The Geogrid Program: Map Projections and Model Domains

Lecture 2

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Lecture Objective and Learning Outcomes

Lecture objective

To explain how the geogrid program defines WRF model domains: the choice of map projection, the location, size and resolution of the domains, and the static geographical fields.

Learning outcomes

By the end of this lecture, students will be able to:

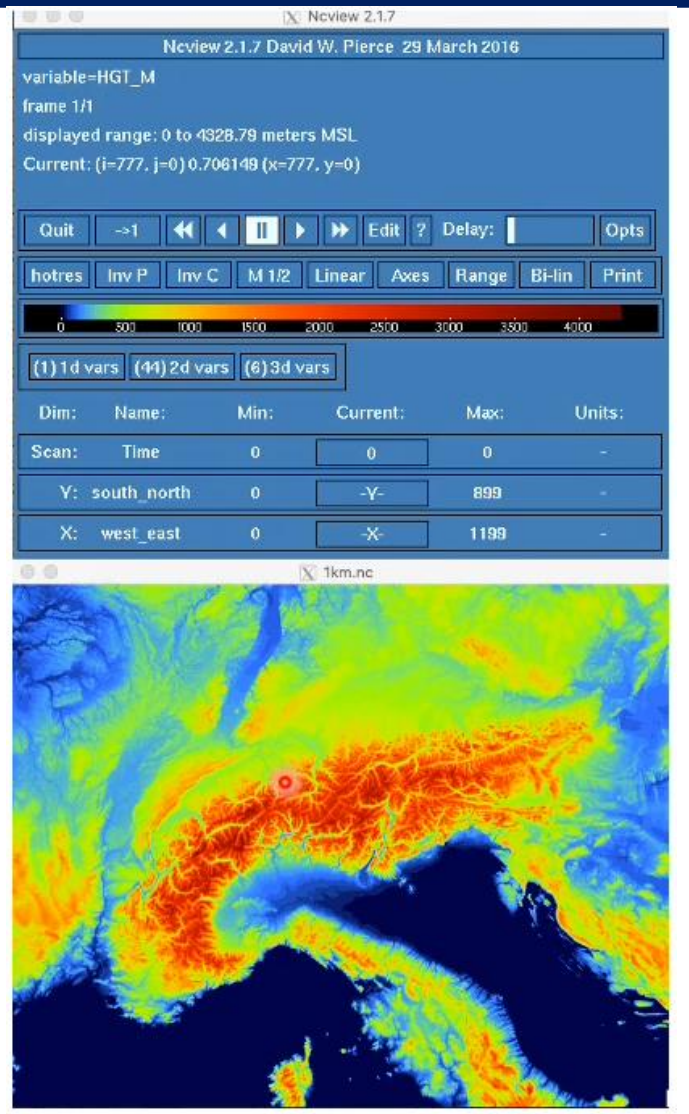
1. explain the two tasks of geogrid: defining the domains and providing static fields;
2. choose a suitable map projection for a domain depending on its latitude;
3. explain why the map scale factor should stay close to 1;
4. set the main domain parameters in the &geogrid section of namelist.wps;
5. describe a nested configuration and list the fields stored in the geo_em files.

What Does WRF Look Like to the User?

A set of programs (mostly in Fortran):

- No GUI,
- Command-line
- Simple graphic tools

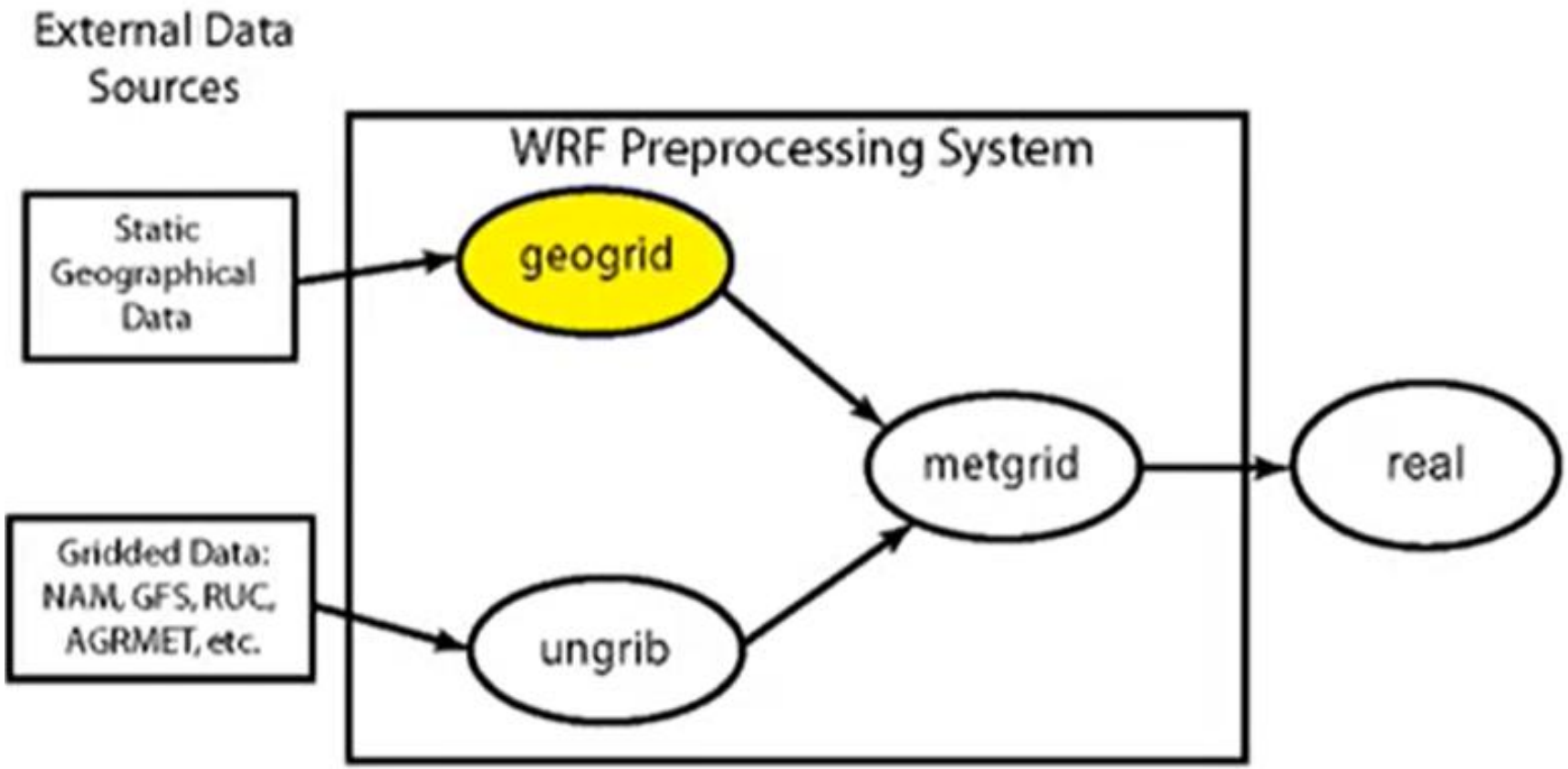
```
> tar -xf WRF-4.1.2.tar.gz
> cd WRF-4.1.2
> configure
> compile em_real >& compile.log &
> cd run/
> ln -s ../../WPS-4.1/met_em.d01.* .
> mpirun -np 4 real.exe
> ls -l wrfinput* wrfbdy*
> mpirun -np 8 wrf.exe
```



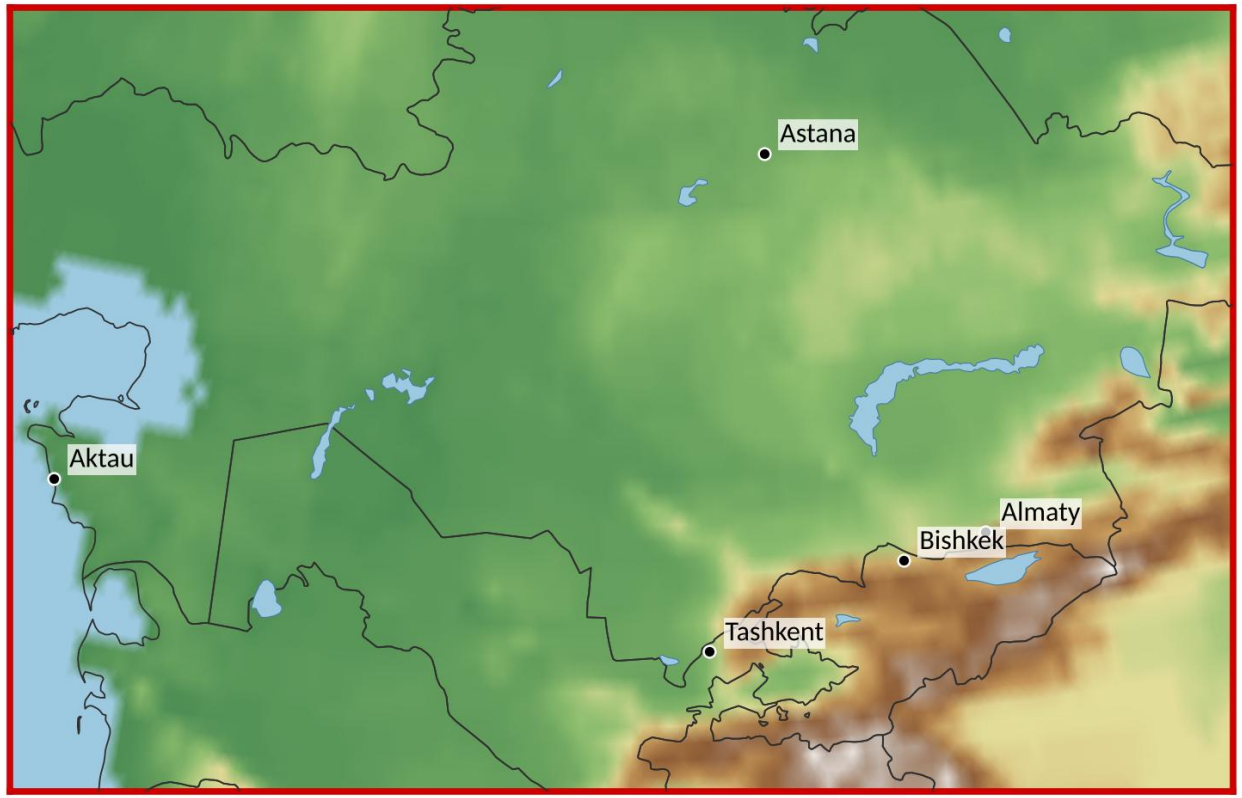
The model has many functions:

- Many ways to run the model
- Decisions needed at every step
- Best practices required

Where Geogrid Fits in the WPS Workflow



The Geogrid Program



Suppose we wish to run a simulation for this domain

- Where is the domain located?
- What area does it cover?
- How well do we resolve the atmosphere and the land surface horizontally?
- Which data do we use for topography, vegetation and soil categories?

Geogrid answers these questions from the point of view of the WRF model

What Geogrid Does

1. Defines the model domains

- Map projection (all domains must use the same projection)
- Geographic location of the domains
- Dimensions of the domains
- Horizontal resolution of the domains

2. Provides static fields at every grid point

- Computes latitude, longitude, map scale factor and Coriolis parameter
- Interpolates terrestrial data from global datasets:
  - topography height
  - land-use category
  - soil type
  - vegetation fraction
  - monthly surface albedo

Choosing a Map Projection

Why do we need a projection?

- The real Earth is (roughly) an ellipsoid
- WRF computational domains are rectangles in a plane

WRF-ARW supports four projections

Lambert conformal

mid-latitudes

Mercator

low latitudes

Polar stereographic

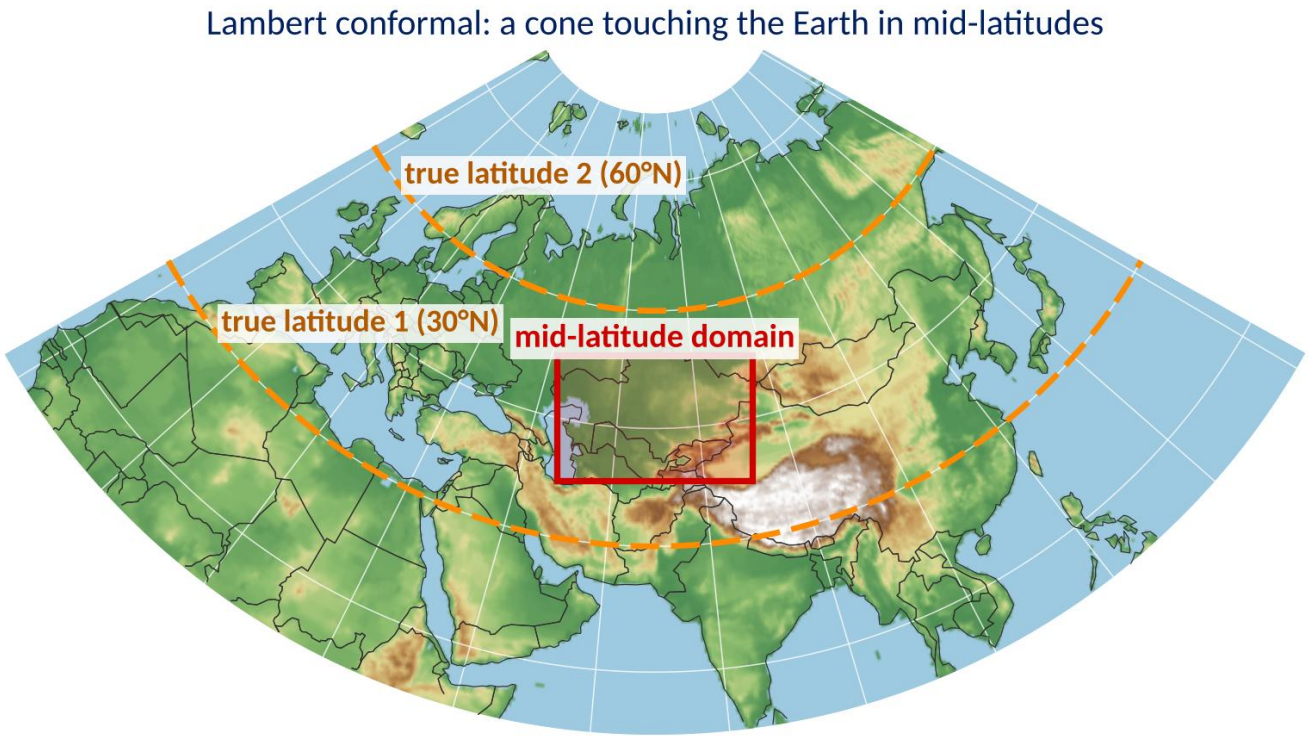
high latitudes

Latitude–longitude

global domains (required)

Projections: Lambert Conformal

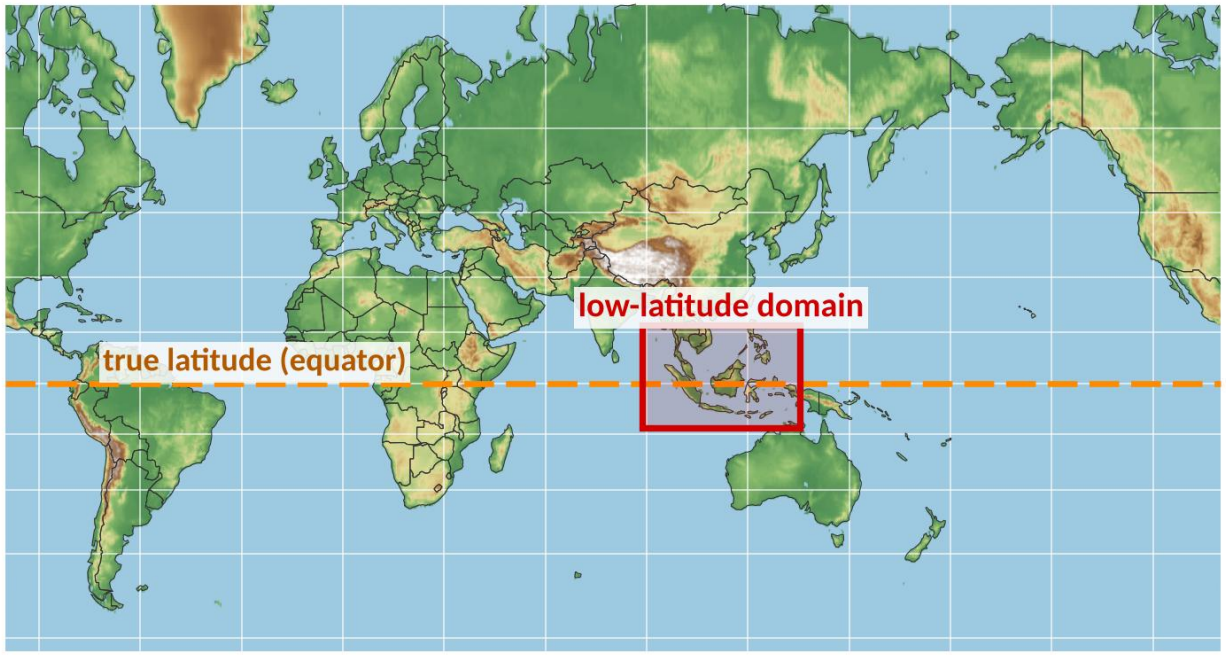
- Well suited for mid-latitudes
- Domain cannot contain either pole
- Domain cannot be periodic in the west–east direction
- One or two true latitudes may be specified (truelat1, truelat2)



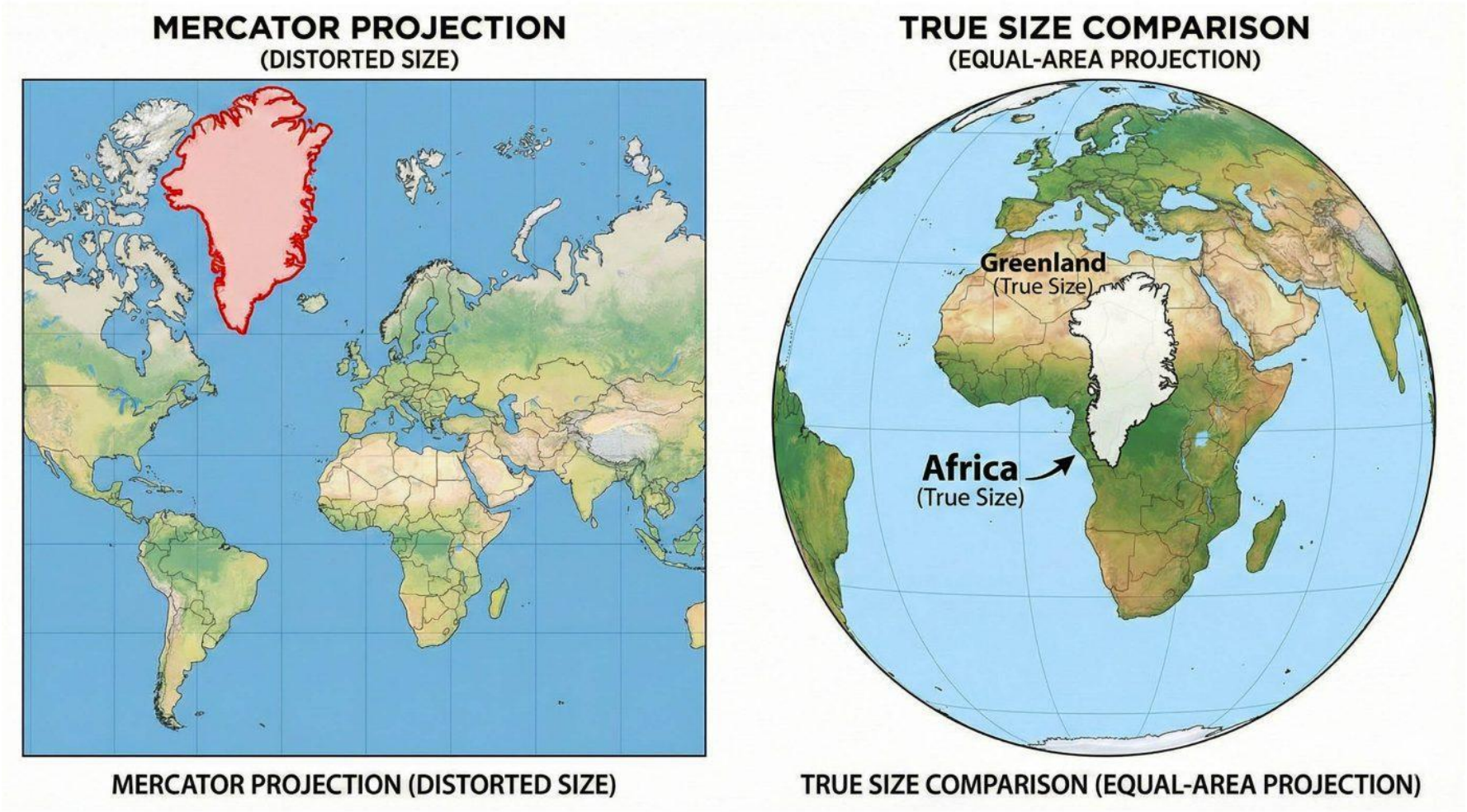
Projections: Mercator

- Well suited for low latitudes
- May be used for a “channel” domain (periodic in the west–east direction)
- A single true latitude is specified

Mercator: a cylinder around the Earth; meridians are parallel

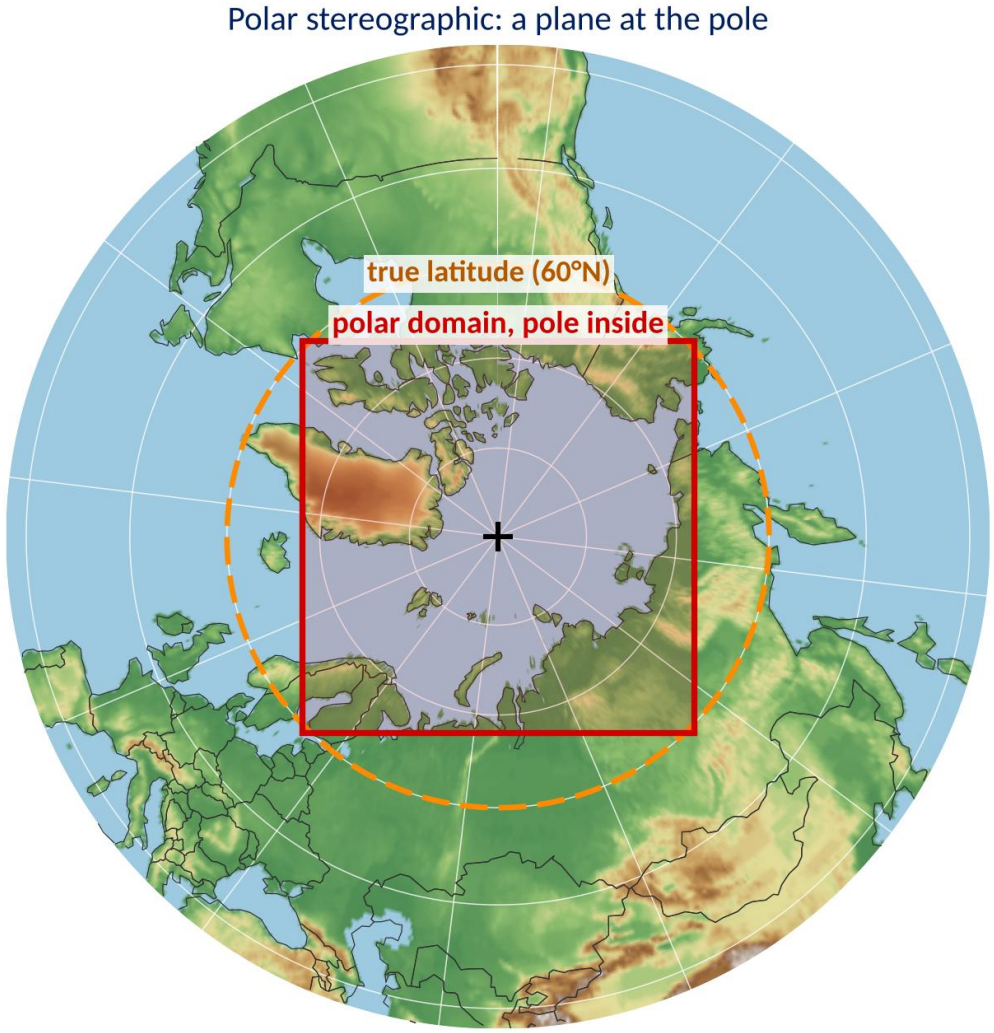


Mercator: Distortion of Area



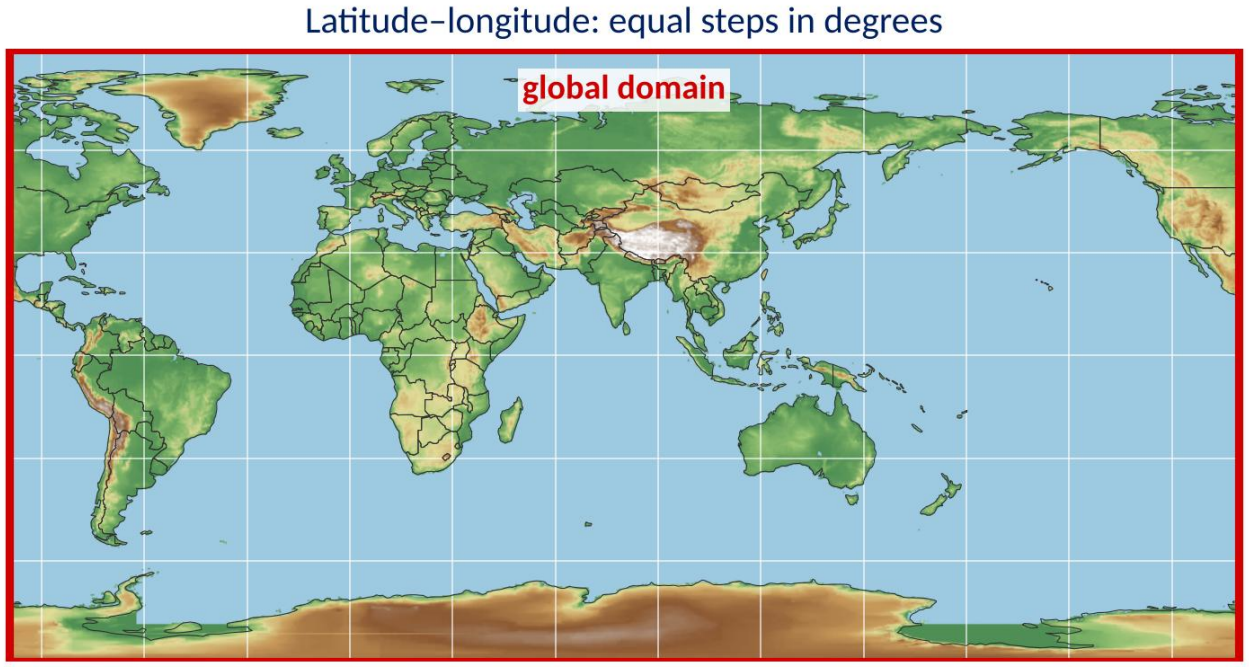
Projections: Polar Stereographic

- Good for high-latitude domains
- The domain may contain a pole
- A single true latitude is specified



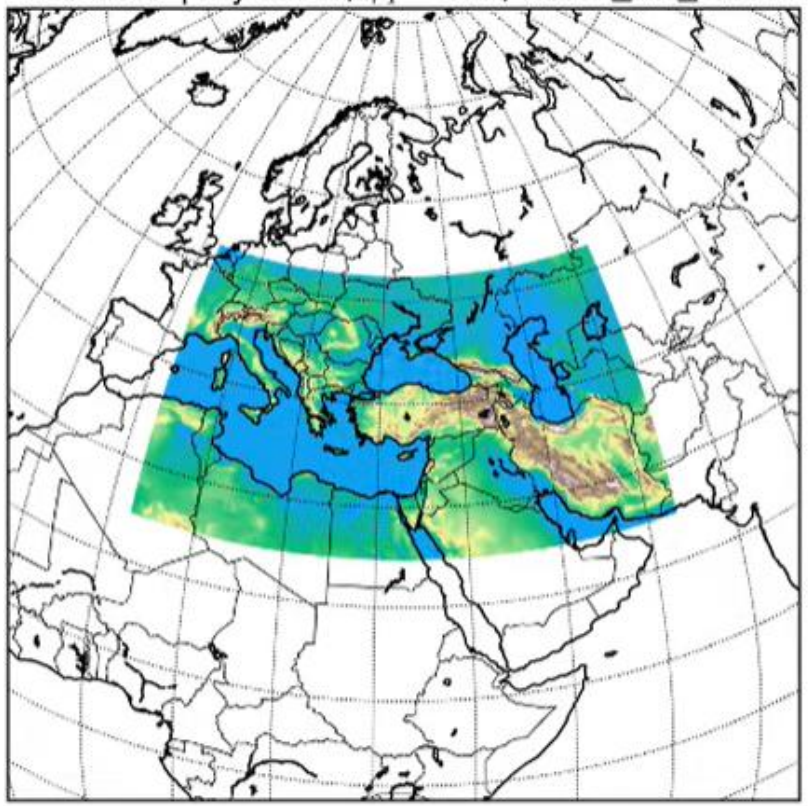
Projections: Cylindrical Equidistant (Lat–Lon)

- Required for global domains
- May be used for regional domains
- Can be used in its normal or rotated aspect
- Grid spacing in kilometres is not uniform



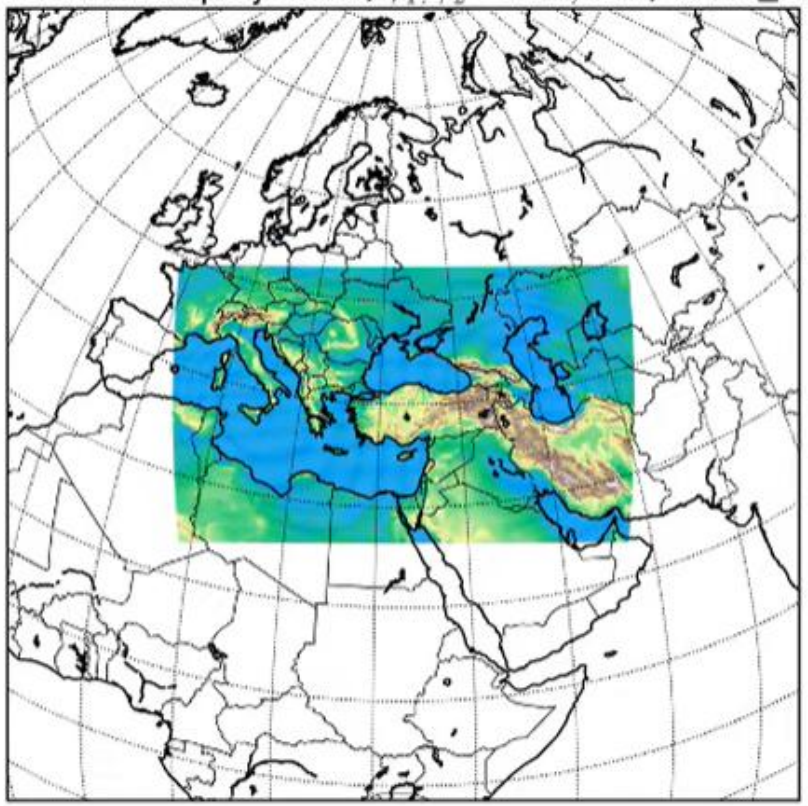
Why Do Projections Matter?

Mercator projection, $\phi_1 = 42.0,\ 0.819 \leq m \leq 1.218$



*For a nominal 12-km grid, the above projection yields grid distances from **9.9 km to 14.6 km**.*

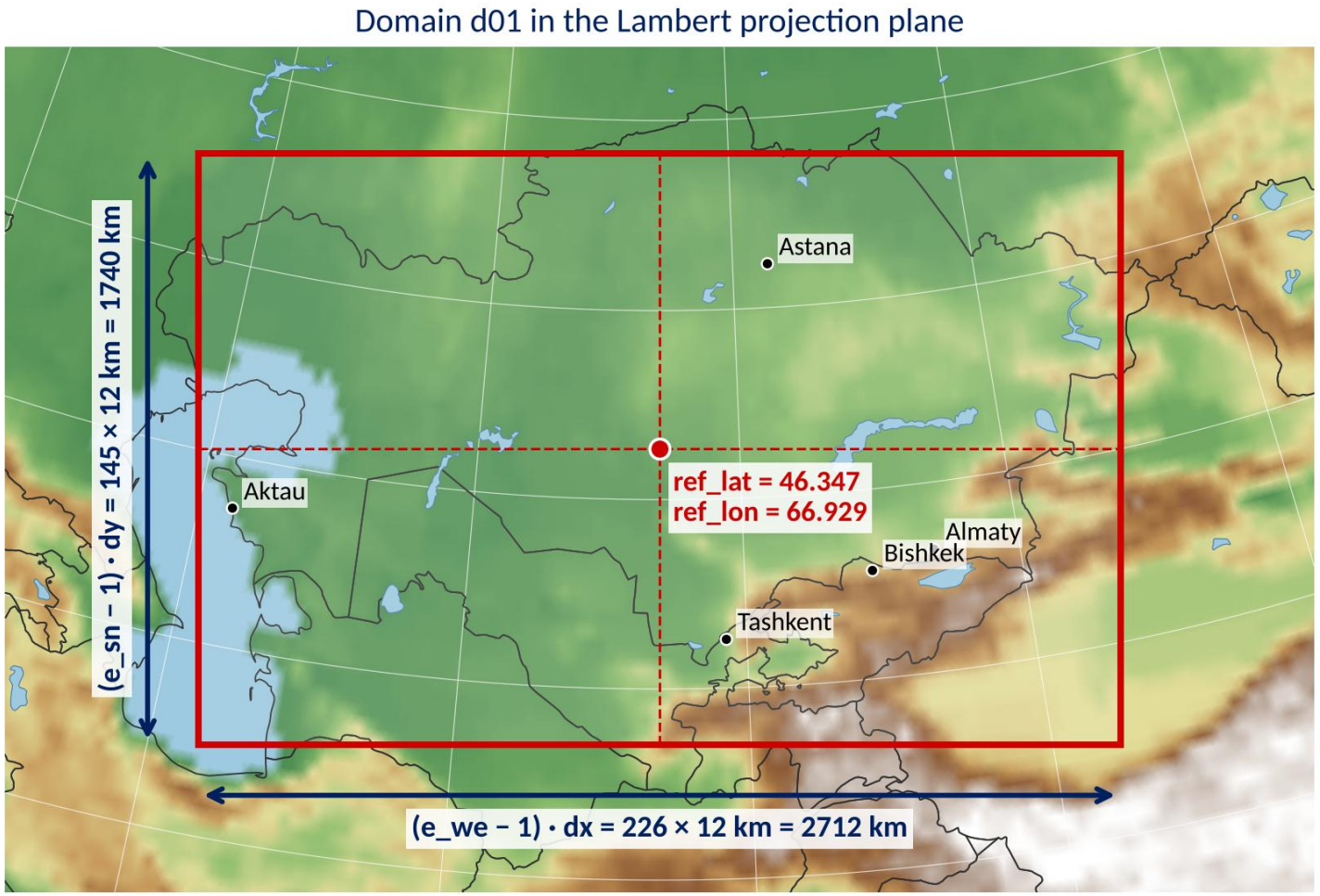
Lambert conformal projection, $\phi_1, \phi_2 = 30.0, 47.5,\ 0.988 \leq m \leq 1.023$



*For a nominal 12-km grid, the above projection yields grid distances from **11.7 to 12.1 km**.*

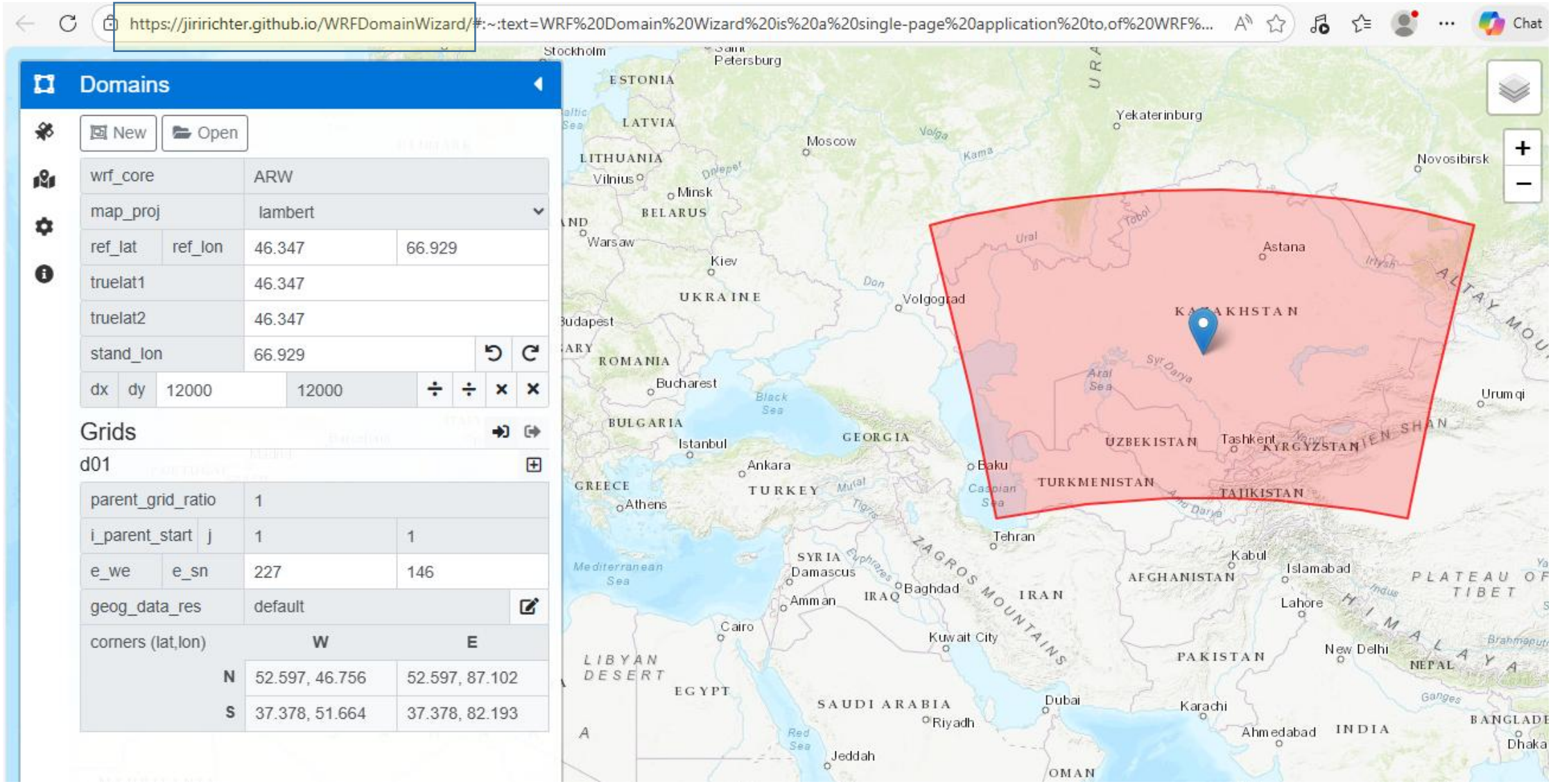
Choose the projection that keeps the map scale factor close to 1 over your domain

Defining a Domain in namelist.wps

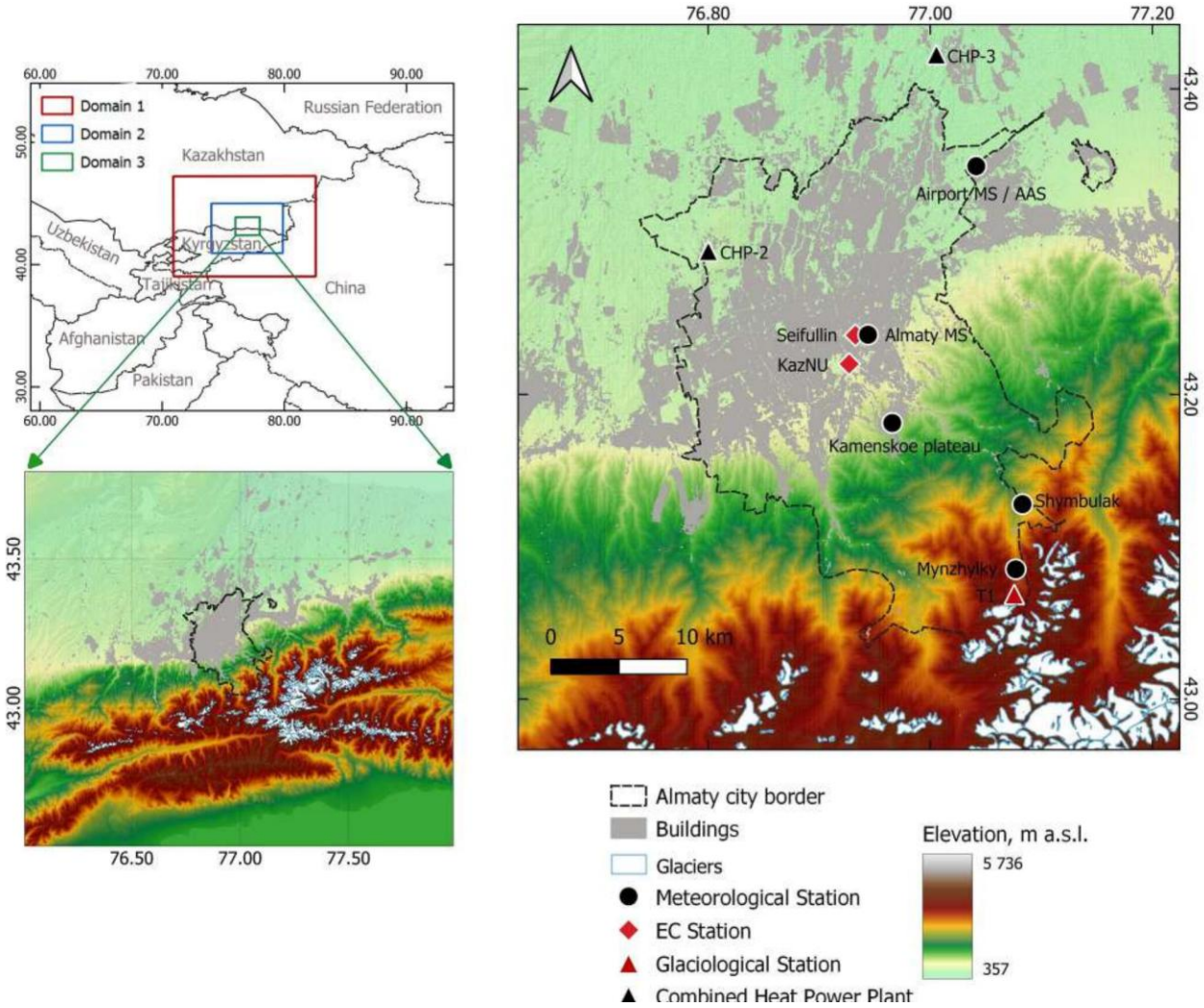



```
&geogrid
 e_we       = 227,
 e_sn       = 146,
 dx         = 12000,
 dy         = 12000,
 map_proj   = 'lambert',
 ref_lat    = 46.347,
 ref_lon    = 66.929,
 truelat1   = 46.347,
 truelat2   = 46.347,
 stand_lon  = 66.929,
 geog_data_res = 'default',
/
```

WRF Domain Wizard



A Real Configuration: Nested Domains for Almaty



WRF-CHIMERE study of black carbon

- Three nested domains: 9 km → 3 km → 1 km (ratio 3 : 1)
- Innermost domain: Almaty and the northern slopes of the Ile Alatau
- 50 vertical levels
- Terrain: GMTED2010, 30 arc-seconds
- Land use: USGS, 24 categories
- Periods: January and July 2023

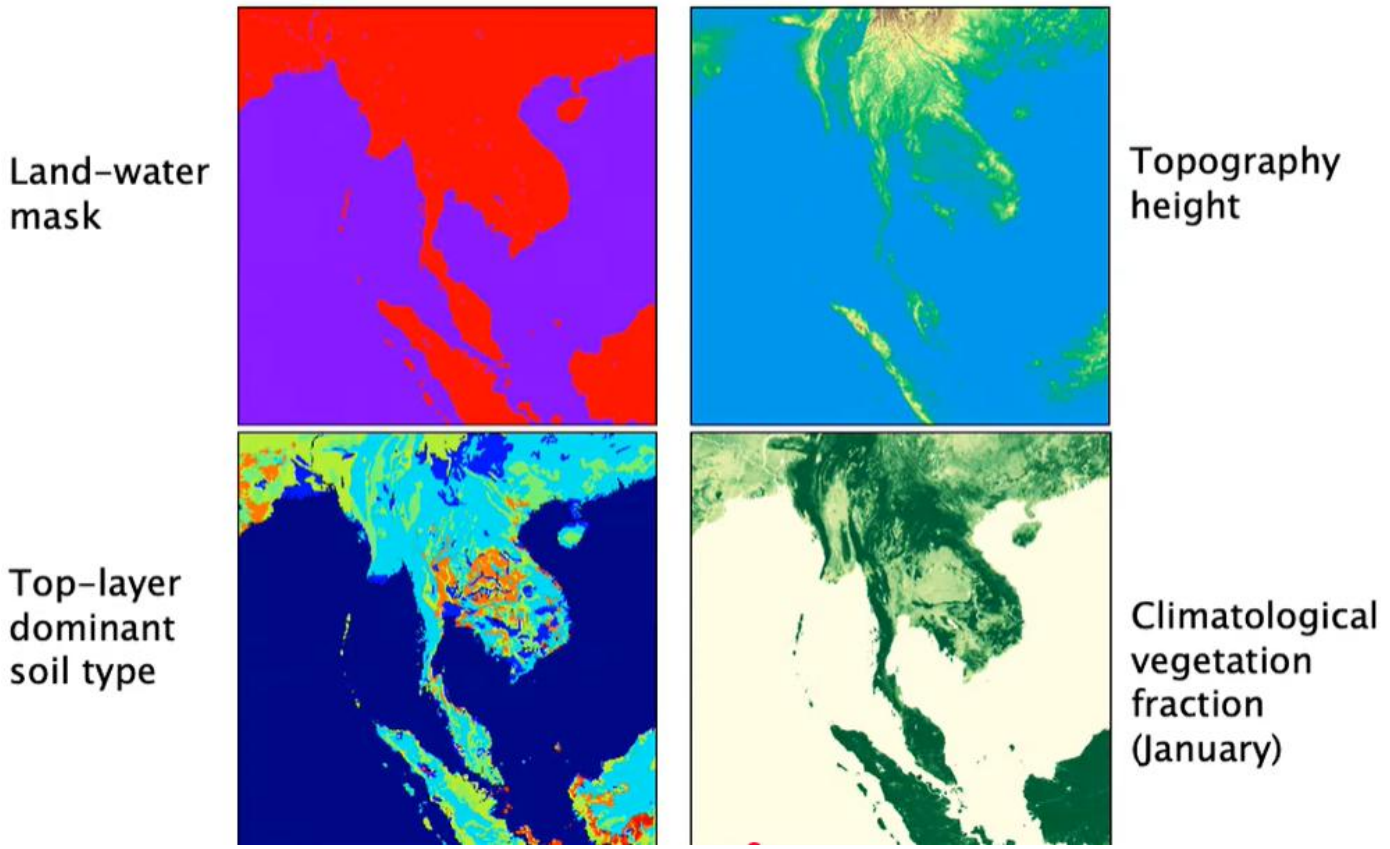
Source: Tursumbayeva et al. (2026), Meteorological Applications, 33, e70183

Geogrid Output Fields

Geogrid interpolates terrestrial, time-invariant fields onto each grid

- Topography height
- Land-use categories
- Soil type (top and bottom layer)
- Annual mean soil temperature
- Monthly vegetation fraction
- Monthly surface albedo

Output: geo_em.d01.nc, geo_em.d02.nc, … (one file per domain)



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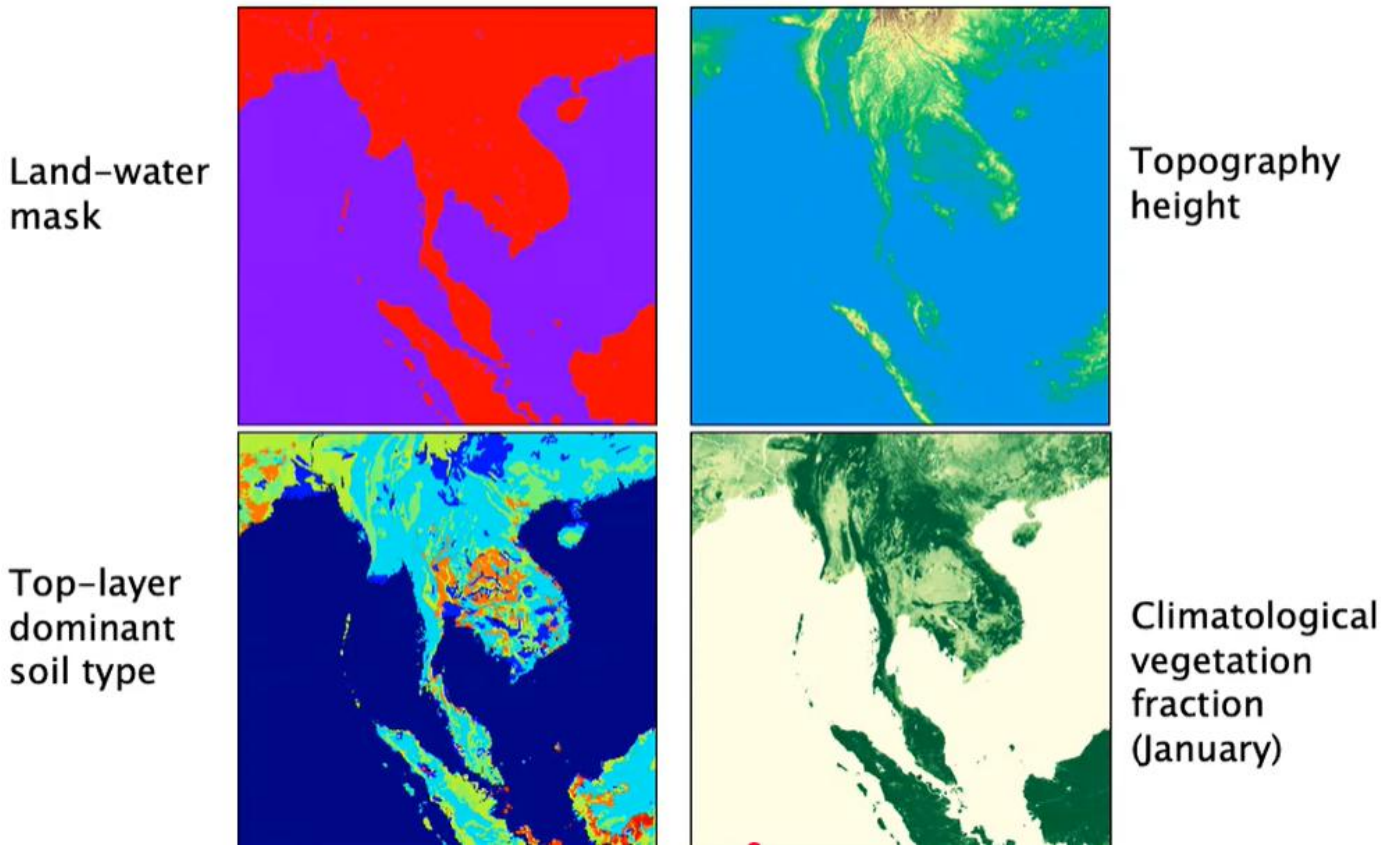

Conclusion

Key points

1. WRF is a set of command-line programs; the user makes decisions at every step.
2. Geogrid defines the domains (projection, location, dimensions, resolution) and interpolates static data onto the grid.
3. Four projections: Lambert conformal (mid-latitudes), Mercator (low latitudes), polar stereographic (high latitudes), latitude–longitude (global domains).
4. Choose the projection that keeps the map scale factor close to 1 over the domain.
5. The domain is set in namelist.wps: e_we, e_sn, dx, dy, map_proj, ref_lat, ref_lon, truelat1, truelat2, stand_lon.
6. Output: one geo_em file per domain with time-invariant fields (topography, land use, soil type, vegetation fraction, albedo).

Self-Check Questions

1. Which questions about a simulation does geogrid answer?
2. Why does WRF need a map projection?
3. Which projection would you choose for a domain over Kazakhstan, and why?
4. What does the map scale factor show, and why should it be close to 1?
5. What do e_we, e_sn, dx and dy define in namelist.wps?
6. Which static fields does geogrid write to the geo_em files?

References

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2. Tursumbayeva, M., Ciarelli, G., Di Antonio, L., Bettineschi, M., Kissebayev, D., & Baimatova, N. (2026). Modelling the Black Carbon Variability and Dynamics in Almaty, Kazakhstan, During Winter and Summer Seasons. Meteorological Applications, 33, e70183. https://doi.org/10.1002/met.70183
3. NCAR Mesoscale and Microscale Meteorology Laboratory. WRF-ARW Version 4 Modeling System User's Guide. https://www2.mmm.ucar.edu/wrf/users/ (Chapter 3: WRF Preprocessing System)
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7. Figure data: NOAA National Geophysical Data Center, ETOPO global relief model; Natural Earth, naturalearthdata.com.