Initial tendencies of cloud regimes in the Met Office Unified Model

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The Met Office Unified Forecast-Climate Model is used to compare the properties of simulated climatological cloud regimes with those produced in short-range forecasts initialised from operational analyses. In general, the cloud regime properties are found to be similar at all forecast times, including the climatological mean. This suggests that weaknesses in the representation of fast local processes are responsible for errors in the simulation of the cloud regimes. The increased horizontal resolution of the model used for numerical weather prediction generally has little impact on the cloud regimes, although the simulation of tropical shallow cumulus is improved, while the relative frequency of tropical deep convection and cirrus compare less favourably with observations. Analysis of initial temperature tendency profiles for each cloud regime indicates that some of the total temperature tendency which leads to a systematic bias in the model climatology is associated with a particular cloud regime.

A clustering algorithm has been applied to ISCCP observational data to define cloud regimes constituting grid-points with similar cloud top pressures (CTP), optical depths and cloud covers (Jakob and Tselioudis, 2003). Cloud regimes have similarly been obtained using ISCCP simulator output from the Met Office climate model (HadGAM1), and the mean of 24 forecasts of the operational NWP model (Figures 1 and 2). The unified nature of the model means that the primary difference between the two model versions is in the resolution. This provides a seamless model forecasting framework with the same formulation of the model physics being used for data assimilation, short range forecast and climate change projection.

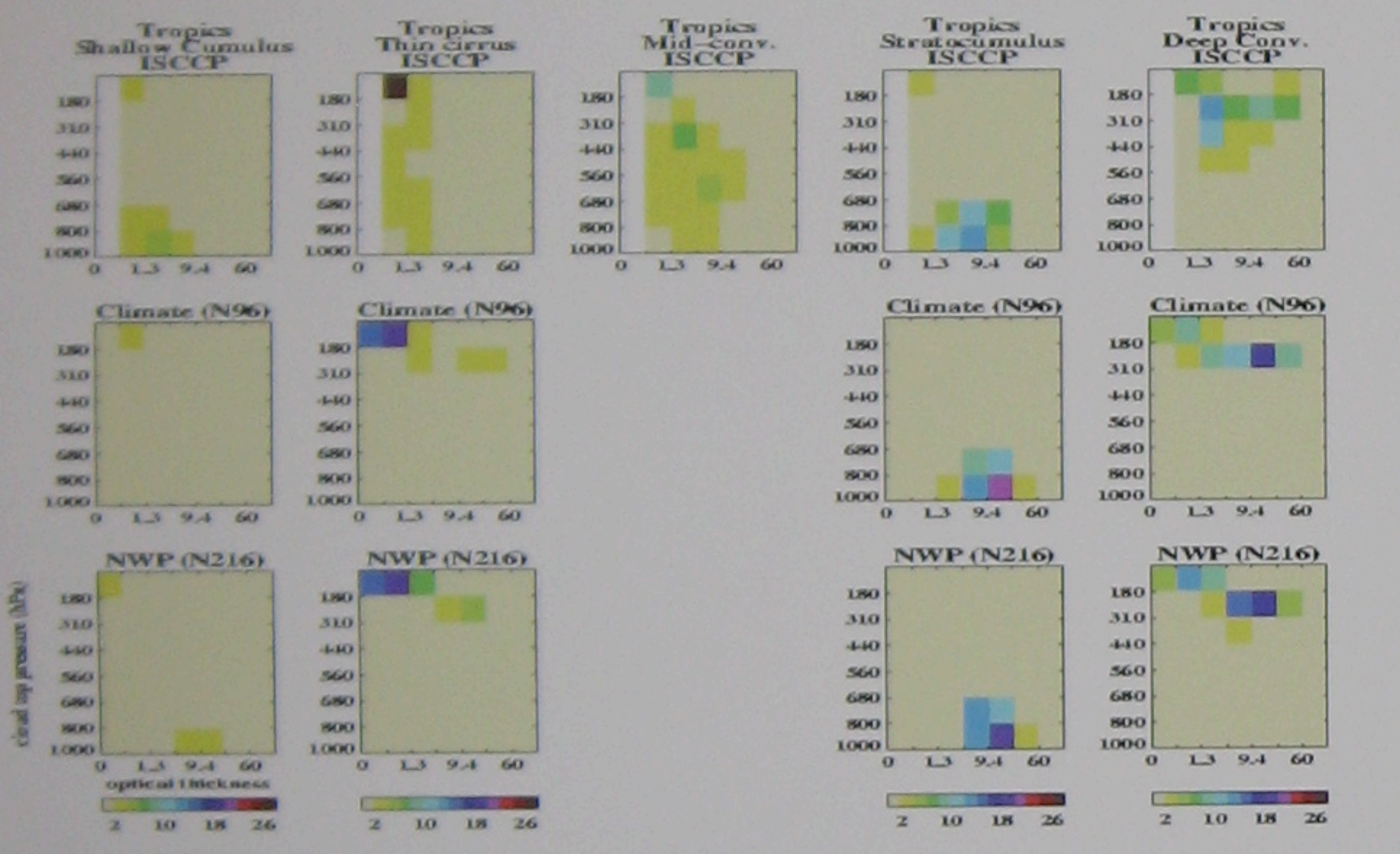

Figure 1. Mean CTP – optical depth regime histograms for the principal cloud regimes over the tropics (20N-20S). Colours indicate the cloud amount (%) in each CTP – optical depth category. Top: Observed climatology by ISCCP; Middle: Mean over the 5-day forecast from the N96 model; Bottom: Mean over the 5-day forecast from the N216 model. The model does not simulate the mid-level convection regime.

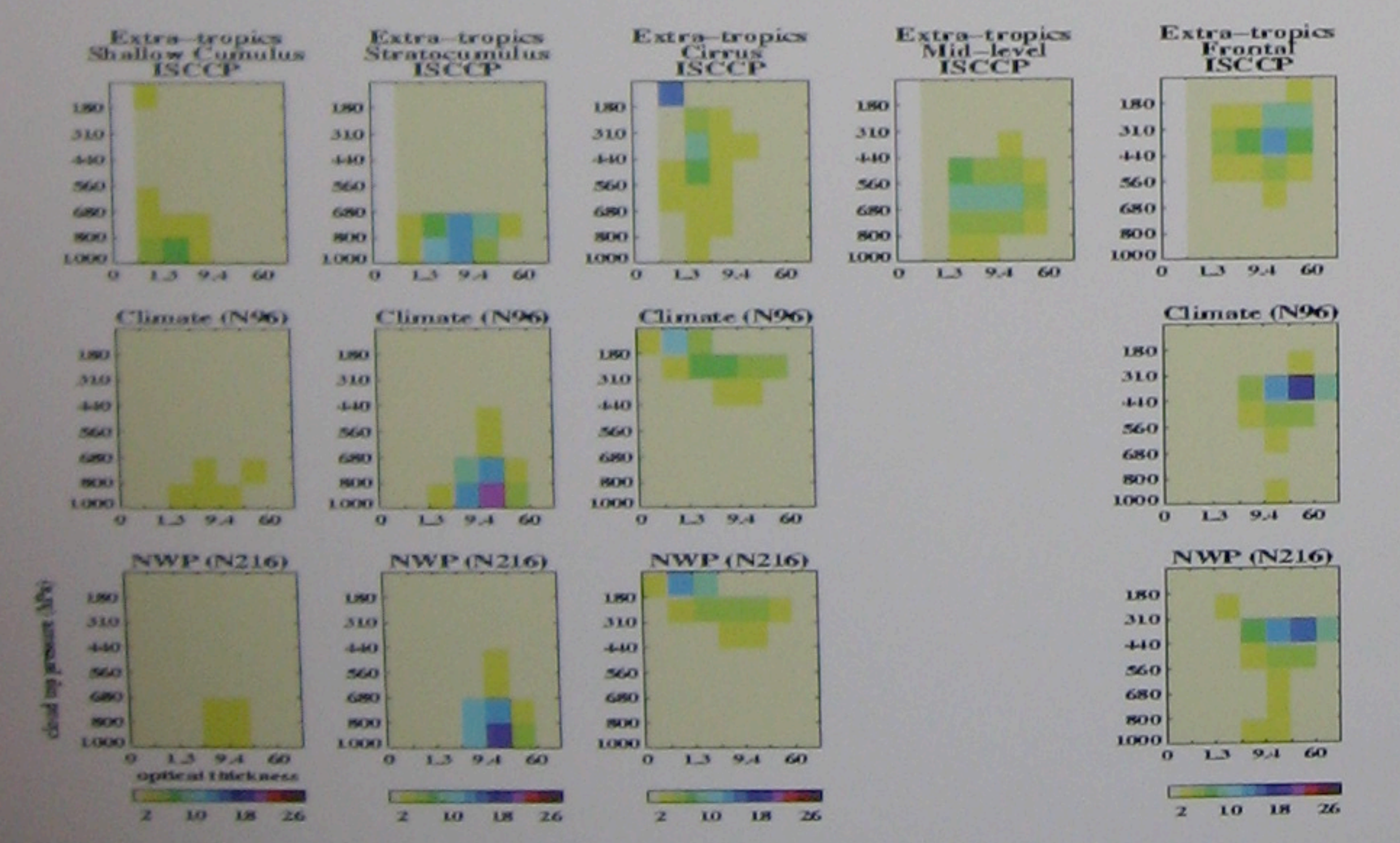

Figure 2. As Figure1 but for the ice-free extra-tropics. The model does not simulate the mid-level cloud regime.

Overall, the increased resolution in the NWP model has little effect on the simulation of the regimes, however the representation of tropical shallow cumulus is improved at higher resolution. The Met Office model (in common with many other GCMs) has difficulty in simulating a regime dominated by cloud with tops at mid-levels.

The evolution of the regime properties during the course of the model forecast (Figure 3) reveals:

- The regime properties are similar after five days to the climatological mean which indicates that errors in the regime properties are associated with fast atmospheric processes.
- The increased resolution used for NWP generally has little effect on the regime properties, although the frequency of tropical cirrus is increased at the expense of deep convection (this compares less favourably with ISCCP).
- With the exception of the relative frequency of tropical deep convection and cirrus, the regime properties show little evolution during the forecast period, even though the initial state is constrained by the data assimilation system. This suggests that most of the errors in the regime properties are due to deficiencies in local processes and their interaction, however the frequency of deep convection is affected by a dynamical response during the model forecast.

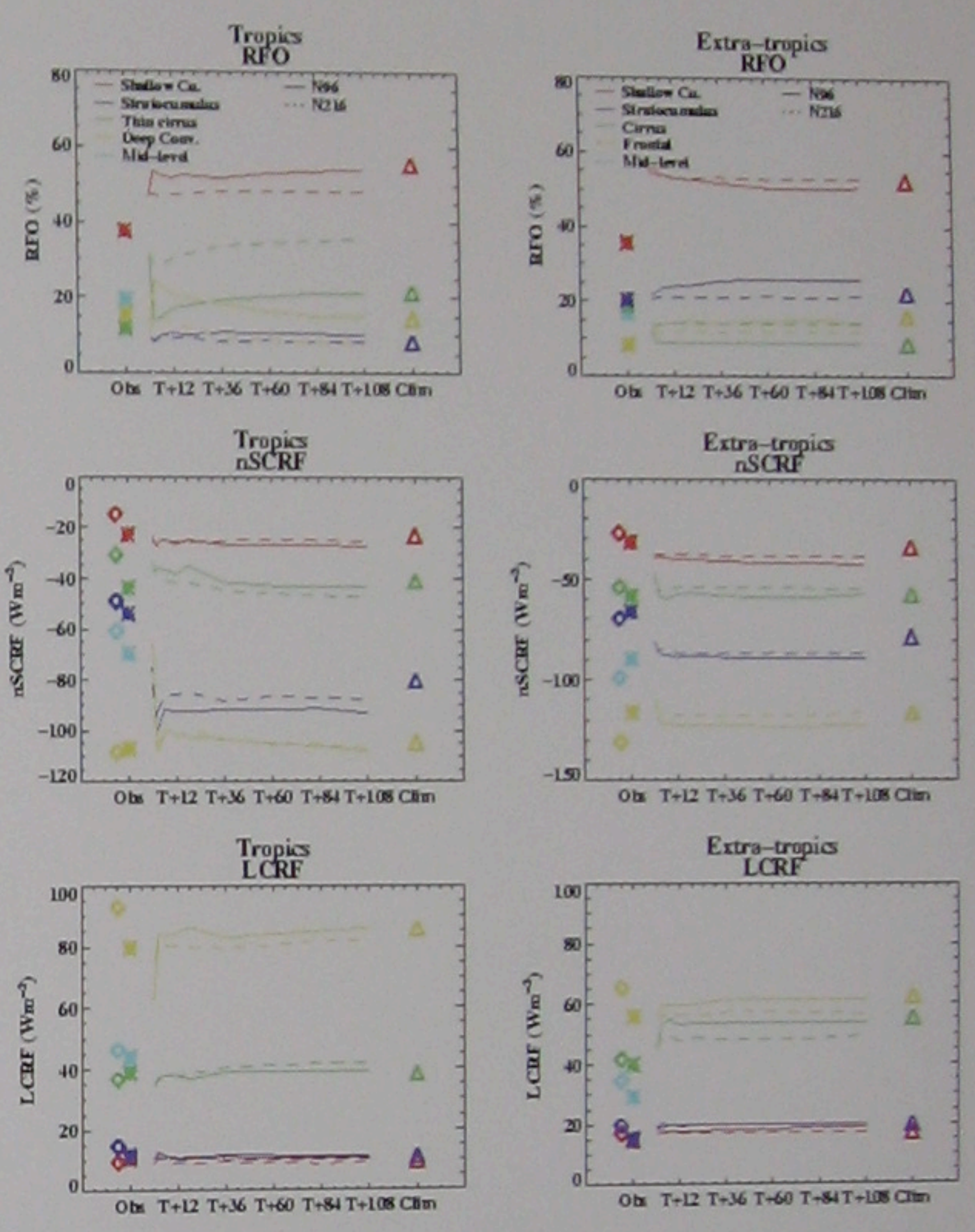

Figure 3. Evolution of the relative frequency of occurrence (RFO), normalised shortwave cloud forcing (nSCRF) and longwave cloud forcing (LWCF), through the model forecast. N96 is shown solid; N216 is shown dashed. Observed climatology from ISCCP is shown with an asterisk; from ERBE is shown with a diamond; HadGAM1 climatology is shown with a triangle.

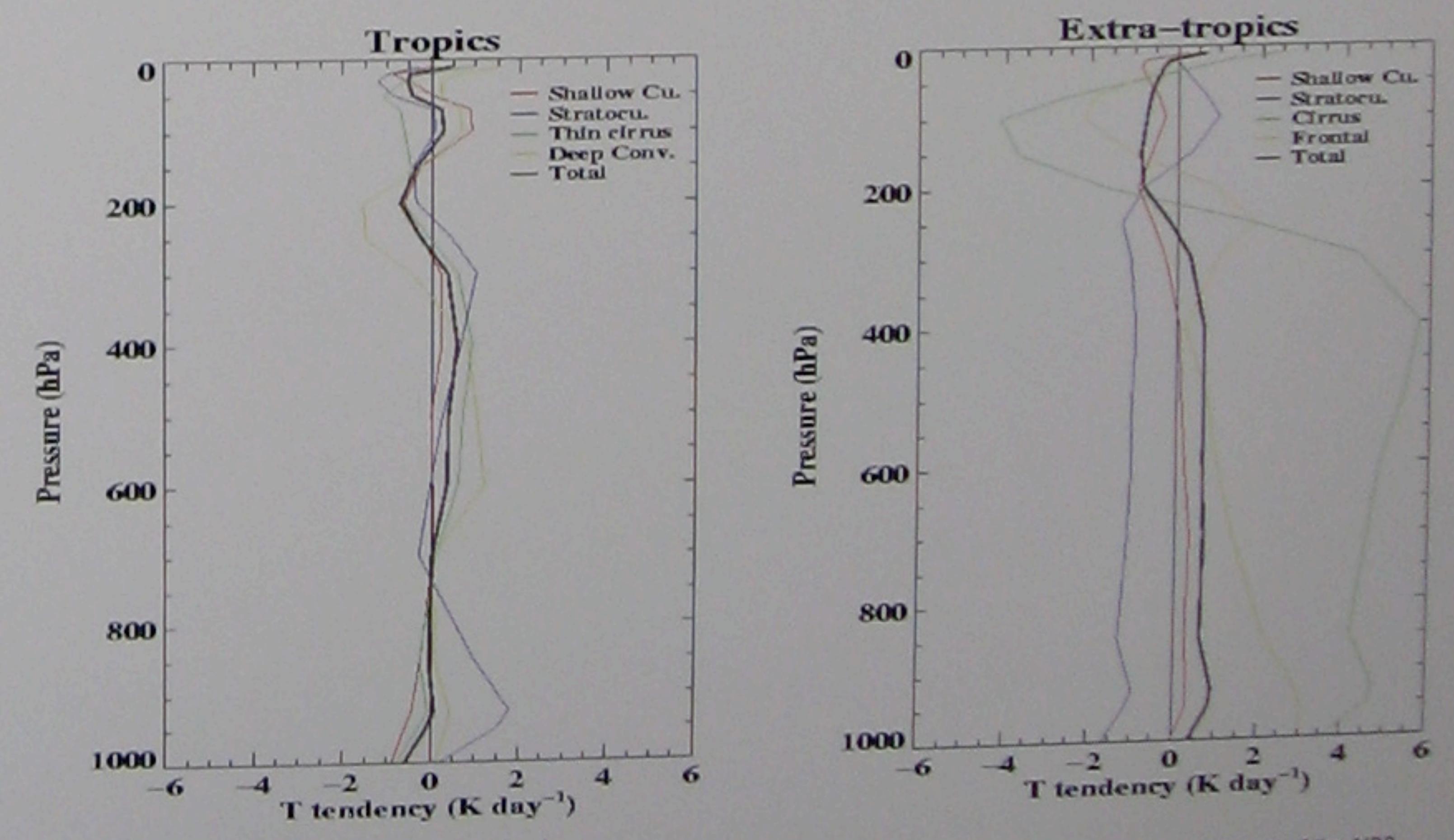

Figure 4. Initial temperature tendency profiles for each regime and the total for the whole region over the first six hours of the N96 forecast.

The initial tendencies of model state variables over the first six hours of the forecast have been examined in the context of the cloud regimes (Figure 4). A strong upper tropospheric cooling with a warming below occurs in the extra-tropical cirrus regime. This is consistent with the regime containing cloud which is too thick and high. This upper tropospheric cool bias is present as a systematic error in the HadGAM1 climatology, indicating the potential benefit of using a unified modelling system to investigate the cause of climate errors through the diagnostic analysis of short-range forecasts.

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