Regional Climate Model

Simulations of Daily Maximum and Minimum Near-Surface Temperatures Across Europe 1961-1990:

Comparisons with Observed Station Data

Anders Moberg and Phil D. Jones, Climatic Research Unit, University of East Anglia

Regional Climate Models (RCM). High-resolution (~50 km) dynamic RCMs nested in Global Climate Models (GCM) are becoming an increasingly important tool in climate research (Giorgi *et al*. 2001).

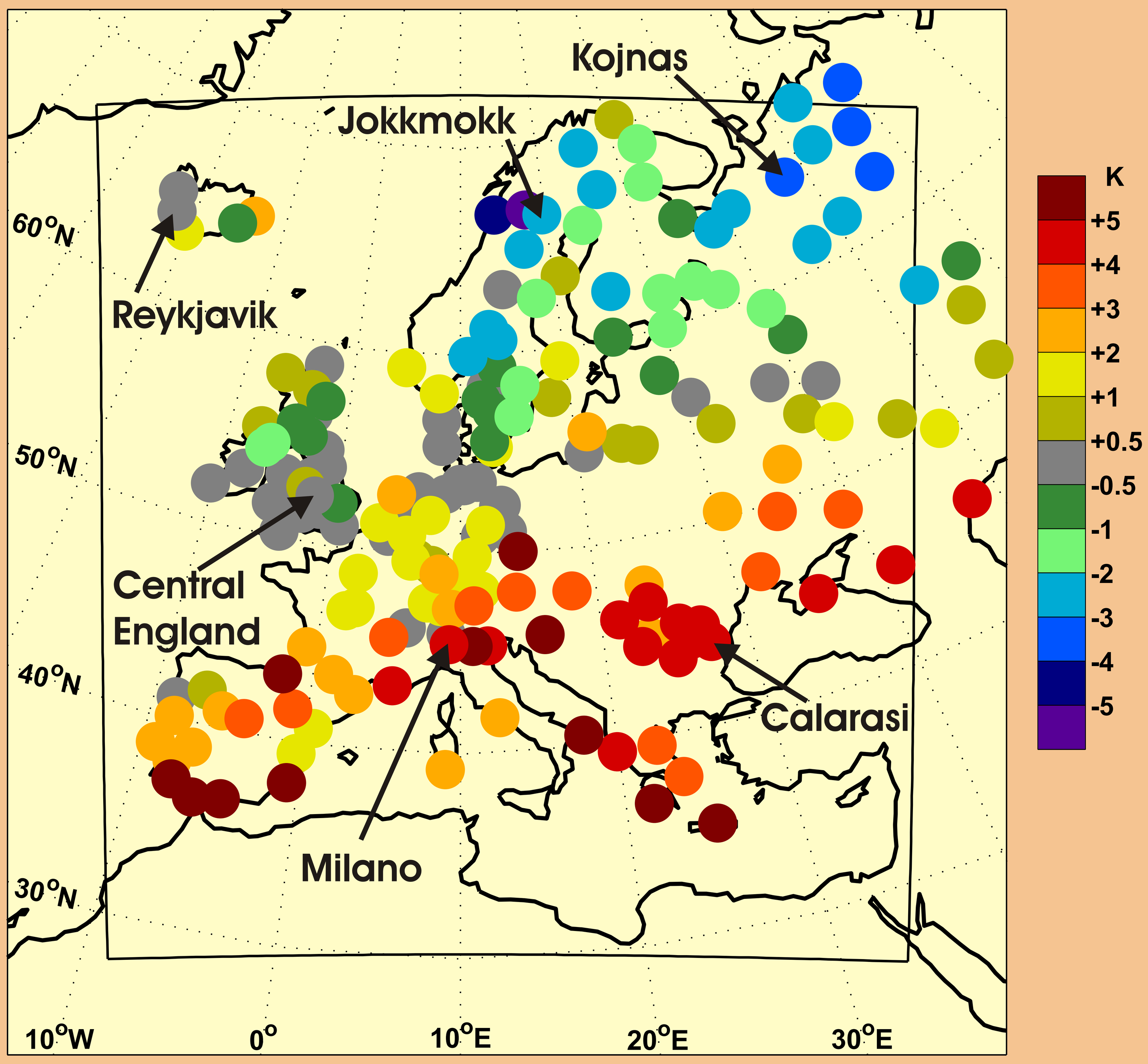
HadRM3H (Hulme *et al*. 2002, Hudson and Jones 2002) is the latest RCM from the Hadley Centre, with a resolution of 0.44° lat/lon. It is forced at its lateral boundaries by an atmosphere-only GCM (HadAM3H). Both models have 19 vertical layers. HadAM3H was run driven by observed 1961-90 sea surface temperatures and sea ice. Initial conditions were interpolated from a transient model run with a coupled ocean-atmosphere model (HadCM3; Gordon *et al*. 2000), where greenhouse gases and aerosols were successively increased from 1860 to 1990 (Johns *et al*. 2001). An ensemble of three members has been obtained for the 1961-90 period, by starting transient runs from different points in a long unperturbed control run.

Station temperatures. Near-surface temperatures (daily Tx and Tn) in HadRM3H are evaluated by comparing with observations from ~180 European land stations. The main data sets are the European Climate Assessment (Klein Tank *et al*. 2002), the British Atmospheric Data Centre (http://badc.nerc.ac.uk/home) and the Swedish Meteorological and Hydrological Institute. Data from each station was compared with model data at the nearest grid-box on land. The model temperatures were adjusted to account for altitude differences.

Seasonal temperature biases. HadRM3H performs well over the U.K. and elsewhere in Europe between 50-55N, with biases mostly within ±0.5 K. Coherent regions with larger seasonally dependent biases, up to more than ±5 K, are found in other areas. A prominent example is a region with warm biases in summer (JJA) south of about 45N, more pronounced for Tx than Tn. Warm summer biases in about the same areas have also been observed in other RCM runs (Christensen *et al*. 1997, Noguer *et al*. 1998), where errors in the parameterization of land schemes have been found to cause a drying out of soils. A positive feedback mechanism with deficient precipitation and cloudiness further enhance surface temperatures. Analyses of the soil moisture content in HadRM3H confirm that the area of warm summer biases in southern Europe is associated with soil dryness in summer. This problem is likely to occur much further north in 'future' integrations of the model, with a greenhouse-gas induced warming.

Annual temperature cycles. Graphs of the modelled and observed average, highest and lowest Tx and Tn values for each calendar day during 1961-90 have been compared for all ~180 sites. Examples from six selected sites are shown, each representing a particular behaviour common to neighbouring sites. At **Reykjavik** (Icelandic coast) the lowest modelled winter Tn are ~15 K below the observed. On the contrary, at **Jokkmokk** (N Sweden) the lowest modelled winter Tn are ~15 K too high. Both Jokkmokk and **Kojnas** (N Russia) illustrate an underestimation of summer Tx in much of northern Europe. Kojnas also illustrates a behaviour in N and NE Europe in spring, where the highest modelled Tx remain constantly near 0 °C from December through mid-April when the curve rises abrubptly. **Central England** represents a region including much of the British Isles and continental Europe between 50-55°N, where the model nearly perfectly simulates the observed annual temperature cycle and variability range. This example also illustrates that in summer the model sometimes produces unrealistically high Tx. This behaviour was observed in the model at sites where the soil occasionally completely dries out, but not at nearby sites where the model soil always remain moist. **Milano** (N. Italy) illustrates that the warm summer bias in southern Europe is associated with a particularly strong overestimation of Tx, leading to modelled mean Tx values being at the same level as the highest observed Tx values. **Calarasi** (Romania) illustrates a combination of a too large modelled diurnal temperature range throughout the year and also different shapes of the modelled and observed annual temperature cycles found in the Romanian region.

Temperature bias (Tx) June-to-August



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Temperature variance ratios. The ratios of the variances (model/observation) in daily Tx and Tn anomalies from smooth annual cycles are calculated. A dominance of sites where the model slightly underestimates the observed variance might be expected, as the model represent grid-box average and the observations come from single stations. A dominant underestimation, however, is only found for Tx in spring (MAM). On all the other seven maps there are coherent regions both with under- and overestimation. For example, the area with warm summer biases in southern Europe coincides well with an area having generally significantly overestimated variance.

Discussion and conclusions. The analyses undertaken here do not diagnose the physical reasons for systematic model errors, but they provide qualitative information about how biases in seasonal mean temperatures are related to systematic errors in the simulation of annual temperature cycles, variances and extreme temperatues. Results from this study imply that model evaluation using only seasonal averages of mean maximum and minimum temperatures may mask severe errors in the simulation of extreme values and the range of variability. Of great current interest, among both scientists and policymakers, is the development of regional scenarios for future changes in climate extremes. In this context, it is crucial that the models realistically simulate all aspects of present-day climate. If significant systematic errors exist in the simulation of extremes under the present conditions, then this may lead to unrealistic projected changes, affecting both climatological averages and the occurrence of extremes. Given the existence of substantial biases in current RCMs, we recommend that results from future scenario integrations from these models are treated with care. Our results underscore the conclusion of Giorgi *et al*. (2001) that research aiming at reducing systematic errors in RCMs should be carried out. This should include a further development of e.g. the physical parametrization of various sub-grid scale processes. It is also essential that the boundary conditions provided by the driving GCMs used are realistic.

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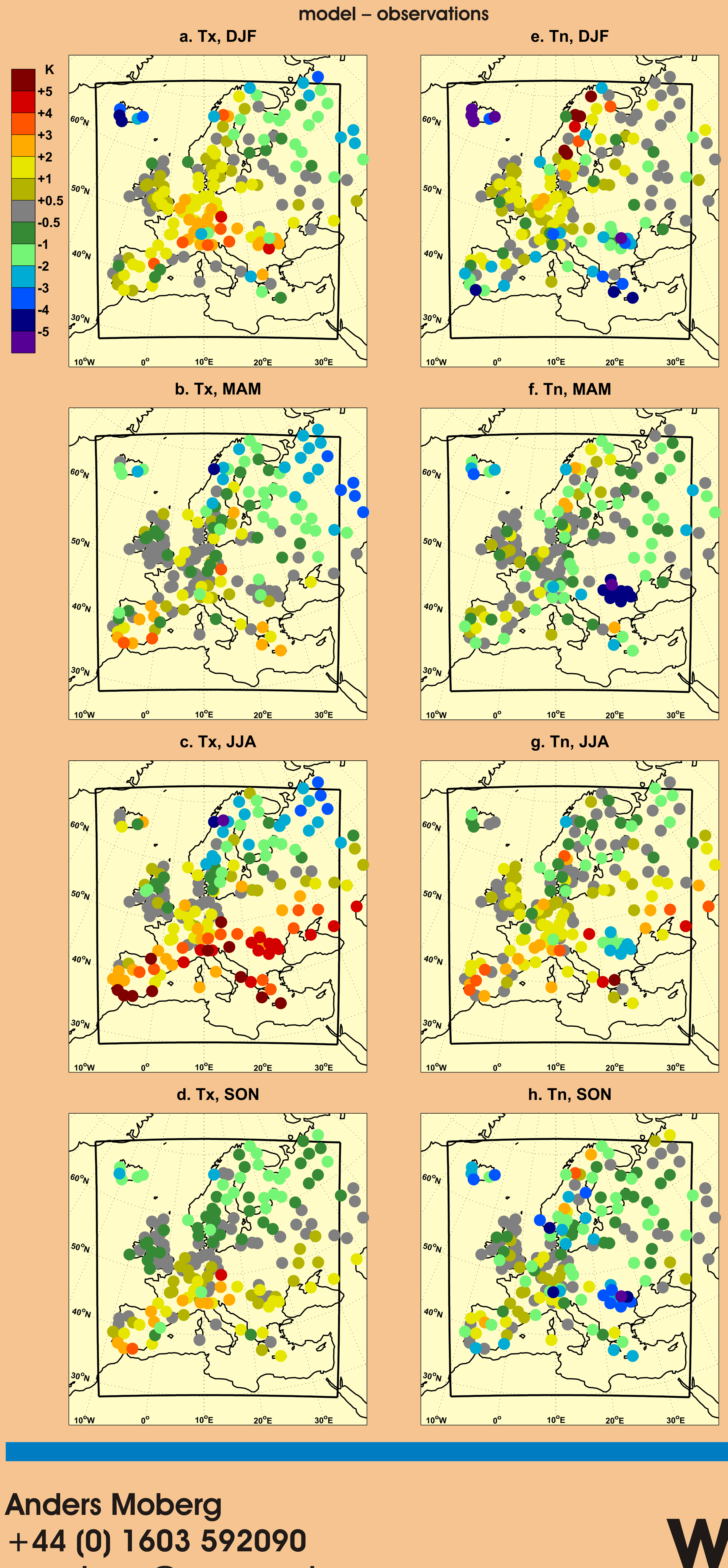
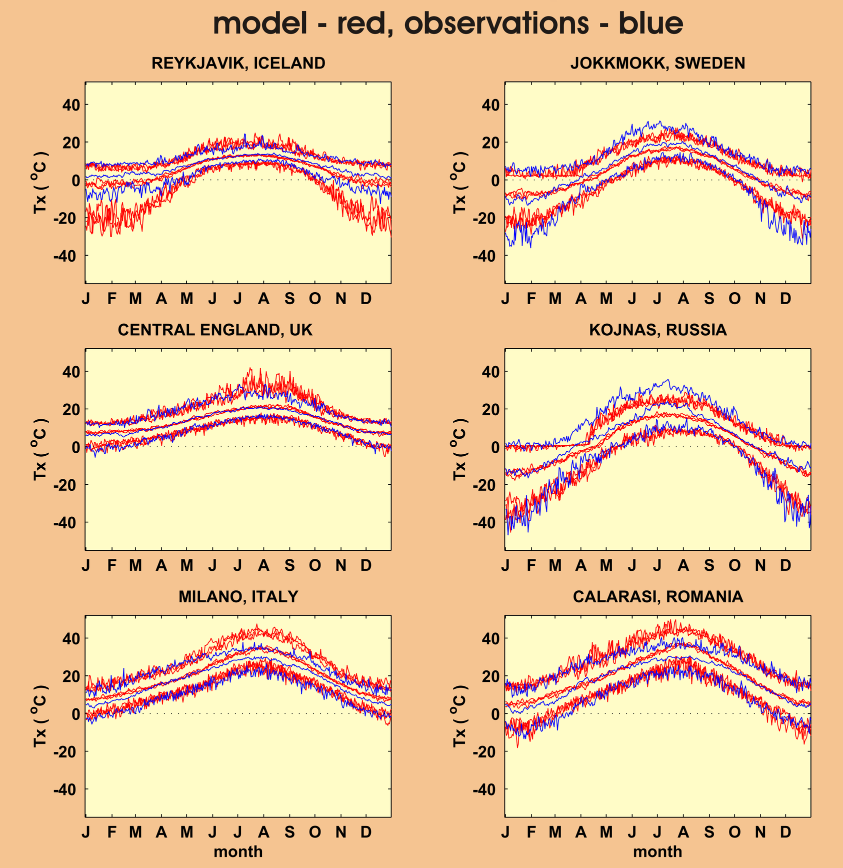
Temperature bias

model – observations



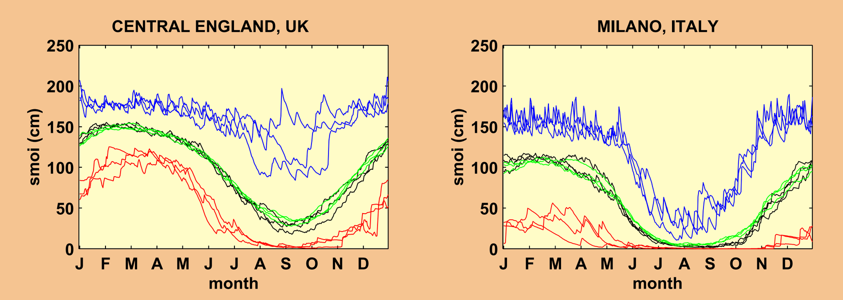
Tx annual cycle

model - red, observations - blue



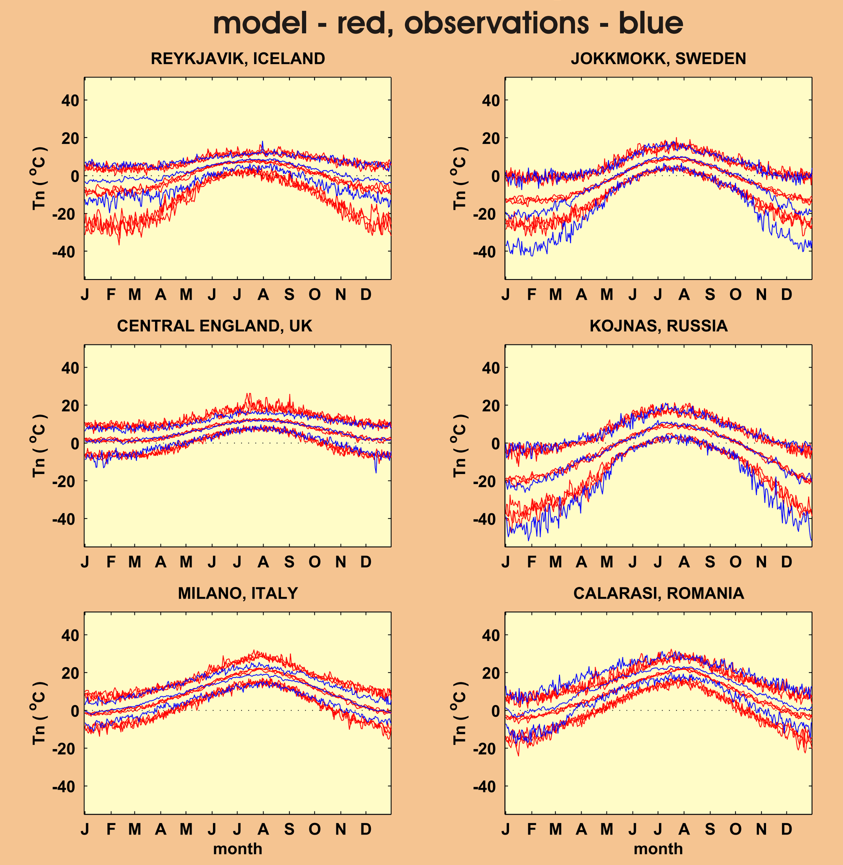
Model soil moisture

highest - blue, mean - green, median - black, lowest - red



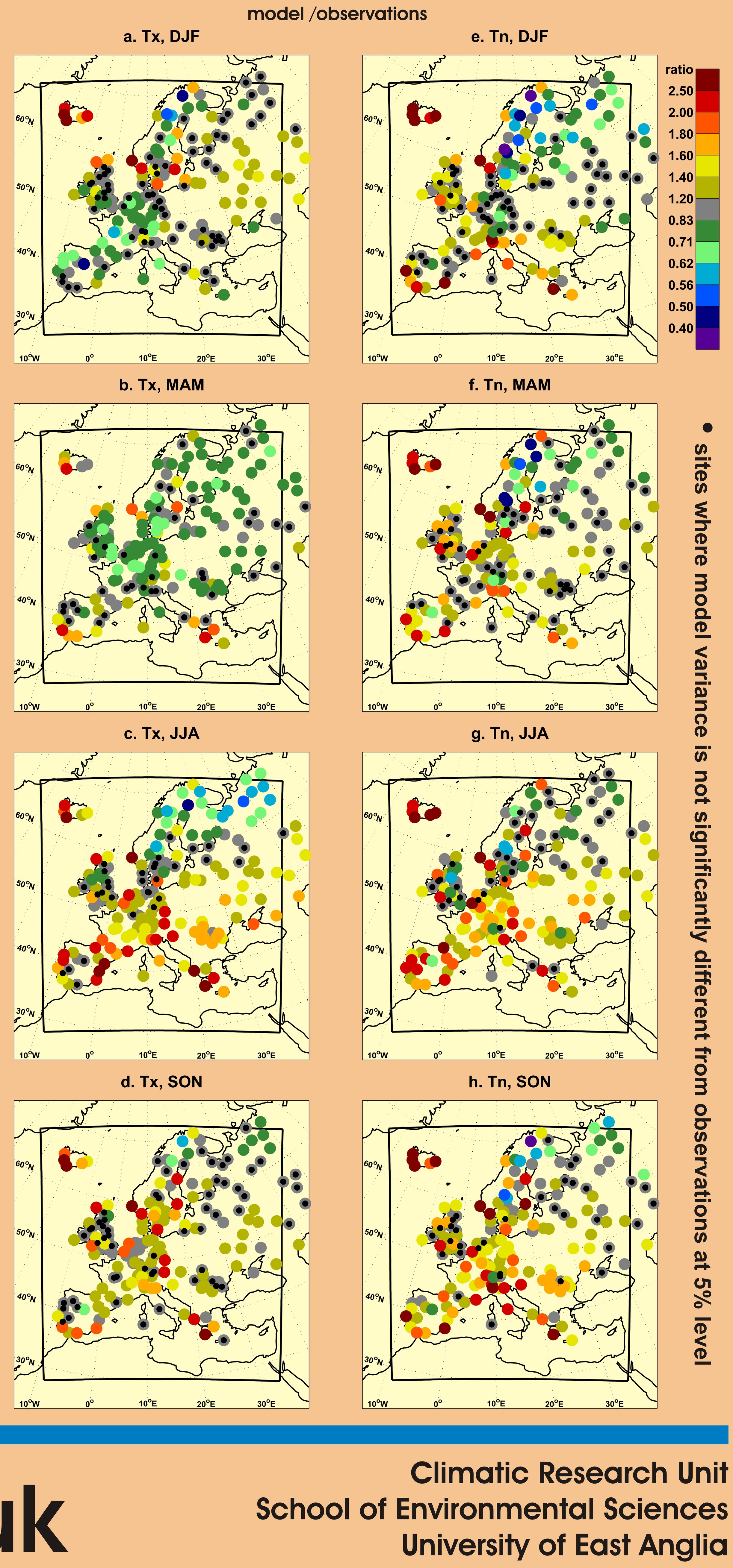
Tn annual cycle

model - red, observations - blue



Temperature variance ratios

model /observations



Anders Moberg
+44 (0) 1603 592090
a.moberg@uea.ac.uk

www.cru.uea.ac.uk

Climatic Research Unit
School of Environmental Sciences
University of East Anglia
Norwich NR4 7TJ, U.K.