Signal and Noise in Global Warming Detection

Final Report

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1. Program Objectives

The specific objectives of this study were the following:

(1) What is the expected sampling error and bias incurred in estimation of the global average temperature from a finite number of point gauges?

(2) What is the best one can do by optimally arranging N point gauges? How can one make best use of existing data at N point gauges by optimally weighting them?

(3) What is a good estimation of the signal of global warming based upon simple models of the climate system?

(4) How do you develop an optimal signal detection technique from the knowledge of signal and noise?

2. Accomplishments

We have solved the problem of optimally deploying N point gauges for a class of model climate systems with idealized statistical behavior (North et al. 1992; Hardin et al. 1992). We have also been able to develop the curve of minimum error for a given number of point gauges as a function of the number of gauges. For our statistical model the Angell-Korshover network gives an estimate with only 15% of the variance being attributable to sampling error. Optimal placement of the same number of gauges would lead to roughly a halving of this.

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We also have solved the problem of optimally weighting data at N point gauges (Hardin and Upson 1993; Shen et al. 1994). This is a more practical approach since historically gauge locations have been poorly designed. The problem was solved both for a simple climate system with idealized statistics and for the surface temperature observations with spatially nonuniform statistics. The results indicate that these optimal estimation techniques are useful and more accurate than other techniques.

In addition to sampling error, aliasing error on sphere has been examined (Li et al. 1997; Li and North 1997). As in spectral analysis of time series variance is leaked from one wavelength to another. This is called aliasing. These studies systematically investigate how power (variance) is aliased in estimating spherical harmonic coefficients from a finite sample on the surface of the earth.

We have developed a simple coupled ocean-atmosphere energy balance climate model capable of reproducing the 0.5°C increase over the last century (Kim et al. 1992). The solution exhibit a transient as well as a stadily increasing part. There is a definite land-sea signature which might possibly be exploited in signal processing of climate data.

Finally, North et al. (1994) and North and Kim (1994) developed an optimal technique of detecting any climatic changes in the midst of background noise. The technique was applied to detecting surface temperature undulations due to fluctuations of the sunspot numbers (irradiance). It is such a weak signal and cannot be detected easily. The optimal detection technique was able to detect it but not with much confidence. The technique was also applied to detecting greenhouse warming signature as manifested in the surface temperature record. These studies demonstrate the utility of the optimal detection technique developed in this project.

The following is the list of papers published in this project:

North, G. R., S. S. Shen, and J. W. Hardin, 1992: Estimation of the global mean temperature with point gauges. *Environmetrics*, **3**, 1–14.

Hardin, J. W., G. R. North, and S. S. Shen, 1992: Minimum error estimates of global mean temperature through optimal arrangement of gauges. *Environmetrics*, **3**, 15–27.

Kim, K.-Y., G. R. North, and J. Huang, 1992: On the transient response of a simple coupled climate system. *J. Geophys. Res.*, **97**, 10069–10081.

Hardin, J. W., and R. B. Upson, 1993: Estimation of the global average temperature with optimally weighted point gauges. *J. Geophys. Res.*, **98**, 23275–23282.

Shen, S. S., G. R. North, and K.-Y. Kim, 1994: Spectral approach to optimal estimation of the global average temperature. *J. Climate*, **7**, 1999–2007.

North, G. R., K.-Y. Kim, S. S. P. Shen, and J. W. Hardin, 1995: Detection of forced climate signals. Part I: Theory. *J. Climate*, **8**, 401–408.

North, G. R., and K.-Y. Kim, 1995: Detection of forced climate signals. Part II: Numerical simulations. *J. Climate*, **8**, 409–417.

Li, T.-H., G. R. North, and S. S. Shen, 1997: Aliased power of a stochastic temperature field on a sphere. *J. Geophys. Res.*, **102**, 4475–4486.

Li, T.-H., and G. R. North, 1997: Aliasing effects and sampling theorems of spherical random fields when sampled on a finite grid. *Annals. of the Inst. of Statist. Mathematics*, in press.