440 TOWARDS A LONG-TERM (MULTI-DECADAL) GLOBAL CLIMATE CHANGE DERIVATIVES TRADING FACILITY

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1. INTRODUCTION

The potential of a Long-Term (multi-decadal) Global Climate Change Derivatives Trading Facility, to enable the trading of financial products related to long-term trends in the world's climate (Figure 1), is explored.

Global mean temperatures (Figure 1A), after having fluctuated between 13.4°C and 14.0°C, prior to the 1920s, have since risen over recent decades to be between 14.5°C and 14.8°C more recently.

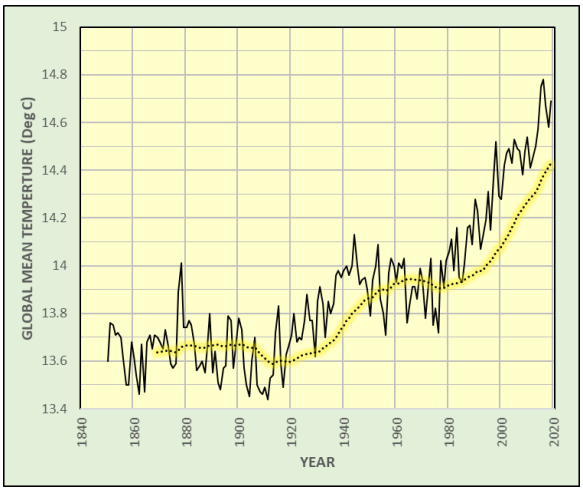

FIGURE 1A Observed annual *global* mean historical temperatures (and associated 30-year running averages). The 30-year running average (yellow-highlighted dotted line) is at its all-time high.

Source: http://www.bom.gov.au/climate/

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The 250-year Central England temperature data set (Figure 1B) displays a similar rise, to that of the world as a whole, since 1920.

After averaging close to 8.5°C for one and a half centuries, recent years have seen temperatures approaching 10°C.

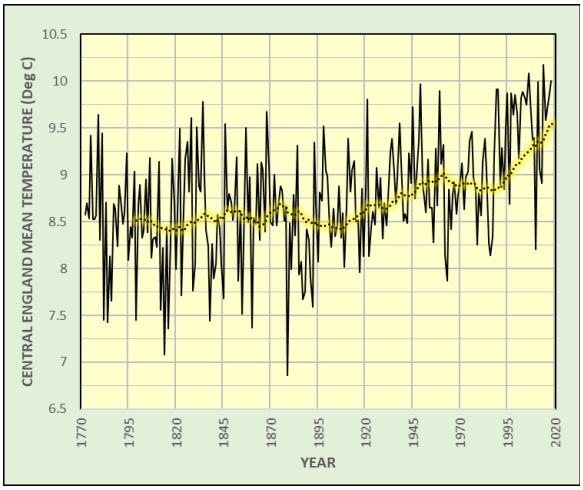

FIGURE 1B Observed annual *Central England* mean historical temperatures (and associated 30-year running averages). The 30-year running average (yellow-highlighted dotted line) is at its all-time high.

Source: https://www.metoffice.gov.uk/hadobs/hadcet/data/download.html

Another very long temperature data set, that for Nuuk, Greenland (Figure 1C), tells a similar story.

Temperatures there are now averaging about 2°C higher than in the early 1800s.

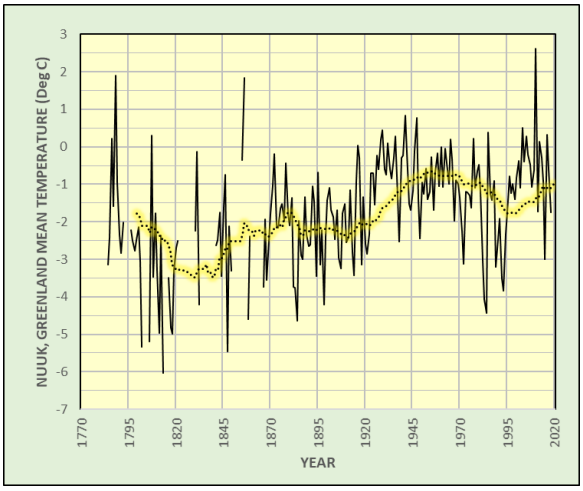

FIGURE 1C Observed annual *Nuuk, Greenland,* mean historical temperatures (and associated 30-year running averages). The 30-year running average (yellow-highlighted dotted line) is close to its all-time high.

Sources:
https://crudata.uea.ac.uk/cru/data/greenland/nuuk.dat

and:

https://www.wunderground.com/history/monthly/gl/nuuk/BGGH/date/2017-12

2. FUTURE TRENDS

The probability distribution of likely trends in the future global mean temperature out to the year 2100 is illustrated by Figure 2. This distribution is derived purely via a statistical model.

The model generates temperatures based upon a 'random walk' (2020-2100) derived on all previous year-to-year fluctuations in global mean temperature (1850-2019) and is driven by a third-order polynomial derived on that same data set (which yields the overall background accelerating temperature rise).

One thousand possible scenarios are generated out to the year 2100. All scenarios display brief periods when the temperature falls, as what has happened historically in the wake of major volcanic eruptions, and for other reasons - hence the small chance that, in the short term, we may see a fall in temperature.

However, by the end of the century, as indicated by the temperatures corresponding to the year 2100 listed on the graphic, all scenarios yield a global mean temperature greater than what we have at present.

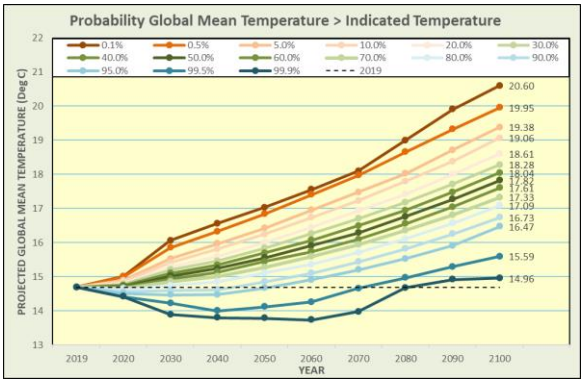

FIGURE 2 Probability distribution of likely trends in future global mean temperature out to the year 2100.

Figure 3 provides in greater detail, *the structure* of the associated probability distribution of future temperature.

3. A CLIMATE CHANGE TRADING FACILITY

We now return to exploring the potential of a Long-Term (multi-decadal) Global Climate Change Derivatives Trading Facility. This facility shall have as its *raison d'être*, the enabling of the trading of financial products related to the aforementioned long-term trends in the world's climate.

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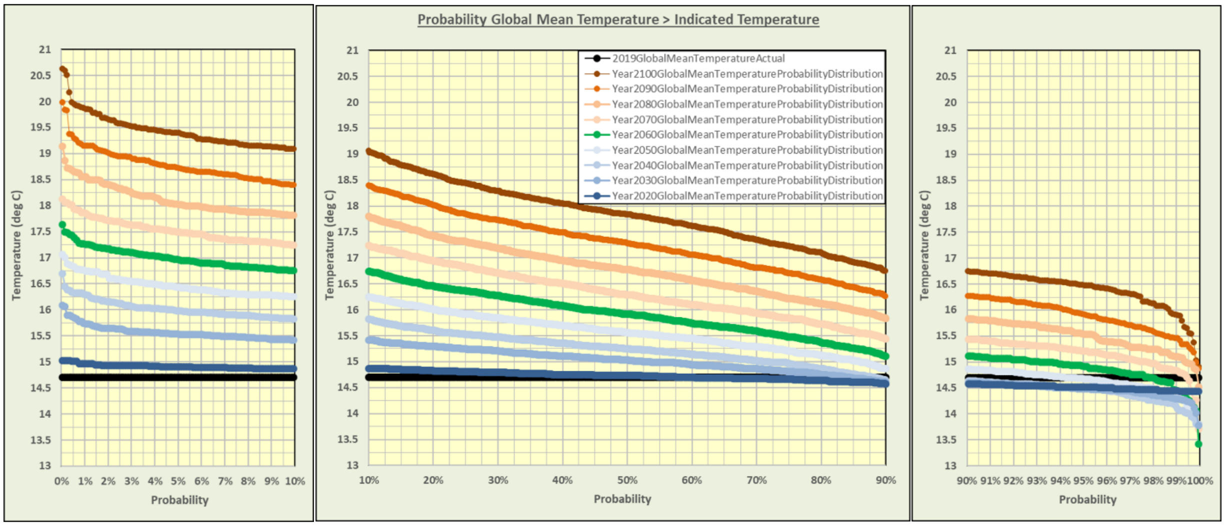

FIGURE 3 Derived in a similar manner to FIGURE 2 but presenting here, in greater detail, *the structure* of the probability distribution of the likely global mean temperature out to the year 2100.

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Such an establishment is seen as enabling the transfer of climate change related financial risk via futures, options, and other insurance linked securities, and would represent a significant contribution to this area of risk management.

A review of the various financial market products that are utilised to manage risk is presented in their various categories.

These include:

• The related areas of insurance linked securities and risk transfer instruments;

• The importance of the developing weather and climate derivatives industry; and,

• The potential application of these fields of knowledge to addressing the financial consequences of anthropogenic climate change.

A description of a ‘simulated’ trading platform, derived from numerical modelling of various processes involved in climate variability and change, is also presented, depicting how such a platform might operate in ‘real-time’.

A trading platform designed along these lines would lead to:

• The implementation of protection strategies, with their implications for future generations;

• The raising of capital for relevant ventures (such as for the generation of renewable energy);

• Speculation (of course), with the interesting side benefit – leading to the emergence of an unbiased consensus view about the future climate - on this subject, Little *et al*. (2015) somewhat bluntly suggest that parties "should either put up their capital … or not"; and,

• Become an impetus to arousing interest in shifting the nature of the conversation about how best to manage financial aspects of climate change risk with a market-based approach.

Regarding financial market securities and bonds, and their potential application to ameliorating the impacts of climate change, the basic approach to addressing some of the financial consequences of global climate change is to regard measures of global climate variability and change in much the same manner as one would a financial commodity's futures or options contract, and to value it accordingly.

How best might one go about implementing the proposed Long-term (multi-decadal) Global Climate Change Derivatives Trading Facility?

This question may be best addressed in the context of an examination of the different types of trading platforms, and how it is perceived the proposed exchange may fit in.

This then leads to the outcome most desired, namely, to see the establishment of such a facility to enable the trading of financial products related to long-term trends in the world's climate (refer, for example, to Figure 4).

4. FINANCIAL MARKET INSTRUMENTS

The current author, in several papers, has explored the role of financial market instruments in the area of climate variability and change.

15.5°C CALL OPTION (European Style) contract
EXPIRING 31-DEC-2100 with a value of US$100/°C

Current Theoretical Price	$21.91*
Last Sale:	$21.90
Bid/Size:	$21.89/30
Offer/Size:	$21.90/10

Buyers			Sellers		
Number	Volume	Bid (US$)	Offer (US$)	Volume	Number
10	30	$21.89	$21.90	10	5
5	50	$21.88	$21.91	30	3
2	120	$21.85	$21.92	25	10
6	13	$21.80	$21.95	3	1
1	2	$21.78	$22.00	10	5
1	4	$21.74	$22.05	3	1
2	4	$21.72	$22.08	5	1

FIGURE 4 Image showing how a page on the trading platform may appear.

*** Note: With the current 81-year bond interest rate of 2.97%, this current theoretical price of $21.91 would be $234.54 in anticipated year-2100 dollars.**

For example, in a much earlier paper, Stern (1992) explored a methodology to assess the risk of climate change. Option pricing theory was used to evaluate securities in terms of the risk faced (both risk on a global scale, and risk on a company specific scale).

One application given was that of the cost of protecting against diminished industrial output because of global warming.

Another application was protecting against decreased value of a manufacturer of ski equipment because of warming.

It was suggested that such securities could be used to help firms hedge against risk related to climate change. The cost of a call option contract on the value of a Futures Global Mean Temperature (GMT) contract was calculated. In determining the cost, the

volatility of the GMT, calculated over 130 years of data, was applied.

With the emergence of very long-term maturity (100-year) bonds, the author updated previous work to establish theoretical 'fair value' premiums (costs) for sets of call and put options about futures contracts related to the annual value of the GMT.

Both call and put options are said to have been purchased at the end of 2019, with strikes of 14.5°C, 14.5°C, ... , 15.5°C, and possessing a premium (value) of $100 per °C upon expiry.

Theoretical 'fair value' prices of call options on GMT futures set to expire on Dec-31 at the end of the first year of each decade out to 2100 are depicted in Figure 5.

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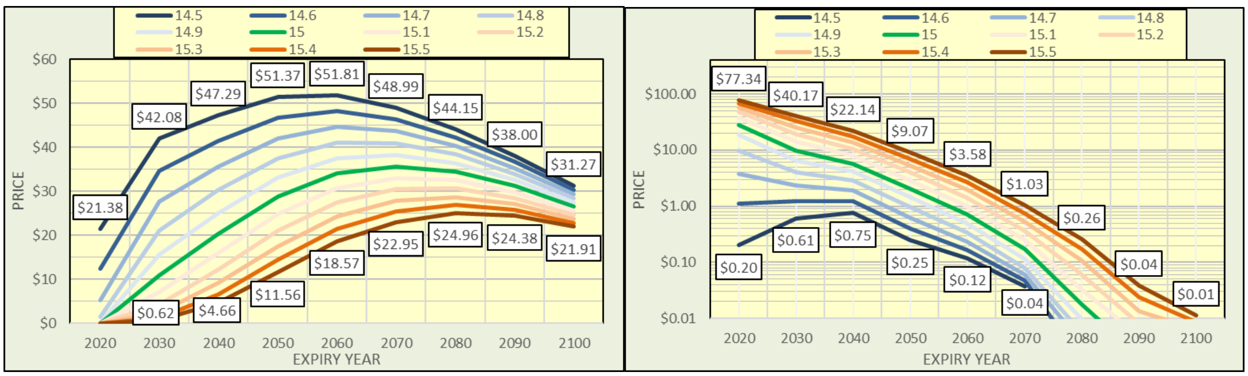

FIGURE 5 Price ($100 / °C) of European Style Call Options (left panel) and European Style Put Options (right panel) for different strikes (14.5 °C, 14.6 °C, … , 15.5 °C) and expiry dates (2020, 2030, … , 2100).

Note: Exercising of European options takes place only on expiry dates.

Note also: The graphic displays prices for both the 14.5 °C and the 15.5 °C strikes.

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5. CONCLUDING REMARKS

It might be noted that regions of the world becoming unviable because of the impact of climate change are not restricted to poorer countries. This aspect has been explored by Sealey et al. (2018), regarding Miami (USA), and has been recently reported upon by Smee (2019), regarding Townsville (Australia).

Subsequent to the American Meteorological Society's Annual Meeting in Phoenix, the author attended the Insurance Linked Securities (ILS) conference, held on Friday, February 1st in New York, under the auspices of the Artemis organisation (Artemis, 2019).

The Red Cross and Red Crescent Societies hosted a side-event the day before the ILS conference, on Thursday January 31st, 2019, on the future of humanitarian aid, titled: Risk Transfer Instruments - Innovations in Refugee & Migrant Financing.

This has relevance in the context of the likely future impact of rising sea levels on the

viability of several very low-lying south west Pacific Ocean islands.

6. REFERENCES

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