Climate change simulations using ECHO-G

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July 22, 2004

This is to report model simulations for HLRE Project No. 193 ("Klimaänderungsuntersuchungen mit Hilfe der Bayesischen Statistik"), which have been performed on the SX-6 machine (Hurrikan) at DKRZ.

1. CPU times

From January 2004 till now, we have consumed about 4000 CPUh to perform climate change experiments with the coupled climate model ECHO-G (Table 1, see below for detailed explanations).

Table 1. List of model simulations finished (thin) and running (thick).

No.	Experiment description	Exptid	Forcing (transient)[#]	Period (years)
1	Natural forcing	a21 a31 a32 a33 a34	N	149 (1850-1998)
2	All forcing or 20C3M (Hegerl et al. 2003)	a41 a42 **a43**	GSTIN	141 (1860-2000)
3	Present-day stabil. at 2000	**a41**	GSTI fixed at 2000	100 (2001-2100)
4	SRES A1B + 100-yr stabil. at 2100	**a51**	GSTI	200 (2001-2200)
5	SRES B1 + 100-yr stabil. at 2100	**a61**	GSTI	200 (2001-2200)

[#]Forcings: N (solar and volcanic forcing with changing solar constant), G (greenhouse-gases, CO2, CH4, N2O, CFC11_equivalent, CFC12), S (sulfate aerosols), T (tropospheric ozone), and I (first indirect effect of sulfate aerosols)

2. Model and experiments

We use ECHO-G for climate change experiments in cooperation with the Meteorological Research Institute METRI of the Korean Meteorological Agency in Seoul. At METRI a 300 year control run as well as pure greenhouse gas szenario simulations were performed also using ECHO-G. By March this year, we have documented as a M&D technical report (Min et al. 2004), analysis results of climatology and internal variability in the 1000-year control run. ECHO-G without [with] interactive aerosols requires about 3 [4] CPUh for one-year integration.

Using ~3000 CPUh we have performed five-member ensemble simulations forced by natural (solar and volcanic) forcing only from 1850-1998 (a21, a31-a34 in Table 1). Forcing data is based on Crowley (2000) and Zorita et al. (2004), such that time series of solar constant is implemented to consider both solar activity and volcanic eruptions (only effect in reflection of incoming short wave radiation) (Fig. 1). Another ~1000 CPUh was used for all forcing simulations including GHGs, aerosols, and natural forcing (a41 and a42 in Table 1). Aerosol forcing covers direct radiation cooling effect and the first indirect effect on cloud.

Initial data for the ensemble simulations were provided by GKSS (one member) and METRI (four members). Main difference in initial conditions from GKSS and METRI exists in background greenhouse-gas (GHG) concentrations: Preindustrial GHG values (CO2=287 ppm, CH4=859.34 ppb, N2O= 265 ppb) in the GKSS restart file while present-day values (CO2=353 ppm, CH4=1720 ppb, N2O=310 ppb) in METRI files (see the numbers in Table 1).

3. Preliminary results

Figure 2 shows the time series of annual mean 2 m temperature anomalies for four member ensemble of pure GHG forcing (performed at METRI), a five member ensemble of natural forcing (a21, a31-34 in Table 1), and two member all forcing runs (a42, a43 in Table 1). They are compared with observations (thick line) including the masking of simulations with missing observations. Observations show two positive trend periods around 1920-1945 and 1975 onward and a slightly cooling period of 1940-1980. The GHG forcing runs exhibit continuous warming trend without any cooling period. Natural forcing runs are capable of explaining parts of warming in 1920-1945, but cannot reproduce the warming in recent decades. Simulations with all forcing included are dramatically in concert with observational temperature behaviors, which supports previous conclusions by IPCC and other model results (e.g. HadCM3 and PCM, see Fig. 1 in Hegerl et al. 2003).

4. Future plan

Model outputs will be analyzed more precisely with the help of Bayesian approach. We also plan to create a four member ensembles for the full forcing case and IPCC scenario experiments (SRES A1B, B1, and A2). Model outputs from these runs will be used to estimate signal and natural variability in our Bayesian process and finally assess anthropogenic climate change for global and regional scales.

References

Crowley, T. J., 2000: Causes of climate change over the past 1000 years. Science, 289, 270-277.

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Zorita, E., et al. 2004: Climate evolution in the last five centuries simulated by an atmosphere-ocean model: global temperatures, the North Atlantic Oscillation and the Late Maunder Minimum, Meteorol. Z., in press.

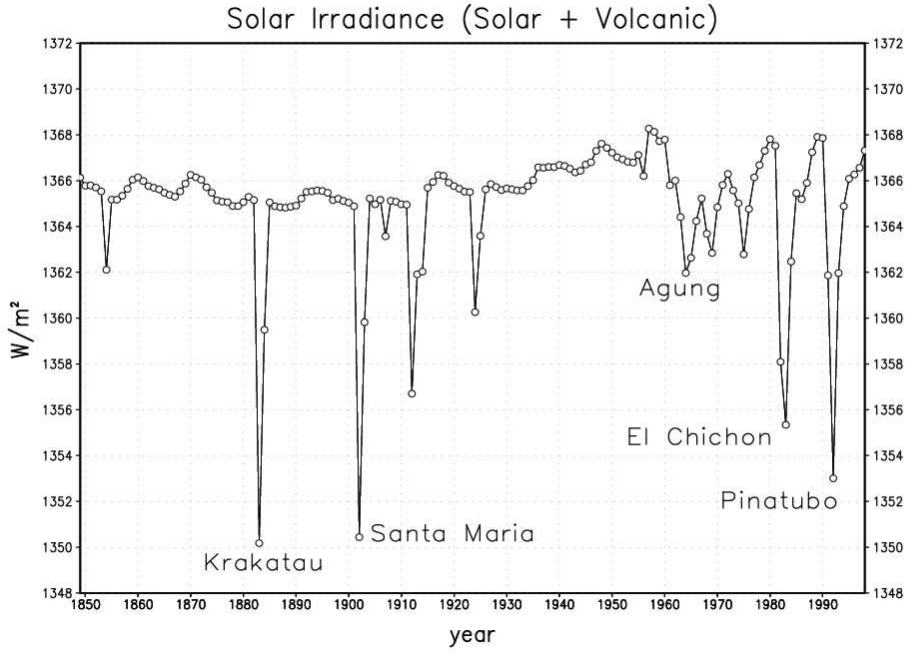

Figure 1. Natural (solar and volcanic) forcing expressed as solar constants [W/m^2].

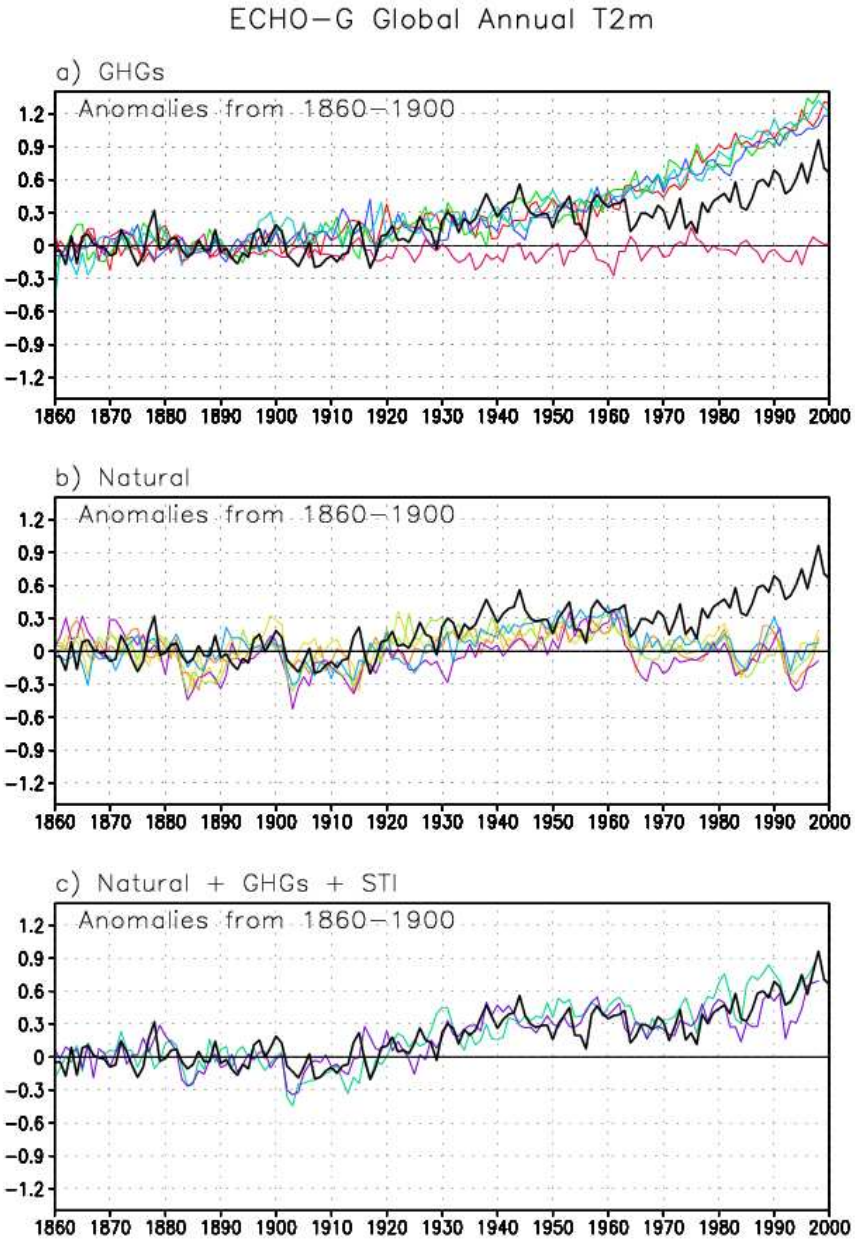

Figure 2. Time series of global annual mean 2 m temperature anomalies from 1860 to 2000: a) GHG forcing run, b) Natural forcing run, and c) all forcing run (see Table 1). Thick lines represent observations. All model data are interpolated into observational grids (5 by 5 degrees) and masked by observational missing coverage.