An Overview of MISR Cloud-Top-Heights and Optical Depth Histograms

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Multiangle Imaging SpectroRadiometer (MISR) attributes

Polar Orbit with 400-km swath

Contiguous zonal coverage:
9 days at equator
2 days at poles

275 m sampling

7 minutes to observe each scene at all 9 angles

9 CCD pushbroom cameras

9 view angles at Earth surface:
70.5°, 60.0°, 45.6°, 26.1° forward of nadir
26.1°, 45.6°, 60.0°, 70.5° backward of nadir

4 spectral bands at each angle
446, 558, 672, 866 nm

14-bit digitization
On-board calibration system
Stereo-imaging

- MISR CTH retrieval is purely geometric and has little sensitivity to the sensor calibration.

- The retrieval has been the focus of several studies including: Hillman et al. (2017), Marchand et al. (2007), Naud et al. (2002, 2004, and 2005a,b), Seiz et al. (2005), Marchand et al. (2001).
Cloud-Top-Height Distribution

Hillman et al. 2017
Tropical Western Pacific –
Comparison of MMF (4km), ISSCP and MISR
Marchand et al. 2009
Trends ?
Extratropical Ocean Basins

North Atlantic

North Pacific

South Atlantic

South Pacific

Joint Histogram

Cloud Top Height (MISR) or Pressure MODIS

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

0.005 0.01 0.015 0.02 0.025 0.03
Trends in MISR Joint-Histograms

Marchand 2013, but for period 2001 to 2013
How are these cloud trends related to a changes in large-scale/synoptic activity?

1) Maximum Covariance Analysis
   Geiss and Marchand, submitted

2) Neural Network Classification
Now compute covariance: \( C = M^T E \)

... and perform SVD: \( C = U \Sigma V^T \)

... so \( U \) contains MISR joint histogram patterns

... and \( V \) contains ERA profiles

... and \( \Sigma \) is a diagonal matrix of the eigenvalues.
MCA Results: North Pacific (Mode 1)
NP1 and Pacific Decadal Oscillation (PDO)
MCA Results: North Pacific (Mode 2)
NP2 and Pacific North America (PNA) Pattern
MCA Results: South Pacific (Mode 1)

MISR Mode 1 (Unitless) %Cov: 29 %Var: 10

ERA Mode 1 (Unitless) %Cov: 29 %Var: 28

Div: 1.01e-06 s⁻¹ Decade⁻¹
q: 3.03e-04 kg kg⁻¹ Decade⁻¹
T: 1.38e+00 C Decade⁻¹
P: 3.32e+00 hPa Decade⁻¹

MISR Δ CF % decade⁻¹

Δ SST: 1.02e-01 C Decade⁻¹
SP1 and El-Nino Southern Oscillation (ENSO)
MCA Results: South Pacific (Mode 2)

MISR Mode 2 (Unitless) %Cov: 25 %Var: 10

ERA Mode 2 (Unitless) %Cov: 25 %Var: 30

\[ \text{Div: } 1.01 \times 10^{-6} \text{ s}^{-1} \text{ Decade}^{-1} \]
\[ q: 3.03 \times 10^{-4} \text{ kg kg}^{-1} \text{ Decade}^{-1} \]
\[ T: 1.36 \times 10^{-2} \text{ C Decade}^{-1} \]
\[ \zeta: 7.54 \times 10^{-6} \text{ s}^{-1} \text{ Decade}^{-1} \]
\[ \omega: 1.78 \times 10^{-2} \text{ Pa s}^{-1} \text{ Decade}^{-1} \]
\[ P: 3.32 \times 10^{-2} \text{ hPa Decade}^{-1} \]

\( \Delta \text{ SST: } 9.82 \times 10^{-2} \text{ C Decade}^{-1} \)
SP2 and **Southern Annular Mode (SAM)**
Key points

• Following the path forged by ISCCP ... a MISR CTH-OD joint histogram dataset & instrument simulator exists and provide a complimentary view of clouds

• MISR CTH is based on a Stereo-Imaging technique:
  • ISCCP CTH (CTP) -> tells us about cloud impact on LW emission.
  • MISR CTH -> tells us where most of the visible photons are being scattered by clouds back toward space.

• MISR CTH -> insensitive to calibration -> good for trends

• Trends exists in the MISR CTH-OD data (not “boring”)
  • North Pacific -> Trends associated with PDO/PNA
  • South Pacific -> Trends associated with ENSO/SAM
  • Mode 1 or 2 in each basin -> shows increasing pressure & anticyclonic motion -> increase in low cloud, less thick OD cloud

Do models show similar relationships ??? ... stay tuned!
Objective is to divide the wide range of large-scale weather patterns into a finite set of types with distinct cloud occurrence profiles.
Example, state # 11 of 13
State # 11
Composite 2001 to 2006
State # 11
Composite 2007 to 2012
State # 11
Antarctica Oscillation (AAO) / Southern Annular Mode (SAM)

Leading EOF (27%) shown as regression map of 700mb height (m)

SLP–based Southern Annular Mode (plotted as correlation)
NCEP – NCAR reanalysis, 1979–2010

Todd Mitchell, JISAO
Is total change in cloud fraction due to change in the distribution of states over time?

\[
\Delta CF_{\text{total}} \approx \sum_{i=1}^{\text{states}} (\Delta CF_i) \cdot RFO_i + \sum_{i=1}^{\text{states}} (CF_i - CF_{\text{total}}) \cdot \Delta RFO_i + \sum_{i=1}^{\text{states}} \Delta CF_i \cdot \Delta RFO_i
\]

- Within State
- Distribution of States
- Cross Term
Comparison of terms for each atmospheric state

OD > 23.0, All Heights

- Within State Change in CF: -105.89%
- Change in State Occurrence: 9.69%
- Cross-term: -3.81%
Comparison of terms for each atmospheric state
Figure 4. Normalized, de-seasonalized TOA BRF time series plots, for the four spectral bands of the MISR Aa camera. Data are normalized such that the mean value is unity. These data present all of the data for the three desert sites used (Libya-1, Libya-4, and Egypt-1), excluding outliers, processed through Step 4b of Section 3.

Limbacher and Kahn 2016
Tropical Western Pacific, 2001

Comparison of MMF (4km) ISSCP and MISR

Marchand et al. 2009
Comparison of MMF Simulations with differing CRM grid-spacing

South American Stratocumulus

Marchand et al. 2007
More multi-layer cloud in southern hemisphere beyond $50^\circ$ S

So some of the ISCCP “mid-level” here is not real ... which is not say there isn’t ALSO more mid-level cloud in SH than NH.
Trends in MODIS (AQUA) Joint-Histograms

North Atlantic
North Pacific
South Atlantic
South Pacific

Cloud Top Pressure (hPa)

TOA

1100 1200 1300 1400 1500

τ: .3 1.3 3.6 9.4 23 60 100 150

MODIS Aqua CF Trends (% decade⁻¹)
Correlations with “known” modes of climatic variability

<table>
<thead>
<tr>
<th>Time Correlation between CPC Indices and MCA Modes</th>
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<tbody>
<tr>
<td>North Pacific Index</td>
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<tr>
<td>Pacific/North American</td>
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<tr>
<td>Nino Region 3.4 Anomaly</td>
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<td>Nino Region 4 Anomaly</td>
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<tr>
<td>Pacific Decadal Oscillation</td>
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<tr>
<td>Southern Annular Mode</td>
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<td>East Atlantic/West Russia</td>
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<tr>
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<tr>
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<td>Nino Region 1+2 Anomaly</td>
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<td>West Pacific</td>
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<table>
<thead>
<tr>
<th>CPC Index Trends (σ 10yr⁻¹)</th>
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<tbody>
<tr>
<td>(0.31)</td>
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<td>(0.33)</td>
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<td>(-0.22)</td>
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State # 2
State # 11
Pacific/ North American Pattern

January

April

July

October

Map showing variations in the Pacific/ North American Pattern across different months.