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EXCELENCIA SEVERO OCHOA

BSC

Climate information from climate forecasts: the way forward
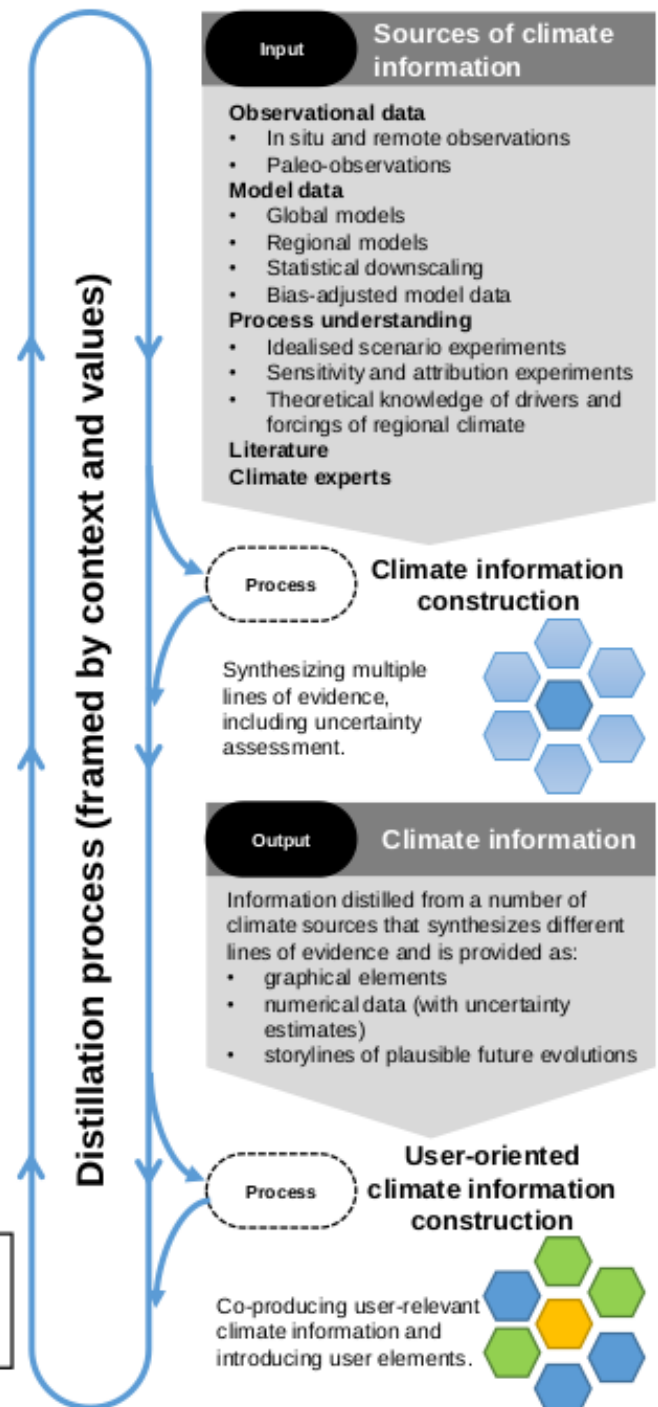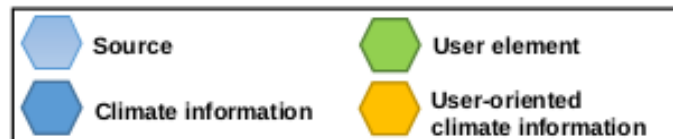
Francisco J. Doblas-Reyes

EUCP
European Climate Prediction system

ICREA

The difficult path going from climate data to climate information

Climate data individually is not able to trigger actions. Other factors are needed, especially at local and regional scales:

- A number of actors need to be involved to lead to action
- Distillation is a process that has been taking place very often in an implicit way following a top-down approach assuming that climate data has value per se

Distillation process (framed by context and values)

Input — Sources of climate information

Observational data
- In situ and remote observations
- Paleo-observations

Model data
- Global models
- Regional models
- Statistical downscaling
- Bias-adjusted model data

Process understanding
- Idealised scenario experiments
- Sensitivity and attribution experiments
- Theoretical knowledge of drivers and forcings of regional climate

Literature
Climate experts

Process — Climate information construction

Synthesizing multiple lines of evidence, including uncertainty assessment.

Output — Climate information

Information distilled from a number of climate sources that synthesizes different lines of evidence and is provided as:
- graphical elements
- numerical data (with uncertainty estimates)
- storylines of plausible future evolutions

Process — User-oriented climate information construction

Co-producing user-relevant climate information and introducing user elements.

Source
Climate information
User element
User-oriented climate information

Barriers for climate data to become information

Some limi... ...of climate data... ...mic

→ **Possible solution:** to distil climate data sources into information to be integrated in decision-making.

↓

Climate services

...opment and ...mate ...mate ...ng

reg...

• **Impleme...** production a...

💡 L...

🧠 **Difficult interpretation**

🖥 **Lack of expert synthesis**

While social and human sciences are key for success, the quality of the service is severely limited by the quality of the current climate data sources

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Climate information: the Filomena case

Climate forecasts weeks in advance allow the management of the logistic of seasonal products, focusing on better marketing campaigns and prices policies to avoid extra costs, and avoid running out of products. An example is offered by the large increase in sales of mountain equipment during the Filomena snow storm, which hit hard the centre and north of the Iberian Peninsula in January 2021.
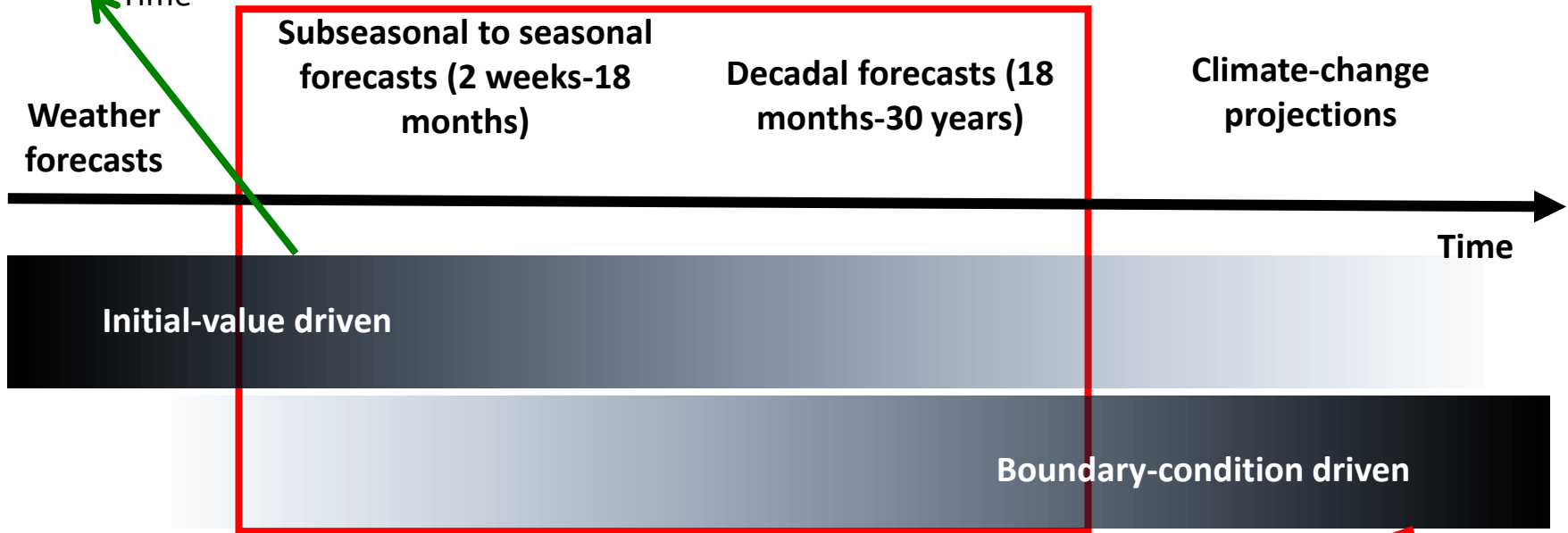
BSC works in a research agreement to design a targeted service for the sector that brings together climate and social scientists with the user.
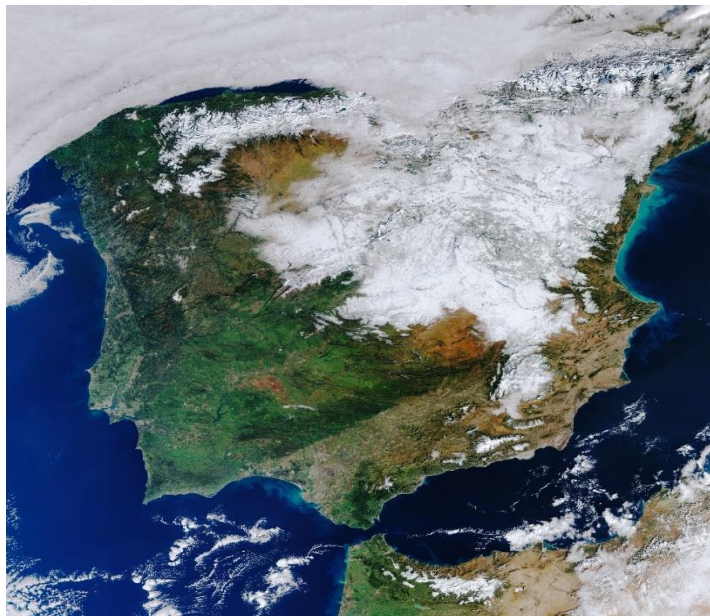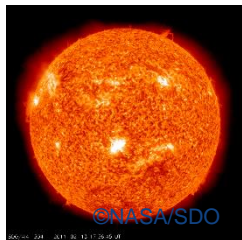
Climate prediction time scales

atmosphere (weather)

land

ocean/sea ice

Predictability

Time
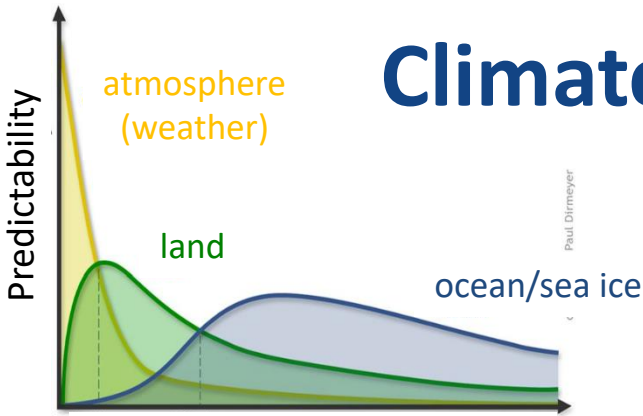
Predictability arising from the memory of slow processes/components in the climate system

Weather forecasts

Subseasonal to seasonal forecasts (2 weeks-18 months)

Decadal forecasts (18 months-30 years)

Climate-change projections

Time

Initial-value driven

Boundary-condition driven

Solar activity

©NASA/SDO

GHG and aerosols

©European Environment Agency

Volcanic aerosols

©Ulet IfansastiGetty Images

Predictability relying on good guess of future changes in the forcing

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Adapted from Meehl et al. (2009) and Mariotti et al. (2018)
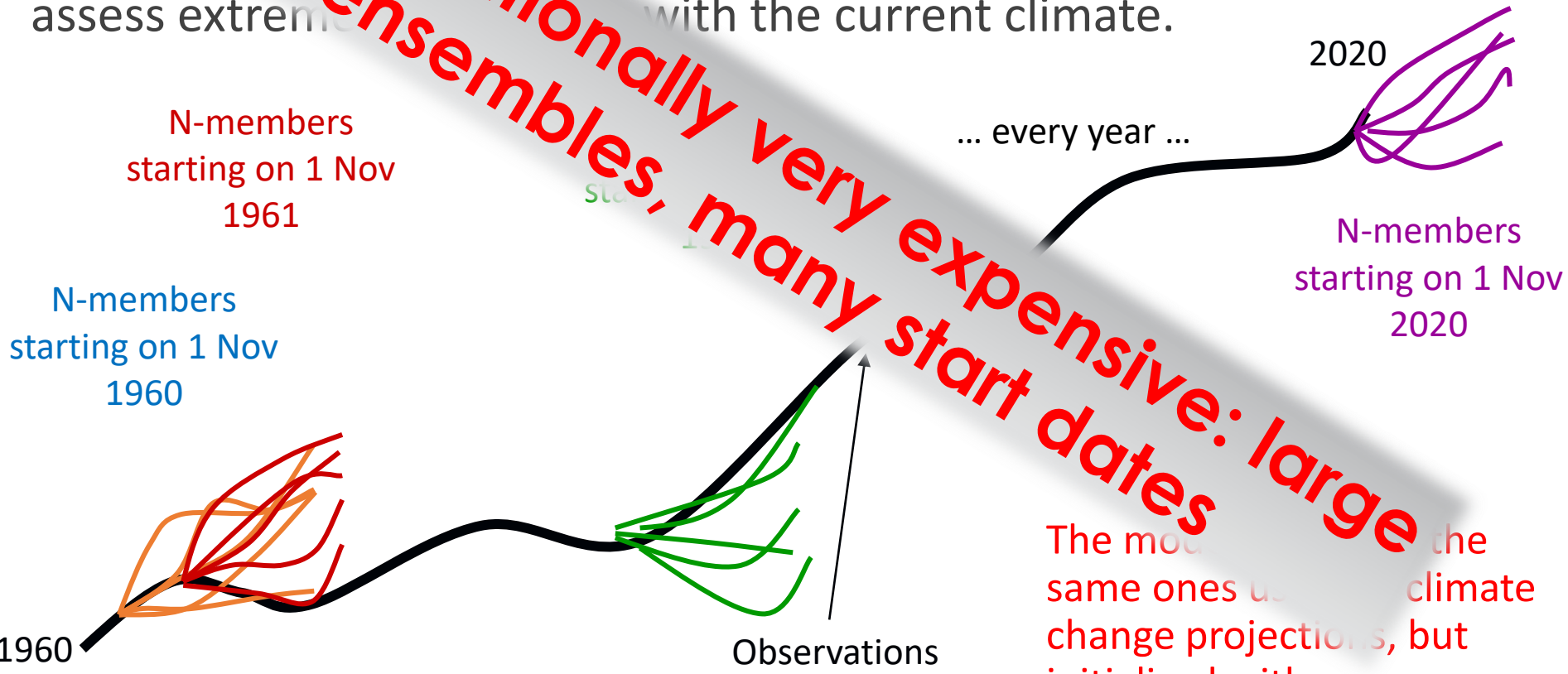
Decadal climate prediction

Decadal prediction is a source of information for the next ten years. It is used to estimate the evolution of global physical variables, but also to assess the carbon fluxes in the ocean, the short-term impact of mitigation measures, updates after climate shocks (volcanoes) or to assess extremes compatible with the current climate.
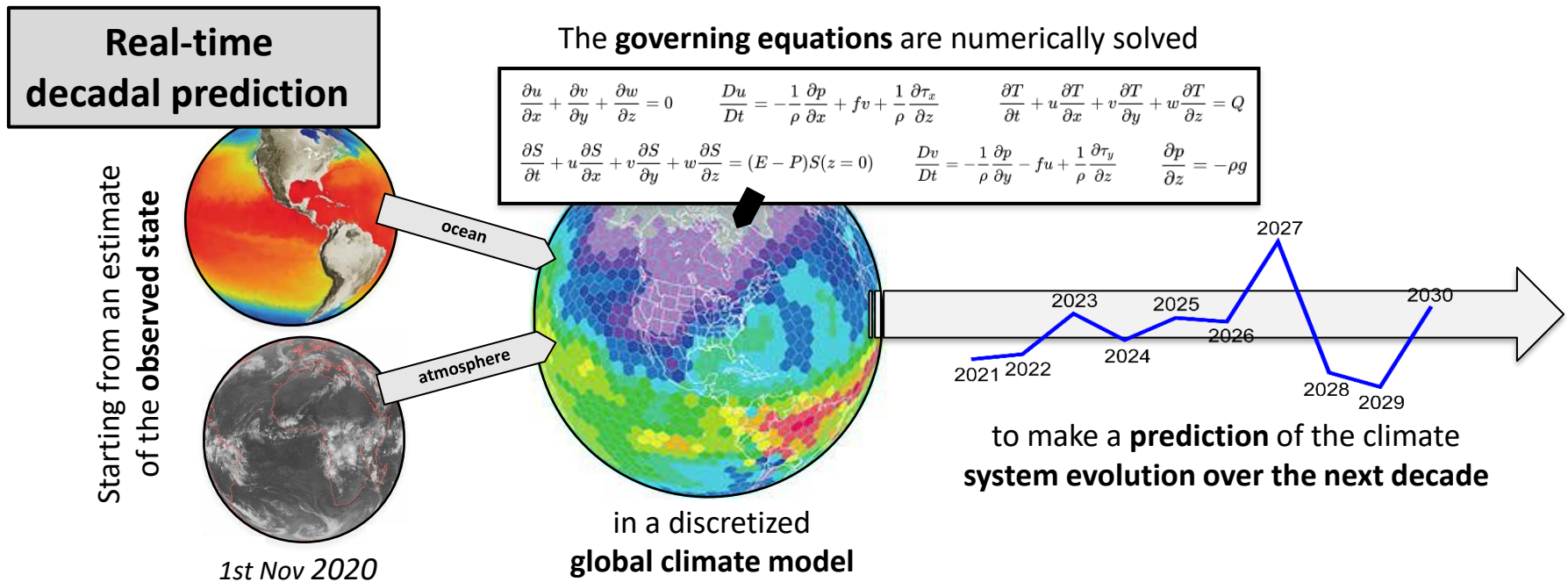
Real-time decadal prediction

Starting from an estimate of the **observed state**

ocean

atmosphere

1st Nov 2020

The **governing equations** are numerically solved

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \qquad \frac{Du}{Dt} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + fv + \frac{1}{\rho}\frac{\partial \tau_x}{\partial z} \qquad \frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = Q$$

$$\frac{\partial S}{\partial t} + u\frac{\partial S}{\partial x} + v\frac{\partial S}{\partial y} + w\frac{\partial S}{\partial z} = (E-P)S(z=0) \qquad \frac{Dv}{Dt} = -\frac{1}{\rho}\frac{\partial p}{\partial y} - fu + \frac{1}{\rho}\frac{\partial \tau_y}{\partial z} \qquad \frac{\partial p}{\partial z} = -\rho g$$

in a discretized **global climate model**

2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

to make a **prediction** of the climate **system evolution over the next decade**

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N-members starting on 1 Nov 1961

N-members starting on 1 Nov 1960

… every year …

2020

N-members starting on 1 Nov 2020

Observations

The models are the same ones used for climate change projections, but initialized with observations.

Computationally very expensive: large ensembles, many start dates

1960

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Decadal climate forecasts are skilful

Skill of decadal predictions is highly sensitive to the ensemble size due to the low signal-to-noise ratio (multi-model sea level pressure correlation with more than 100, left, and 10 members, right). Careful member selection (160 members) unveils untapped skill for northern European precipitation for the next nine years (bottom).


ACC

-0.9   -0.6   -0.3   0.0   0.3   0.6   0.9

10-member ACC

-0.9   -0.6   -0.3   0.0   0.3   0.6   0.9

ACC = 0.72 (P < 0.01), RPC = 1.1

NAO-matched

— Observations
— Model

1960   1970   1980   1990   2000

Start of 8-year period

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Smith et al. (2020, Nature)
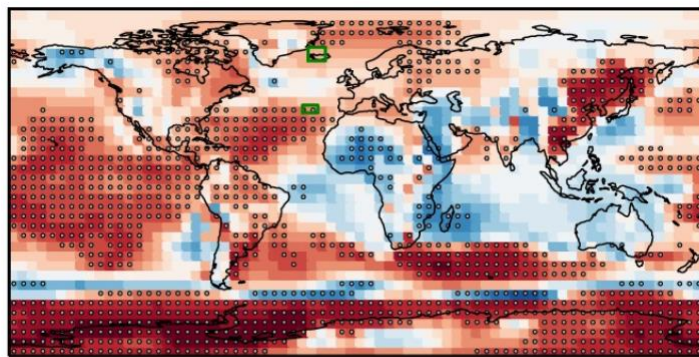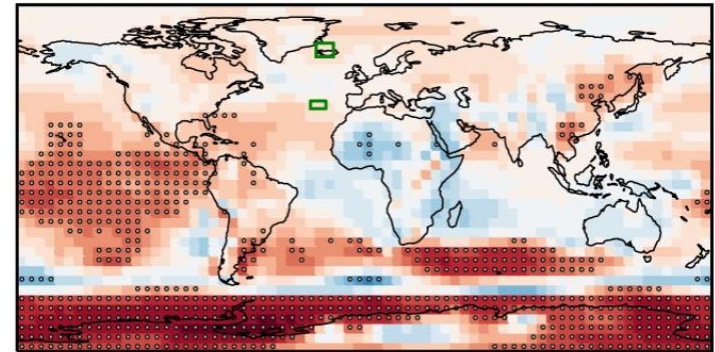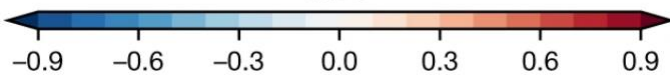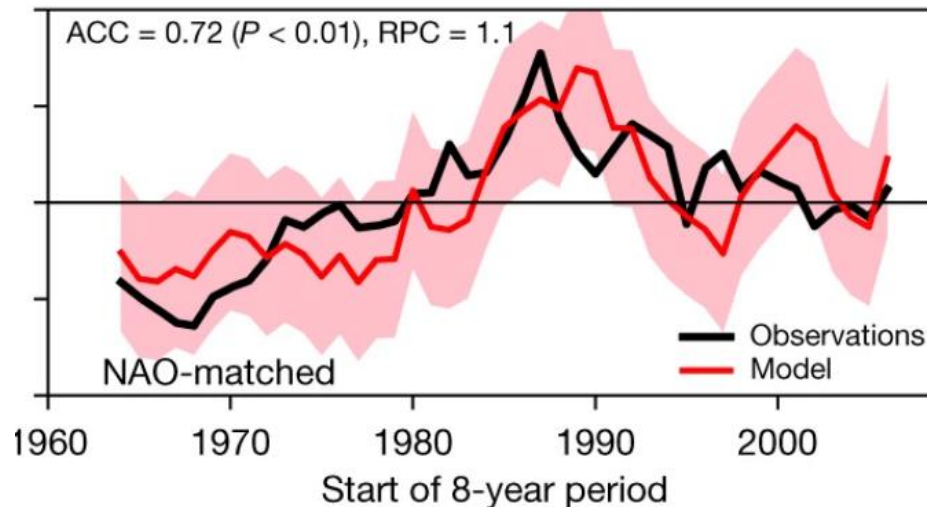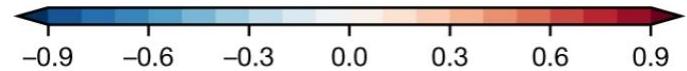
Decadal prediction of crop yield indices

C3S promotes the evaluation of the European multi-model through the illustration of the decadal prediction added value in, among other sectors, the agricultural sector using indicators defined by key stakeholders like the EC Joint Research Centre.

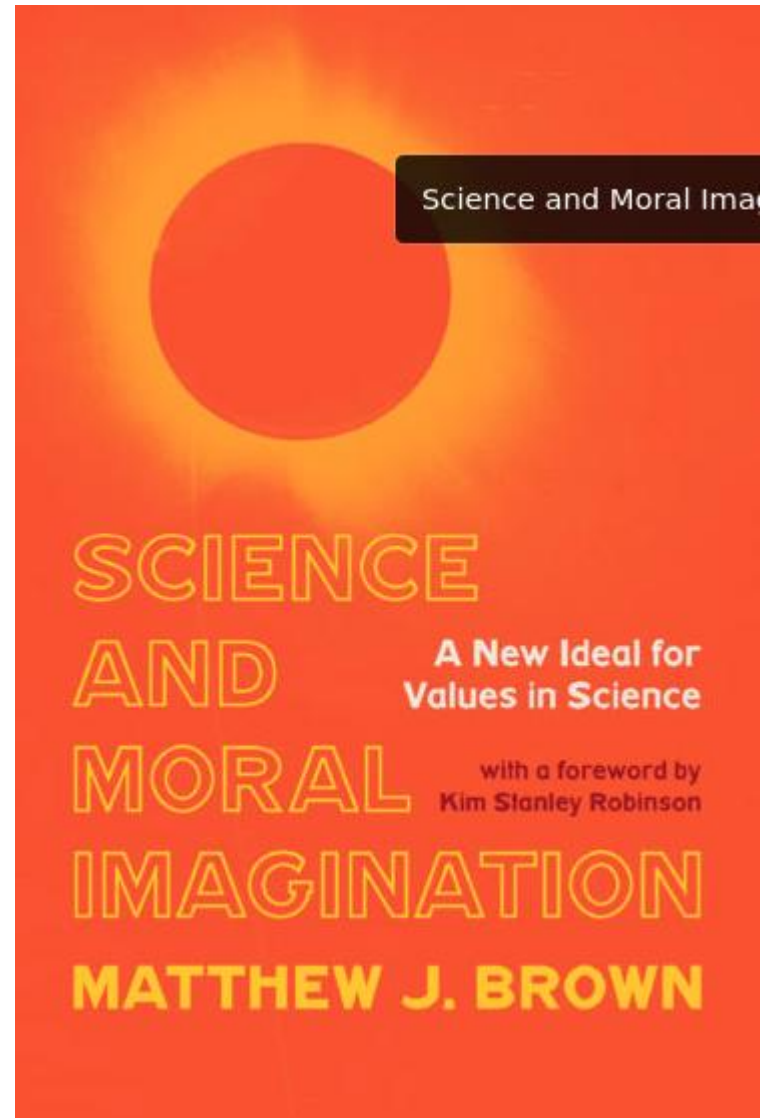Local wheat harvesting months
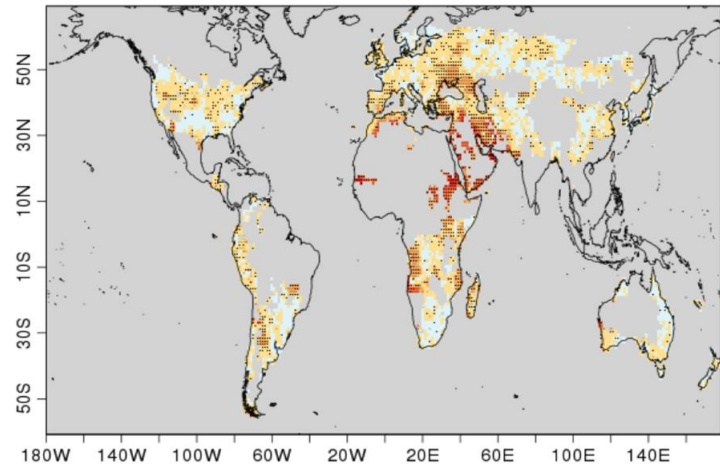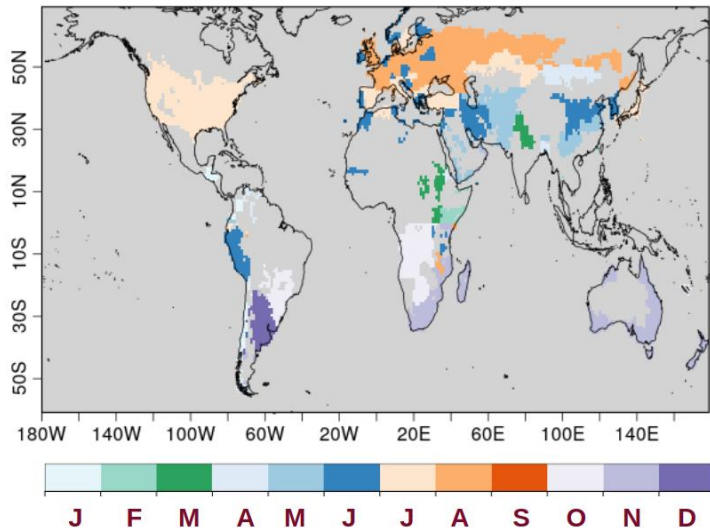
SPEI6

RPSS (3 cat.)
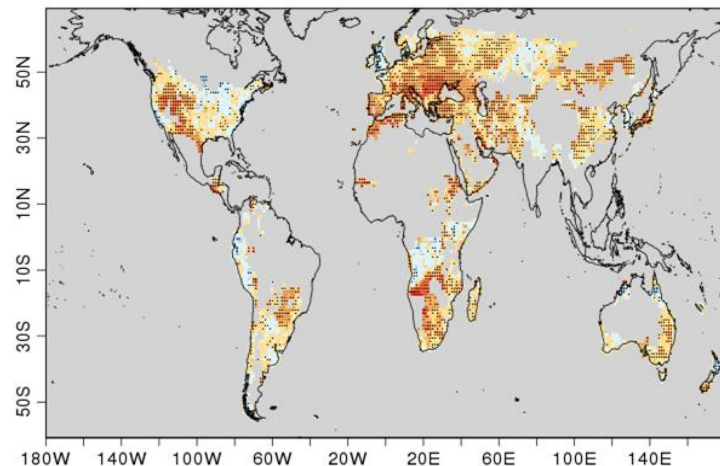
HMDI3

Indicators:

- Drought: Standardized Precipitation Evapotranspiration Index (SPEI6)
- Heat stress: Heat Magnitude Day Index (HMDI3)

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Copernicus
Europe's eyes on Earth

Climate Change Service

Solaraju-Murali et al. (2021, NPJ Climate)

But climate data sources are not good enough

Reliance on not good enough models leads to overconfidence, which, in turn, leads to underestimation of uncertainties and of physical risk.

Science and Moral Ima[ge]

SCIENCE
AND
MORAL
IMAGINATION

A New Ideal for
Values in Science

with a foreword by
Kim Stanley Robinson

MATTHEW J. BROWN

Climate modelling needs to evolve

Is Climate Change Inconvenient or Existential? Only Supercomputers Can Do the Math

BSC is a developer of the global high-resolution Earth system model configuration of EC-Earth, a global 10-km simulator (atmosphere, ocean, sea ice, BGC, land surface).

Accurate prediction
that are too expensi

By Sabine Hossenfelder
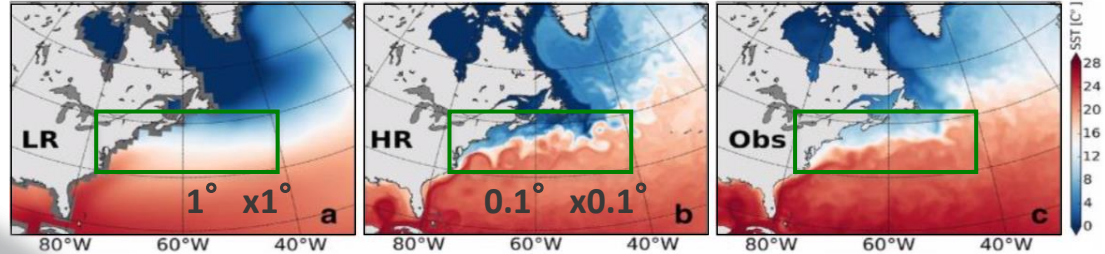
Dr. Hossenfelder is a research fel

June 12, 2019

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More realistic physical processes, initialization

Feedback from SST on ● ocean grid (ideal)
◄ atmosphere grid (actual, via coupler)

What model should do What model

Snapshot of a monthly SST field (*Kirtman and Siqueira 2016*)

Essential to resolve **frontal interactions** in the **Gulf Stream** and the local **ocean eddy-forcing**
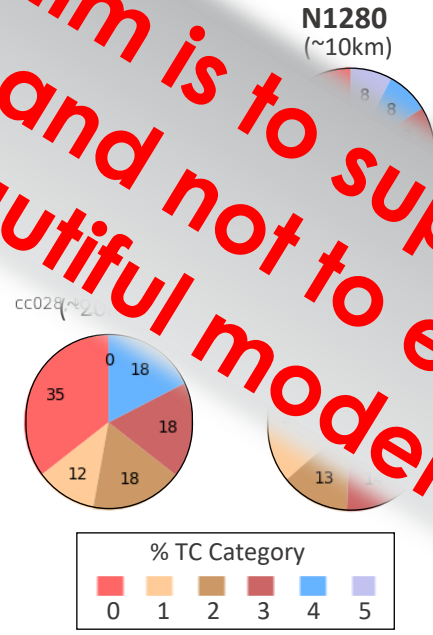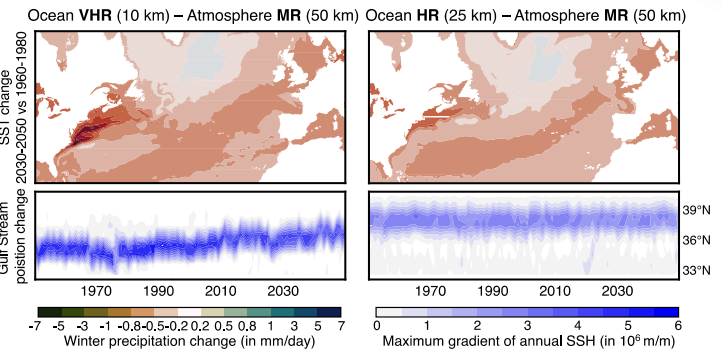
Moreton et al. (2020)
Eddy trajectories (> 6 months)

Moreton et al. (under review)
Damping is **too weak** if **atmosphere grid** is **not fine enough**: implications for fluxes and eddy lifetimes

Ocean **VHR** (10 km) – Atmosphere **MR** (50 km) Ocean **HR** (25 km) – Atmosphere **MR** (50 km)
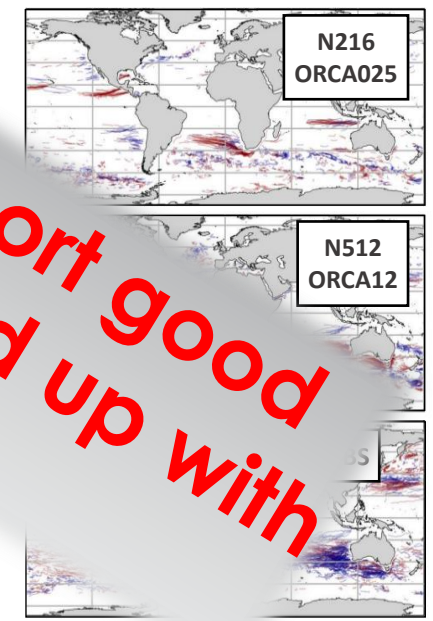
Moreno-Chamarro et al. (2021)
Gulf Stream more variable and **sensitive** if **ocean eddies** are **resolved**

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PRIMAVERA

Proportion of storms in each TC category (based on MSLP) **improve with atmospheric resolution**

% TC Category
0 1 2 3 4 5

Cyclonic   Anti-cyclonic

N216 ORCA025

N512 ORCA12

Long-lived eddies require of **higher ocean resolutions**

Important: the aim is to support good decision-making and not to end up with just a beautiful model

Computational efficiency of climate models

One example: load balance of components of an Earth system model.
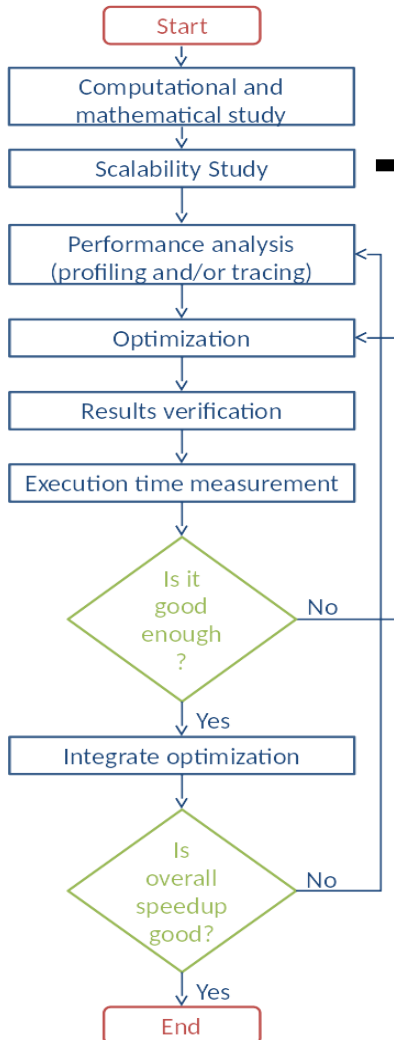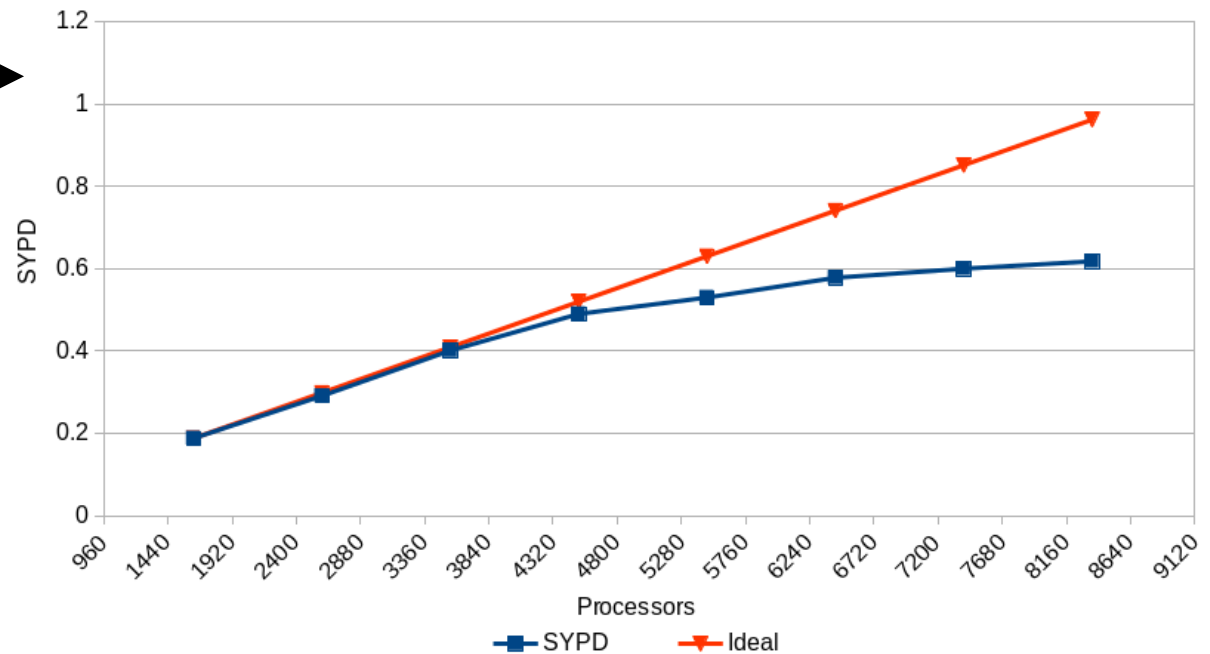
The role of DestinE

DestinE can play a key role in changing the operational climate prediction scene to **benefit local and regional actors**:

- **Better use of observations**: Climate forecasting has underused the available observations so far.

- **Better models**: Climate models still have substantial systematic errors that limit forecast usefulness.

- **New platforms**: Prepare models for new HPC and HPDA platforms and enable ambitious experiments.

- **Upgraded workflows and data treatment**: Fit in the new generation of machines workflows with very rich data streams to satisfy user requirements.

- **Climate predictions and climate projections**: Improvements in any of the two types of data sources will benefit the other one, there is no "either … or".

Salience

Credibility

Legitimacy

Power

Reputation

Values

Transparency

Standards

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