A seamless avenue to drive wind resource time series modeling:

the MPAS model and the mesoscale reframed

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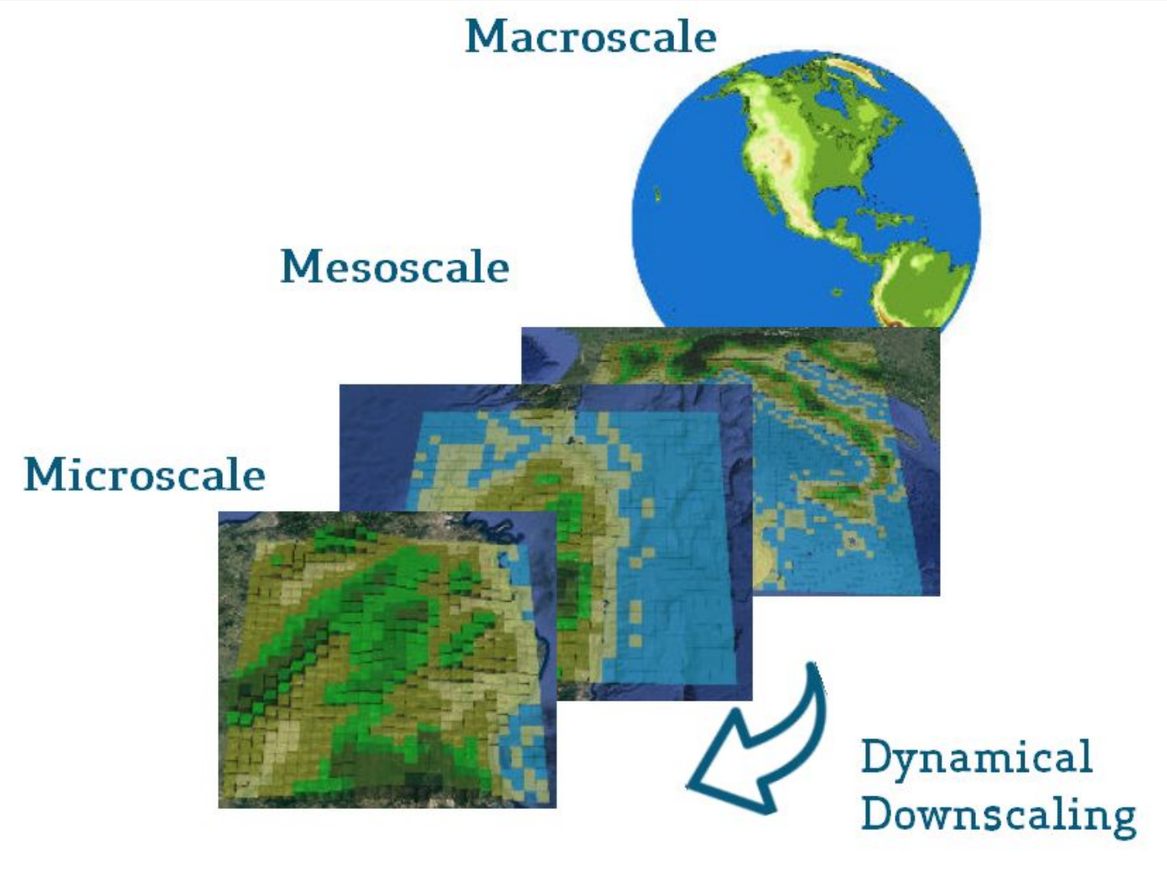
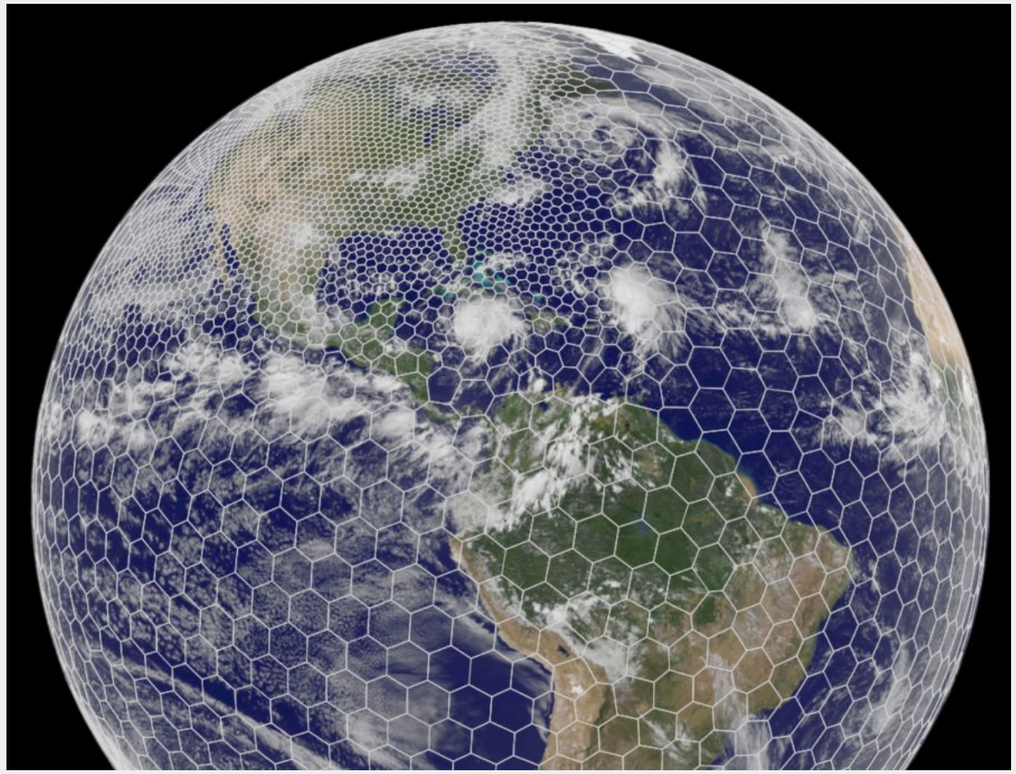
Introduction



- Wind industry has benefited from:
  - Better macroscale input data (reanalysis like ERA5)
  - Better microscale models (like WRF-LES)
- Reference downscaling tool: **WRF model**
- Is it time to change the downscaling method itself?

Outline

- **Introducing MPAS**
- **Why a new model?**
- **Validation of wind towers**
  - **WRF & MPAS simualtions**
  - **Results**
- **Conclusions & Next Steps**
- **Questions & Answers**

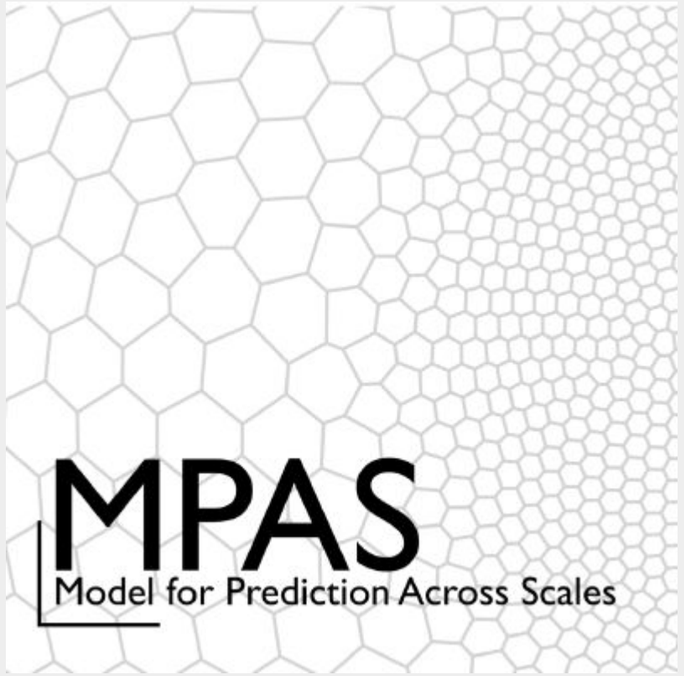


Source: *MPAS Tutorial*

Introducing MPAS

“The Model for Prediction Across Scales (MPAS) is a collaborative project for developing atmosphere, ocean and other earth-system simulation components for use in climate, regional climate and weather studies.”

https://mpas-dev.github.io/



MPAS infrastructure - NCAR, LANL, others.

MPAS - Atmosphere (NCAR) ← Advanced Research WRF

MPAS - Ocean (LANL)

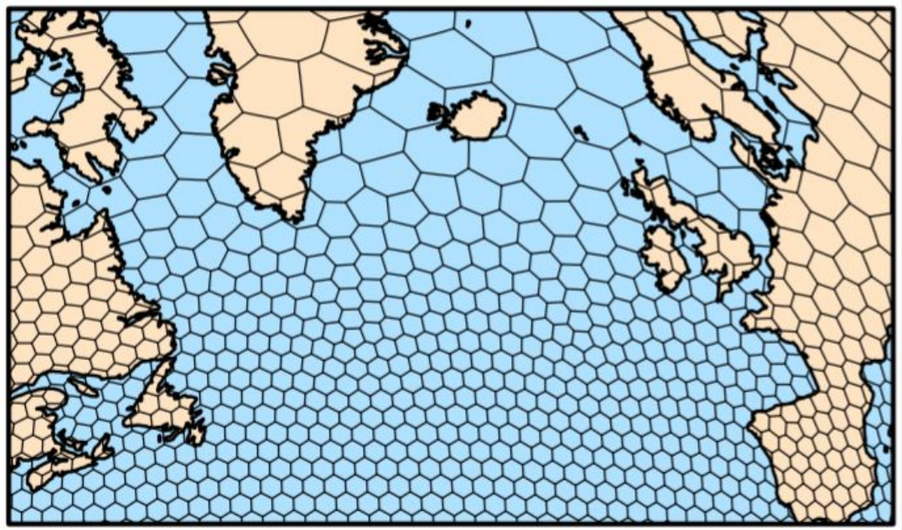
MPAS – Land and Sea Ice, etc. (LANL and others)

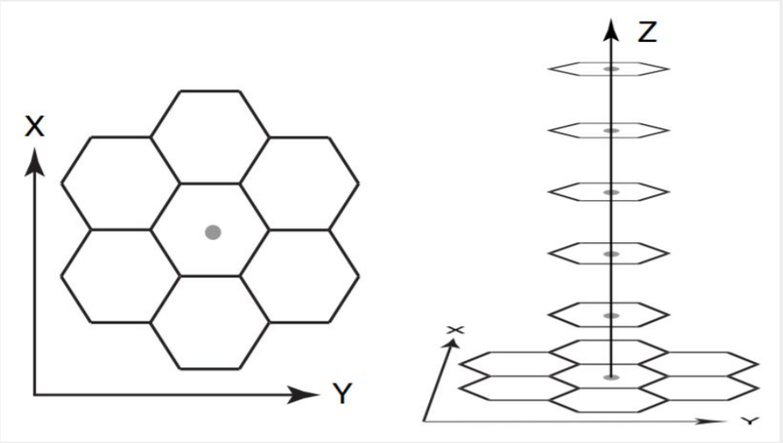
Los Alamos NATIONAL LABORATORY EST. 1943 | U.S. DEPARTMENT OF ENERGY | Office of Science | NSF | NCAR

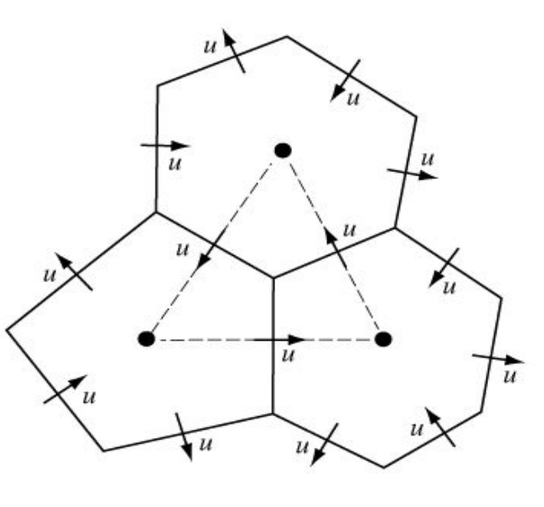
Introducing MPAS

SPACE DISCRETIZATION

- Unstructured 2D horizontal grid → Spherical Centroidal Voronoi Tesselation
- Structured vertical coordinate
- C-grid staggering





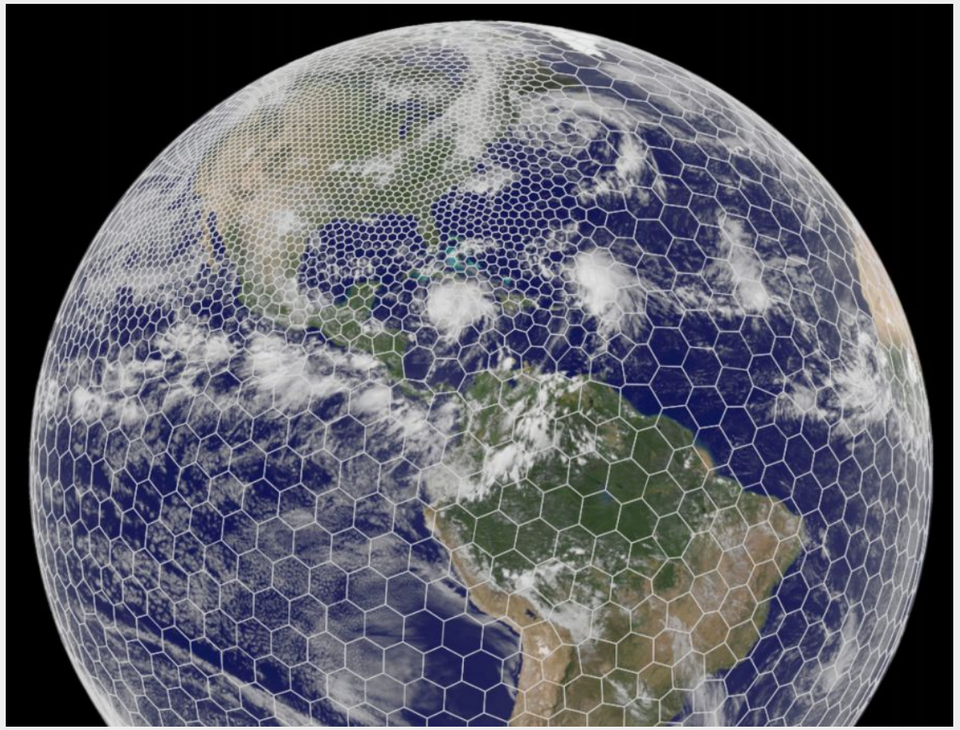


Source images: *MPAS Tutorial*

Introducing MPAS

MESH GENERATION

- Iterative process (Lloyd's method) to generate a valid mesh from a user-defined density function
- MPAS does not release a mesh generation tool (yet)
- Several meshes are available for download:
  - Quasi-uniform meshes
    → from 480km to 3km resolution
  - Variable-resolution meshes
    → Can be rotated
- Meshes can be partitioned to allow parallel computation



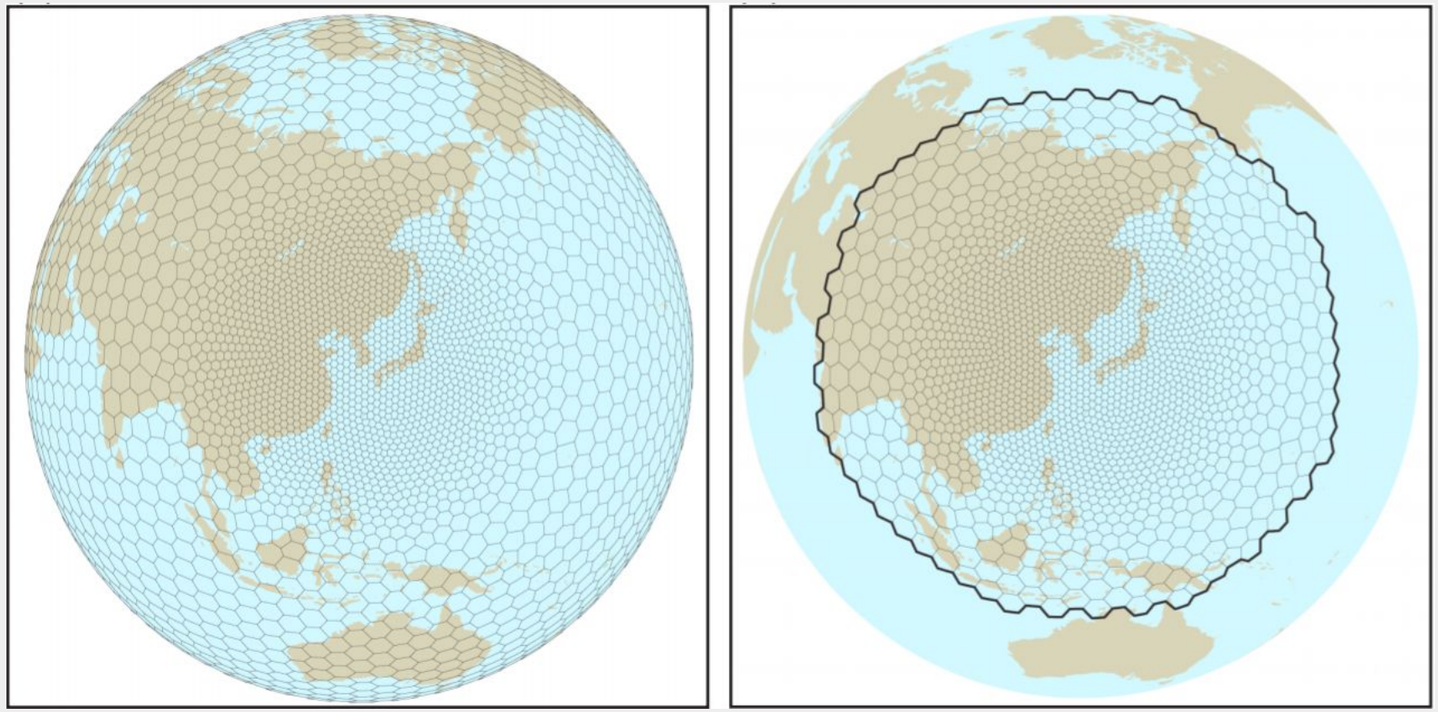
Source: *MPAS Tutorial*

Introducing MPAS

LIMITED AREA SIMULATIONS

- Since version 7.0 (June 2019)
- Regions are cut from valid global meshes

  → they can have variable resolution (grid refinement)
- Boundary conditions can be updated with reanalysis data
- Seamless interaction between scales



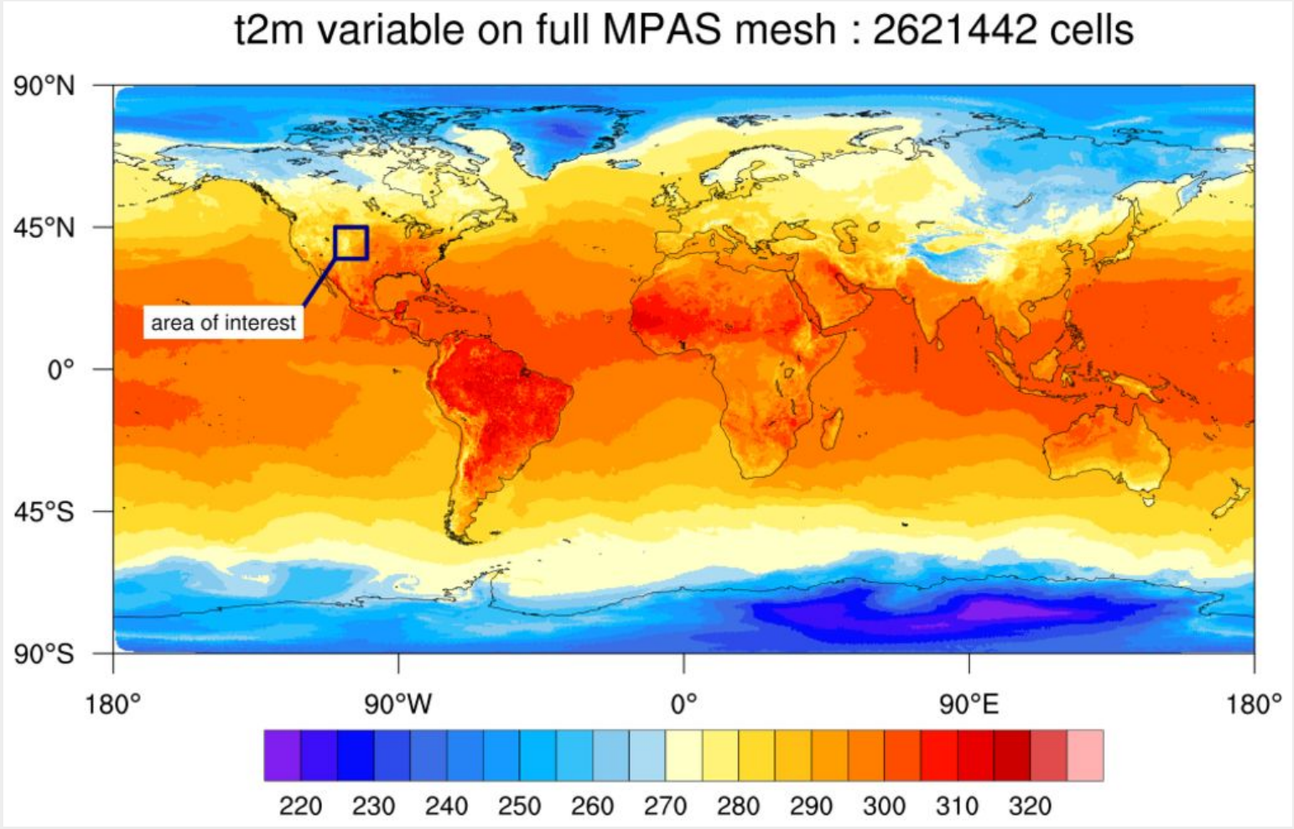
Source: *DOI:10.5772/55922*

Introducing MPAS

MPAS- Atmosphere

- MPAS - Atmosphere solver:
  - Dynamical Core
  - Atmospheric Physics

- In both aspects using methods and parametrizations very similar to those employed in the Advanced Research **WRF model**



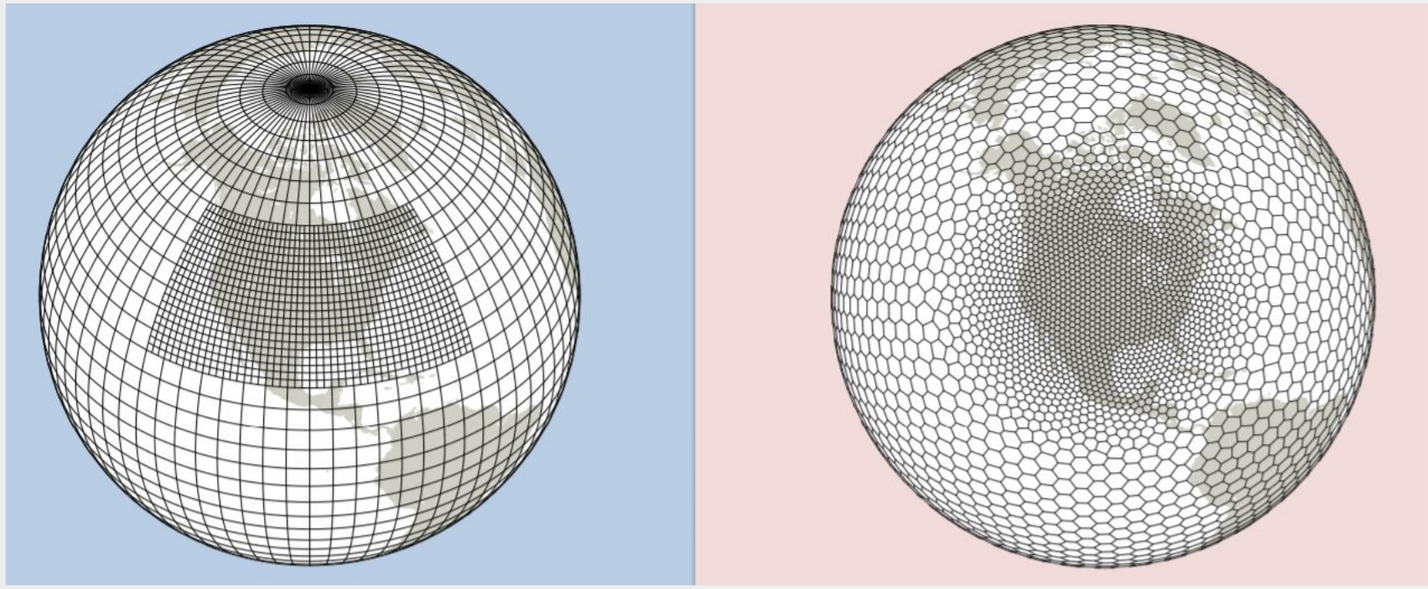
Source: *NCL Graphs: MPAS*

Why a new model?

Why MPAS?

It solves some WRF limitations:

- Deformation due to projections
- Flow distorsion at nest boundaries
- Poor interaction between scales
- Poor scaling on parallel computers
- Polar filtering needed



Source: *MPAS Tutorial*

Why a new model?

Wind Resource Assesment in MPAS

Long term wind data time series at specific locations or small regions

Required MESH:

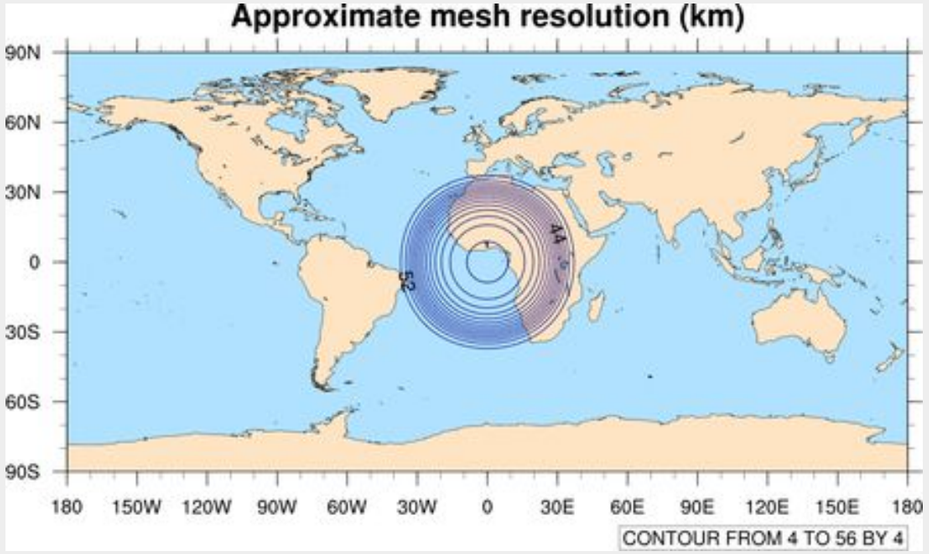
- Variable resolution mesh
  - Central high resolution area to improve the accuracy of the results.
  - Smooth transition from central resolution (high) to low resolution (reanalysis).
  - Smallest possible number of cells to reduce computation cost and time.

Why a new model?

We are not there yet

- Best available candidate: 3km- 60km mesh
  - 3km is not very high resolution
  - The 3km area is larger than needed
  - A Limited Area Simulation until aprox. 30 km requires nearly a million of cells.

Too time consuming



Source: *MPAS available meshes*

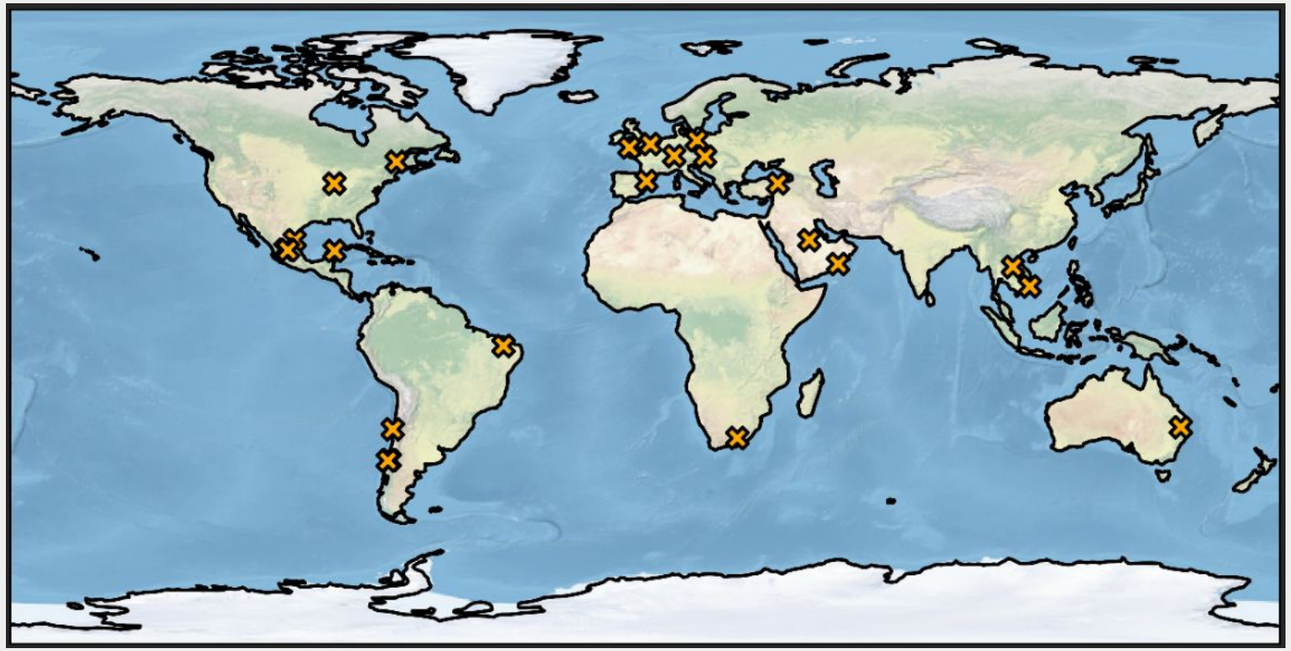
Validation of wind towers

23 sites

4 simulations by site:

- 1 year

- ERA5 reanalysis



MPAS	mpas.15.200	mpas.10.150
resolution	15 km	10 km
radius	200 km	150 km

WRF	wrf.9.wn	wrf.9.nn
resolution	9 km	9 km
nudging*	yes	no

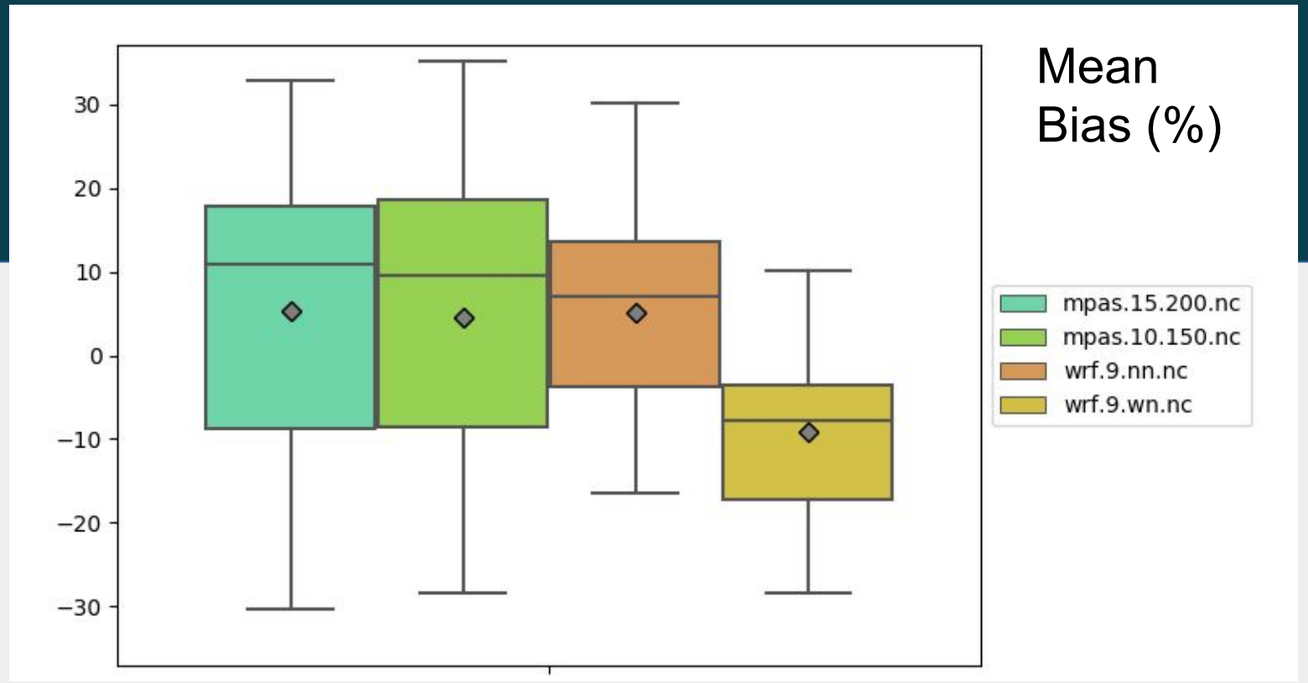
***Nudging**: Option available in WRF to control the simulation using reanalysis values

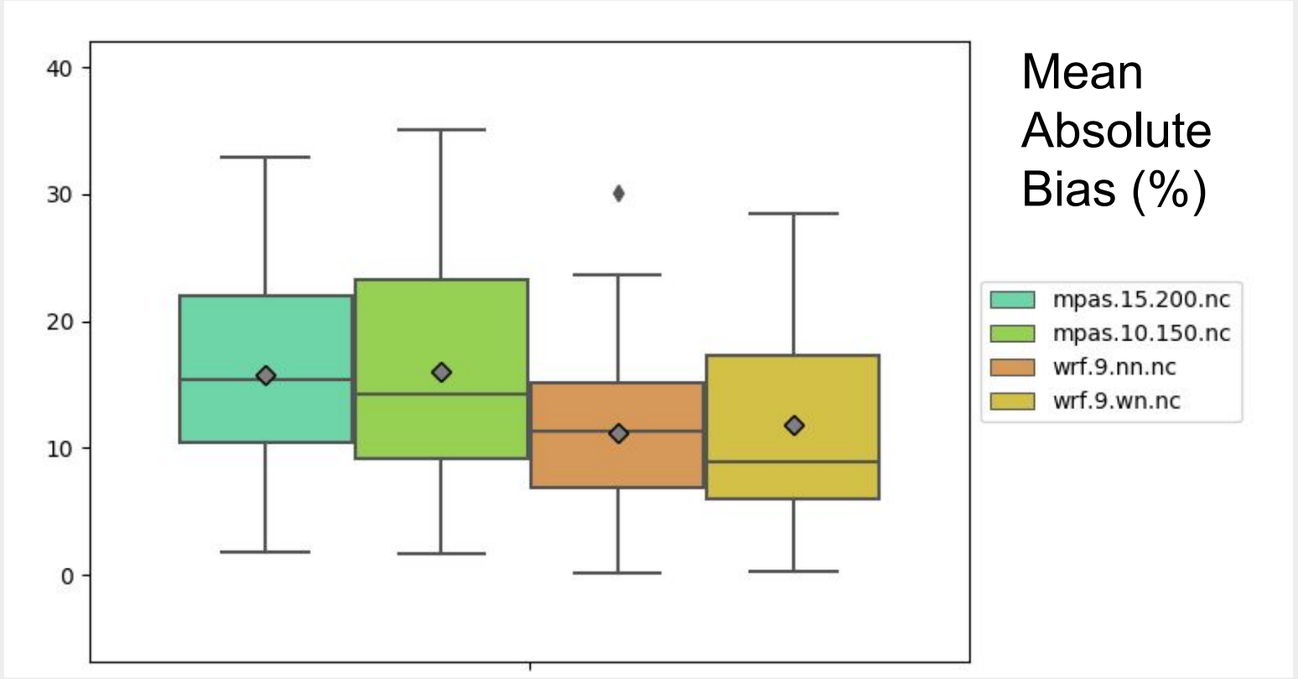
Results

Wind speed bias (%)

	Mean bias (%)	Mean absolute bias (%)
mpas.15.200	5.36 ± 17.50	15.78 ± 8.70
mpas.10.150	4.55 ± 18.28	16.07 ± 9.26
wrf.9.nn	5.08 ± 12.52	11.16 ± 7.32
wrf.9.wn	-9.07 ± 11.09	11.77 ± 8.01

- High bias are expected due to resolution
- MPAS results are spread wider than WRF and very similar for both simulations



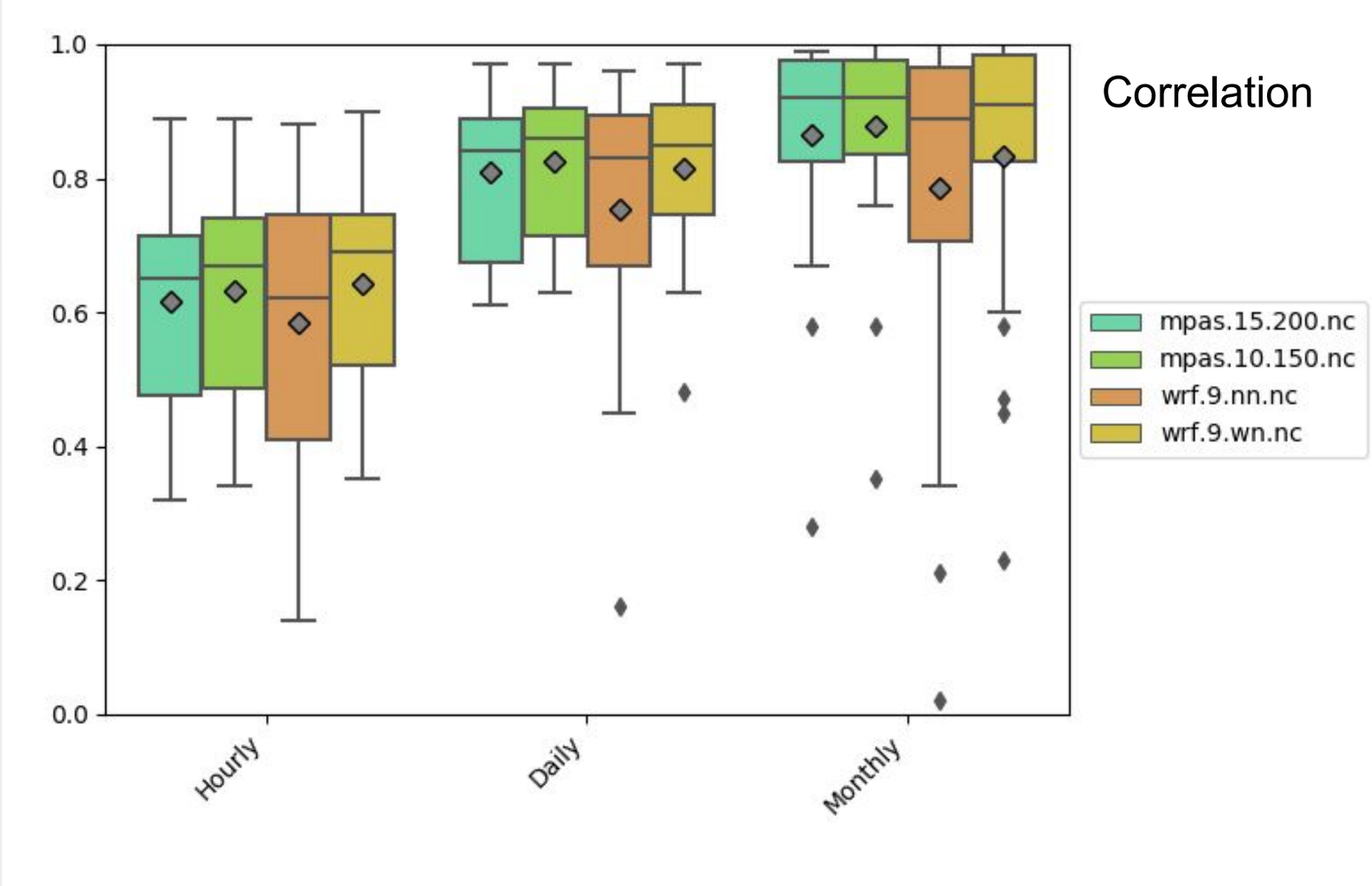


Results

Correlation with wind data

	Hourly	Daily	Monthly
mpas.15.200	.62 ± .16	.81 ± .11	**.86 ± .17**
mpas.10.150	.63 ± .16	.82 ± .10	**.88 ± .15**
wrf.9.nn	.58 ± .21	.75 ± .20	.78 ± .27
wrf.9.wn	.64 ± .16	.82 ± .12	.83 ± .21

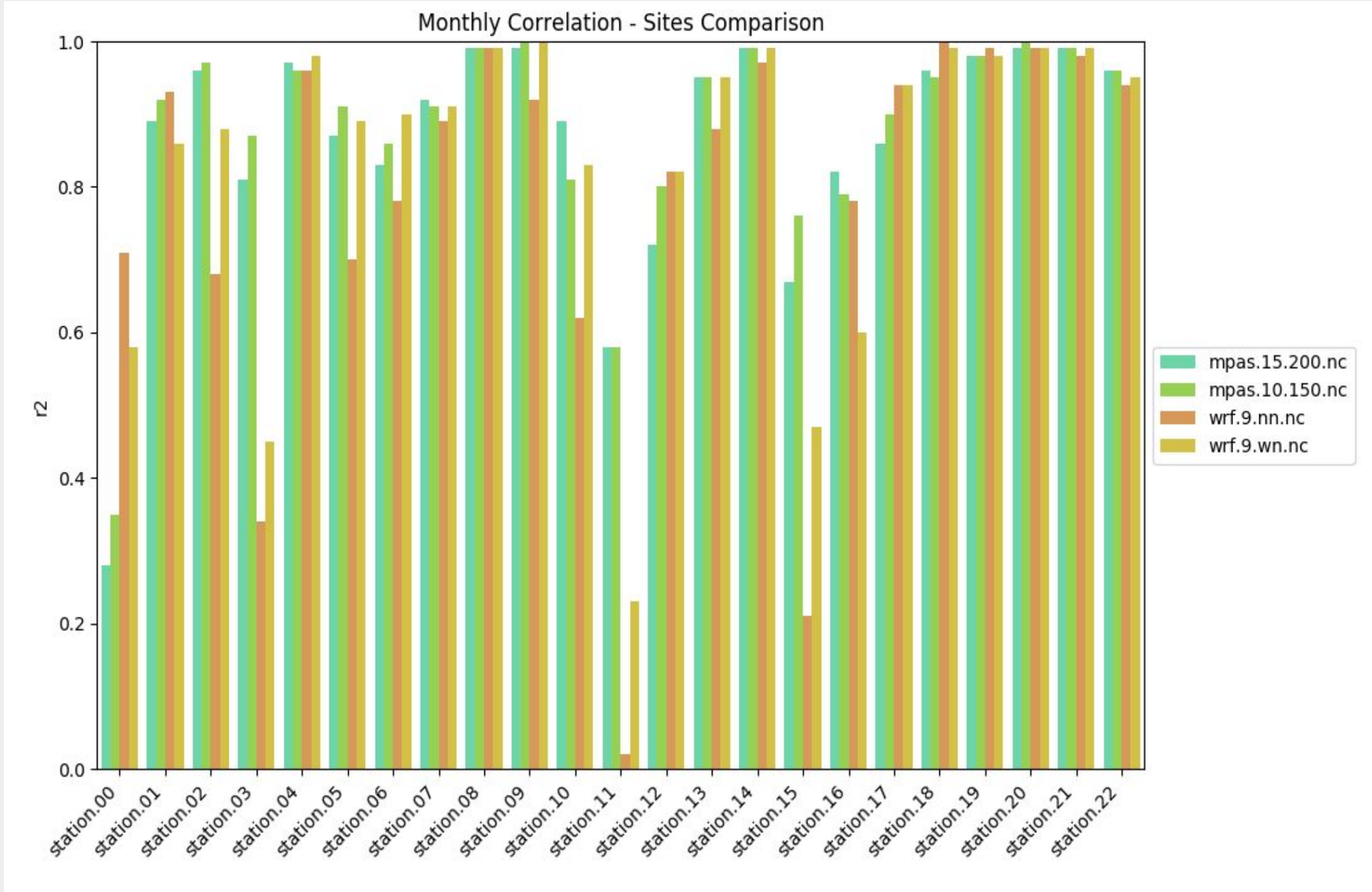
- Both MPAS simulations (without nudging) correlate better than WRF simulations, even when nudging is applied.



Results

Monthly Correlation.
By Sites.

- There are 3 sites where WRF without nudging gives less than 0.4 correlation. Nudging improves a little bit and MPAS performs significantly better.
- In station.00 the opposite happens.



Results

Computation: One Core

	Grid preparation time (min)	Average simulation 30h (min)
mpas.15.200	30	15
mpas.10.150	40	18
wrf.9.nn	0.5	12
wrf.9.wn	0.5	12

- MPAS is prepared to be run in parallel
- The test simulations were run using one core because of Vortex cluster current behaviour.
- Using one core, MPAS does not seem to go faster than WRF (for a comparable number of grid cells)

Conclusions & Next Steps

Right now there are limitations/doubts:

- The available meshes only reach 3km resolution
- Limited Area regions contain many cells due to a lack of suitable global meshes
- No nudging available.
- MPAS does not seem to go faster than WRF (without parallel computing)

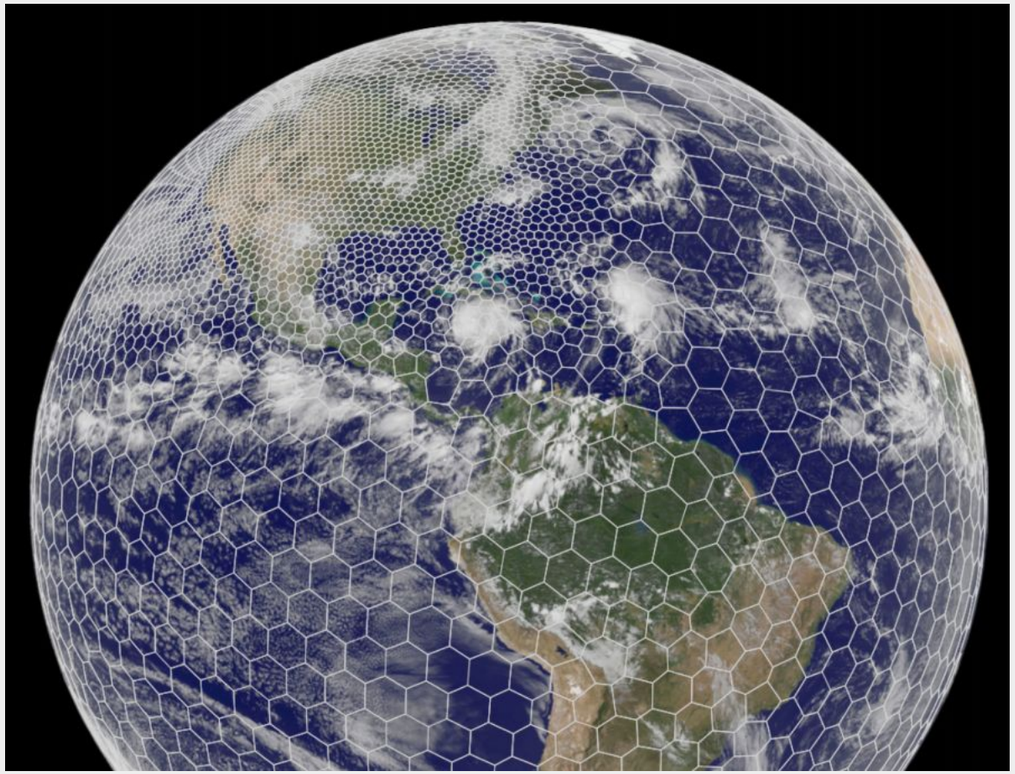
Some interesting ideas:

- Excellent monthly correlations: does MPAS grid structure capture the long term and large scale characteristics better?
- Parallel computing may be the key to run longer and more demanding simulations

Next Steps & Conclusions

New Version of MPAS coming up

It is interesting to follow the development and perform further tests.



Thank you for your attention

Questions?