# Animating multiple model-generated climate data-sets for the Mediterranean Region

ParaView User Day Europe

September 2023 – Lyon, France

Marco Miani - **Computational Support Specialist**

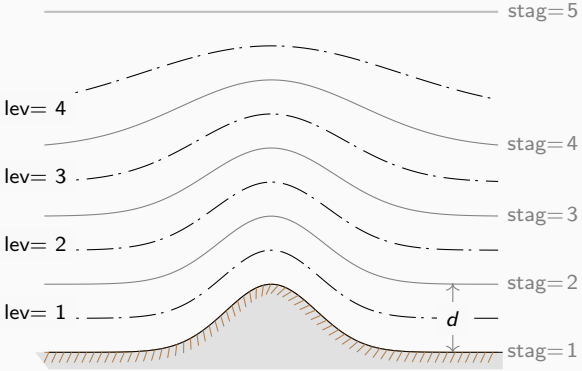
Climate and Atmosphere Research Center **(CARE-C)**
Environmental Prediction Department
The Cyprus Institute


# Background & Dissemination

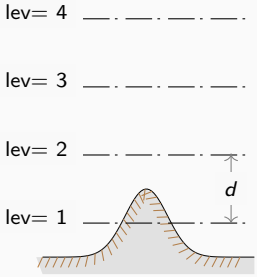
# Motivation & Problem Statement

**Motivation**: Restore vertical topology when using PARAVIEW and WRF data.
**Statement** : $z = f(time, lon, lat, vert)$ must be computed, 'replacing' $vert$

Terrain following: N unstaggered, N+1 staggered (N = 4)




"blind" Isobaric



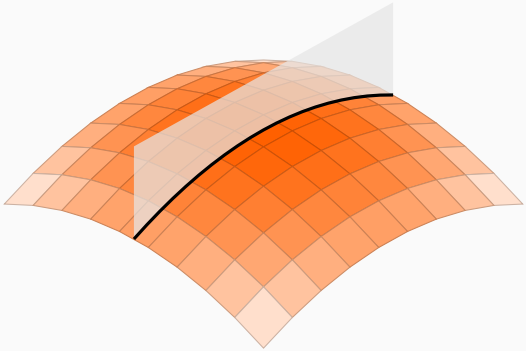
# WRF model data – Terrain Following Coordinates

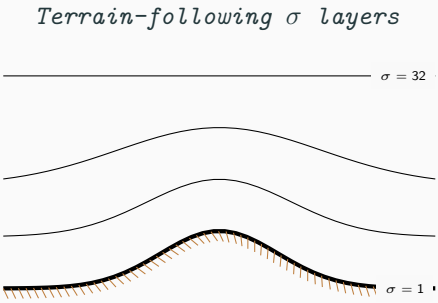
```
(netCDF)olddog@local:\~$ ncdump -h wrfoutput_File.nc
dimensions:
        Time          =  UNLIMITED   // (24 currently)
        west_east     =  115
        south_north   =  85
        bot_top_stag  =  32
        bot_top       =  31
variables:
        float XLAT  (Time, south_north, west_east) ;
        float XLONG (Time, south_north, west_east) ;
        float PH (Time, bot_top_stag, south_north, west_east) ;
        float press (Time, bot_top, south_north, west_east) ;
```

$$z(t,k,j,i) = PTOP + lev(k)*(PS(t,j,i)-PTOP)$$

[Eaton et al., 2022]

# Terrain following coordinates (a.k.a. sigma levels)

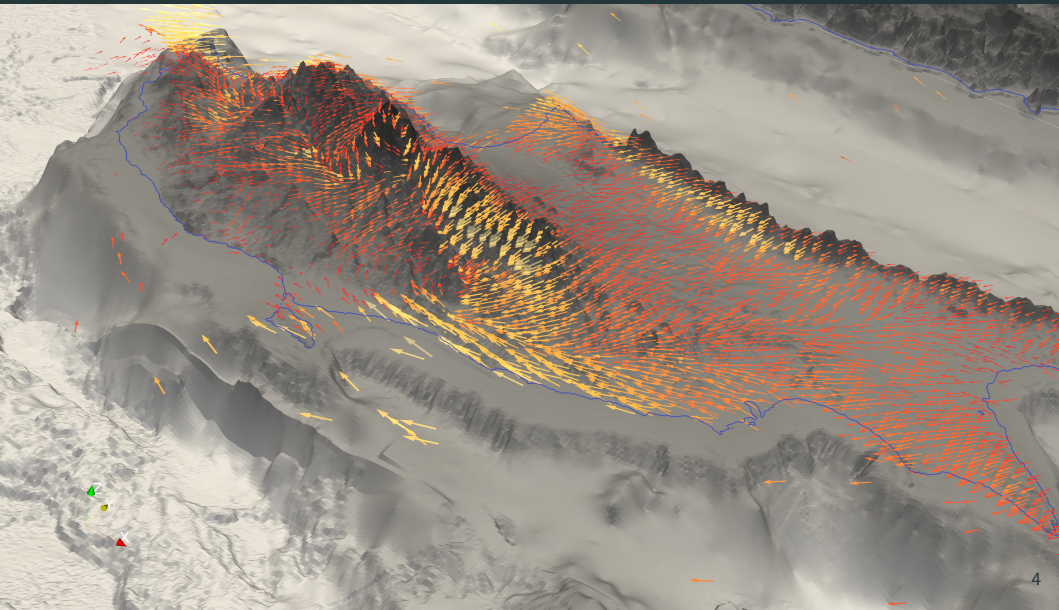


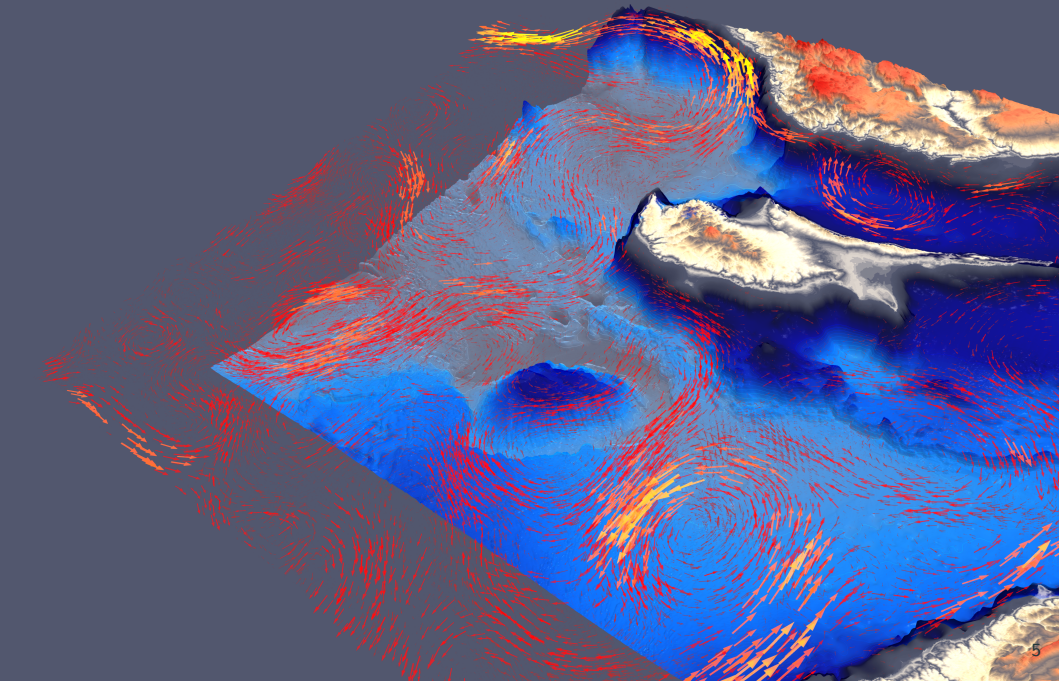



PARAVIEW parses the *level index*,
not the actual *level height*.

Note that: *index* level is constant.
However, *level height* is not!

# Terrain following wind field *(lev=1)*



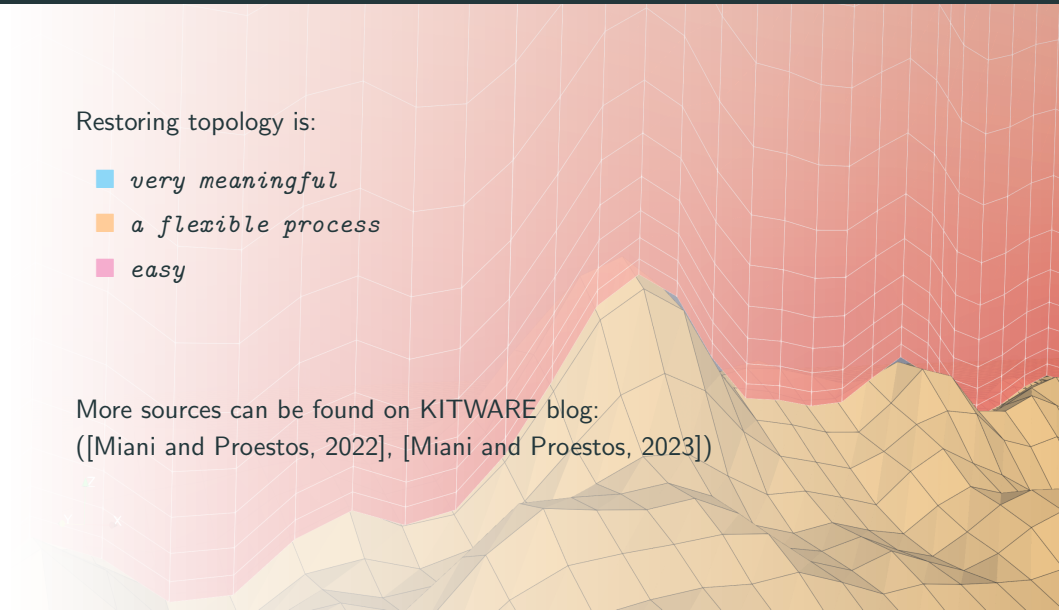


# Conclusions + Example (WRF, terrain following)

Restoring topology is:

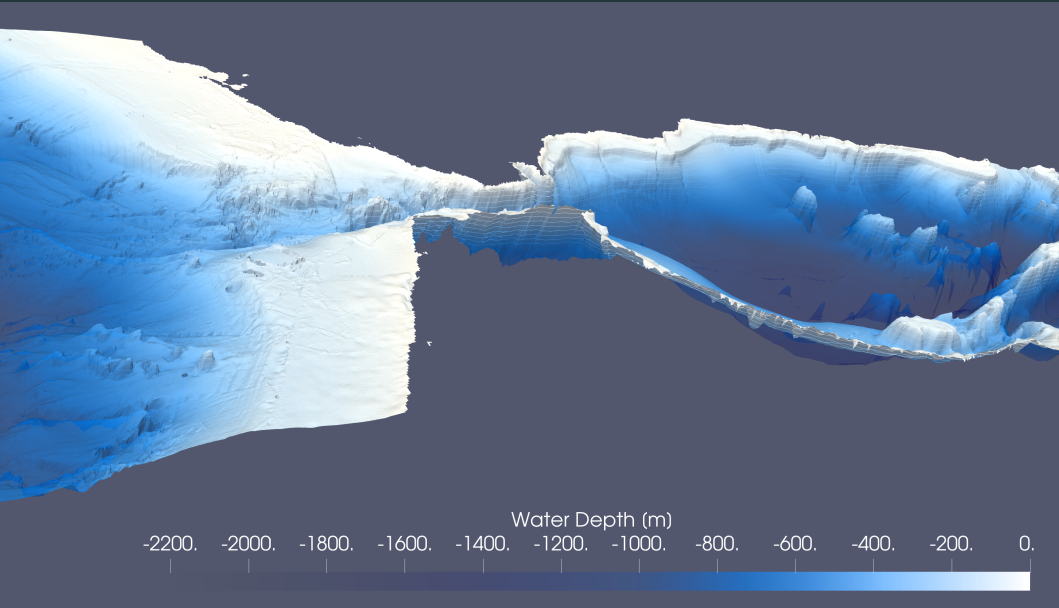
- *very meaningful*
- *a flexible process*
- *easy*

More sources can be found on KITWARE blog:
([Miani and Proestos, 2022], [Miani and Proestos, 2023])



# Animated Results: The Strait of Gibraltar

# High-Resolution Bathymetry



# References i



Eaton, B., Gregory, J., and Drachand, B. (version 1.11 draft, 31 August, 2022).
**Description of CF conventions.**
NetCDF Climate and Forecast (CF) Metadata Conventions.


Miani, M. and Proestos, Y. (2022).
**Scientific Visualization of Weather Research and Forecasting Model output in Paraview.**
KITWARE Official Blog Post (last accessed: Sept. 2023).


Miani, M. and Proestos, Y. (2023).
**Exporting WRF model results in Structured Grid format (.vts) – A PARAVIEW direct import.**
KITWARE Official Blog Post (last accessed: Sept. 2023).

# Acknowledgments

**Climate & Atmosphere Research Centre – The Cyprus Institute**

A regional Centre of Excellence for climate and atmosphere research in the Eastern Mediterranean and Middle East region

☞ https://emme-care.cyi.ac.cy/

The Cyprus Institute
RESEARCH•TECHNOLOGY•INNOVATION

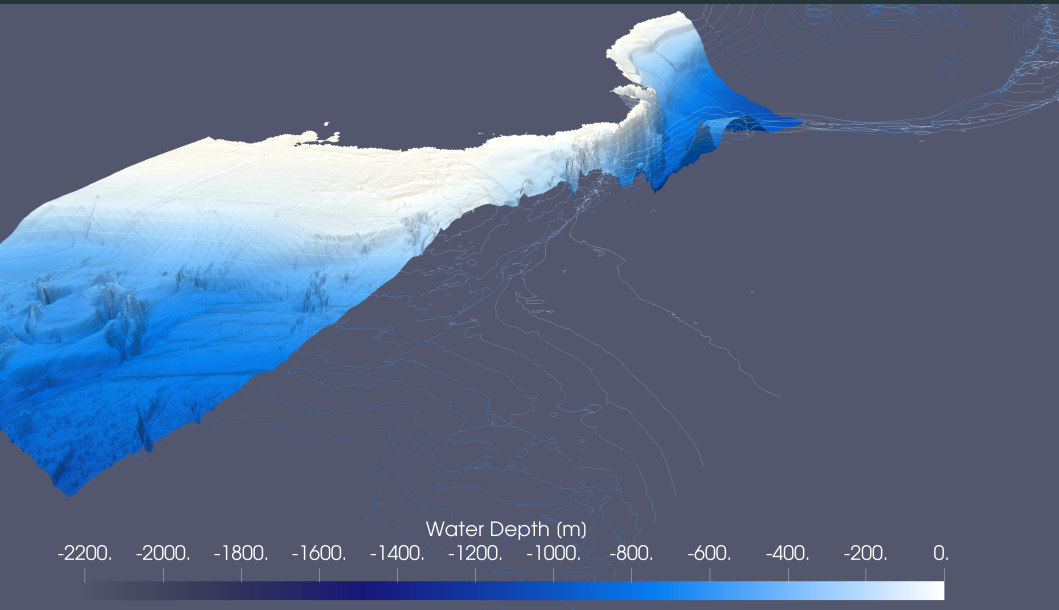
EMME-CARE
EASTERN MEDITERRANEAN MIDDLE EAST – CLIMATE & ATMOSPHERE RESEARCH CENTRE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 856612 and the Cyprus Government

*Supporting Slides*

```
import evtk as ev; import xarray as xr; import numpy as np

ds = xr.tutorial.open_dataset("ROMS_example.nc").isel(ocean_time=0)

#Restore topology and append
Zo_rho = (ds.hc * ds.s_rho + ds.Cs_r * ds.h) / (ds.hc + ds.h)
z_rho  = ds.zeta + (ds.zeta + ds.h) * Zo_rho
ds.coords["z_rho"] = z_rho.transpose()  #    transpose :
                                        #    lat,lon -> lon, lat

#Assign actual values for: x, y, z
for k in range(0, len(ds.s_rho)):
    x[k,:,:] = ds.lon_rho.values.T      #  T stands for transpose
    y[k,:,:] = ds.lat_rho.values.T
    z[k,:,:] = ds.z_rho.isel(s_rho=k).values.T

#Actual conversion !
ev.hl.gridToVTK('outFile',x,y,z,pointData = {'salt' : ds.salt.values})
```

# High Resolution Bathymetry (clipped), with contour lines



# Illustrating grid staggering and de-staggering

z = (PBH + PH)/9.81 [lat,lon index: 31, 31 - time index 0] Terrain height: 651.6 m

```
|---stag: 1  z: 651.6 m  [Terrain]
|     interface altitude : 680.1 m
|     DEstaggered layer  : 1
|     layer thickness    : 57.1 m
|---stag: 2  z: 708.6 m

|---stag: 2  z: 708.6 m
|     interface altitude : 749.7 m
|     DEstaggered layer  : 2
|     layer thickness    : 82.1 m
|---stag: 3  z: 790.8 m

|---stag: 3  z: 790.8 m
|     interface altitude : 844.7 m
|     DEstaggered layer  : 3
|     layer thickness    : 107.8 m
|---stag: 4  z: 898.6 m
```

```
|---stag: 30  z: 18163.8 m
|     interface altitude : 18573.0 m
|     DEstaggered layer  : 30
|     layer thickness    : 818.4 m
|---stag: 31  z: 18982.2 m

|---stag: 31  z: 18982.2 m
|     interface altitude : 19389.7 m
|     DEstaggered layer  : 31
|     layer thickness    : 814.9 m
|---stag: 32  z: 19797.2 m

|---stag: 32  z: 19797.2 m
|     interface altitude : 20202.8 m
|     DEstaggered layer  : 32
|     layer thickness    : 811.2 m
|---stag: 33  z: 20608.4 m [Model Top]
```

# U-Boats, Density Currents, and the Strait of Gibraltar

During WW2, German U-Boats used the currents to pass into the Med Sea undetected, by maintaining silence with engines off. No U-Boats ever made it back into the Atlantic and all were sunk in battle ("*Mausefalle*", a mousetrap).

On 18 September of 1984, a Soviet submarine trying to utilize the heavy shipping traffic to remain undetected, demonstrated how valuable a thorough knowledge of the oceanography in the strait can be. The submarine attempted to pass through the narrow straits while staying relatively close to the underside of a heavy tanker. This plan backfired, however, when an internal wave* caused the submarine to rise up unexpectedly and collide with the bottom of the tanker.

*The surface water in the strait consists of eastward flowing Atlantic water. At depth, there is dense, high-salinity westward flowing water. The water between these two layers is a mixing zone. Here internal gravity waves happen to form.