

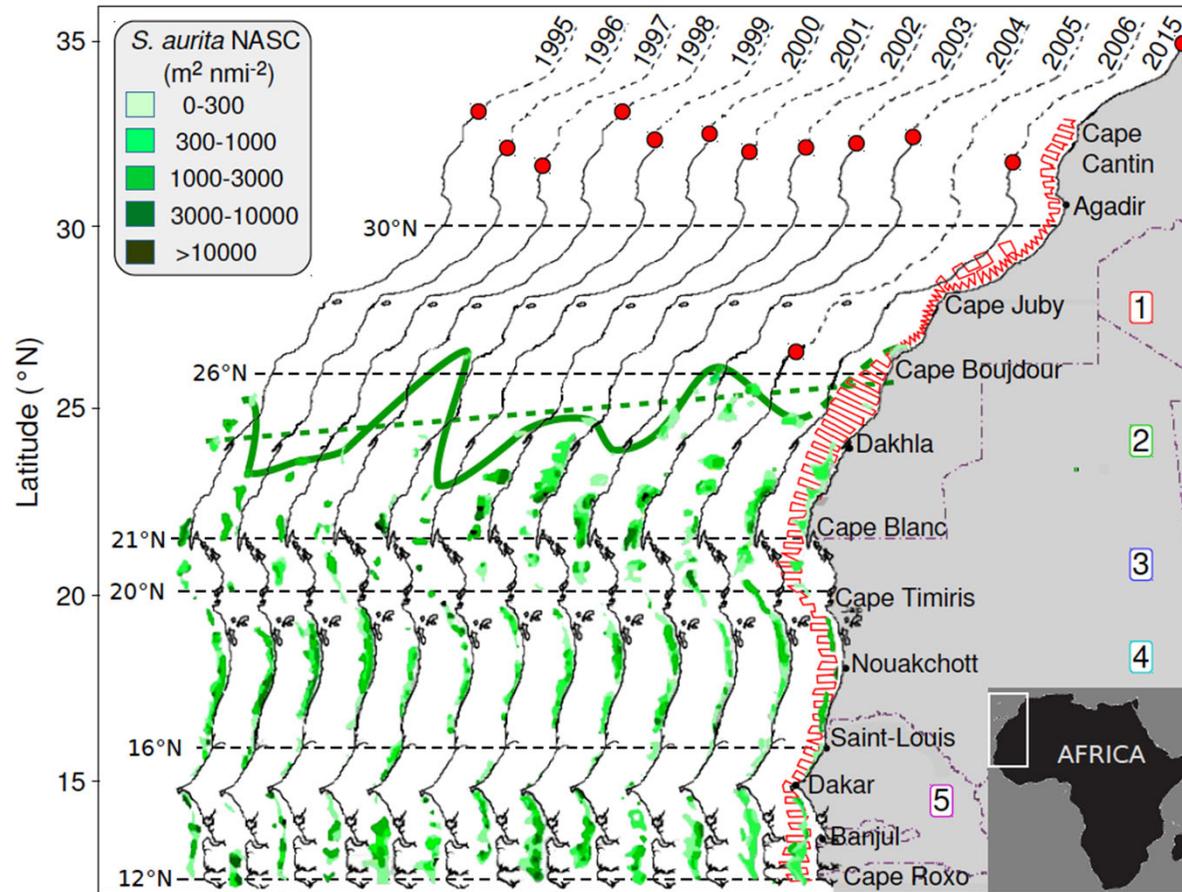
Ocean predictions and observations in response to the climate emergency

Dr. Noel Keenlyside

TRIATLAS/Blue-Action – University of Bergen



Ecosystem surprises: Shifting fish stock

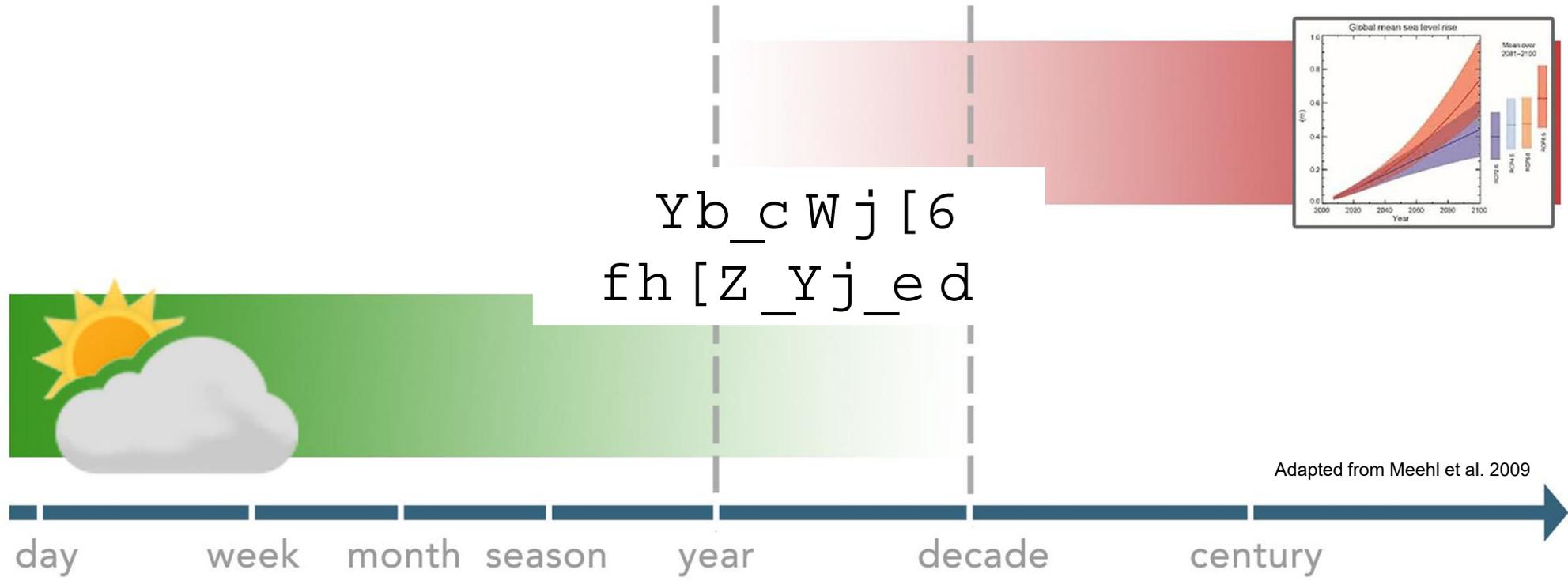


Annual shift of biomass of *Sardinella* derived from hydroacoustic surveys

Courtesy: Abdoulaye Sarre



Delivering useful information on near-term change



Adapted from Meehl et al. 2009

m { w < ~ { "6α " { z iY < i\$ f

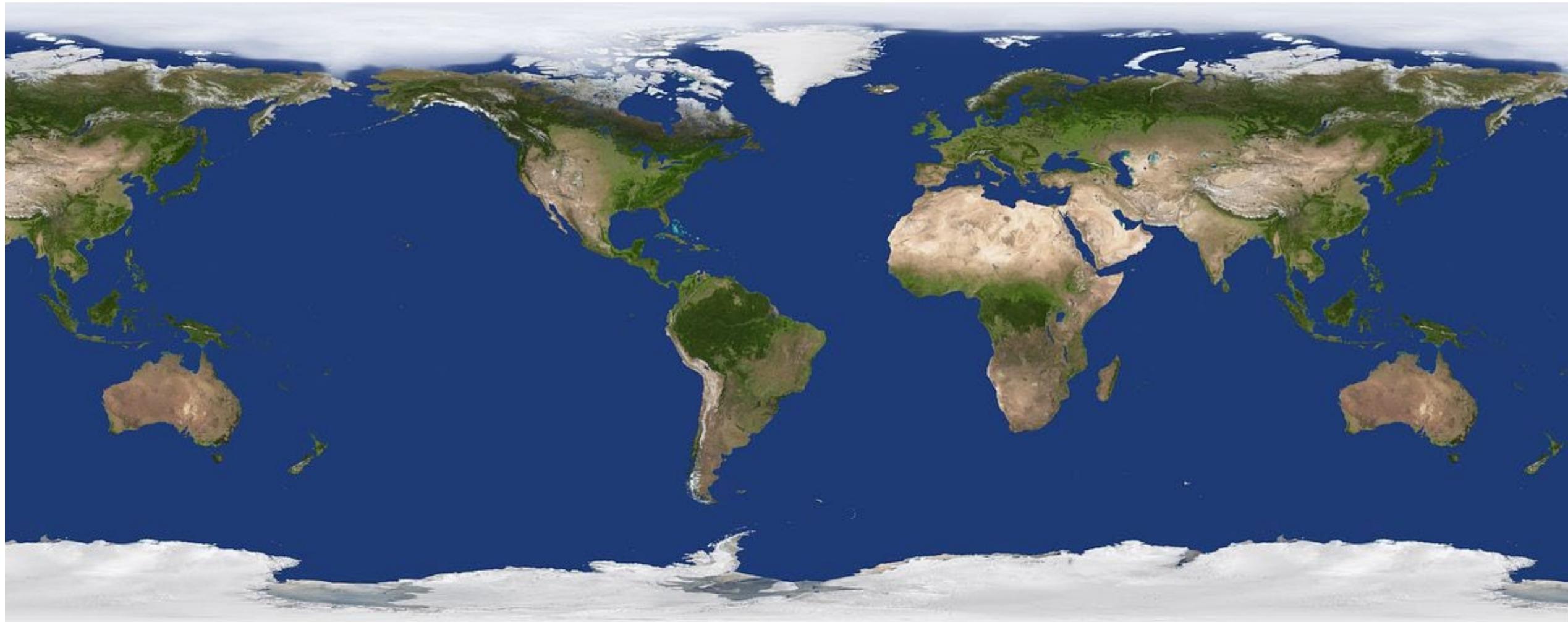
Y/i¥ w < { 6y~w f } {



What can ocean observations tell us about the climate?

Dr. Marilena Oltmanns

Blue Action - National Oceanography Centre



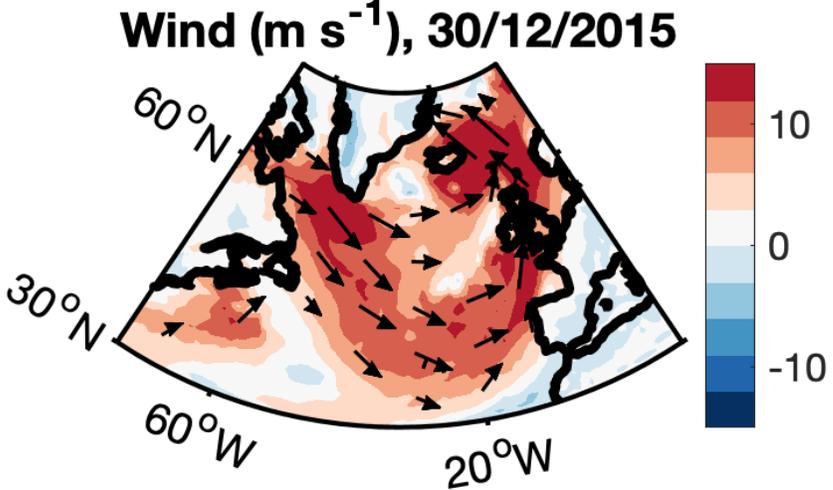
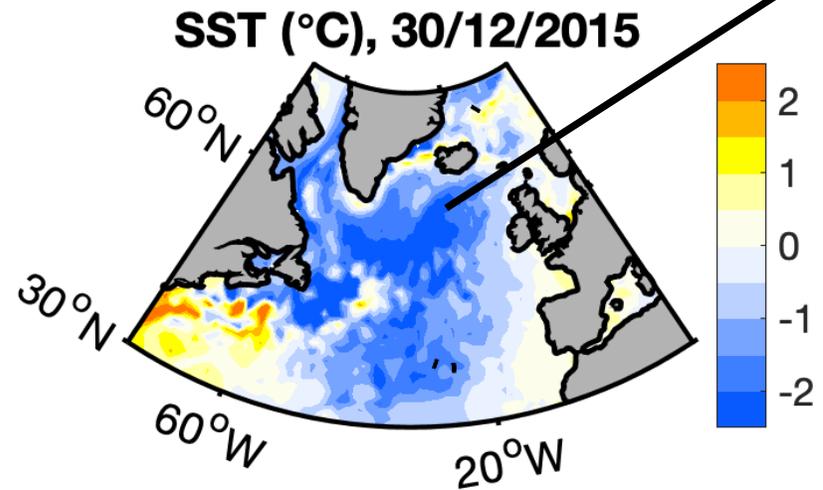
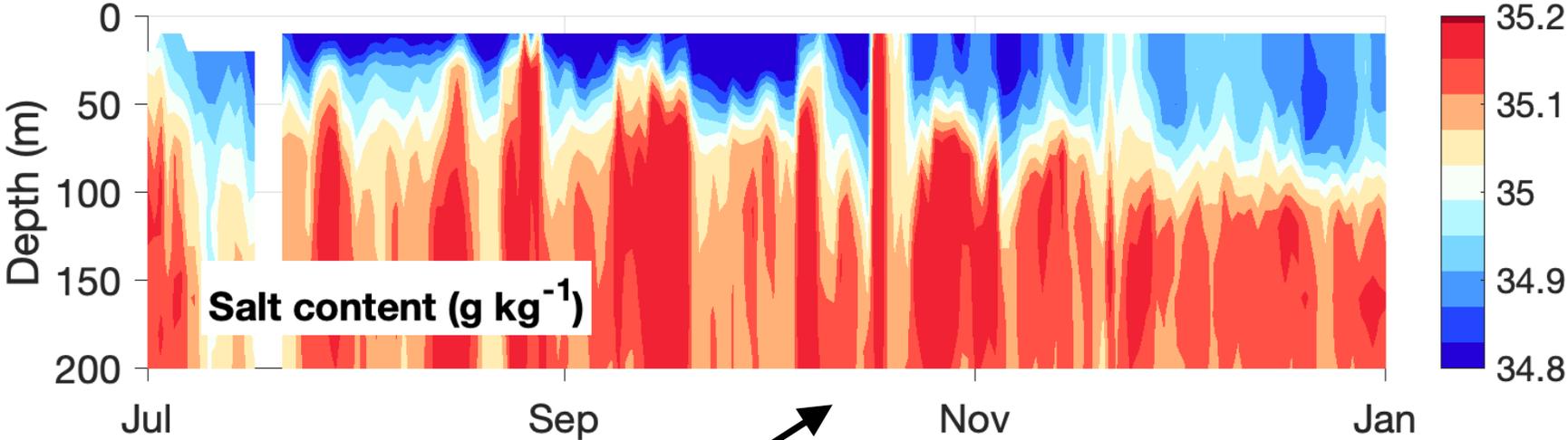


What is the role of the ocean in weather extremes?

From 1970 to 2019, there were over 11,000 reported disasters due to weather extremes, with over 2 million deaths and \$ 3.64 trillion losses.

WMO Atlas of Mortality and Economic Losses

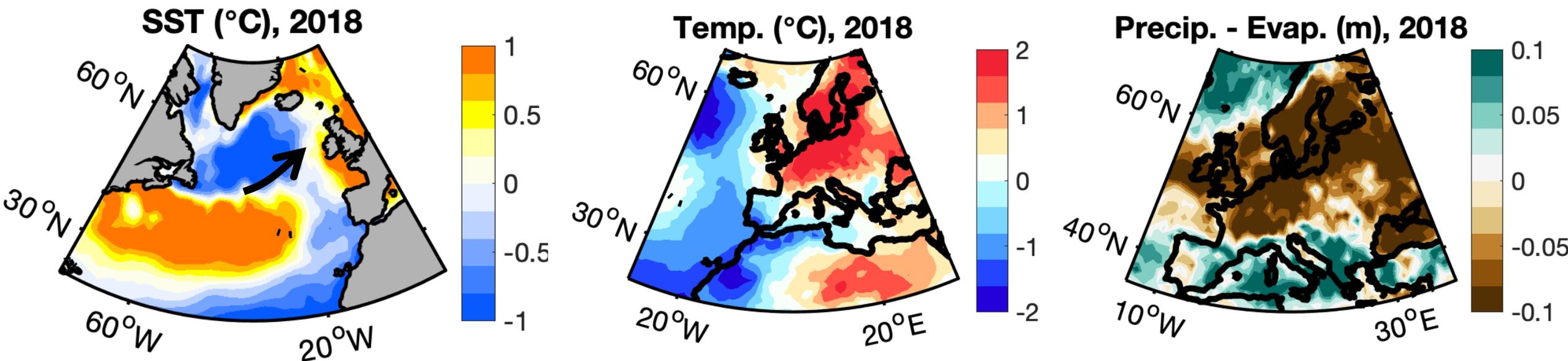
What is the role of the ocean in weather extremes?



Arctic meltwater creates temperature fronts in the North Atlantic promoting storms in winter.

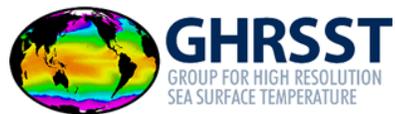
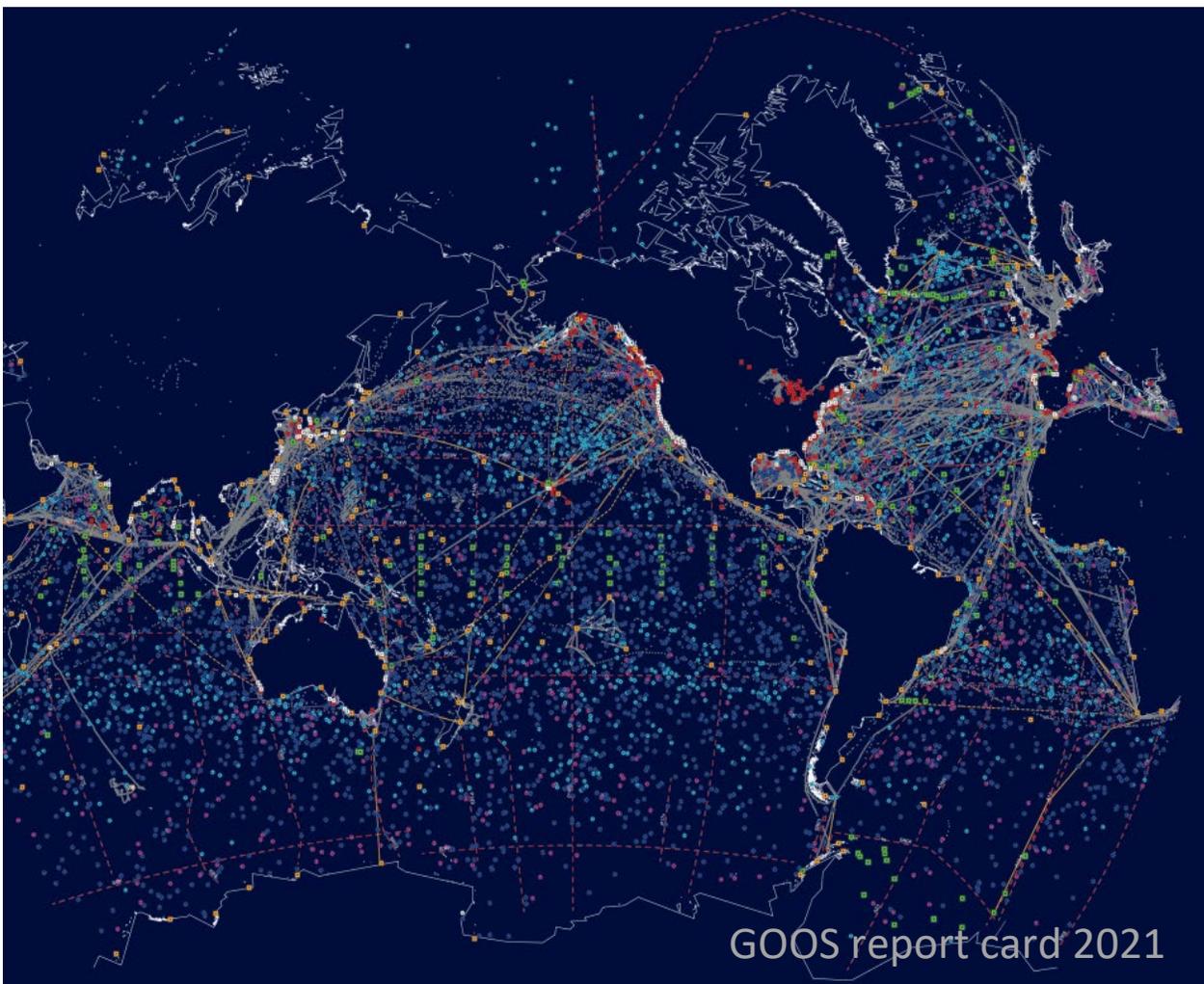
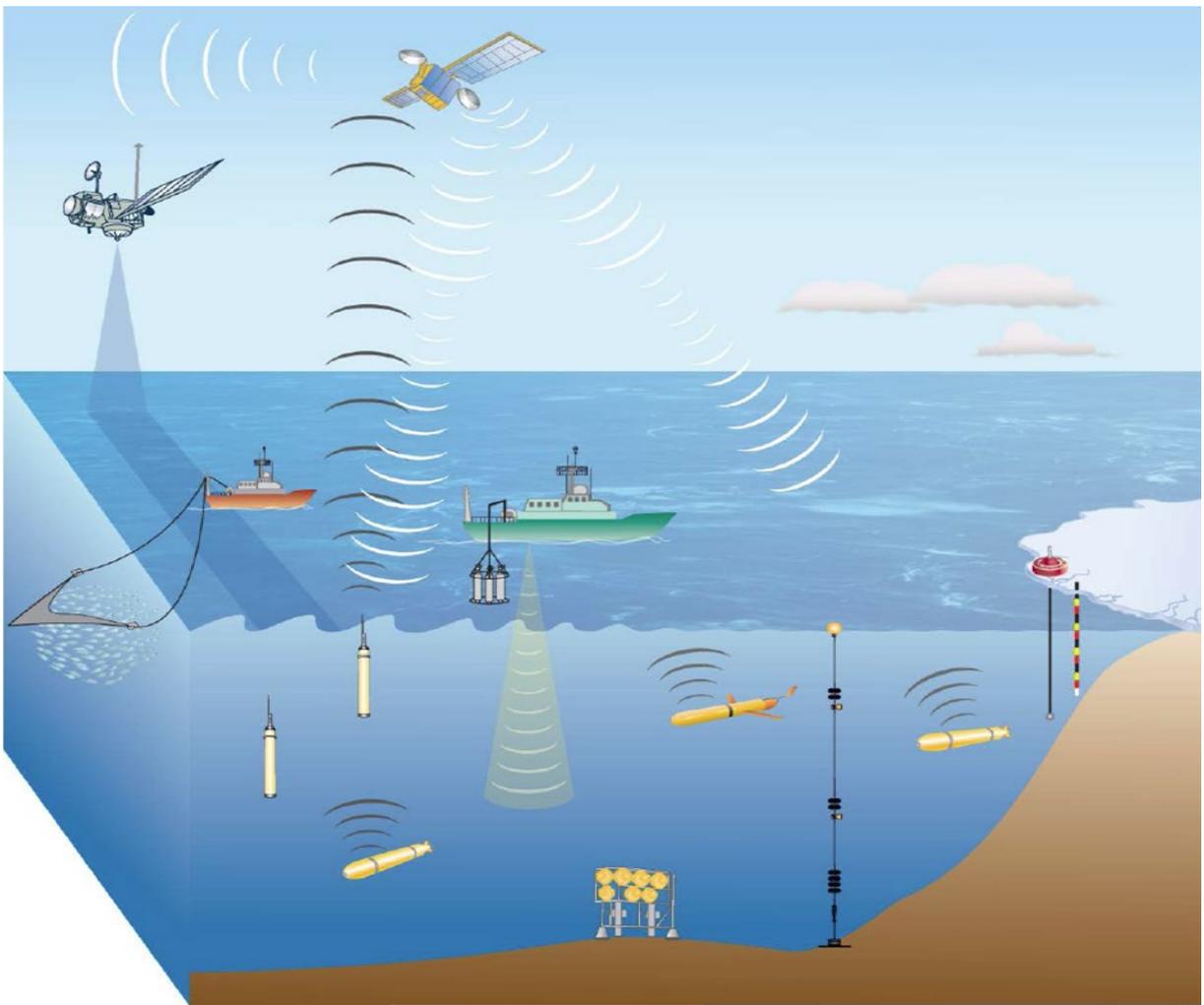


What is the role of the ocean in weather extremes?



The storms lead to new fronts in summer, resulting in shifts of the jet stream and heat waves and droughts over Europe.

Global ocean observing is needed to deliver essential data.



Take home messages



- The ocean plays a key role in the Earth's climate system.
- To understand feedbacks in the climate system and to make predictions, we rely on ocean observations.
- Global observing and modelling is a big challenge that requires global collaboration.



Summary



- The North Atlantic climate is very sensitive to small freshwater variations.
- There is an increasing risk of a very large Arctic freshwater discharge.
- Global climate models have difficulties to capture freshwater variations.



Why is satellite remote sensing of Sea-Surface Temperature important for climate monitoring and modelling?

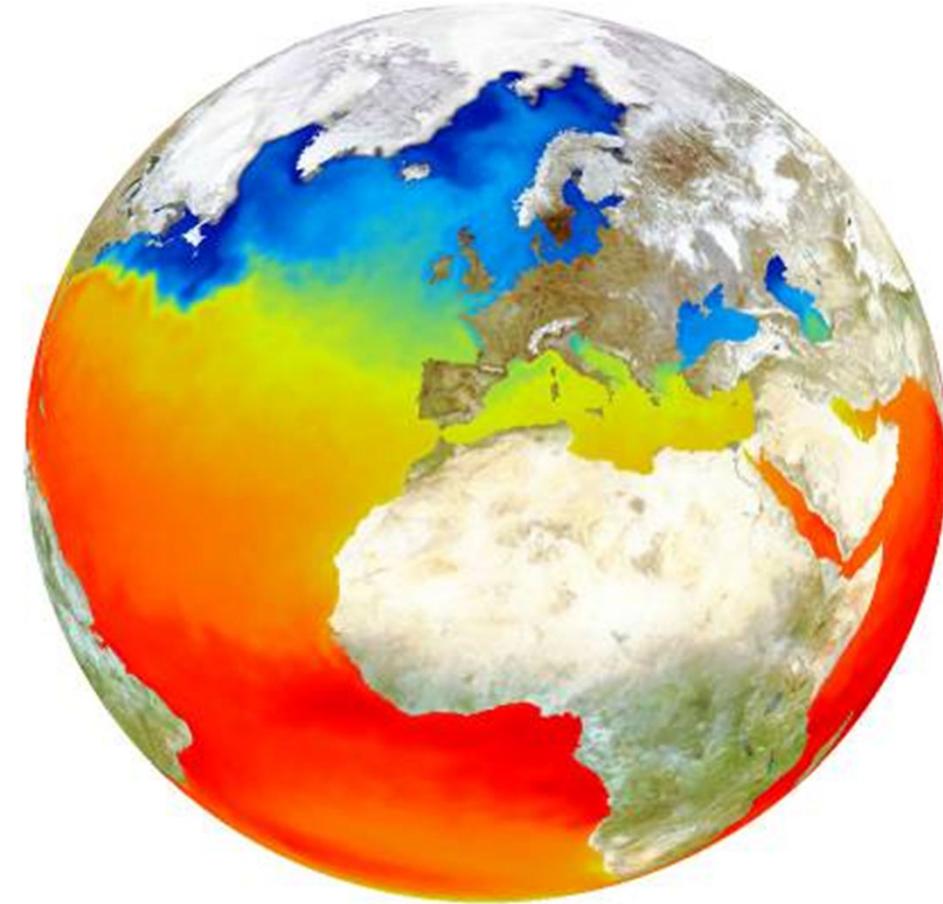


Anne O'Carroll

EUMETSAT / GHRSSST

Anne.OCarroll@eumetsat.int

@annegocarroll



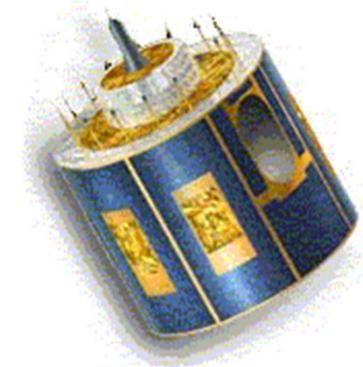
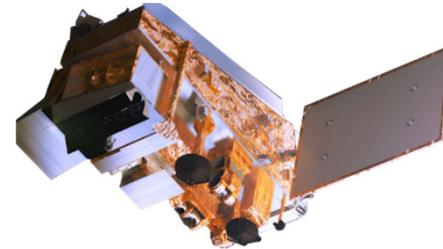
Satellite Sea-Surface Temperature (SST)



As global and regional earth temperatures continue to increase, Sea-Surface Temperature from satellite remote sensing continue to be

crucial for understanding, monitoring and modelling the climate

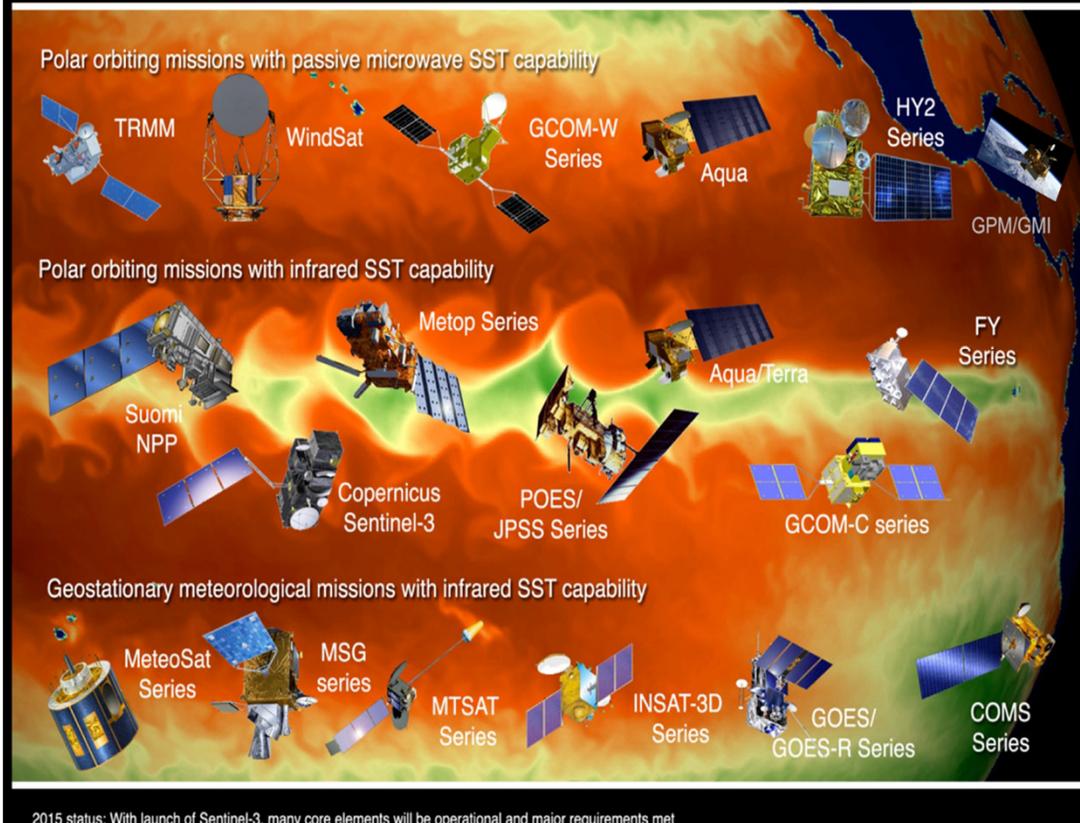
Group for High Resolution Sea-Surface Temperature (GHR SST) coordinates on providing satellite-derived global Sea-Surface Temperature with good estimates of uncertainty to operational users, climate / ocean monitoring / prediction and the science community



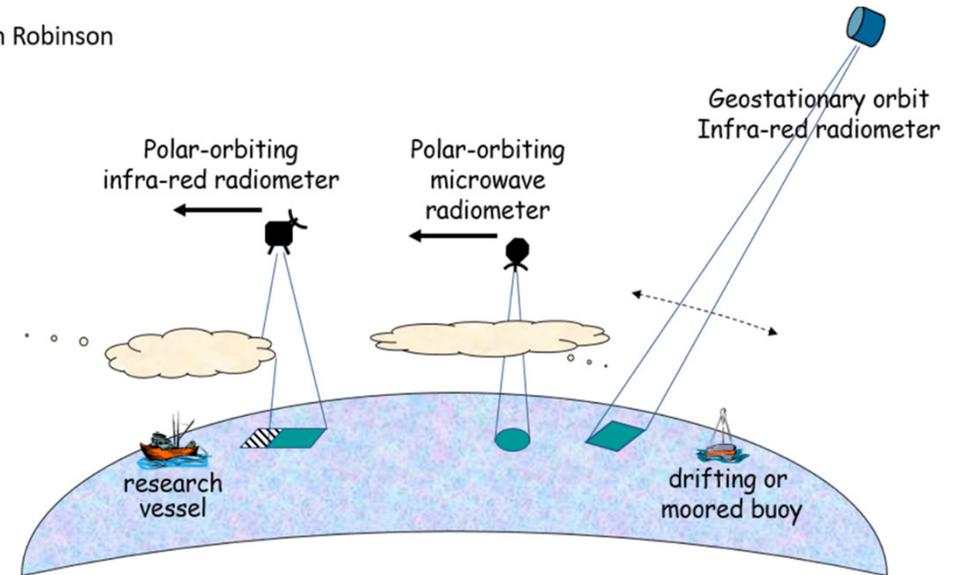
Constellation of satellite Sea-Surface Temperature observing system

CEOS Virtual Constellation for Sea Surface Temperature (SST-VC)

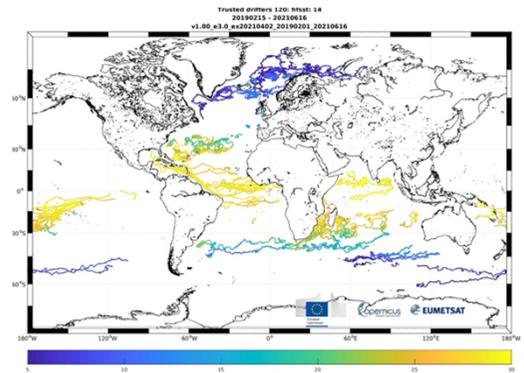
Providing best quality SST data for wide application through international collaboration, scientific innovation, and rigor



Ian Robinson



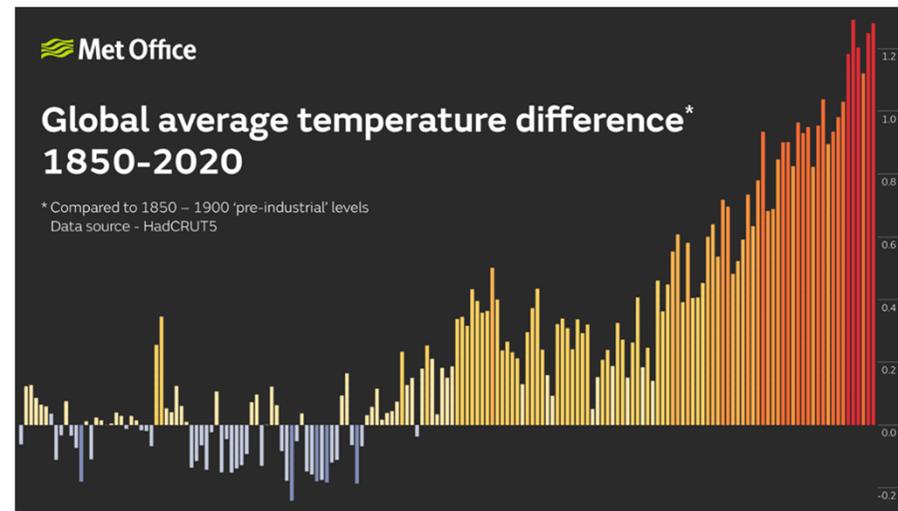
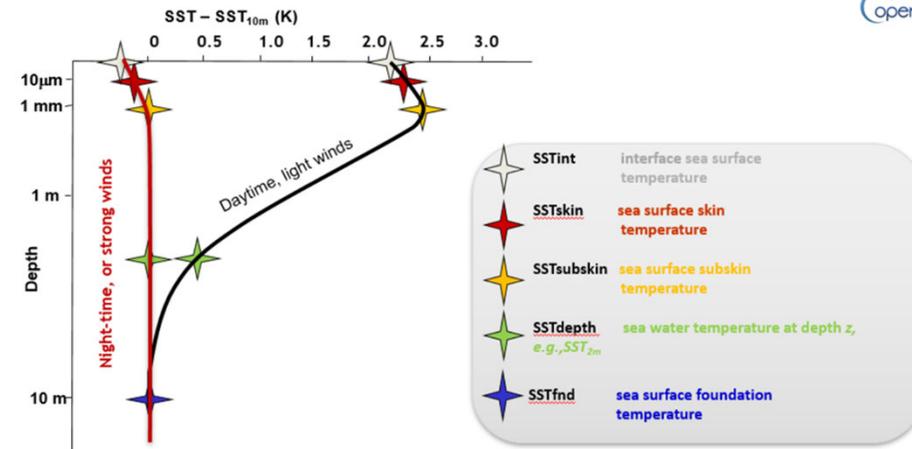
Fiducial Reference Measurements (FRM) also crucial for satellite validation and ensuring quality, consistency and traceability



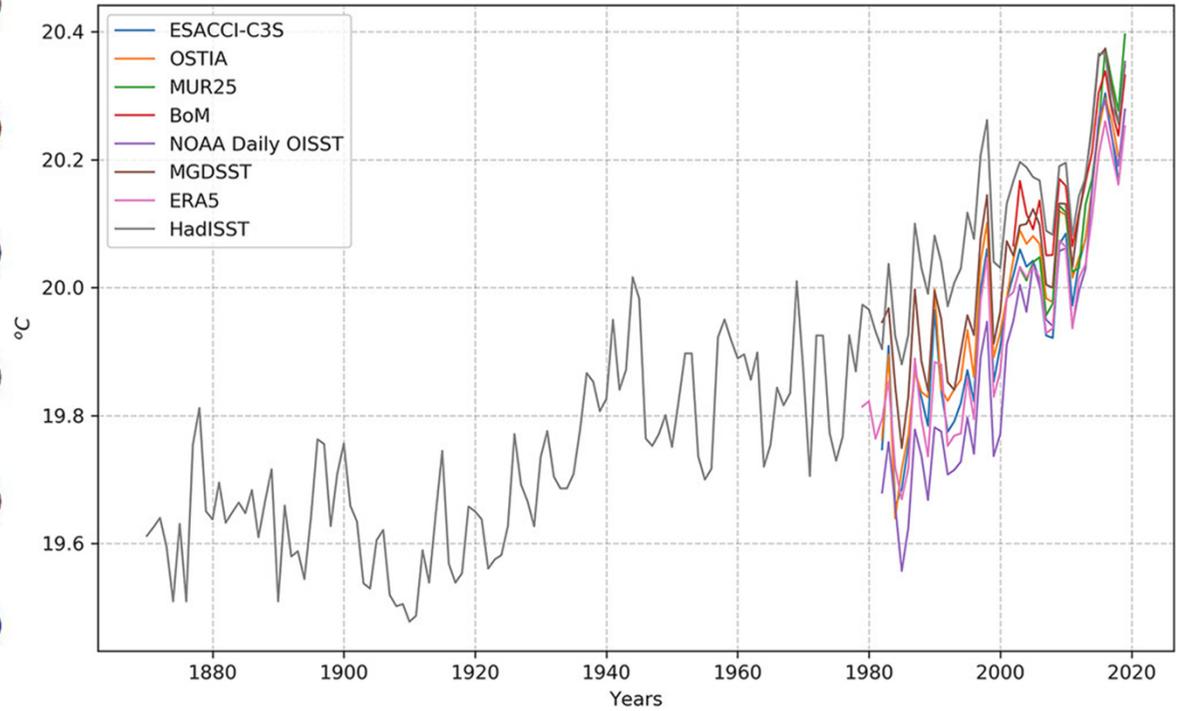
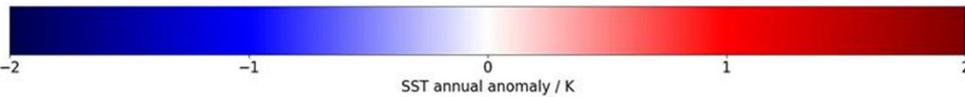
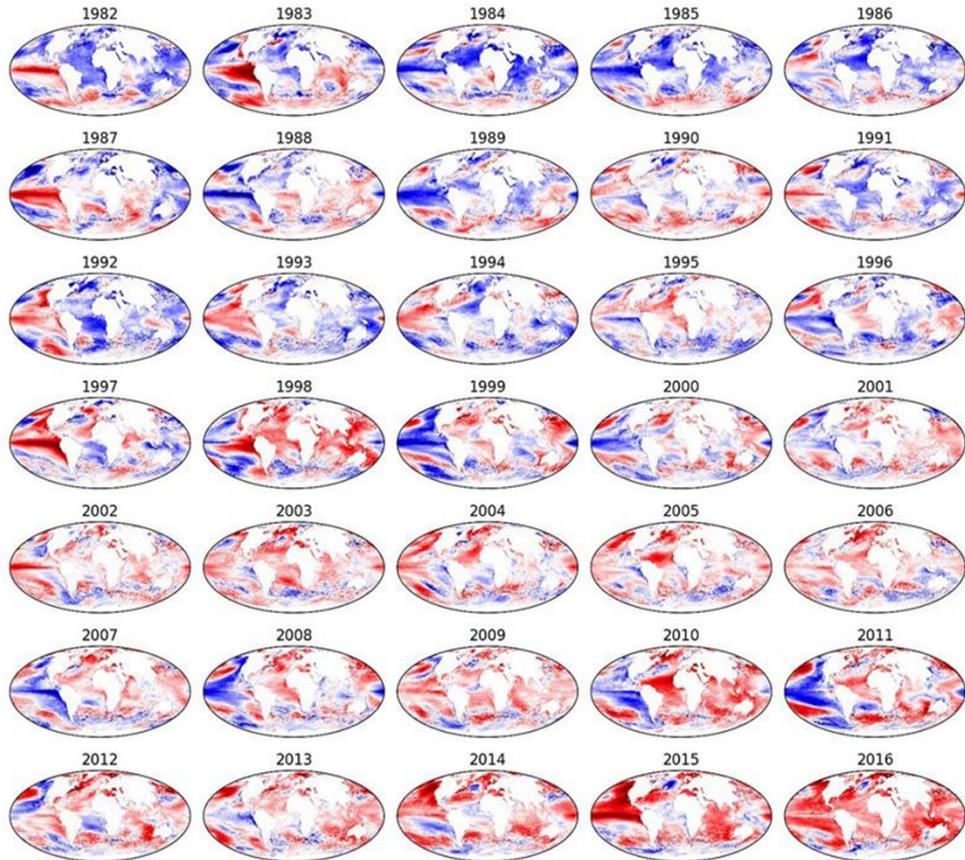
Why is Sea-Surface Temperature from satellites important?

Essential for climate monitoring, modelling and seasonal predictions:

- Improves seasonal predictions
- Influences atmospheric circulation
- Influences Weather forecasting boundary condition
- Influences density and circulation of oceans
- Impacts ocean biogeochemistry and marine ecosystems



Improving climate monitoring and prediction

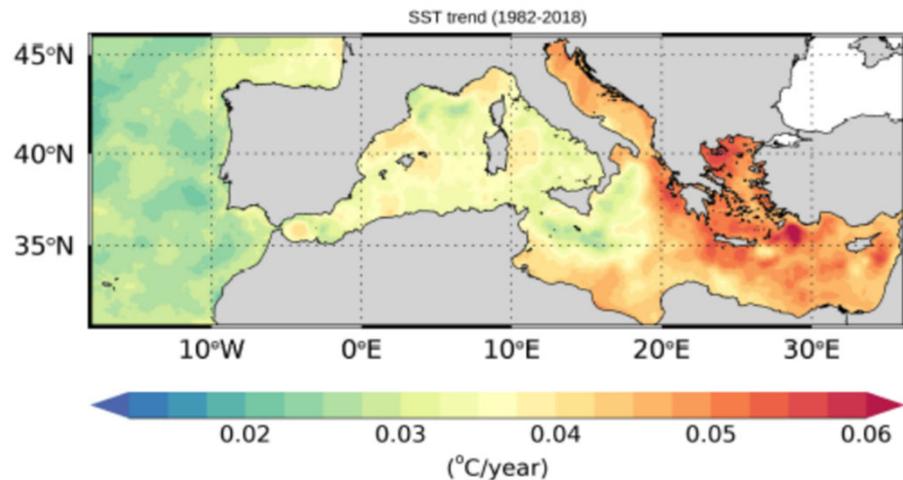


Yang et al. (2021) *Journal of Climate* <https://doi.org/10.1175/JCLI-D-20-0793.1>

Merchant et al. (2019) *Scientific data* <https://www.nature.com/articles/s41597-019-0236-x>

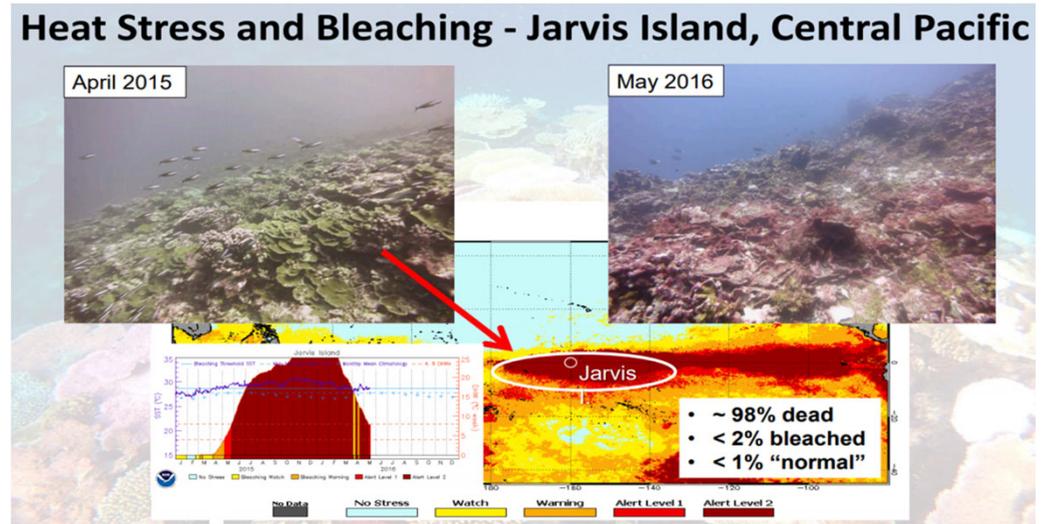
Applications of Sea-Surface Temperature

Marine heat waves



Shows a nearly continuous warming trend of $0.041 \pm 0.006^\circ\text{C} / \text{year}$ giving a total increase of 1.5°C from 1982 to 2008 (Pisano et al. 2020)

Coral heat stress Sea-Surface temperature user needs



Skirving et al. (2020) *Coral heat stress user SST requirements*
<https://doi.org/10.5281/zenodo.4700411>

Challenges for improving Sea-Surface Temperature

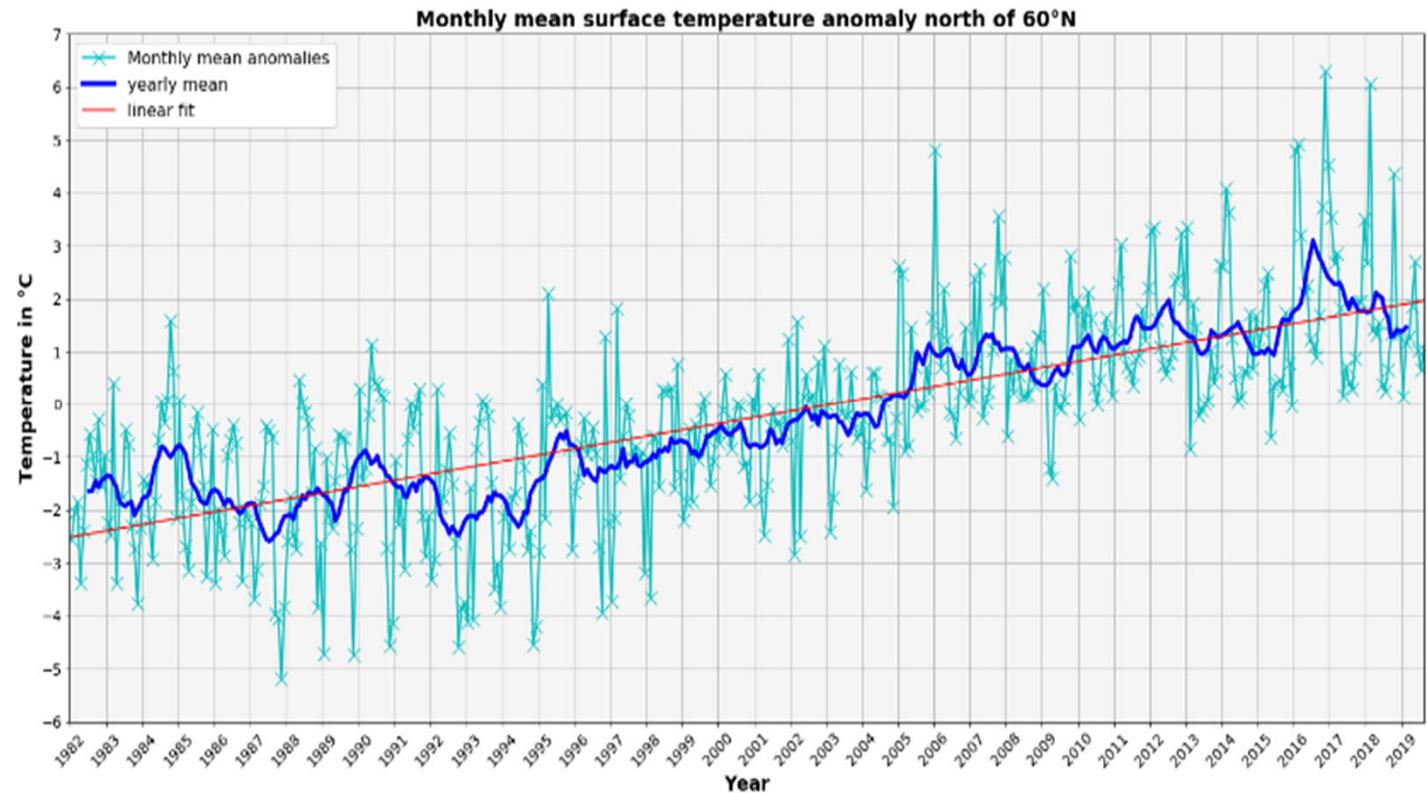
Improving SST data quality in the Arctic

4°C increase in Arctic Ocean (>60 °N) surface temperature

SST and Ice-Surface Temperature products enable Arctic monitoring

Challenges? Lack of in situ data, accurate identification of sea-ice

Need: Improvement of Passive Microwave (PMW) data availability in Arctic



Hoeyer et al. (2021) <https://www.youtube.com/watch?v=KXPBqUWLFgs>

Challenges for improving Sea-Surface Temperature



Improving coastal SST data quality

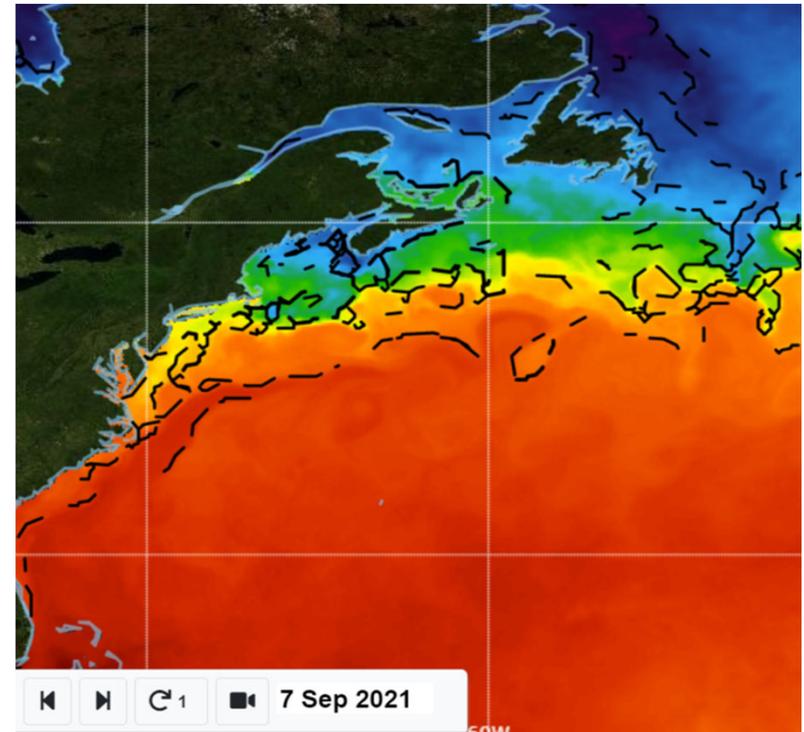
Challenges: greater variability in Water Vapour, temperature and aerosol, changes in surface emissivity and turbidity/cloud detection

Need: high spatial resolution satellite data from multiple sources.

Improving SST feature resolution

Challenge: Reliance on high resolution infra-red data but limited by cloud cover

Need: Focus on new techniques e.g. in coastal, upwelling, polar and dynamic regions



<https://www.star.nesdis.noaa.gov/socd/ov/>

Innovation and priorities for Sea-Surface Temperature



Summary of priorities in next decade:

- Arctic and high-latitudes; coastal data quality; SST feature resolution

Observational needs of Sea-Surface Temperature:

- Continuity and redundancy of the constellation of satellite Sea-Surface Temperature observing system
- New generation of geostationary and polar-orbiting sensors has begun but innovation to translate these to higher resolution and better accuracy Sea-Surface Temperature products is still needed
- Continued investment into Fiducial Reference Measurements (FRM) with known uncertainties for traceability and long-term assessment of stability of satellite SST

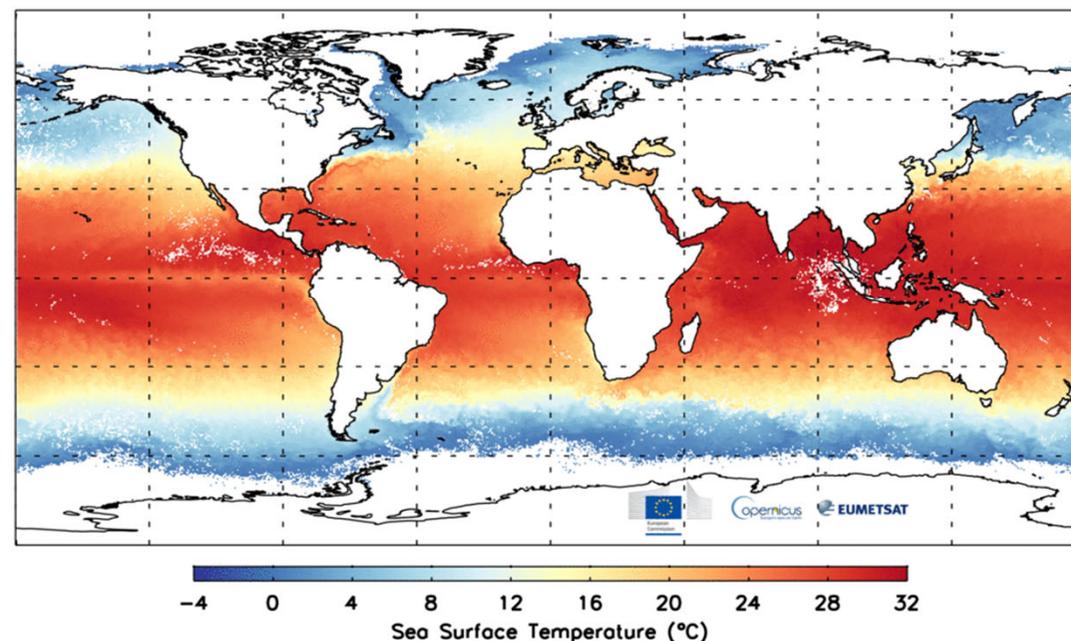
O'Carroll et al, OceanObs19, <https://www.frontiersin.org/articles/10.3389/fmars.2019.00420/full>



Key take home messages

- Sea-Surface Temperature is essential for operational meteorology, oceanography and seasonal predictions
- SST is crucial for climate monitoring, modelling and predictions
- Need continuity and redundancy of the constellation of satellite Sea-Surface Temperature observing system
- Improvements related to identified user needs in products, algorithms and Fiducial Reference Measurements needed

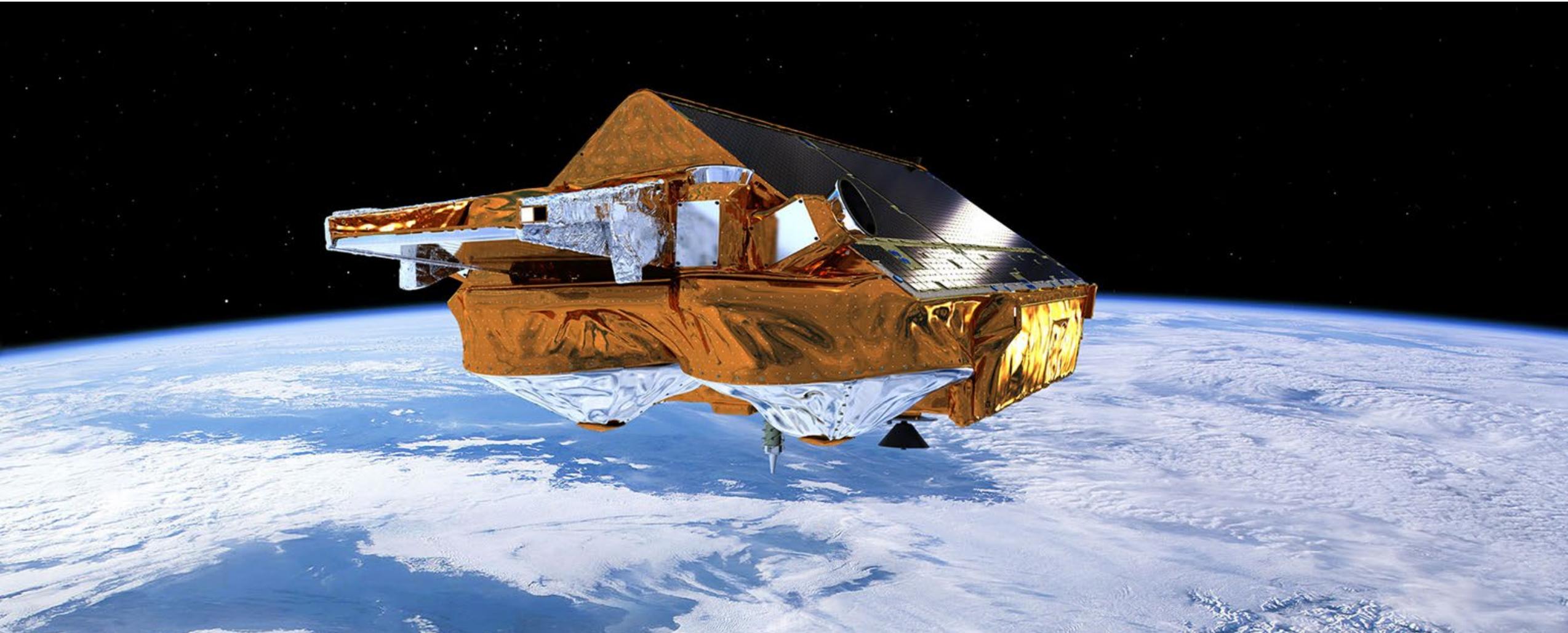
Copernicus Sentinel-3 SLSTR SST 20160501



Exploiting observations to improve the predictive capacity in the Arctic, including its climate impacts

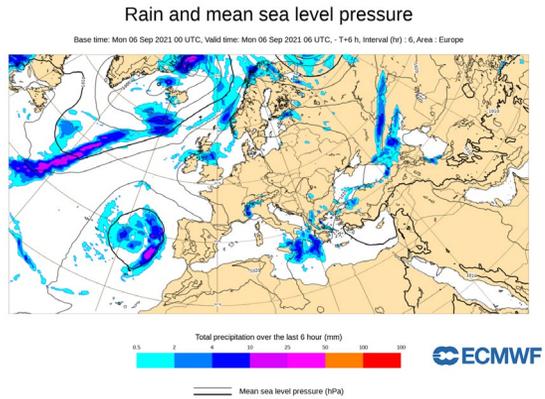


Dr. Pablo Ortega
Barcelona Supercomputing Center

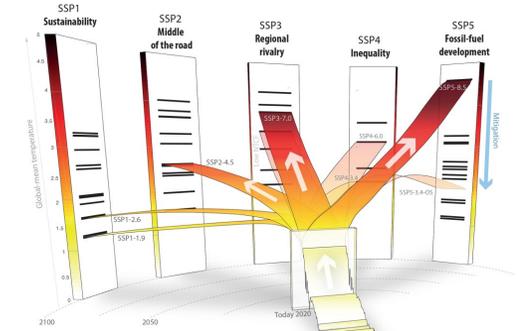


Fundamentals of Climate Prediction

Weather forecasts



Climate projections



Meinshausen et al. (2020)

Days

Weeks

Months

Seasons

Years

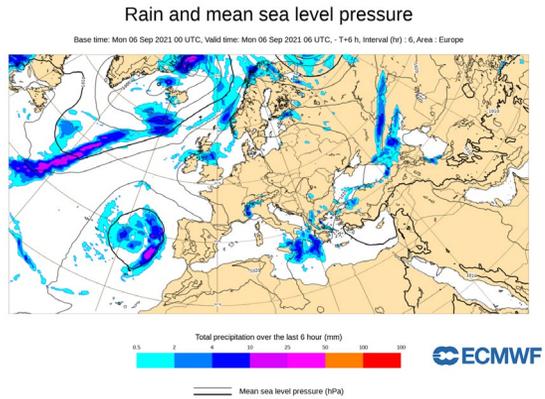
Decades

Centuries

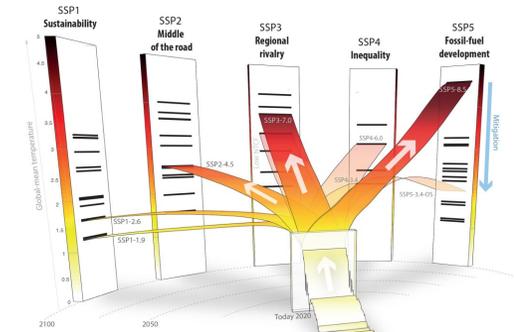


Fundamentals of Climate Prediction

Weather forecasts



Climate projections



Meinshausen et al. (2020)

Days

Weeks

Months

Seasons

Years

Decades

Centuries

GHGs and Aerosols

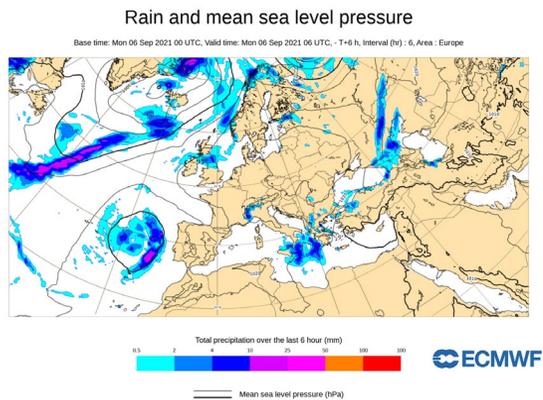


Good guess of future changes in radiative forcing factors

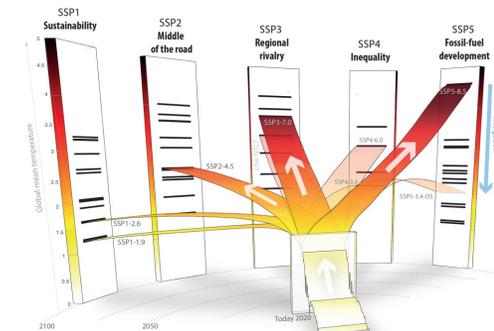


Fundamentals of Climate Prediction

Weather forecasts



Climate projections



Meinshausen et al. (2020)

Days Weeks

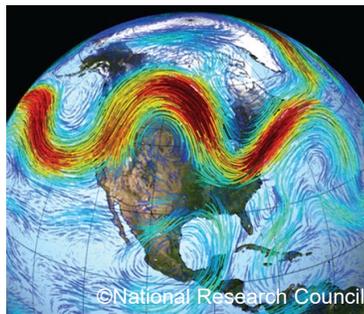
Months

Seasons

Years

Decades Centuries

Current Meteorological state



Initialization of **internal sources of predictability**

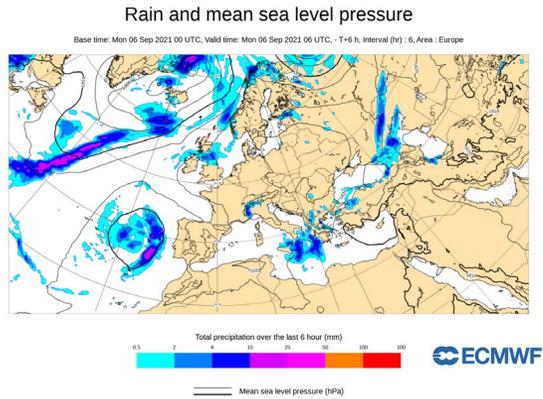
Good guess of future changes in **radiative forcing factors**

GHGs and Aerosols

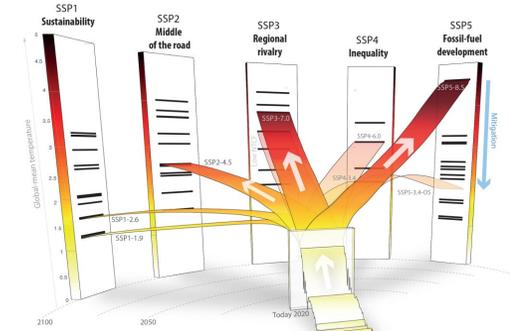


Fundamentals of Climate Prediction

Weather forecasts



Climate projections



Meinshausen et al. (2020)

Days

Weeks

Months

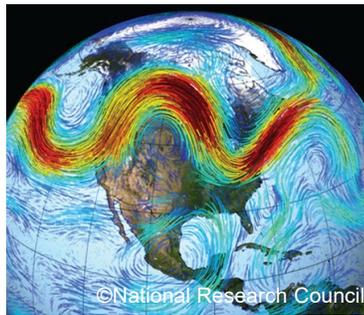
Seasons

Years

Decades

Centuries

Current Meteorological state



Initialization of **internal sources of predictability**

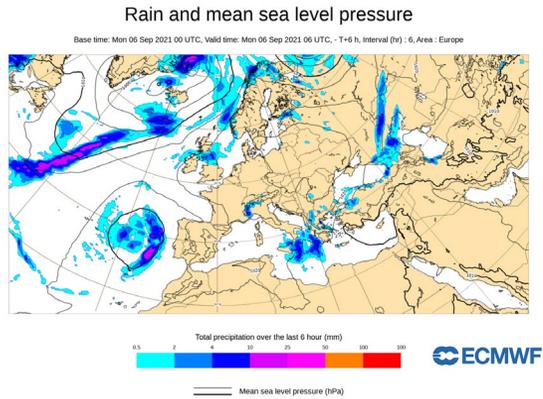
Good guess of future changes in **radiative forcing factors**

GHGs and Aerosols

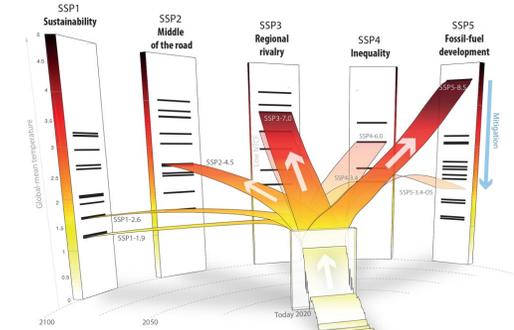


Fundamentals of Climate Prediction

Weather forecasts



Climate projections



Meinshausen et al. (2020)

Days

Weeks

Months

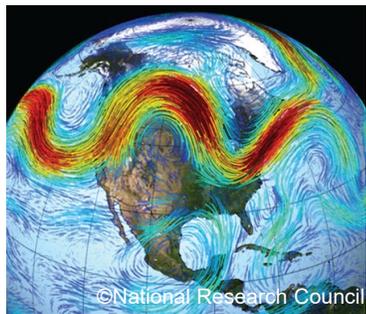
Seasons

Years

Decades

Centuries

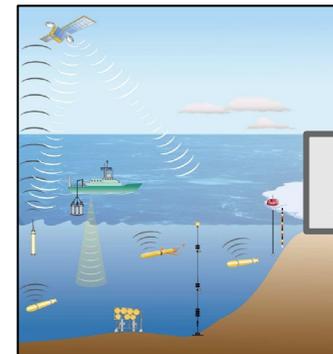
Current Meteorological state



Initialization of internal sources of predictability

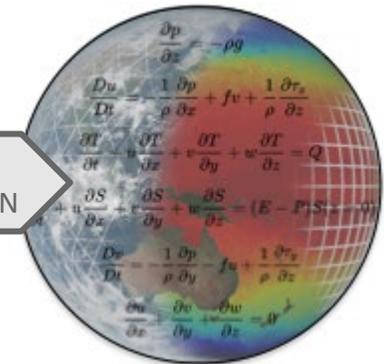


Observations



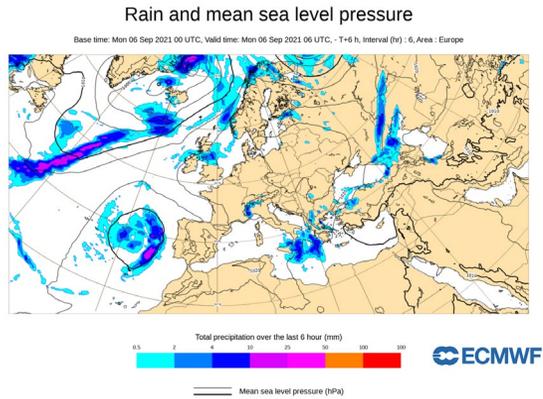
DATA ASSIMILATION

Global Earth System Model

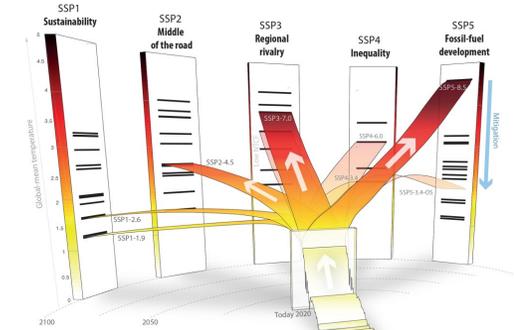


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Weather forecasts



Climate projections



Meinshausen et al. (2020)

Days

Weeks

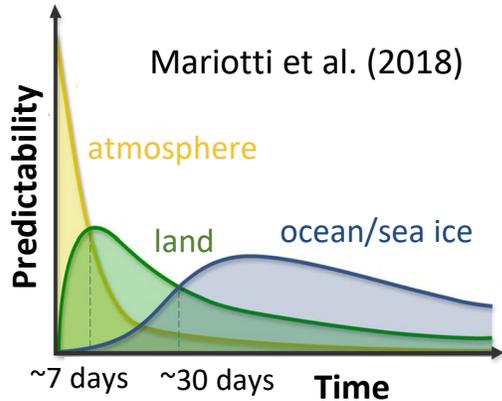
Months

Seasons

Years

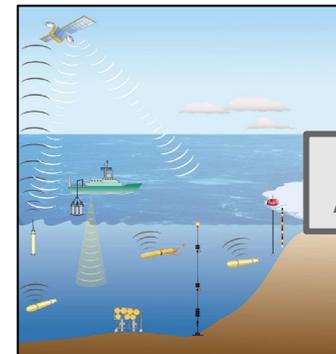
Decades

Centuries

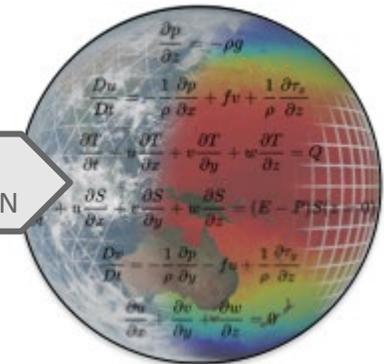


Predictability from slowly varying components of the Earth system

Observations



Global Earth System Model



DATA ASSIMILATION

A growing network of Arctic observations

YOPP
YEAR OF POLAR PREDICTION

The Year of Polar Prediction (YOPP) Improving Polar Weather and Sea Ice Forecasts

Forecast Model Grid Boxes

Weather and Sea Ice Modeling

Observing Platforms

Environmental Forecasting

Forecast Users

esa

APPLICATIONS

Contract signed to build Arctic weather satellite

MOSAIC
International Arctic Drift Expedition

SHIP OPERATIONS

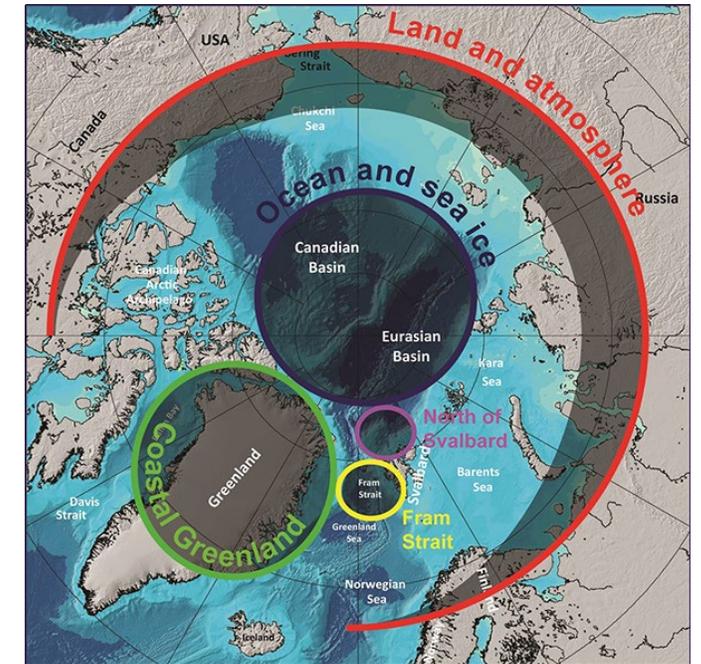
Winch Control Station

Helicopters

Engines

Server Room and IT

Cargo Hold



INTAROS Data Catalogue

Ocean moorings, Weather stations, Cruise Campaigns
Satellites, Supersites, Gliders, Floats,...

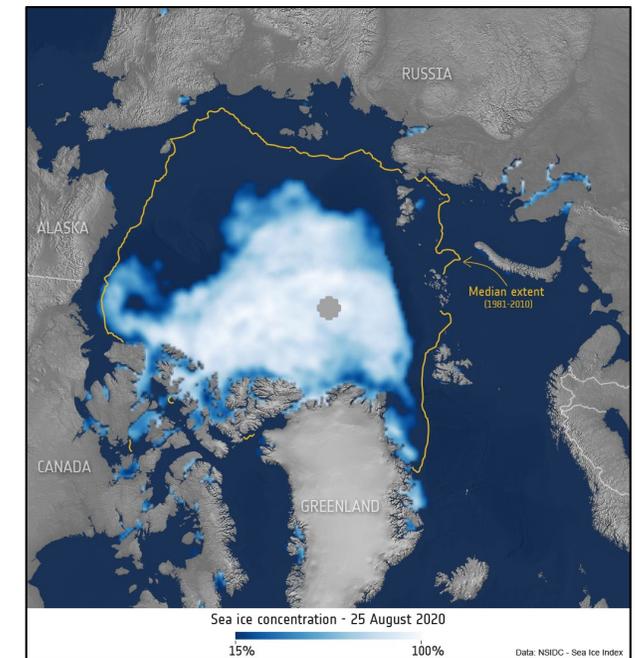


A growing network of Arctic observations

Satellite data are particularly useful for Arctic climate prediction

- Several decades of **uninterrupted spatially continuous fields** are already available covering the **whole Arctic region**
- This includes **key variables for the Arctic** such as:
 - **Sea ice concentration** (since 1979)
 - **Sea ice thickness** (since 2002)
- Thanks to their homogeneity in time and space, satellite data can be **easily assimilated** for forecast initialization

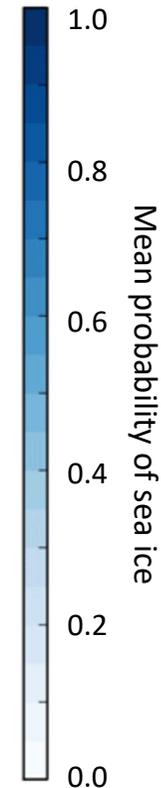
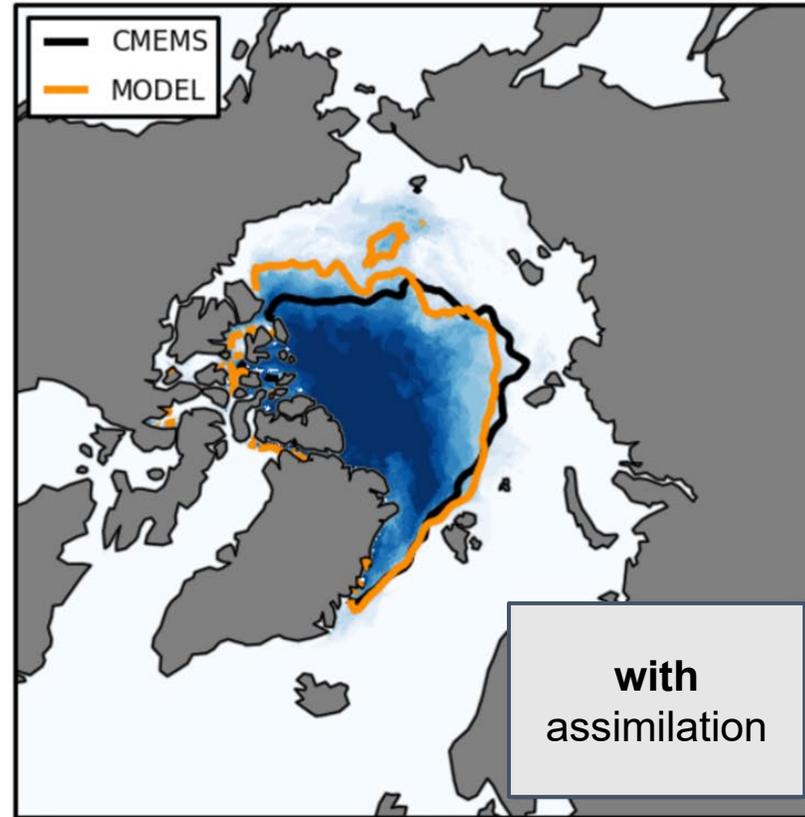
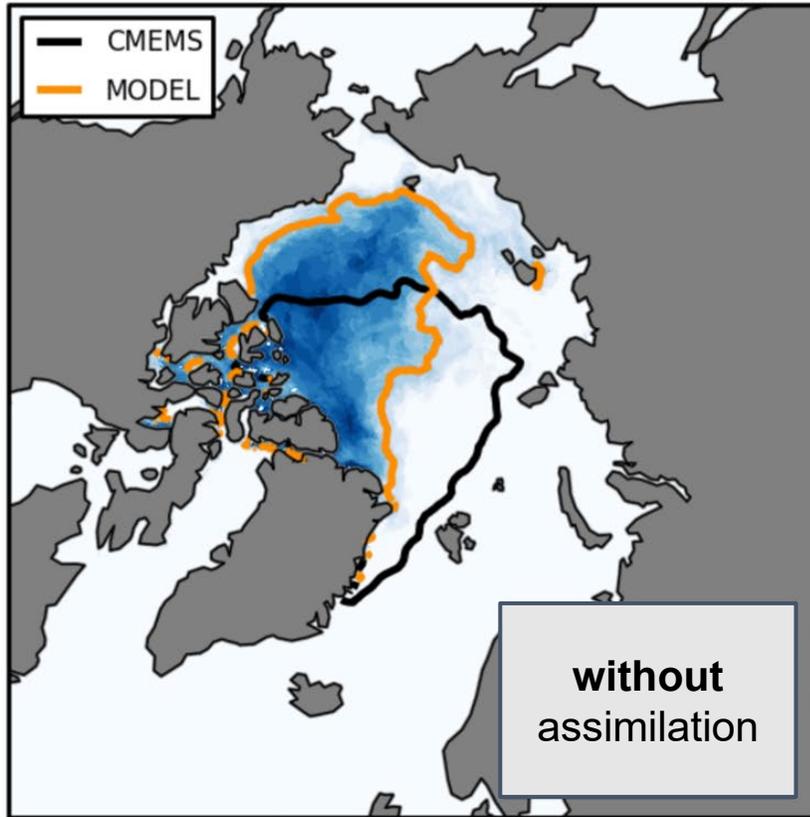
Sea ice concentration - 25 August 2020



Benefits of assimilating sea ice data (on Arctic)

Improvements in prediction skill for september sea ice edge

Assimilating Sea Ice Thickness



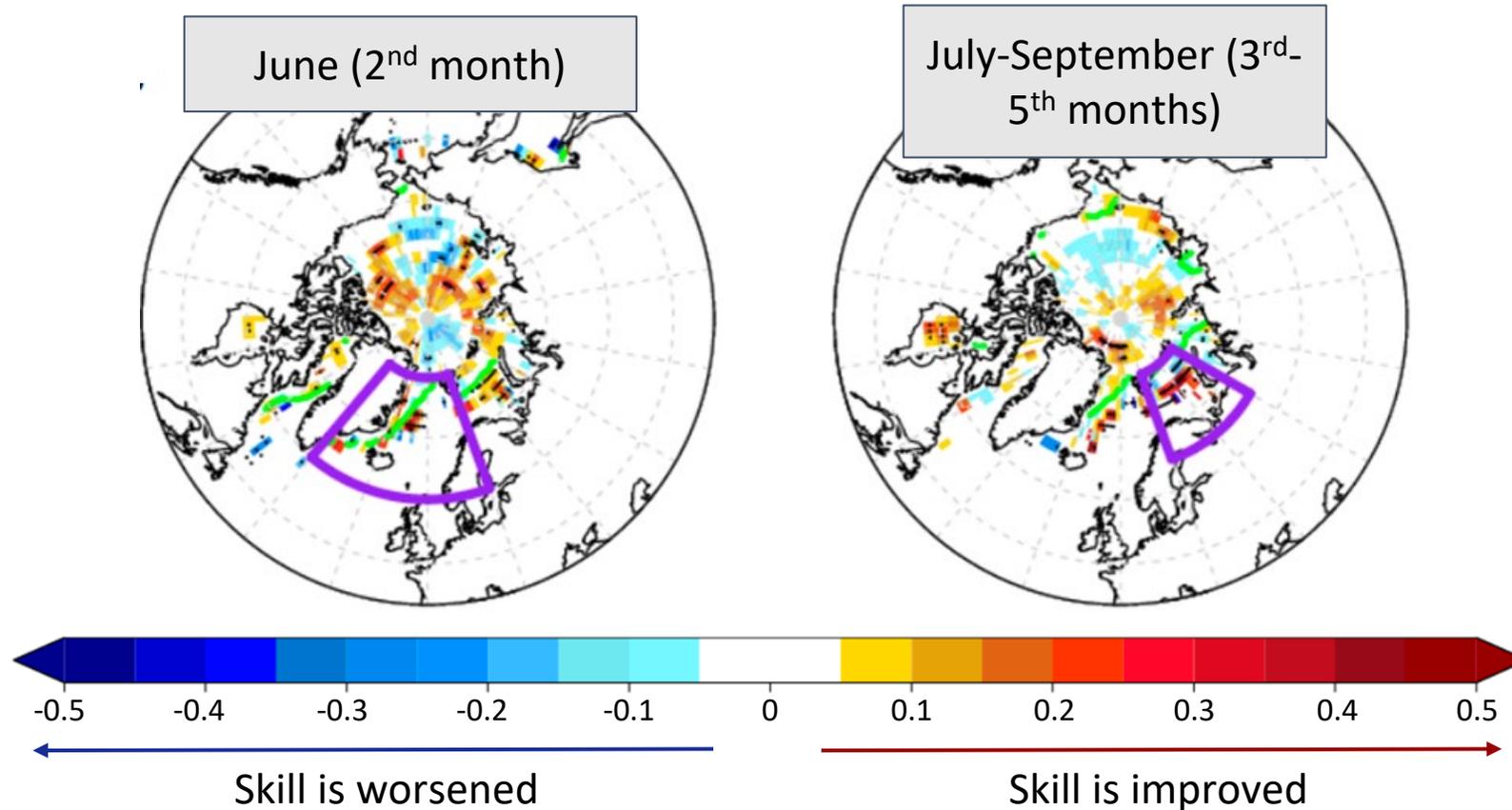
Model: **HadGEM**
Start month: **May**
Period: **2012**

Blockley & Peterson (2018)

Benefits of assimilating sea ice data (on Arctic)

Improvements in prediction skill for summer sea ice concentrations

Assimilating
Sea Ice Concentrations



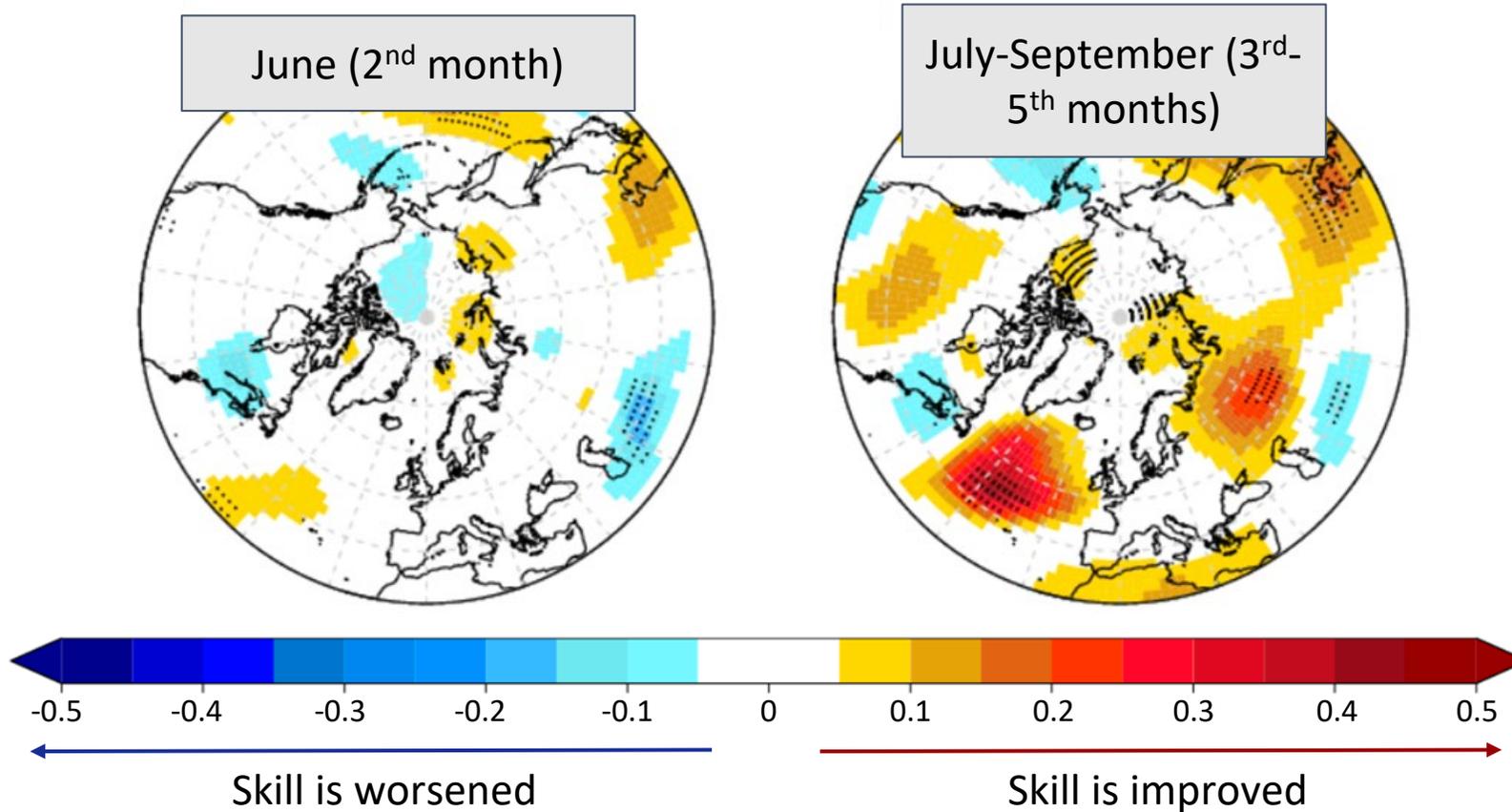
Model: **EC-Earth**
Start month: **May**
Period: **1992-2018**

Acosta-Navarro et al (in prep)

Benefits of assimilating sea ice data (beyond)

Improvements in prediction skill for summer atmospheric circulation

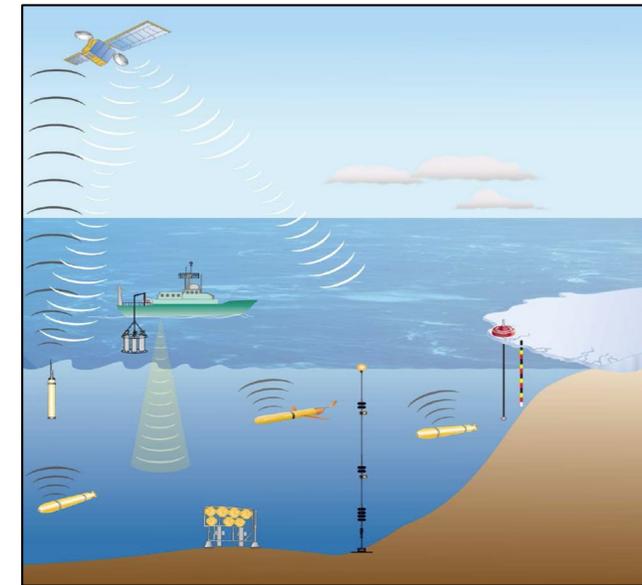
Assimilating Sea Ice Concentrations



Key take home messages

- **Arctic climate predictions are improving** their accuracy (and usefulness), benefiting from the increased observational network in the region
- **Benefits** in prediction skill are **also tangible beyond the Arctic**
- **Outside of the Arctic, ocean campaigns**, targeting in particular the ocean subsurface, **are also critical to** improve our understanding of the processes that govern the ocean circulation, its impacts on decadal variability (including the North Atlantic Cold Blob), and their **predictability**.

Sustained **observations** are **essential** to maintain and further develop current climate prediction capabilities



From Climate Predictions to Ecological Predictions

Mark R Payne

Danish Meteorological Institute

✉ mapa@dmi.dk 🐦 [@MarkPayneAtWork](https://twitter.com/MarkPayneAtWork)



Weather
Forecasts

Climate Predictions

Climate
Projections



Investment



Monitoring



Management Rules



Staffing / Resources



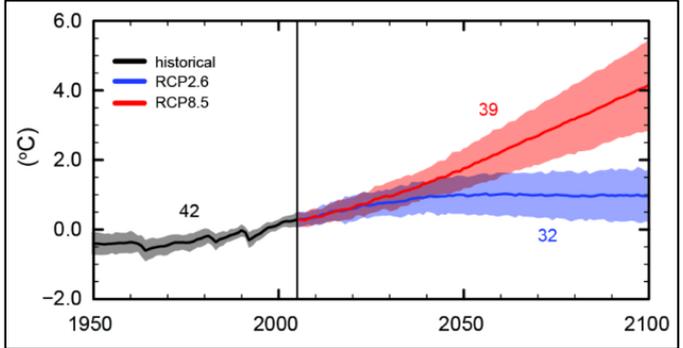
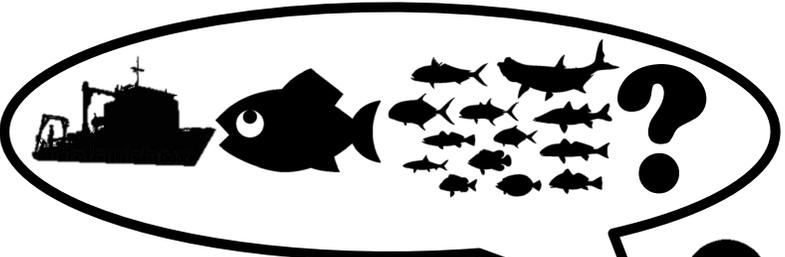
Quota



Industry
Operations



Resilience and
Sustainability



Days

Weeks

Months

Seasons

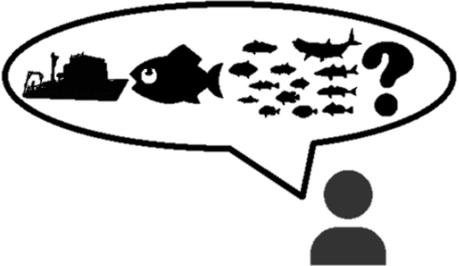
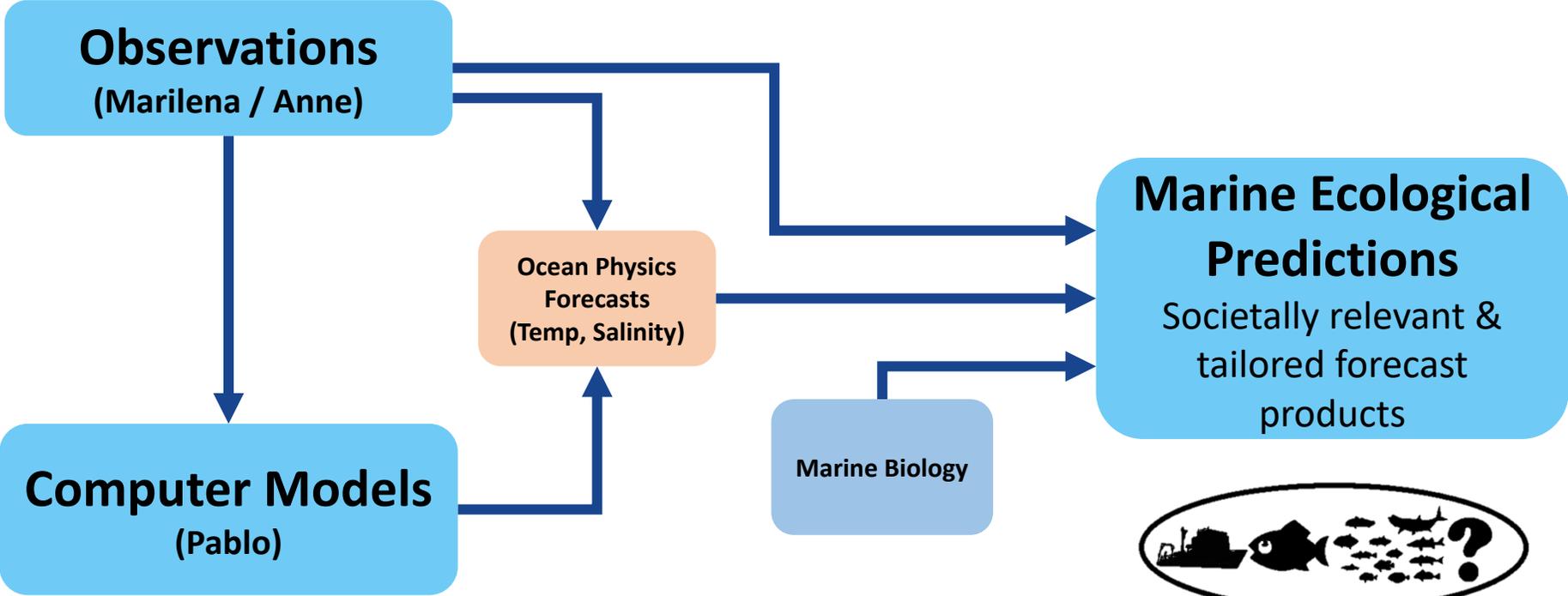
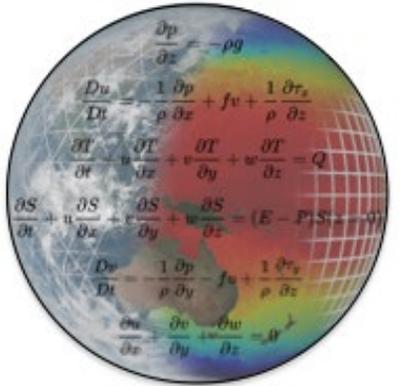
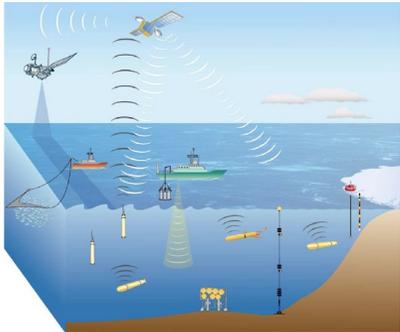
Years

Decades

Centuries



Building Marine Ecological Predictions

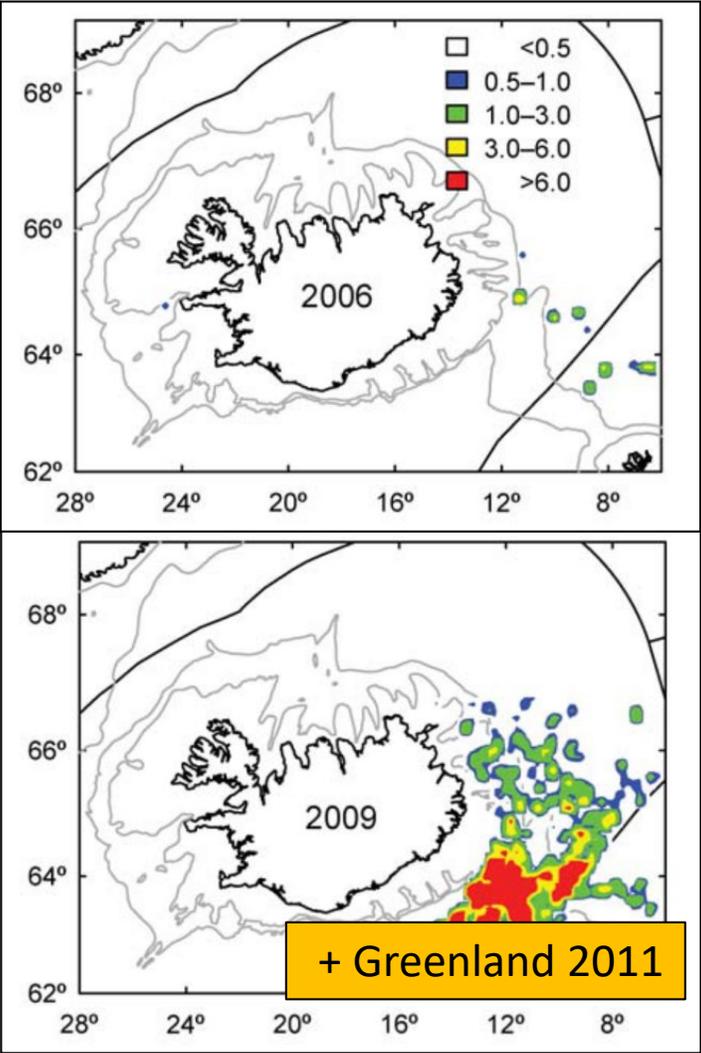


Data Information



The Great "Mackerel War"

Climate change enables a shift in fish distributions



BBC NEWS NE SCOTLAND, ORKNEY & SHETLAND

3 February 2013 Last updated at 18:29 GMT

Iceland goes it alone on mackerel quota

The Icelandic government has announced that it is lowering its mackerel fishing quota for 2013 by 15%.

It said the move is part of the country's commitment to the "long-term sustainability" of stocks.

The European Commission has said it "regrets" Iceland's announcement of a unilateral quota.

The Commission said it remained committed to a "stable and predictable" mackerel situation.

The European Commission said it is still seeking a multilateral agreement on mackerel.

THE WALL STREET JOURNAL

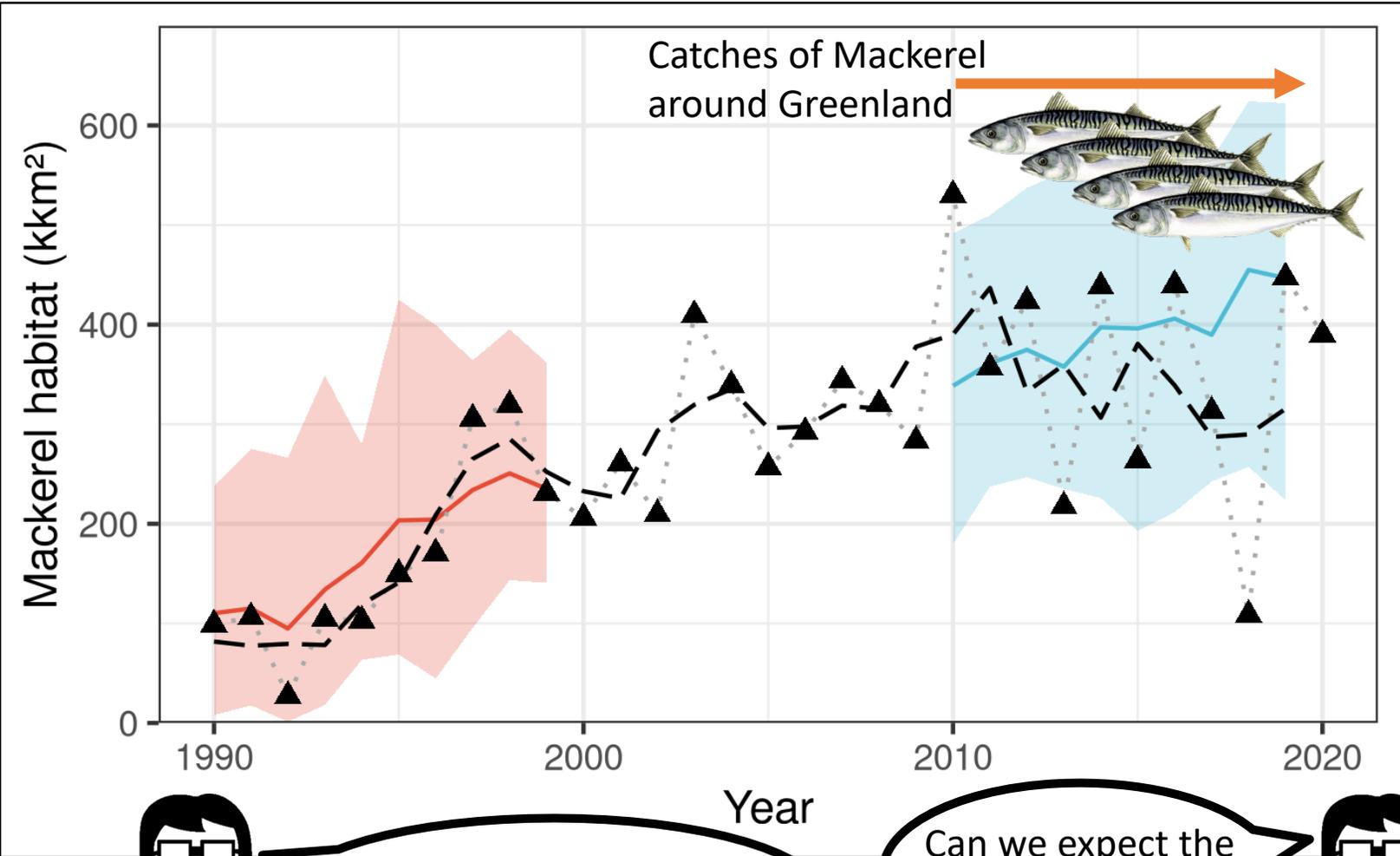
Taiwan Speaker's Concession to...

State TV: Mali's President Names New Pr...

Own Mackerel-Fishing Quota With Norway, Faroe Islands



Could we have foreseen this shift?



Observations

- ▲ Habitat
- - Rolling mean

Forecast

- 1990
- 2010



There's no mackerel now. What about the future?

Can we expect the Mackerel to remain?



Ecological forecasts can support decision making in a changing climate



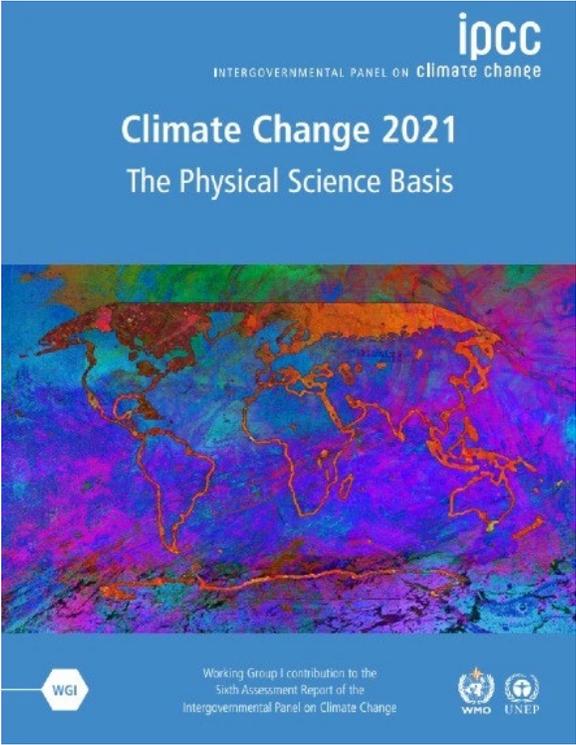
How do we go forward?



Development needs to be driven by the needs of society



Broadening the range of applications



Incorporation into Climate Adaptation and Management



From Climate Predictions to Ecological Predictions

Take home messages



Ecological variability can be predicted on seasonal to- decadal time-scales

Basis for early warning systems and climate adaptation

Society has a key role to play in guiding and shaping these forecasts



Mark R Payne

✉ mapa@dmi.dk 🐦 @MarkPayneAtWork



Scotland and global climate change

Dr. Bee Berx
Blue Action – Marine Scotland





There is a global climate
emergency.



There is a global climate
emergency.



There is a global climate
emergency.



There is a global climate
emergency.



BLUE ACTION 
Arctic Impact on Weather and Climate

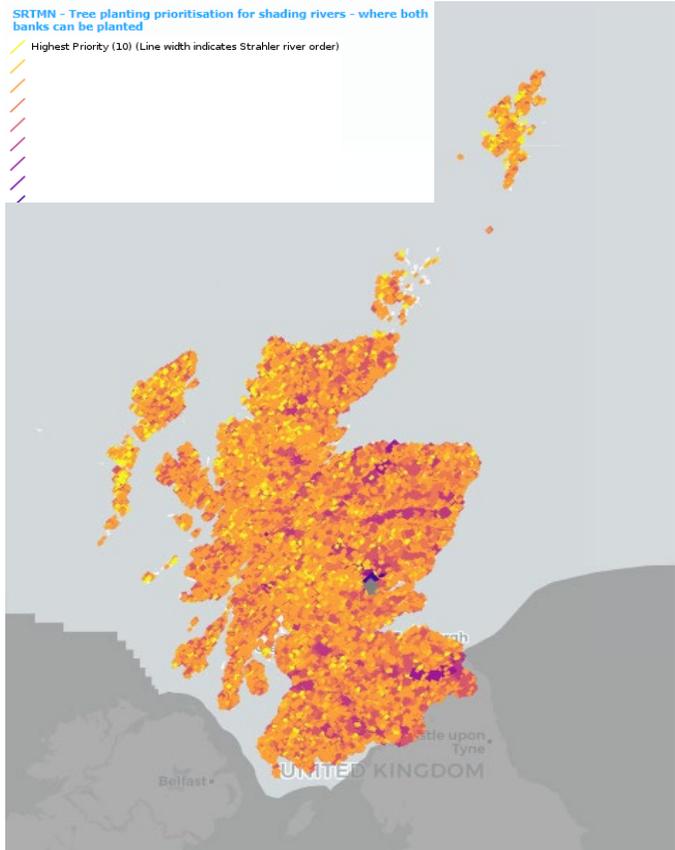
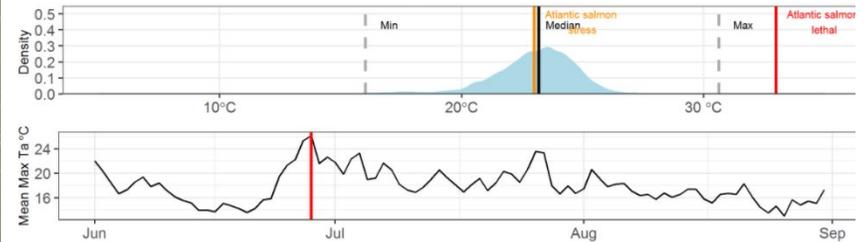
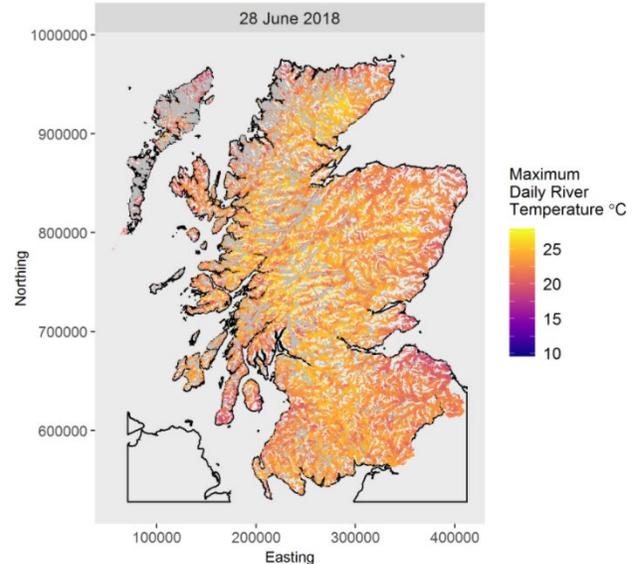
Days Weeks Months Seasons Years Decades Centuries

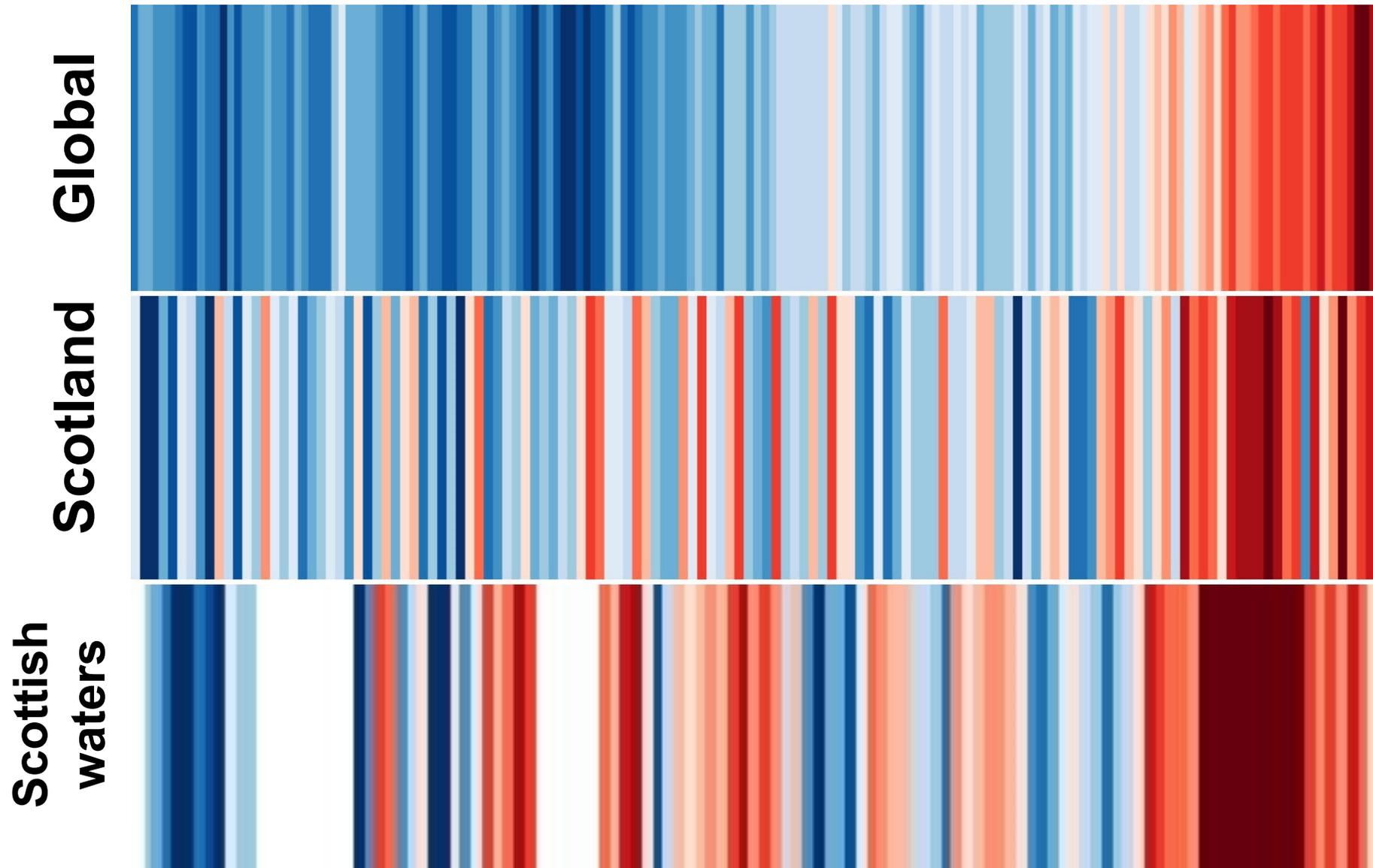


BLUE ACTION 



River temperatures, salmon and bankside trees





Scottish
waters

Global

Scotland



Scotland's climate is changing!



We could experience a **hot summer** like 2018 on average every other year by **2050**



Extreme weather events, such as Storm Ali in September 2018, are expected to become **more frequent**.



Sea level rose by **8cm** between **1900** and **1990**, and is likely to have risen by a similar amount by **2030**.

CLIMATE READY SCOTLAND: Second Scottish Climate Change Adaptation Programme 2019-2024

September 2019

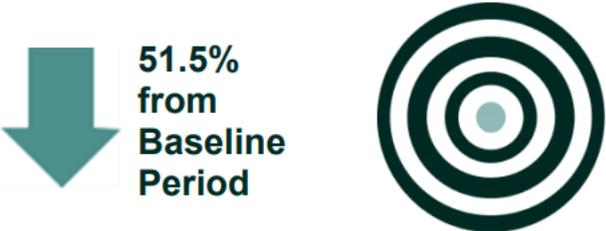


Scottish Government
Riaghaltas na h-Alba
gov.scot

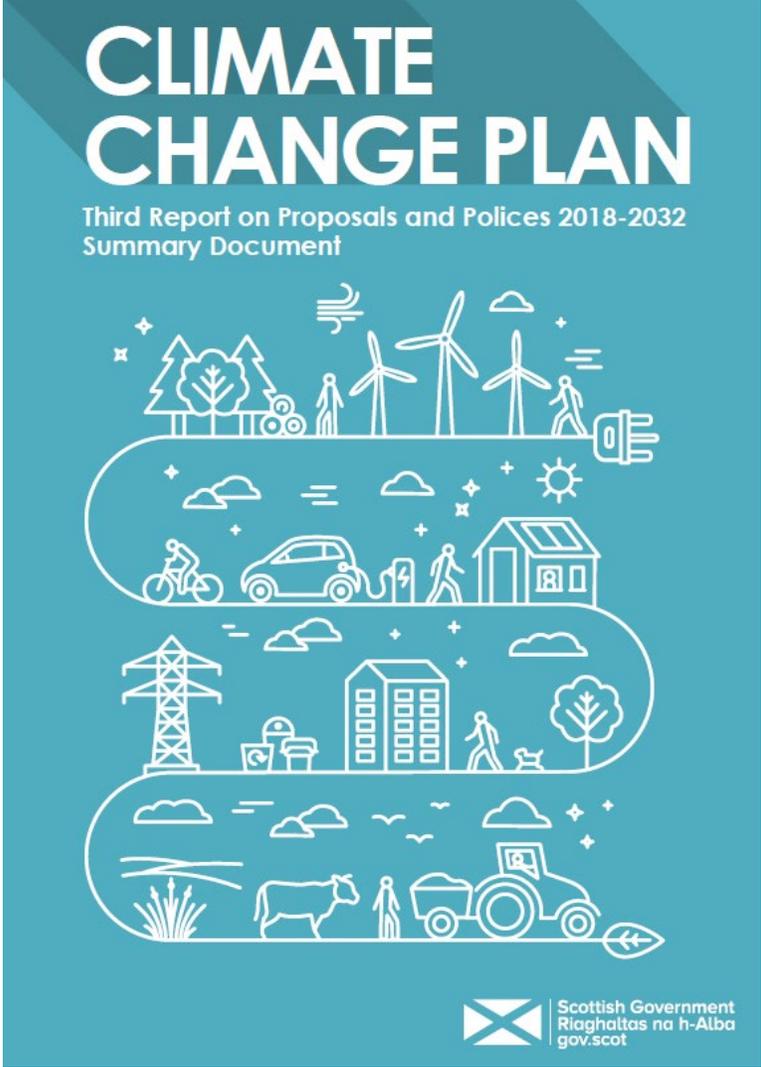
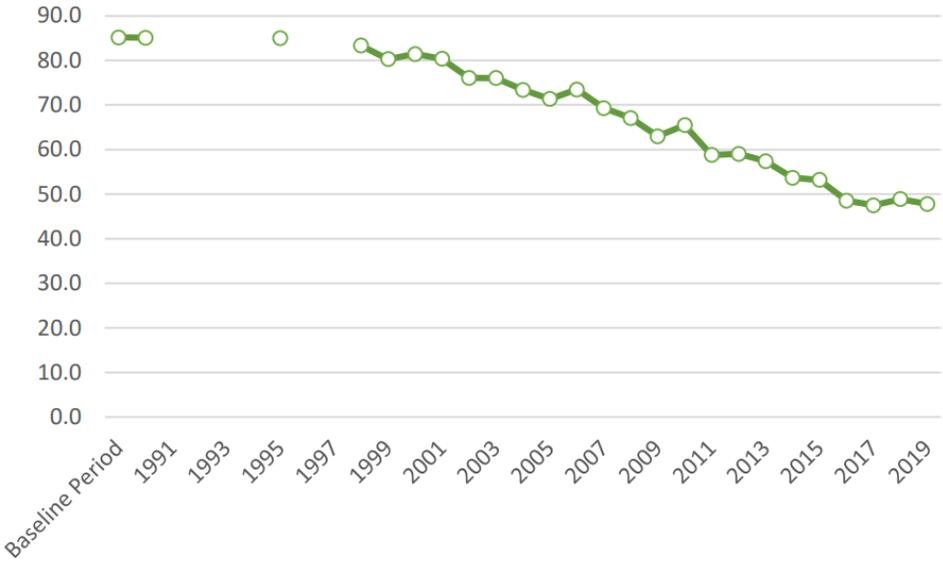


Scotland's Ambitions

Scottish Greenhouse Gas Emissions 2019

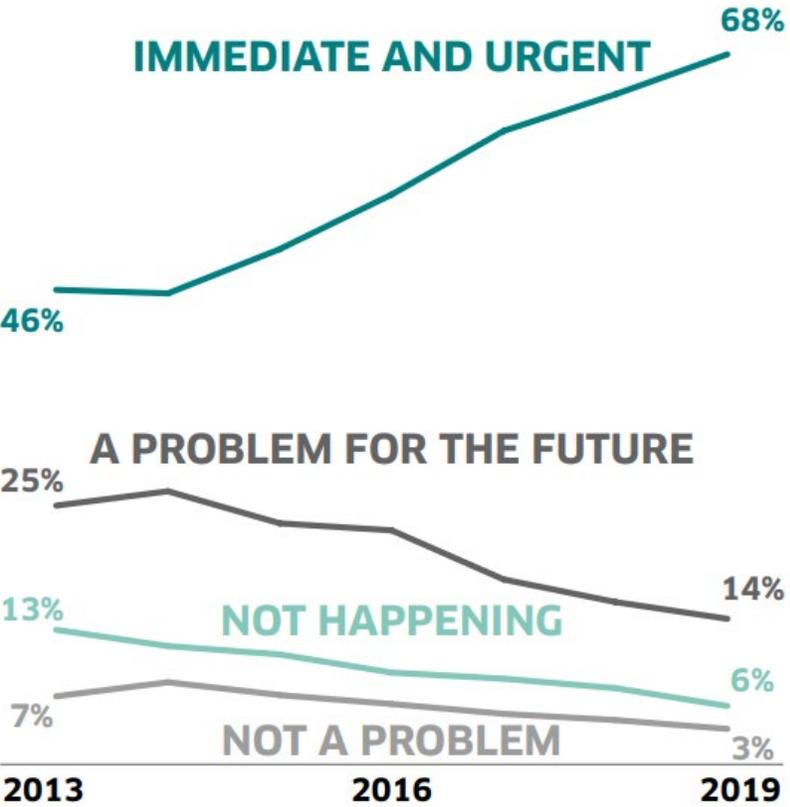


Scottish Greenhouse Gas Emissions, 1990 to 2019. Values in MtCO_{2e}



An engaged society

Climate Change is ...



The majority of adults in all age groups recognised climate change as an immediate and urgent problem

Among adults aged 75 and over, this number had increased from 46% in 2018 to 56% in 2019.



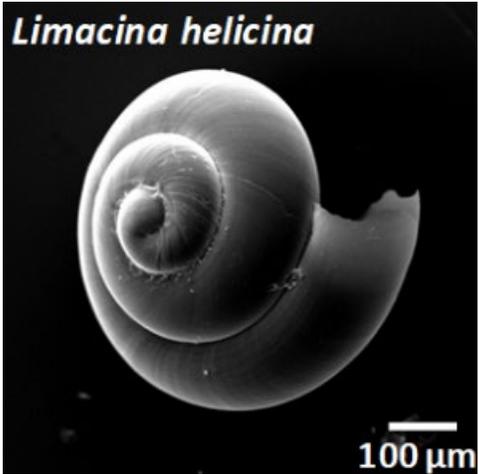
Scottish Centre for Aquatic Climate Studies



SCACS

The SCACS has three overarching aims:

- To facilitate the coordination of climate change science funded by the Scottish Government in the marine and freshwater environment
- To translate research outputs relating to climate change in the aquatic environment to policy makers and others.
- To create stronger links between Scottish Government and academia for aquatic research addressing climate change impact, monitoring, mitigation and adaptation.



Climate Change and the Blue Economy

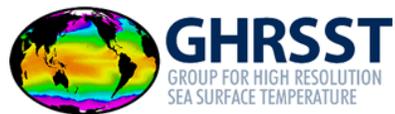


marinescotland

BLUE ECONOMY

Supporting the Just Transition to Net Zero

Enable resilience to impacts of climate change



Ocean predictions and observations in response to the climate emergency

Mark R Payne

Danish Meteorological Institute

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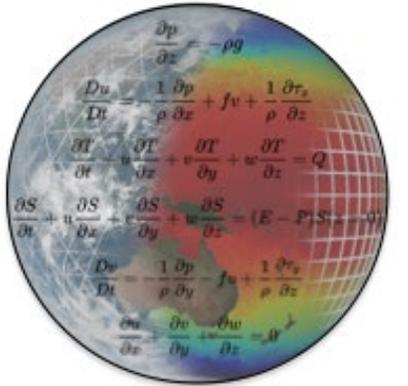
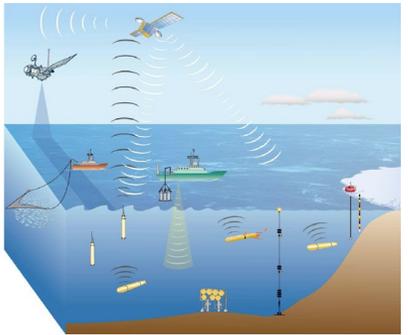
Adaptation is also necessary



Impacts for Ocean-Dependent Communities



A Predicted Ocean for Climate Adaptation

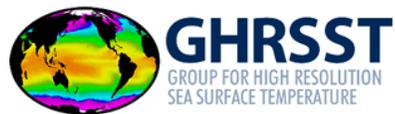


Observations
(Marilena / Anne)

Computer Models
(Pablo)

Marine Ecological Predictions
(Mark)

Policy and Decision Making
(Bee)



Ocean predictions and observations in response to the climate emergency



We have the tools to foresee the Ocean of the future

We need to link our science across disciplines and globally

Science and society must work together to shape and use forecasts

