

MIR

ECMWF's New Interpolation Package

P. Maciel, [T. Quintino](#), B. Raoult, M. Fuentes, S. Villaume

ECMWF

mars-admins@ecmwf.int



Upgrading the Interpolation Package

Interpolation is **pervasive**:

- Product generation
- Access to data archive (MARS)
- Visualisation of products
- Web services



Used by many operational systems at ECMWF

MIR

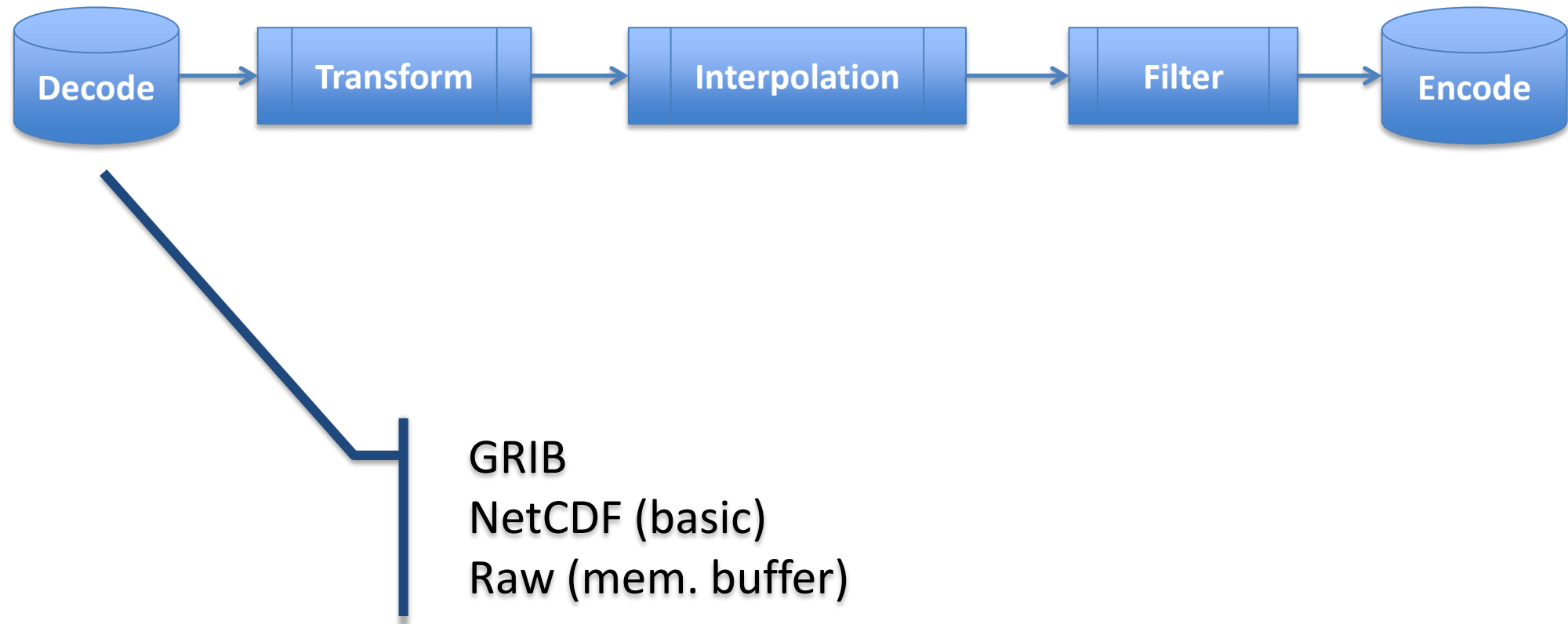
Key Features

- **Flexible** and maintainable design
 - Configuration driven
 - Plugin based (users can extend)
 - Share **data-structures** with future IFS dynamical core
- **Any-to-Any** Grid algorithm
 - There is **always** a default algorithm
- Kernel based on linear **Interpolation Operators**
 - Enabling caching of operators
 - **Linear Algebra backend** support for GPU's & Accelerator cards (Intel Phi)

Flexible Design

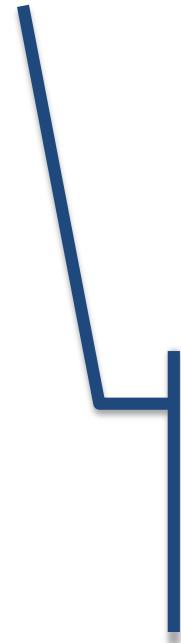
Architecture

Construct an Action Plan

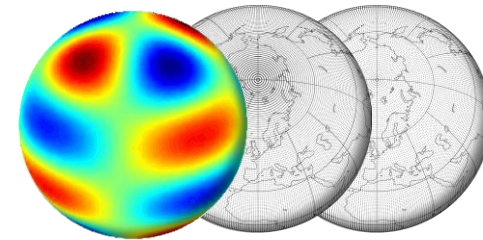


Architecture

Construct an Action Plan

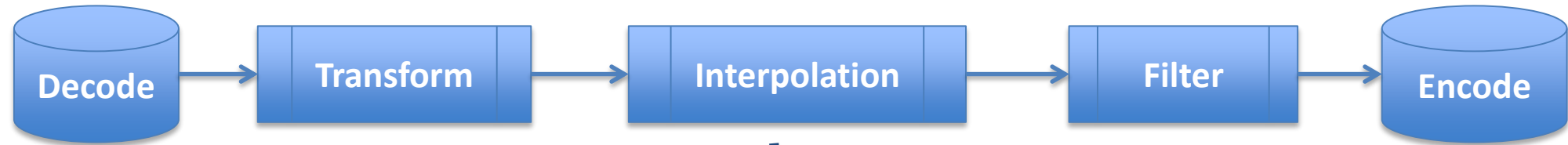


SH to SH,
VOD-2-UV
SH to Grid



Architecture

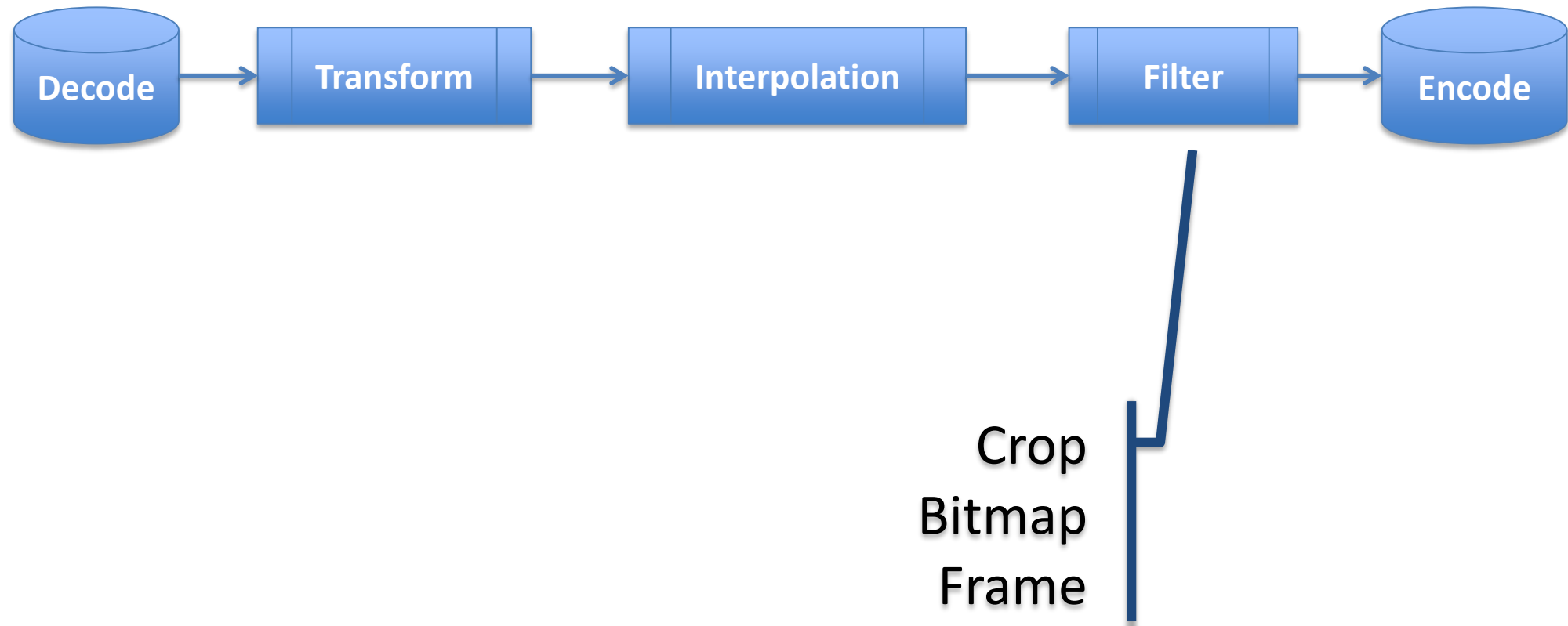
Construct an Action Plan



Compute Interpolation Operator
Caching of operators
Linear algebra kernel

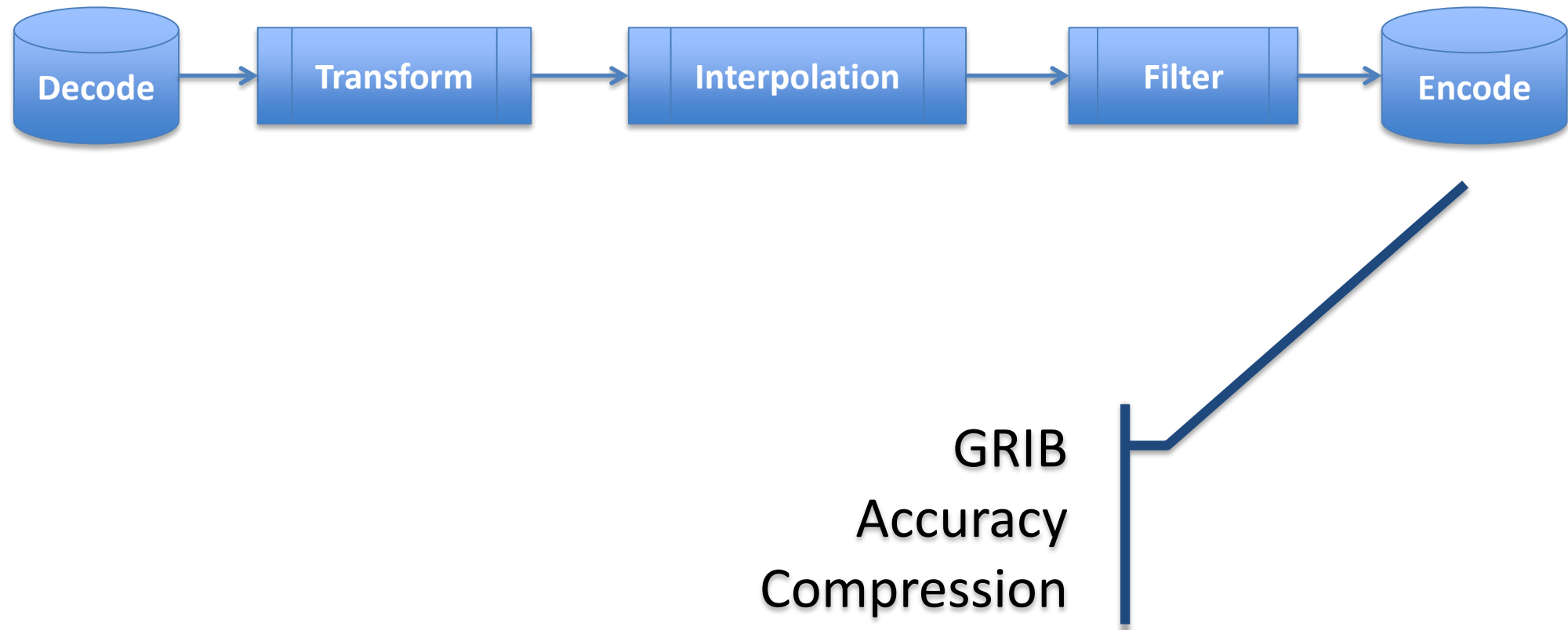
Architecture

Construct an Action Plan



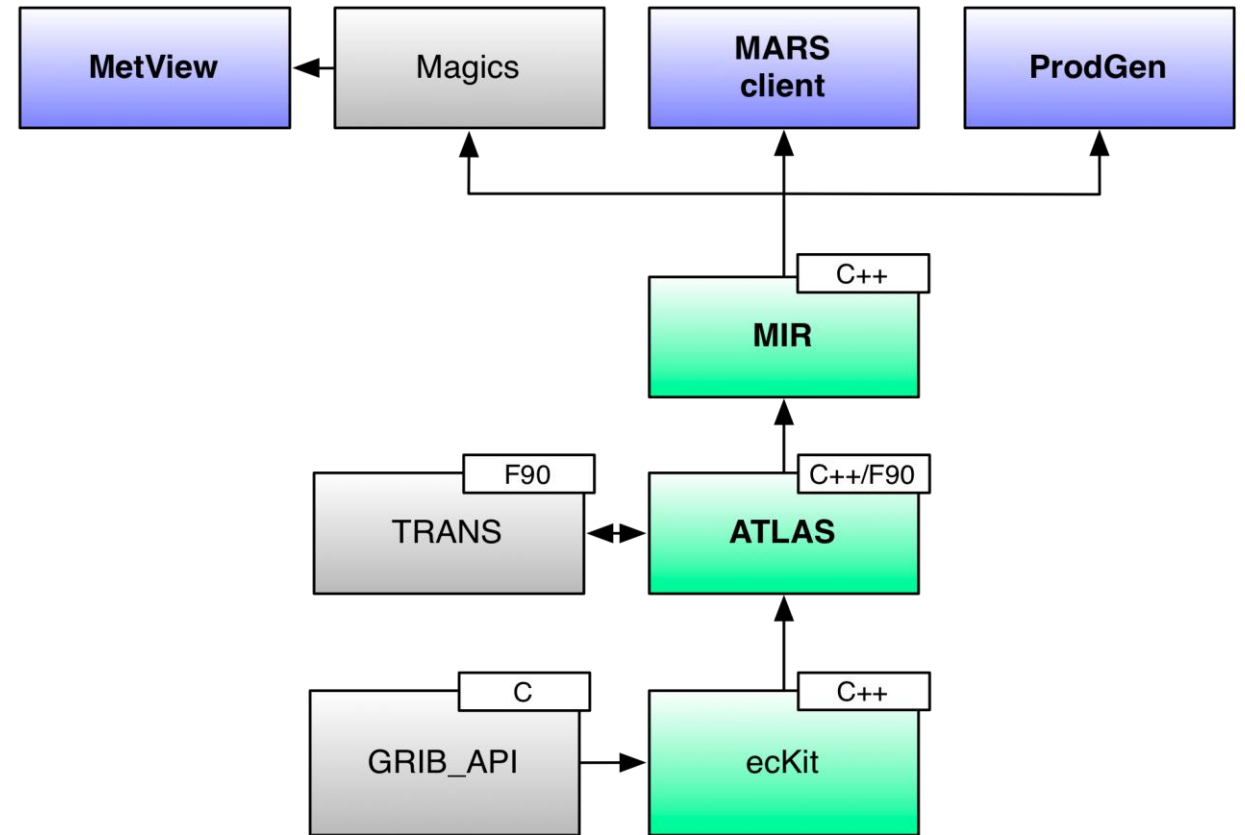
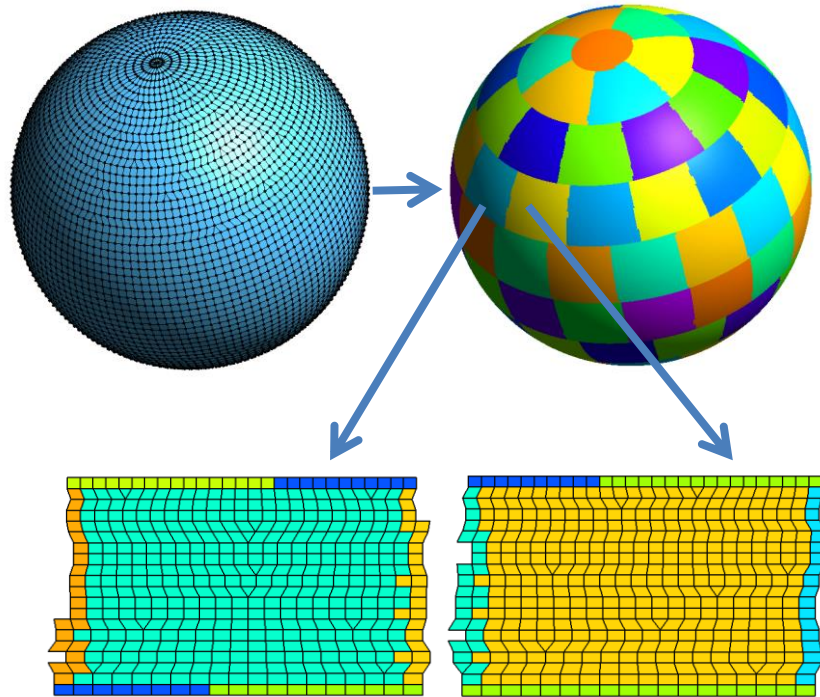
Architecture

Construct an Action Plan



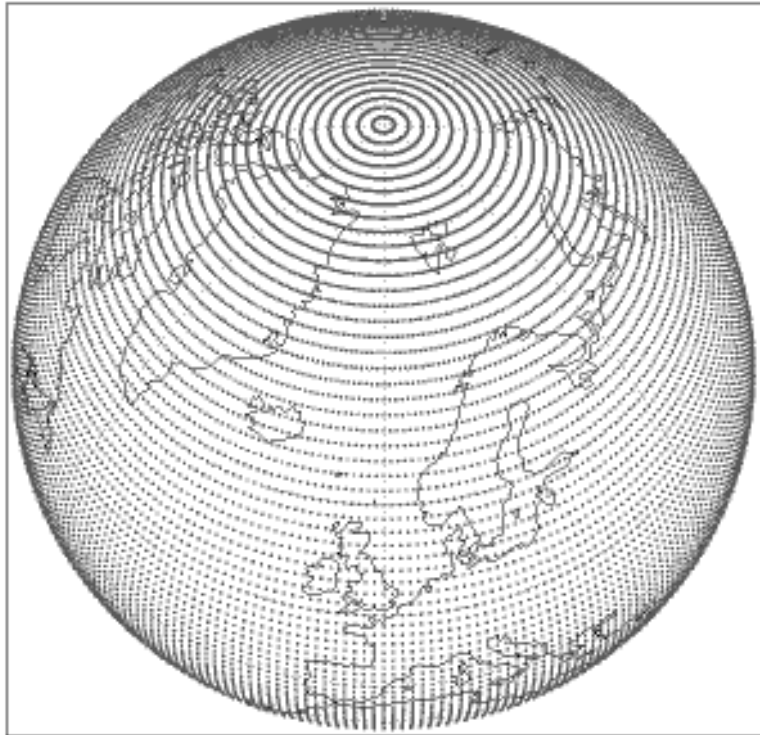
Atlas Library

- Framework for parallel, dynamic data structures
- Supporting multiple types of grids
- Fully written in **C++** (Fortran 2003 interfaces)
- Basis to develop **scalable** dynamical core

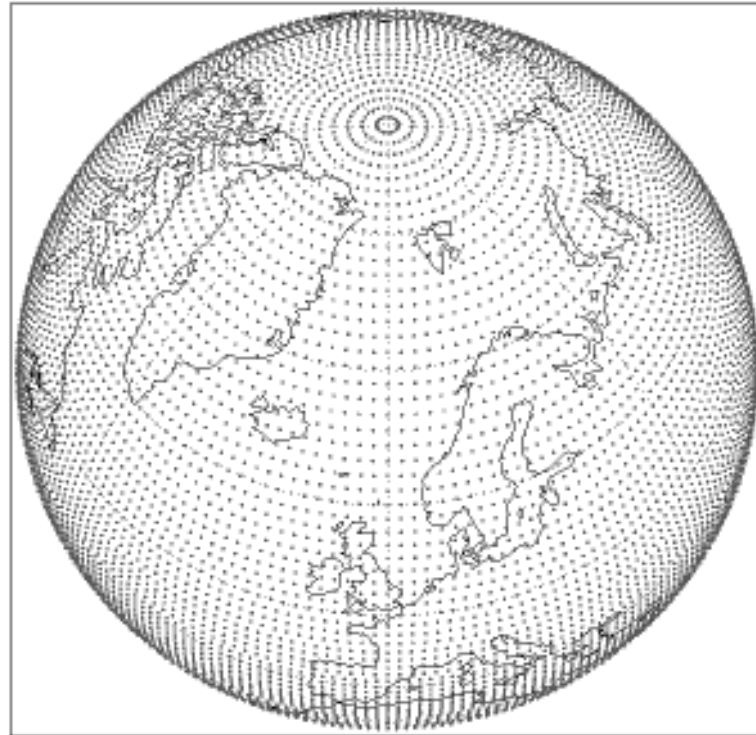


Any-to-Any Grid

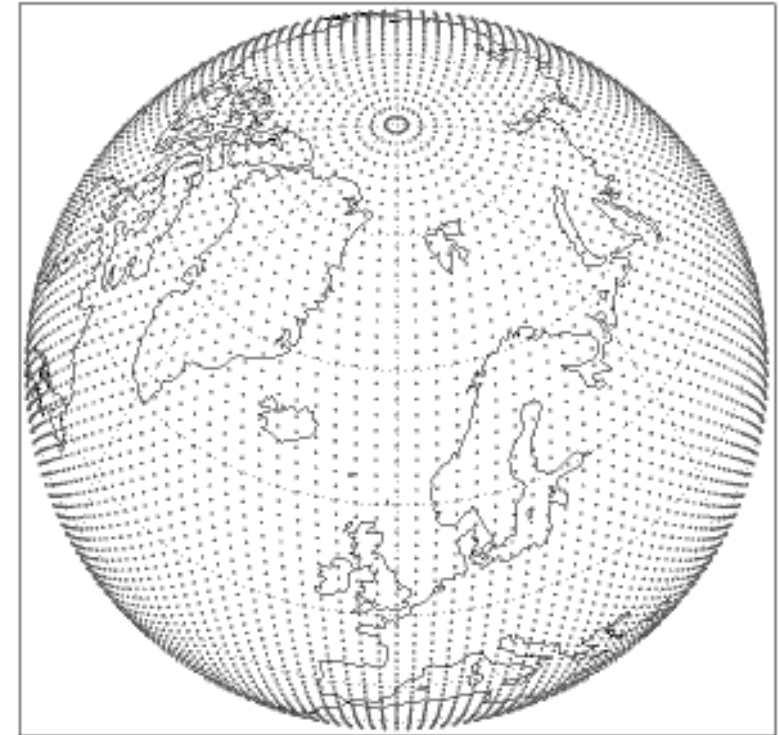
A Myriad of Grids



Lat-Lon

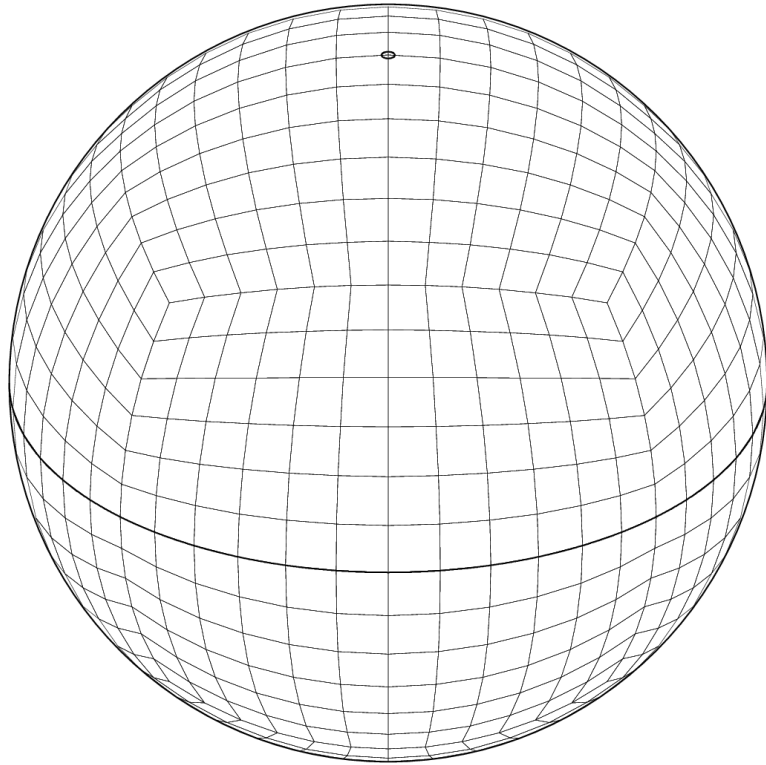


Reduced Gaussian



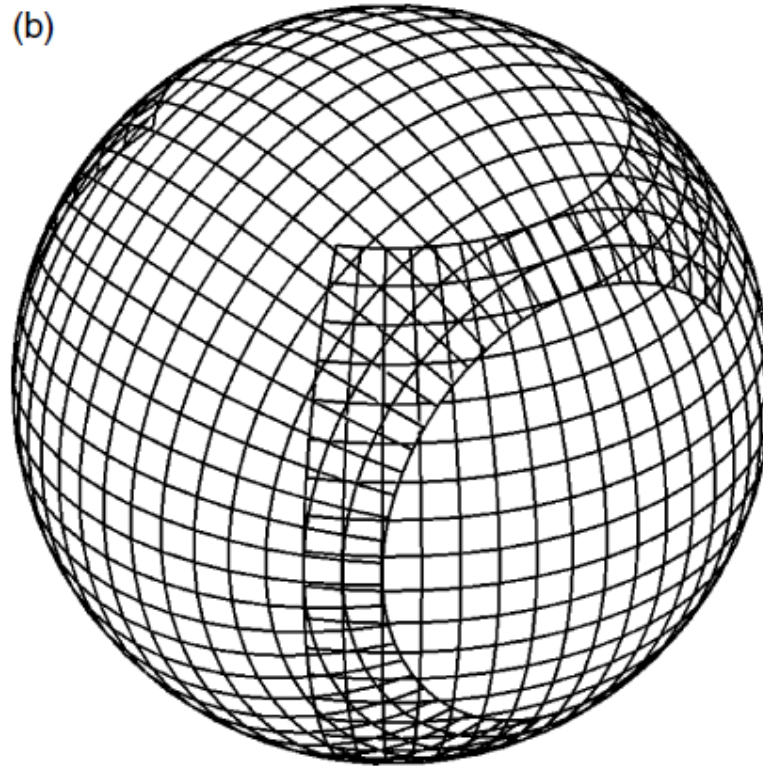
**Reduced Gaussian
Octahedral**

A Myriad of Grids

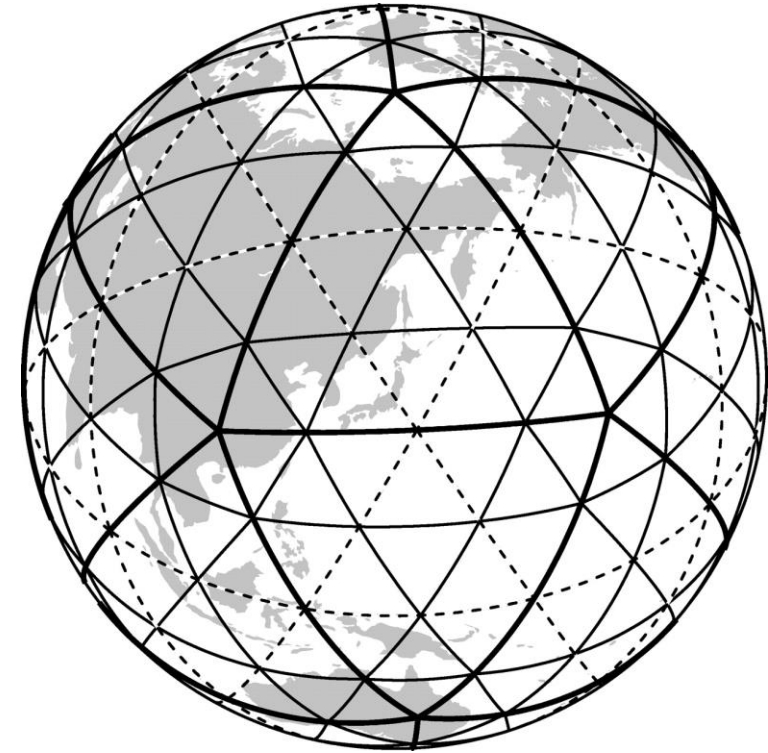


Cubed Sphere

(b)



Yin Yang



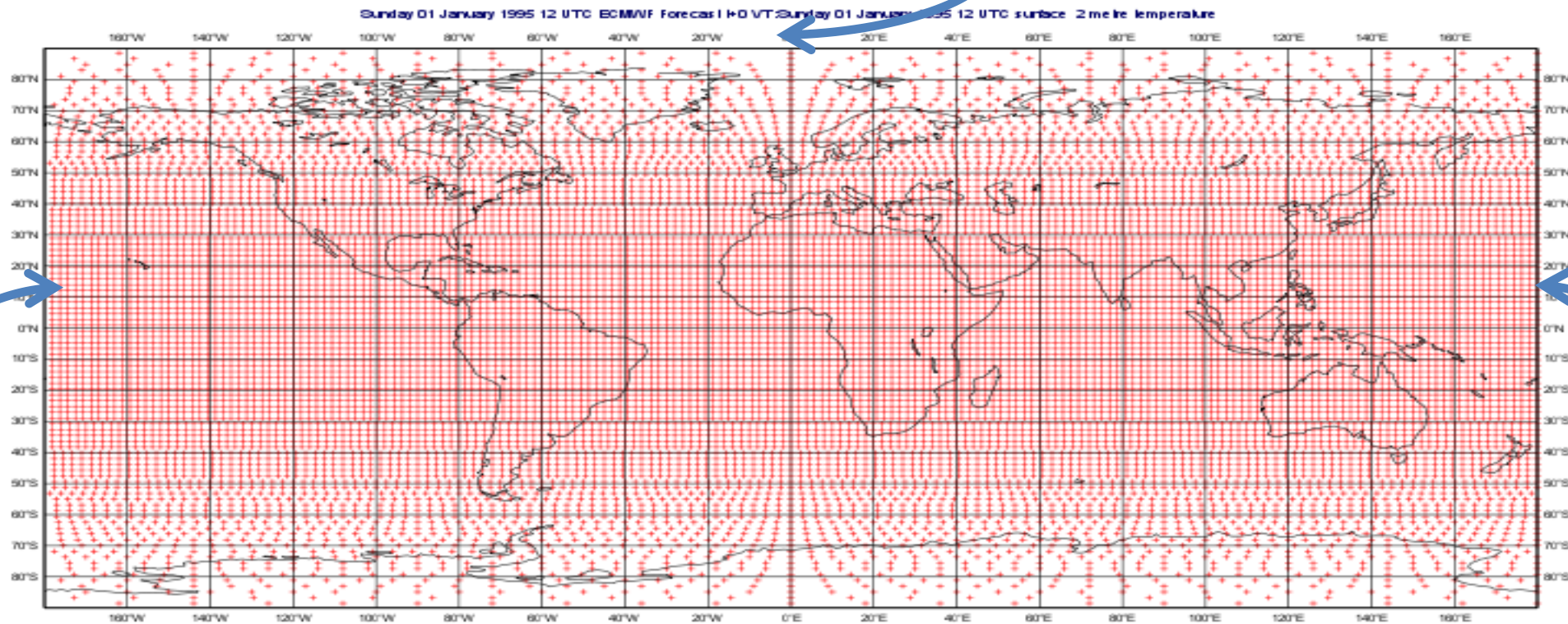
Icosahedral

How to support ***all*** this in **one** algorithm?



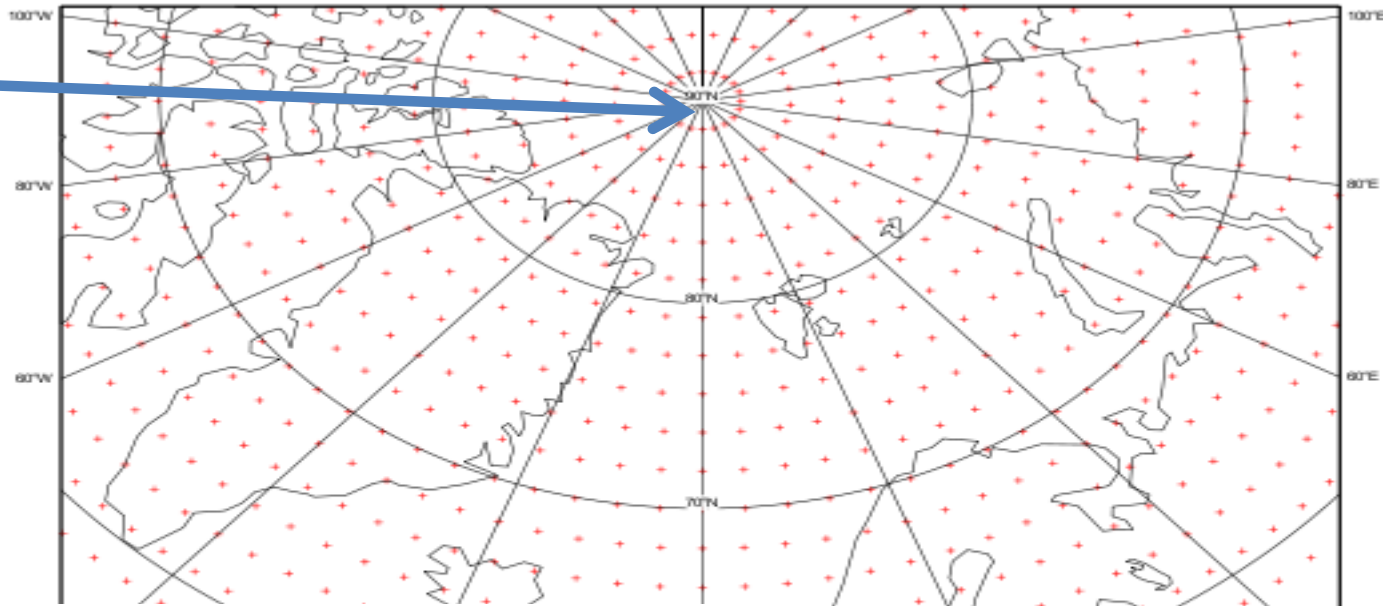
Issues with latitude/longitude coordinate system

What about the poles?

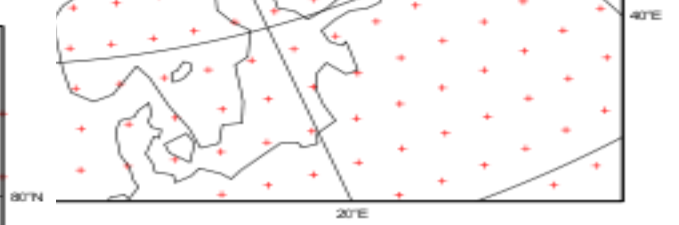
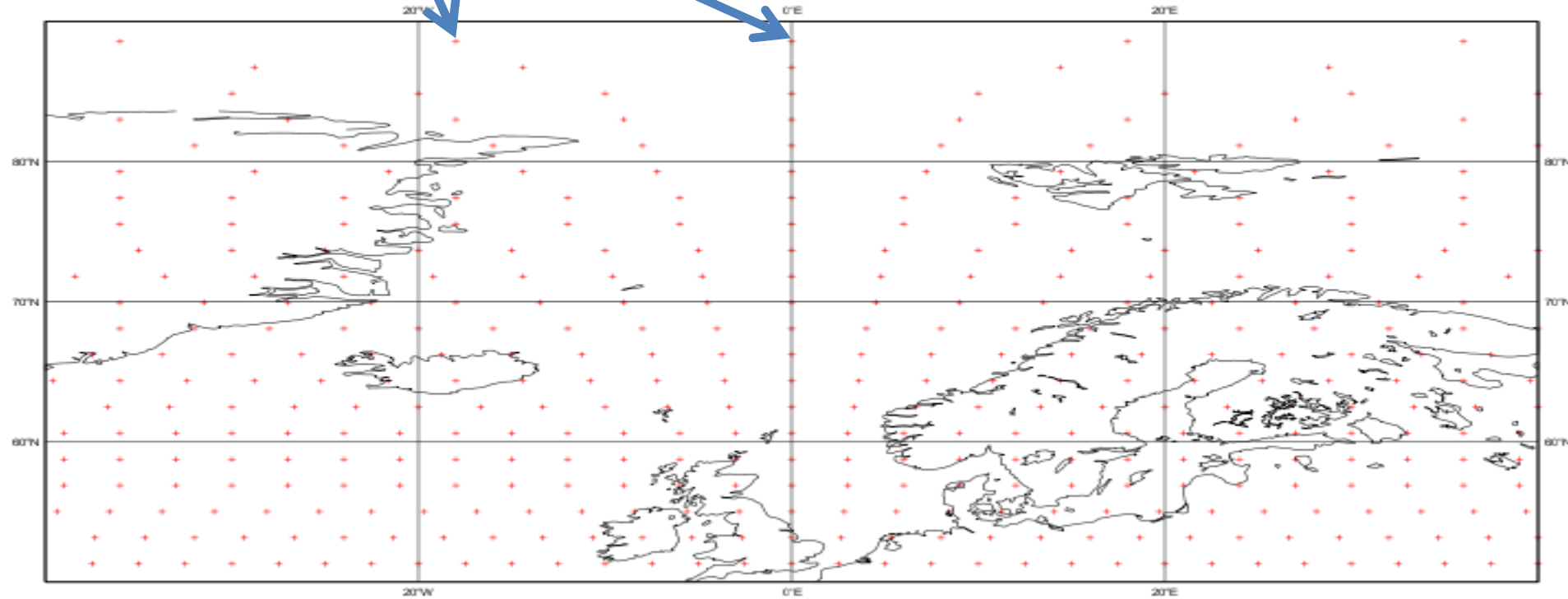
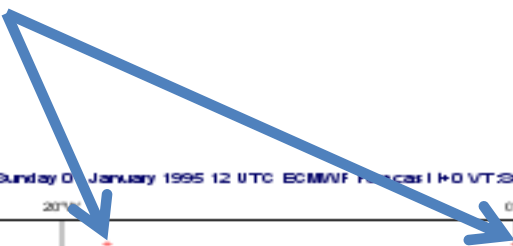


These points are close to each other

They are very close in this projection



These points are far away in lat/lon
(cylindrical projection)



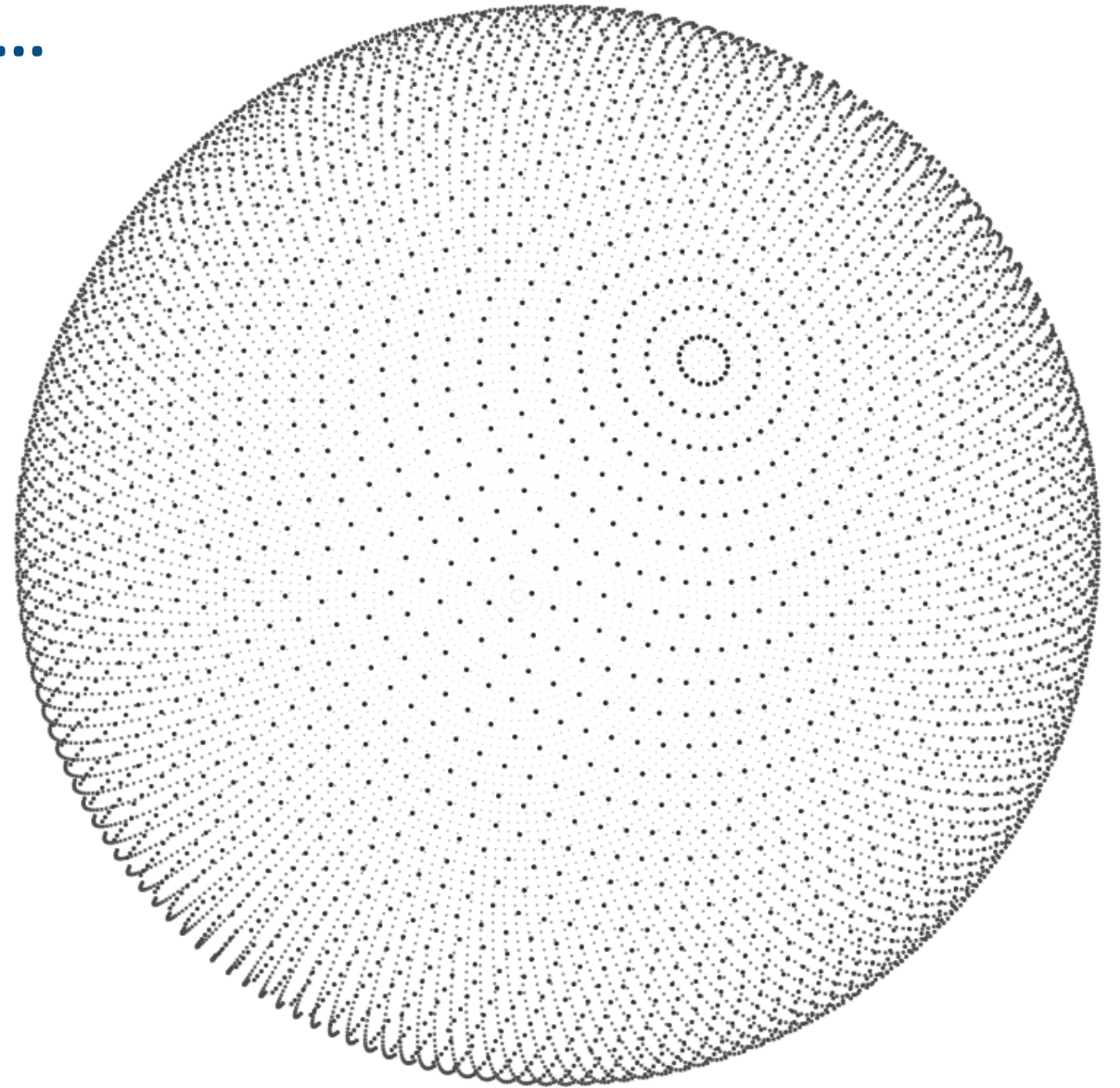
But the earth is (almost) a 3D sphere...

The poles are not special

The anti-meridian is not special

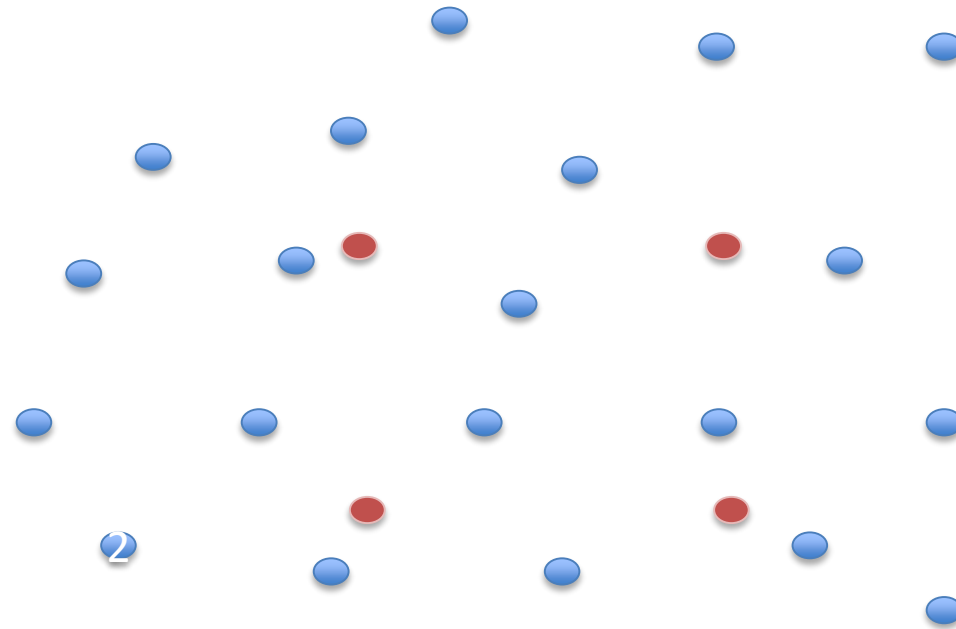
Use (X,Y,Z) instead of latitude/longitude

Distances are computed in 3D space



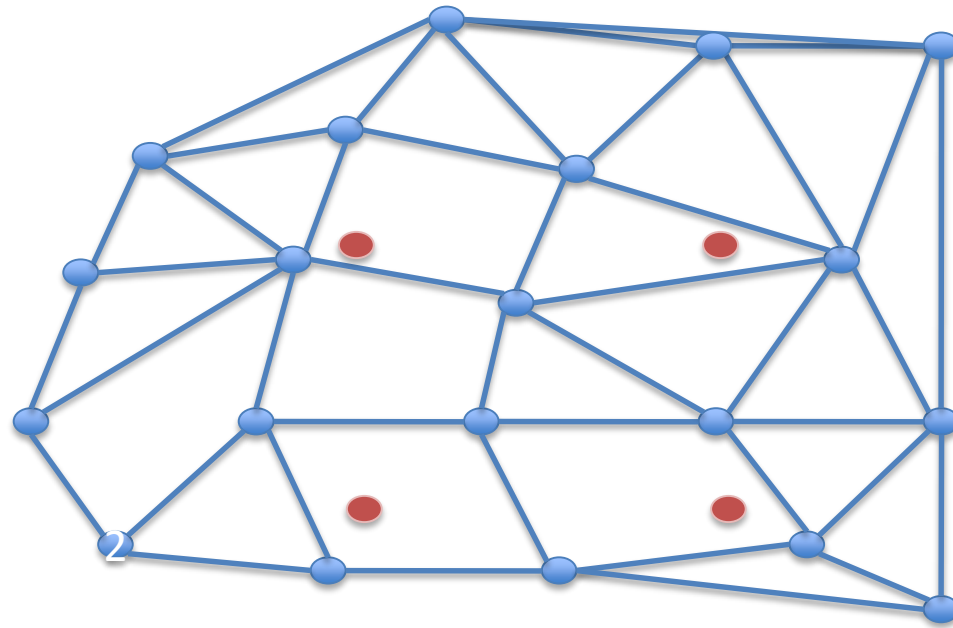
How does it work?

- Input points
- Output points



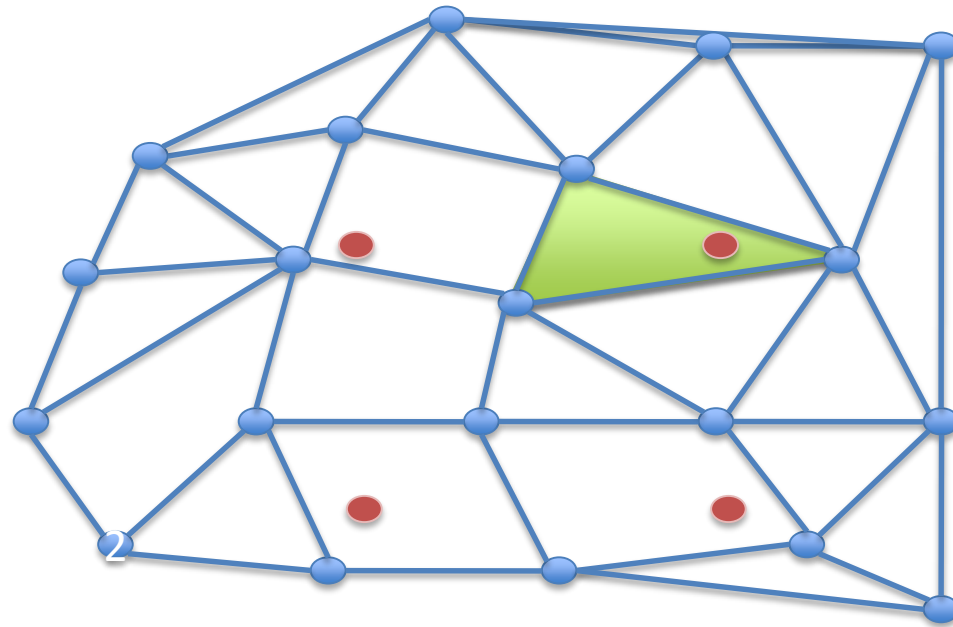
Tessellation

Build a Finite-Element discretisation space

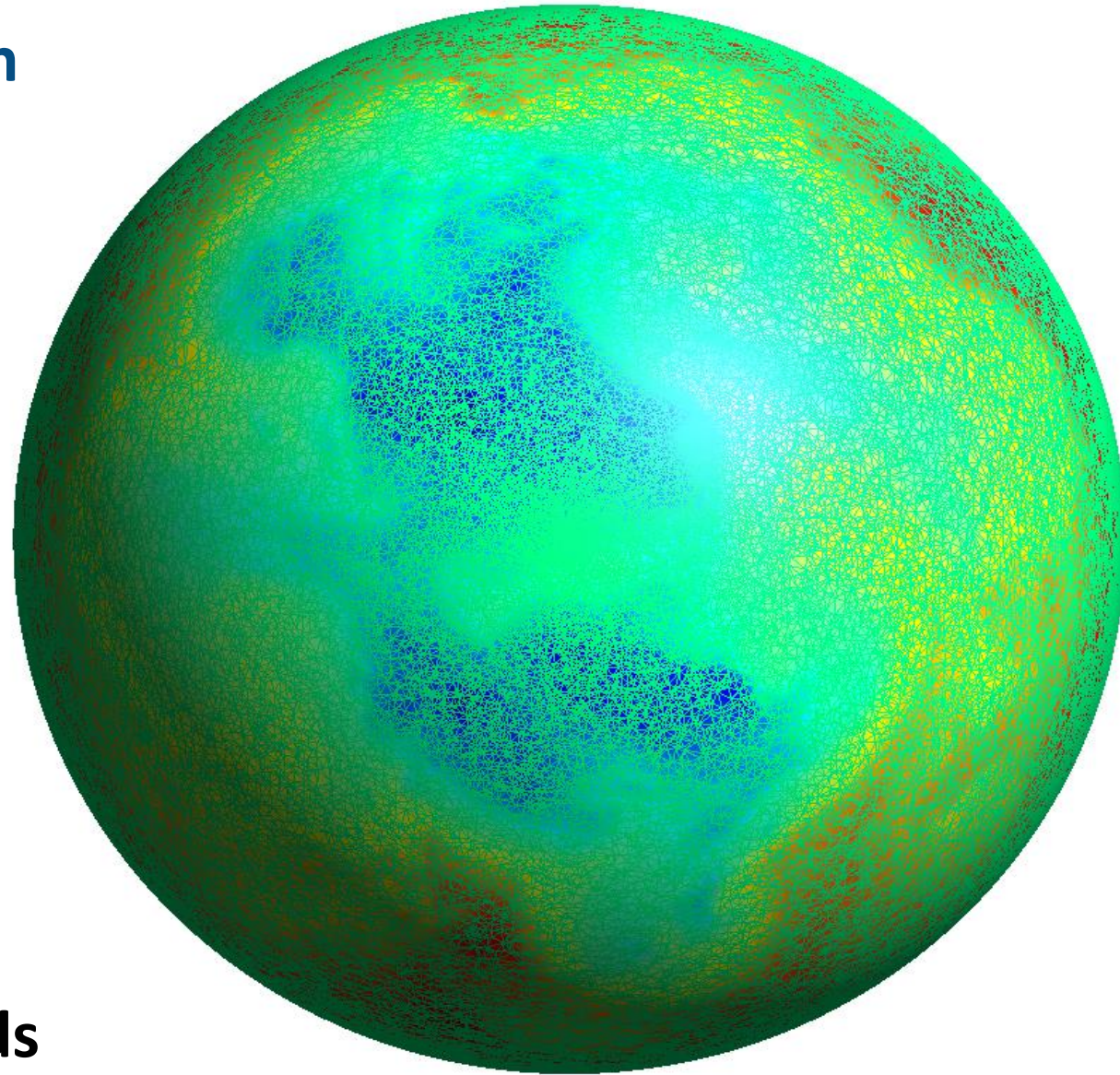


Projection

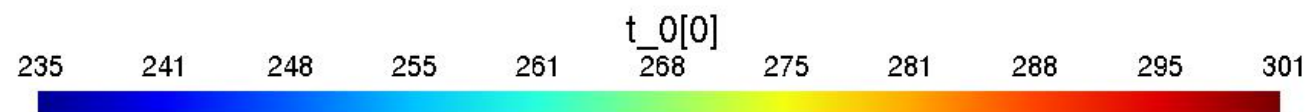
Use very efficient **Ray-Tracing** algorithms...



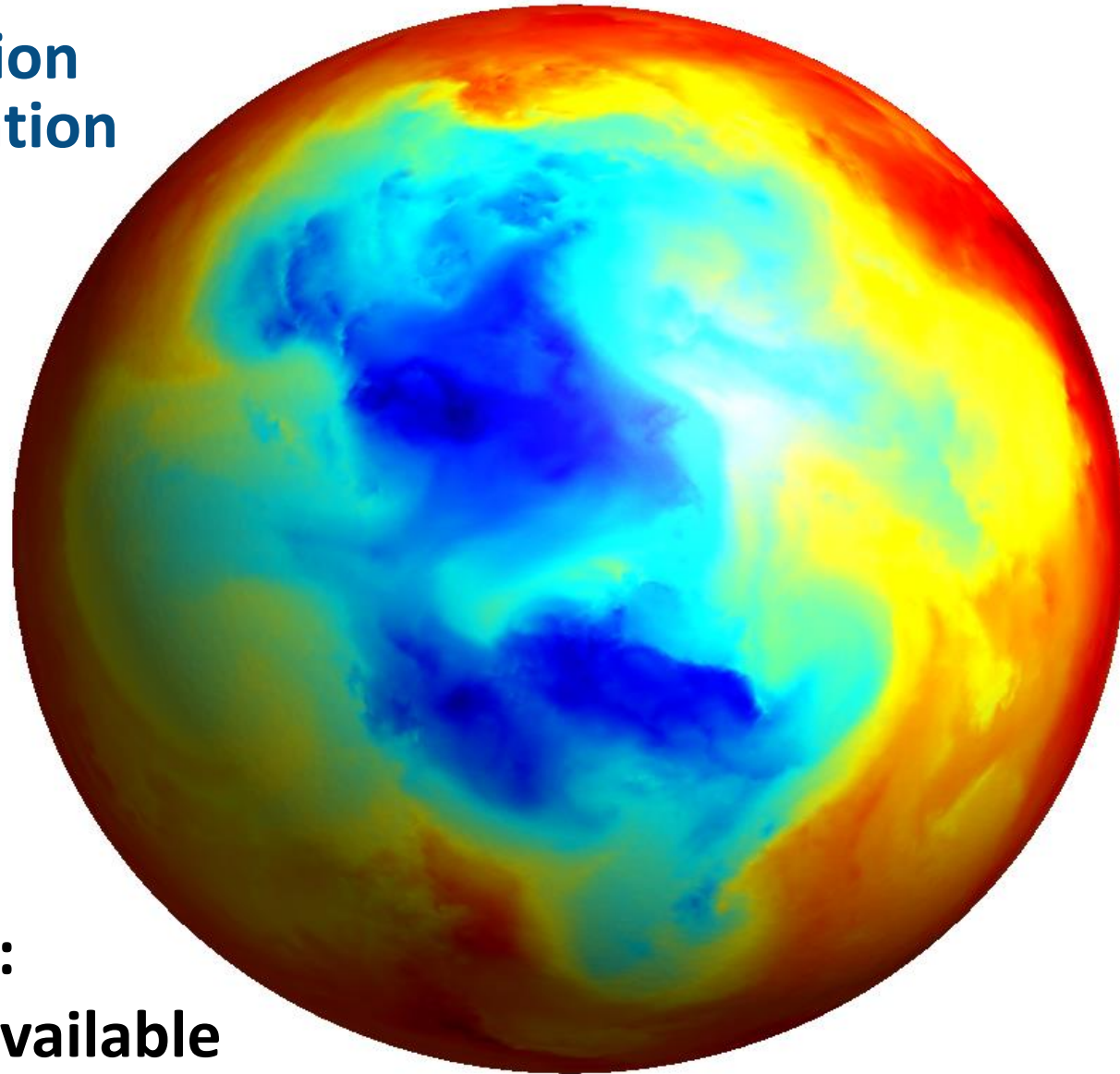
Tessellation



Support fully
unstructured grids

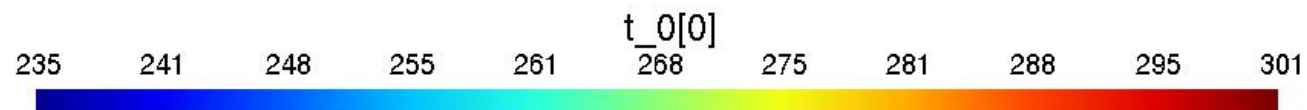


3D Projection + Interpolation



Algorithm choice:

- Optimised if available
- Unstructured fallback



Interpolation Operators

Interpolation Operator

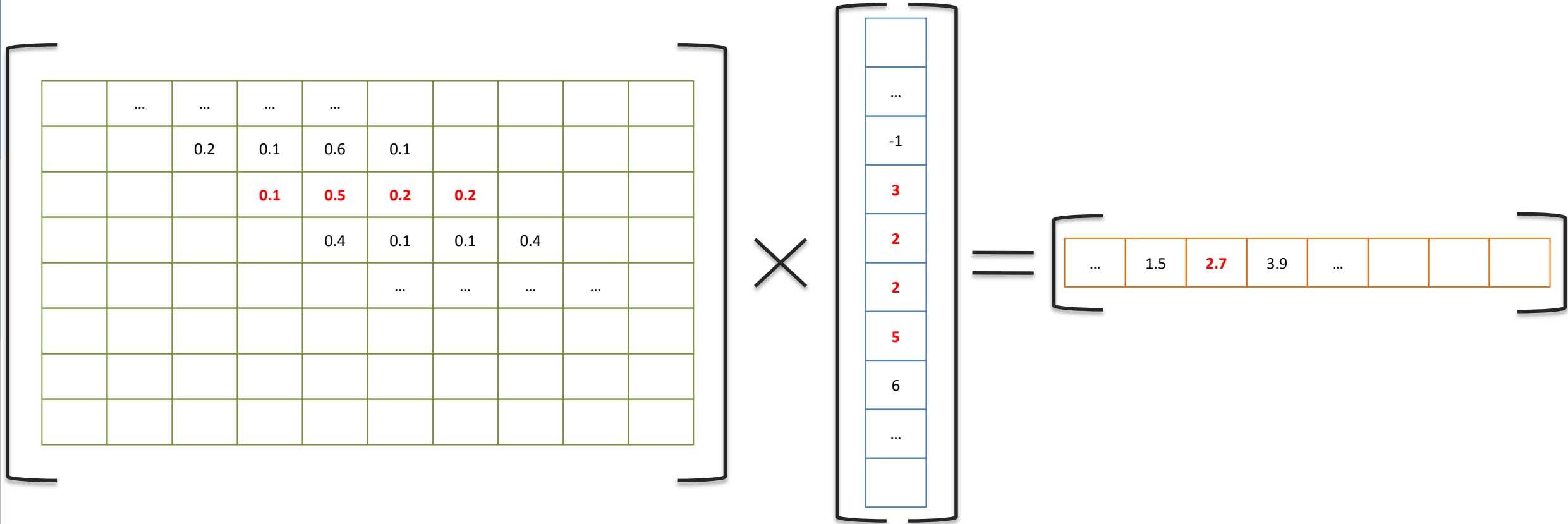
$$F_i = \sum w_{ij} G_j$$

w_{ij} only depends on:

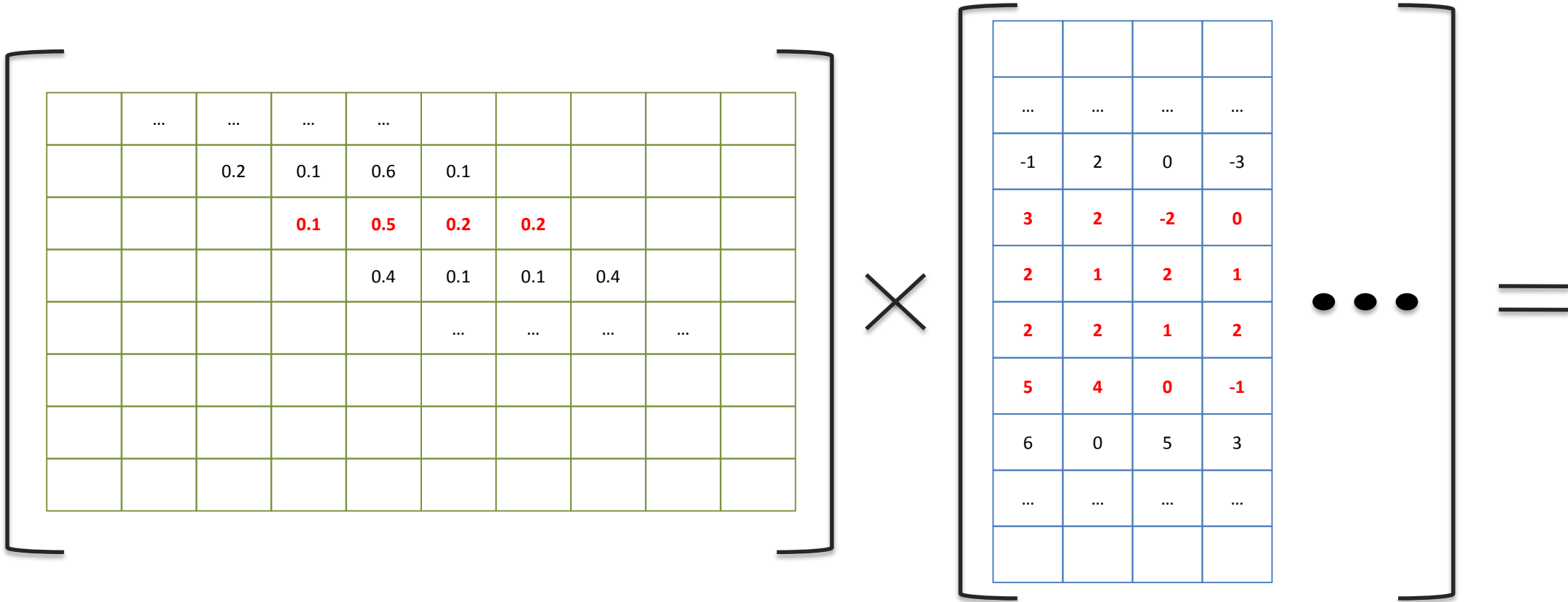
- Input grid, output grid, interpolation method, LSM

Can be cached!

Matrix multiplication: Linear Operator



Matrix multiplication: Batch Interpolation

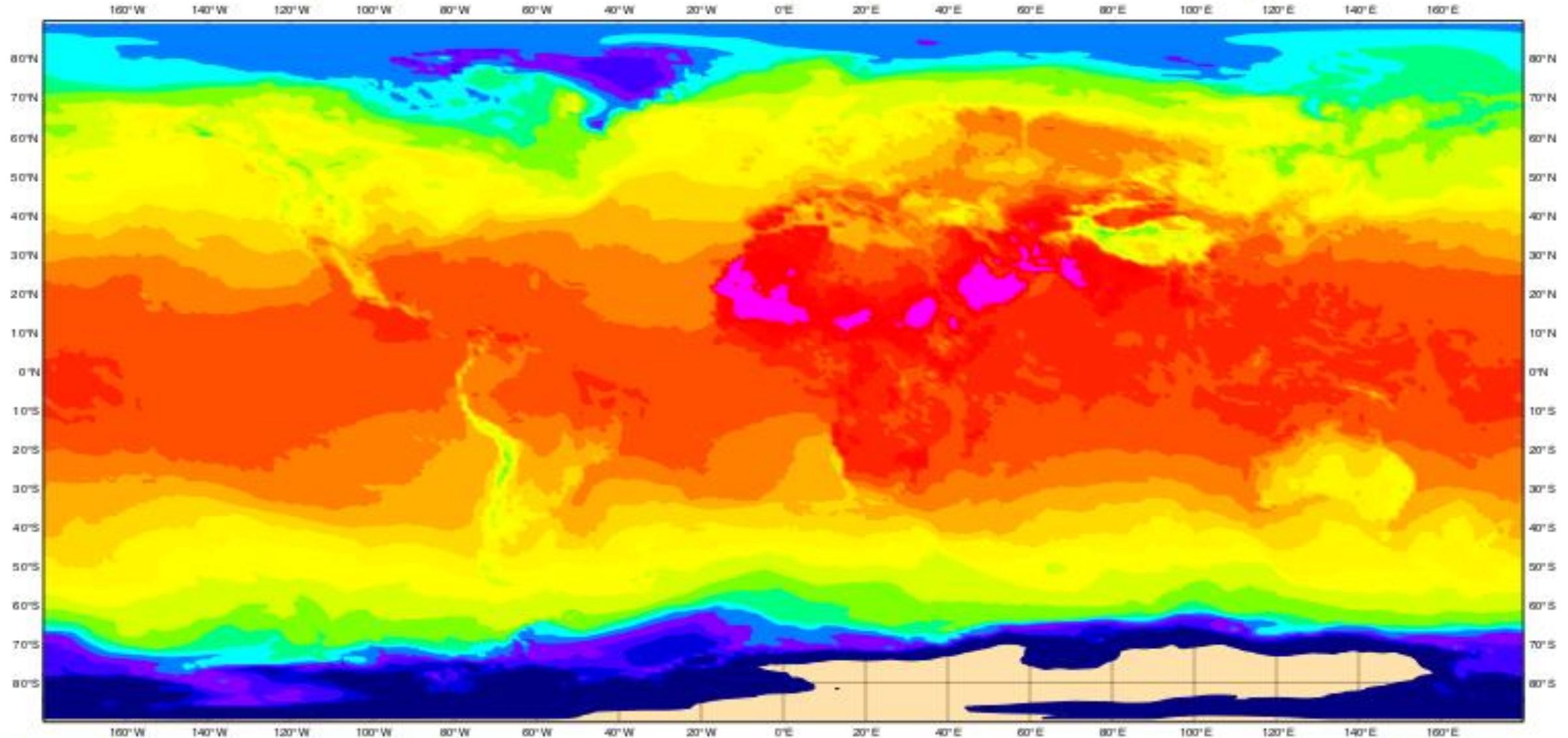


CPU Cache and GPU friendly => SPEED

Features

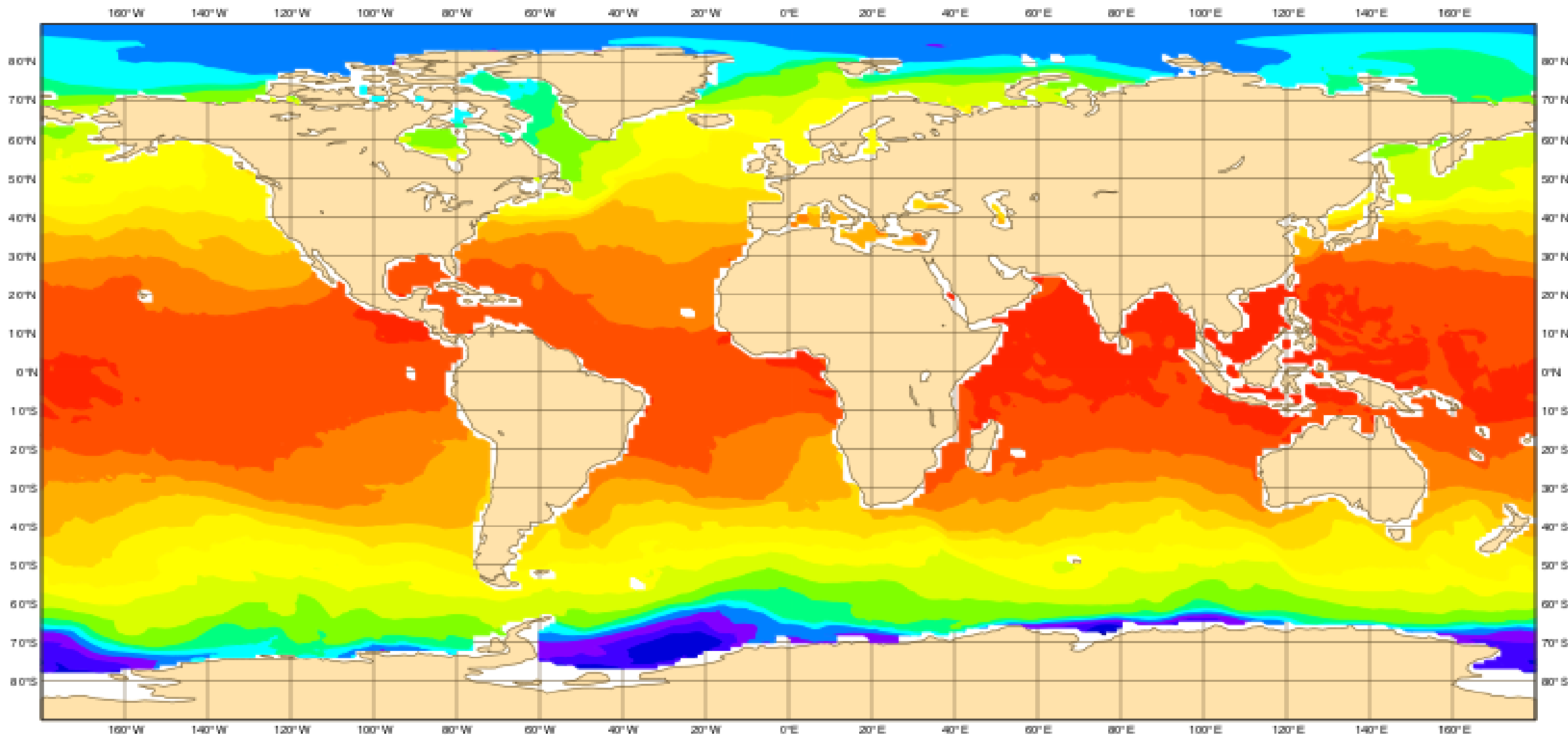
2t: N640 ► LL 0.25/0.25 + rotation + crop + frame

Thursday 14 May 2015 12 UTC ecmf t+0 VT:Thursday 14 May 2015 12 UTC surface 2 metre temperature



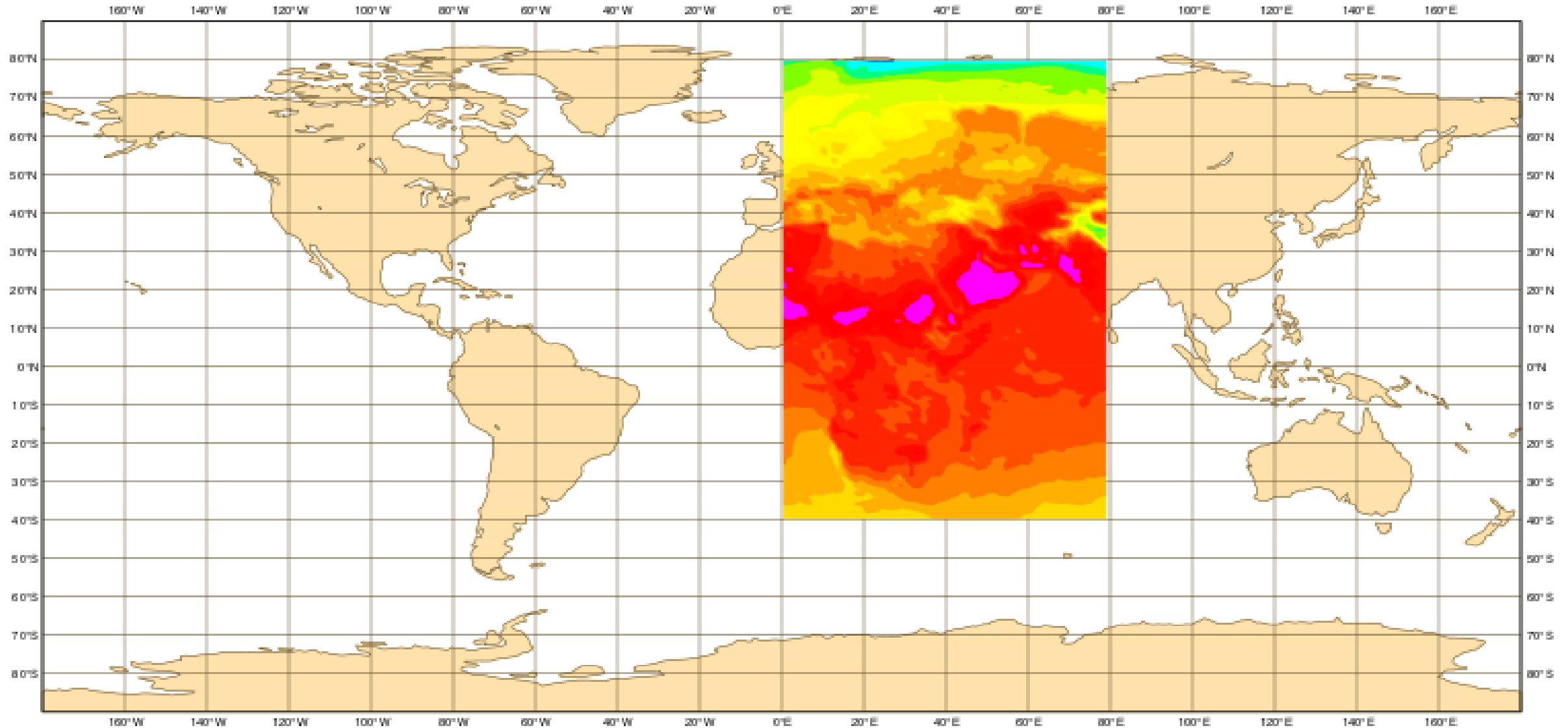
2t N640 -> 1x1 + bitmap (MIR)

Thursday 14 May 2015 12 UTC ecmf t+0 VT:Thursday 14 May 2015 12 UTC surface 2 metre temperature



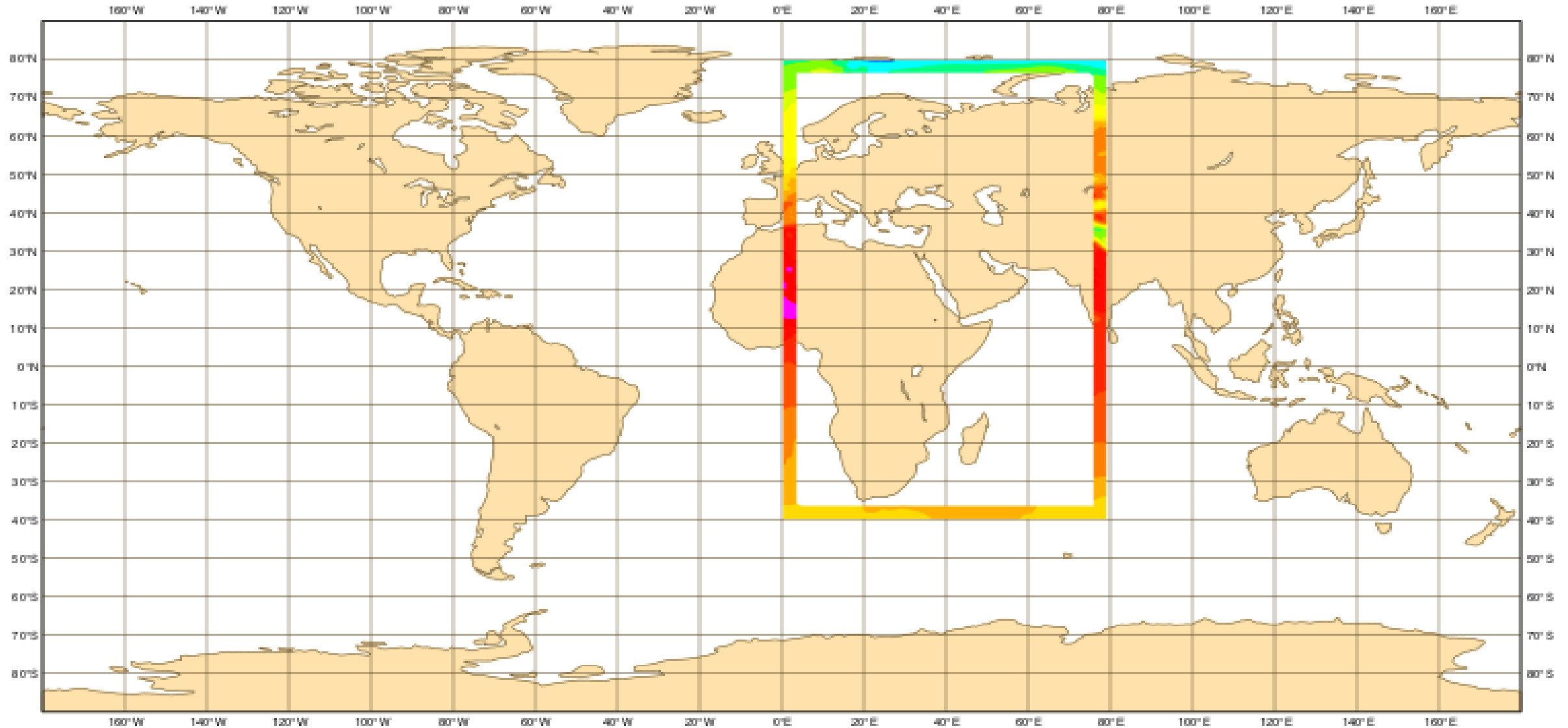
2t N640 -> 1x1 + crop (MIR)

Thursday 14 May 2015 12 UTC ecmf t+0 VT:Thursday 14 May 2015 12 UTC surface 2 metre temperature



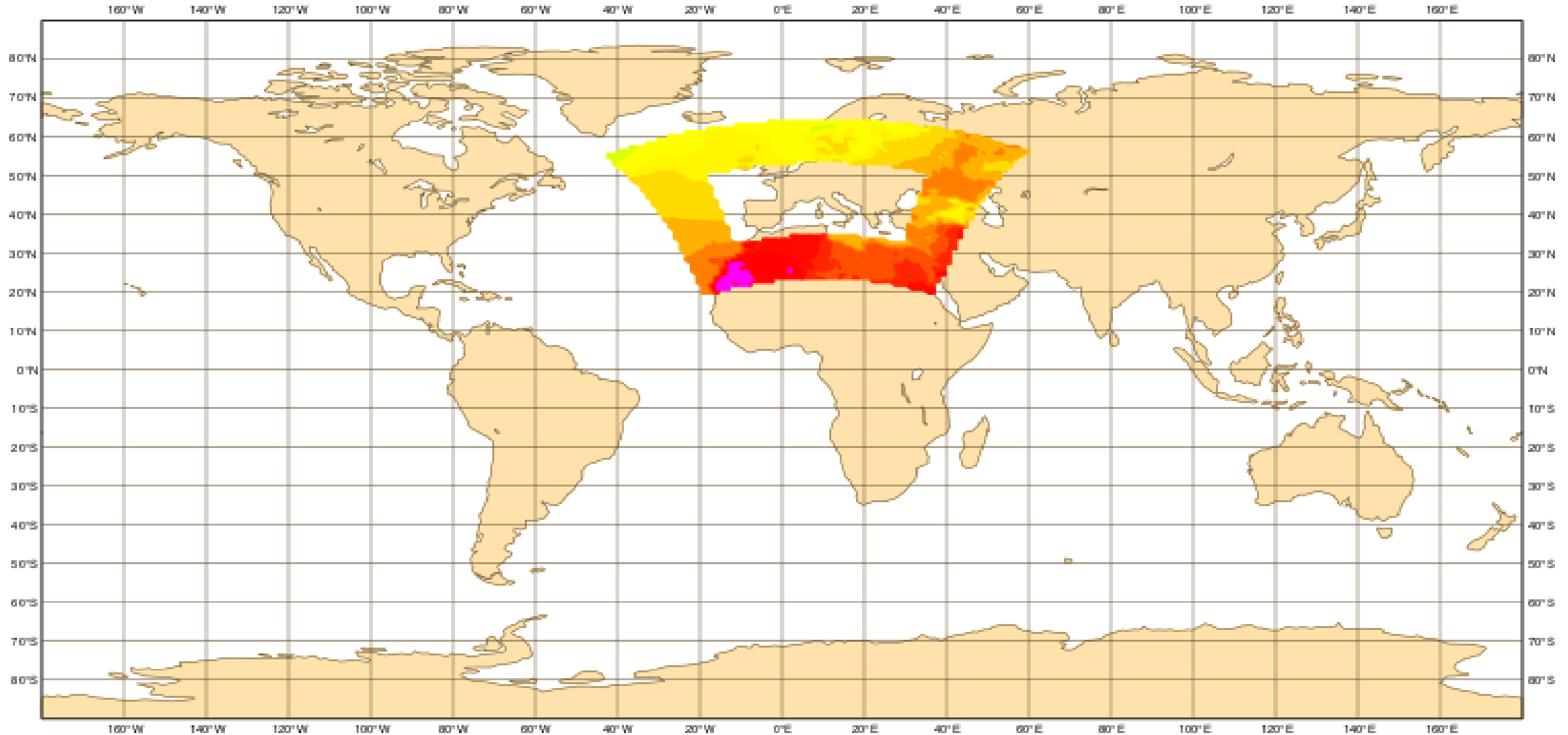
2t N640 -> 1x1 + crop + frame (MIR)

Thursday 14 May 2015 12 UTC ecmf t+0 VT:Thursday 14 May 2015 12 UTC surface 2 metre temperature



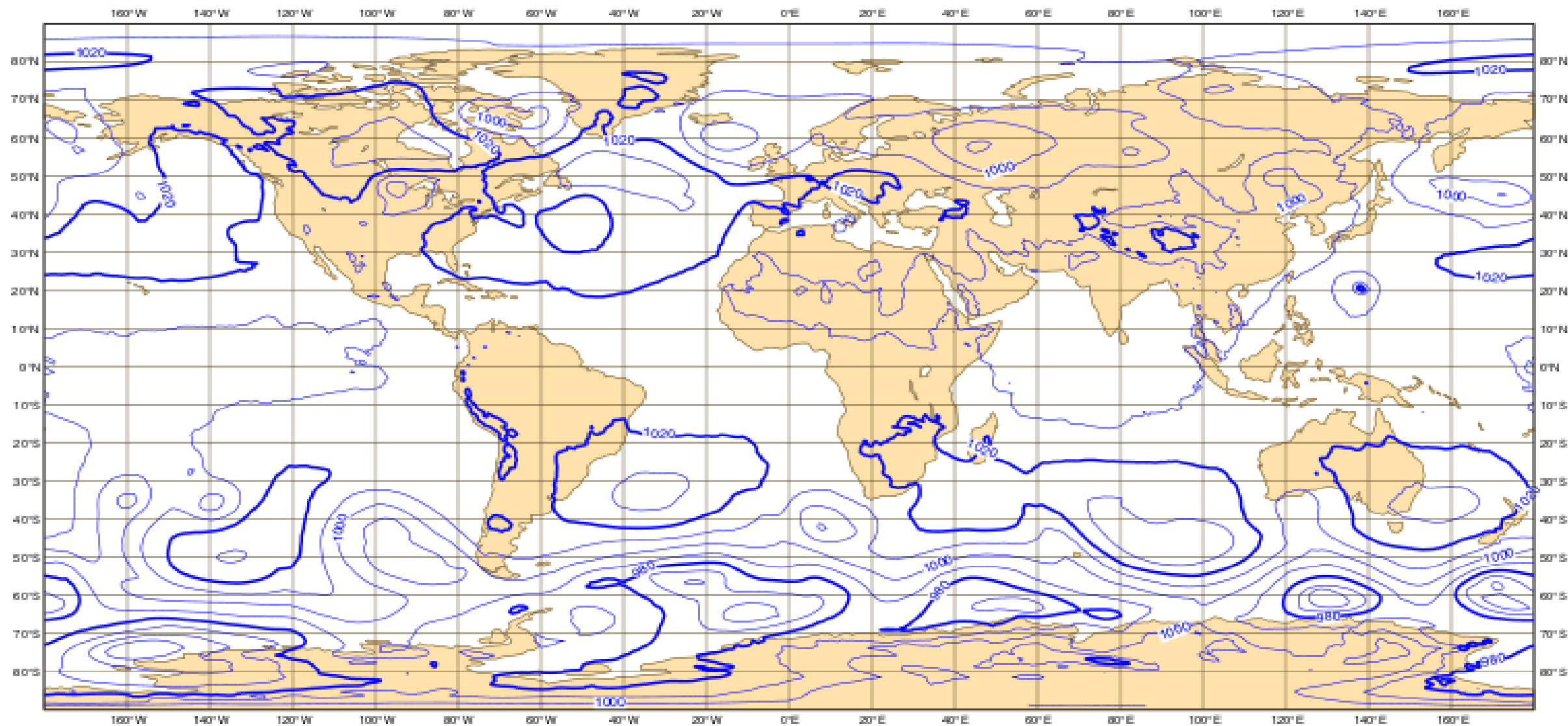
2t: N640 ► LL 0.25/0.25 + rotation + crop + frame

Thursday 14 May 2015 12 UTC ecmf t+0 VT:Thursday 14 May 2015 12 UTC surface 2 metre temperature



ECMWF IFS MSL 18 May 2015 (N640)

Monday 18 May 2015 00 UTC ecmf t+0 VT:Monday 18 May 2015 00 UTC surface Mean sea level pressure

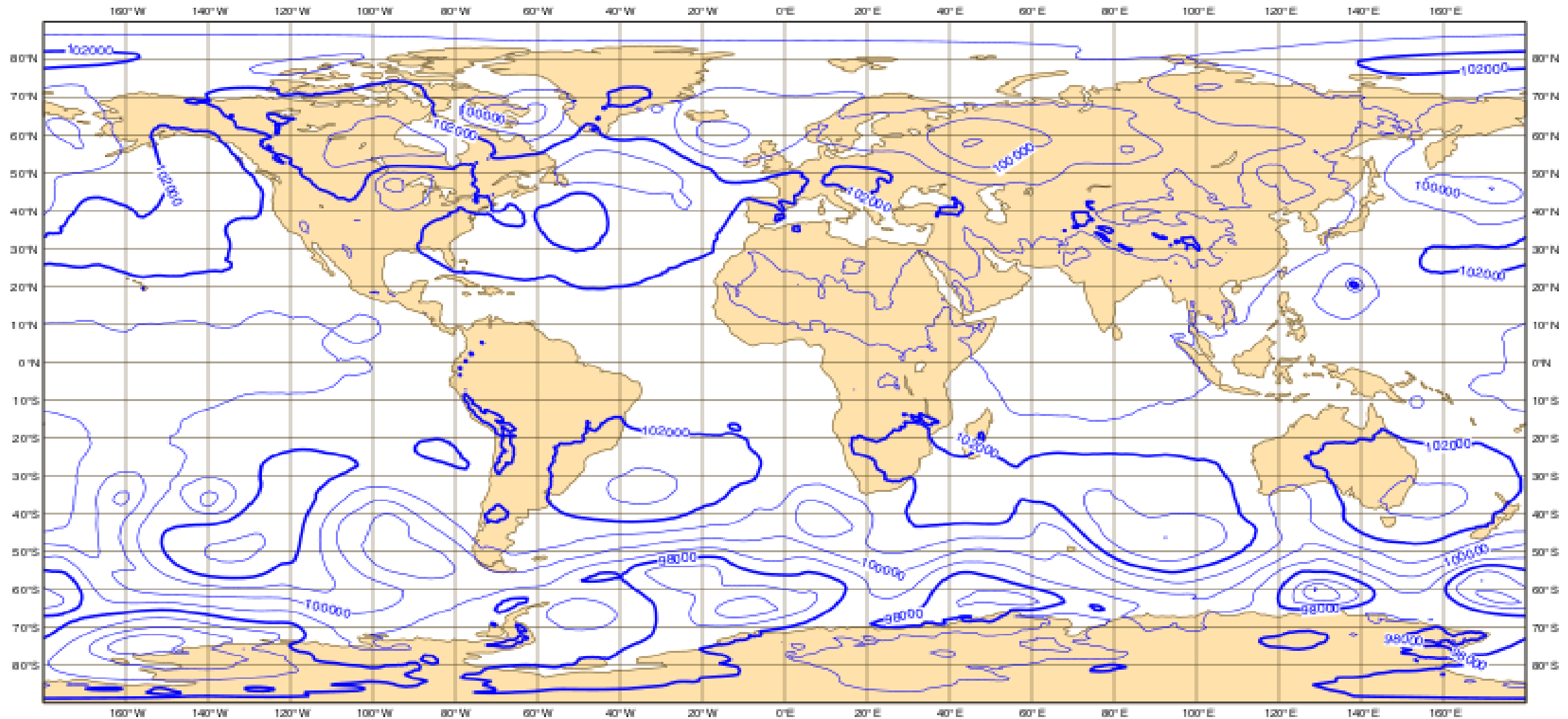


Icosahedral (ICON) to Octahedral (IFS)

ICON grid treated as unstructured 2,949,120 points

Monday 18 May 2015 00 UTC edzw t+0

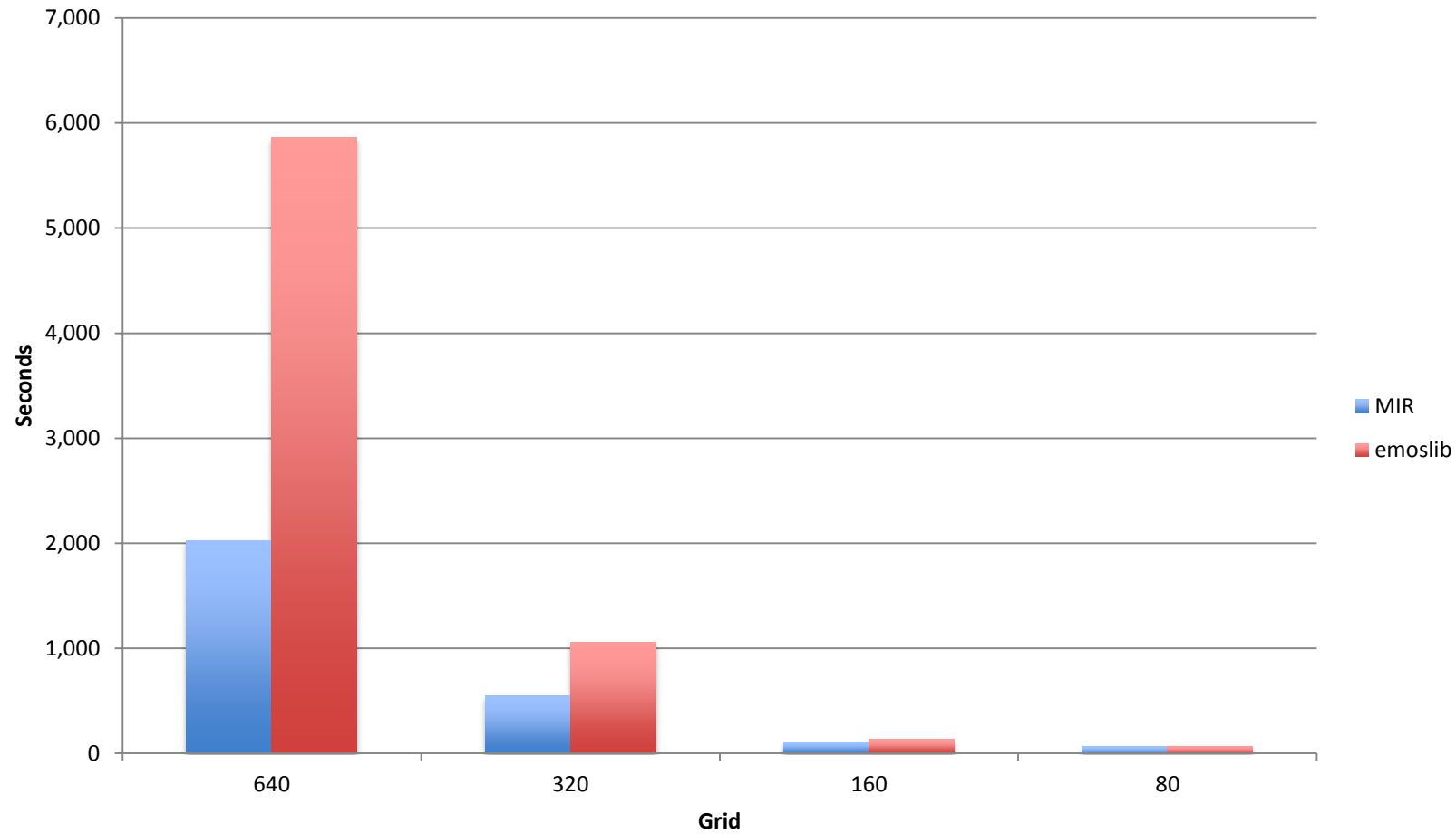
VT:Monday 18 May 2015 00 UTC meanSea Pressure reduced to MSL



Performance

Performance Comparison SH-to-Grid (preliminary)

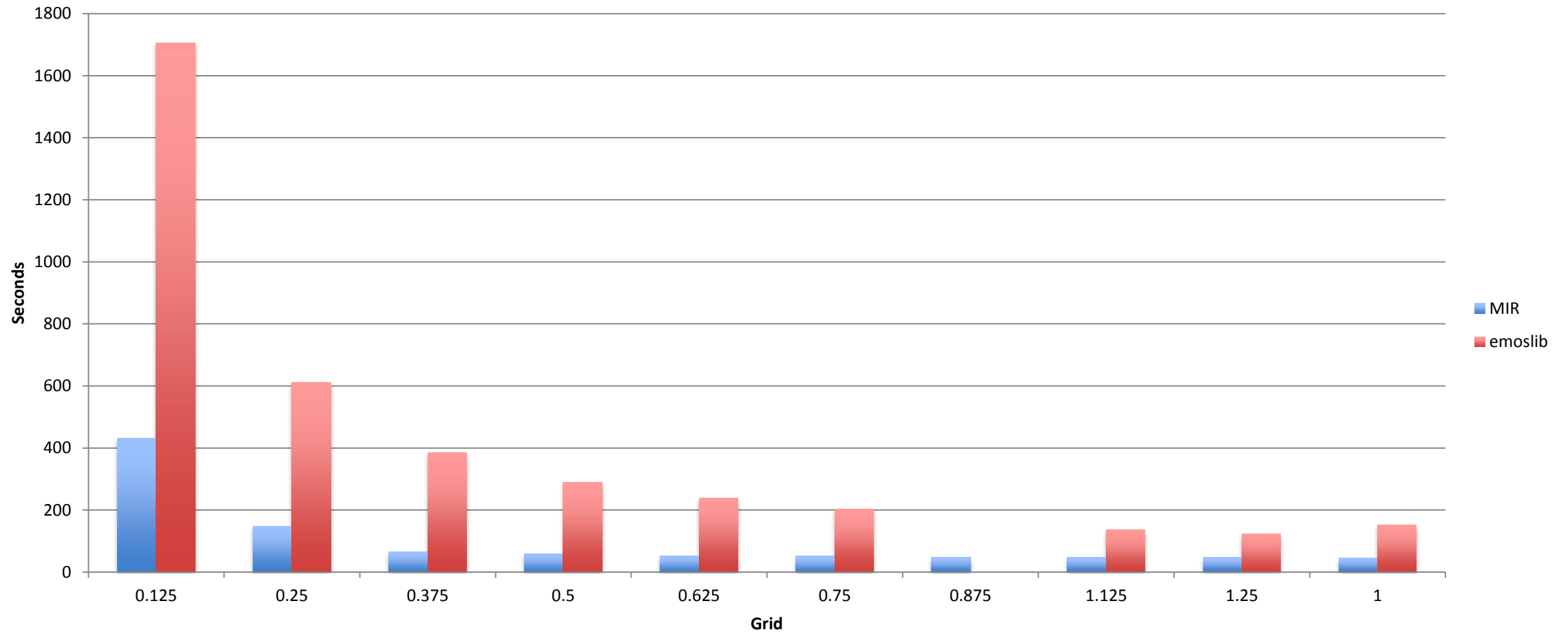
3000+ fields from T1279 to reduced GG (auto truncation)



2x-3x single core performance

Performance Comparison Grid-to-Grid (preliminary)

3000+ fields from Reduced N640 to LL grid



4x single core performance

Benchmarks

- Interpolation is driven by the size of the output grid

Scalability

Grid	N Points	Memory [GiB]	Wall Time [ms]	Speed [Mp/s]
N160	204 k	1.7	28.4	7.2
N256	524 k	1.8	33.0	15.9
N512	2097 k	1.8	51.2	40.9
LL 0.1/0.1	6483 k	2.6	99.9	64.9
N1024	8388 k	2.7	115.4	72.7
LL 0.05/0.05	25 927 k	6.1	252.2	102.8

Status

- Feature complete
- Going through validation
- Preparing Alpha release
- Seeking expert users feedback

Credits

- Pedro Maciel
- Tiago Quintino
- Baudouin Raoult
- Willem Deconinck
- Nils Wedi
- Mats Hamrud

All interpolations are wrong. Some are less wrong than others ...