Summary of the Climate Dialogue

on

Long-Term Persistence

Authors: Marcel Crok, Bart Strengers (PBL), Bart Verheggen (PBL), Rob van Dorland (KNMI)

This summary is based on the contributions of Rasmus Benestad, Armin Bunde and Demetris Koutsoyiannis who participated in this Climate Dialogue that took place in May 2013.

April 2014

Long term persistence and trend significance

"Is global average temperature increase statistically significant?" To answer this question one needs to make assumptions on the statistical nature of the temperature time series and to choose what statistical model is most appropriate.

If the temperature of this year is not related to that of last year or next year we can use statistics to determine whether the increase in global temperature is significant or not. In such an "uncorrelated climate", i.e. if the temperature of this year is fully independent of other years, the average value becomes zero (or a fixed value) quickly and deviations from the mean last only shortly. However, if there is (strong) temporal dependence the moving average can have large deviations from the mean. This is called long-term dependence or long-term persistence (LTP).

The three participants agree that LTP exists in the climate (Table 1), but they disagree about the exact definition and the physical processes that lie behind it. Benestad and Bunde describe LTP in terms of "long memory". Koutsoyiannis holds the opinion that LTP is mainly the result of the irregular and unpredictable changes that take place in the climate (Table 2). Both Bunde and Koutsoyiannis are in favour of a formal (mathematical) definition of LTP, which states that on longer time scales climate variability decreases—but not as much as implied by classical statistics.

Benestad said that ice ages and the El Niño Southern Oscillation (ENSO) are examples of LTP processes. Bunde and Koutsoyiannis disagreed (Table 3).

Table 1

	Benestad	Bunde	Koutsoyiannis
Does LTP exist in the climate?	Yes	Yes	Yes

Table 2

	What is long-term persistence (LTP)?
Benestad	LTP describes how slow physical processes change over time, where the gradual nature is due to some kind of 'memory'.
Bunde	LTP is a process with long memory; the value of a parameter (e.g. temperature) today depends on all previous points.
Koutsoyiannis	It is unfortunate that LTP has been interpreted as memory; it is the change, mostly irregular and unpredictable in deterministic terms, that produces the LTP, while the autocorrelation results from change.

Table 3

	Benestad	Bunde	Koutsoyiannis
Quasi-oscillatory phenomena like ENSO can be described as LTP.	Yes	No	No

Is LTP relevant for the detection of climate change?

There was confusion about the exact meaning of the IPCC definition about detection. The definition reads: "Detection of change is defined as the process of demonstrating that climate or a system affected by climate has changed in *some defined statistical sense* without providing a reason for that change. An identified change is detected in observations if its likelihood of occurrence by chance *due to internal variability alone* is determined to be small."

Bunde and Koutsoyiannis both think detection is mainly a matter of statistics while Benestad thinks it also involves a physical interpretation of distinguishing unforced internal variability from forced changes.

Table 4

	Benestad	Bunde	Koutsoyiannis
Is detection purely a matter of statistics?	No, laws of physics sets fundamental constraints	Yes	Not purely but primarily yes

LTP versus AR(1)

Bunde and Koutsoyiannis argue that LTP is the proper model to describe temperature variability, that climate scientists in general use a Short Term Persistence (STP) model like AR(1) which leads to a strong overestimation of the significance of trends (Table 5). Koutsoyiannis showed that the clustering of warm years, for example, is orders of magnitude more likely to happen if you use an LTP model. Benestad agrees that the AR(1) model may not necessarily be the best model. He argues that in general statistical models and LTP in particular, used for the detection of trends involve circular reasoning when applied to what is called the instrumental period, because in this period the data embed both "signal" and "noise". LTP or STP or whatever statistical model are meant to describe "the noise" only in his opinion (Table 6). Koutsoyiannis in response gave a few examples why in his opinion the danger of circular reasoning is not justified in this case (see Extended Summary).

Table 5

	Benestad	Bunde	Koutsoyiannis
Is LTP relevant/important for the statistical significance of a trend?	Yes (though physics still needed)	Yes, very much	Yes, very much

Table 6

	What is the relevance of LTP for the detection of climate change?
Benestad	Statistical LTP-noise models used for the detection of trends involve circular reasoning if adapted to measured data. State of the art detection and attribution is needed.
Bunde	For detection and estimation of external trends ("detection problem") one needs a statistical model and LTP is the best model to do this.
Koutsoyiannis	LTP is the only relevant statistical model for the detection of changes in climate.

Table 7

	Benestad	Bunde	Koutsoyiannis
Is the AR(1) model a valid model to describe the variability in time series of global average temperature?	No, if physics based information is neglected	No	No
Does the AR(1) model leads to overestimation of the significance of trends?	Yes, if you don't also take into account the physics-based information	Yes	Yes

LTP and chaos

There was disagreement about the relation between LTP and chaos (Table 8). According to Benestad chaos theory implicates the memory of the initial conditions is lost after a finite time interval. Benestad interprets "the system loses memory" as "LTP is not a useful concept". Koutsoyiannis considers memory as a bad interpretation of LTP: it is the change which produces the LTP and thus LTP is fully consistent with the chaotic behaviour of climate.

Table 8

	Benestad	Bunde	Koutsoyiannis
Is the climate chaotic?	Yes	Yes	Yes
Does chaos mean memory is lost and does this apply for climatic timescales as well?	Yes	Chaos is not a useful concept for describing the variability of climate records on longer time scales	No; LTP is not memory
Does chaos exclude the existence of LTP?	Yes, at both weather and climatic time scales	No	No; on the contrary, chaos can produce LTP
Does chaos contribute to the existence of LTP?	No, but chaos may give an impression of LTP	Yes	Yes, LTP does involve chaos

Signal and noise

There was disagreement about concepts like signal and noise. According to Benestad the term "signal" refers to manmade climate change. "Noise" usually means everything else, and LTP is 'noise in slow motion' (Table 9). Koutsoyiannis argued that the "signal" vs. "noise" dichotomy is subjective and that everything we see in the climate is signal. To isolate one factor and call its effect "signal" may be misleading in view of the nonlinear chaotic behavior of the system. Bunde does assume there is an external deterministic trend from the greenhouse gases but he calls the remaining part of the total climate signal natural "fluctuations" and not noise (Table 9). All three seem to agree that one cannot use LTP to make a distinction between forced and unforced changes in the climate (Table 10).

Table 9

	Signal versus noise
Benestad	The signal is manmade climate change; the rest is noise and LTP is noise in slow motion.
Bunde	My working hypothesis: there is a deterministic external trend; the rest are natural fluctuations which are best described by LTP.
Koutsoyiannis	Excepting observation errors, everything we see in climate is signal.

Table 10

	Benestad	Bunde	Koutsoyiannis
Is the signal versus noise dichotomy meaningful?	Yes	Yes	No*
Can LTP distinguish between forced and unforced components of the observed change?	No	No	*
Can LTP distinguish between natural fluctuations (including natural forcings) and trends?	No	Yes	*

* Koutsoyiannis thinks that even the formulation of these questions, which imply that that the description of a complex process can be made by partitioning it into additive components and trying to know the signatures of each one component, indicates a linear view for a system that is intrinsically nonlinear.

Forced versus unforced

According to Bunde Natural Forcing plays an important role for the LTP and is omnipresent in climate. Koutsoyiannis agreed that (changing) forcing can introduce LTP and that forcing is omnipresent, but LTP can also emerge from the internal dynamics alone.

Table 11

	Benestad	Bunde	Koutsoyiannis
Does forcing introduce LTP?	Yes	Yes	Yes
Is forcing omnipresent in the real world climate?	Yes	Yes	Yes
What according to you is the main mechanism behind LTP?	Forcings	Natural Forcing plays an important role for the LTP and is omnipresent in climate	I believe it is the internal dynamics that determines whether or not LTP would emerge

Is the warming significant?

The three participants gave different answers on the key question of this Climate Dialogue, namely of the warming in the past 150 years is significant or not. They used different methods to answer the question. Benestad is most confident that both the changes in land and sea temperatures are significant. Bunde concludes that due to a strong Long Term Persistence the increase in sea temperatures are not significant but the land and global temperatures are. Koutsoyiannis concludes that for most time lags the warming is not significant. In some cases it maybe is.

Table 12

	Benestad[I]	Bunde[II]	Koutsoyiannis[III]
Is the rise in global average temperature during the past 150 years statistically significant?	Yes	Yes[IV]	No[V]
Is the rise in global average sea surface temperature during the past 150 years statistically significant?	Yes	No	No
Is the rise in global average land surface temperature during the past 150 years statistically significant?	Yes	Yes	No

[I] Benestad's conclusions are based on the difference between GCM simulations with and without anthropogenic forcing (Box 10.1 or Figs 10.1 & 10.7 in AR5)

[II] Based on the Detrended Fluctuation Analysis (DFA) and/or the wavelet technique (WT).

[III] Based on the climacogram and different time lags (30, 60, 90 and 120 years).

[IV] This change is 99% significant according to Bunde.

[V] For a 90 year time lag and a 1% significance level it maybe is significant (see guest blog).

Is there a large contribution of greenhouse gases to the warming?

Bunde is more convinced of a substantial role for greenhouse gases on the climate than Koutsoyiannis although he admits he cannot rule out that the warming on land is (partly) due to urban heating. Bunde said he may not fully agree with Koutsoyiannis: "We cannot show in our analysis of instrumental temperature data that GHG are responsible for the anomalously strong temperature increase that we see and that we find is significant, but it is my working hypothesis." Koutsoyiannis believes the influence of greenhouse gases is relatively weak, "so weak that we cannot conclude with certainty about quantification of causative relationships between GHG and temperature changes". Benestad on the other hand said the increased concentrations of GHGs is the only plausible explanation for the observed global warming, global mean sea level rise, melting of ice, and the accumulation of ocean heat.

Table 13

	Benestad	Bunde	Koutsoyiannis
Is the warming mainly of anthropogenic origin?	The combination of statistical information and physics knowledge lead to only one plausible explanation: GHGs	Yes, it is my working hypothesis	No, I think the effect of CO2 is small