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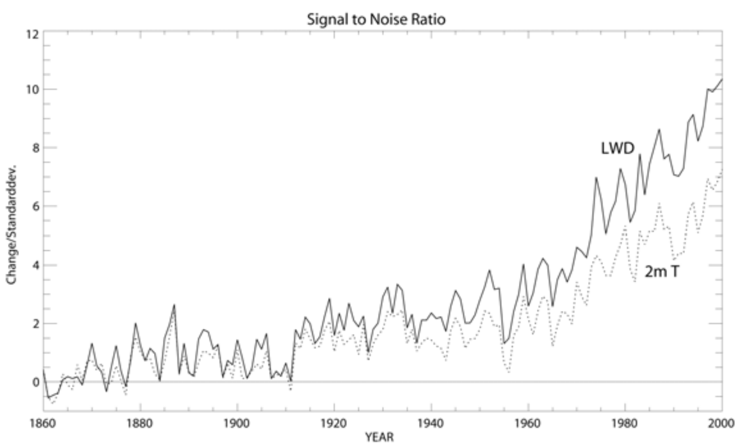
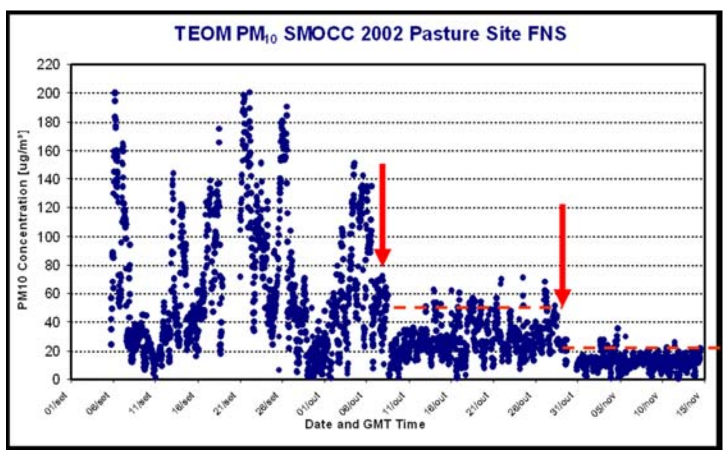
BSRN LONGWAVE DOWNWARD RADIATION MEASUREMENTS SHOW PROMISE FOR GREENHOUSE DETECTION STUDIES



THE INCREASE IN THE LWD RATIO SIGNIFICANTLY PRECEDES THE TEMPERATURE RATIO INCREASE

Ratio between the GCM-projected global annual mean change signal in a transient GCM experiment (Roeckner et al., 1999) and the interannual variability in terms of standard deviations in an unperturbed control run ("signal to noise ratio") for longwave downward radiation (solid line) and surface temperature (dashed line). See article on page 9.

LBA SHOWS IMPACT OF AEROSOLS ON ONSET OF PRECIPITATION



Evolution of the concentration of aerosol with diameter less than 10 μ (PM10) measured in central Rondônia in a pasture site during September to November 2002. The arrows indicate the first significant rainfall by October 7 and the onset of regular rainfall in the beginning of November. See article on page 4.

GCSS/ISCCP CLOUD REGIME ANALYSIS POINTS THE WAY FOR GCM MODEL IMPROVEMENT (Page 6)

CLOUD REGIMES, MODEL EVALUATION AND MODEL DEVELOPMENT

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Developing representations of clouds in models of the atmosphere is a complex process. This is particularly true for those models in which the fundamental scales of cloud system dynamics are not resolved and in which clouds, therefore, need to be represented in the form of parametrizations. All current global climate and Numerical Weather Prediction (NWP) models fall into this category.

Model development necessarily relies on, and often begins with, model evaluation, whose role it is to identify areas in which model simulations are erroneous and, ideally, to prioritize the order in which shortcomings should be addressed. Many techniques for model evaluation have been developed and applied--ranging from the evaluation of the climate of a model to very detailed case studies, such as are carried out in the GEWEX Cloud System Study (GCSS). Such case studies are often conducted with simplified versions of the climate and NWP models, usually employing single column versions of these models (SCMs). Detailed observations together with Cloud System Resolving Models (CSRMs) are frequently used in such studies to help identify potential flaws in the formulation of the parametrizations in the SCMs.

Given the current focus of GCSS on case studies, it is a valid question how those studies are linked to the errors identified in the full climate or NWP models. Unfortunately, at this point in time, this link, while being recognized as being essential, is weak. Recent research into strengthening the link between large-scale model simulations and case studies has focussed on what can be loosely termed as "regime-dependent model error analysis." The basic idea of this approach is to divide the multitude of cloud states observed in the atmosphere into recurring regimes, either by using cloud observations directly or by exploiting the very strong link between the dynamical state of the atmosphere and associated cloud systems.

The following example illustrates the potential of using regime-dependent model evaluation techniques to identify shortcomings in model parametrizations. It is based on recent studies by Jakob and Tselioudis (2003) and Jakob et al. (2004), who use data from the International Satellite Cloud Climatology Project (ISCCP; Rossow and Schiffer, 1983) to identify cloud regimes in the Tropical Western Pacific (TWP). By performing a cluster analysis on two-dimensional histograms of the statistical distribution of cloud top pressure (CTP) and cloud optical thickness (τ) in 280 km x 280 km grid-areas, these studies identify four major TWP cloud regimes:

1) Suppressed shallow cloud regime (SSC);

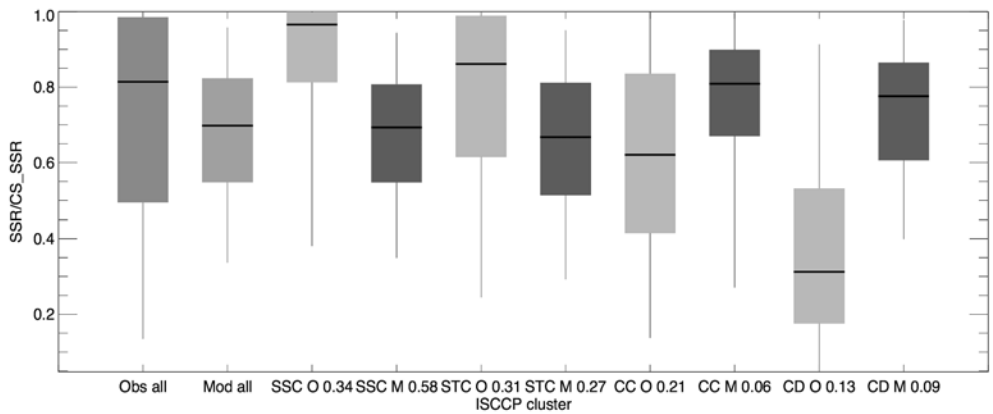
2) Suppressed regime dominated by thin cirrus clouds (STC);

3) Convectively active regime with large cirrus coverage (CC);

4) Convectively active regime dominated by a large coverage with optically thick anvil clouds (CD).

Since it is possible to assign one of the above regimes to every grid-cell of the ISCCP data set every 3 hours, other available data can be distributed by cloud regime to reveal the radiative, cloud and thermodynamic characteristics of each regime (Jakob et al., 2004). Note that current results are restricted to local daytime since satellite channels in the visible part of the spectrum are required to retrieve "τ" in the ISCCP data. It is furthermore possible to simulate the CTP-τ histograms as derived by ISCCP from cloud fields simulated in climate and NWP models, thereby enabling the evaluation of those models in terms of the observed cloud regime.

The figure on page 7 provides an example for such an evaluation using the ratio of surface solar radiation to its clear-sky value. The data used in the comparison was collected by the U. S. Department of Energy's Atmospheric Radiation Measurement Program (ARM; Ackerman and Stokes, 2003) at one of its TWP measurement sites on Manus Island (2.1°S, 147.4°E). The model results are drawn from the model grid-point nearest to Manus in short-range (6h) forecasts performed as part of the ERA-40 project (Simmons and Gibson, 2000). Three-hourly data (dictated by the availability of the cloud regime identification from ISCCP) for the years 1999-2000 has been used in the comparison. The figure displays the sample distributions of the solar radiation ratio in form of box-whisker diagrams (see the figure caption for a more detailed explanation).



Surface solar radiation normalized by clear sky values at Manus Island for the years 1999-2000. Left-most two boxes: all observations (left) and all ERA40 values (right); Right eight boxes: Observations (light) and ERA40 (dark) distributed by cloud regime (see text for details). Horizontal lines – median; boxes 25-to-75 percentiles; whiskers 5 and 95 percentile.

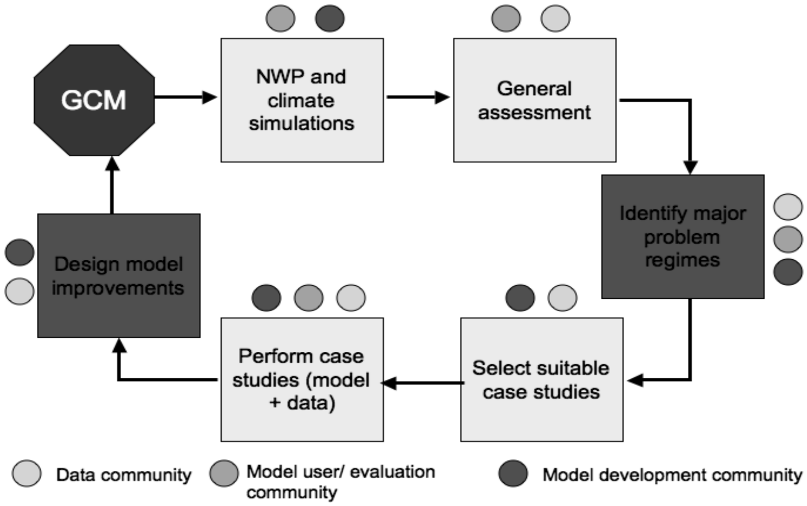
The two boxes on the far left show the distributions using all observations (left) and model values (right) in the sample, while the next eight boxes show the observations (light) and model results (dark) stratified by cloud regime. Note that the model cloud regime is identified by the minimum distance of the model CTP-τ histogram from each of the four observed cloud regime mean histograms.

Overall, the model shows a negative bias in the solar radiation reaching the surface accompanied by an underestimation of the observed variability. While certainly useful, it is very difficult for a model developer to draw conclusions for model improvement based on this result alone, since many model states (in the dynamic, thermodynamic and cloud sense) are mixed together. It is the regime-dependent analysis of model error that helps to reveal the main reasons for the overall model error. **From the figure above it is evident that the largest negative bias in solar radiation exists in the two suppressed cloud regimes (left four boxes), while in convectively active regimes (right four boxes) the model in fact exhibits a positive bias.** The influence of the negative bias in suppressed conditions on the mean bias is further enhanced by the overestimation of the frequency of occurrence of such regimes in the model, as indicated by the numbers next to the regime acronyms in the figure. The model predicts suppressed conditions 85% of the time compared to the observed 65%. It is also apparent that the lack of variability in the overall model results is mainly (but not exclusively) caused by a lack of "between-regime" variability.

A number of other interesting shortcomings can be identified from the figure above. However, the main purpose of displaying it here is to highlight the usefulness of regime-dependent model error analysis. In this case it was shown that a major model error in one of the most convectively active regions on earth is actually caused by errors at (the frequently observed) times when deep convection is suppressed. Further understanding and eventually alleviating this model error will very likely require additional tools, in particular, the use of case studies as routinely performed in GCSS. However, through the analysis performed here it is now possible to identify what kind of case study is required to address the model failure. **Hence, regime-dependent model error analysis can be seen as a crucial link between overall "model climate" assessment and detailed process case studies.**

This link is further illustrated in the figure on page 8, which attempts to conceptualise the process of model development (in particular, that of parametrizations). It is imperative to better understand this process for the community to make progress in the crucial areas of climate and NWP model development. The figure shows the basic steps involved in the process, their links and the communities involved. It is important to recognize that model development cannot solely rely on the model development community (e.g., parametrization developers) but must include the model user and data communities. These communities have to play crucial roles in analysing models, setting development priorities, providing evaluation tools and data sets, as well as physical insight into the processes that are parametrized in the climate and NWP models.

The centrepiece of the model development process is the GCM, which is used in either NWP or



Schematic of the model development process.

climate simulations. Both the NWP and climate community possess standard tools that are regularly applied in the general assessment of the model and help to reveal its overall errors. Actual model development on the other hand often relies on case studies, as indicated in the bottom row of the figure above. The two links between the case and GCM studies are the regime-dependent model error analysis advocated above and the implementation of actual parametrization improvements resulting from insight of the various model evaluation activities. The former enables the choice of "the right case study," while the latter constitutes the ultimate aim of the entire process – model improvement. Both are crucial elements in the chain of model development activities. Hence, it is important to strengthen activities in the community in both of these areas.

The above brief analysis of the model development process highlights some interesting challenges to research programs, which often tend to focus on only one aspect of the model development loop. GCSS for instance has very successfully addressed the part of the process that relates to case studies in the area of cloud and convection parametrization. From the above discussion it appears advisable to cover the entire process either within a research program or through strong collaboration between programs. Furthermore it is evident from the above figure that no single step in the model development process involves just one community. It is therefore essential for progress that strong links between the model development, model user and data community are built into any research program that aims to improve models. In GCSS it is our intention to meet these challenges by broadening future activities so that they encompass most of the activities involved in the model development process.

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CLOUDS, CLIMATE AND MODELS MEETING

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Progress in our ability to observe and model cloud systems and their impact on climate will be reviewed. Key areas for discussion will be methodologies and metrics in assessing clouds and precipitation in model simulations; the fundamental role of precipitation in cloud systems; and progress in the representation of clouds in the large-scale and cloud-system models. For more information, see the GCSS homepage: http://www.gewex.org/gcss.html.