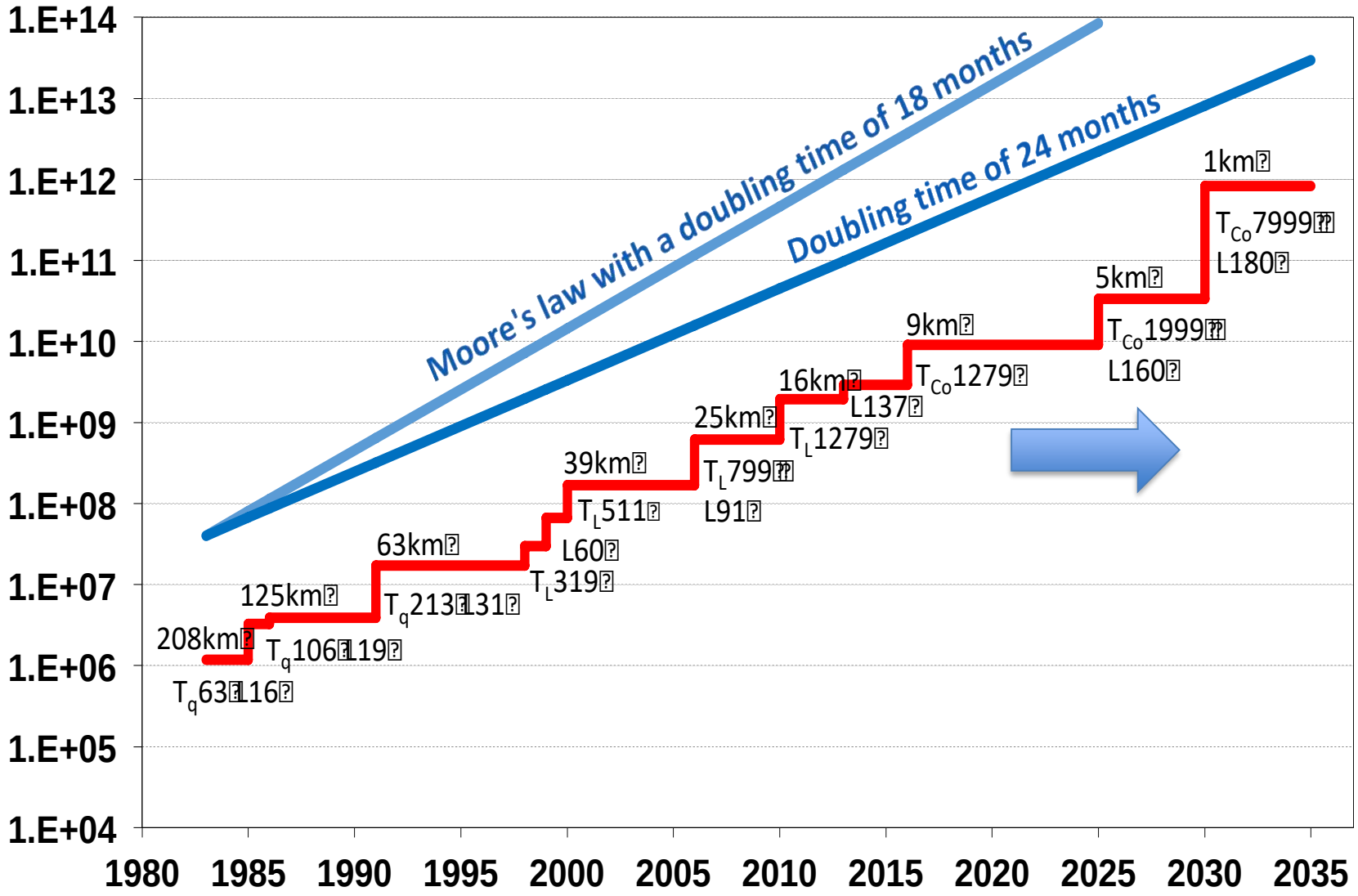
A baseline for global weather and climate simulations at 1km resolution

Nils P. Wedi
European Centre for Medium-Range Weather Forecasts (ECMWF)

19th Workshop on high performance computing in meteorology, September 2021

Computational power drives spatial resolution



(Schulthess et al, 2019)

ECMWF's progress in degrees of freedom
(levels x grid columns x prognostic variables)

ECMWF Scalability Programme

nextgenio

LEXIS

EuroEXA

ESCAPE

MAESTRO DATA ORCHESTRATION

EPiGRAMHS

ESCAPE 2

esiwace2 CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

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

ExtremeEarth

DIGITAL TWINS

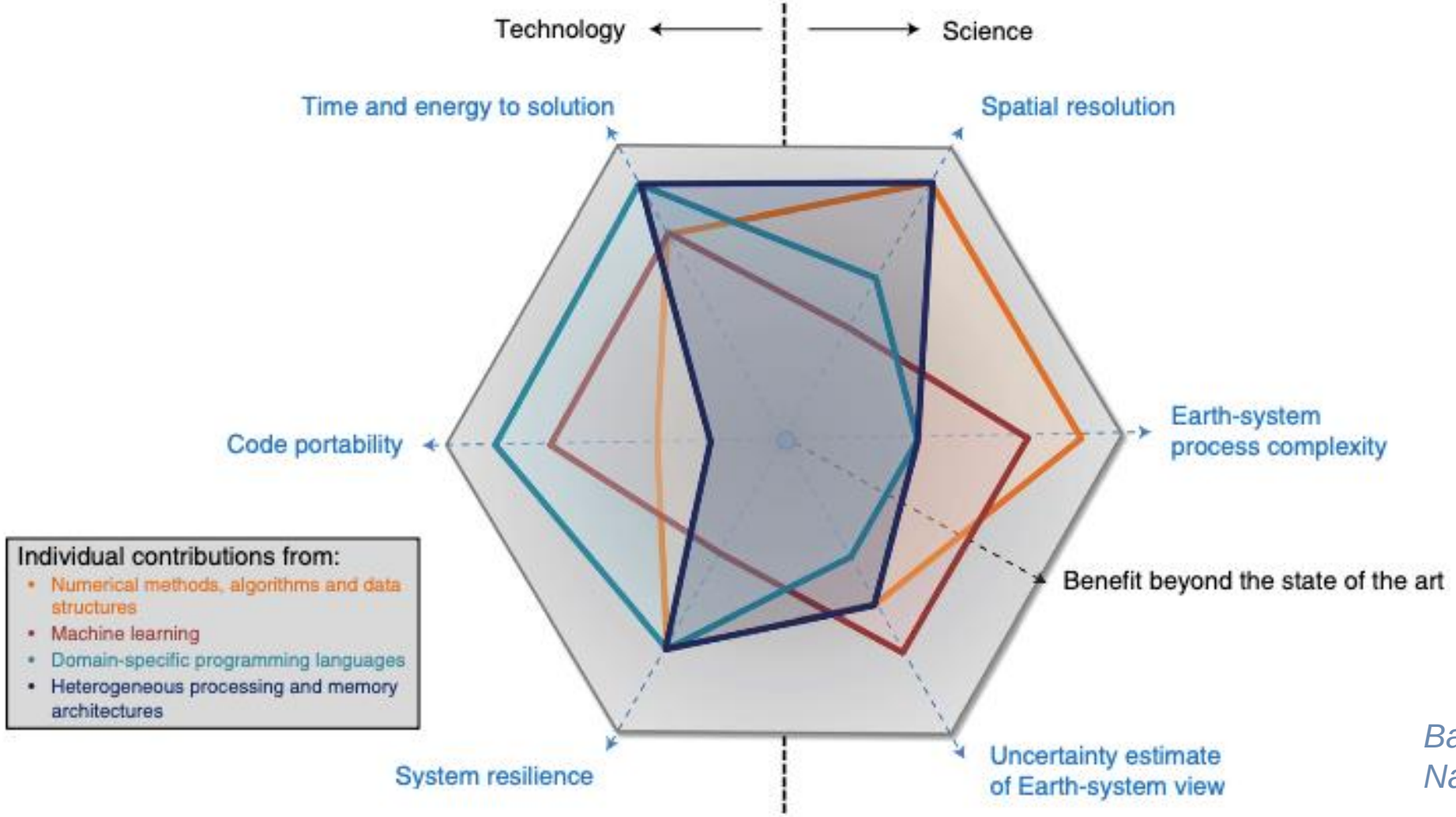
857

The ECMWF Scalability Programme: Progress and Plans

Peter Bauer, Tiago Quintino, Nils Wedi, Antonino Bonanni, Marcin Chrust, Willem Deconinck, Michail Diamantakis, Peter Düben, Stephen English, Johannes Flemming, Paddy Gillies, Ioan Hadade, James Hawkes, Mike Hawkins, Olivier Iffrig, Christian Kühnlein, Michael Lange, Peter Lean, Pedro Maciel, Olivier Marsden, Andreas Müller, Sami Saarinen, Domokos Sarmany, Michael Sleigh, Simon Smart, Piotr Smolarkiewicz, Daniel Thiemert, Giovanni Tumolo, Christian Weihrauch, Cristiano Zanna

February 2020

Expected contribution of main system developments necessary to achieve key science and computing technology performance goals.



Bauer et al,
Nature Computational Science, 2021

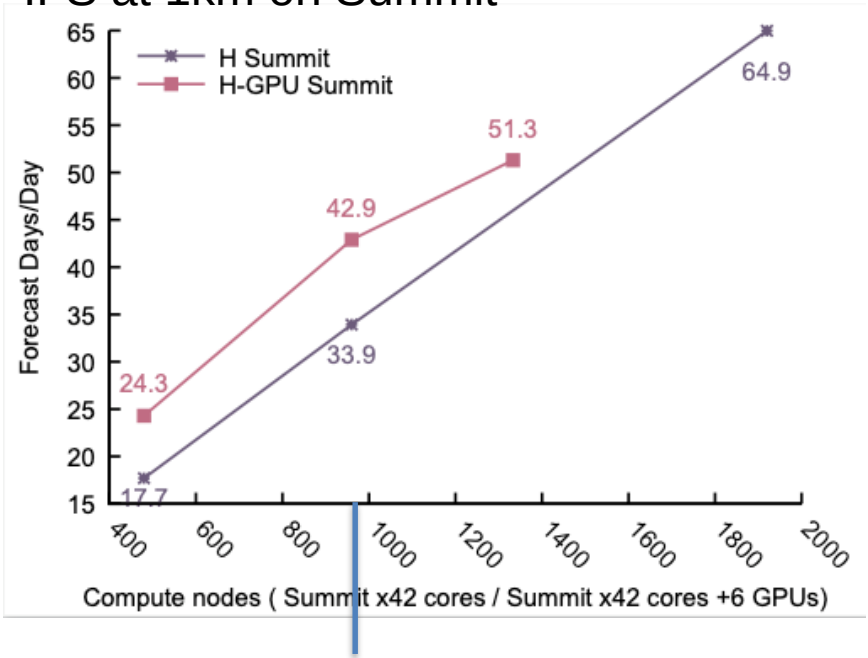
Hybrid CPU-GPU compute

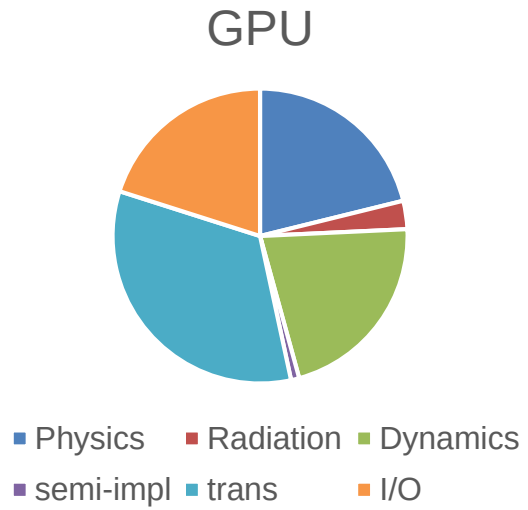
Erik Lindahl, Professor of Biophysics at Stockholm University, **"Strategies & Lessons from Scaling Programs that are hard to Scale - Molecular Dynamics on Accelerators & Exascale Resources"**

"**Use the CPU where it excels:** Standard C++ code, rapid deployment of algorithms, task parallelism, random memory access (e.g. neighborsearching) Ideally 99% of code, but 1% of runtime

Use the GPU where it excels: FLOPS Ideally 1% of code, but 99% of runtime"

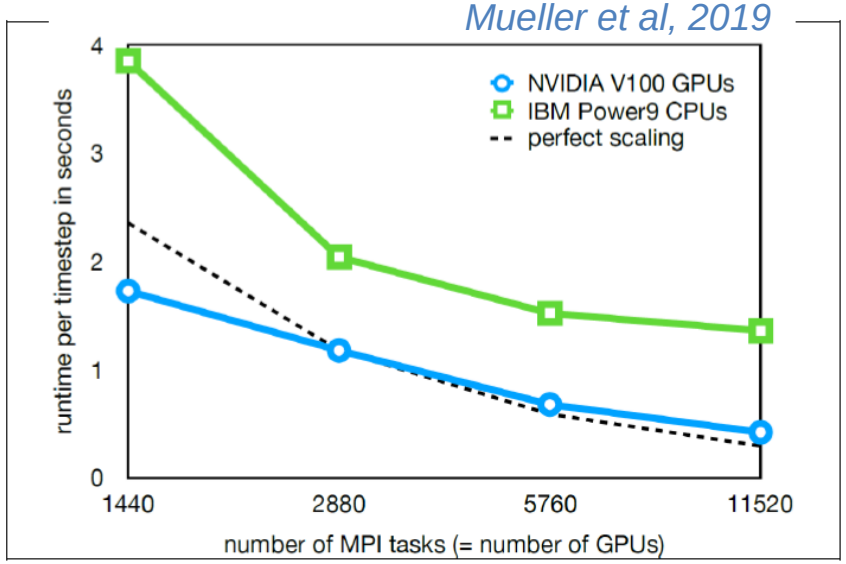
IFS at 1km on Summit





=> IFS spectral transforms (LT/FFT) on GPUs

Mueller et al, 2019



The **OLCF INCITE programme** supported
the simulation of two seasons (7 months) at 1.4 km globally on 960 Summit nodes

Innovative I/O management, data compression and governance

T. Quintino, O. Iffrig, S. Smart , et al

ECMWF NWP

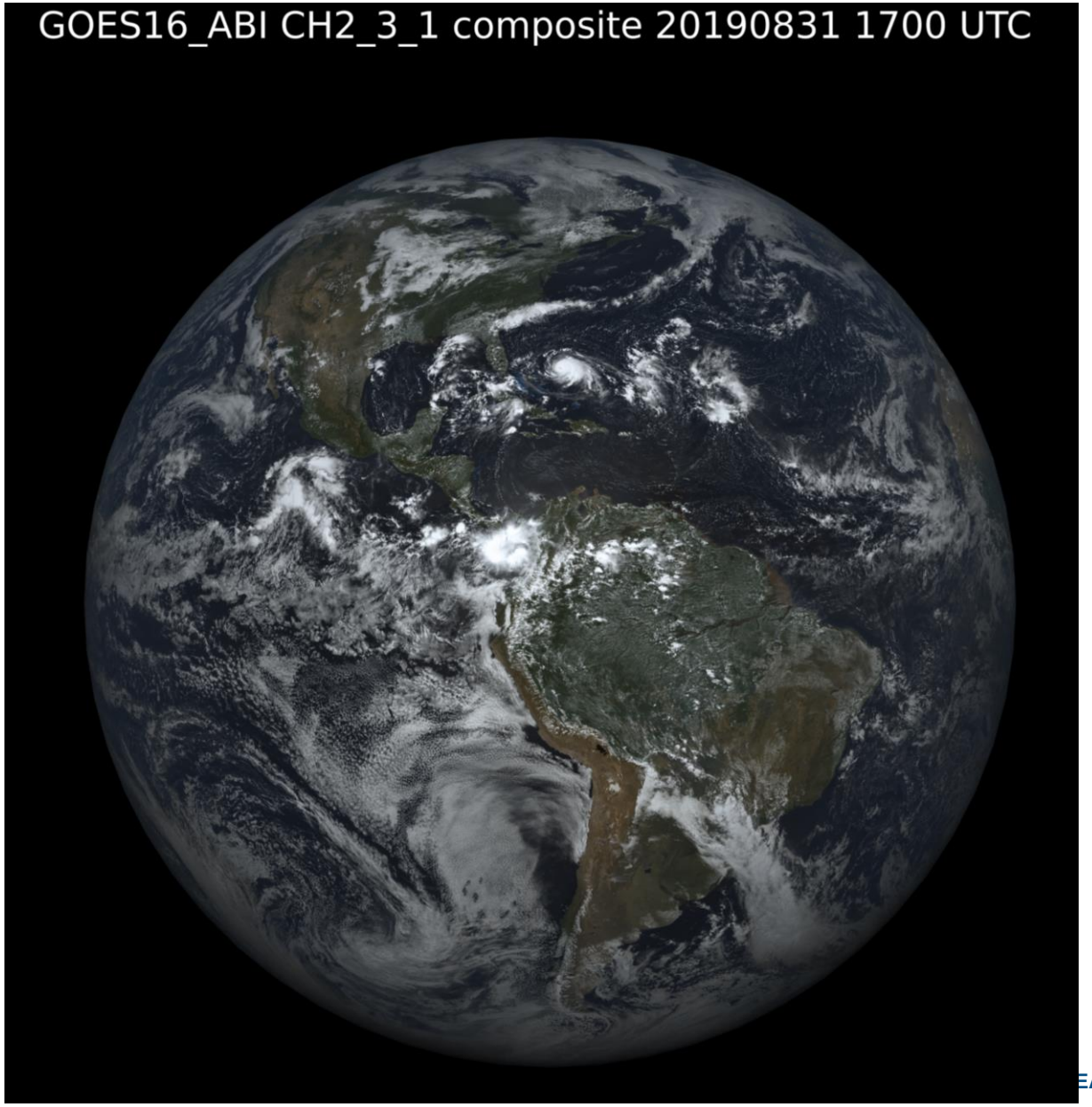
6,599,680 points x 137 levels x 10 vars
at ~9km ~ **9 Billion points or ~100TB/day**

Digital Twin prototype

Exploiting node-local NVMe
and asynchronous data transfers

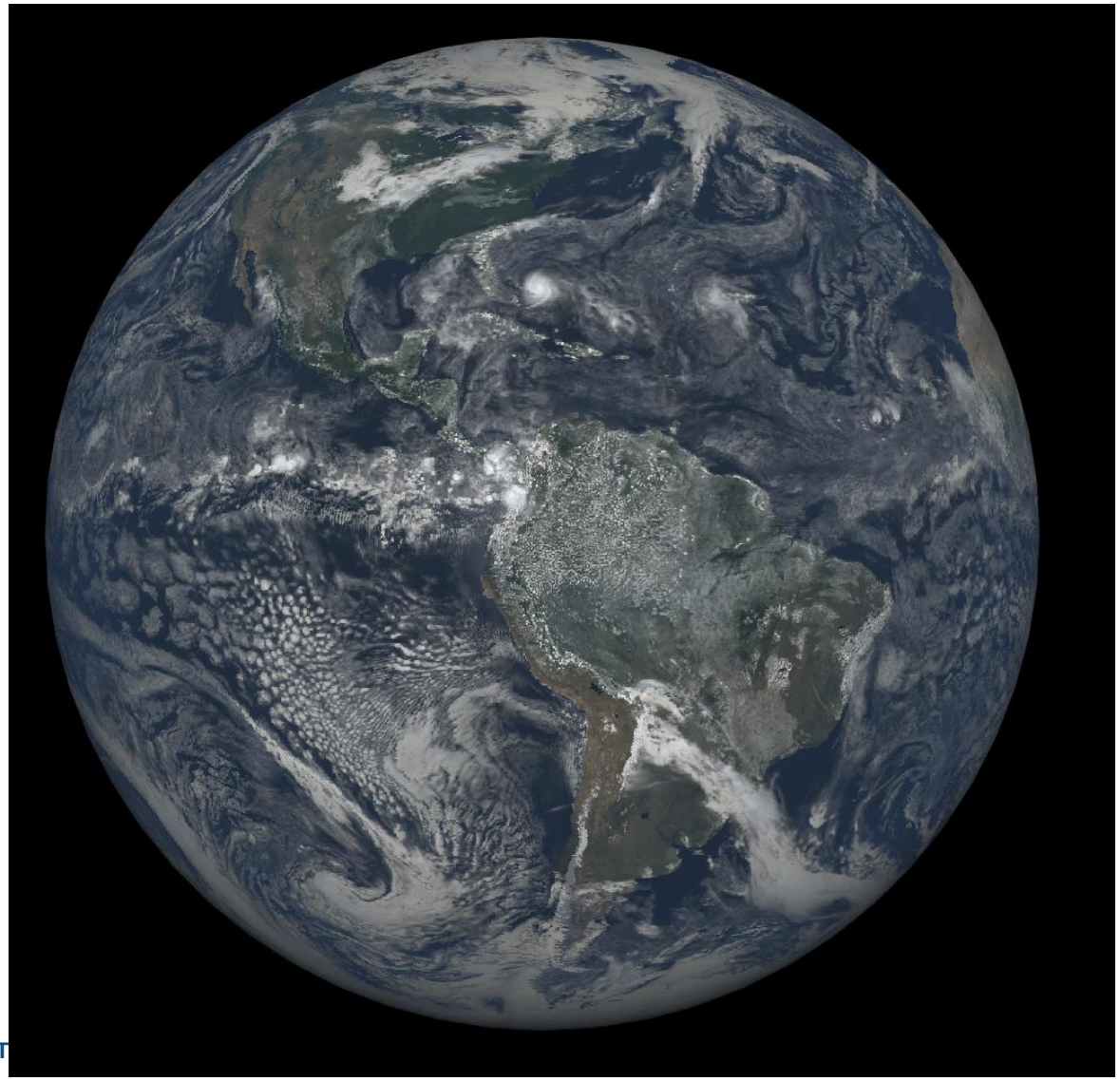
TCo7999 L137
256,800,000 points x 137 levels x 10 variables at ~1,4km
352 billion points x 960 pp steps ==
~100TB/simulated month
Same amount produced in 6 days with 15min pp

RTTOV-MFASIS (satellite image simulator) to produce simulated visible images from IFS 3D data

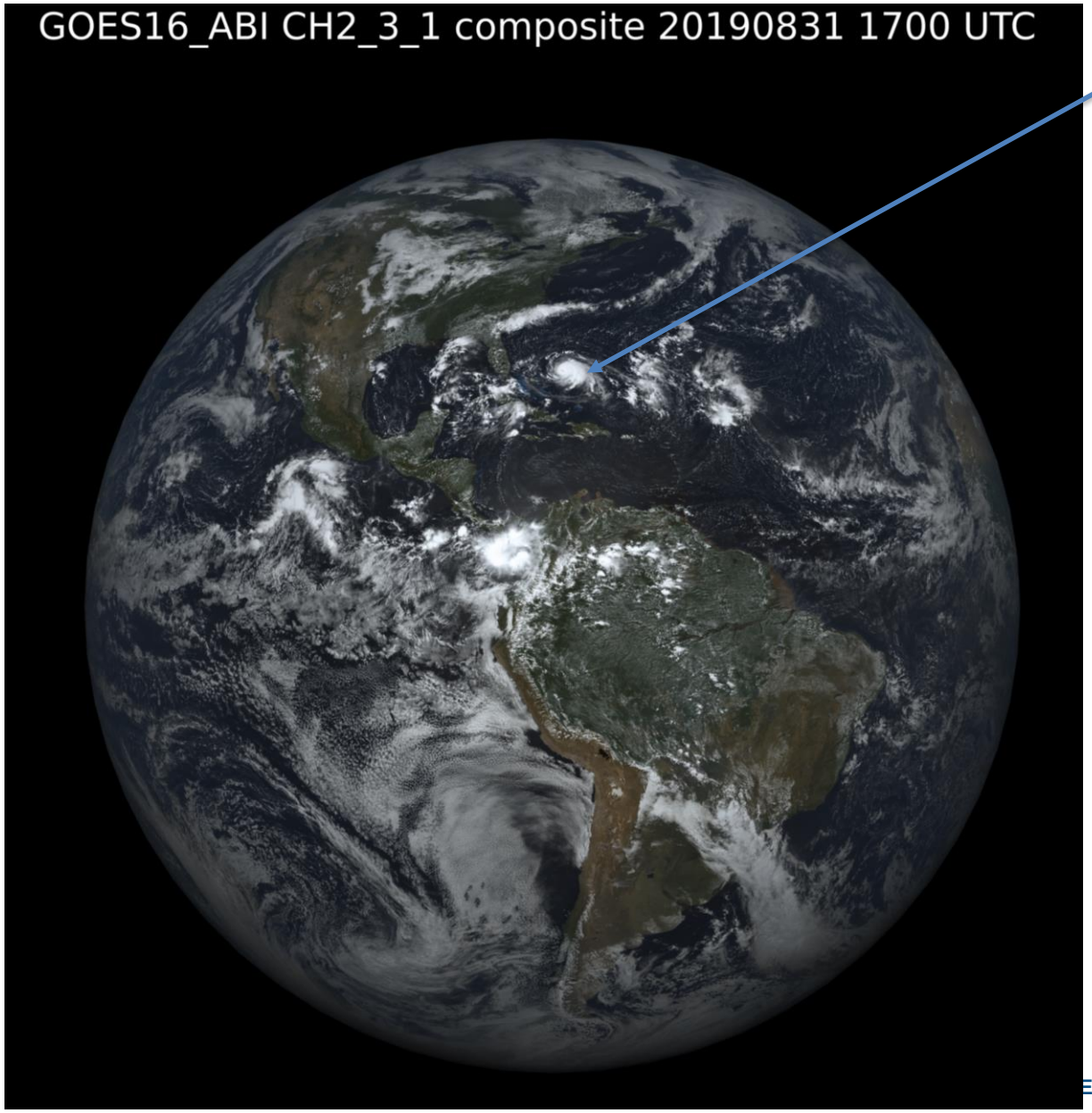


IFS FC+89h at 9 km (oper)

Philippe Lopez



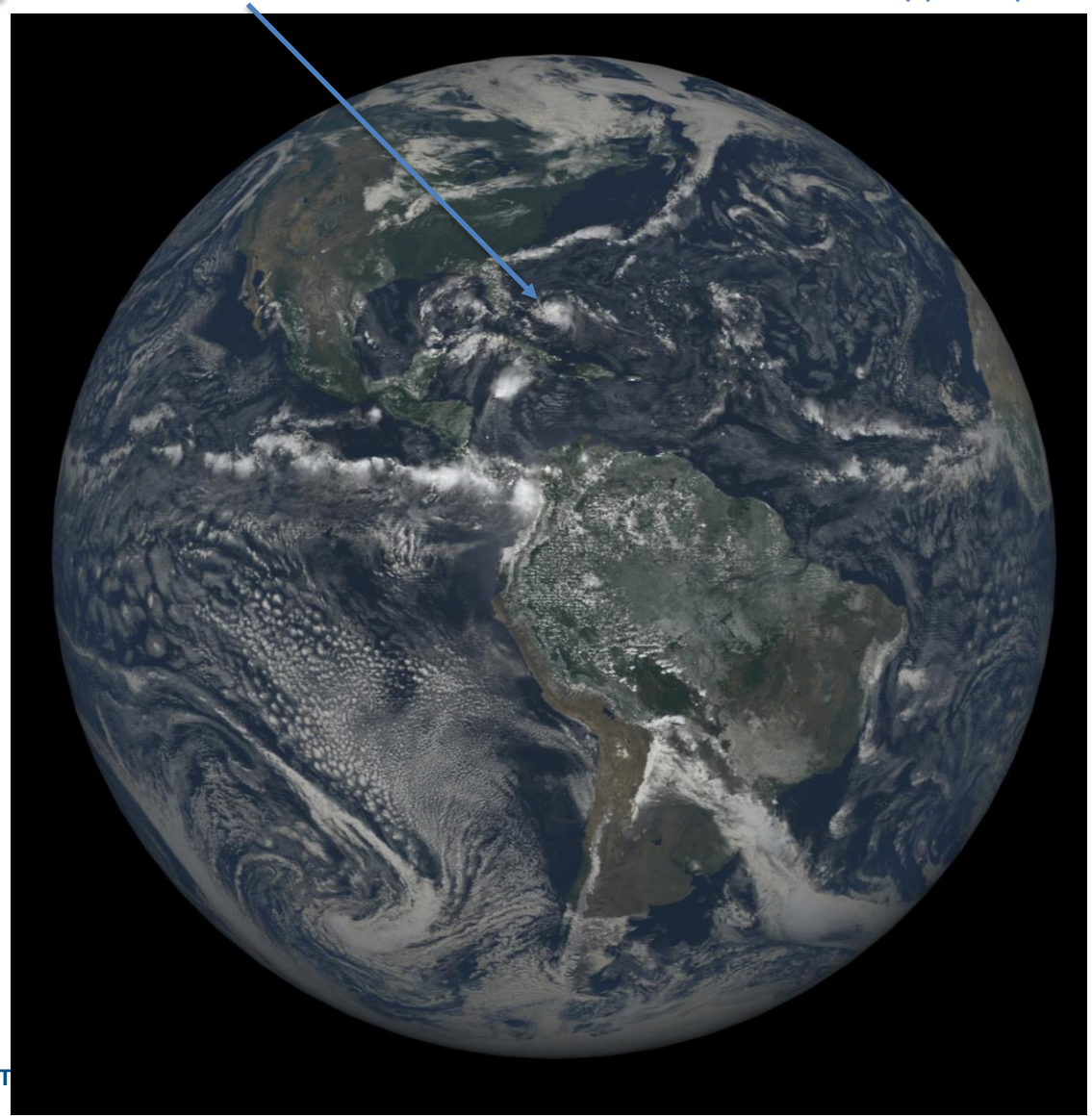
RTTOV-MFASIS (satellite image simulator) to produce simulated visible images from IFS 3D data



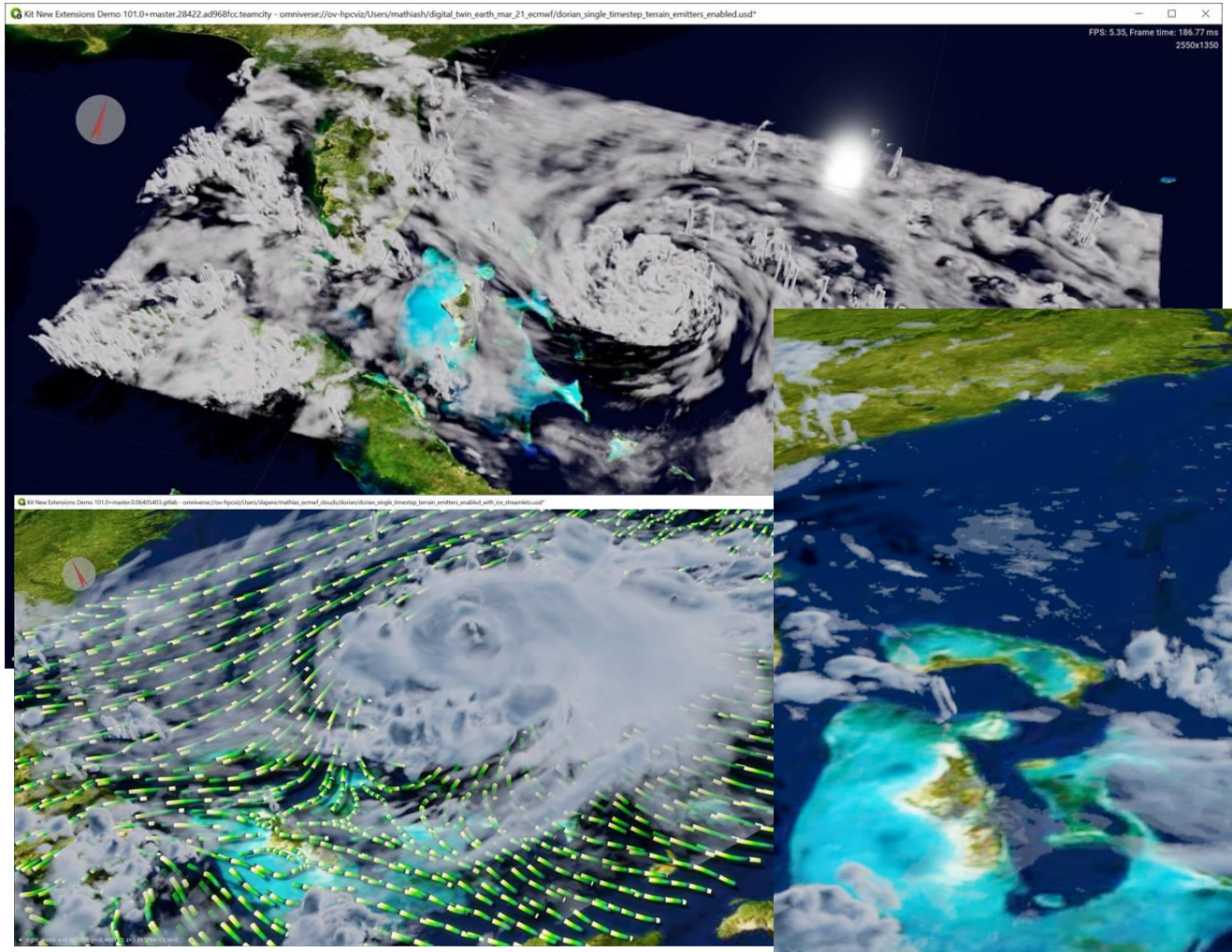
IFS FC+89h at 1.4 km

Huricane Dorian

Philippe Lopez



Extremes



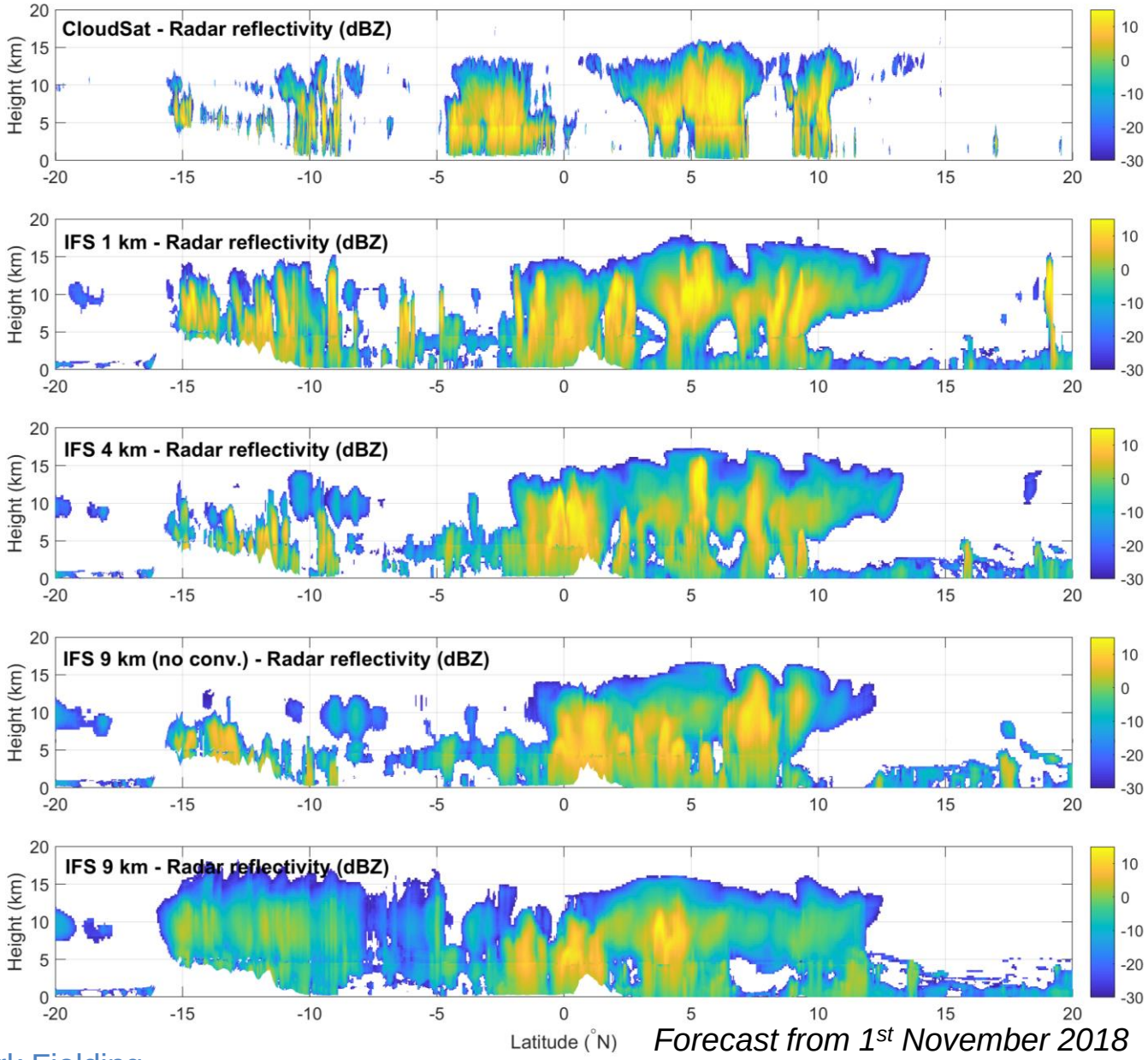
Hurricane Dorian 4-6 day forecast in August 2019 on Summit

GPU accelerated visualization with Omniverse

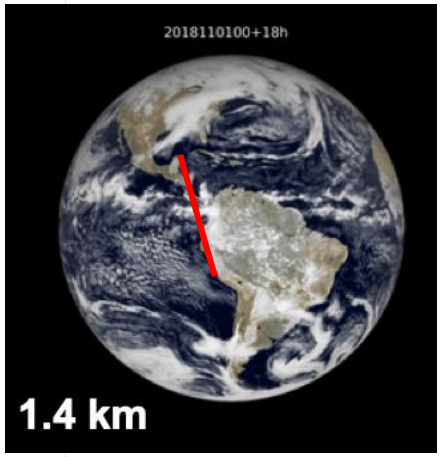
Mathias Hummel, Peter Messmer (NVIDIA);
Pedro Maciel (ECMWF)

ECMWF EUROPEAN CENTRE FOR

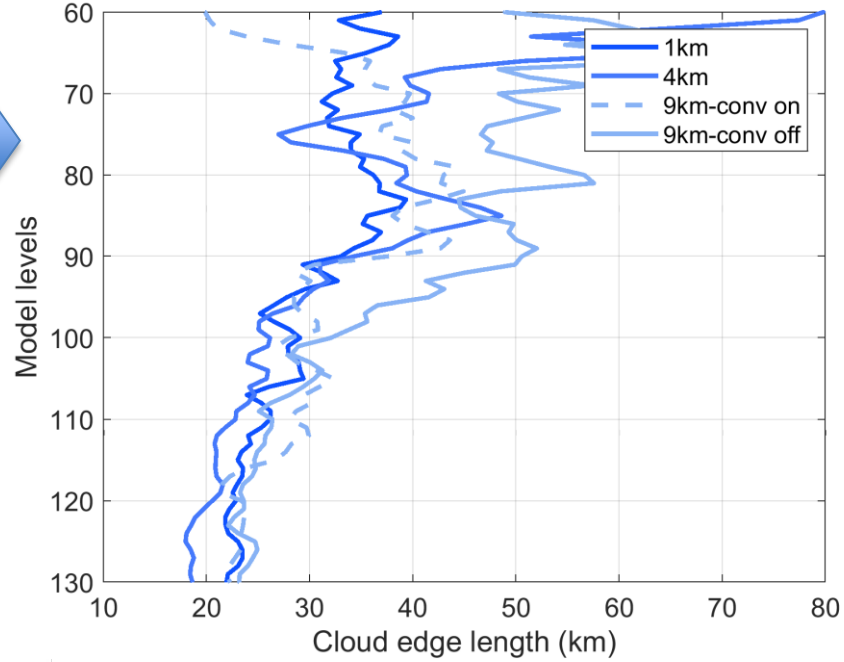
Using CloudSat observations in the evaluation of 3D km-scale simulation data …



Forecast from 1st November 2018



- Radar observation operator is highly effective tool for evaluating convection in high-resolution model forecasts

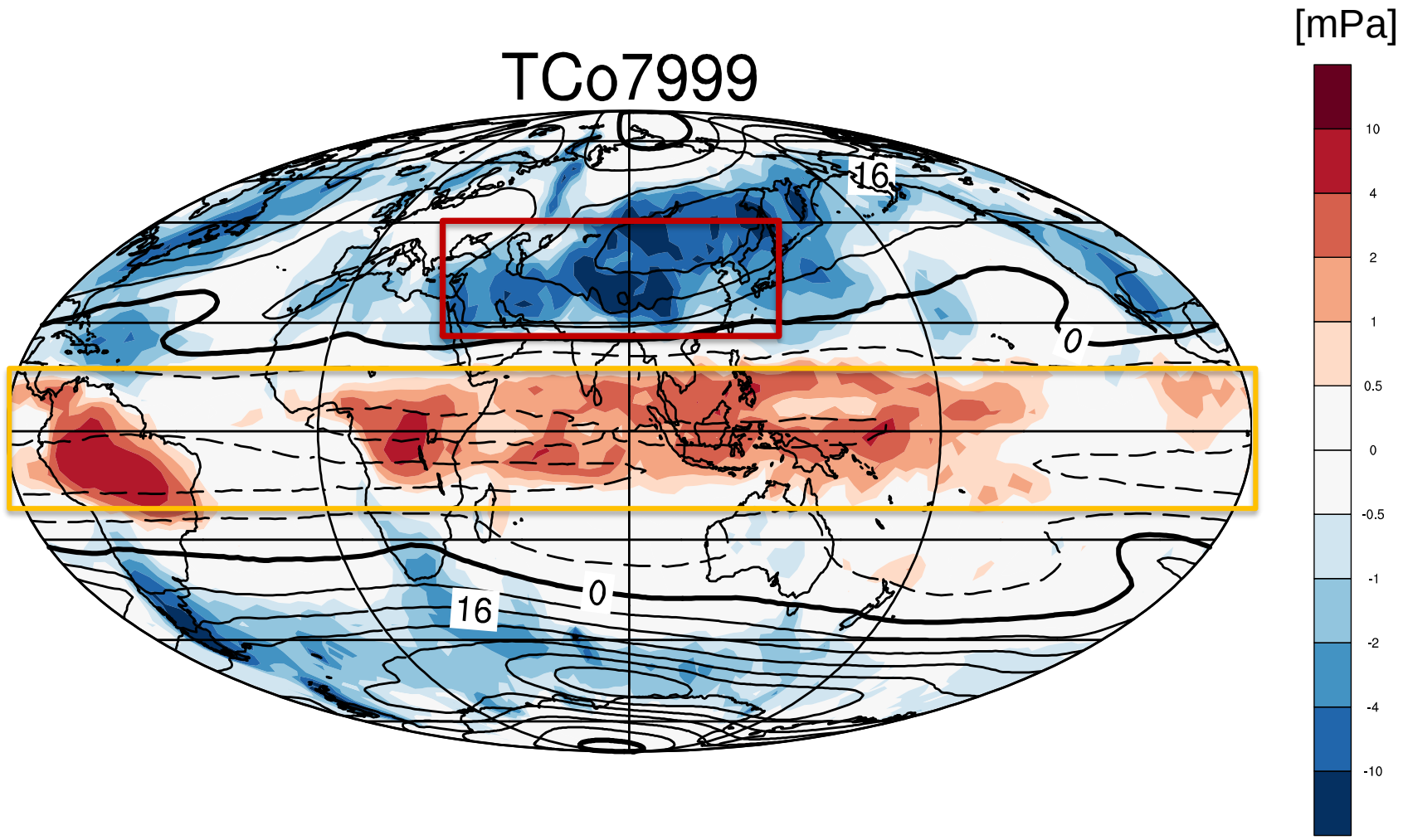


Unpicking the effects of resolution and convection parameterization on 3D structure

Mark Fielding

Stratosphere

Resolved zonal gravity wave momentum flux at 50hPa from 1 km IFS simulations on Summit for 5-15 Nov 2018.

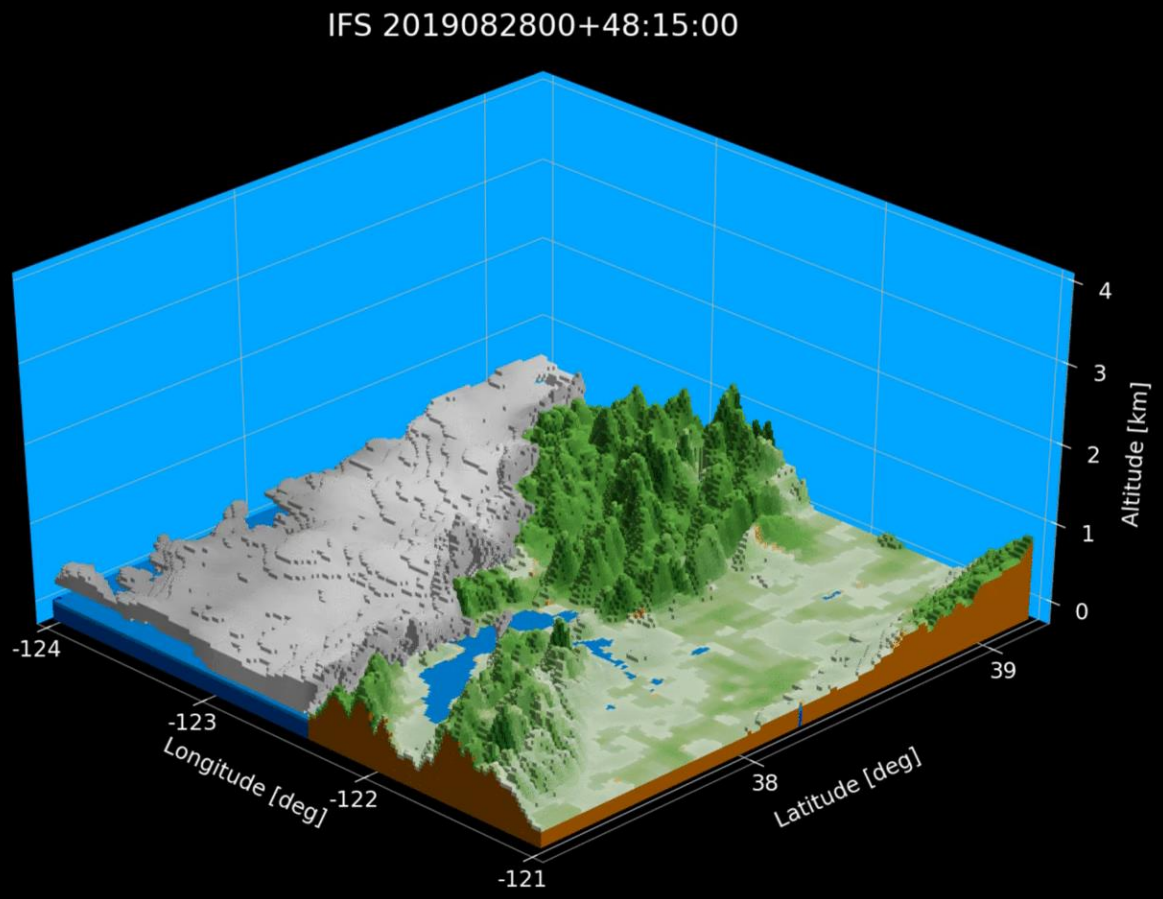


At 1km resolution, smaller-scale GWs are as or more important than long- and meso-scale GWs.

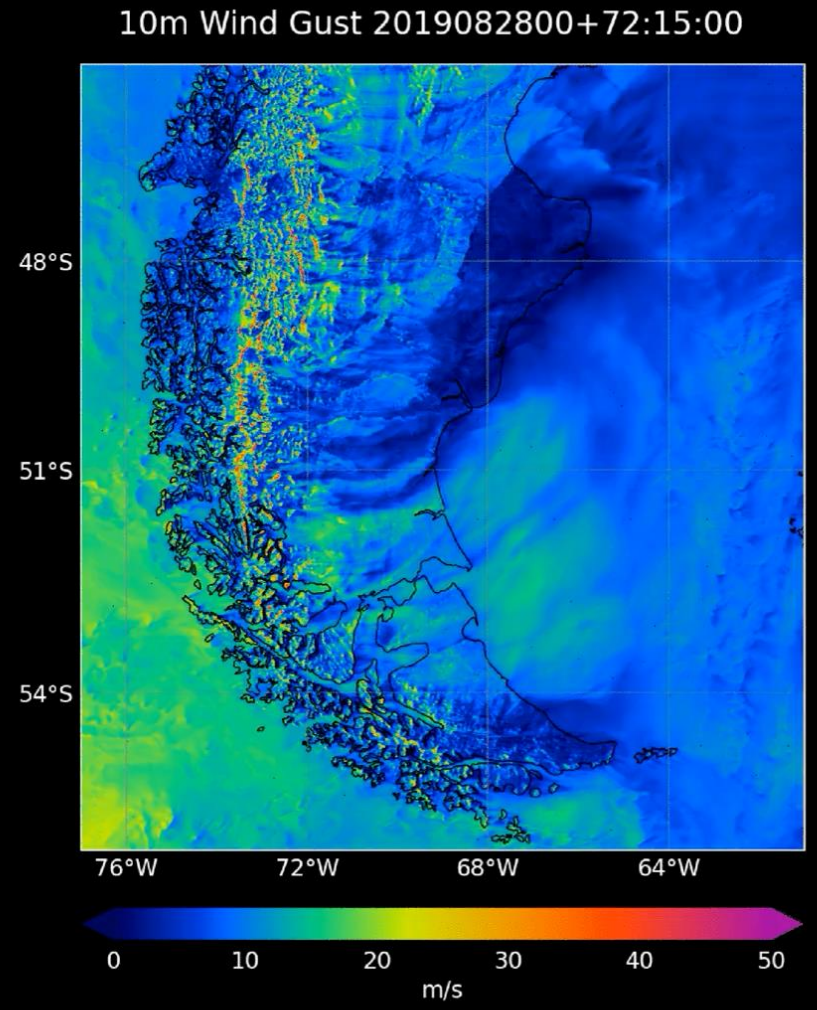
Polichtchouk, Wedi & Kim (submitted)

Californian coastal fog
Forecast from 28 August 2019 00Z, Steps: +48h to +72h every 15mn.

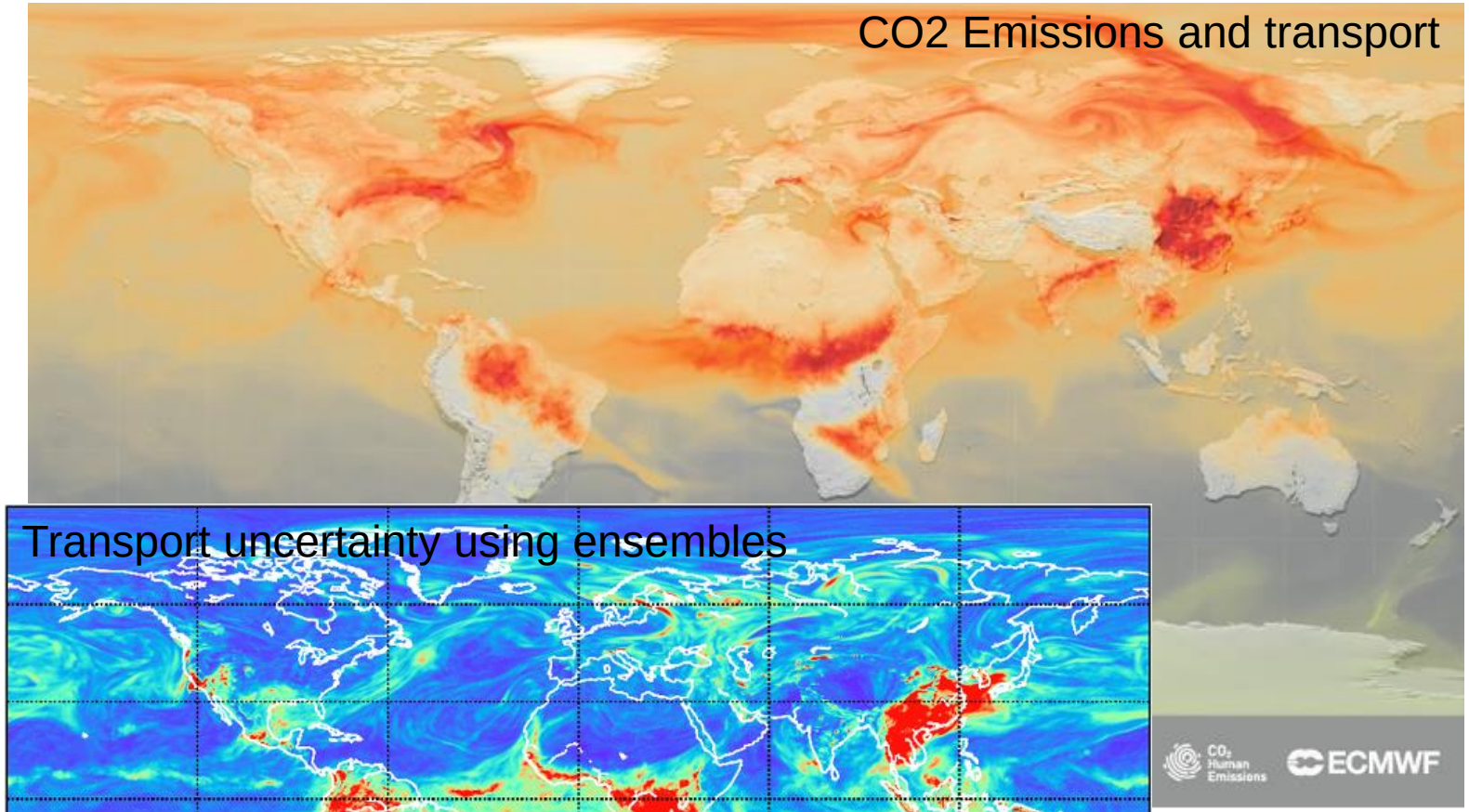
Philippe Lopez

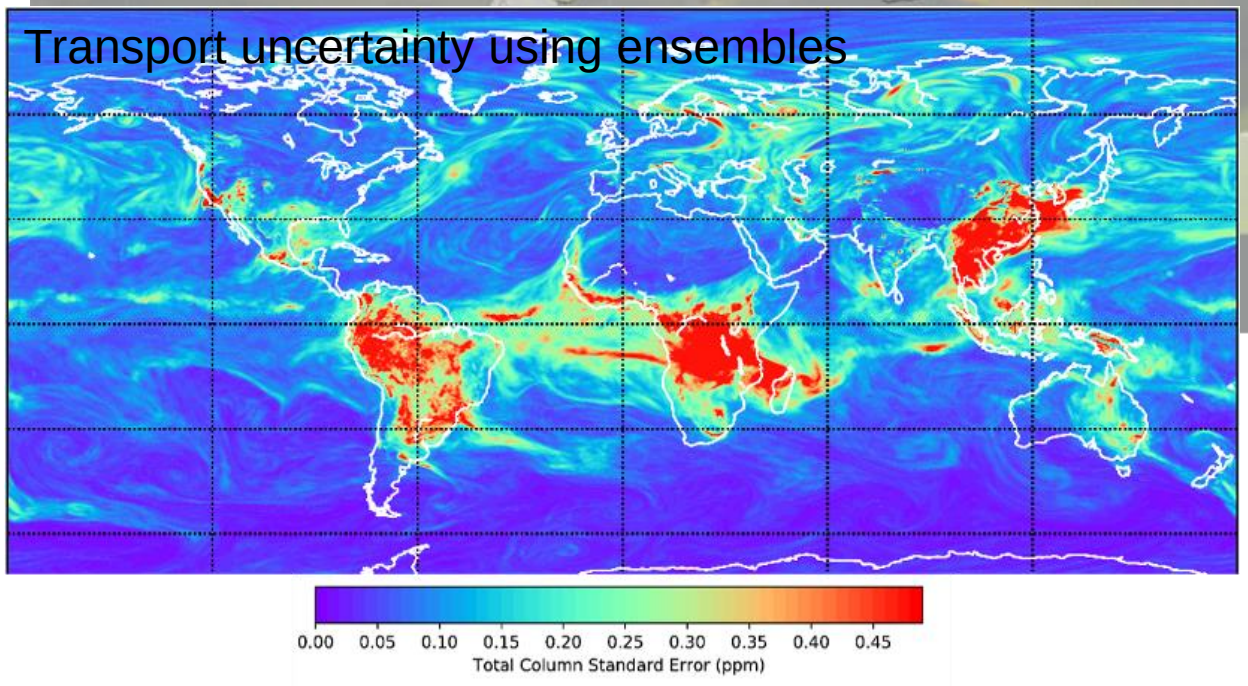


Patagonian wind gusts
Forecast from 28 August 2019 00Z, Steps: +72h to +96h every 15mn.



ECMWF





Looking ahead:

Atmosphere Monitoring Service

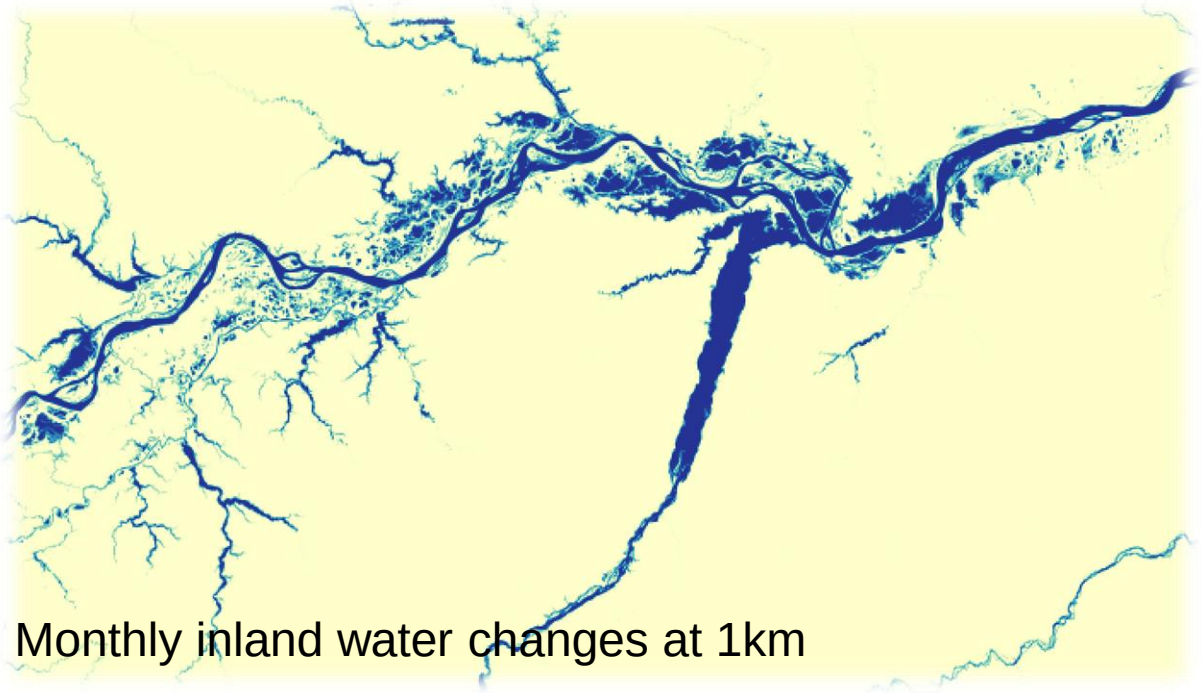
atmosphere.copernicus.eu

CO_2 Human Emissions

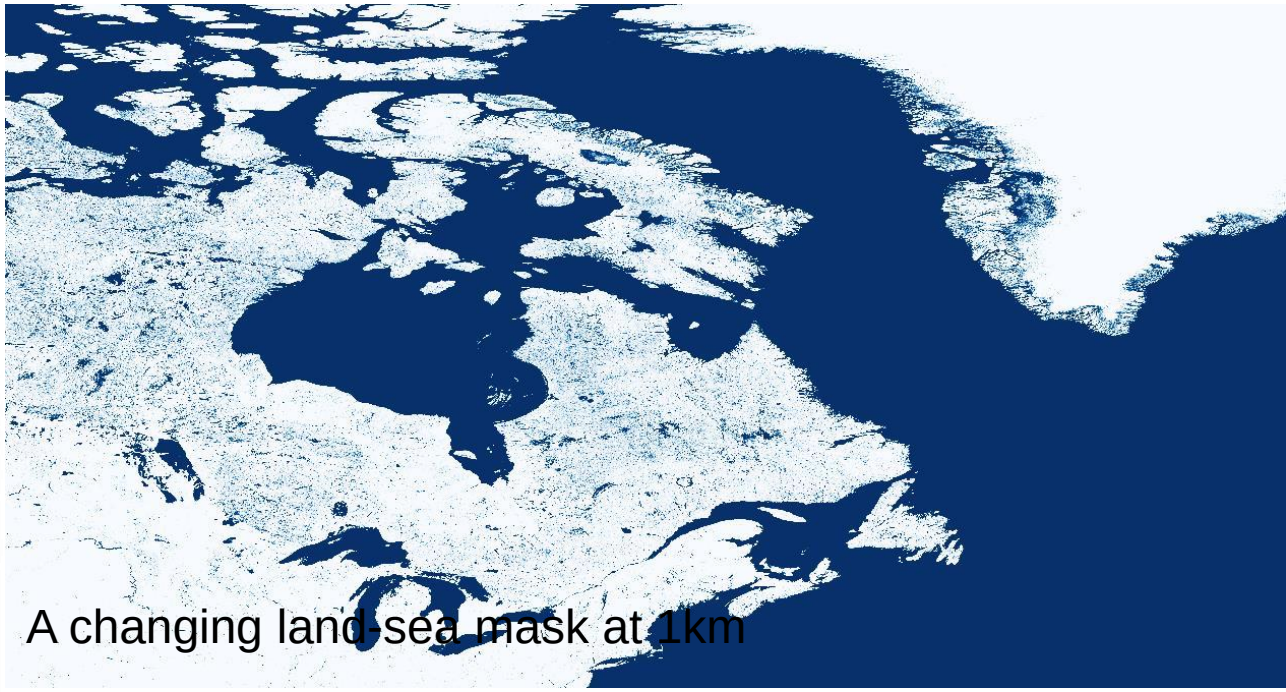
Balsamo et al, 2021

Capturing changing landscapes

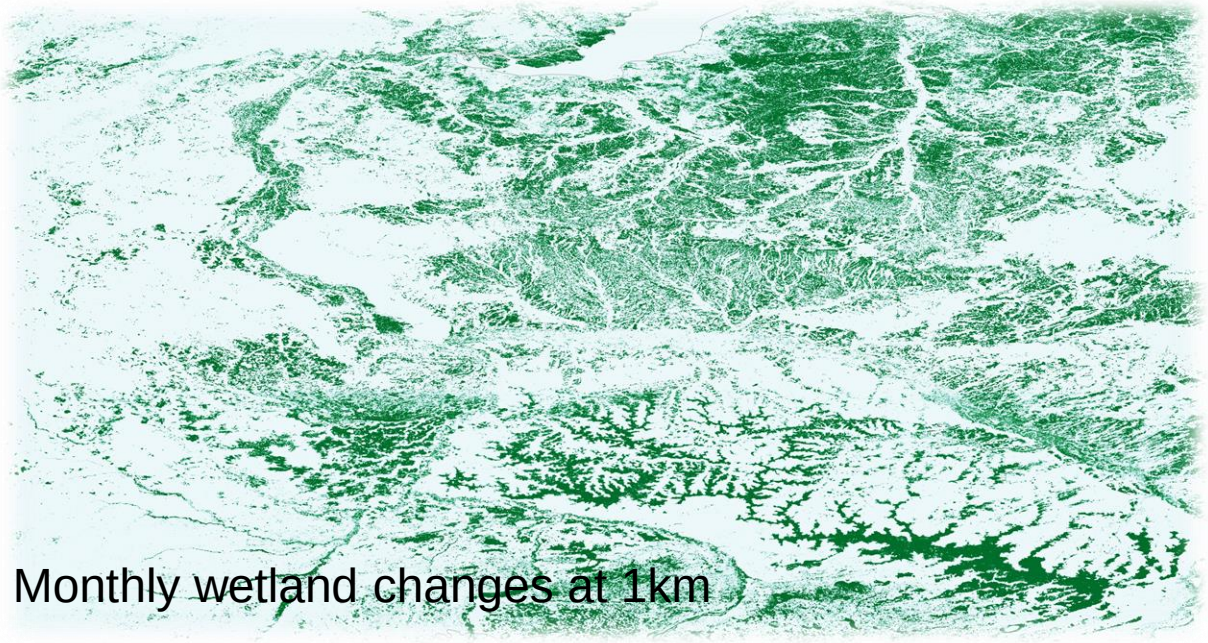
Water resources & management
Land use and coastal area management and risk
Estimate methane emissions



Monthly inland water changes at 1km

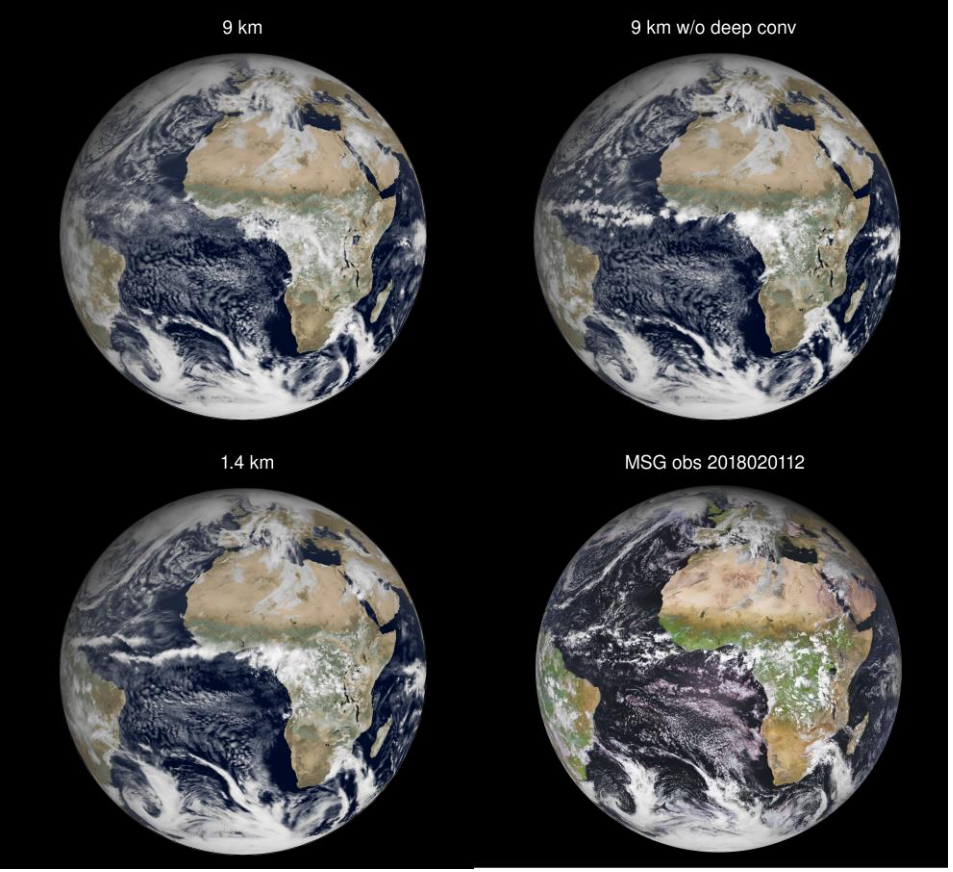


A changing land-sea mask at 1km



Monthly wetland changes at 1km

M. Choulga, G. Balsamo, S. Boussetta, J. McNorton

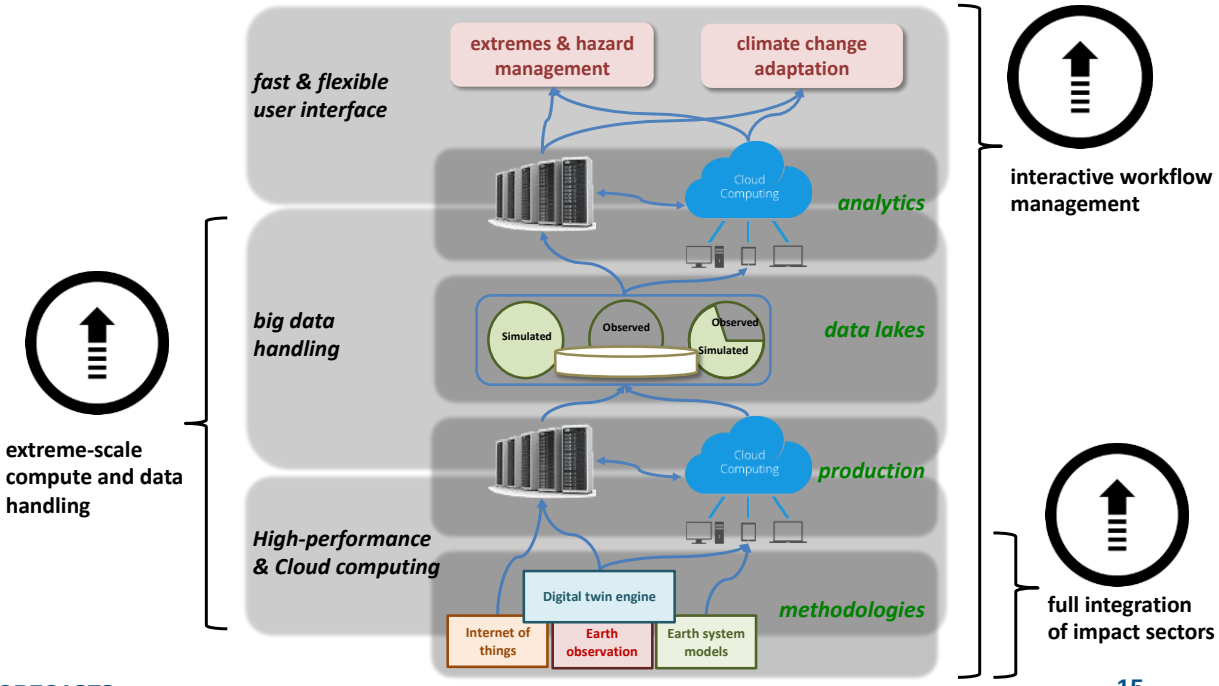


Wedi et al, JAMES, 2020

Towards a Digital Twin of the Earth System

A unified digital environment for the assessment and prediction of environmental extremes at km-scale for informed decision making at city, catchment, coastline, country and continental scale.

https://ec.europa.eu/digital-single-market/en/destination-earth-destine



EuroHPC Joint Undertaking

=> See the presentations this afternoon!

Acknowledgements

- The work benefitted from close collaboration between high-resolution simulation model benchmarking and advanced methodologies presently being developed for heterogeneous high-performance computing platforms at ECMWF in the ***ESCAPE-2*** **(No. 800897),** ***MAESTRO*** **(No. 801101),** ***EuroEXA*** **(No. 754337), and** ***ESiWACE-2*** **(No. 823988) projects** funded by the ***European Union's Horizon 2020*** future and emerging technologies and the research and innovation programmes.

- **EarthCARE** work was partially supported by the ***ESA funded*** project, Operational Assimilation of Space-borne Radar and Lidar observations for Numerical Weather Prediction (4000116891/16/NL/LvH) and the follow-on PEARL Cloud - Preparation for EarthCARE Assimilation of Radar and Lidar Cloud Observations - ESA ESTEC contract (4000128669/19/NL/CT).

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- Thanks to **ECMWF staff** and many international collaborations who directly or indirectly contributed to this presentation.