The scientific origins of the gradualist adaptation narrative and how to move beyond it

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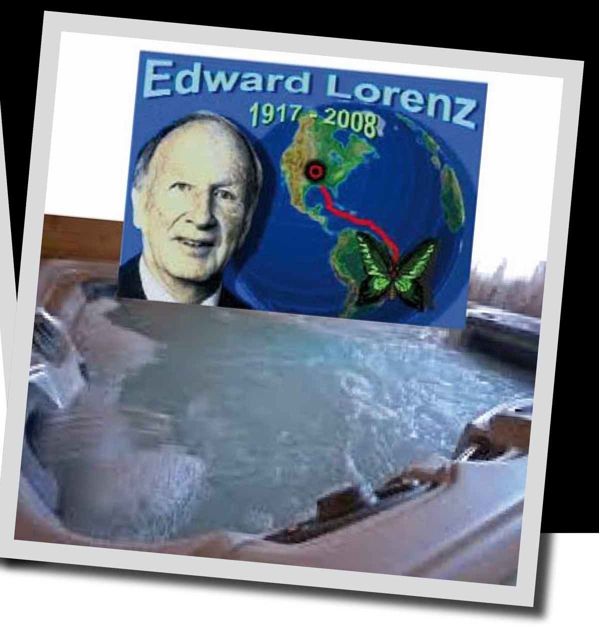
Within limits, the impacts of gradual climate change should be manageable.[1] Therefore, climate change adaptation can be understood as: (a) adapting to gradual changes in average temperature, sea level and precipitation.[2] Gradual climate change allows for a gradual shift in the mix of crops and to alternative farming systems.[3]

So why are Gauss and Newton in the bath and Ed Lorenz in the hot tub?



Physics says that climate change cannot be gradual

The First Law of Thermodynamics (conservation of energy) describes how much the Earth will warm. Greenhouse gases trap heat in the atmosphere but because air holds little heat, most goes into the ocean. This heat is re-released into the atmosphere as Earth warms towards equilibrium.

Under the simplest model, the ocean behaves like a bath that warms under the heat of a radiator. The warm bathwater then heats the atmosphere above until they are at similar temperatures. This heat transfer is usually represented as a linear process and communicated as smooth curves of change.

The Second Law of Thermodynamics describes how climate will change. The climate system evolves into a state where it can change into the maximum number of future possibilities. In a complex system, influenced by radiation imbalances, rotation, tides, gravity, wind, atmospheric friction and ocean-atmosphere interactions, the process of heat transfer is strongly non-linear, characterised by multiple state changes. The ocean-atmosphere system behaves more like a hot tub than a bath. (See the widespread non-linear behaviour in the diagram opposite.)

Why then, is adaptation dominated by a gradualistic narrative? It's time to get out of the bath.

Origin of the gradualist narrative

The gradualistic narrative can be explored through the structure of a scientific paradigm, which consists of three main elements – **theory**, **methods** and **values**.

Theory forms the core of science and is justified by evidence. **Methods** are used to analyse and communicate evidence and are associated with a set of **values**. Scientific values include reproducible observations and experiments, objectivity, peer review and the development of models with predictive skill.

If theory suggests that climate change is non-linear, why is it so often represented as a gradual process? The reasons are in the historical development of scientific methods and their related values (see timeline below).

The origin of the gradualist narrative has its roots the scientific enlightenment. The subsequent development of methods and values have failed to address the non-linearity present in scientific theory and evidence (see 1963 on the timeline).

The climate science community decides how their findings should be communicated and delivered. Critical information about changing climate risk is being discarded in the process.

Risks of the gradualist adaptation narrative

Expectations of gradual change lead to the following shortcomings:

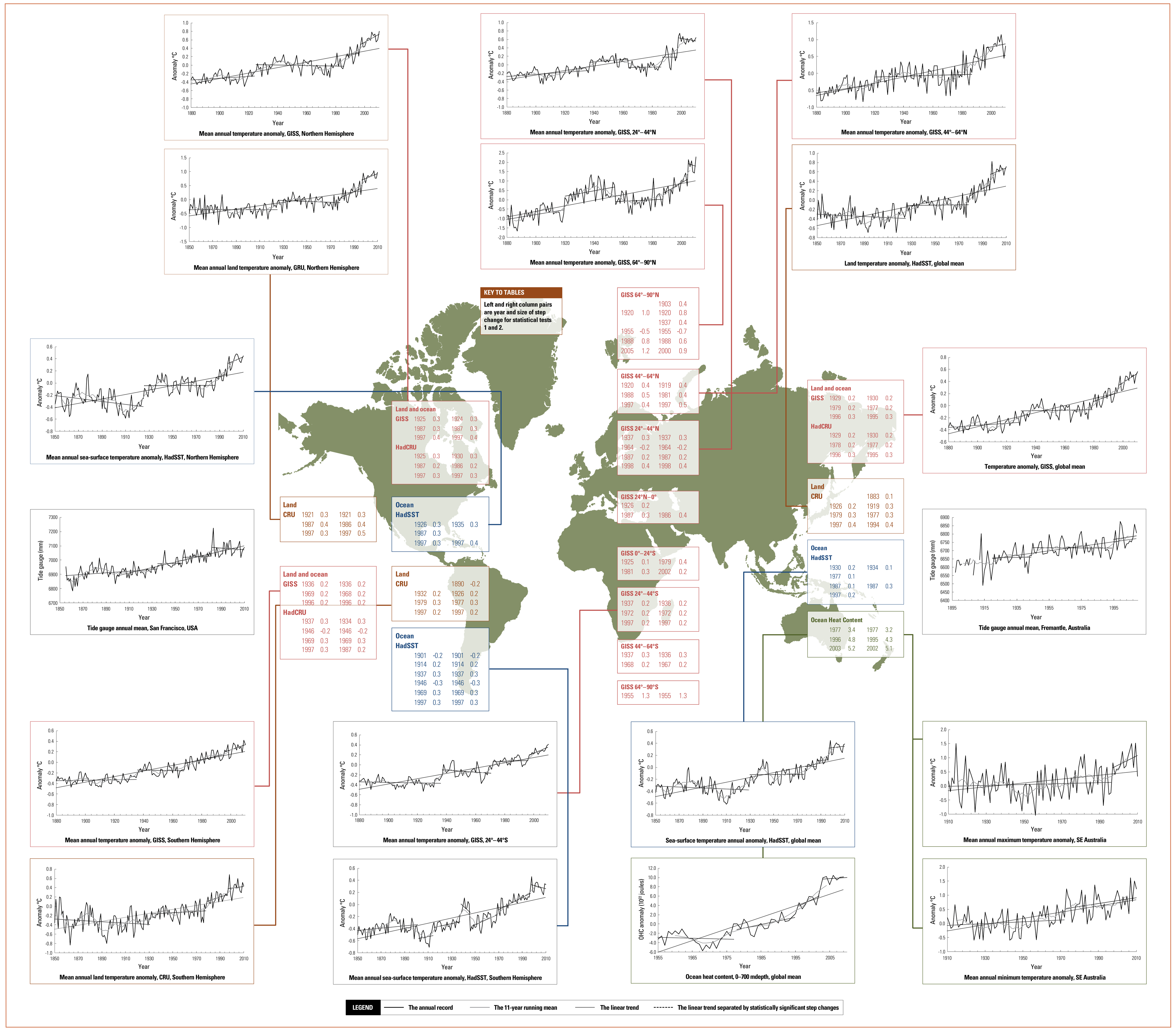
- Observed changes in climate risk are being dismissed as short-term random variability when they are not.
- Adaptation is delayed in anticipation of changes being gradual over time.
- Delay increases the risk of under-adaptation and irreversible loss.
- Incremental change is being preferred to transition or transformation.

Reactive responses to rapid changes after the fact are more expensive than planned adaptation.

Beyond gradualism

The following actions will ensure that theory, methods and values are more consistent with each other and can better address changing climate risk:

- Recognise the social constructions inherent in the scientific method and ensure that it accurately reflects theory and observations.
- Cease the scientific gatekeeping of climate information and develop communication strategies with the users of that information.
- Address risk more comprehensively in how climate data is prepared and communicated.
- Explore the set of adaptation options on the table in order to determine which information may be most relevant to decision-making.
- Develop scenarios that anticipate rapid changes in risk but that are inherently unpredictable.
- Develop statistics for assessing the magnitude and likelihood of rapid changes in climate.
- Improve the scientific understanding of why and how non-linear changes in climate occur, to improve their detectability, and perhaps, prediction.



Date	1654	1687	1783	1809	1824	1850	1940s	1963	1970s	1979	1990	2013
Villains involved	Fermet and Pascal	Newton	Lavoisier	Gauss	Carnot and others (later)	Clausius, Rankin and others	Many	Lorenz	Many	Hasselmann	Santer and others	Most climatologists
Theoretical advance	Calculation of the odds	Law of Gravity	Calorific law (conservation of heat)	Statistical theory	Second Law of Thermodynamics	First Law of Thermodynamics	Information theory	Chaos theory (deterministic non-periodic flow)	Detection of climate change	Temporal and spatial detection of climate change	Scalability of climate change signals over 3+ decadal time scales	Climate variables gradually respond to increasing greenhouse gases
Methodological development	Mathematics of chance (risk)	The square of the distance between objects	Heat balance	Least squares analysis	Thermodynamic equilibrium	Conservation of heat (heat and work in 20th century)	Signal-to-noise models	'Strange' attractors, butterfly effect, Lorenz equations	Signal-to-noise models used in past and present climate data	Signal-to-noise models used in climate model data	Pattern scaling	Pattern scaling, signal-to-noise, lines of best fit
Scientific value	Predictability	Balance and order, universality	Balance, measurement	Balance, order, management of uncertainty	Balance, irreversibility, harnessing of energy	Balance, order	Separating useful information from noise	Non-linearity, chaos	Extraction of climate signal from 'noisy' data	Attribution, prediction of change	Predictability	Predictability – separate the signal from the noise

1654 1687 1783 1809 1824 1850 1940s 1963 1970s 1979 1990 2013

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References 1. www.pc.gov.au; 2. www.prevention.web; and 3. www.ers.usda.gov

NCCARF National Climate Change Adaptation Research Facility

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