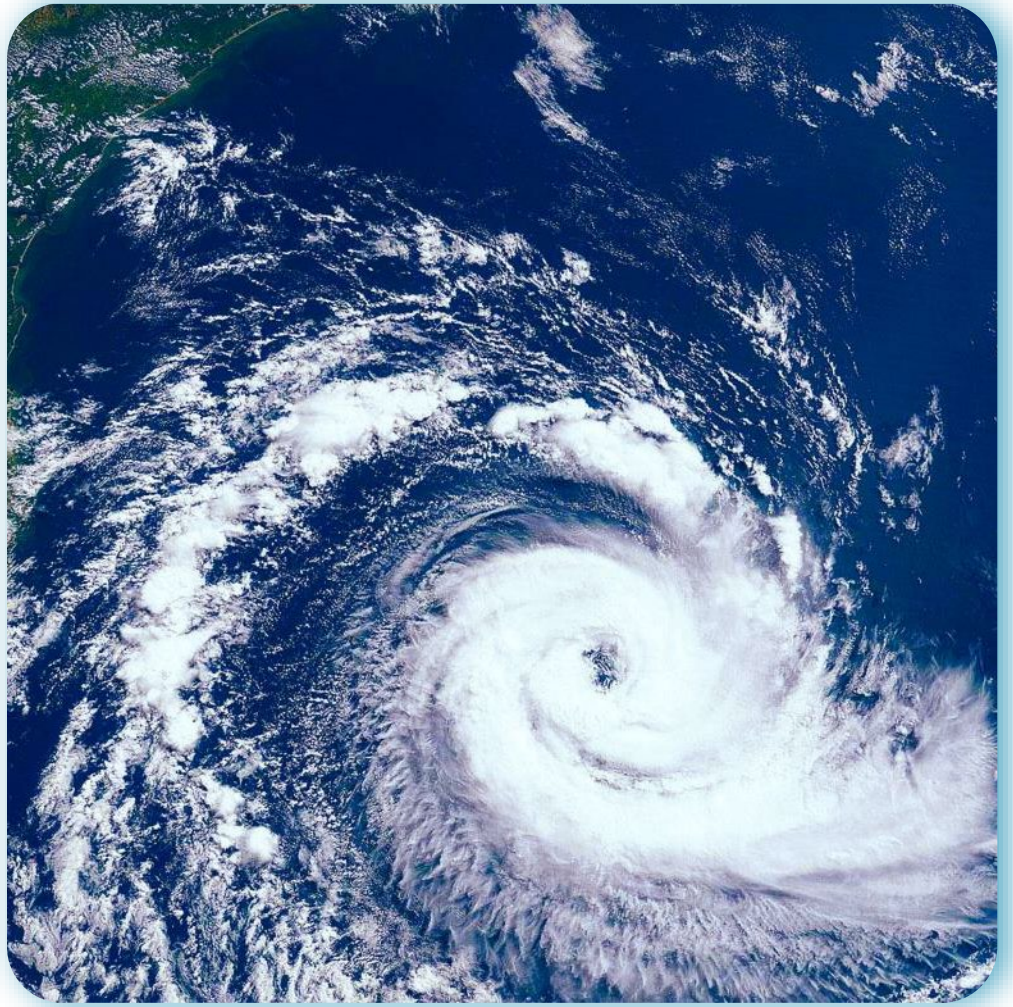

CRUCIAL

Expert prediction markets for climate risk

Mark Roulston
Senior Research Fellow

Kim Kaivanto
Senior Lecturer in Economics

Lancaster University Management School

10/07/2025

www.crucialab.net

Lancaster University Management School

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Expert prediction markets for climate risks

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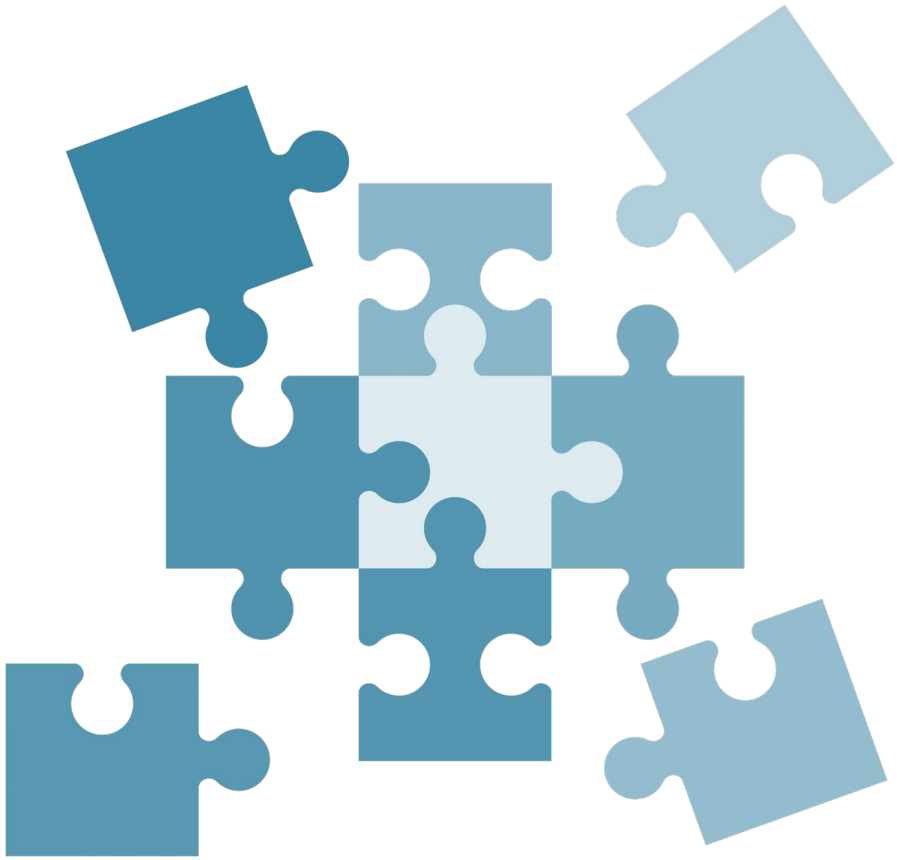
1. Three challenges of climate forecasting

Challenge #1

Fragmentation of expertise

- Forecasting physical climate, *given greenhouse gas concentrations*, requires expertise in meteorology, oceanography and other physical sciences.
- Predicting future greenhouse gas concentrations involves knowledge of economics, policy, and technological innovation.
- Some of this knowledge is codified in climate models and economic models.
- But experts also have “tacit” knowledge: e.g., the strengths and weaknesses of different models.



Challenge #2

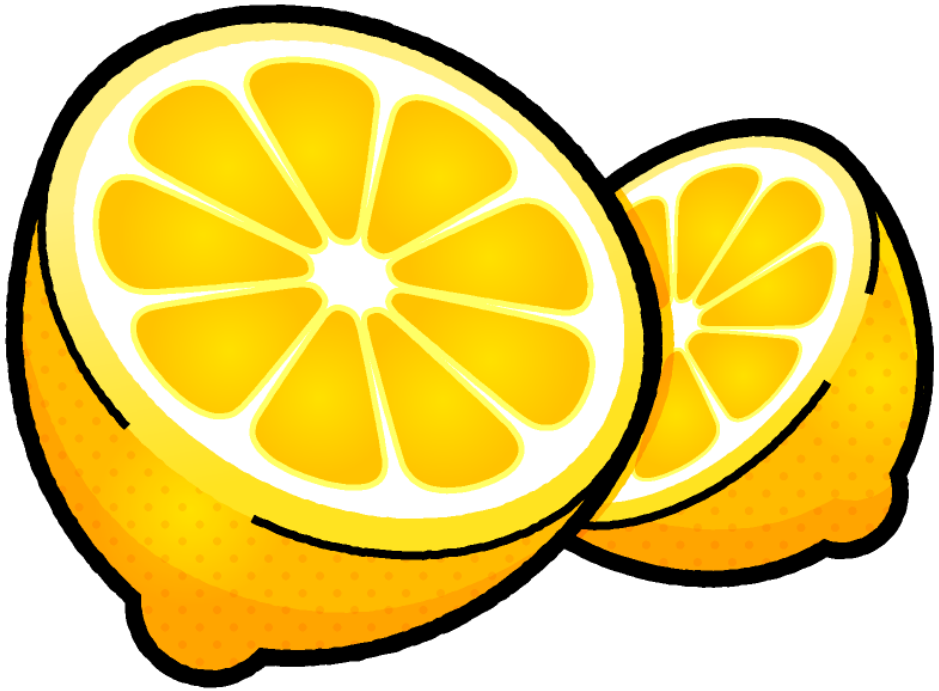
Information asymmetry

- Short-range (days ahead) weather forecasters can establish statistically meaningful track records demonstrating skill.
- This is harder for seasonal forecasters (months ahead) and practically impossible for climate forecasters (years to decades).
- Climate forecasters can’t demonstrate skill and forecast users can’t verify the quality of the forecasts.
- This “information asymmetry” (or “market for lemons”) can lead to a spiral of falling prices and declining quality.
- Warranties are a solution to information asymmetry.

The Market for "Lemons": Quality Uncertainty and the Market Mechanism

George A. Akerlof

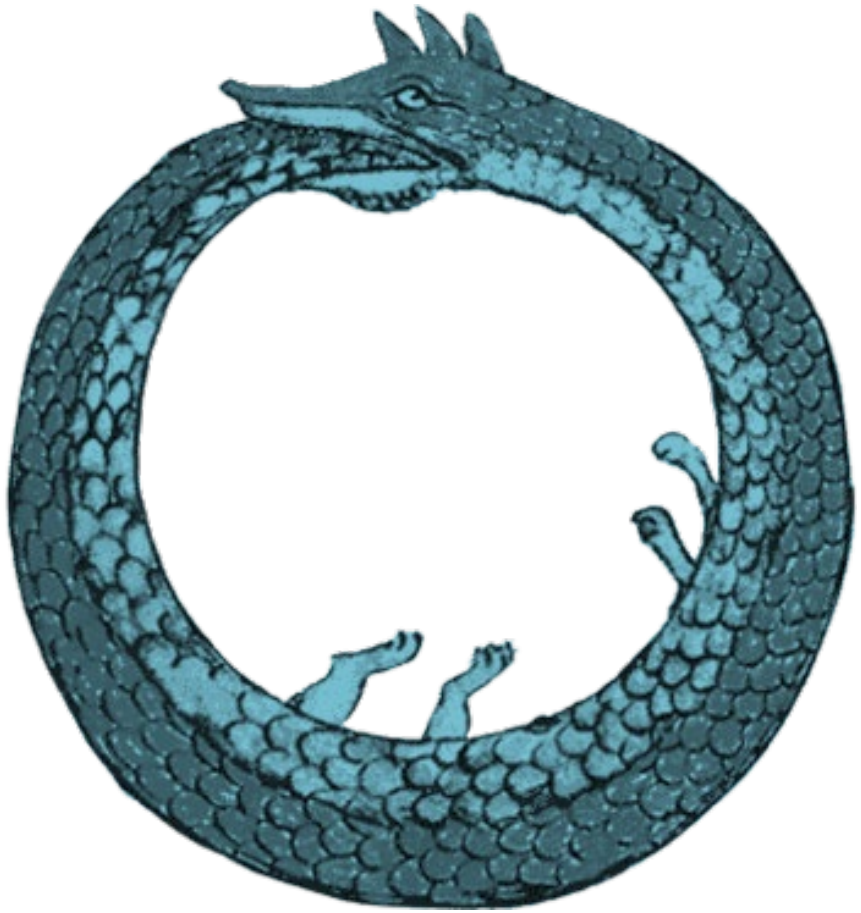
Quarterly Journal of Economics, Volume 84, Issue 3 (Aug., 1970), 488-500.



Challenge #3

“Circularity”

- Physical climate forecasts are conditional on future greenhouse gas concentrations.
- Future greenhouse gas concentrations will (partly) depend on policy.
- Policy will be influenced by climate forecasts.
- Analogous to inflation forecasting and interest rate setting.
- Climate simulations are made under different emissions scenarios.
- Probabilities must be assigned to emissions pathways to produce **unconditional** forecasts of climate.



2. Prediction markets

What are prediction markets?
(also called “information markets”)

- Financial markets (stock markets and futures markets) perform “information discovery” as a secondary function.
- Information discovery is the primary function of prediction markets, not the transfer of assets or risks.
- They use the mechanics of betting as a way of eliciting and aggregating the collective expertise and knowledge of participants.

Contingent securities

“Arrow-Debreu securities”

- Arrow-Debreu securities pay out 1.00 unit if a specified event occurs at a specified time.
- e.g., I will pay you €1.00 if it snows in Paris on Christmas Day 2025.
- If **PRICE = EXPECTED VALUE** price can be interpreted as probability of event.
- Securities must be traded to discover the price.
- Details of the trading mechanism matter.

Kenneth Arrow (By Linda A. Cicero, Stanford News Service; CC BY 3.0)

Gérard Debreu (By Konrad Jacobs, Mathematisches Institut Oberwolfach; CC BY-SA 2.0 DE)

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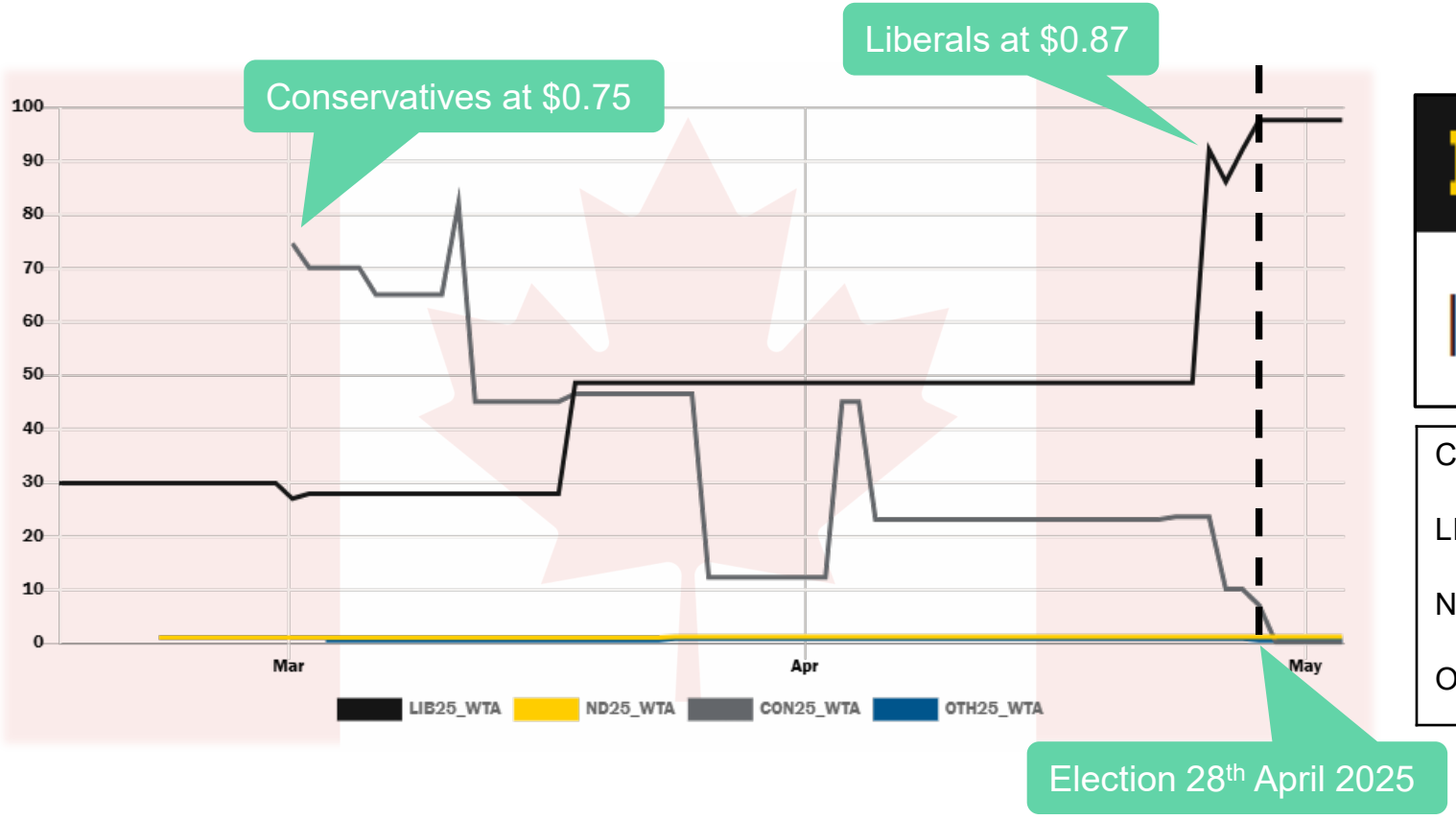
The Iowa Electronic Markets (IEM)

- Founded in 1988 by the University of Iowa.
- Focus on predicting elections.
- Has an exemption from the Commodity Futures Trading Commission (CFTC)
- Stakes and participants are limited.



IOWA Henry B. Tippie College of Business

Iowa Electronic Markets

CON25_WTA	$1 if Conservative Party win most seats
LIB25_WTA	$1 if Liberal Party win most seats
ND25_WTA	$1 if the New Democratic Party most seats
OTH25_WTA	$1 if none of the named contracts pay out

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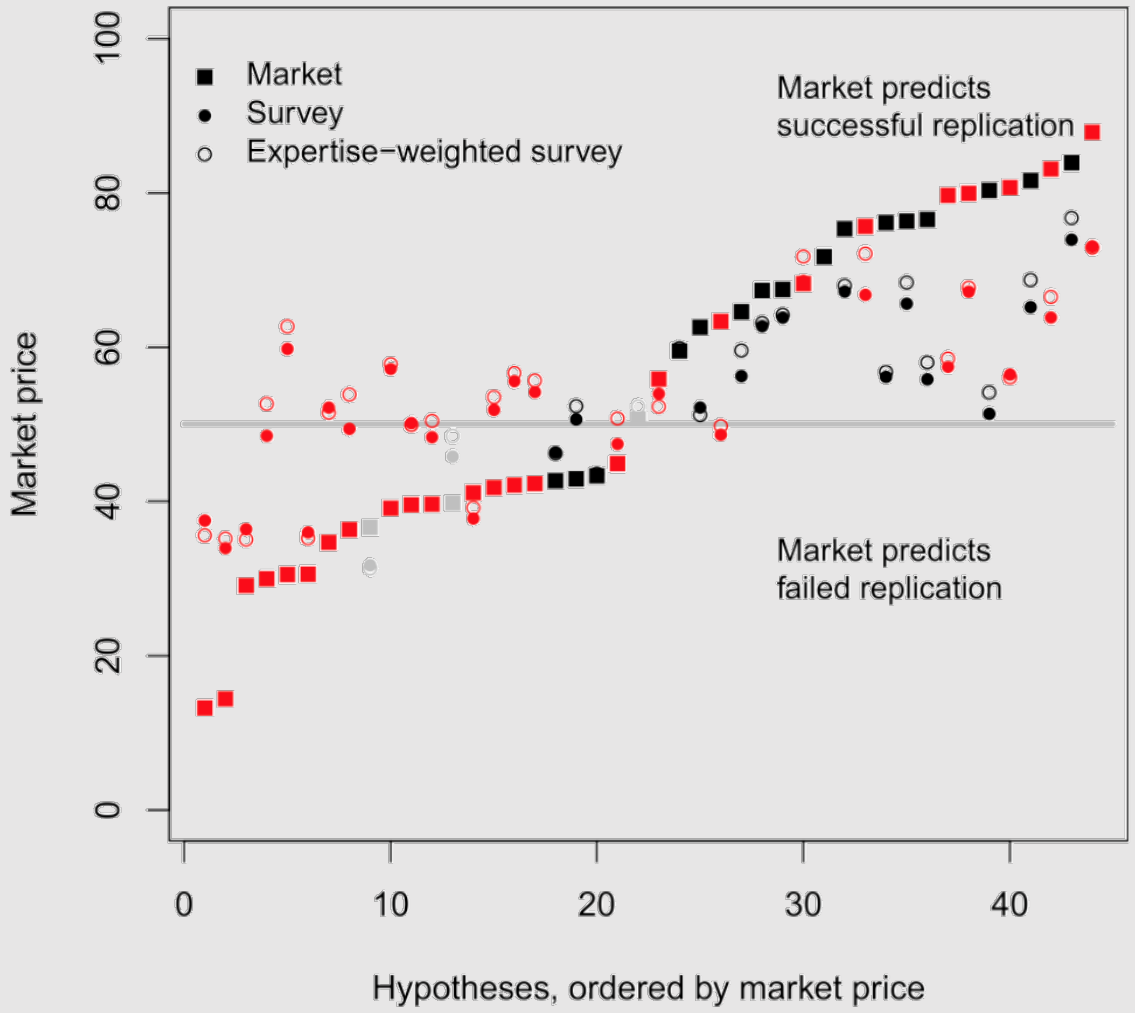

Prediction market performance. Final market prices and survey predictions are shown for the replication of 44 publications from three top psychology journals. The prediction market predicts 29 out of 41 replications correctly, yielding better predictions than a survey carried out before the trading started. Successful replications (16 of 41 replications) are shown in black, and failed replications (25 of 41) are shown in red. Gray symbols are replications that remained unfinished (3 of 44).

Prediction markets with experts

Predicting replicability

- An expert prediction market to predict whether experimental psychology studies would replicate.
- Prediction market approach outperformed surveys.
- Prediction markets “correct” in 71% of replications (actual outcome was most probable).
- Simple average survey correct in 58%.
- Weighted average survey correct in 50%.

Dreber, Anna, et al. "Using prediction markets to estimate the reproducibility of scientific research." *Proceedings of the National Academy of Sciences* 112.50 (2015): 15343-15347.

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Prediction markets for climate

Not a new idea

CLA LAW REVIEW

Energy and Climate Change: A Climate Prediction Market

Michael P. Vandenbergh
Kaitlin Toner Raimi
Jonathan M. Gilligan

ABSTRACT

State-Contingent Pricing as a Response to Uncertainty in Climate Policy*

Ross McKitrick
Department of Economics
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July 2011

ENERGY, ENVIRONMENT & NATURAL RESOURCES

CLIMATE CHANGE REGULATION AND PREDICTION MARKETS

An impartial party—the market—can weigh in on the climate's future.

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Faculty Scholarship

2-2019

Betting on Climate Policy: Using Prediction Markets to Address Global Warming

Gary M. Lucas Jr
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Felix Mormann
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Using Prediction Markets to Guide Global Warming Policy*

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December 9, 2008

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Scholarly Publications

2011

A Prediction Market for Climate Outcomes

Shi-Ling Hsu
Florida State University College of Law

Using Prediction Markets to Evaluate Various Global Warming Hypotheses

Mark Boslough, Sandia National Laboratories

Intrade is an online trading exchange that has created a family of 17 climate prediction markets for an experiment to be presented at the AGU Fall 2011 Meeting. Each contract can be described as "Global temperature anomaly for 2012 to be greater than ***x*** °C or more," where the figure ***x*** ranges in increments of .05 from .30 to 1.30 (relative to the 1951–1980 base period), based on data published by NASA GISS. Each market will settle at $10.00 if the published global temperature anomaly for 2012 is equal to or greater than ***x***, and will otherwise settle at $0.00.

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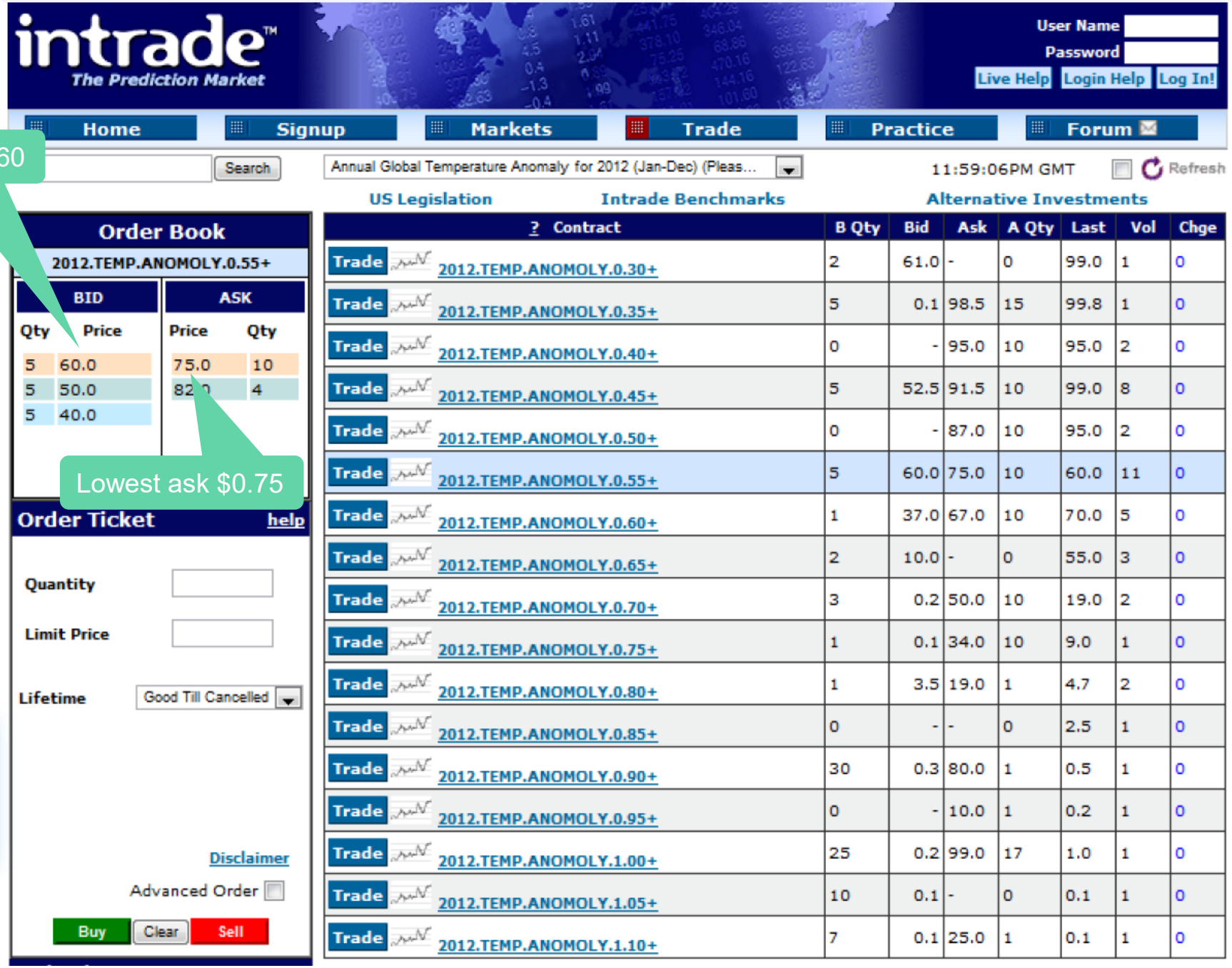
Prediction markets and climate

- Early experiment with a prediction market for year-ahead global temperature.
- Temperature anomaly was partitioned into 0.05°C intervals.
- Used the InTrade platform with a *continuous double auction*.
- Suffered from high “bid-ask” spreads.



? Contract	B Qty	Bid	Ask	A Qty	Last	Vol	Chge
Trade 2012.TEMP.ANOMOLY.0.30+	2	61.0	-	0	99.0	1	0
Trade 2012.TEMP.ANOMOLY.0.35+	5	0.1	98.5	15	99.8	1	0
Trade 2012.TEMP.ANOMOLY.0.40+	0	-	95.0	10	95.0	2	0
Trade 2012.TEMP.ANOMOLY.0.45+	5	52.5	91.5	10	99.0	8	0
Trade 2012.TEMP.ANOMOLY.0.50+	0	-	87.0	10	95.0	2	0
Trade 2012.TEMP.ANOMOLY.0.55+	5	60.0	75.0	10	60.0	11	0
Trade 2012.TEMP.ANOMOLY.0.60+	1	37.0	67.0	10	70.0	5	0
Trade 2012.TEMP.ANOMOLY.0.65+	2	10.0	-	0	55.0	3	0
Trade 2012.TEMP.ANOMOLY.0.70+	3	0.2	50.0	10	19.0	2	0
Trade 2012.TEMP.ANOMOLY.0.75+	1	0.1	34.0	10	9.0	1	0
Trade 2012.TEMP.ANOMOLY.0.80+	1	3.5	19.0	1	4.7	2	0
Trade 2012.TEMP.ANOMOLY.0.85+	0	-	-	0	2.5	1	0
Trade 2012.TEMP.ANOMOLY.0.90+	30	0.3	80.0	1	0.5	1	0
Trade 2012.TEMP.ANOMOLY.0.95+	0	-	10.0	1	0.2	1	0
Trade 2012.TEMP.ANOMOLY.1.00+	25	0.2	99.0	17	1.0	1	0
Trade 2012.TEMP.ANOMOLY.1.05+	10	0.1	-	0	0.1	1	0
Trade 2012.TEMP.ANOMOLY.1.10+	7	0.1	25.0	1	0.1	1	0

Prediction-Market-Based Quantification of Climate Change Consensus and Uncertainty

Sandia National Laboratories

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Discrete Math & Complex Systems
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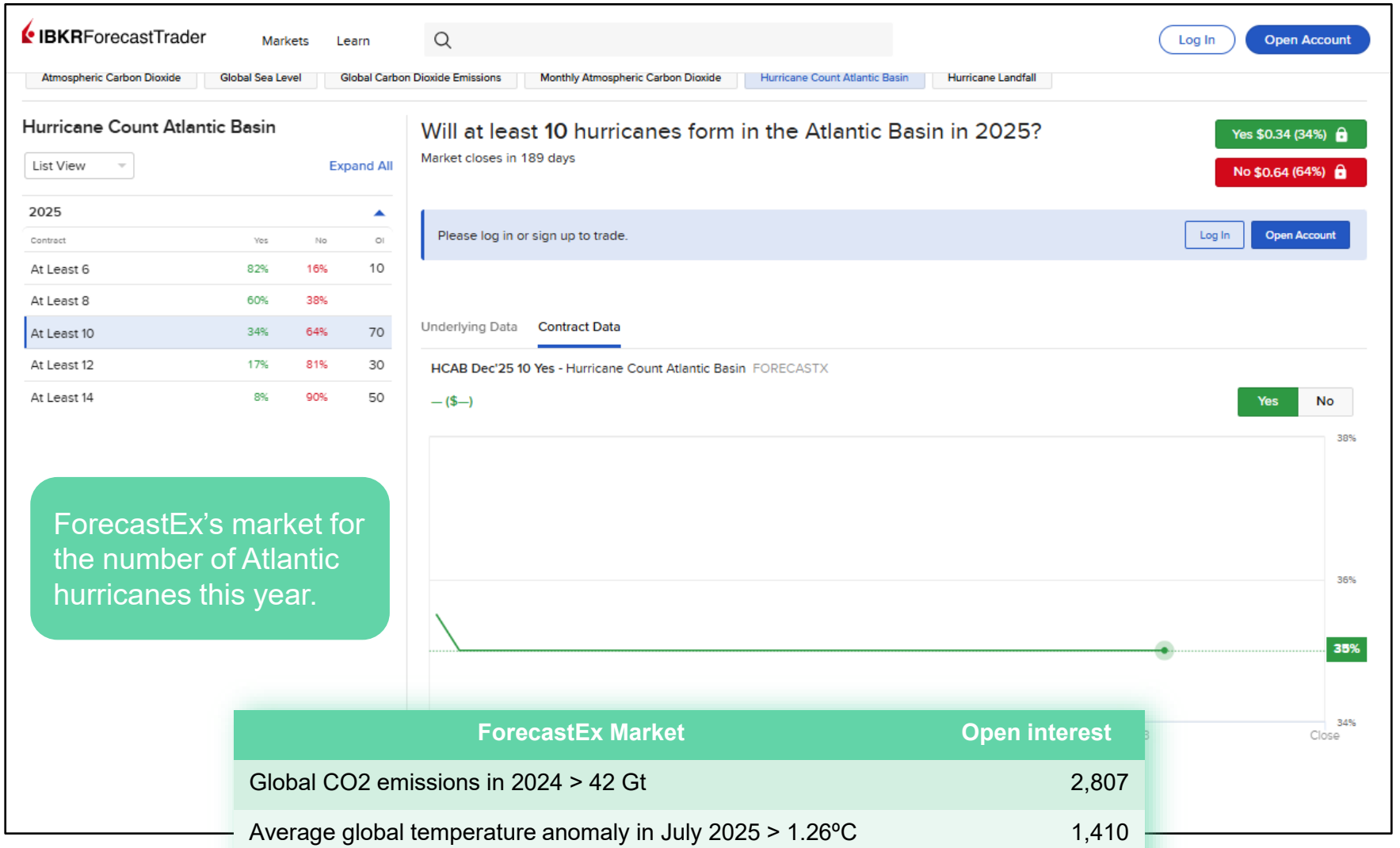
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Commercial prediction markets

- Kalshi and ForecastEx are US-based futures exchanges specializing in “event contracts”.
- Both have some contracts related to weather and climate.
- 75% of Kalshi’s trading volume is on sport-related contracts.
- UK-based Smarkets has hosted climate-related markets, but they didn’t attract much activity.



ForecastEx’s market for the number of Atlantic hurricanes this year.

ForecastEx Market	Open interest
Global CO2 emissions in 2024 > 42 Gt	2,807
Average global temperature anomaly in July 2025 > 1.26ºC	1,410
At least 10 hurricanes form in Atlantic in 2025	70
Atmospheric CO2 > 427ppm in 2025	71
Andrew Cuomo to win NYC mayor Democratic Primary	143,350
US Fed Funds Target Rate > 3.875% on July 30 2025	97,647

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3. The liquidity problem

The problem of low liquidity

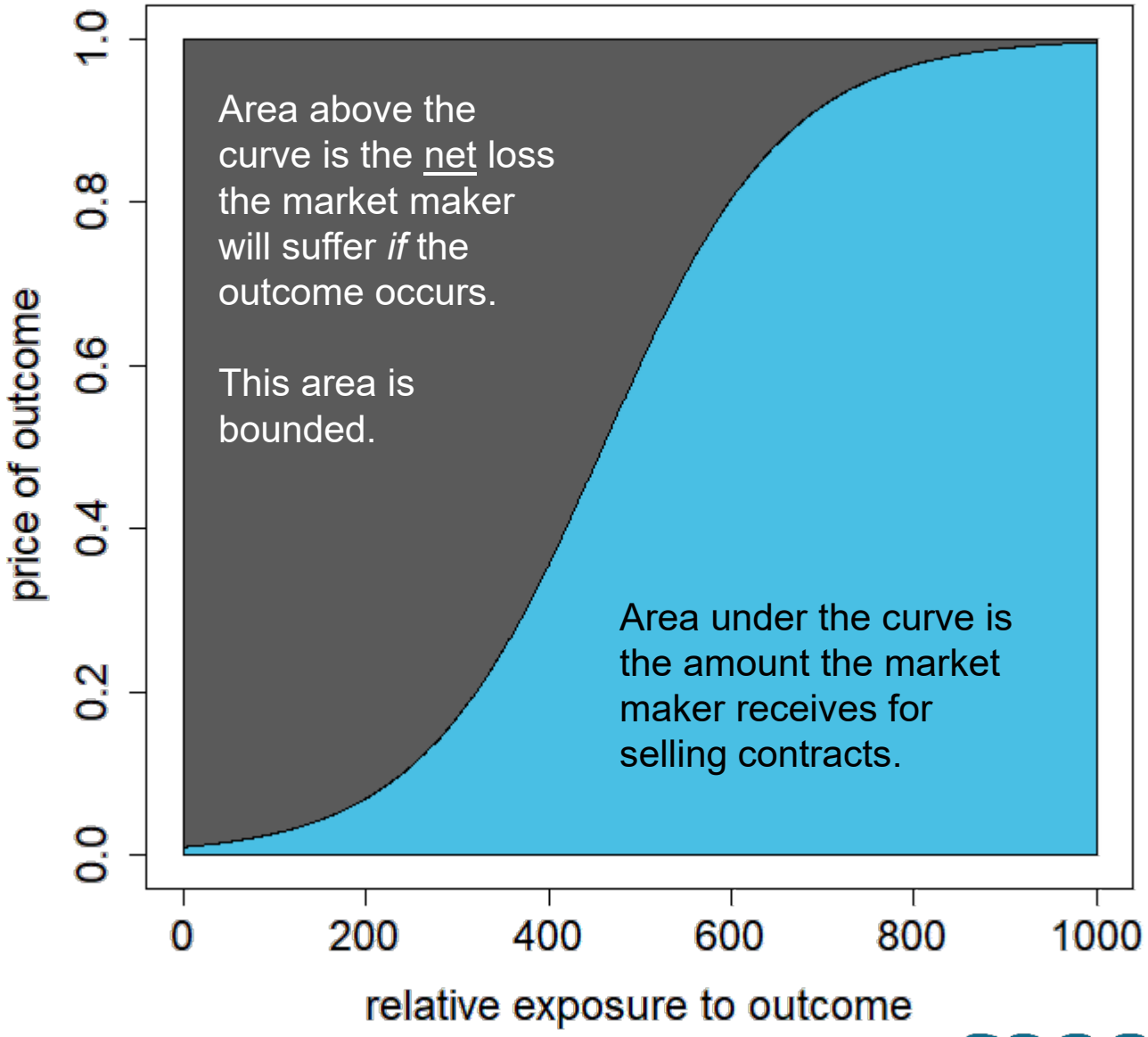
Information discovery isn't free

- Many prediction markets are "zero-sum".
- **rewards of people who are right = losses of people who are wrong**
- They must attract uninformed participants (or hedgers) to subsidise information discovery.
- Some topics — *e.g.* sports betting — can attract the less-informed.
- More specialized markets struggle to attract "noise traders".
- Low liquidity leads to large "bid-ask" spreads and stale prices.

Information costs money — there is no free lunch!

Automated market makers
Logarithmic market scoring rule

- Algorithmic market maker will always buy and sell outcomes.
- Quotes prices between 0.00 and 1.00 based on its relative exposure.
- Market maker's maximum net loss is bounded.
- Rewards are linear in the *logarithmic score*.
- This market maker *wants* to lose money in return for accurate information.
- Makes the market "positive sum".
- Fundamentally different to profit-seeking market makers and bookmakers.



Hanson, Robin. "Combinatorial information market design." Information Systems Frontiers 5.1 (2003): 107-119.

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Sponsored prediction markets

“X-prizes” for climate forecasting

- Participants are not a source of revenue but a source of information.
- Markets can be sponsored by private or public sector organisations.
- Markets do not have to be “pay-to-play” — this eliminates regulatory obstacles.
- Sponsored markets are like inducement prizes (X-Prize, Longitude Prize)
- Market mechanism can allocate funds in proportion to the contributions participants make to the accuracy of the collective forecasts.

Above: Harrison H4 chronometer, built by John Harrison who won part of the Longitude Reward offered by the British government in 1714

Right: Captain James Cook took a copy of the H4 on his third voyage in 1776-80.

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4. What is CRUCIAL?

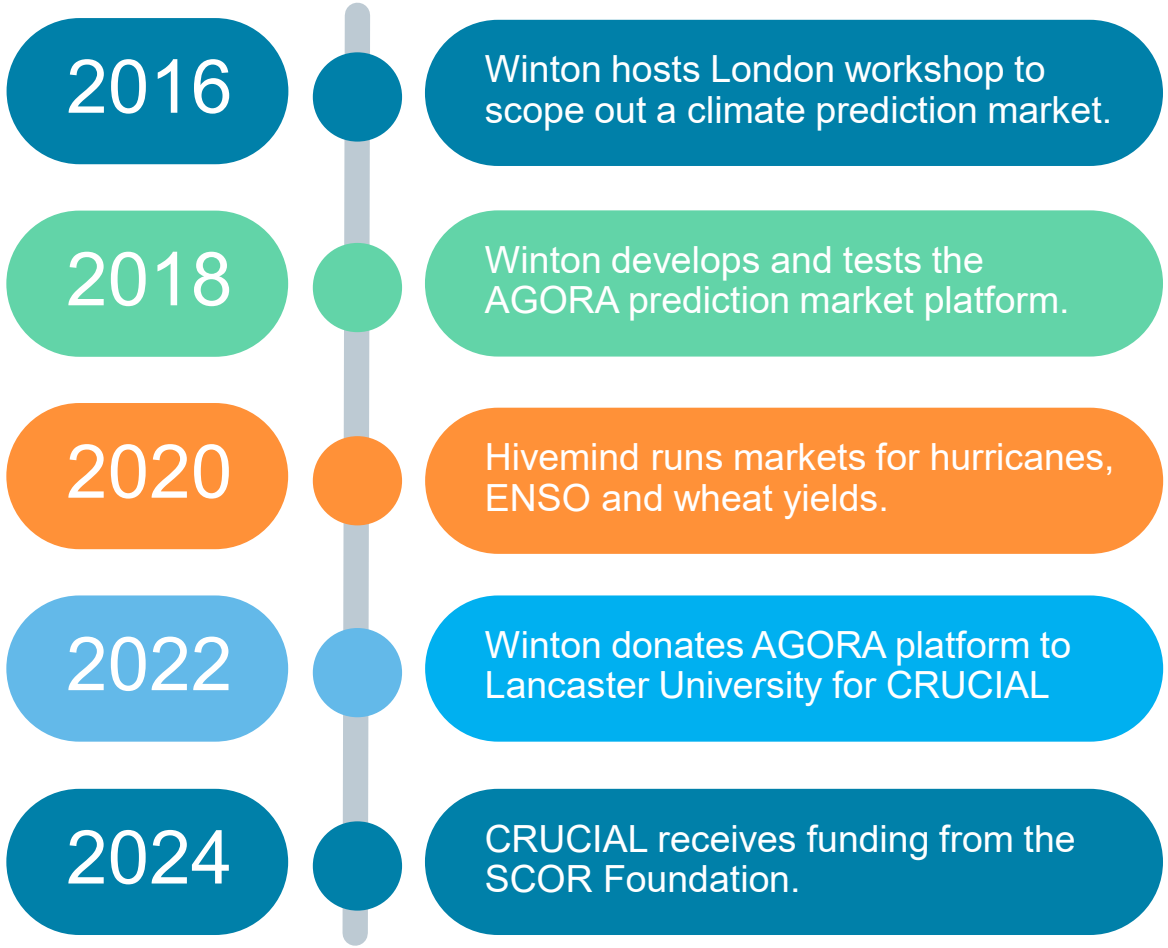
CRUCIAL

Climate Risk and Uncertainty Collective Intelligence Aggregation Laboratory

CRUCIAL is an initiative that uses prediction markets — with expert participants — to aggregate climate forecasting models and expertise.

CRUCIAL prediction markets…

- …are not “pay-to-play”.
- …have expert participants from academia and the private sector.
- …are sponsored.
- …reward participants who improve the accuracy of collective forecasts.



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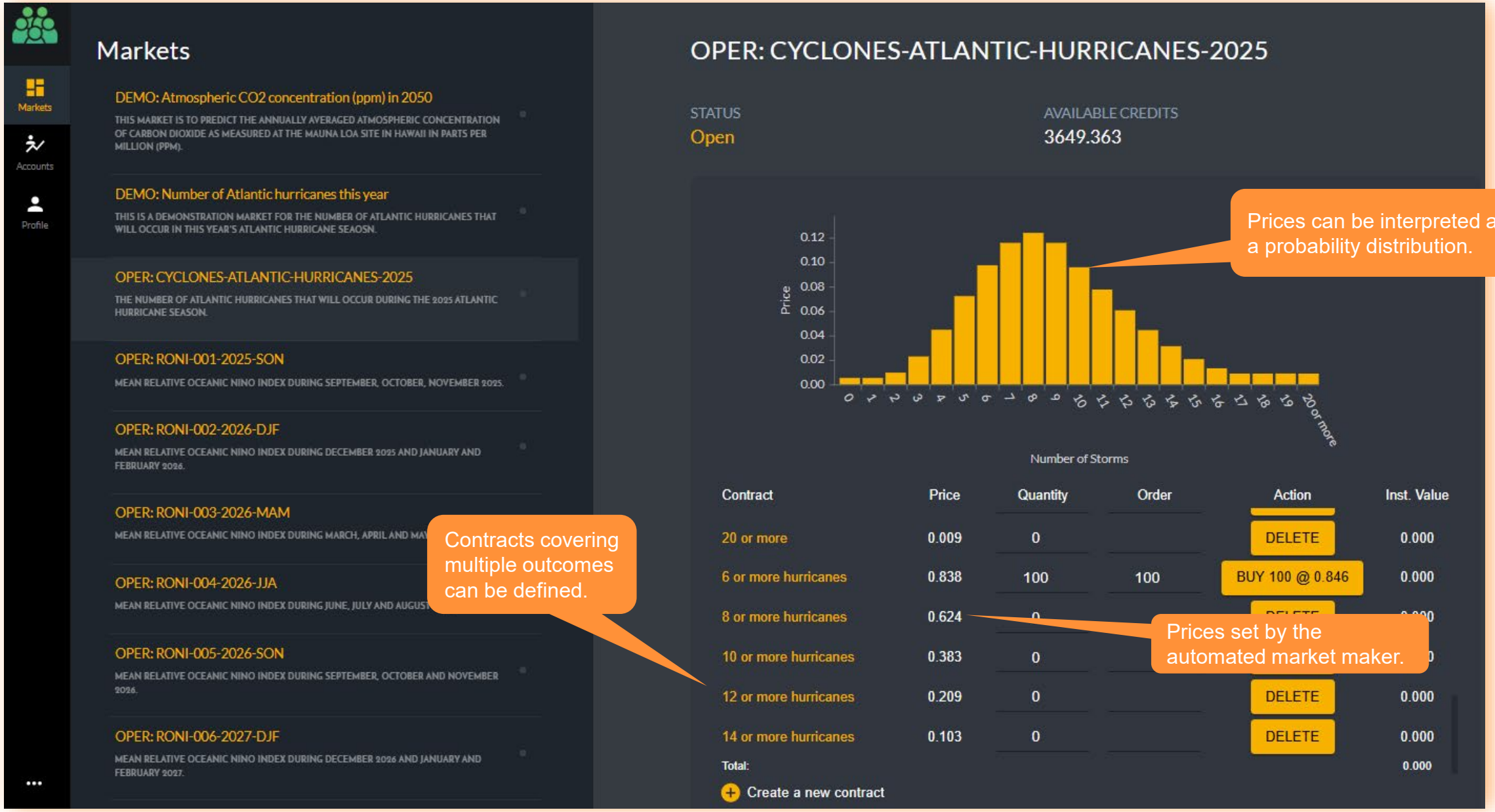

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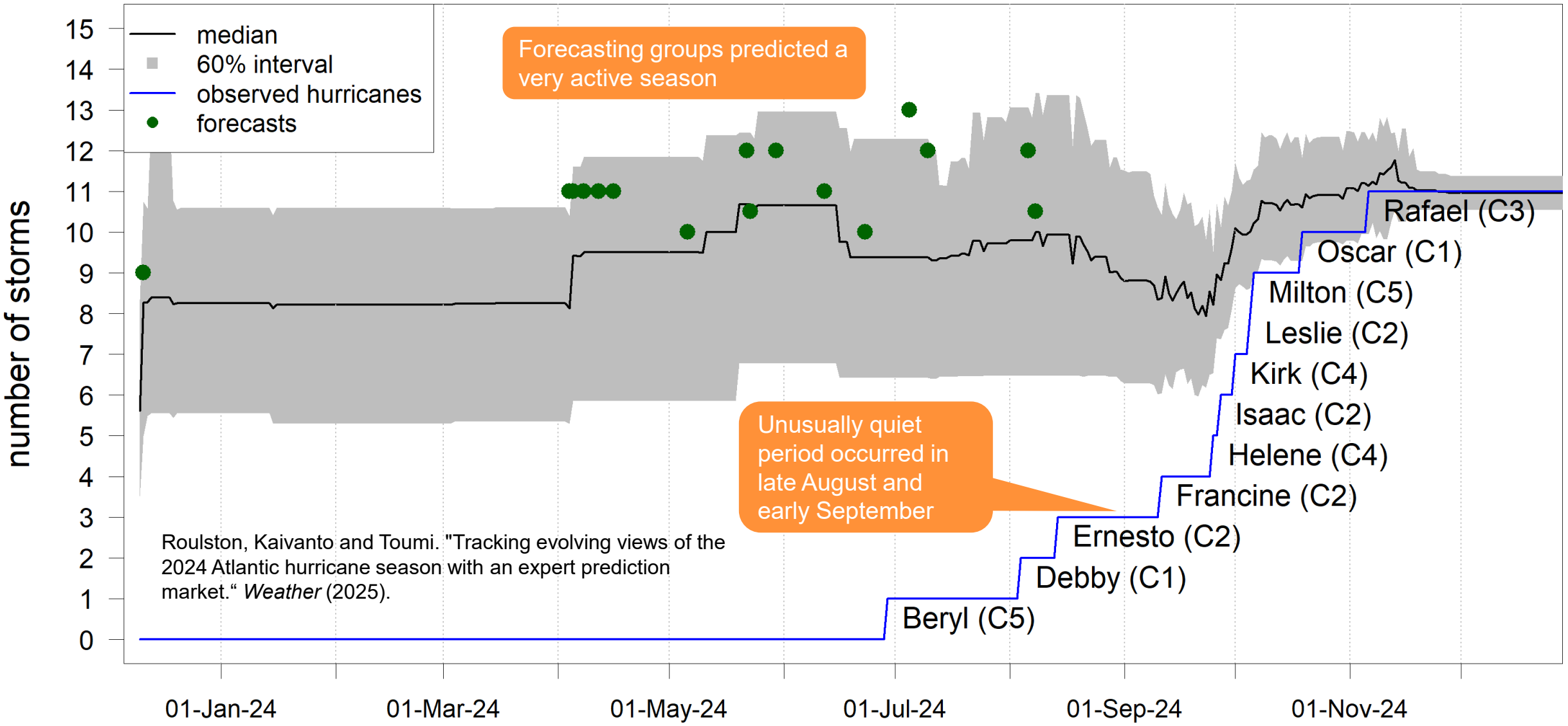
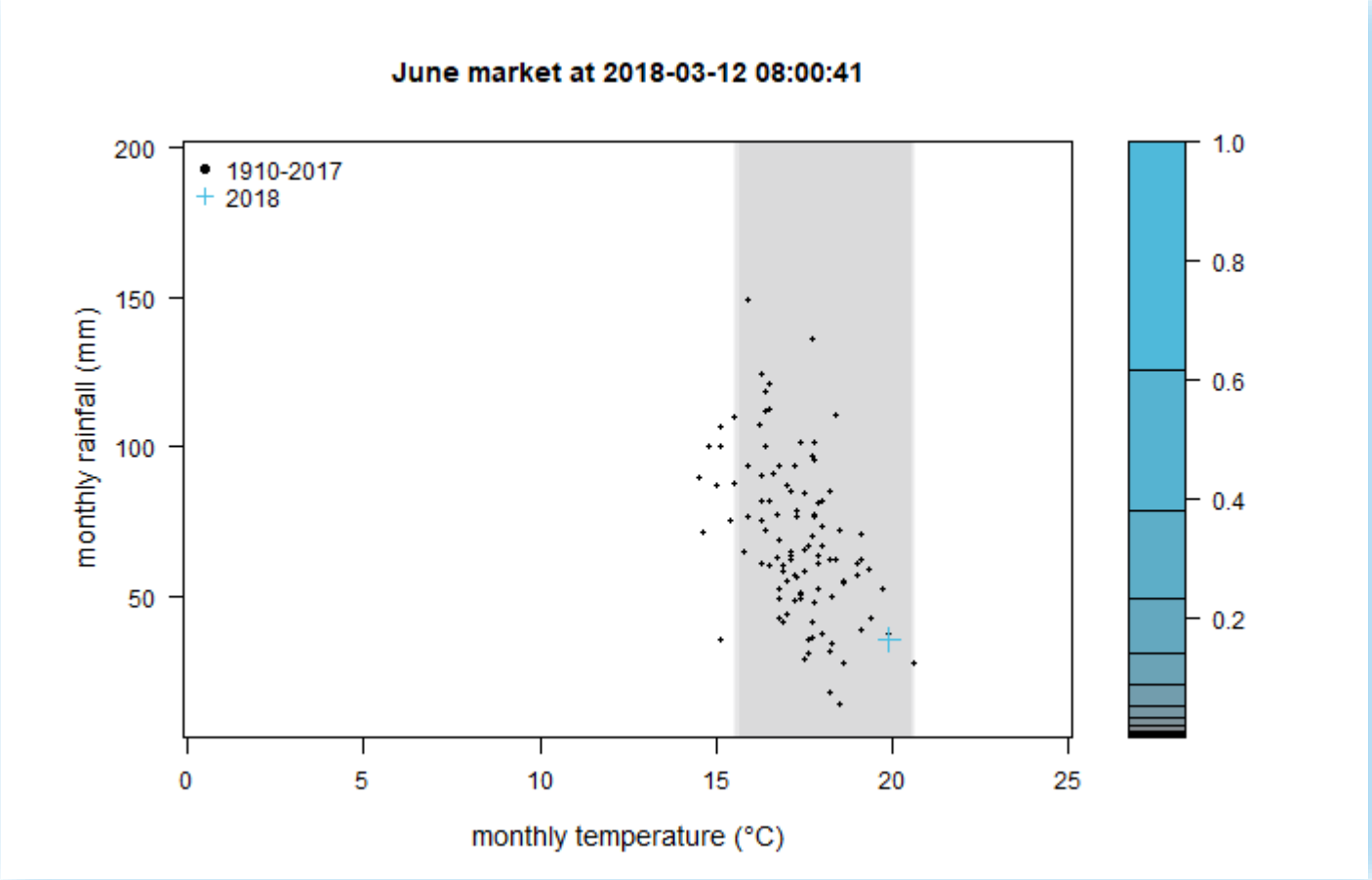
The CRUCIAL Atlantic Hurricane Market 2024



A 2-dimensional market

Monthly temperature and rainfall

- Simultaneous prediction of UK monthly temperature and rainfall.
- Space divided into 5,207 outcomes (0.2°C x 5mm).
- 6 markets: April, May, June, July, August, September 2018.
- All markets opened in March 2018.
- 24 teams from UK universities endowed with virtual credits.
- Teams accumulating most credits received rewards totaling £55,000 (from Winton Group)
- Demonstrates viability of granular two-dimensional markets.



Roulston and Kaivanto. "Joint-outcome prediction markets for climate risks." *PloS one* 19.8 (2024): e0309164.

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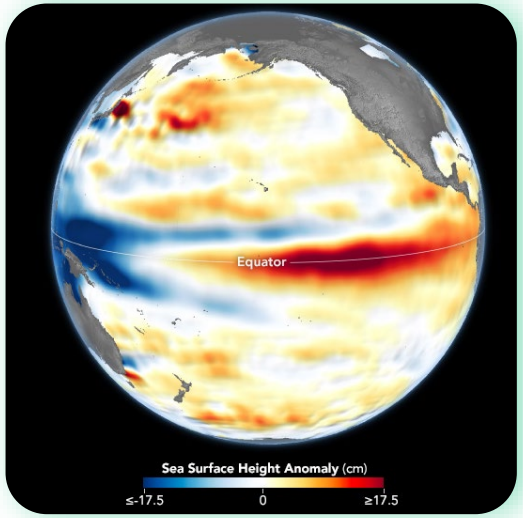
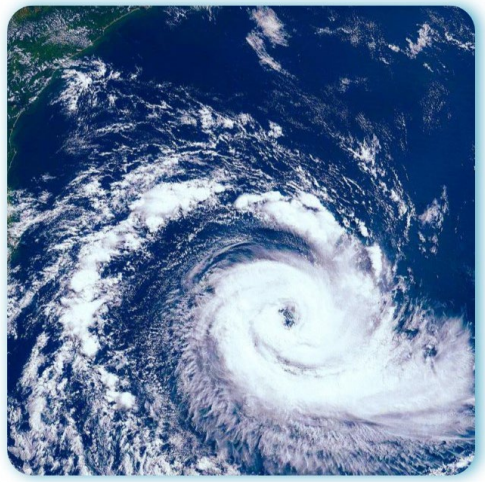
Pilot markets



El Niño/La Niña

UK wheat yield



Atlantic hurricanes

UK monthly rainfall

UK monthly temperature

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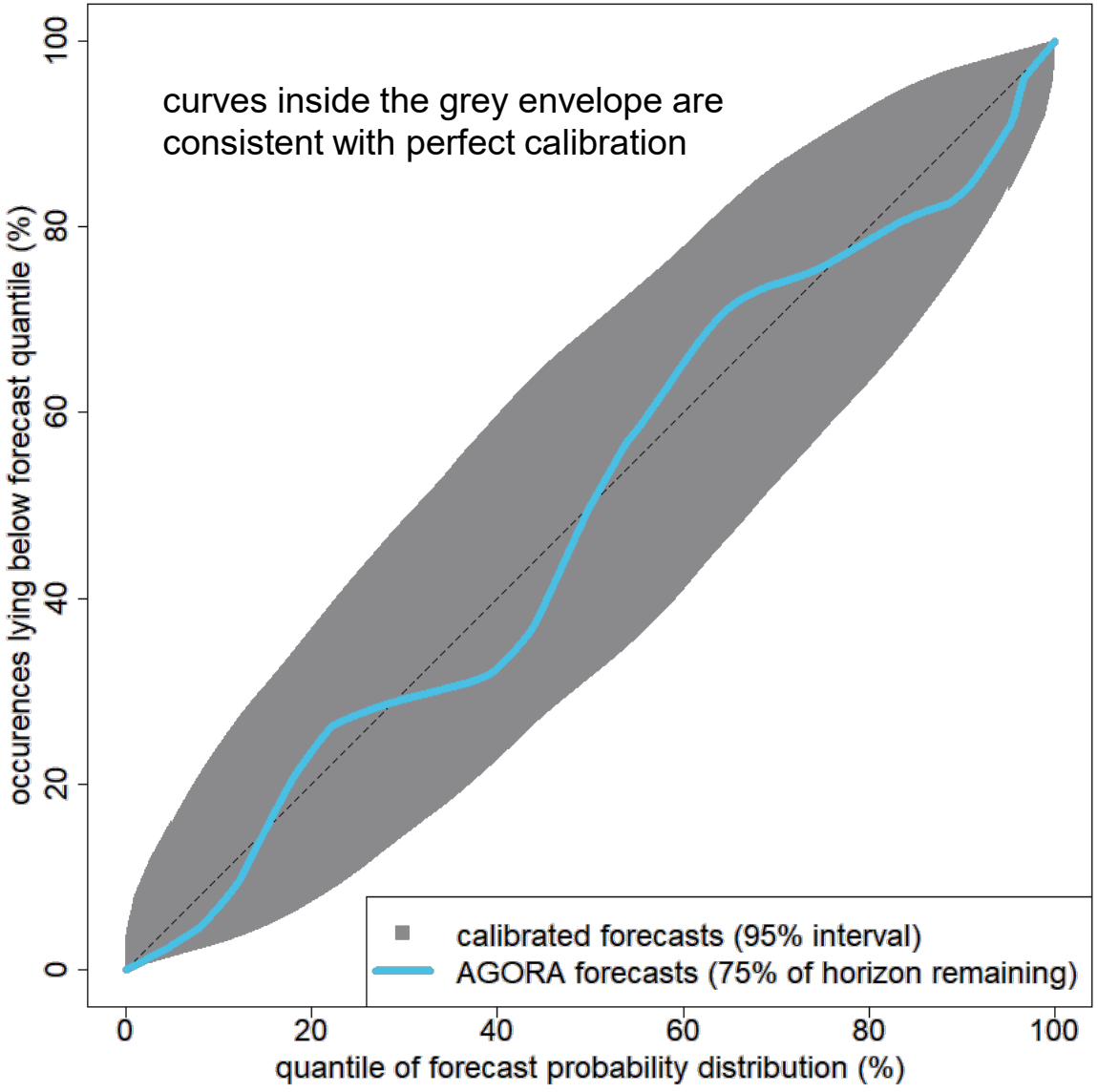
How good are market-based forecasts?

A calibration study

- Risk forecasts should be *calibrated*: **Frequencies of outcomes should match predicted probabilities.**
- Prediction horizons up to one year ahead.
- Prediction market forecasts for climate risks made using expert participants are consistent with good calibration.



Roulston and Kaivanto. "Can expert prediction markets forecast climate-related risks?." *Bulletin of the American Meteorological Society* 105.10 (2024): E1898-E1914.

WINTON Lloyd's Lab HIVEMIND AGORA Agrimetrics THE CATALYST FOR CHANGE

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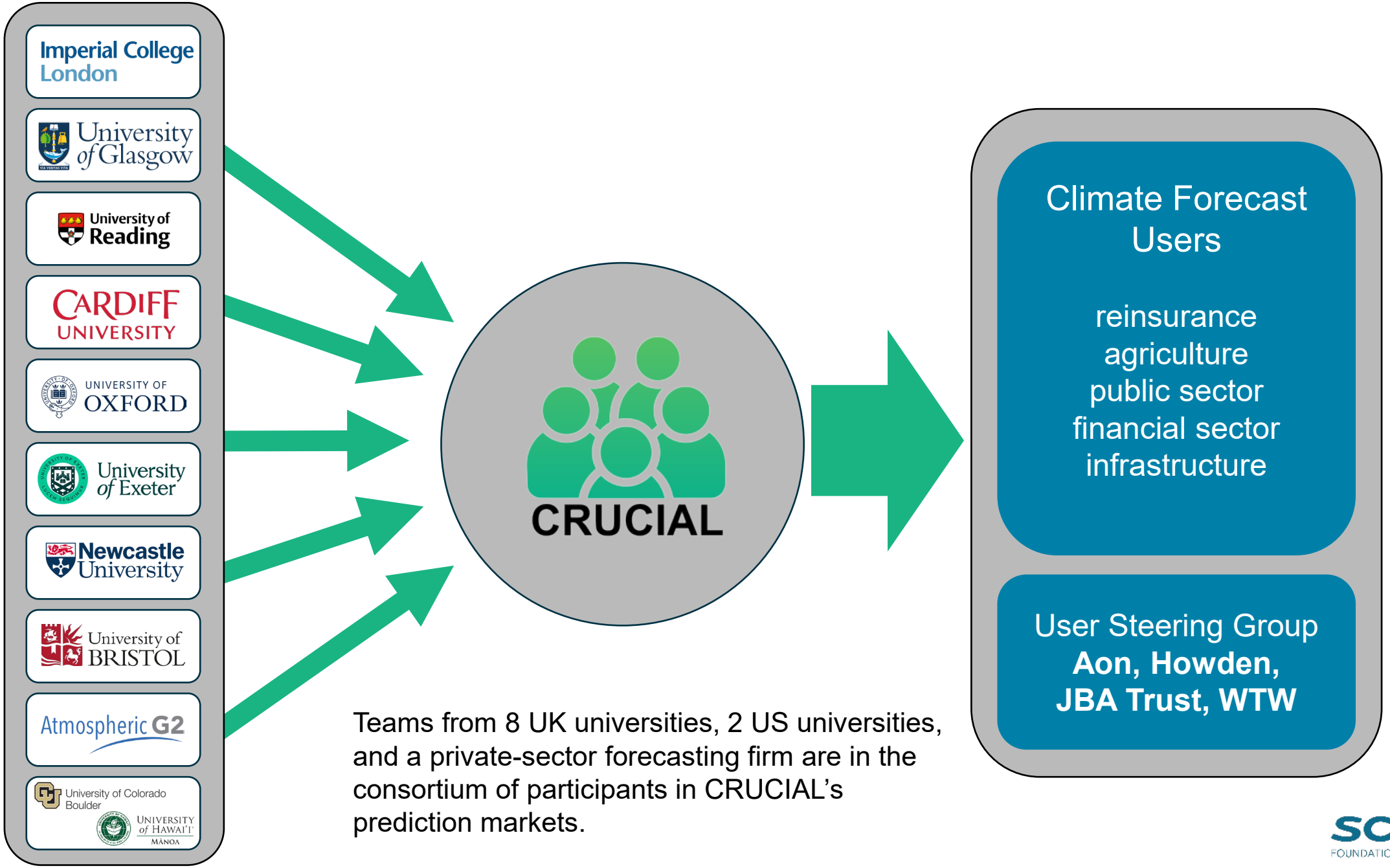
5. Current activity at CRUCIAL



Teams from 8 UK universities, 2 US universities, and a private-sector forecasting firm are in the consortium of participants in CRUCIAL's prediction markets.

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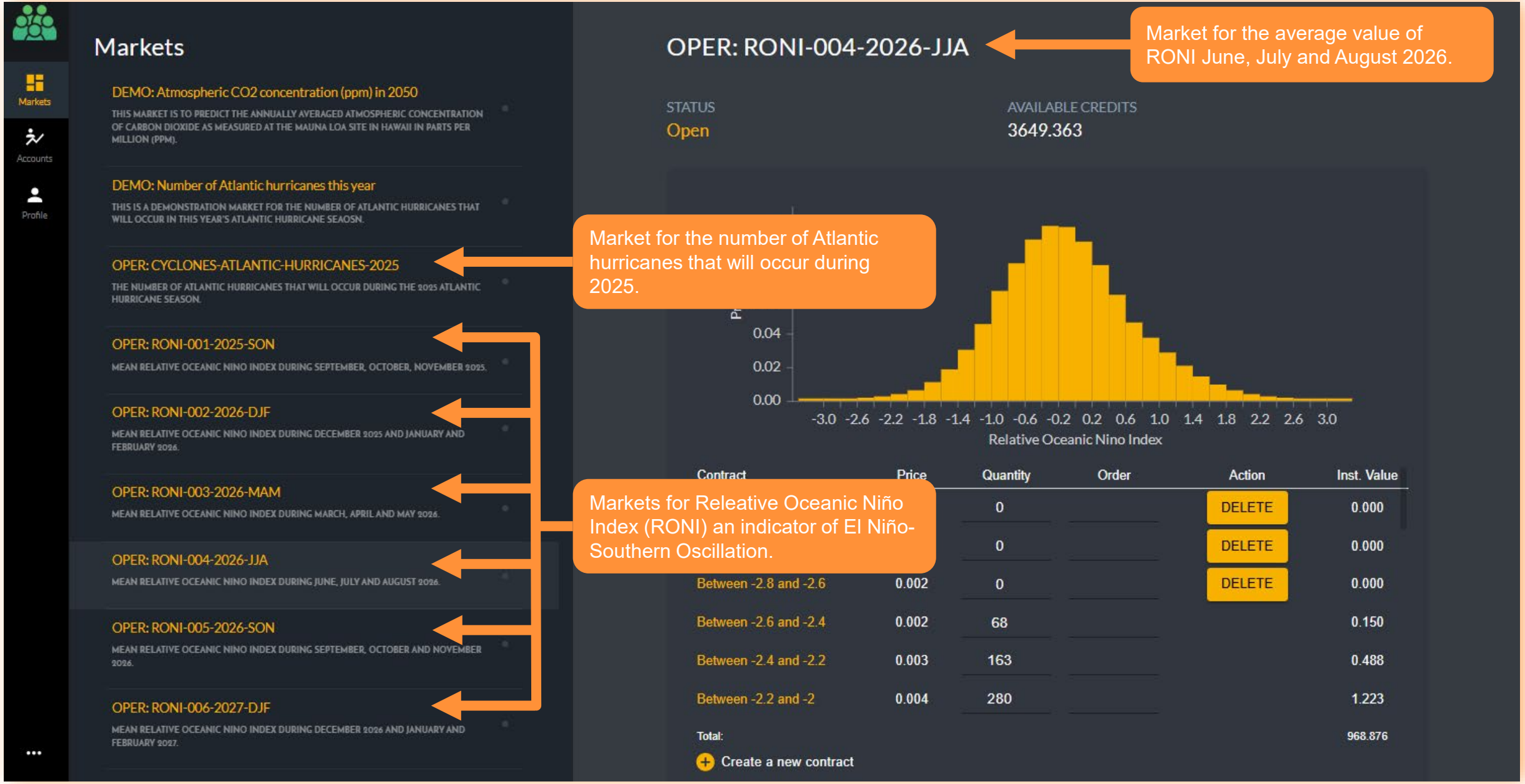

Markets
DEMO: Atmospheric CO2 concentration (ppm) in 2050
THIS MARKET IS TO PREDICT THE ANNUALLY AVERAGED ATMOSPHERIC CONCENTRATION OF CARBON DIOXIDE AS MEASURED AT THE MAUNA LOA SITE IN HAWAII IN PARTS PER MILLION (PPM).
DEMO: Number of Atlantic hurricanes this year
THIS IS A DEMONSTRATION MARKET FOR THE NUMBER OF ATLANTIC HURRICANES THAT WILL OCCUR IN THIS YEAR'S ATLANTIC HURRICANE SEAOSN.
OPER: CYCLONES-ATLANTIC-HURRICANES-2025
THE NUMBER OF ATLANTIC HURRICANES THAT WILL OCCUR DURING THE 2025 ATLANTIC HURRICANE SEASON.
OPER: RONI-001-2025-SON
MEAN RELATIVE OCEANIC NINO INDEX DURING SEPTEMBER, OCTOBER, NOVEMBER 2025.
OPER: RONI-002-2026-DJF
MEAN RELATIVE OCEANIC NINO INDEX DURING DECEMBER 2025 AND JANUARY AND FEBRUARY 2026.
OPER: RONI-003-2026-MAM
MEAN RELATIVE OCEANIC NINO INDEX DURING MARCH, APRIL AND MAY 2026.
OPER: RONI-004-2026-JJA
MEAN RELATIVE OCEANIC NINO INDEX DURING JUNE, JULY AND AUGUST 2026.
OPER: RONI-005-2026-SON
MEAN RELATIVE OCEANIC NINO INDEX DURING SEPTEMBER, OCTOBER AND NOVEMBER 2026.
OPER: RONI-006-2027-DJF
MEAN RELATIVE OCEANIC NINO INDEX DURING DECEMBER 2026 AND JANUARY AND FEBRUARY 2027.
Markets
Accounts
Profile
OPER: RONI-004-2026-JJA
Market for the average value of RONI June, July and August 2026.
STATUS
Open
AVAILABLE CREDITS
3649.363
Market for the number of Atlantic hurricanes that will occur during 2025.
0.04
0.02
0.00
-3.0 -2.6 -2.2 -1.8 -1.4 -1.0 -0.6 -0.2 0.2 0.6 1.0 1.4 1.8 2.2 2.6 3.0
Relative Oceanic Nino Index
Markets for Releative Oceanic Niño Index (RONI) an indicator of El Niño-Southern Oscillation.
Contract
Price
Quantity
Order
Action
Inst. Value
0
DELETE
0.000
0
DELETE
0.000
Between -2.8 and -2.6
0.002
0
DELETE
0.000
Between -2.6 and -2.4
0.002
68
0.150
Between -2.4 and -2.2
0.003
163
0.488
Between -2.2 and -2
0.004
280
1.223
Total:
968.876
Create a new contract

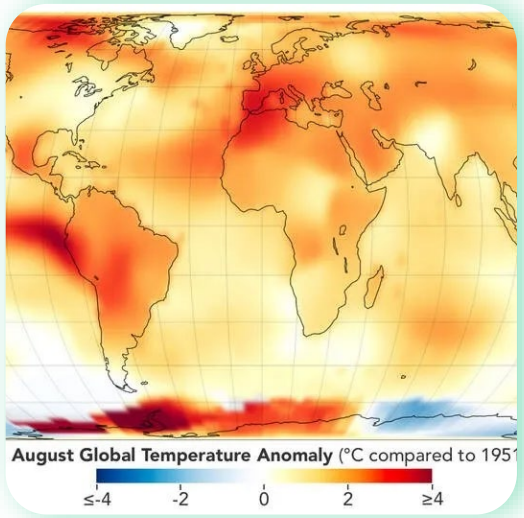
6. The future of CRUCIAL

Potential long-range markets

Arctic sea ice

GHG emissions

Sea-level rise



Global temperature

Renewable share

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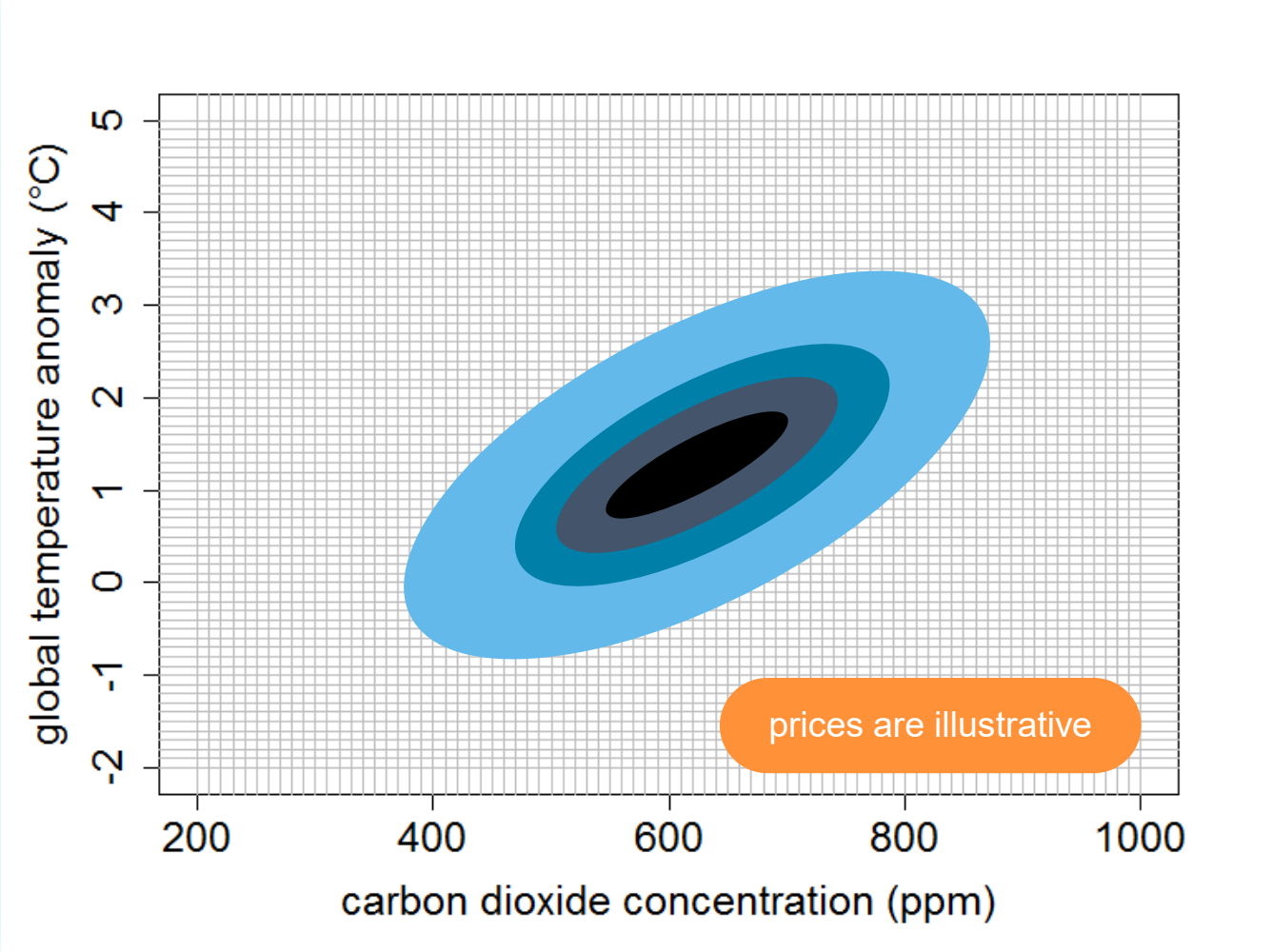
Solving the “circularity” problem

Joint-outcome markets for GHGs and temperature

If a market predicts a temperature rise of 1.5°C is this because…

- climate sensitivity is low *or*
- big GHG emissions reductions are anticipated?

A joint-outcome space for GHG concentrations *and* temperature can differentiate these possibilities.



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Challenges faced by long-range markets

- Time value of money
  - Denominate the market in an asset that accrues interest
- Longevity of institutions
  - Participants must have confidence market operator will be around for decades.
  - Funds held in bankruptcy-protected trust.
  - Specified wind-up procedures.
  - Confidence in the availability of data for settlement.
- Effectiveness of incentives
  - Participation of institutions with longer horizons than individuals.
  - Work-place pensions rely on deferred incentives.

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Prediction markets could be a new kind of scientific institution

Prediction markets can combine…

- the concept of inducement prizes
- the ability of markets to aggregate information.

When the primary deliverable of research is a forecast, prediction markets offer…

- a more effective way to synthesize information.
- a more efficient and accountable way to distribute funding.

Further reading

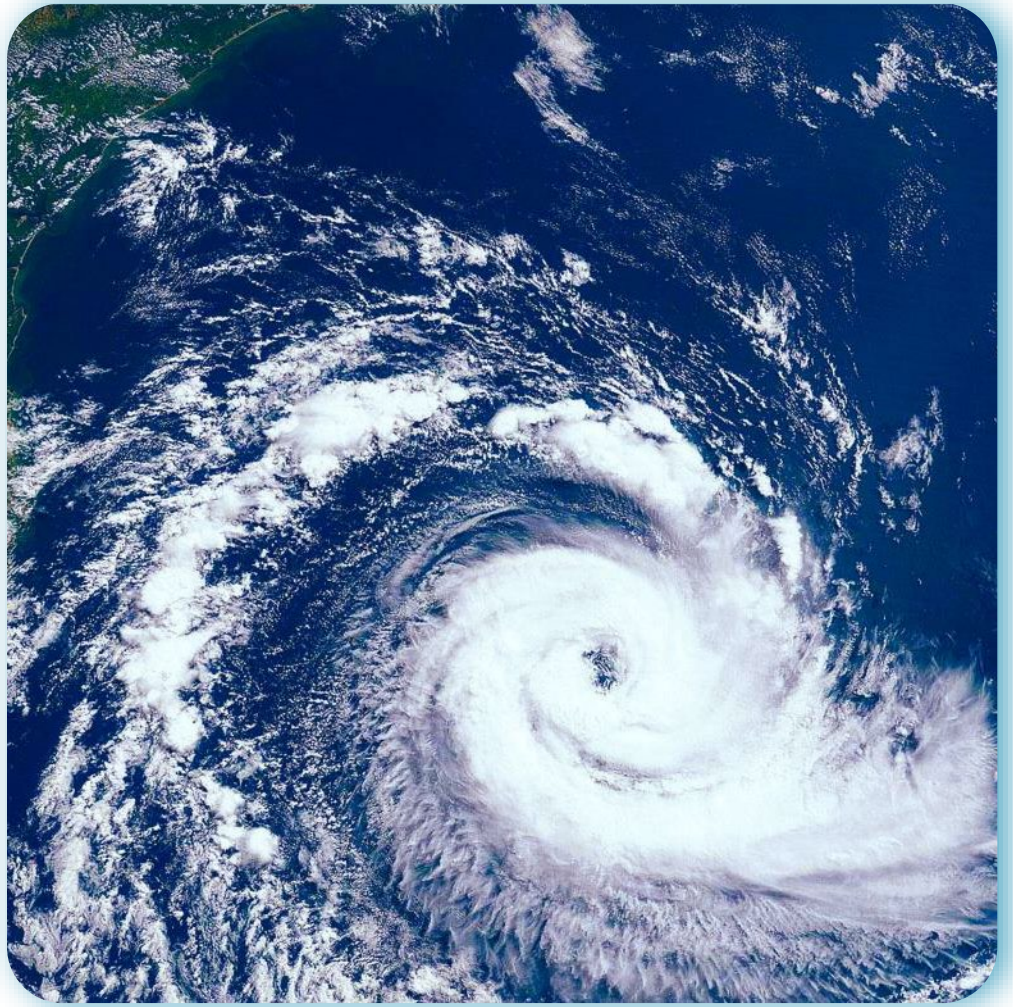
Roulston, M., Kaplan, T., Day, B. and Kaivanto, K., 2022. Prediction-market innovations can improve climate-risk forecasts. *Nature Climate Change*, **12**(10), pp.879-880. https://doi.org/10.1038/s41558-022-01467-6

Roulston, M. and Kaivanto, K., 2024. Can expert prediction markets forecast climate-related risks? *Bulletin of the American Meteorological Society*. https://doi.org/10.1175/BAMS-D-24-0135.1

Roulston, M. and Kaivanto, K., 2024. Joint-outcome prediction markets for climate risks. *PLOS ONE.* https://doi.org/10.1371/journal.pone.0309164

Roulston, M., Kaivanto, K. and Toumi, R., 2025. Tracking evolving views of the 2024 Atlantic hurricane season with an expert prediction market. *Weather* https://doi.org/10.1002/wea.7730

www.crucialab.net



Thank You

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