Regional regimes with drought and extreme wet conditions:
Possible changes in XXI century from IPSL-CM2 simulations

I.I. Mokhov, J.-L. Dufresne, V.Ch. Khon, H. Le Treut, V.A. Tikhonov

Obukhov Institute of Atmospheric Physics RAS, Moscow, Russia
Laboratoire Meteorologie Dynamique du CNRS, Paris, France

In this study we analyse possible regional changes of drought and extreme wet conditions in the XXI century relative XX century from simulations of a coupled atmosphere-ocean general circulation model (AOGCM) IPSL-CM2 with a carbon cycle for the 1860-2100 period (Friedlingstein et al., 2001; Dufresne et al., 2002). The IPSL-CM2 includes the LMD-5.3 AGCM (Le Treut and Li, 1991), the OPA-ice OGCM (Delecluse et al., 1993) and the OASIS coupleur (Terray et al., 1995). The carbon model includes the SLAVE code (Friedlingstein et al., 1995; Ciais et al., 1999) for the terrestrial part and the the IPSL-OGCM1 code (Aumont et al., 1999), based on the HAMOCC3 biochemical scheme (Maier-Reimer, 1993) for the ocean part. The scenario with the carbon dioxide emissions due to fossil and land use from observations up to 1990 (Andres et al., 1996) and the IPCC SRES98-A2 emission scenario from 1990 to 2100 (Nakicenovic et al., 2000) in these simulations were used.

There are different characteristics of drought and wet regimes. In particular, we analyzed model simulations of extremal meteorological conditions in May-July for the basic cereals-producing regions in the eastern European (EEP) and western Asian (WAP) parts of the former Soviet Union in comparison with observations from (Meshcherskaya and Blazhevich, 1997) for 1891-1995. In this case, for instance, the index D characterized the drought conditions with the negative precipitation anomalies дPr (normalized on the long-term mean value, MV, of precipitation) larger than -20% and positive temperature anomalies дT larger than 1K. The index W characterized the wet conditions with дPr>20% and дT<-1K. Two additional indices were also analyzed: D-W and S=(дT/$У_{дT}$ - дP/$У_{дP}$), where $У_{дT}$ and $У_{дP}$ are respective standard deviations (SD).

There is a quite good agreement between model simulations and observations for SD of дPr (±0.16 and ±0.15) and for MV and SD of дT (0 ± 1.3^{o}C and 1.0 ± 1.0^{o}C) in the EEP. There is also good agreement in the WAP for MV of дT (0^{o}C and 0^{o}C) with a larger deviations for respective SD (0 ± 1.4^{o}C and 0 ± 0.9^{o}C) and for SD of дPr (±0.10 and ±0.17).

Model simulations reproduce quite well the dependence of дPr on дT for EEP (dPr/dT = -$0.06\pm0.01^{o}C^{-1}$ with coefficient of correlation r=0.47, while from observations dPr/dT = -0.07 $\pm0.01^{o}C^{-1}$, r=0.52) for the period 1891-1995. The reproduction of this dependence for WAP is not so well (from observations dPr/dT = $-0.11\pm0.02^{o}C^{-1}$ with r=0.58, while no significant relation was found from model results).

Table 1 shows changes of different characteristics in summer between XXI and XX centuries from model simulations for East (EER: 46.1-53.2 ^{o}N, 39.4-50.6 ^{o}E) and West (WER: 46.1-53.2 ^{o}N, 0-11.2 ^{o}E) European regions. The D and M values characterize the portions (%) of total area under corresponding conditions during summer months. According to Table 1 model results display that the increase of temperature in the XXI century is accompanied in both regions by the decrease of precipitation and M and by the increase of D, D-M and S. It should be noted that changes in EER are not statistically significant. The appropriate changes in WER are more remarkable. Model simulations show the SD increase (in brackets) in the XXI century for temperature in both regions and for precipitation in WER, while the SD decrease for precipitation in EER. The drought indices display the general SD increase, while the wet conditions index M shows the SD decrease.

This work was supported by the CNRS/RAS Program and by the Russian Foundation for Basic Research.

Table 1.

Region	Century	T,°C	Pr	D, %	M, %	DM, %	S
EER	XX	0 (± 1.2)	1 (± 0.2)	3.6 (± 8.1)	3.0 (± 7.5)	0.6 (± 11.6)	0 (± 1.0)
	XXI	2.2 (± 1.5)	0.9 (± 0.2)	12.5 (± 13.1)	0.3 (± 2.0)	12.3 (± 13.5)	1.4 (± 1.0)
WER	XX	0 (± 0.9)	1 (± 0.1)	3.2 (± 6.4)	1.3 (± 4.5)	1.9 (± 8.0)	0 (± 0.7)
	XXI	2.9 (± 1.5)	0.8 (± 0.2)	30.2 (± 19.4)	0	30.2 (± 19.4)	2.4 (± 1.3)

References

1. Friedlingstein P., L. Bopp, P. Ciais, J.-L Dufresne, L. Fairhead, H. LeTreut, P. Monfray, and J. Orr, 2001: Positive feedback between future climate change and the carbon cycle. Geophys. Res. Lett. V.28. No.8. P.1543-1546.
2. Dufresne J.-L., P. Friedlingstein, M. Berthelot, L. Bopp, P. Ciais, L. Fairhead, H. LeTreut, P. Monfray, J. Orr, 2002: Direct and indirect effects of future climate change on land and ocean carbon. Geophys. Res. Lett.
3. Meshcherskaya A.V., and V.G. Blazhevich, 1997: The drought and excessive moisture indices in a historical perspective in the principal grain-producing regions of the Former Soviet Union. J. Climate. V.10. P.2670-2682.
4. Le Treut, H., and Z.X. Li, 1991: Sensitivity of an atmospheric general circulation model to prescribed SST changes: feedback effects associated with the simulation of cloud optical properties. Clim. Dyn., **5**, 175-187.
5. Delecluse, P., G. Madec, M. Imbard, and C. Levy, 1993: OPA version 7, Ocean General Circulation Model, Reference Manual., Tech. Rep., IPSL.
6. Terray, L., E. Sevault, E. Guilyardi, and O. Thual, 1995: The OASIS Coupler User Guide Version 2.0., Tech. Rep., CERFACS TR/CMGC/95-46.
7. Friedlingstein, P., I. Fung, E. Holland, et al., 1995: On the contribution of CO_2 fertilization to the missing biospheric sink. Glob. Biogeochem. Cycles, **9**, 541-556.
8. Ciais, P., P. Friedlingstein, D. Shimel, and P. Tans, 1999: A global calculation of the dC of soil respired carbon: Implications for the biospheric uptake of anthropogenic CO_2. Glob. Biogeochem. Cycles, **13**, 519-530.
9. Aumont, O., J. Orr, P. Monfray, G. Madec, and E. Maier-Reimer, 1999: Nutrient trapping in the equatorial Pacific: The ocean circulation solution. Glob. Biogeochem. Cycles, **13**, 351-369.
10. Maier-Reimer, E.,1993: Transport and storage of CO_2 in the ocean - an inorganic ocean-circulation carbon model. Glob. Biogeochem. Cycles, **7**, 645-677.
11. Andres, R., G. Marland, I. Fung, and E. Matthews, 1996: A 1^o x 1^o of carbon dioxide emissions from fossil fuel consumption and cement manufacture, 1950-1990. Glob. Biogeochem. Cycles, **10**, 419-429.
12. Nakicenovic, N., J. Alcamo, G. Davis, et al., 2000: IPCC Special Report on Emissions Scenarios. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 599 pp.