds.
• Combination of O2 A-Band and Rayleigh pressure carries information on cloud vertical extent → we're getting there.
• O2 performs well for lower clouds where the MODIS CO2 is not sensitive and the IR can be biased by temperature inversion.