Agricultural resilience to extreme weather events - taking stock of and reanalysing dependencies and history in climate risk management

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The getting of climate wisdom?

- Climate forensics & predictive capabilities for extreme weather events (EWE) in agricultural, energy, water, weather and insurance markets?
- Assimilation of information & methodologies to make industry sectors & communities more resilient to EWEs, at various time horizons?
- Are interacting climate modes, reanalysis, RCM & palaeo-tempestology techniques useful for the understanding / design & popularising of Community Weather-based Alternative Risk Techniques (CWART)?
Resilience and the importance of extreme weather events

Red triangle gives overall risks from past behaviour/settings and current portrayal of hazards.

Exposure gives current or future positions over various horizons

Blue triangle corresponds to sustainable growth in demanding environment

Vulnerabilities of various types

Hazards (single/multiple etc)

Capacity implies here active resilience techniques

Opportunities arise when doing risk assessment & system review

Shape and size of Climate Risk Diamond evolves over time
What procedures are useful in optimising farm performance measures of several types at the various timescales caused by EWE and climate change-induced impacts?

What information is essential for financial management of residual climate risk due to EWE via insurance, derivatives, bonds, microfinance and new methods of governance?

What useful overlaps in CRM are there between different industry sectors (e.g. agribusiness, water resources, power, tourism ....)?
Australian agricultural storyline

- Single farmer wishing to optimise crop management, using seasonal forecasting and alternative risk transfer (ART) such as weather derivatives.
- Enterprise risk management for agribusinesses operating across multiple regions and climate zones.
- Agricultural co-operatives (Irrigation Companies) investigating insurance for improving adaptation efforts in water demand, harvesting and energy.
- More efficient alternatives to “emergency assistance measures”
- Environmentally sustainable & GHG-friendly irrigation systems, & carbon-neutral catchments.
Stages of weather history in the climate “present”?

- Various biophysical proxies
- Long duration
- Low resolution
- Relevance??
- Dependencies!
- Reinsurance

Observational

- Surface, upper-level, satellite, response
- Short duration
- High resolution
- High relevance

Pre-observational or palaeoclimate proxy data

- Seasonal & decadal forecasting
- GCM scenarios
- Probabilistic
- Low to moderate duration, resolution and relevance?

GCM predictions and scenarios

Reanalysis

- Reconstructions but consistent
- Moderate duration
- Moderate resolution
- Moderate relevance
- Characterisation, design and pricing,
Taking stock of weather history - Reanalysis 101; the Atmospheric Circulation Reconstructions over the Earth project.

- Horizontal surface pressure fields + ensemble Numerical Weather Prediction model give 6 hourly 2 degrees 120 + years of surface + upper-level weather parameters and flux variables and errors.
- Virtual history of radiosonde and fluxmeter stations worldwide.
- Downscaling often needed for many purposes but 0.5-1 degree resolution (experimental) captures tropical cyclones and heat waves etc with reasonable weather observations.
- Detailed event analysis, precursors to EWE, statistical linkages and teleconnections worldwide and over 120+ years.
- Cross-linking with GCM testing and palaeoproxy data aids coherent view of climatic “present” and insurance viability.
- Will form key roles in major education programmes such as GLOBE and ACRE/Google.
What information, space/time and duration/resolution?

- Time extent > 10 x period of dominant mode
- Centennial duration (palaeo and RCM?) for estimating EWE dependencies.
- Sub-diurnal for many responses (GDD, HDD, RD)
- Coarse spatial resolution OK for U/L precursors, or downscaling responses?
- Downscale for site info, statistical has many uses.
- Site or satellite observations for detail e.g. basis risks?
- Non-stationarity &/or anthrop CC complicate answer!

Figure 1. Knowledge Discovery in Climate
Data Mining for Climate Change and Impacts
Auroop R Ganguly and Karsten Steinhæuser
Evaluating weather and climate risk – history, predictions and/or collective experience?

*Reanalysis* – intelligent use of past information with modern modelling to create consistent, long-term, spatially-extended data sets (meteorology, climate, production etc).

*Forecasting* – prediction of outcomes based on varying degrees and different approaches (deterministic, statistical, semi-empirical and artificial intelligence) of understanding of processes and history over different timescales, spatial resolution, costs and accuracy.

*Risk Management* – actions to control, retain, reduce and/or distribute risk or expand current exposures.

*Enterprise Risk Management* – combining disparate risks, time horizons and instruments into a single, multi-year program of action.

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**Weather derivative contract design**

- **Abnormal weather conditions**
  - Complicated mechanism
  - Weather derivative: \( \text{Payoff} = f(W, a) \)

- **Risk / uncertainty in revenue, cost, earning**

  - **Basis risks** – residual risk where actual loss is uncompensated by CRM procedures, due to inadequacies in spatio-temporal representations and contract design.

  - **Alternative Risk Transfer (ART)** – product, channel or solution that transfers risk exposures between insurance and capital markets to achieve specific (Climate) Risk Management (CRM) – weather insurance, bonds and derivatives, catastrophe bonds..
Taking stock of weather quasi-cycles and environmental memory processes.

- {ENSO, SAM, MJO, NAO..} – Climate “modes” or “oscillations” with CAI descriptors
- “Atmospheric bridges & oceanic tunnels” - teleconnections
- Commodity production and price depends on CAI (one or many?) + other determinants like oil price?
- More modes may emerge from 120+ year reanalysis – is there a minimal set for given region?
- Short-term memory (STM) – due to nearest neighbours in time or space; autoregressive descriptions, persistence types, AI techniques for weaker non-linearities.
- Long-range dependence (LRD) or long-memory processes – ocean heat or soil moisture storage - embedded memory of growth processes; often associated with (multi)-fractality.
- Intermittency or burstiness – sudden changes in volatility that can encourage clustering of extremes, phase transitions and critical point behaviour.
- Aggregation of low-correlation signals >> fat-tailed distributions >>enhanced univariate extremes.
- Spectral peaks “above noise” but red noise (LRD) needs treating before causality testing?
- Simple indices such as SOI for strong modes, space-time models for weaker modes?
Taking stock of dependencies in climate and production measures.

**Extreme Value Theory**
- **Prob.** \( (X > u) \): Univariate Extreme Value Theory (EVT)
- **Prob.** \( (Y > v \mid X = x) \): Extremes and Multiple Covariates
- **Prob.** \( (Y > v \mid X > u) \): Multivariate Extreme Value Theory

**Gaps for real applications**
- **Large-scale data:** Scale up extreme value theory for automated use
- **Geospatial-temporal extremes:** Extend multivariate EVT for space and time

**Hydrologic Observations**
- Grid-based Precipitation

**Climate Model Simulations**
- 1870 to Now: Past
- Now to 2100: Future

- \( F(X,Y) = C(X,Y) F(X) F(Y) \); **Copula C** connects two univariate pdfs to multivariate pdf, either overall or in tails. Used in insurance, hydrology etc
- Investigate causes, importance, estimation methods, multivariate signals.
- Non-stationarity important, especially in hydromet. and attribution studies.
- Non-linearities prevalent in geophysical processes, producing signal amplification, regime shifts and unexpected behaviour.
- Spatiotemporal structural methods such as “climate network analysis” characterise changing connectivity of ocean-atmosphere, with some predictive capacity.
### Key characteristics of EWE for assessment, model selection, pricing and prediction?

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Important determinants</th>
<th>Insurance interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return periods</td>
<td>Cycles, Short-Term Memory, Long-Range Dependence</td>
<td>Pricing, client education, business and insurance cycles</td>
</tr>
<tr>
<td>Clustering, temporal</td>
<td>LRD, “burstiness or intermittency”</td>
<td>Reinsurance layering</td>
</tr>
<tr>
<td>Spatial distributions</td>
<td>Process characteristics</td>
<td>Insurance cycles and pricing?</td>
</tr>
<tr>
<td>“Loss” measures</td>
<td>Maximum probable loss, expected shortfall</td>
<td>Risk management, all sectors</td>
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<tr>
<td>Interdependence</td>
<td>Multivariate copulas?</td>
<td>Catastrophe reinsurance</td>
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<tr>
<td>Asymptotes</td>
<td>Outliers, kings, swans &amp; iceberg risks</td>
<td>Reinsurance viability, retrocession</td>
</tr>
<tr>
<td>Climate variability</td>
<td>Inter-annual and decadal cycles</td>
<td>Pricing</td>
</tr>
<tr>
<td>Climate change</td>
<td>Trends, change in system characteristics</td>
<td>Viability of reinsurance and adaptation measures</td>
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Coping and risk management of Extreme Weather Events in agricultural context require a combination of insurance, forecasting, adaptive operation strategies, full use of historical information (e.g. reanalysis and palaeo-climate), and appropriate consideration of community vulnerabilities, uncertainties, and communication requirements.
### MCV project methodologies and expected outcomes – example of heat stress in cattle, poultry and pigs?

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>I. Heat stress in Confined Animal Feedlot Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical conditions</td>
<td>Multi-day “heatwaves” with poor night-time relief</td>
</tr>
<tr>
<td>Key climate &amp; meteorology?</td>
<td>Synoptic blocking</td>
</tr>
<tr>
<td>Key parameters</td>
<td>Accumulated Temperature, Rain, Black Globe T</td>
</tr>
<tr>
<td>Key Indices (Illustrative)</td>
<td>MJO, STR.....</td>
</tr>
<tr>
<td>Current Insurance</td>
<td>Mortality only, but major impacts on production,</td>
</tr>
<tr>
<td></td>
<td>immune systems, reproductive capacity etc</td>
</tr>
<tr>
<td>Index products?</td>
<td>Some in various parts of Asia</td>
</tr>
<tr>
<td>Reanalysis for</td>
<td>Strategic risk and forecast validation, new product</td>
</tr>
<tr>
<td>insurance/adaptation?</td>
<td>design? Stress database available for Aust/US.</td>
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</table>
EWE treatment important in community education, disaster relief planning, insurance design and viability, RCM utility and industry strategy.

Reanalysis widens information windows and opportunities.

Stochastic properties heavily linked to adaptation cost/benefits.

IBI and WART work well in sponsored, single-sector, “aid” applications. Other locations/situations may need cross-sector diversification.

We expect that:

- Model/observational error fields may be key consideration in ART where seasonal climate forecasting is needed.
- There may be some dependence measures that are relatively independent of mild/medium/severe or even abrupt climate change.
- Copula/CVAR approaches should be useful in many agri-finance-insurance evaluations of EWEs.
We live in exciting times when we seek sunshine behind seemingly threatening clouds.

“When you don’t know where you’re going, it’s important to remember where you came from” – African proverb.

“Only by transmitting the past to our children can we enable them to invent their future” (Alain 1989).

“Man can believe the impossible, but man can never believe the improbable.” – Oscar Wilde.