Use of radiosonde data for validation of regional climate modelling simulations over Cyprus

Panos Hadjinicolaou[1], Silas Michaelides[2] and Andreas Poyiadjis[2]

[1]Ecognosia, Environmental Research and Information Centre, Nicosia, Cyprus
[2]Meteorological Service, Nicosia, Cyprus

Abstract

The available radiosonde data from Athalassa – Nicosia in Cyprus cover a period from 1982 to present and provide a useful validation dataset for atmospheric and climate model studies in the Eastern Mediterranean region. In this paper, a comparison is being made between the radiosonde observations made at Athalassa - Nicosia, Cyprus and the corresponding output for Nicosia from a recent long-term dynamical downscaling simulation of the present climate in Southeast Europe with the PRECIS regional climate model. In the present context, we compare surface and upper air temperature and relative humidity monthly time-series from the radiosonde station with the corresponding model output.

1. Introduction

According to the Intergovernmental Panel on Climate Change, the global average surface temperature has increased in the 20th century by about 0.6^{o}C, temperatures have risen during the past four decades in the lowest 8 kilometres of the atmosphere, snow cover and ice extent have decreased and global average sea level has risen and ocean heat content has increased (IPCC, 2001). The same report states that concentrations of atmospheric greenhouse gases and their radiative forcing have continued to increase as a result of human activities and concludes that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities".

Estimates of the impacts of climate change (and related adaptation measures) can be obtained from scenarios of the future climate produced by the predictions of Global Climate Models (GCMs) forced by projected Greenhouse Gas (GHG) concentrations. Although GCMs contain all the important physical processes of the climate system, their predictions lack the detail useful in the local level because of the relatively crude horizontal resolution (of a few hundred kilometres). Regional Climate Models (RCMs) can be used in conjunction to GCMs in order to provide the finer detail of the climate change projections by "dynamically downscaling" the meteorological information of the GCMs from the global scale to the regional scale (few tens of kilometres).

The PRECIS (Providing REgional Climates for Impact Studies) RCM was developed by the Hadley Centre (UK Met. Office) as an alternative, user-friendly and resource-inexpensive climate modelling tool which can be used to provide accurate climate change scenarios in the regional scale. The model was applied in South-East Europe and the first results of a 3-year simulation of the recent past are validated here for the region of

Cyprus. Attention is given to the UT/LS region where changes in the tropopause height provide an alternative indicator of the anthropogenic effect on climate (Santer, 2004).

2. Methodology and datasets

2.1 Model description and datasets

The PRECIS RCM is based on the atmospheric component of HadCM3 climate model (Gordon et al., 2000) and it is described extensively in Jones et al. (2004). The atmospheric dynamics module of PRECIS is a hydrostatic version of the full primitive equations and uses a regular latitude-longitude grid in the horizontal and a hybrid vertical coordinate. There are 19 levels from the ground up to 0.5 hPa and the horizontal resolution is 0.22^o x 0.22^o or, 25 x 25 km, while the model time-step is 5 minutes.

The ERA-40 Lateral Boundary Conditions (LBC) are the drivers of the simulation and are produced from the original European Centre for Medium-range Weather Forecasts (ECMWF) ERA-40 meteorological analyses (a re-analysis dataset of the global atmosphere from 1958 to 2001, with 1.5^o x 1.5^o horizontal resolution, Uppala et al., 2006). Hadley Centre (David Hein, personal communication) has prepared a part of the ERA-40 dataset for a broad region of S.E. Europe (with corner coordinates -15^oW, 55^oE, 55^oN, 20^oS). The ERA-40 LBC are available every 6 hours and during the simulation are "informing" the PRECIS model for the "observed" meteorological conditions. The model then adjusts its own meteorological field (produced by its own physics at 0.22^o x 0.22^o horizontal resolution) to the ERA-40 information. The outcome is a high resolution meteorological field with realistic detail in the local level, derived from the global scale analyses (Figure 1).

Monthly values of measured surface air temperature and relative humidity and upper air temperature from radiosondes by the Meteorological Service of Cyprus (MSC) in the Athalassa, Nicosia for 1982-1984 are compared to the model time-series in the corresponding grid box.

2.2 Model domain

The model domain has horizontal resolution of 0.22^o x 0.22^o or 25 x 25 km and is shown in figure 1 (left). The domain boundaries cover a broad region including most of the Balkans, Anatolia and the Middle East. A compromise had to be made between the domain's size and the computational speed of the experiments. In that respect, Cyprus is well placed within these boundaries and especially within the inner domain (bound by the shaded "buffer zones" adjacent to the domain boundaries), allowing for the optimum dynamical downscaling. Figure 1 (right) shows a magnification of the whole model domain in the area of interest. Cyprus consists of 14 grid boxes with dimensions 0.22^o x 0.22^o or 25 x 25 km. This horizontal resolution is the highest than can employed by the PRECIS model and one of the highest used so far in long-term regional climate modelling (Déqué, 2004). The selected number of grid boxes corresponds to an area of 14 x 25 x 25 = 8750 km^2, or 95% of the total area of the island (~9250 km^2).

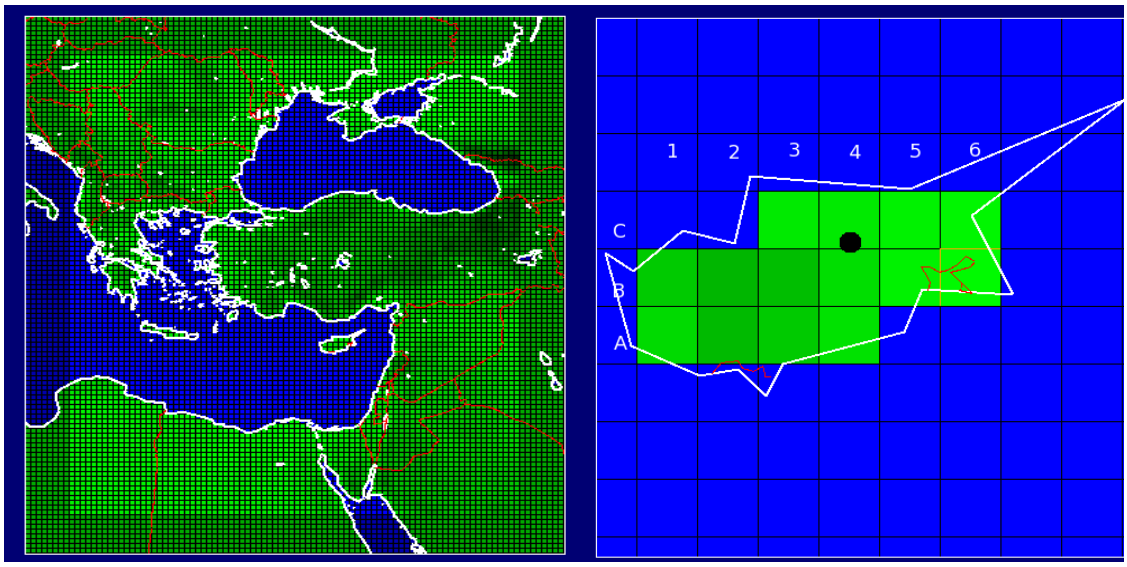

Figure 1: Model domain. a) Overall domain (left), with (98 x 112) grid boxes, b) Magnified domain over Cyprus (right), The black dot indicates Nicosia (grid C4). The brightness of the green colour in every grid depends on the height. All grid boxes in both images have dimensions 25 x 25 km.

For the purpose of model output extraction and validation with the MSC observations, grid C4 (Figure 1, right) was selected as representative of the location of Nicosia. Geographically, this grid lies in the Nicosia area and the corresponding model orographic height (126 m) is very close to the height of the location of the meteorological observations (163 m in Athalassa).

3. Validation with radiosonde data

Monthly time-series from the model output for the test simulation period 1982-1984 are compared to the corresponding radiosonde measurements for the surface and the levels above.

3.1 Comparison with surface parameters

In figure 2 the monthly evolution of the time-series of surface air temperature and relative humidity agree very well with the MSC observations, capturing both the annual cycle and the inter-annual variability.

3.2 Comparison with upper air parameters

In figures 3-6 the monthly temperature time-series from the MSC radiosondes are compared with the corresponding output from the PRECIS model and the driving ECMWF ERA-40 analyses. At this preliminary stage of the PRECIS output analysis, only the daily

mean values were extracted from the model and therefore should include a small overestimation compared to the 12 UTC values (that the other two datasets use in the plots).

Closer to the surface (at 500 hPa shown in figure 3), both the original ECMWF analyses and the dynamically downscaled from PRECIS are very close to the observed ones. At 250 hPa (figure 4), still within the troposphere, the comparison is similar. The quantitative agreement at higher levels (100 and 50 hPa , figures 5 and 6), above the tropopause, is less good (the PRECIS output underestimates the measurements), although in all cases, the temporal evolution is captured satisfactorily.

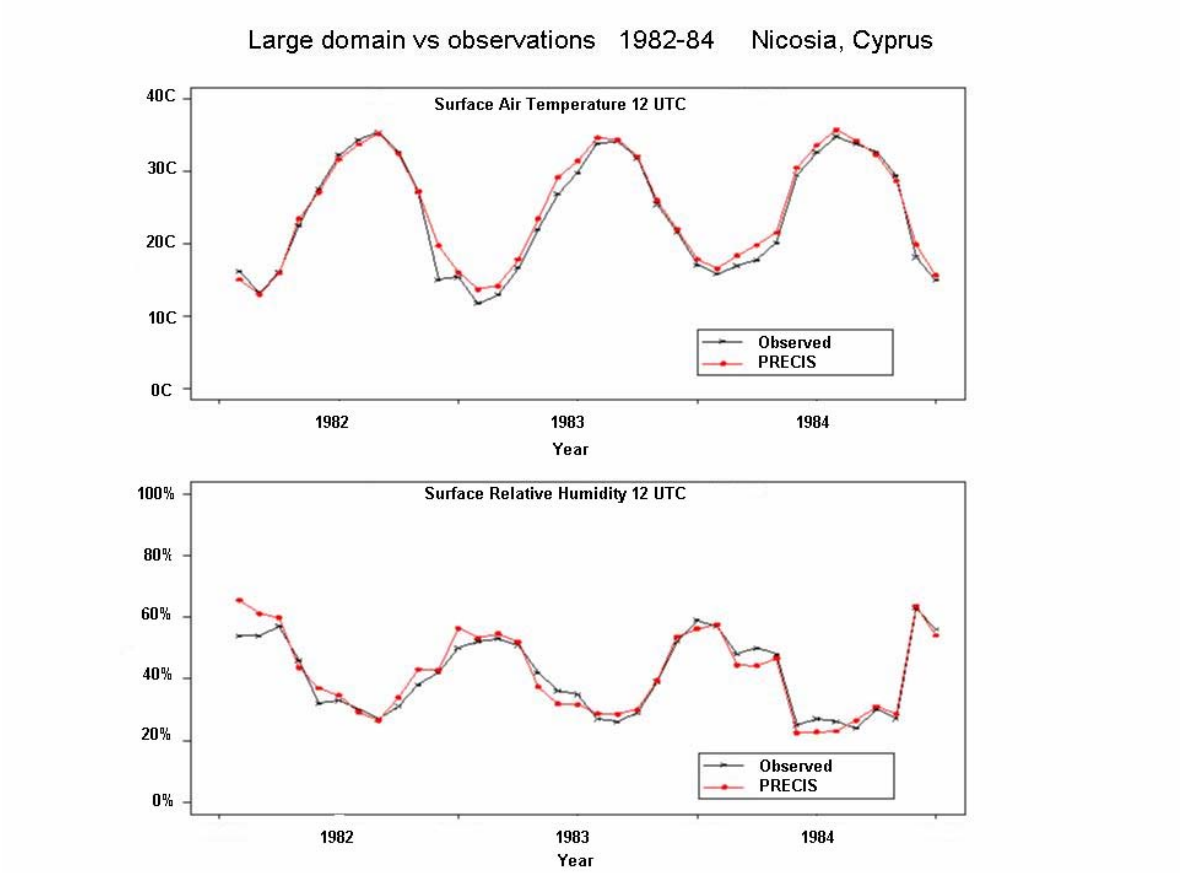

Figure 2. Time-series of surface temperature and relative humidity in Nicosia from the model and from Athalassa radiosondes by the Meteorological Service of Cyprus.

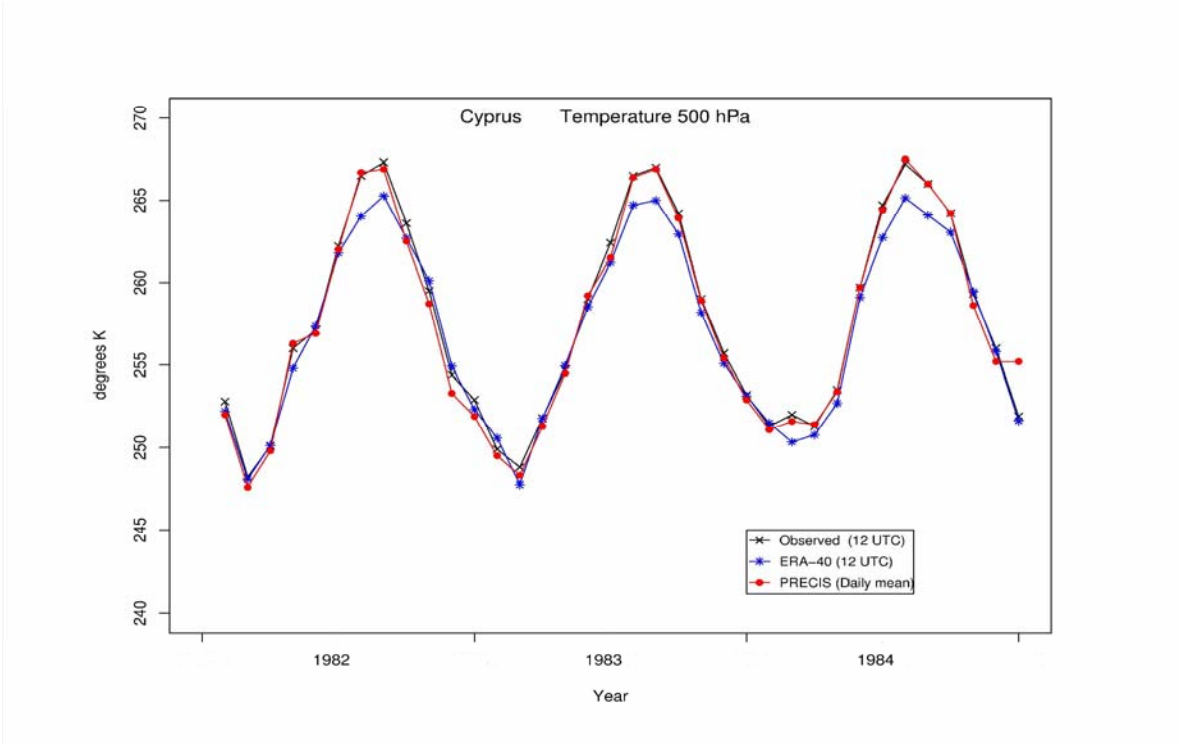
Cyprus Temperature 500 hPa
degrees K
270
265
260
255
250
245
240
1982
1983
1984
Year
Observed (12 UTC)
ERA-40 (12 UTC)
PRECIS (Daily mean)

Fig.3

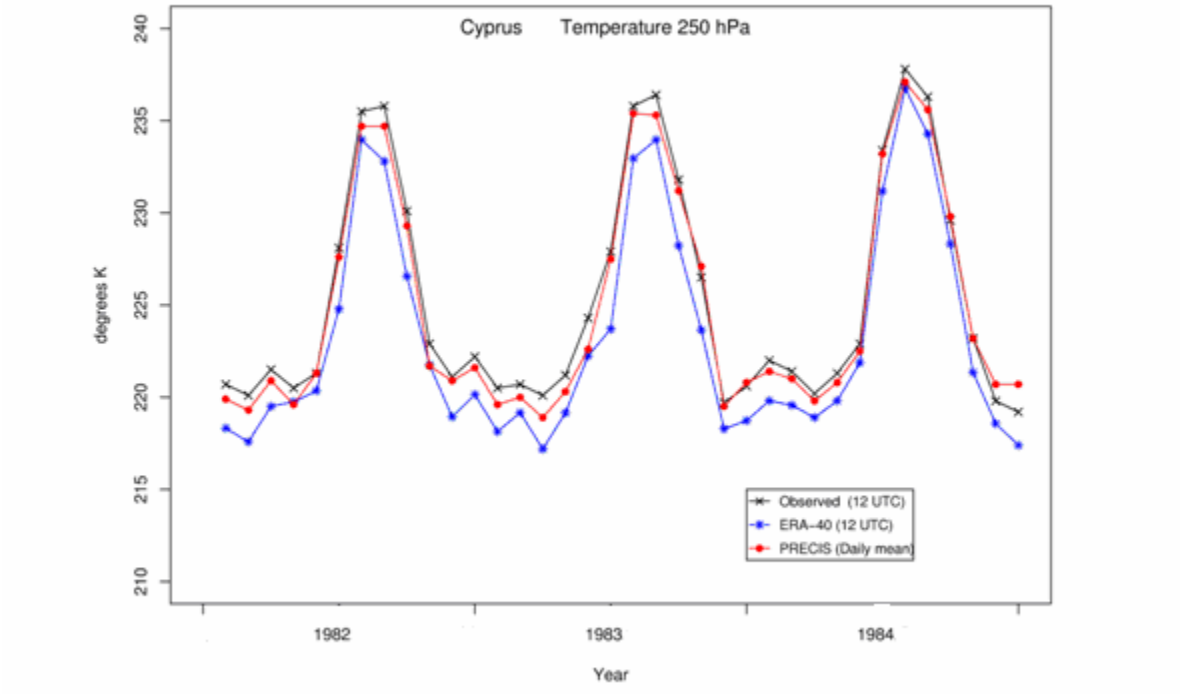
Cyprus Temperature 250 hPa
degrees K
240
235
230
225
220
215
210
1982
1983
1984
Year
Observed (12 UTC)
ERA-40 (12 UTC)
PRECIS (Daily mean)

Fig. 4

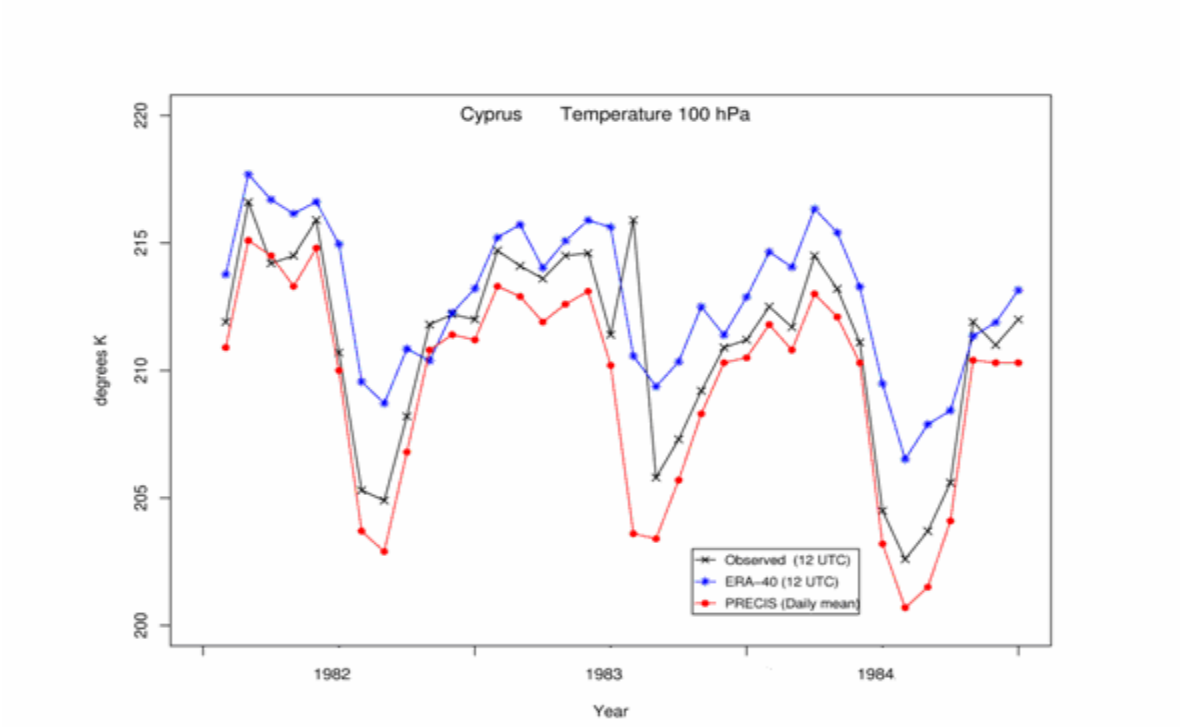
Cyprus Temperature 100 hPa
degrees K
220
215
210
205
200
1982
1983
1984
Year
Observed (12 UTC)
ERA-40 (12 UTC)
PRECIS (Daily mean)

Fig.5

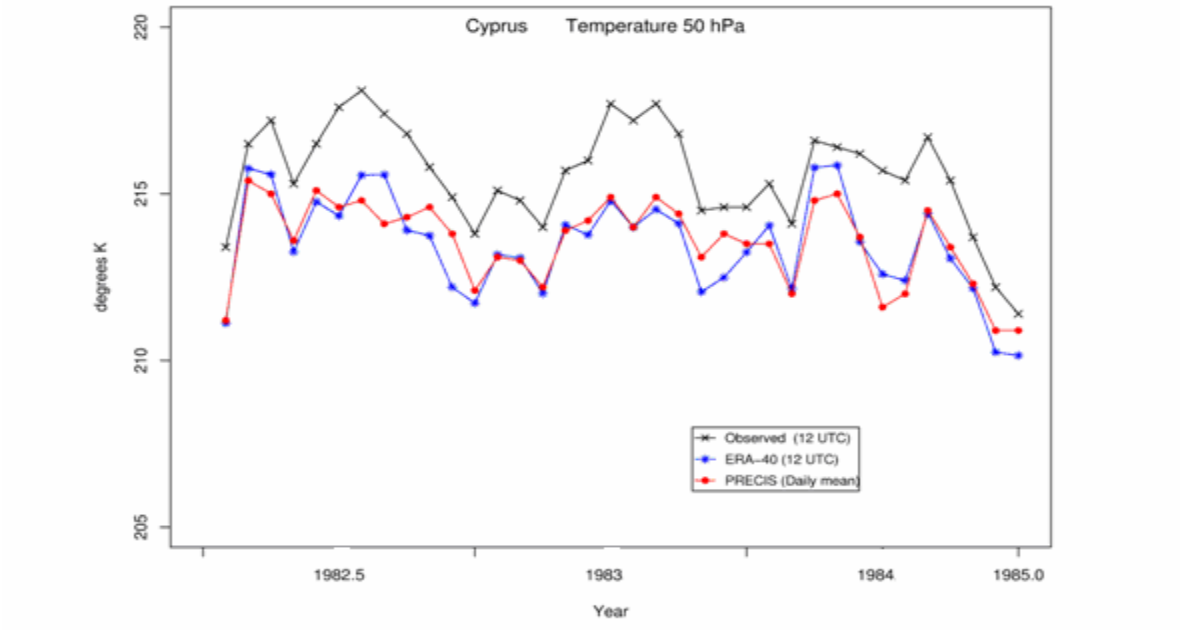
Cyprus Temperature 50 hPa
degrees K
220
215
210
205
1982.5
1983
1984
1985.0
Year
Observed (12 UTC)
ERA-40 (12 UTC)
PRECIS (Daily mean)

Fig. 6.

Figures 3-6: Time-series of temperature over Nicosia in Nicosia from the model (red, daily mean), the Athalassa MSC radiosondes (black, 12 UTC) and the driving ECMWF ERA-40 analyses, at 500, 250, 100 and 50 hPa.

4. Conclusions

The comparison of the results of the PRECIS simulation over Cyprus with the CRU and MSC observations shows that the model can reproduce satisfactorily the temporal evolution of temperature and other meteorological parameters. This adds to a similar validation study over Taiwan (Wang and Shallcross, 2005) demonstrating the ability of PRECIS to simulate well and with very high resolution the climate of recent past. A complete and statistically robust validation using the output of a 30-year simulation, which is currently under way, will help validate better the capability of the PRECIS model to reproduce the climate of the recent past in the Eastern Mediterranean.

Acknowledgments

This study is part of work funded by the Experienced Expatriate Programme of the Research Promotion Foundation, Cyprus. The author is grateful to the PRECIS team at the Hadley Centre, UK and especially David Hein, David Hussel and Wilfran Moufouma-Okia.

References

Déqué, M. 2004: *Uncertainties in PRUDENCE simulations: Global high resolution models*, PRUDENCE deliverable D1A5 (http://prudence.dmi.dk/public/publications/index.html).

Gordon, C.C., Cooper, C., Senior, C.A., Banks, H., Gregory, J.M., Mitchell, J.F.B and Wood, R.A., 2000: The simulation of SST, sea ice extents and ocean heat transport in a version of the Hadley centre coupled model without flux adjustment, *Clim. Dyn*., 16, 147-168.

IPCC, 2001: *Climate Change 2001, The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK.

Jones, R.G., Noguer, M., Hassell, D.C., Hudson, D., Wilson, S.S., Jenkins, G.J. and Mitchell, J.F.B., 2004: *Generating high resolution climate change scenarios using PRECIS*, Met Office Hadley Centre, Exeter, UK, 40pp.

Santer, B. D., et al. (2004), Identification of anthropogenic climate change using a second-generation reanalysis, J. Geophys. Res., 109, D21104, doi:10.1029/2004JD005075.

Uppala, S.M., Kållberg, P.W., Simmons, A.J., 2005: The ERA-40 re-analysis, *Quart. J. Royal Meteorol. Soc*., 2005, 131, 612, 2961-3012, doi:10.1256/qj.04.176.

Wang, K.-Y., Shallcross, D.E., 2005: Simulation of the Taiwan climate using the Hadley Centre PRECIS regional climate modelling system: The 1979-1981 results, *Terr. Atmos. Ocean. Sciences*, 16, 5.

Wilson, M.F. and Henderson-Sellers, A., 1985: A global archive of land cover and soils data for use in general circulation climate models, *J. Climatol*., 5, 119-143.
Wilson, S., Hassell, D., Hein, D., Jones, R. and Taylor, R. 2004: Installing and using the Hadley Centre regional climate modelling system, PRECIS.