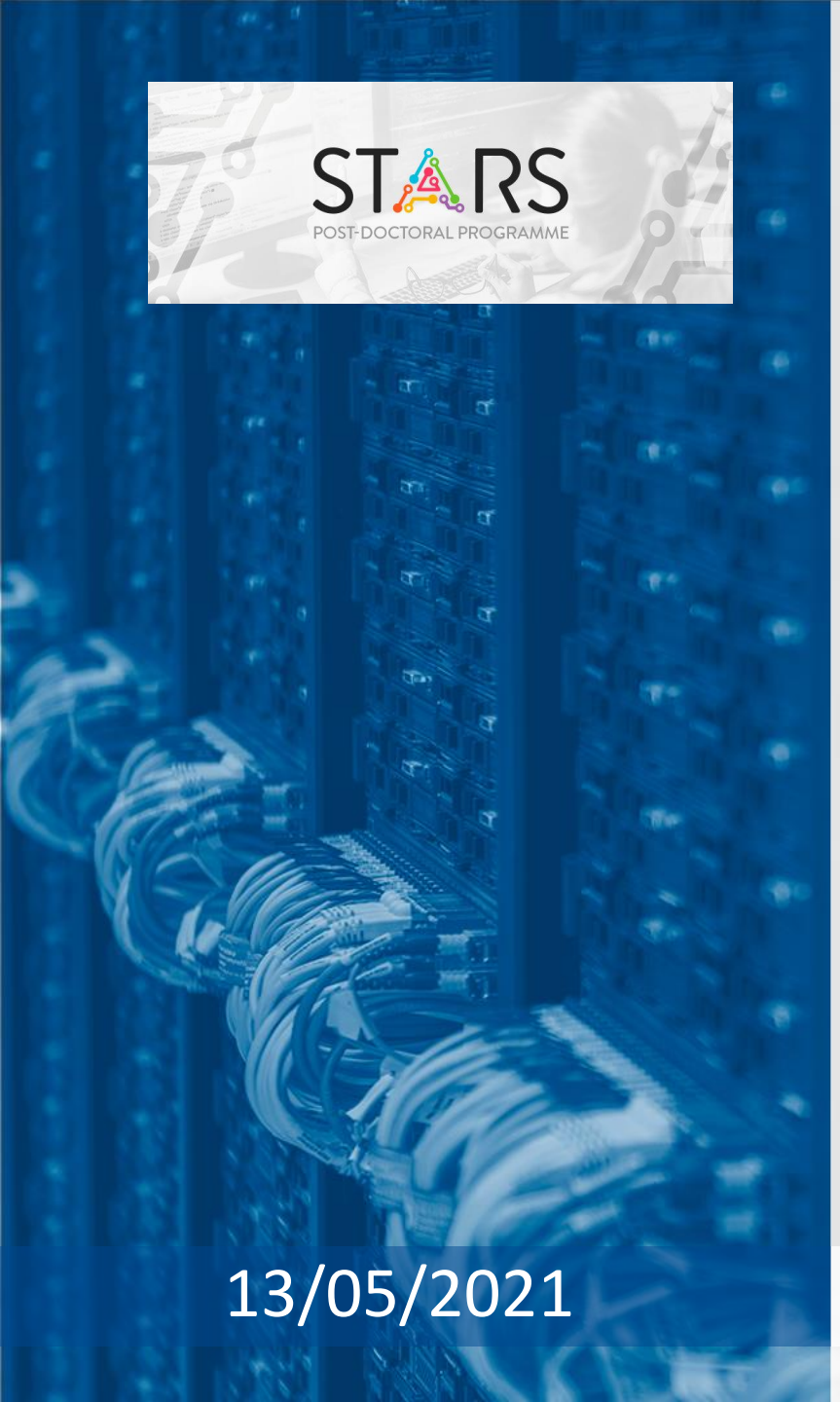


STARS
POST-DOCTORAL PROGRAMME

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EUCP
European Climate Prediction system

High-Resolution Decadal Prediction

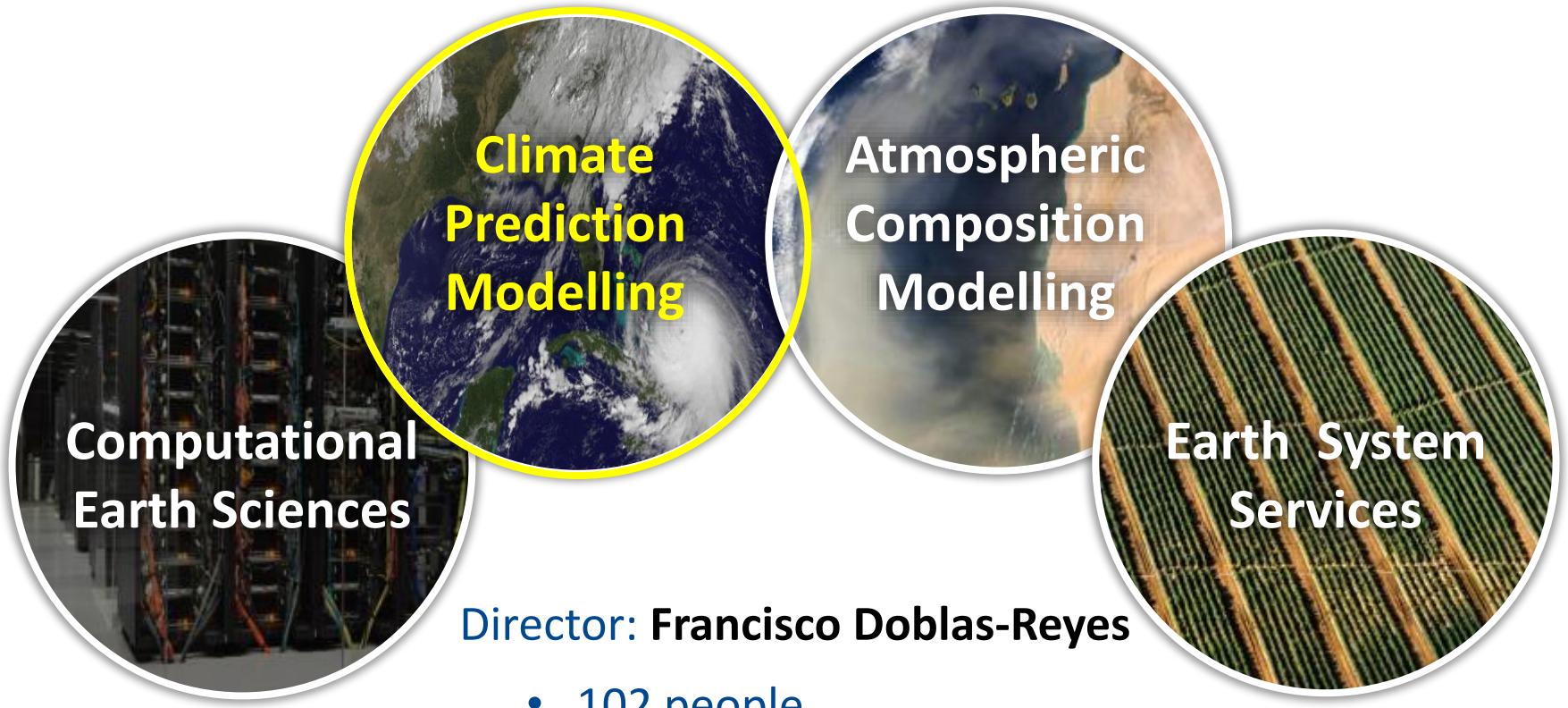
Aude Carréric, Pablo Ortega

13/05/2021

8th BSC Doctoral Symposium

Earth Science Department

Environmental modelling and forecasting, with a particular focus on weather, climate and air quality



Director: **Francisco Doblas-Reyes**

- 102 people
- Leading: H2020 projects, COPERNICUS contracts, ERC Consolidator Grant and hosts an AXA Chair

Context and motivation

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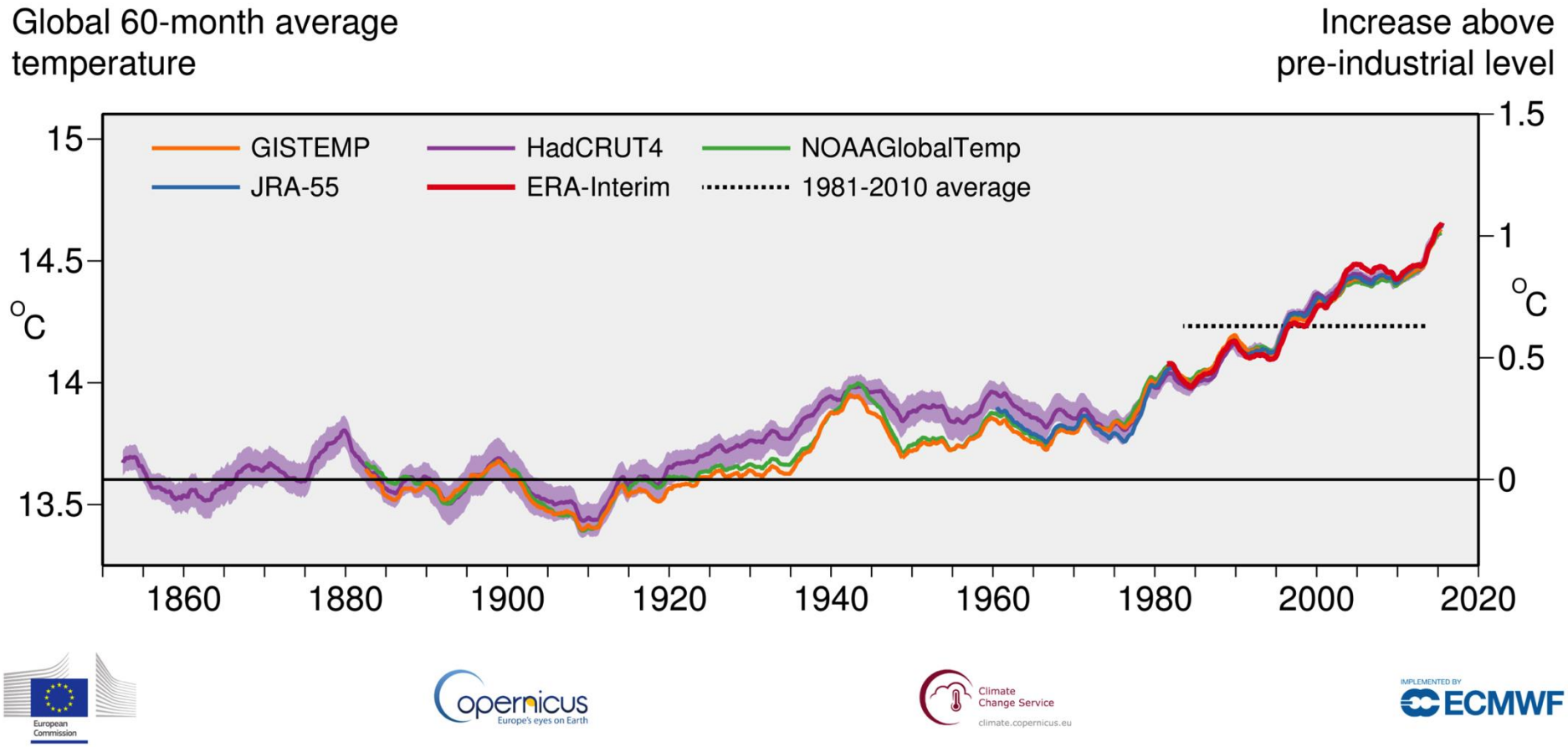
Centro Nacional de Supercomputación

Climate is changing…



…we need to prepare for climate conditions to come

https://climate.copernicus.eu/ESOTC/2019/surface-temperature

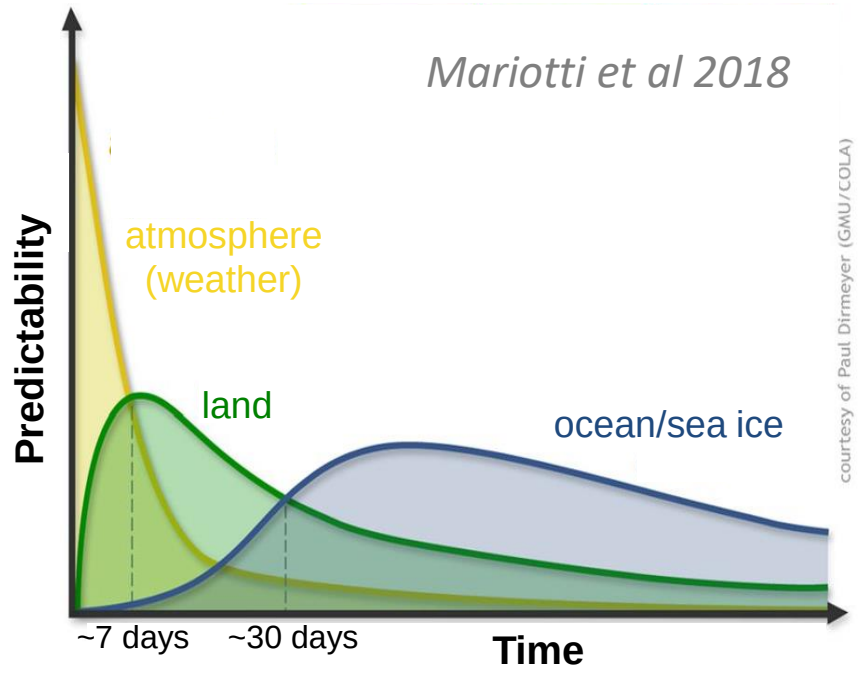
Climate Prediction

Weather forecasts — 1-15 days

Climate predictions — 10-32 days (Sub-seasonal) | 1-15 months (Seasonal) | 1-30 years (Decadal)

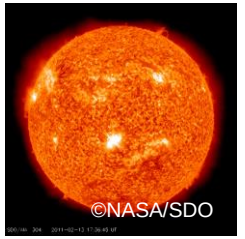
Climate projections — 20-100 years

Initial value problem: Predictability arising from the memory of slow processes and components in the climate system



Forced boundary condition problem: Predictability relying on good guess of future changes in radiative forcing

Solar Activity



Volcanic Aerosols

GHGs

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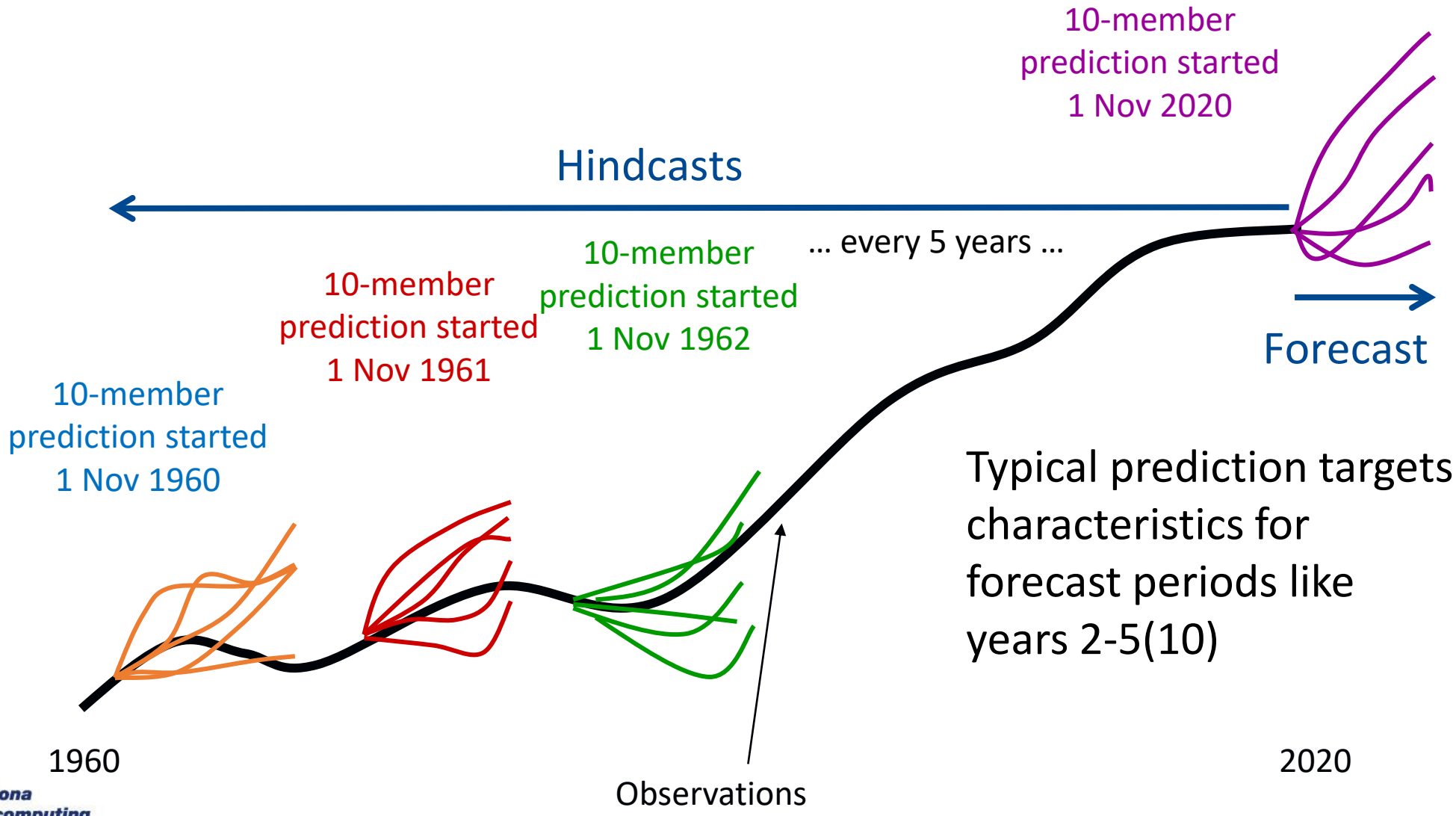
Introduction to Climate Prediction Systems



Typical prediction targets characteristics for forecast periods like years 2-5(10)

Producing Decadal Climate Prediction Systems

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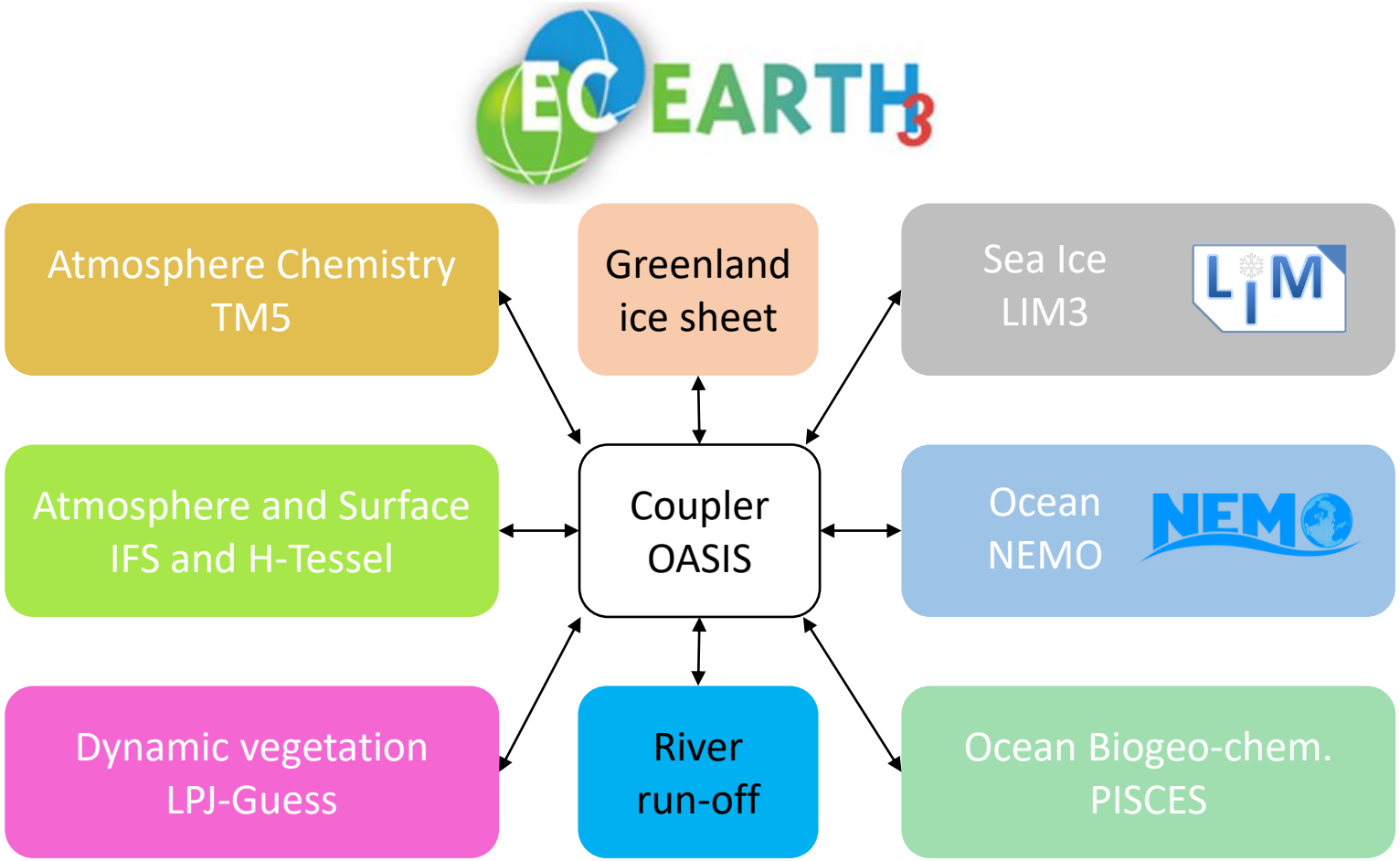
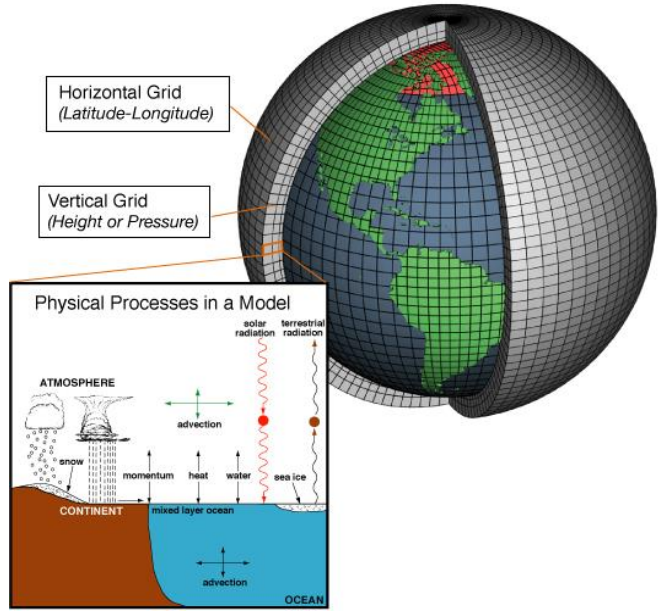
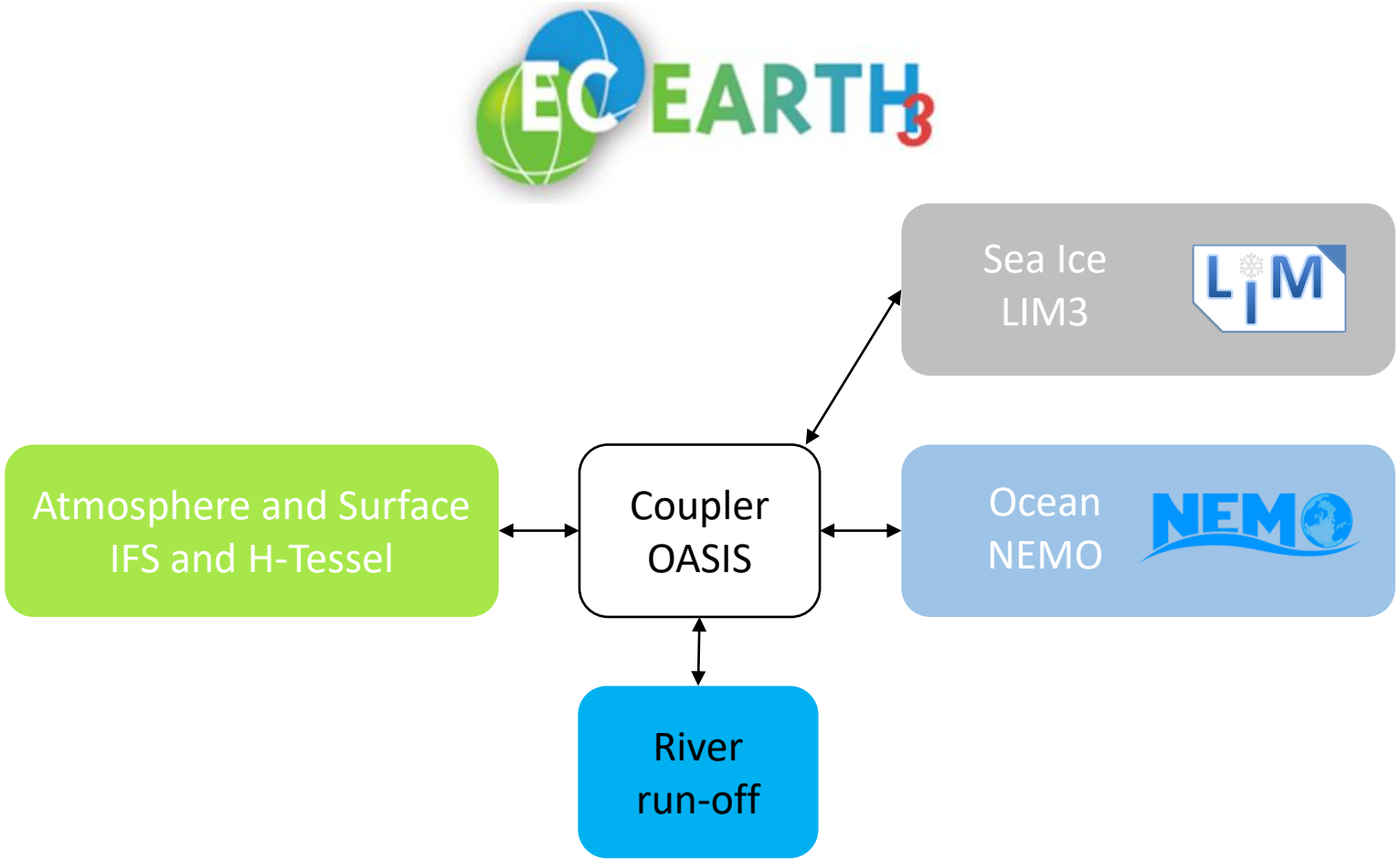
Earth System Model (ESM)

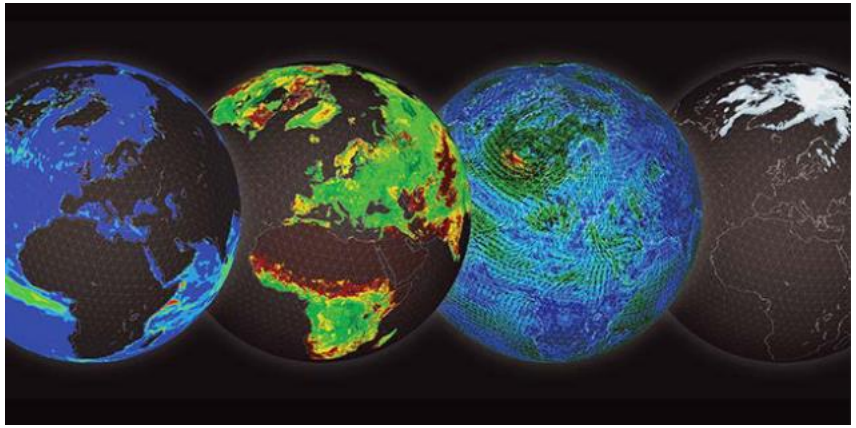




Atmosphere-Ocean Global Climate Model (AOGCM)



Ocean – Land – Atmosphere – Sea Ice



High-resolution version of EC-Earth3

Model Components

IFS (Atmospheric Model):
T511 ~39km
L91 (top 0.01hPa) ~mesosphere
IFS-HTESSEL (Land Model)

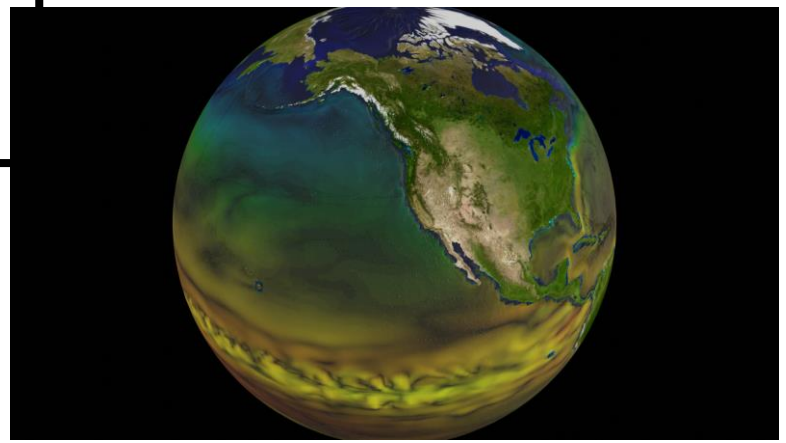
NEMO (Ocean Model):
Nominal 0.25˚ resolution
L75 levels (thousands km deep)

LIM (Sea-ice Model):
Multiple (5) ice category

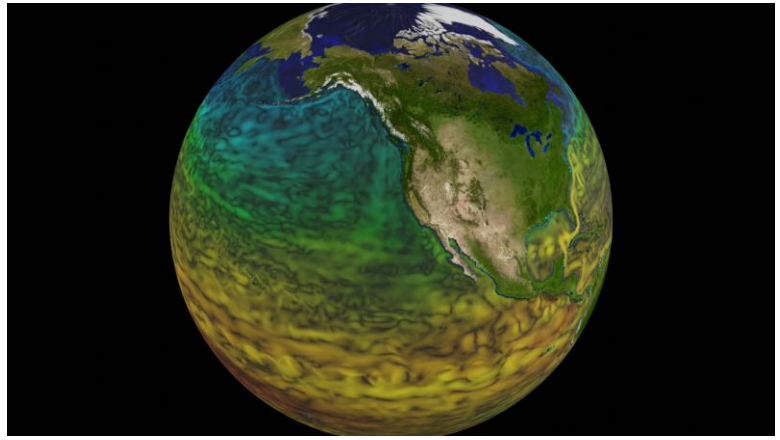
Representation of previously unresolved processes (e.g. ocean eddies) that are important for **ocean-atmosphere interactions**

→ expectation to better reproduce both climate mean state and variability

Courtesy of O. Tinto



ORCA grid 1°



ORCA grid 0.25°

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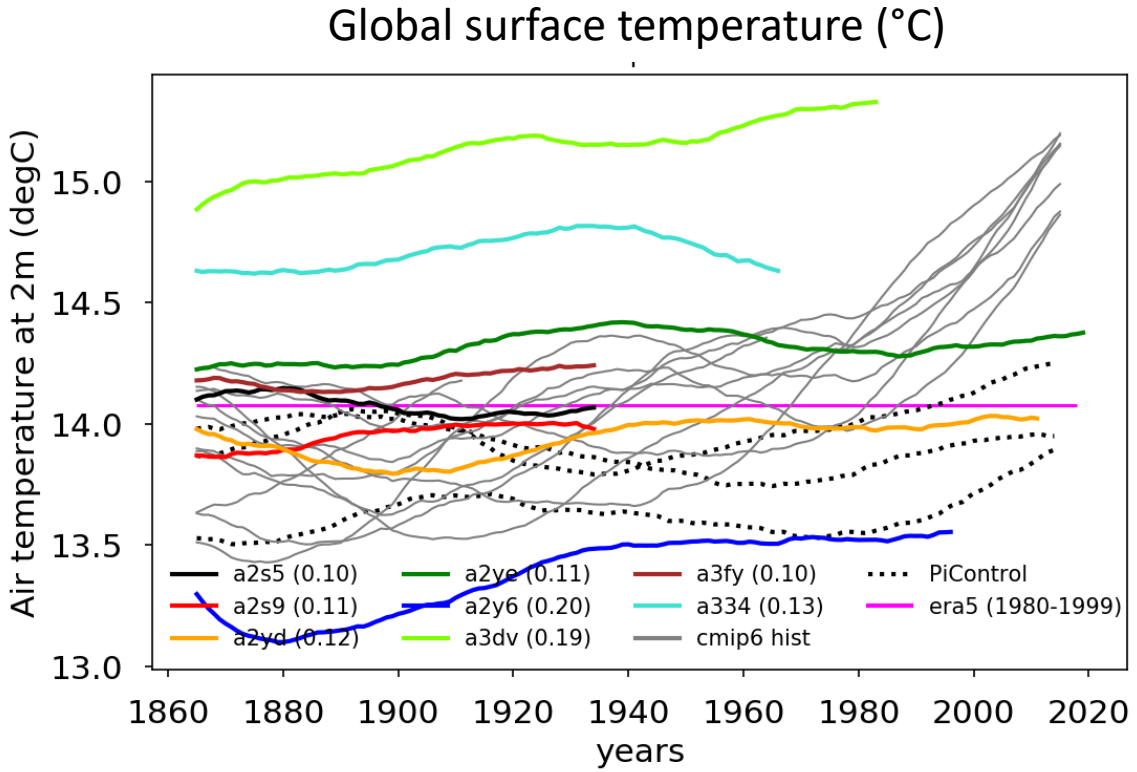
Producing decadal prediction system

1. **Tuning of the model**



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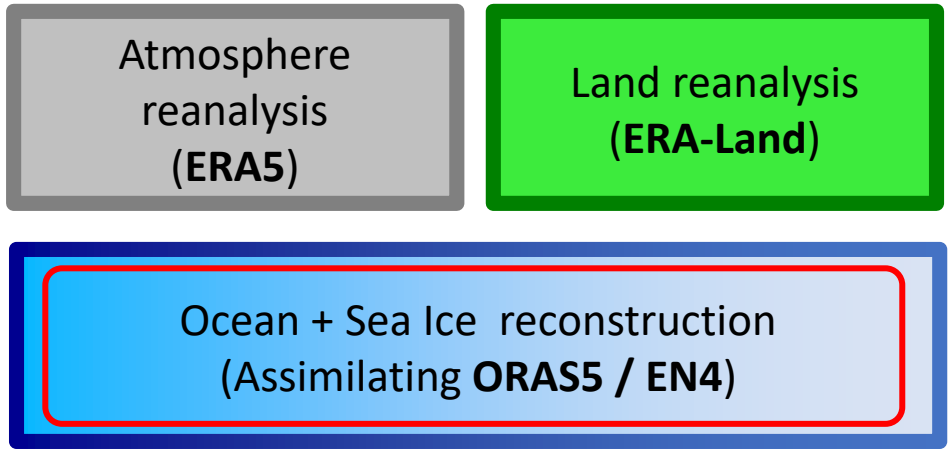
Producing decadal prediction system

1. Tuning of the model

2. Production of the initial conditions for the prediction system

ATM:
Interpolated to model grid with OpenIFS



In-house reconstruction produced at BSC

OCE + **SI**:
Historical reconstruction with NEMO stand-alone, forced with ERA5 fluxes, and nudged globally towards 3D T and S from ORAS5 (EN4)

Producing decadal prediction system

1. **Tuning of the model**

2. **Production of the initial conditions for the prediction system**

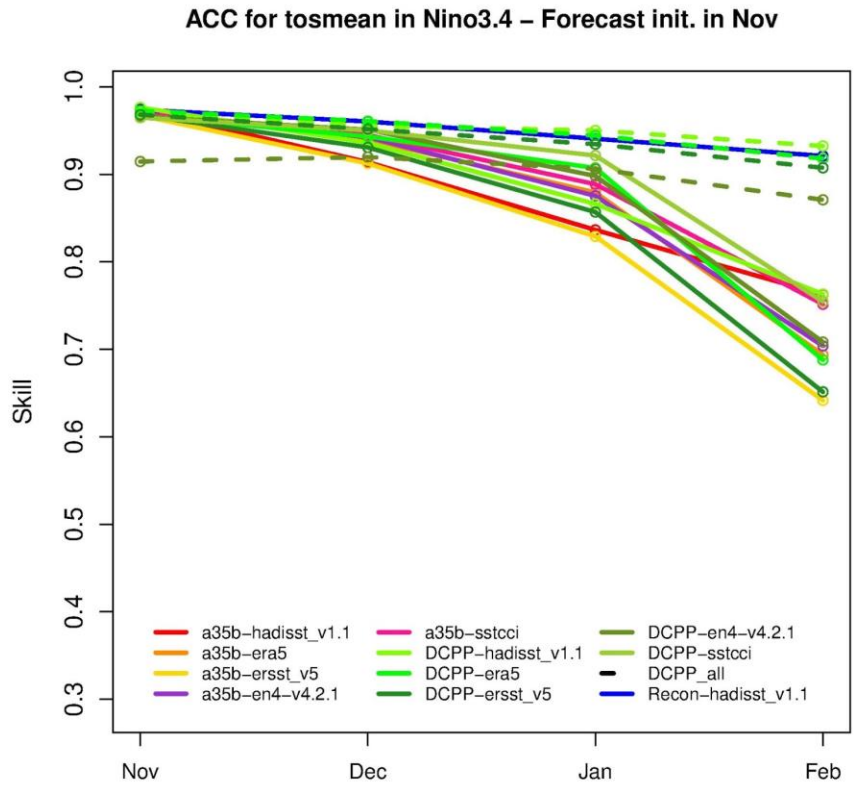
3. **Production of a seasonal forecast system**

Start Date
1st November
1st May

Ensemble Size
10 members

Period Covered
1980-2020

Forecast range
4 months



Producing decadal prediction system

1. **Tuning of the model**

2. **Production of the initial conditions for the prediction system**

3. **Production of a seasonal forecast system**

4. **Production of the decadal prediction system**

Start Date	**Ensemble Size**	**Period Covered**
1st November Every year	10 members	1980-2020
		Forecast range 10 years

Total of 4100 simulated years

- 74,42 million CPU hours
- 2.5 Simulated Year Per Day (SYPD):
  25 days for a member of 10 years

Computationally challenging
→ MareNostrum4

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Perspectives

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Planned work

Perspectives

- Estimate the impact of the increased horizontal resolution on the prediction quality of the EC-Earth model
- Focus on ENSO predictive skill and its associated teleconnections

The grand challenge of current decadal prediction systems is to improve the predictive skill over the continents, which we can expect to be improved by a better simulation of air-sea teleconnections at high-resolution.

Thanks!

aude.carreric@bsc.es

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Initial Conditions

ATM:
Interpolated to model grid with OpenIFS (performed locally at BSC)

Atmosphere reanalysis (**ERA5**)

Land reanalysis (**ERA-Land**)

Ocean + Sea Ice reconstruction (Assimilating **ORAS5 / EN4**)

In-house reconstruction produced at BSC

LAND:
Offline land-surface simulation forced by bias-corrected ERA-Interim outputs

Kindly provided by Emanuel Dutra

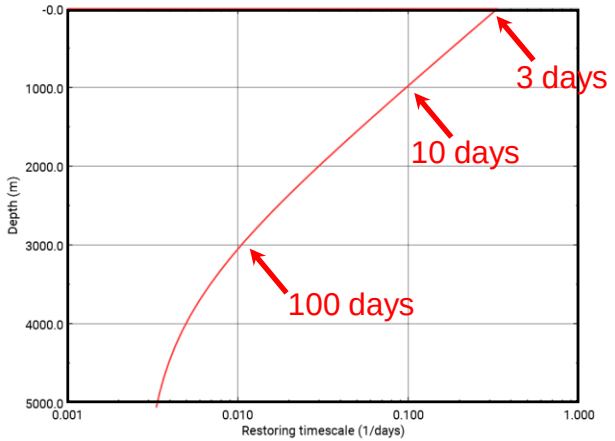
OCE + SI:
Historical reconstruction with NEMO stand-alone, forced with ERA5 fluxes, and nudged globally towards 3D T and S from ORAS5 (EN4)

Default surface restoring coefficients

γ_T = **-40W/m²/K**

γ_S = **-150 kg/m2/s/psu**

Default 3D restoring timescales



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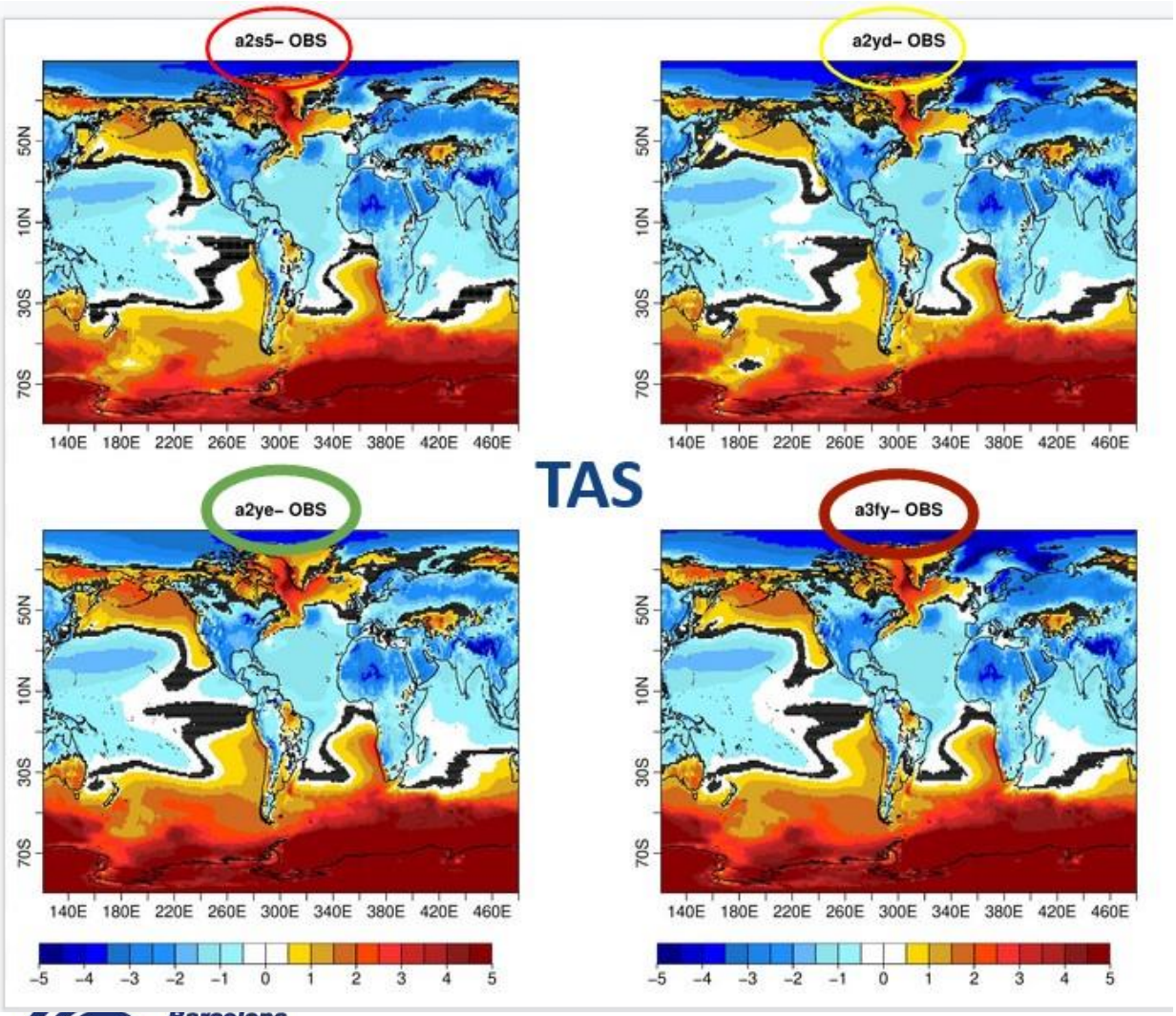
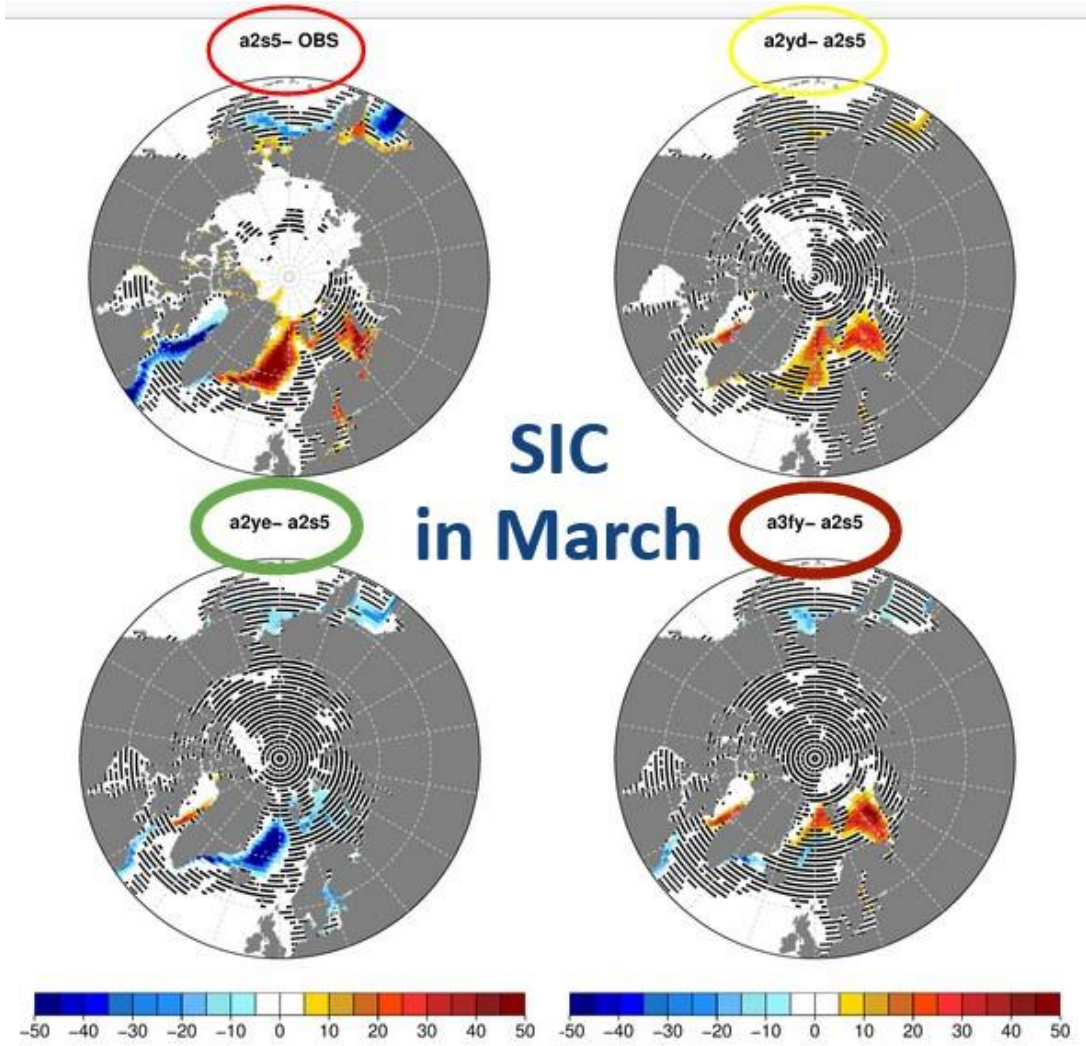
HPC resources

	SYPD (Simulated Years per Day)	ASYPD	RSYPD	CHSY (Core hours per simulated year)	SIM run time avg (h)	Chunksize (nb of months per jobs)	Total nb of proc
a2s5	3.4577	2.6879	2.4036	16658.38	6:52	12	2400
a2s9	3.4559	1.0724	2.0819	16667.13	6:56	12	2400
a2yd (176 considered perf)	3.4797	1.2223	1.1368	16553.12	7:15	12	2400
a2ye (177 considered perf)	3.4611	1.2139	1.2857	16642.33	6:38	12	2400
a2y6*	3.6385	2.1503	1.2934	15830.6	6:24	12	2400
a3dv (143 considered)	3.4523	0.8155	2.4173	16684.74	7:02	12	2400
a3fy	3.4415	2.2221	0.869	16737.03	6:22	12	2400
t0dt (88 considered)	3.4573	3.3246	2.7906	16660.51	6:56	12	2400
t0dz (90 considered)	3.4641	2.9986	2.8921	16627.64	6:55	12	2400
t0e0 (89 considered)	3.4261	2.9012	2.7034	16812.19	7:01	12	2400
a334 LR CMIP6 (248 considered)	18.4739	15.7337	3.5756	997.73	1:17	12	768
Reconstruction							
a30v (418 considered)	1.5946	1.3464	0.4464	11558.73	1:15	1	768
a3h7 (38 considered)	3.4572	1.529	0.6714	8663.62	8:04	12	1248
a3mu	3.4951	3.3736	3.3887	8569.83	6:52	12	1248
Seasonal forecast							
a35b (80 chunks considered)	3.1211	0.348	1.656	18455.3	0:38	1	2400
a3m9 (304 chunks considered)	3.0307	0.3486	1.9266	19005.92	1:09	1	2400
a3mj (45 chunks)	3.514	0.833	3.2084	16391.35	3:59	7	2400

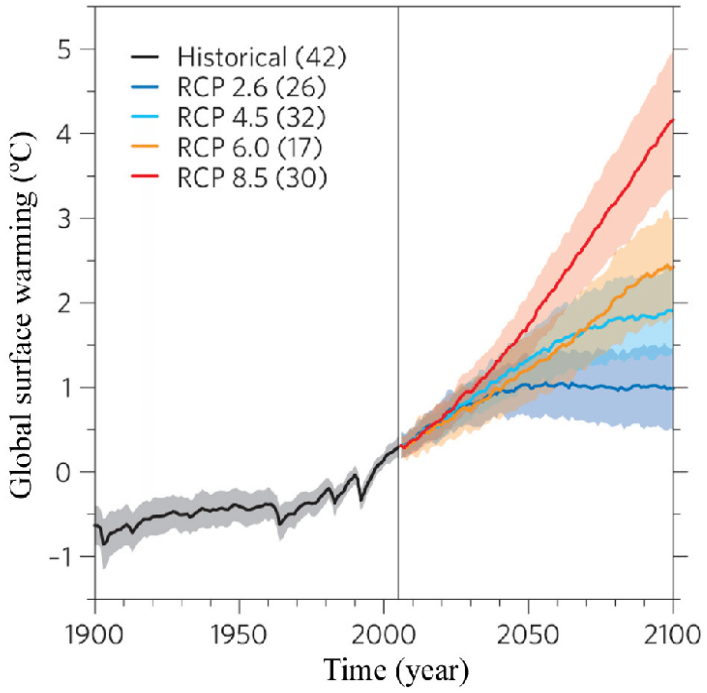
Tuning results



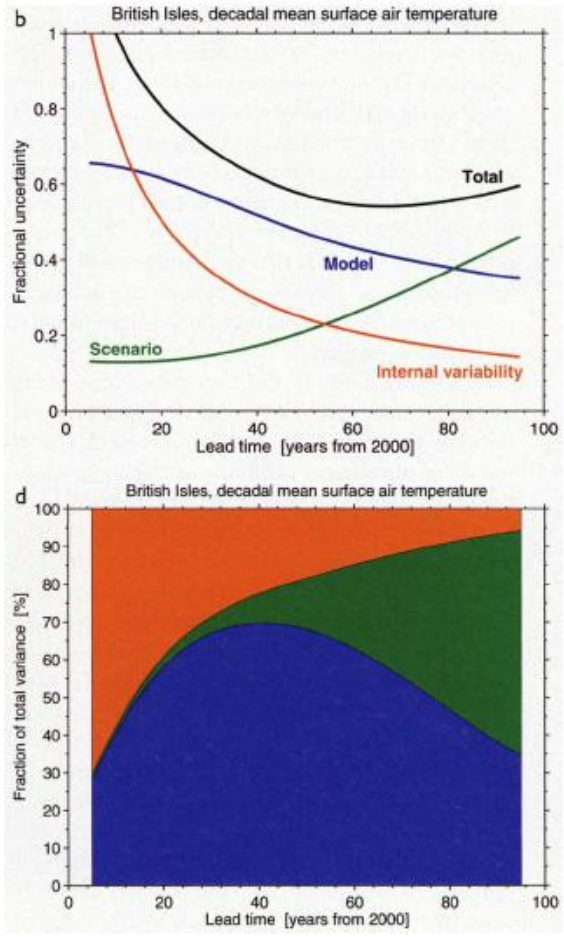


Future climate simulations

Global temperature changes (CMIP5)



Knutti and Sedlácek (2013)



Sources of uncertainty include internal variability, model differences and scenario spread

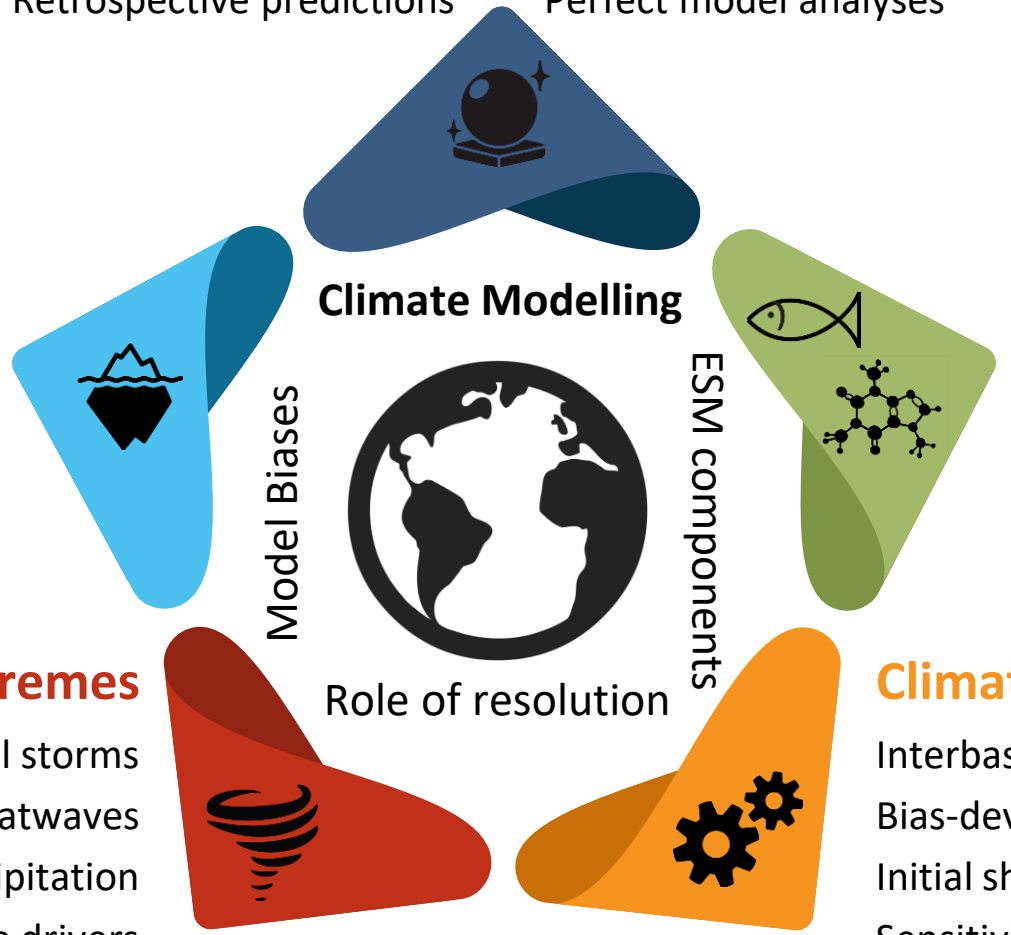
Internal variability dominates during first decades

Hawkins & Sutton (2009)

Climate Prediction Group

Seasonal-to-decadal Climate Prediction

Real time predictions
Retrospective predictions
Initialization/Assimilation
Perfect model analyses



Sea Ice

Predictability
Feedbacks
Remote Impacts

Biogeochemistry

Marine ecosystems
Carbon cycle
Wildfires
Predictability
Climate Change Mitigation

Climate Extremes

Tropical/extratropical storms
Heatwaves
Heavy precipitation
Attribution to climate drivers
Feedbacks

Climate Mechanisms

Interbasin teleconnections
Bias-development
Initial shocks
Sensitivity studies