



Hadley Centre technical note 76

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Regional Assessment of QUMP 17-member ensemble

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Introduction

The object of this project was to assess the ability of the second 17-member Qump ensemble to reproduce the climate for the period 1961-1990 over different regions of the globe. One or more of the ensemble members which most closely reproduced the observed climate variables could then be used to drive the regional climate model. Any biases in the Qump ensemble members will also be evident. The particular Qump ensemble analysed is described briefly in the next section, followed by a description of the climatologies used to validate the ensemble. Next the analysis of the ensemble's ability to reproduce observed climate, using annual and then monthly data, is described. Finally, these results are summarised.

Qump Ensemble

The model data analysed are taken from the second 17-member Qump ensemble. This ensemble used multi-parameter perturbations to the atmospheric component of the fully coupled atmosphere-ocean model HadCM3. Previous Qump ensembles used the atmospheric component of HadCM3 coupled to the slab ocean model. For this report, results from the 'Hist 2' set of experiments was used, which covered the period 1949-1989. Results from 1960-1989 were used in this assessment. The Qump simulations of the period 1960-1989 will, on average, represent the observed climate for the similar period 1961-1990 (observations for this period are readily available; see next section). However, model results and observations from the same year will not necessarily agree. All model simulations that make up the entire Qump ensemble are summarised in Appendix A. The model data used are monthly mean values of mean sea level pressure, surface temperature, precipitation and height at a pressure of 500 hPa.

The HadCM3 model consists of an atmosphere component at a resolution of $3.75^\circ \times 2.5^\circ$, and 19 vertical levels extending to a height of 10 hPa. The horizontal resolution is equivalent to a surface resolution of about 420 km x 280 km at the equator. The ocean model has a higher resolution of $1.25^\circ \times 1.25^\circ$.

Generation of Climatologies

Climatologies for surface pressure, temperature, precipitation and height at 500 hPa were generated using observations obtained from the 'HadObs' data site (www.hadobs.org) or the Climatic Research Unit (CRU), www.cru.uea.ac.uk. The climatologies generated are 30 years long, and contain monthly mean values (except precipitation, which contains monthly totals). The period 1961-1990 was selected, as data for this period are readily available. The method used to generate each climatology is described below. The observations were processed so that they were on the same horizontal grid points as the model results.

Mean Sea Level Pressure

Dataset HadSLP2. This dataset was regridded from $5^\circ \times 5^\circ$ to the resolution of HadCM3.

Surface Temperature

The surface temperature climatology was created by combining two datasets, an average surface temperature climatology for the period 1961-1990, and a set of anomalies for the same period. The average surface temperature climatology was obtained from CRU dataset “ctmp6190.dat”, which is available at a resolution of $0.5^{\circ} \times 0.5^{\circ}$. The temperature anomalies were obtained from the CRUTEM3 dataset, which is available at a resolution of $3.75^{\circ} \times 2.5^{\circ}$. The average surface temperature climatology was regridded to the same resolution as the CRUTEM3, and then added to the anomalies in the CRUTEM3 dataset. Finally, the data were converted from Centigrade to Kelvin by adding 273.15 to all values. It should be noted that this dataset only covers the land areas, and that there are no data for some locations.

Precipitation

Dataset “gu23wld0098.dat” was obtained from CRU. This dataset contains precipitation measurements gridded to the resolution of HadCM3. Like the temperature dataset, no data are available at some locations.

Height at a Pressure of 500 hPa (Z500)

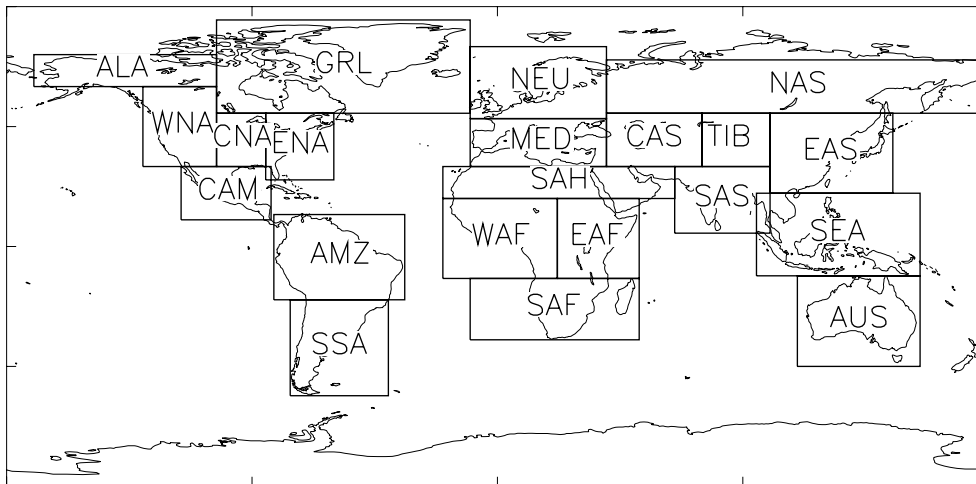
Obtained from processed NCEP analyses, and regridded from a resolution of $5^{\circ} \times 5^{\circ}$ to the resolution of HadCM3.

Comparisons of Qump Ensemble with Observations

The results from the Qump ensemble were compared with observations in many different regions of the Earth. These regions were originally defined by Giorgi and Francisco (2000); they are listed in Table 1, and illustrated in Figure 1. These authors defined these particular regions because they are sufficiently large that they include at least several grid points from the older HadCM2 model (which has the same horizontal resolution as HadCM3), and the regions represent (broadly) different climatic regimes. The comparison was carried out using a similar methodology to that described by Giorgi and Francisco (2000). First, annual mean values for both the observations and model results at each model grid point were calculated. Only grid points where both an observation and a modelled value were available for every year were used. The average observed and modelled values over each region were then calculated, so that 30 annual mean values for both the modelled and observed variables were generated. The mean, median, 5th and 95th percentile values were then calculated from these annual means.

Table 1. List of abbreviations of names of each region, and their full names (see Figure 1).

Abbreviation	Area	Abbreviation	Area
ALA	Alaska	WAF	West Africa
GRL	Greenland	EAF	East Africa
WNA	West North America	SAF	South Africa
CNA	Central N. America	NAS	Northern Asia
ENA	East North America	CAS	Central Asia
CAM	Central America	TIB	Tibet
AMZ	Amazonia	SAS	South Asia
SSA	Southern S. America	EAS	East Asia
NEU	Northern Europe	SEA	South-East Asia
MED	Mediterranean	AUS	Australia
SAH	Sahara		

**Figure 1.** Map of regions used to assess performance of Qump Ensemble (regions originally defined by Giorgi and Francisco, 2000); see also Table 1.

Annual Mean Results

The objective of this comparison was to see if the Qump ensemble as a whole encompassed the range of observations for each meteorological variable. Using results at individual grid points within each region, the differences between the model and observations at were calculated, weighting each difference with the cosine of the latitude. These differences were then used to calculate the bias and root-mean-square error (RMSE) for the modelled results over each region, and these quantities are shown in Figure 2.

The annual means of the observations and modelled variables are shown in Figure 3. For each panel of Figure 3, the mean values are illustrated by the diamond (observations), solid circle (Qump ensemble mean), or cross (individual ensemble members). The 5th and 95th

percentile values are represented by the error bars. Finally, the median value is represented by the horizontal line close to the mean value.

Overall, the following remarks can be made from the comparison using annual mean results. The Qump ensemble has a slight bias in mean sea level pressure (MSLP), as it consistently underestimates this quantity in most locations (the exceptions are Alaska, Greenland, Northern Europe and North Asia). This global mean bias in MSLP exists in the Qump models because the initial atmospheric conditions were taken from a long spin up which didn't include a fix to conserve atmospheric mass (Overall though, as circulation depends on pressure gradients, it shouldn't make much difference and could easily be corrected in a regional model run).

The ensemble reproduces the observed temperatures and precipitation amounts for the period 1961-1990 very well. For the two regions Southern South America and South-East Asia, the ensemble has a warm bias of approximately 0.8 °C. For the regions West North America, Alaska and Tibet, the model overestimates annual precipitation by 0.3 – 1.0 mm day⁻¹, and for South-East Asia and South Asia, the model underestimates annual rainfall by 0.8 – 1.0 mm day⁻¹. Generally, the model reproduces the observed heights at a pressure of 500 hPa, although there is a slight low bias over a number of locations. The overall variability of individual ensemble members is similar to or larger than that seen in the observations, although there are some exceptions. The range of each variable from the ensemble as a whole is always larger than that observed.

The ensemble mean is often different to the observational mean, but the range of the individual ensemble members usually includes the observations. For example, consider the results for North Asia. The ensemble mean values indicate that the Qump ensemble is slightly warmer and wetter than the observations. However, the temperatures simulated under ensemble member d are very close to the observations. Similarly, for precipitation, ensemble members b, c and d reproduce the observations closely. None of the ensemble members capture the entire range of observed surface pressure, although member 'a' covers most of the range. Member n most closely reproduces the observed heights at 500 hPa. As with this location, different ensemble members reproduce each of surface temperature, precipitation and height at 500 hPa the most accurately.

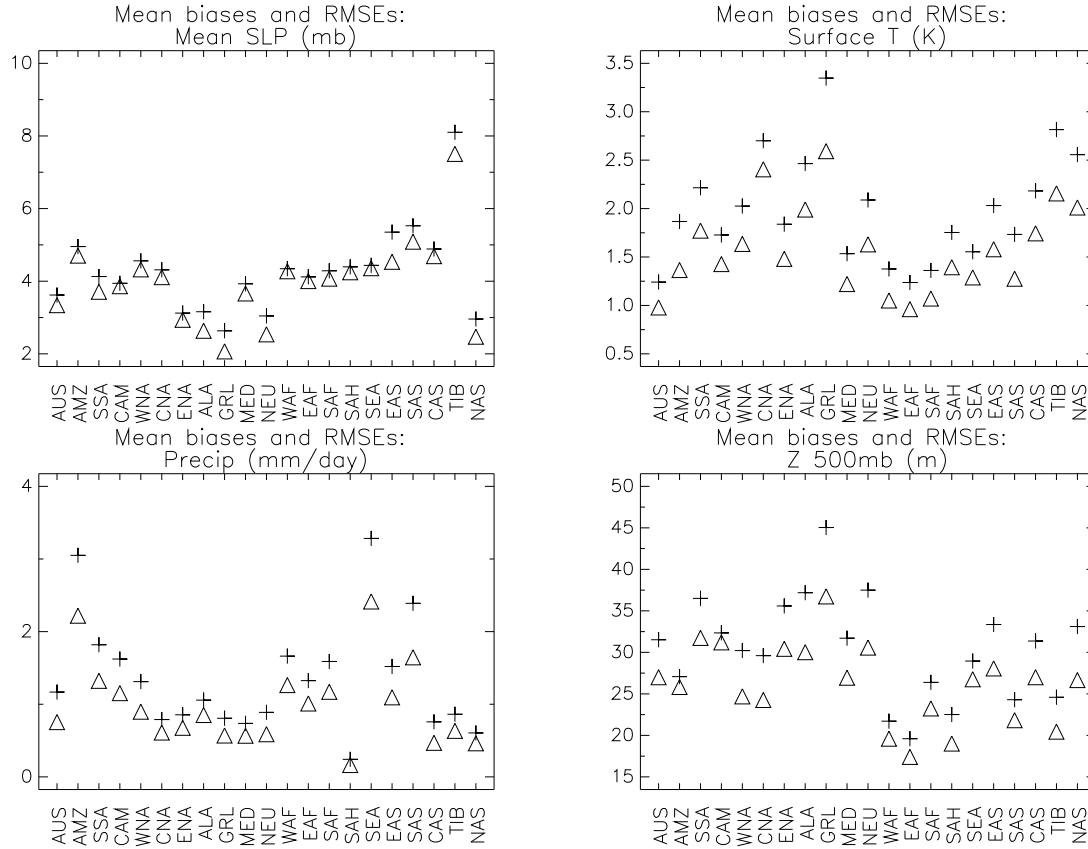
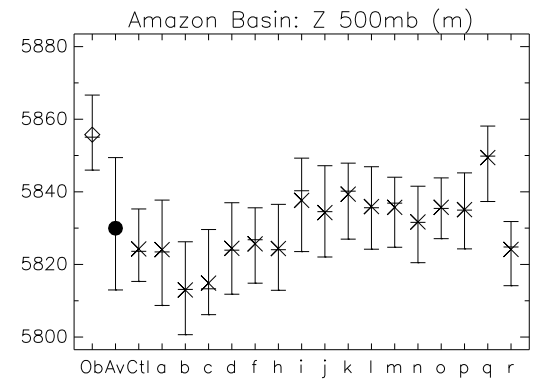
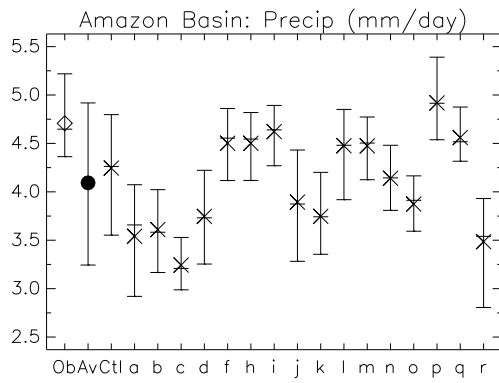
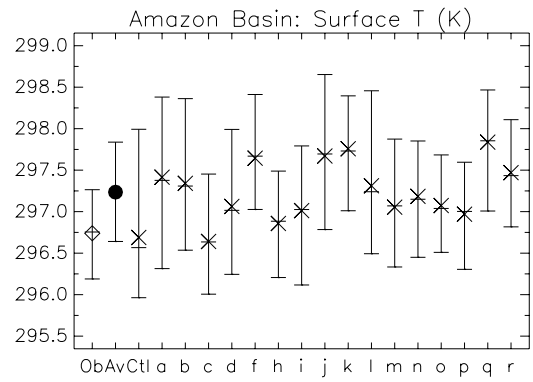
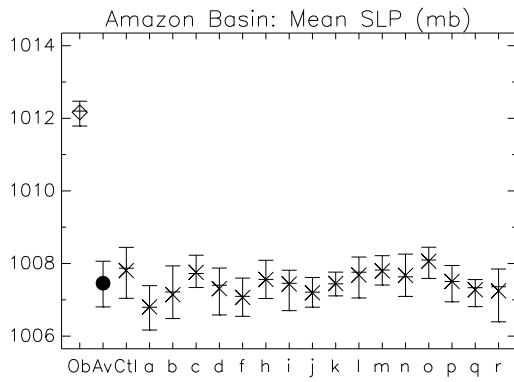
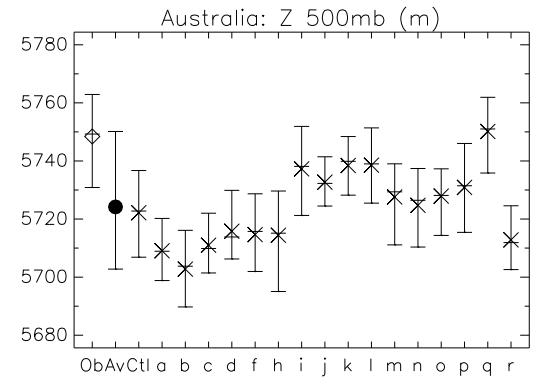
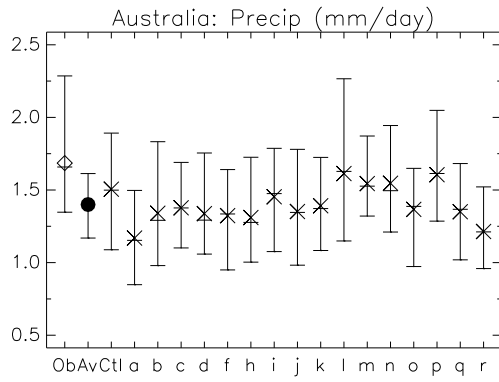
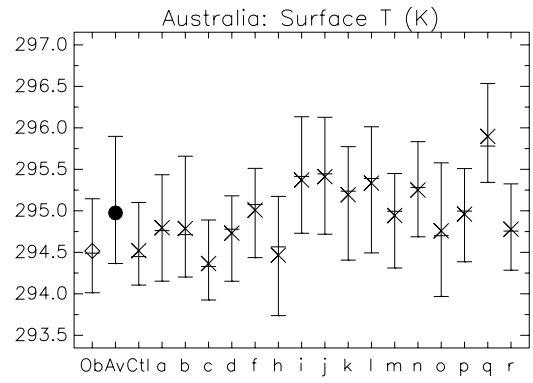
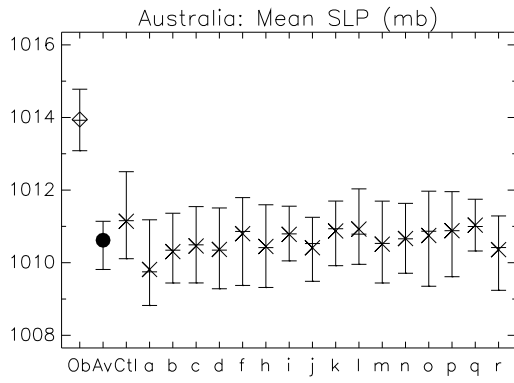
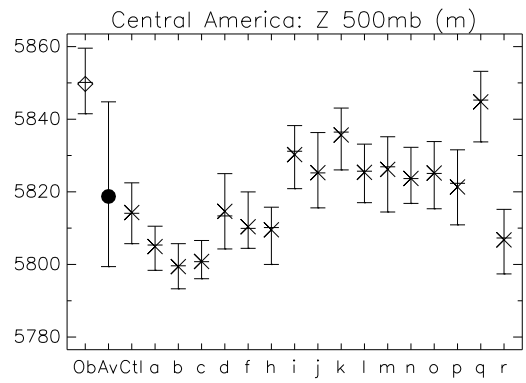
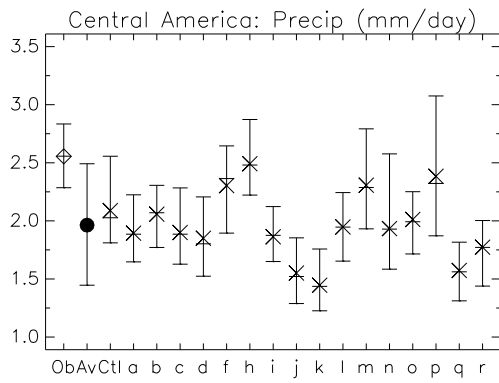
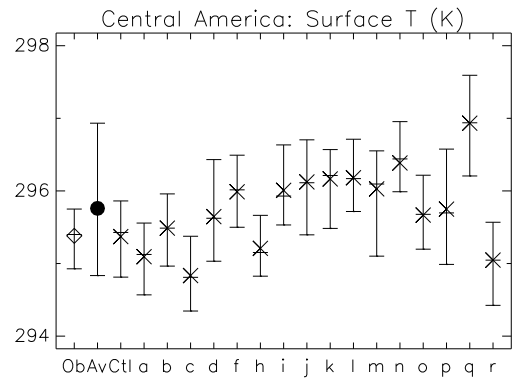
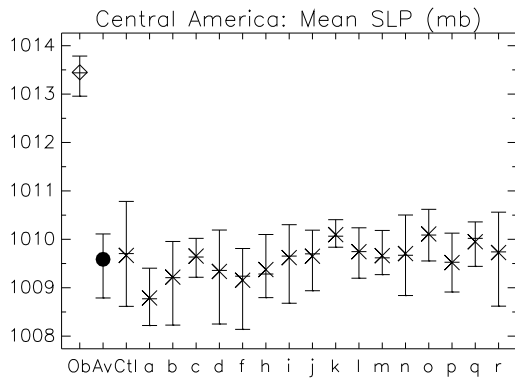
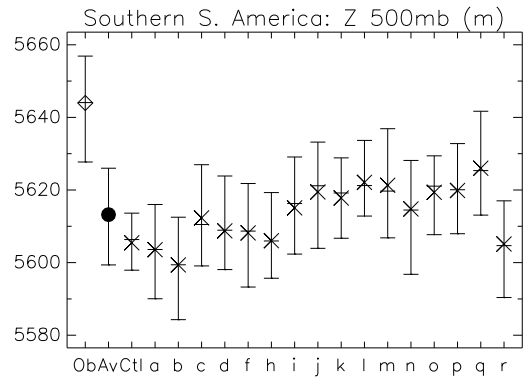
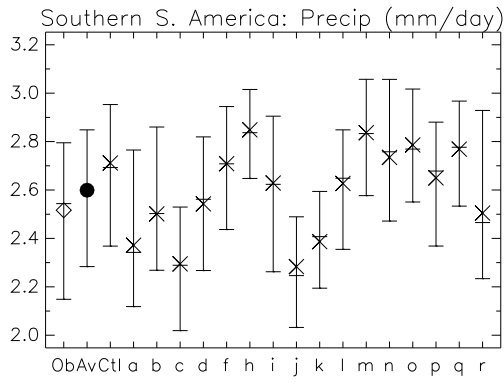
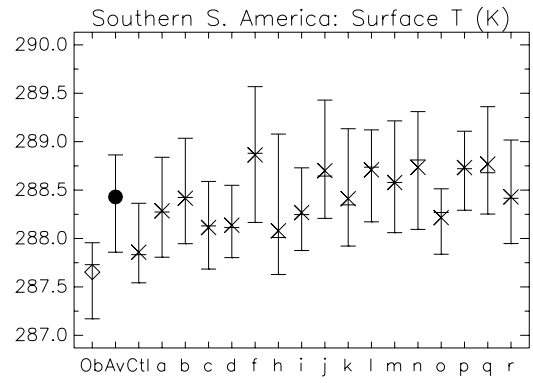
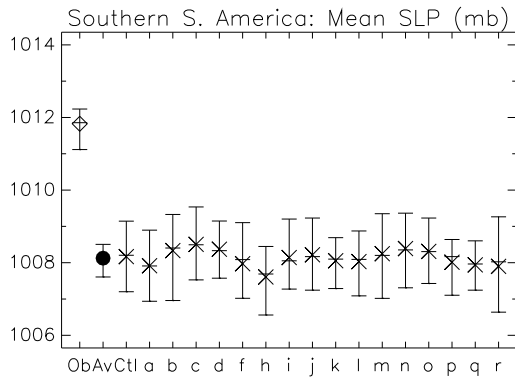
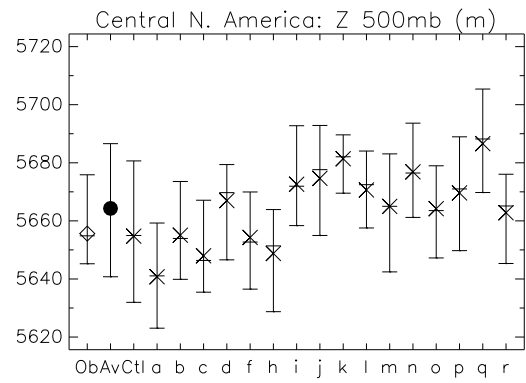
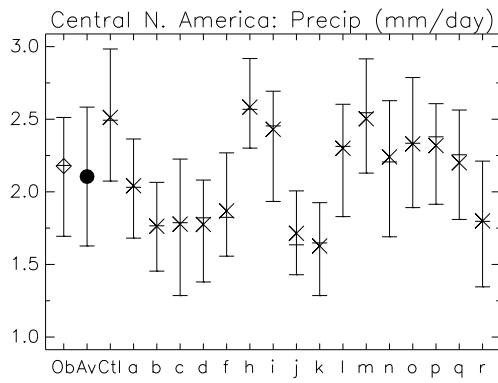
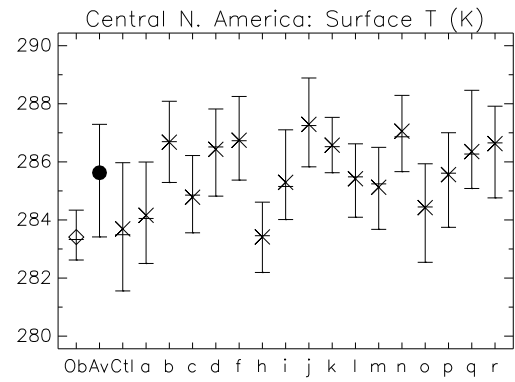
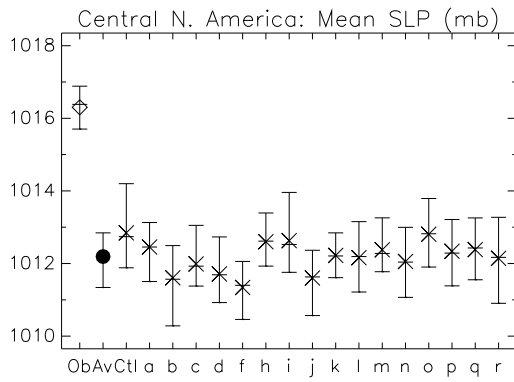
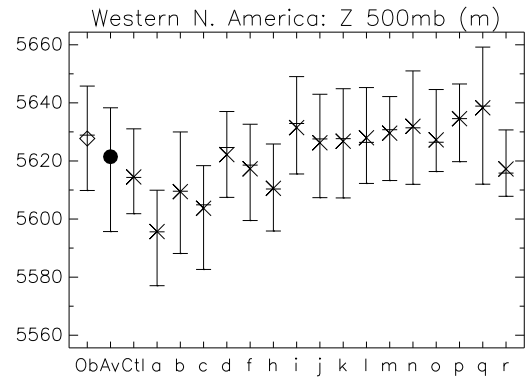
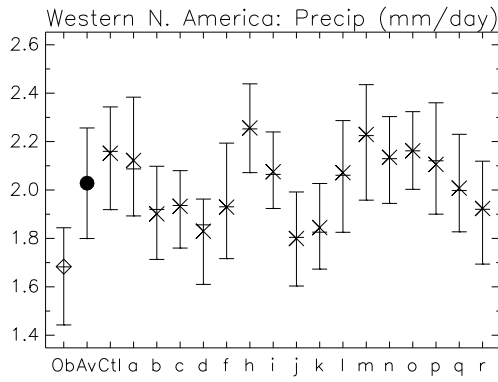
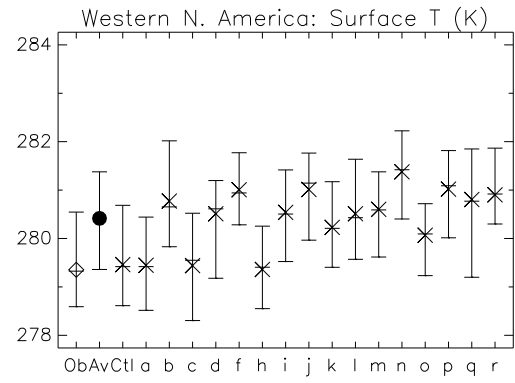
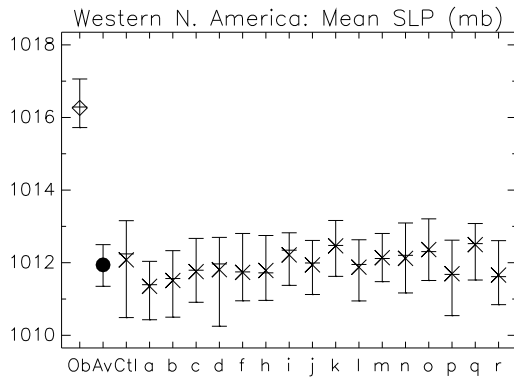


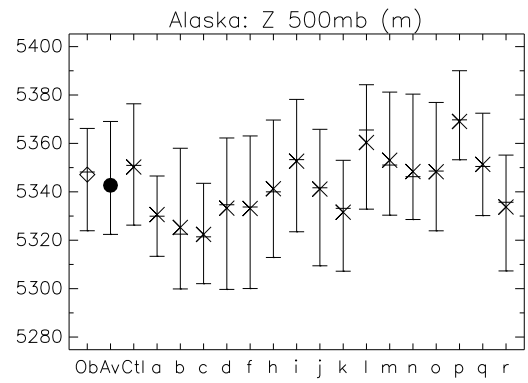
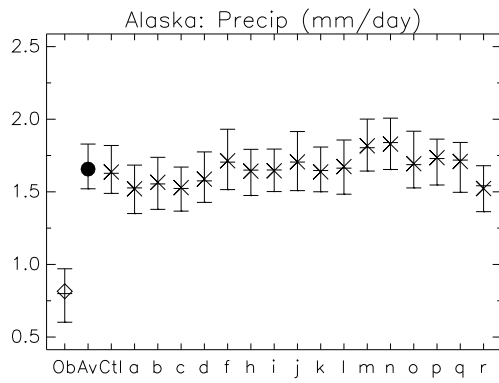
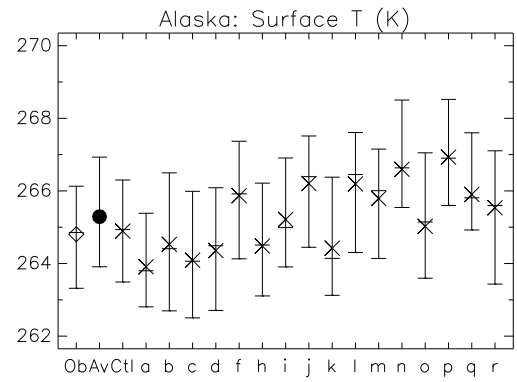
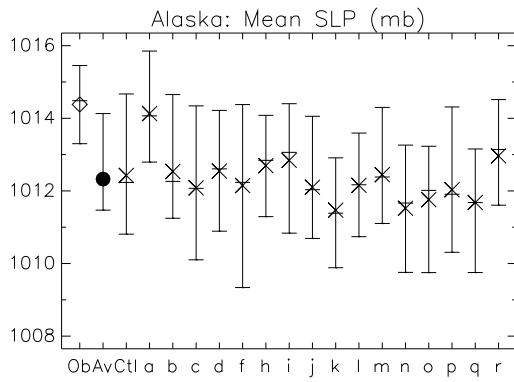
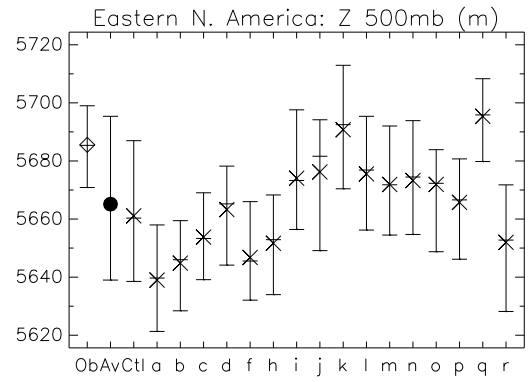
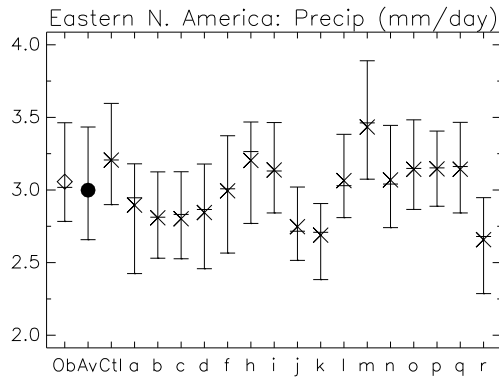
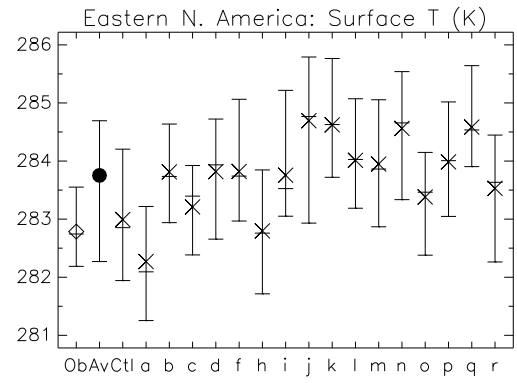
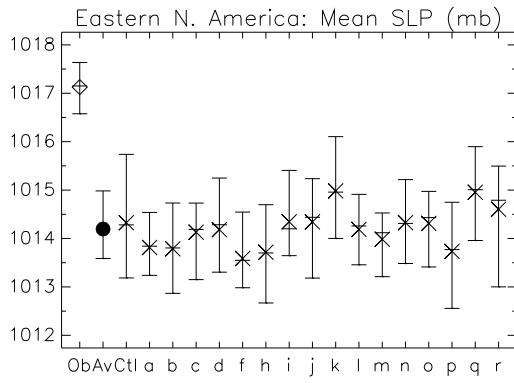
Figure 2. Average bias (triangles) and root mean square errors (rmse; plus signs) averaged across the entire Qump ensemble, for the regions illustrated in Figure 1.

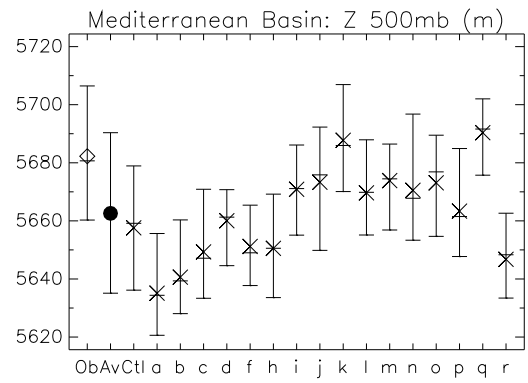
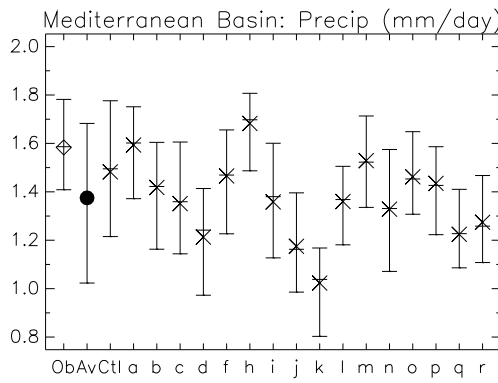
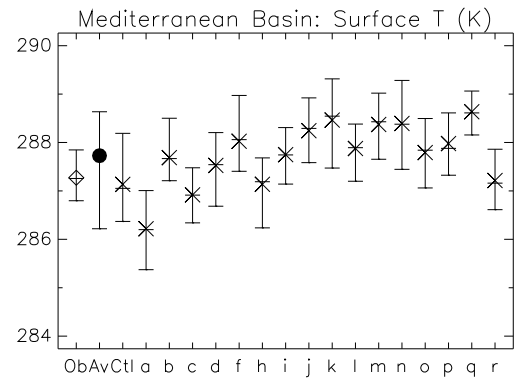
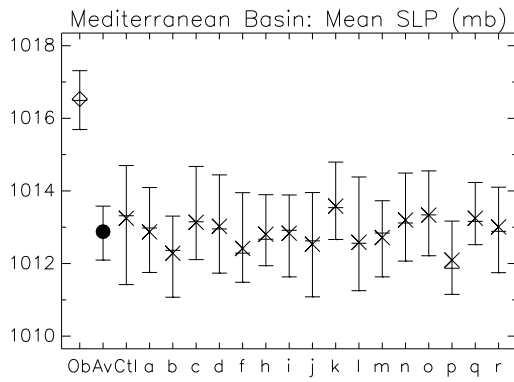
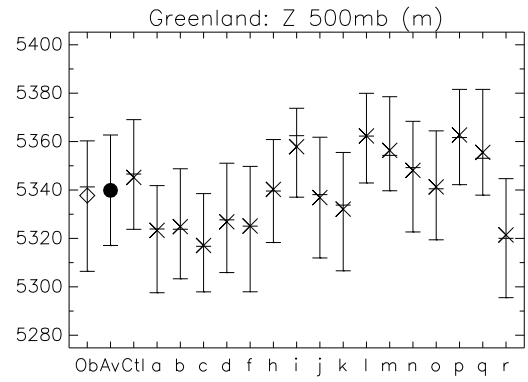
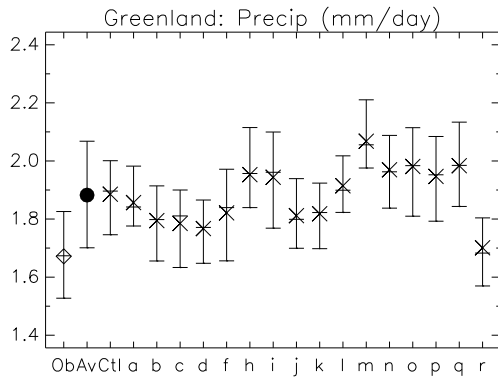
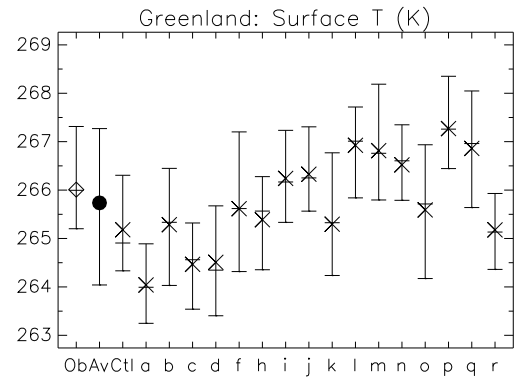
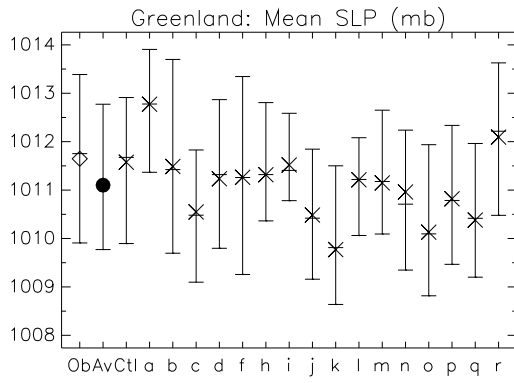
Figure 3 (on following pages). Comparison of observations and Qump 17-member ensemble, using annual mean values for each of the given areas. The central symbol (diamond for Observations (Ob), solid circle for the ensemble mean (Av), and a cross for each individual ensemble member) represents the mean value, and the central horizontal bar the median. The first ensemble member is an unperturbed simulation, and is marked as ‘Ctl’ on the x-axis. The error bars (on both the observations and model results) represent the 5th and 95th percentile values, except for the ensemble mean, where the bars show the maximum and minimum mean values of the entire ensemble, and so represent the uncertainty of the ensemble as a whole. The four variables shown are mean sea level pressure (Mean SLP), surface temperature (K), precipitation (mm/day), and height at a pressure of 500 mbar.

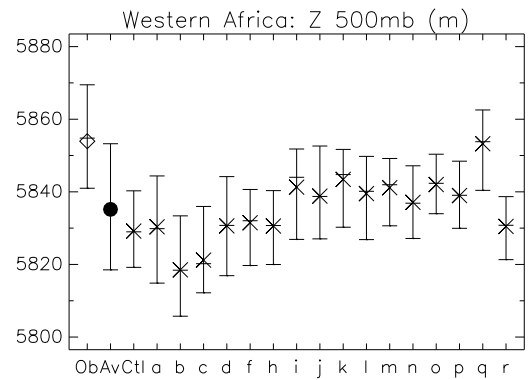
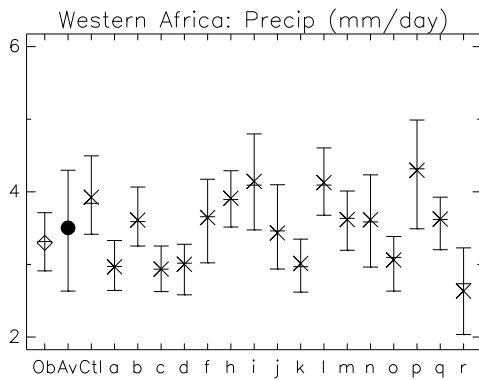
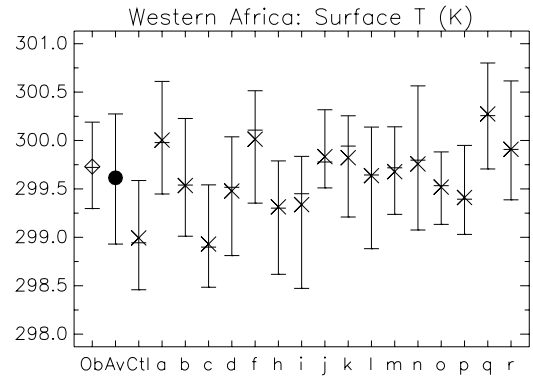
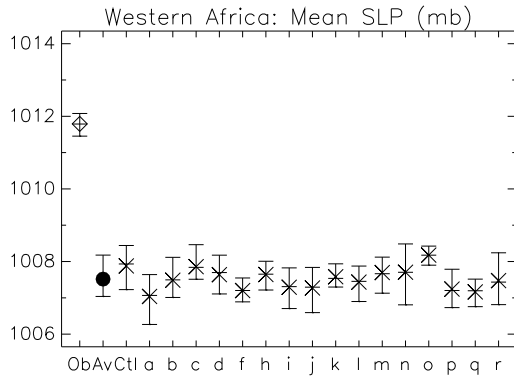
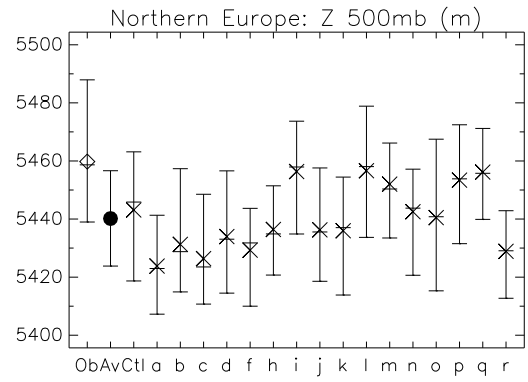
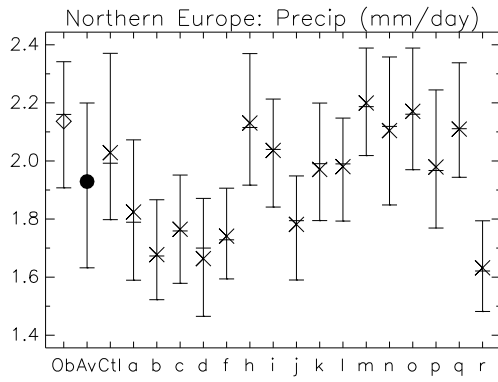
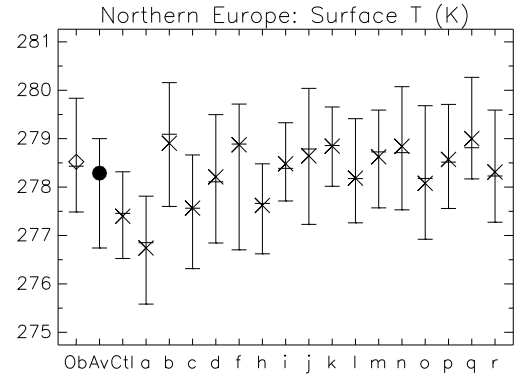
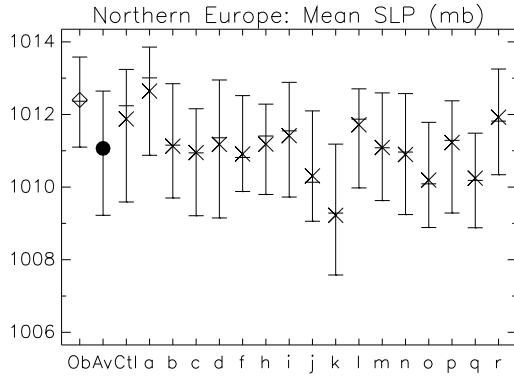


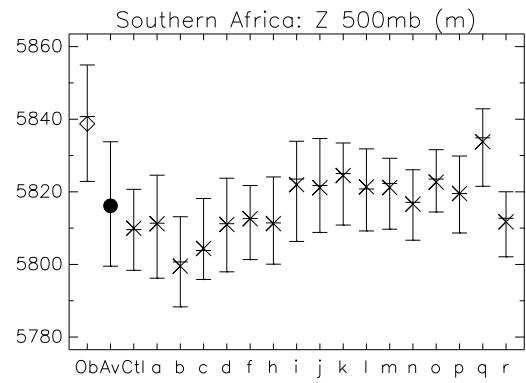
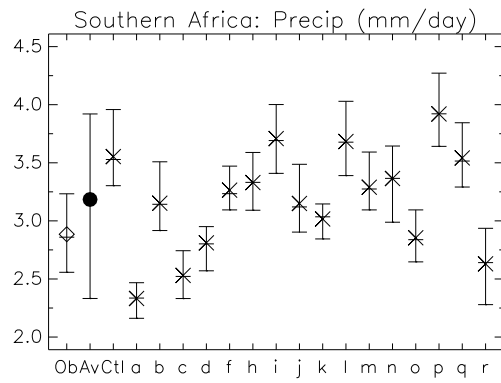
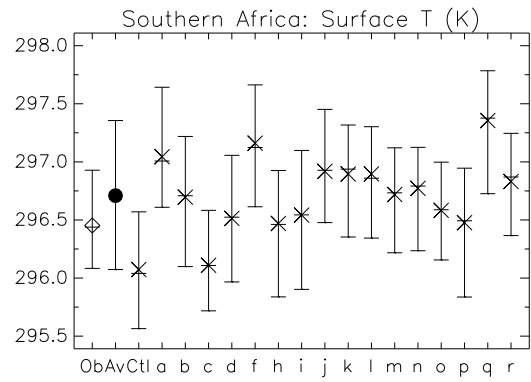
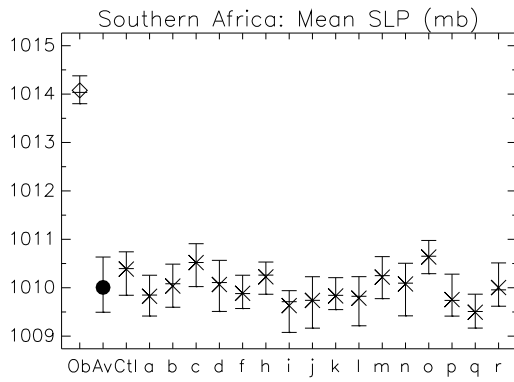
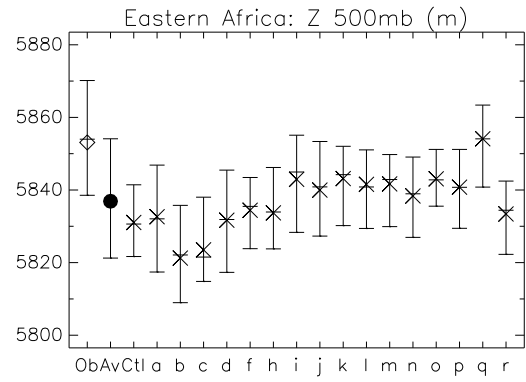
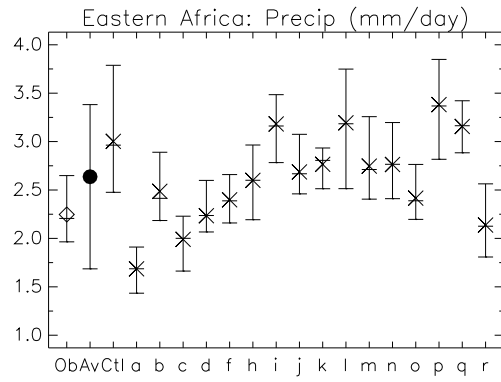
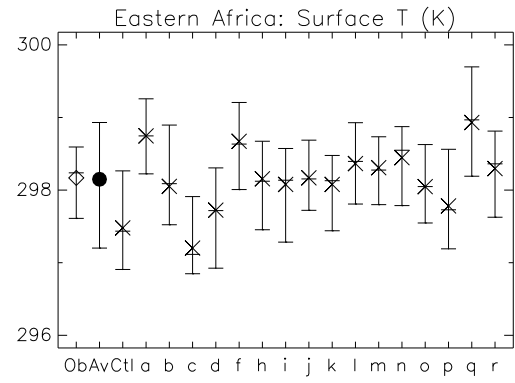
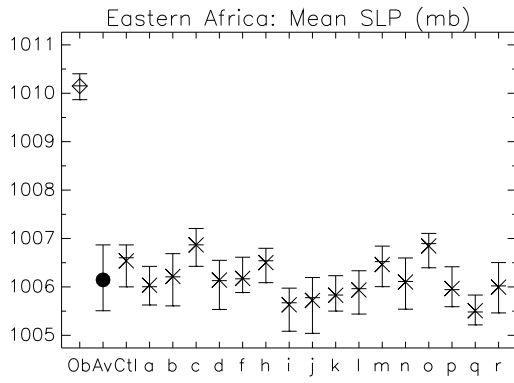


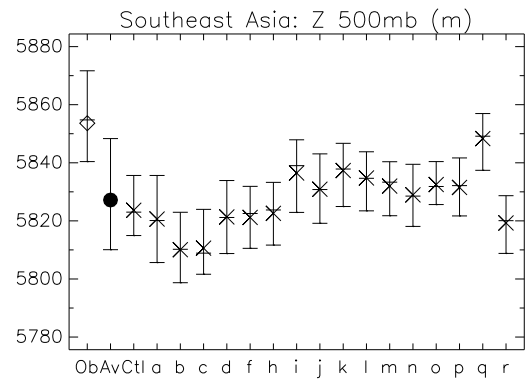
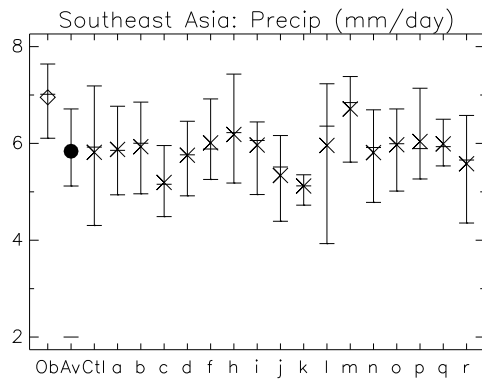
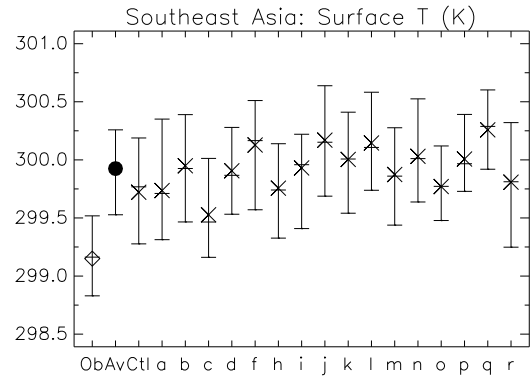
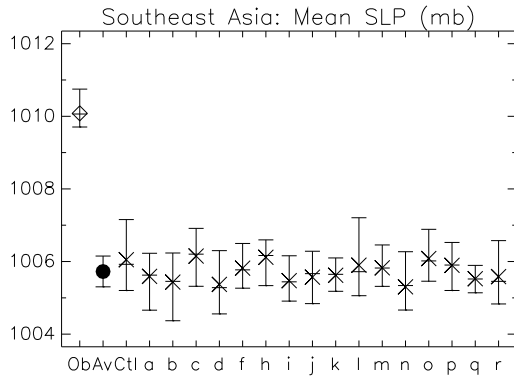
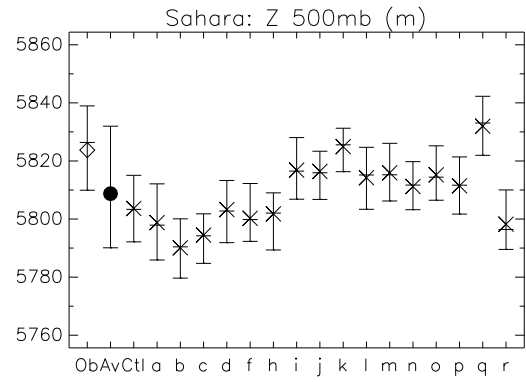
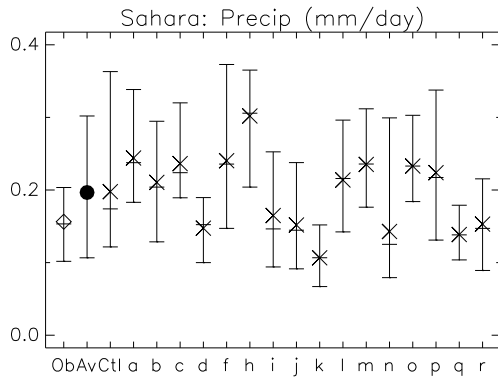
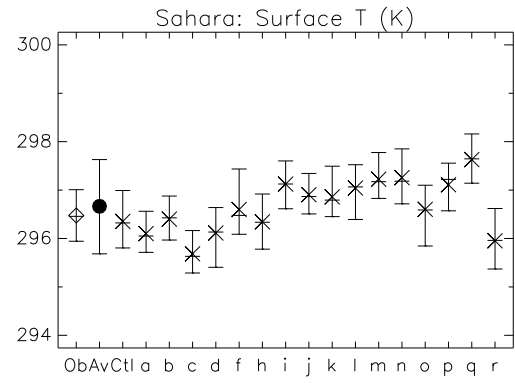
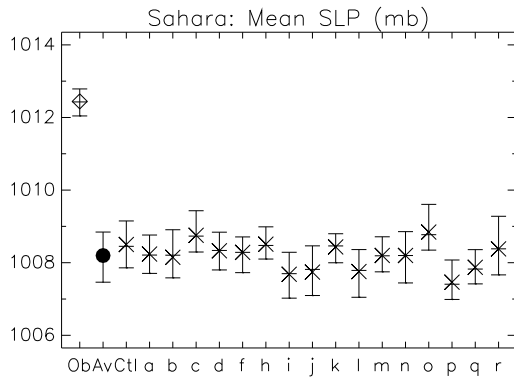


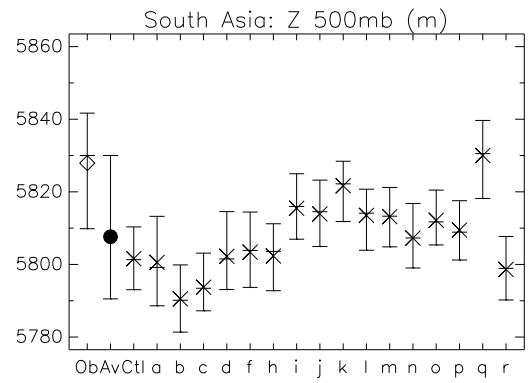
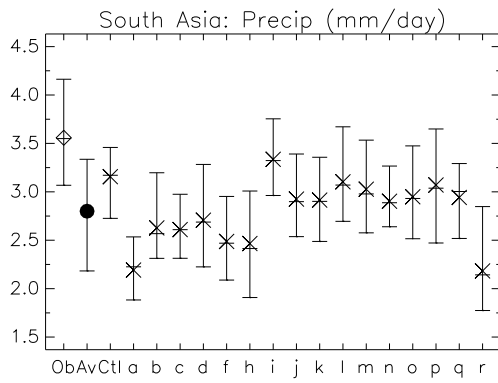
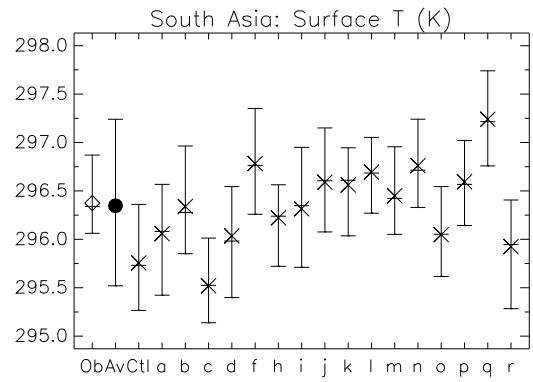
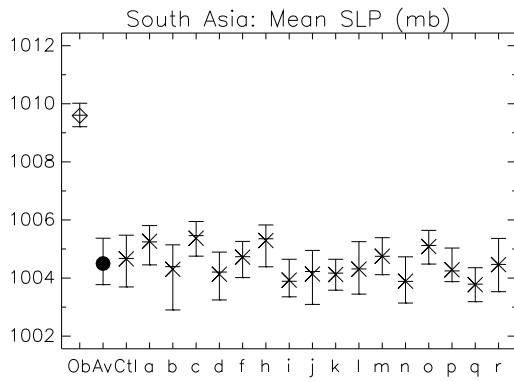
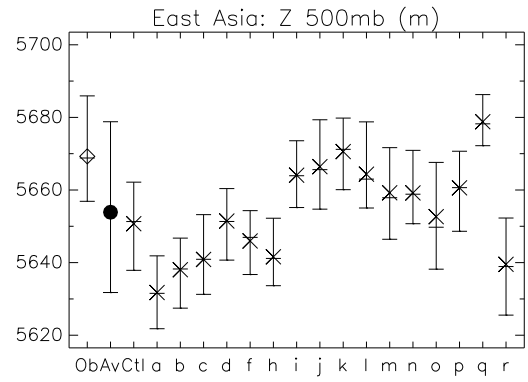
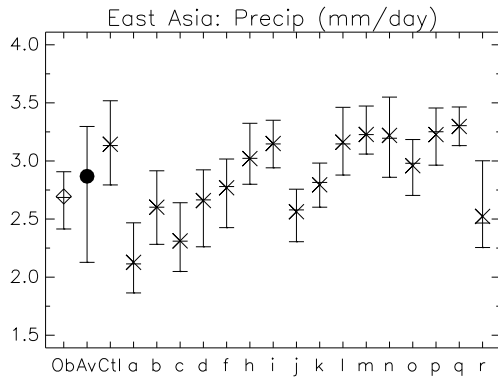
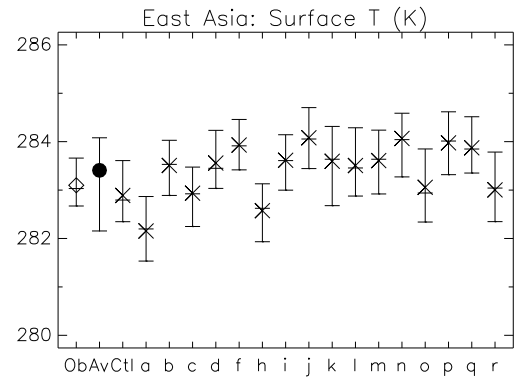
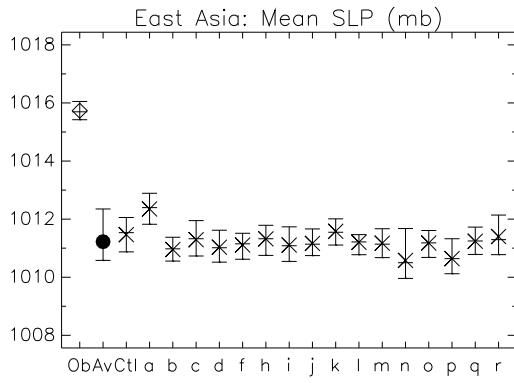


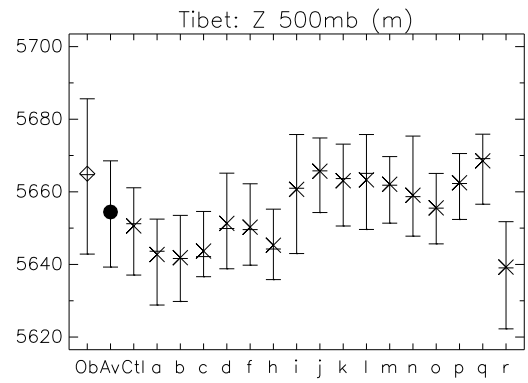
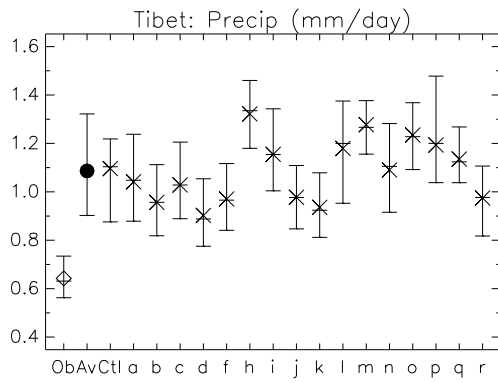
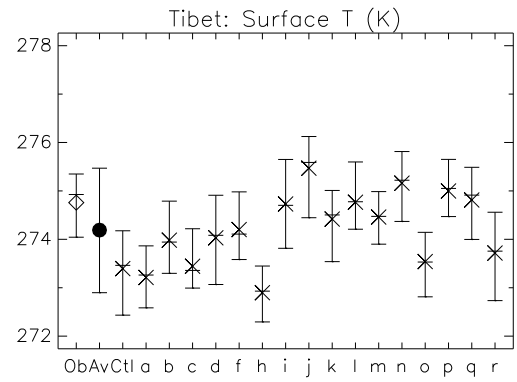
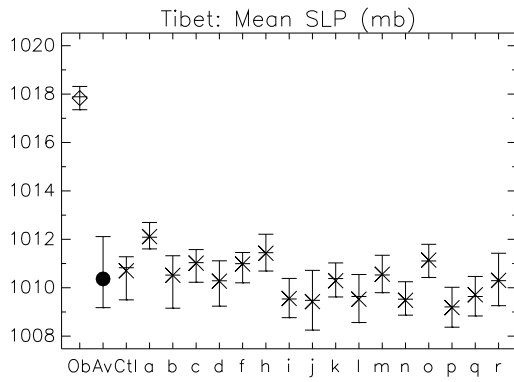
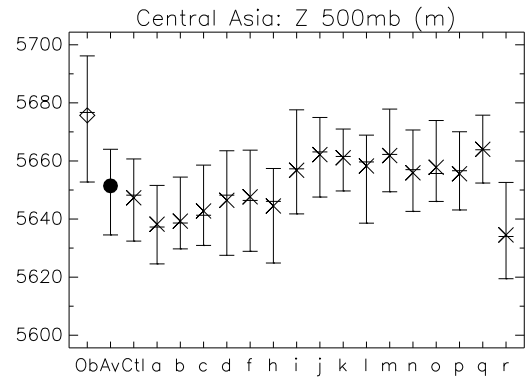
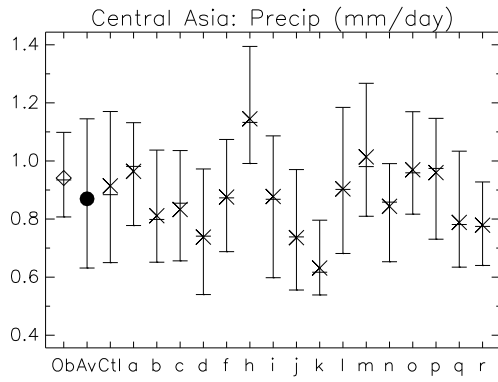
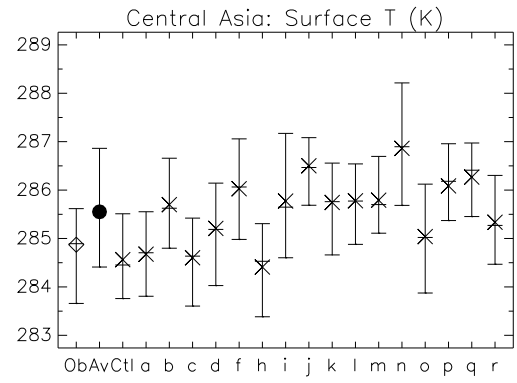
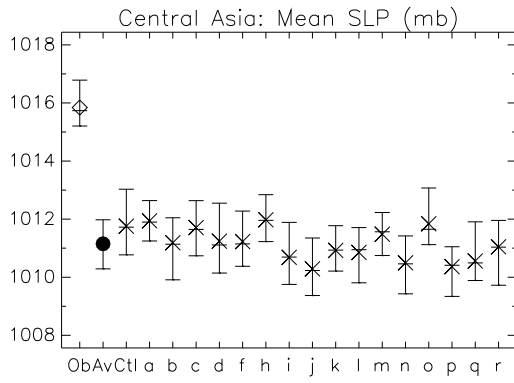


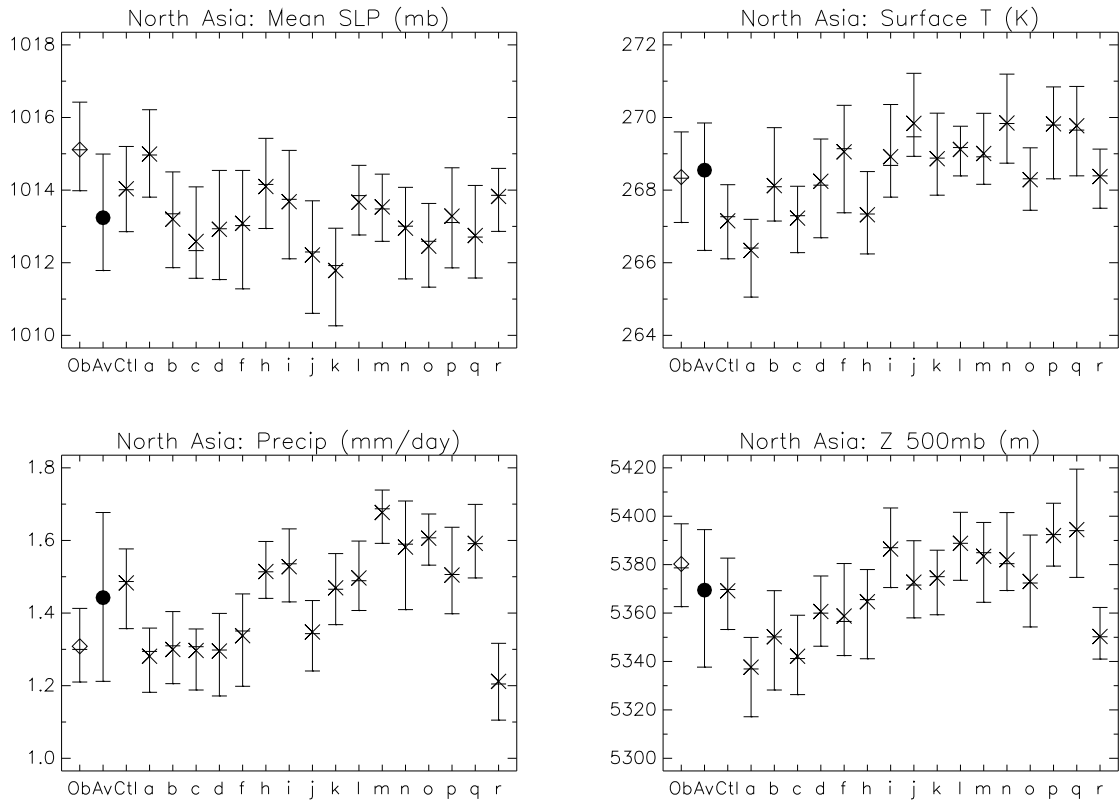












Monthly Mean Results

An analysis by month was also performed, using a similar approach to that described above. For each land region (see Figure 1 and Table 1) a mean value of each climate variable was calculated for each month in every year from both the observations and modelled results. From these series of monthly and regionally averaged values, the overall mean, median, 5th and 95th percentile values of each climate variable were calculated. The results are shown in Figure 4. The observations are represented by the diamonds and the corresponding 5th-95th percentile range by the error bars. The mean results for each ensemble member are shown in grey, and the ensemble mean is shown by the thick red line. The two thin red lines show the 5th-95th percentile range of the entire ensemble.

Overall, the ensemble range (relative to the observations) for surface pressure and precipitation is greater than that for surface temperature and height at 500 hPa for most regions, the exceptions being Africa and south-east Asia. The ensemble also underestimates the surface pressure over most regions, for the reasons explained above.

For the regions which cover North and Central America (GRL, ALA, WNA, CNA, ENA and CAM), the Qump ensemble reproduces the temperature and height at 500 hPa very well, although it tends to overestimate the summer values. There is a large range of values for precipitation for most regions, although the ensemble mean values are close to the observations. However, the ensemble generally underestimates the highest precipitation values measured between June and September over Central America.

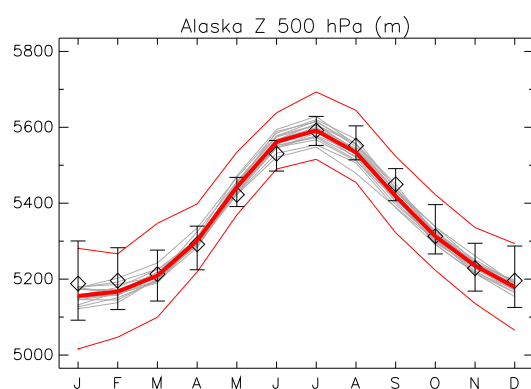
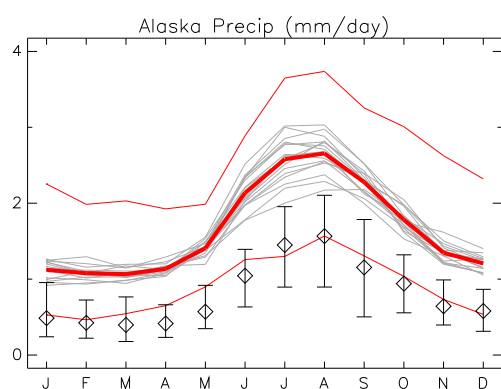
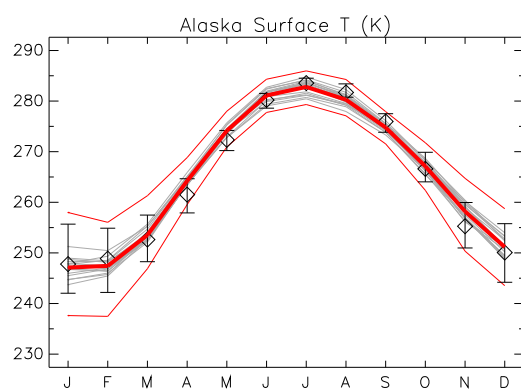
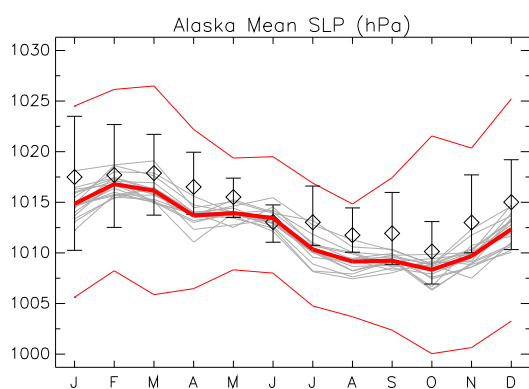
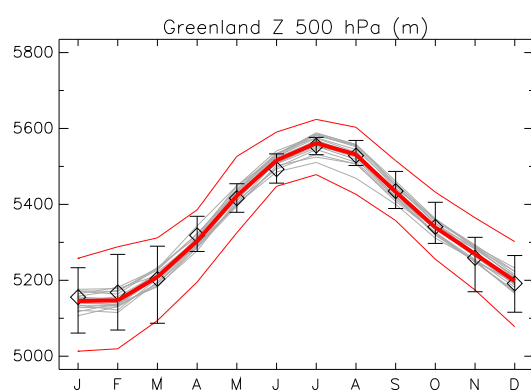
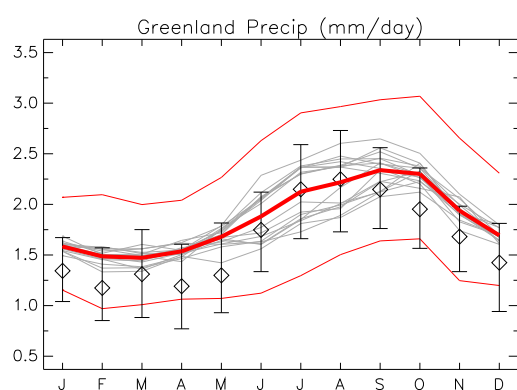
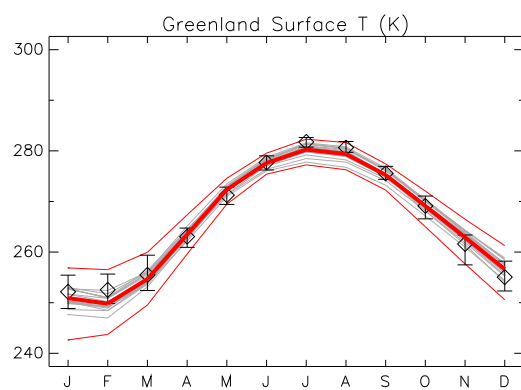
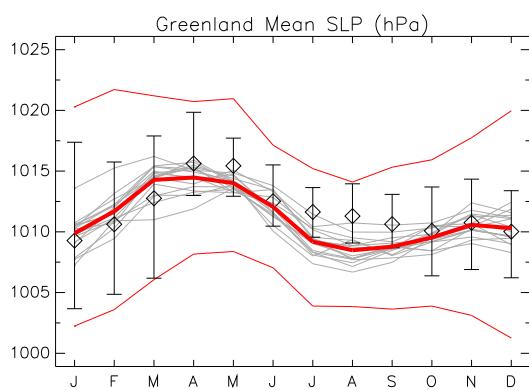
For South America (AMZ), there is considerable spread amongst the ensemble for all four variables. The range of temperatures observed is captured by some ensemble members, but others overestimate the minimum in June, July and August. The ensemble tends to underestimate precipitation, but some members do agree well with the observations. The height at 500 hPa is also underestimated. Over southern South America (SSA), the ensemble reproduces the observed values more accurately. The height at 500 hPa is underestimated, although the observations lie within the range of the ensemble.

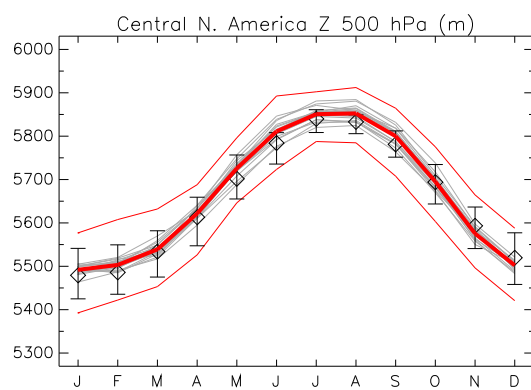
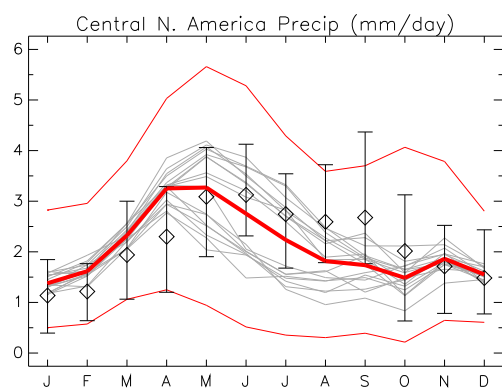
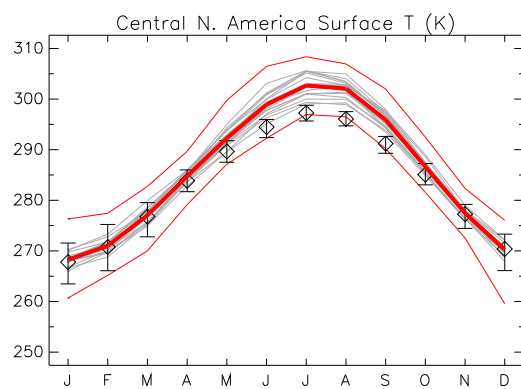
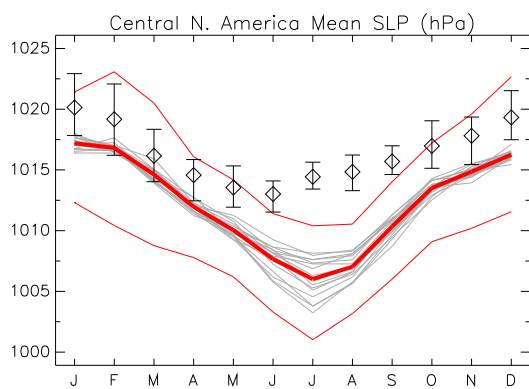
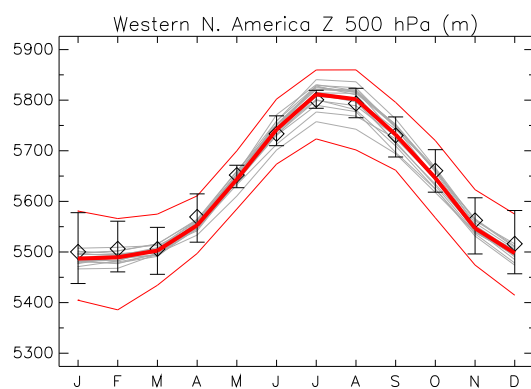
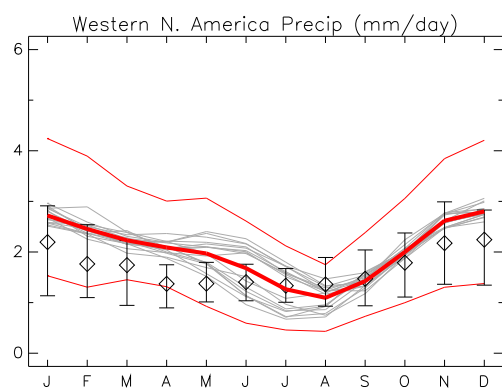
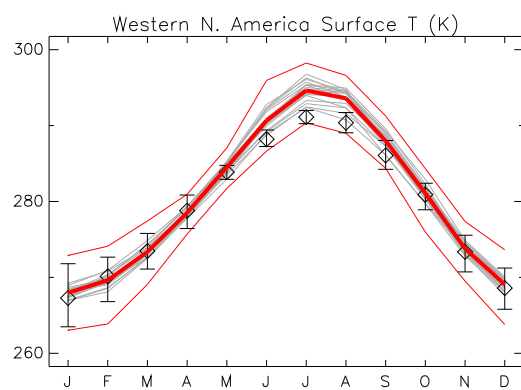
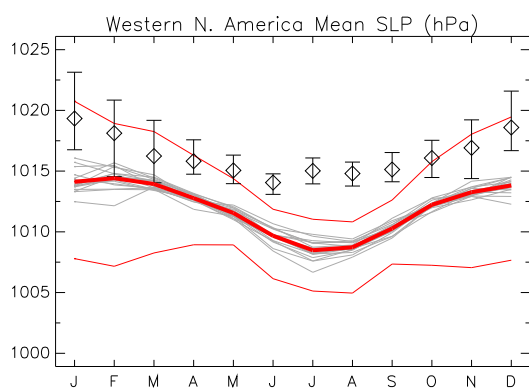
Europe is represented by the regions NEU and MED. For NEU, the Qump ensemble reproduces the observed climate very well, except for precipitation. The ensemble members lie in 2 distinct groups, but neither reproduces the observed monthly cycle of the precipitation. For the Mediterranean area (MED), the ensemble again reproduces the observed climate, including precipitation, but slightly underestimates the surface pressures.

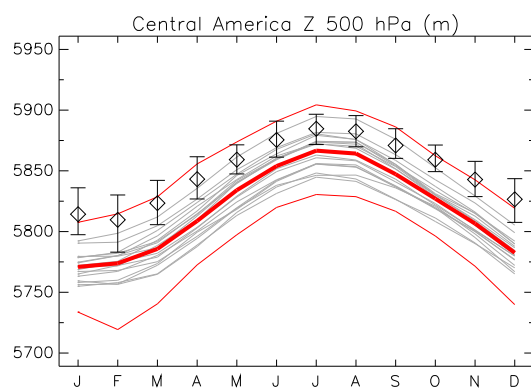
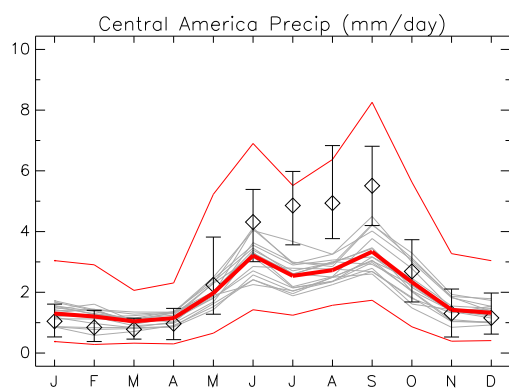
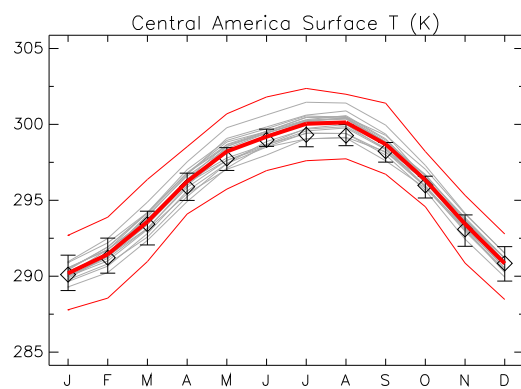
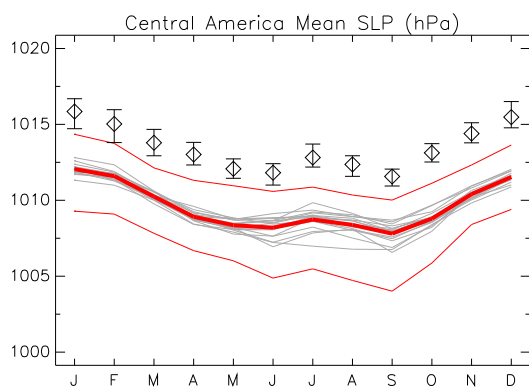
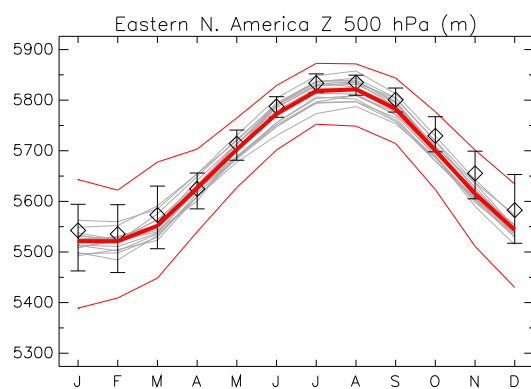
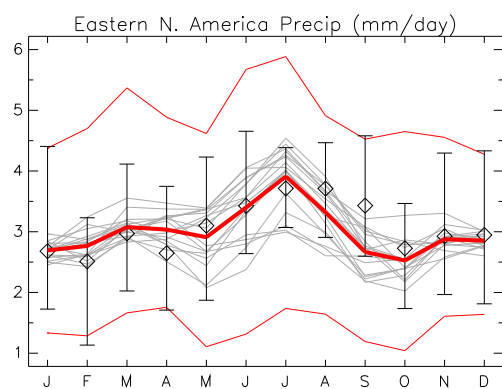
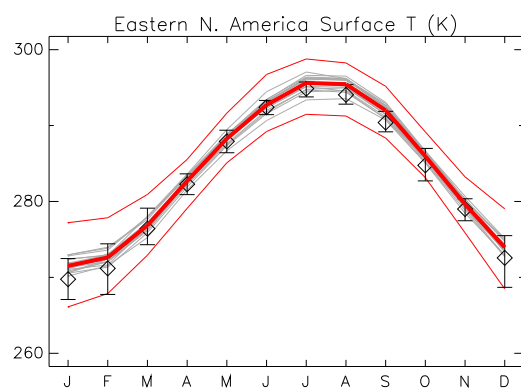
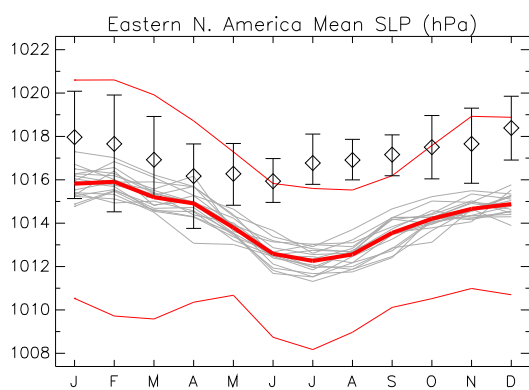
For the African regions (SAH, WAF, EAF and SAF), there is a much greater spread in the results between the ensemble members than for most other regions. The ensemble reproduces the observed surface temperatures very well, and captures the monthly cycle in the other three climate variables, except for precipitation over the Sahara (SAH), where there is very large variation between the ensemble members (as evidenced by the width of the 5th-95th percentile range, shown by the thin red lines). The ensemble tends to underestimate the heights at 500 hPa pressure and surface pressure.

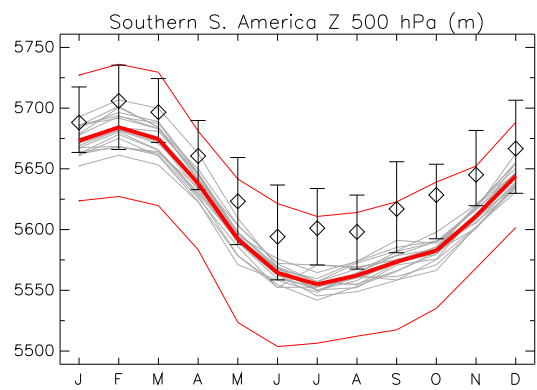
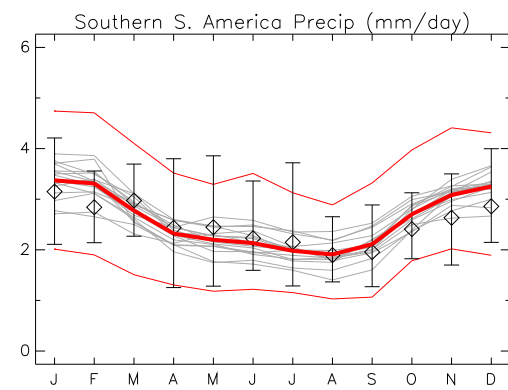
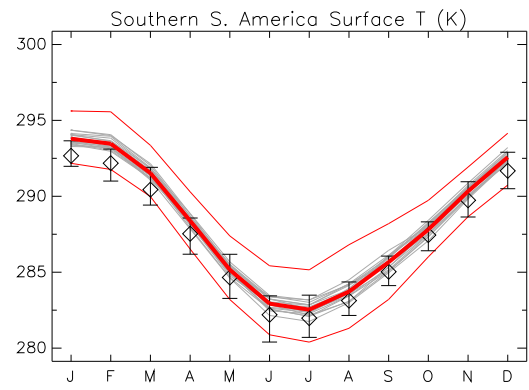
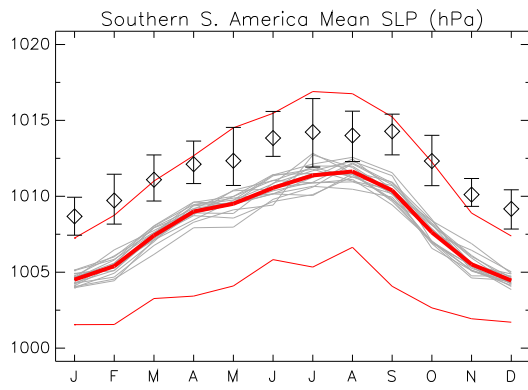
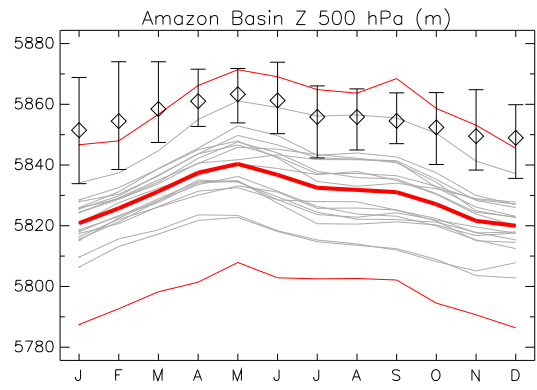
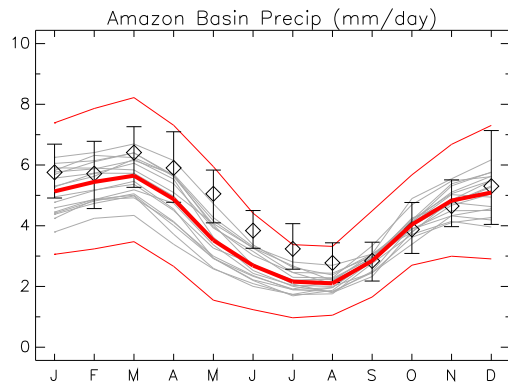
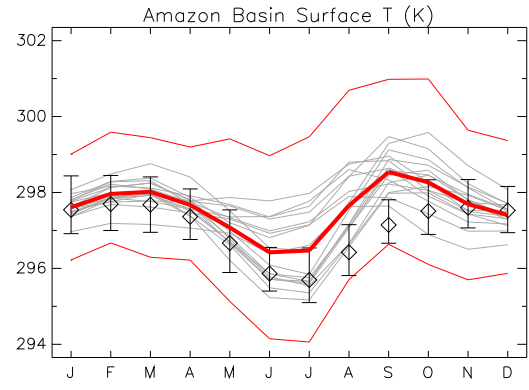
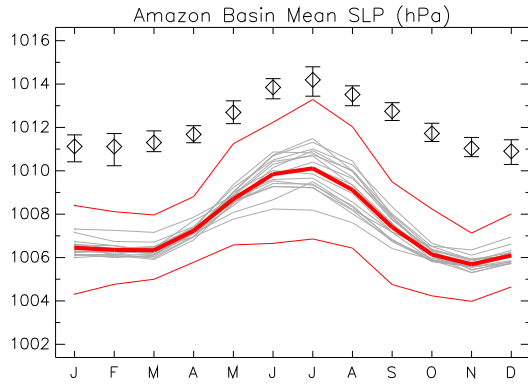
Over most of the Asian regions (NAS, CAS, TIB, SAS, EAS and SEA), the ensemble reproduces the climate accurately, except for precipitation over Tibet and central Asia. The ensemble performs the worst over south-east Asia (SEA), where it overestimates surface temperature by approximately 1 °C, and underestimates the height at 500 hPa. Finally, the ensemble reproduces the climate of Australia (AUS) accurately, although it does underestimate the 500 hPa height and surface pressure.

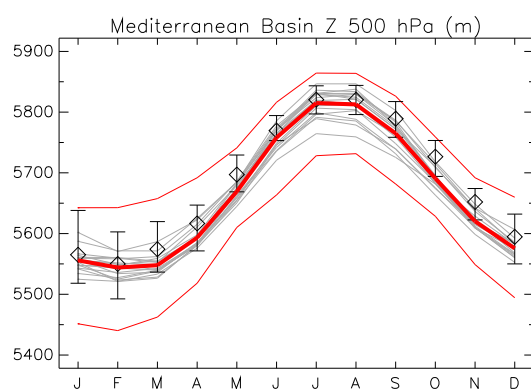
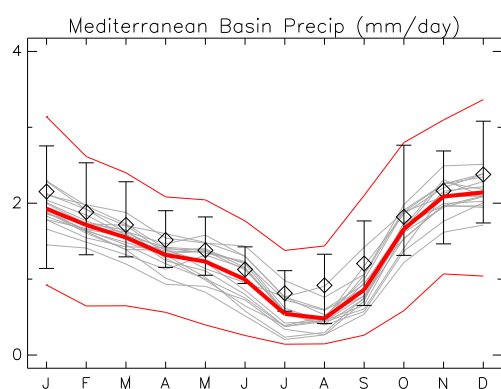
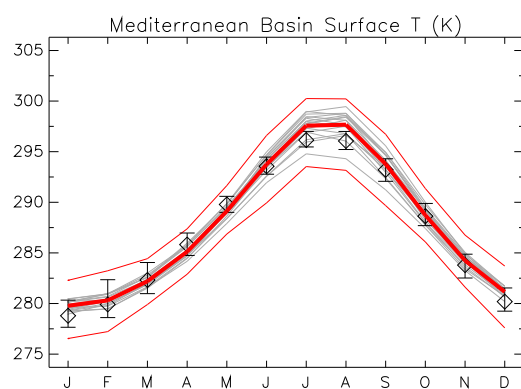
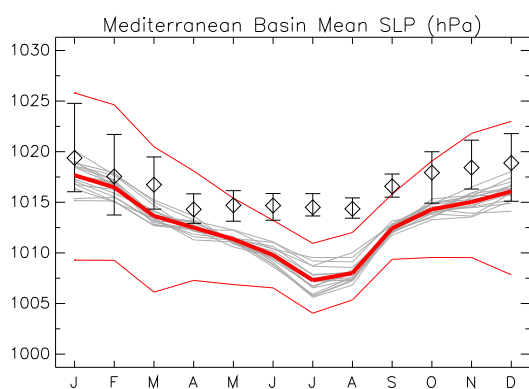
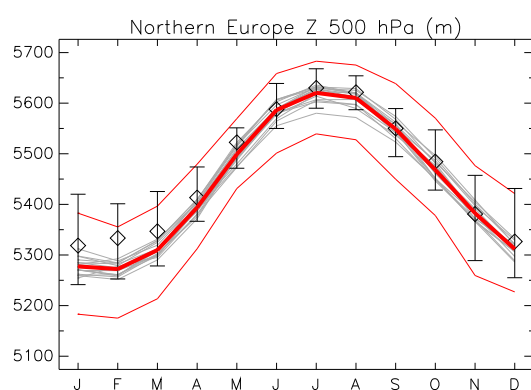
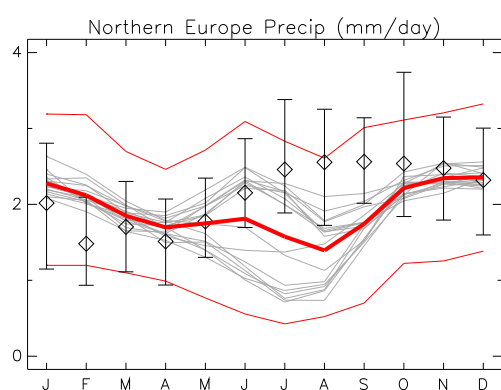
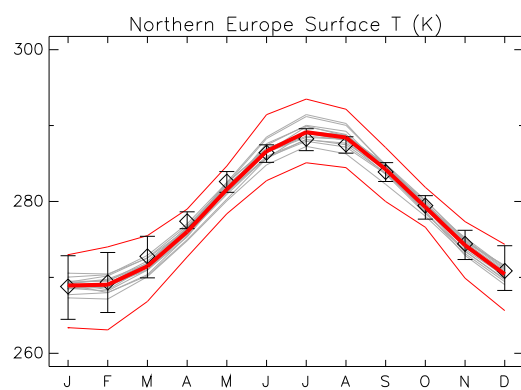
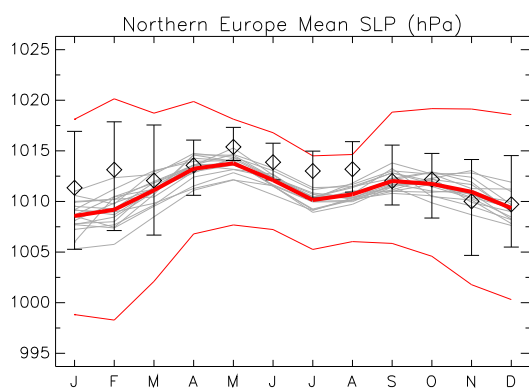
Figure 4 (on following pages). Comparison of monthly mean results from Qump ensemble with observations for the period 1961-1990, averaged over the areas illustrated in Figure 1 (which are listed in Table 1). The averages were calculated by weighting each model result within the area by the cosine of the latitude, as described by Giorgi and Francisco (2000). The observations and corresponding 5th-95th percentile range are illustrated by the black diamonds and vertical bars respectively. The mean results for each ensemble member are illustrated by the light grey lines, and the mean of the whole ensemble is shown by the thick red line. The thin red lines show the 5th and 95th percentile range of the entire ensemble.

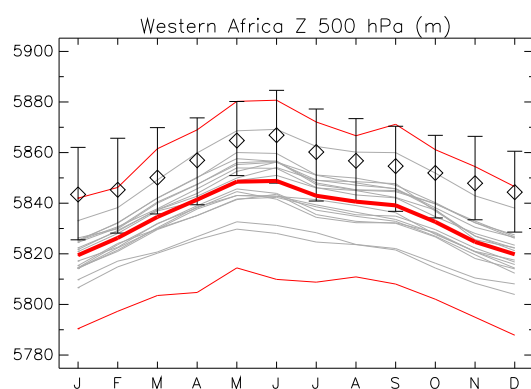
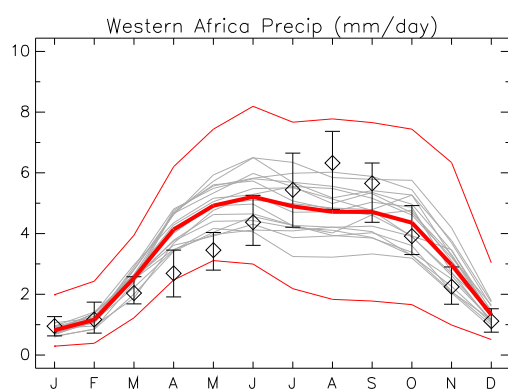
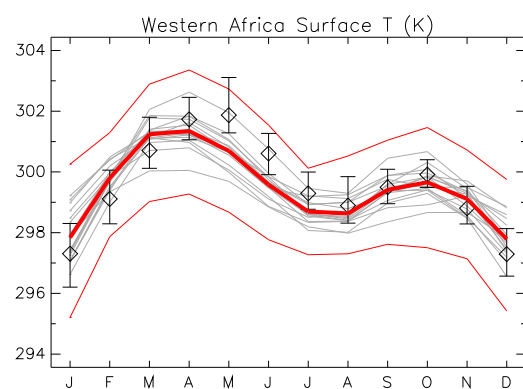
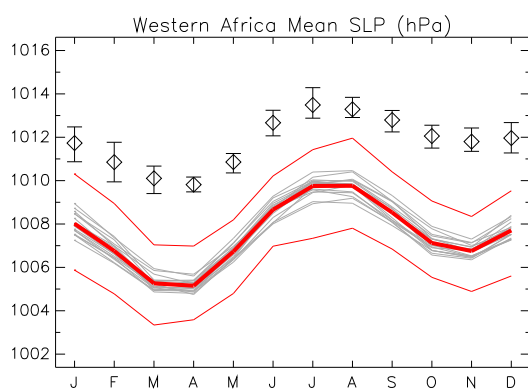
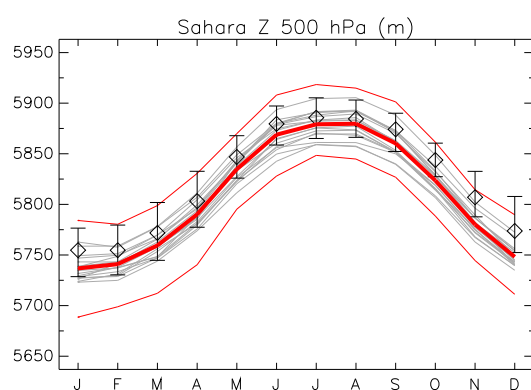
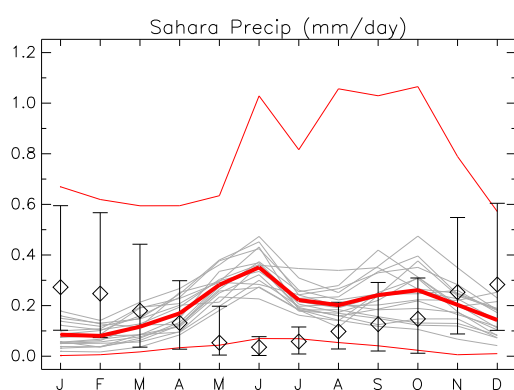
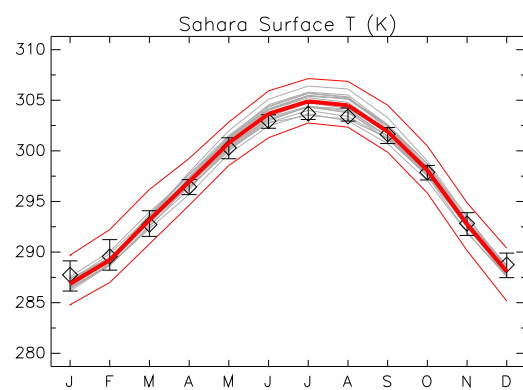
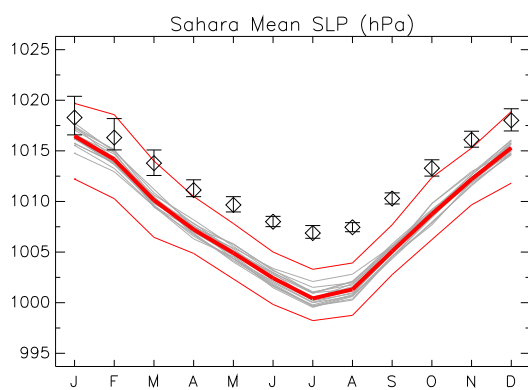


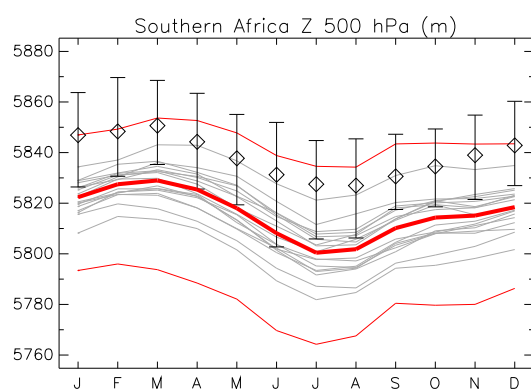
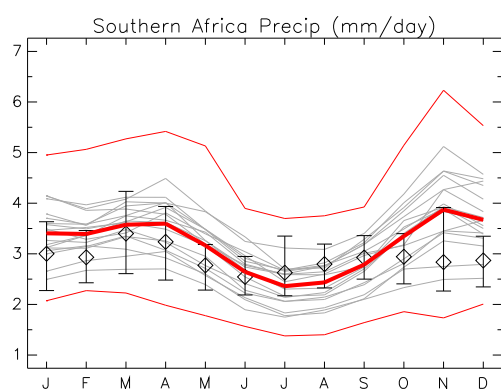
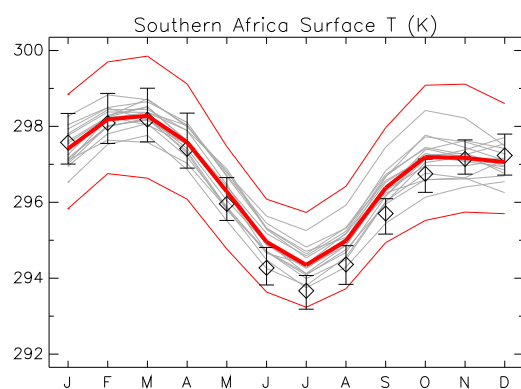
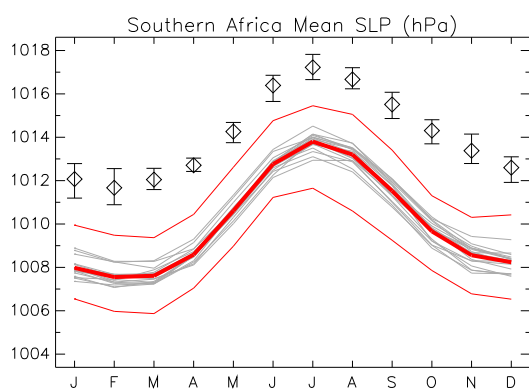
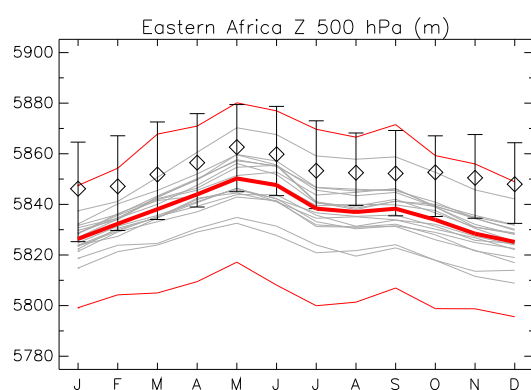
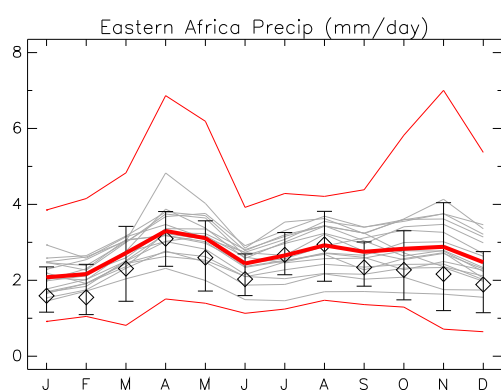
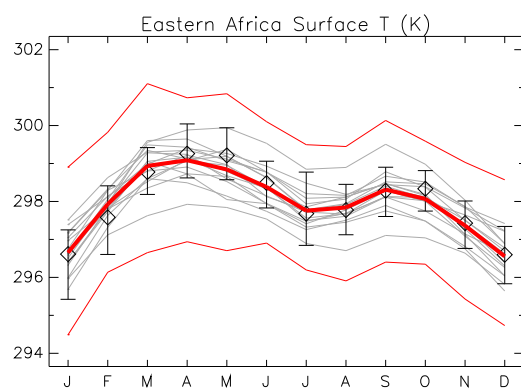
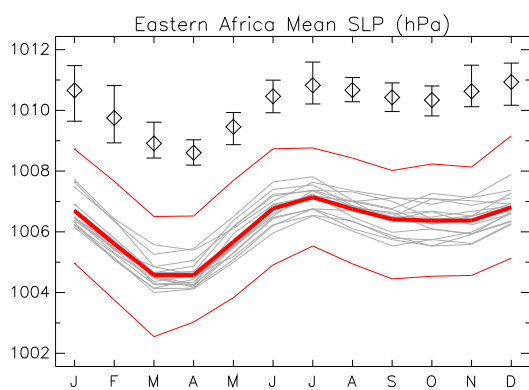


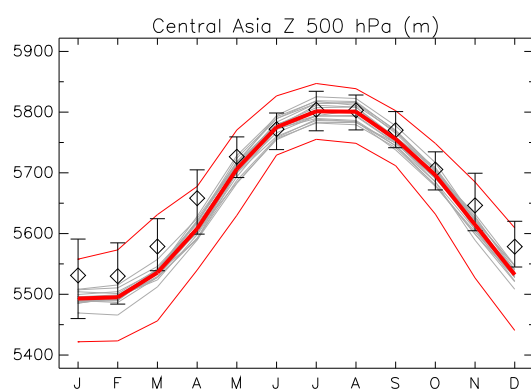
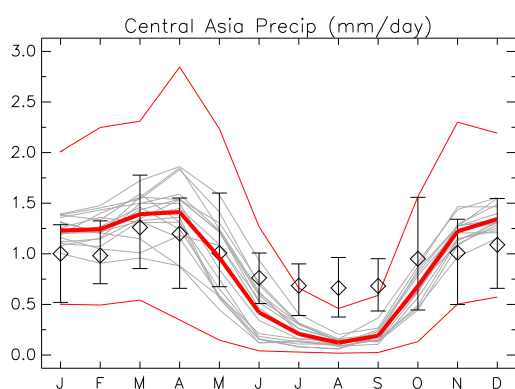
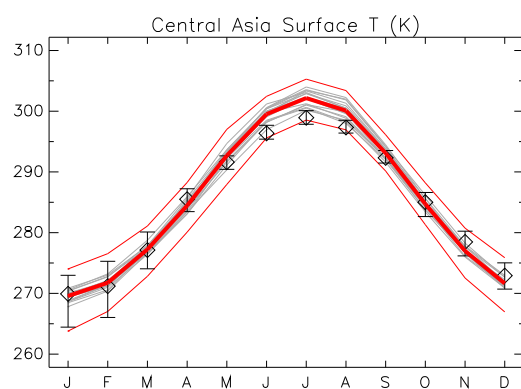
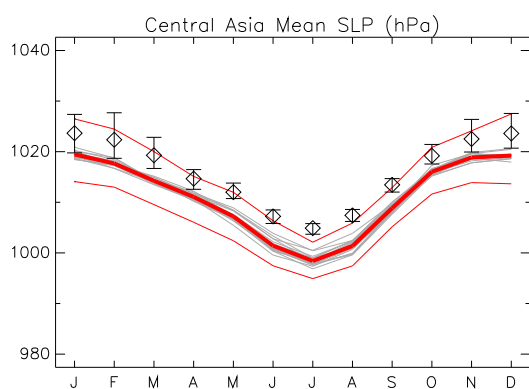
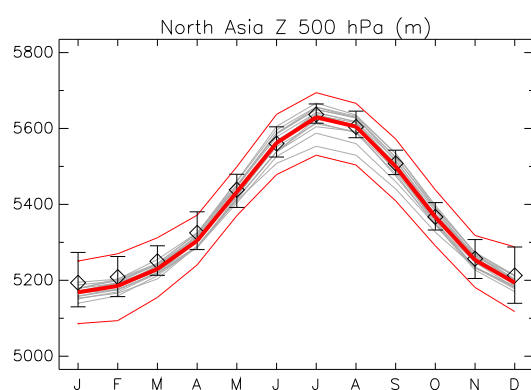
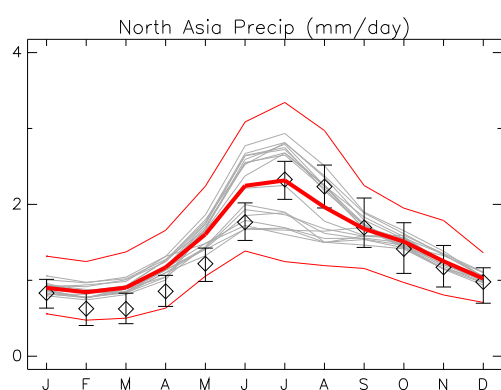
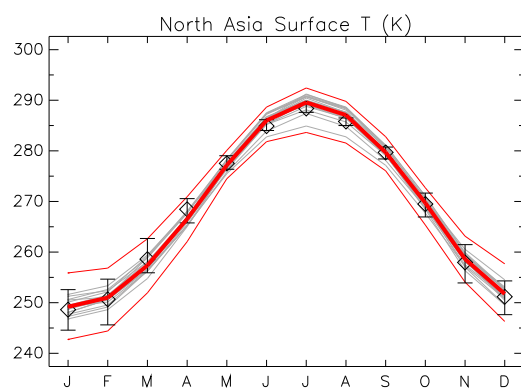
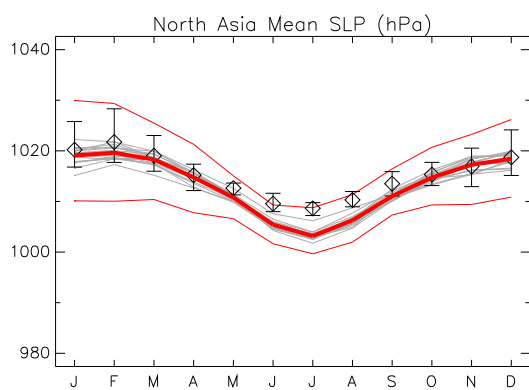


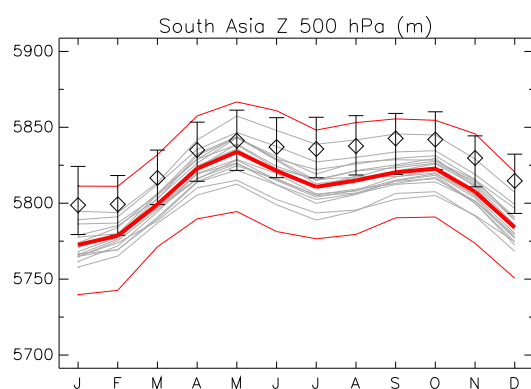
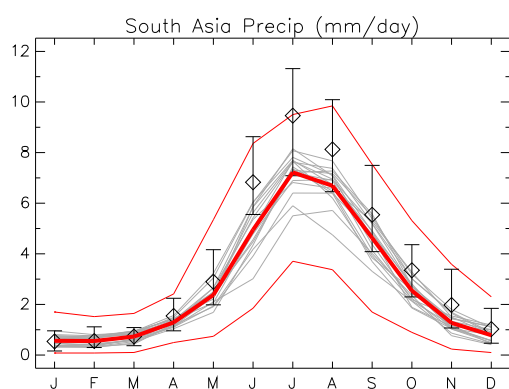
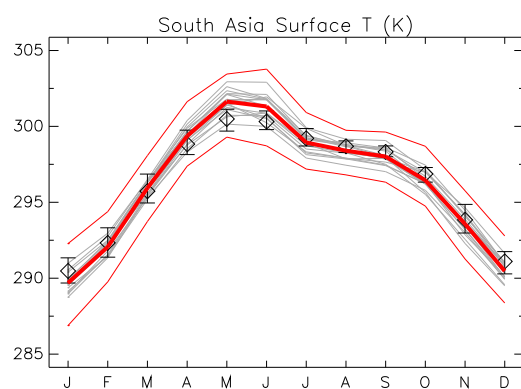
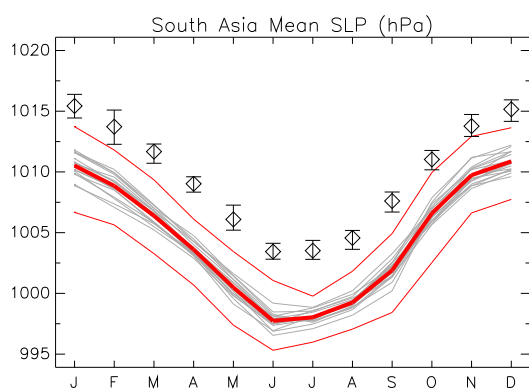
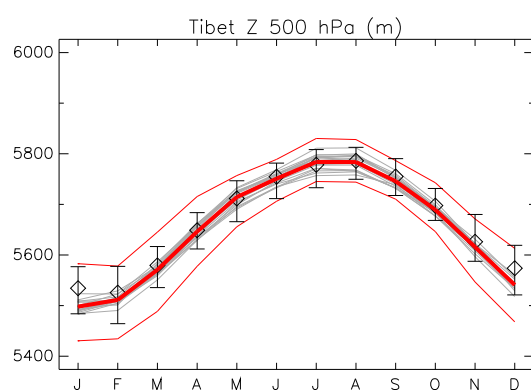
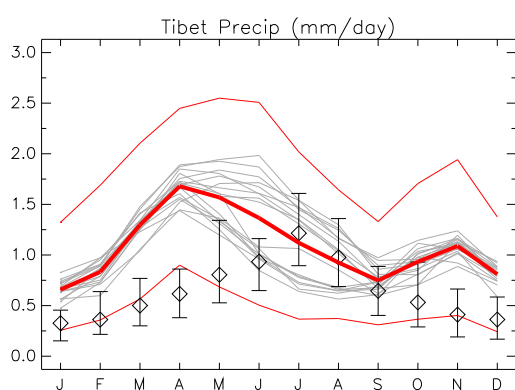
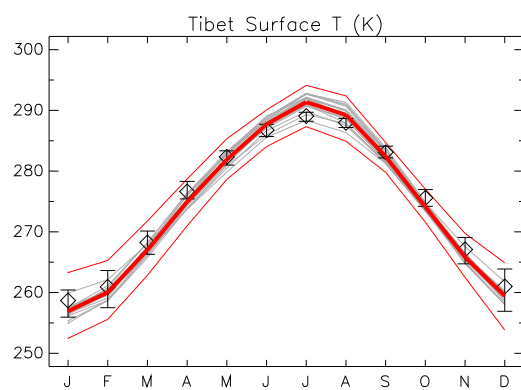
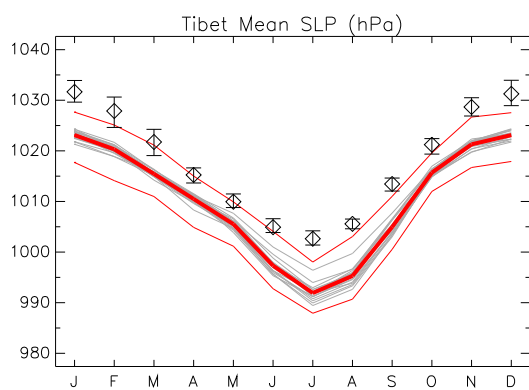


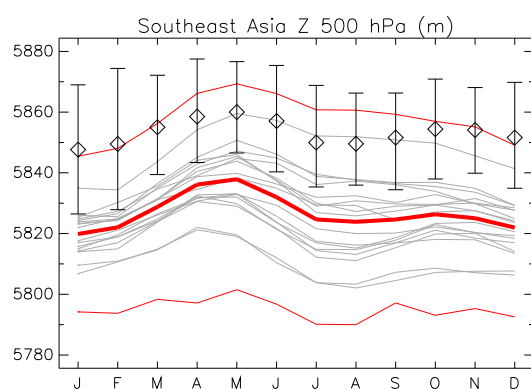
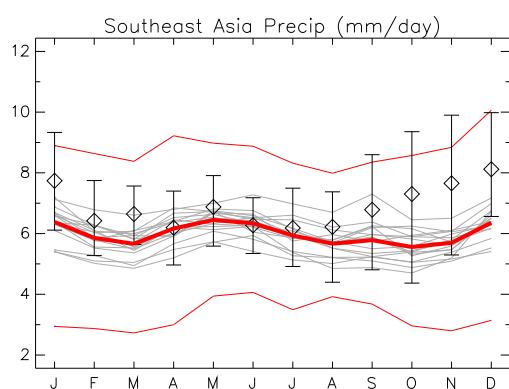
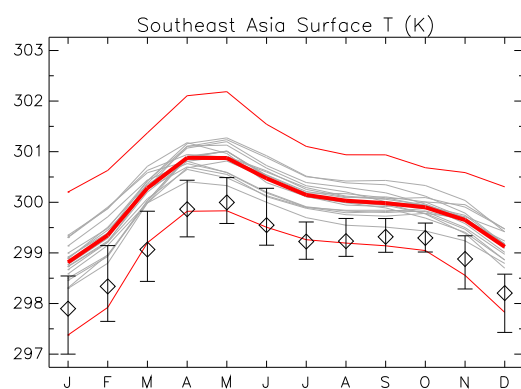
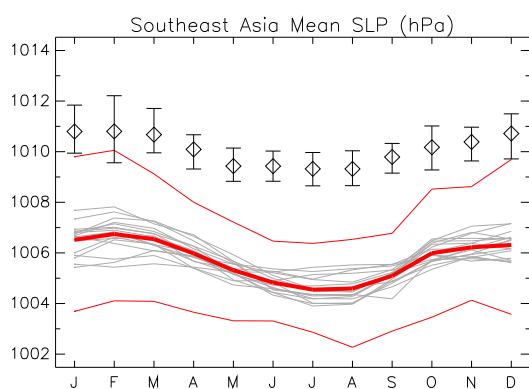
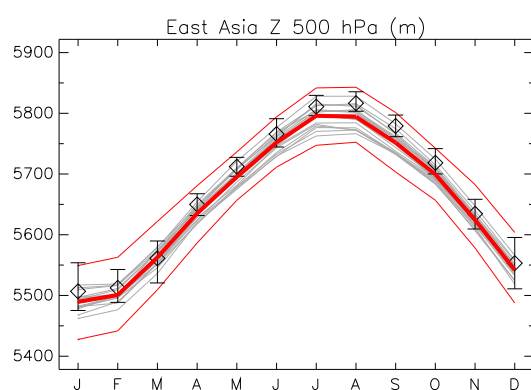
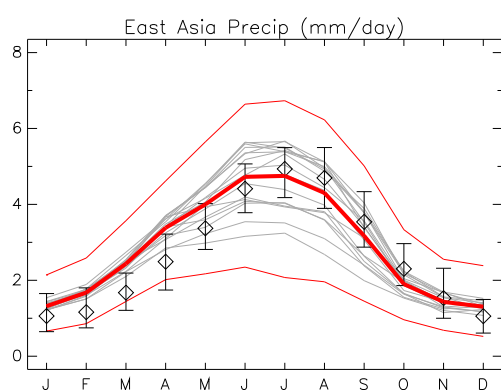
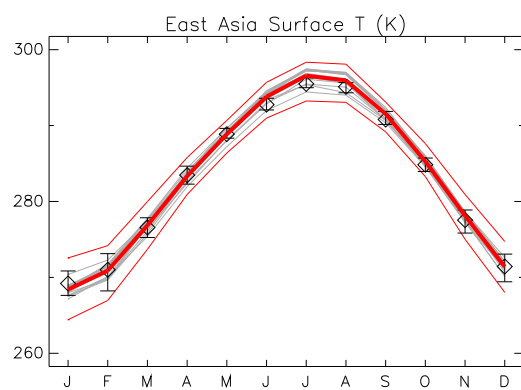
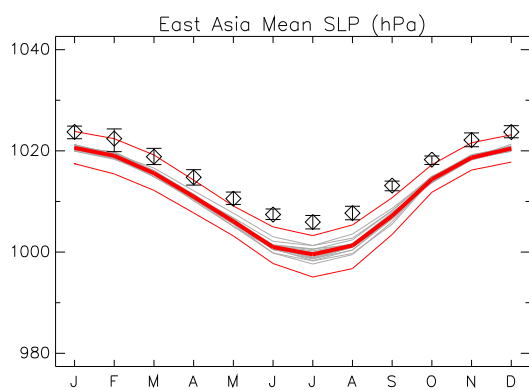


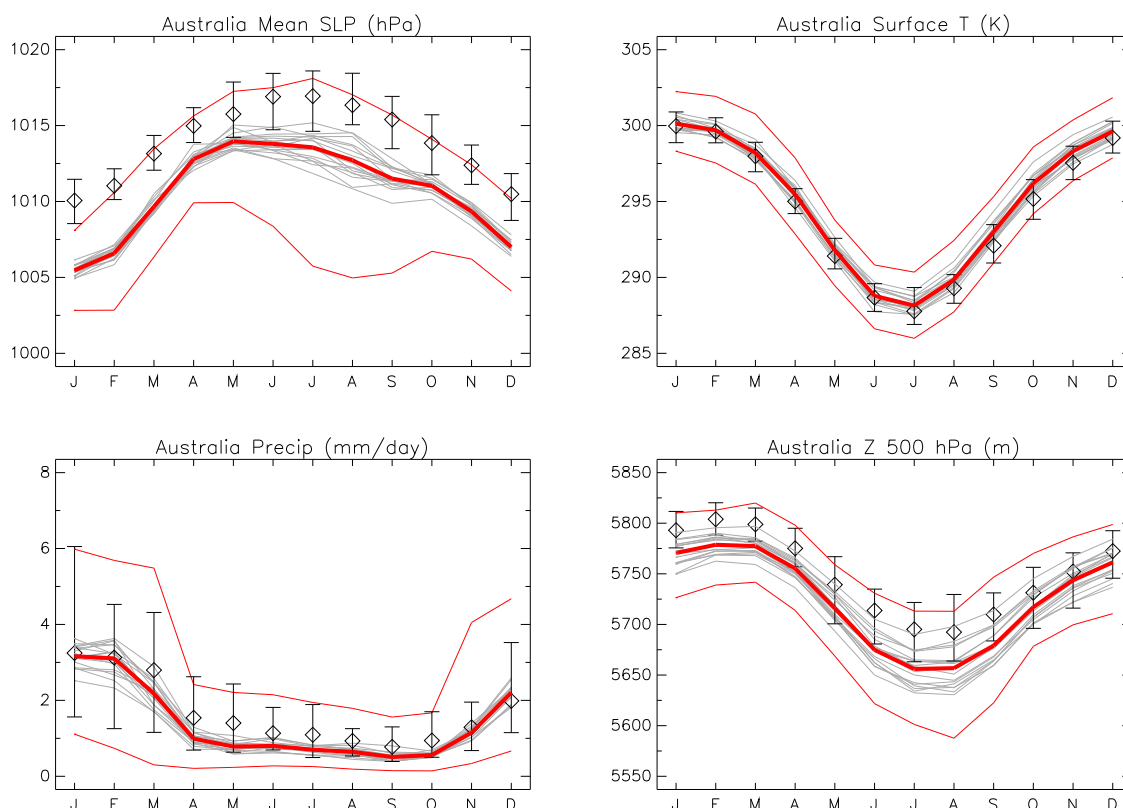












Summary

The climate data from the Qump 17 member ensemble have been compared with observations for the period 1961-1990. The ensemble captures the observed climate in all the regions used in this report. It reproduces observed temperatures, precipitation amounts and heights at 500 hPa well, but the modelled surface pressures are slightly too low when compared with the observations, owing to the way the Qump models were initialised. There is often a greater spread in the ensemble results for precipitation than the other three climate variables considered here, and the ensemble does not always capture the observed monthly cycle (e.g. Northern Europe (NEU)); however, the annual average precipitation values are close to observations. For annual means, often 1 or more ensemble members closely reproduce the observed climate, but for monthly means, the ensemble mean could be considered. The regions used in this project to assess the Qump ensemble performance are large, and so this comparison could hide disagreements between the ensemble and the observed climate at smaller scales.

Appendix A

Summary of all simulations which make up second 17-member Qump ensemble (multi-parameter perturbations).

	Haney	FluxAdj	Hist1	Hist2	A1B	Control	1%	B1	A1FI	SO2_Hist	SO2_A1B
Standard	aenwb	aenwd	aenwg	aenwh	aenwl	aenwp	aenwq	aenwr	agnhs	afksa	afksb
Template Job	aenub	aenuc	aenud	aenuf	aenug	aenuh	aenui	aenuj	agnht	aenuk	aenul
Expt	aepf	aesk	aevq	aexs	aeyj	afcr	afcq	afid	agnh	afjo	afmm
Perturbed Jobs	aepfa	aeska	aevqa aevqb	aexsa aexsb	aeyja aeyjb	afkra	afcqa	afida afidb	agnha	afjoa afjob	afmma
	aepfb	aeskb	aevqc aevqd	aexsc aexsd	aeyjc aeyjd	afcrb	afcqb	afidc afidd	agnhb	afjoc afjod	afmmb
	aepfc	aeskc	aevqf aevqh	aexsf aexsh	aeyjf aeyjh	afcrc	afcqc	afidf afidh	agnhc	afjof afjoh	afmmc
	aepfd	aeskd	aevqi aevqj	aexsi aexsj	aeyji	afcrd	afcqd	afidi afidj	agnhd	afjoi afjoj	afmmd
	aepff	aeskf	aevqk aevql	aexsk aexsl	aeyjj	afcrf	afcqf	afidk afidl	agnhf	afjok afjol	afmmf
	aepfh	aeskh	aevqm	aexsm aexsn	aeyjk	afcrh	afcqh	afidm	agnhh	afjom	afmmh
	aepfi	aeski	aevqn aevqo	aexso aexsp	aeyjl	afcri	afcqi	afidn afido	agnhi	afjon afjoo	afmmi
	aepfj	aeskj	aevqp aevqq	aexsq aexsr	aeyjm	afcrj	afcqj	afidp afidq	agnhj	afjop afjoq	afmmj
	aepfk	aeskk	aevqr		aeyjn	afcrk	afcqk	afidr	agnhk	afjor	afmmk
	aepfl	aeskl			aeyjo	afcrl	afcql		agnhl		afmml
	aepfm	aeskm			aeyjp	afcrm	afcqm		agnhm		afmmm
	aepfn	aeskn			aeyjq	afcrn	afcqn		agnhn		afmmn
	aepfo	aesko			aeyjr	afcro	afcqo		agnho		afmmo
	aepfp	aeskp				afcrp	afcqp		agnhp		afmmp
	aepfq	aeskq				afcrq	afcqq		agnhq		afmmq
	aepfr	aeskr				afcrr	afcqr		agnhr		afmmr
Exec	aepf	aesk	aevq	aexs	aeyj	afcq	afcq	afid	agnh	aevq	aevq
Start	-	-	1859/12/01	1949/12/01	1989/12/01	1859/12/01	1859/12/01	1999/12/01	1999/12/01	1859/12/01	1989/12/01
Stop	-	-	1949/12/01	1989/12/01	2099/12/01	2009/12/01	2009/12/01	2099/12/01	2099/12/01	1989/12/01	2099/12/01
Runtime	100 yr	150 yr	90 yr	40 yr	110 yr	150 yr	150 yr	100 yr	100 yr	130 yr	110 yr