Climate Change

Use of reanalysis in climate services: examples of sector applications

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Thanks to: Sebastian Hendrik Sterl (IRENA), Alberto Troccoli (WEMC), Carlo Buontempo (ECMWF), Anca Brookshaw (ECMWF) Copernicus Climate Change Service (C3S) colleagues

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Key messages

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- Significant advances and evolution of reanalyses have made them one key dataset in many climate sector applications

- Continuous analysis of user requirements is one key driver for the evolution of reanalysis products

In this presentation:

- Applications based on ERA5 & implications for ERA6 Copernicus Climate Change Service(C3S) reanalyses

- Address key questions about the use and the evolution of reanalyses systems, from Climate Service Application perspective

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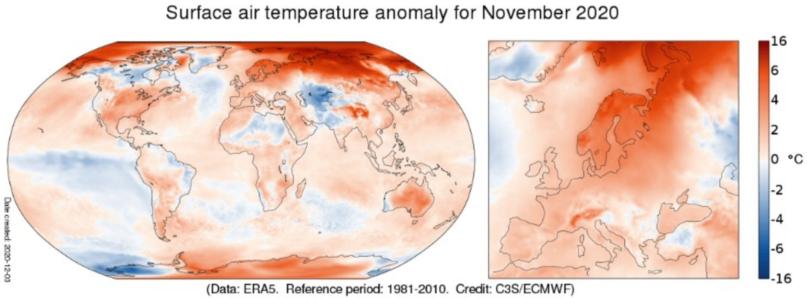
The ERA5 global reanalysis

ERA5 is in production at ECMWF for C3S

Atmosphere, land, ocean waves

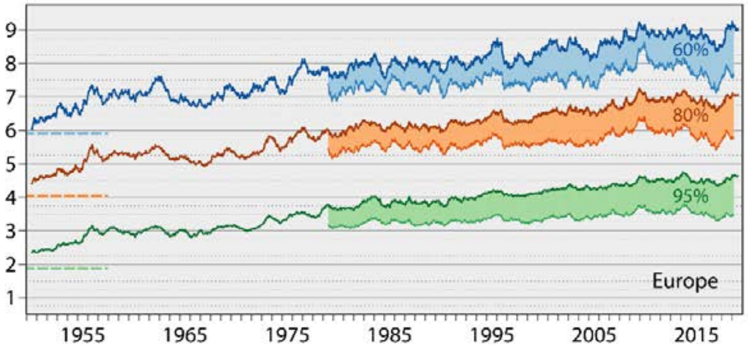
ERA5 has replaced ERA-Interim

(ERA-I was stopped end August 2019)



Improvements compared to ERA-Interim:

- Benefit from additional 10 years R&D development
- Much higher resolution; **31km** versus 80km
- More and better input data
- **Hourly output**
- 10-member EDA-based **uncertainty estimate** (at 63km)
- Continued close to real time; latency of 5 days
- Reaches further back in time (1950 versus 1979) (highest quality over data rich areas)



Forecasts from ERA5 have higher skill than those from ERA-Interim

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Climate Monitoring from ESOTC 2021 – Low wind

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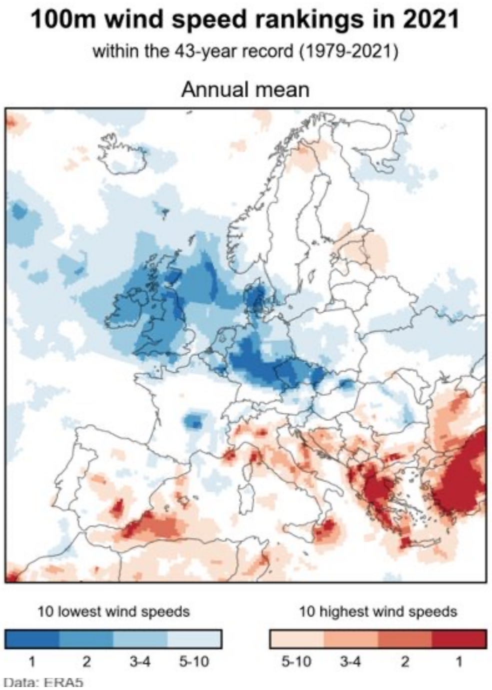

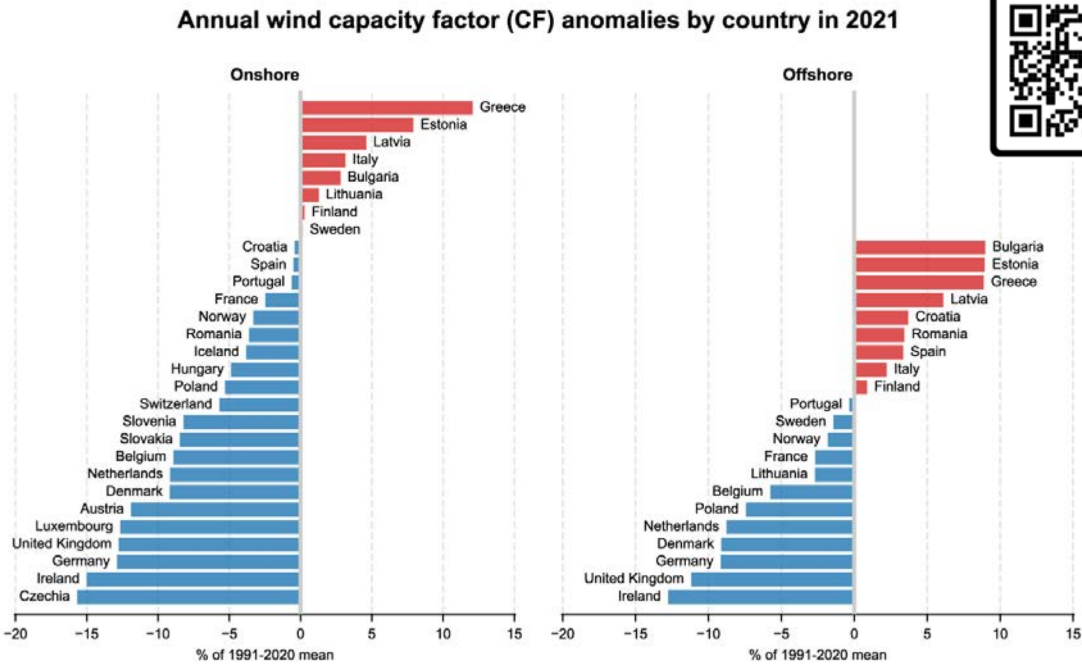

Wind speed and wind capacity factor derived from ERA5 reanalysis data set

European State of the Climate 2021, Copernicus Climate Change Service, Full report: climate.copernicus.eu/ESOTC/2021

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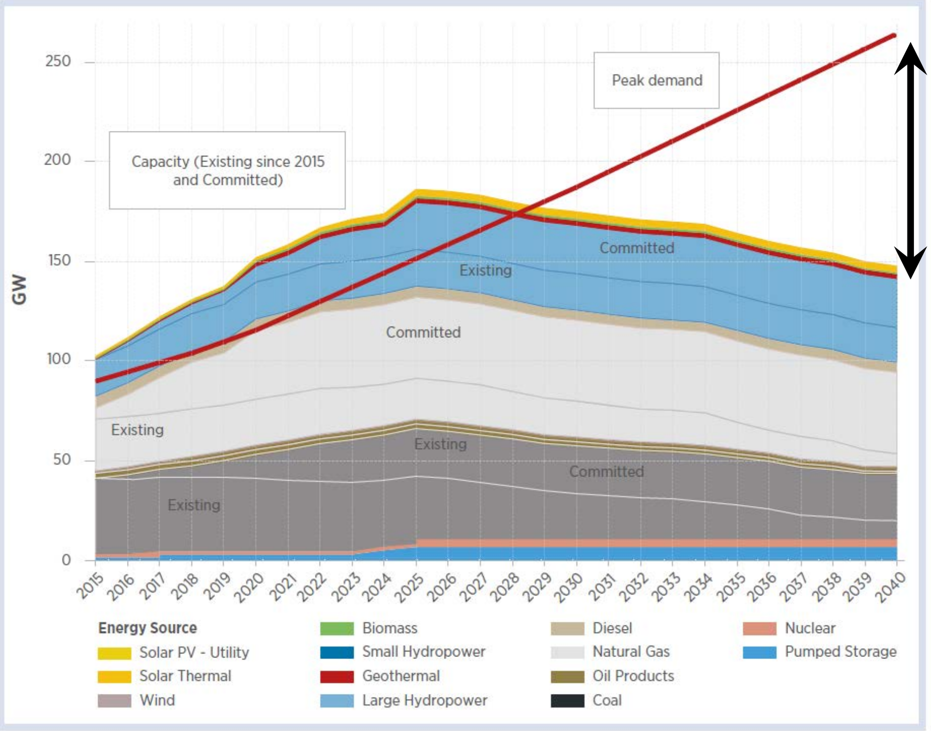
The need for capacity expansion planning

Peak demand and capacity mix timeline including committed plants and retirement schedule of existing plants in the ACEC countries, 2015–2040



https://www.irena.org/publications/2021/Apr/Planning-and-prospects-for-renewable-power-Eastern-and-Southern-Africa

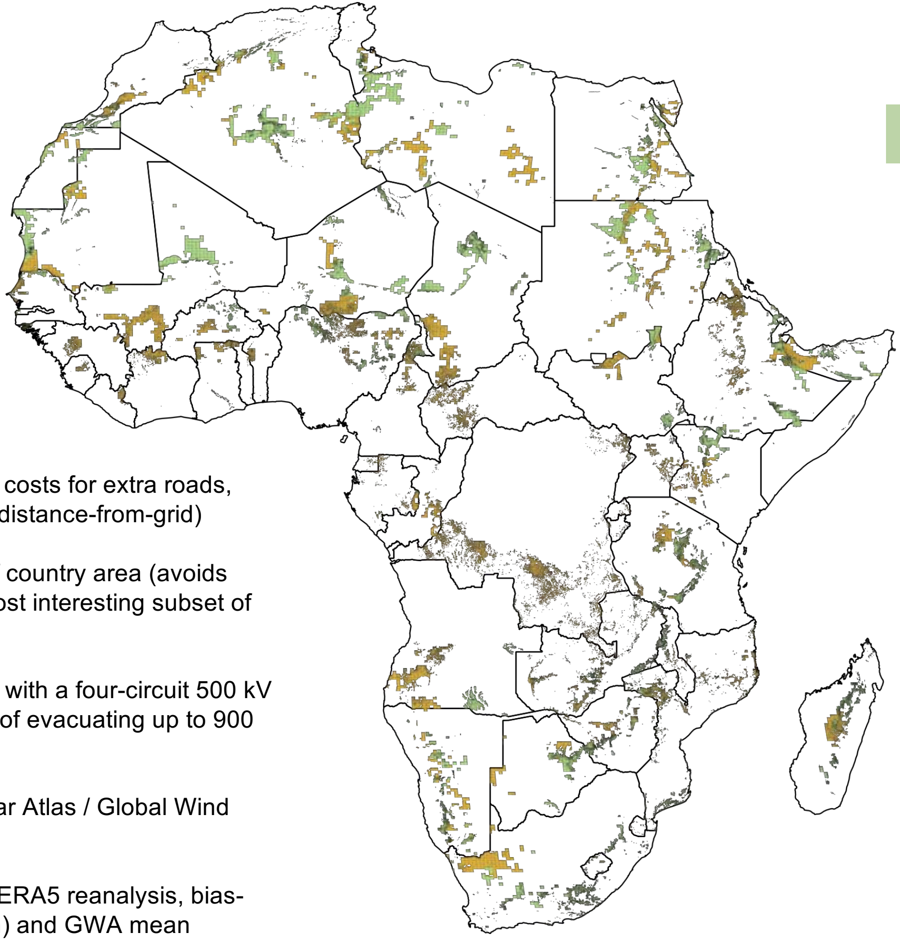
IRENA
International Renewable Energy Agency

- Existing and committed capacity will generally not be enough to meet future demand
- Need for new technologies to close gap
- Models based on cost-optimisation to pick best technologies for closing this gap
- This needs all technologies (incl. solar, wind) to be represented in detail (costs, availability &c.)
- Need for **model-ready** databases on solar & wind deployment options that capture spatiotemporal variability

African Renewable Electricity Profiles (AfREP) databases: solar and wind (Model Supply Regions)

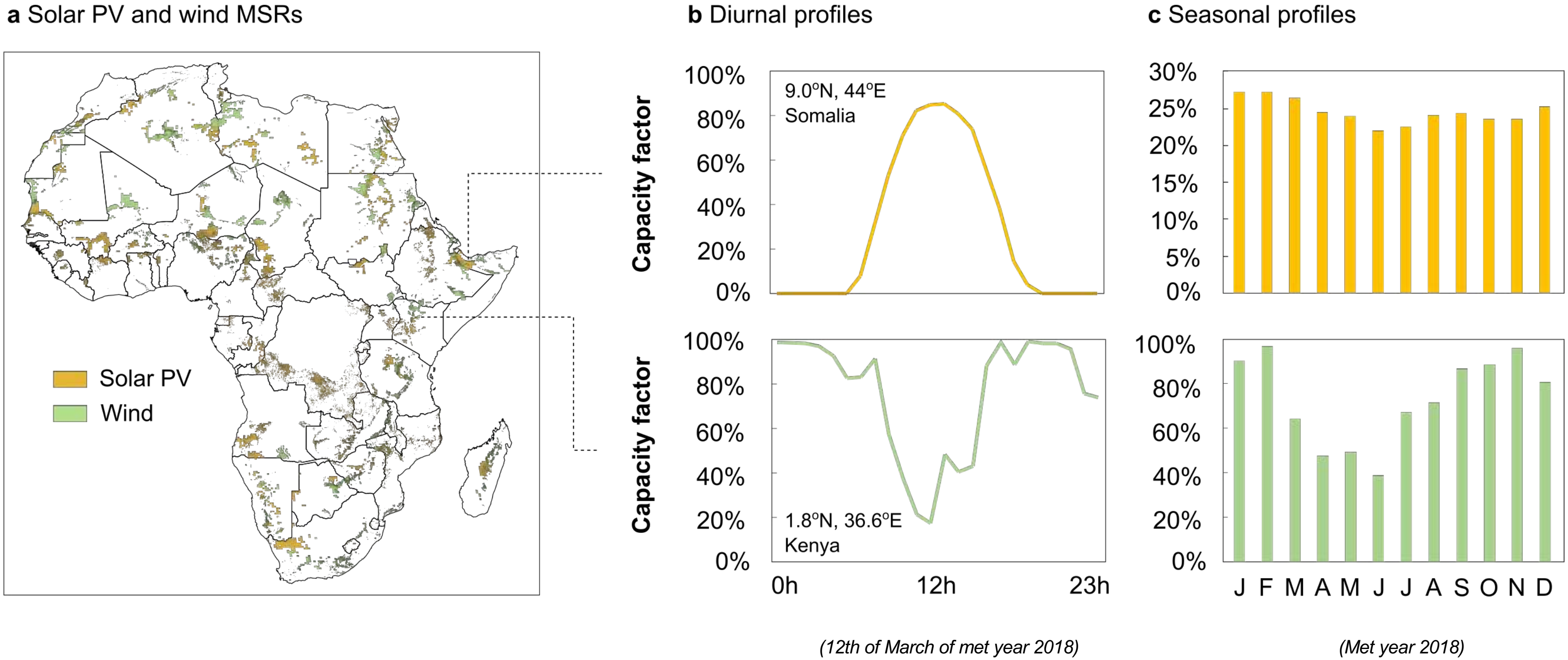
Solar PV

Wind (onshore)



- Lowest cost locations in each country (including costs for extra roads, transmission lines & substations, depending on distance-from-grid)
- Screened up to a (maximum) coverage of 5% of country area (avoids making models unduly heavy while capturing most interesting subset of potential)
- Limit of MSR area: ~3GW, based on evacuation with a four-circuit 500 kV line, with a single 500 kV line assumed capable of evacuating up to 900 MW and one extra line included for N-1 security
- Spatial resolution: 1x1 km, based on Global Solar Atlas / Global Wind Atlas
- Temporal resolution: hourly, based on ECMWF ERA5 reanalysis, bias-corrected to GSA mean (additive bias-correction) and GWA mean (empirical quantile mapping)

Analysing Africa's solar and wind Model Supply Regions (MSRs) – up to 5% of country area



S. Sterl, B. Hussain, A. Miketa, Y. Li, B. Merven, M. Bassam Ben Ticha, M.A. Eltahir Elabbas, W. Thiery, and D. Russo. *An all-Africa dataset of energy model "supply regions" for solar PV and wind power*. Submitted to Scientific Data (2022).

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Energy Sector: User Response

What do you see are the most significant advances for the field of reanalysis in the next 5-10 years?

- Higher resolution reanalysis → More realism
- Reduce the bias → Handling of systematic errors
- Outputs tailored at energy modeling community→ New products
- Longer timeseries - back in time→ However, biases a problem

What observational datasets are required ?

- Gridded observation datasets or at least highly quality controlled data
- Direct wind speed measurements at 100m height
- More data for validation in certain parts of the world (esp. African continent)
- Reprocessed and rescued data

Are there significant barriers for quantifying uncertainty in your field?

- Missing information on sub-grid scale
- Suggestion to add statistics (RMSE, bias) w.r.t. reference data, e.g. station observations

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Catastrophic forest fire June 2017

Raging fires run along a mountainside near Braga in northwestern Portugal. Wild fires have broken out in Santa Marta, Sameiro, Taipas and Braga. *Global Media Group/Sipa USA/REX/ Shutterstock*


ECO portuguese economy

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Tragedy in Pedrógão Grande: 64 confirmed deaths and 254 injured

ECO News
22 June 2017

Death toll rises to 64 and there are 254 injured
Pedrógão Grande fire, in Leiria. Portugal's Pres
painful moments, but states it is time to fight


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Driving through the killer inferno: Terrifying moment motorist escapes wildfires blamed on 'terrorist arsonists' that have claimed dozens of lives in Portugal and Spain

Burned cars at N236 road between Figueiró dos Vinhos and Castanheira de Pera, near Pedrógão Grande, central Portugal, 18 June 2017. *EPA/MIGUEL A. LOPES*

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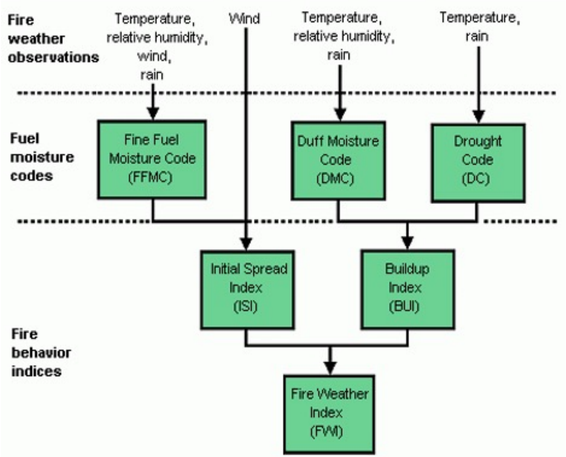
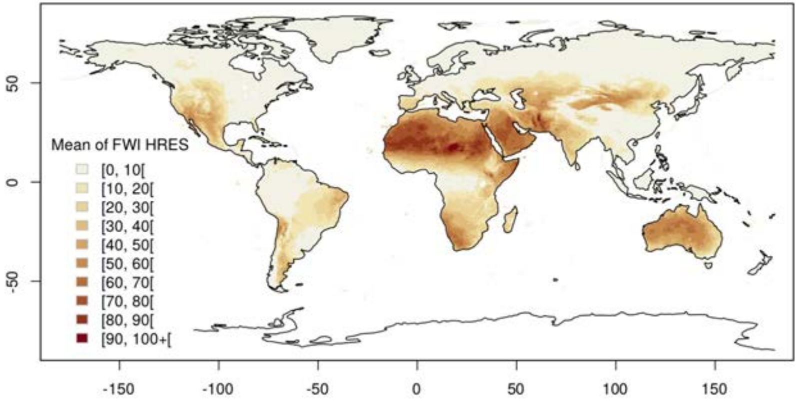
Fire Weather Index

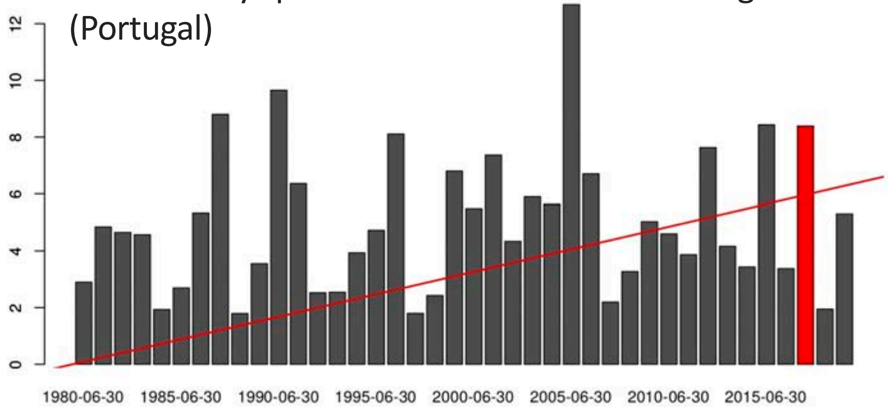
- Forest fires are becoming more devastating and less predictable
- Need to characterise temporal trends and quantify impacts on population, ecosystems and infrastructures
- Current limitations in fire observations
- FWI : the meteorological conditions that would cause flames to spread out of control, conditional on an ignition occurring





Vitolo, C., Di Giuseppe, F., Barnard, C. et al, Sci Data 7, 216 (2020). https://doi.org/10.1038/s41597-020-0554-z

The monthly spread of the ensemble at Pedrógão Grande (Portugal)



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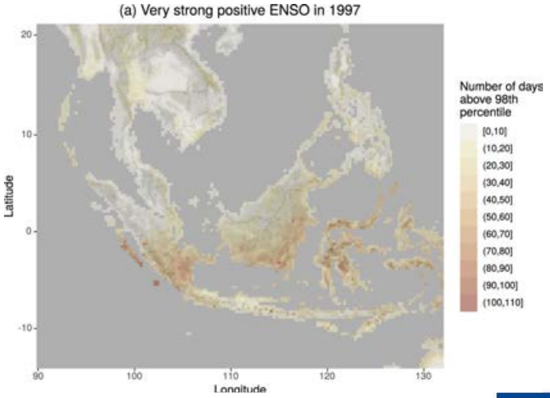
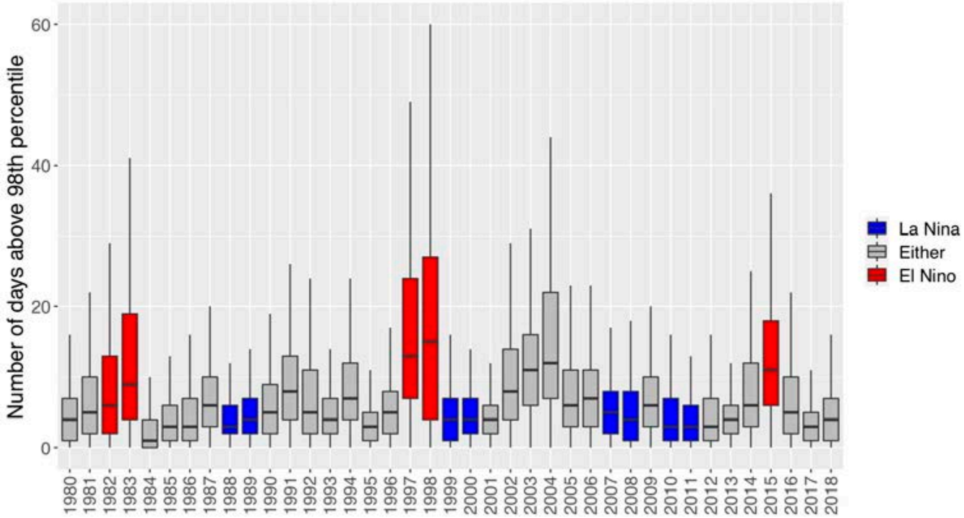
FWI & ENSO: Health Sector

El Nino can establish favorable conditions for the triggering and sustainability of wildfires in several areas around the world

Reanalyses: FWI used to investigate the climatology of wildfire danger & links to ENSO





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Fire Weather Index (Health, forestry, tourism..): User response

How is uncertainty quantified for your application? Are there significant barriers for quantifying uncertainty in your field?

- need uncertainty estimation to interpret temporal variations
- need of longer timeseries back in time

What modeling components are mature enough to enable reanalysis for your specific science question or application?

- interactive or changing Land Use and Land Cover
- Improved boundary layer processes

Other use area

- Use of ERA5 to initialize ensemble re-forecasts
  - Improvement in skill when initialized with ERA5 w.r.t. ERA-Interim
  - Benefit of use of the ERA5 Ensemble Data Assimilation to perturb the re-forecast initial conditions

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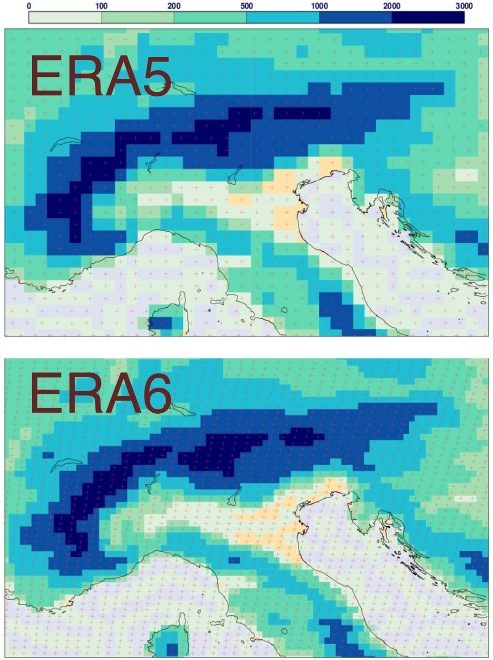
Evolution towards ERA6

In a nutshell: ERA6 will make use of:

- ✓ additional 8 years of ECMWF R&D plus dedicated reanalysis developments
- ✓ enhanced computer power and storage technologies
- ✓ more and better observations, reprocessed and rescued, satellite and in-situ from our C3S contractors
- ✓ invaluable feedback from the C3S reanalysis user community (nearly 80k registered ERA5 users on the CDS)



Improved realism:

- Higher resolution (18km vs 31 for ERA5), also for the ocean waves
    - Regional downscaling via e.g., C3S regional reanalysis
    - ERA6-Land product (9km)
- Towards coupled Earth system:
    - Ocean coupling, either two-way or one-way from OCEAN6
- Improved forcing fields, potentially time-varying vegetation (outcomes from CONFESS)

- Improve on systematic model bias,
    - better mean state and long-term trends
    - via better model
    - plus weak-constraint 4D-Var

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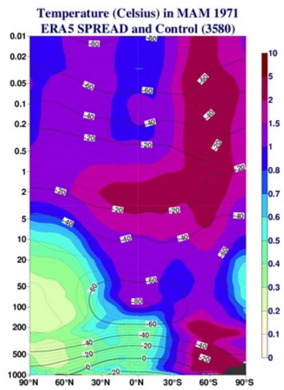
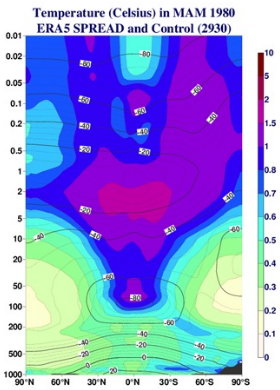
Evolution towards ERA6

Enhanced uncertainty estimate:

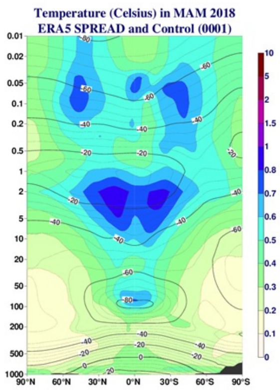
- based on user feedback and user uptake
- improve the tuning of the 'error of the day'
- provide an estimate for the mean state



1971 ERA5:
Upper-air data



1980 ERA5:
Early-satellite era



2018 ERA5:
Recent observing system

More tailored products:

- enhance output in the boundary layer, potentially adding height levels
- additional parameters, like relative humidity at 2m height
- limit the need to process/download large volumes,
  as overall dataset volumes increase considerably:
    - enhance monthly products, daily products, etc

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Special Issue of Meteorological Applications

Special issue of the open-access journal Meteorological Applications to document recent innovative applications of reanalysis data in climate services

Meteorological Applications Open Access RMetS
Science and Technology for Weather and Climate

Chief Editors: Cristina Charlton-Perez and Dino Zardi
Impact factor: 2.119
2020 Journal Citation Reports (Clarivate Analytics): 64/94 (Meteorology & Atmospheric Sciences)
Online ISSN: 1469-8080

Topics:

- Reanalyses in climate and atmosphere monitoring
- Use of reanalyses for different sector applications (energy, insurance, agriculture, water…): current applications and limitations with suggestions for future developments
- Use of reanalyses for atmospheric and climate model evaluations
- The current use of reanalyses for climate impact modelling
- The role of reanalyses in the user engagement for SMEs
- Use of reanalyses to inform national adaptation plans
- Current applications of ocean reanalyses

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