WORLD CLIMATE RESEARCH PROGRAMME

Lighthouse Activity on Explaining and Predicting Earth System Change

June 2021

Co-chairs:
Rowan Sutton, NCAS & U. Reading, U.K.
Kirsten Findell, GFDL, U.S.A.

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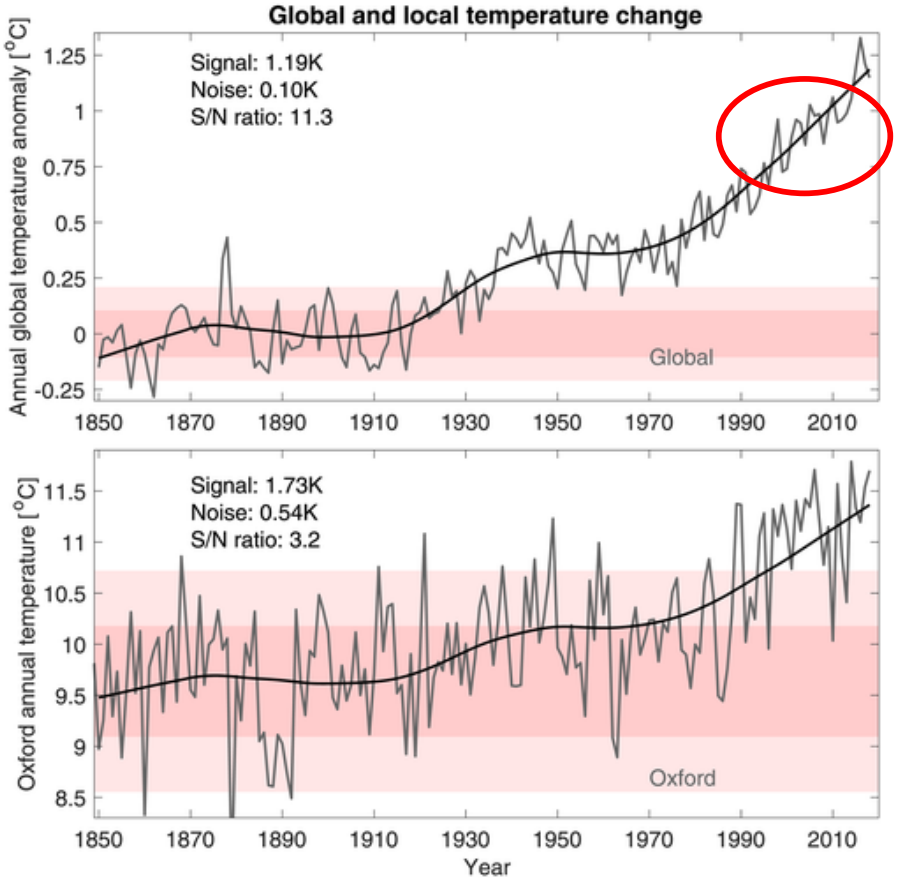
WCRP Lighthouse Activity on Explaining and Predicting Earth System Change

The signal of anthropogenic climate change is emerging progressively from the background of natural variability.

Emergence is seen on multi-annual and longer timescales and is becoming ever more apparent on smaller spatial scales and in a greater range of variables.

Yet capabilities for quantitative explanation and prediction of changes on these timescales are exceedingly primitive (e.g. “hiatus”)

We are particularly poor at explaining changes in dynamical variables, e.g. atmosphere and ocean circulation
- These play a key role in shaping hazards



Hawkins et al, GRL, *Observed emergence of the climate change signal: from the familiar to the unknown*, 2020

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Motivation

- The formulation of robust policies for mitigation of, and adaptation to, climate change requires quantitative understanding of how and why specific changes are unfolding in the Earth system.
- Quantitative process-based explanation (attribution) of observed changes is essential for quantifying current risks and fundamental to confidence in climate predictions and projections.

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Overarching objective

- ***To design, and take major steps toward delivery of, an integrated capability for quantitative observation, explanation, early warning and prediction of Earth System Change on <u>global and regional scales</u> and <u>multi-annual to decadal timescales.</u>***

  - *Examples: "hiatus", changes in IPO phase, changes in AMOC, rapid regional ocean warming, persistent drought.*

  - *Changes in ocean and atmosphere circulation and their influence on hazards is a specific focus – key issue for adaptation.*

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Science Plan Structure

Theme 1: Monitoring and modelling Earth System Change

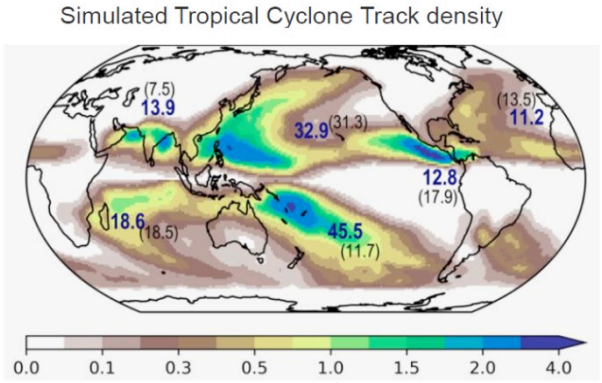
- Observational and modelling requirements to monitor, explain and predict earth system change
- Convergence between climate modelling and Earth system data assimilation & reanalysis

Theme 2: Integrated attribution, prediction, projection and early warning

- Quantitative process-based attribution of Earth System Change
- Integrated attribution, prediction and projection (building on GC in NTCP) including signal-to-noise "paradox"
- Contribute to WMO State of Global Climate & Annual to Decadal Climate Update reports
- Early warning of major changes – collaboration with SLC

Theme 3: Assessment of Current and Future hazards

- Focus on classes of events rather than individual events
- Understanding the natural and anthropogenic drivers of changing hazards in different regions; extending "event attribution" methodologies
- Collaboration with My Climate Risk & RifS



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Cross-cutting approaches / activities

Integrated use of observations and models

- Characterization and quantification of uncertainties - fundamental to attribution
- To what extent are models and observing systems adequate for the tasks?

Case studies of significant changes and multi-annual-to-decadal events

- Targeted research to quantify, explain and assess the predictability of carefully selected recent events
- Integrating insights of all three Themes.

Large ensembles

- Large ensemble single forcing experiments necessary for quantitative explanation of Earth System change
- High resolution ensembles necessary to understand circulation change and modulation of hazards
- Collaboration with Digital Earths

Relevance to WCRP Strategic Plan

WCRP Objective 1: *Fundamental understanding of the climate system*

WCRP Objective 2: *Prediction of the near-term evolution of the climate system*

WCRP Objective 4: *Bridge climate science and society*

- Predictions and early warnings
- Quantification of regional hazards and risks
- Collaboration with My Climate Risk and RifS

WCRP workshop on attribution of multi-annual to decadal changes in the climate system

World Climate Research Programme

Format: virtual workshop (free registration and attendance)

When: 22-24 September 2021 **Abstract submission deadline:** 30 June 2021

The aim of this workshop is to document current research, identify challenges, and explore potential pathways towards building an operational capability to attribute multi-annual to decadal changes in the climate system on global-to-regional scales. Key areas to be addressed include:

- To what extent is the observing system adequate for the task and how best to use the observations
- Approaches to assess the roles of internal variability and external factors including greenhouse gases, aerosols, solar variations, volcanic eruptions, ozone, land use etc
- To what extent are models adequate for the task and how to account for model errors, including underestimated signals
- To what extent responses to different forcings add linearly
- Analysis of physical processes
- Linking large scale circulation to regional weather and climate hazards
- Steps needed to build an operational capability

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Collaboration, engagement and co-design

Theme		WCRP Homes	Grand Challenges	Other LHAs	WCRP Projects	External Partners
1	Monitoring and modelling Earth System change	ESMO, CLIVAR, SPARC, CliC	Climate Sensitivity, Carbon Feedbacks, Melting Ice, NTCP	Digital Earths, Safe Landing Climates	CMIP	**GCOS, GOOS** WGNE
2	Integrated attribution, prediction and projection	CLIVAR, GEWEX, SPARC, CliC, ESMO (WGSIP)	Near-term climate prediction (NTCP)	Digital Earths, Safe Landing Climates (e.g. emergent constraints)	DAMIP	**WMO**
3	Assessment of current and future hazards	CLIVAR, GEWEX, SPARC, CliC, RifS, Models & Data	Extremes, (+ Water, Sea-level change and coastal impacts)	My Climate Risk, Digital Earths	Global Extremes Project (GEP)	**WWRP**

Engagement with funding agencies will also be essential

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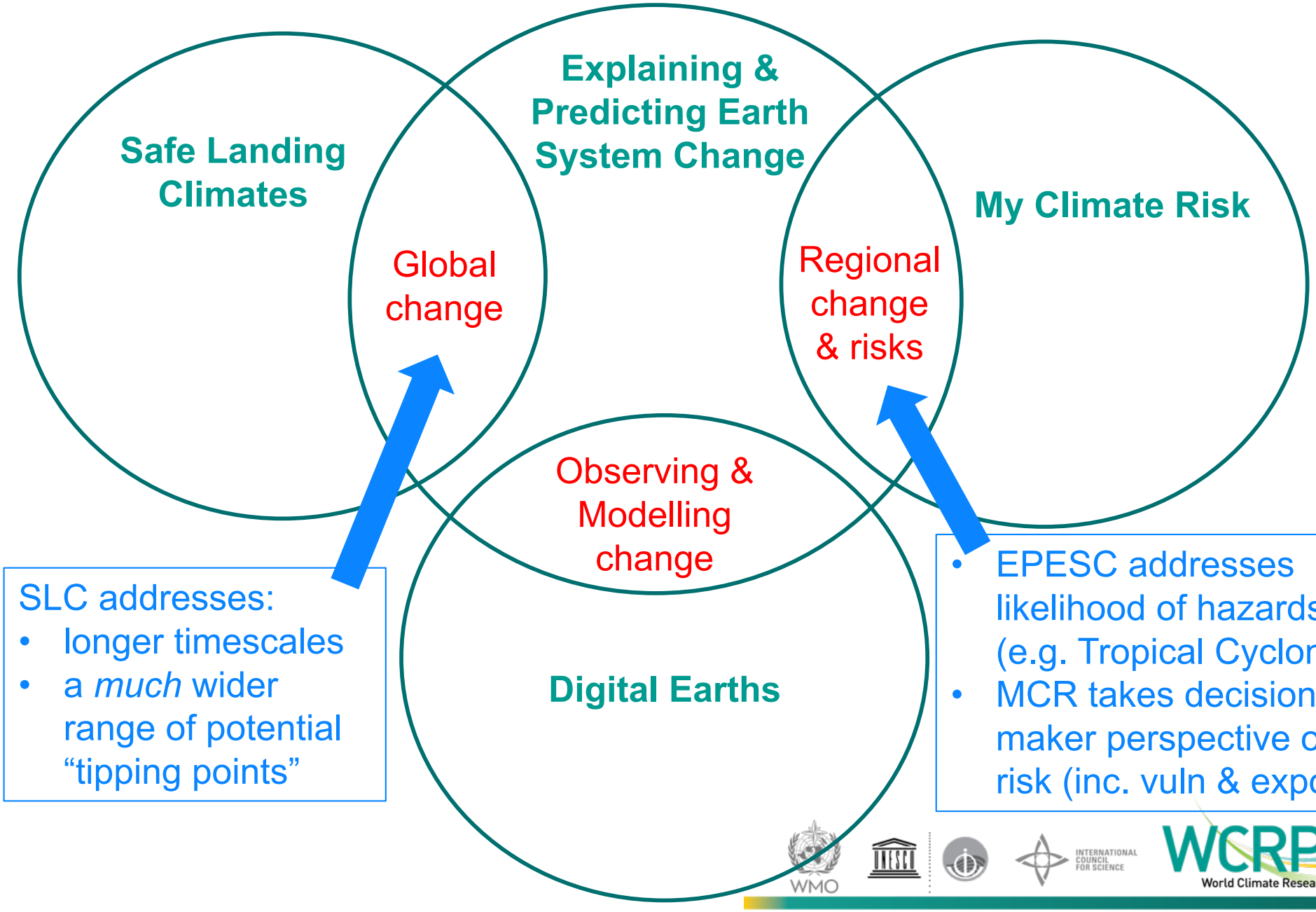
Collaboration with other LHAs



SLC addresses:
- longer timescales
- a *much* wider range of potential "tipping points"

- EPESC addresses likelihood of hazards (e.g. Tropical Cyclones)
- MCR takes decision-maker perspective on risk (inc. vuln & expo)

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Implementation and Timeline

Following JSC acceptance of Science Plan:

- Publication of Science Plan (submission Q4 2021; *BAMS*)
- Virtual workshop on attribution of multi-annual to decadal changes in the climate system
- Selection of key case studies, informed by workshop presentations and discussions (Q4 2021)
- Submission of Implementation Plan to JSC (Q4 2021)

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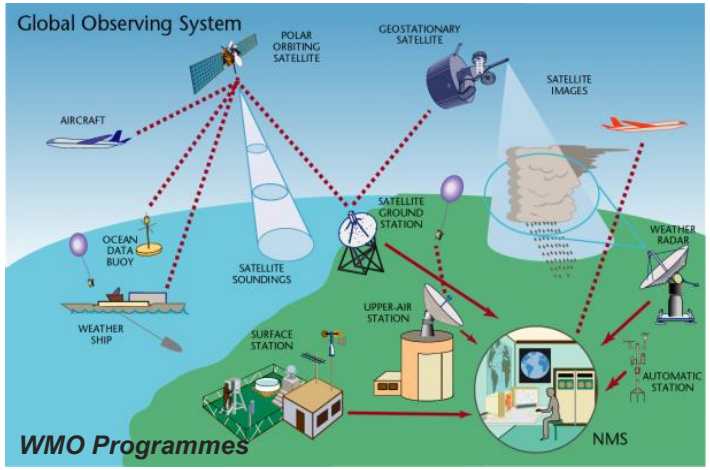
Implementation and Timeline

Within a year of launch (in early 2022), expected progress on case study efforts:

- **Attribution** of causal forcing factors, event evolution and early indicators of case study onset (Theme 2)
- Can the current **observing system** capture early indicators and monitor event evolution? Recommendations for system improvements (Theme 1)
- Assessment of case study **hazard risks** (Theme 3)
- Can **models** simulate the full evolution of the case study event? Relevant model biases? Methods to reduce these biases through improved process representation and/or model calibration (all themes).



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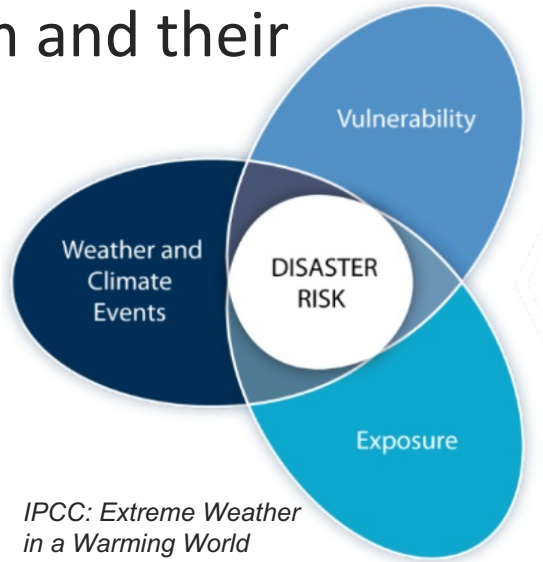
Longer term deliverables

Within the first five years we aim to have:

- Established methodologies for novel case study application;
- An international open-access multi-model archive of seasonal-to-decadal hindcast and forecast data;
- Improved capabilities for prediction of multi-annual to decadal changes in the climate system and their impacts on hazards; and
- Quantitative assessments of the current risk of specific hazards and future risk under defined scenarios.



IPCC: Extreme Weather in a Warming World

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Deliverables and Outcomes

Ultimate Outcome:

A design of, and major steps toward delivery of, an integrated capability for quantitative observation, explanation, early warning and prediction of Earth System change on global and regional scales, with a focus on multi-annual to decadal timescales.

Extra slides

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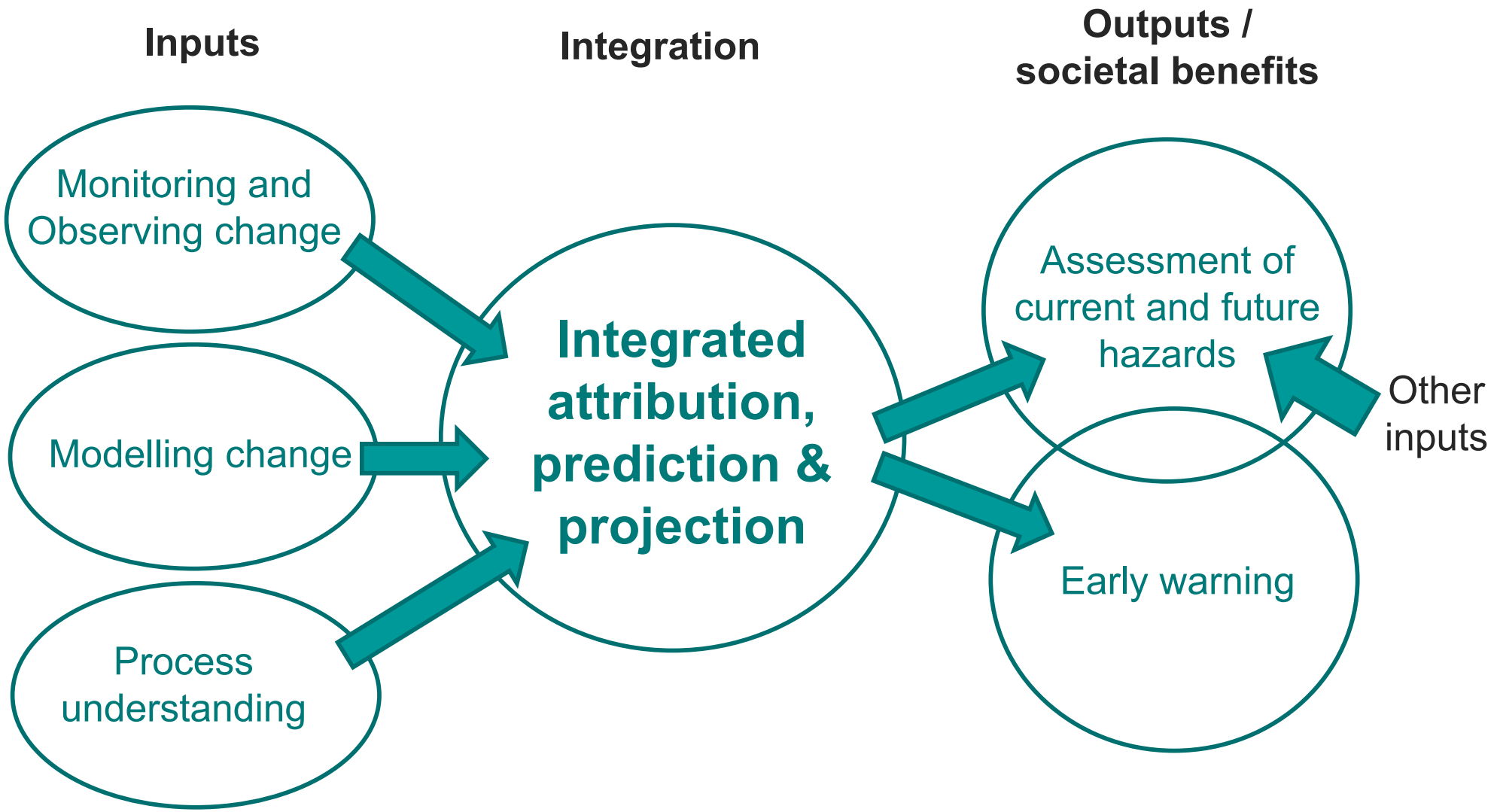

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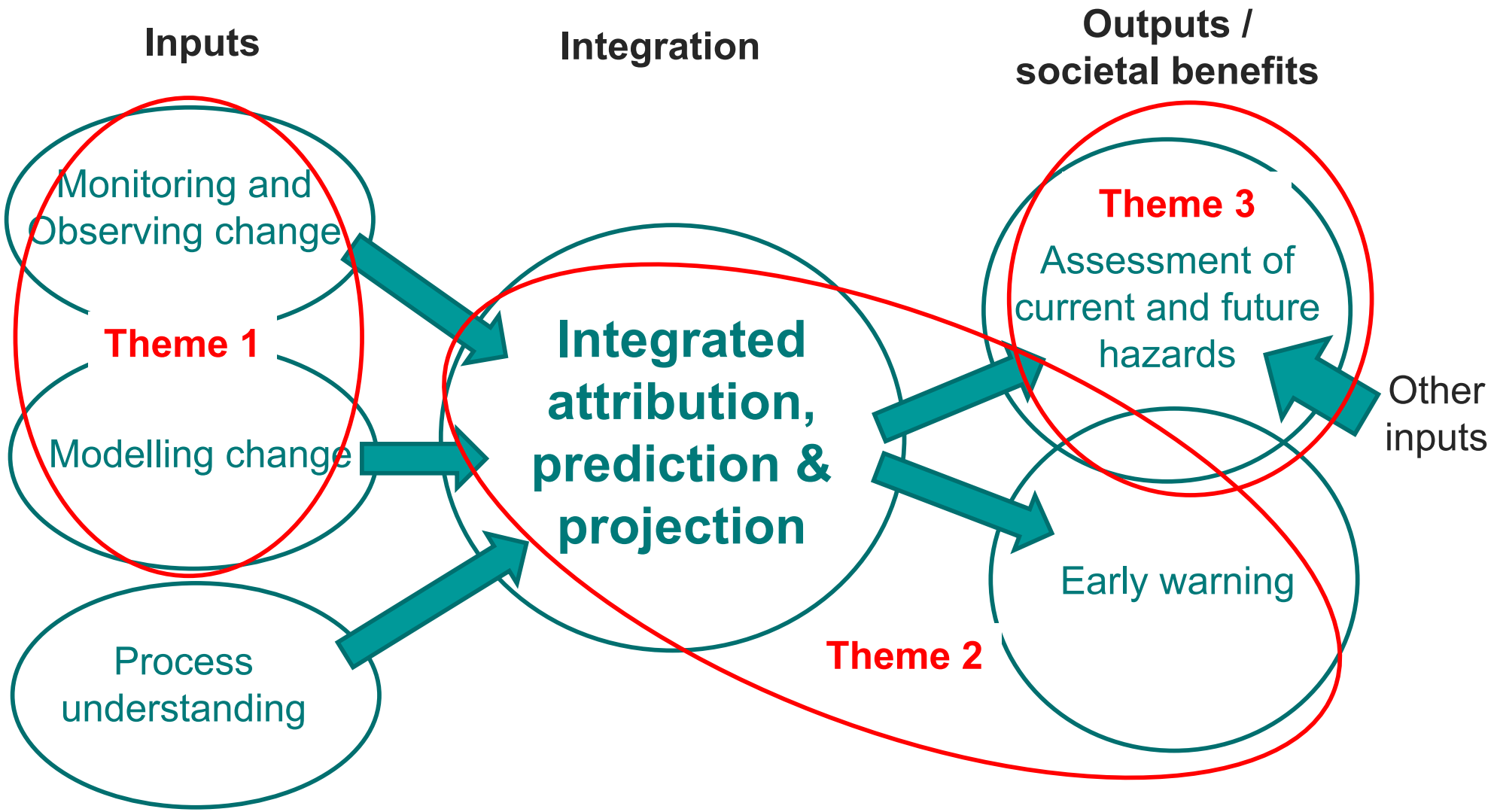

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Headline output: quantitative explanation of Earth System change

WMO OMM
World Meteorological Organization
Organisation météorologique mondiale

EMBARGO 1400 CET (1300 GMT) WEDNESDAY 2 DECEMBER 2020

State of the Global Climate in 2020

WORLD METEOROLOGICAL ORGANIZATION
Commission for Basic Systems / Commission for Climatology

Global Annual to Decadal Climate Update

Target years: 2019 and 2019-2023 TRIAL PHASE

Executive Summary

This update presents a summary of annual to decadal predictions from WMO designated Global Producing Centres and non-designated contributing centres for the period 2019-2023. Latest predictions suggest that:

- Annual global temperature is likely to be at least 1°C warmer than preindustrial levels in each of the coming 5 years
- There is a small but growing chance (~10%) that one of the next 5 years will be at least 1.5°C warmer than preindustrial levels

These headline reports currently include virtually no information on the attribution/explanation of multiannual to decadal changes in the Earth System

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Headline output: quantification of current and future weather and climate hazards

- *Where can specific hazards occur?*
- *How are hazard locations and other properties modulated by natural variability on interannual to decadal timescales, and how predictable are these modulations?*
- *How has climate change affected the distribution and other properties of specific hazards and what further changes should we anticipate?*

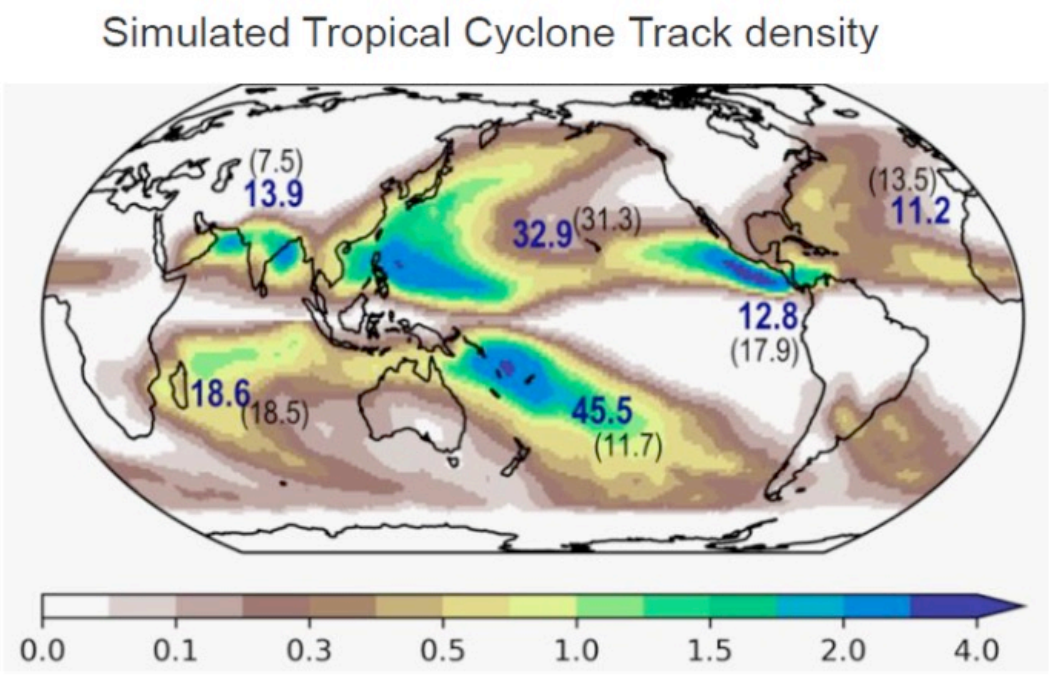

Figure from Pier Luigi Vidale

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