

# MIR

## ECMWF's New Interpolation Package

P. Maciel, [T. Quintino](#), B. Raoult, S. Siemen

ECMWF

[tiago.quintino@ecmwf.int](mailto:tiago.quintino@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

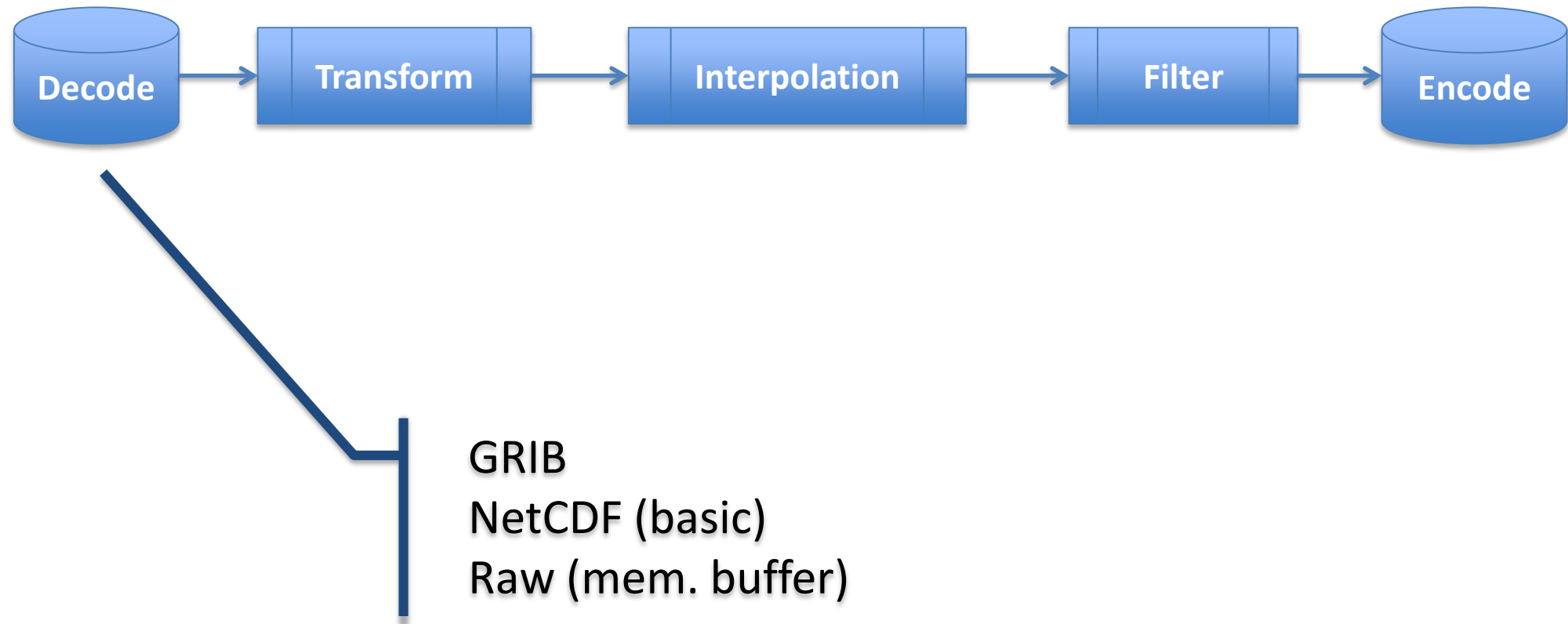
## Key Features

- **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

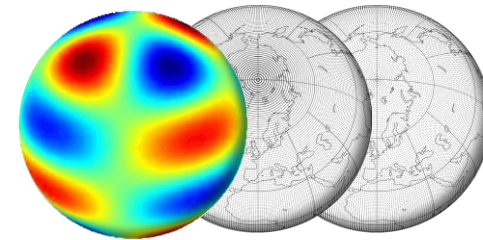


# Architecture

## Construct an Action Plan



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



# Architecture

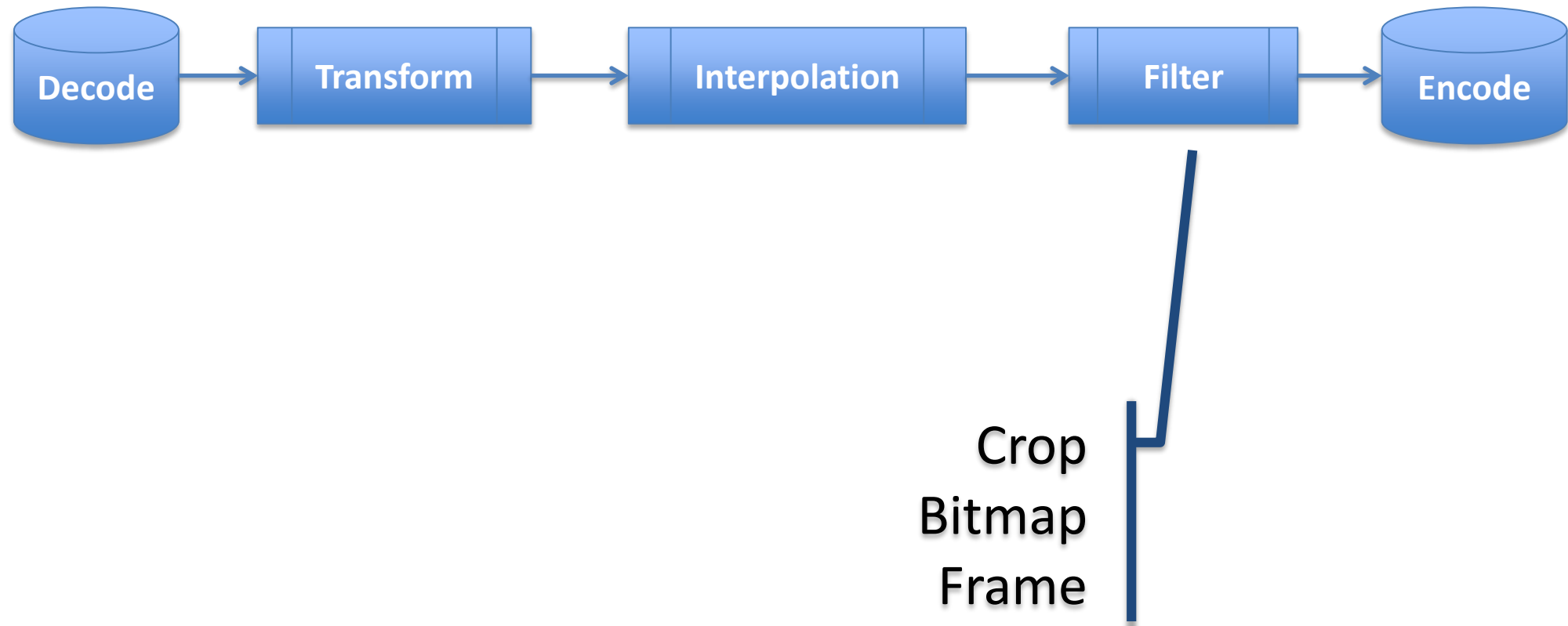
## Construct an Action Plan



Compute Interpolation Operator  
Caching of operators  
Linear algebra kernel

# Architecture

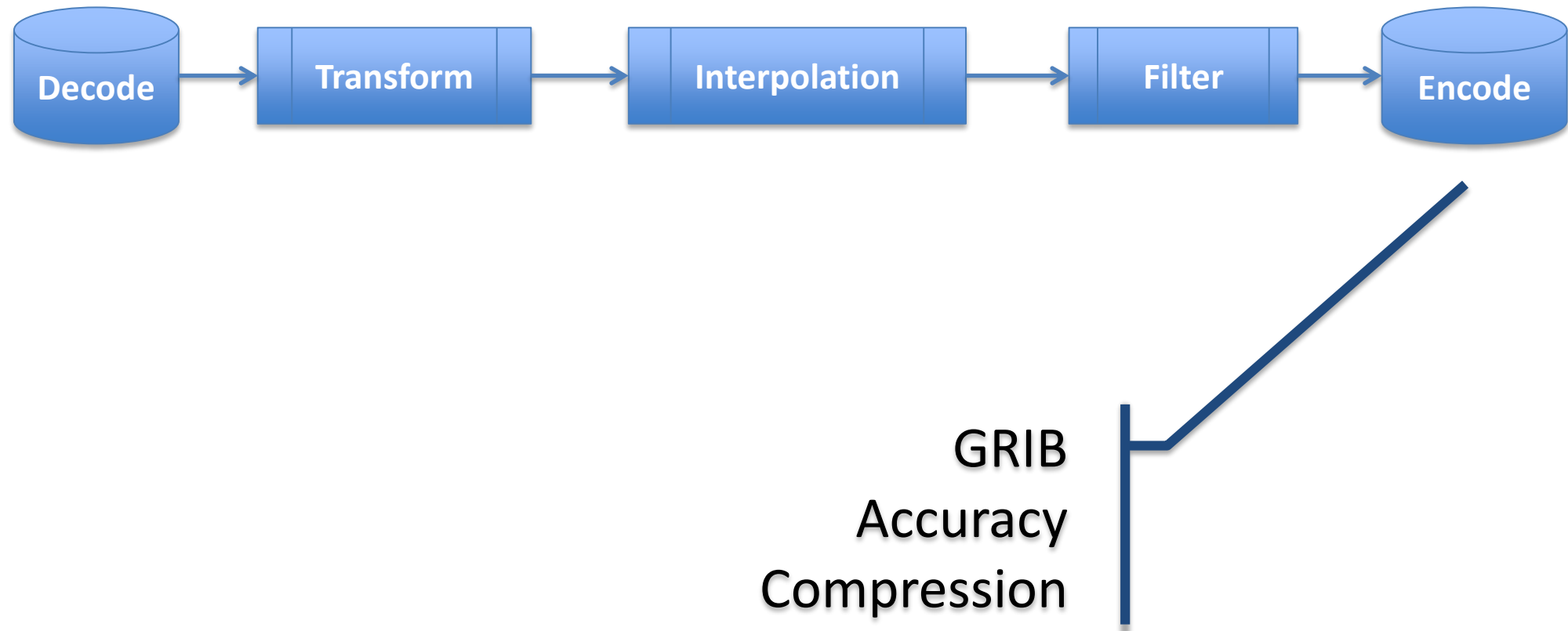
## Construct an Action Plan





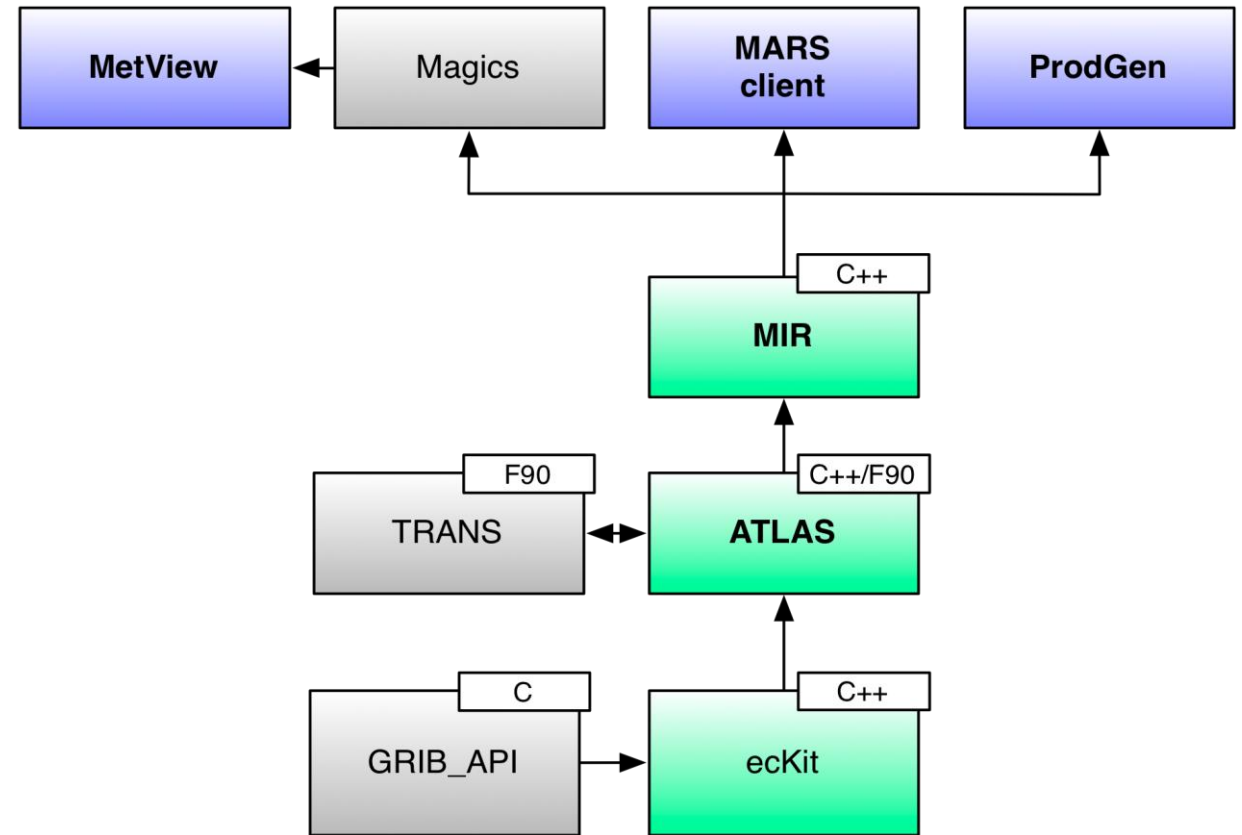
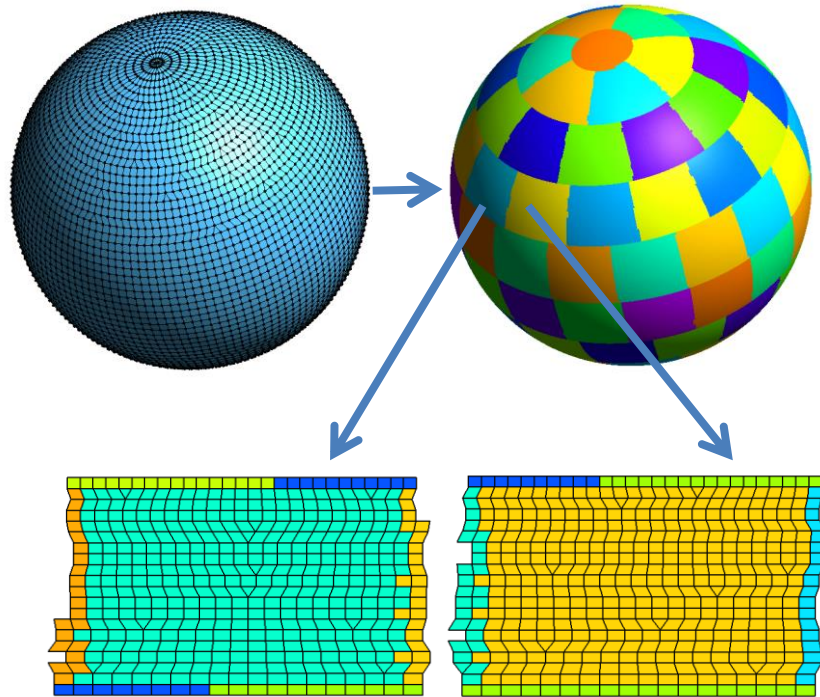
# Architecture

## Construct an Action Plan



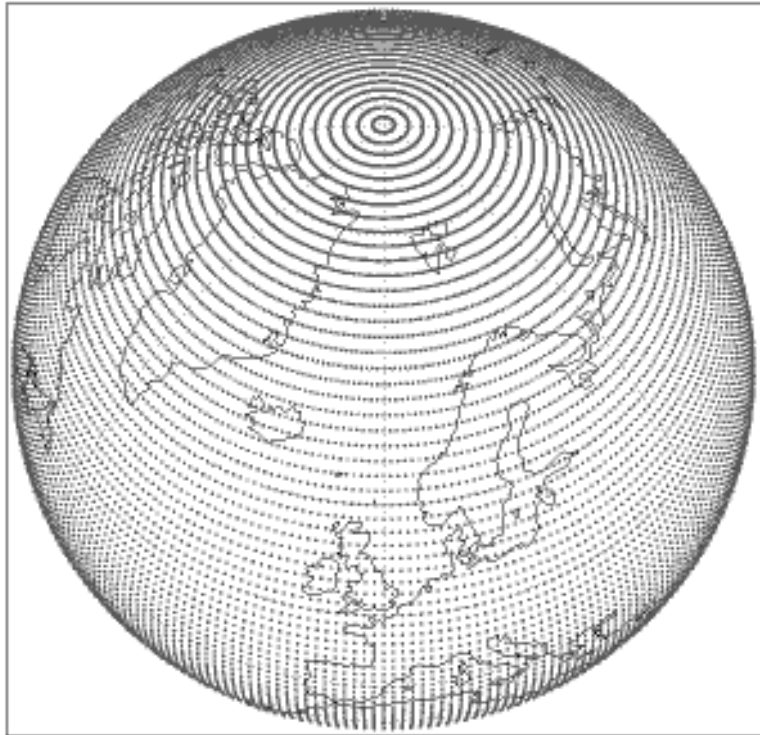
# Atlas Library

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

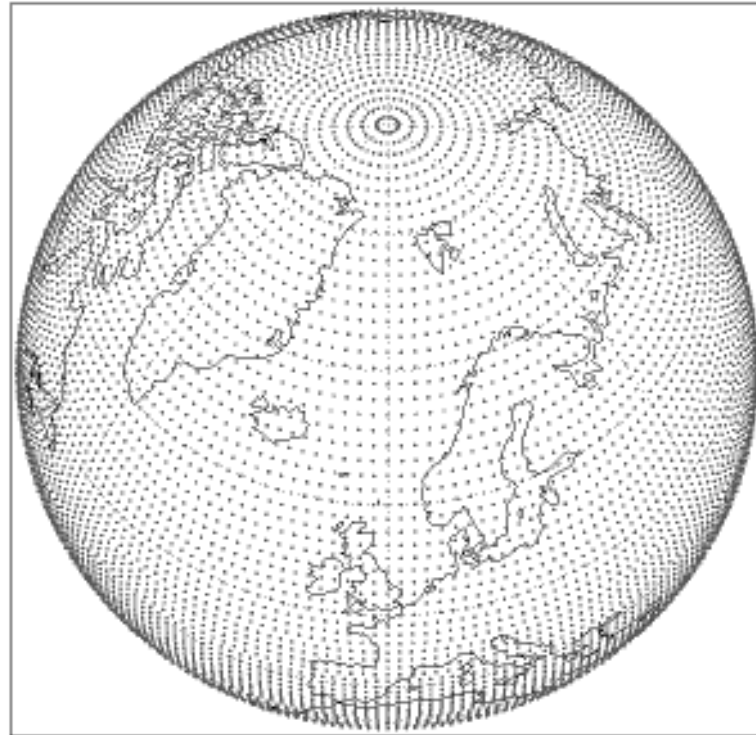


# Any-to-Any Grid

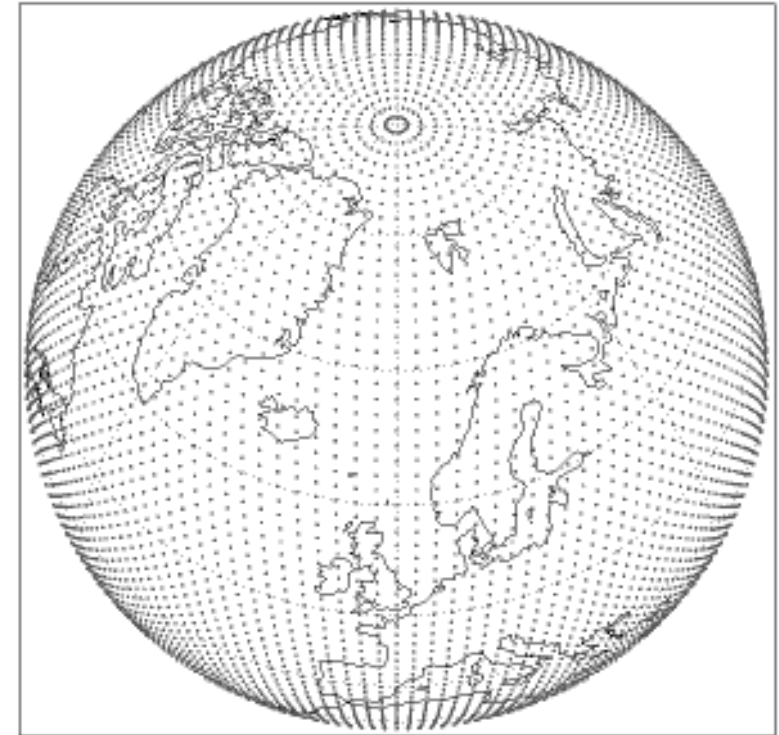
# A Myriad of Grids



Lat-Lon

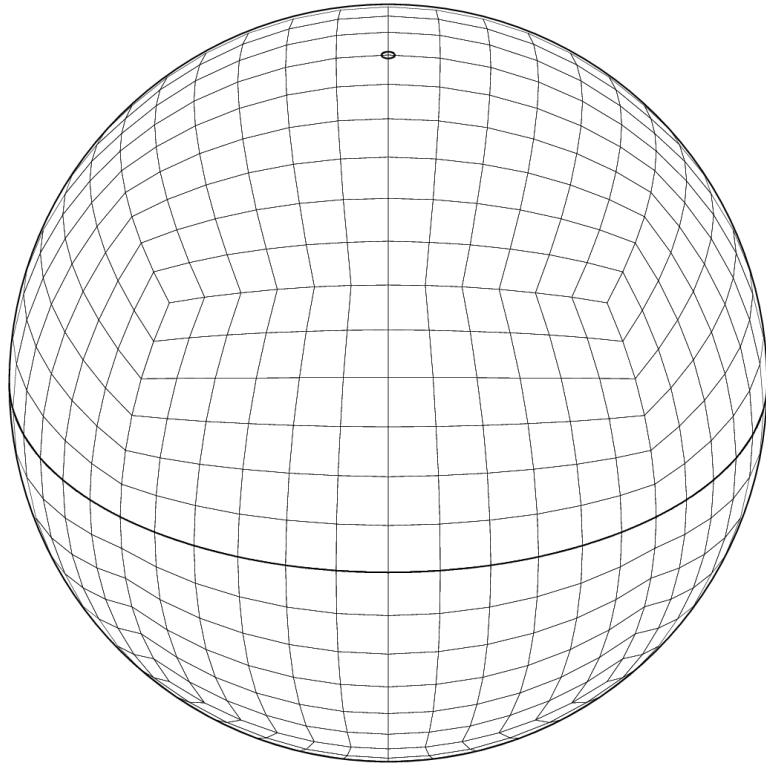


Reduced Gaussian



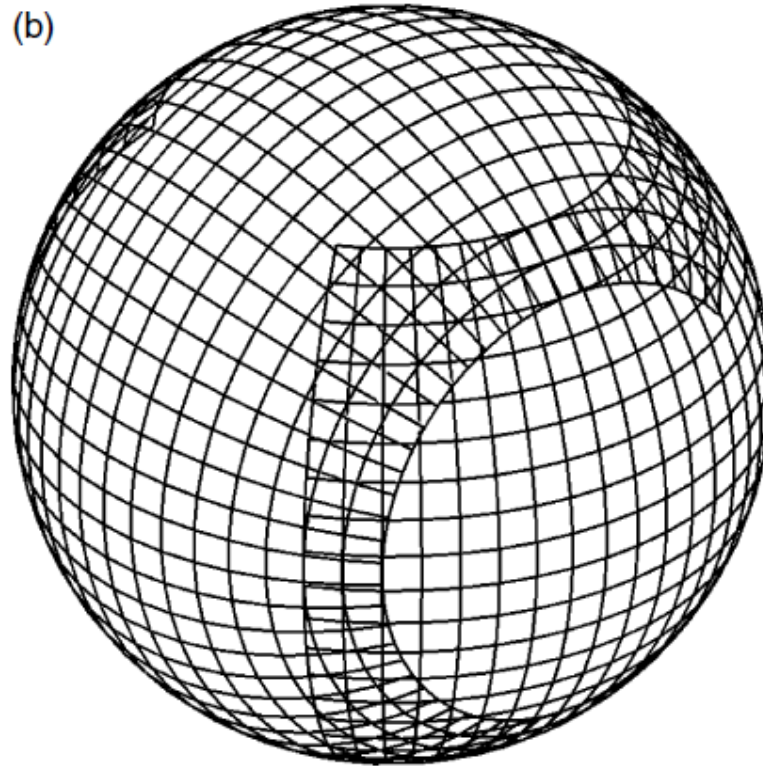
Reduced Gaussian  
Octahedral

# A Myriad of Grids

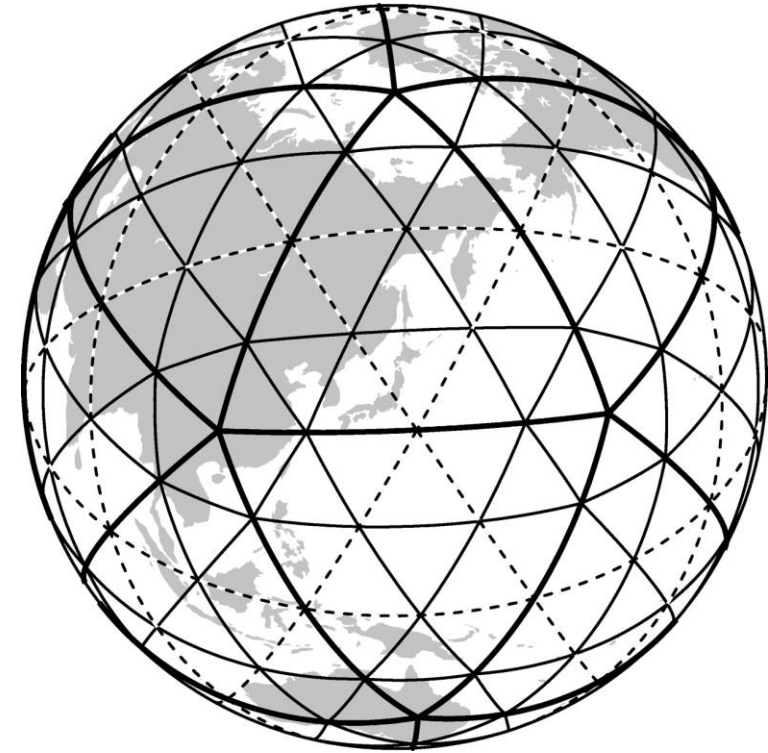


Cubed Sphere

(b)



Yin Yang



Icosahedral

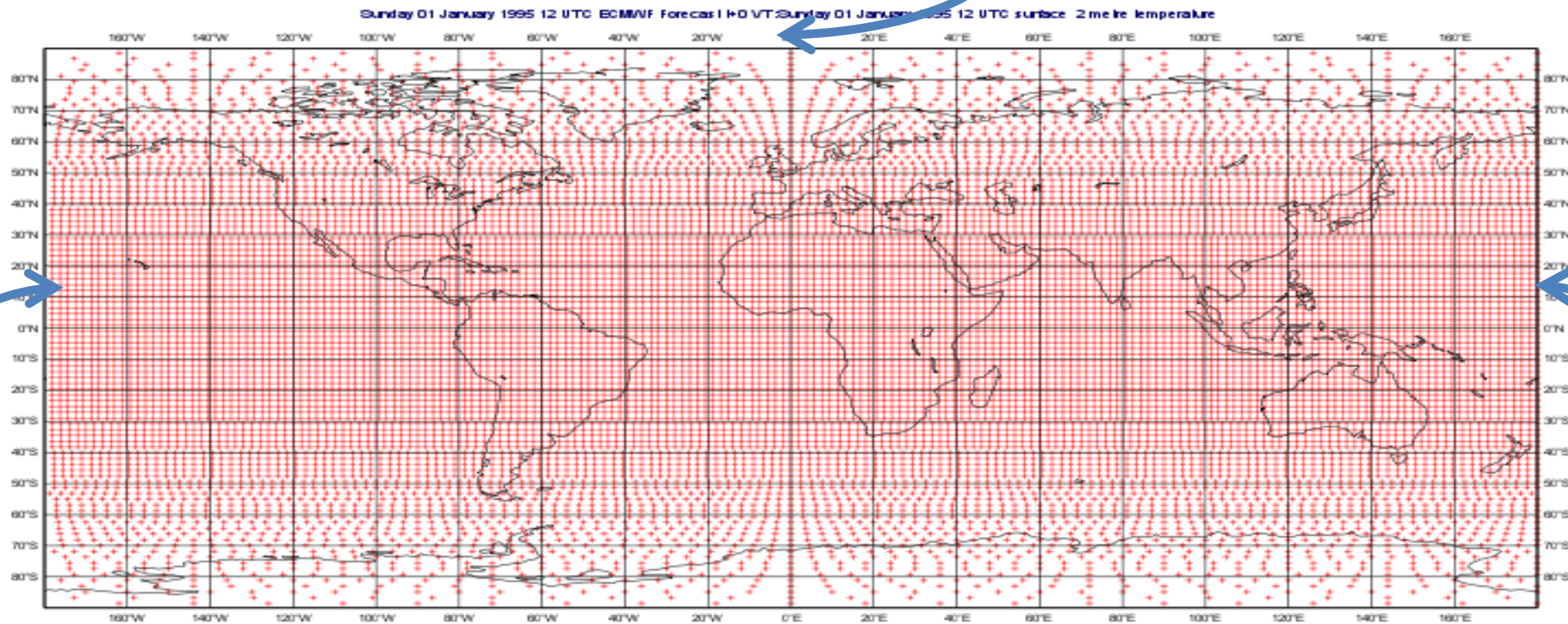
How to support **\*all\*** this in **one** algorithm?





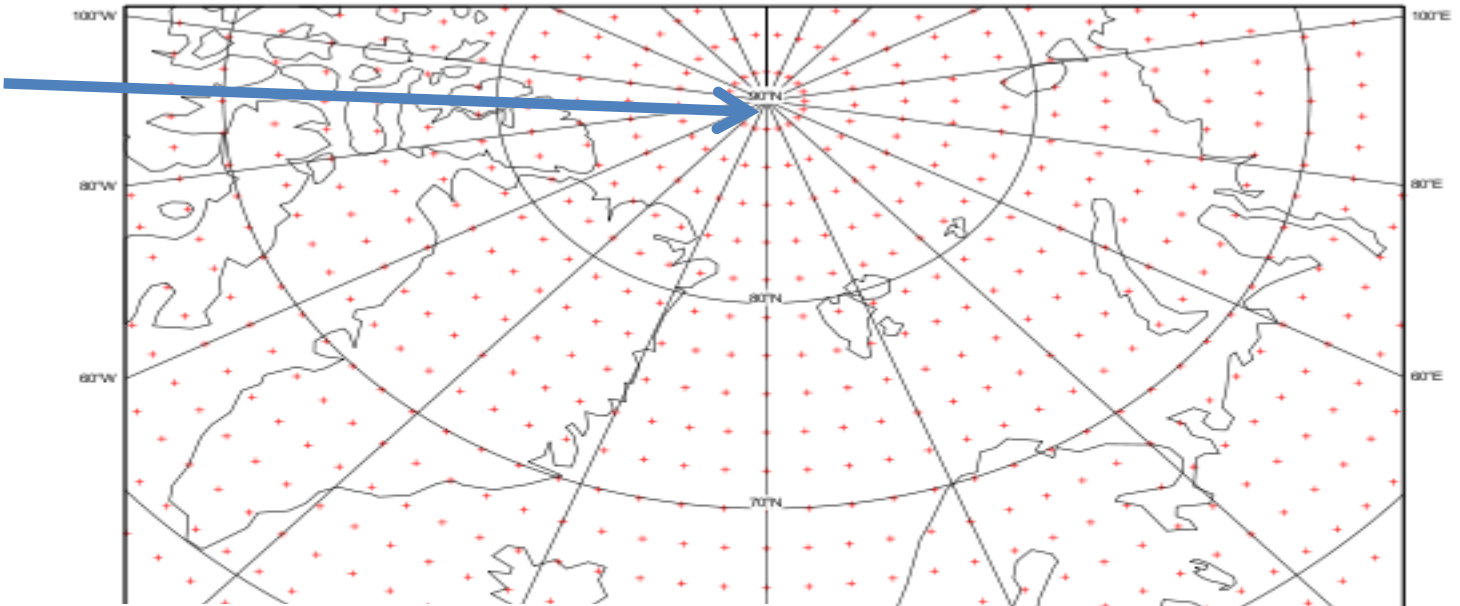
# Issues with latitude/longitude coordinate system

What about the poles?

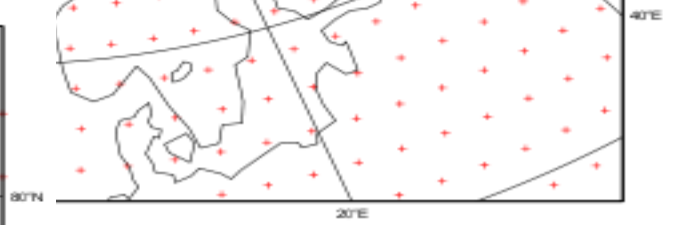
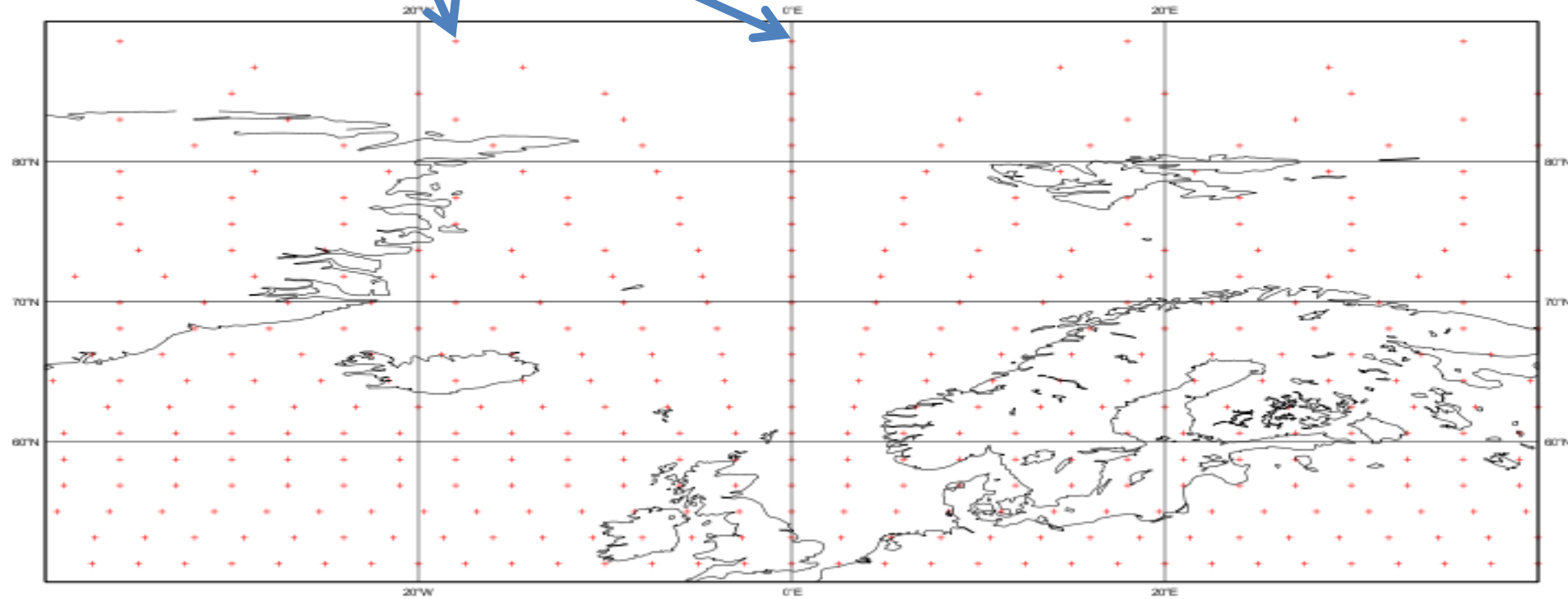
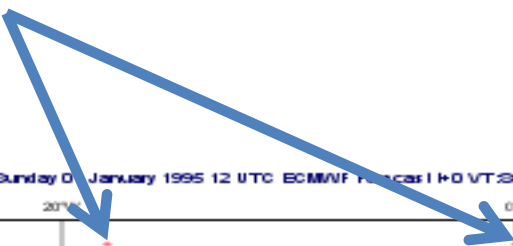


These points are close to each other

They are very close in this projection



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





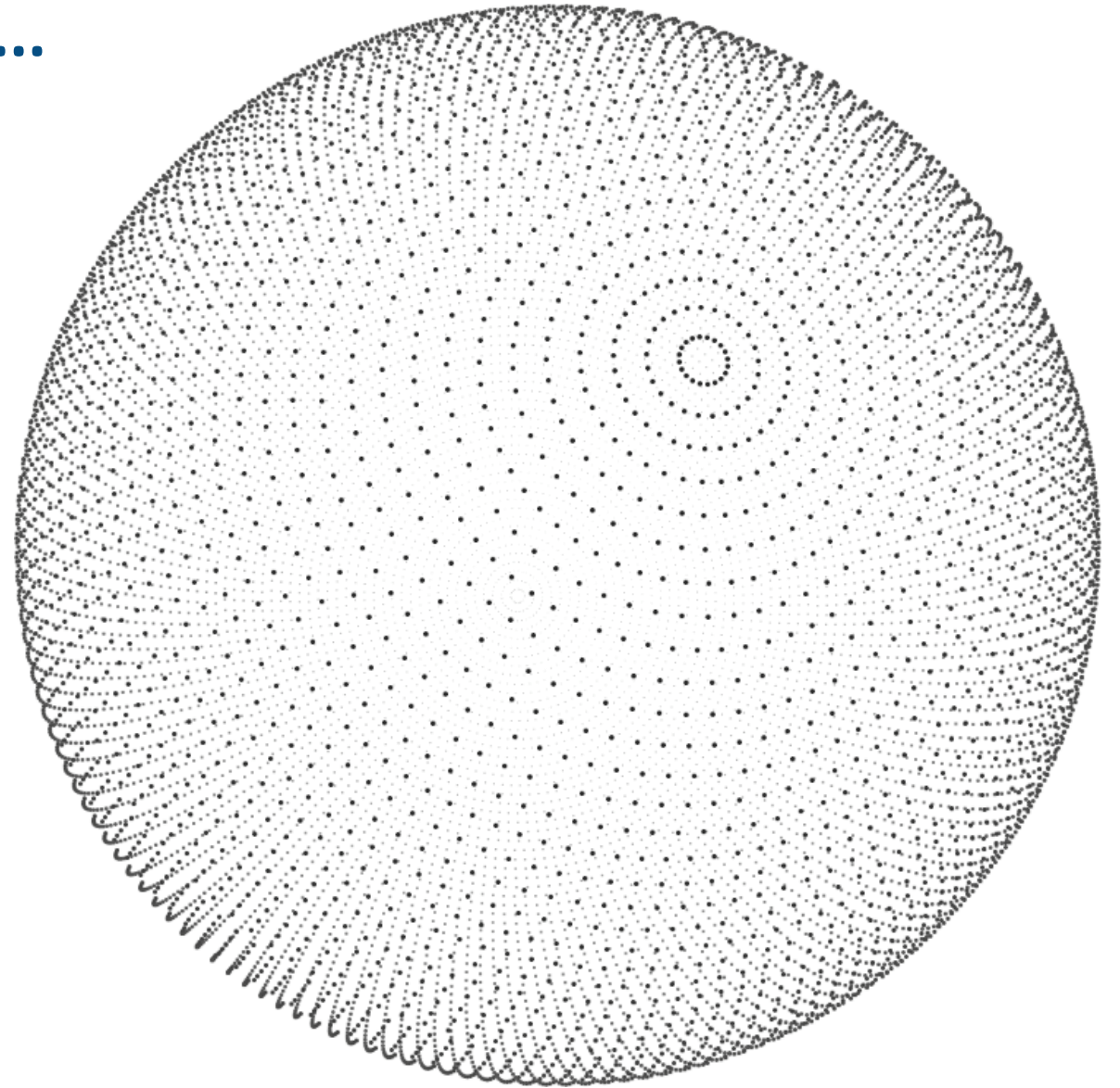
## But the earth is (almost) a 3D sphere...

The poles are not special

The anti-meridian is not special

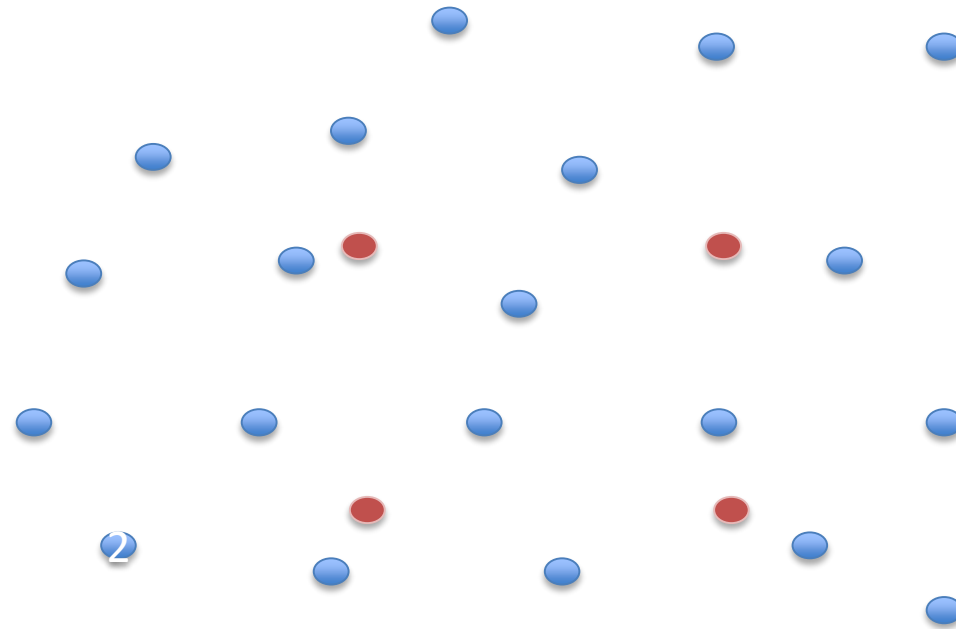
Use (X,Y,Z) instead of latitude/longitude

**Distances are computed in 3D space**



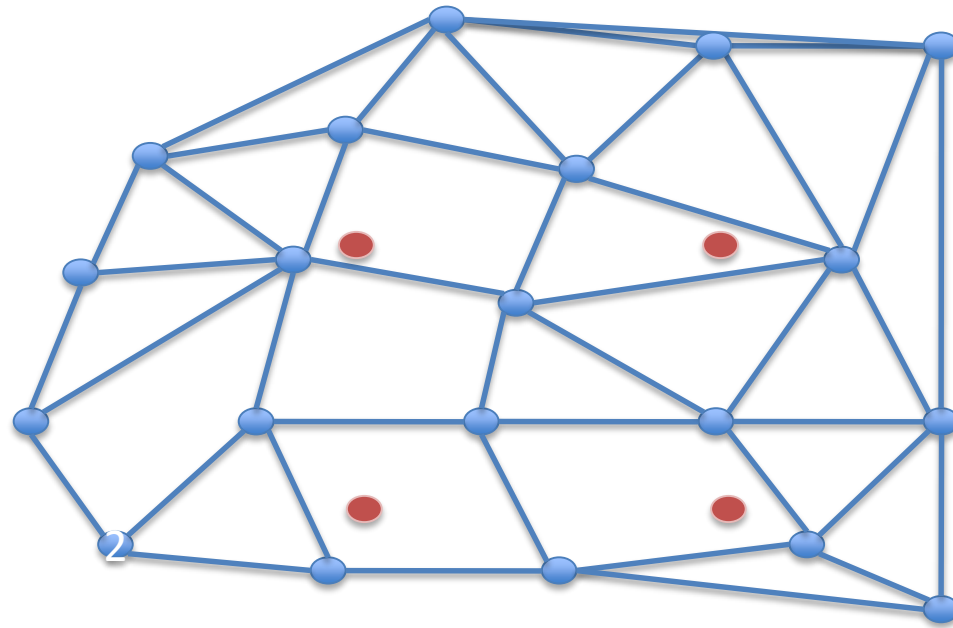
# How does it work?

- Input points
- Output points



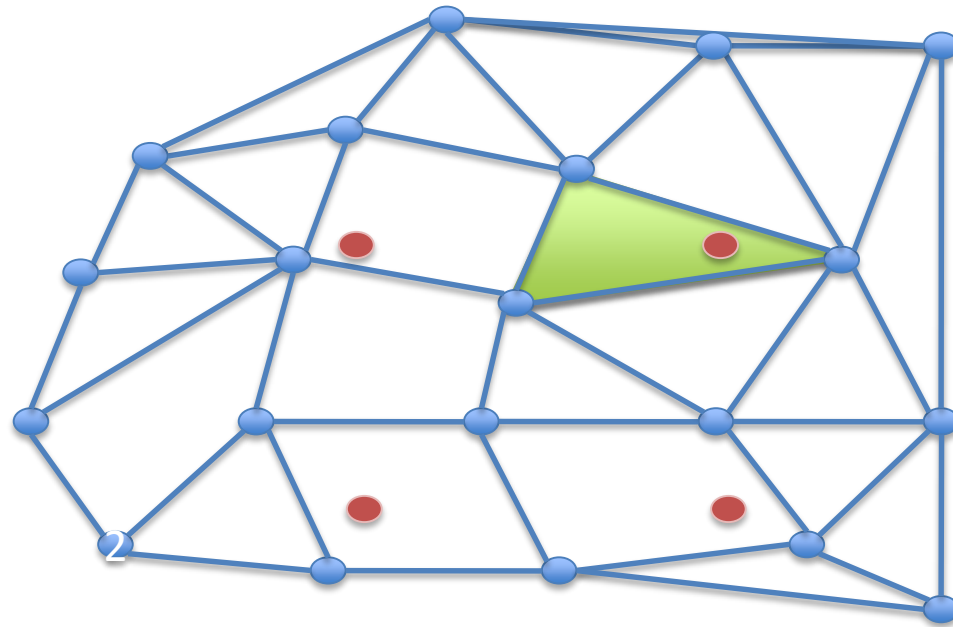
# Tessellation

Build a Finite-Element discretisation space

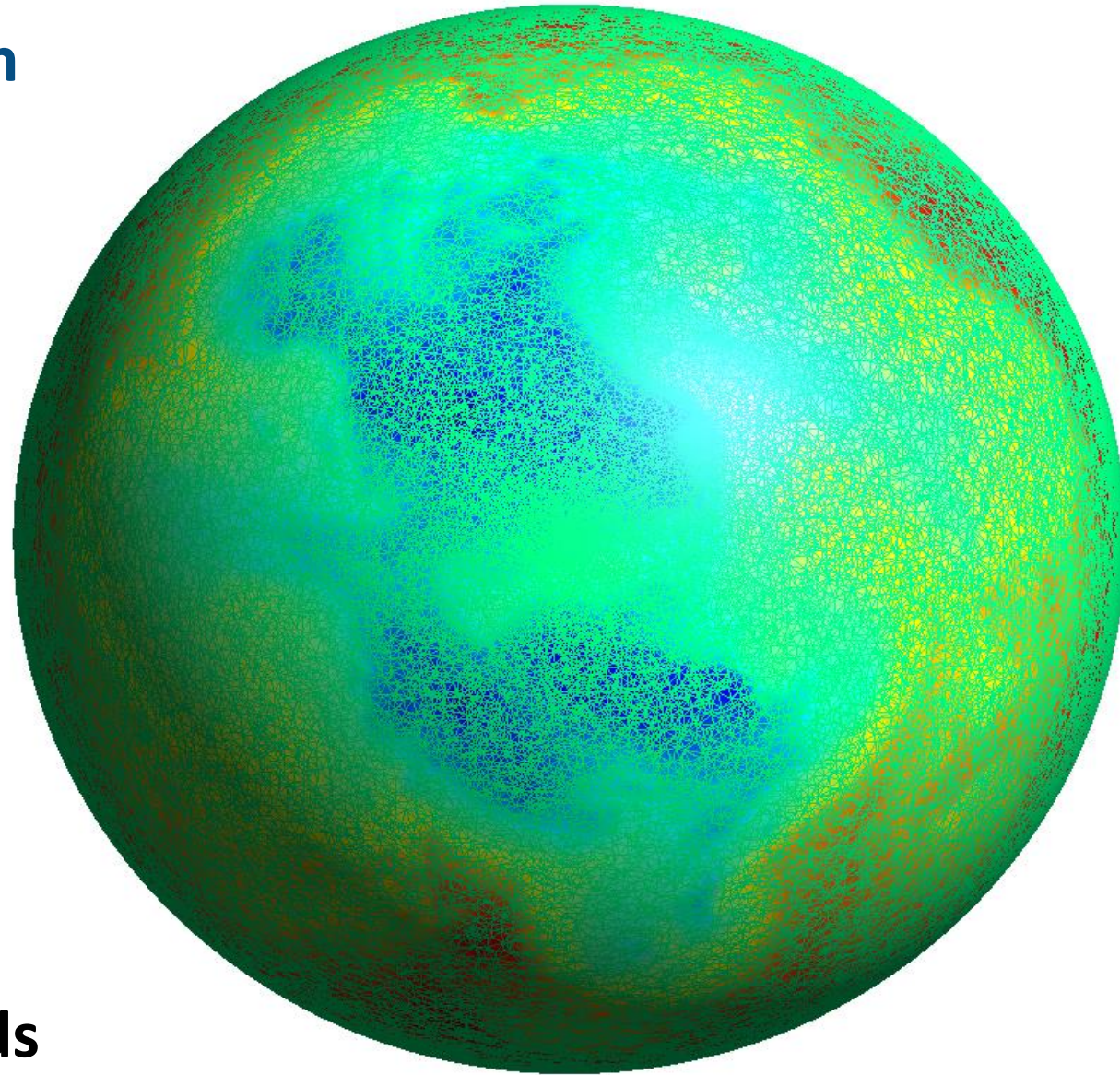


# Projection

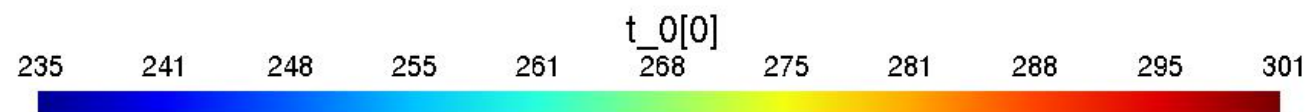
Use very efficient **Ray-Tracing** algorithms...



# Tessellation

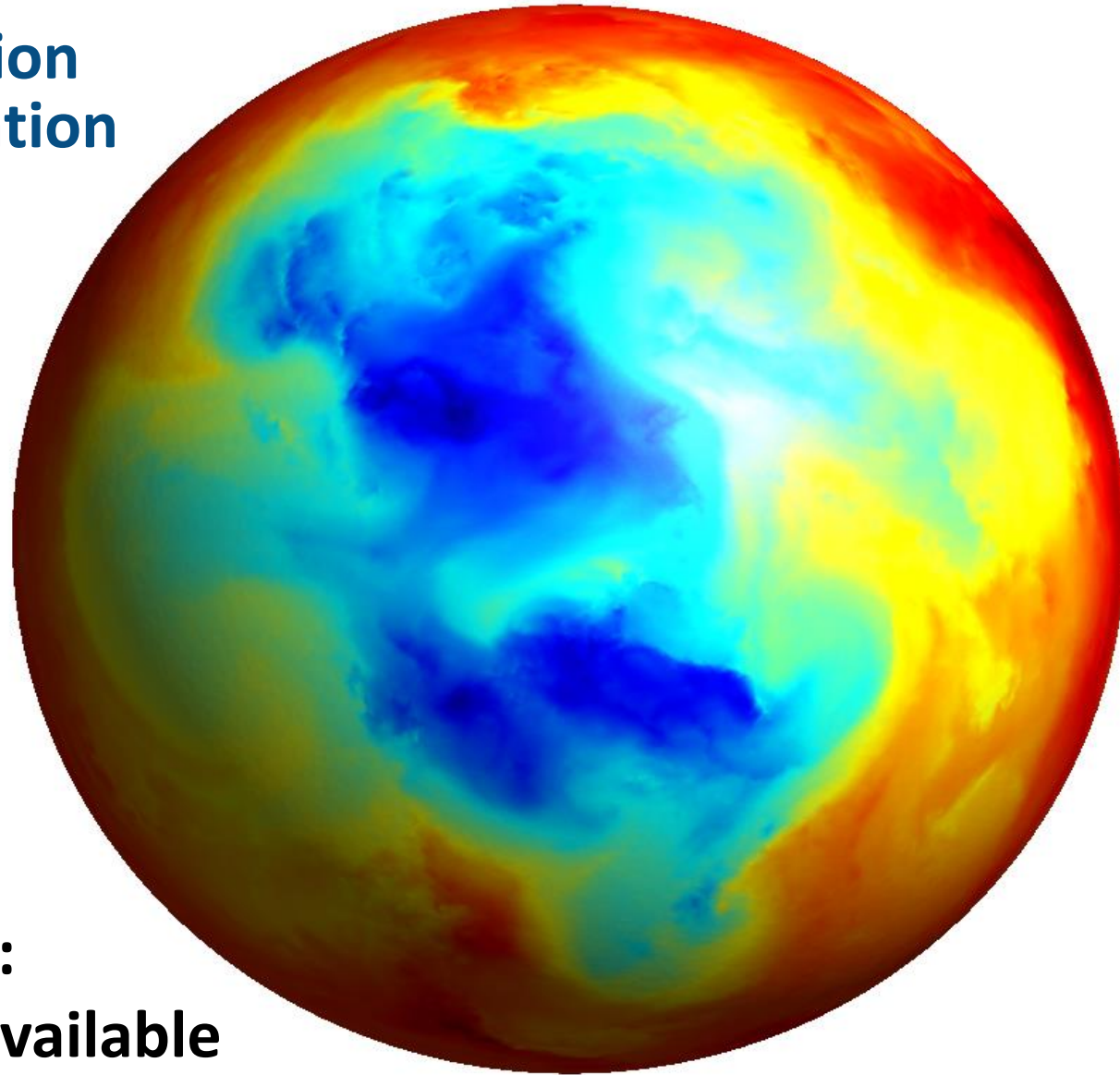


Support fully  
unstructured grids



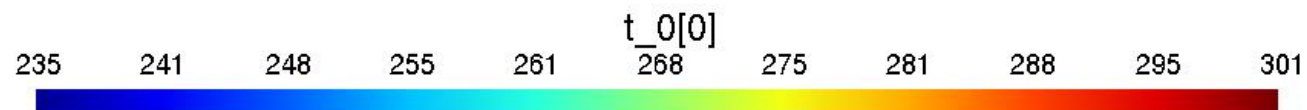


## 3D Projection + Interpolation



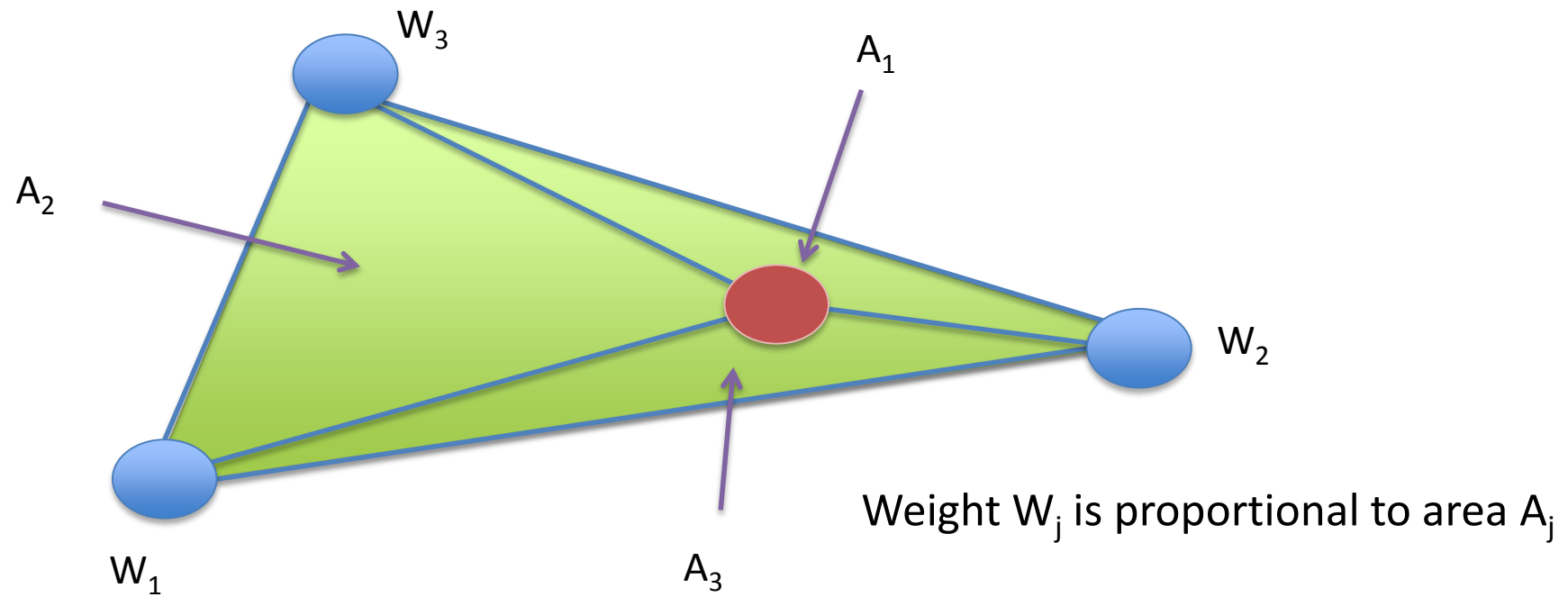
### Algorithm choice:

- Optimised if available
- Unstrucutred fallback



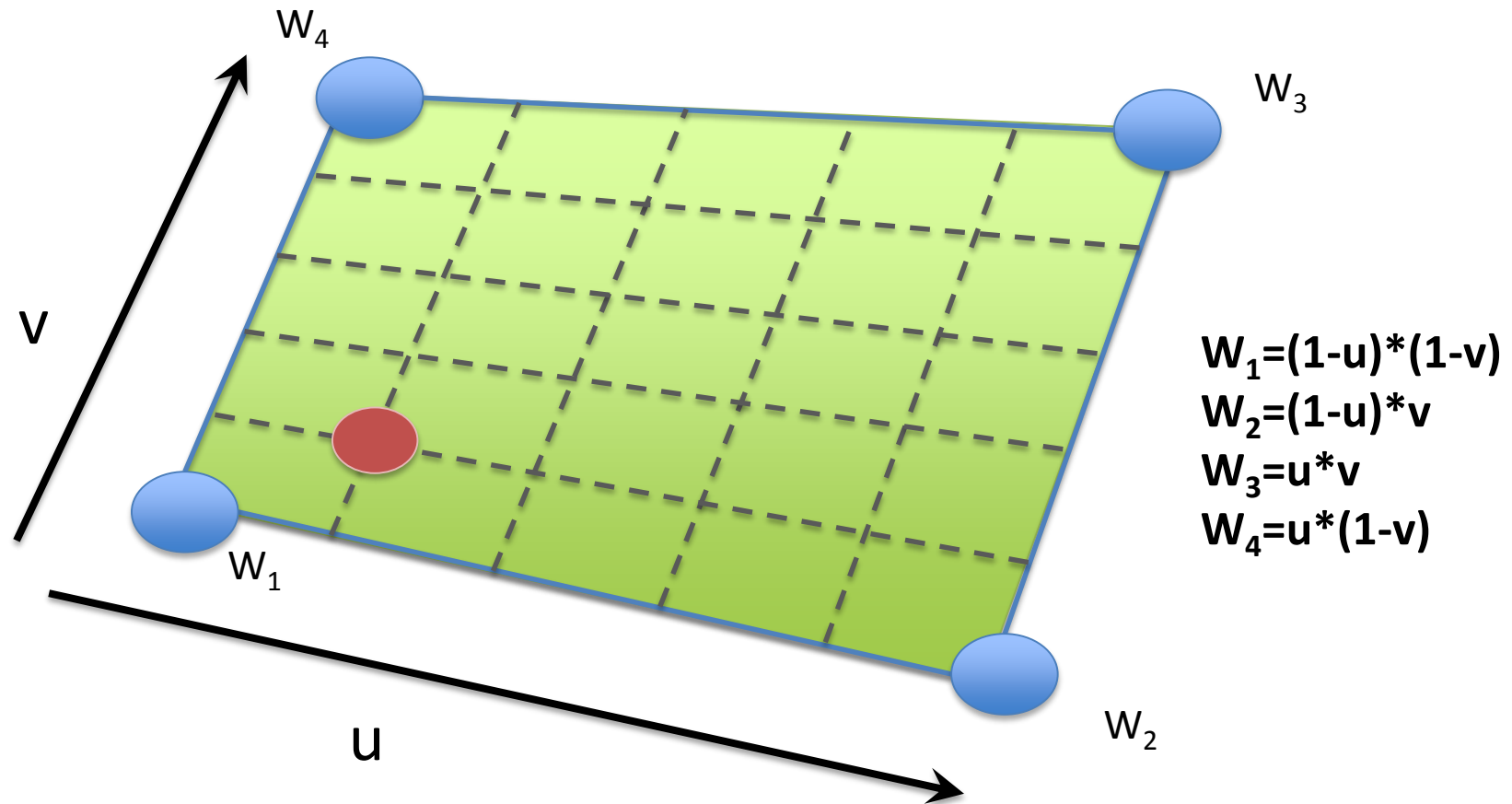
# Interpolation Operators

# Interpolation weights





# Interpolation Weights



# Interpolation Operator

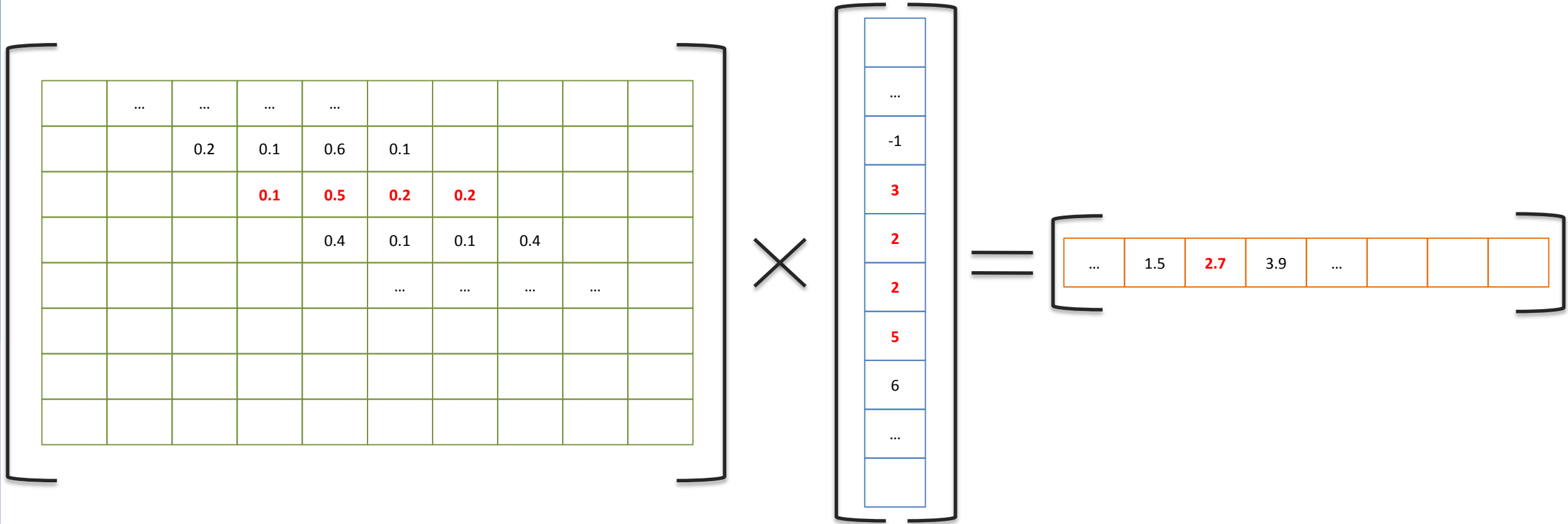
$$F_i = \sum w_{ij} G_j$$

$w_{ij}$  only depends on:

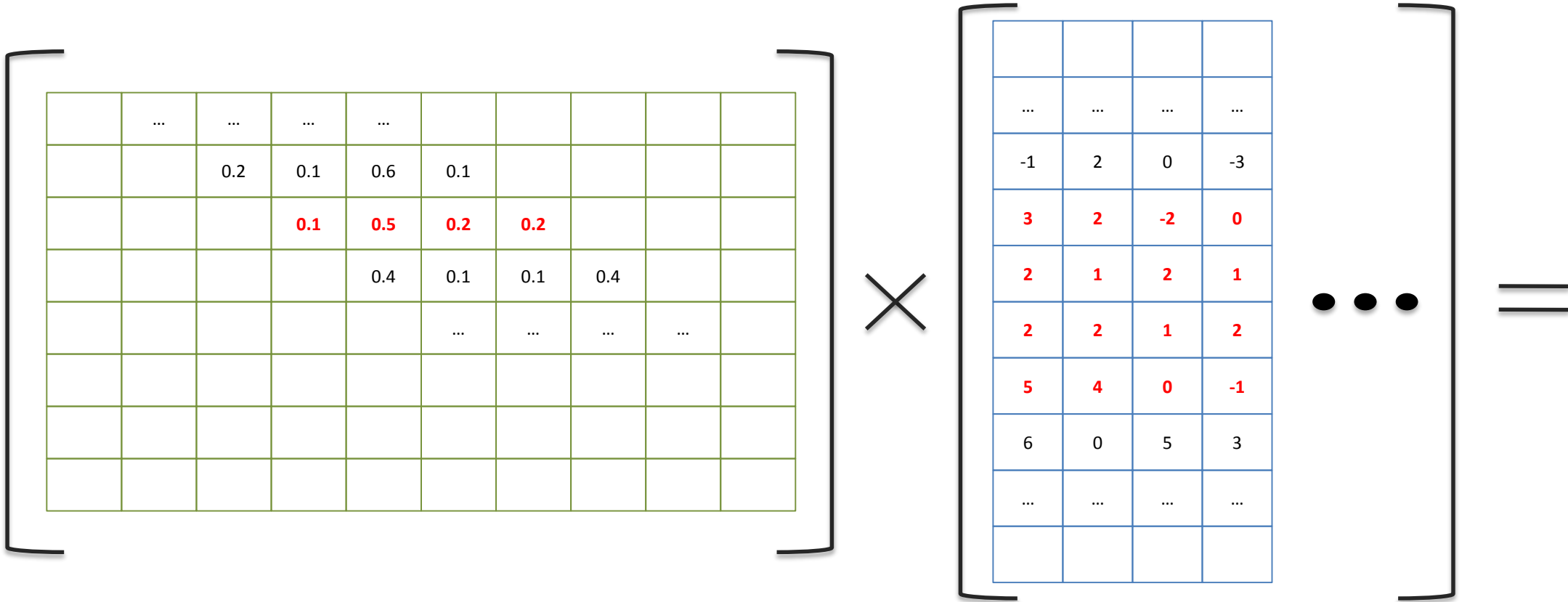
- Input grid, output grid, interpolation method, LSM

**Can be cached!**

# Matrix multiplication: Linear Operator



# Matrix multiplication: Batch Interpolation

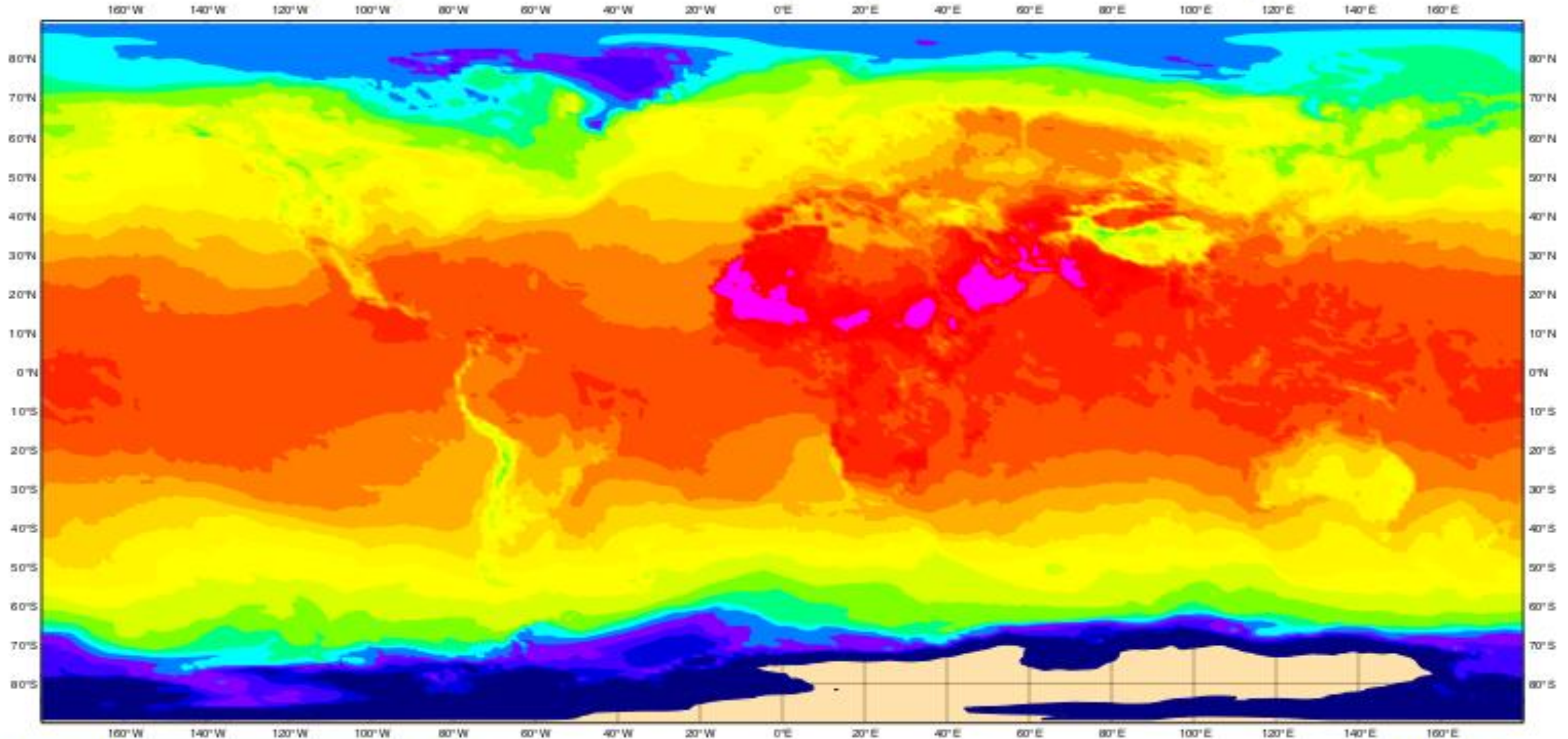


**CPU Cache and GPU friendly => SPEED**

# Features

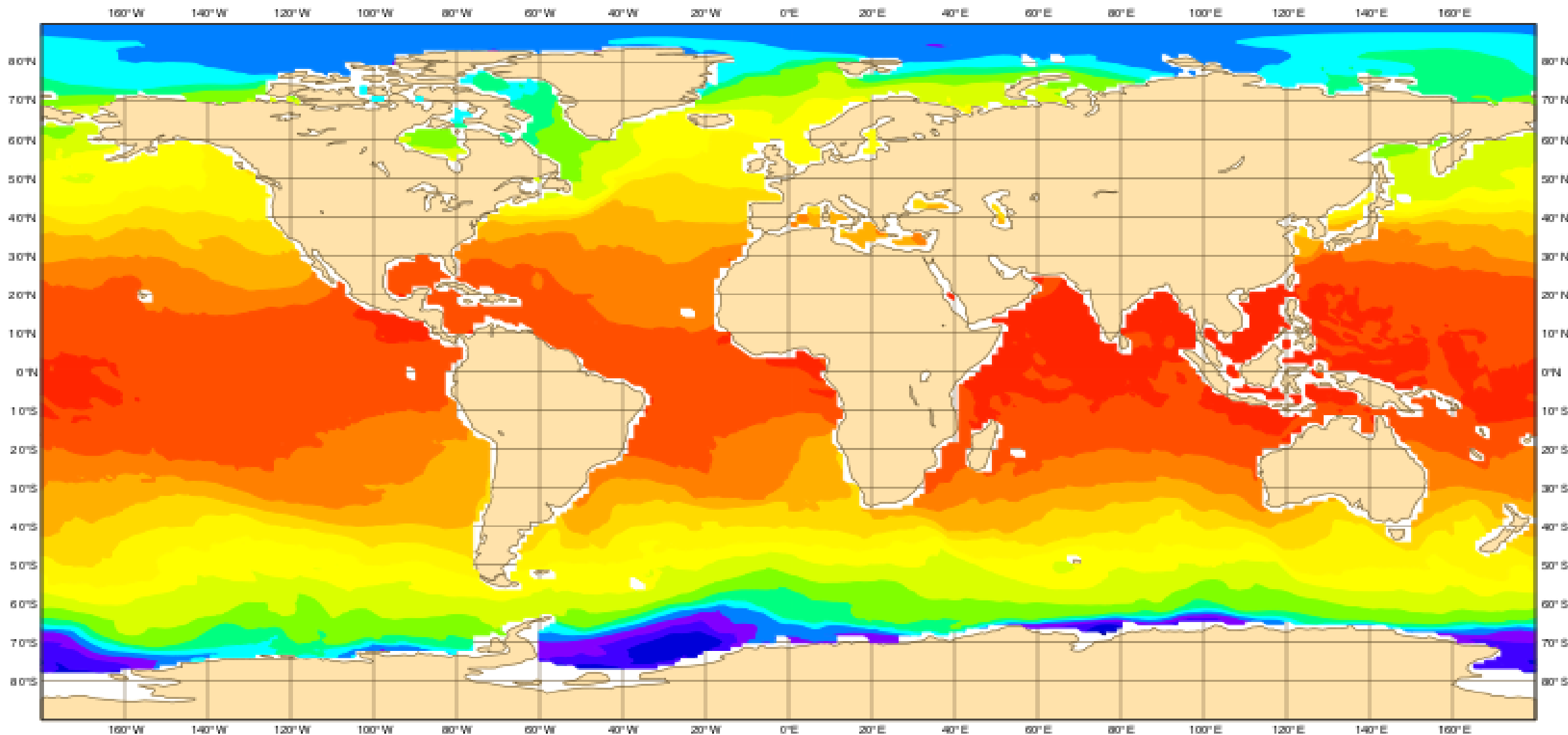
## 2t: N640 ► LL 0.25/0.25 + rotation + crop + frame

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



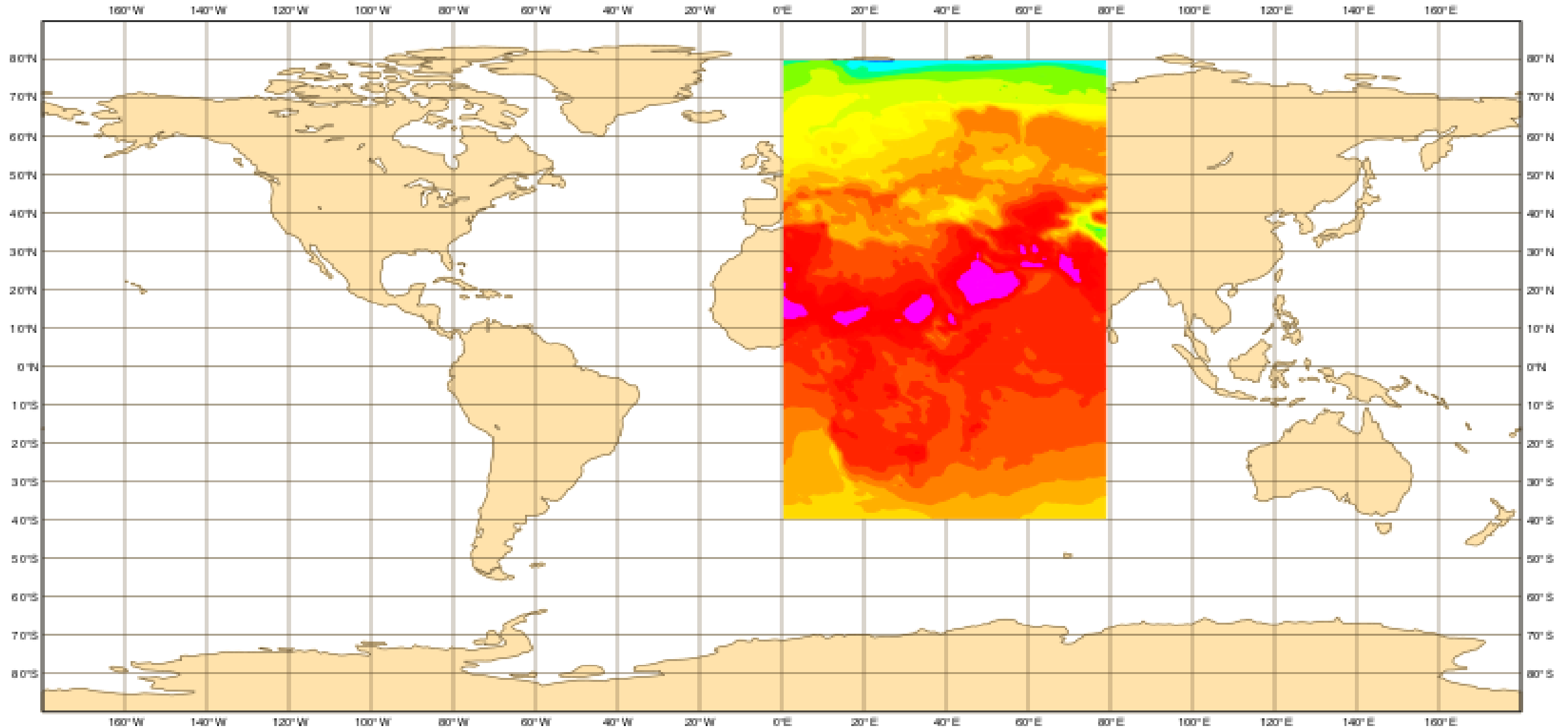
# 2t N640 -> 1x1 + bitmap (MIR)

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)

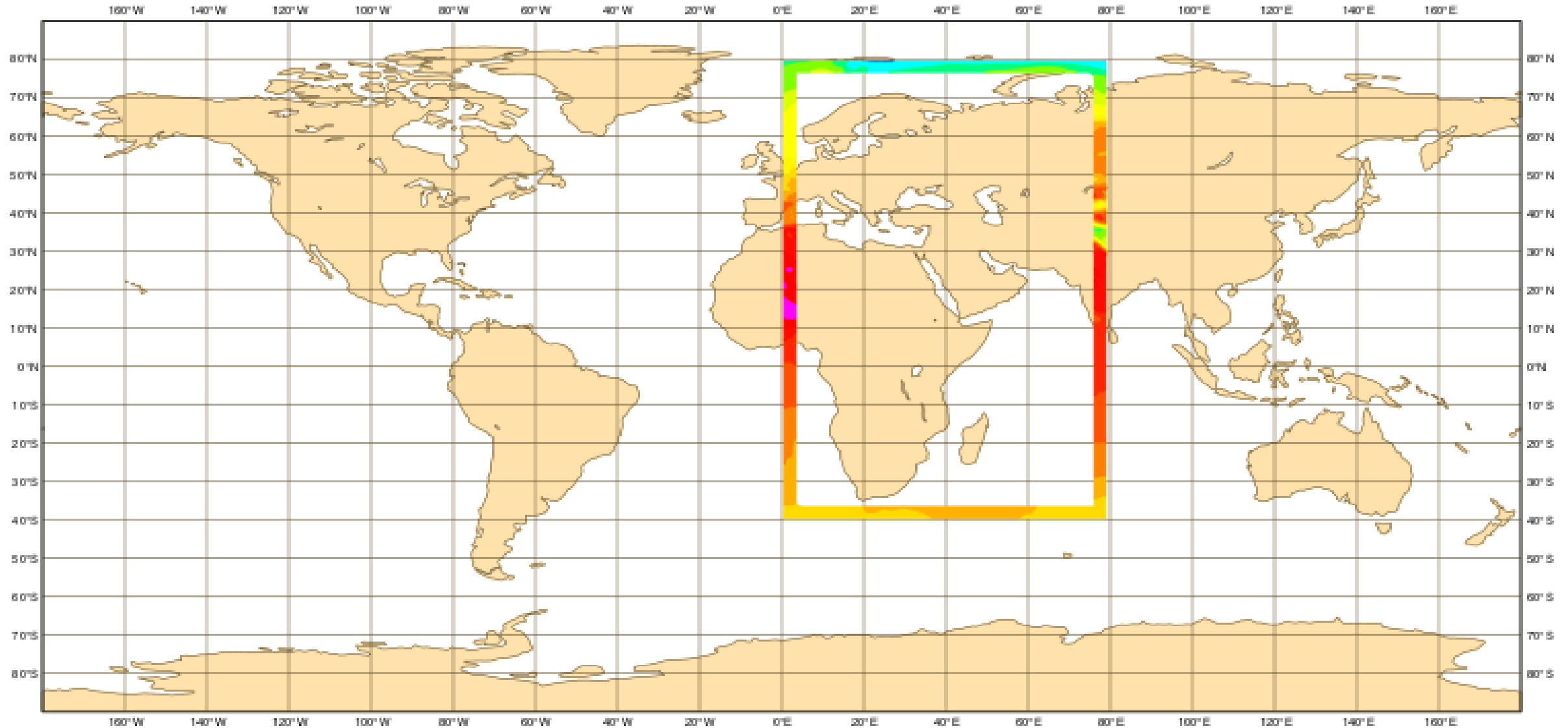
Thursday 14 May 2015 12 UTC ecmf t+0 VT:Thursday 14 May 2015 12 UTC surface 2 metre temperature





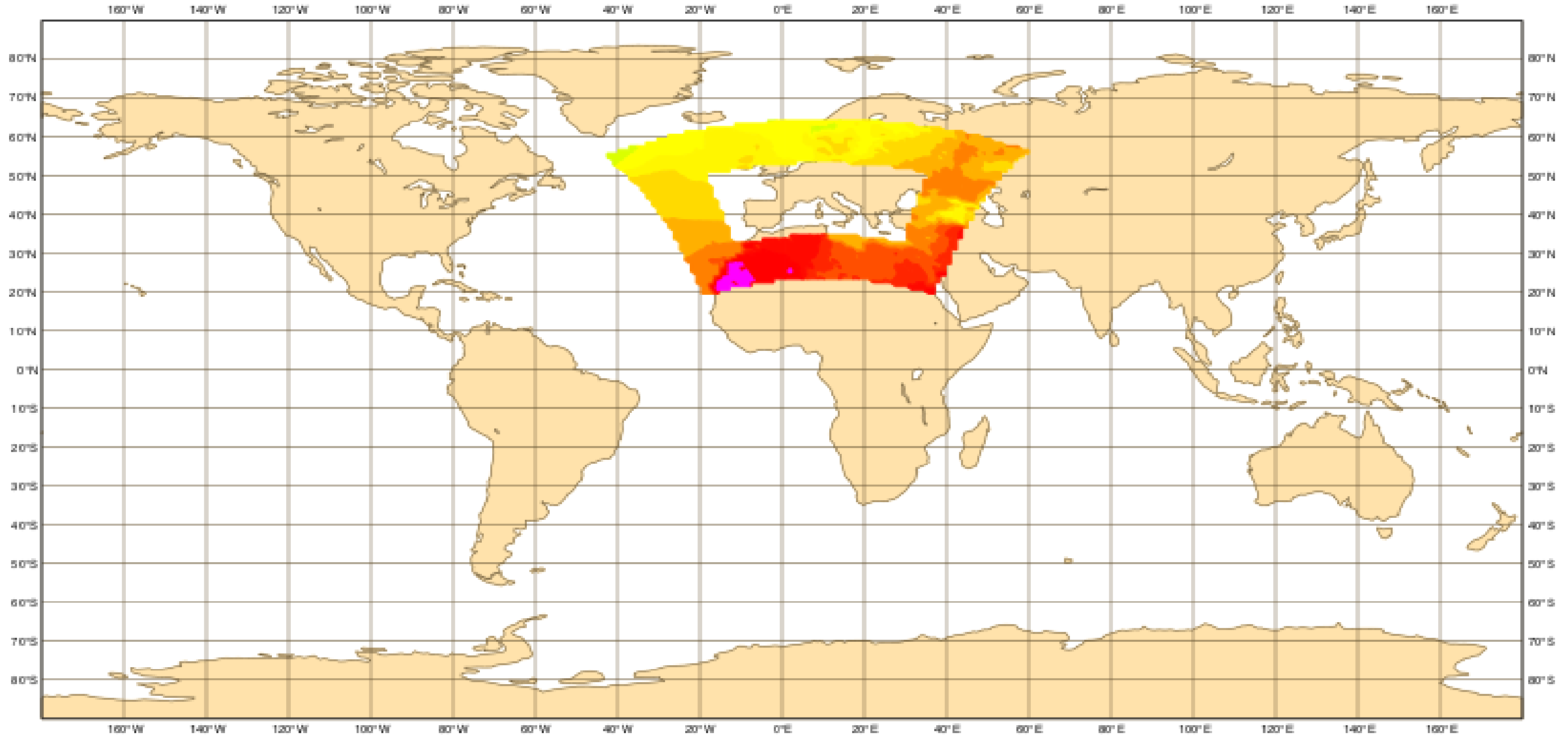
# 2t N640 -> 1x1 + crop + frame (MIR)

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



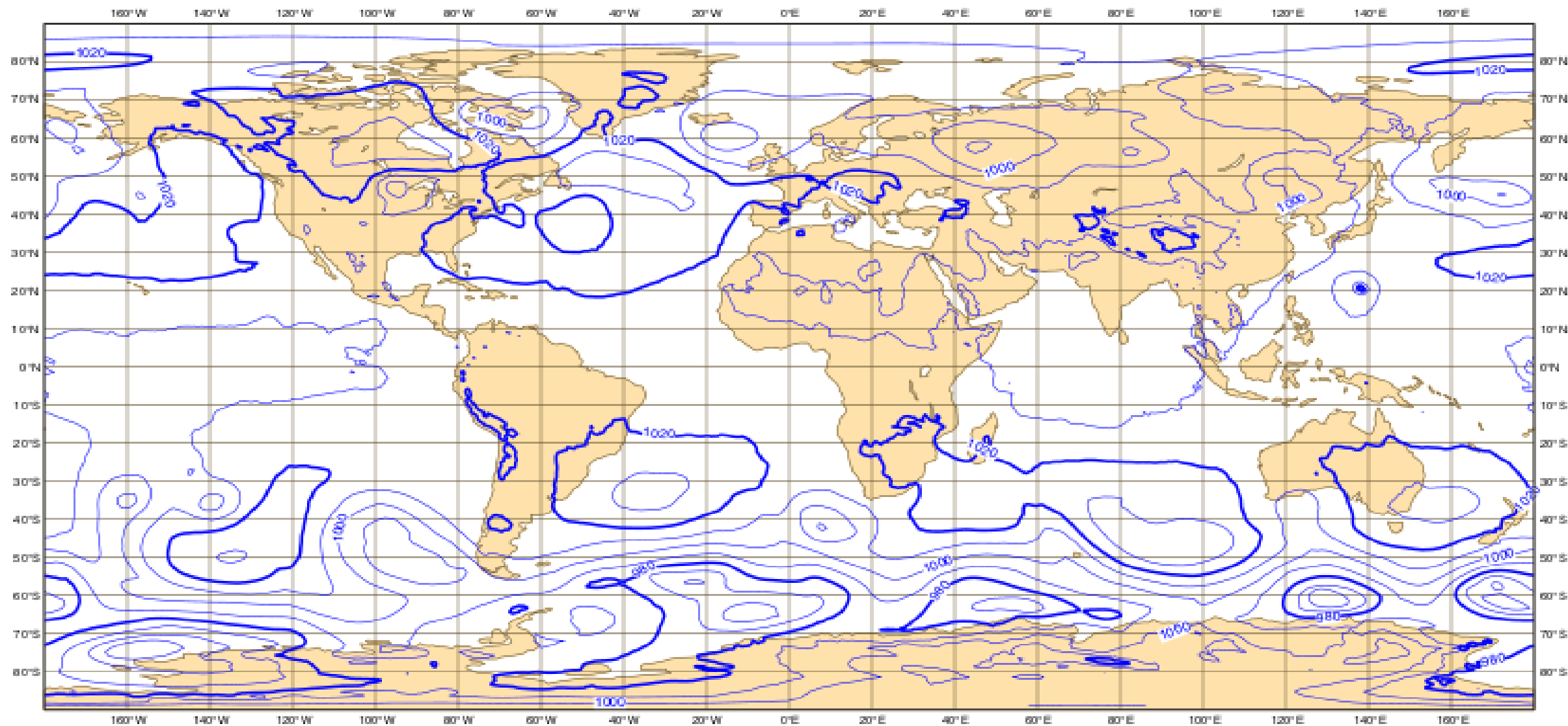
## 2t: N640 ► LL 0.25/0.25 + rotation + crop + frame

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

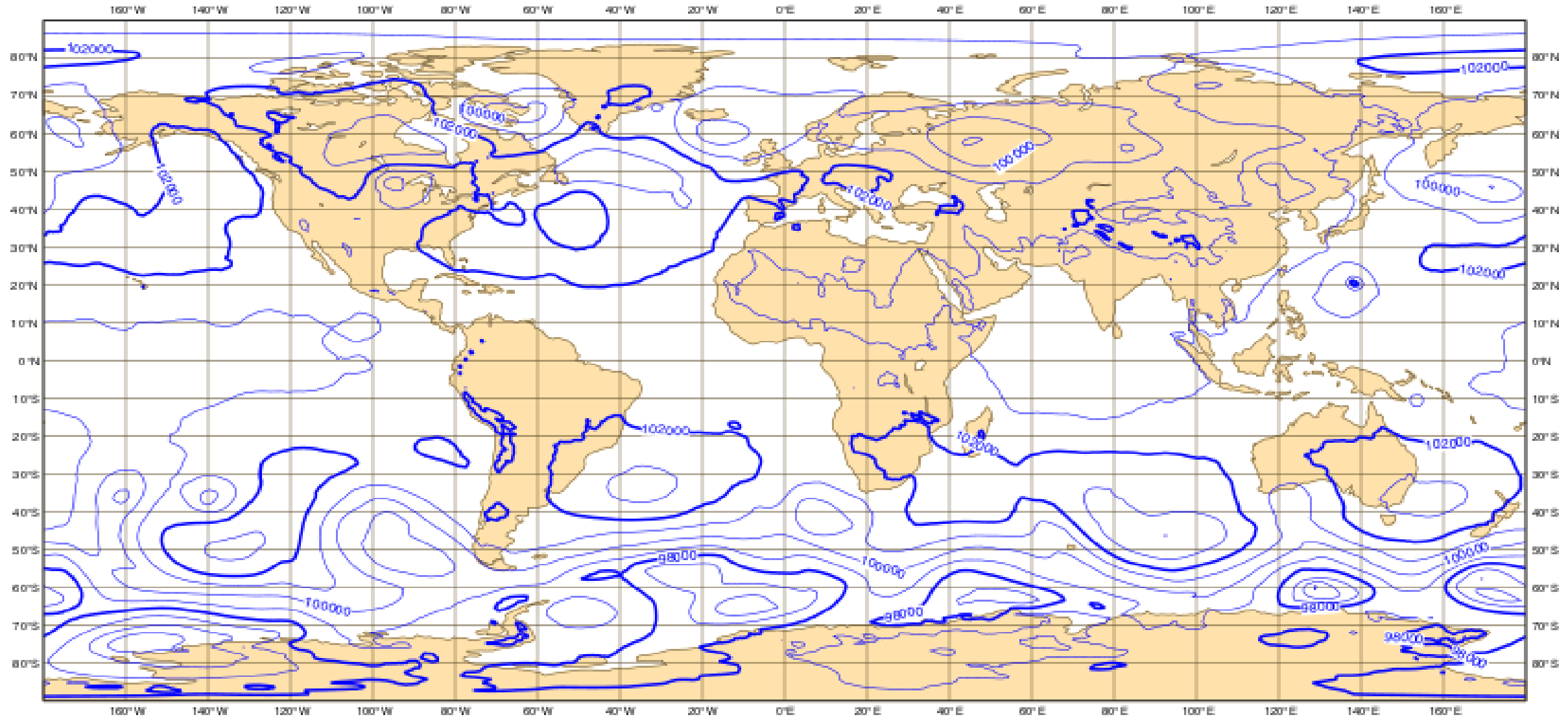


# Icosahedral (ICON) to Octahedral (IFS)

*ICON grid treated as unstructured 2,949,120 points*

Monday 18 May 2015 00 UTC edzw t+0

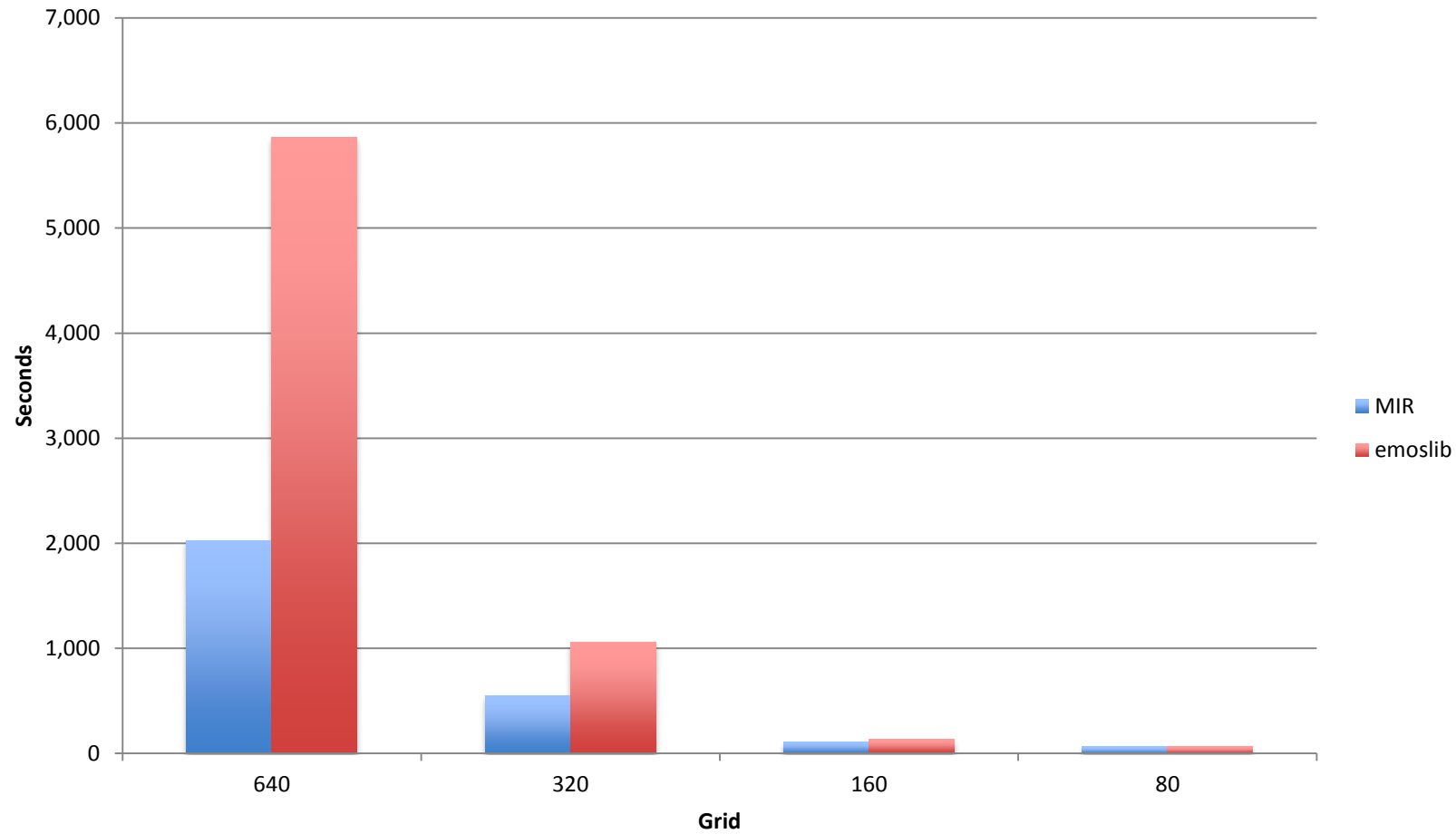
VT:Monday 18 May 2015 00 UTC meanSea Pressure reduced to MSL



# Performance

# Performance Comparison SH-to-Grid (preliminary)

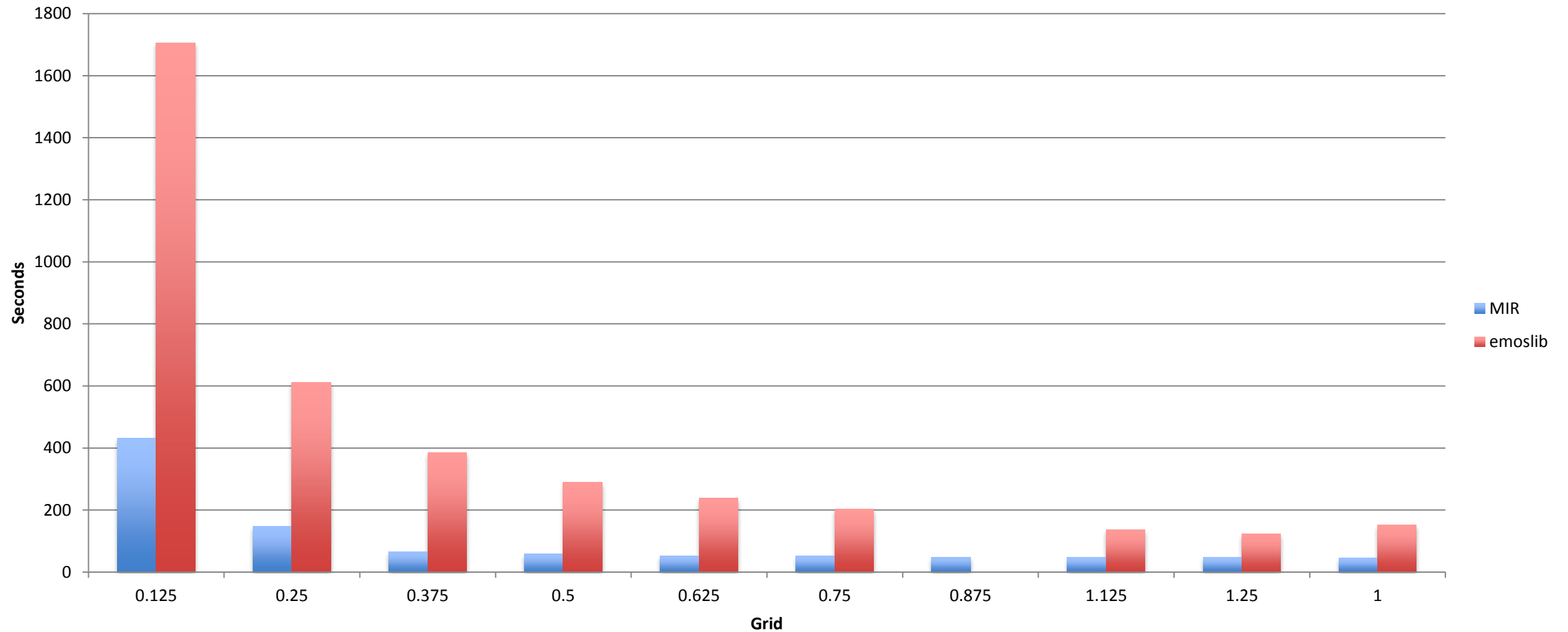
3000+ fields from T1279 to reduced GG (auto truncation)



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 ...