Step change hypothesis and working paper **with 11 comments**

Imagine you didn't know anything about climate change and the greenhouse effect but were interested and you know a bit about general science. Would you accept the following story?

"Earth's climate is a large, complex system, affected by forces that produce both linear and nonlinear responses. Shortwave radiation – basically UV – from the sun comes in and heats up the planet, producing infrared radiation. Some UV gets reflected straight back out by clouds, snow and ice and stuff. The land can heat up quite a lot, but it cools back down again and doesn't store much. If a forest is cleared and replaced by buildings, it will warm up a bit but the effect is only local."

"But the ocean – that's another story. It absorbs a lot of radiation, so is taking up heat all the time. Huge streams of energy are entering and leaving the ocean store each year. Some is 'dry' or sensible heat, which is ordinary warmth. Some is 'wet heat' or evaporated moisture. Energy gets taken up when the moisture is evaporated and it will be released again when the moisture cools, condenses and then gets rained out. In this way, the oceans provide a lot of heat to the land every year, largely as rainfall and a bit of snow."

"The atmosphere doesn't store much energy – but does transport it. In the past 60 years, the atmosphere has added about the same amount of heat as the ground surface, while the ocean has warmed by about 30 times that much. The whole atmosphere holds about the same heat as the top 3 metres of ocean (10 feet, if you're American). So the land might warm and cool a lot in a year, but it doesn't carry over much energy from one year to the next. The atmosphere can't carry much and ice will but is too slow. Only the ocean has enough carry-over energy likely to affect climate on decadal timescales (There are exceptions but they're short-lived)."

"Greenhouse gases in the atmosphere trap some of the heat produced from the incoming solar radiation. Most of this goes into the ocean and this maintains the atmosphere at temperatures roughly 30 °C (54 °F) warmer than they would otherwise be. The atmosphere actually doesn't store any heat on its own – it is warmed or cooled by the things around it. That was already said above in another way but is really important."

"The heat produced and stored in the system is forced in two directions. One is to the top of the atmosphere to escape into space so that the energy out equals the energy in. The other is from the equator to the poles, warm to cool, where it also radiates out into space. The transport from the equator to the poles is seriously nonlinear. The rotation of the Earth and drag of the atmosphere produce vortices that include the coriolis effect, but these exist throughout the ocean and the atmosphere. This creates the environment for complex system interactions, in a similar way that pendulums of different length create patterns that may oscillate between organised waves and chaotic motion."

"The oscillators in the climate system that have the largest effect on climate are formed from the interactions between the atmosphere and the ocean. They have been call strange attractors because these systems can flip between different fairly stable states. Strange attractors were first described over 50 years ago by Ed Lorenz (more popularly being called the Butterfly Effect). They are produced by store of energy in motion being perturbed by small changes. The ocean is the store and the atmosphere supplies the perturbation. Normally, there are a number of these oscillations in the climate system and they affect things like regional temperature and rainfall, storminess and so on. They can energetically connect areas that are a long way apart, so that ocean warming in one region can affect rainfall in another."

"These oscillators can rapidly switch between states and some do so on decadal timescales. The stable states in between shifts are called regimes, and they are involved in the transport of energy vertically to the top of the atmosphere, and horizontally from the equator to the poles. Oscillators of different periodicity combine to perturb these regimes, and these are affected by internal and external sources of energy. Examples are the El Niño Southern Oscillation that flips between El Niño (heating), normal and La Niña (cooling) every few years, and the Atlantic Meridional Oscillation that flips on decadal timescales. These interact with each other, and act as a type of thermostat, being governed by the energy status of the climate at any one time. Under our current state of knowledge individual flips are not really predictable, but their long-term behaviour follows statistical patterns such as power laws."

"So what happens when more greenhouse gases are added to the atmosphere? If the atmosphere warms in place, then the airmass would gradually get warmer, forming a trend over time. But what if the added energy follows the same pathway as it normally does and becomes stored in the ocean? The atmosphere would not warm straight away and the heat in the ocean would immediately be entrained into these nonlinear systems. Some is mixed into the deep ocean, but sea surface temperatures remain fairly constant until an instability threshold is reached, and the system needs to do some work. It reorganises and a large amount of heat is released into the atmosphere. When the system settles back, higher temperatures at the sea surface and in the atmosphere are maintained."

"Upon release, this heat would be rapidly transmitted to adjacent land surfaces. Once in the atmosphere, positive feedbacks then lead to warming that respond to the atmosphere's inherent climate sensitivity. This process leads to step-like warming where the warming process looks like a stepladder, over long time scales (50+ years) forming a complex trend."
"Increasing the rate of change by continuing to add greenhouse gases to the atmosphere will forces these step change closer together and probably more locally distributed, much like a boiling pot. At that stage, rising temperatures will look more like an escalator than a stepladder."

"Reducing greenhouse gas emissions, then reducing greenhouse gases will slow this process down, making the gaps between step changes long and eventually stabilising the atmosphere. Maybe even inducing steps to cause cooling. Can we do this before large ice sheets near the poles melt?"

I have had no trouble explaining most of this to the ordinary person but the climate science community is another thing entirely. The received wisdom of trend analysis and efforts to defend the trend in the climate wars has meant that to many, trends are rusted on science.

This little narrative is the product of many year's work. It has resulted in a couple of papers in the literature, one on step changes in south-eastern Australia, and another looking at Valuing Adaptation to Rapid Change. A submission of two key papers on the statistics of step changes in observations and models written with Jim Ricketts was rejected without review late last year by one journal and rejected with prejudice early this year by another.

These were then merged and beefed up with a good deal of science philosophy and some of the theoretical reasoning in the above narrative. It will be submitted into an open review journal in the next week. Hopefully they like it enough to open it up for review. Because of the extensive arguments put and the evidence tested, it's a long paper. Another five just are about ready to go, most quite lengthy.

The problem with publishing these days is that it is difficult to get such things into the literature. Publishing is geared towards making limited advances in 3,000 words. Arguing against a long-held paradigm is not part of the deal.
For that reason, we have decided to release all of the past three years work as working papers, while the later papers are reformatted and submitted to journals. This is for a few reasons:

If the case is put out piecemeal it will be picked apart piecemeal.If the above story is correct, or close to the mark, then climate is not being analysed appropriately and climate risk is not being characterised properly. Other work needs doing and this has been burning a hole through the desk for far too long. I might get a life. The first few working papers are legacy papers that have been rolled into others as the research developed. The first *Reconciling anthropogenic climate change and variability on decadal timescales* was originally written for a journal submission which fell through. It was developed into four more, three of which will be posted soon. Also posted will be the two papers that were rejected, along with another three earmarked for submission.

Some will frown and disapprove that research is being posted without peer review because that's not real science, is it? However, the frustration of watching a whole heap of rubbish getting posted about trend analysis in climate on one hand and a whole heap of rubbish about how climate is not a trend on the other, is too much to bear. We are in the middle of the next big shift right now. As this El Niño settles back into a more normal pattern we will find the shallow oceans and atmosphere are appreciably warmer than they were between 1997 and 2014. Things might be stable for a few years, who knows?, but another one will be on the way somewhere down the track. Previous step changes were 1968-70 southern hemisphere, 1979-80 global, 1987-88 northern hemisphere and 1997-98 global.

Every one of these step changes takes the world into new territory. So far this time, it's been the biggest mangrove die-off ever seen in northern Australia, kelp forests of south-west WA killed off by record warm waters, the largest coral bleaching yet witnessed and unprecedented wildfires in North America. And that's the short of it.

Some of the above narrative may be wrong, maybe all of it – but if it means that climate science takes nonlinearity a little more seriously and treats it as more than just 'noise', it will be worthwhile. This page will be updated as the working papers are linked in.

Finally, doing a project this size means that I have had a lot of help from a number of people, picking up other work, helping with this project and dealing with someone who's attention is elsewhere. Celeste Young stepped in and got the Valuing Adaptation to Rapid Change project over the line in 2012-2013 when it was dead in the water and is still doing the same for other projects. Jim Ricketts has coded an objective multi-step bivariate model that allows rapid assessment of step changes over large data sets. My work colleagues have had to adjust as other projects have slowed down. Most of the work has been unfunded, so it has received a large amount of in-kind assistance. My Australian climate colleagues and adaptation experts worldwide have also kept faith as we have worked hard to make the case for viewing climate in a very different light to how it is normally seen.

Working Papers

Jones, R.N. (2015) Reconciling anthropogenic climate change and variability on decadal timescales. Climate Change Working Paper No. 31.

This paper was completed in late 2014, so while reasonably comprehensive, has been superseded by subsequent work (which will be posted soon).

Jones, R.N. (2015) Reconciling anthropogenic climate change and variability on decadal timescales: narratives and hypotheses. Climate Change Working Paper No. 32.

This paper was developed from Climate Change Working Paper No. 31 and serves as an introduction to Climate Change Working Papers No. 33 to 36.

Jones, R.N. (2015) Reconciling anthropogenic climate change and variability on decadal timescales: history and philosophy. Climate Change Working Paper No. 33.

Why are we putting straight lines though complex trends? I try to answer this.

Jones, R.N. and Ricketts, J.H. (2015) Analysing steps in global and regional observed air temperature. Climate Change Working Paper No. 34.

Straightforward analysis of step changes in temperature, showing they are spatially organised. This paper has been merged with the following paper.

Jones, R.N. and Ricketts, J.H. (2015) Analysing steps in modelled global surface air temperature. Climate Change Working Paper No. 35.

Climate models do a pretty good job of reproducing historical step changes. Steps and shifts also explain total warming in the 21st century better than internal trends.

Jones, R.N. (2015) Reconciling anthropogenic climate change and variability on decadal timescales: the challenge. Climate Change Working Paper No. 36.

If climate change is episodic rather than gradual, we will need to re-think the way we analyse and communicate it. Check out the cover. It has elephants.

Jones, R.N. and Ricketts, J.H. (2016) The climate wars and "the pause" – are both sides wrong? Climate Change Working Paper No. 37

This paper was borne out of the frustration that both sides of this debate were so totally focused on trends and winning the war that how the climate changes is secondary.

Jones, R.N. and Ricketts, J.H. (2016) Reconciling the signal and noise of atmospheric warming on decadal timescales. Climate Change Working Paper No. 38

This paper does the full-on step and trend severe testing. So which regime reigns supreme?

Jones, R.N. and Ricketts, J.H. (2016) Atmospheric warming 1997–2014: hiatus, pause or regime? Climate Change Working Paper No. 39

This paper looks more closely at the hiatus, pause or regime in warming. No cherries here.