



# **EUCLIPSE**

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EUCLIPSE Deliverable 1.5  
Final versions of model evaluation packages

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In order to improve models it is necessary to assess where they fail. Climate models are routinely subjected to a variety of tests to assess their capabilities. A large number of approaches to make such assessments exist.

A traditional approach of evaluation of clouds in GCMs has been based on comparing climatological maps and often zonal averages of mean cloud properties (typically Cloud Radiative Forcing, total cloud amount or precipitation) simulated by the GCM with observational data [Cess et al. 1990, 1996, Yu et al. 1996, Gates et al. 1999, Weare 2004, Pincus et al. 2008, Gleckler et al. 2008].

Although such comparisons are useful for identifying gross errors in GCMs, averaging over time can obscure the presence of compensating errors. An agreement of such metrics between simulated and observed cloud variables does not mean that the model produces correct clouds properties and might occur due to cancellation of a host of errors in the spatial or temporal frequency and or due to compensating errors in mean cloud properties of different cloud types. Moreover this first order evaluation does not give access to cloud processes.

Apart from the mean state, the time variability of cloud properties simulated by GCMs is also evaluated (in inter annual or seasonal time scale). Tsushima and Manabe [2001] examine the annual variation of the global mean surface temperature using radiative flux data from ERBE and comparing them to the outputs of three GCMs. Clement et al. [2009] evaluate the long-term cloud variability in inter annual time scales. Seasonal sensitivities of clouds in 10 GCMs are evaluated in Zhang et al. [2005]. Slingo et al. [2004] evaluate the representation of the diurnal cycle in the Hadley Center climate model. Del Genio et al. [1996] evaluate the simulated diurnal, seasonal, and interannual variability of cloud properties.

Other studies compare mean cloud properties in selected geographical regions of particular interest (eg. mid-latitude north Pacific, Californian stratocumulus region, Hawaii trade-cumulus region, tropical warm pool region, and Pacific ocean transect) that show different cloud regimes [Webb et al. 2001, Lin and Zhang 2004, Teixeira et al. 2011].

The use of active sensors (CloudSat, CALIPSO) make it possible to evaluate the three-dimensional structure of clouds. Chepfer et al. [2008] use the lidar CALIPSO and the CALIPSO simulator to evaluate the vertical structure of clouds in a GCM. The radar CloudSat observations and the radar simulator are used in Haynes et al. [2007] to compare observed and simulated radar reflectivity profiles, while joint height-radar reflectivity histograms are examined in regions of particular cloud regimes in Bodas-Salcedo et al. [2008] and Marchand et al. [2009].

To learn something about the sources of errors and uncertainty in models, a process-oriented evaluation is needed [Eyring et al. 2011]. Several more advanced methods have been developed that provide a more detailed analysis of clouds in GCMs and aim to evaluate model cloud, radiation, and precipitation properties in a process-oriented manner and make a direct connection between cloudiness and the processes that produce it.

The evaluation of the relationship between cloud properties or between cloud properties and atmospheric conditions carried out in some studies, increases our confidence in the ability of models to simulate cloud variations under environmental changes and cloud feedbacks. The variation of cloud variables is highly nonlinear and is supposed to be mimic to models physical parameterisation. The evaluation of the relationship between cloud properties at time and space scales close to cloud-related processes (significantly different to the yearly, seasonal and monthly ones used in most studies), facilitates the link between observations and model parameterisations. Rossow and Schiffer [1991] use ISCCP observations to make the link between cloud top pressure and cloud optical thickness for different cloud types. Webb et al. [2001] use ISCCP and CERES data to evaluate the relation between the daily mean cloud amount and albedo in three GCMs. 2-D histograms of daily mean cloud fraction and cloud albedo simulated with CanAM4 are evaluated in Cole et al. [2011]. Konsta et al. [2011] use 2-D histograms of daily mean cloud reflectance PARASOL and cloud fraction CALIPSO to evaluate LMDZ using CALIPSO and PARASOL simulator. Klein and Hartmann [1993] made the correlation between the stratiform low cloud cover with the Sea Surface Temperature (SST) and with the lower tropospheric Stability (LTS) that has been used in the parameterization of low cloud cover in GCMs. Wood and Hartmann [2006] define a more refined measure of inversion strength and show the relationship between their estimated inversion strength (EIS) and stratus cloud amount. Bennhold and Sherwood [2008] evaluate the relationship between static stability and upper tropospheric humidity in three GCMs. The observed relationships among SST, clouds and cloud radiative forcing are investigated in Bony et al. [1997]. The observed relationship between cloud optical thickness and cloud temperature [Tselioudis and Rossow, 1994] is used in Tselioudis et al. [1998] to evaluate a GCM.

Cloud properties are strongly dependent on the variability of dynamic and thermodynamic atmospheric conditions, thus it is crucial for models to be able to capture such dependencies. The process-based evaluation of models requires the application of methodologies that stratify model and observational outputs into regimes that have physical meaning. The main idea is to break up the complex cloud, radiation, and precipitation fields into clusters where a certain combination of atmospheric processes dominates the cloud and rain formation process. In that way model deficiencies in a particular meteorological regime that are detected can be attributed to the specific process or processes that are dominant in the deficient cloud system, this evaluates the results of GCM parameterizations and provides more insight into sources of error. The methods include compositing and clustering.

In compositing techniques, one or more atmospheric properties are used to define atmospheric states on which cloud, radiation, and precipitation properties are composited into different dynamic and/or thermodynamic regimes. Peterson et al. [1992] associated monthly or seasonal cloud anomalies to sea surface temperature anomalies on observations and on outputs of a GCM. Tselioudis et al. [2000] use the sea level pressure anomaly to separate

cloud types in low, near-normal and high pressure regimes in the northern midlatitudes and compare histograms of cloud optical thickness and cloud top pressure observed and simulated for the different cloud regimes. The large-scale midtropospheric vertical velocity at 500hPa pressure is used to define dynamical regimes and composite and compare the simulated and observed cloudiness for the whole range of midlatitude dynamic regimes [Tselioudis and Jakob 2002] and over the summertime midlatitude North Pacific Norris and Weaver [2001]. Bony et al. [2004] sorts the tropics into dynamical regimes based on the monthly mean pressure velocity at 500hPa ( $\omega_{500}$ ) used as a good measure of the large scale dynamics. This methodology is also applied by Bony and Dufresne [2005] who evaluate the radiative response of tropical clouds simulated by 15 coupled models, by Wyant et al. [2005] that evaluate several cloud properties (clouds vertical distribution, relative humidity, cloud water path, cloud optical thickness) of three GCMs and by Konsta et al. [2011] that use CALIPSO cloud cover and vertical structure to evaluate LMDZ cloudiness. Williams et al. [2003] and Ringer and Allan [2004] sort with respect to both  $\omega_{500}$  and SST in order to analyze tropical cloudiness, allowing clearer separation of cloud regimes and Williams et al. [2006] composite changes in cloud properties by the change in  $\omega_{500}$  and saturated lower tropospheric stability.

Clustering techniques where properties of the cloud field are used to define distinct groupings of cloud types that form distinct cloud systems corresponding to particular regimes. Jakob and Tselioudis [2003] applied a statistical clustering technique to ISCCP data over the tropical warm pool to joint cloud optical depth ( $\tau$ )-cloud top pressure (CTP) histograms of cloud amount and identify dominant modes of cloud variability. Gordon et al. [2005] use a similar clustering approach but just use the ISCCP grid-box-mean cloud albedo ( $\alpha$ ), CTP and total cloud cover (TCC) to determine typical cloud regimes associated with extratropical cyclones. Williams and Tselioudis [2007] and Chen and Del Genio [2008] apply the clustering of the full  $\tau$ -CTP histograms of cloud amount to comparable ISCCP simulator data from GCMs. Williams and Webb [2008] apply an alternative clustering method for assigning model data to observed cloud regimes removing some of the subjectivity involved in obtaining and comparing the regimes. Zhang et al. [2010] use the cluster analysis method on combined data from CloudSat and CALIPSO to evaluate cloud statistics of a climate model.

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## Table of Evaluation Techniques

	<b>Technique</b>	<b>Diagnostic</b>	<b>Variables</b>	<b>Observ. used</b>	<b>Bibliography</b>
1 <sup>st</sup> order evaluation	Mean Cloud properties	Maps, Global Means, Zonal Means	Cloud Radiative Properties, Total Cloud Fraction, Low-Mid-High level Cloud Fraction	ISCCP, ERBE, CERES	Cess et al. 1990, 1996, Yu et al. 1996, Gates et al. 1999, Weare 2004, Pincus et al. 2008, Gleckler et al. 2008
	Spatial and temporal variability of cloud properties	Temporal (interannual seasonal and diurnal) variability, Regional distribution of cloud properties, Cloud Vertical Distribution (Zonal Mean 3D Cloud Fraction, Joint height-radar reflectivity/lidar scattering ratio histograms)	Cloud Radiative Properties, Total Cloud Fraction, 3D Cloud Fraction, Radar Reflectivity, Lidar Scattering Ratio	ERBE, CERES, ISCCP, Meteosat, CALIPSO, CloudSat	Tsushima and Manabe 2001, Clement et al. 2009, Zang et al. 2005, Slingo et al. 2004, Del Genio et al. 1996, Webb et al. 2001, Lin and Zhang 2004, Teixeira et al. 2011, Chepfer et al. 2008, Haynes et al. 2007, Bodas-Salcedo et al. 2008, Marchand et al. 2009
Process-oriented techniques	Correlation techniques	Relationship between cloud properties (i.e. cloud optical thickness versus cloud top pressure, cloud cover versus albedo/OLR/cloud optical thickness), Relationship between cloud properties and atmospheric states (low cloud cover versus lower tropospheric stability/sea surface temperature, low cloud optical thickness versus temperature)	Cloud Radiative properties, Cloud Fraction, Cloud Vertical Distribution	ISCCP, ERBE, CERES, HIRS, PARASOL, CALIPSO	Rossow and Schiffer 1991, Webb et al. 2001, Cole et al. 2011, Konsta et al. 2011, Klein and Hartmann 1993, Wood and Bretherton 2006, Florian and Sherwood 2008, Tselioudis et al. 1998

Compositing	Cloud Properties composited by regimes of Sea Level Pressure Anomaly, Mid-Tropospheric Vertical Velocity, Sea Surface Temperature, Saturated Lower Tropospheric Stability	Total Cloud Fraction, Low-Mid-High level Cloud Fraction, Optical Thickness, Cloud Top Height, Cloud Radiative Properties (albedo, OLR LW-SW-Net Cloud Radiative Forcing), SLPA, $\omega_{500}$ , SST, $\theta'_{es}$	ISCCP, ERBE, CERES, PARASOL, CALIPSO	Peterson et al. 1992, Tselioudis et al. 2000, Tselioudis and Jakob 2002, Norris and Weaver 2001, Bony et al. 2004, Bony and Dufresne 2005, Wyant et al. 2005, Konsta et al. 2011, Williams et al. 2003, Ringer and Allan 2004, Williams et al. 2006
Clustering	Clustering histograms of cloud amount in joint cloud optical depth – cloud top pressure classes, joint histograms of atmospheric pressure and signal strength	Cloud Fraction, Cloud optical thickness, Cloud Top Height	ISCCP, ERBE, MODIS, CloudSat, CALIPSO	Jakob and Tselioudis 2003, Gordon et al. 2005, Williams and Tselioudis 2007, Chen and Del Genio 2008, Williams and Webb 2008, Zhang et al. 2010

## **Evaluation Toolkit**

### **Simulator package**

- The CFMIP Observation Simulator Package - COSP (including CALIPSO, CloudSat, ISCCP, MISR, RTTOV, TRMM, MODIS, PARASOL simulators)  
<http://cfmip.metoffice.com/COSP.html>

### **Correlation between cloud properties**

- 2D histogram of instantaneous cloud reflectance (PARASOL) and cloud fraction (CALIPSO):  
[ftp://ftp.climserv.ipsl.polytechnique.fr/cfmip/goccp/MULTI-SENSORS/CRef/ref\\_cf.m](ftp://ftp.climserv.ipsl.polytechnique.fr/cfmip/goccp/MULTI-SENSORS/CRef/ref_cf.m)
- Relationship between instantaneous cloud reflectance (PARASOL) and vertical profile of cloud fraction (CALIPSO):  
[ftp://ftp.climserv.ipsl.polytechnique.fr/cfmip/goccp/MULTI-SENSORS/CRef/cf3d\\_ref.m](ftp://ftp.climserv.ipsl.polytechnique.fr/cfmip/goccp/MULTI-SENSORS/CRef/cf3d_ref.m)
- Joint height-SR histogram of Scattering Ratio (CALIPSO):  
[ftp://ftp.climserv.ipsl.polytechnique.fr/cfmip/goccp/SR\\_histo/SR\\_histo.m](ftp://ftp.climserv.ipsl.polytechnique.fr/cfmip/goccp/SR_histo/SR_histo.m)

### **Clustering methods**

- Mean Cloud Top Pressure (CTP) - Cloud Optical Depth ( $\tau$ ) clusters (ISCCP):  
<http://isccp.giss.nasa.gov/climanal5.html>
- Cloud Regime Error Metric describing the ability of models to simulate the correct radiative properties and frequency of occurrence of large-scale cloud regimes:  
<http://cfmip.metoffice.com/codes.html>

### **Compositing methods**

- Climatology of Midlatitude Storminess, allowing to composite cloud properties in the area of influence of midlatitude storms  
<http://gcss-dime.giss.nasa.gov/mcms/mcms.html>
- Tropical El Niño Southern Oscillation Anomaly Database  
<http://gcss-dime.giss.nasa.gov/ARRA/arra.html>