How do we know that human influence is changing the climate in the Baltic Sea region?

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1. The BACC report

When the Assessment of Climate Change for the Baltic Sea Basin (BACC) was "invented" during a BALTEX meeting in Roskilde in September 2004, a key questions was to what extent the scientific community would actually *know* or merely *claim* that anthropogenic climate change would take place in the Baltic Sea basin. To find out, a systematic survey was conducted in the published literature about the state of knowledge. A voluntary group of about 80 scientists from 12 countries has reviewed and assessed the published literature on climate change in the Baltic Sea region. Now, in 2007, the assessment is available (*BACC-group*, 2007; *von Storch* et al., 2007).

For temperature, it was stated: "In the past century here has been a marked increase of temperature of more than 0.7 ^{o}C in the region…. Consistent with this increase in mean and extreme temperatures, other variables show changes, such as increase of winter runoff, shorter ice seasons and reduced ice thickness on rivers and lakes in many areas. These trends are statistically significant but they have not been shown to be larger than what may be expected from natural variability. In addition, no robust link to anthropogenic warming, which on the hemispheric scale has been causally related to increased levels of greenhouse gases in the atmosphere in 'detection and attribution' studies, has been established. However, the identified trends in temperature and related variables are consistent with regional climate change scenarios prepared with climate models. Therefore, it is plausible that at least part of the recent warming in the Baltic Sea basin is related to the steadily increasing atmospheric concentrations of greenhouse gases. Efforts are needed which systematically examine the inconsistency of recent trends with natural variability, circulation changes as well as the consistency with elevated greenhouse gas concentrations as a potential cause." For precipitation, wind speed and salinity, among others, no statements concerning anthropogenic signals are made.

2. Different approaches for assessing quality of changes

A variety of methods are in use to assert the quality of changes, if they are just coincidental or systematic. The principal problem is displayed by Figure 1. Depending on the fantasy of the analyst, the data show oscillations, a trend or a regime shift (in the sense of a break point). The best explanation is, however, that the series shows irregular low-frequency variability, with a tendency towards smaller values in later years than during some decades in the first third of the series.

Obviously, fitting statistical models, such as that of a break point or of a linear or non-linear trend is not really providing the needed answers. There are two reasons, one is: Even stationary time series with red or even long memory may show intermittently such behavior. The other is – how would we know that the behavior in the window of documented changes extends into the future?

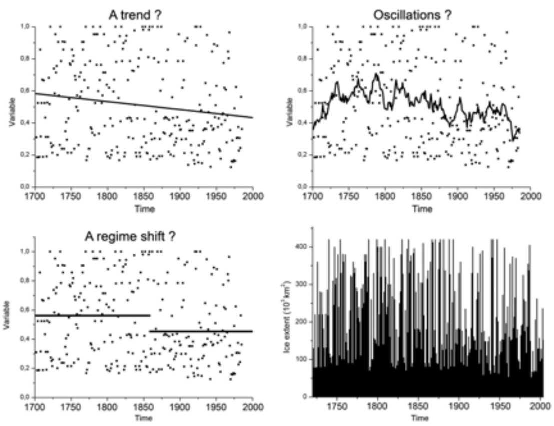

Figure 1. Difficulty to interpret a times series, as to whether it goes along with oscillations, a regime shift or a trend (after *Omstedt*, pers. comm.; also *BACC-group*, 2007)

3. Testing significance of trends

To solve the first problem, many ask – is the break point or the trend "statistically significant"? This is a well defined statistical procedure, which is in very many cases erroneously administered because of sheer incompetence. The problem is that often people implicitly operate with a null hypothesis, which is to be rejected, that a series of randomly drawn numbers have constant mean values. In that case the data have no memory, and the application of a procedure based on this assumption requires data which are serially uncorrelated. They are in most cases not. Thus in many cases the supposedly "significant" trend are technically not statistically significant.

But, even when the test is done correctly, what does the acceptance of the alternative hypothesis "there is a nonzero trend" imply? It implies, if we would repeat to collect the same data in a parallel world, we may expect to see again a trend. It does not imply that the trend will continue into the future.

An example is the annual cycle – when we test temperature variations from May through July on the Northern Hemisphere, we likely will reject the null hypothesis of no trend; and indeed, when we again examine the temperature series from another year, we will again see a temperature rise during that time. However, this finding does not imply that the trend will continue into September, October and so forth.

A major problem with "significant trends" is that the mathematics behind the word "significant" are not understood but are blended with the lay term "significance" (meaning – relevance).

In case of BACC, the literature screened contained a number of statistical analyses of trends, some of which were correct, others not.

4. The detection problem.

In fact, when considering a time series, which contains a trend, we do not need to do a significance test, except if we think that our data exhibit some uncertainties due to the observational process. Otherwise we know that the time series has a trend, with some given slope, during the interval. There is no uncertainty about it. The uncertainty we are interested is – is this slope larger than what we may expect as part of the natural climate variability to happen without increasing greenhouse gas concentrations?

This is the “detection problem” (Hasselmann, 1979, 1993). Statistically it means that we consider naturally occurring trends as being drawn from a random variable with a distribution function F(p), with p representing probability. Detection means to reject the hypothesis that recent trends T are sufficiently rare under the null hypothesis, e.g., T > F(95%).

5. Arguments, why a trend should be maintained in the future.

Statistics can hardly help us to decide if a trend will continue into the future. When talking about the future, we are in most cases leaving the statistical area of quantifying the risk of incorrect assessments. Instead we are entering the field of plausibility.

When we have convinced ourselves that a recent trend or adopted regime is related to some process, which in itself is predictable, then the trend or regime will continue if this process will prevail to act. This is a physical argument, not a statistical argument.

6. Attribution

The process of assigning a plausible cause for observed changes is named “attribution” (e.g., IDAG, 2005). This is usually a second step after a successful detection. A number of different candidate causes, which may be responsible for the change, which was found beyond the range of normal variations, is screened how well it fits the observed changes. Eventually that mix of causes is adopted as “best explanation” which describes the past changes best.

The famous assessment of the 3rd Assessment Report of the IPCC (*Houghton* et al. , 2001) that about 2/3 of the global warming since the middle of the 19th century would be due to elevated greenhouses gases, has been obtained is this way.

For the Baltic Sea catchment, the BACC initiative found no efforts to formally detect non-natural changes; also no efforts to objectively assign anthropogenic and natural factors to the observed warming in the region.

7. Consistency arguments

In view of the failure of the scientific community to rigorously address the abnormality of the recent warming in the Baltic sea region, and its possible causes, the BACC assessment offered a consistency argument, which is quoted in Section 1 of this extended abstract – namely: The recent warming during the industrial period in the Baltic Sea region is consistent with the global scale changes of air temperature. The latter, however, underwent a rigorous “detection and attribution”-analysis with the result that, first, the recent warming was beyond the range of natural variability and, second, that the best explanation of the recent warming was to relate 2/3 of it to elevated levels of greenhouse gases (e.g., IDAG, 2005).

We have now begun another line of consistency analysis. We ask if the most recent trends are consistent with what contemporary regional climate models envisage as the response to elevated GHG concentrations. In this way, we offer the possibility to falsify the hypothesis of a presently observable anthropogenic signal. A possible outcome of our analysis is "no falsification" of the hypothesis “trend is man-made”. Our method can not discriminate the plausibility of different forcing-effects but merely assess the consistency of recent changes with an a-priori assumed mechanism, in particular increased levels of GHGs in the atmosphere. Obviously, a regular “detection and attribution" analysis is more informative, but our method is applicable also in cases of considerably less data and without reference to sometimes hardly available estimates of natural variability.

Of course, this rests on the assumption that our contemporary models are good enough for projecting anthropogenic climate change. We believe that they are, but we have to acknowledge that a conclusive proof of that assumption is not possible at this time.

If recent trends fails to be consistent with the expected trend, then in principle three reasons may be thought of - the model is insufficient (e.g., the expected signal is false), the natural variability overwhelms the signal, or more than the expected mechanism is at work, for instance decreasing concentrations of industrial aerosols in parallel to an increase of GHG gases.

A first case study, dealing with winter precipitation amounts in the Baltic Sea region, is offered by Bhend and von Storch (2007) at this conference.

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