# Earth's System Approach to Climate, Weather and Environment

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

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

WMO OMM

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**

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# A little preamble....

# Where do we stand today ?

***Last week @ WMO…***



***Yesterday @ WMO…***

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

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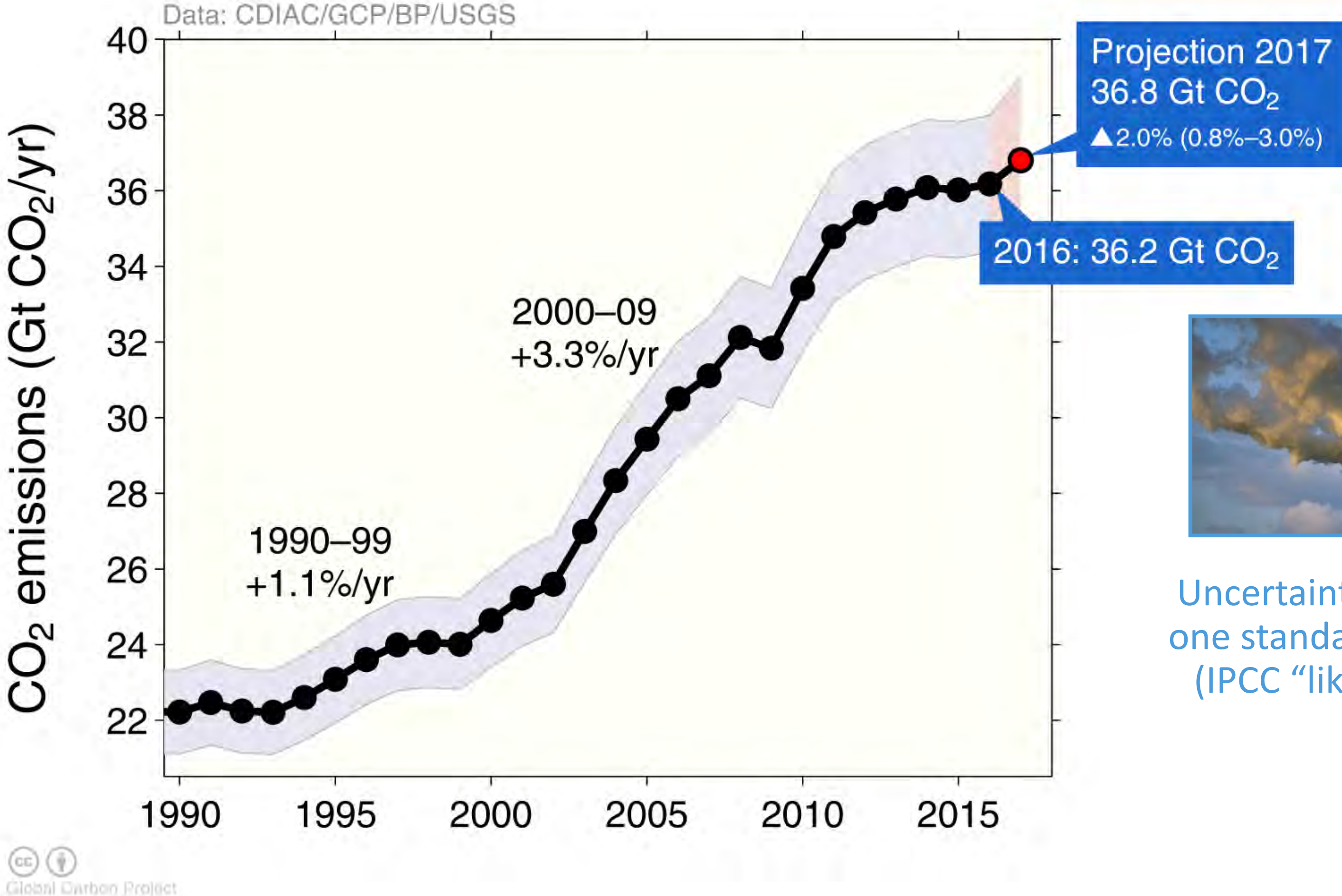
# Emissions from fossil fuel use and industry

Global emissions from fossil fuel and industry: 36.2 ± 2 Gt$CO_2$ in 2016, 62% over 1990

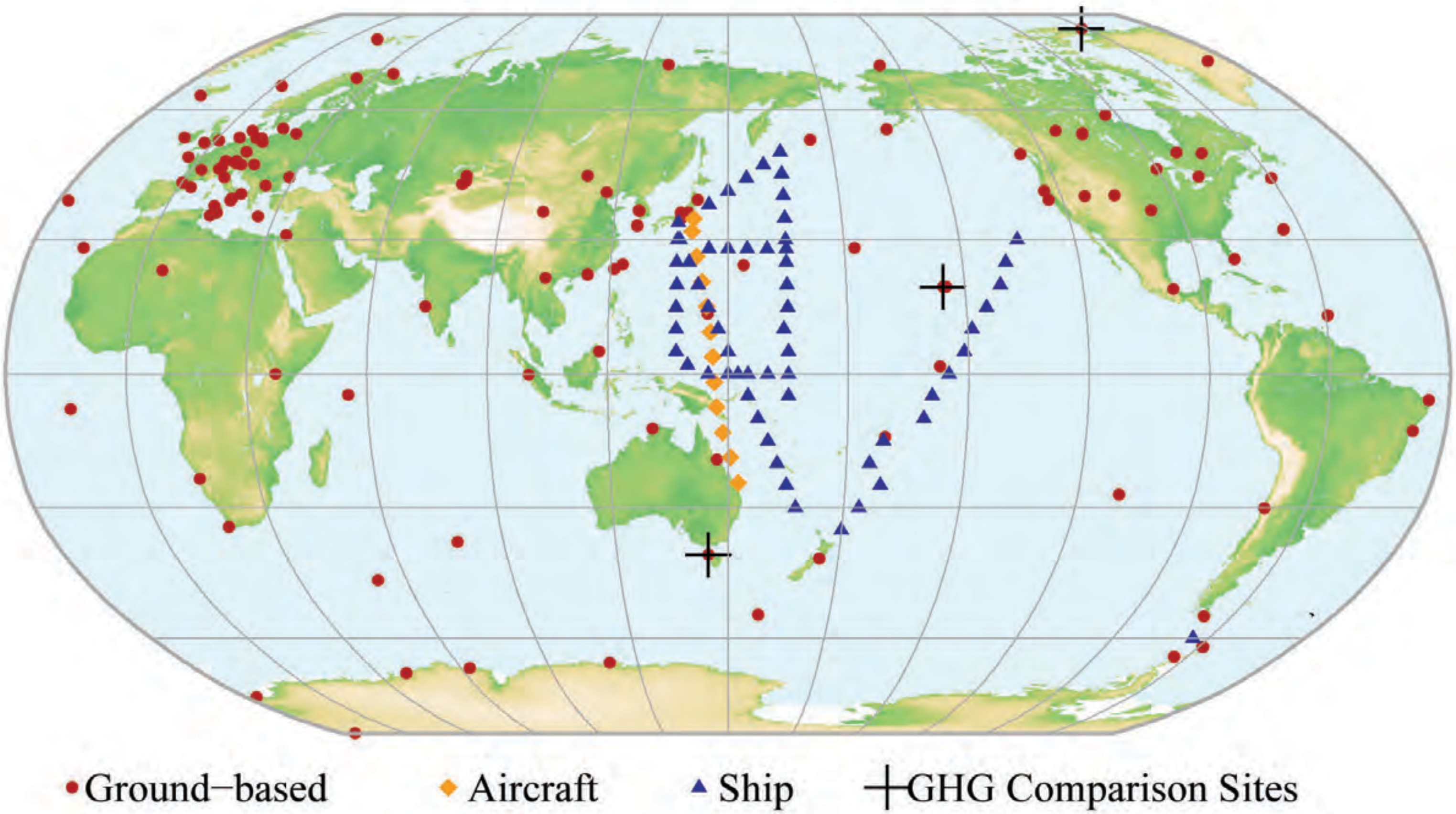
- Projection for 2017: 36.8 ± 2 Gt$CO_2$, 2.0% higher than 2016




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

# Greenhouse gas observations WMO Global Atmosphere Watch (GAW)

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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 $N_2O$.

# Carbon dioxide level highest in 3 million years...

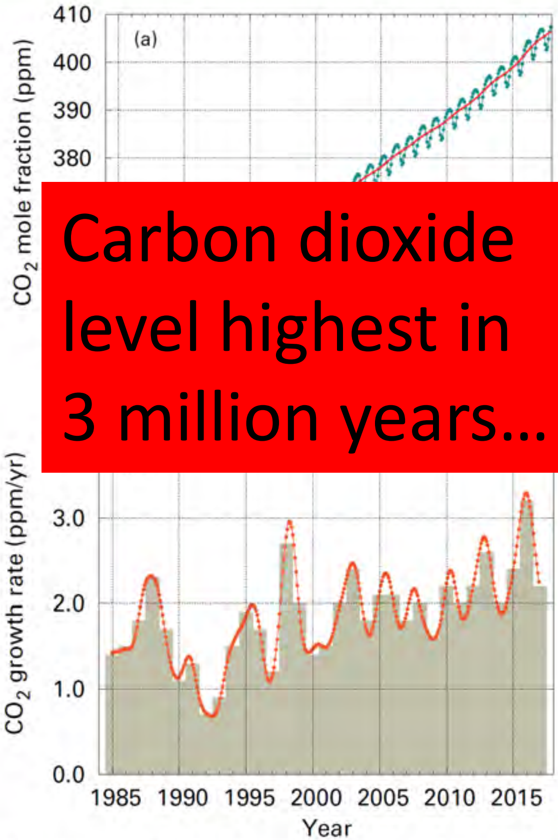


Figure 4. Globally averaged $CO_2$ mole fraction (a) and its growth rate (b) from 1984 to 2017. Increases in successive annual means are shown as the shaded columns in (b). The red line in (a) is the monthly mean with the seasonal variation removed; the blue dots and line depict the monthly averages.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

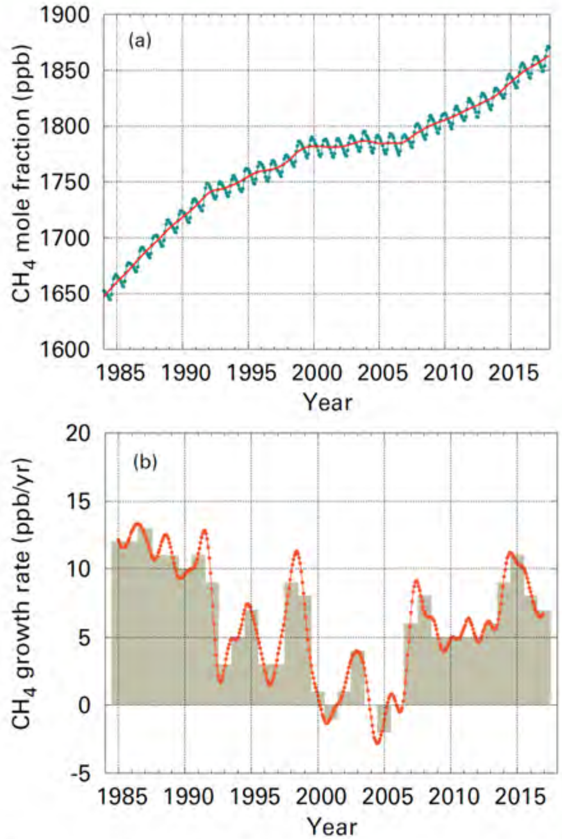


Figure 5. Globally averaged $CH_4$ mole fraction (a) and its growth rate (b) from 1984 to 2017. Increases in successive annual means are shown as the shaded columns in (b). The red line in (a) is the monthly mean with the seasonal variation removed; the blue dots and line depict the monthly averages.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

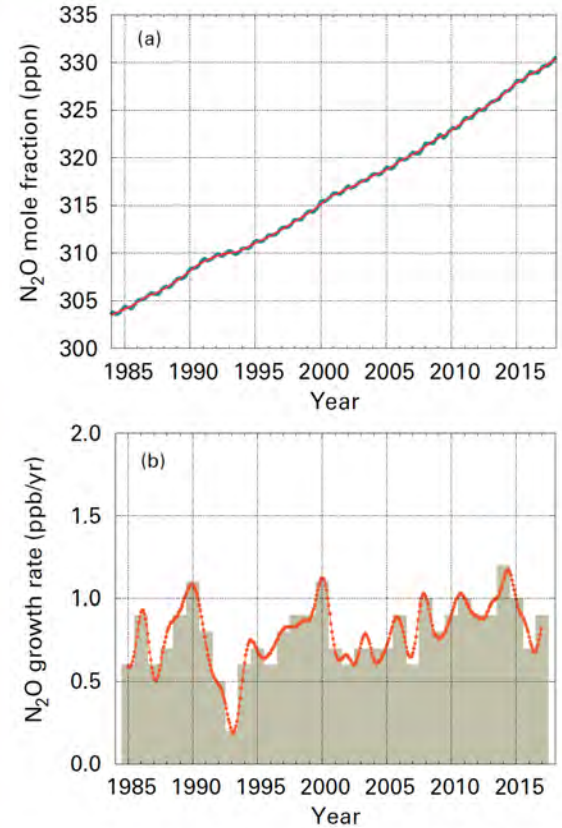


Figure 6. Globally averaged $N_2O$ mole fraction (a) and its growth rate (b) from 1984 to 2017. Increases in successive annual means are shown as the shaded columns in (b). The red line in (a) is the monthly mean with the seasonal variation removed; in this plot it is overlapping with the blue dots and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

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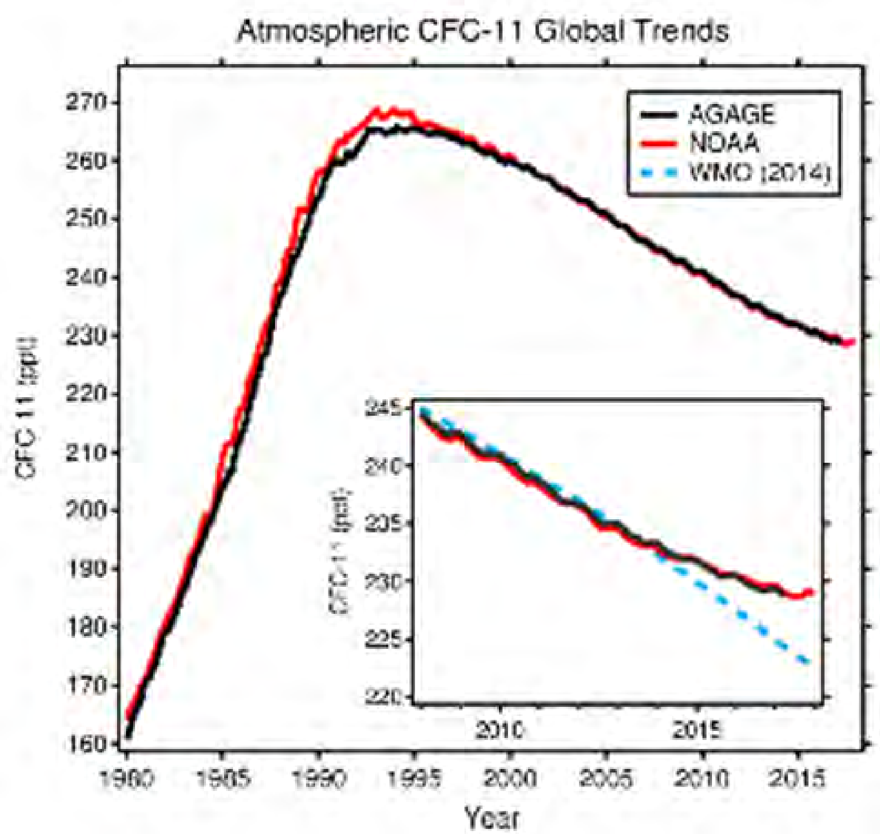
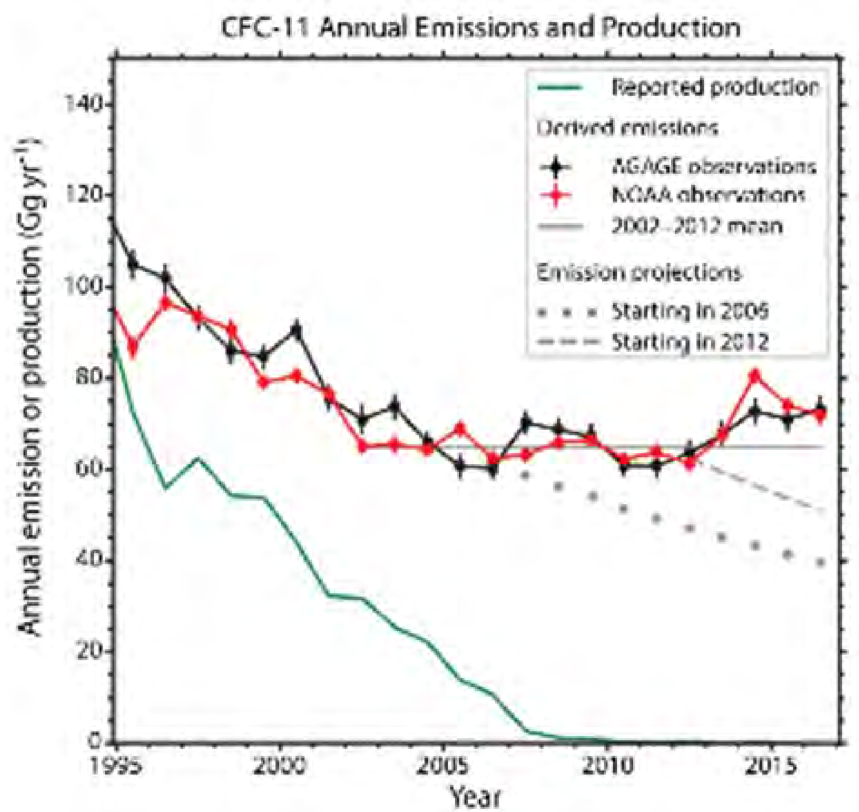
# Atmospheric “discoveries”




**New emissions of CFC-11 from East Asia**

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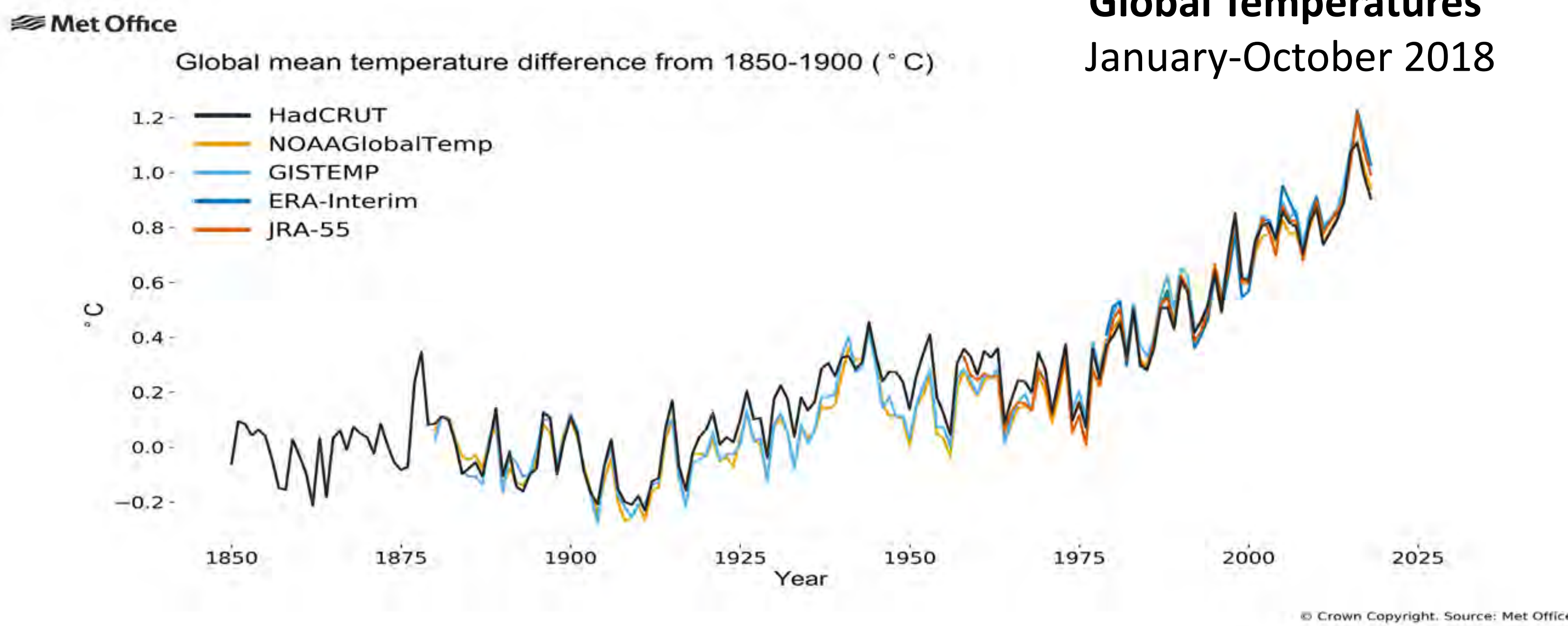
# WMO State of Climate 2018

## (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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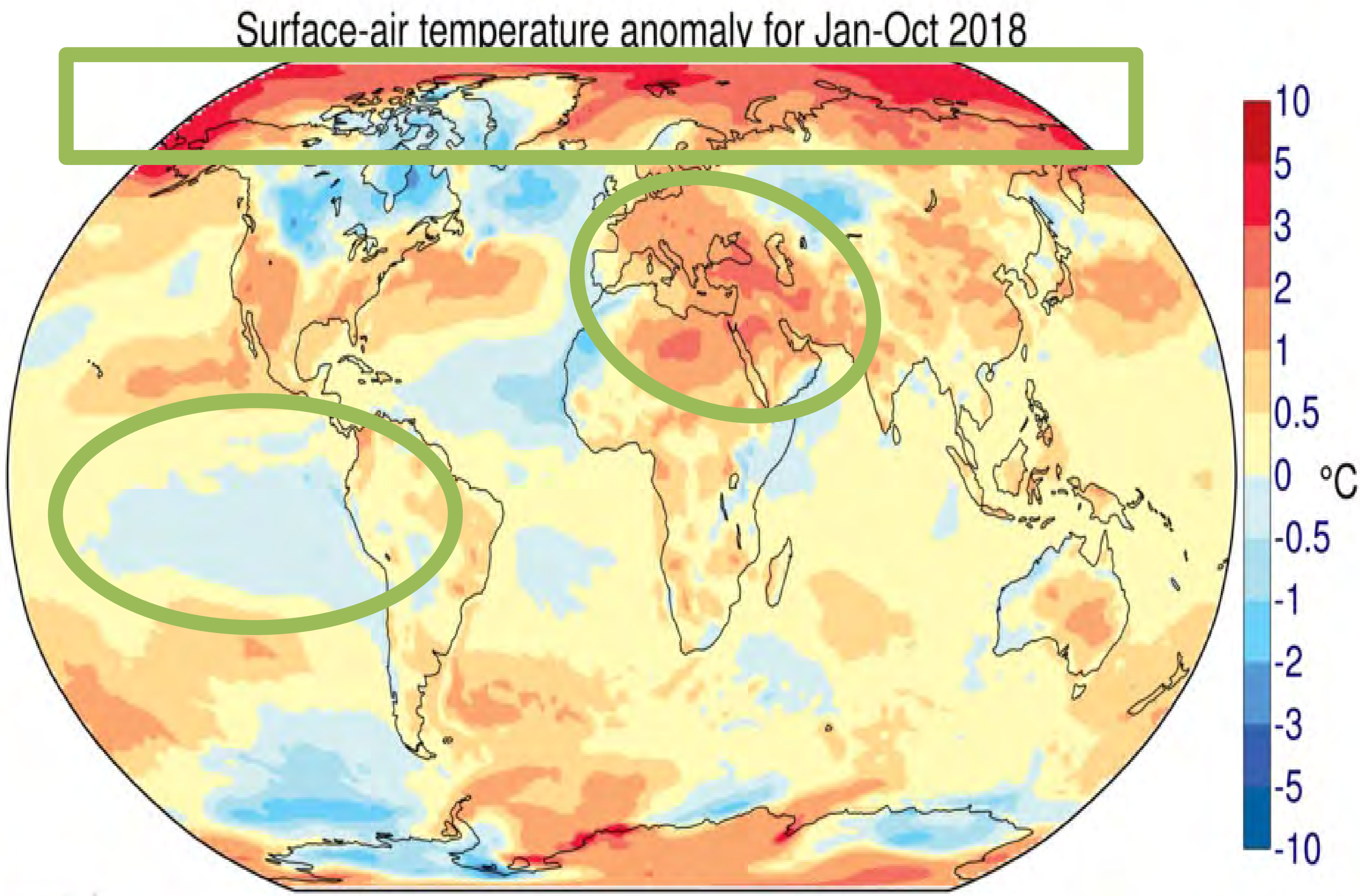
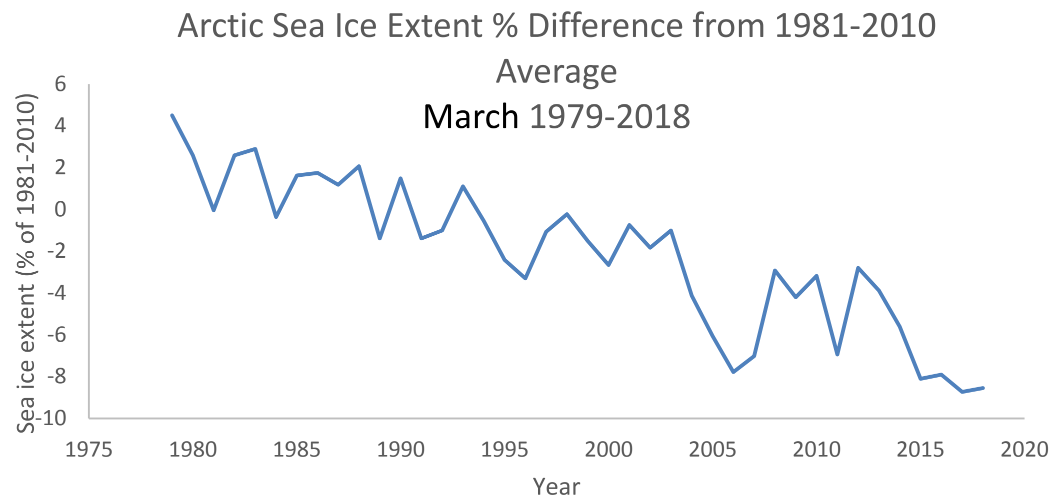
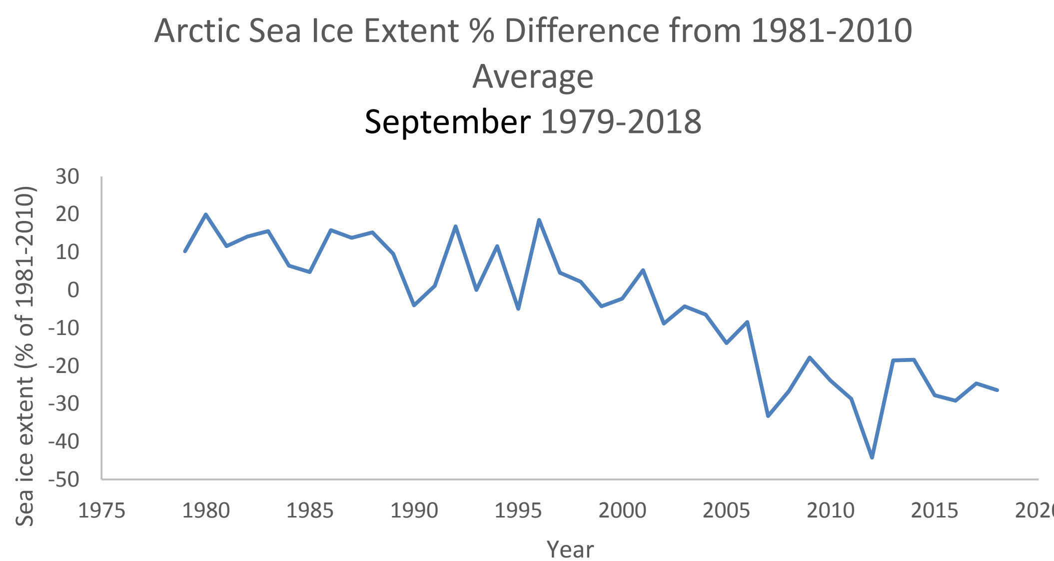

Surface-air temperature anomaly for Jan-Oct 2018
10
5
3
2
1
0.5
0 °C
-0.5
-1
-2
-3
-5
-10
opernicus
Climate Change Service
ECMWF

# 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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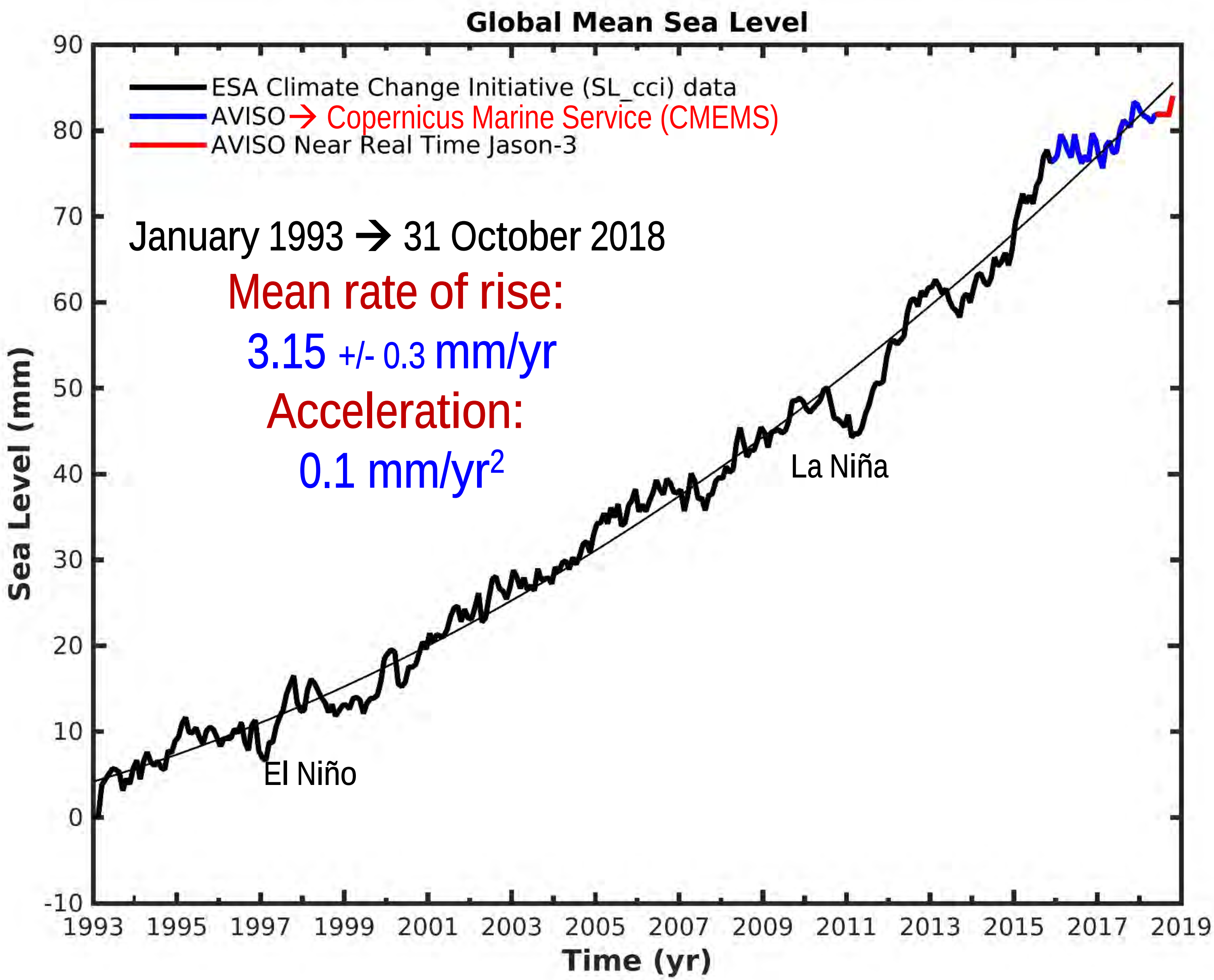
# Global Mean Sea Level (Altimetry Era)



# 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)

# 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.

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# Climate and Weather Research Historical background

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

WMO the specialized agency of the United Nations for meteorology

World Weather Watch

GARP (Global Atmospheric Research Programme) established by WMO (World Meteorological Organization)

Conduct of GARP Regional Experiments:
GATE:GARPAtlanticTropicalExperiment
MONEX:MonsoonExperiment
ALPEX:AlpineExperiment
AMEX:AirMassTransformationExperiment

WCRP, World Climate Research Programme (WMO, ICSU)

WGNE, Working Group on Numerical Experimentation

WWRP (World Weather Research Programme). MAP & Sidney2000

THORPEX (Observing System and Predictability Experiment)

Sub-Seasonal to Seas
Polar Prediction Projects

High Impact Weather Project

1st World Weather Research Open Science Conference, Canada

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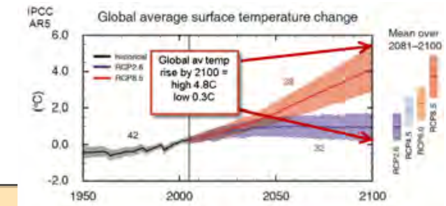
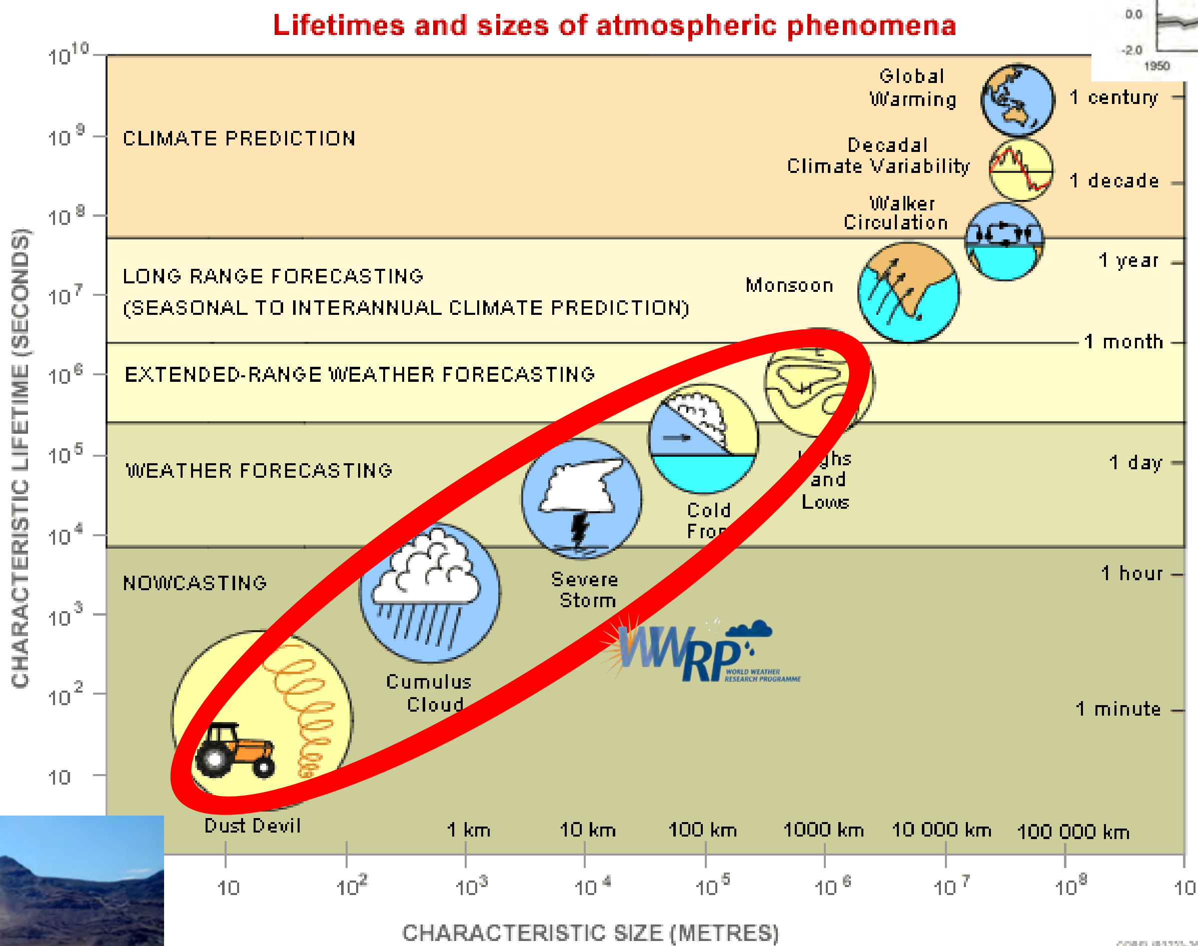
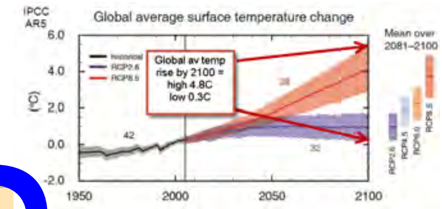
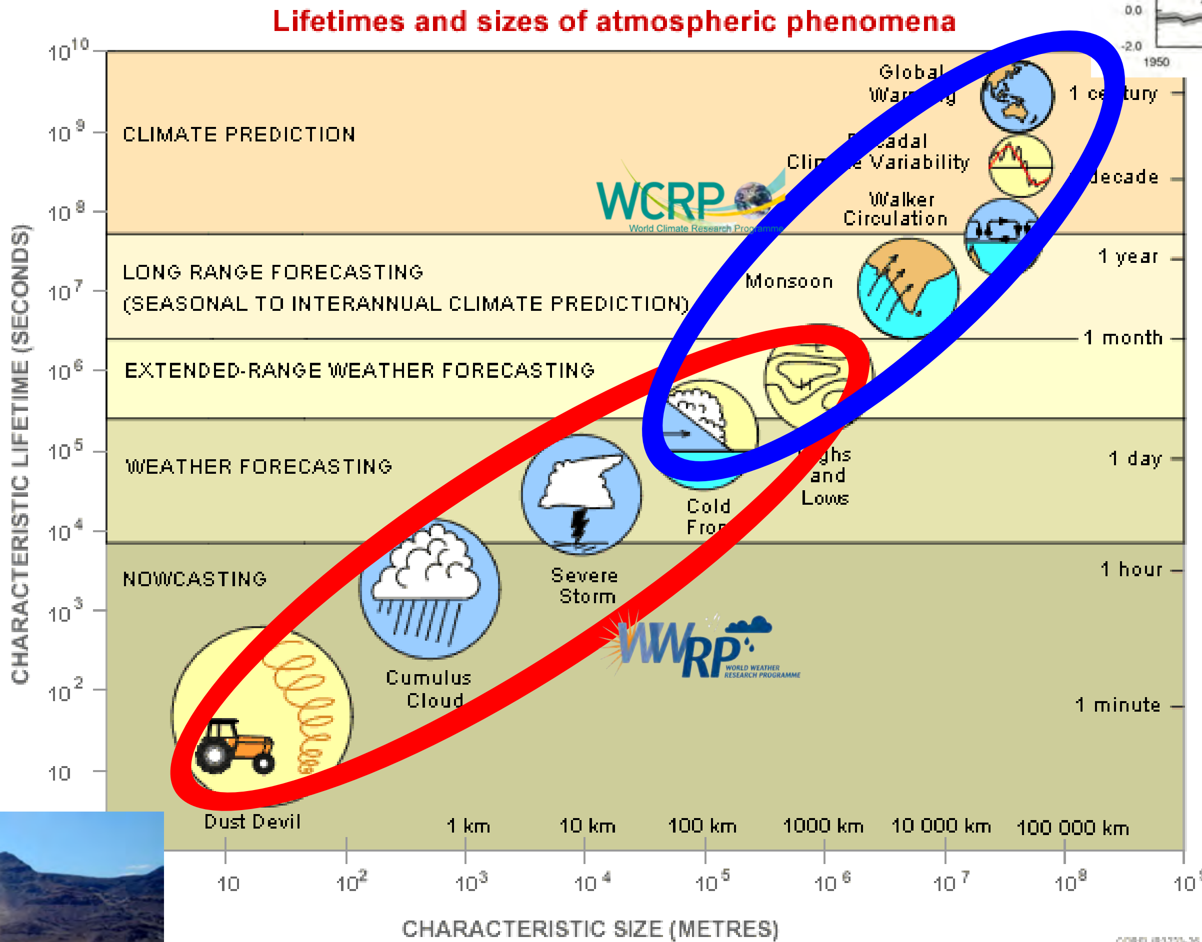
# Weather and Climate Research



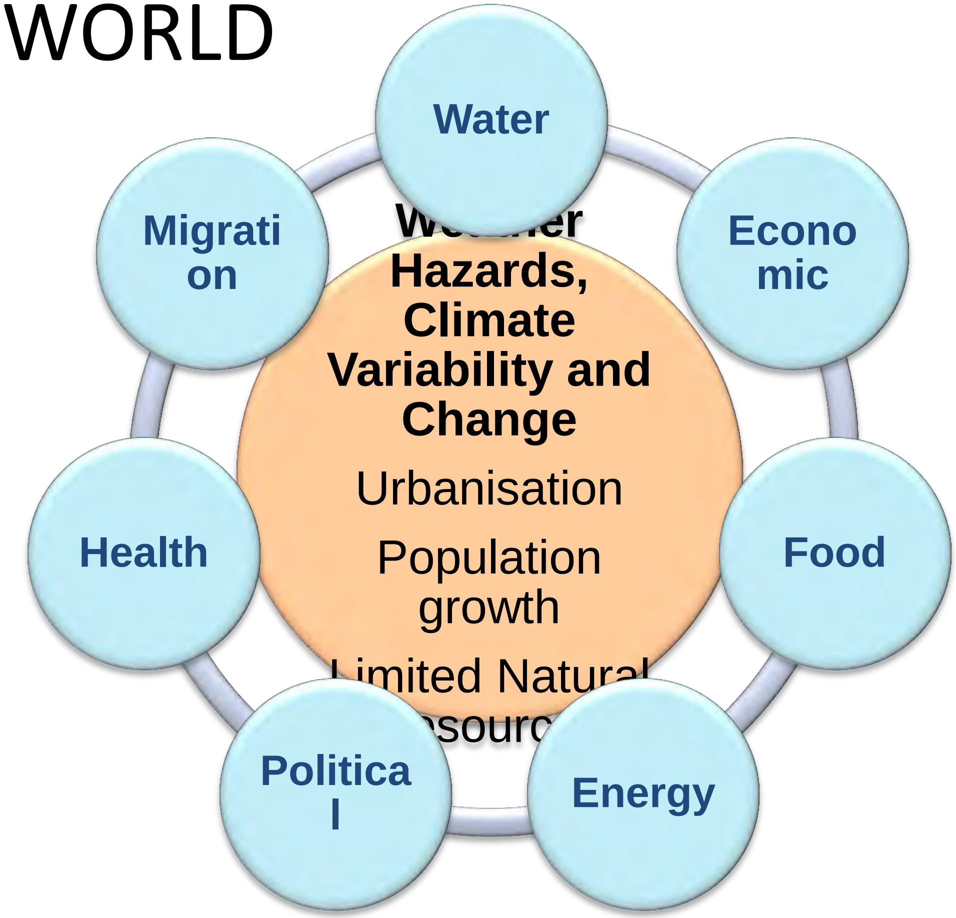

# Weather and Climate Research




# 21st CENTURY CHALLENGES IN AN INTERCONNECTED WORLD

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.

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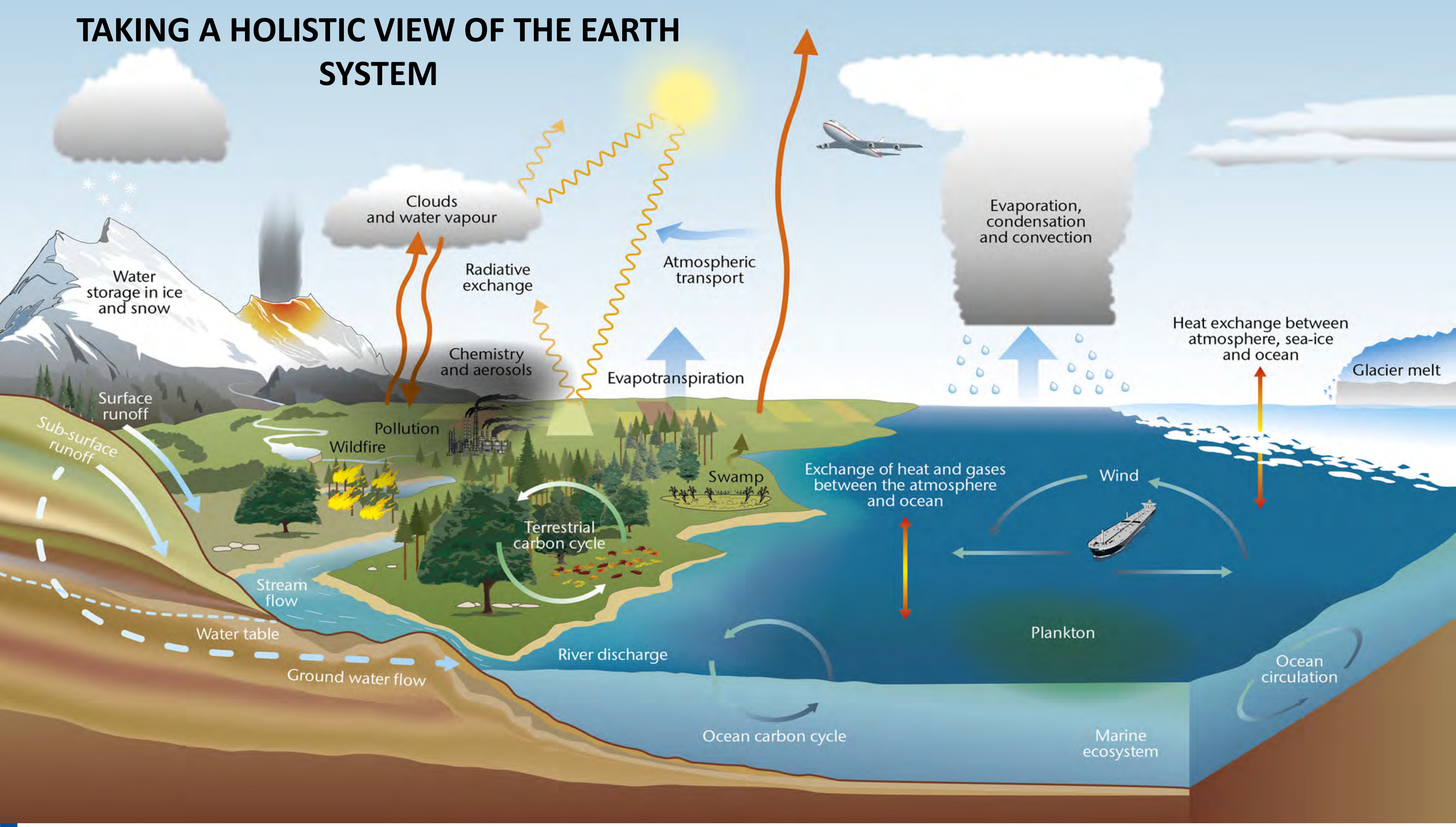
# TAKING A HOLISTIC VIEW OF THE EARTH SYSTEM

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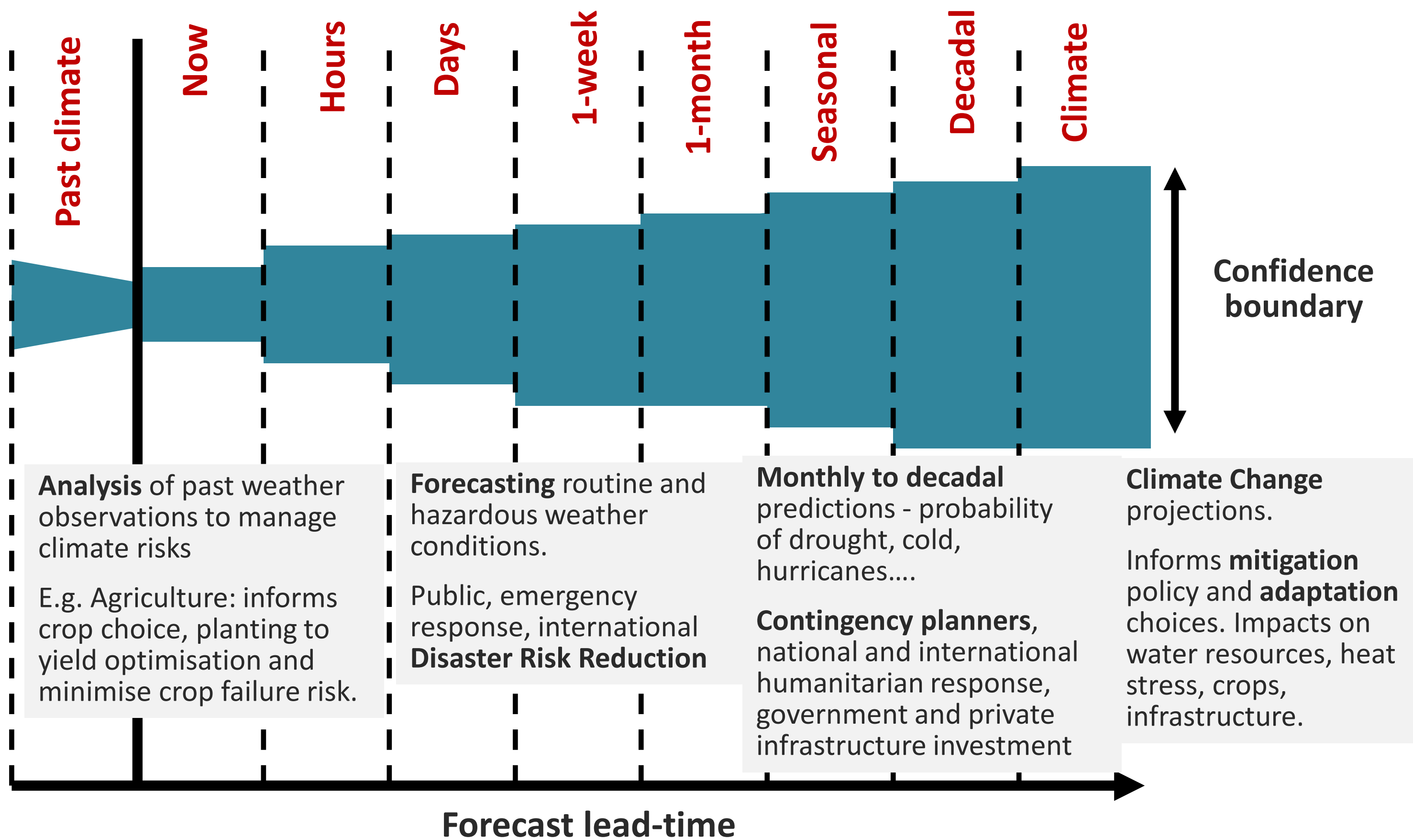
# New Tools in the Toolbox:

## Seamless Prediction Across Timescales

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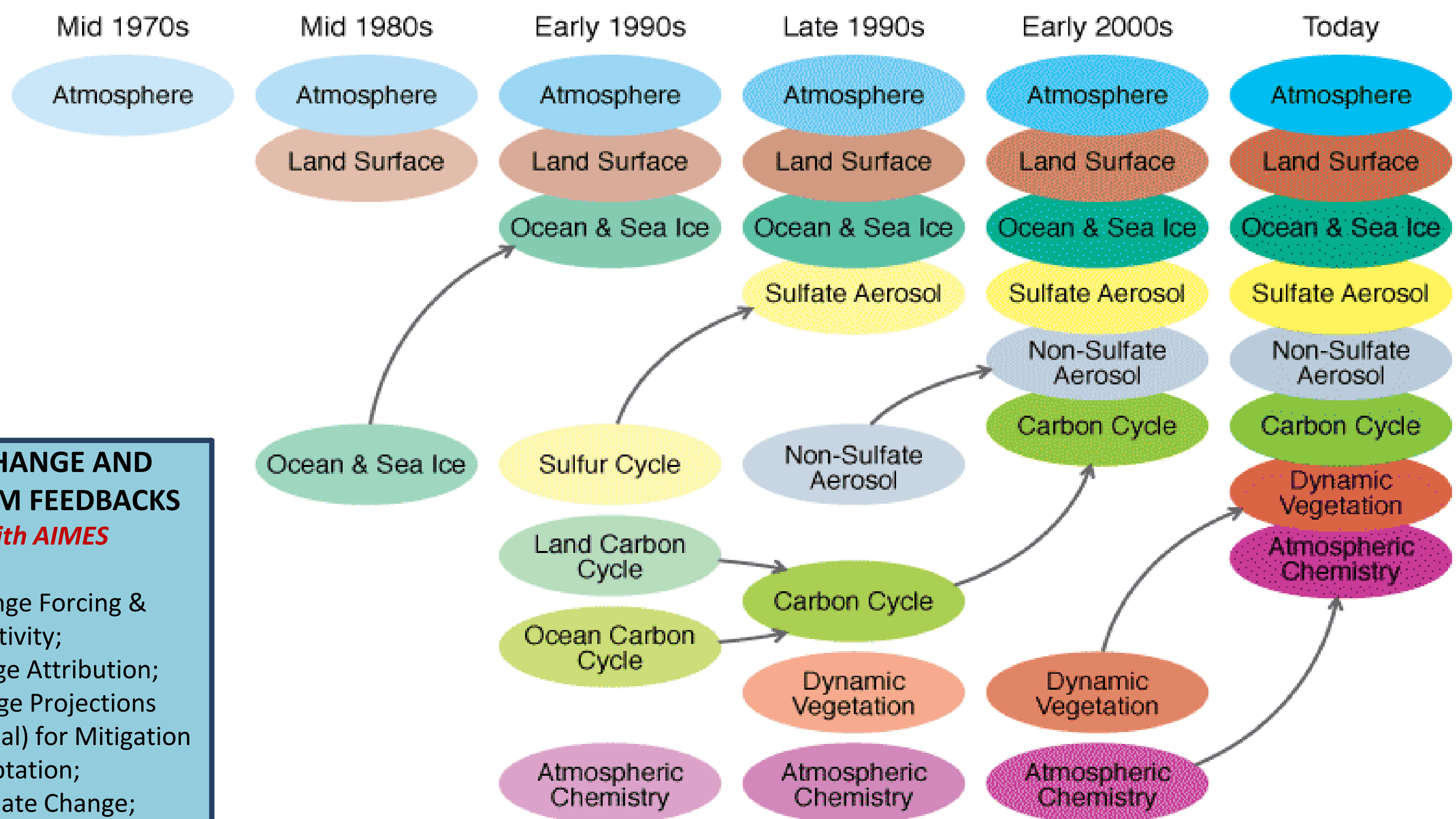
# There is no logical scientific argument for separating the physical climate system from full Earth system science

Evolution of Climate Models to Earth System Models




**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

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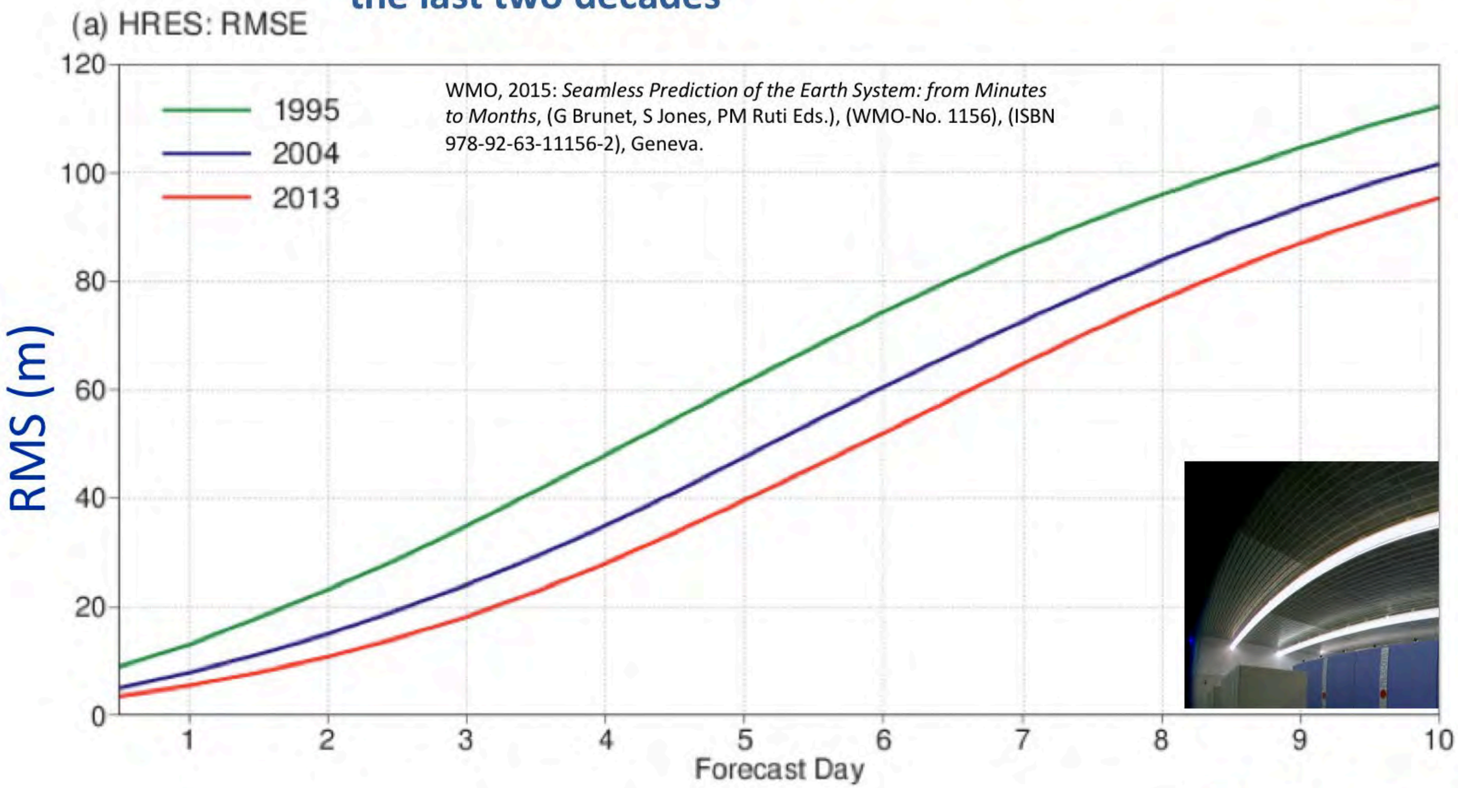
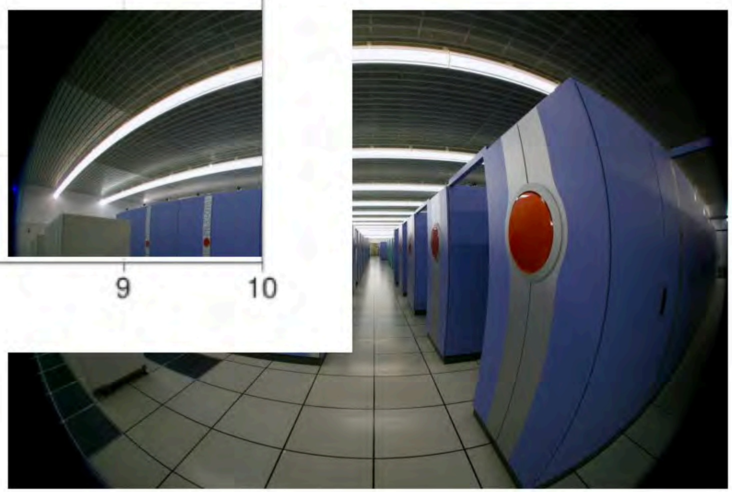
# Improving the skill – big resources

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




WMO, 2015: *Seamless Prediction of the Earth System: from Minutes to Months*, (G Brunet, S Jones, PM Ruti Eds.), (WMO-No. 1156), (ISBN 978-92-63-11156-2), Geneva.

ECMWF



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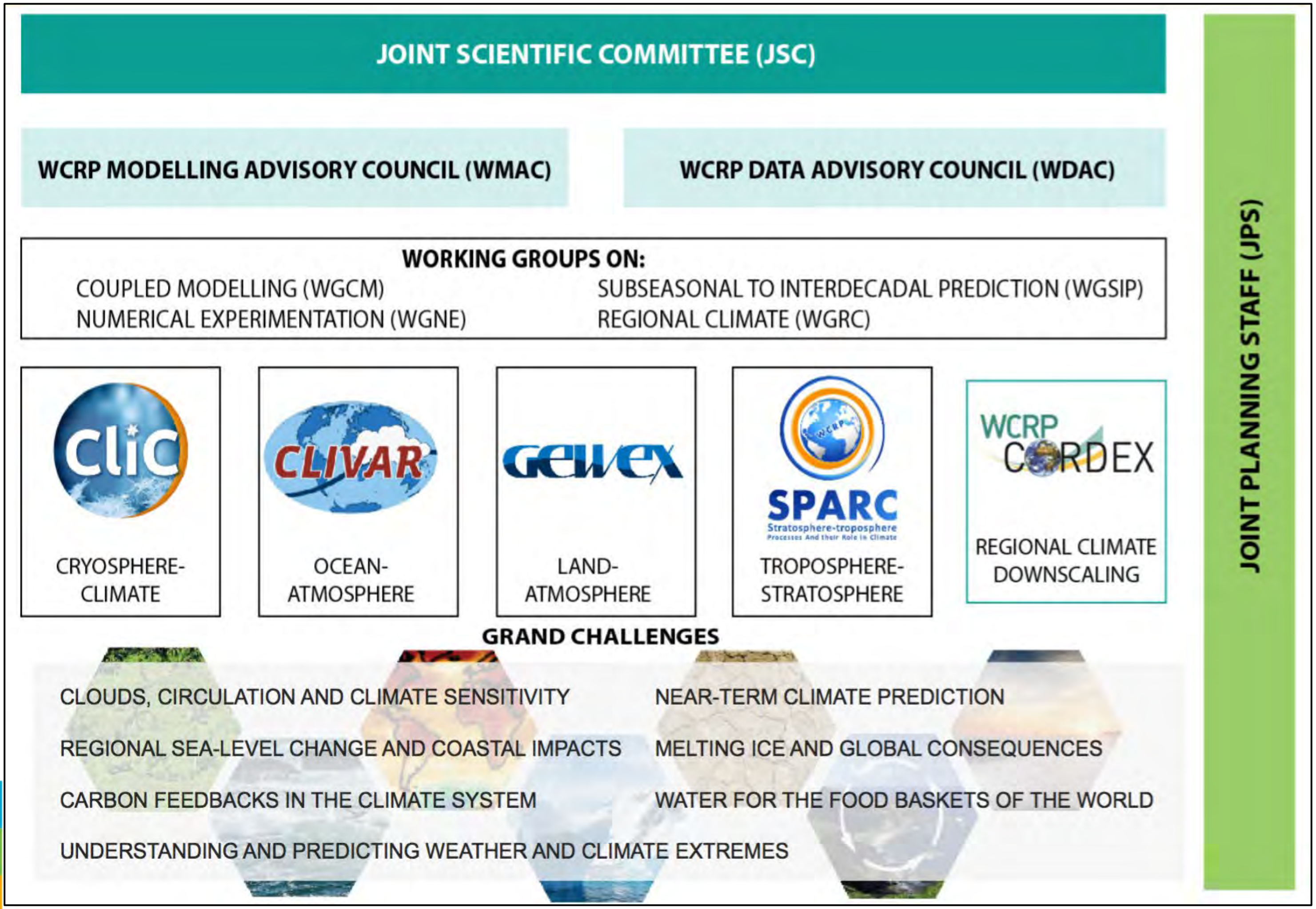
# Overarching Conclusions of the Review Panel

- 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.




# 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**

# 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.***

**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/ICSU**

**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, ……..)

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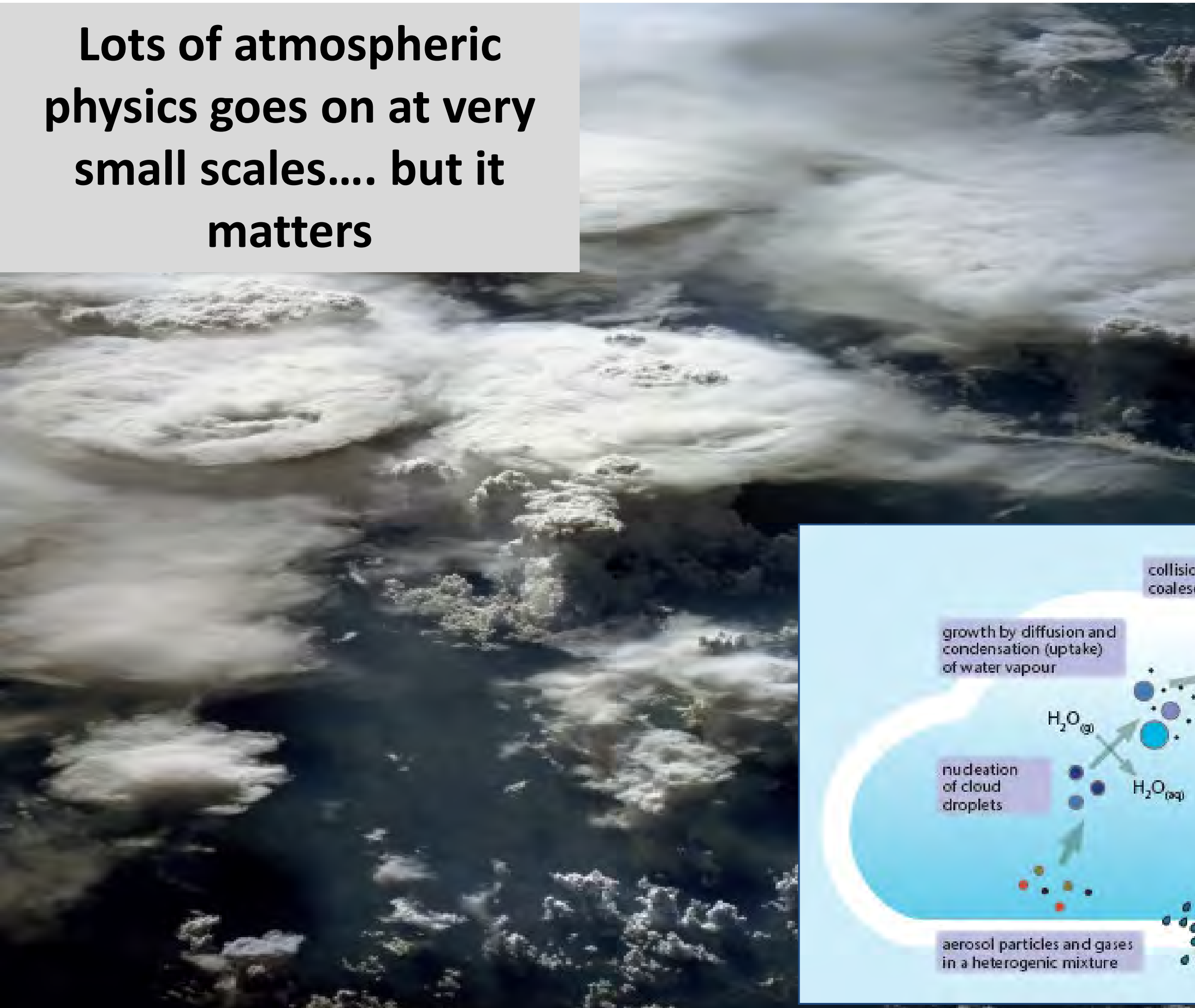
# WCRP CAPABILITY THEMES

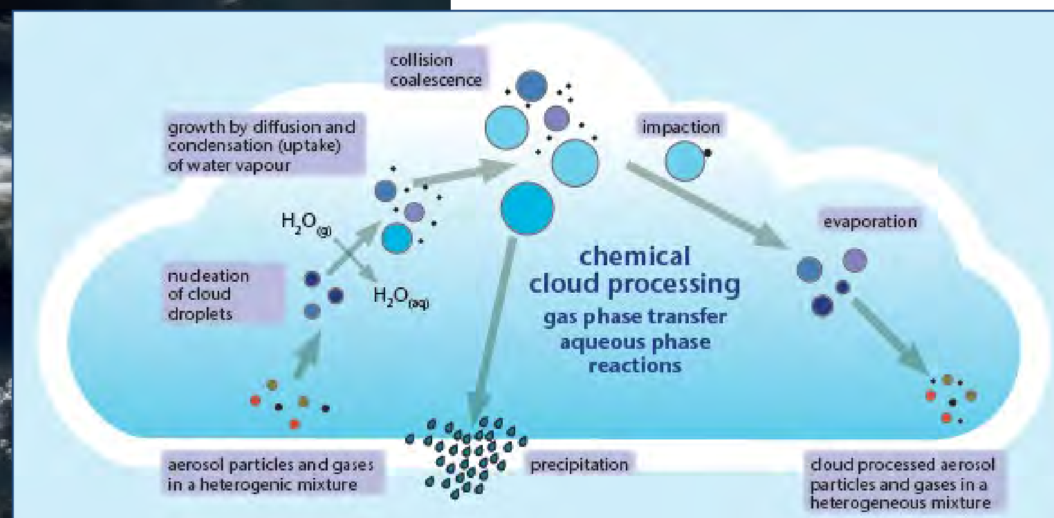
| EARTH SYSTEM PROCESSES ACROSS SCALES *Jointly with WWRP* | CLIMATE VARIABILITY, PREDICTABILITY & PREDICTION *Jointly with WWRP S2S* | CLIMATE CHANGE AND EARTH SYSTEM FEEDBACKS *Jointly with ICSU AIMES* |
|---|---|---|
| Energy, Water & Carbon Cycles; Fundamental Atmospheric Physics (e.g. Convection); 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 |

# Lots of atmospheric physics goes on at very small scales…. but it matters



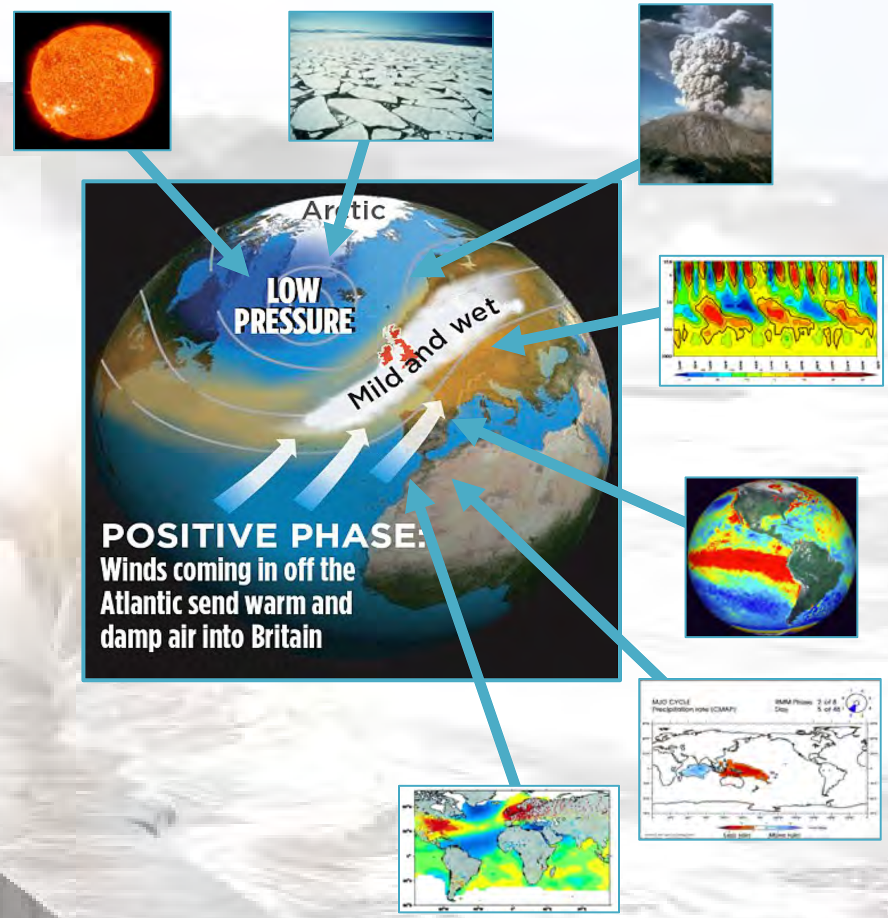
**EARTH SYSTEM PROCESSES ACROSS SCALES**
***Jointly with WWRP***

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



# Monthly to Decadal Prediction: Understanding near-term risks

There are many drivers of seasonal weather and each 'loads the dice' in a different way.




**CLIMATE VARIABILITY, PREDICTABILITY & PREDICTION**

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

# WCRP CAPABILITY THEMES

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

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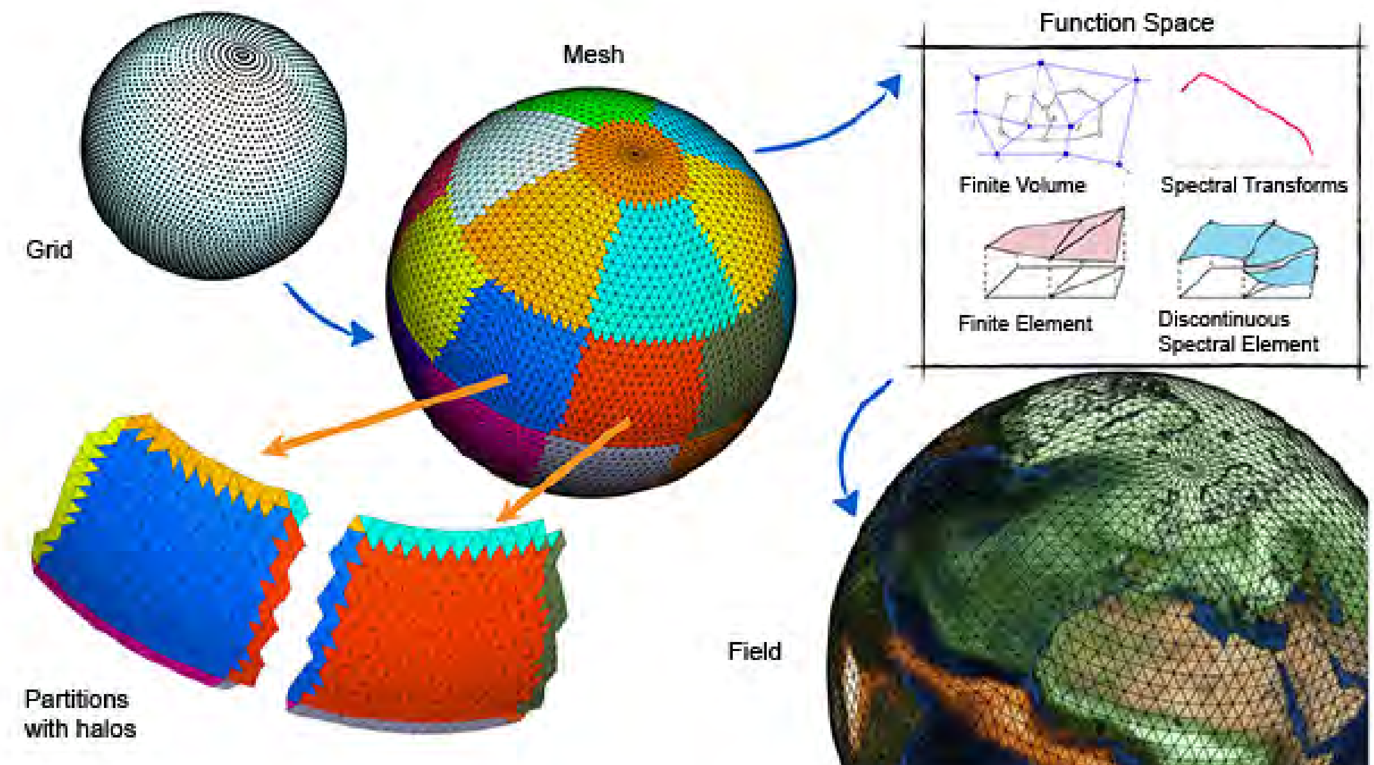
**WCRP CROSS-CUTTING RESEARCH PROJECTS** (*on occasions with* ***WWRP****, Future Earth…..*)

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

## WCRP CROSS-CUTTING RESEARCH PROJECTS

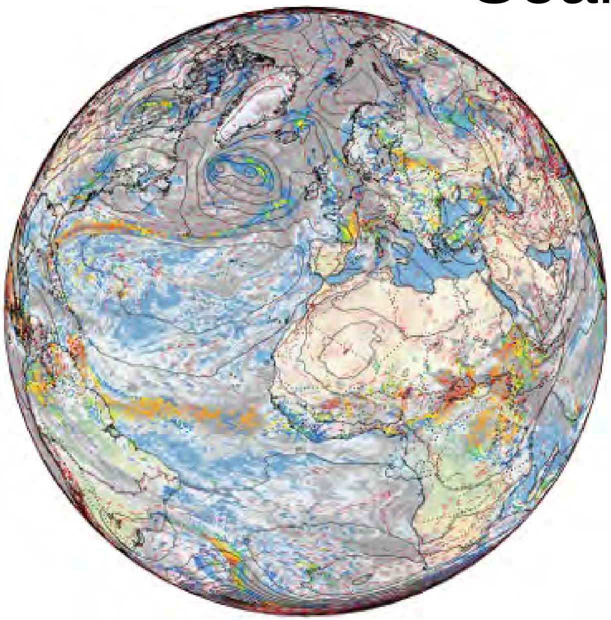
## WCRP WORKING GROUP ON CLIATE MODEL DEVELOPMENT *jointly with WGNE*

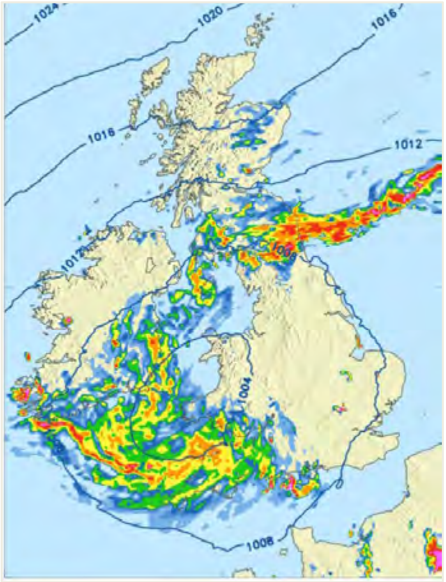
## WCRP WORKING GROUP ON CLIMATE INFORMATION FOR REGIONS

*linking with Future Earth*

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

# New Tools in the Toolbox:
## Seamless Prediction Across Space Scales







N x Global predictions at ~10km with lead times of days to years:

**Synoptic drivers**

<N x Regional predictions at <1km with lead times of hours to years:
**Local meteorology**

Probability of local hazards:
**Impact Scenarios & Narratives**

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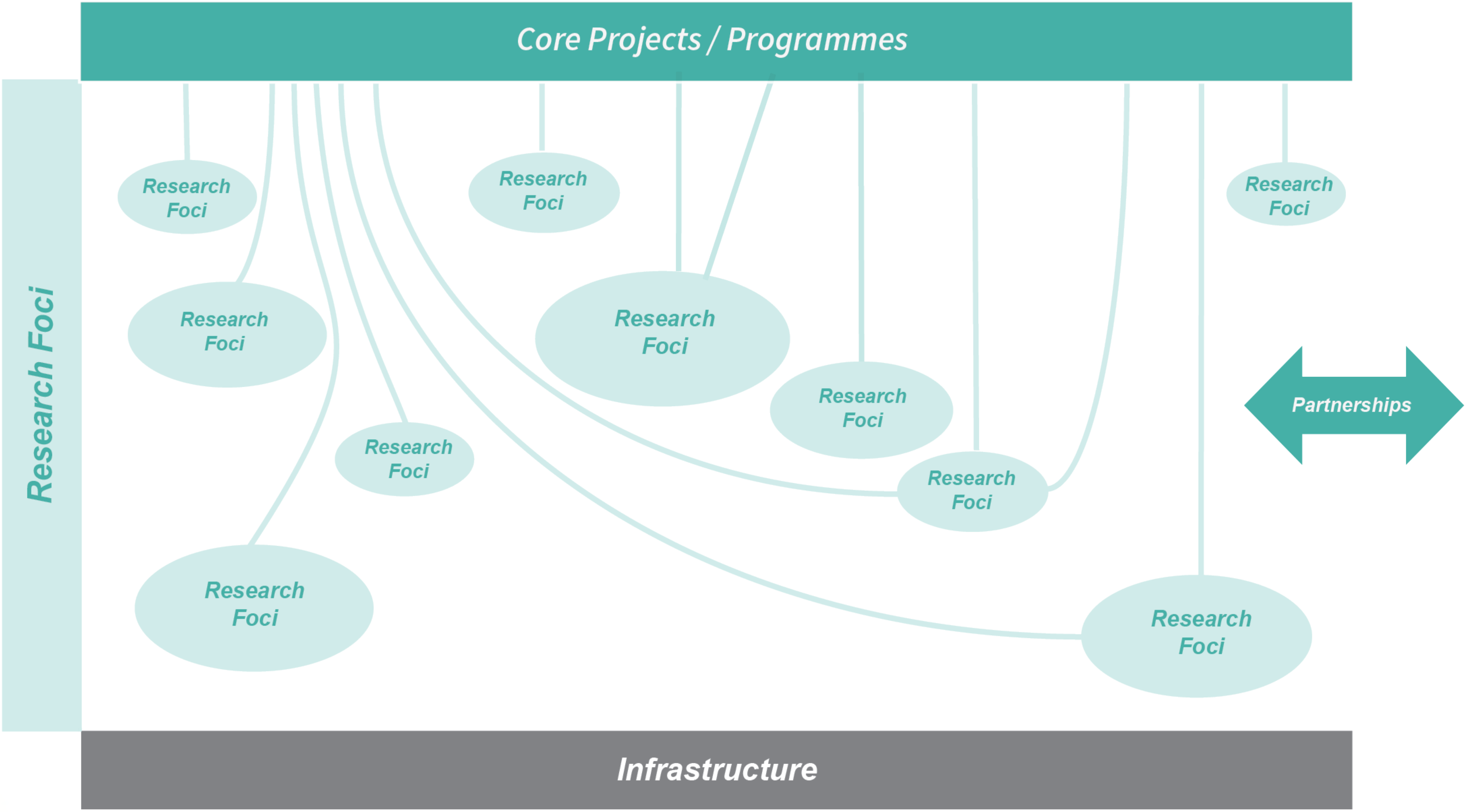
# Recommendation 8: Partnership

***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.


Core Projects / Programmes
Research Foci
Research Foci
Research Foci
Research Foci
Research Foci
Research Foci
Research Foci
Research Foci
Research Foci
Research Foci
Research Foci
Research Foci
Partnerships
Infrastructure

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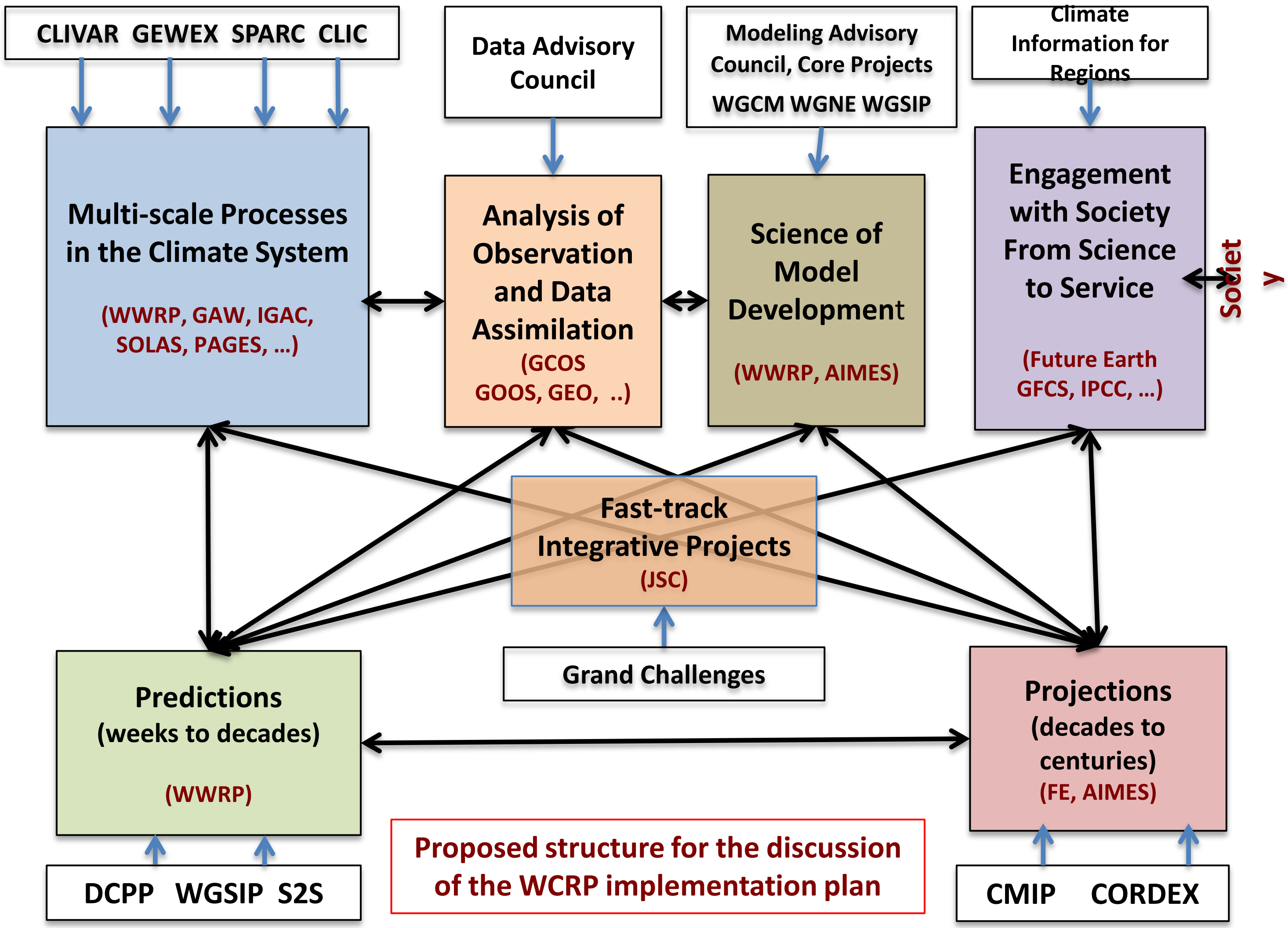


Proposed structure for the discussion of the WCRP implementation plan

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# Thank you
# Merci

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

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World Meteorological Organization
Organisation météorologique mondiale