Climate Change

Prototype decadal climate services

Nick Dunstone
Met Office, UK

Copernicus Europe's eyes on Earth | European Commission | ECMWF

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Overview

- **EU C3S funded project (C3S_34c) to:**

  co-develop prototype decadal climate services for sector users

- **Four research institutions, four decadal prediction systems, four sector users:**
  - **four prototype decadal climate services**

- **18-month project that finished in June this year**

- **Here I'll give a brief overview of the four prototype decadal climate services developed and outline the key lessons we learned**

Many people involved in the project:

DWD: Barbara Frueh, Andreas Paxian, Klaus Pankatz, Katja Reinhardt

BSC: Balakrishnan Solaraju Murali, Francisco Doblas-Reyes, Nube González-Reviriego, Andria Nicodemou, Louis-Philippe Caron

CMCC: Eirini Tsartsali, Panos Athanasiadis, Stefano Materia, Silvio Gualdi

Met Office: Nick Dunstone, Julia Lockwood, Adam Scaife, Doug Smith, Leon Hermanson, Hazel Thornton

ECMWF Copernicus Europe's eyes on Earth European Commission

Robust decadal hindcast skill using large multi-system ensembles

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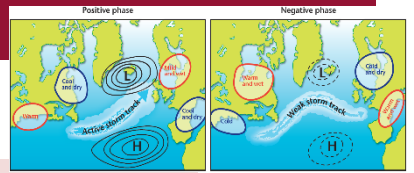
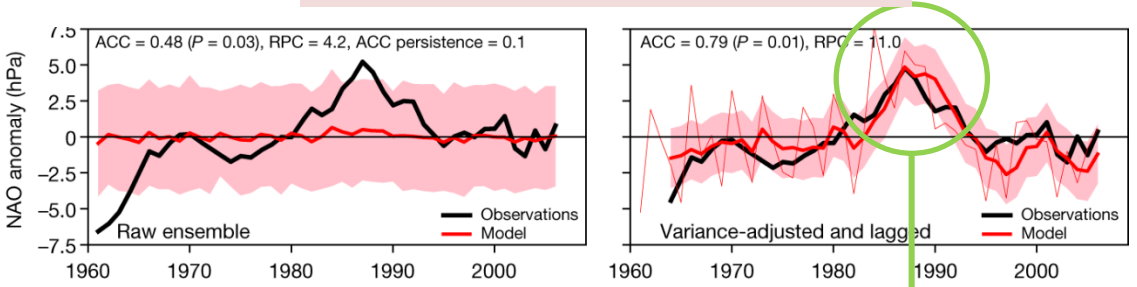
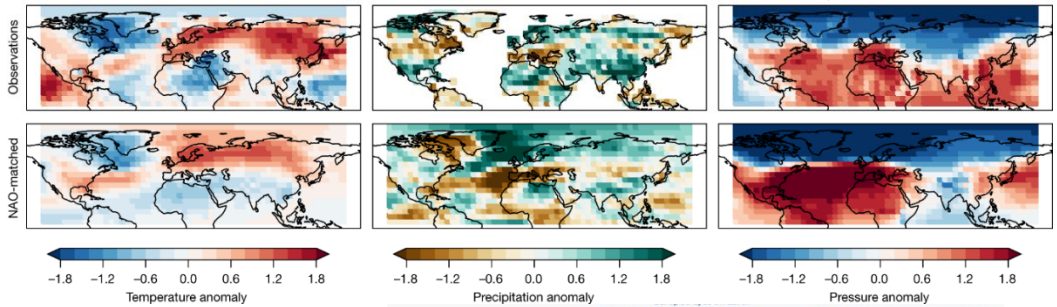
Years 2-9



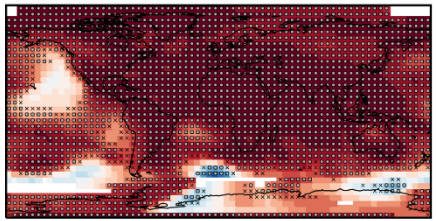
NAO shown to be skilful on decadal timescale – Smith et al 2020 (Nature)



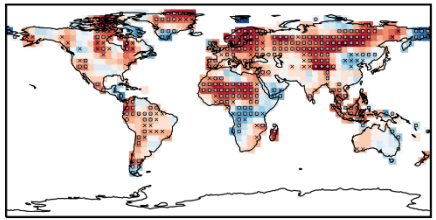
Skilful predictions of European winter temperature, rainfall and pressure anomalies during 1986-1997



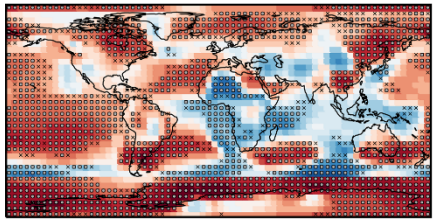
Total skill
(a) Temperature



(c) Precipitation



(e) Pressure



Smith et al 2019

Smith et al 2020

Operational decadal predictions

Climate Change

WMO operational decadal predictions

WMO Lead Centre for Annual-to-Decadal Climate Prediction

The Met Office is a designated Lead Centre for Annual-to-Decadal Climate Prediction (LC-ADCP). The LC-ADCP collects and provides hindcasts, forecasts and verification data from a number contributing centres worldwide.

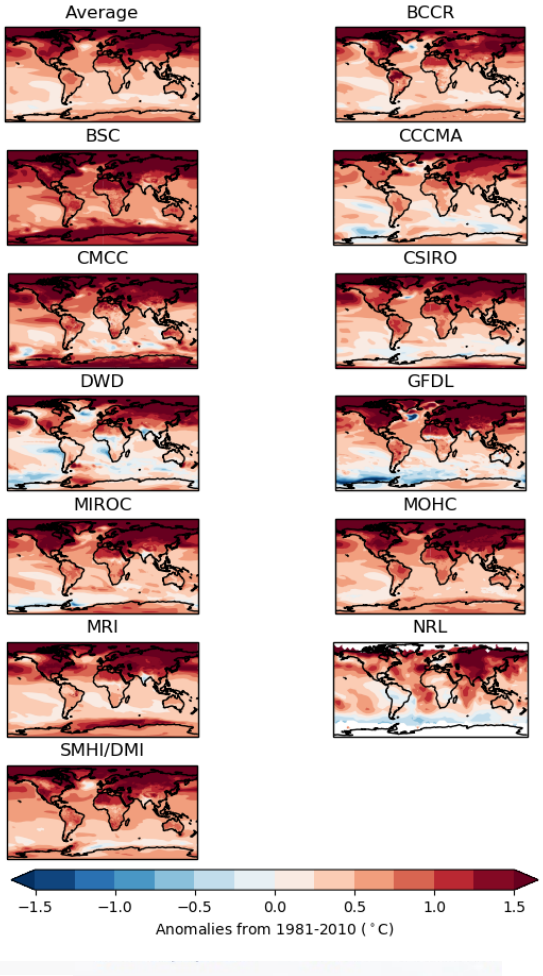
Global Producing Centres

BSC | CCCMA | CSIRO | DWD | MOHC

Contributing Centres

BCCR	DMI	LASG	MRI	Reading
CERFACS	GFDL	MIROC	NCAR	SMHI
CMCC	IPSL	MPI	NRL	

2020 predictions for 2021-2025 surface temperature



Web site: http://www.wmolc-adcp.org

Lead centre: Met Office

International effort

Operational decadal climate services

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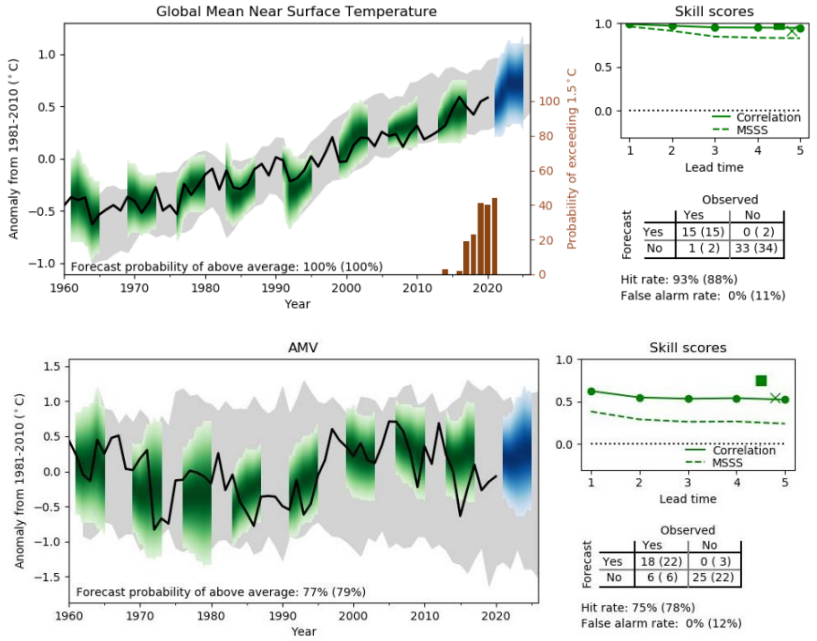

WMO Global Annual to Decadal Climate Update

"It is about as likely as not (**40% chance**) that at least one of the next 5 years will be 1.5°C warmer than pre-industrial levels and the chance is increasing with time"

- **Issued annually, the Global Annual to Decadal Climate Update uses the decadal forecasts collected by the WMO Lead Centre.**
- **Currently presents annual mean year 1 and years 1-5 forecast maps for: temperature, precipitation and sea-level pressure.**
- **It also gives forecasts of large-scale indices such as global mean surface temperature, AMV and Nino3.4.**

Need regional decadal climate services for sector users…

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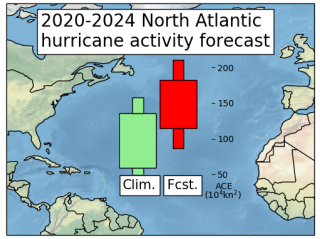
Overview of sectors and partners

INSURANCE

Met Office Hadley Centre

(partner: Willis Re)

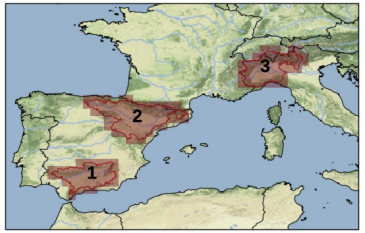


Predictions of 5 year N. Atlantic hurricane activity and US total insured losses

ENERGY

cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

(partner: Enel)

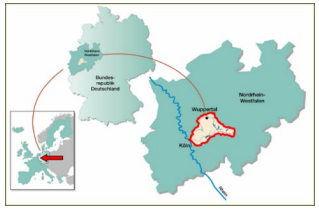


Predictions of 10 year precipitation for hydropower industry

INFRASTRUCTURE

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

(partner: Wupperverband)

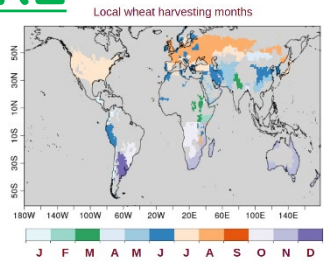


Predictions of 3 year high-resolution SPEI drought index for water management.

AGRICULTURE

BSC Barcelona Supercomputing Center
Centro Nacional de Supercomputación

(partner: Joint Research Centre)



Predictions of 5 year SPEI drought for global wheat producing regions

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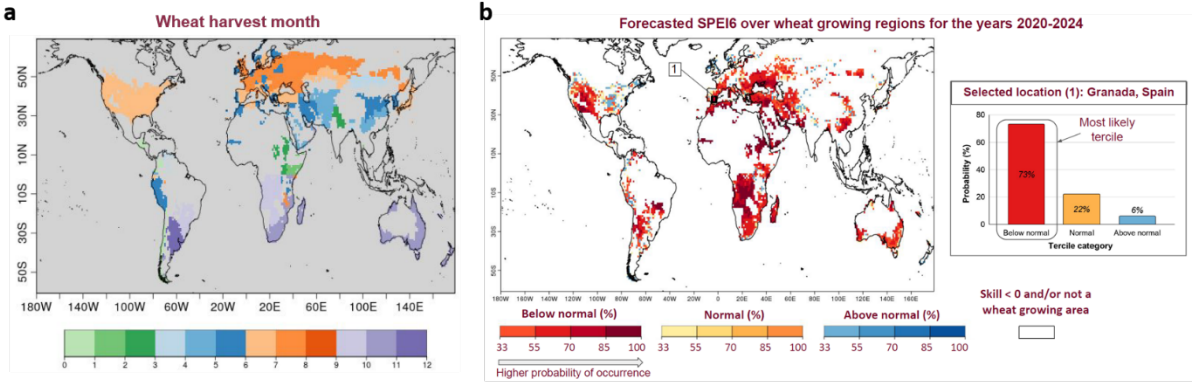
Agriculture prototype decadal service

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

More details in final talk of session by Bala Solaraju-Murali



- **Joint Research Centre (JRC) interested in predictions of global wheat production**
- **Need to tailor forecast for each region according to local harvest month**
- **Standardized Precipitation Evapotranspiration Index (SPEI) is calculated over preceding 6 months growing season**

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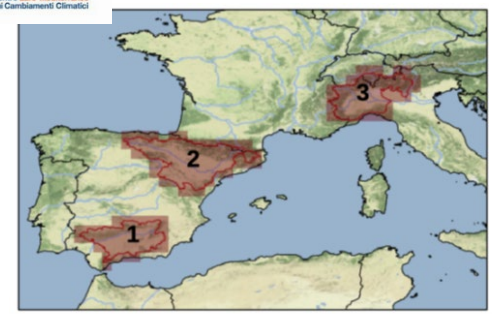
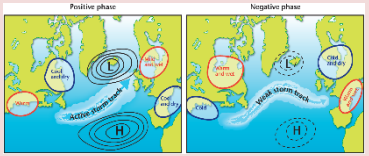
Energy prototype decadal service

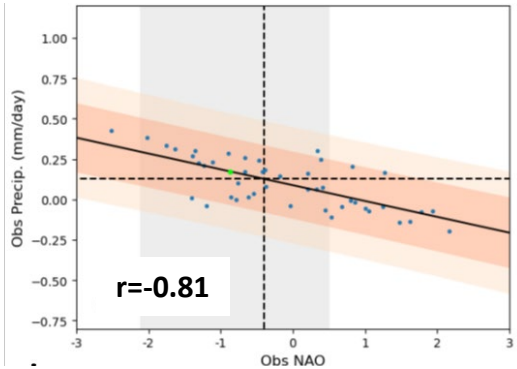


- ENEL interested in decadal predictions of precipitation for hydropower
- Direct model forecast precipitation is not skilful
- However, can use forecast NAO as a predictor…

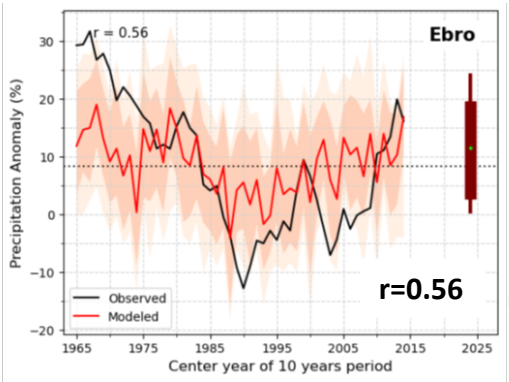


More details in next talk by Eirini Tsartsali

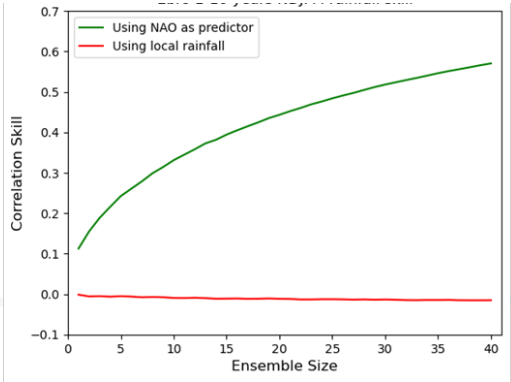
Observed NAO is strong driver of Ebro rainfall variability



Using forecast NAO as a predictor is skilful



Large ensembles required for skill in NAO and hence Ebro rainfall



Infrastructure prototype decadal service

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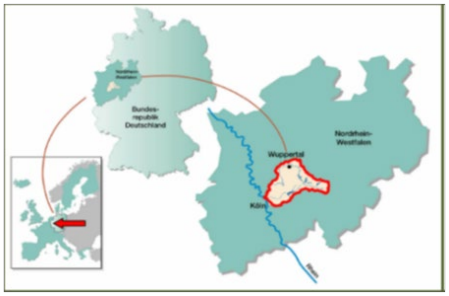
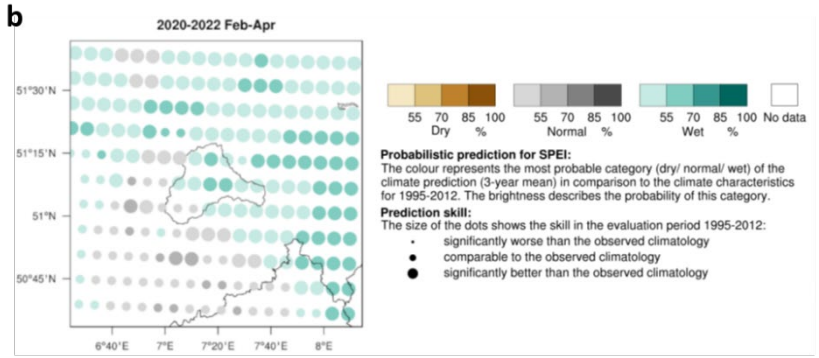
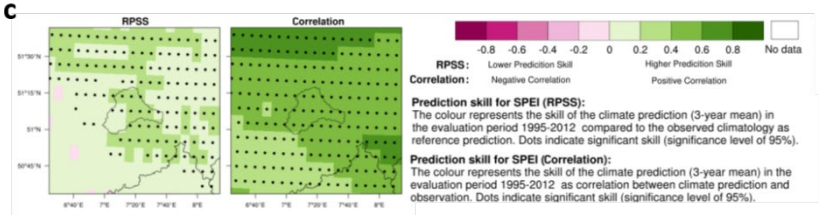
Deutscher Wetterdienst
Wetter und Klima aus einer Hand







- **Wupperverband are interested in decadal drought indices for water management in the Wupper catchment of NW Germany and requested high-resolution predictions at 11km resolution**
- **Empirical-statistical downscaling was performed using EPISODES (Kreienkamp et al 2018) from GCM output over wider Northern Europe region**
- **Due to daily data requirements only 10 member MPI-ESM system could be used to calculate required SPEI drought indices**
- **Feb-Apr for years 1-3 was selected as skilful for 2019 based forecast. However, when new MPI system ran, this was no longer skilful**
- **=> multi-system large ensembles give most robust estimate of prediction skill**

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European Commission

Insurance prototype decadal service - 1

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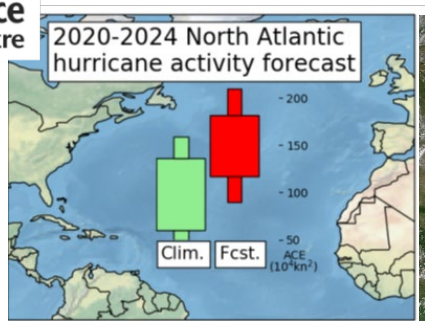
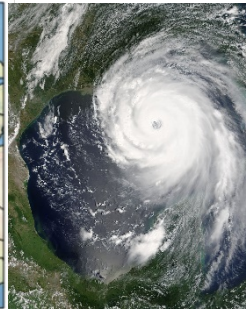
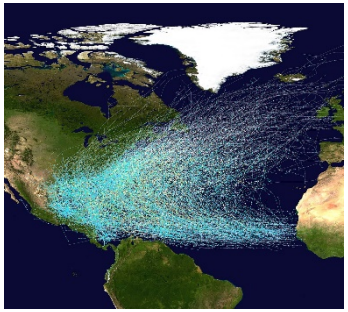
Met Office Hadley Centre

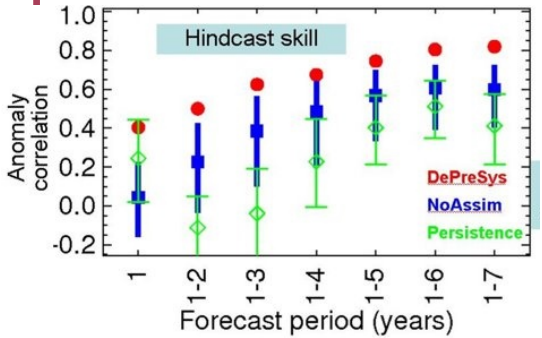




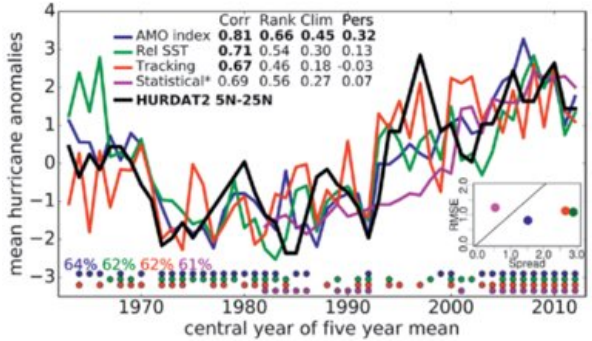


- **Willis Re involved in (re)insurance industry and interested in decadal predictions of N. Atlantic tropical storm activity and ultimately insured losses along US coastline**

Previous papers show skilful initialised decadal predictions of N. Atl tropical storm frequency

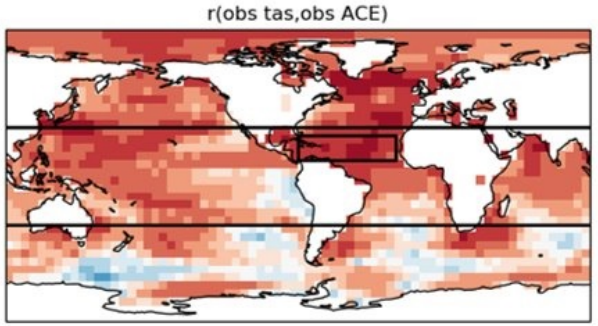


Smith et al 2010



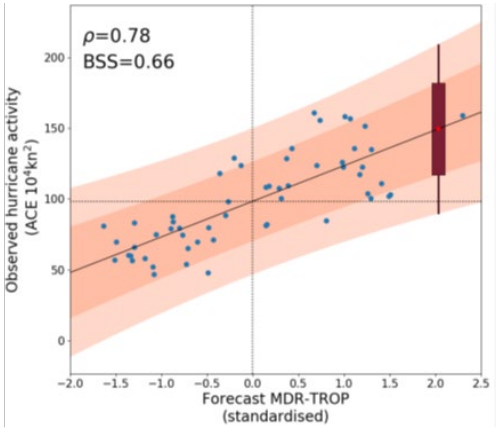
Caron et al 2018

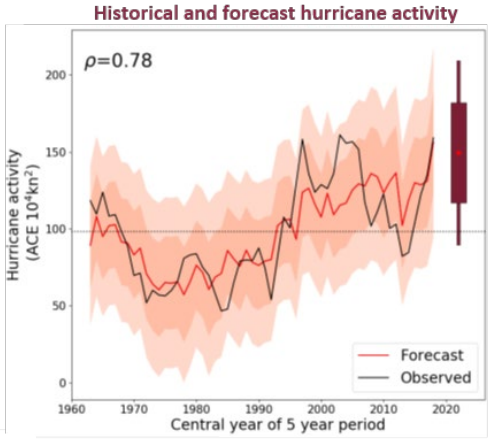
SST index MDR-TROP chosen for this climate service

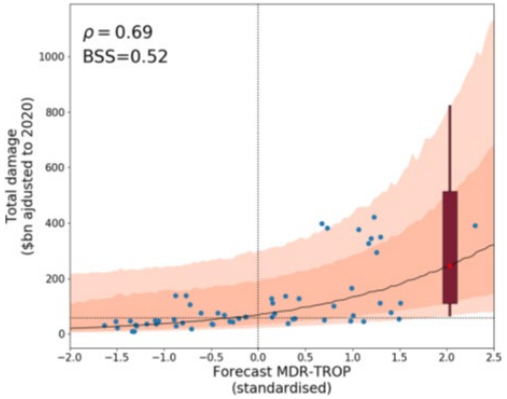


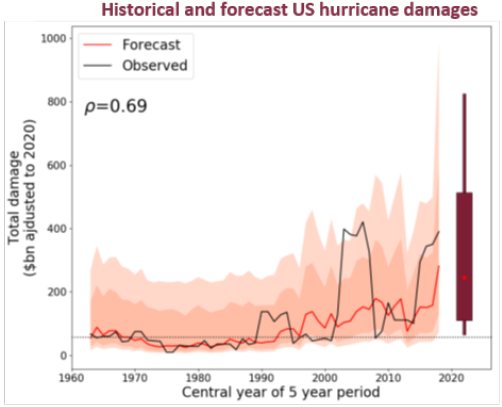
Insurance prototype decadal service - 2

Climate Change









Use the statistical relationship in hindcast between the predicted yr2-5 MDR-TROP index and the observed N. Atlantic hurricane activity (ACE) to make forecast.

2020-2024 is forecast to be very active

Here we also attempt to predict total loss in $USD.

Relationship is non-linear and has large uncertainty due to very extreme loss events from major hurricanes hitting population centres (e.g. hurricanes Andrew, Katrina)

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Co-development and presentation

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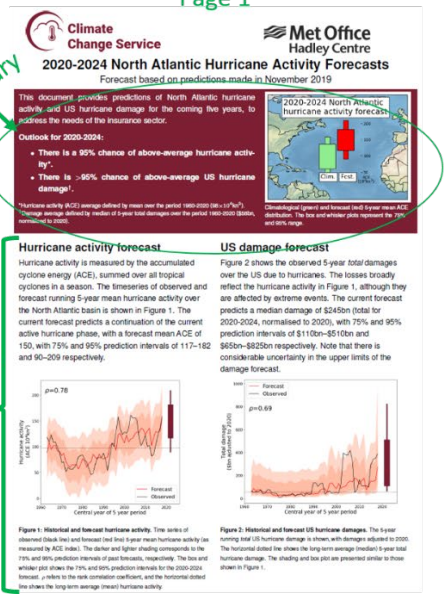
Regular discussions with engaged user throughout the co-development

A common 2-page template was designed for the climate service 'product sheets'

These were presented at a 'showcase event' in Feb 2020 where a wider group of sector users were invited to give broader feedback

Page 1


Climate Change Service

Met Office Hadley Centre

2020-2024 North Atlantic Hurricane Activity Forecasts

Forecast based on predictions made in November 2019

This document provides predictions of North Atlantic hurricane activity and US hurricane damage for the coming five years, to address the needs of the insurance sector.

Outlook for 2020-2024:

- There is a 95% chance of above-average hurricane activity*.
- There is >95% chance of above-average US hurricane damage†.

2020-2024 North Atlantic hurricane activity forecast

Hurricane activity forecast

Hurricane activity is measured by the accumulated cyclone energy (ACE), summed over all tropical cyclones in a season. The timeseries of observed and forecast running 5-year mean hurricane activity over the North Atlantic basin is shown in Figure 1. The current forecast predicts a continuation of the current active hurricane phase, with a forecast mean ACE of 150, with 75% and 95% prediction intervals of 117–182 and 90–209 respectively.

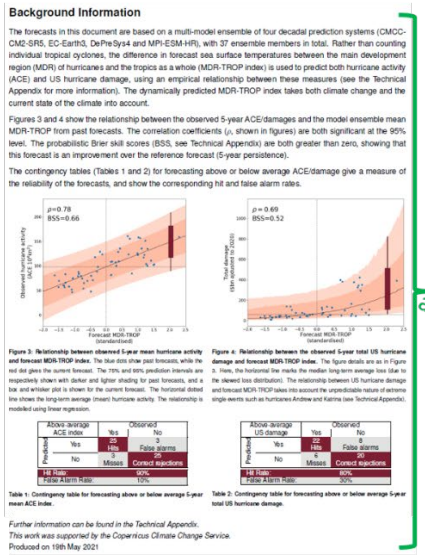
US damage forecast

Figure 2 shows the observed 5-year total damages over the US due to hurricanes. The losses broadly reflect the hurricane activity in Figure 1, although they are affected by extreme events. The current forecast predicts a median damage of $245bn (total for 2020-2024, normalised to 2020), with 75% and 95% prediction intervals of $110bn–$510bn and $65bn–$825bn respectively. Note that there is considerable uncertainty in the upper limits of the damage forecast.

Forecast summary

Forecast detail and historical context

Page 2


Background Information

The forecasts in this document are based on a multi-model ensemble of four decadal prediction systems (CMCC-CM2-SR5, EC-Earth3, DePreSys4 and MPI-ESM-HR), with 37 ensemble members in total. Rather than counting individual tropical cyclones, the difference in forecast sea surface temperatures between the main development region (MDR) of hurricanes and the tropics as a whole (MDR-TROP index) is used to predict both hurricane activity (ACE) and US hurricane damage, using an empirical relationship between these measures (see the Technical Appendix for more information). The dynamically predicted MDR-TROP index takes both climate change and the current state of the climate into account.

Figures 3 and 4 show the relationship between the observed 5-year ACE/damages and the model ensemble mean MDR-TROP from past forecasts. The correlation coefficients (ρ, shown in figures) are both significant at the 95% level. The probabilistic Brier skill scores (BSS, see Technical Appendix) are both greater than zero, showing that this forecast is an improvement over the reference forecast (5-year persistence).

The contingency tables (Tables 1 and 2) for forecasting above or below average ACE/damage give a measure of the reliability of the forecasts, and show the corresponding hit and false alarm rates.

Figure 3: Relationship between observed 5-year mean hurricane activity and forecast MDR-TROP index. The blue dots show past forecasts, while the red dot gives the current forecast. The 75% and 95% prediction intervals are respectively shown with darker and lighter shading for past forecasts, and a box and whisker plot is shown for the current forecast. The horizontal dotted line shows the long-term average (mean) hurricane activity. The relationship is modelled using linear regression.

Figure 4: Relationship between the observed 5-year total US hurricane damage and forecast MDR-TROP index. The figure details are as in Figure 3. Here, the horizontal line marks the median long-term average loss (due to the skewed loss distribution). The relationship between US hurricane damage and forecast MDR-TROP takes into account the unpredictable nature of extreme single events such as hurricanes Andrew and Katrina (see Technical Appendix).

Table 1: Contingency table for forecasting above or below average 5-year mean ACE index.

Table 2: Contingency table for forecasting above or below average 5-year total US hurricane damage.

Further information can be found in the Technical Appendix.

This work was supported by the Copernicus Climate Change Service.

Produced on 19th May 2021

Methods and retrospective skill & reliability assessment

ECMWF Copernicus Europe's eyes on Earth European Commission

Now live on C3S website:

https://climate.copernicus.eu/sectoral-applications-decadal-predictions

OVERVIEW | PROTOTYPE SERVICE FOR AGRICULTURE

Overview

The agriculture sector is heavily influenced by changes in the frequency and severity of extreme weather events. The climate can affect crop management, the crop yield and quality, and the development of crop diseases and pests. Future climate information is thus essential for adaptation to the effects of climate variability, improving production quality and quantity.

In the short-to-medium term, weather, sub-seasonal and seasonal forecasts can inform decisions on the best planting and harvest dates, the selection of crops, use of fertilisers and crop rotations. In the long term, climate predictions and projections can help with decisions on whether new crop varieties should be developed, or whether new water management and irrigation infrastructure might be needed in the future.

While decadal predictions are still not widely used in the field of agriculture, they are recognised as potentially important in supporting planning decisions that require several years to be implemented, such as equipment purchase (e.g. for irrigation), emergence of new pests/diseases, use of new varieties etc. Climate information for the next 1-5 years can also be useful for planning supply chain contracts. Finally, decadal forecasts can have an impact on strategic policies related to agriculture, from regional to the EU's common agricultural policy (CAP).

Prototype service for agriculture

A prototype service was developed to provide users with multi-year predictions of drought conditions over global wheat harvesting areas for the following 5 years. The full prediction products and further information can be found below:

- Forecast for 2020-2024, started in November 2019

OVERVIEW | PROTOTYPE SERVICE FOR INFRASTRUCTURE

Overview

The infrastructure sector is heavily affected by climate variability and change, which alter the frequency and intensity of extreme events (e.g. floods and droughts), and cause long-term changes in the climate conditions. This can affect critical infrastructures, such as road, railway and ship traffic connections, as well as power and water supply networks. In particular, changes in precipitation and hydrological conditions are resulting in longer drought periods and influence the water availability in river catchments and dams, thus affecting the availability of drinking water, ecological flow, industrial activities and shipping.

Robust climate predictions can help the infrastructure sector develop strategies and plans for adaptation to climate variability and change. In the short-to-medium term, weather, sub-seasonal and seasonal forecasts can help anticipate extreme weather conditions early enough to set up measures to secure critical infrastructures, as well as reduce damages to water and energy supply due to floods. In the long term, climate predictions and projections can help develop optimised adaptation strategies, such as constructing adequate flood protection systems or setting up alternative water distribution plans.

Decadal predictions are already used in some water management organisations as input data for surface or groundwater modelling, and for the calculation of statistical drought and runoff indices. The correlation between these indices and water availability serves to improve catchment and infrastructure management, and assess future water security. Furthermore, the future behaviour of rainfall events and their hydrological impacts can be investigated to develop suitable measures. Thus, decadal predictions are potentially important for water managers, transportation planners and power suppliers in order to support long-term planning decisions for the next 1-10 years.

Prototype service for infrastructure

A prototype service was developed to provide users with high-resolution decadal predictions of drought conditions for the Wupper catchment in Germany in the following 3 years. The full prediction products and further information can be found below:

- Forecast for 2020-2022, started in November 2019

ABOUT | BACKGROUND | SECTORS | OPERATIONAL SERVICE | PROJECT PARTNERS

About

This demonstrator service aims to provide sector-specific decadal prediction products to specific users from four different sectors: agriculture, energy, infrastructure and insurance. Predictions on the decadal timescale (1-10 years) can be used for long-term planning and potentially facilitate the adaptation of different sectors to climate variability and change.

This service works closely with individual stakeholders from each sector to develop decadal predictions for specific variables in the form of four case studies, which can be used in the decision-making and planning processes of the users.

By engaging users from different sectors, this demonstrator service covers a wide range of user needs and provides a broad range of candidate products.

Background

PREDICTION PRODUCTS

- AGRICULTURE
- ENERGY
- INFRASTRUCTURE
- INSURANCE

USER GUIDANCE

TECHNICAL APPENDIX
Coming soon

Update for November 2020 forecasts soon…

OVERVIEW | PROTOTYPE SERVICE FOR ENERGY

Overview

The energy sector is a broad industry that includes power generation using fossil fuels, as well as renewable sources, such as wind, solar and hydropower. Weather and climate variability have major impacts all along the energy value chain, from generation to transmission, demand, distribution and retail. For example, increased cloud cover leads to reduced solar power generation, or frequent and intense droughts lead to reduced availability of hydropower. In the transition of the energy sector to de-carbonisation, weather and climate information is important not only to anticipate supply and demand, but to also secure the energy infrastructure.

In the short-to-medium term, weather, sub-seasonal and seasonal forecasts can help in planning the operation and maintenance of infrastructure, securing the energy supply and demand balance. These forecasts can also help provide warnings on weather extremes to prevent damages, disruptions and power outages. In the long term, climate predictions and projections can help in financial risk assessment, investments and general planning.

Decadal predictions can be useful for assessing the available resources, and integrating new infrastructure and storage capacity in order to plan the operation and management of the entire power system. Also, since the energy infrastructure (solar parks, wind farms, dams etc.) involves long-term investments, decadal predictions can support decision making on such investments in order to minimise losses.

Prototype service for energy

A prototype service was developed to provide users with decadal predictions of precipitation aggregated over three river catchments for the following 10 years. This prototype service focuses on hydropower generation and provides skilful predictions on indicators that are important for determining the water inflow to the dams and the expected energy production. The full prediction products and further information can be found below:

- Forecast for 2020-2029, started in November 2019

OVERVIEW | PROTOTYPE SERVICE FOR INSURANCE

Overview

Extreme weather events, such as hurricanes, windstorms and flooding, can cause billions of dollars' worth of damage to properties worldwide. Insurance companies have to cover a large proportion of these costs, and therefore understanding the likely locations, frequency and severity of these events allows them to estimate how much risk is involved when taking on a customer, as well as how much capital to keep in reserve to cover potential claims.

Weather and climate forecasts on timescales of days to decades can be used in the insurance sector for determining the climatological probability of extreme events. In the short term, weather forecasts can help in taking steps to limit damages when an extreme event is imminent, such as alerting customers to take preventative action. On longer timescales, climate predictions can be used for planning long-term business strategies and risk reduction measures.

Decadal timescales (1-10 years) are of particular interest to the insurance sector since contracts are typically 1-5 years long. Advance knowledge of the likelihood of a particularly active period for a hazard, such as hurricanes or European windstorms, could help to inform the insurers of the risk involved in new contracts for this period, whether their current pricing structure is adequate, and if they need to take out insurance themselves (re-insurance). Currently, statistical predictions of hurricane activity on 5-year timescales are issued by some risk modelling companies, which are also used by the insurance industry.

Prototype service for insurance

A prototype service was developed to provide users with decadal predictions of North Atlantic hurricane activity and US hurricane damage for the following 5 years. Dynamical decadal prediction systems (those using initialised climate models) were used, providing an independent view on the coming risk and complementing existing forecasts. The full prediction products and further information can be found below:

- Forecast for 2020-2024, started in November 2019

Climate Change

Some of the lessons learned…

Skilful and <u>useful</u> sector decadal climate services are possible!

Users:

- Users generally see potential value in decadal climate services, but need more examples
- Co-development successful – could be taken further to more user centric variables
- Need to find common language and avoid climate science and statistical 'jargon'
- Some difficulties found interacting with insurance sector in particular - commercial sensitivity
- Common format of product sheet helpful in this project but could be better tailored by sector need
- Need to explore more practically 'useful' verification scores for users

Scientific:

- Use of large ensembles (often using multiple systems) key to robust skill
- Use of skilful large-scale circulation indices can give improvements over gridpoint model output
- Close gap between seasonal and decadal - 'interannual' timescale of user interest

How to facilitate more decadal climate services:

- Improve skill ☺ (e.g. larger ensembles, higher resolution)
- Stimulate 'intermediate' users (e.g. scientific consultancy) to explore decadal services
- Improve availability/access/usability of decadal prediction data (e.g. webportal and tools)
- Need to gain user confidence by demonstrating useful real-time forecasts

BAMS article in prep. (Dunstone et al 2022)

Thanks for listening.

ECMWF Copernicus Europe's eyes on Earth European Commission

Climate Change

Project/development timeline

Collect sector user needs

Collect user feedback

Showcase event to obtain feedback of wider group of sector users

Start

Nov. 2019

Decide on: variable, region & forecast period

Develop methodology and assess skill

Produce prototype climate service product sheets

Publish product sheets on C3S website and update climate service annually

Finish

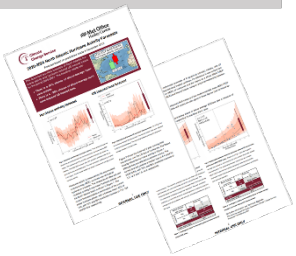
Jun. 2021

Knowledge of current decadal prediction capability

Obtain multi-model decadal hindcasts from CMIP6 DCPP

Design common template for product sheets

Obtain latest multi-model decadal forecasts



ECMWF Copernicus Europe's eyes on Earth European Commission