EUCLIPSE

EU Cloud Intercomparison, Process Study & Evaluation Project

Grant agreement no. 244067

UPDATE - Deliverable D1.5 – Final versions of model evaluation packages

Delivery date: 18 months

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 cloud properties, and might occur due to cancellation of a host of errors in the spatial or temporal frequency or due to compensating errors in mean cloud properties of different cloud types. Moreover this first order evaluation does not provide information on the operation of cloud processes in the models.

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 global mean surface temperature in relation to radiative flux data from ERBE and compare the results 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 include 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 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 parametrisations. Rossow and Schiffer [1991] use ISCCP observations to map the variation of 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 parametrization 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 cloud behaviour in the GISS 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 parametrizations and provides more insight into sources of error. Regime separation methods that have been used recently in model cloud evaluation 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 (ω_{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 ω_{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 ω_{500} and saturated lower tropospheric stability.

Clustering techniques use properties of the cloud field to define distinct groupings of cloud types that form distinct cloud systems corresponding to particular regimes. Jakob and Tselioudis [2003] apply a statistical clustering technique to ISCCP data over the tropical warm pool to joint cloud optical depth (τ)-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 (α), 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 τ-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.

The analysis techniques discussed above are summarized in the Table provided at the end of the report, in an attempt to present in a condensed form the major techniques used in model cloud evaluation. In addition, an Evaluation Toolkit is included following the table, that provides links to sites that host model evaluation techniques and/or the relevant observational datasets. This toolkit will be continuously updated throughout the duration of EUCLIPSE as old methods will be tested and new will be derived in the data analysis phase of the project.

References

Bodas-Salcedo, A., M.J. Webb, M.E. Brooks, M.A. Ringer, K.D. William, S.F. Milton, and D.R. Wilson, 2008: Evaluating cloud systems in the Met Office global forecast model using simulated CloudSat radar reflectivities, J. Geophys. Res., 113, D00A13, doi:10.1029/2007JD009620.

Bony, S., K-M. Lau, Y. C. Sud, 1997: Sea Surface Temperature and Large-Scale Circulation Influences on Tropical Greenhouse Effect and Cloud Radiative Forcing. J. Climate, 10, 2055–2077.

Bony S. and J.-L. Dufresne, 2005: Marine boundary layer clouds at the heart of cloud feedback uncertainties in climate models. Geophys. Res. Lett. 32(20):L20806.

Bony S., J.-L. Dufresne, H. Le Treut, J.J. Morcette, C.A. Senior, 2004: On dynamic and thermodynamic components of cloud changes. Clim. Dyn. 22:71-86. doi:10.1007/s00382-003-0369-6.

Cess R. D., G. L. Potter, J,.P. Blanchet, G.J. Boer, A. D. Del Genio, M. Deque, V. Dymnikov, V. Galin, W.L. Gates, S.J. Ghan, J.T. Kiehl, A.A. Lacis, H. Le Treut, Z.-X. Li, X.-Z. Liang, B.J. McAvaney, V.P. Meleshko, J.F.B. Mitcell, J.-J. Morcette, D.A. Randall, L. Rikus, E.Roeckner, J.F. Royer, U. Schlese, D.A. Sheinin, A. Slingo, A. P. Sokolov, K. E. Taylor, W.M. Washington, R.T. Wetherald, I. Yagai, and M.-H. Zhang, 1990: Intercomparison and Interpretation of Climate Feedback Processes in 19 Atmospheric General Circulation Models. J. Geophys. Res., 95, D10, 16.601-16615.

Cess R. D., M.H. Zhang, W.J. Ingram, G.L. Potter, V. Alekseev, H.W. Barker, E. Cohen-Solal, R.A. Colman, D.A. Dazlich, A.D. Del Genio, M.R. Dix, V. Dymnikov, M. Esch, L.D. Fowler, J.R. Fraser, V. Galin, W.L. Gates, J.J. Hack, J.T. Kiehl, H.L. Treut, K.K.W. Lo, B.J. McAvaney, V.P. Meleshko, J.J. Morcette, D.A. Randall, E. Roeckner, J.F. Royer, M.E. Schlesinger, P.V. Sporyshev, B. Timbal, E.M. Volodin, K.E. Taylor, W. Wang, and R.T. Wetherald, 1996: Cloud feedback in atmospheric general circulation models: An update. J. Geophys Res., 101:12791-12794

Chen Y. and A. D. Del Genio, 2008: Evaluation of tropical cloud regimes in observations and a general circulation model. Clim. Dyn. 32:355-369. doi:10.1007/s00382-008-0386-6.

Chepfer H., S. Bony, D. Winker, M. Chiriaco, J.-L. Dufresne, and G. Seze, 2008: Use of CALIPSO lidar observations to evaluate the cloudiness simulated by a climate model. J. Geophys. Res. 35, L15704, doi:10.1029/2008GL034207.

Clement A.C., R. Burgman, and J.R. Norris, 2009: Observational and Model Evidence for Positive Low-Level Cloud Feedback. Science, 325, 460-464.

Cole J., H.W. Barker, N.G.Loeb, and K.von Salzen, 2011: Assessing simulated clouds and radiative fluxes using properties of clouds whose tops are exposed to space, J. Clim, submitted.

Del Genio A. D., M.-S. uYao, W. Kovari and K. K.-W. Lo, 1996: A prognostic cloud water parameterization for global climate models. J. Clim., 9:270-304.

Eyring V., P. Friedlingstein, R. Knutti, O. Boucher, W.J. Collins, N. De Noblet-Ducoudre, T. Fichefet, A. Hall, C. Heinze, H. Hewitt, C. Jones, W. Knorr, J.-F. Lamarque, M.G. Lawrence, I.C. Prentice, M. Scholze, M. Schulz, J. Teixeira, G. Tselioudis, M. Vancoppenolle, and P. F. J. Van Velthoven, 2011, under preparation.

Bennhold, F. and S. Sherwood, 2008: Erroneous Relationships among Humidity and Cloud Forcing Variables in Three Global Climate Models. *J. Climate*, 21, 4190–4206.

Gates, W. L., J. S. Boyle, C. Covey, C. G. Dease, C. M. Doutriaux, R. S. Drach, M. Fiorino, P. J. Gleckler, J. J. Hnilo, S. M. Marlais, T. J. Phillips, G. L. Potter, B. D. Santer, K.R. Sperber, K. E. Taylor, and D. N. Williams, 1999: An overview of the results of the Atmospheric Model Intercomparison Project (AMIP I). Bull. Amer. Meteorol. Soc., 80, 29-56.

Gleckler P.J., K.E. Taylor, and C. Doutriaux, 2008: Performance metrics for climate models. J. Geophys. Res., 113. doi:10.1029/2007JD008972.

Gordon N.D., J.R. Norris, C.P. Weaver, S.A. Klein, 2005: Cluster analysis of cloud regimes and characteristic dynamics of midlatitude synoptic systems in observations and a model. J. Geophys. Res., 110. doi:10.1029/2004JD005027.

Haynes J.M., R.T. Marchand, Z. Luo, A. Bodas-Salcedo, and G. L. Stephens, 2007: A Multipurpose Radar Simulation Package: QuickBeam, Bull. Amer. Meteorol. Soc., 88, 1723-1727.

Pincus R., C.P. Batstone, R.J. Patrick-Hofmann, K.E. Taylor, and P.E. Gleckler, 2008: Evaluating the present-day simulation of clouds, precipitation and radiation in climate models. *J. Geophys. Res.*, 113, D14209, doi:10.1029/2007JD009334.

Jakob C. and G. Tselioudis, 2003: Objective identification of cloud regimes in the Tropical Western Pacific. J.Geophys. Res. Lett., 30(21), 2092, doi:10.1029/2003GL018367.

Klein S.A. and D. L. Hartmann, 1993: The seasonal cycle of low stratiform clouds, J. Clim., 6, 1588-1606.

Konsta D., J.-L. Dufresne, H. Chepfer, A. Idelkadi, G. Cesana, 2011: Evaluation of clouds simulated by the LMDZ5 GCM using A-train satellite observations (CALIPSO-PARASOL-CERES), Clim. Dyn. under preparation

Lin W.Y. and M.H. Zhang, 2004: Evaluation of clouds and their radiative effects simulated by the NCAR community atmospheric model CAM2 against satellite observations. J. Clim. 17:3302-3318.

Marchand R., J. Haynes, G.G. Mace, T. Ackerman, and G. Stephens, 2009: A comparison of simulated cloud radar output from the multiscale modeling framework global climate model with CloudSat cloud radar observations. J. Geophys. Res., 114, D00A20, doi:10.1029/2008JD009790.

Norris J.R. and C.P. Weaver, 2001: Improved techniques for evaluating GCM cloudiness applied to the NCAR CCM3. J. Clim. 14:2540-2550.

Peterson, T., T. Barnett, E. Roeckner, and T. Vonder Haar, 1992: An analysis of the relationship between cloud anomalies and sea surface temperature anomalies in a global circulation model, J. Geophys. Res., 97(D18), 20497-20506.

Ringer M.A. and R.P. Allan, 2004: Evaluating climate model simulations of tropical cloud, Tellus, 56:308-327.

Rossow, W.B., and R.A. Schiffer, 1999: Advances in understanding clouds from ISCCP, *Bull. Amer. Meteorol. Soc.*, 80, 2261-2288.

Slingo A., K.I. Hodges and G.J. Robinson, 2004: Simulation of the diurnal cycle in a climate model and its evaluation using data from Meteosat 7, Q. J. R. Meteorol. Soc., 130, 1449-1467.

Teixeira, J., S. Cardoso, M. Bonazzola, J. Cole, A. DelGenio, C. DeMott, C. Franklin, C. Hannay, C. Jakob, Y. Jiao, J. Karlsson, H. Kitagawa, M. Köhler, A. Kuwano-Yoshida, C. LeDrian, J. Li, A. Lock, M.J. Miller, P. Marquet, J. Martins, C.R. Mechoso, E. van Meijgaard, I. Meinke, P.M.A. Miranda, D. Mironov, R. Neggers, H.L. Pan, D.A. Randall, P.J. Rasch, B. Rockel, W.B. Rossow, B. Ritter, A.P. Siebesma, P.M.M. Soares, F.J. Turk, P.A. Vaillancourt, A. Von Engeln, and M. Zhao, 2011: Tropical and sub-tropical cloud transitions in weather and climate prediction models: the GCSS/WGNE Pacific Cross-section Intercomparison (GPCI). *J. Climate*, in press, doi:10.1175/2011JCLI3672.1.

Tselioudis, G., and W.B. Rossow, 1994: Global, multiyear variations of optical thickness with temperature in low and cirrus clouds. *Geophys. Res. Lett.*, 21, 2211-2214, doi:10.1029/94GL02004.

Tselioudis G., A.D. DelGenio, W. Kovari, M.-S. Yao, 1998: Temperature Dependence of Low Cloud Optical Thickness in the GISS GCM: Contributing Mechanisms and Climate Implications. J. Climate, 11, 3268-3281.

Tselioudis G., Y. Zhang anud W.B. Rossow, 2000: Cloud and radiation variations associated with northern midlatitude low and high sea level pressure regimes. J. Clim., 13(2):312-327.

Tselioudis, G., and C. Jakob, 2002: Evaluation of midlatitude cloud properties in a weather and a climate model: Dependence on dynamic regime and spatial resolution. *J. Geophys. Res.*, 107(D24), 4781, doi:10.1029/2002JD002259

Tsushima Y. and S. Manabe, 2001: Influence of cloud feedback on annual variation of global mean surface temperature, *J. Geophys. Res.*, 106(D19), 22635-22,646.

Weare, B.C., 2004: A comparison of AMIP II model cloud layer properties with ISCCP D2 estimates, Clim. Dyn., 22: 281-292.

Webb M., C. Senior, S. Bony and J.-J. Morcette, 2001: Combining ERBE and ISCCP data to assess clouds in the Hadley Centre, ECMWF and LMD atmospheric models. Clim. Dyn., 17: 905-922.

Williams K. D., M.A. Ringer, C. A. Senior, 2003: Evaluating the cloud response to climate change and current climate variability. Clim. Dyn., 20:705-721.

Williams K. D. and M.J. Webb, 2008: A quantitative performance assessment of cloud regimes in climate models. Clim. Dyn., 33: 141-157, DOI: 10.1007/s00382-008-0443-1.

Williams K. D. and G. Tselioudis, 2007: GCM intercomparison of global cloud regimes: present-day evaluation and climate change response. Clim. Dyn., 29: 231-250, DOI: 10.1007/s00382-007-0232-2.

Williams K. D., M.A. Ringer, C.A. Senior. M.J. Webb, B.J. McAvaney, N. Andronova, S.Bony, J.-L. Dufresne, S. Emori, R. GuOhmura, T. Knutson, B. Li, K. Lo, I. Musat, J. Wegner, A. Slingo, and J.F.B. Mitchel, 2006: Evaluation of a component of the cloud response to climate change in an intercomparison of climate models. Clim. Dyn., 26: 145-165, DOI: 10.1007/s00382-005-0067-7.

Williams K.D., C.A. Senior, A. Slingo, and J.F.B. Mitchell, 2005: Towards evaluating cloud response to climate change using clustering technique identification of cloud regimes. Clim. Dyn., 24: 701-719, DOI: 10.1007/s00382-004-0512-z.

Wood R. and C.S. Bretherton, 2006: On the relationship between stratiform low cloud cover and lower -tropospheric stability. J. Climate, 19, 6425-6432.

Wyant M.C., C.S. Bretherton, J.T. Bacmeister, J.T. Kiehl, I.M. Held, M. Zhao, S.A. Klein, and B.J. Soden, 2006: A comparison of low-latitude cloud properties and their response to climate change in three AGCMs sorted into regimes using mid-tropospheric vertical velocity. Clim.Dyn., 27: 261-279, DOI: 10.1007/s00382-006-0138-4.

Yu W., M. Doutriaux, G. Seze, H. Le Treut, and M. Desbois, 1996: A methodology study of the validation of clouds in GCMs using ISCCP satellite observations. Clim. Dyn., 12: 389-401.

Zhang M.H. W.Y. Lin, S.A. Klein, J.T. Bacmeister, S. Bony, R.T. Cederwall, A.D. Del Genio, J.J. Hack, N.G. Loeb, U. Lohmann, P. Minnis, I. Musat, R. Pincus, P. Stier, M.J. Suarez, M.J. Webb, J.B. Wu, S.C., Xie, M.-S. Yao, and J.H. Zhang, 2005: Comparing clouds and their seasonal variations in 10 atmospheric general circulation models with satellite measurements. *J. Geophys. Res.*, 110, D15S02, doi:10.1029/2004JD005021.

Zhang Y., S.A. Klein, J. Boyle, and G.G. Mace, 2010: Evaluation of tropical cloud and precipitation statistics of Community Atmosphere Model version 3 using CloudSat and CALIPSO data. *J. Geophys. Res.*, 115, D12205, doi:10.1029/2009JD012006.

Table of Evaluation Techniques

	Technique	Diagnostic	Variables	Observations used	Bibliography
1st 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, Zhang 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	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

		stability/sea surface temperature, low cloud optical thickness versus temperature)			
	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, ω_{500}, SST, θ'_{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

- 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

- Joint height-SR histogram of Scattering Ratio (CALIPSO):
  ftp://ftp.climserv.ipsl.polytechnique.fr/cfmip/goccp/SR_histo/SR_histo.m

Clustering methods

- Mean Cloud Top Pressure (CTP) - Cloud Optical Depth (τ) 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 ElNino Southern Oscillation Anomaly Database
  http://gcss-dime.giss.nasa.gov/ARRA/arra.html