8th Annual Earth System Grid Federation

High Performance Data Analytics and Machine Learning developments in Ophidia

Sandro Fiore
Head of the Data Science and Learning Research Team
CMCC Advanced Scientific Computing Division

Donatello Elia
CMCC Advanced Scientific Computing Division

Giovanni Aloisio
Director of the CMCC SuperComputing Centre
CMCC Strategic Council member

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NextData

is-enes INFRASTRUCTURE FOR THE EUROPEAN NETWORK FOR EARTH SYSTEM MODELLING

Introduction

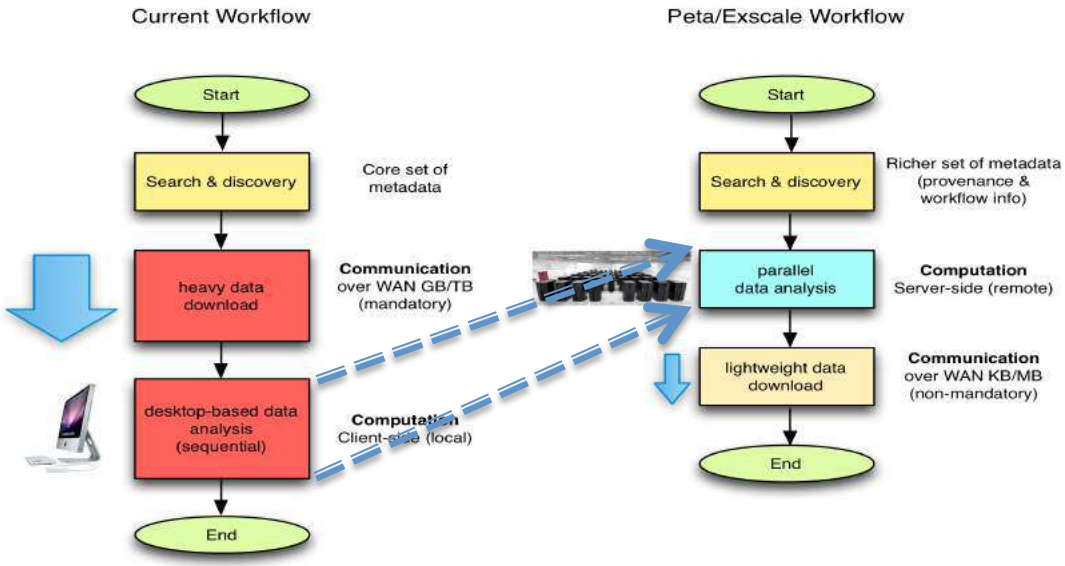
- Research challenge: HPC & big data convergence at extreme-scale for eScience
- Goal: Scalable HPDA&ML software stack for eScience
- International Context: IESP (2008-2011), BDEC (2012-2018) and now BDEC2 (2018-2020)
- European projects: EESI (2008-2011), EESI2, EXDCI and now EXDCI2 (2018-2020)
- Research project: Ophidia (design study 2011, implementation 2012 - present)

- This talk focus: Ophidia2.0

Ophidia

- Ophidia is a CMCC research project addressing fast and big data challenges for eScience
- It provides a paradigm shift, from sequential & client- to parallel & server-side data analysis

Paradigm shift at scale



*S. Fiore, A. D'Anca, C. Palazzo, I. Foster, D. N. Williams, G. Aloisio, "**Ophidia: toward bigdata analytics for eScience**", ICCS2013 Conference, Procedia Elsevier, Barcelona, June 5-7, **2013***

Key Features in Ophidia

- eScience framework
- Server-side
- Parallel
- In-memory
- Declarative
- Datacube oriented (multi-dimensional OLAP support)

- (Shared) Sessions
- Workflows and applications
- Interactive and batch support
- HPC and HTC tasks
- Both domain-oriented (e.g. nc) and domain-agnostic support (e.g. OLAP)

Multi-dimensional data and storage model

- OLAP-based (ndim-datacube)
- Dimension-independent
- Implicit and explicit dimensions
- Partition & distribution
- Flexible and scalable

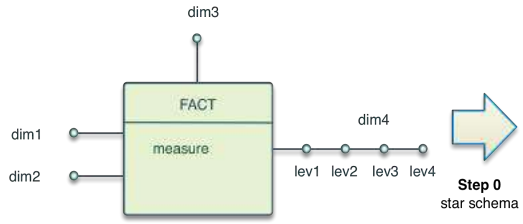


Fig. 2.a
classic DFM

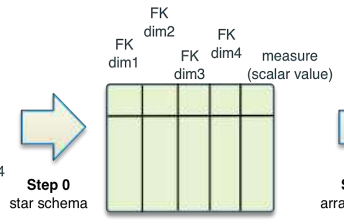


Fig. 2.b
classic ROLAP implementation

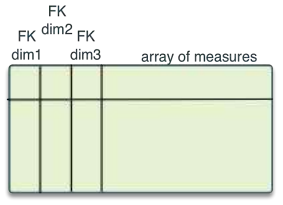


Fig. 2.c
ROLAP implementation supporting n-dim arrays

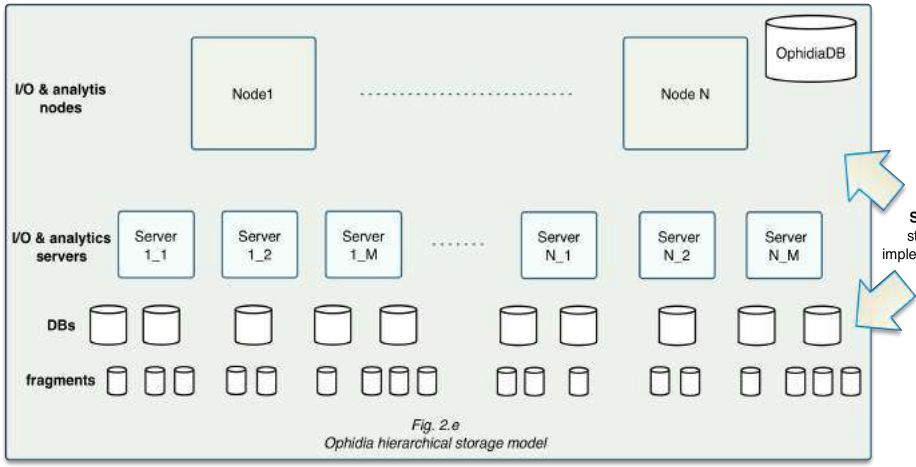


Fig. 2.e
Ophidia hierarchical storage model

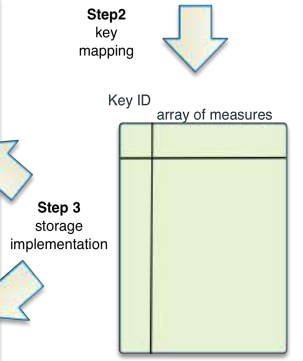
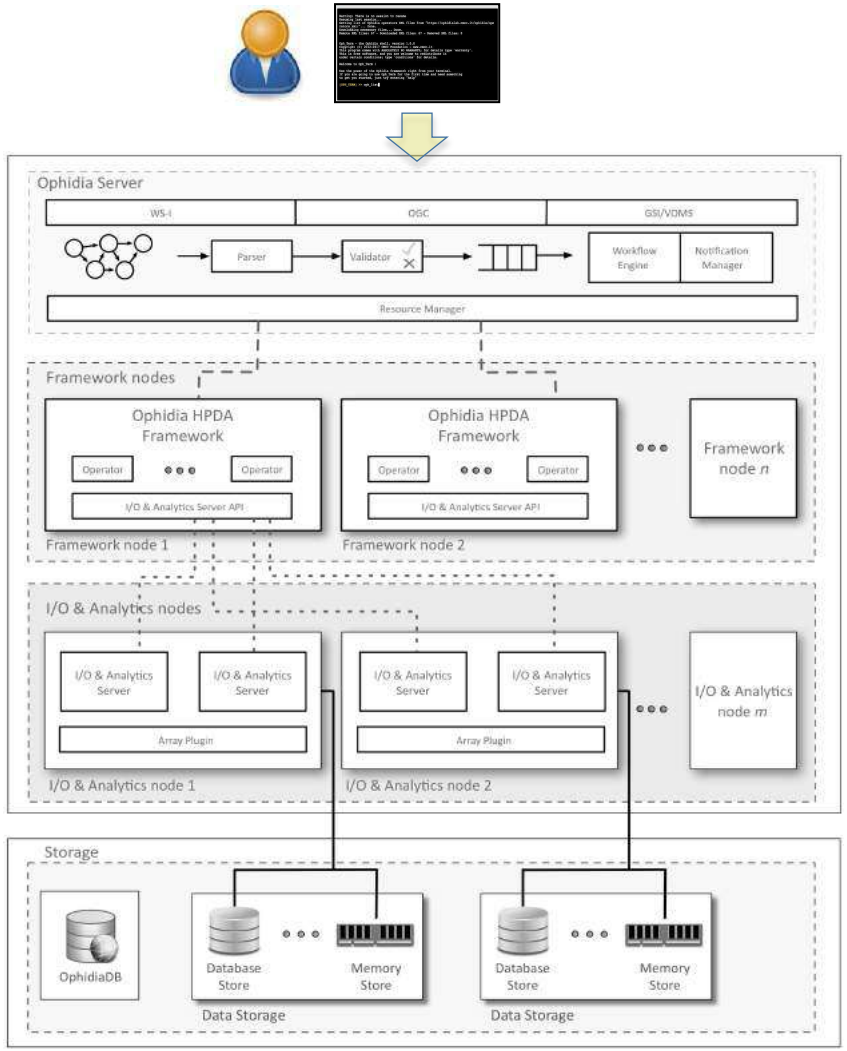


Fig. 2.d
key based ROLAP implementation supporting n-dim arrays

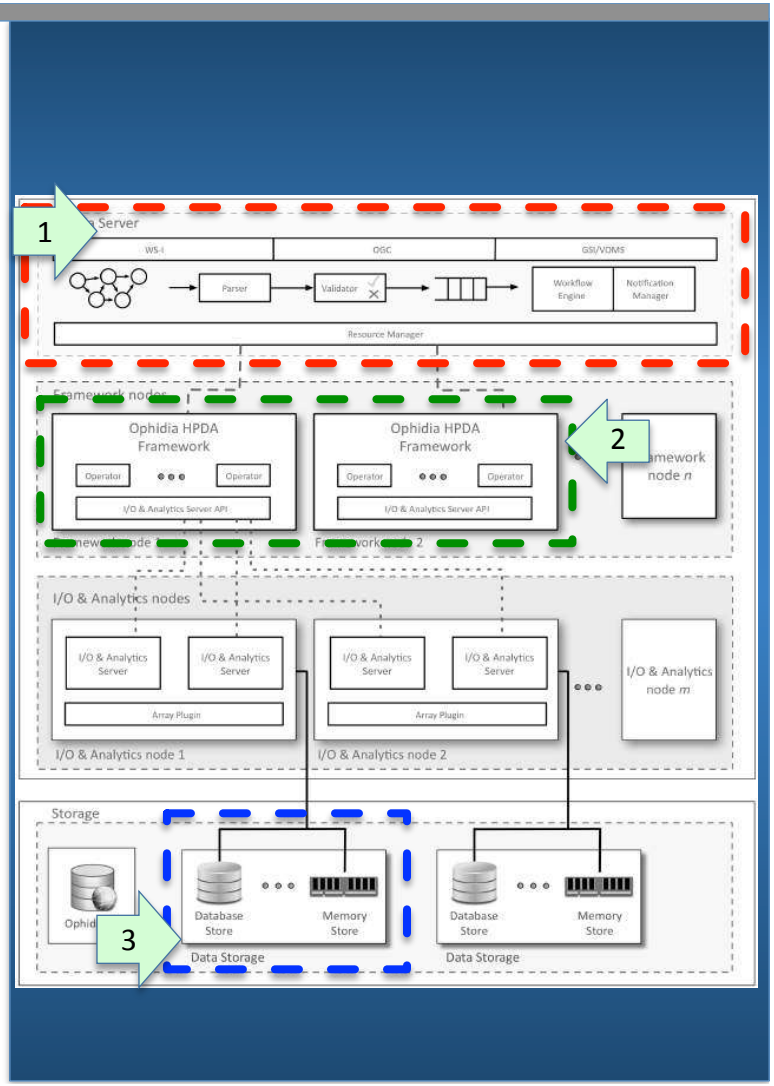
Ophidia2.0 Architecture

- Interoperable interface (e.g. OGC WPS)
- Modular and extensible
- Parallel framework runtime
- I/O & analytics runtime
- Multiple storage back-ends
- Supports ranging from single operators to complex analyses

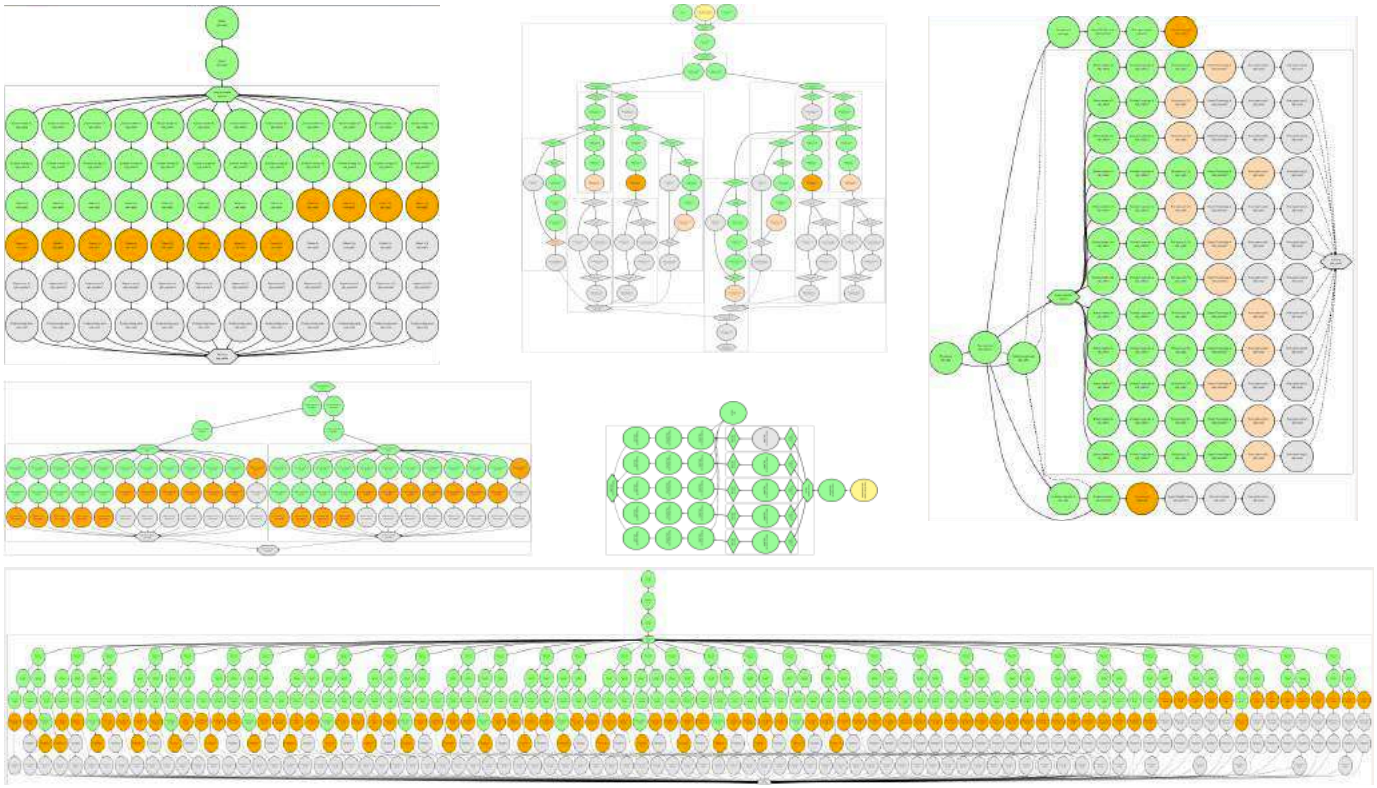


Three levels of parallelism

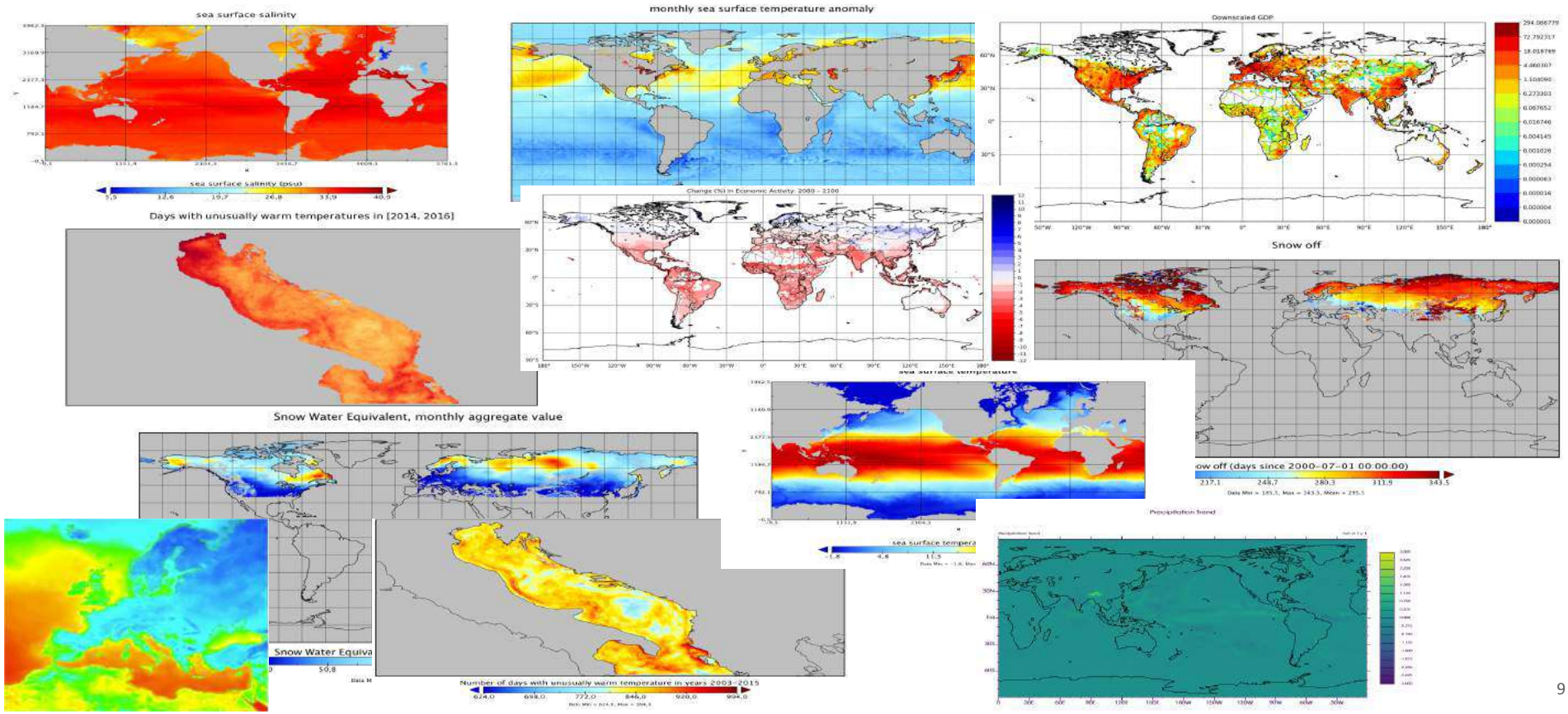
- Datacube-level parallelism
  - HTC paradigm
  - At the front-end level
  - Based on the “massive” operator concept
- Fragment-level parallelism
  - HPC paradigm
  - MPI/Pthread
  - At the HPDA framework level
- Array-level parallelism
  - HPC paradigm
  - OpeMP based
  - At the I/O & analytics server level



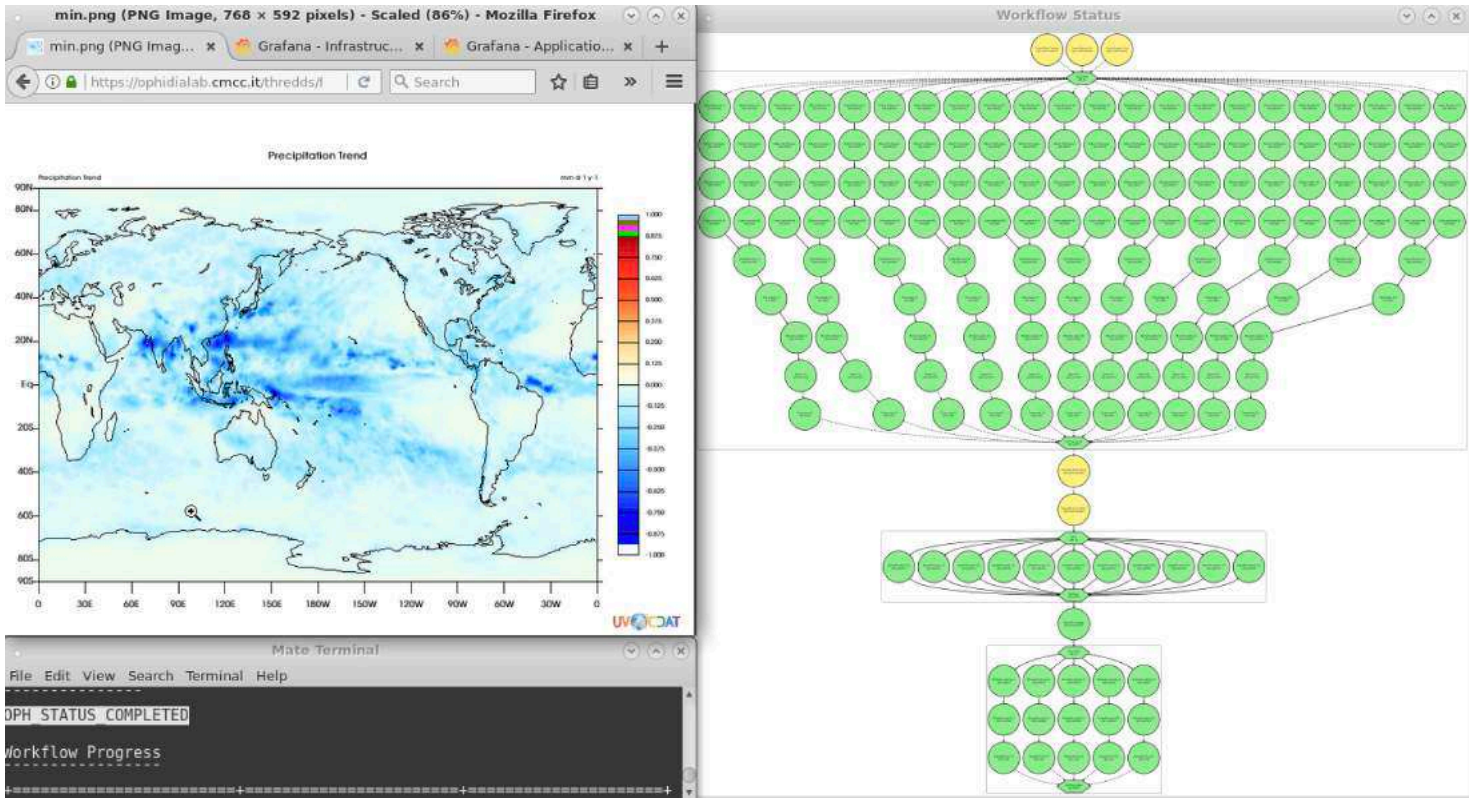
Analytics Workflow support (runtime perspective)



Analytics Workflow support (end-user perspective)



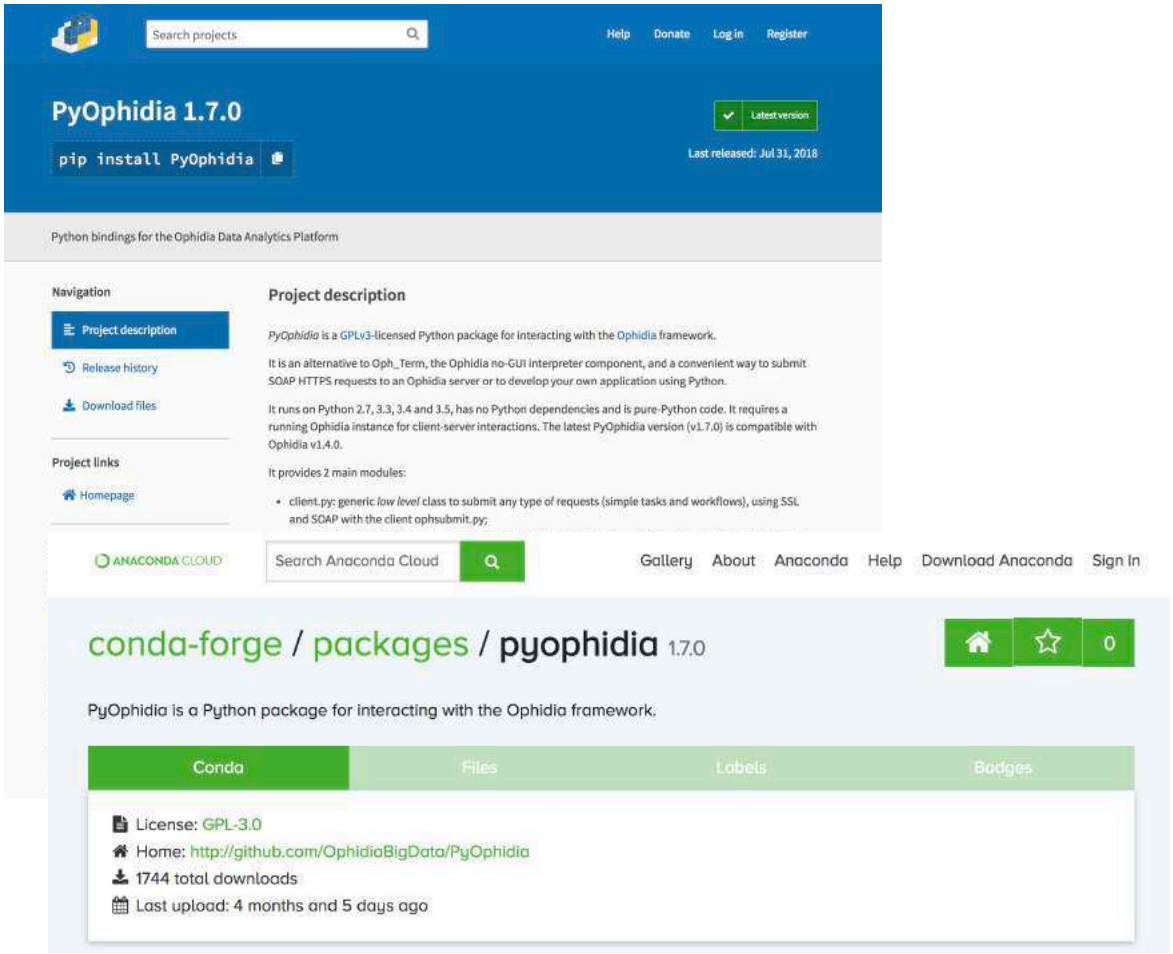
Multi-model analytics workflow case study (CMIP5-based)



The ESiWACE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 675191 http://www.esiwace.eu

Programmable framework

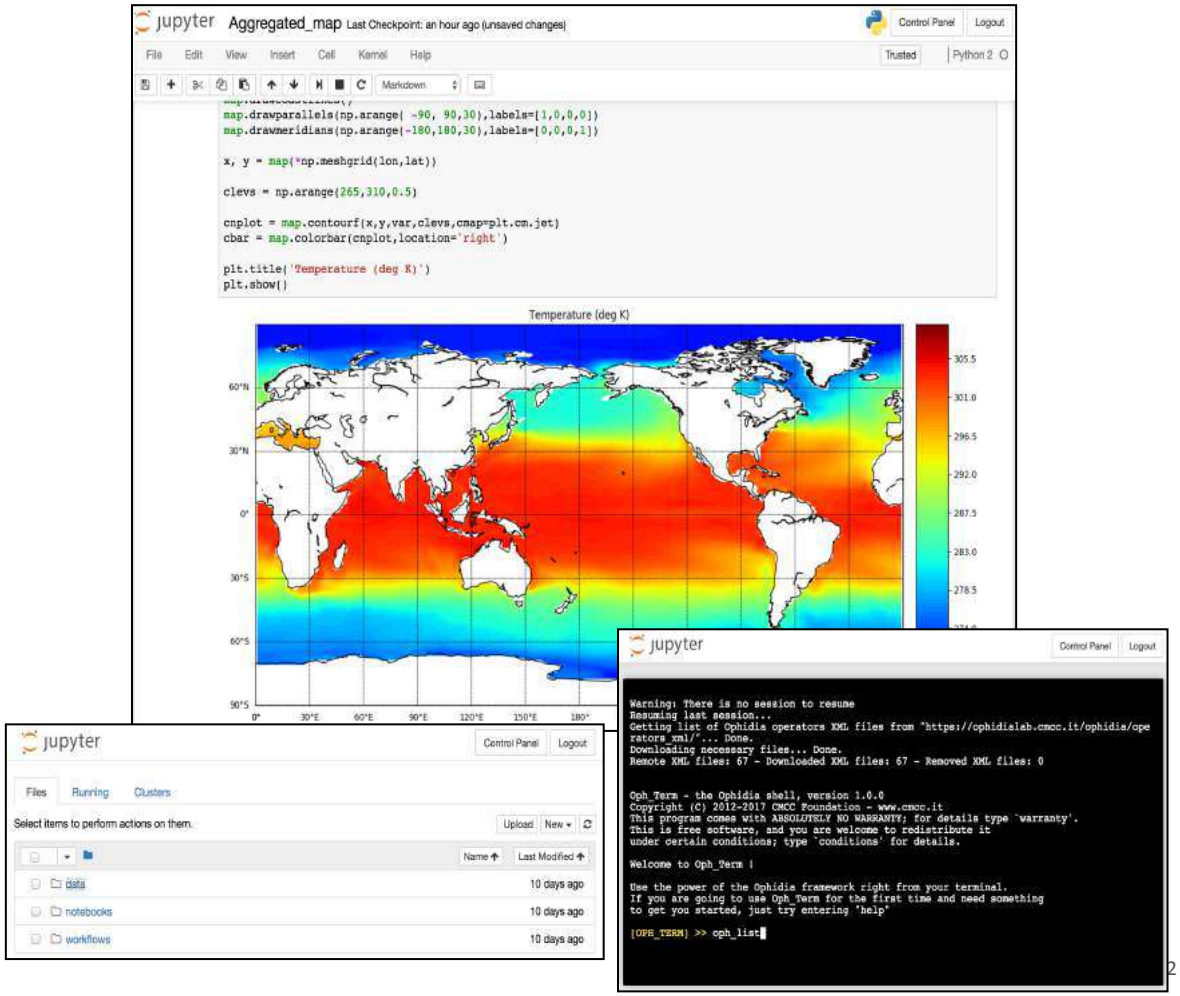
- PyOphidia provides a Python binding to Ophidia
- Consists of two classes:
  - Client class: connections, submissions, workflows, sessions
  - Cube class: datacube operators
- Available in conda-forge



https://pypi.org/project/PyOphidia/

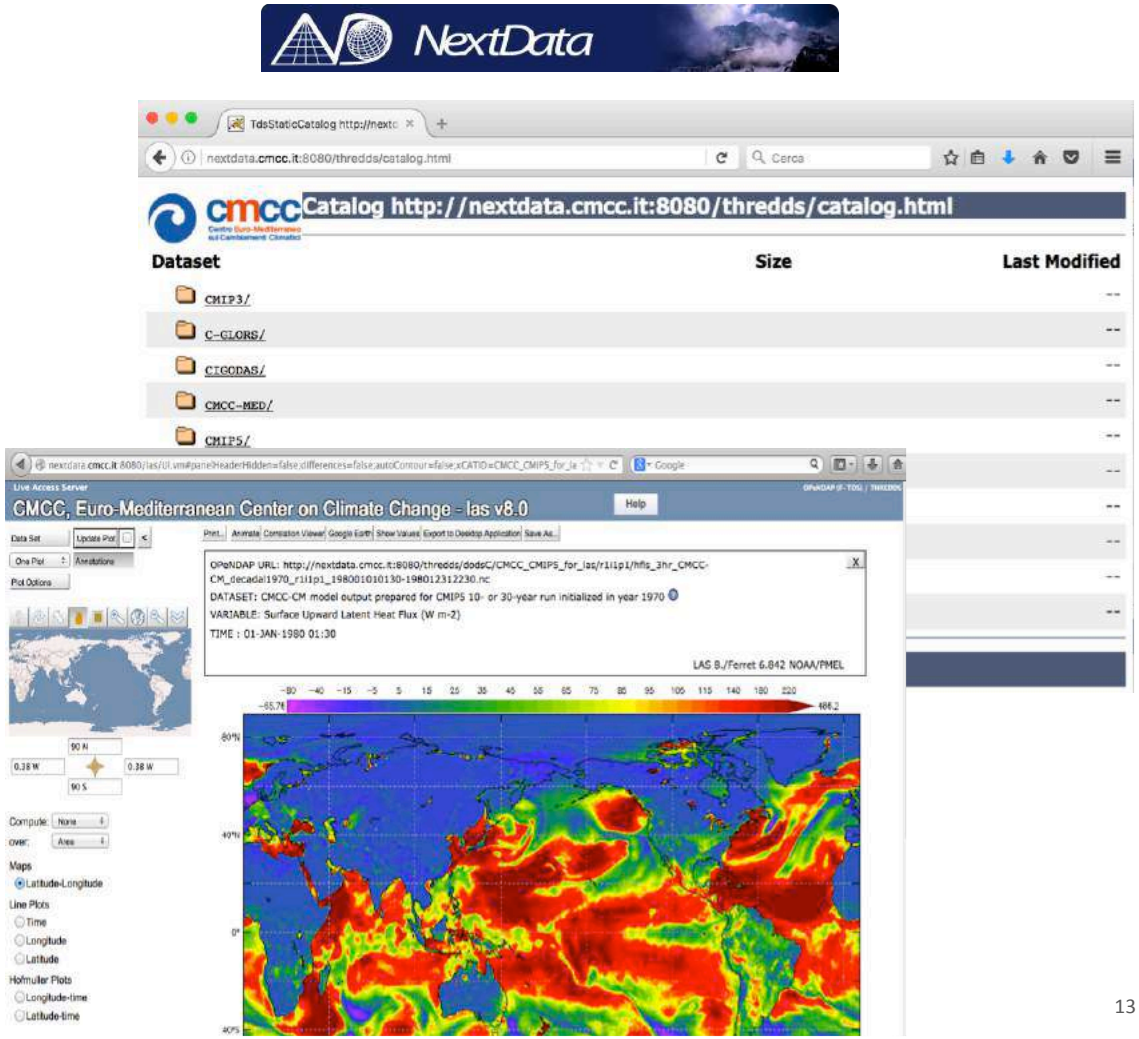
JupyterHub front-end

- Web access/env
- Integrated into the HPC environment (e.g. GPFS)
- Access via VPN
- Multiplexed front-end
- Fat-node hosting
- Terminal features available too (embedded)
- Integrated into the EOSC-hub project (ECAS thematic service)



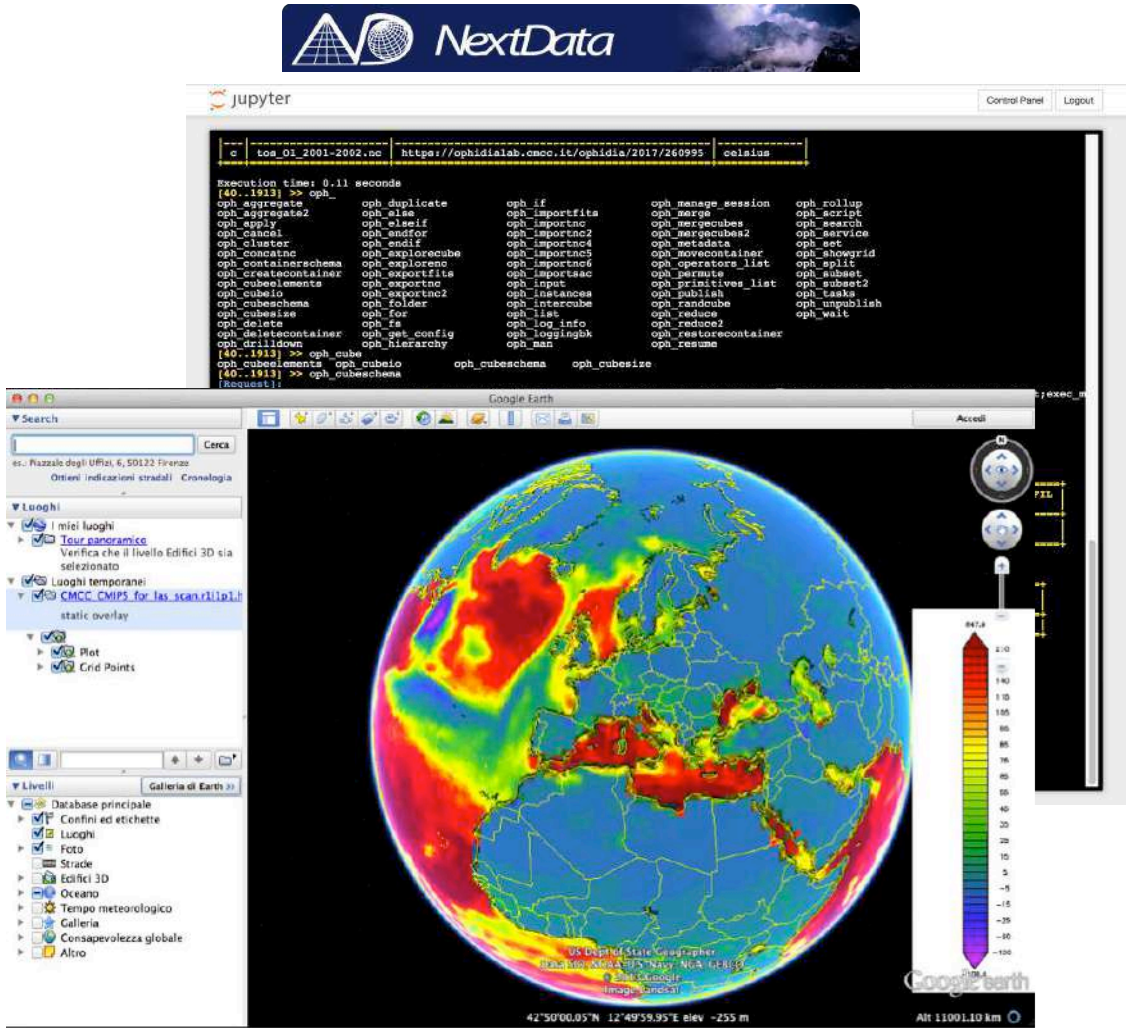
Analytics back-end for the NextData project (I)

- Ophidia is also exploited in the NextData project
- Computing & data capabilities integrated into the same environment
  - Several datasets published by CMCC modelling divisions
  - Catalogue browsing
  - Data download
  - Visualization capabilities
  - Computing



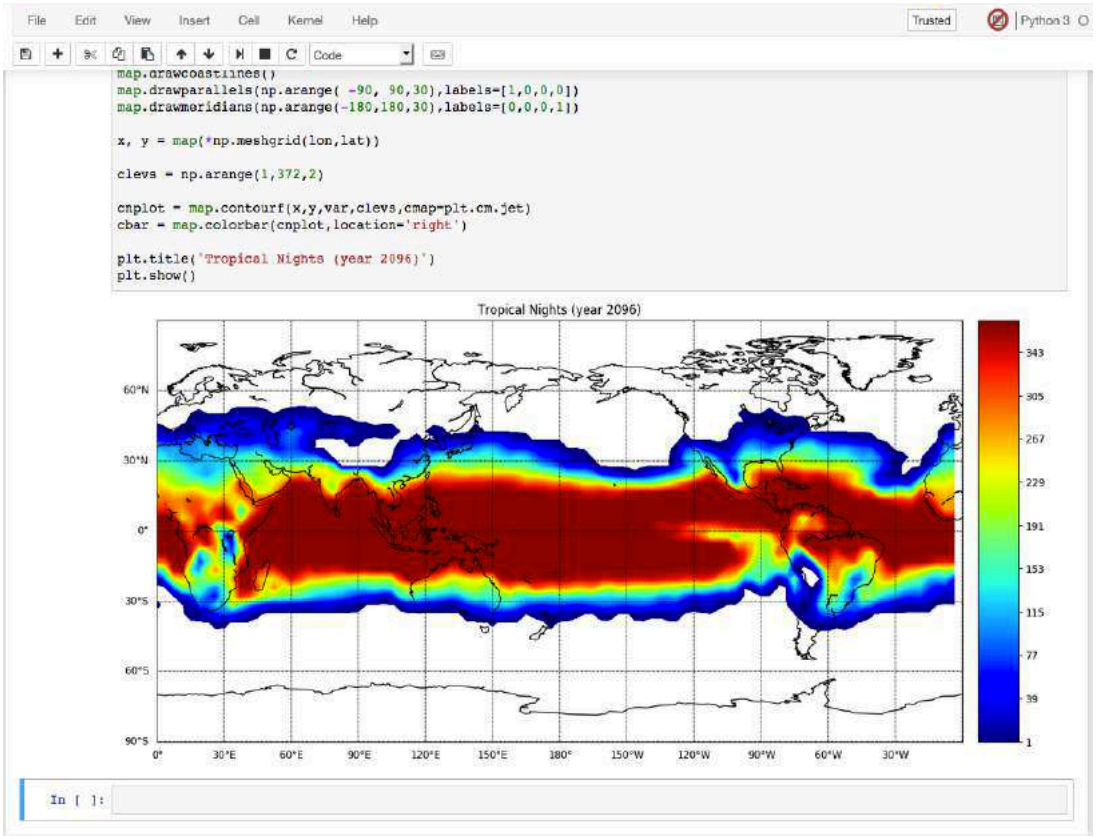
Analytics back-end for the NextData project (II)

- Computing & data capabilities integrated into the same environment
- Terminal-based capabilities
- Google Earth (viz)



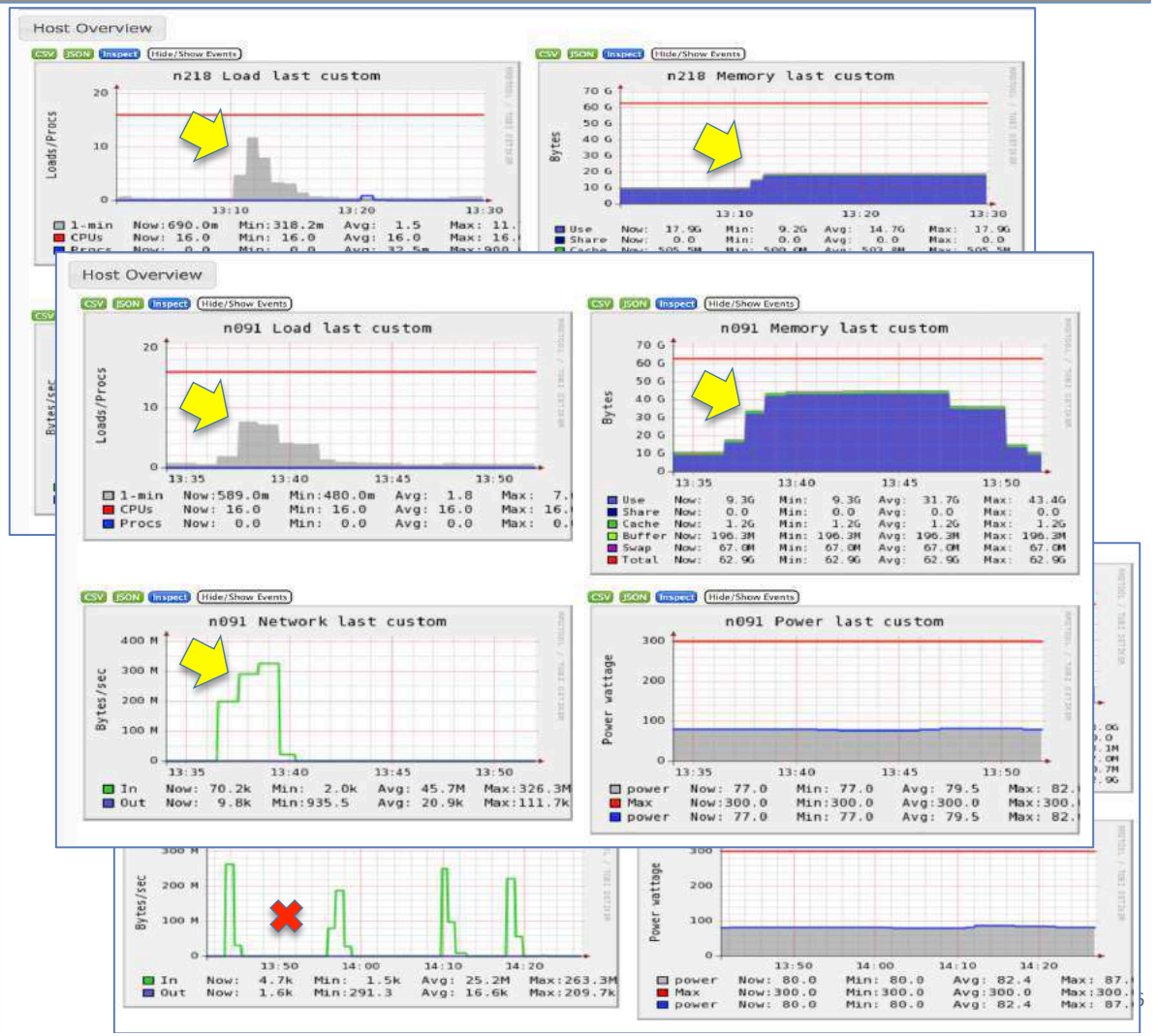
Analytics back-end for the NextData project (III)

- Programmatic access to the back-end datasets
  - Based on Python language
  - Jupyter Notebooks
  - Through PyOphidia



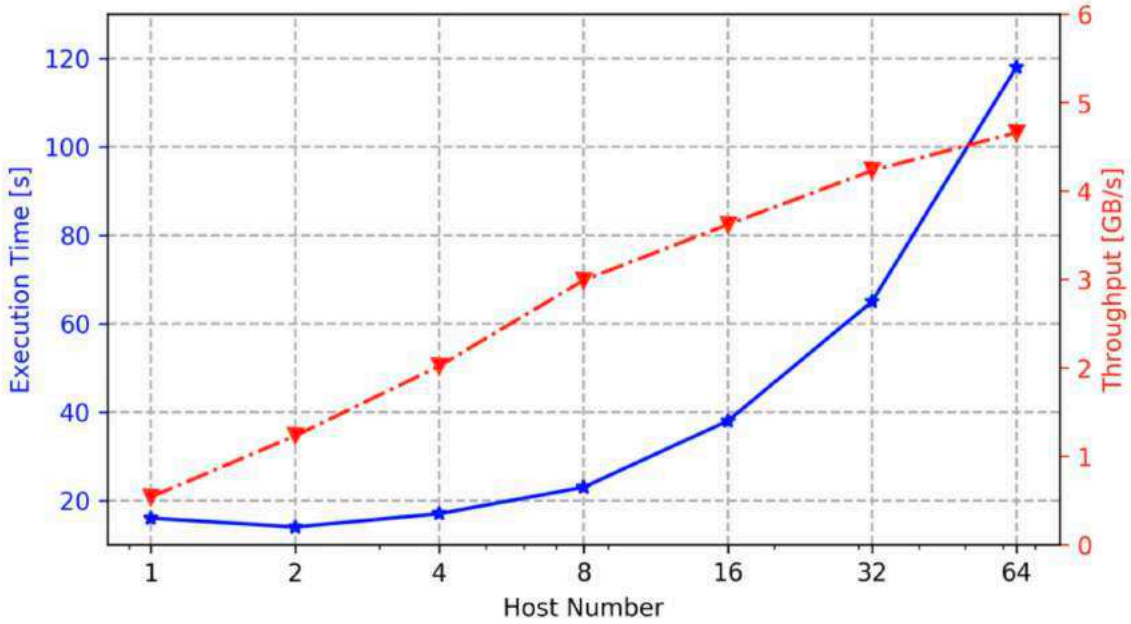
Parallel Import Monitoring

- ophclient.submit(”oph_importnc2 src_path=[path=*.nc;]”)
- *Three scenarios on a I/O and analytics node*
  - *Single import*
  - *Multiple imports/delete*
  - *Multiple imports on the same node*
- *Network traffic*
  - *Inbound burst*
  - *No outbound data*
- *Memory increase*
- *Cache effects*



Parallel Import Benchmark (preliminary insights)

- *Importnc2 operator*
- *HTC importnc2 statements*
- *Weak scalability benchmark*
- *Metrics*
  - *Execution time [s]*
  - *Throughput [GB/s]*
- *From 1 to 64 input files*
  - *1 HPDAnode/1 input file*
  - *16 fragments/node*
  - *1 file 8.5GB (0.53TB)*
- *Up to 64 nodes → 1024 cores*



Cores	16	32	64	128	256	512	1024 (12%)
Size	8,5	17	34	68	136	272	544
Time [s]	16	14	17	23	38	65	118
BW [GB/s]	0,54	1,23	2,02	2,99	3,62	4,23	4,66 (76%)

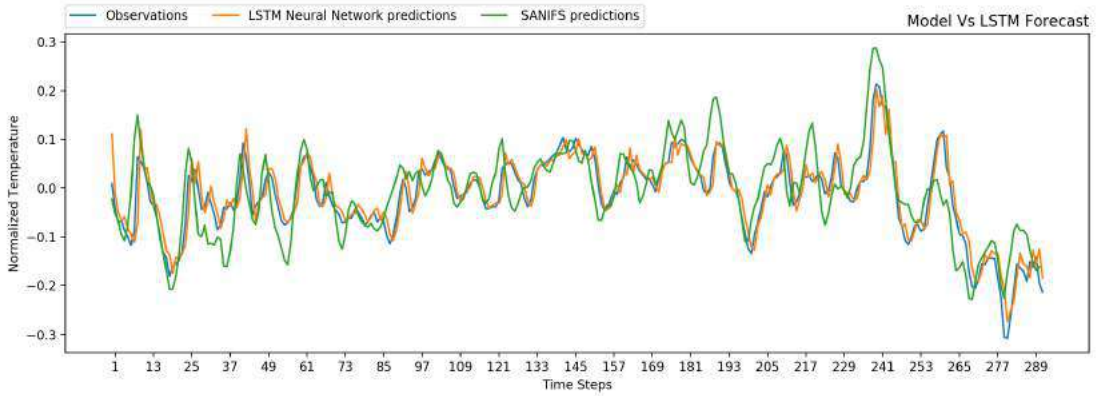
Robustness test up to 4096 threads and 2.1TB on 1024 cores have been performed

LSTM Primitives and SANIFS use case

- Time-series predictive analytics
- The algorithm has been divided in two phases: training and test/prediction
- Implementation based on the KANN library
- After the training, the resulting neural network with updated parameters is saved as a binary array in a datacube. It can then be reused in the test phase
- For test and prediction we defined another primitive
- The primitives can run in the *oph_apply* operator

```
oph_lstm(input_OPH_TYPE, output_OPH_TYPE, measure,
dim_in, dim_out, n_h_layers, n_h_neurons, [dropout],
[learning_rate], [unrolled_len], [minibatch_size],
[max_epoch])
```

```
oph_lstm_predict(input_OPH_TYPE, output_OPH_TYPE,
measure_a, measure_b, test)
```



Conclusions

- Ophidia2.0 provides a stronger integration of big data and HPC
  - **Major step forward w.r.t. Ophidia1.4 and HPDA paradigm**
  - **Tight integration with HPC eco-system**
  - New flexible and dynamic deployment approach
  - **New release of the native I/O and analytics server**
  - Improved management of multi-user scenarios
  - **Three levels of parallelism to address higher scalability**
  - Process-level (vs thread-level) connection to the OphidiaDB
- Planned to be released by this month (January 2019 at the latest). Stay tuned!

Thanks!

Do you want to join this effort?

Please get in touch with us soon

sandro.fiore@cmcc.it