A codesign effort to get ECMWF's IFS model to an extreme O(100) OpenMP threads per MPI task for the [Peta,Exa]Scale

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esiwace
CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

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Outline

- Getting IFS to sustained [Peta,Exa] Scale performance
- A little bit about IFS today
- Motivational reasearch in the CRESTA project (2012-2014)
- comodels an evolutionary OpenMP approach to scaling an IFS model

Getting a future IFS model to sustained [Peta, Exa] Scale performance is dependent on all major developments in progress at ECMWF that are being presented at this workshop (and elsewhere) – a huge team effort

Sadly, there is no magic bullet!

But we are still looking just in case

Technology applied at ECMWF for the last 30 years …

- A spectral transform, semi-Lagrangian, semi-implicit (compressible) hydrostatic model
- How long can ECMWF continue to run such a model?
- IFS data assimilation and model must EACH run in under ONE HOUR for a 10 day global forecast

IFS ‘today’ (MPI + OpenMP parallel)

IFS = Integrated Forecasting System

Graphic shows the TCo1279 (9km global) IFS grid space domain decomposition with 1,600 MPI tasks (12 threads / task) on 400 XC-30 Ivybridge nodes implemented operationally in April 2016. All nodes now XC-40 Broadwell.

Within the EU funded CRESTA project we have run a TC3999 2.5km global IFS model on TITAN with up to 28,672 MPI tasks each with 8 cores (OpenMP threads), for a total of 229,376 cores.

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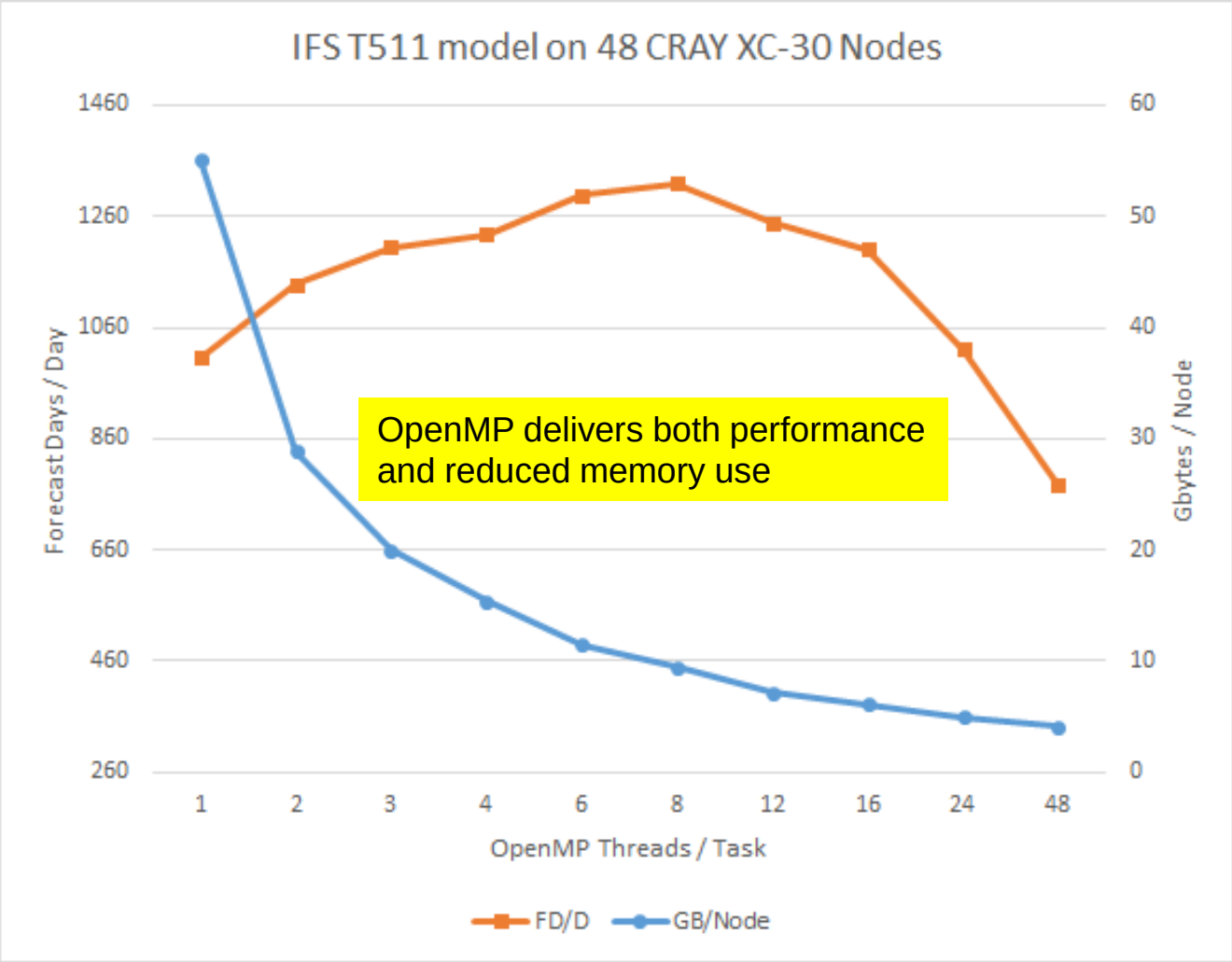

Performance and memory utilisation of an IFS TL511 model on 48 CRAY XC-30 nodes. The blue curve denotes Gigabytes of required memory per node whereas the orange curve shows simulated forecast days per wall clock time day.

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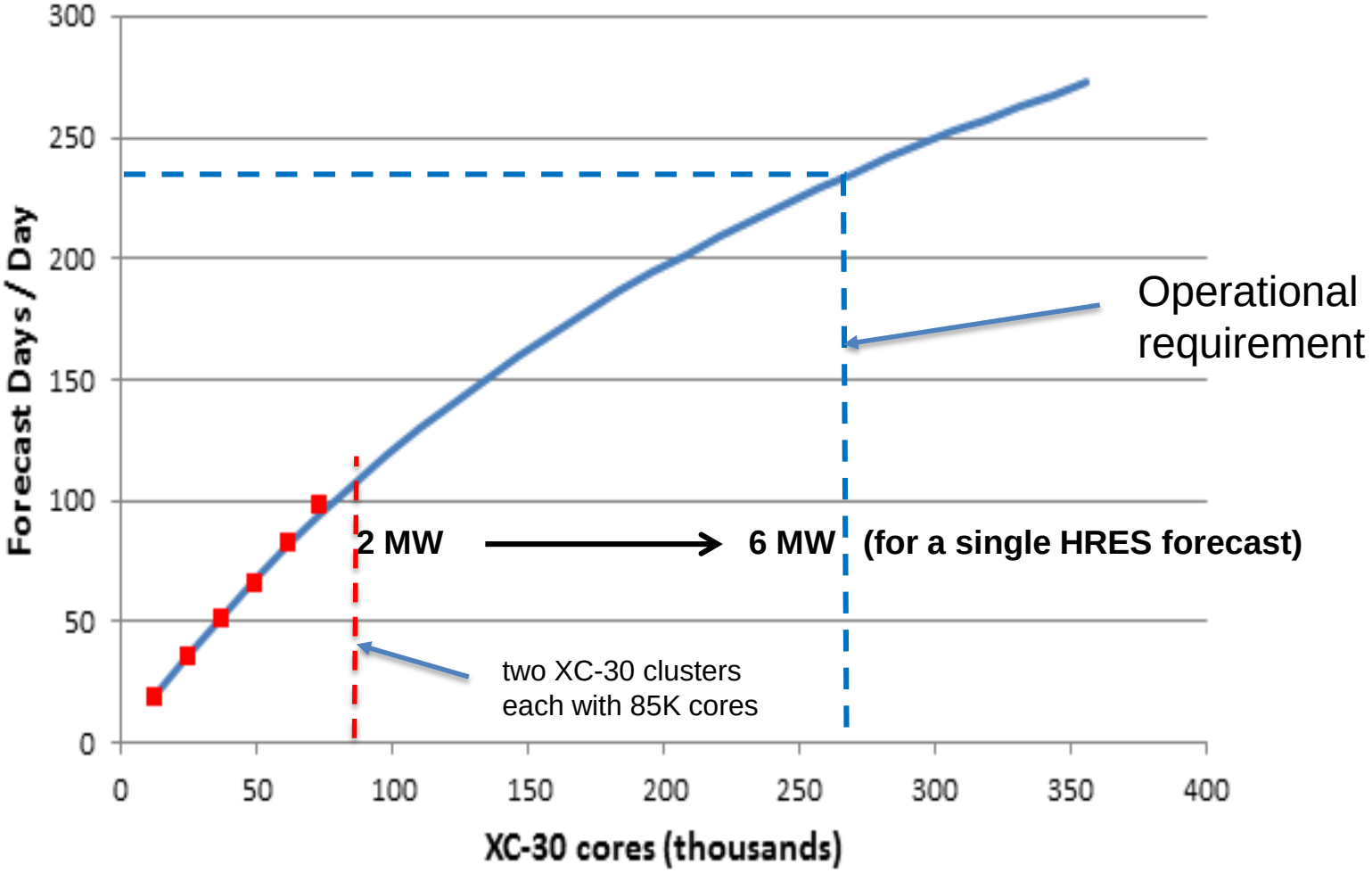
For models >= T1279 **12** threads / task gives optimal performance

Predicted 2.5 km model scaling on a XC-30



ECMWF require system capacity to run simultaneously 10 to 20 HRES forecasts

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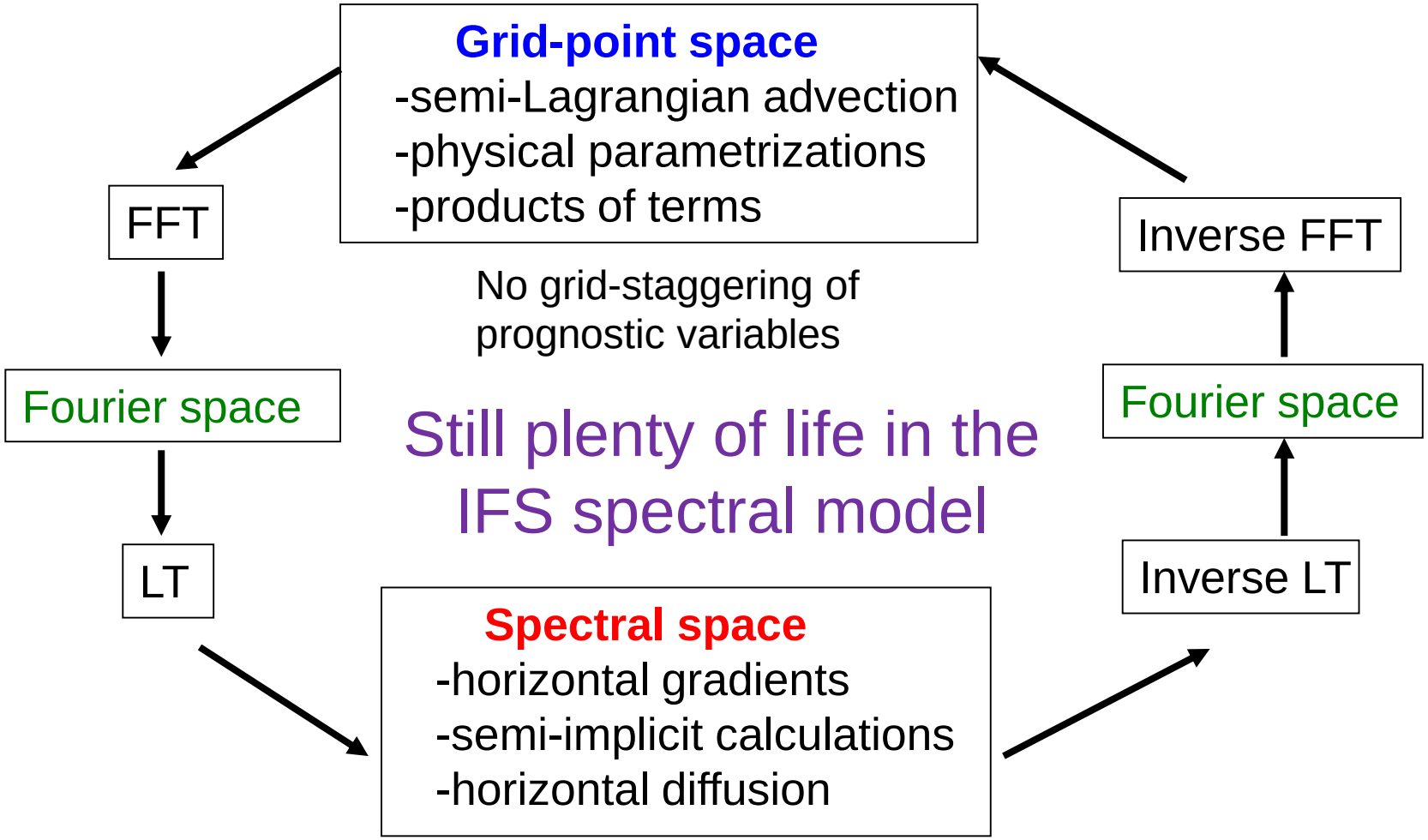
Schematic description of the spectral transform method in the ECMWF IFS model (single time-step)

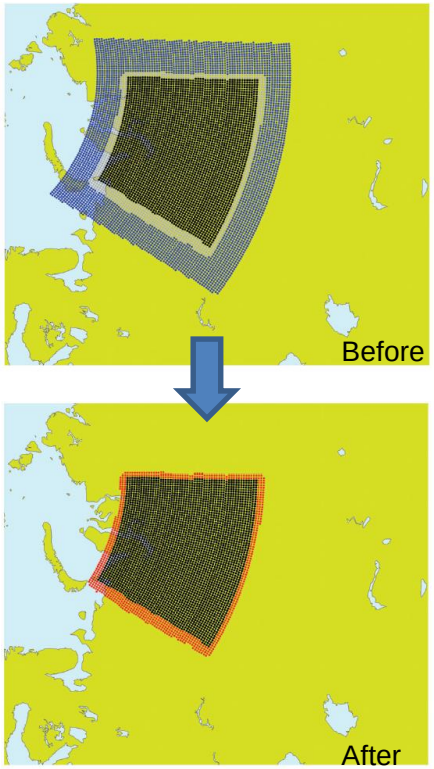


FFT: Fast Fourier Transform, LT: Legendre Transform

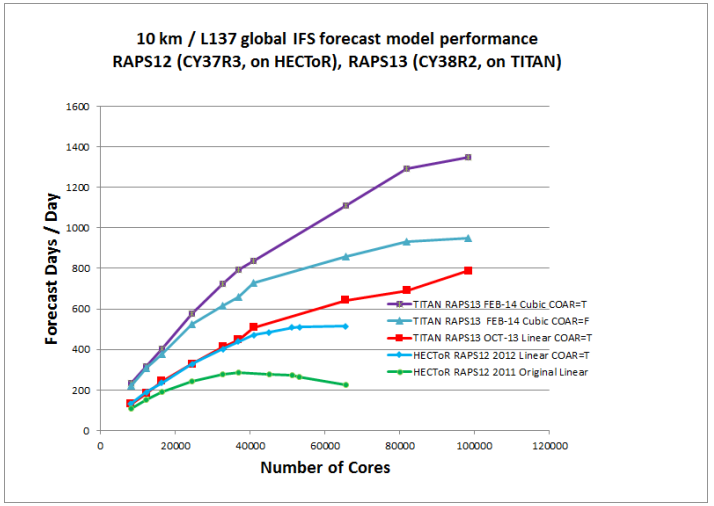
Incremental developments / research in the CRESTA project (2012-2014)

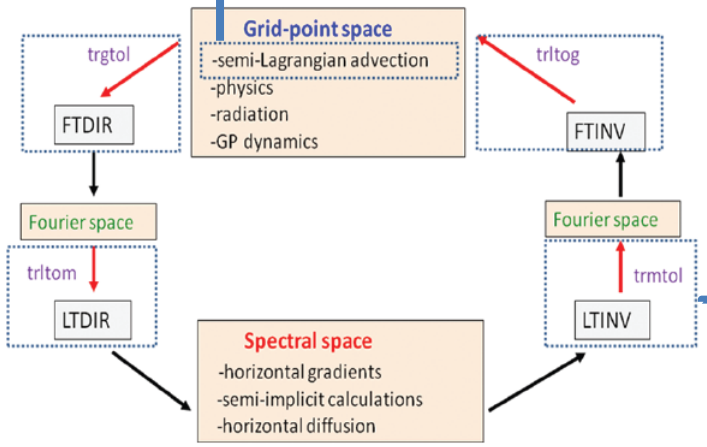
- Overlapping communication and computation using Fortran 2008 coarrays
- Radiation in parallel (separate model and radiation tasks)
- Scaling IFS to 229K cores on TITAN (5km and 2.5km global)
- Application of Fast Legendre Transform
- Initial development of the Atlas library to support an alternative dynamical core option
- Spectral Transform test on TITAN GPUs

CRESTA: Incremental model upgrades



MPI halos defined during runtime





Overlap of computation and communication (the dotted boxes) using Coarrays in Fortran 2008

[Mozdzynski et al. 2015: A PGAS implementation of the ECMWF IFS. Int. J. High-Perf. Comp. App.]

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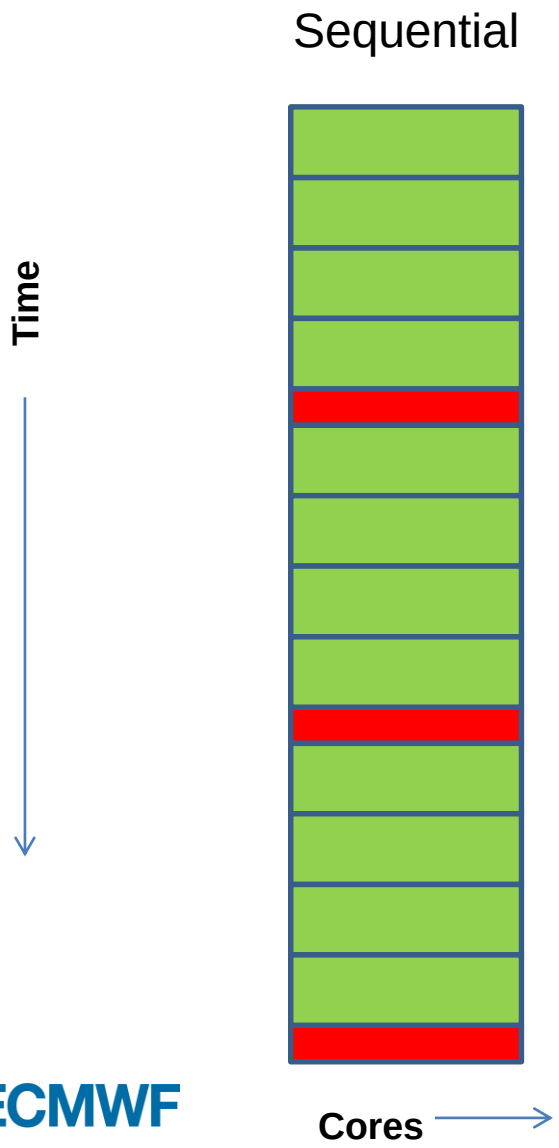
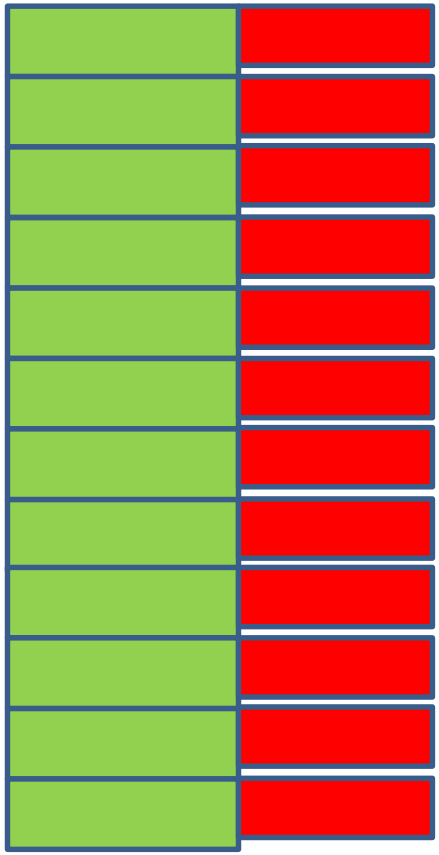
CRESTA : Radiation in Parallel (using separate MPI tasks, 2013-2014)

(Radiation computations, model)





http://www.ecmwf.int/sites/default/files/elibrary/2014/11300-reorganization-radiation-transfer-calculations-ecmwf-ifs.pdf

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Papers/Technical Memoranda

https://www.researchgate.net/publication/285711190_The_modelling_infrastructure_of_the_Integrated_Forecasting_System_Recent_advances_and_future_challenges

Mozdzynski G, Morcrette J-J, ECMWF Technical Memorandum 721, http://www.ecmwf.int/sites/default/files/elibrary/2014/11300-reorganization-radiation-transfer-calculations-ecmwf-ifs.pdf

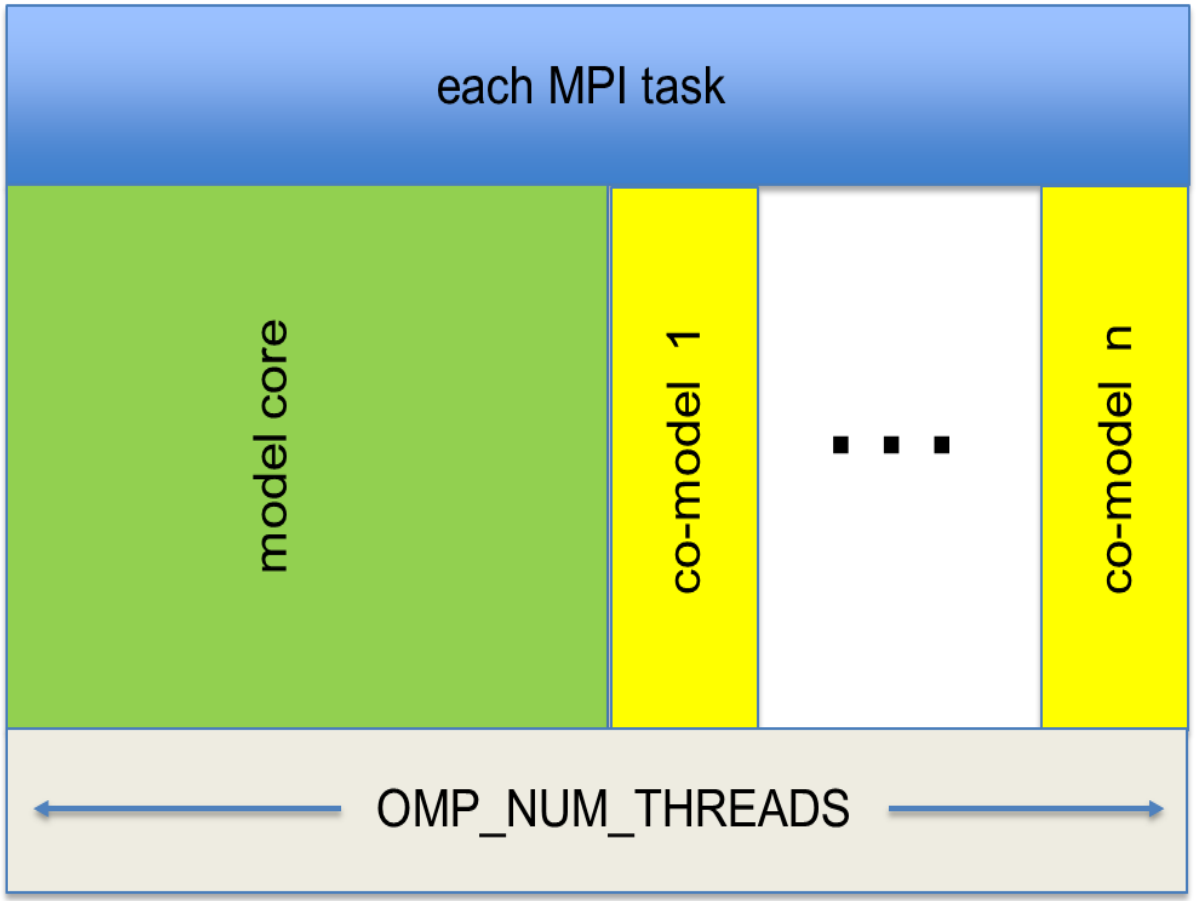
Mozdzynski, G., M. Hamrud, N.P. Wedi (2015), A Partitioned Global Address Space implementation of the European Centre for Medium Range Weather Forecasts Integrated Forecasting System, Int. J. High Perform. Comput. Appl., 29(3), 261-273

Mozdzynski G., A new partitioning approach for ECMWF's integrated forecasting system (IFS), p 148-166 in Proceedings of the Twelfth ECMWF Workshop: Use of High Performance Computing in Meteorology, 30 October – 3 November, 2006, Reading, UK, World Scientific (2007) 273 pp.

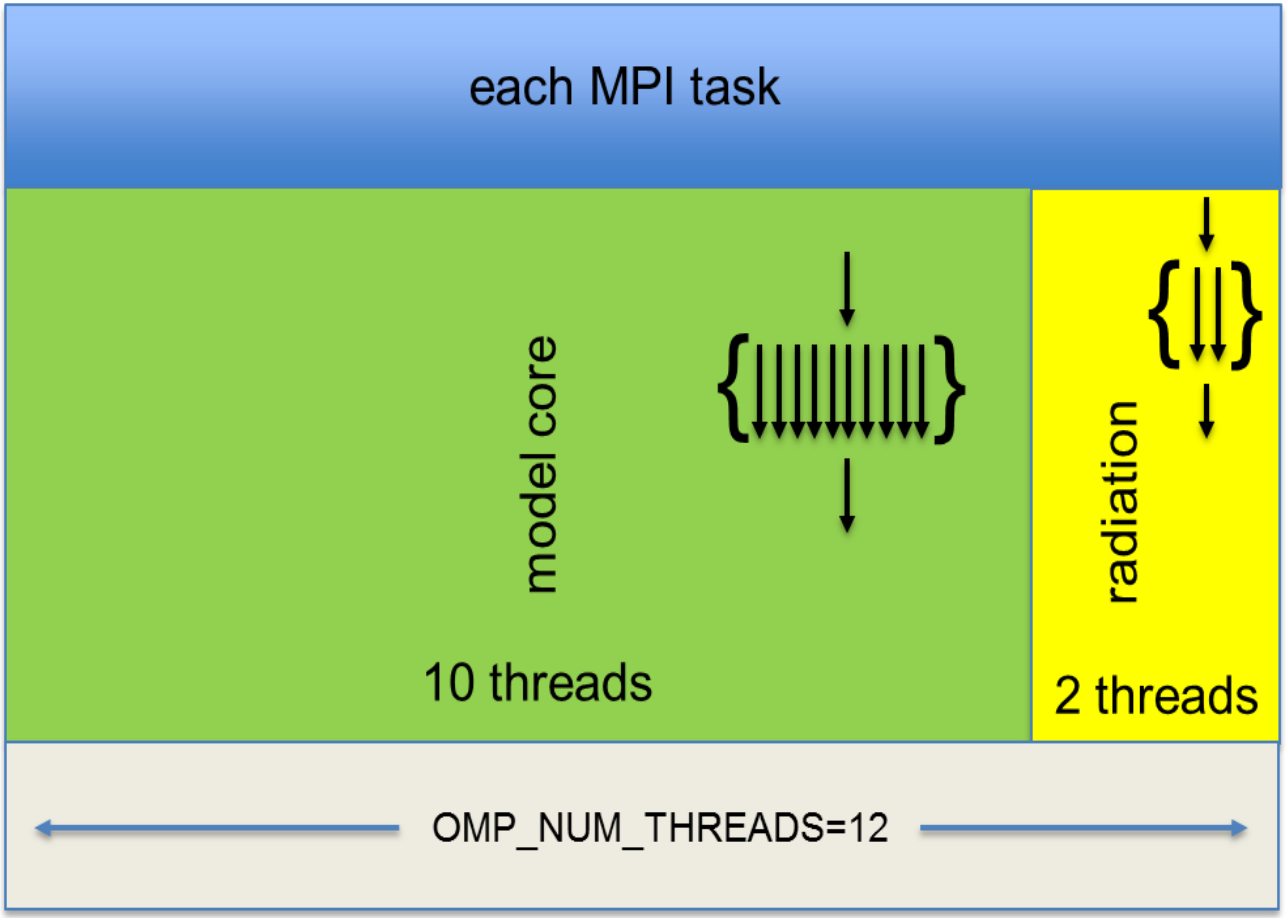
comodels – a potential future ESM architecture to exploit extreme parallelism with O(100) threads per MPI task

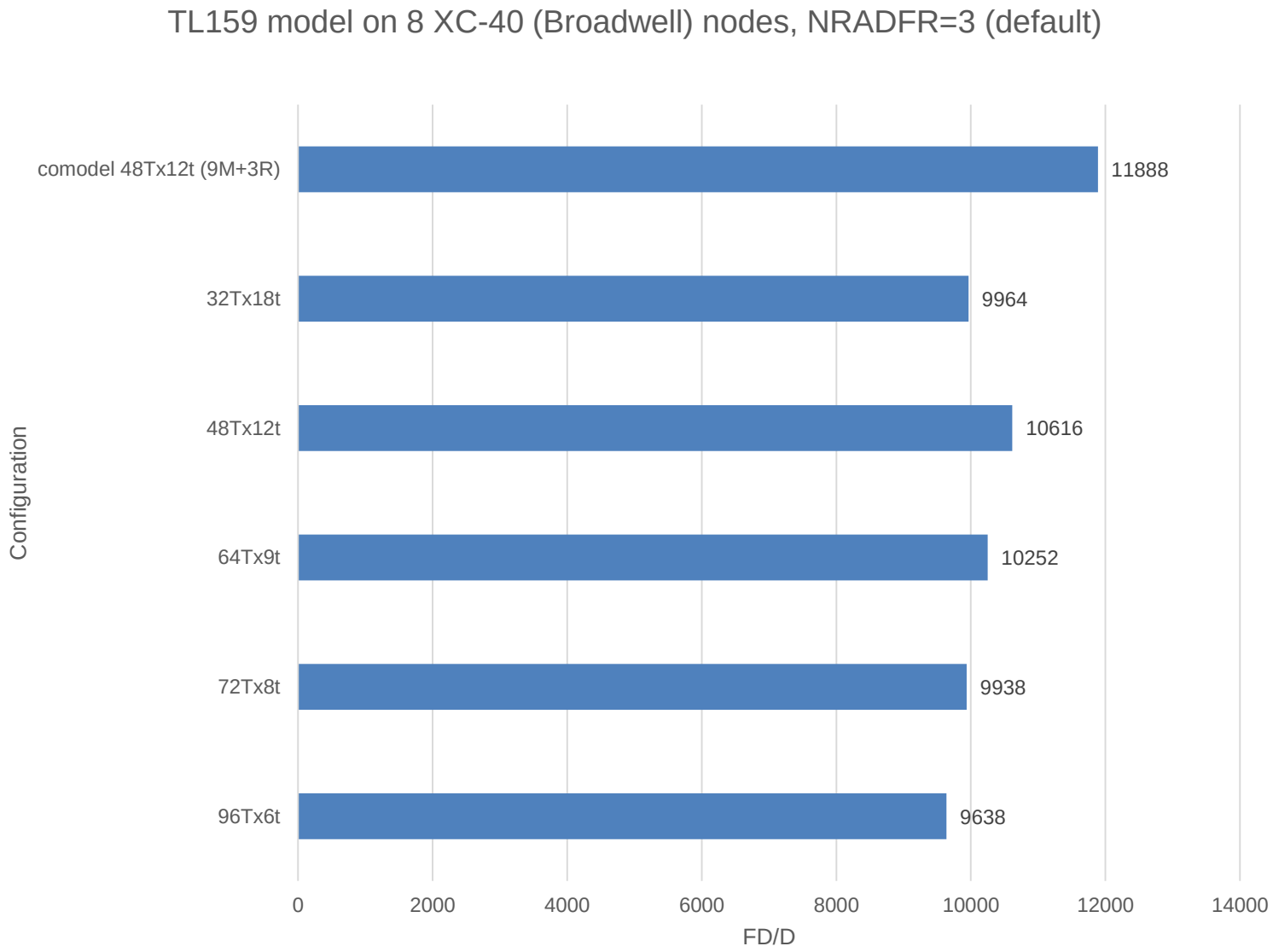
- Example comodels (Dynamics, Physics, Wave, Radiation, Ocean, Land Surface, Ice, etc.)
- comodels execute in parallel with other comodels using data from previous time step
- Implemented using existing OpenMP 4.0 capabilities
- comodels all run on the same set of MPI tasks
- No additional MPI communication required
- Individual comodels can still have message passing internal to their comodel and OpenMP
- Number of threads to be used in each comodel a practical choice
- Xeon Phi, GPUs and conventional servers can all be supported
- ECMWF “Radiation in parallel implementation” explored this concept (lagged model/radiation scheme but with separate MPI tasks for model and radiation), this required additional MPI communication, was bad for performance, bad for code maintenance, inflexible, overall a bad approach

comodels generic structure



comodels initial prototype example (model + radiation)





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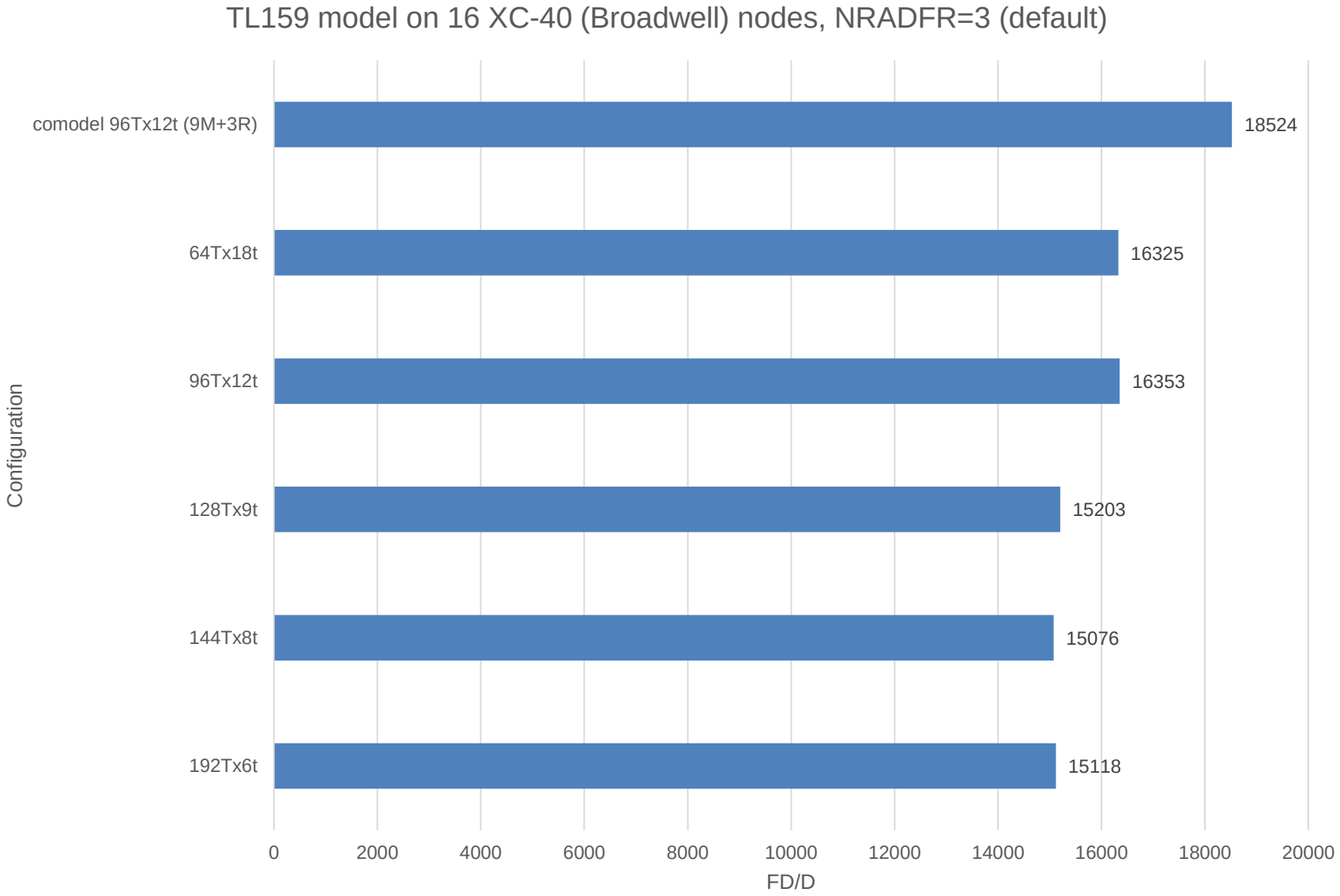

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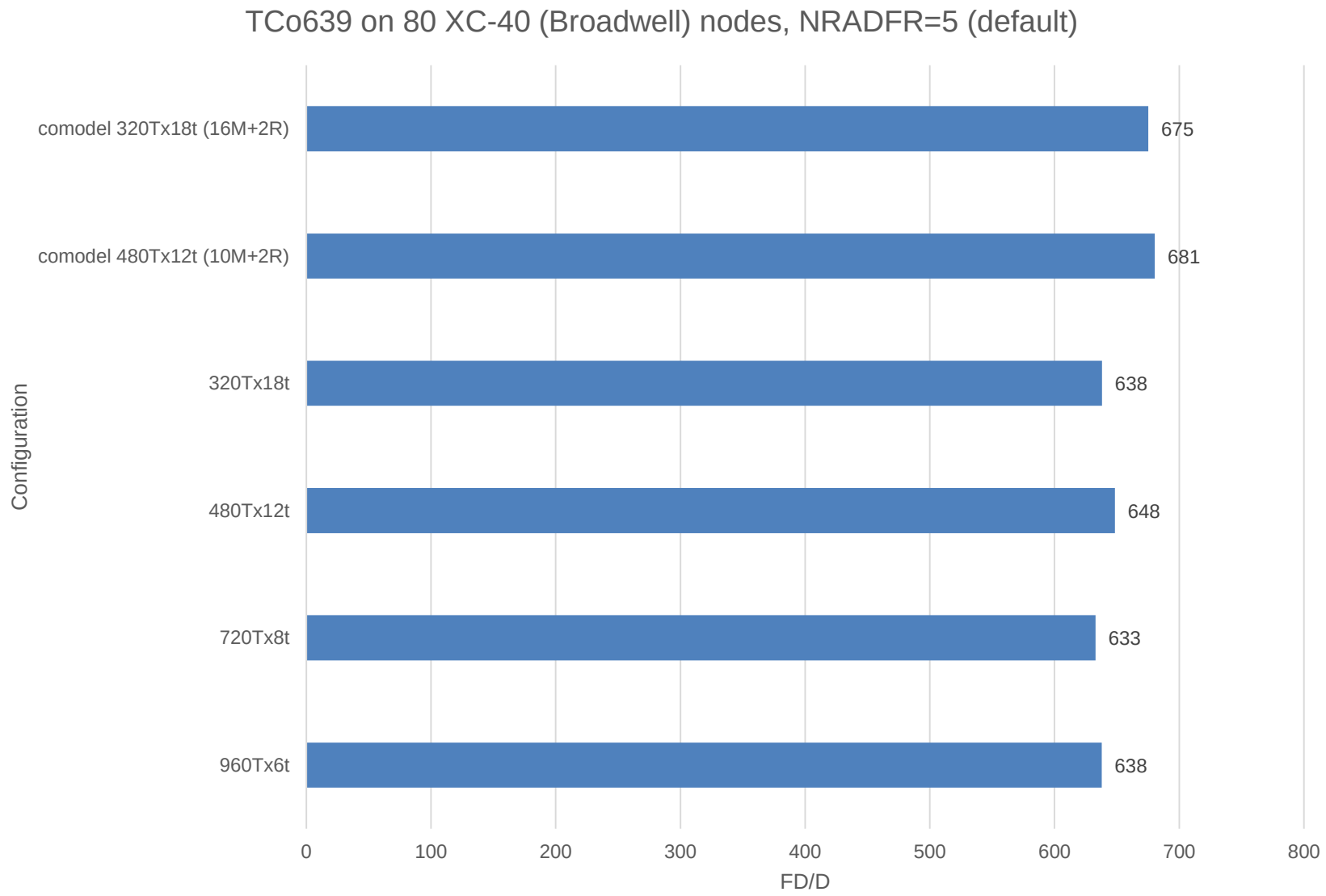

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Some implementation details

- OMP thread synchronisation
  - between model ‘core’ master thread and each comodel master thread
  - technically challenging
  - a lot of offline testing
  - thank you to Mark Bull and Harvey Richardson for all the much needed support
- using OMP_NESTED
- comodels use data from previous model ‘core’ synchronisation time-step
  - using ‘old’ data could be problematic for low resolution cases but not expected to an issue for a high-res ESM
  - e.g. radiation computations are run every NRADFR model time-steps (e.g. a model hour or potentially 30 minutes in the future)
  - requires some careful synchronisation for the initial synchronisation time-steps

Future work

- make comodel synchronisation more modular
  - retain diagnostics to show where model ‘core’ and/or comodels have excessive synchronisation wait times
  - To help finding optimal thread distribution
- initial meteorological evaluation for radiation comodel (1Q2017)
  - expecting no surprises here as this was done before for “radiation in parallel” MPI task implementation (see TM721)
- add the IFS wave mode (WAM) as the second comodel (1H2017)
  - a first example of a comodel doing MPI communication internally
  - may need MPI ‘thread-multiple’ MPI support
- explore alternative synchronisation using OMP tasking
  - comodel thread distribution could then be (potentially) fully dynamic


Thank you for your attention
Questions?