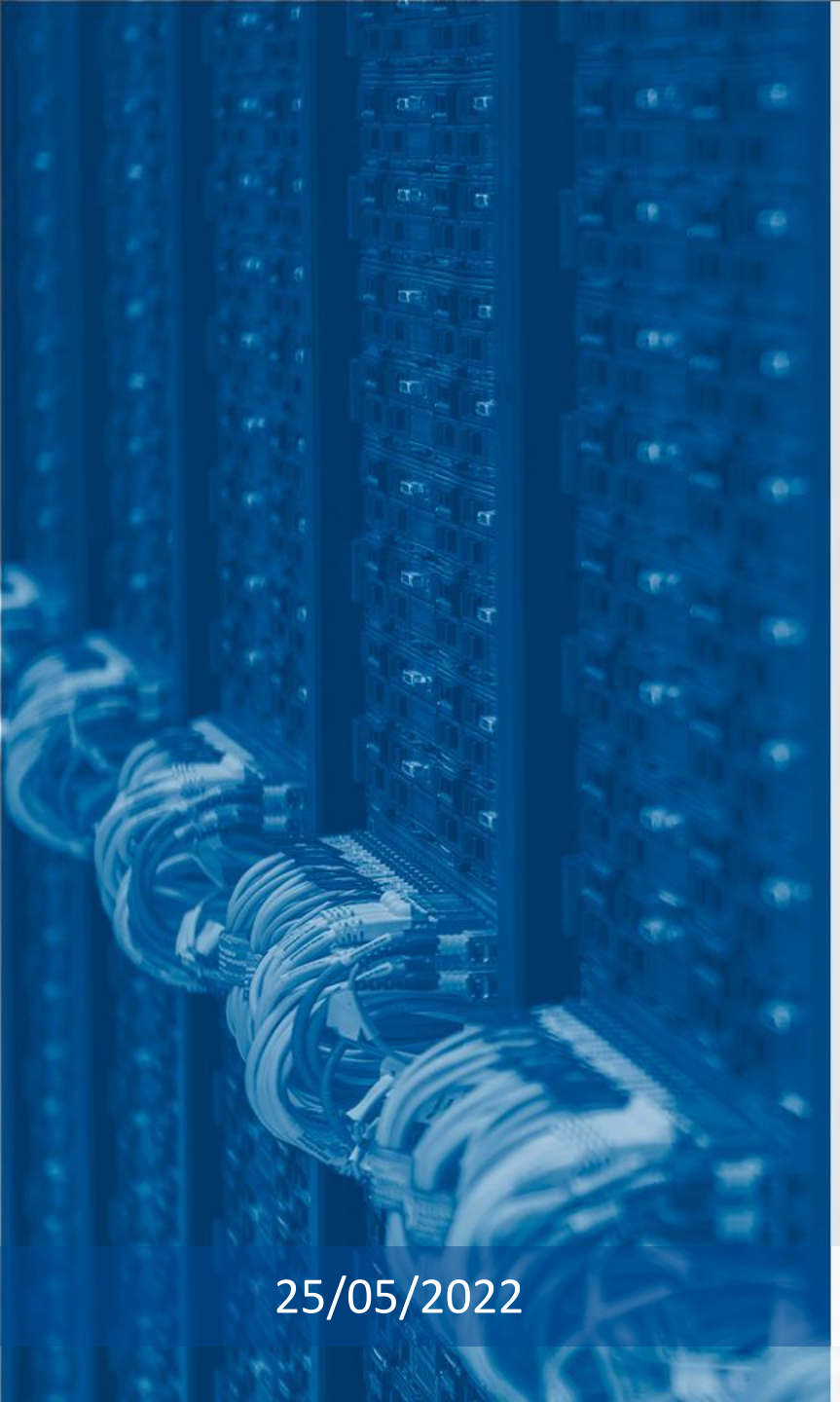

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Sharing is encouraged

# Exploring the SZ lossy compressor use for the XIOS I/O server


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The research leading to these results has received funding from the EU H2020 Framework Programme under grant agreement no. 823988



25/05/2022

EGU General Assembly 2022 , Vienna, Austria

# Introduction

- The increase in the forecast capability of Earth System Models (ESMs) is strongly linked to the spatial resolution to solve more complex problems.
- This requires a large demand of computing power and it might generate a massive volume of model output which implies:
  - Data must be **efficiently** written into the storage system.
  - No more **offline post-processing** is affordable due to the size of the “raw” data.
  - A **high cost** of storage systems due to the huge data size.
- In this new exascale era, it will be mandatory to implement an efficient I/O management for ESMs.

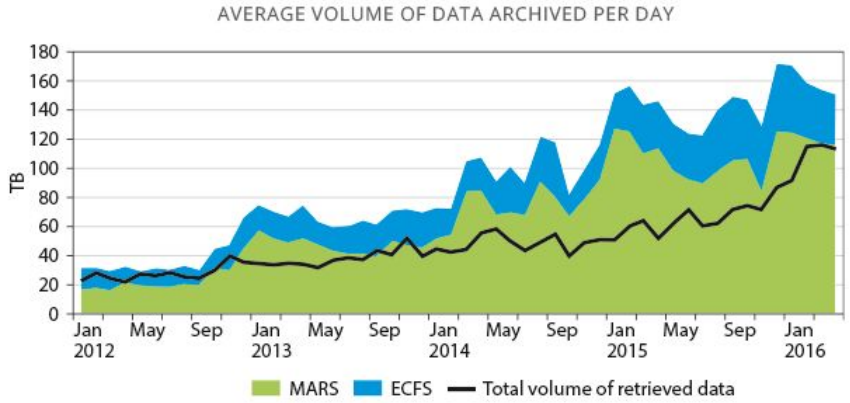



Figure source: ECMWF

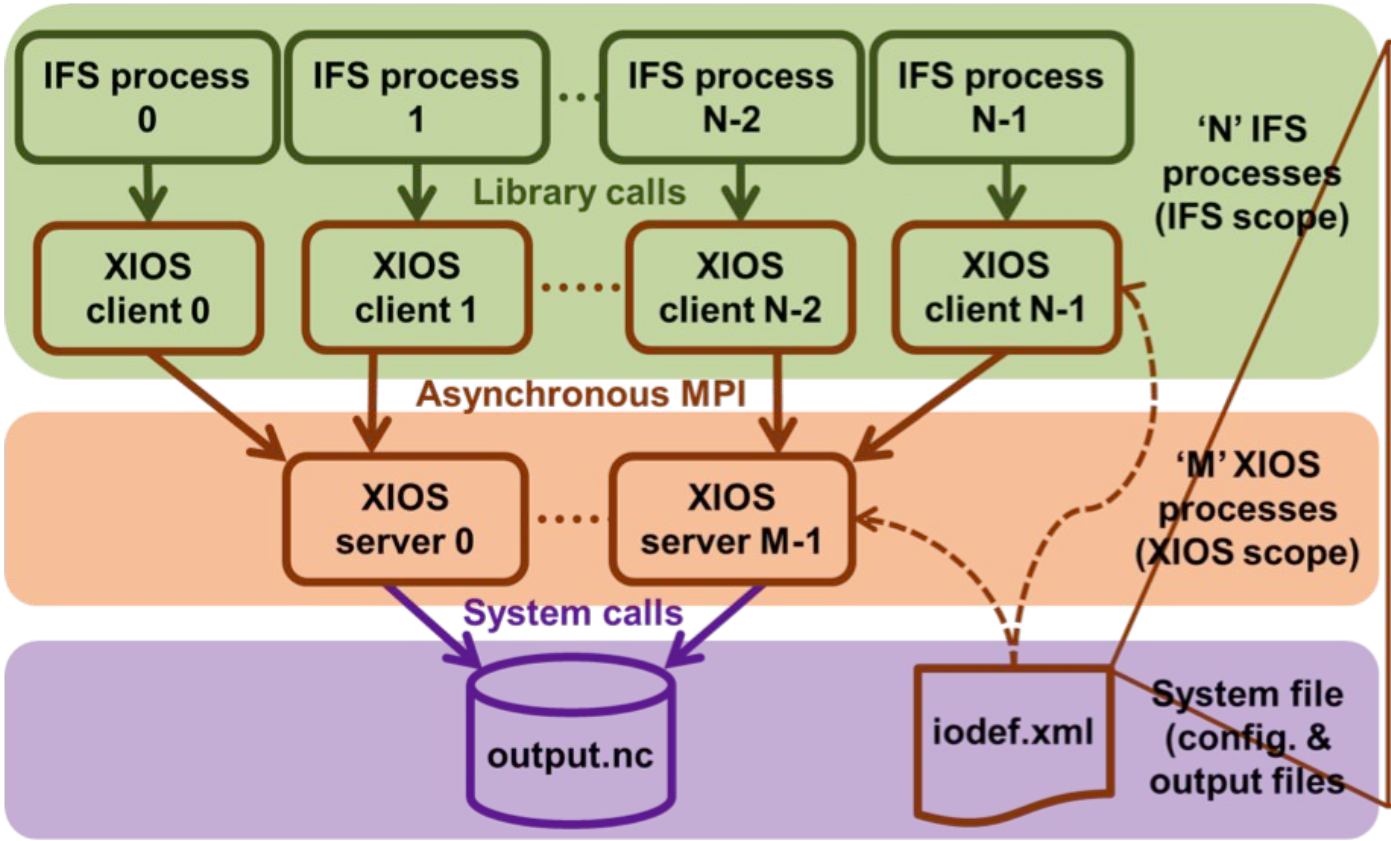
# The XIOS I/O server

- The I/O issue is typically addressed by adopting scalable parallel I/O solutions.
- In the climate community, a widely I/O tool used is **XIOS**.
- The XML Input/Output Server (XIOS) is an asynchronous MPI parallel I/O server developed by the Institut Pierre-Simon Laplace (IPSL).
- Output files are in **NetCDF** format.
- XIOS offers **lossless data compression** using gzip through HDF5.

# Test case: OpenIFS and XIOS integration

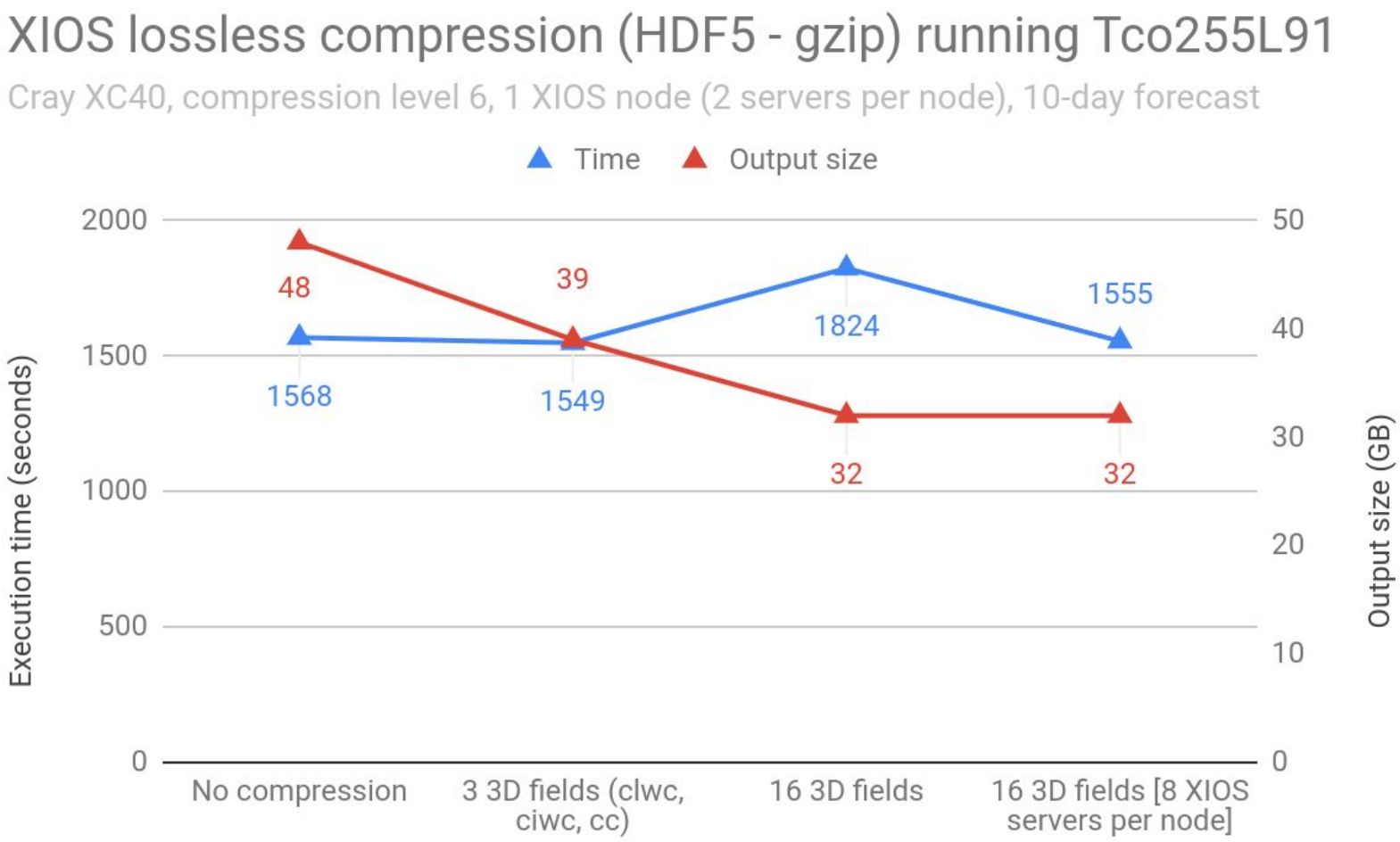
- **OpenIFS** is an atmospheric general circulation model developed and maintained by the European Centre for Medium-Range Weather Forecasts (ECMWF).
- In the past we integrated XIOS into OpenIFS to address the former inefficient sequential I/O scheme (Yepes-Arbós et al.,2022).
- Although the **overhead** of outputting data through XIOS is really **small** for current resolutions, in the **future** this may well become a **bottleneck** because of the exponential growth of the output volume.
- The default lossless compression filter of HDF5 **does not fit** our needs:
  - If compression ratio is high, it takes too much **time**.
  - If it takes a reasonable amount of time, **compression ratio** is not enough.

# OpenIFS-XIOS integration scheme

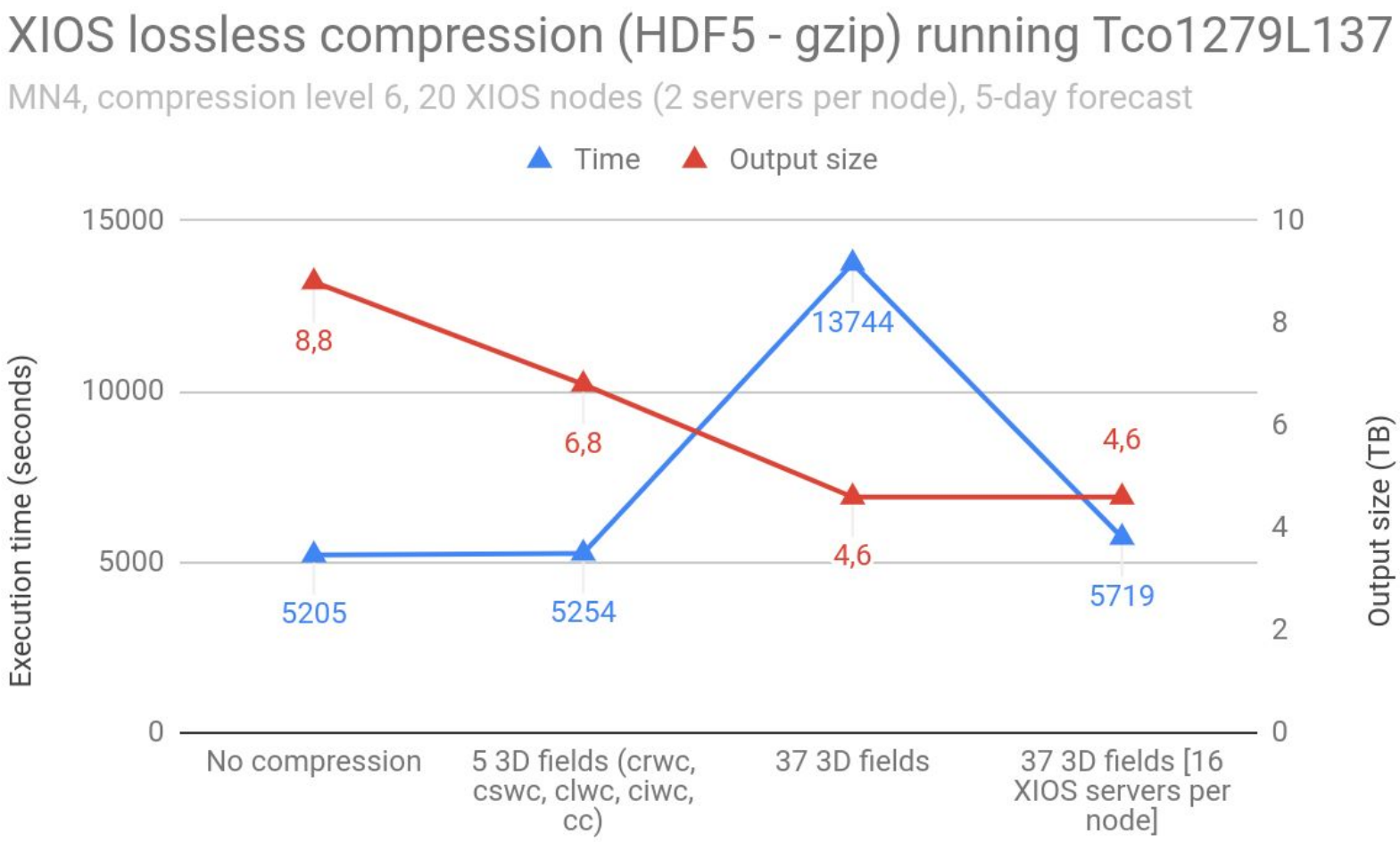



```
<grid id="grid_3d">
   <domain id="domain_2d"
   type="rectilinear" ni_glo=… />
   <axis id="axis_1d" n_glo=… />
</grid>

<field_definition>
   <field id="temp" grid_ref="grid_3d" />
   <field id="pressure" grid_ref="grid_3d" />
</field_definition>

<file_definition>
   <file name="output" freq_output="1mo">
      <field field_ref="temp" />
      <field field_ref="pressure" />
   </file>
</file_definition>
```

# What about XIOS compression?

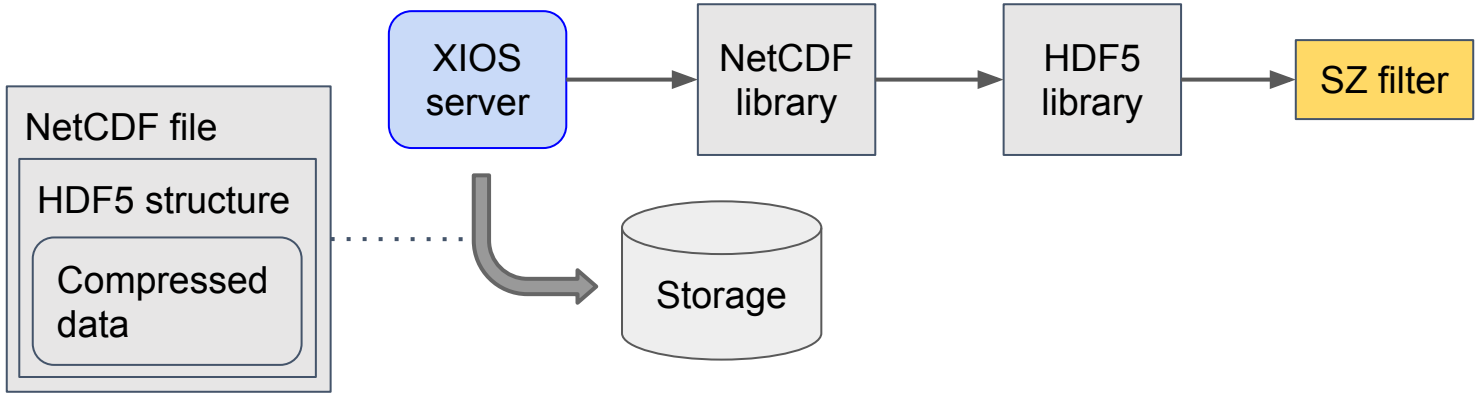


# What about XIOS compression?

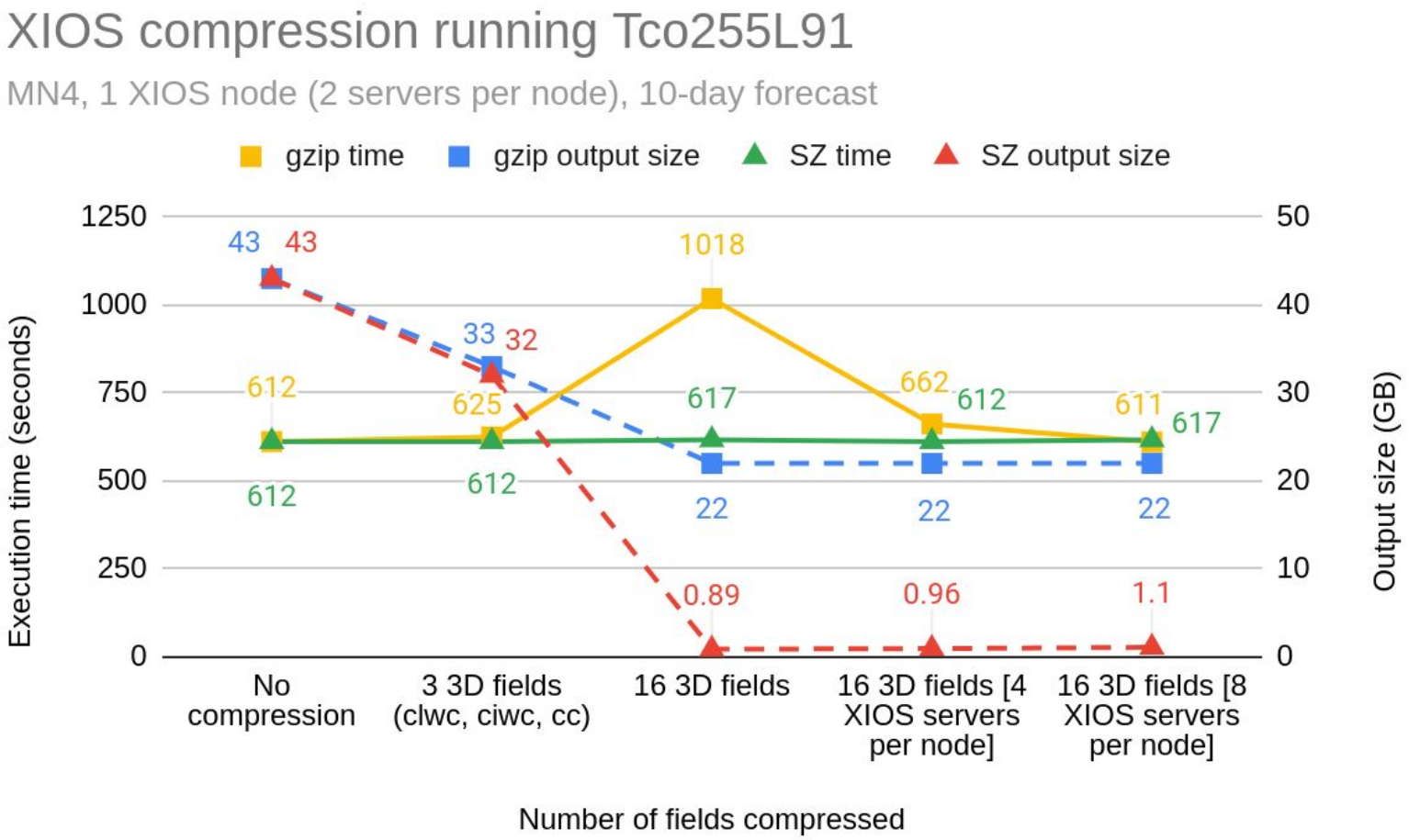


# SZ lossy compression filter in XIOS

- Alternatively to lossless compression we wanted to test **lossy compression** and in particular, the **SZ** compressor from the Argonne National Laboratory (ANL).
- We started a collaboration with ANL to explore if SZ is suitable for XIOS regarding these points:
  - Reach high **compression ratios**.
  - Enough compression **speed** to considerably mitigate the I/O overhead.
  - Keep high **accuracy**.
- The SZ compressor is registered as a third-party filter of HDF5 which facilitates the integration in XIOS:



# gzip vs. SZ compression: preliminary results




- gzip: compression level 6
- SZ: relative error bound 0.01

# Technical validation

- Specific humidity (q):

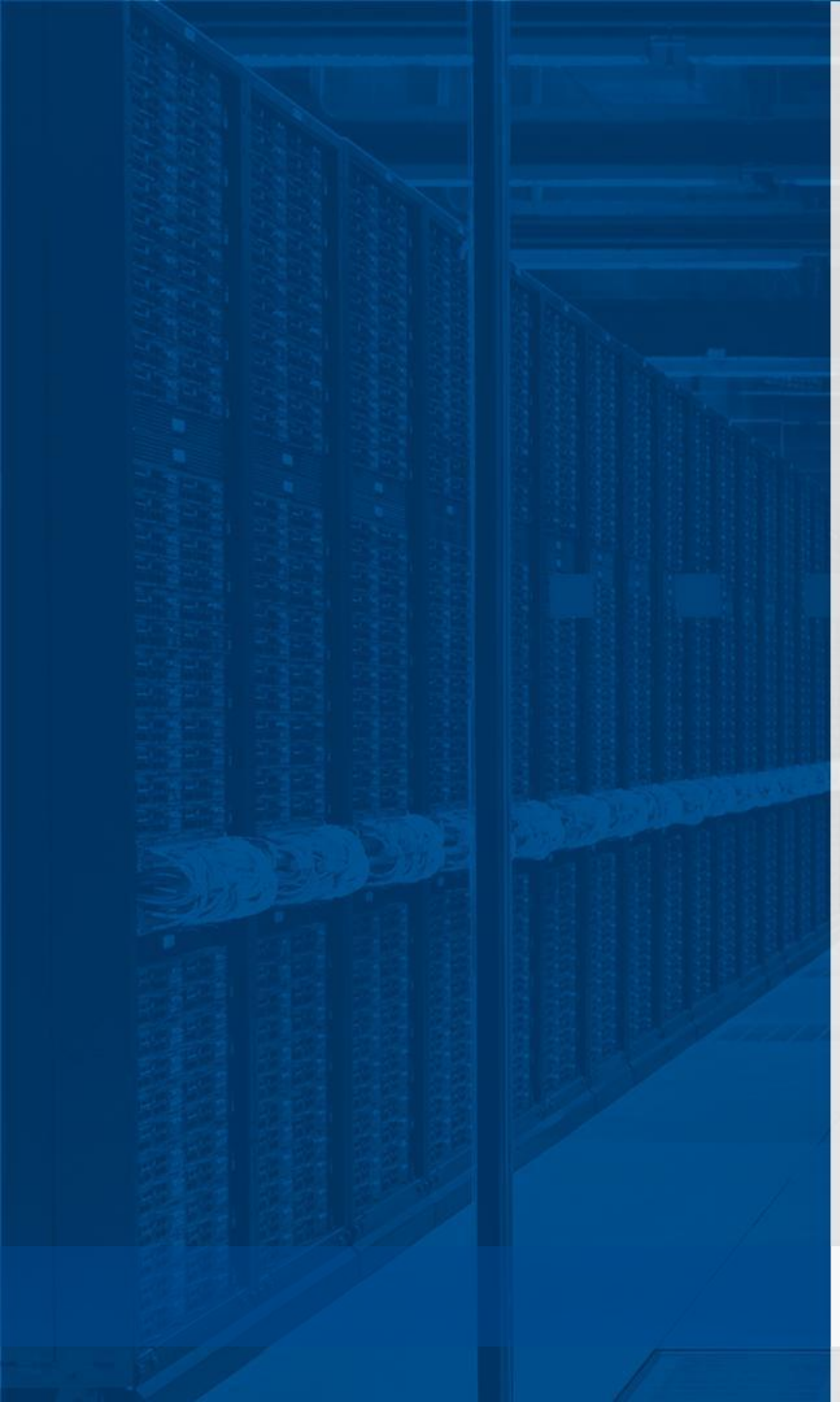
```
This is little-endian system.
reading data from q_reduced_pl_0000.dat
Min = 9.9999999392252902908E-09, Max = 0.027128605172038078308, range = 0.027128595172038139083
Max absolute error = 0.0002728566
Max relative error = 0.010058
Max pw relative error = 26571.363721
PSNR = 48.814234, NRMSE = 0.0036248356857680394394
normErr = 1.430658, normErr_norm = 0.032378
pearson coeff = 0.999425
```

- Temperature (t):

```
This is little-endian system.
reading data from t_reduced_ml_0000.dat
Min = 178.822265625, Max = 312.271209716796875, range = 133.448944091796875
Max absolute error = 1.4429931641
Max relative error = 0.010813
Max pw relative error = 0.007225
PSNR = 45.400245, NRMSE = 0.0053701664860087792303
normErr = 15926.175641, normErr_norm = 0.002937
pearson coeff = 0.999734
```

# Conclusions and future work

- Preliminary results are promising: the SZ lossy compressor is **faster** than the default gzip lossless compressor, achieving much **higher** compression ratios.
- ANL added support to set different compression parameters per field.
  - Change XIOS code to read individual compression parameters and set the SZ filter via the NetCDF API.
  - This will allow us to tune the **accuracy of each field** depending on scientific needs.
- Discuss with climate scientists the adequate compression parameters (error bounds) for each field depending on the acceptable errors.
- Test the SZ filter with the new HDF5 parallel I/O.
- This work will be further explored and extended in upcoming projects such as EERIE.



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# Thank you

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