Supplement to
"How scientific is climate science?"

Notes

What the IPCC chapter said about the global temperature increase

The 2007 Assessment Report of the IPCC has a chapter entitled "Observations: surface and atmospheric climate change" (here "surface" refers to the surface of Earth, i.e. where people live). This chapter presents the global temperature measurements, illustrated in Figure 1. The chapter's principal conclusion is given in its first sentence (in bold). The conclusion is this: "Global mean surface temperatures have risen by 0.74°C ± 0.18°C when estimated by a linear trend over the last 100 years (1906–2005)". (Here "0.74°C ± 0.18°C" means that the IPCC is 90% confident that the temperature rise is in the range 0.56 to 0.92 °C, per century.) A trend that is so far above zero with such confidence is extremely significant.

A non-AR1 assumption dismissed by the IPCC chapter

In 2005, two scientists at the U.S. Geological Survey, T.A. Cohn and H.F. Lins, published a research article that considers an assumption other than AR1. The article concludes that if the other assumption is valid, then the increase in global temperatures is not significant.

The article by Cohn & Lins is cited by the IPCC chapter. The citation is in a single paragraph in an appendix (§3.A). The paragraph acknowledges that "the statistical significances of … AR1-based trends could be overestimated". It then claims that assumptions other than AR1 should not be adopted because "the results depend on the [assumptions] used, and more complex [assumptions] are not as transparent and often lack physical realism". The first part, that the results depend on the assumptions used, is correct, but is obviously not a reason for relying on AR1. The second part, concerning more complex assumptions, might be true in some cases (depending on which assumption is chosen). The third part, concerning whether the assumptions are physically realistic, is an important issue.

An assumption is physically realistic if it appears to be consistent with our understanding of how things physically work. Here is an example of an *un*realistic assumption: assuming that a coin, when flipped, always moved through the air up and down in a perfectly straight line. The IPCC report does not consider whether the AR1 assumption is physically realistic: this is a failing of the report. The issue, however, was considered in a 2008 research paper co-authored by NASA climatologist G.A. Schmidt and leading global-warming researcher M.E. Mann (both major advocates of global warming). The paper strongly argued that AR1 is physically unrealistic, and so some other assumption must be used. That implies the claim in the IPCC appendix, about avoiding assumptions other than AR1 on the basis of physical realism, is severely misguided.

Whether the assumption considered by Cohn & Lins is appropriate is unknown (although some support for it was given in 2007 by Koutsoyiannis & Montanari). The IPCC chapter, though, gives highly dubious reasons for rejecting that assumption.

Other assumptions mentioned by the IPCC report

A few assumptions other than AR1 are briefly mentioned in a later chapter of the IPCC report, in §9.4.1. The crucial issue—that whatever assumption is used, it must be justified—is not addressed. That significance can vanish with some assumptions is not indicated.

What the Climate Change Science Program said about the AR1 assumption

The CCSP report claims that AR1 is "an assumption that is a good approximation for most climate data". The claim is given without any evidence, argumentation, or reference. In fact, methods for testing the claim—which demonstrate that the claim is false—are taught in introductory (undergraduate) courses in time series: for some textbooks, see the Bibliography.

Statistical details

The annual global temperature data was downloaded via http://data.giss.nasa.gov/gistemp/ on 2010-11-17. The available data was for years 1881–2009. It is given as differences from the mean, in hundredths °C. (The mean used in Figure 1 is from NASA's Earth Fact Sheet; the accuracy of that mean is irrelevant for the analysis herein.)

The IPCC and the CCSP use slightly different methods to fit a straight line to the temperature data. The CCSP uses ordinary least squares, and then finds approximate confidence intervals assuming that the residuals conform to AR(1). The IPCC uses generalized least squares and REML, assuming AR(1). The difference between the two methods is negligible; using ML instead of REML also makes negligible difference: see the R session below.

Herein, the IPCC/CCSP model is compared, via AICc, to a driftless ARIMA(3,1,0) model.

```
> # Assign the annual global temperature data (source: NASA)
> gistemp<- ts(c(-21, -26, -27, -32, -32, -29, -36, -27, -17, -39, -
28, -32, -33, -33, -25, -14, -11, -26, -16, -8, -15, -25, -30, -35, -
24, -19, -39, -33, -35, -33, -34, -32, -30, -15, -10, -30, -39, -33,
-20, -19, -15, -26, -22, -22, -17, -2, -15, -13, -26, -8, -2, -8, -
19, -7, -12, -5, 7, 10, 1, 4, 10, 3, 9, 19, 6, -5, 0, -4, -7, -16, -
4, 3, 11, -10, -10, -17, 8, 8, 6, -1, 7, 4, 8, -21, -11, -3, -1, -4,
8, 3, -10, 0, 14, -8, -5, -16, 12, 1, 8, 19, 26, 4, 25, 9, 4, 12, 27,
31, 19, 36, 35, 13, 13, 23, 37, 29, 39, 56, 32, 33, 47, 56, 55, 48,
63, 55, 58, 44, 57), start=1881)

> # Show that the three methods give essentially the same result
> library(nlme)  # nlme contains gls
> ols<- lm(gistemp ~ time(gistemp)); coefficients(ols)
  (Intercept) time(gistemp)
-1134.0286319     0.5820159
> gls.REML<- gls(gistemp ~ time(gistemp), cor=corARMA(p=1,q=0),
method="REML"); coefficients(gls.REML)
  (Intercept) time(gistemp)
-1137.7531478     0.5842142
> gls.ML<- gls(gistemp ~ time(gistemp), cor=corARMA(p=1,q=0),
method="ML"); coefficients(gls.ML)
  (Intercept) time(gistemp)
 -1137.362997      0.583983
> phi<- coefficients(arima(resid(ols), order=c(1,0,0),
include.mean=FALSE))[1]  # for the CCSP confint approximation
> ci.ccsp<- coefficients(ols)[2] + sqrt((1+phi)/(1-phi))*
(coefficients(ols)[2] - confint(ols)[c(4,2)])
> ci.ccsp; confint(gls.REML)[c(2,4)]; confint(gls.ML)[c(2,4)]
[1] 0.4612661 0.7027656
[1] 0.4596008 0.7088276
[1] 0.4677889 0.7001771

> # Check AICc of IPCC/CCSP model and driftless ARIMA(3,1,0)
> calcAICc<- function(aicx,n,k)  aicx+(2*k*(k+1))/(n-(k+1))
> arima310z<- arima(gistemp, order=c(3,1,0))  # uses drift zero
> calcAICc(AIC(gls.ML), length(gistemp), 1+0+3)
[1] 964.7413
> calcAICc(AIC(arima310z), length(gistemp), 3+0+2)
[1] 951.2024

> # Find likelihood of IPCC/CCSP model relative to the ARIMA model
> exp((951.2024-964.7413)/2)
[1] 0.001148326
```

Bibliography [annotated]

Burnham K.P., Anderson D.R. (2002), *Model Selection and Multimodel Inference* (Springer). [The standard reference for AIC (Akaike Information Criterion) and similar; strongly recommends AICc; §2.6 and §8.6 discuss how to interpret differences in AICc values.]

Cohn T.A., Lins H.F. (2005), "Nature's style: naturally trendy", *Geophysical Research Letters*, 32, L23402; doi:10.1029/2005GL024476. [Dismissed by Trenberth et al.]

Cowpertwait P.S.P., Metcalfe A.V. (2009), *Introductory Time Series with R* (Springer). [Presents what its title says; §4.6.3 gives argumentation for using AR4 *without* a trend for global temperature measurements; see also Shumway & Stoffer.]

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Koutsoyiannis D., Montanari A. (2007), "Statistical analysis of hydroclimatic time series", *Water Resources Research*, 43, W05429, doi:10.1029/2006WR005592. [One of the few research articles that discusses non-AR assumptions (see also Cohn & Lins).]

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Shumway R.H., Stoffer D.S. (2011), *Time Series Analysis and Its Applications—With R Examples* (Springer). [An introductory text, more advanced than that of Cowpertwait & Metcalfe; Example 2.5 argues that it is better to consider changes in global temperatures than to use a linear trend; set problems 3.33 and 5.3 elaborate on that.]

Trenberth K.E., Jones P.D., Ambenje P., Bojariu R., Easterling D., Klein Tank A., Parker D., Rahimzadeh F., Renwick J.A., Rusticucci M., Soden B., Zhai P. (2007), "Observations: surface and atmospheric climate change", *Climate Change 2007: The Physical Science Basis* (editors—Solomon S., Qin D., Manning M., Chen Z., Marquis M., Averyt K.B., Tignor M., Miller H.L.) Chapter 3 (Cambridge University Press). [The chapter of the Fourth Assessment Report by the IPCC that treats surface climate; this is the chapter that is the source for the IPCC (2007) claim that global temperatures are increasing at 0.74°C ± 0.18°C per century; Appendix A describes statistical methods.]

Wigley T.M.L. (2006), "Statistical issues regarding trends", *Temperature Trends in the Lower Atmosphere* (editors—Karl T.R., Hassol S.J., Miller C.D., Murray W.L.) Appendix A (Washington D.C.: U.S. Climate Change Science Program). [Describes the statistical method used for the CCSP trend analysis.]

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—Douglas J. Keenan