The MAELSTROM project has received funding from the European High-Performance Computing Joint Undertaking (JU) under grant agreement No 955513. The JU receives support from the European Union’s Horizon 2020 research and innovation programme and United Kingdom, Germany, Italy, Luxembourg, Switzerland, Norway.

Welcome & Introduction
Peter Dueben (ECMWF)

Empowering weather & climate forecast:
ML Apps & Datasets
ML Workflow Tools
Hardware Systems
**Timetable**

### MAELSTROM

<table>
<thead>
<tr>
<th>8:30 GMT</th>
<th>10:30</th>
<th>11:00</th>
<th>12:30</th>
<th>13:30</th>
<th>15:30</th>
<th>17:30</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td><strong>ML Apps &amp; Datasets</strong></td>
<td><strong>Our sister projects</strong></td>
<td><strong>External science talks</strong></td>
<td><strong>Coffee break</strong></td>
<td><strong>Lunch break</strong></td>
<td><strong>Coffee break</strong></td>
</tr>
<tr>
<td>Peter Dueben (ECMWF)</td>
<td>Bing Gong (JSC)</td>
<td><strong>TimeX</strong> Giovanni Samaey (KU Leuven) Martin Schreiber (TUM)</td>
<td><strong>Time-consistent downscaling of atmospheric fields with generative adversarial networks</strong> Jussi Leinonen (MeteoSwiss)</td>
<td><strong>Coffee break and more time for discussion</strong></td>
<td><strong>Deep learning for earth sciences in the HPC context</strong> Thorsten Kurth (NVIDIA)</td>
<td><strong>Interactive part</strong></td>
</tr>
<tr>
<td><strong>ML Workflow Tools</strong></td>
<td><strong>Hardware Systems</strong></td>
<td><strong>Deep-Sea</strong> Estela Suarez (JSC)</td>
<td><strong>Pangeo: an OS ecosystem for data-intensive science</strong> Ryan Abernathey (Columbia)</td>
<td><strong>Interactive part</strong></td>
<td><strong>Interactive part</strong></td>
<td><strong>Interactive part</strong></td>
</tr>
<tr>
<td>Fabian Emmerich (4cast)</td>
<td>Andreas Herten (JSC) Daniele Gregori (E4)</td>
<td><strong>Red-Sea</strong> Nikos Xrysos (FORTH)</td>
<td><strong>Deep learning for earth sciences in the HPC context</strong> Thorsten Kurth (NVIDIA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interactive part</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TimeX**

Giovanni Samaey (KU Leuven)
Martin Schreiber (TUM)

**Deep-Sea**

Estela Suarez (JSC)

**Red-Sea**

Nikos Xrysos (FORTH)

**External science talks**

**Time-consistent downscaling of atmospheric fields with generative adversarial networks**
Jussi Leinonen (MeteoSwiss)

**Pangeo: an OS ecosystem for data-intensive science**
Ryan Abernathey (Columbia)

**Deep learning for earth sciences in the HPC context**
Thorsten Kurth (NVIDIA)
Housekeeping

We will use Slido for Polls and Surveys (anonymously)
Please scan the QR code or access via slido.com using #MSC2022

As an attendee you can view the webinar but will not have video or audio functionality

Please ask questions via the Q&A option

Please raise your hands if you want to ask a question verbally and wait for a prompt to appear on your screen to allow you to unmute yourself.
Predictions of weather and climate are difficult as the Earth system is huge, complex and chaotic, and as the resolution of our models is limited.

However, we have a several hundred peta-byte of Earth system data from observations and model output.

- There are many application areas for machine learning in numerical weather predictions.
MAELSTROM – Why now?

Increase in data volume

New computing hardware

New machine learning software

Increase in knowledge
Challenges

Different philosophies & toolsets
Integration difficult
Off-the-mill tools not sufficient
Reliability not proven yet
Scaling up to petaflop yet to be learnt
The state-of-the-art – Machine learning at ECMWF

- Unstructured grids / COE
- Soil moisture assimilation / CNRS
- CAMS emulator
- Bias correction in 4D-Var
- Estimates of the first guess of model error in OOPS
- NOGWD emulation / Oxford
- Low dimensional ocean models / Imperial College
- ecPoint / Highlander
- ML4Land / ESoWC
- Wildfire prediction
- Tropical Cyclone detection / COE
- ecRad emulation / MAELSTROM
- Al4Emissions / ESoWC
- Lookdown induced NO2 changes
- Study tropical cyclone genesis / CLINT
- S2S prediction correction
- S2S Challenge / WMO
- Observation operators
- Observation quality control
- Bias correction in 4D-Var in 3D / COE
- Assimilate scatterometer backscatter
- Unstructured grids / COE
- Soil moisture assimilation / CNRS
- CAMS emulator
- Bias correction in 4D-Var
- Estimates of the first guess of model error in OOPS
- NOGWD emulation / Oxford
- Low dimensional ocean models / Imperial College
- ecPoint / Highlander
- ML4Land / ESoWC
- Wildfire prediction
- Tropical Cyclone detection / COE
- ecRad emulation / MAELSTROM
- Al4Emissions / ESoWC
- Lookdown induced NO2 changes
- Study tropical cyclone genesis / CLINT
- S2S prediction correction
- S2S Challenge / WMO
- Observation operators
- Observation quality control
- Bias correction in 4D-Var in 3D / COE
- Assimilate scatterometer backscatter

High-performance and (big) data processing infrastructure

- Observations
- Data assimilation
- Numerical weather forecasts
- Post-processing and dissemination

- Sea ice surface emissivity
- Learn machine learning model in 4D-Var / Fellow Bocquet
- MAELSTROM co-design cycle
- CliMetLab
- Wave model emulation / Oxford
- Learn and understand model error from observations / IFAB
- Precipitation downscaling / Oxford
- Tropical Cyclone Tracking with CliMetLab
- Ensemble post-processing / Microsoft
- Fastem-7 for RTTOV ocean emissivity / CNRS
- Machine learning – IFS coupling with Infero
- Anomaly detection / ESoWC
- SPARTACUS emulation / Reading
- Neural Network preconditioner / Oxford
- Precipitation downscaling / Warwick and Bristol

COE == Centre of Excellence with ATOS and NVIDIA
ESoWC == ECMWF Summer of Weather Code
The perspective – Full ML models for weather and climate?

NVIDIA’s Earth-2 is coming with FourCastNet – see Thorsten’s talk Climate?
A myriad of options for machine learning approaches

Dense Neural Networks, LSTMs, ConvGru, Attention Layers, Transformer networks, # of hidden layers, different normalisation of inputs, batch normalisation, tanh, relu, gelu, softplus, elu, selu, leaky relu, softmax, sigmoid function, generative adversarial networks, recurrent neural networks, encoding/decoding networks, random forests, boosting methods, clustering techniques, singular vector decomposition, causal discovery, ablation studies, root mean square error, variational auto encoder, gradient descent, stochastic gradient decent, adagrad, adadelta, RMSprop, Adam, # of epochs, # of batches, learning rate, overfitting, dropout, Bayesian networks, Gaussian processes, half precision, sparse networks… Argh…

+ a myriad of options for machine learning hardware

= confused scientists
The MAELSTROM approach
We are MAELSTROM
MAELSTROM – How to get involved?

- Visit our **project webpage**: [www.maelstrom-eurohpc.eu](http://www.maelstrom-eurohpc.eu)
- Use our **benchmark datasets**
- Use our **machine learning blueprints** for other applications
- Use of **machine learning workflow tools**
- Use of **compute system designs**
- **Talks, deliverables and publications**
- Two **dissemination workshops** are planned for April 2022 and Spring 2024 at ECMWF
- Two **hackathons** foreseen (2022 in Juelich and 2023 at ECMWF)
Questions?

Please also join us for the ECMWF Machine Learning Workshop Tu-Fr
https://events.ecmwf.int/event/294/

This presentation reflects the views only of the author, and the European High-Performance Computing Joint Undertaking or Commission cannot be held responsible for any use which may be made of the information contained therein.