Earth's System Approach to Climate, Weather and Environment

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WMO Chief Scientist and Director Research
(including WCRP, WWRP, GAW, …)

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

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World Meteorological Organization
Organisation météorologique mondiale

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

UN World Conference on Disaster Risk Reduction
2015 Sendai Japan

2015: A Landmark Year

- Over 190 countries signed up to reduce emissions, with the target to stay within a 2ºC world.

- 15-year agreement for the substantial reduction of disaster risk and losses in lives, livelihoods and health.

- 2030 agenda with 17 goals to end poverty and hunger, improve health and education, making cities more sustainable, combating climate change, and protecting oceans and forests.

Understanding and Quantifying Weather and Climate Risk are at the Core of these Actions

A little preamble....

Where do we stand today ?

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Last week @ WMO…

Yesterday @ WMO…

WMO State of the 2018 Climate report paints 2018 as a devastating, record-breaking year….

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WMO GREENHOUSE GAS BULLETIN NOVEMBER 2018

	CO_2	CH_4	N_2O
Global abundance in 2017	405.5 ± 0.1 ppm	1 859 ± 2 ppb	329.9 ± 0.1 ppb
2017 abundance relative to year 1750*	146%	257%	122%
2016-17 absolute increase	2.2 ppm	7 ppb	0.9 ppb
2016-17 relative increase	0.55%	0.38%	0.27%
Mean annual absolute increase of last 10 years	2.24 ppm yr^{-1}	6.9 ppb yr^{-1}	0.93 ppb yr^{-1}

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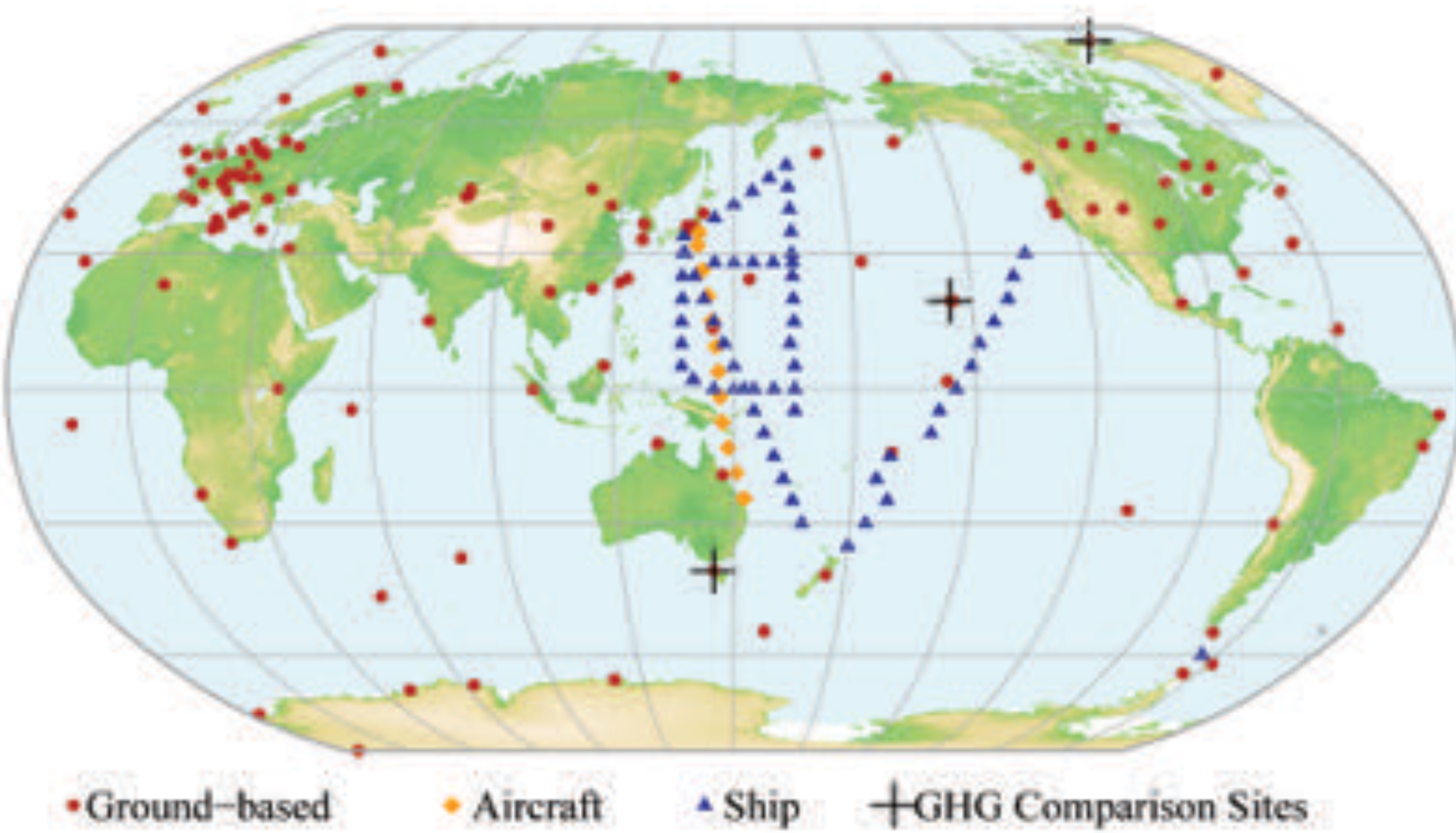
The number of stations used for the analyses is 129 for CO_2, 126 for CH_4 and 96 for N_2O. Assuming a pre-industrial mole fraction of 278 ppm for CO_2, 722 ppb for CH_4 and 270 ppb for N_2O.

Greenhouse gas observations
WMO Global Atmosphere Watch (GAW)



Carbon dioxide level highest in 3 million years…

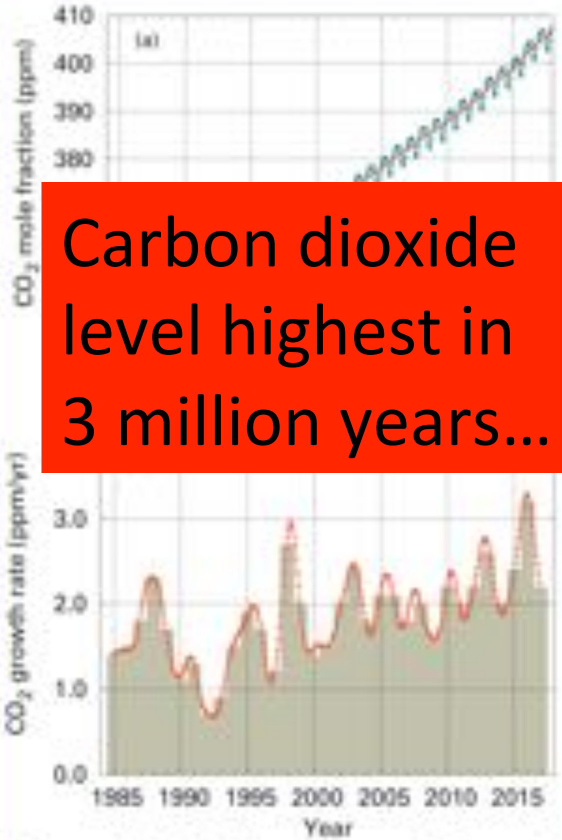


Figure 4. Globally averaged CO_2 mole fraction (a) and its growth rate (b) from 1984 to 2017. Increases in successive annual means are shown as the shaded columns in (b). The red line in (a) is the monthly mean with the seasonal variation removed; the blue dots and line depict the monthly averages. Observations from 129 stations have been used for this analysis.

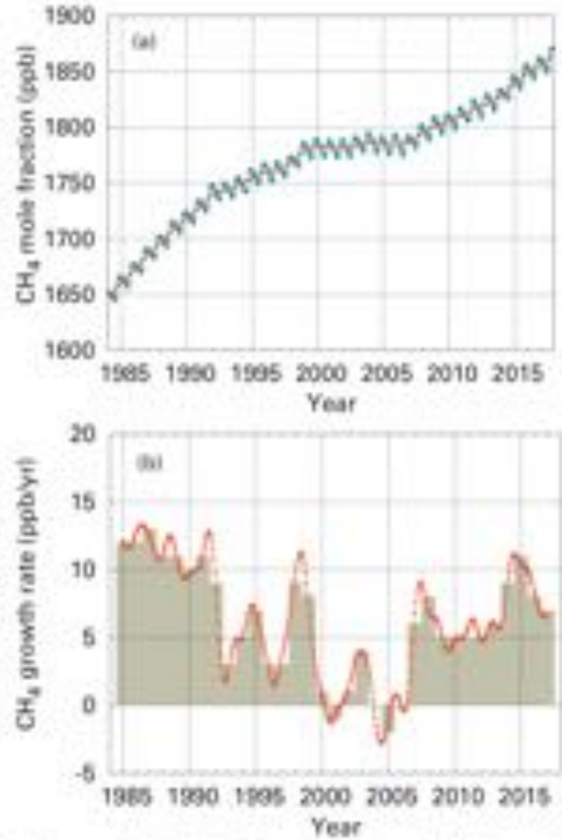


Figure 5. Globally averaged CH_4 mole fraction (a) and its growth rate (b) from 1984 to 2017. Increases in successive annual means are shown as the shaded columns in (b). The red line in (a) is the monthly mean with the seasonal variation removed; the blue dots and line depict the monthly averages. Observations from 126 stations have been used for this analysis.

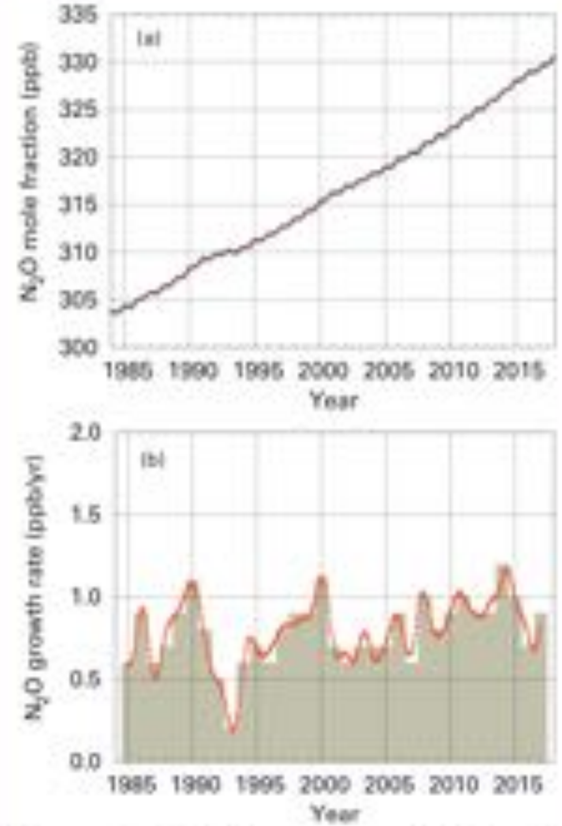
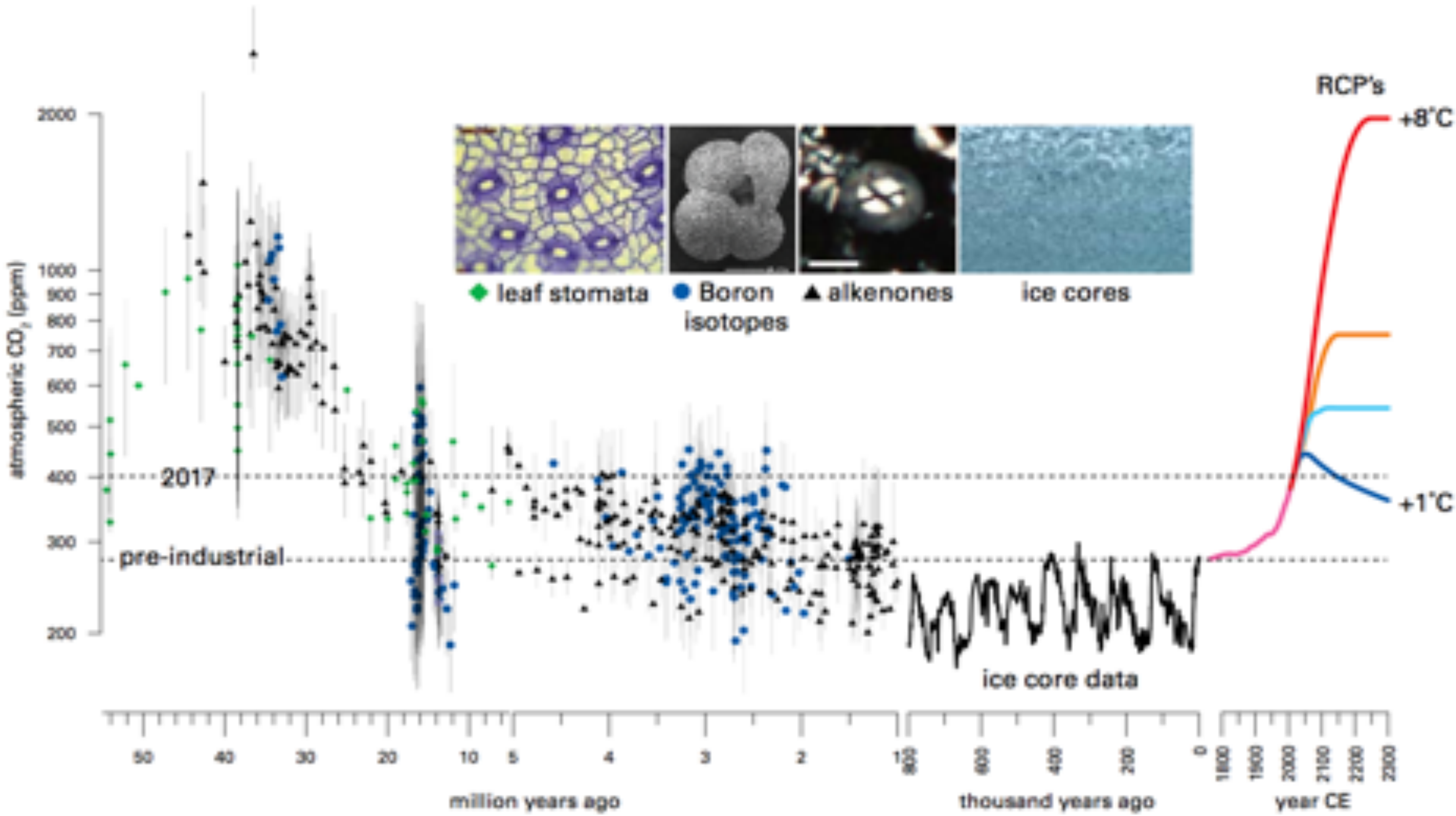
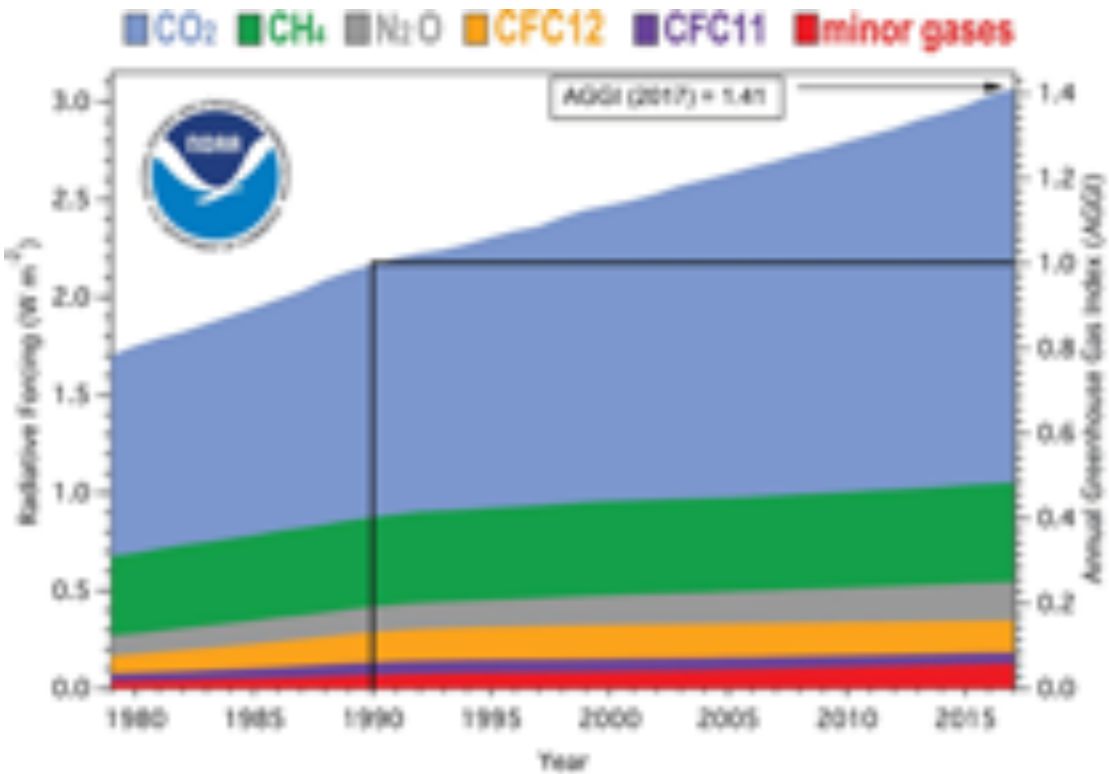


Figure 6. Globally averaged N_2O mole fraction (a) and its growth rate (b) from 1984 to 2017. Increases in successive annual means are shown as the shaded columns in (b). The red line in (a) is the monthly mean with the seasonal variation removed; in this plot it is overlapping with the blue dots and line that depict the monthly averages. Observations from 96 stations have been used for this analysis.

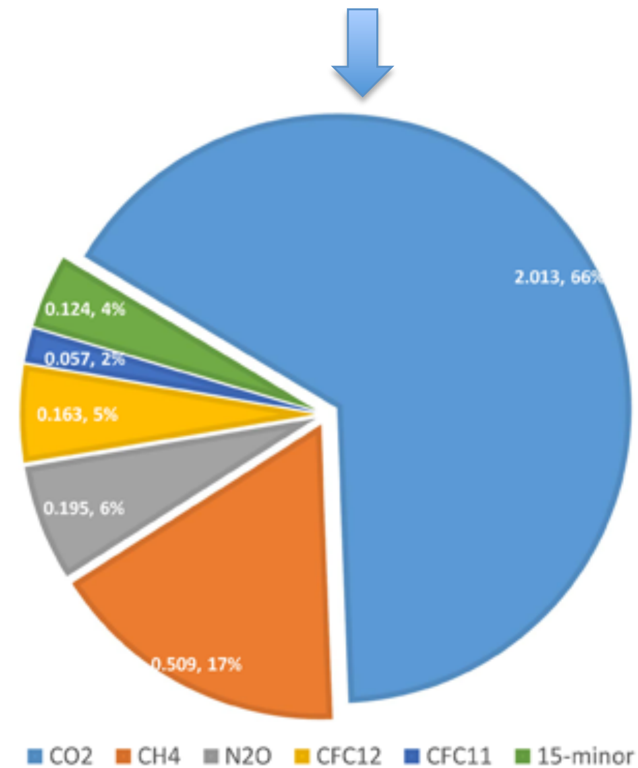
Reconstruction of atmospheric CO2



Radiative forcing



Since pre-industrial



- equivalent CO_2 mole fraction is 493 ppm
- CO_2 contributes 82% to the increase in RF within last 5 years

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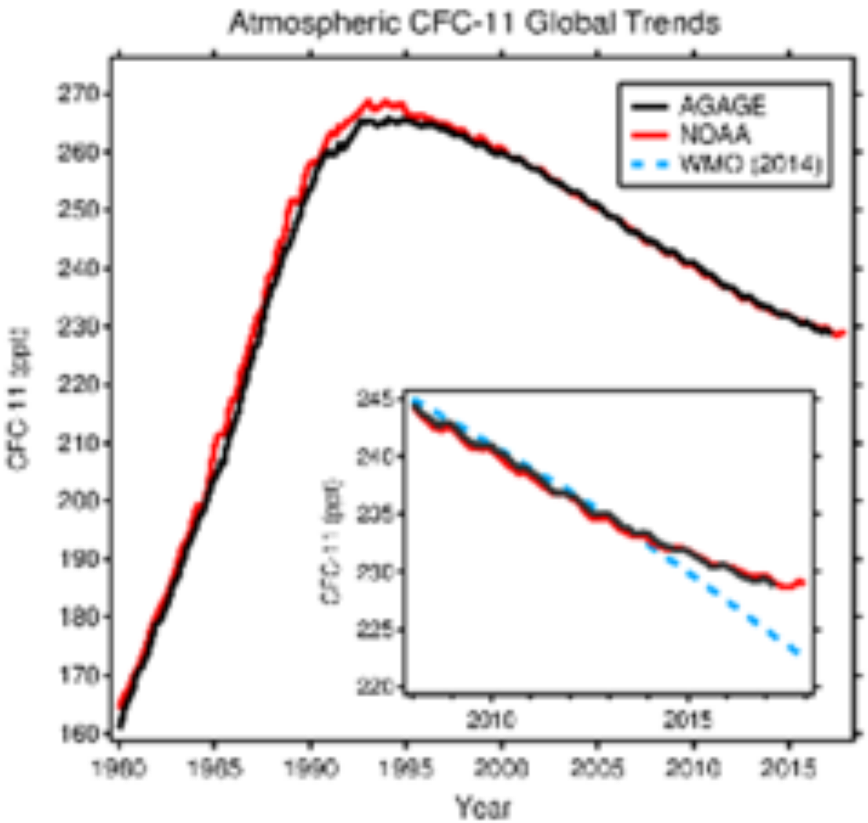
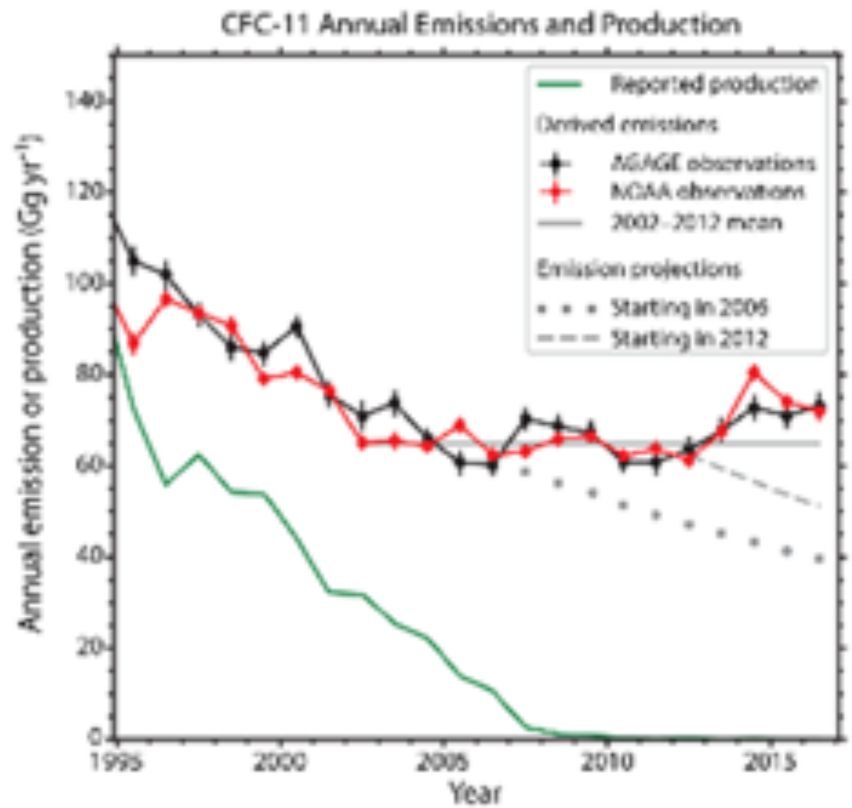
Atmospheric “discoveries”





New emissions of CFC-11 from East Asia

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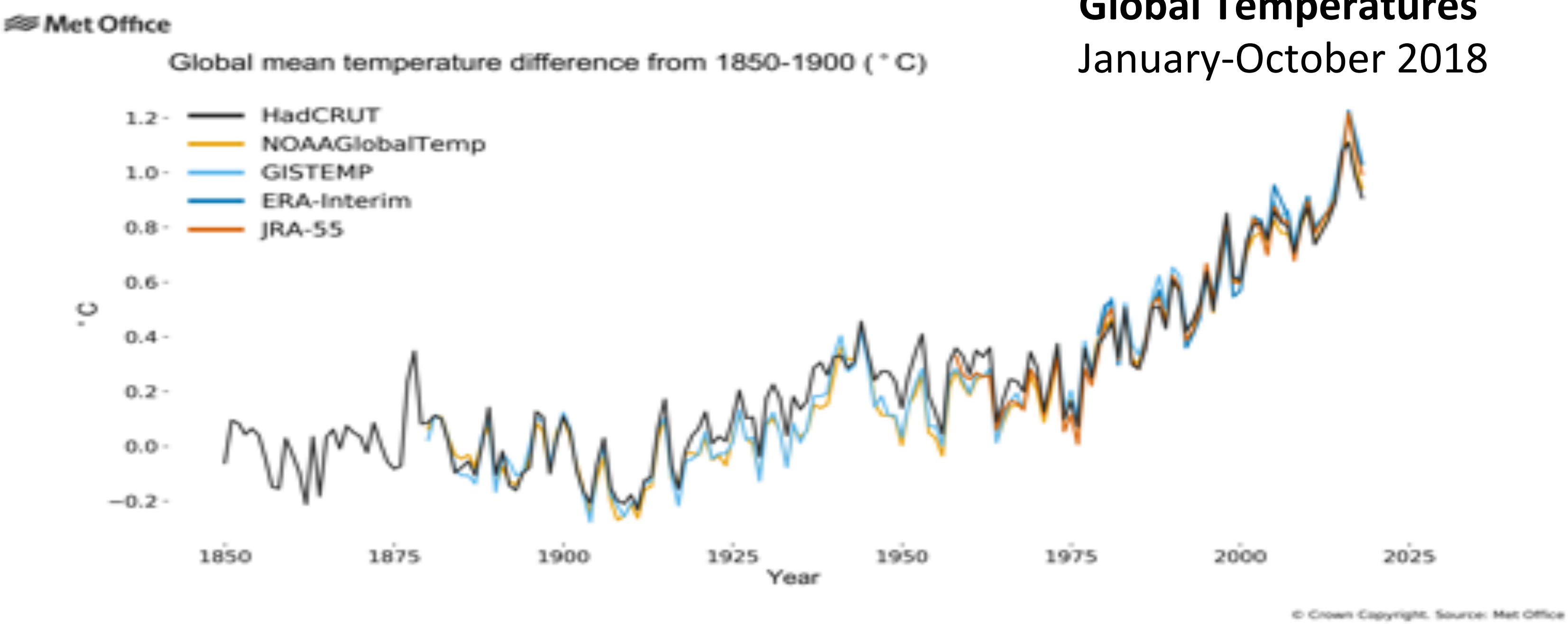
WMO State of Climate 2018

(pre-release yesterday in Geneva)

Global Temperatures
January-October 2018



- 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 Nino2015, 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.

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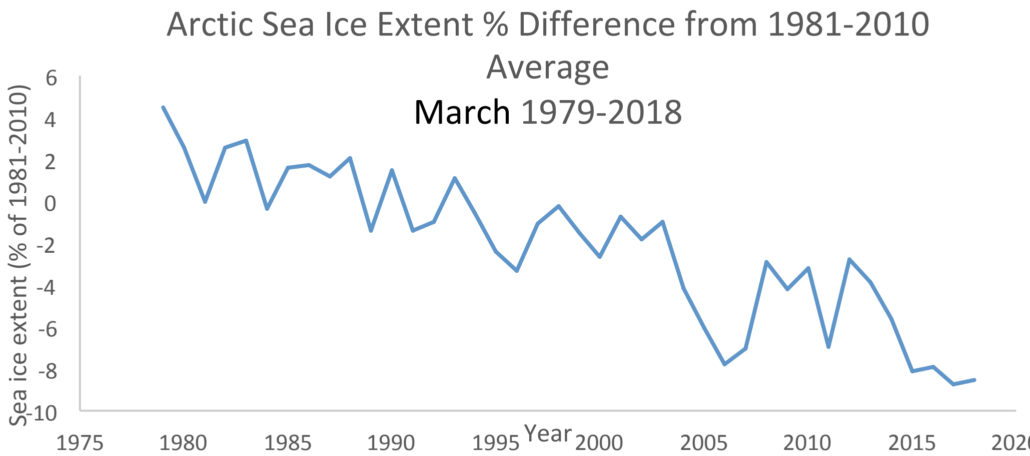
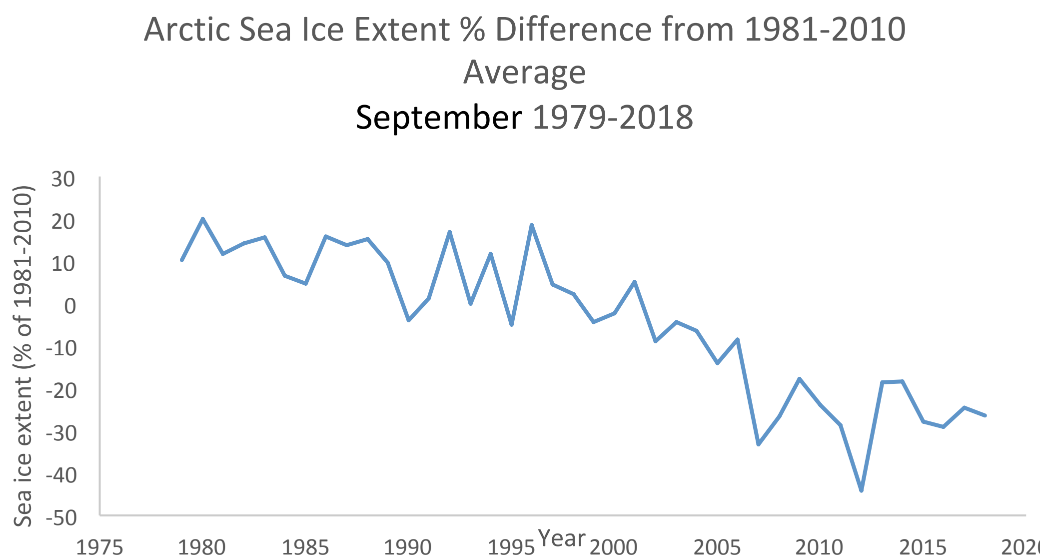
Arctic Sea Ice in 2018

March
14.48 million square kilometres, approximately 7% below the 1981-2010 average (15.64 million square kilometres), the 3rd lowest on record



September
4.62 million square kilometres, approximately 28% below average (6.40 million square kilometres), the 6th smallest September extent on record.



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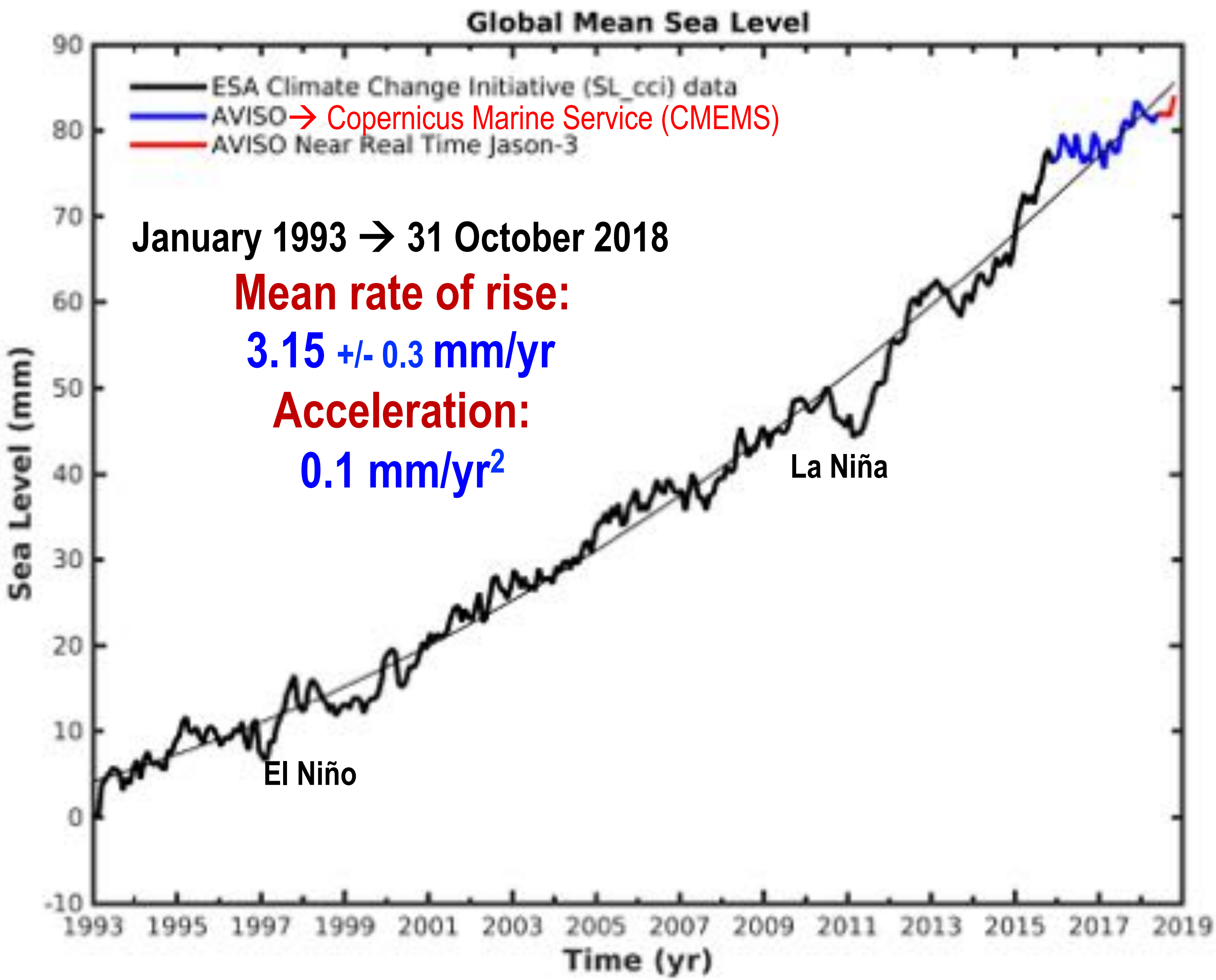
Global Mean Sea Level (Altimetry Era)



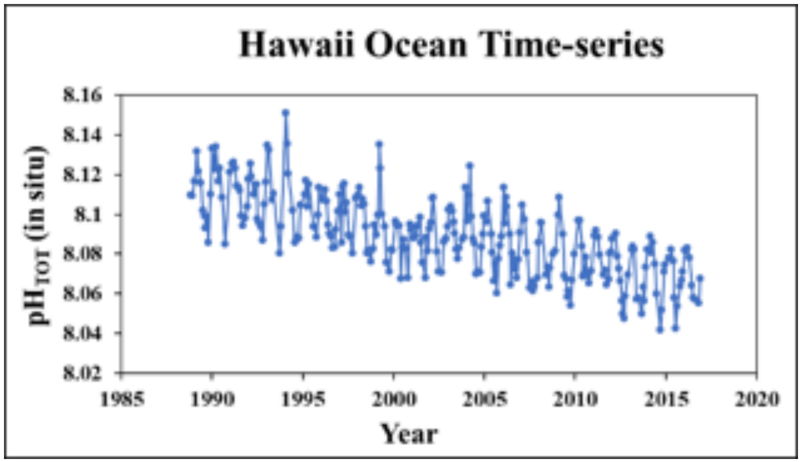
Global Mean Sea Level Rise

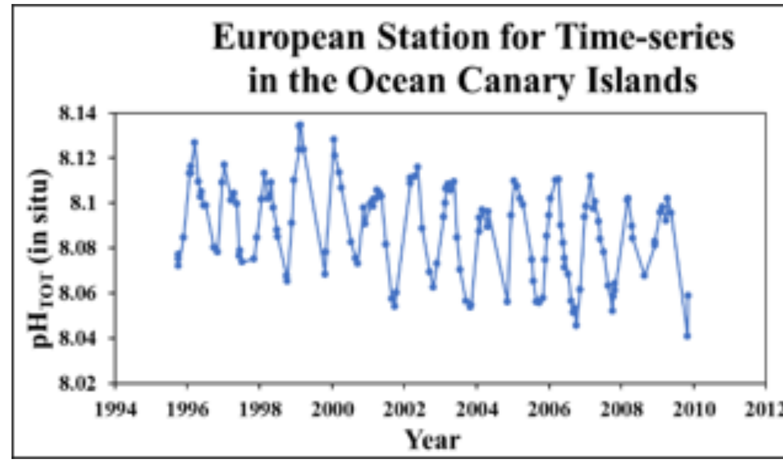
1993-2018 → 3.15 +/- 0.1 mm/yr
1993-2017 → 3.1 +/- 0.1 mm/yr

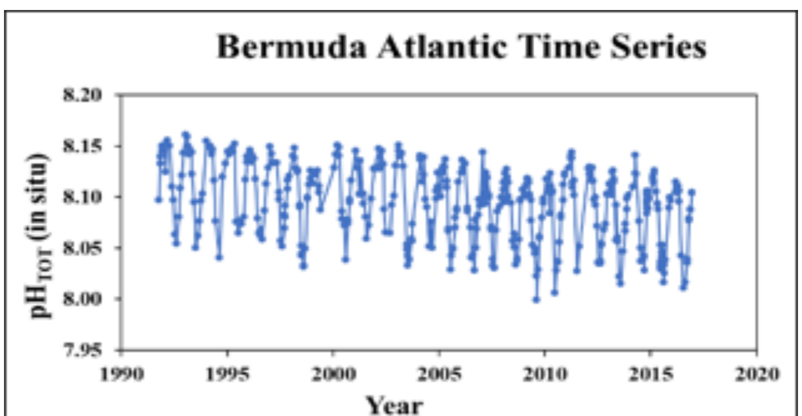
2014-2018 → 4.5 +/- 0.3 mm/yr
2014-2017 → 5.1 +/- 0.3 mm/yr

(formal error, 1 standard deviation)

Ocean acidification







Open-ocean sources over the last 30 years have shown a clear trend of decreasing pH.

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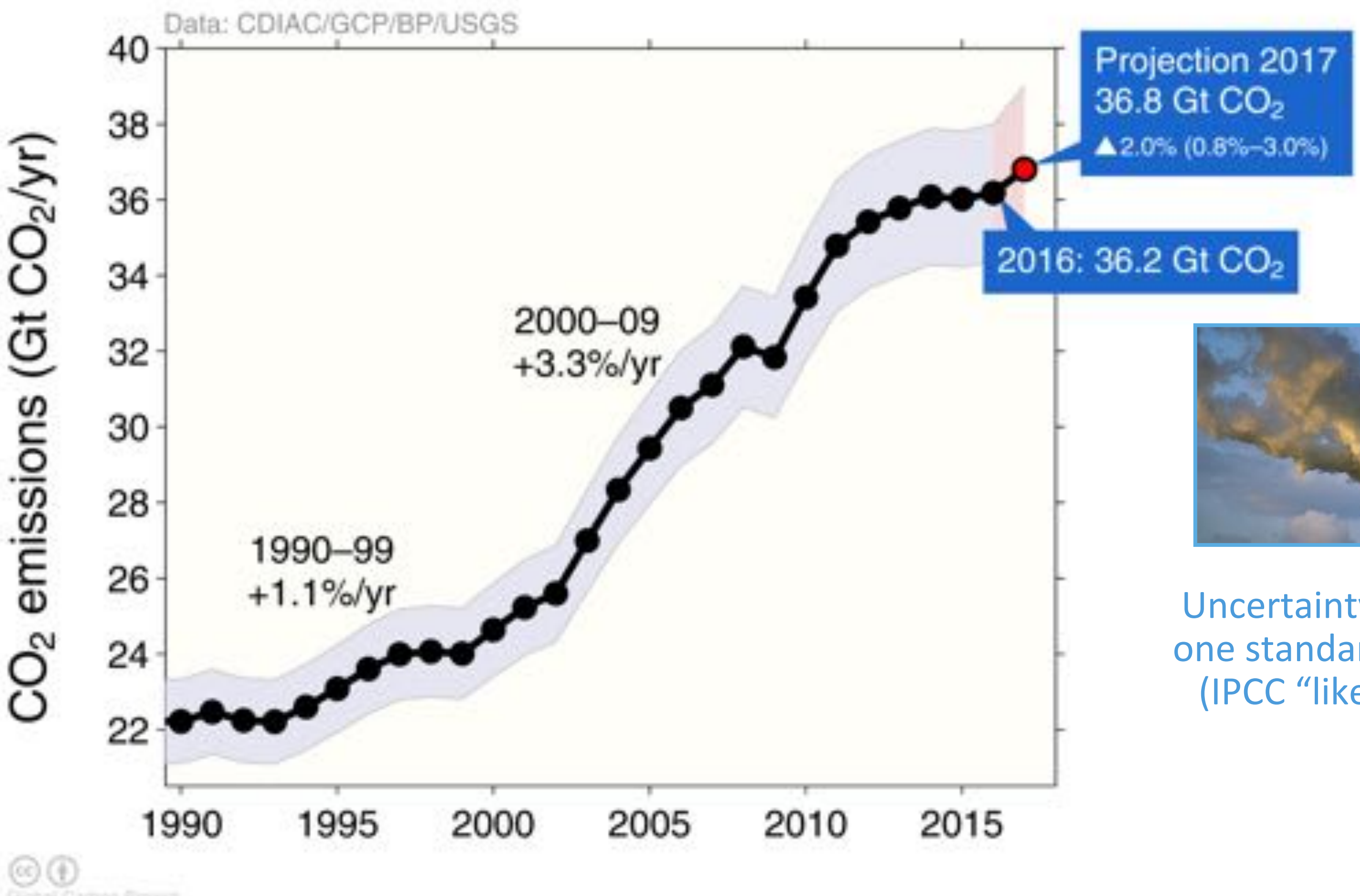
Credit: Richard Feely (NOAA- PMEL) and Marine Lebrec (IAEA OA-ICC)

Emissions from fossil fuel use and industry

Global emissions from fossil fuel and industry: 36.2 ± 2 GtCO_2 in 2016, 62% over 1990

- Projection for 2017: 36.8 ± 2 GtCO_2, 2.0% higher than 2016



Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

Estimates for 2015 and 2016 are preliminary. Growth rate is adjusted for the leap year in 2016.

Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

Climate and Weather Research Historical background

1950 63 1967 1970 ---- 1974 1985 1985 1998 2004 2013 2014 2015

- 1950: WMO the specialized agency of the United Nations for meteorology
- 63: World Weather Watch
- 1967: GARP (Global Atmospheric Research Programme) established by WMO (World Meteorological Organization)
- 1970 ---- 1974: Conduct of GARP Regional Experiments:
  GATE:GARPAtlanticTropicalExperiment
  MONEX:MonsoonExperiment
  ALPEX:AlpineExperiment
  AMEX:AirMassTransformationExperiment
- 1985: WCRP, World Climate Research Programme (WMO, ICSU)
- 1985: WGNE, Working Group on Numerical Experimentation
- 1998: WWRP (World Weather Research Programme). MAP & Sidney2000
- 2004: THORPEX (Observing System and Predictability Experiment)
- 2013: Sub-Seasonal to Seas Polar Prediction Projects
- 2014: 1st World Weather Research Open Science Conference, Canada
- 2015: High Impact Weather Project

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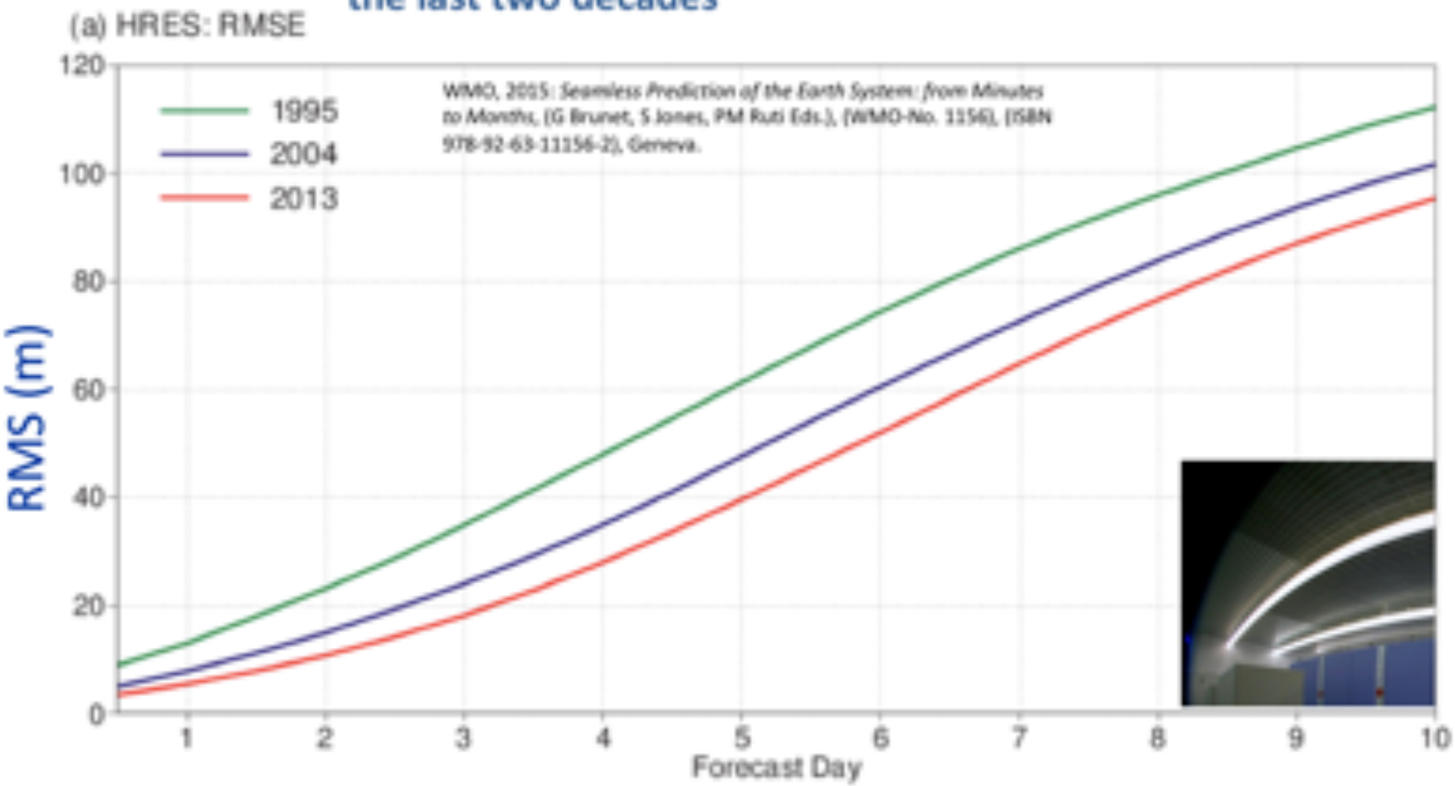
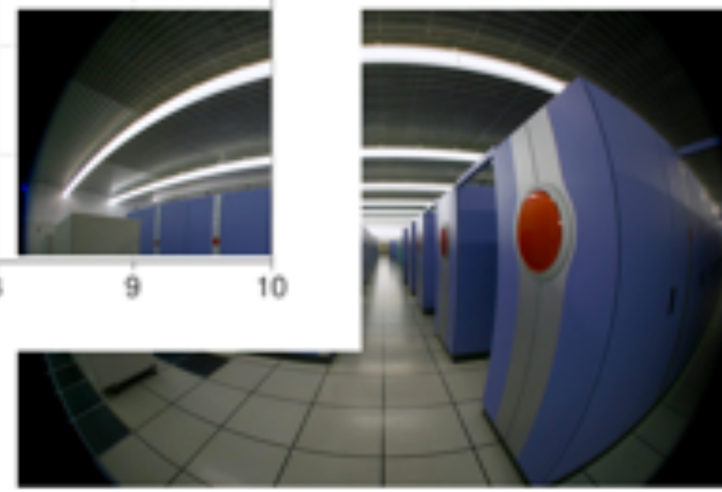
Improving the skill – big resources

ECMWF's forecast Z500hPa extra-tropical error growth over the last two decades



ECMWF



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WORLD CLIMATE RESEARCH PROGRAMME
WCRP

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The Future of WCRP….

Terms of Reference for WCRP Review

- To ascertain the effectiveness of WCRP in delivering its mandate to determine:
  - To what extent climate can be predicted;
  - The extent of man's influence on climate.
- To assess how well it partners with other organisations.
- To advise on the future structure, governance and resourcing of the programme.

Overarching Conclusions of the Review Panel

- WCRP is at a critical point in its history, and **significant changes are required in its governance, structure and delivery** for it to fulfil its mission in the context of 21st century challenges.
- Without a strong foundation in climate science and prediction, none of these challenges can be addressed in a robust, cost-effective and durable way.
- Since its inception, the key strength of WCRP has been its focus on cutting-edge physical climate science **where international coordination enables scientific advances that would not happen otherwise**. This must continue to be its focus; that means prioritising what it does and recognising where **its unique role as a facilitator and integrator of climate research makes a difference**.
- WCRP needs to articulate and demonstrate its core values more effectively, along with the societal relevance of its work. It is **not the role of WCRP to deliver the end products and services**, but it should provide the bedrock knowledge on which these can be developed.

Recommendation 5: Structure

The JSC, in consultation with the newly created Governing Board, should work with the science community to establish a new structure for the WCRP research effort that best serves its new strategy and involves a simplified set of delivery mechanisms.

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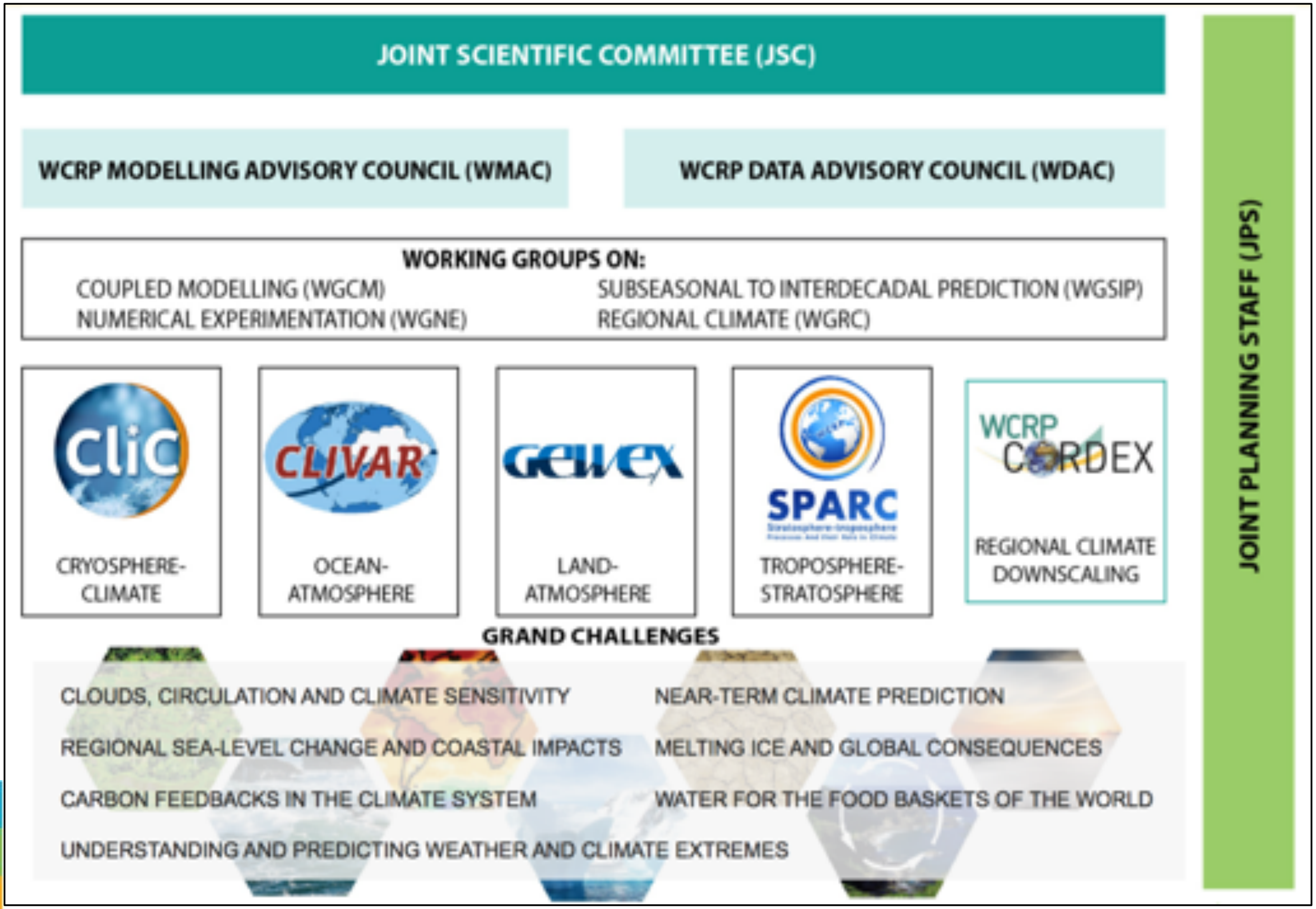


CURRENT WCRP STRUCTURE

Unwieldy, complex and confusing.

Core Projects stuck in the past?

Where is whole system approach?

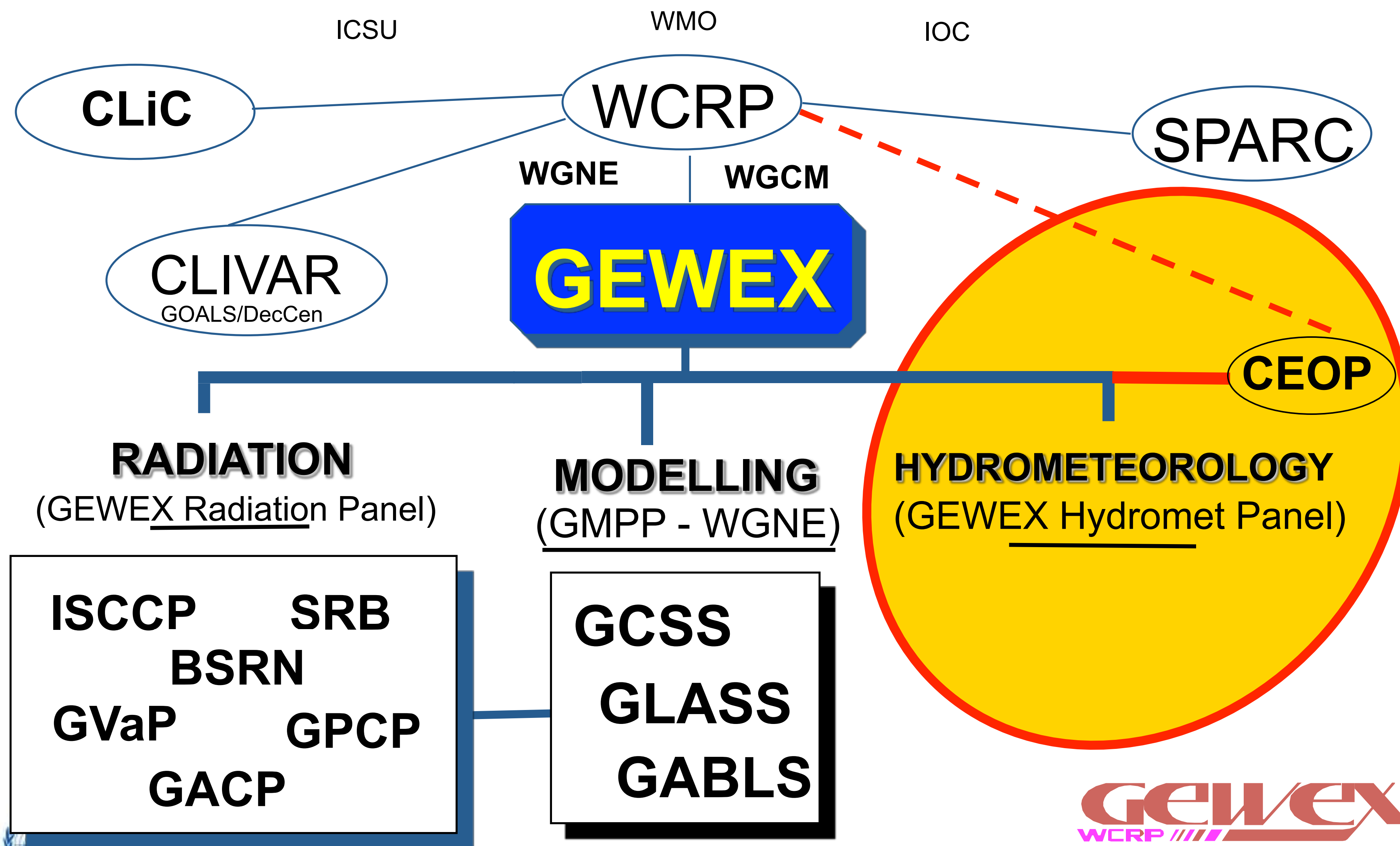
Where is next generation model development?

Where is the pathway to climate services?

Where is climate change?

CURRENT STRUCTURE IS NOT THE STRUCTURE FOR THE FUTURE

ORGANIZATION



Updated GEWEX Science Questions :

1. *Are the Earth's Energy Budget and Water Cycle Changing?*

Is the Water Cycle Accelerating?

2. *How do Processes Contribute to Feedback and Causes of Natural Variability?*

3. *Can We Predict these Changes on up to S - IA?*

4. *What are the Impacts of these Changes on Water Resources?*

WMO/IOC

GLOBAL CLIMATE OBSERVATIONS, ANALYSES & MONITORING

(CCI, GCOS…)

WCRP CAPABILITY THEMES

EARTH SYSTEM PROCESSES ACROSS SCALES
Jointly with WWRP

CLIMATE VARIABILITY, PREDICTABILITY & PREDICTION

CLIMATE CHANGE AND EARTH SYSTEM FEEDBACKS
Jointly with AIMES

WCRP CROSS-CUTTING RESEARCH PROJECTS
(on occasions with WWRP, Future Earth…..)

WCRP WORKING GROUP ON CLIMATE MODEL DEVELOPMENT
jointly with WGNE

WCRP WORKING GROUP ON CLIMATE INFORMATION FOR REGIONS
linking with Future Earth

WMO/ISC

GLOBAL ATMOSPHERIC COMPOSITION
GHG Monitoring; Air Quality Prediction; Atmospheric Chemistry Processes & Modelling

(GAW, SPARC,IGAC)

CLIMATE CHANGE ASSESSMENTS AND CLIMATE SERVICES (UNFCCCC, IPCC, GFCS, Copernicus, VIACS, ……..)

WCRP CAPABILITY THEMES

EARTH SYSTEM PROCESSES ACROSS SCALES *Jointly with WWRP*	CLIMATE VARIABILITY, PREDICTABILITY & PREDICTION *Jointly with WWRP S2S*	CLIMATE CHANGE AND EARTH SYSTEM FEEDBACKS *Jointly with ICSU AIMES*
Energy, Water & Carbon Cycles; Fundamental Atmospheric Physics (e.g. Convection); Land Surface Processes & Land-Atmosphere Coupling; Ocean Processes & Ocean-Atmosphere Coupling; Cryosphere Processes	Ocean, Land, Cryosphere, Atmosphere & Solar Drivers; Climate Dynamics, Modes of Variability & Teleconnections; Monthly to Decadal Predictability & Prediction	Climate Change Forcing & Sensitivity; Climate Change Attribution; Climate Change Projections (Global & Regional) for Mitigation & Adaptation; Abrupt Climate Change; Geoengineering Assessment

WCRP CAPABILITY THEMES

EARTH SYSTEM PROCESSES ACROSS SCALES *Jointly with WWRP*	CLIMATE VARIABILITY, PREDICTABILITY & PREDICTION	CLIMATE CHANGE AND EARTH SYSTEM FEEDBACKS *Jointly with AIMES*
Energy, Water & Carbon Cycles; Fundamental Atmospheric Physics (e.g. Convection); Land Surface Processes & Land-Atmosphere Coupling; Ocean Processes & Ocean-Atmosphere Coupling; Cryosphere Processes	Ocean, Land, Cryosphere, Atmosphere & Solar Drivers; Climate Dynamics, Modes of Variability & Teleconnections; Monthly to Decadal Predictability & Prediction	Climate Change Forcing & Sensitivity; Climate Change Attribution; Climate Change Projections (Global & Regional) for Mitigation & Adaptation; Abrupt Climate Change; Geoengineering Assessment

WCRP CROSS-CUTTING RESEARCH PROJECTS (*on occasions with **WWRP**, Future Earth…..*)

Examples: Regional Sea Level Rise, Coastal Impacts and Cities,
Weather and Climate Extremes, now and in the future
Water Cycle and the Food Baskets of the World
Fate of the Antarctic and Greenland Icesheets
Is the Jet Stream changing its Behaviour?
Climate Change and Human Health

WCRP CAPABILITY THEMES

EARTH SYSTEM PROCESSES ACROSS SCALES *Jointly with WWRP*	CLIMATE VARIABILITY, PREDICTABILITY & PREDICTION	CLIMATE CHANGE AND EARTH SYSTEM FEEDBACKS *Jointly with AIMES*
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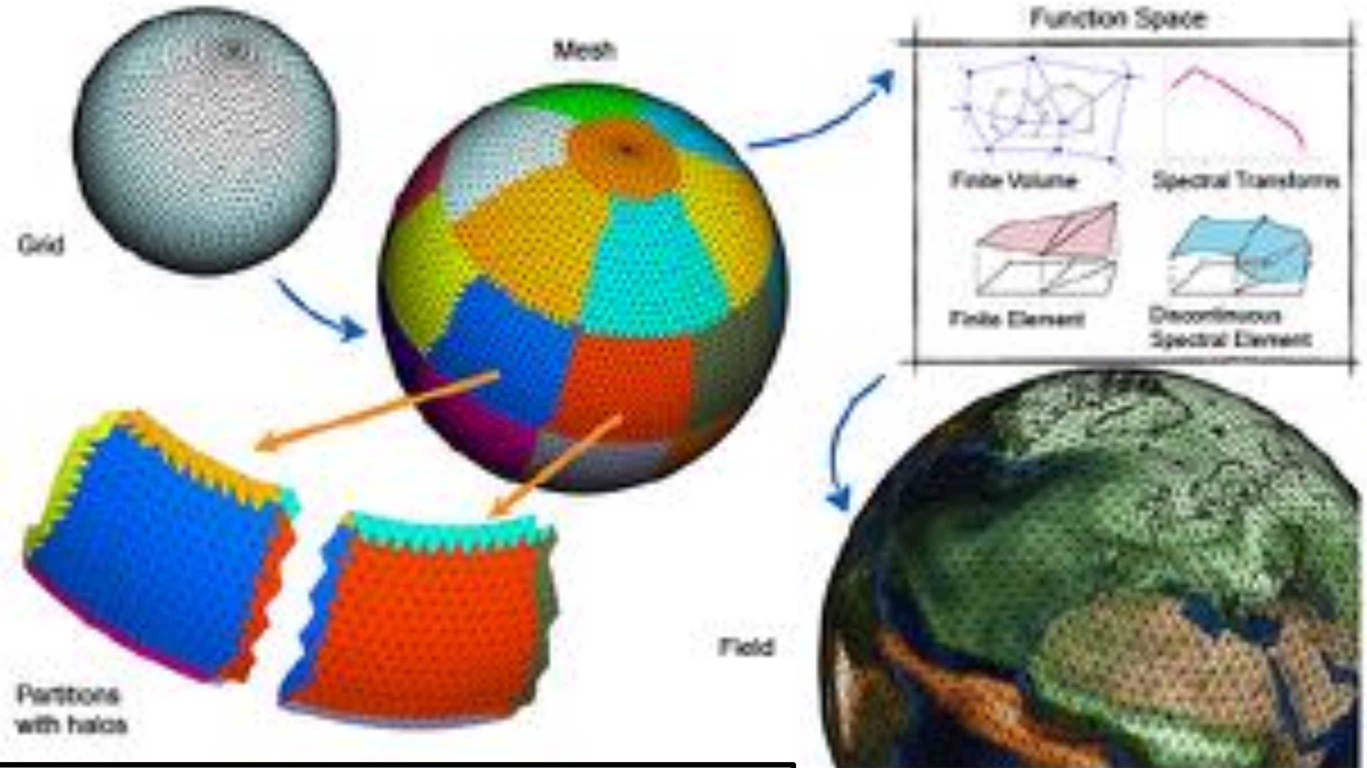
WCRP CROSS-CUTTING RESEARCH PROJECTS (*on occasions with* ***WWRP****, Future Earth…..*)

WCRP WORKING GROUP ON CLIMATE MODEL DEVELOPMENT *jointly with* ***WGNE***
Identifying Systematic Errors; Improving Climate Models & Building Next Generation Earth System Models; Planning for Exascale Computing

Is there a need now to distinguish between science for model development and using models for science?

Next Generation Codes and Exascale Computing



WCRP WORKING GROUP ON CLIMATE MODEL DEVELOPMENT *jointly with WGNE*
Identifying Systematic Errors; Improving Climate Models & Building Next Generation Earth System Models; Planning for Exascale Computing

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WCRP CAPABILITY THEMES

EARTH SYSTEM PROCESSES ACROSS SCALES
Jointly with WWRP

Energy, Water & Carbon Cycles;
Fundamental Atmospheric Physics (e.g. Convection);
Land Surface Processes & Land-Atmosphere Coupling;
Ocean Processes & Ocean-Atmosphere Coupling;
Cryosphere Processes

CLIMATE VARIABILITY, PREDICTABILITY & PREDICTION

Ocean, Land, Cryosphere, Atmosphere & Solar Drivers;
Climate Dynamics, Modes of Variability & Teleconnections; Monthly to Decadal Predictability & Prediction

CLIMATE CHANGE AND EARTH SYSTEM FEEDBACKS
Jointly with AIMES

Climate Change Forcing & Sensitivity;
Climate Change Attribution;
Climate Change Projections (Global & Regional) for Mitigation & Adaptation;
Abrupt Climate Change;
Geoengineering Assessment

WCRP CROSS-CUTTING RESEARCH PROJECTS

WCRP WORKING GROUP ON CLIATE MODEL DEVELOPMENT *jointly with WGNE*

WCRP WORKING GROUP ON CLIMATE INFORMATION FOR REGIONS

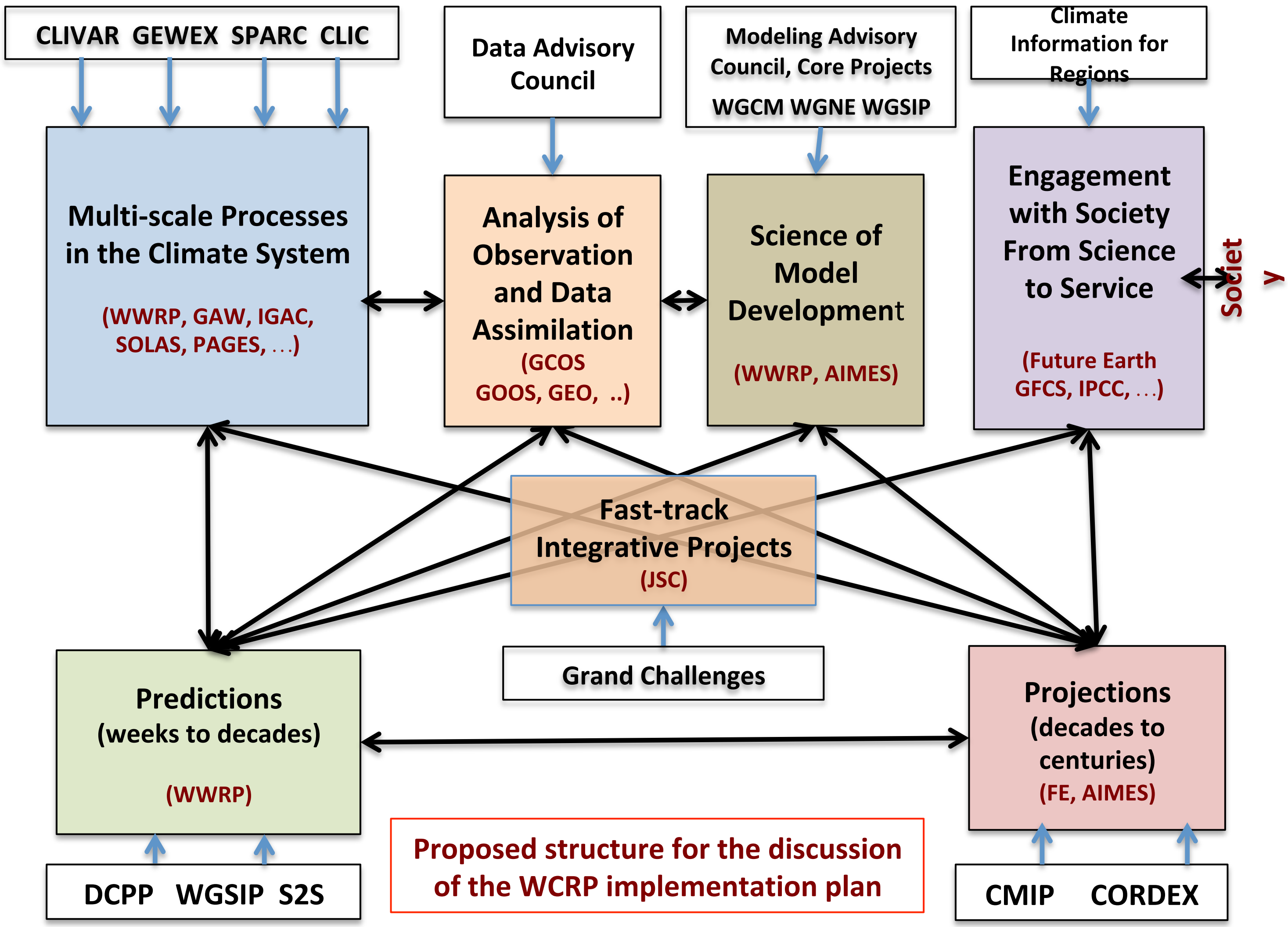
linking with Future Earth

Regional downscaling methods; Application-inspired Climate Science; Transdisciplinary Engagement

Recommendation 8: Partnership

WCRP should seek to develop strategic and strong partnerships with other WMO research programmes (specifically WWRP and GAW), with GCOS, and with Future Earth.

- WCRP urgently explores the option of the co-design and co-production of projects that address key scientific challenges of common interest to WCRP, WWRP, GAW and Future Earth.


CLIVAR GEWEX SPARC CLIC
Data Advisory Council
Modeling Advisory Council, Core Projects
WGCM WGNE WGSIP
Climate Information for Regions
Multi-scale Processes in the Climate System
(WWRP, GAW, IGAC, SOLAS, PAGES, …)
Analysis of Observation and Data Assimilation
(GCOS GOOS, GEO, ..)
Science of Model Development
(WWRP, AIMES)
Engagement with Society From Science to Service
(Future Earth GFCS, IPCC, …)
Society
Fast-track Integrative Projects
(JSC)
Grand Challenges
Predictions
(weeks to decades)
(WWRP)
Projections
(decades to centuries)
(FE, AIMES)
DCPP WGSIP S2S
CMIP CORDEX
Proposed structure for the discussion of the WCRP implementation plan

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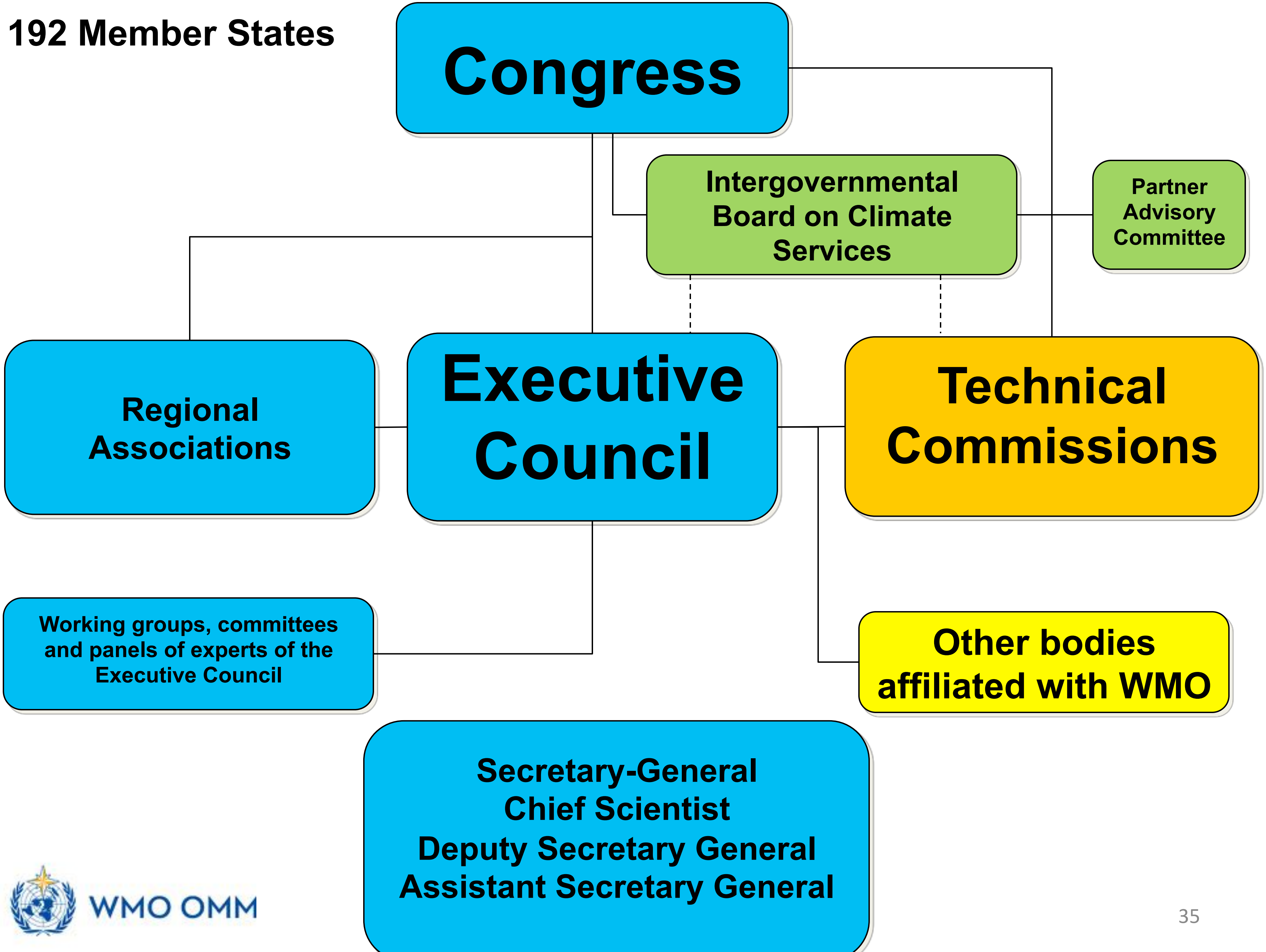
WMO New Strategy

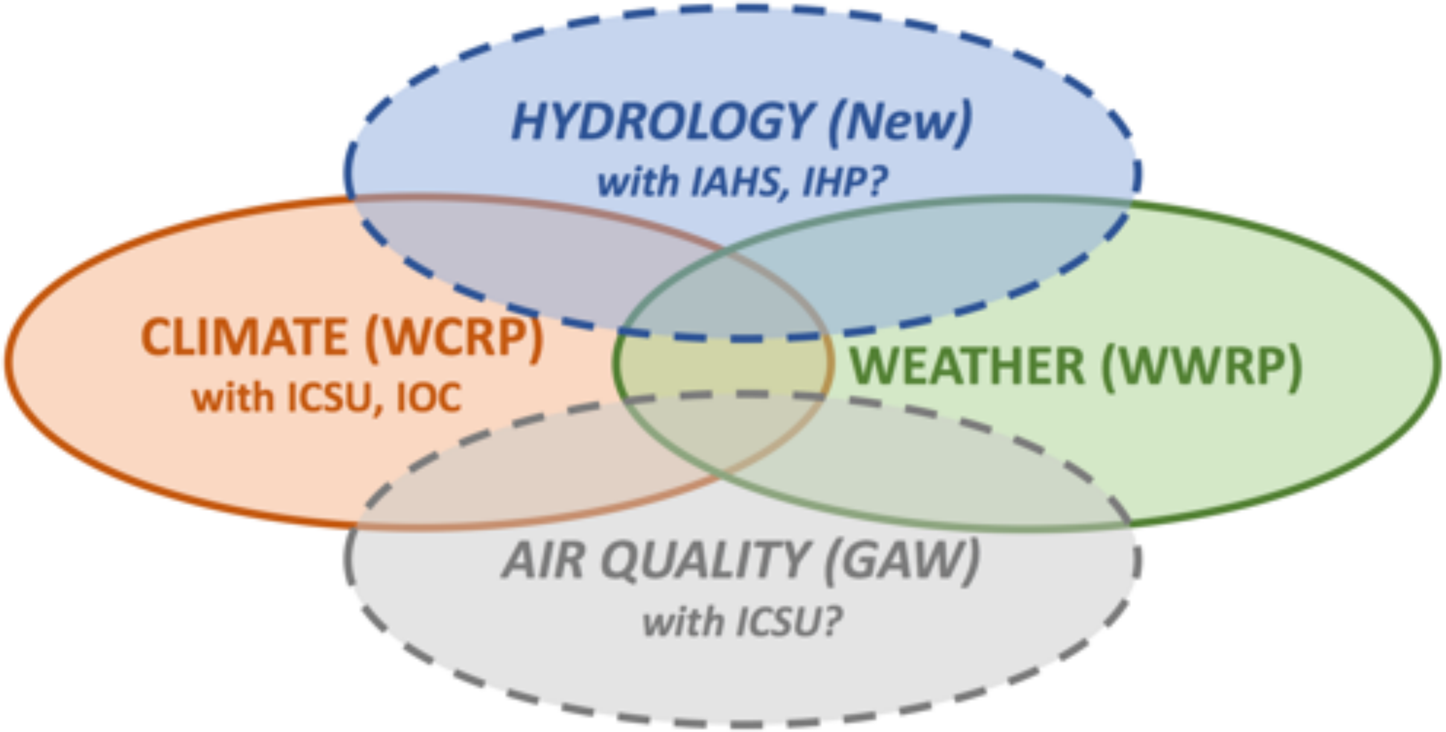
- Effectiveness and efficiency

- **Seamless integrated approach (spatial, temporal):**
  - **Earth System approach**
  - **WMO acting as one**

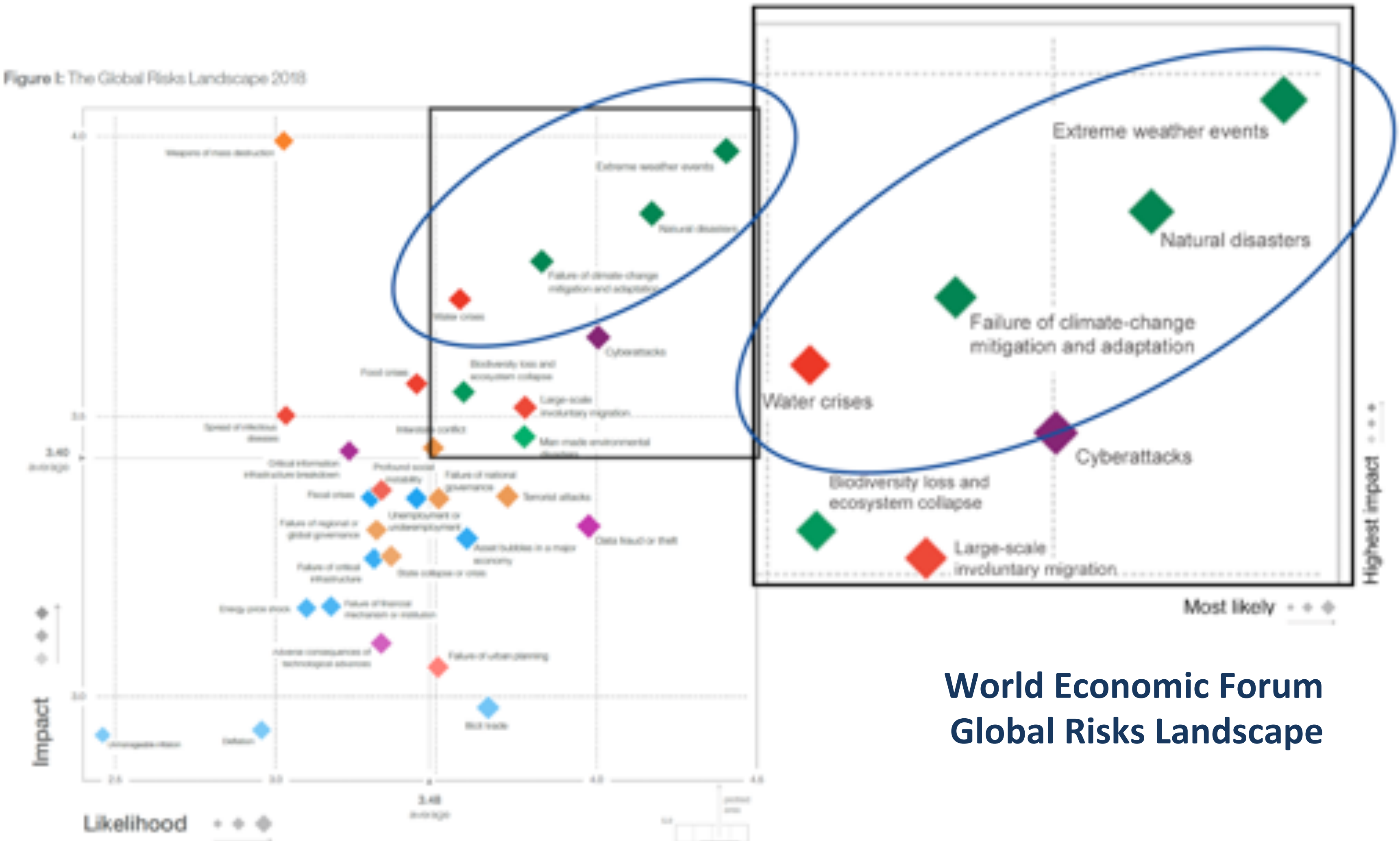
- Wider engagement of Members & national experts
- Agility to uptake new challenges and tasks
- Improved collaboration with partners


192 Member States
Congress
Intergovernmental Board on Climate Services
Partner Advisory Committee
Regional Associations
Executive Council
Technical Commissions
Working groups, committees and panels of experts of the Executive Council
Other bodies affiliated with WMO
Secretary-General
Chief Scientist
Deputy Secretary General
Assistant Secretary General

WMO SCIENCE ADVISORY PANEL
WMO RESEARCH BOARD



Perspective for the coming decade



World Economic Forum
Global Risks Landscape

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WMO Strategic Operating Plan

Vision 2030

By 2030, a world where all nations, especially the most vulnerable, are more resilient to the socioeconomic impact of extreme weather, climate, water and other environmental events, and empowered to boost their sustainable development through the best possible services, whether over land, at sea or in the air

Overarching Priorities

- Enhancing preparedness for, and reducing losses of life and property from hydrometeorological extremes
- Supporting climate-smart decision making to build resilience and adaptation to climate risk
- Enhancing socioeconomic value of weather, climate, hydrological and related environmental services

Core Values

• Accountability for Results and Transparency • Collaboration and Partnership • Inclusiveness and Diversity •

Long-Term Goals

1. **Better serve societal needs:** Delivering authoritative, accessible, user-oriented and fit-for-purpose information and services
2. **Enhance Earth system observations and predictions:** Strengthening the technical foundation for the future
3. **Advance targeted research:** Leveraging leadership in science to improve understanding of the Earth system for enhanced services
4. **Close the capacity gap:** Enhancing service delivery capacity of developing countries to ensure availability of essential information and services
5. **Strategic realignment of WMO structure and programmes:** Effective policy- and decision-making and implementation

Strategic Objectives 2020-2023 focus

1.1 **Strengthen national multi-hazard early warning/alert systems** and extend reach to better enable effective response to the associated risks

1.2 Broaden the provision of **policy- and decision-supporting climate information and services**

1.3 Further develop **services** in support of **sustainable water management**

1.4 Enhance the value and innovate the provision of **decision-supporting weather information and services**

2.1 Optimize the **acquisition of observation data** through the WMO Integrated Global Observing System

2.2 Improve and increase **access to, exchange and management of current and past Earth system observation data and derived products** through the WMO Information System

2.3 Enable **access and use of numerical analysis and prediction products** at all temporal and spatial scales from the WMO seamless Global Data Processing and Forecast System

3.1 **Advance scientific knowledge of the Earth system**

3.2 Enhance the **science-for-service value chain** ensuring scientific and technological advances **improve predictive capabilities**

3.3 **Advance policy-relevant science**

4.1 **Address the needs of developing countries** to enable them to provide and utilize essential weather, climate, hydrological and related environmental services

4.2 **Develop and sustain core competencies and expertise**

4.3 **Scale-up effective partnerships for investment** in sustainable and cost-efficient infrastructure and service delivery

5.1 **Optimize WMO constituent body structure** for more effective decision-making

5.2 **Streamline WMO programmes**

5.3 **Advance equal, effective and inclusive participation** in governance, scientific cooperation and decision-making

Objectives of CB Reform

Effectiveness and efficiency
Seamless integrated approach (spatial, temporal):

- Earth System approach
- WMO acting as one

Engagement of Members' experts
Agility to uptake new challenges and tasks
Improved collaboration with partners

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Alignment of WMO Structure

Strategic Plan

Long-Term Goal 1: Services

Long-Term Goal 2: Systems

Long-Term Goal 3: Science

Long-Term Goal 4: Capacity

Global lead/regional expertise

Commission for Services and Applications

Commission for Observation, Infrastructure and Information Systems

Research Board

Technical Coordination Committee

Regional Associations

Policy, coordination, integration, foresight

Policy Advisory Committee

Joint WMO-IOC Committee for Oceanography and Meteorology

Scientific Advisory Panel

Long-Term Goal 5: Governance

E-70C Recommendations to Congress

Established by EC-70

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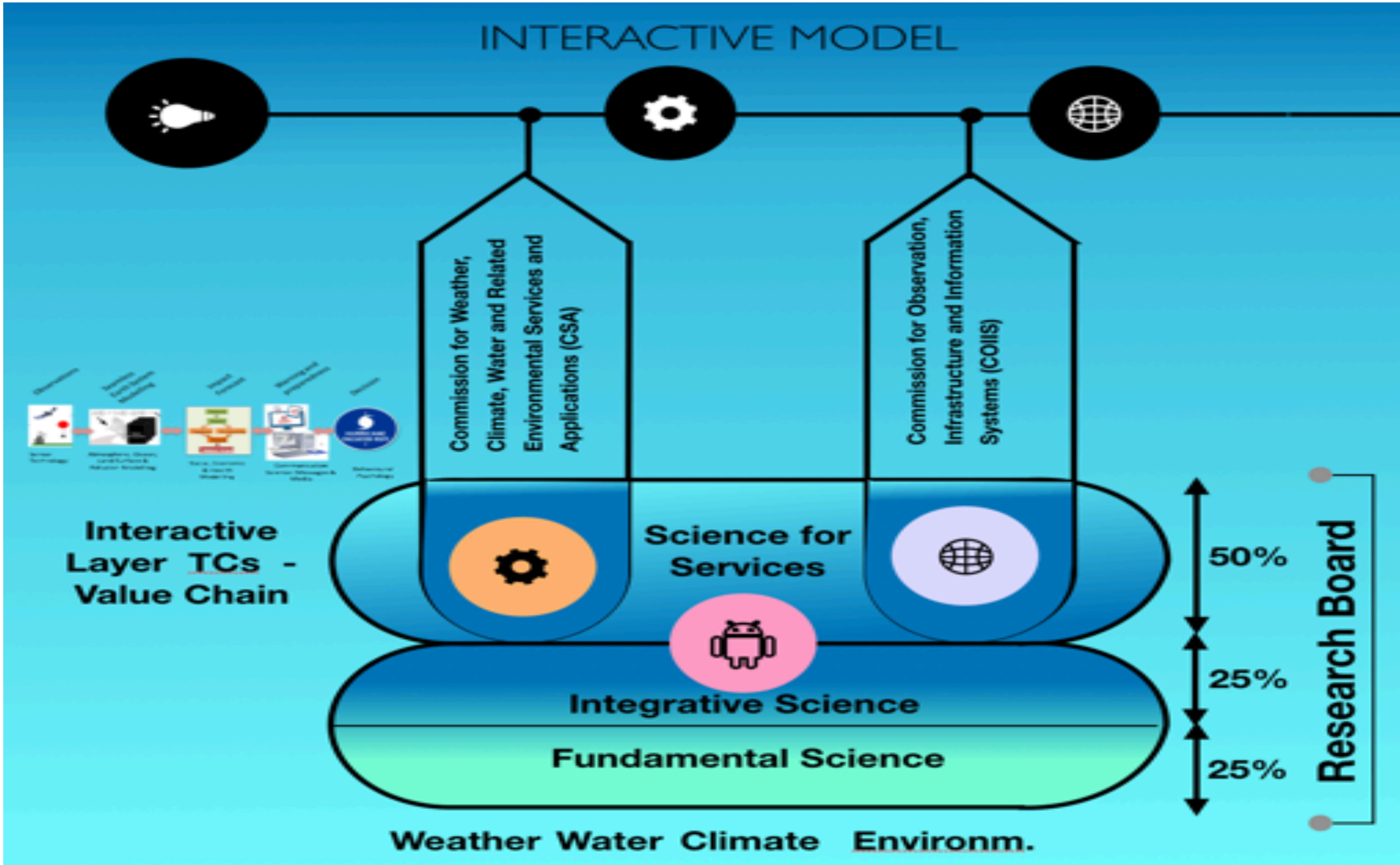
Interactive Model for Supporting Seamless Science and Science for Service & Innovation



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Thank you
Merci