Earth System Approach to Climate, Weather, Water and Environment

a new WCRP strategy

Professor Pavel Kabat

Chief Scientist, WMO
Director WCRP
Climate change & services

Solar, wind & hydro use

Climate resilience

Big data, innovations

Gender-sensitive services

Water resource management

DRR, Adaptation, carbon & climate monitoring

Sea level rise, climate<>oceans

Climate change <>ecosystems

Climate driven conflicts

Resources for climate adaptation & DRR
Biggest risks for world economy 2019

- Water crises
- Biodiversity loss and ecosystem collapse
- Failure of climate change mitigation and adaptation
- Natural disasters
- Cyberattacks
- Interstate conflict
- Man-made environmental disasters
- Large-scale involuntary migration
- Extreme weather events

World Economic Forum Global Risks Landscape 2019
Distribution on natural disasters 1998-2017
90.6 % weather related
Carbon dioxide level highest in 3 million years

**CO₂**
- Increase: 146%
- Lifetime: several thousands years
- Contribution to warming: 66%

**CH₄**
- Increase: 257%
- Lifetime: 12 years
- Contribution to warming: 17%

**N₂O**
- Increase: 122%
- Lifetime: 114 years
- Contribution to warming: 6%
• 2018 0.98±0.12°C above pre-industrial (1850-1900), 2018 set to be 4th warmest year on record
• 2015 and 2016 were affected by strong El Niño
• 2015, 2016, 2017 and 2018 are the 4 warmest years on record
• In contrast to the two warmest years, 2018 began with weak La Niña conditions, typically associated with lower global temperatures.
• By October, sea-surface temperatures in the eastern Tropical Pacific were showing signs of a return to El Niño conditions. If El Niño develops, 2019 is likely to be warmer than 2018.
Uneven economic impact of current warming
Impact of 1°C temperature increase on per capita output

Source: International Monetary Fund (IMF) World Economic Outlook
Exposure to extreme weather and climate events threatens to derail the sustainability of economic development and social welfare across the globe, and to threaten the securities on which we rely for our health and well-being.
The Science Requirements are Changing...
There is no logical scientific argument for separating the physical climate system from full Earth system science.
Weather and Climate Research

Lifetimes and sizes of atmospheric phenomena

- **CLIMATE PREDICTION**
  - Global Warming: 1 century
  - Decadal Climate Variability: 1 decade

- **LONG RANGE FORECASTING**
  - (SEASONAL TO INTERANNUAL CLIMATE PREDICTION)
  - Monsoon: 1 year

- **EXTENDED-RANGE WEATHER FORECASTING**
  - 1 month

- **WEATHER FORECASTING**
  - 1 day

- **NOWCASTING**
  - 1 hour

- **CHARACTERISTIC SIZE (METRES)**

- **CHARACTERISTIC LIFETIME (SECONDS)**

- **EXTENDED-RANGE WEATHER FORECASTING**

- **WEATHER FORECASTING**

- **NOWCASTING**

- **Dust Devil**
- 1 km
- 10 km
- 100 km
- 1000 km
- 10,000 km
- 100,000 km
New Tools in the Toolbox: Seamless Prediction Across Timescales

Past climate

Now

Hours

Days

1-week

1-month

Seasonal

Decadal

Climate

Confidence boundary

Forecast lead-time

Analysis of past weather observations to manage climate risks

E.g. Agriculture: informs crop choice, planting to yield optimisation and minimise crop failure risk.

Forecasting routine and hazardous weather conditions.

Public, emergency response, international Disaster Risk Reduction

Monthly to decadal predictions - probability of drought, cold, hurricanes....

Contingency planners, national and international humanitarian response, government and private infrastructure investment

Climate Change projections.

Informs mitigation policy and adaptation choices. Impacts on water resources, heat stress, crops, infrastructure.
... a new challenge – how will our (near) future (climate & weather) models look like?

- Why do we need ExtremeEarth?
- What is the scientific reasoning behind ExtremeEarth?
- What are the key technologies for realizing ExtremeEarth?
- How will ExtremeEarth produce socio-economic impact?
- What is the ExtremeEarth partnership?

www.extremeeearth.eu
Despite tremendous progress in climate modelling....our ability to provide robust estimates of the risk to society...is still constrained by... (many things)
What does x1000 mean?

In the past:

$x1000 = 15 \text{ years} = 10^{15} \text{ scale}$

$= 2 \text{ M€ electric power / year}$

In the future:

$x1000 = ?? \text{ years} = 10^{18} \text{ scale}$

$= ?? \text{ M€ electric power / year}$

Codes are only 5% efficient!

[The Economist, 16 March 2016]

The end of Moore’s law
Convergence of Key Technologies through EEsC

The EEsC will turn workflows inside out: users drive configuration of models and observations.

AI techniques play a crucial role in all areas!

Science for services – Quality, relevance and impact

User interactions force exploration of «What works»:

- Postprocessing:
  - General public
  - Energy sector
  - Floods, water
  - Air quality
  - Ecosystems
  - Transport (air, shipping, road, rail)
  - Offshore
  - Marine resources
  - Waves, storm surges
  - Agriculture and food
  - Tourism
  - Emergency preparedness - HiW

- Observations
- Verification

- Core service (R&D driven production)
- Storage
- Research - interactive
- Research, more user involvement

Earth System Model formulation, processes
Data assimilation
EPS
Observations, Emission fluxes,

BACKEND
FRONTEND
Seamless towards impacts

Weather & climate extremes

Weather analysis & forecast data

Extraction of relevant information

Placing into situational context

Impact Estimation

Reducing risk and response Scenarios

Co-Design of Information Outputs with Stakeholder Communities
## WCRP Overall Review

<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>WEAKNESSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Active global science community collaborating toward common goals</td>
<td>• Overly complex structure</td>
</tr>
<tr>
<td>• Excellent reputation and legitimacy (long history of global leadership) and strong co-sponsor backing</td>
<td>• Lack of clarity of focus/vision and boundaries</td>
</tr>
<tr>
<td>• Global research products</td>
<td>• Insufficient funding – complex and competitive</td>
</tr>
<tr>
<td>• Participation of leading scientists – strong scientific expertise</td>
<td>• Ineffective communication, successes not well showcased</td>
</tr>
<tr>
<td></td>
<td>• Not well connected to National Research Programmes, funding agencies, services etc. – requires global travel</td>
</tr>
<tr>
<td></td>
<td>• Reliance on voluntary efforts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OPPORTUNITIES</th>
<th>THREATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Climate important to societal questions, particularly climate change</td>
<td>• Budget cuts and inefficient funding - leading to demotivation of volunteers/community</td>
</tr>
<tr>
<td>• Benefits (funding, in kind) associated with closer collaboration with operational agencies, international programs, etc. (stakeholders)</td>
<td>• Organizations with overlapping or perceived as overlapping mandates</td>
</tr>
<tr>
<td>• Leadership needed to capitalize on new technologies</td>
<td>• Fast-changing and reactive political landscape</td>
</tr>
<tr>
<td>• Many emerging areas of research</td>
<td>• Perception that fundamental climate science is 'done' - reduction in support for fundamental science - perceived as irrelevant</td>
</tr>
</tbody>
</table>
CURRENT WCRP STRUCTURE

Unwieldy, complex and confusing.

Core Projects stuck in the past?

Where is whole system approach?

Where is next generation model development?

Where is the pathway to climate services?

Where is climate change?

CURRENT STRUCTURE IS NOT THE STRUCTURE FOR THE FUTURE
WCRP Strategic Plan 2019-2028

• Developed 2017-2019 with extensive consultation
• Approved June 2019

Our Vision
A world that uses sound, relevant, and timely climate science to ensure a more resilient present and sustainable future for humankind.

Our Mission
The World Climate Research Programme (WCRP) coordinates and facilitates international climate research to develop, share, and apply the climate knowledge that contributes to societal well-being.

www.wcrp-climate.org/wcrp-sp
WCRP Strategic Plan: Overview

- A hierarchy of simulation tools
- Sustained observations and reference data sets
- Need for open access
- High-end computing and data management

Scientific Objectives

1. Fundamental understanding of the climate system
2. Prediction of the near-term evolution of the climate system
3. Long-term response of the climate system
4. Bridging climate science and society
Scientific Objectives

We will support and facilitate the advancement of sciences that enable an integrated and fundamental understanding of the climate, its variations and its changes, as part of a coupled physical, biogeochemical, and socio-economic system.

Emphases:
- **Climate dynamics**: past and future global and regional changes in oceanic and atmospheric circulations
- **Reservoirs and flows**: radiative, hydrologic, cryospheric and biogeochemical changes to the reservoirs and flows of energy, water, carbon, and other climate-relevant compounds
We will push the frontiers of predictions and quantify the associated uncertainties for sub-seasonal to decadal time scales across all climate system components.

Emphases:
• **Advancing prediction capabilities** of component systems and their coupling: Deterministic, statistical and machine learning approaches. Data assimilation, complex networks, and ensemble generation
• **Predicting extreme events**: regional climate hotspots and potential for crossing thresholds. Interactions between fast and slow extremes
We will quantify the responses, feedbacks, and uncertainties intrinsic to the changing climate system on longer (decadal to centennial) timescales.

Emphasis:
• **Simulation capabilities:** Development of integrated models that account for the slowly varying interactions and highly non-linear processes. Representation of the complex interactions between aquifers, vegetation and soil carbon, permafrost, glaciers, and ice sheets, and human activities.
We will support innovation in the generation and delivery of decision-relevant information and knowledge about the evolving Earth system.

Emphases:

• **Interactions with social systems**: Social processes and emergent behaviour in the Earth System. Interactions and feedbacks between climatic and socioeconomic systems

• **Engaging with society**: Actionable climate information, scientific assessments, educational approaches and public communication strategies
Critical Infrastructure

I. A hierarchy of simulation tools
II. Sustained observations and reference data sets
III. Need for open access
IV. High-end computing and data management
What is an Implementation Plan?

- It will put the WCRP Strategic Plan into action
- It will include: resources, structures, milestones, deliverables, measures of success, risk assessment

Development of the Implementation Plan must:

- Be a transparent «bottom-up» approach involving the entire community
- Include consultation with the scientific community, agencies, academies, sponsors and other stakeholders
- Ensure a fit-for-purpose structure, an effective governance, required resources, budgets and finance management.
Key Science Question areas

Considering all scales

1. How to improve climate modelling and process understanding?
2. What is the impact of different forcings?
3. How can we better understand climate sensitivity?
4. How can we improve climate predictions?
5. What opportunities do new technologies provide?
6. What can we expect in regional climate hotspots?
7. What is the interaction between climate and development trends?
8. How will reservoirs change in the future?
9. What will be the impact of Geoengineering?
10. How will climate extremes occur in the future?

Parameterization

Aggregation and scaling

Aerosols

Disruptive technology

Data-model fusion

Heat

Carbon

Urbanization

Land-use Change

Evolution

Water

Weather - Climate - Water
Refining Key Science Question areas

We will refine science question areas via consultation with:

- The WCRP Community
- Science Plans of the WCRP family
- Partners (including by co-design)
- Horizon scanning done by Partners
- Gap and needs assessments
Implementation Plan: Draft Structure

1. Introduction
2. The WCRP Strategy: Vision, Mission and Objectives
3. Engagement
4. Framework
5. Partnerships
   - Identifying key partners
   - Co-designing science questions
   - Identifying common infrastructure
   - Clarifying their role in the Strategy
   - Reaffirming current, and building new
6. Implementation
   - Transition Plan
   - Schedule: Gantt chart, milestones, deliverables
7. Measures of success
8. Risks and contingencies

Phase I (by April 2020)
Phase II (by April 2022)

Fully consultative development
Will include:
- Support functions (including support offices)
- External governance: sponsors, Joint Scientific Committee, Governing Board, Joint Planning Staff (Secretariat)
- Internal structure and governance
- Resources, budgets, finance management
Future WMO: Integrated seamless Earth-system science and science for services approach
Thank you
Merci