Cloud regimes from joint histograms of passive retrievals and their potential applications

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“Weather states” (Rossow et al. 2005), often referred to as cloud regimes

- Patterns of cloud property joint distributions at mesoscale (cloud type mixtures or cloud regimes) that may indicate distinct states of the tropical atmosphere.
- These patterns can be used as the basis for multi-scale, multi-variate compositing of other observations to understand how different cloud regimes affect the atmospheric diabatic heating.
- Distinct values of the diabatic heating of the atmosphere by radiation, precipitation and surface fluxes can be associated with these regimes.
Application 1: CRE attribution to cloud regimes

Net TOA CRE from CERES

(Courtesy of Norman Loeb)
Application 1: CRE attribution to cloud regimes

\[ CRE = CF \left[ F_{clr} - F_{ovc} (p_c, \tau_c) \right] \]

• What are their CREs (LW/SW, TOA/SFC) when they occur?

• Which are the most/least important radiatively (max/min % contributors to total CRE)?

• Are the WS well-separated (distinct) radiatively?

• CRE comes from ISCCP FD dataset

• Evaluation tool for assessing GCM CRE realism

• Oreopoulos and Rossow (JGR, 2011)
ISCCP extended tropics weather states
TOA CRE, extended tropics (8 WS)

annual TOA CRE, extended tropics:

SW CRE (Wm\(^{-2}\))

LW CRE (Wm\(^{-2}\))

annual TOA CRE contribution, extended tropics

SW CRE contribution (%)

LW CRE contribution (%)

WS1  CF-1st, RFO-7th
WS3  CF-4th, RFO-2nd
WS4  CF-6th, RFO-4th
WS8  CF-8th, RFO-1st

highest RFO
lowest RFO
SFC vs TOA SW CRE, extended tropics

\[
\text{CRE}_{\text{SFC}} = 3.5238 - 1.086 \times \text{CRE}_{\text{TOA}}
\]

\[R = 0.99783\]

predictably linear and not very interesting!
SFC vs TOA LW CRE, extended tropics

![Image of scatter plot showing annual CRE in the extended tropics with LW CRE at SFC and TOA, and regions labeled as SFC > TOA, TOA > SFC, ATM heat, and ATM cool.]

- **WS2** and **WS5** heat and cool regions are depicted in the bottom left and right sections of the diagram, respectively.
Atmospheric LW CRE from CERES

Atmospheric LW CRE $= -0.8 \text{ W m}^{-2}$

(Courtesy of Norman Loeb)
Application 2: Attribution of tropical precipitation to cloud regimes

Lee et al. (2012)
ISCCP extended tropics weather states
WS1 dwarfs the precipitation of the other cloud regimes
Precipitation rates are greater when in temporal proximity to WS1
Lessons and future applications

• Cloud radiative effects and precipitation can be partitioned by cloud regimes; this can in principle be done globally.

• The ISCCP cloud regimes are indeed radiatively distinct in terms of CRE and hydrologically distinct in terms of precipitation.

• The radiative or hydrological importance of a cloud regime depends not only on instaneous strength but also on frequency of occurrence.

• With ISCCP cloud simulator similar analysis for GCMs possible, potentially a great validation tool.

• Extending cloud regime analysis to MODIS-Aqua offers many A-Train compositing opportunities (e.g., AIRS, CALIPSO, CLOUDSAT, CERES).
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MODIS ET WS (1x1)
MODIS 3°x3°
MODIS-Aqua (3°x3°)

ISCCP, courtesy of W. B. Rossow

Occurrences in % of 12’th sum
Additional slides
annual average, extended tropics

cloud fraction when present

weather state

annual average, midlatitude north

annual average, midlatitude south

weather state
The problem (2)

- Here the discussion is in terms of “cloud regimes” or “cloud mixtures” or “weather states” (see Rossow et al., GRL, 2005; Oreopoulos and Rossow 2011)
- WS are the cluster centroids of Cloud Top Pressure – Cloud Optical Thickness histograms according to ISCCP (can be defined differently for other observations)
TOA CRE, midlatitude north (9 WS)

lowest CF

WS1 CF-1st, RFO-5th

WS5 CF-7th, RFO-7th

WS6 CF-9th, RFO-1st

WS3 CF-2nd, RFO-3rd
TOA CRE, midlatitude south (8 WS)
SFC vs TOA LW CRE, midlatitude north

![Graph showing SFC vs TOA LW CRE, midlatitude north. The graph includes data points andlegend indicating SFC > TOA and TOA > SFC regions.](image)

Legend:
- ATM cool
- ATM heat
- SFC > TOA
- TOA > SFC

Data regions:
- WS2
- WS4
- WS9

Note: The graph legend and data points represent annual CRE, midlatitude north.
The problem (1)

- Breakdown of Cloud Radiative Effect (aka Cloud Radiative Forcing) by cloud type
- Many ways to define cloud type

Chen et al. 2000

Hartmann et al. 1992