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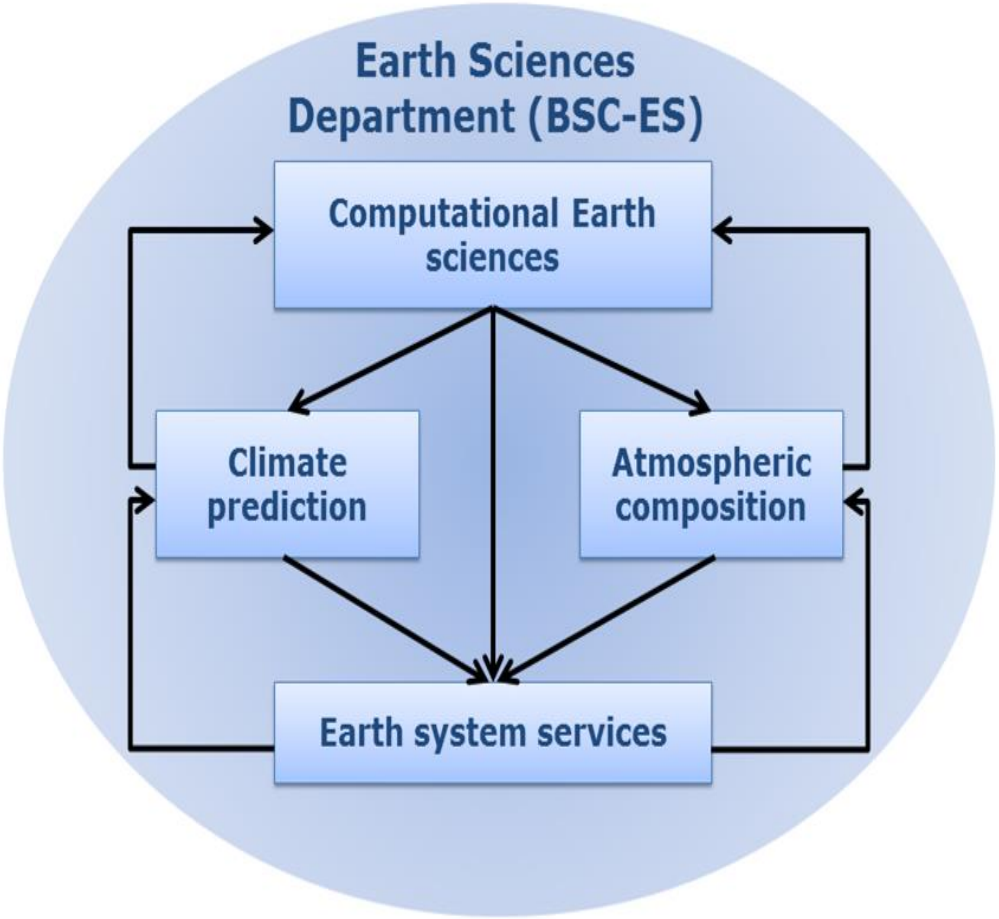
Barcelona, 10 March 2016

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

EARTH SCIENCES DEPARTMENT

BSC-ES



Objectives

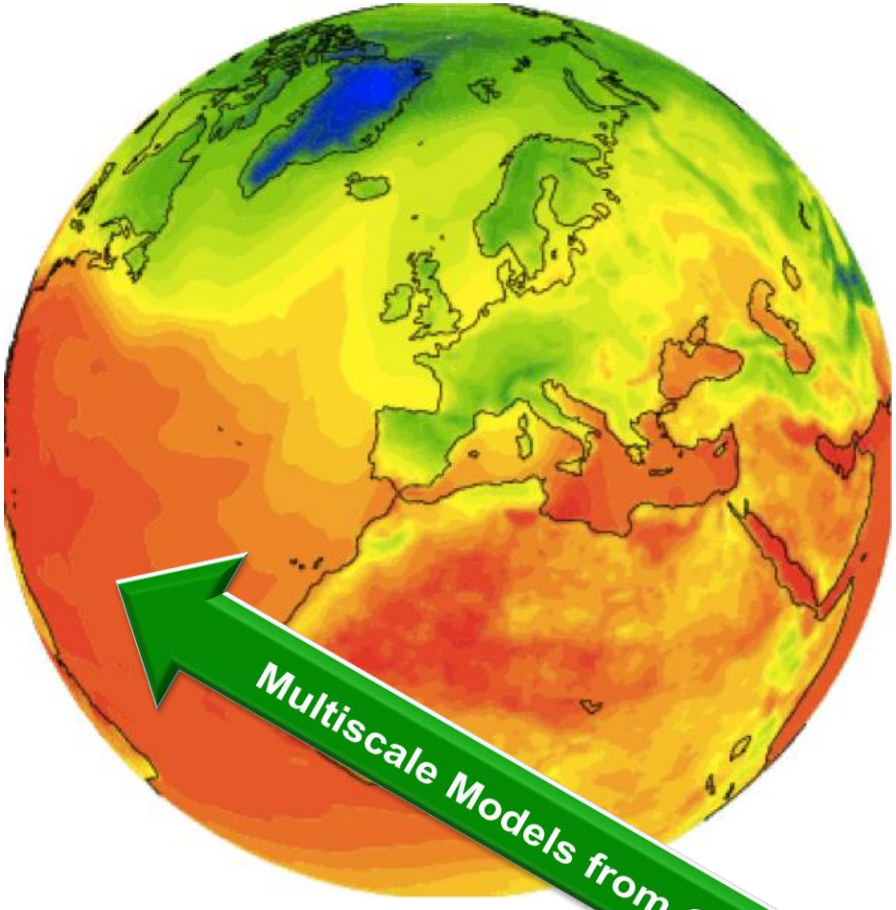
Develop a capability to model air quality processes from urban to global scales and the impacts on weather, health and ecosystems

Implement climate prediction system for subseasonal-to-decadal climate prediction

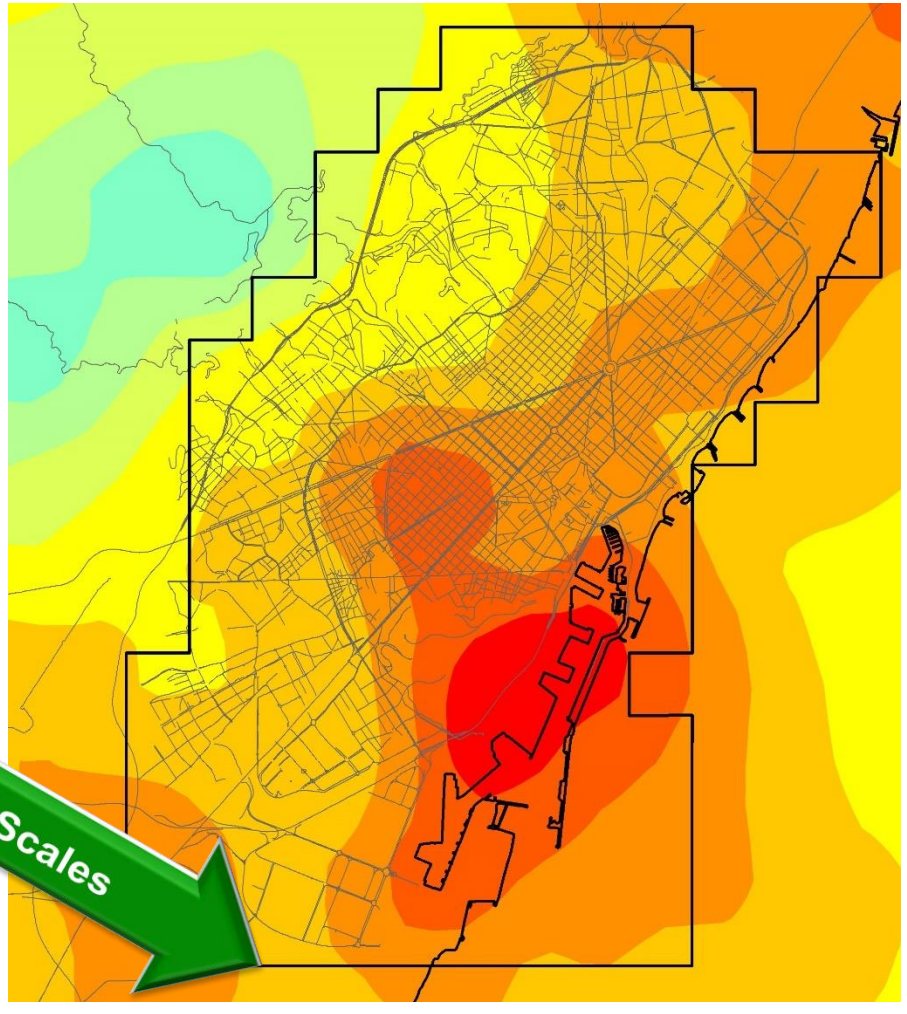
Develop user-oriented services that favour both technology transfer and adaptation

Use cutting-edge HPC and Big Data technologies for the efficiency and user-friendliness of Earth system models

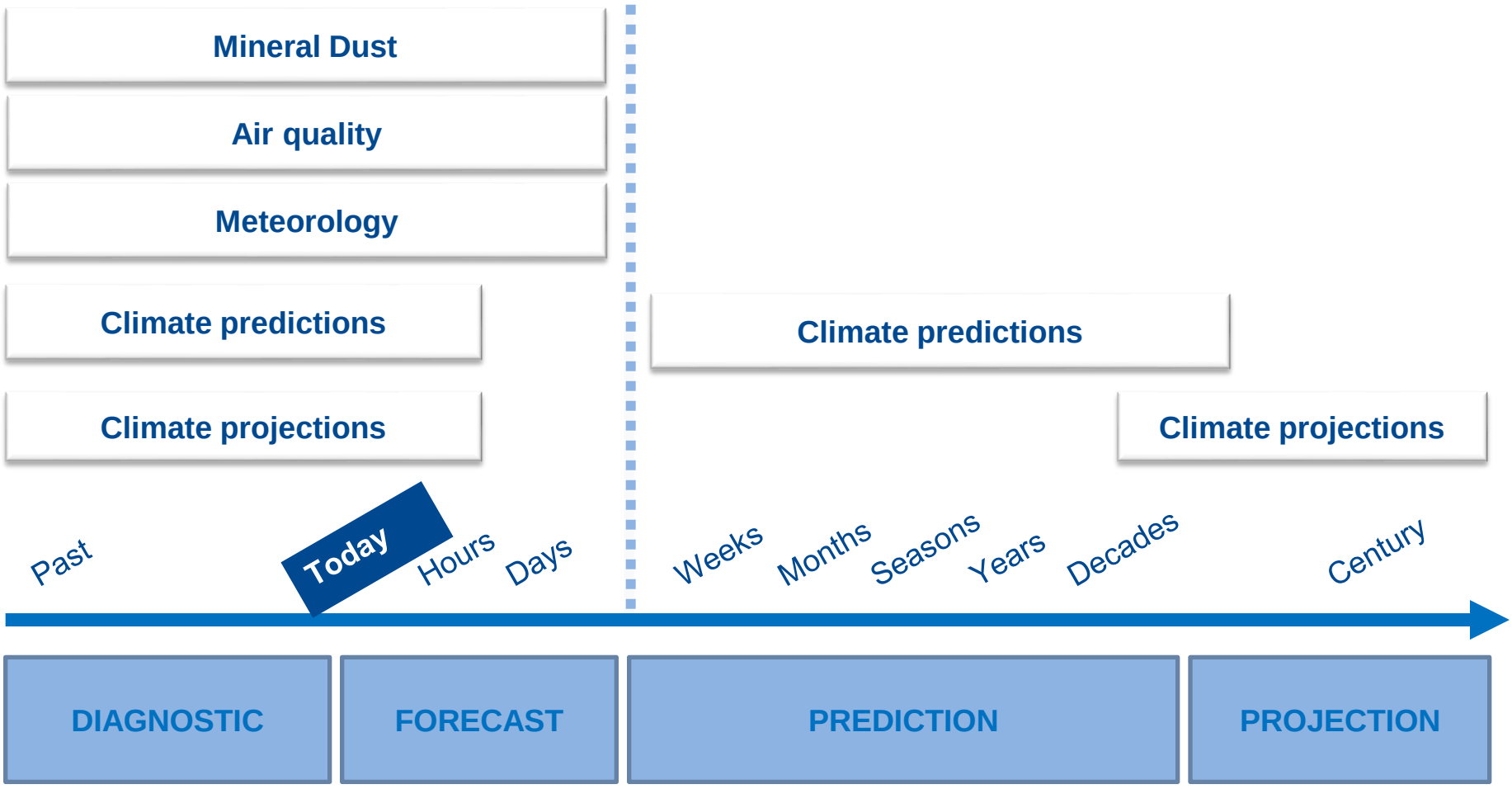
Spatial scales



Multiscale Models from Global to Local Scales



Temporal scales



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Atmospheric Composition

Atmospheric composition research

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1. **Development of air quality models**
   - Development of the online multiscale NMMB/BSC-CTM model
   - Development of urban (microscale) models

2. **Air quality assessment**
   - Impact of air quality sources and regions
   - Air quality trends analysis

3. **Emission modelling**
   - HERMESv2.0 bottom-up emission model

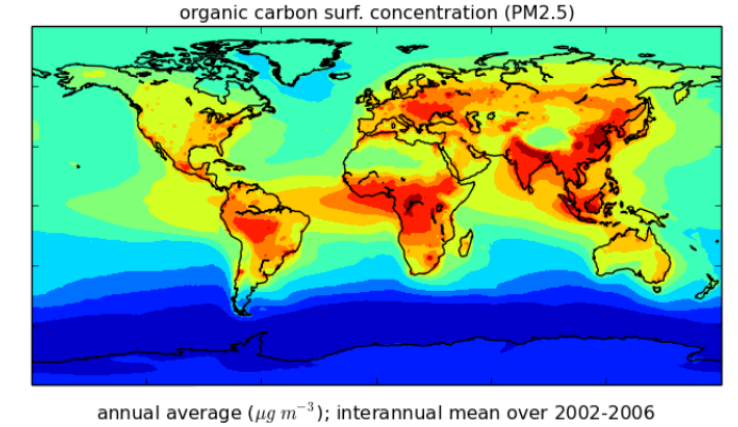
4. **Mineral dust modelling**
   - Operational forecasts: NMMB/BSC-Dust model, BSC-DREAM8b model
   - Data assimilation
   - Mineral dust mineralogy

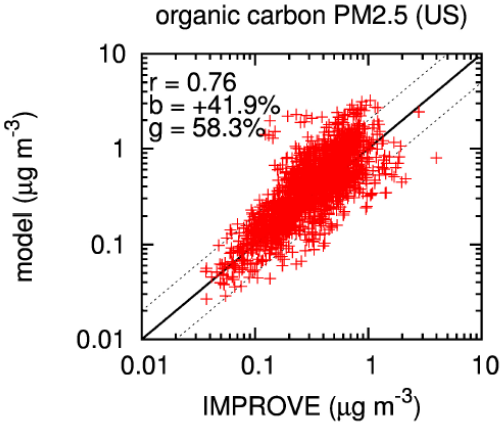
5. **Aerosols interaction with radiation**
   - Short to long term analysis
   - Aerosols' optical properties

1) Air quality modelling – from global to local

- *Global aerosols and chemistry NMMB/BSC-CTM*

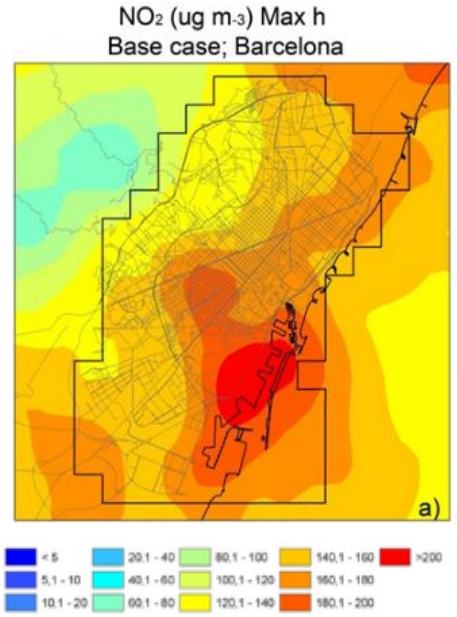
Anthropogenic and biomass burning emissions: ACCMIP (annual)
Fires' inj. height: IS4F (monthly)
Simulated years: 2002–2006 (monthly means eval.)

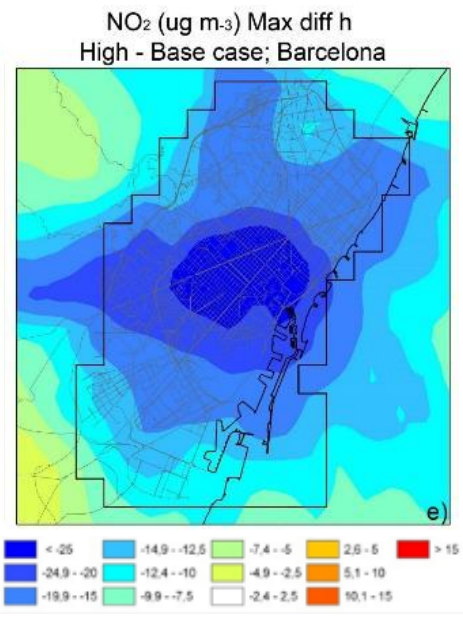




- *CALIOPE 1km – Barcelona*

WRF-HERMES-CMAQ model

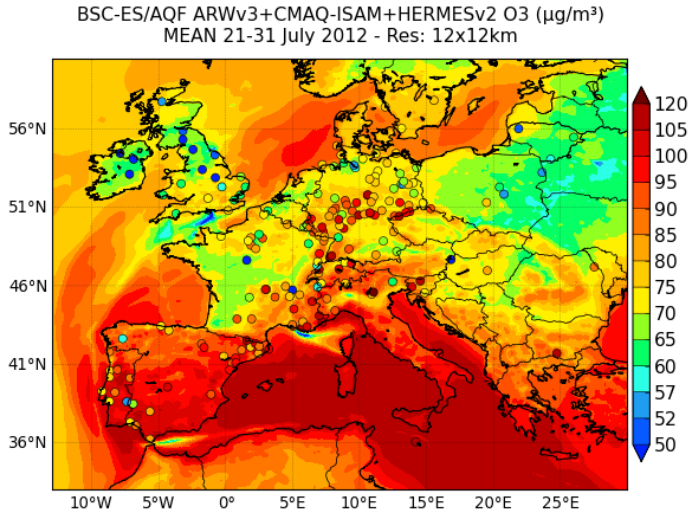


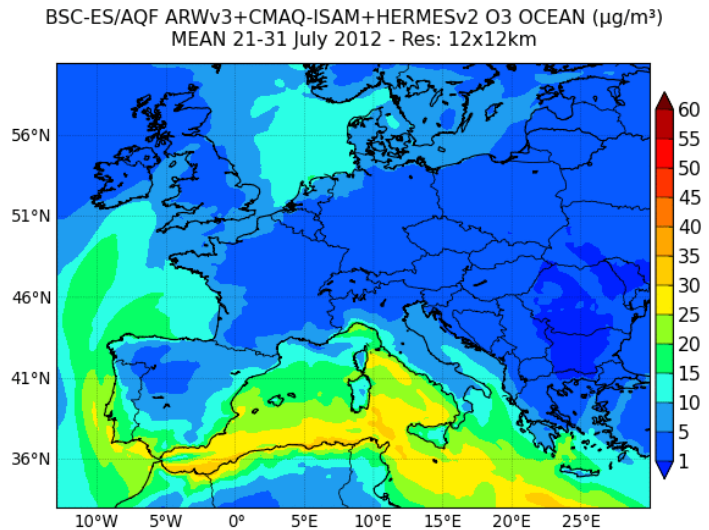


2/3) Air quality assessment. Emission modelling

- *Source attribution – Europe*

CALIOPE – EU (12 km)

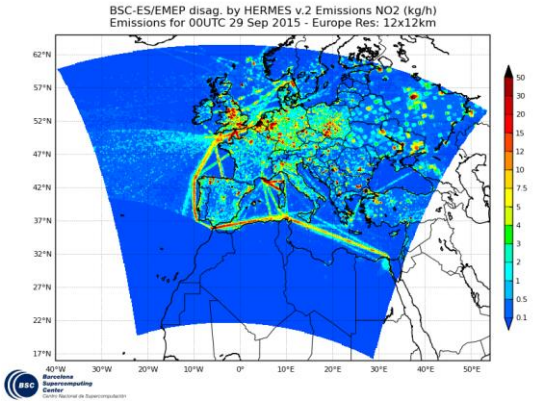


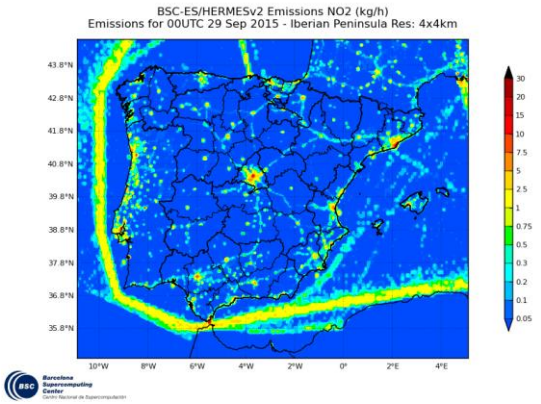


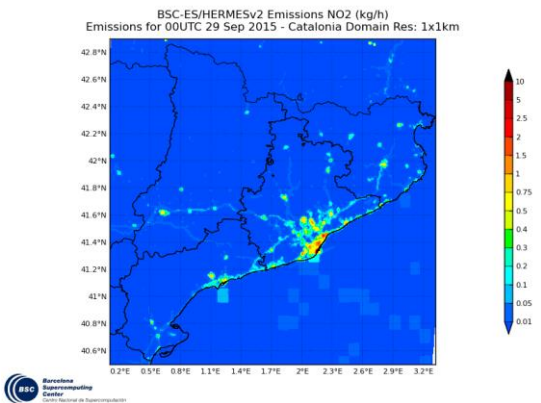
O_3 from shipping

- *HERMES in-house emission model*

HERMESv2.0
Hourly gridded emissions of anthropogenic and biogenic pollutants







4) Mineral dust modelling: data assimilation

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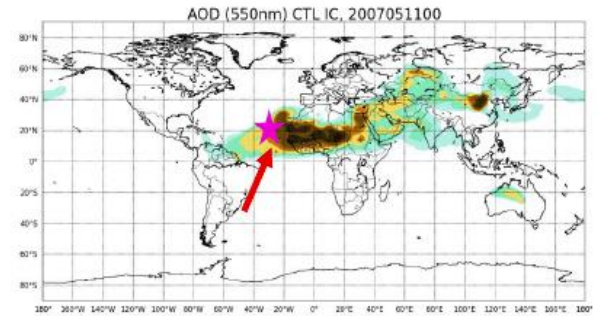
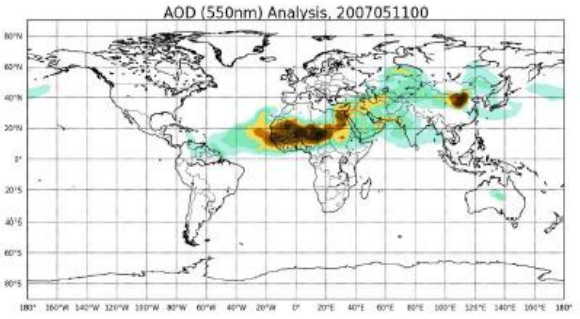
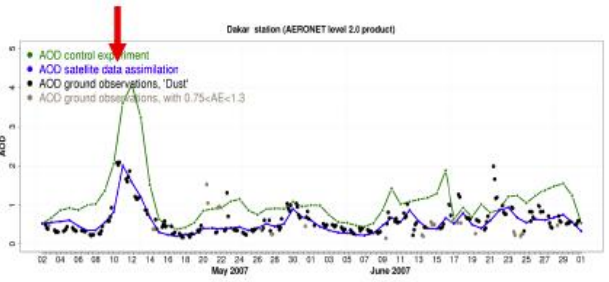
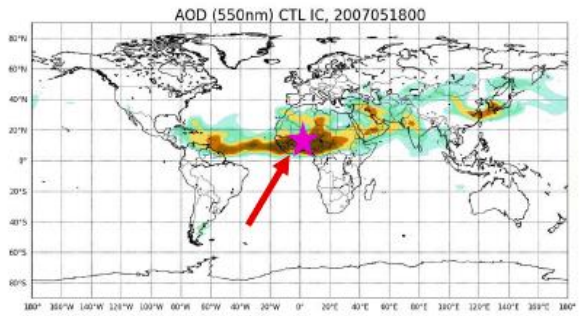
Short-range transport

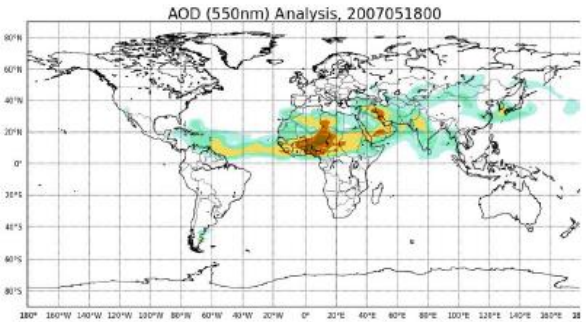


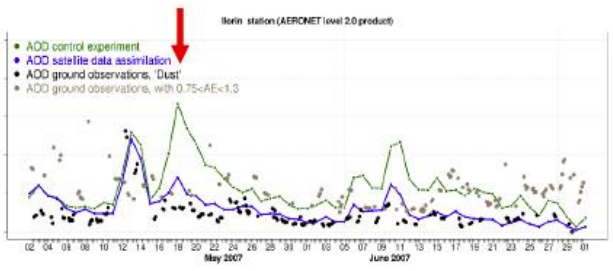




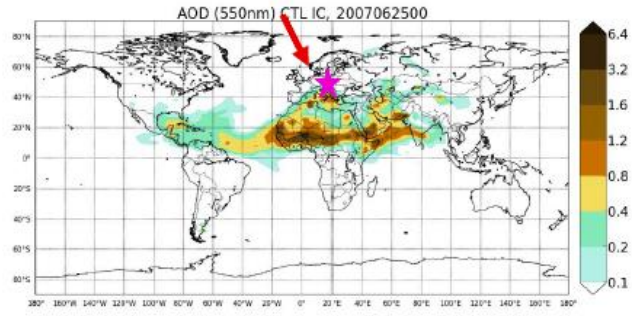
Near sources

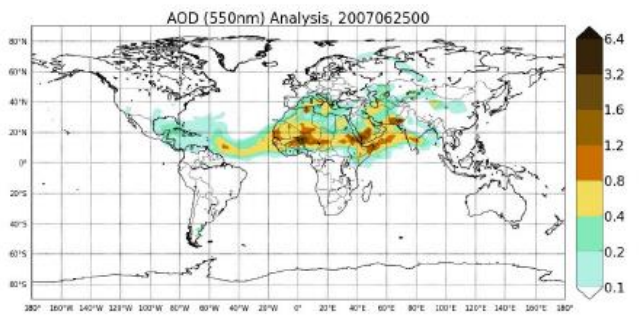


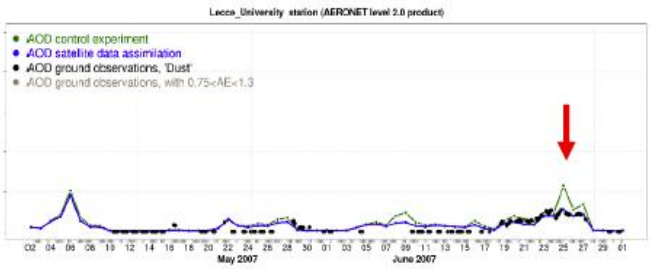




Long-range transport



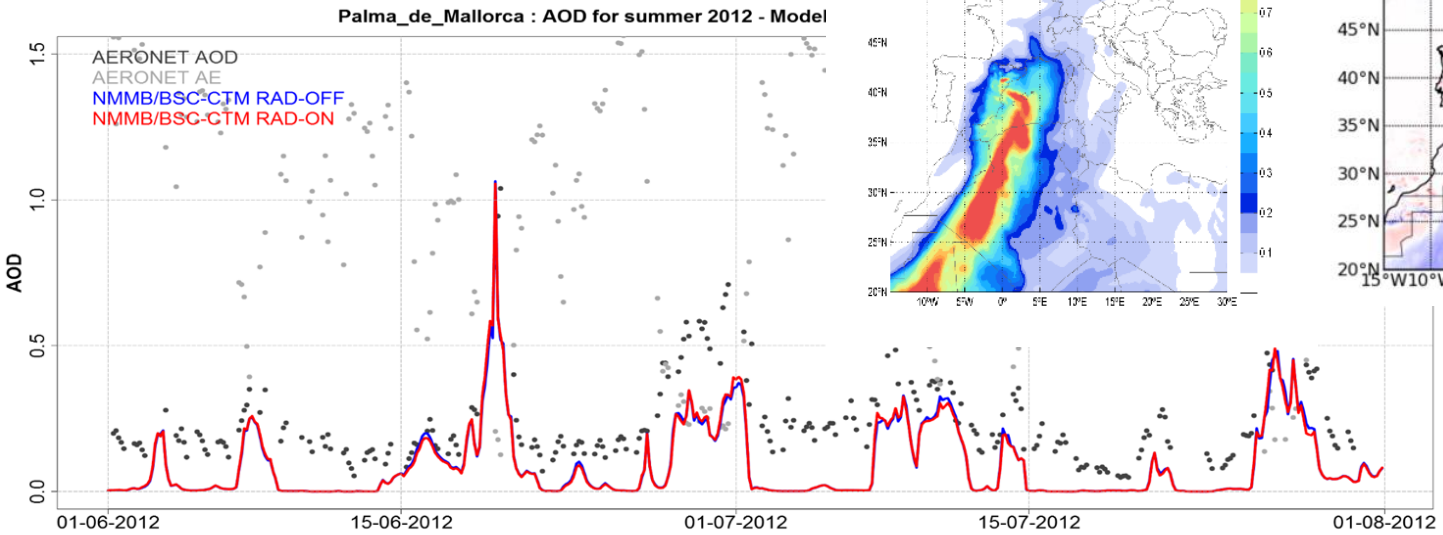


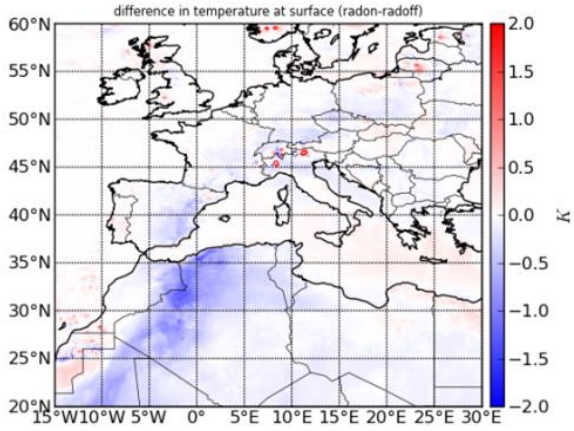


AERONET stations
Black dot → dust AOD AE<=0.75 ;
Grey dots → uncertain type of AOD with 0.75<AE<1.3

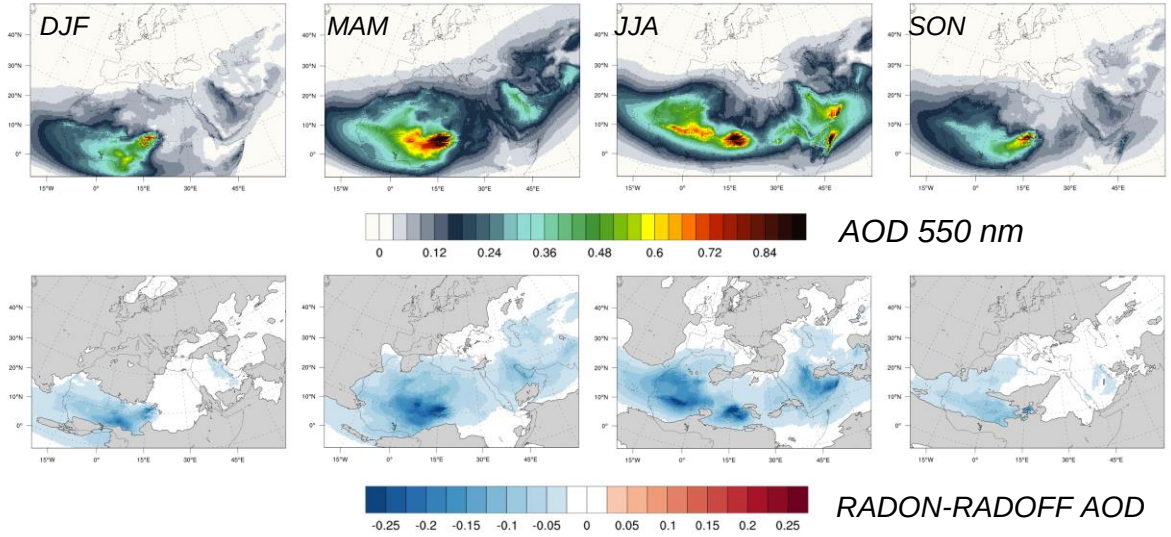
5) Aerosols interaction with radiation

NMMB/BSC-CTM mineral dust interaction with radiation





NMMB/BSC-CTM RCM 1994-2013 (online vs offline mineral dust - radiation)



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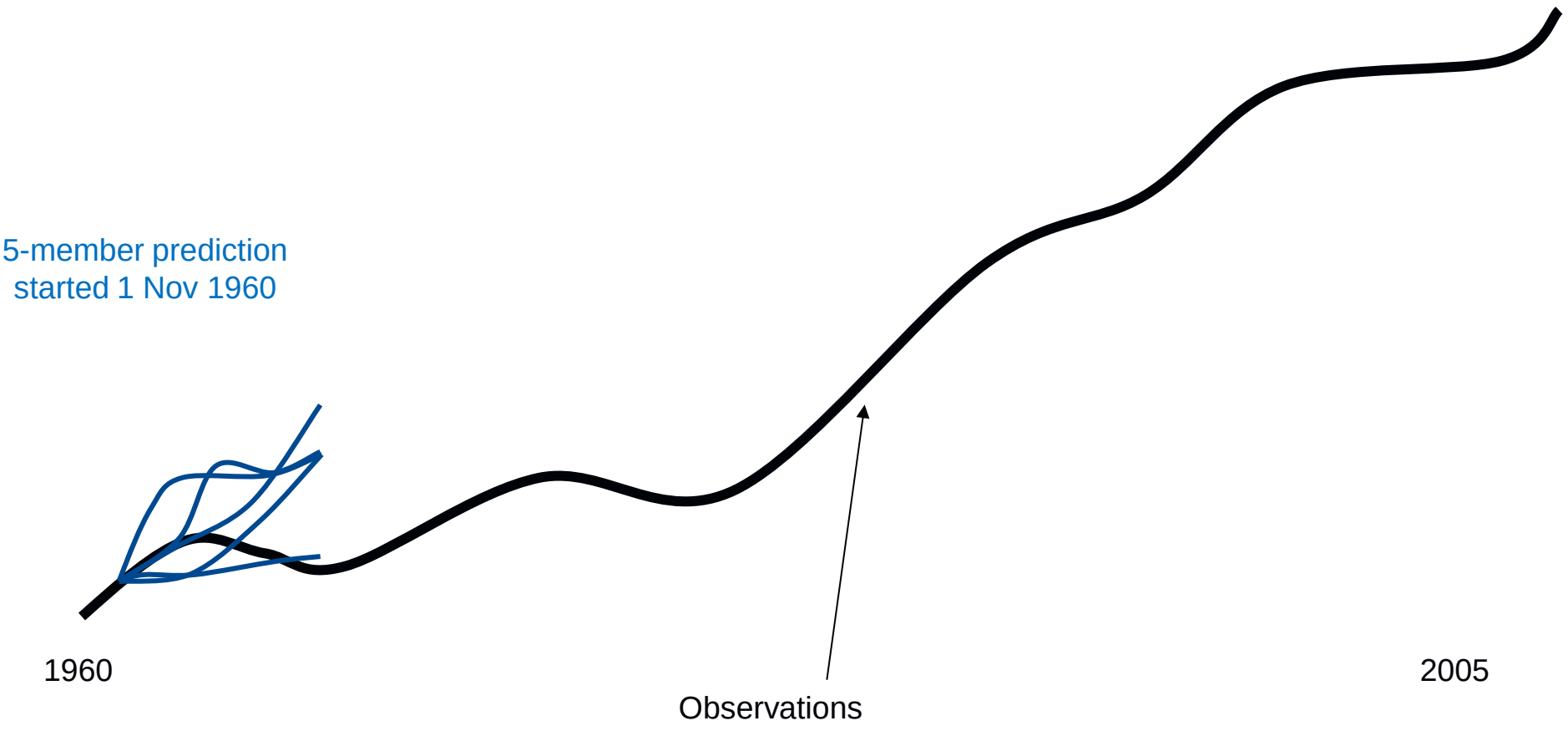
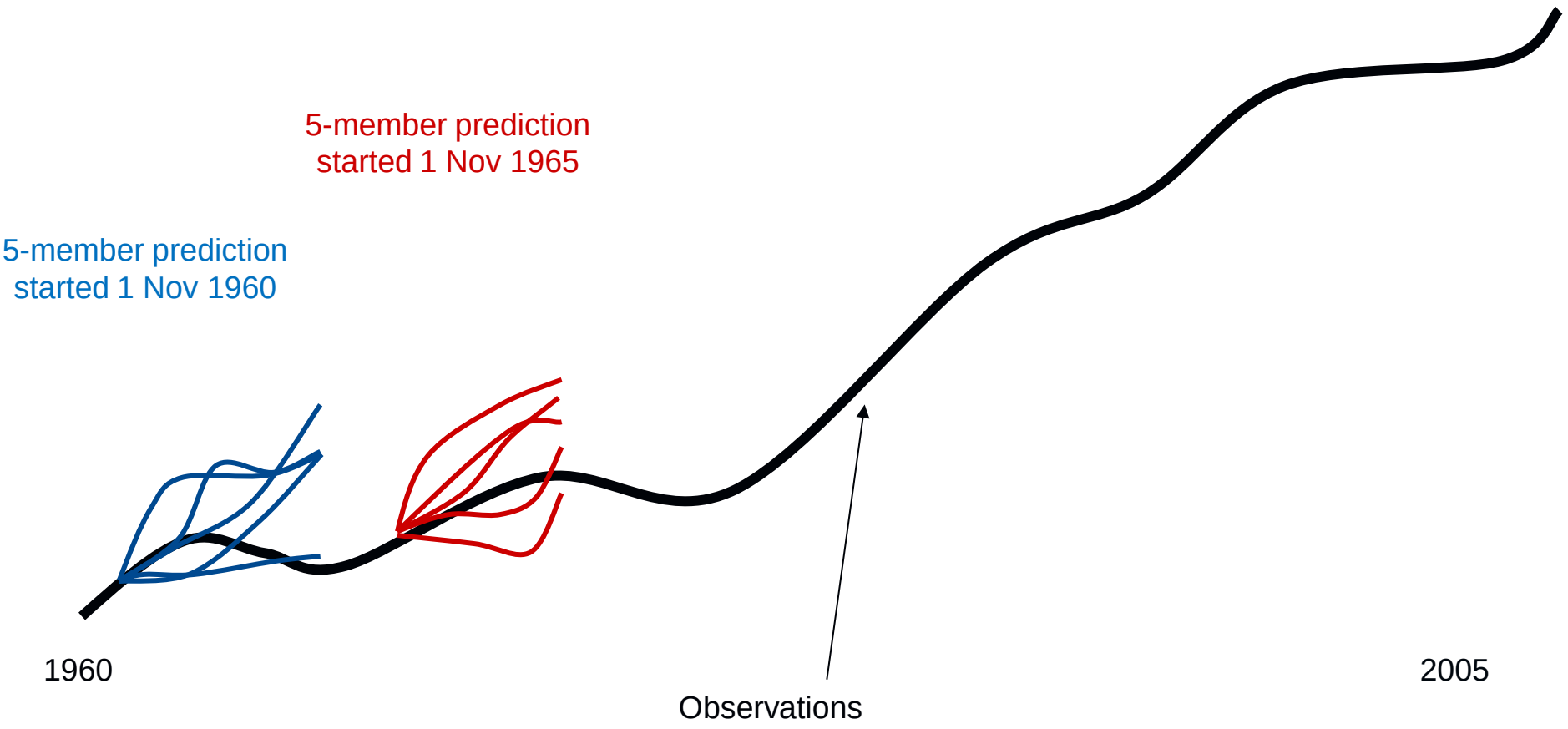
Climate Prediction

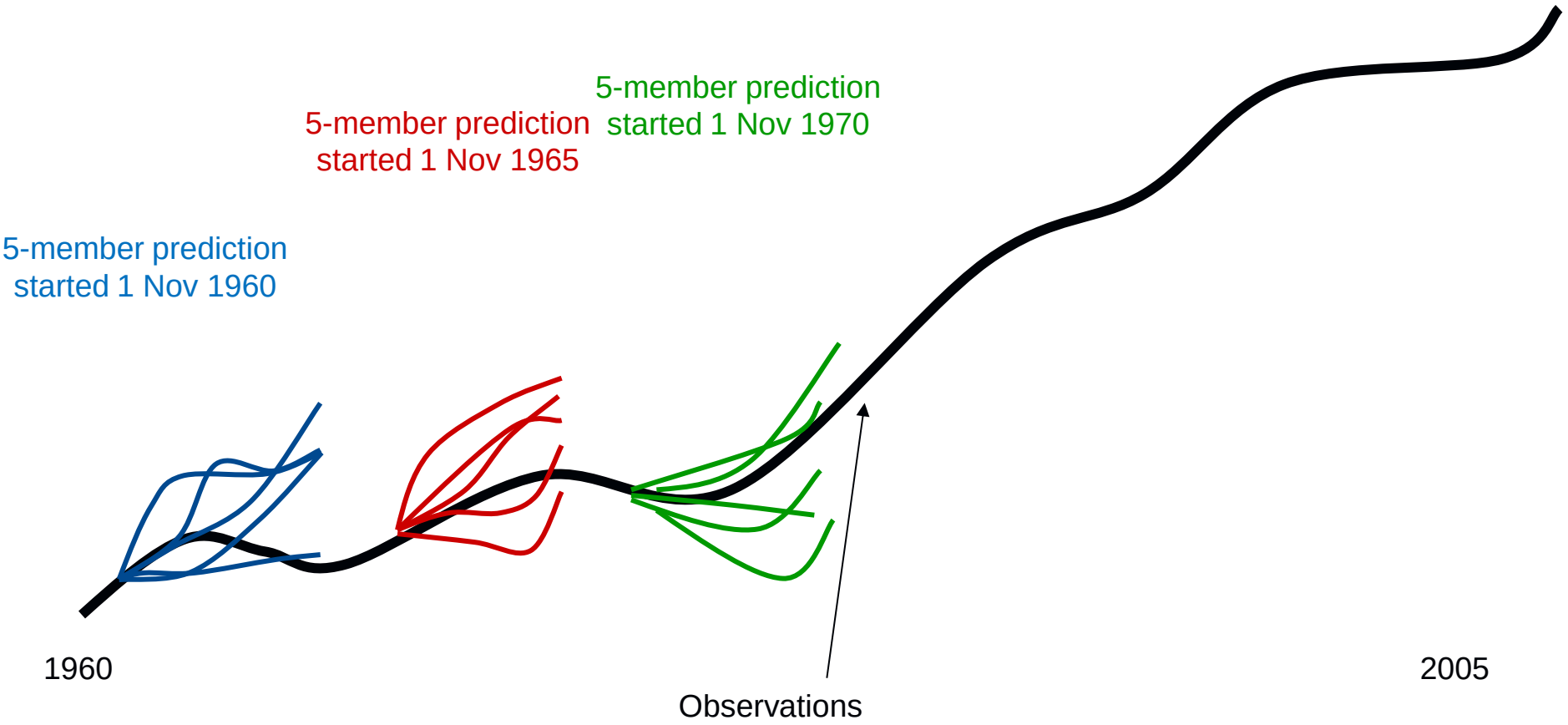
Climate prediction experiments



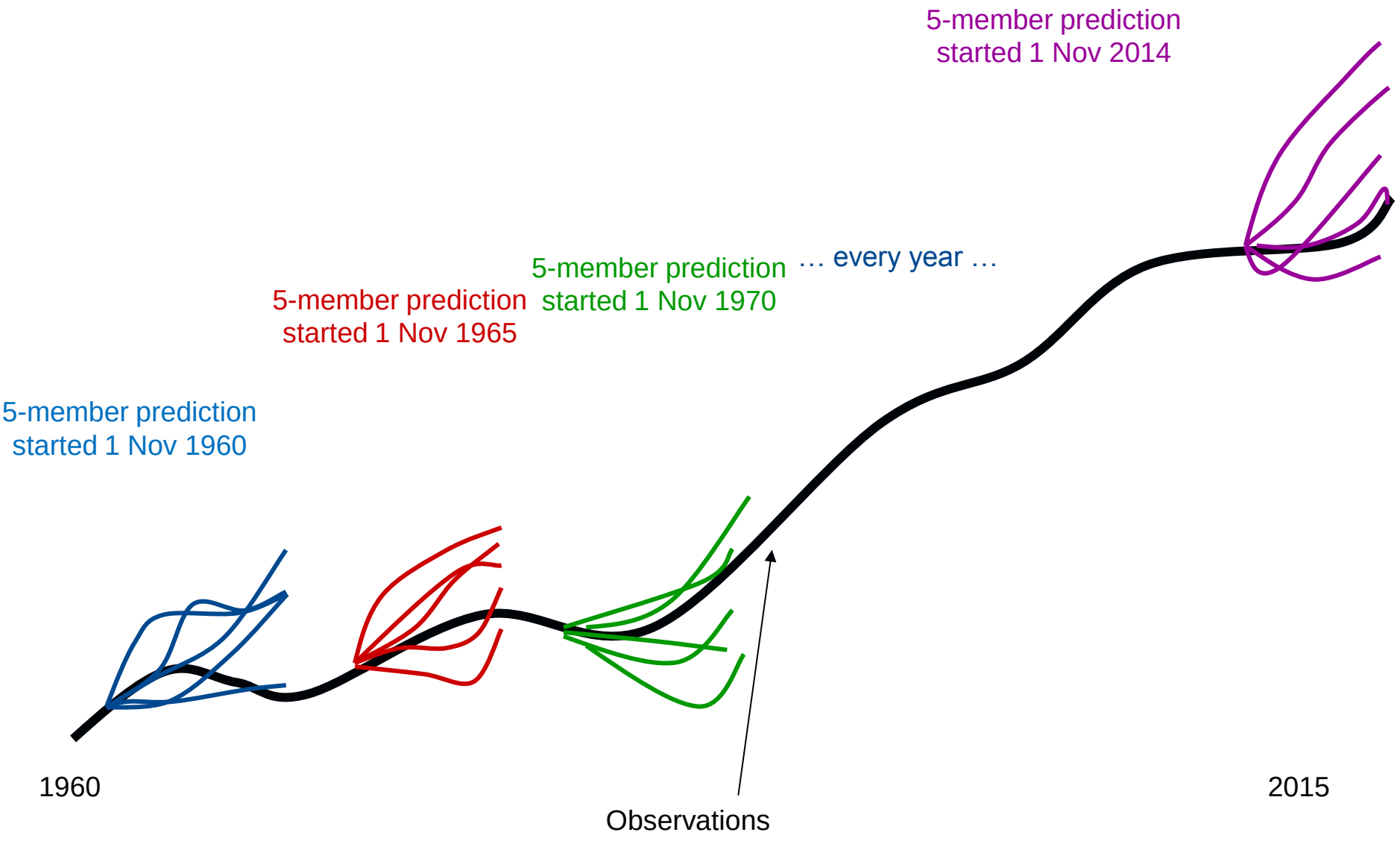
Climate prediction experiments



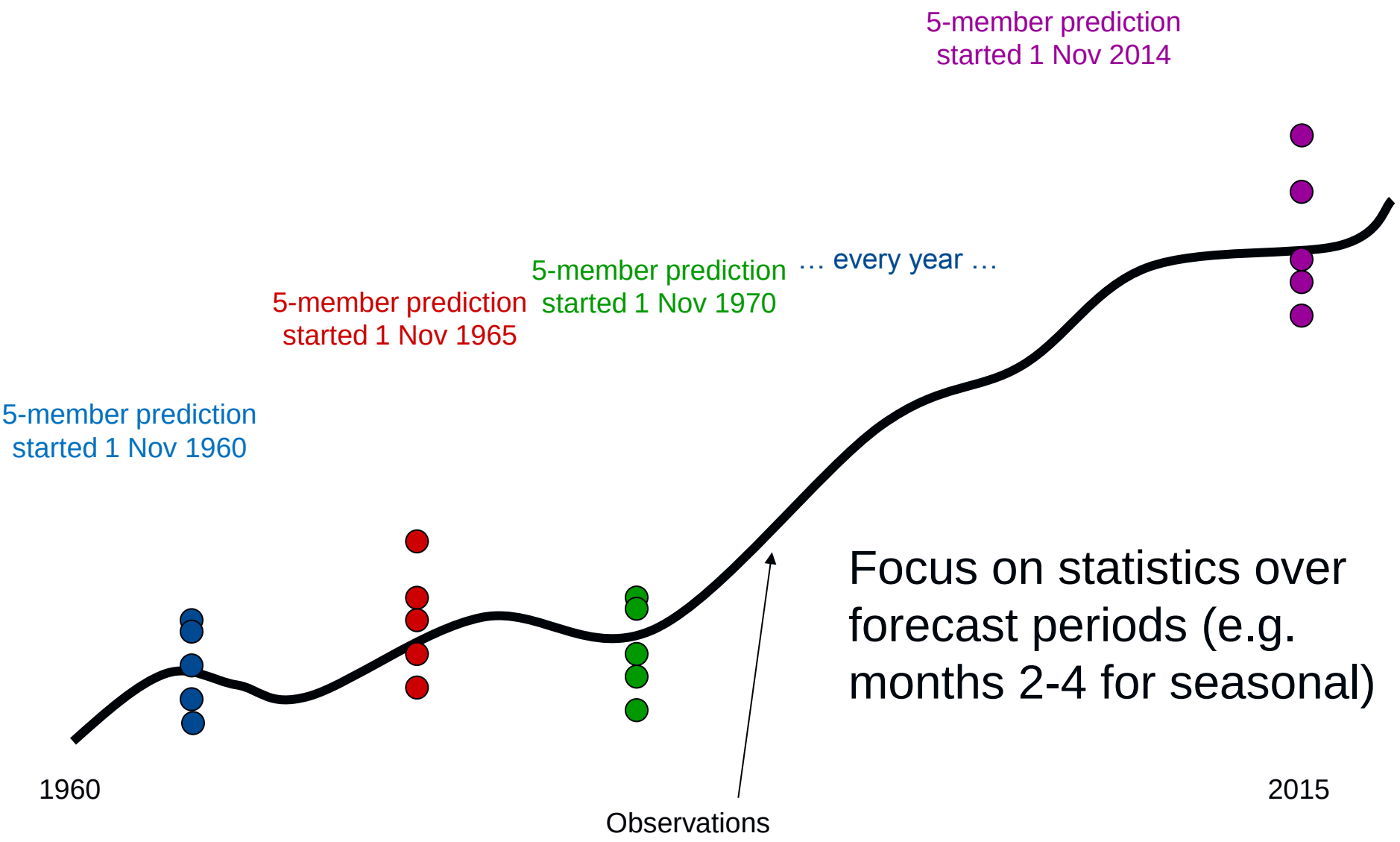
Climate prediction experiments



Climate prediction experiments



Climate prediction experiments



Focus on statistics over forecast periods (e.g. months 2-4 for seasonal)

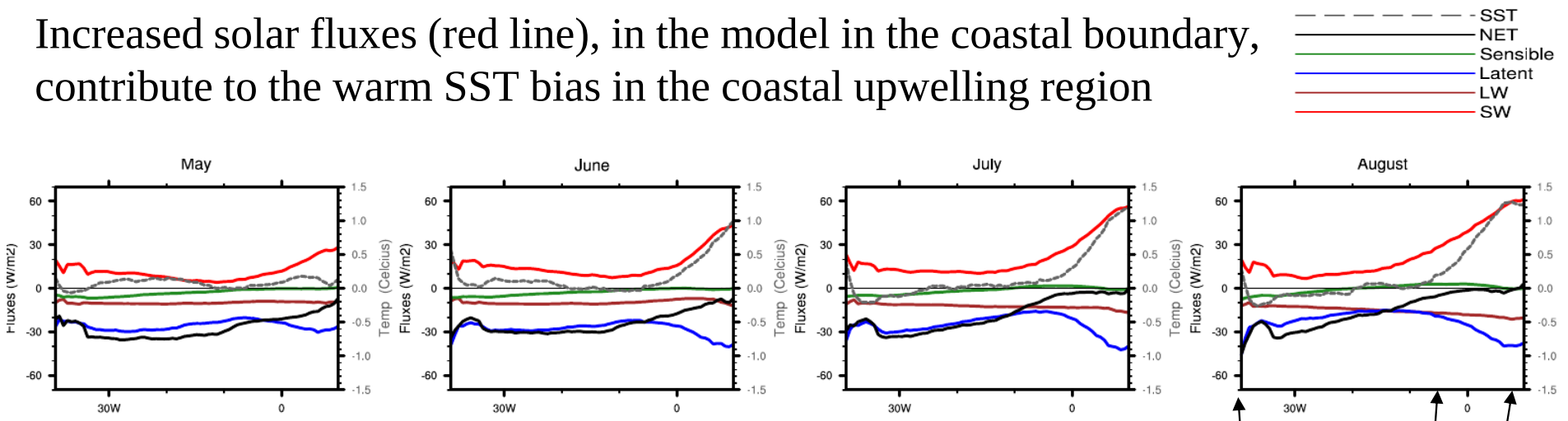
Climate prediction research

1. **Reanalysis, data assimilation and initialization**
   - In-home sea-ice reconstruction / reanalysis
   - Data assimilation techniques to exploit existing atmospheric and oceanic reanalysis
   - Development of initialization methods (anomaly versus full-field)
2. **Model bias analysis and correction**
   - Mechanisms leading to model bias
   - Bias correction techniques accounting for the sensitivity of bias to prediction start date
3. **Improvement of forecast systems through better process representation**
   - New parameterizations and model components
   - Parameter calibration
   - High resolution
4. **Identifying sources of skill (i.e. soil moisture, sea ice thickness, aerosols, biogeochemistry)**
   - Multi-faceted forecast quality assessment and sensitivity experiments
5. **Techniques for attribution of extreme events**
   - Analysis of case studies : 2014 Antarctic sea ice maximum, 2010 heat wave

2) Understanding Tropical biases

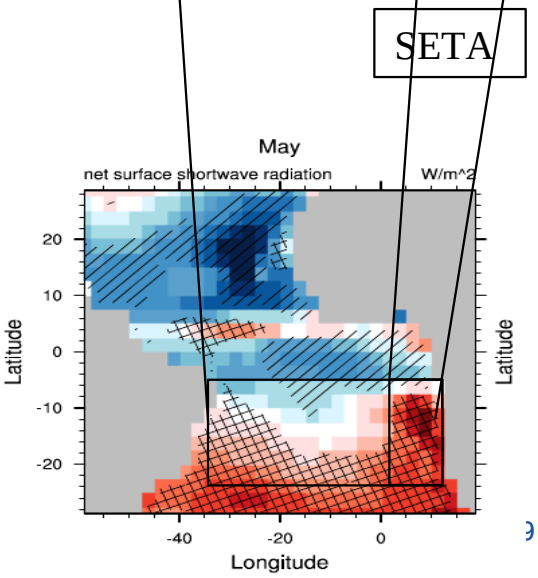
Ec-Earth3.1 10-member seasonal climate forecasts initialized on 1st May from 1993 to 2009 from ERA-interim and GLORYS2v1 reanalyzes

Increased solar fluxes (red line), in the model in the coastal boundary, contribute to the warm SST bias in the coastal upwelling region



Surface heat fluxes observations: Tropflux (Kumar et al, 2012)

Increased solar fluxes (red colors), in the model occur because of less clouds (dashed pattern) compared to observations



ISCCP: Rossow, W.B., and Schiffer, R.A., 1999: Advances in Understanding Clouds from ISCCP. Bull. Amer. Meteor. Soc., 80, 2261-2288.

3) Climate response to volcanoes

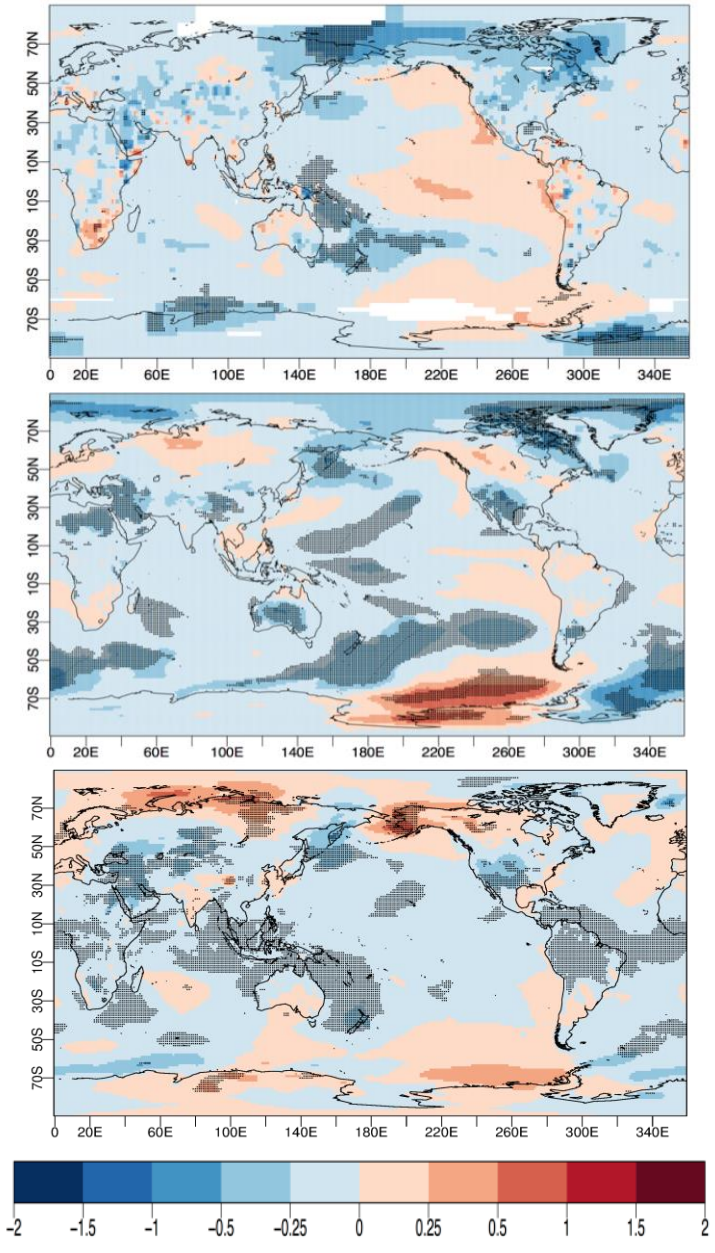
Ec-Earth2.3 5-member decadal climate forecasts initialized on 1st November from 1960 to 2005 with observed or idealized volcanic forcings.

Surface temperature anomaly averaged over forecast years 1-3 averaged over forecasts initialized right before the Pinatubo, Agung and Chichon volcanic eruptions

Observation

Hindcast using observed volcanic forcing

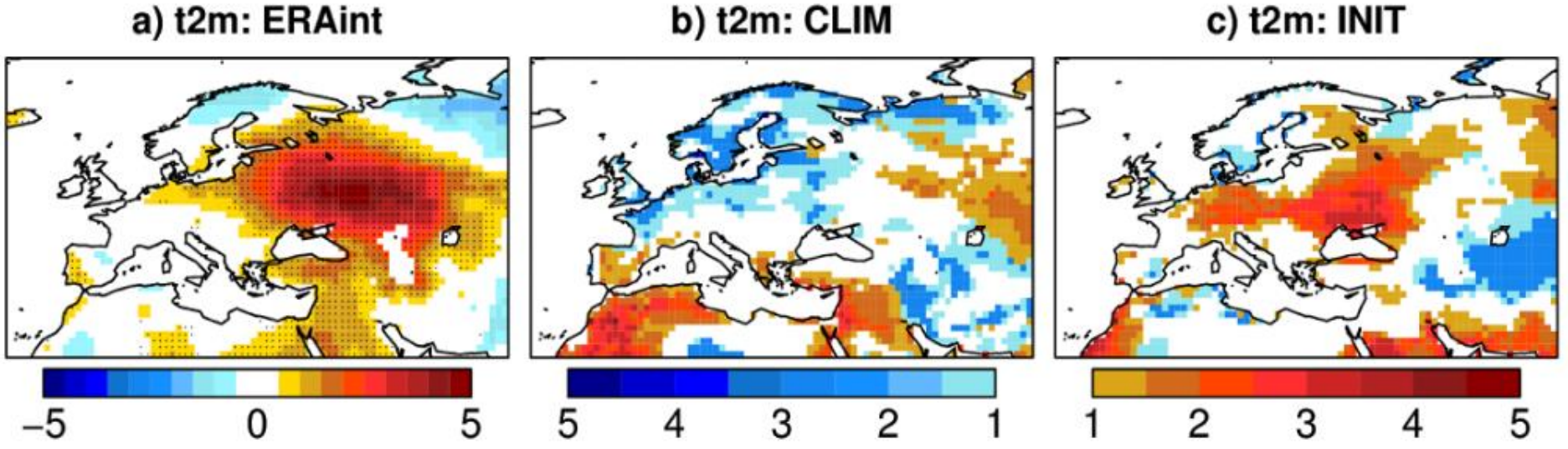
Forecast using idealized volcanic forcing



M. Ménégoz (BSC)

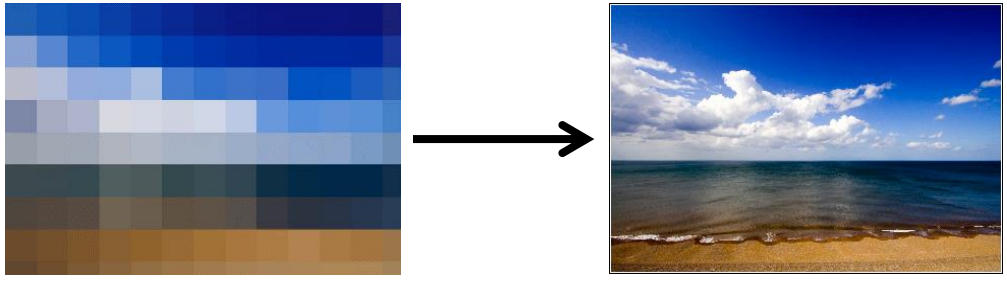
4) Impact of land surface initialization

JJA near-surface temperature anomalies in 2010 from ERAInt (left) and odds ratio from experiments with a climatological (centre) and a realistic (right) land-surface initialisation. Results for EC-Earth2.3 started in May with initial conditions from ERAInt, ORAS4 and a sea-ice reconstruction over 1979-2010.



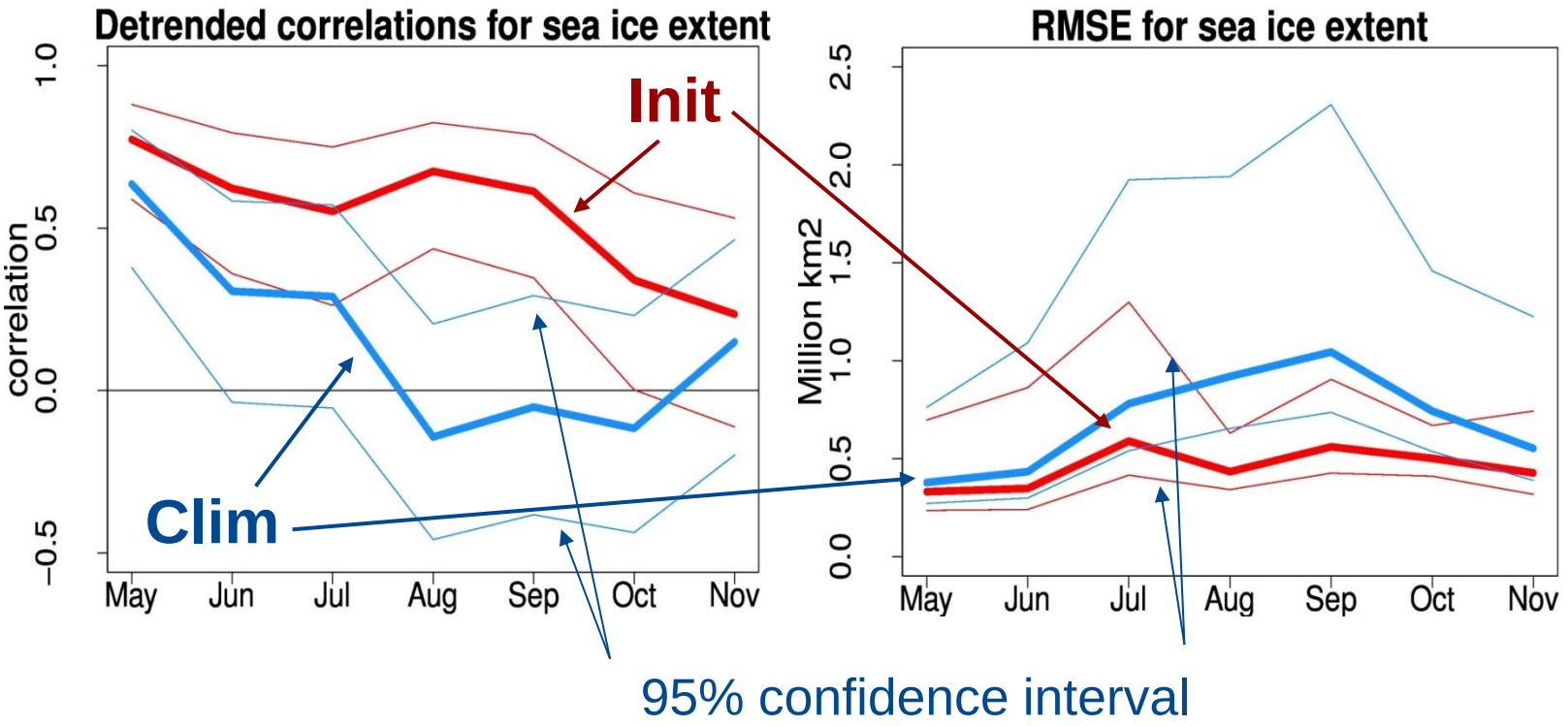
Similar results found for EC-Earth3 and high resolution (25 km).

Prodhomme et al. (2015, Clim. Dyn.)



4) Impact of Arctic sea ice initialisation

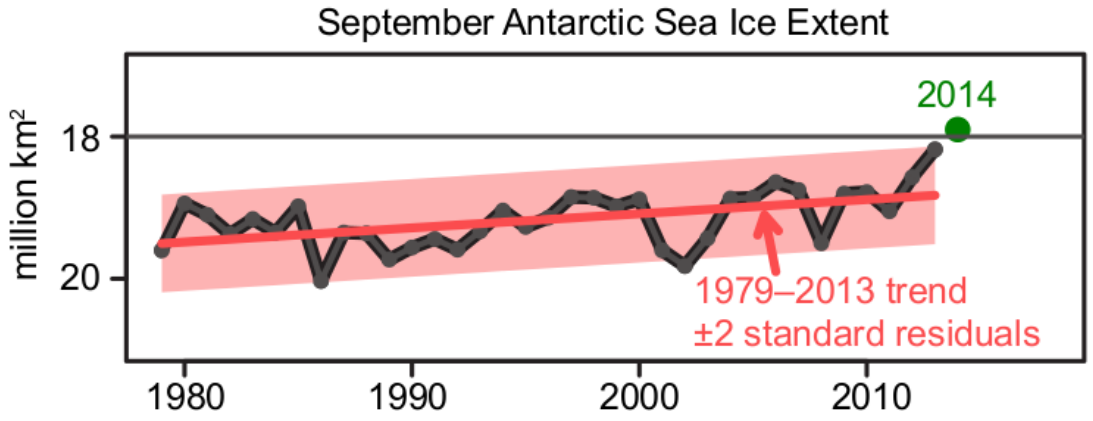
Ec-Earth2.3 5-member seasonal climate forecasts initialized on 1st May from 1979 to 2012 from either a sea ice reconstruction (Init) or a climatology of this reconstruction (Clim). No impact on the atmosphere prediction skill

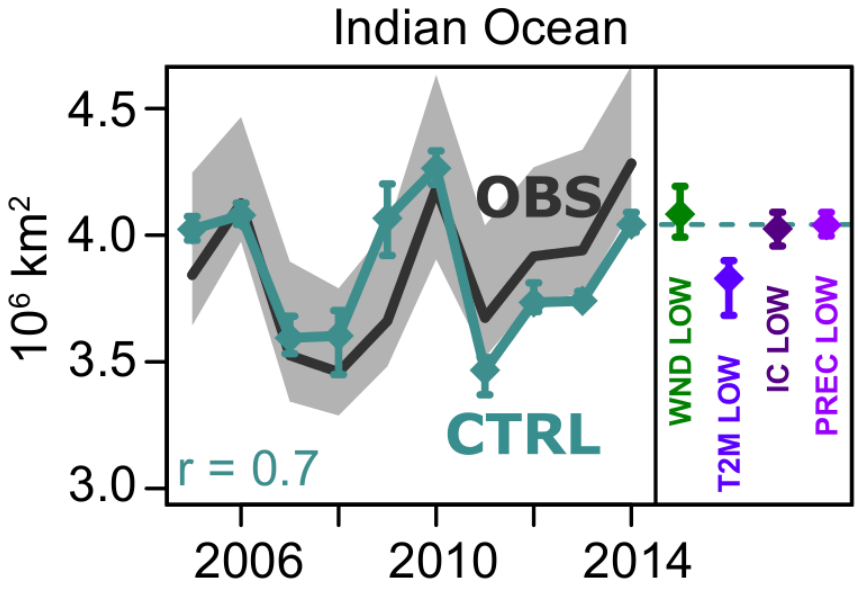


Guemas et al (2016, GRL)

5) Antarctic sea ice record maximum

2014 was an exceptional year for the Antarctic sea-ice extent. A set of sensitivity experiments with NEMO allows to attribute it to anomalous southerly advection of cold air (Indian sector) and ocean pre-conditioning (Ross Sea).





Massonnet et al. (2015, BAMS)

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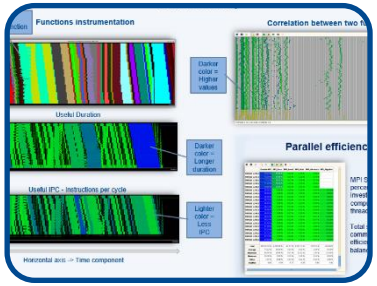
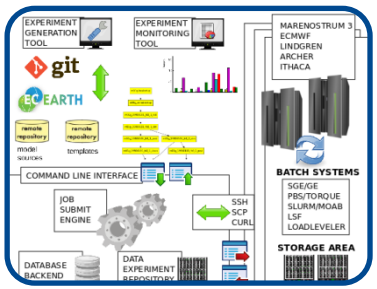
Computational Earth Sciences

Computational Earth Sciences



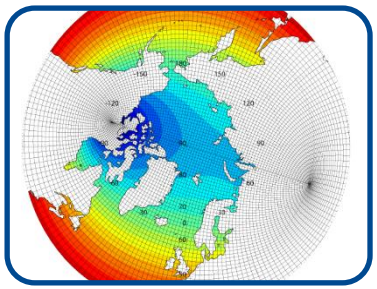
Profiling and Optimization

- Provide HPC Services
- Apply new computational methods



Software Development

- Development of HPC user-friendly software framework
- Support the development of atmospheric research software



Data Management

- Big Data in Earth Sciences
- Provision of data services
- Visualization

Computational Earth Sciences

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1. **Efficient use of the computational resources by the research groups**
- Provide HPC Services such as performance analysis, identification of bottlenecks and application of optimizations
- Research on new computational methods to apply on Earth Sciences models

2. **Development of HPC user-friendly software framework for Earth system modelling and the management of operational systems**
- Support the development of atmospheric research software
- Maintain and improve operational systems

3. **Provision of data services**
- Develop, manage and maintain a common data service framework
- Deploy an infrastructure ready to overcome the Big Data challenge in Earth sciences

4. **Guidance on the use of IT resources**
- Design and maintain an IT infrastructure allowing the research teams the accomplishment of their objectives

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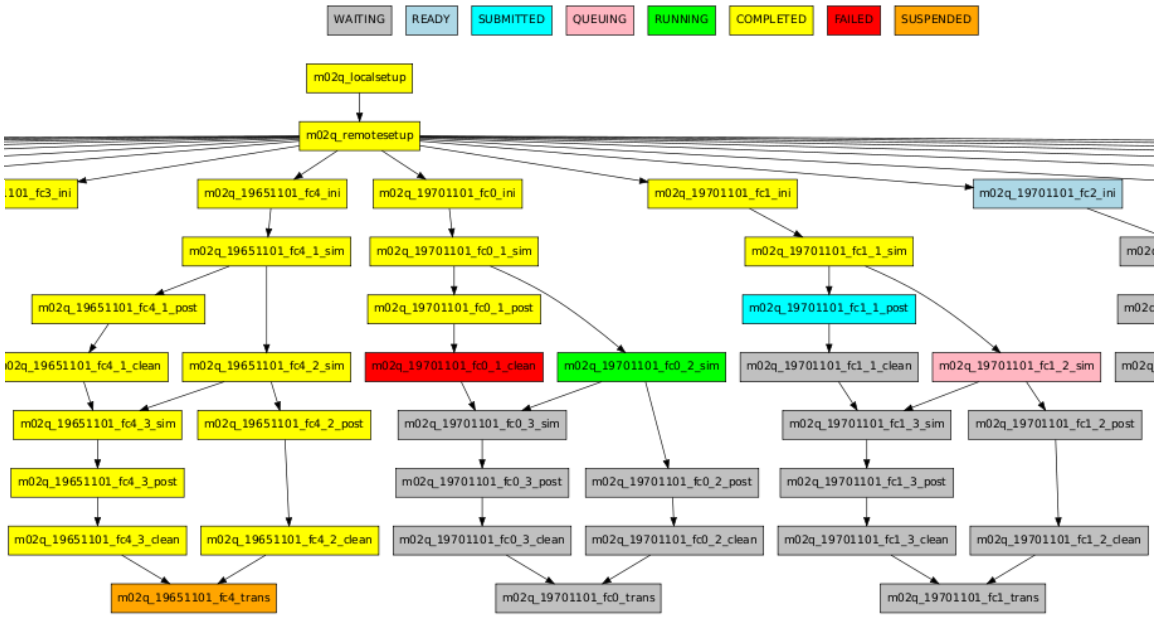
Workflows: Autosubmit

- **Automatisation:** Preparing and running, postprocessing and output transfer, all managed by Autosubmit. No user intervention needed.
- **Provenance:** Assigns unique identifiers to each experiment and stores information about model version, configuration options, etc
- **Failure tolerance:** Automatic retrials and ability to repeat tasks in case of corrupted or missing data.
- **Versatility:** Currently runs EC-Earth, NEMO and NMMB models **on several platforms**.

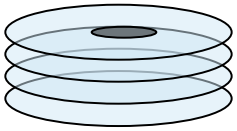
Workflow of an experiment monitored with Autosubmit (yellow = completed, green = running, red = failed, …)



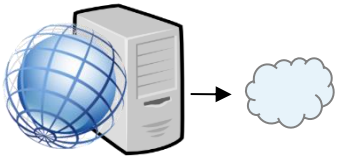
Efficient data analysis

S2dverification is an R package to verify seasonal-to-decadal forecasts by comparing simulations with observational data. It allows analysing data available either locally or remotely. **It can also be used online as the model runs.**

s2dverification package



LOCAL STORAGE



ESGF NODE
or
OPeNDAP SERVER

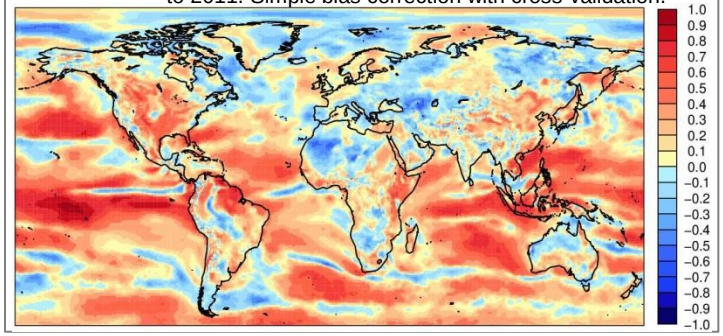
- Supports datasets stored locally or in ESGF (OPeNDAP) servers.
- Exploits multi-core capabilities
- API available
- Collects observational and experimental datasets stored in multiple conventions:
  - NetCDF3, NetCDF4
  - Supports specific folder and file naming conventions.

BASIC STATISTICS

SCORES
EXTREMES

PLOTS

Anomaly Correlation Coefficient. 10M Wind Speed ECMWF S4 1 month lead with start dates once a year on first of November and Era-Interim in DJF from 1981 to 2011. Simple bias correction with cross-validation.



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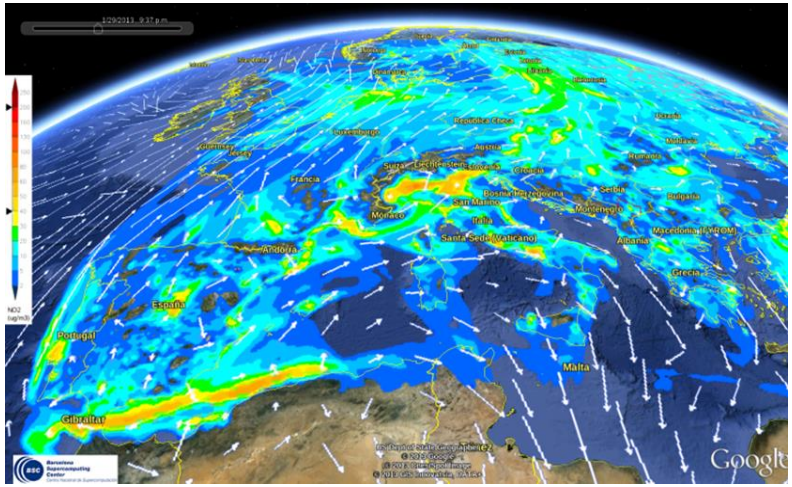
Earth Science Services

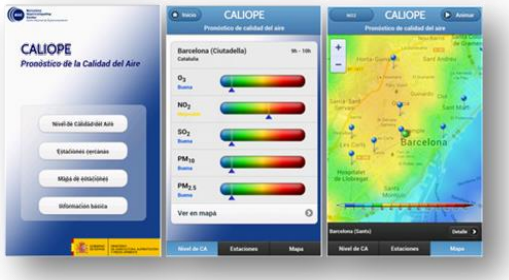
Air quality forecast system: CALIOPE

Provides air quality related information for the coming days and for the application of short term action plans for air quality managers.



Information is delivered using both online or custom applications:

www.bsc.es/caliope

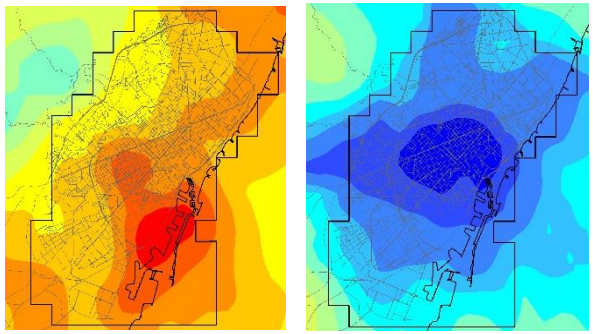


ANDROID APP ON Google play

Available on the App Store

Air quality impact assessment

Air quality modelling provides comprehensive description of air quality problems by relating emission sources and atmospheric conditions



Left: NO_2 maximum h values in Barcelona (red >200 µg/m^3)
Right: Reductions due to fleet electrification (blue >25 µg/m^3)

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Mineral Dust Services

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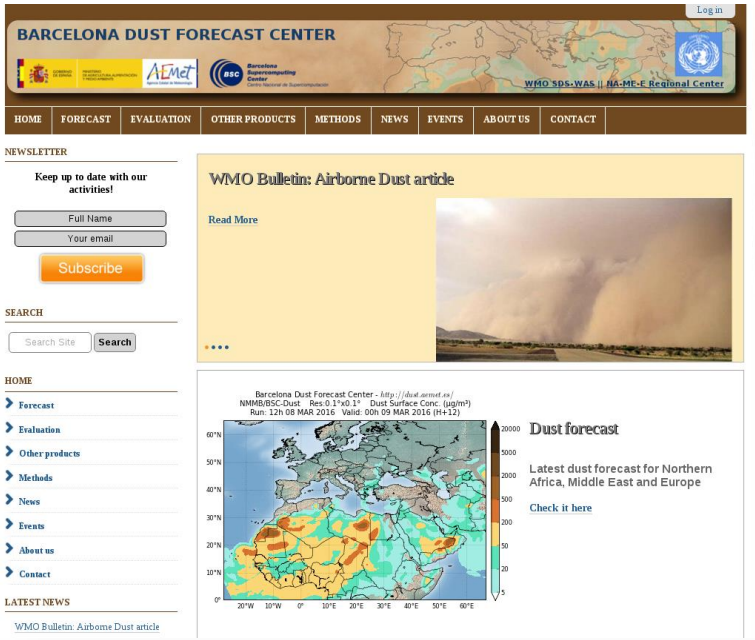
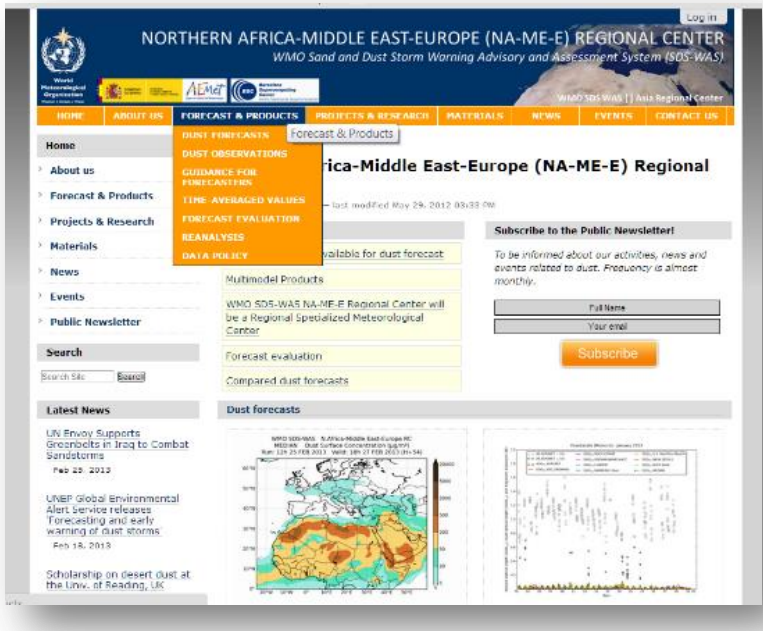
Mineral dust forecasts

- Barcelona Dust Forecast Center. First specialized WMO Center for mineral dust prediction. http://dust.aemet.es started in 2014

- SDS-WAS. North Africa, Middle East and Europe Regional Center. http://sds-was.aemet.es started in 2010





Seasonal wind power predictions

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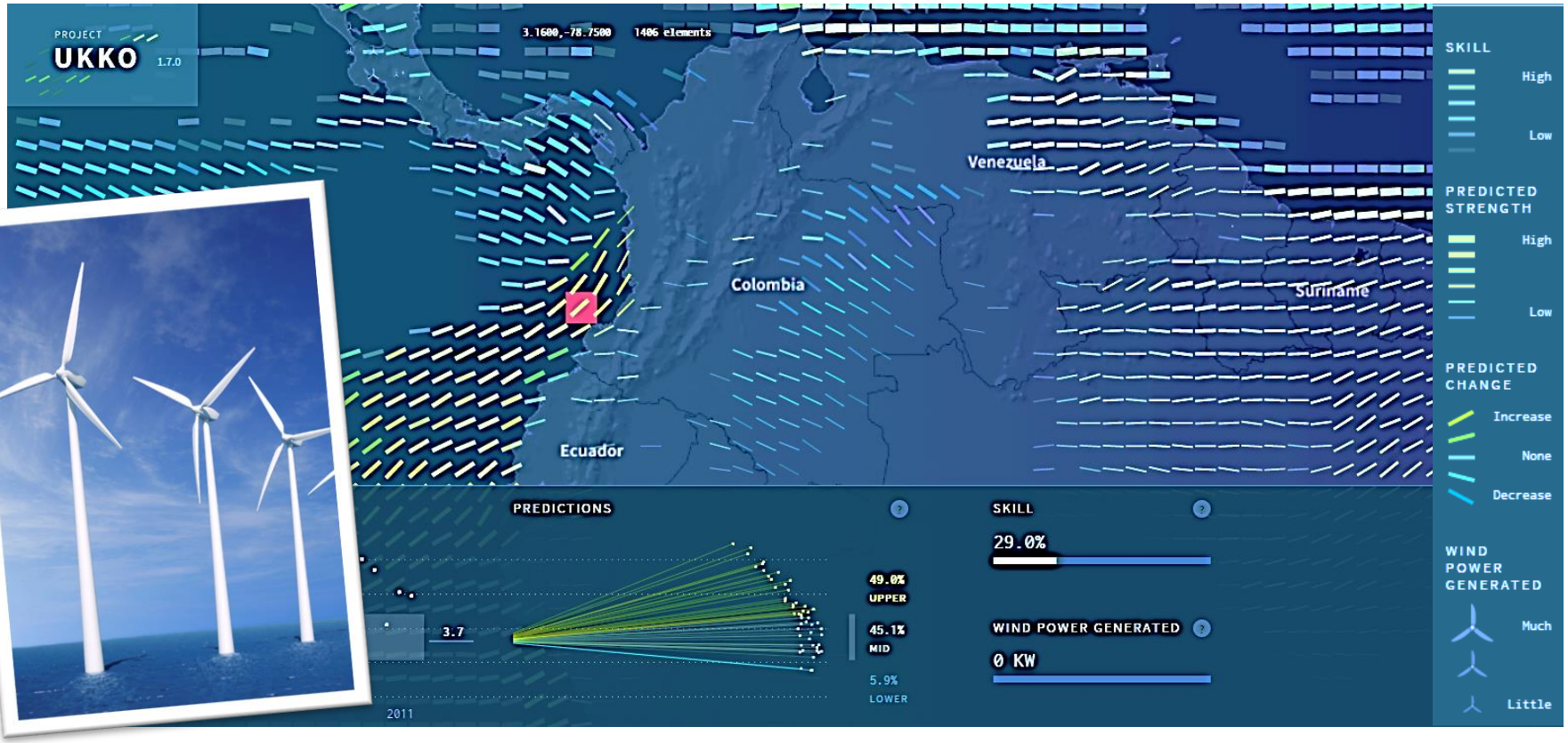
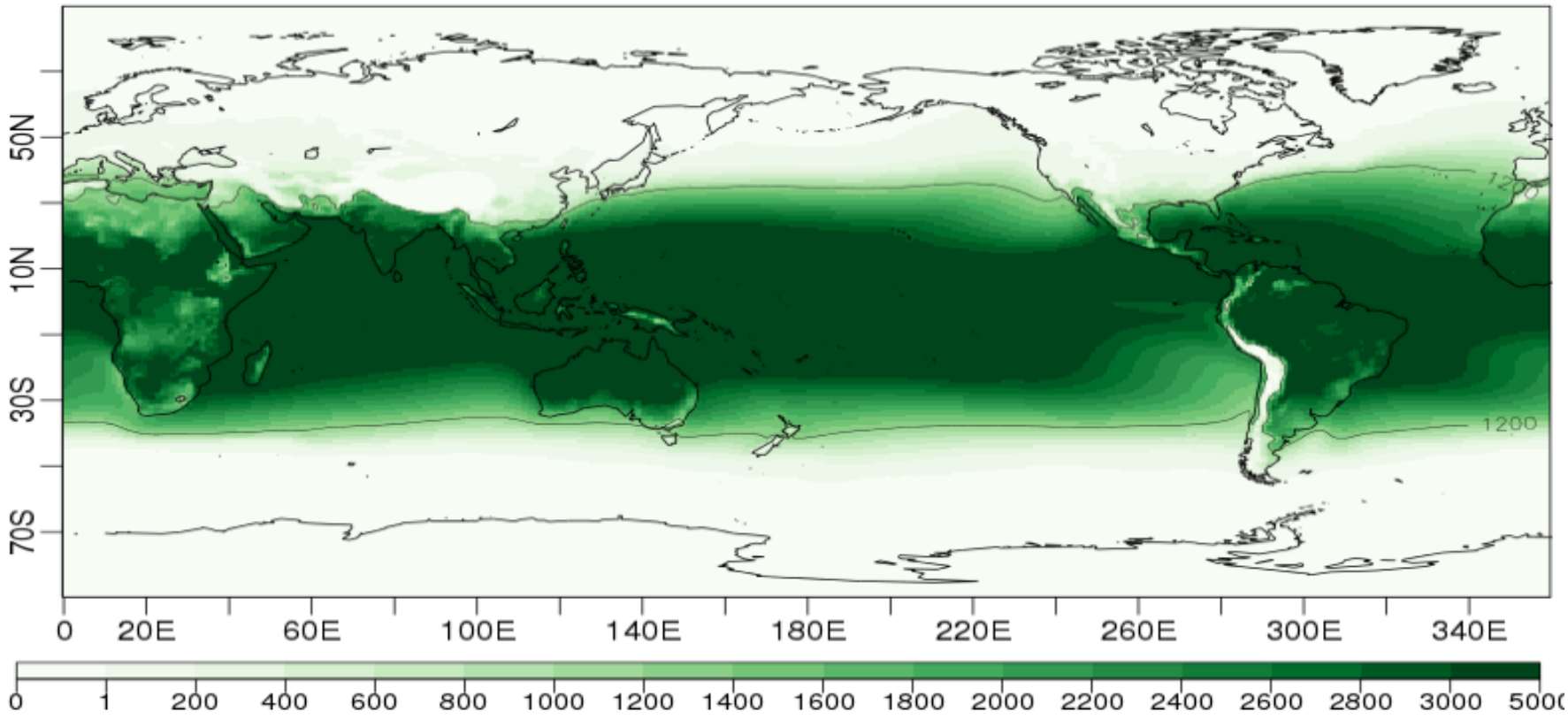


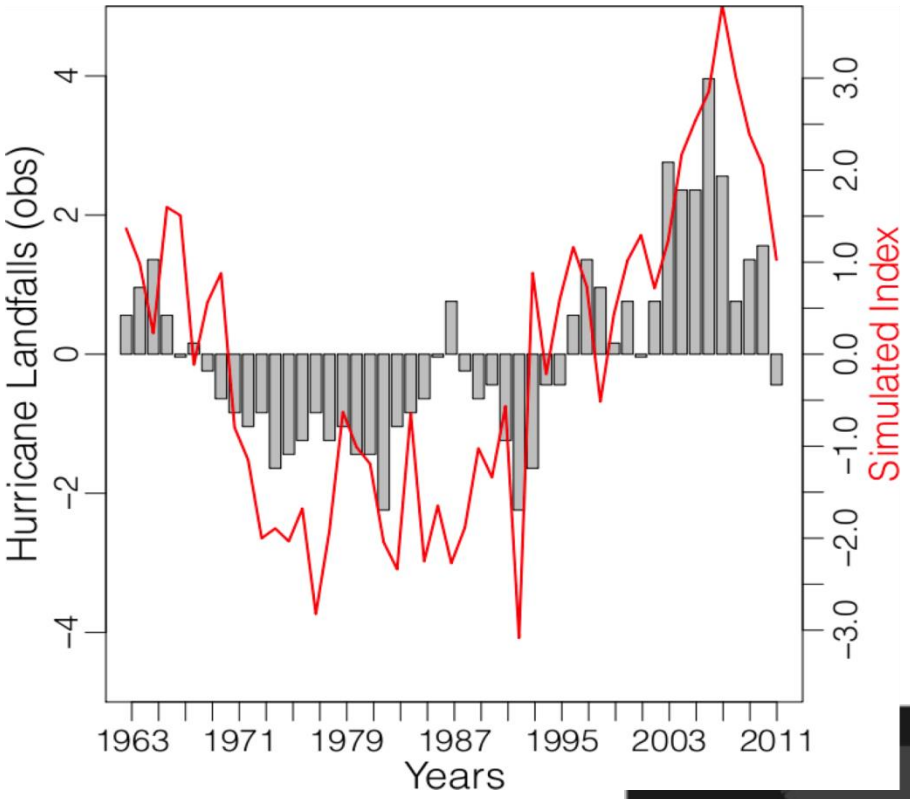
RESILIENCE
PROTOTYPE

SPECS
EUPORIAS
Clim4Energy
SEVENTH FRAMEWORK PROGRAMME
NEWA
EDF
edp renewables
ALSTOM
VORTEX
natural power
EnBW

Winkler Index: Oct-Abr



Hurricane landfall predictions



Decadal climate predictions initialized every year from 1960 to 2005. Hurricane landfall anomalies averaged over forecast years 1-5

L.P. Caron (BSC)

Synergies

Observations of aerosols and vertical profiles of the atmosphere

- Models evaluation, initialization, data assimilation (AC, CES)
- Aerosols interaction with meteorology (AC)

Extreme events modelling and understanding meteorological processes affecting the Mediterranean

- Air quality dynamics and source apportionment (AC)

Climate variability and tipping points

- Bias correction analysis in climate prediction (CP)
- Attribution of extreme events (CP)
- Identification of sources of skill in climate prediction (CP)

Data analysis for final-user derived applications

- Climate predictions or meteorological forecasts for energy applications (Services)
- Data management, visualization, analysis (CES)

www.bsc.es

Thank you