Europe month-ahead temperature is more predictable than suggested by numerical models.
Energy sector needs reliable subseasonal-to-seasonal weather forecasts

Renewables are increasing the weather dependence
Climate extremes threatens energy security
Optimize resource management
Weather forecasting 2+ weeks ahead is notoriously difficult

<table>
<thead>
<tr>
<th>Days</th>
<th>&gt; 2 weeks</th>
<th>The prediction desert</th>
<th>Seasons</th>
</tr>
</thead>
</table>

Weather forecasts

Forecasts rely on atmospheric memory

Subseasonal to seasonal (S2S) forecasts

The image shows a map of the Earth with various weather patterns and systems, highlighting the complexity of weather forecasting beyond 2 weeks.
Climate dynamics on subseasonal-to-seasonal timescales

2010-02-05

Ocean temperatures

Cold

Warm

Based on ERA-5 reanalysis data
Climate dynamics on subseasonal-to-seasonal timescales

Cold and Warm based on ERA-5 reanalysis data

Low-pressure systems (cold/wet weather)

High-pressure systems (hot/dry weather)

2010-02-05
Predicting extremes far in advance?

**Ideal world:**
highly accurate predictions:

- Very extreme events
- High spatial detail

**Reality:**
simplify prediction task:

- Moderate events
- Low spatial detail

User

Ideal world:

![User](image)

Expert

![Expert](image)

Detailed information
Reliability

Motivation
Intro
Performance
Physics
Vision
A comparison of approaches

Numerical weather prediction
Small-scale and fast processes
- Turbulence
- Heat exchange
- Moisture exchange
- Ocean eddies

Difficult for Dynamical models

Simulation of the Earth's physical processes
A comparison of approaches

Numerical weather prediction

Prediction power within the atmosphere
Prediction power within the ocean
Prediction power within land
Prediction power within the atmosphere

Artificial Intelligence model

Smart learning of slow moving climate components

Prediction power within the atmosphere
Prediction power within the ocean
Prediction power within land

Prediction power

2 weeks
1 Months
2 Months

Time

Land

Motivation
Intro
Performance
Physics
Vision
Skill comparison

**1-month ahead** temperature forecast, 1981-2021

**ECMWF SEAS5**

*preliminary results*

Average correlation coefficient:

0.10

0.51

**Data-driven forecasts**

*preliminary results*

- Average correlation coefficient:

0.2

0.3

0.4

0.5

0.6

0.7

0.8

Correlation Coefficient
Ocean driving December temperature in Germany?

December Sea Surface Temperature (SST) versus December area-averaged German temperature
Visualize influence of ocean on circulation (geopotential height)

Lagged features
Visualize influence of ocean on circulation (geopotential height)
Windows of opportunity

Normal state
Weak boundary forcing
Less predictive power

Extreme state
Strong boundary forcing
Higher predictive power
Windows of opportunity

Performance **non-confident** forecasts

target = DJF

target = MAM

target = JJA

target = SON

Performance **confident** forecasts

target = DJF

target = MAM

target = JJA

target = SON

correlation coefficient: 0.24 0.63

Motivation  Intro  Performance  Physics  Vision
Accurate & transparent subseasonal-to-seasonal weather forecasting

Machine learning  Physics  User needs
Feel free to reach out, 4 of us are present at ICEM23!

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