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J. Slingo
K. Hodges
K. Sperber

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TROPICAL VARIABILITY AND THE VALIDATION OF CONVECTIVE PARAMETRIZATIONS

Julia Slingo[1], Kevin Hodges[2] and Ken Sperber[3]

[1]Centre for Global Atmospheric Modelling, Department of Meteorology,
University of Reading, Reading, UK.
[2]Environmental Systems Science Centre, Department of Geography,
University of Reading, Reading, UK.
[3]PCMDI, Lawrence Livermore National Laboratory, Livermore, USA.

1. INTRODUCTION

The weather in the tropics is dominated by the effects of cumulus convection, be it the daily cycle of rain over the continents, tropical cyclones or the seasonal monsoon rains. In turn, the heating associated with cumulus convection is the dominant driving mechanism for the tropical circulation. In the last two decades, observations of the tropics by satellites have revealed a rich tapestry of space and time scales in convective activity. These range from individual clouds, to cloud clusters associated with synoptic scale disturbances (e.g. easterly waves), through to super cloud clusters which display intraseasonal behavior. On the planetary scale, tropical convection shows seasonal and interannual variability associated with, for example, monsoons and the effects of ENSO. The links, both potential and definite, between these various scales of tropical variability are described schematically in Figure 1.

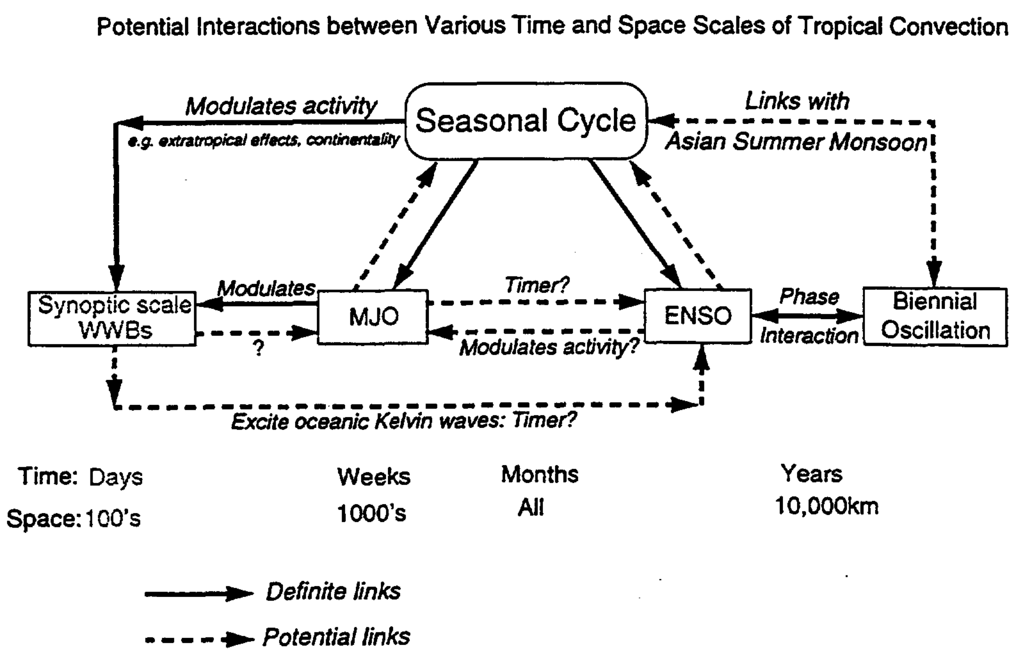


Figure 1: Schematic showing potential interactions between space and timescales of tropical variability.

Here the seasonal cycle is shown as the dominant mode of variability, influencing and being influenced by other scales. For example, the seasonality of the Madden-Julian Oscillation (MJO) is well known (e.g. Matthews and Hoskins 1996), being most prevalent during northern winter and spring. However, there is also increasing evidence that the phase of the MJO can influence the timing of the onset of both the Austral and Asian Summer Monsoons and thus modulate the seasonal cycle.

The organization of tropical convection is important for a variety of reasons. The development and maintenance of equatorial waves is crucial for forecasting in the tropics. Tropical weather sytems may also influence the extratropics by their direct migration polewards into the mid-latitude storm tracks. The diabatic heating over the region of high SSTs in Indonesia and the West Pacific (known as the warm pool) is strongly modulated by the MJO. Variations at these lower frequencies may induce a far-field response in the extratropics with a suggestion that lack of activity at these timescales in the tropics may be linked to a reduced incidence of blocking events in the extratropics (Ferranti et al. 1990). It is also believed that the spectrum of wave activity emanating from the tropical troposphere may be instrumental in the excitation of the stratospheric Quasi-Biennial Oscillation (QBO) and Semi-Annual Oscillation (SAO; see, for example, Andrews et al. 1987 and references therein).

As the results from TOGA COARE have demonstrated, the various temporal and spatial scales of organised tropical convection play an important role in forcing the tropical oceans through variations in the surface stress and energy balance. For example, westerly wind bursts (WWB), which are known to excite oceanic Kelvin waves (e.g. Kessler et al. 1995), themselves potential players in El Niño, appear to be closely related to the active phase of the MJO. In turn the MJO shows both pronounced seasonality and strong interannual variability in its occurrence (Slingo et al. 1996). The relationship between the activity of the MJO and WWBs, equatorial ocean waves and El Niño is not known.

It is clear from the above discussion that an accurate simulation of the various time and space scales of tropical convection should be a fundamental requirement for forecast and climate models. In the following sections research will be described which investigates the ability of current GCMs to address this requirement and how it depends on the parametrization of cumulus convection. Certain phenomena have provided the foci for discussion, specifically the forcing of tropical convection by the extratropics, and the MJO. One of the main purposes of this paper is to demonstrate the type of diagnostics which should be applied to GCMs when assessing the skill of the model and the validity of the convection scheme. In the final section, a technique for studying the behaviour of tropical weather systems in a statistical manner will be described, and its application to ECMWF ReAnalyses (ERA) and to geostationary satellite imagery will be discussed.

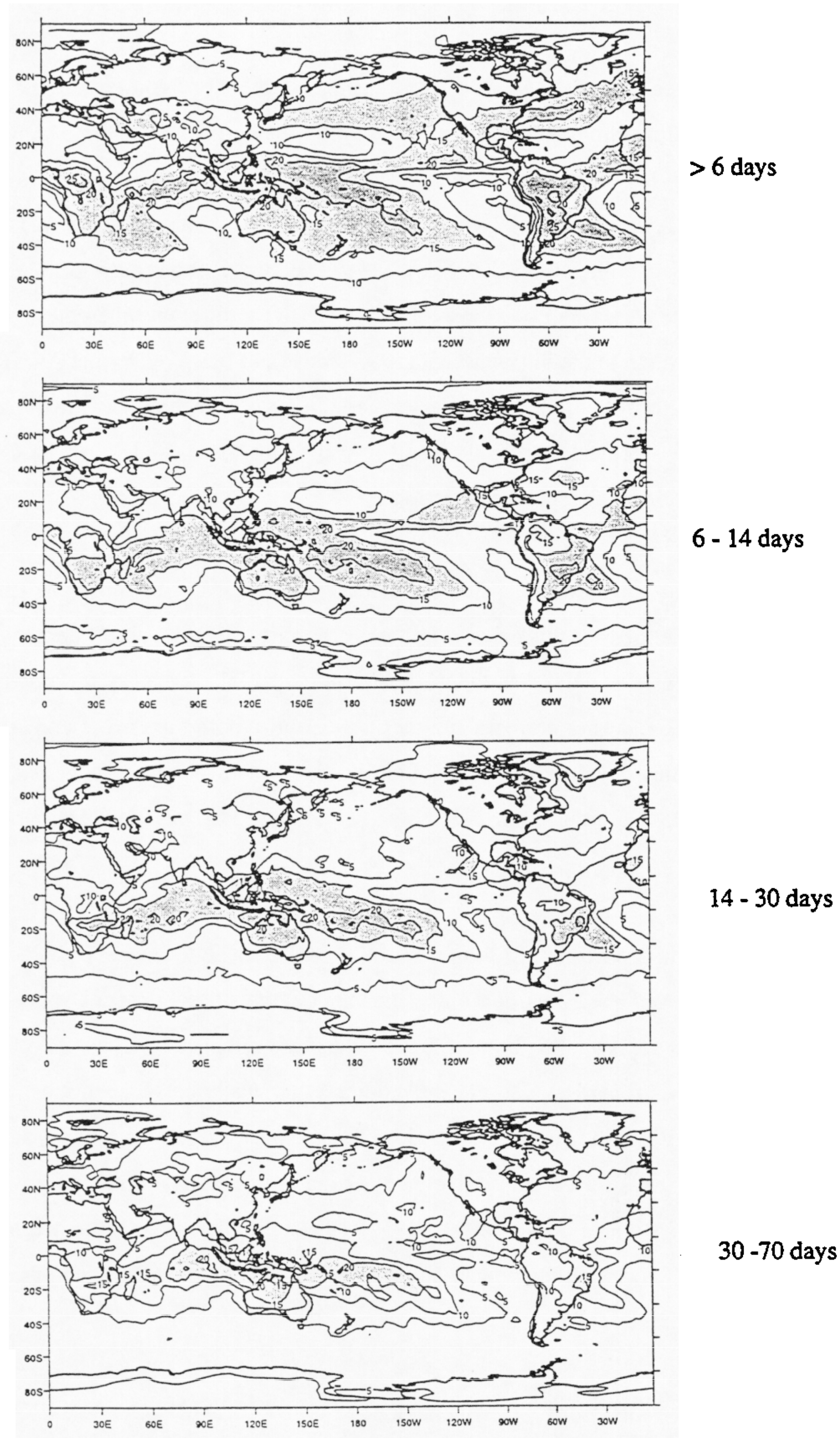
2. SENSITIVITY OF TROPICAL VARIABILITY TO CONVECTIVE PARAMETRIZATION

Slingo et al. (1992, 1994) showed that the analysis of the transient behaviour of convection in a GCM and a comparison with observations provided useful information on the performance of the convective parametrization. The motivation for these studies arose from the increasing number of papers which described the observed variance of tropical cloudiness for different timescales based on data from geostationary and polar orbiting satellites (e.g. Salby et al. 1991). Figure 2 shows an example of the amplitude of the variability in the Outgoing Longwave Radiation (OLR) at different timescales, varying from the synoptic (> 6 days) through to the intraseasonal (30 - 70 days), as observed by the AVHRR on NOAA satellites. This extended record of daily data on a regular 2.50 grid, comparable to the horizontal resolution of climate models, has proved extremely useful in providing basic validation of a GCM's simulation of the temporal bahaviour of tropical convection.

Figure 2 shows the distributions for northern winter (December - March) and for northern summer (May - September). Although the focus of this paper is tropical variability, Figure 2 nicely demonstrates the dominance of the synoptic scale (< 6 days) in the winter storm tracks. The tendency for easterly (4-5 day) waves to be more prevalent during northern summer is evident in both the Pacific and Atlantic ITCZ. At intraseasonal timescales the variability is confined to the eastern hemisphere. As noted by Matthews and Hoskins (1996), the intraseasonal activity shows more eastwards extension during northern winter.

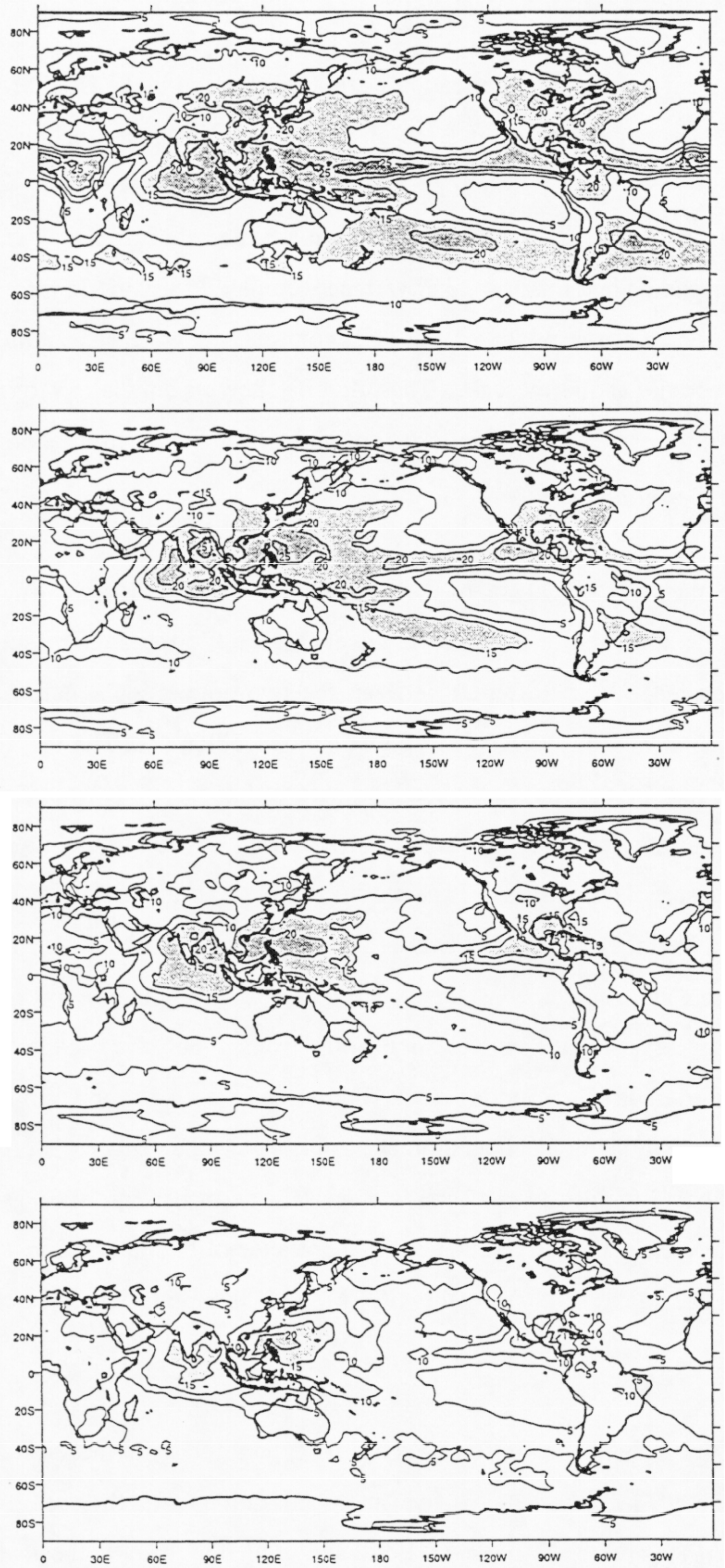
Although observed OLR and window brightness temperature (e.g. Global Cloud Imagery (GCI); Salby et al. 1991) can provide important measures of tropical transience, their use in model validation is limited by the model's ability to represent the correct link between convective activity and cloudiness, including its associated radiative properties. Consequently, other dynamically based quantities, such as the transient eddy kinetic energy and the variance of the lower tropospheric relative vorticity, are often used to study the impact of changes in the convective parametrization on the synoptic activity in the tropics. Examples of this are shown in Slingo et al. (1992, 1994). Similar diagnostics from NWP analyses have been used for validation, although care has to be taken that the model and analysis fields are at the same horizontal resolution.

In the following subsection, results from experimentation with the UGAMP GCM (UGCM) are described in which the sensitivity of the tropical variability to different convection schemes have been studied; a full description of this work can be found in Slingo et al. (1994).



(a) December - March

Figure 2: Partitioning of the variability in observed OLR (Wm^{-2}) between different time scales.



< 6 days

6 - 14 days

14 - 30 days

30 - 70 days

(b) June - September

Figure 2 Continued

2.1 Comparison of Kuo and Betts/Miller convection schemes

Two very different approaches to convective parameterization were implemented in the UGCM; a Kuo scheme which depends on moisture convergence, and the Betts/Miller adjustment scheme which involves a relaxation to observed thermodynamic structures. Both convection schemes gave reasonable simulations of the time mean climate, but the representation of the main modes of tropical variability was markedly different. The Kuo scheme had much weaker variance, confined to synoptic frequencies near 4 days and a poor simulation of intraseasonal variability. In contrast, the convective adjustment scheme had much more transient activity at all timescales. Thus, despite showing simulations of similar quality for the time mean climate, the UGCM has demonstrated marked sensitivity to the convective parametrization in its representation of tropical transience.

The results described above have shown that analysis of the time mean circulation is not sufficient to demonstrate the applicability of a parametrization scheme. Slingo et al. (1994) discuss the reasons why the simulation of the tropical transience is so different between the two convection schemes. They identified the moisture convergence closure in the Kuo scheme as being problematic. The fact that the heating by the Kuo scheme is limited by the moisture accession means that it may have difficulty in initiating a disturbance which would then provide the necessary moisture accession to maintain itself. Also, the heating may then not be sufficiently large to generate the correct transient modes. As Slingo et al. note, in a time mean sense a balance should exist between moisture accession and precipitation, but this is not necessarily true on an instantaneous basis. Similarly, the coincidence of moisture convergence and convection is a necessary diagnostic relation in the tropics, but it is not clear that it should be a requirement for the initiation of convection at each timestep in a GCM, or a limit on the precipitation rate. Instability may be sufficient, such as diurnal heating over land. This constraint may also mean that the Kuo scheme has difficulty in responding to certain perturbations, such as upper tropospheric troughs in the Pacific wave guide. In Section 3 the importance of this interaction with the extratropics is described in detail using results from the UGCM with the Betts/Miller convection scheme.

Another feature of the Kuo scheme is its tendency to form a split ITCZ, particularly in the West Pacific. This characteristic has been noted in other convective parametrizations which use moisture convergence closure (e.g Tiedtke 1989, and see Miller et al. 1992) and has led to the hypothesis that this closure may be responsible (Hess et al. 1993). Certainly, frictional convergence cannot be maintained on the equator because of the Coriolis parameter. Thus, in the case of a uniform surface evaporation field, for example, such schemes would preferentially form disturbances off the equator.

3. ROLE OF THE EXTRATROPICS

Studies of tropical-extratropical interaction have traditionally considered the role of the tropics on the extratropical circulation primarily through teleconnections operating at timescales in excess of a few days. Typical examples are the well-known PNA patterns in response to El Niño. With the advent of satellite imagery it has become increasingly apparent that tropical-extratropical interaction also occurs in the opposite direction, i.e. the extratropics influencing the tropics. There are many examples where the extratropics have a direct effect on the tropics, modulating the convective activity on a variety of space and timescales. No longer is it possible to view the tropical circulation and its associated convective activity in isolation from the extratropics. Specific examples of the influence of the extratropics include incursions of upper tropospheric troughs (e.g. Kiladis and Weickmann 1992) and lower tropospheric cold surge events (e.g. Boyle and Chen 1987).

The influence of the extratropics on tropical convection depends strongly on season. During northern summer, the greater continentality of the northern hemisphere gives rise to vigourous monsoon circulations, particularly the Asian summer monsoon, with their accompanying easterly return flow in the upper troposphere. In addition, the strong meridional surface temperature gradients force lower tropospheric easterly jets, particularly over North Africa, on which tropical waves can develop and propagate (e.g. Thorncroft 1995). The synoptic behaviour of the northern summer tropics is dominated by equatorial waves with pronounced periodicities, such as the 4-5 day easterly waves. Since the upper tropospheric zonal wind is easterly at all longitudes near the equator during northern summer, the propagation of extratropical wave energy into the deep tropics during northern summer is likely to be very restricted and the tropics will be isolated from the extratropics, at least in the upper troposphere.

In contrast to northern summer, the northern winter upper tropospheric zonal wind displays significant regions of equatorial westerlies in the Atlantic and East Pacific Oceans. The importance of these regions, named wave ducts or waveguides, in allowing transient interactions between the tropics and extratropics has been widely studied (e.g. Tomas and Webster 1994). The incursion of extratropical upper tropospheric troughs in these waveguides has been observed to trigger tropical convection over the East and central Pacific (e.g. Liebmann and Hartmann 1984), and Kiladis and Weickmann (1992) were able to show a consistent dynamical relationship between tropical convective activity and these troughs. The implication of this result is that the timescales for convection in the tropical East and central Pacific during northern winter are likely to be strongly influenced by the timescale associated with the extratropical synoptic weather systems.

The results from a perpetual January integration of the UGCM with the Betts/Miller convection scheme have been used to demonstrate the importance of the extratropics in forcing, and influencing, the timescales of tropical convection during northern winter (Slingo 1997). Two specific examples of extratropical forcing have been studied, namely the interaction with extratropical upper tropospheric troughs in the Pacific waveguide and the influence of lower tropospheric winter monsoon cold surges over Indonesia and the West Pacific. The model has shown considerable skill in representing these important interactions with the extratropics and the model results have been used to elucidate the connection between the forcing and the response.

An interesting result of the study has been the apparent coherent relationship between convective activity over different parts of the tropical Pacific Ocean as a consequence of a well defined sequence of events involving tropical-extratropical interactions in both directions. This relationship has been summarised in the schematic shown in Figure 3.

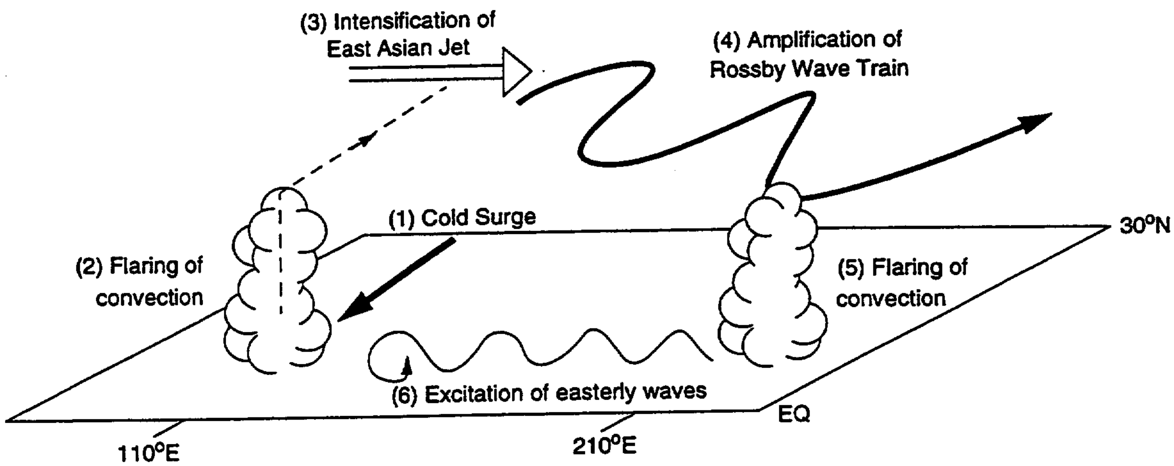


Figure 3: Schematic showing the sequence of events describing tropical-extratropical interaction processes over the Pacific Ocean as simulated by the UGCM. The sequence begins with the initiation of a cold surge event (1) and ends with the excitation of tropical easterly waves (6). From Slingo (1997).

It begins with a cold surge event in the lower troposphere which is initiated by the passage of mid-latitude weather systems and modulation of the strength and position of the Siberian anticyclone. The cold surge enhances convection over the maritime continent, intensifying the local Hadley Circulation which in turn interacts with the extratropics by accelerating the East Asian Jet. The subsequent eastwards extension of the East Asian Jet and amplification of a Rossby wavetrain lead to the intrusion of an upper tropospheric trough into the deep tropics over the East Pacific some 4-5 days later, resulting in a flaring of convection. The final link in the chain is the excitation of equatorial easterly waves by the enhanced convection in the East Pacific. These easterly waves, propagating across the Pacific with a phase speed of near 7ms-1, contribute to convective activity in the West Pacific and can subsequently interact with later cold surge events. The interactions described here demonstrate how inextricably linked are the tropics and mid-latitudes over the Pacific Ocean during northern winter, and suggests that it would be seriously misleading to consider the tropics in isolation from the extratropics.

If, as this study suggests, the incidence of tropical synoptic disturbances depends on interactions with the extratropics, then it is essential that a GCM is able to simulate these interactions correctly. This means, firstly, that the simulated mean climate must be sufficiently accurate to allow the extratropics to influence the tropics (e.g. a good simulation of the equatorial westerly waveguides), and secondly, that the convective parametrization is formulated in such a way as to recognize and respond to extratropical phenomena. This second requirement does not appear to be trivial. For example, the results of a UGCM simulation with a version of the Kuo convective parametrization (Slingo et al. 1994) have shown that, although the equatorial westerlies are well simulated and upper tropospheric extratropical troughs penetrate into the deep tropics, the convection scheme does not respond to these troughs. This is because, firstly, the Kuo scheme, as implemented in the UGCM, requires large scale moisture convergence before convection can be initiated, and, secondly, it has not been formulated to allow for convection to occur with its roots in the free troposphere, not just in the boundary layer.

4. THE MADDEN-JULIAN OSCILLATION

The Madden-Julian Oscillation (MJO) is the dominant mode of variability in the tropics at timescales in excess of one week but less than one season. When it is active it represents a substantial modulation of the convective activity over the Indian and West Pacific Oceans. In the last decade many studies of its structure have been made using satellite data and NWP analyses and the basic characteristics of the MJO are now well documented. However, despite numerous analyses of atmospheric data and investigations with a wide range of numerical models, from very simple equatorial beta planes to complex atmospheric GCMs, the nature of the MJO, particularly its periodicity, its seasonality and its sporadic occurrence, has eluded researchers. The fact that the majority of AGCMs fail to simulate the MJO with any fidelity is a cause for concern (Slingo et al. 1996). The MJO is crucial for weather forecasting and seasonal prediction both for the tropics and midlatitudes. Additionally, it is essential that climate models are able to simulate it, since the MJO may be a major player in El Niño, and changes in the intensity or nature of the MJO would themselves constitute an important change in climate.

In the following subsections the current skill in simulating the MJO will be described. The possibility that it may be a coupled phenomenon, involving coherent links with the ocean, will be discussed.

4.1 **Results from AMIP I**

Slingo et al. (1996) describe the results of a study of the ability of 15 atmospheric GCMs to simulate the MJO, performed as part of the Atmospheric Model Intercomparison Project (AMIP). The models displayed a wide range of skill in simulating the MJO. Most models showed evidence of an eastward propagating anomaly in the velocity potential field, although in some models there was a greater tendency for a standing oscillation, and in one or two the field was rather chaotic with no preferred direction of propagation. The results of the space-time spectral analysis showed that no model produced spectra which compared well with the results from the ECMWF analyses. An example of this is shown in Figure 4, where the space-time spectra for the wave number 1 velocity potential has been plotted for the ECMWF analyses, and for three examples of models with strong intraseasonal activity and for three models with weak intraseasonal activity.

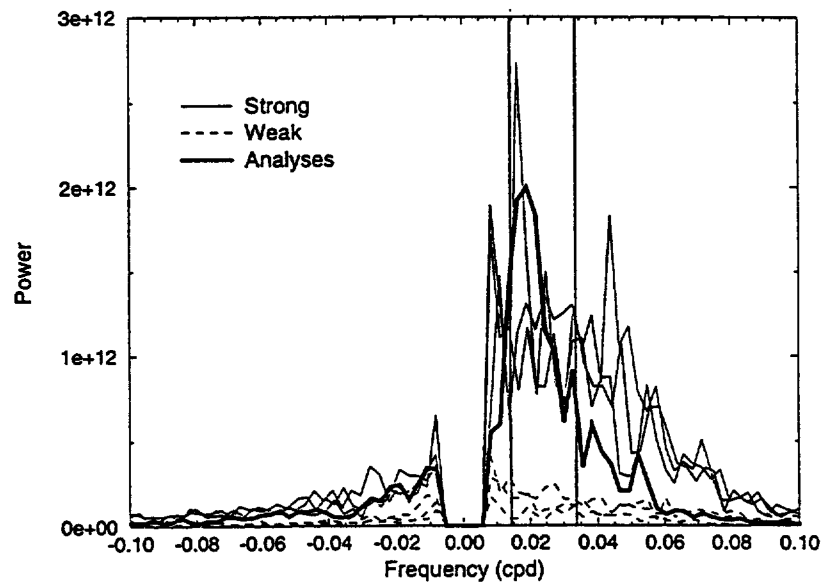


Figure 4: Space-time spectra of wave #1 upper tropospheric velocity potential from ECMWF analyses, three AGCMs with strong and three AGCMs with weak intraseasonal activity. The vertical lines correspond to eastward moving waves with periodicities of 30 and 70 days. Results are taken from the AMIP I (Slingo et al. 1996).

No model reproduced the dominant peak near 50 days, seen in the ECMWF analyses; those models which had reasonable power at intraseasonal timescales, tended to have relatively more power at higher frequencies (< 30 days). Also the majority of models failed to properly partition the variance between eastward and westward moving modes.

The relationship between a model's intraseasonal activity, its seasonal cycle and characteristics of its basic climate was also examined by Slingo et al. (1996). It was clear that those models with weak intraseasonal activity tended also to have a weak seasonal cycle. It is becoming increasingly evident that an accurate description of the basic climate may be a prerequisite for producing a realistic intraseasonal oscillation. In particular, models with the most realistic intraseasonal oscillations appeared to have precipitation distributions which were well correlated with warm SSTs. These models predominantly employed convective parametrizations which were closed on buoyancy rather than moisture convergence. This was the key result from Slingo et al. (1996) and supports the earlier results described in Slingo et al. (1994) and discussed in Section 2.1.

From the study of 15 AGCMs in Slingo et al. (1996), it was found that the Goddard Laboratory for Atmospheres (GLA) and the United Kingdom Meteorological Office (UKMO) AGCMs simulated the most realistic MJOs, such that when a clear eastward propagating signal was evident, the period of the oscillation was realistic. Subsequently the structure of the MJOs simulated by these two models has been studied in depth and compared with a parallel diagnosis of the NCEP/NCAR Reanalyses. The full results of that study are described in Sperber et al. (1997). The models have successfully captured many aspects of the planetary scale flow associated with the MJO, such as the development of the forced Rossby modes during the active phase of the oscillation. However a notable failure of the models was the inability to simulate the observed large scale organization of convection over the Indian Ocean and its subsequent coherent eastwards progression over Indonesia and the West Pacific.

Sperber et al. (1997) also investigated the applicability of current theories for the maintenance and propagation of the MJO. The results from the NCEP/NCAR Reanalyses and from the models demonstrated that evaporative wind feedback (WISHE; Emanuel 1987, Neelin et al. 1987) and frictional wave-CISK (Hendon and Salby 1994) were not the dominant processes by which the eastward propagation of the MJO is maintained. Sperber et al. (1997) therefore speculated that another process might be involved and suggested that lack of an interactive ocean might be the cause of the models' systematic failure to simulate the eastward transition of convection and latent heat flux from the Indian Ocean into the western Pacific Ocean.

4.2 The MJO as a coupled ocean-atmosphere phenomenon?

The evidence that the MJO influences the ocean on intraseasonal timescales is mounting, suggesting therefore that the MJO may be a coupled phenomenon which requires an interactive ocean surface to produce the correct organization of convection and its eastwards propagation. Zhang (1996), using extended timeseries covering several years from the TOGA TAO array, has shown that a coherent relationship between SSTs and atmospheric forcing at intraseasonal timescales may exist. He notes that the intraseasonal variability of SST, although generally weaker than the seasonal and interannual variability, is easily detectable. He also notes that the coherence between the atmospheric forcing and the SST variations is significant for timescales in excess of 4-5 days and that the atmosphere appears to force the SST. The question of whether there is a (perhaps non-local) response by the atmosphere to these changes in SST has not been addressed.

Sperber et al. (1997), using cases of strong MJOs observed during 1987/88, examined the SST and its relationship to the active phase of the MJO. Their results indicated that the MJO may evolve as a coupled ocean-atmosphere mode and supported those of, for example, Gutzler et al. 1994, Chen et al. 1996, and Lau and Sui 1996. Sperber et al. (1997) showed that convection in the active phase of the MJO tended to occur over warmer than normal SSTs. Subsequently, in the vicinity of the enhanced convection, cloud shielding and enhanced latent heat flux served to cool the local SST, resulting in a zonal gradient of SST with warmer values to the east, potentially providing the impetus for convection to develop further east. To the west of the convection, evaporative cooling dominated, with a cooling of the local SSTs, such that the western limit of the convection was eroded. These results suggested that the local gradient of SST could be important for the eastward migration of the MJO, and are consistent with observations from the TOGA-COARE Intensive Flux Array (Lau and Sui 1996).

Although the above discussion has focused on the MJO, there is increasing evidence, particularly from TOGA-COARE, that variability in the tropics on different space and time scales is intimately linked. The possibility that coupling between the atmosphere and the ocean at all scales may be important for determining the mean climate and its low frequency variability is an area of increasing interest. Clearly much more research is needed to identify the potential interaction between convection and SSTs at all space and time scales, from the diurnal cycle through to interannual variability associated with the Tropical Biennial Oscillation (TBO) and ENSO.

5. NEW APPROACHES AND DATASETS FOR THE VALIDATION OF TROPICAL VARIABILITY

It is clear from the above discussion that a study of the temporal and spatial characteristics of tropical convection is essential if the correctness of a model's physical parametrizations, particularly cumulus convection and its closure assumptions, are to be assessed. The practice of validating a convection scheme by testing it on observed data, such as GATE wave composites, may not be sufficient since the disturbance, and hence the moisture accession, is already in place. There currently appears to be no systematic way of testing convection schemes to ensure that they are capable of generating the correct modes of tropical transience. The development of more sophisticated techniques to identify the spatial and temporal characteristics of tropical convection and associated dynamics is needed. In the following subsection a new diagnostic tool is described which has proved valuable for assessing, statistically, the ability of GCMs to simulate synoptic behaviour in the tropics and extratropics.

It is also essential to obtain more validation data which describe the temporal characteristics of convection, their seasonal and interannual variability. Satellite observations, such as the initial analysis of ISCCP data presented by Salby et al. (1991), may be particularly relevant. Similarly, suitable studies of NWP analyses, such as those described by Lau and Lau (1990), may be useful. With the availability of high resolution ERA data more sophisticated analysis of the variability of the tropical circulation will be possible. In addition the development of a comprehensive archive of satellite-observed cloud brightness temperature is planned in the near future which will enable a wide range of diagnostic and model validation studies to be made.

5.1 Objective Tracking Method (TRACK)

The TRACK program, developed by Hodges (1994, 1996), automatically and objectively identifies suitable features in time sequences of meteorological and oceanographic data. These features are tracked through the time sequence to produce feature trajectories. These trajectories are then analysed to produce statistical diagnostic fields which can be used in the validation of GCMs of the atmosphere and ocean.

A wide range of techniques have been used within the TRACK program, many adapted to work directly in a spherical domain. To identify suitable features, numerical methods and techniques from spatial data analysis and image processing have been used. To perform the tracking, an existing technique from dynamic scene analysis has been adapted to work directly on the sphere. Finally to perform the statistical analysis, nonparameteric kernel estimators have been used with new, efficient spherical kernels. This means that the statistical fields can be determined directly on the sphere negating the systematic error often introduced when using projections to estimate statistical quantities. Also, cross-validation and adaptive smoothing have been explored for the spherical domain to determine suitable values of the smoothing parameters of the spherical kernels. Both density and regression estimators are used to produce the following statistical diagnostic fields:

1. Mean feature strength.
2. Standard deviation of feature strength.
3. Mean feature speed.
4. Standard deviation of feature speed.

5. Feature density.

6. Genesis density.

7. Lysis density.

8. Track density.

9. Mean track lifetime.

10. Mean track flux.

The TRACK program has been used in a wide number of applications which are described on the ESSC web site (http://www.nerc-essc.ac.uk/~kih/TRACK/track.html) and include:

- Storm track diagnostics from AMIP integrations, ERA data.
- Tropical cyclone diagnostics from ERA data, Meteosat and ISCCP data.
- Tracking ocean eddies in the Aghulas Current and the southern Indian and Atlantic Oceans from the Parallel Ocean Program (POP) model.

Figure 5 shows an example of the statistics of cloud clusters for July-September from 8 years of Meteosat data (1983-90), taken from the ISCCP B3 archive. The data has been smoothed on to a 1.50 grid to eliminate small clouds, but to retain the mesoscale structure of the squall lines. The statistics show that the mean lifetime of the cloud clusters increases from less than 1 day over Africa to more than 2 days over the Atlantic. The clusters move westwards with a mean speed in excess of 13 m/s over Africa, but slow down over the Atlantic to speeds nearer 8 m/s, typical of tropical easterly waves. Figure 5 shows that the clusters have prefered regions of development (genesis) and decay (lysis), often associated with orography over Africa. The clusters tend to achieve colder temperatures (i.e. deeper convection) over Africa, weakening slightly off the West African coast, before deepening again over the central Atlantic.

The example shown in Figure 5 demonstrates the considerable information on the temporal and spatial behaviour of tropical variability provided by the TRACK program. The program is also being applied to the ERA data and will be used to relate the cloud cluster statistics to the easterly wave dynamics.

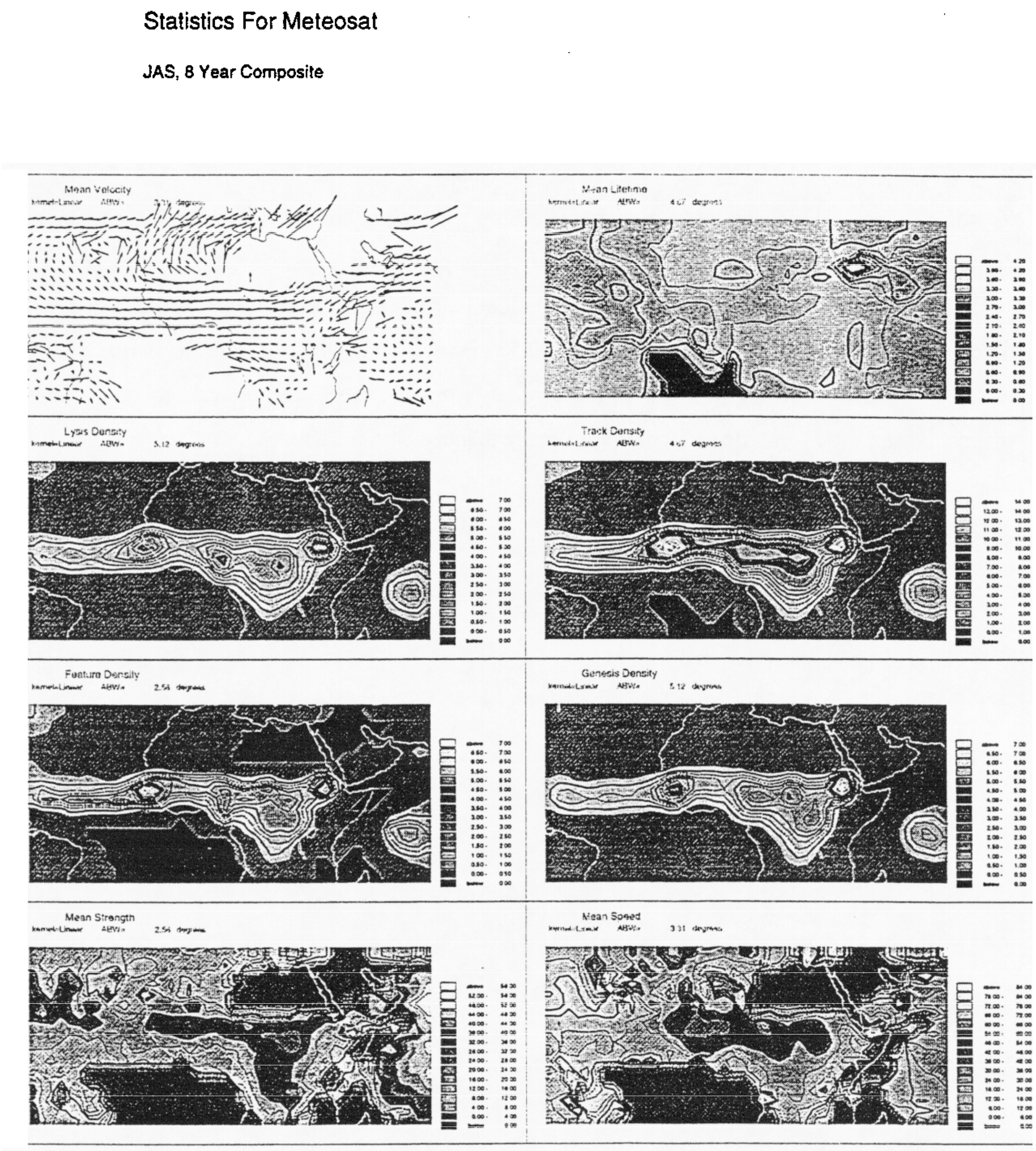


Figure 5: Example of statistics generated by the TRACK program from 8 years of Meteosat data.

5.3 New validation datasets.

The importance of using dynamical quantities, as well as satellite cloud observations, for studying tropical variability was stressed earlier. Previously it has proved difficult to obtain reliable results from NWP analyses, particularly for synoptic scale variability, mainly because the tropics tend to be data sparse. Thus the analysis is dominated by the first guess and hence depends on the forecast model's skill in representing tropical disturbances. However, preliminary results from the ERA dataset look more promising and a range of studies to investigate various aspects of tropical variability (e.g. cold surges, westerly wind bursts) are already in progress.

To complement the ERA dataset, a project to develop a global archive of cloud brightness temperature from the ISSCP B3 data will commence shortly. This project, entitled 'Cloud Archive User Service (CLAUS)' is being funded by the EC through the Centre for Earth Observation. CLAUS will construct a dataset of cloud brightness temperature on a 0.50 grid at 3-hourly intervals for the period of ISCCP, i.e. 1983 - present. The archive will be made widely available to the user community and a range of diagnostic and model validation studies are already planned within CLAUS.

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Technical Information Department • **Lawrence Livermore National Laboratory**
University of California • Livermore, California 94551