NCL - a workhorse for data analysis and visualization in climate research

Karin Meier-Fleischer (1), Michael Böttinger (1), and Mary Haley (2)
(1) Deutsches Klimarechenzentrum (DKRZ), Hamburg, Germany, (2) NCAR/CISL, Boulder (CO), USA

What are expectations about a data analysis and visualization tool for climate research?

A Swiss Army Knife

that can do everything!

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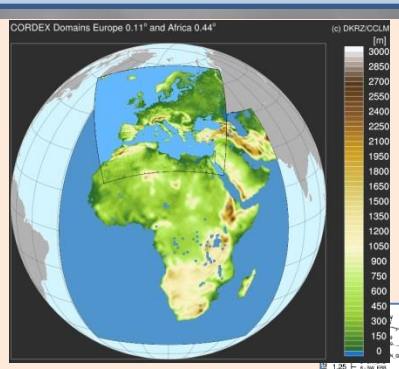
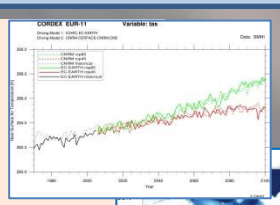
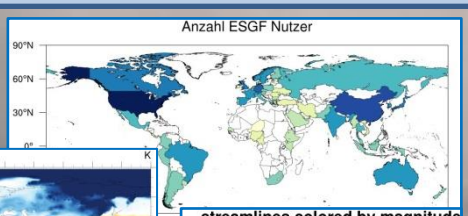
Get back to reality…

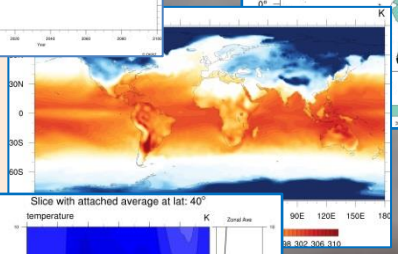
NCL can do a lot

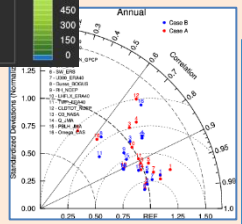
- Easy to use
- Many visualization options
- Pre-defined analysis functions
- Fast quick looks as well as high quality graphics
- Handling recti-, curvilinear and unstructured data
- Examples
- Documentation, active user community
- Common file formats to store the graphics

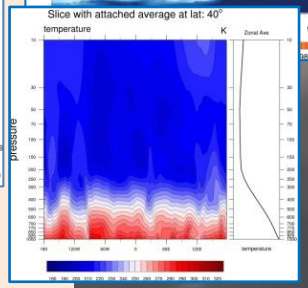


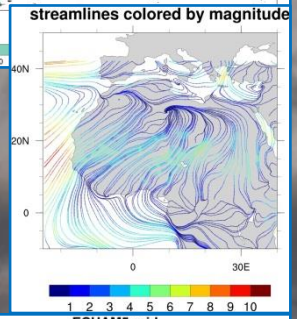


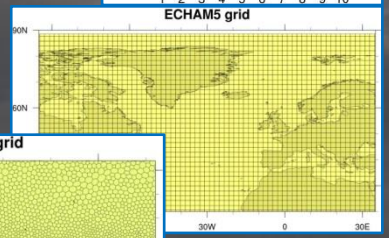


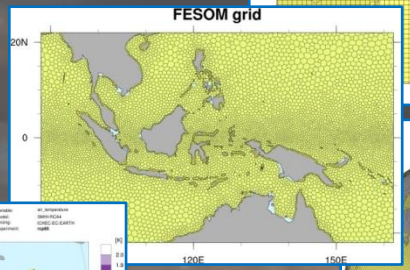


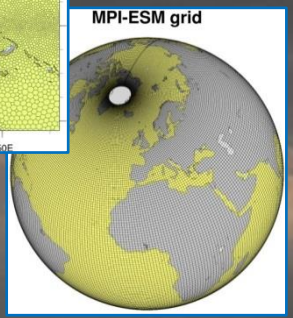


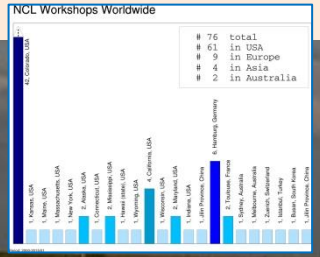


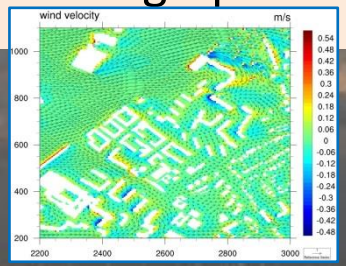


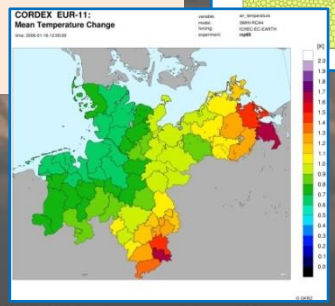












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Climate Models

Grid Types

Data Formats

Data Types

Output Types

Analysis Functions

Visualization Types

Benefits

Use cases

DKRZ's Involvement

- **Climate simulations** are carried out with **coupled Earth system models**
- **Supercomputers** and storage systems are used over years
- **Results**: very large and complex data sets
- **Data analysis and visualization** are essential part of the scientific workflow
- Different classes of **tools** are used for the analysis and visualization
- **This PICO: Focus on NCL** (NCAR Command Language), an interpreted language developed at the National Center for Atmospheric Research in Boulder, Colorado.

NCL - a workhorse for data analysis and visualization in climate research

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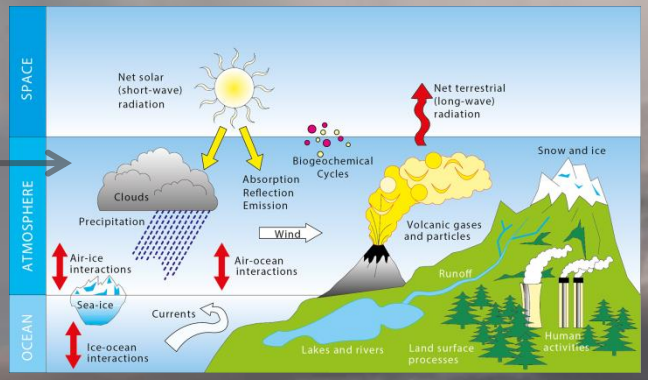
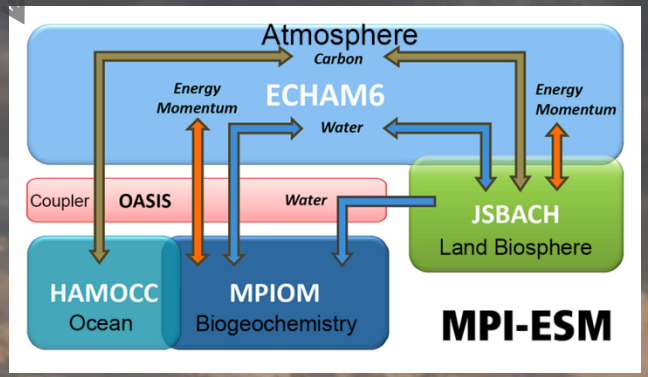
Climate Models

To understand the **climate system,** the different **physical** and **bio-geochemical processes and interactions** in atmosphere, ocean and on the land surface need to be taken into account.

To facilitate simulations of the whole Earth system, **coupled numerical models** of the different subsystems are used. Due to the model complexity, the spatial model resolution, the long simulation periods and the use of ensemble techniques to reduce the model uncertainty, powerful **supercomputers and storage systems** are needed for this research.





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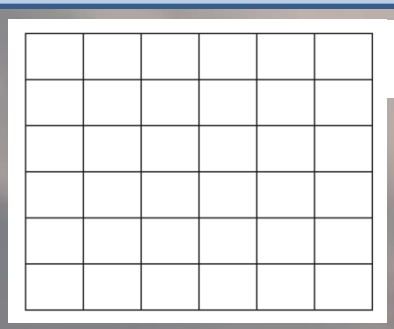
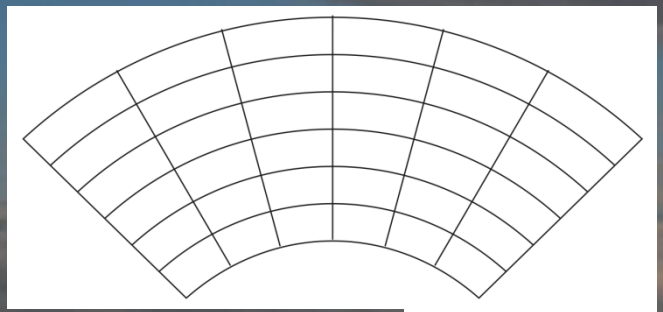
Grid Types

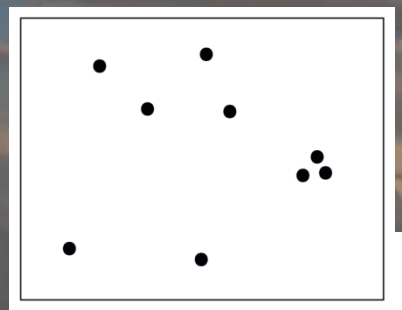
Numerical climate models require atmosphere and ocean to be divided into **grid cells**. Depending on the **discretization** and **numerical scheme** used, we have to deal with different **grid types** of the 3D time-dependent data. The algorithms used for the visualization are usually computationally less expensive for simpler grid types.

Simple grid type: **regular**, **rectilinear**
Complex grid types: **curvilinear**, **unstructured**


Regular


Rectilinear


Curvilinear


Unstructured

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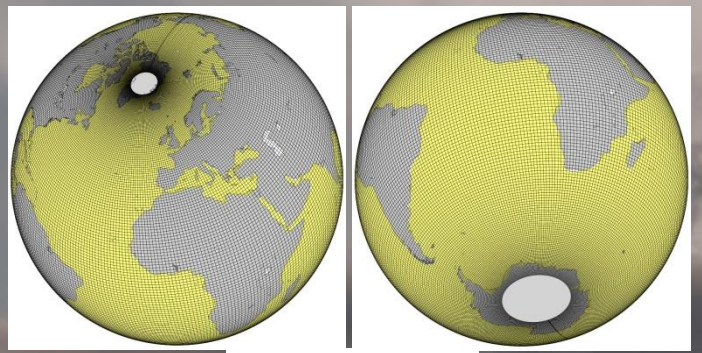
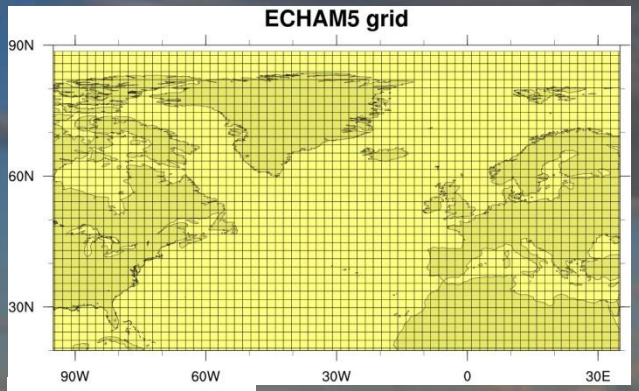
Grid Types of some models

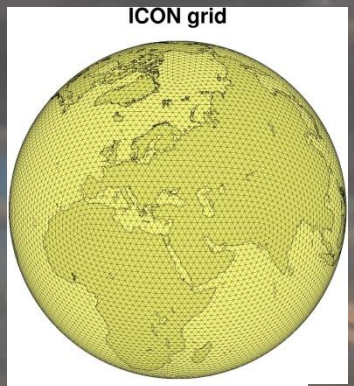
ECHAM → rectilinear
MPIOM → curvilinear
ICON → unstructured
FESOM → unstructured



Curvilinear



Rectilinear



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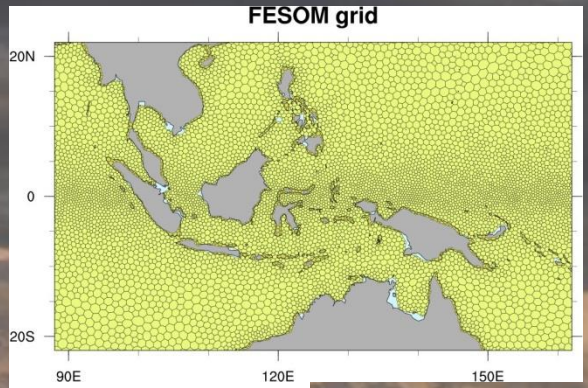

Unstructured

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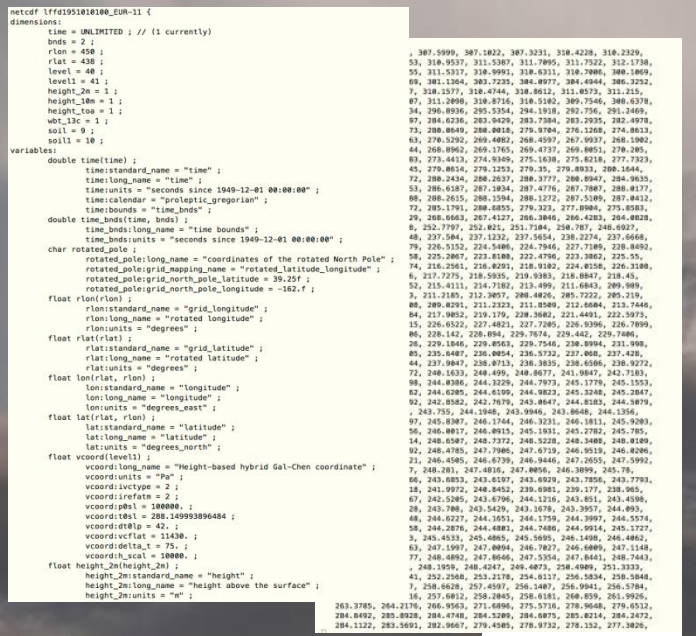
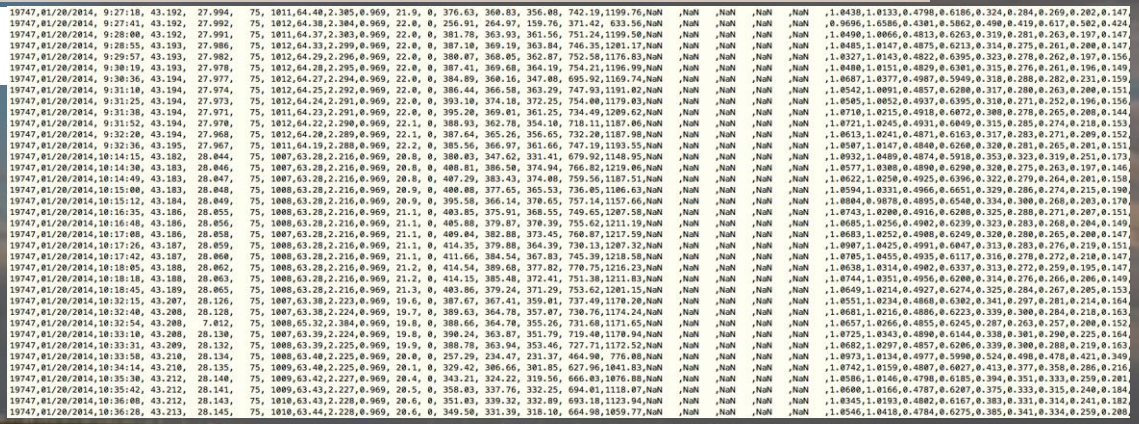
Data Formats

- ASCII
- Binary
- GRIB 1, GRIB 2
- netCDF 3, netCDF 4
- HDF4, HDF5
- HDF_EOS2, HDF_EOS5
- Shapefile



netCDF

ASCII



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NCL

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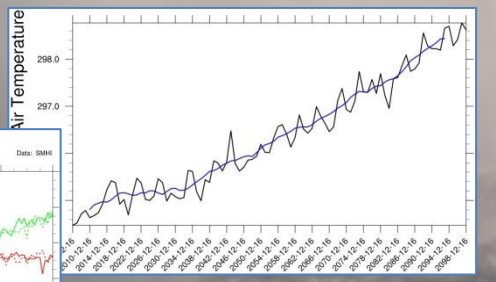
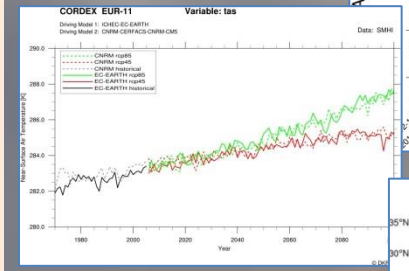
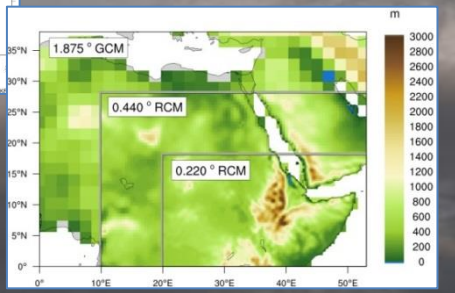
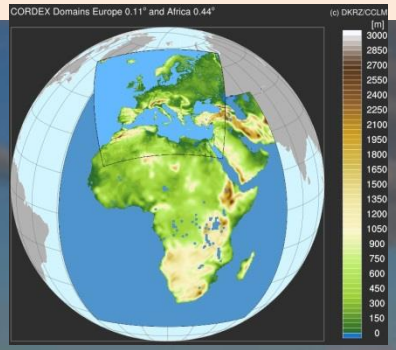
NCL (**N**CAR **C**ommand **L**anguage)

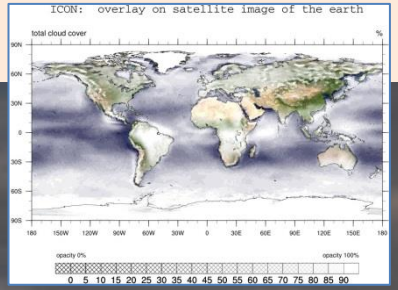
is an interpreted language which allows performing standard analysis operations and producing graphical output loosely coupled with the simulations. About 600 built-in functions specifically for climate model data, facilitating analysis of scalar and vector quantities as well as numerous state-of-the-art 2D visualization methods, and 18 map projections are provided.

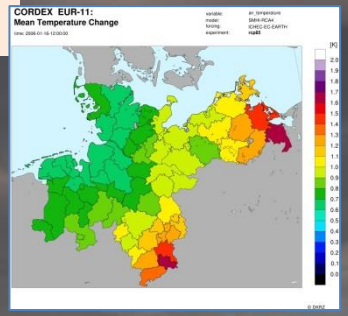


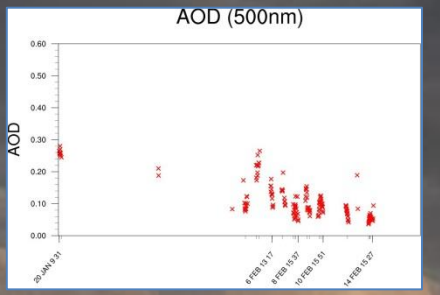


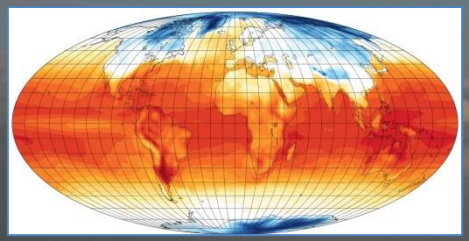


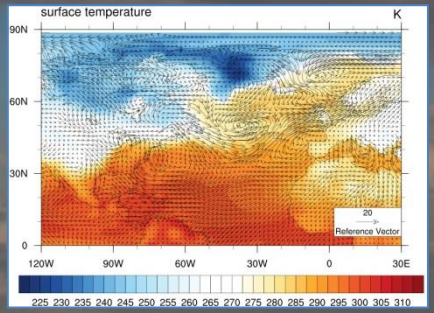


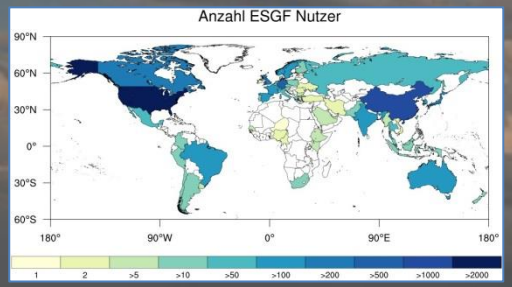












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Data Types

- ASCII
- Binary
- GRIB1, GRIB2
- netCDF3, netCDF4
- HDF4, HDF5
- HDF_EOS2, HDF_EOS5
- Shapefiles

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NCL Export Data Types

- **PS**
- **EPS**
- **EPSI**
- **PDF**
- **PNG**
- **SVG**
- **NCGM**
- **X11** (graphics output only to X11 window)

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NCL Analysis Functions

(more than 600 built-in analysis and visualization functions)

Earth Science:	
Climatology	seasonal means, standard deviations of monthly means, daily/monthly anomalies of daily data climatology, long term daily means, daily from monthly climatology, …
CESM	Functions for Community Earth System Model
Date	Date conversion and formatting routines, …
Lat/Lon functions	Generates Gaussian latitudes, land sea mask, reorder longitude array, …
Metadata/missing values	Copy/delete metadata, set/get missing value, set/get attributes, …
Meteorology	Zonal mean, weighted average, potential vorticity, sea level pressure, …
Oceanography	Convert ocean depth to pressure, remap POP grid, …
WRF functions	Specific functions and procedures for WRF ARW model data

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NCL Analysis Functions

Arithmetic and statistics:	
Arithmetic functions	sin, cos, tan, atan, atan2, averages, variance, min/max, …
Cumulative distribution functions	Binominal density, number of success, number of binominal trials, …
Empirical orthogonal functions	Calculates empirical orthogonal functions via a correlation matrix, …
ESMF regridding	From rectilinear, curvilinear, and unstructured grid to any of these types
Interpolation	Bilinear, cubic spline, natural neighbor, inverse distance weighted, …
Random number generators	Pseudo random numbers and 2D arrays, using gamma distribution, …
Regridding	rectilinear, curvilinear, unstructured, area conserve, local area, …
Singular value decomposition	Singular value decomposition to return the left and right homogeneous and heterogeneous arrays associated with the two input datasets, …
Spherical harmonics	Wind components via spherical harmonics, given vorticity and divergence on a fixed grid, …

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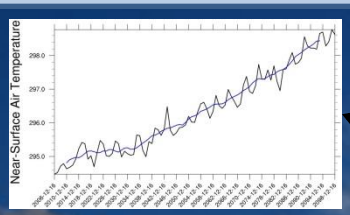
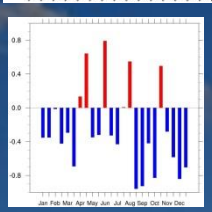
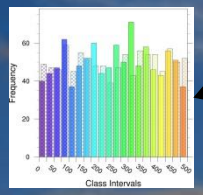
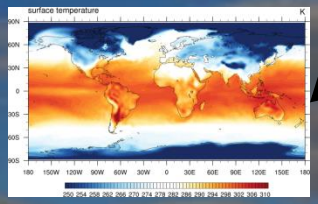
NCL Visualization Types

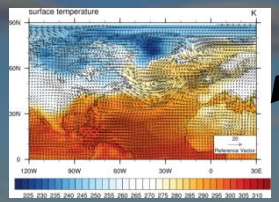
XY-plot	Wind rose
Bar chart	Scatter plot
Histogram	Box plot
Contour	Pie chart
Vector	Overlay
Map	Panel
Slice	Evans plot
Streamlines	Taylor diagram
Attach plots	Shapefiles
Wind Barbs	....

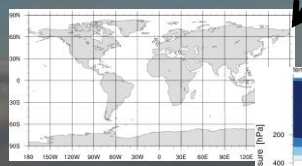


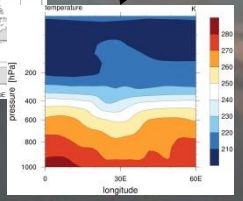


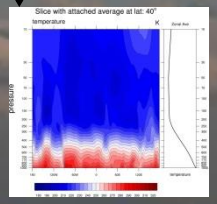


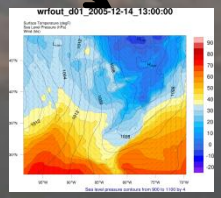


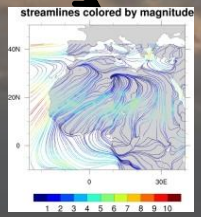


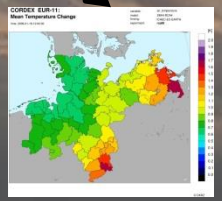


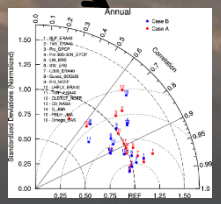


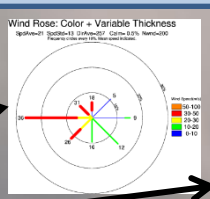


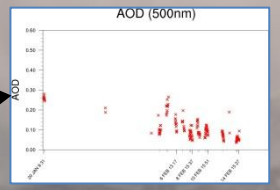


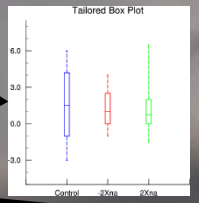


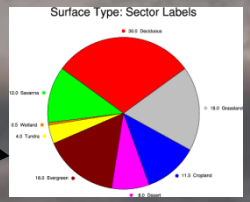


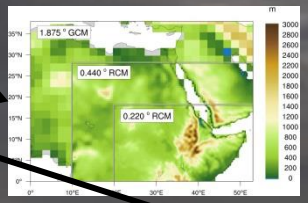


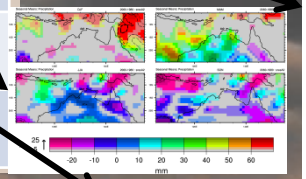


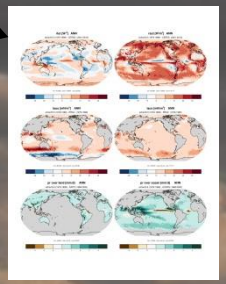










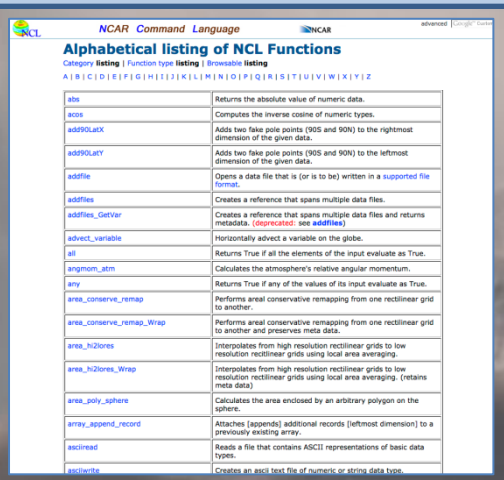


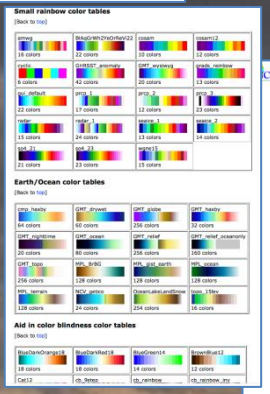
NCL - a workhorse for data analysis and visualization in climate research

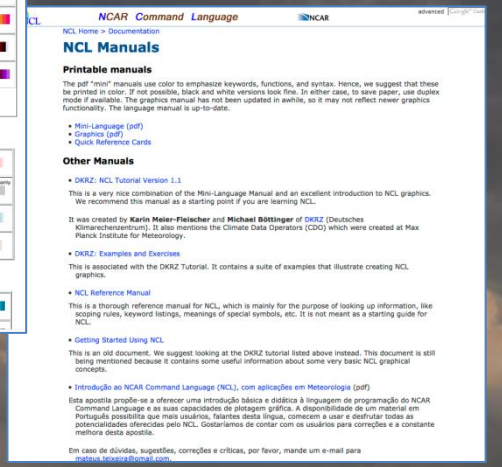
Karin Meier-Fleischer (1), Michael Böttinger (1), and Mary Haley (2)
(1) Deutsches Klimarechenzentrum (DKRZ), Hamburg, Germany, (2) NCAR/CISL, Boulder (CO), USA

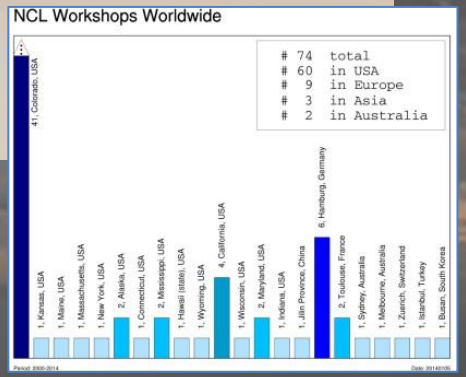
Benefits

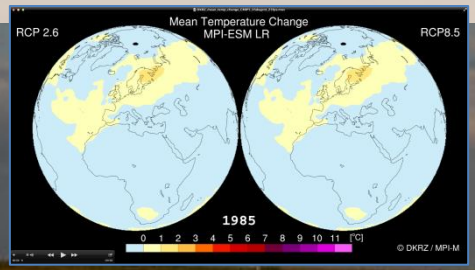
- Many built-in functions
- Common programming features
- Algebra that supports array operations
- Manipulation of metadata
- Configuration of the graphics
- Simple import of data
- Simple export of computed data
- Over 1300 example scripts
- More than 200 color tables
- Help via email lists
- Documentation
- Workshops
- Webinars











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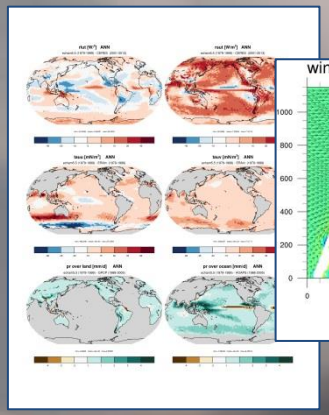
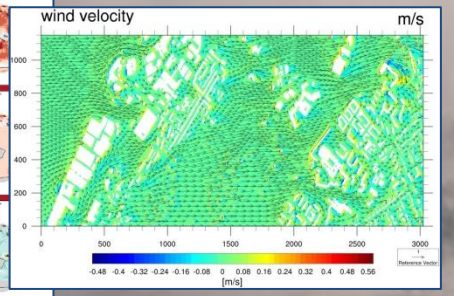
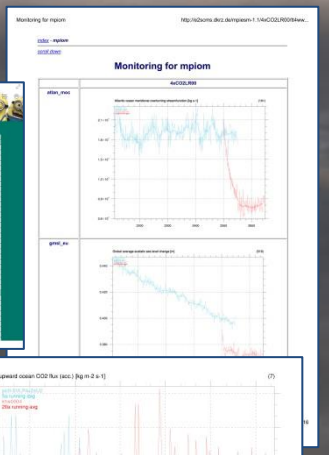
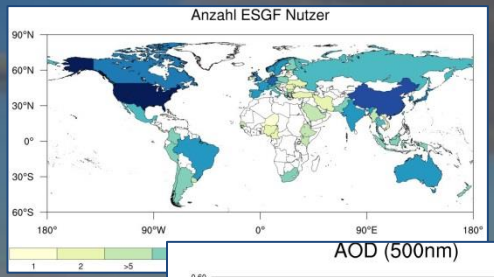
Use Cases

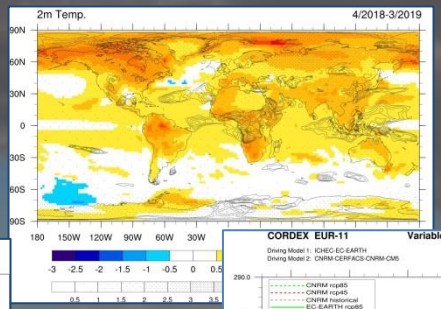
- **Data processing and analysis**
- **Quick look** visualization with default settings for interactive data exploration
- **Online monitoring**: Institutes like the **Max-Planck-Institute for Meteorology** integrate NCL visualizations into the modeling workflow for online monitoring of the simulations.
- Reproducible **publication quality visualizations** (vector graphics)

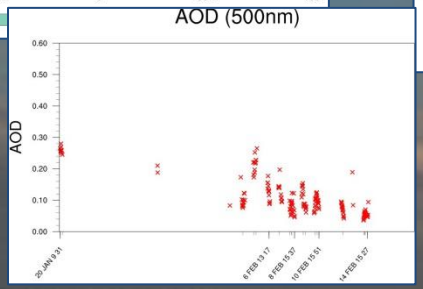


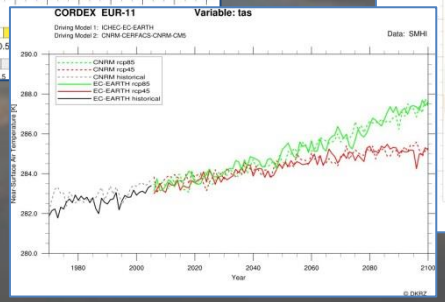


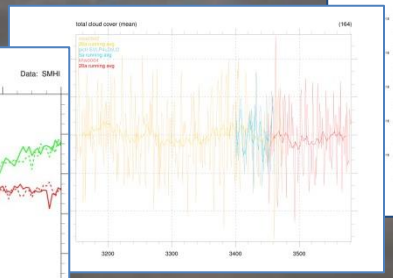


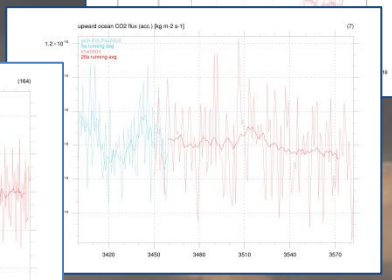












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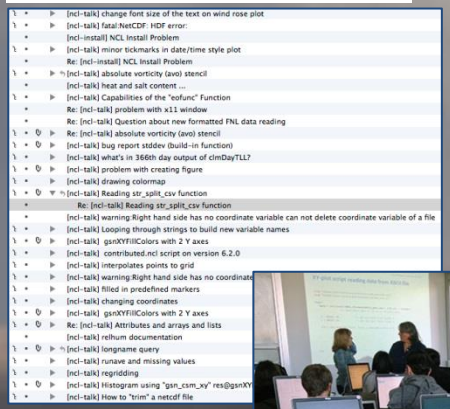
DKRZ's Involvement

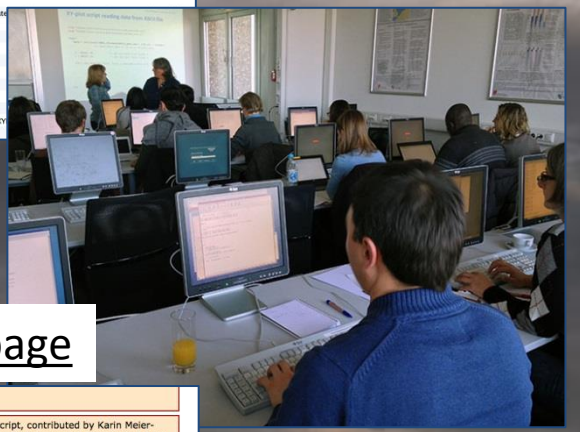
DKRZ's high-performance computing facilities enable simulating, analyzing and visualizing complex processes in the climate and Earth system.

As part of its services, DKRZ installs and maintains domain specific software tools like NCL. DKRZ is working closely with the developers of NCL on the **documentation**, **examples**, **teaching** and **guidance** for NCL users.

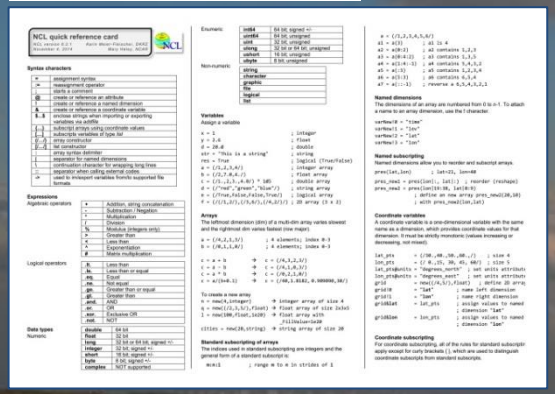
ncl-talk mailing list



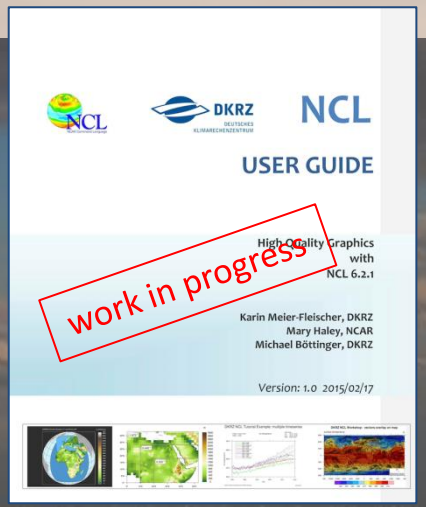
Workshops



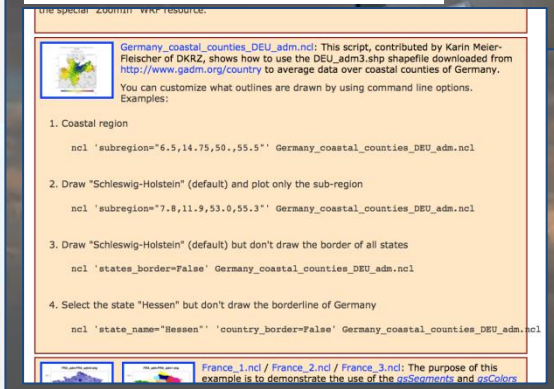
Reference cards



User Guide



NCL examples page



Major contributor

NCL - a workhorse for data analysis and visualization in climate research

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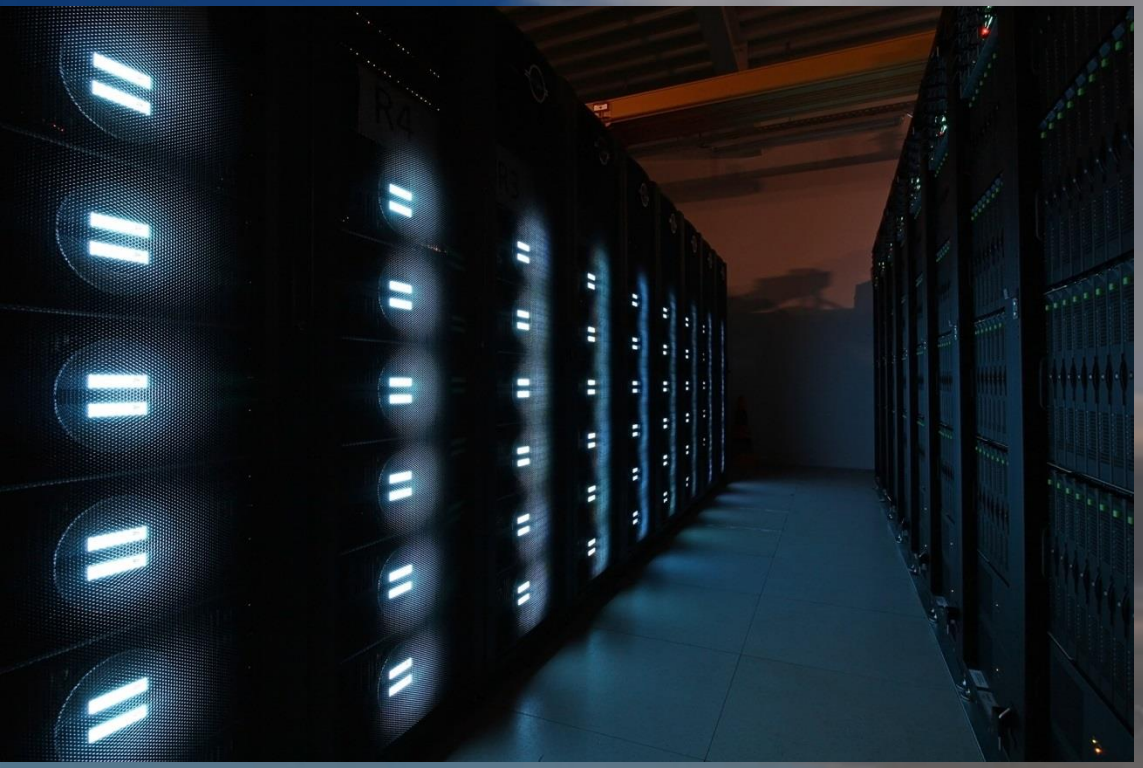

The new High Performance Computer System for Earth System Research (HLRE-3) 1st phase :

- 41 racks
- 1500 compute nodes (a total of 36000 cores)
- 75 TByte main memory
- 20 PByte parallel file system

The 2nd phase of HLRE-3 the extension will additionally roughly double computing and disk storage.

- 3 PFlops peak performance
- 50 PByte parallel file system

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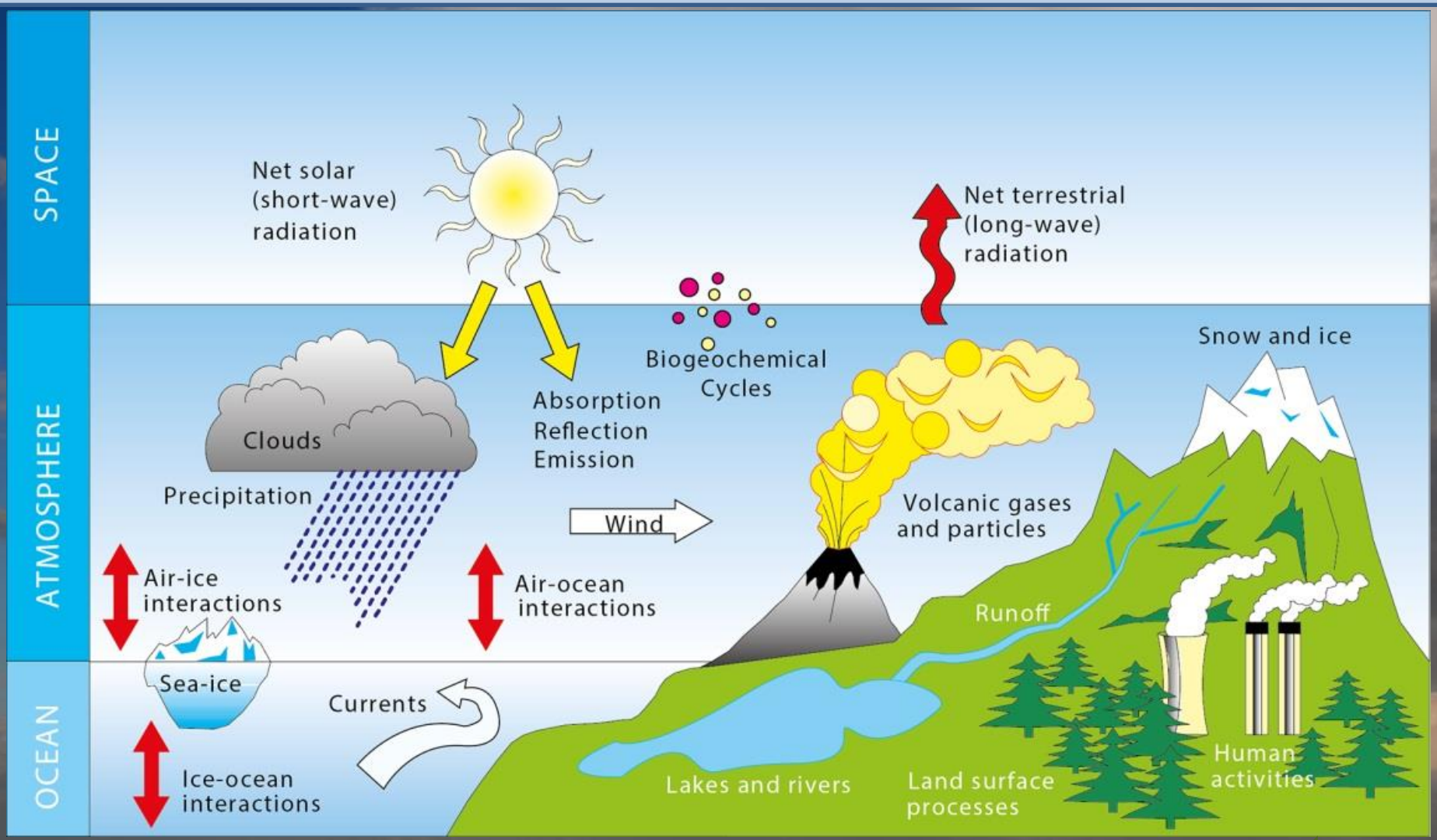

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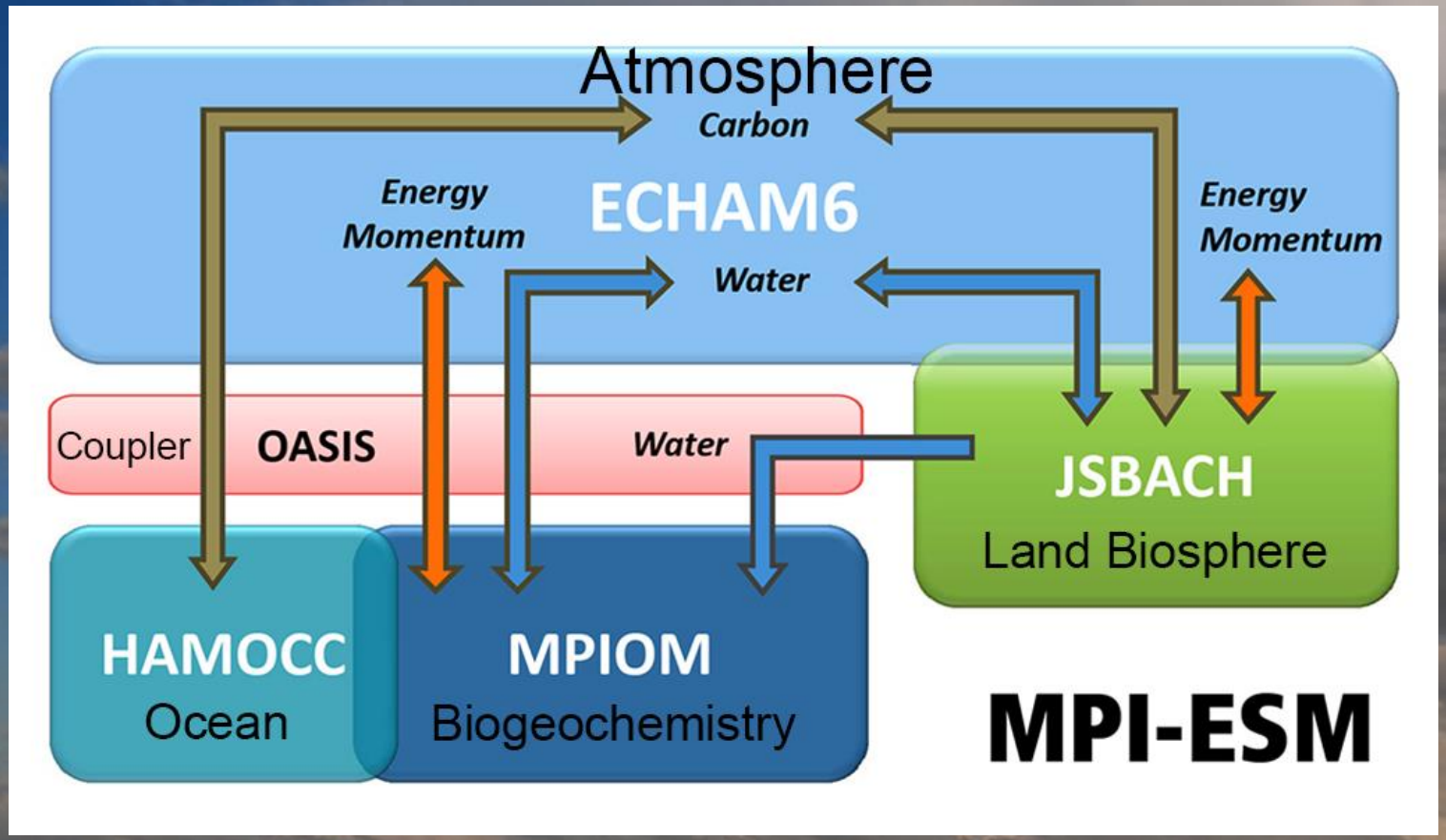

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```
netcdf lffd1951010100_EUR-11 {
dimensions:
        time = UNLIMITED ; // (1 currently)
        bnds = 2 ;
        rlon = 450 ;
        rlat = 438 ;
        level = 40 ;
        level1 = 41 ;
        height_2m = 1 ;
        height_10m = 1 ;
        height_toa = 1 ;
        wbt_13c = 1 ;
        soil = 9 ;
        soil1 = 10 ;
variables:
        double time(time) ;
                time:standard_name = "time" ;
                time:long_name = "time" ;
                time:units = "seconds since 1949-12-01 00:00:00" ;
                time:calendar = "proleptic_gregorian" ;
                time:bounds = "time_bnds" ;
        double time_bnds(time, bnds) ;
                time_bnds:long_name = "time bounds" ;
                time_bnds:units = "seconds since 1949-12-01 00:00:00" ;
        char rotated_pole ;
                rotated_pole:long_name = "coordinates of the rotated North Pole" ;
                rotated_pole:grid_mapping_name = "rotated_latitude_longitude" ;
                rotated_pole:grid_north_pole_latitude = 39.25f ;
                rotated_pole:grid_north_pole_longitude = -162.f ;
        float rlon(rlon) ;
                rlon:standard_name = "grid_longitude" ;
                rlon:long_name = "rotated longitude" ;
                rlon:units = "degrees" ;
        float rlat(rlat) ;
                rlat:standard_name = "grid_latitude" ;
                rlat:long_name = "rotated latitude" ;
                rlat:units = "degrees" ;
        float lon(rlat, rlon) ;
                lon:standard_name = "longitude" ;
                lon:long_name = "longitude" ;
                lon:units = "degrees_east" ;
        float lat(rlat, rlon) ;
                lat:standard_name = "latitude" ;
                lat:long_name = "latitude" ;
                lat:units = "degrees_north" ;
        float vcoord(level1) ;
                vcoord:long_name = "Height-based hybrid Gal-Chen coordinate" ;
                vcoord:units = "Pa" ;
                vcoord:ivctype = 2 ;
                vcoord:irefatm = 2 ;
                vcoord:p0sl = 100000. ;
                vcoord:t0sl = 288.149993896484 ;
                vcoord:dt0lp = 42. ;
                vcoord:vcflat = 11430. ;
                vcoord:delta_t = 75. ;
                vcoord:h_scal = 10000. ;
        float height_2m(height_2m) ;
                height_2m:standard_name = "height" ;
                height_2m:long_name = "height above the surface" ;
                height_2m:units = "m" ;
```

...

```
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   256.5717, 256.9416, 257.6012, 258.2045, 258.6181, 260.859, 261.9926,
   263.3785, 264.2176, 266.9563, 271.6896, 275.5716, 278.9648, 279.6512,
   284.8492, 285.8928, 284.4748, 284.5209, 284.6075, 285.0214, 284.2472,
   284.1122, 283.5691, 282.9667, 279.4505, 278.9732, 278.152, 277.3026,
```

...

Model output: 1 single time step ~19 MB

NCL - a workhorse for data analysis and visualization in climate research

Karin Meier-Fleischer (1), Michael Böttinger (1), and Mary Haley (2)
(1) Deutsches Klimarechenzentrum (DKRZ), Hamburg, Germany, (2) NCAR/CISL, Boulder (CO), USA

```
19747,01/20/2014, 9:27:18, 43.192,  27.994,   75, 1011,64.40,2.305,0.969, 21.9, 0, 376.63, 360.83, 356.08, 742.19,1199.76,NaN  ,NaN  ,NaN  ,NaN  ,NaN  ,1.0438,1.0133,0.4798,0.6186,0.324,0.284,0.269,0.202,0.147,
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```
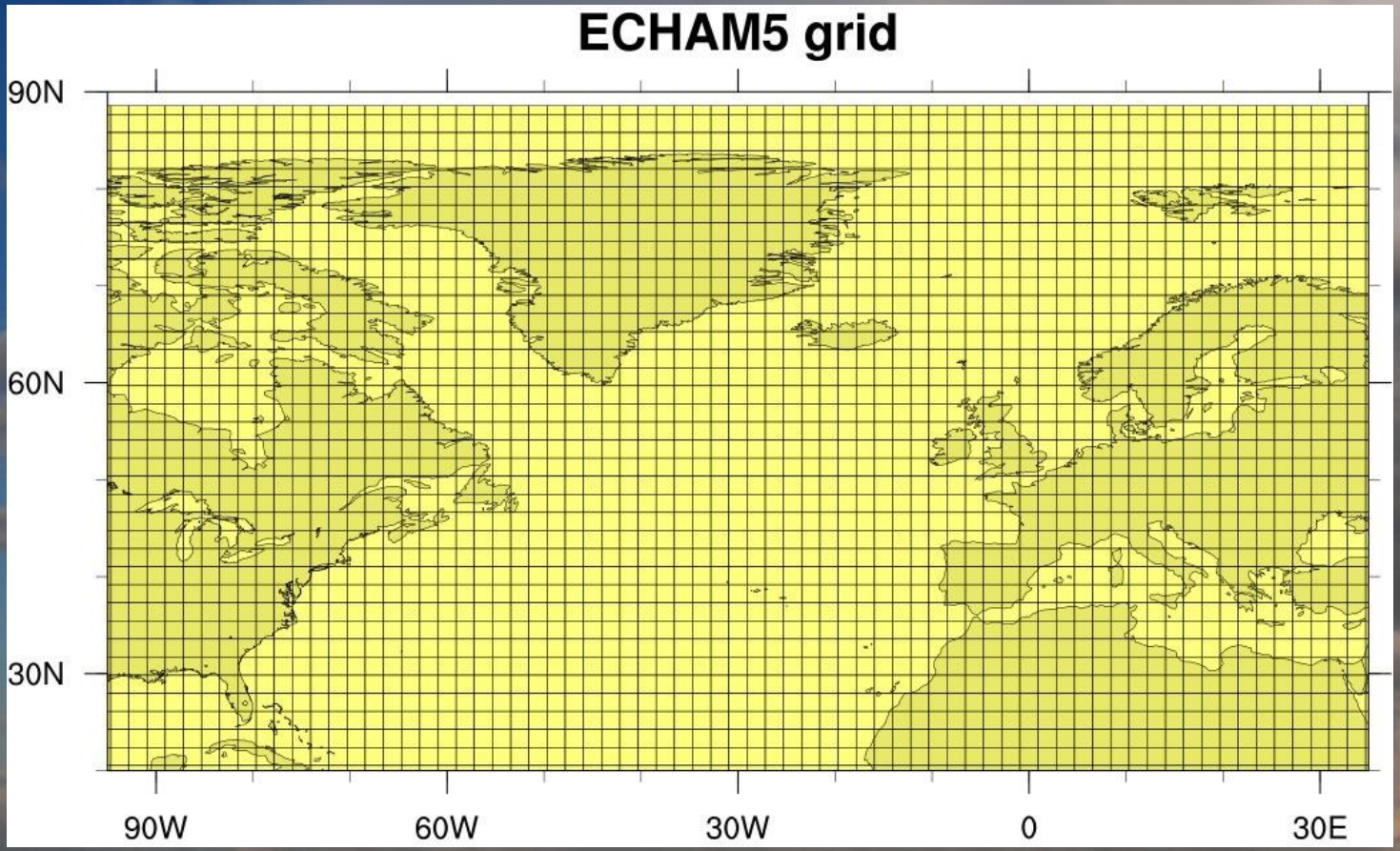

...

NCL - a workhorse for data analysis and visualization in climate research

Karin Meier-Fleischer (1), Michael Böttinger (1), and Mary Haley (2)
(1) Deutsches Klimarechenzentrum (DKRZ), Hamburg, Germany, (2) NCAR/CISL, Boulder (CO), USA

ECHAM5: rectilinear grid



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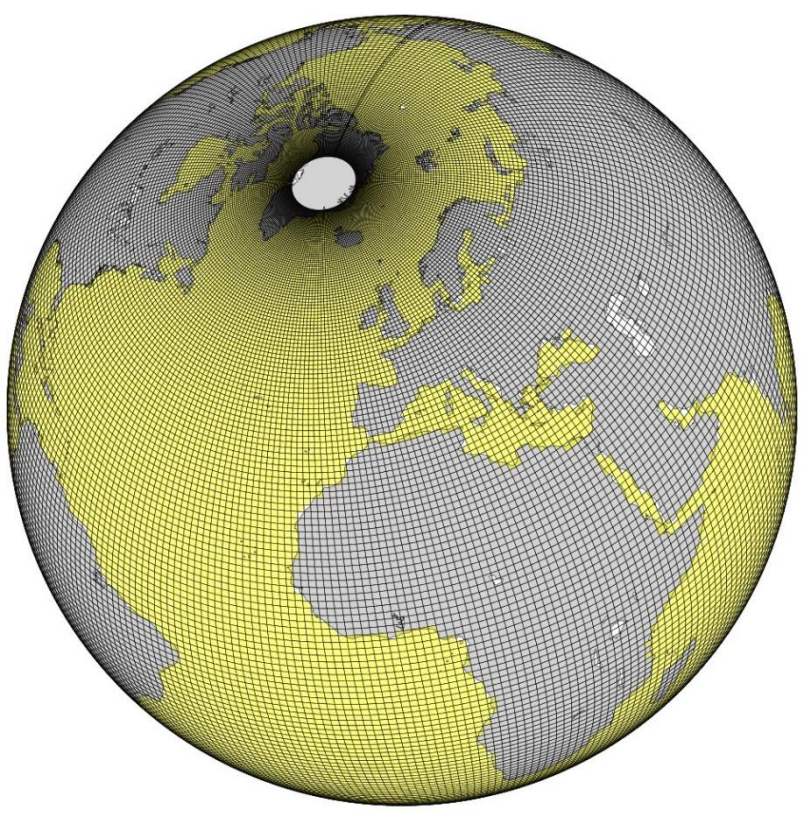
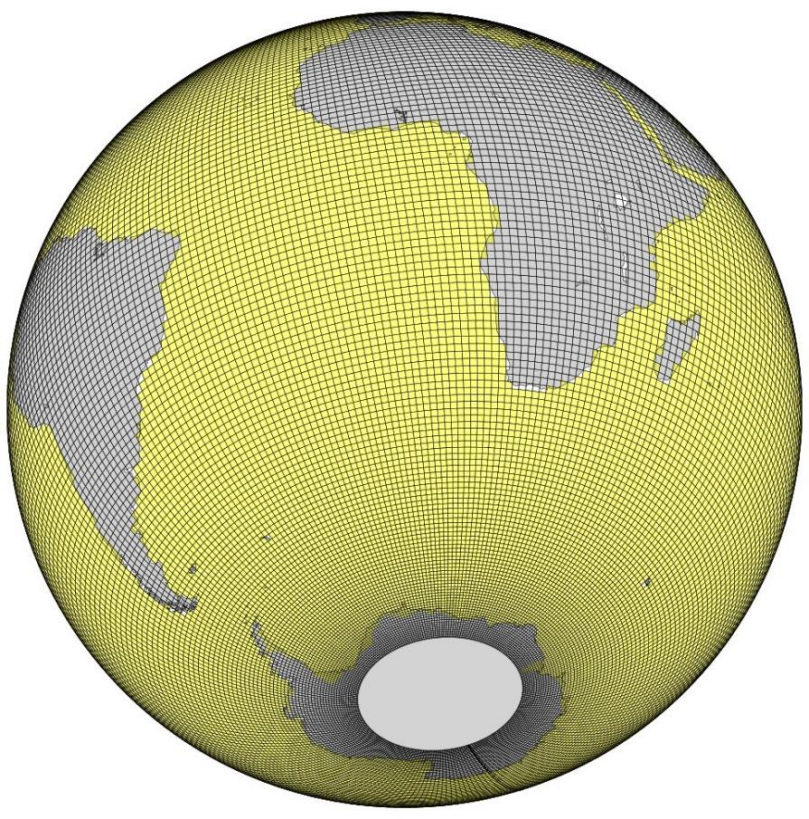
MPIOM: curvilinear grid





Script

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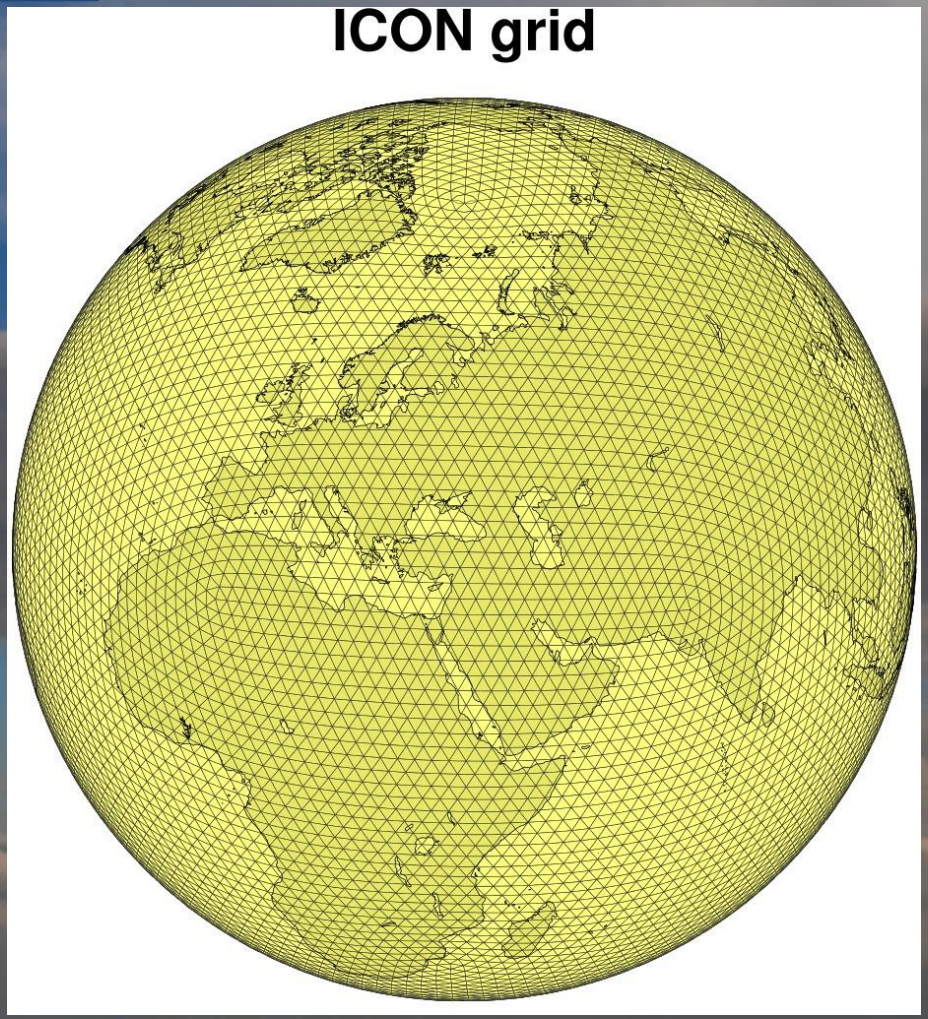
ICON: unstructured grid



Script

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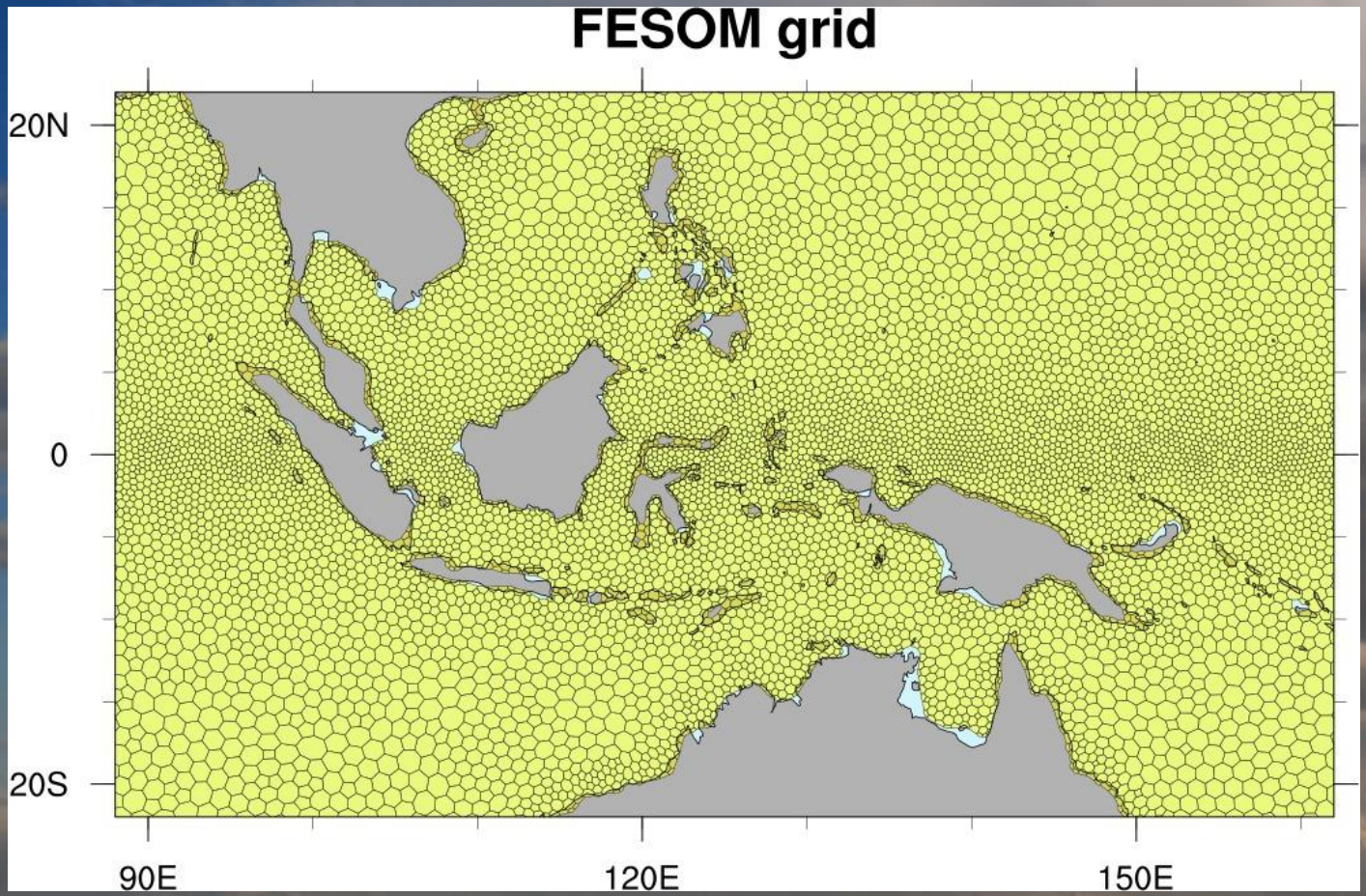
FESOM: unstructured grid



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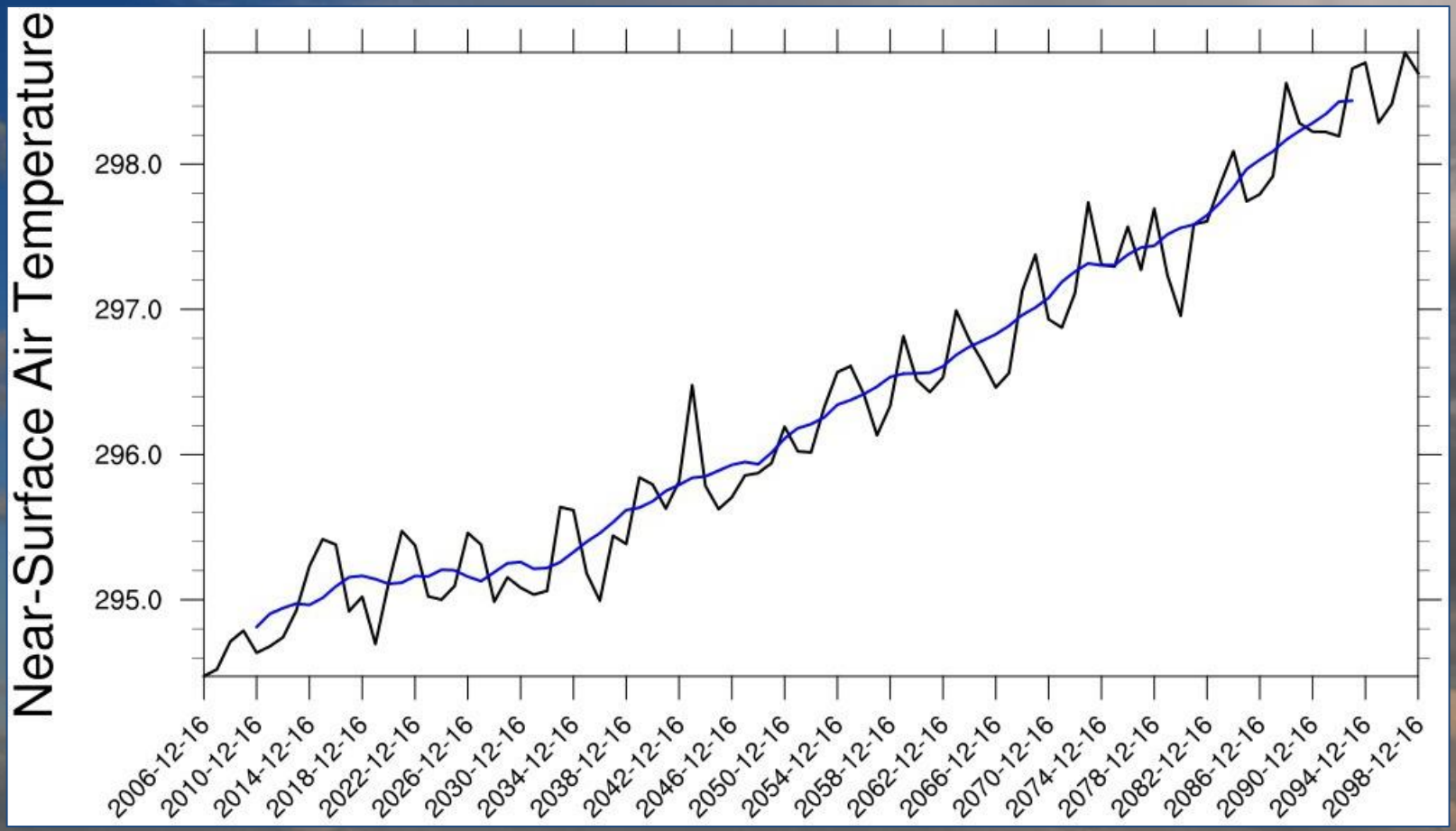
XY-plot



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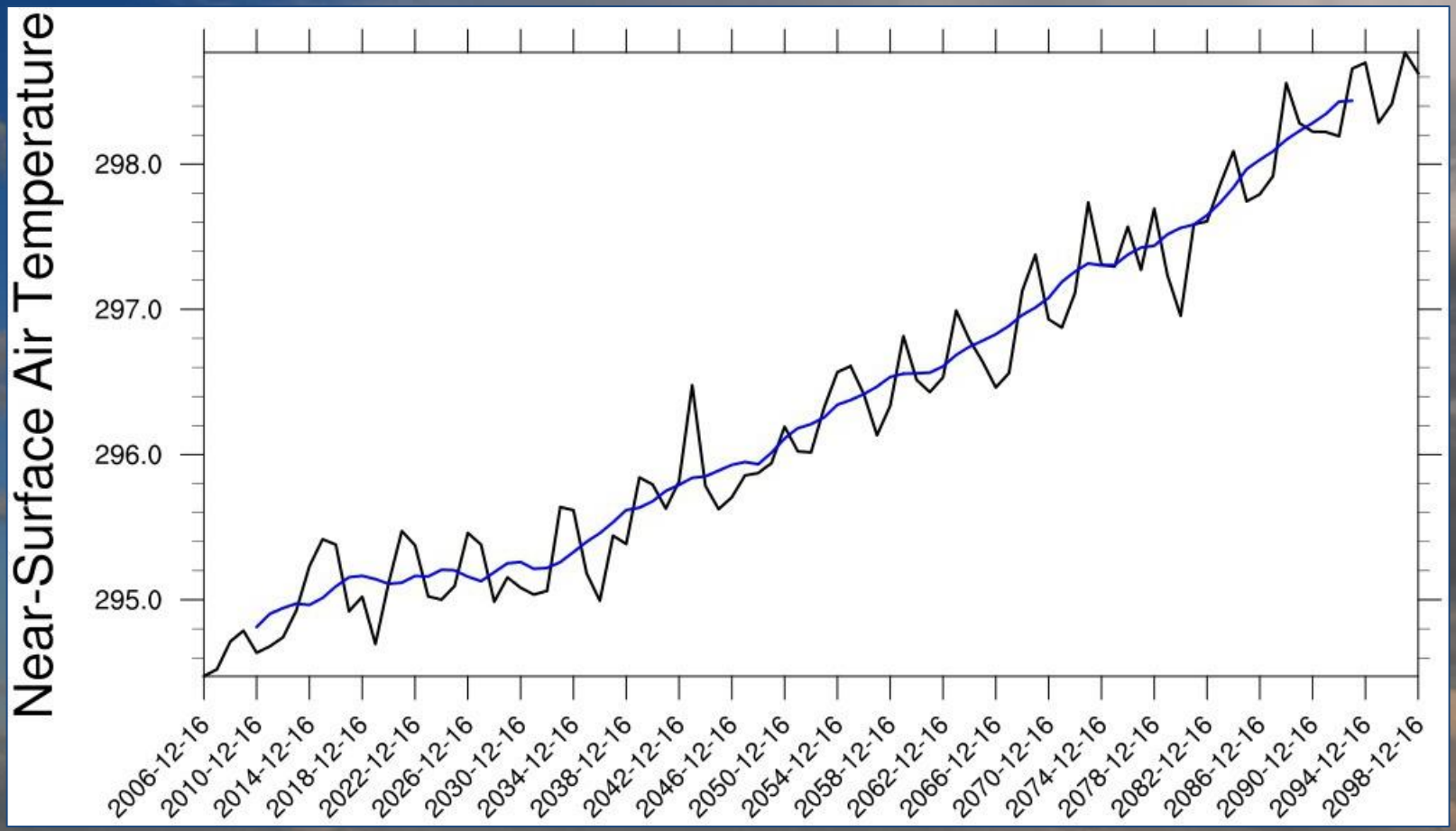
XY-plot



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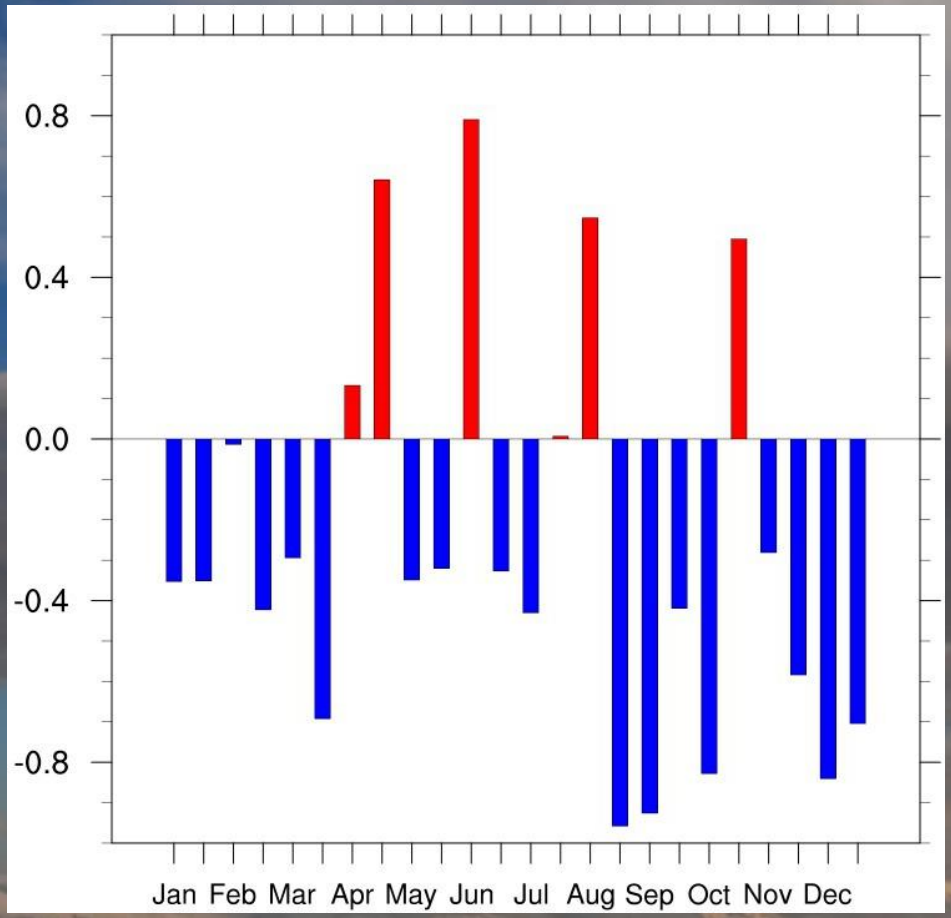
Bar chart



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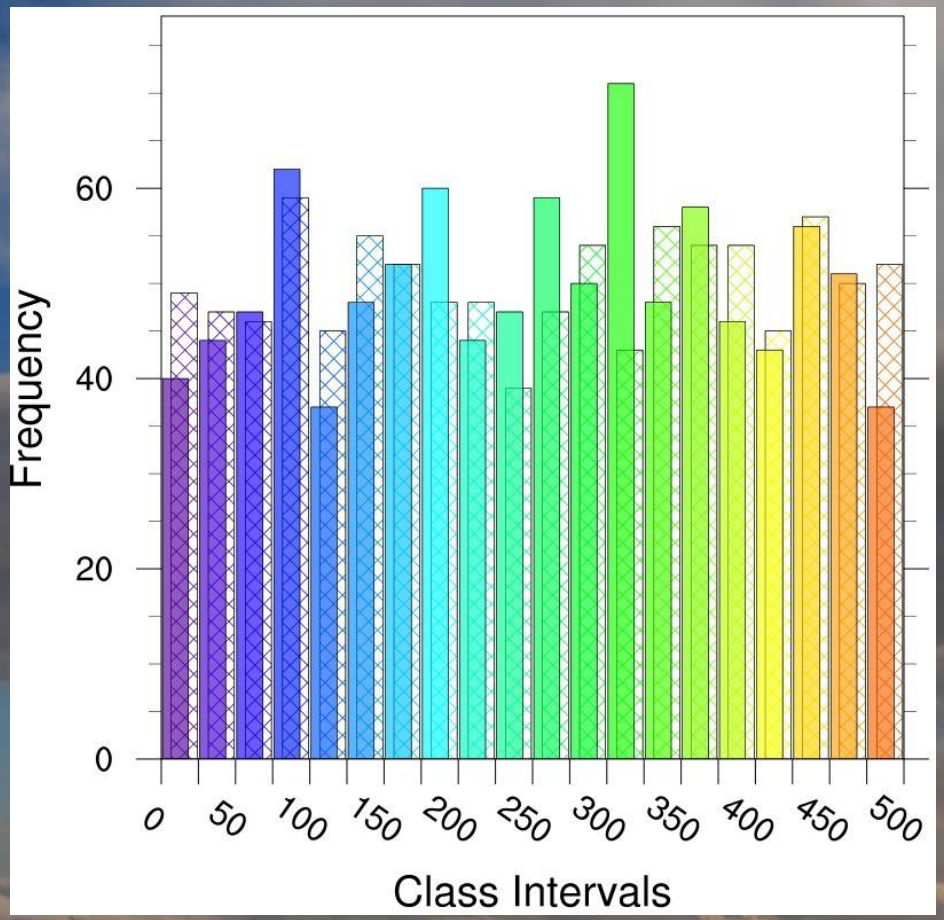
Histogram



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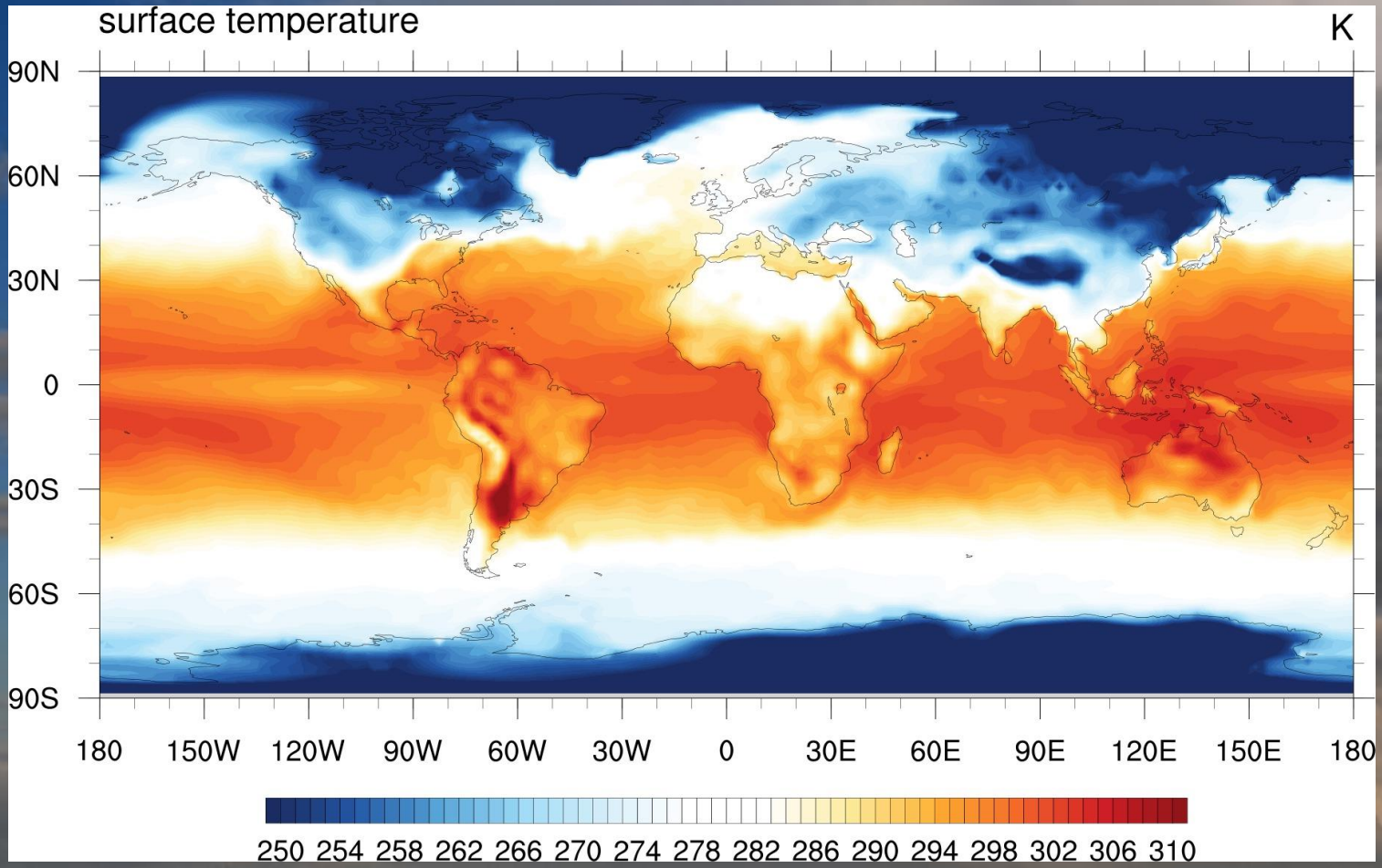
Filled Contours



Script

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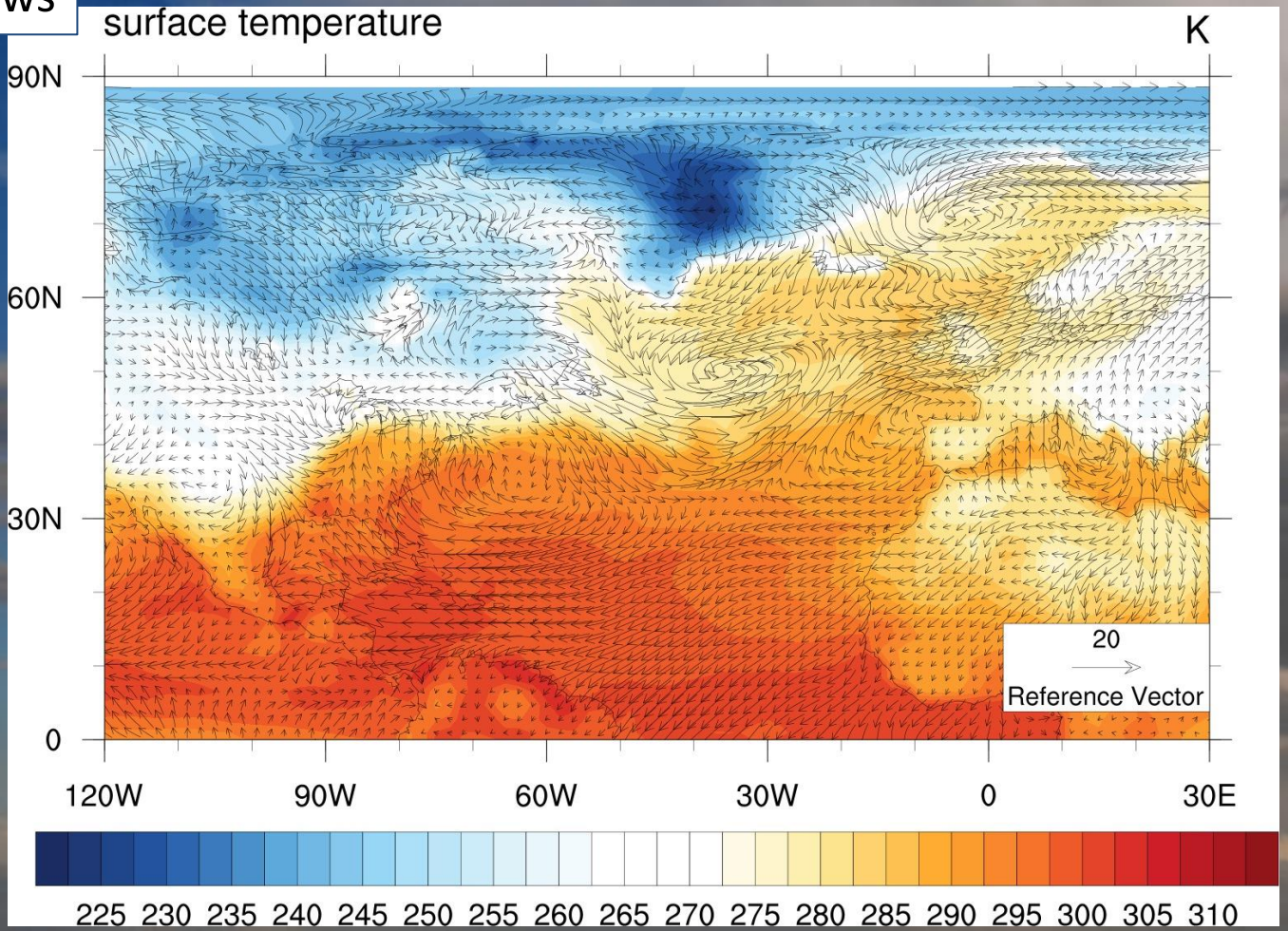
Vector Arrows



Script

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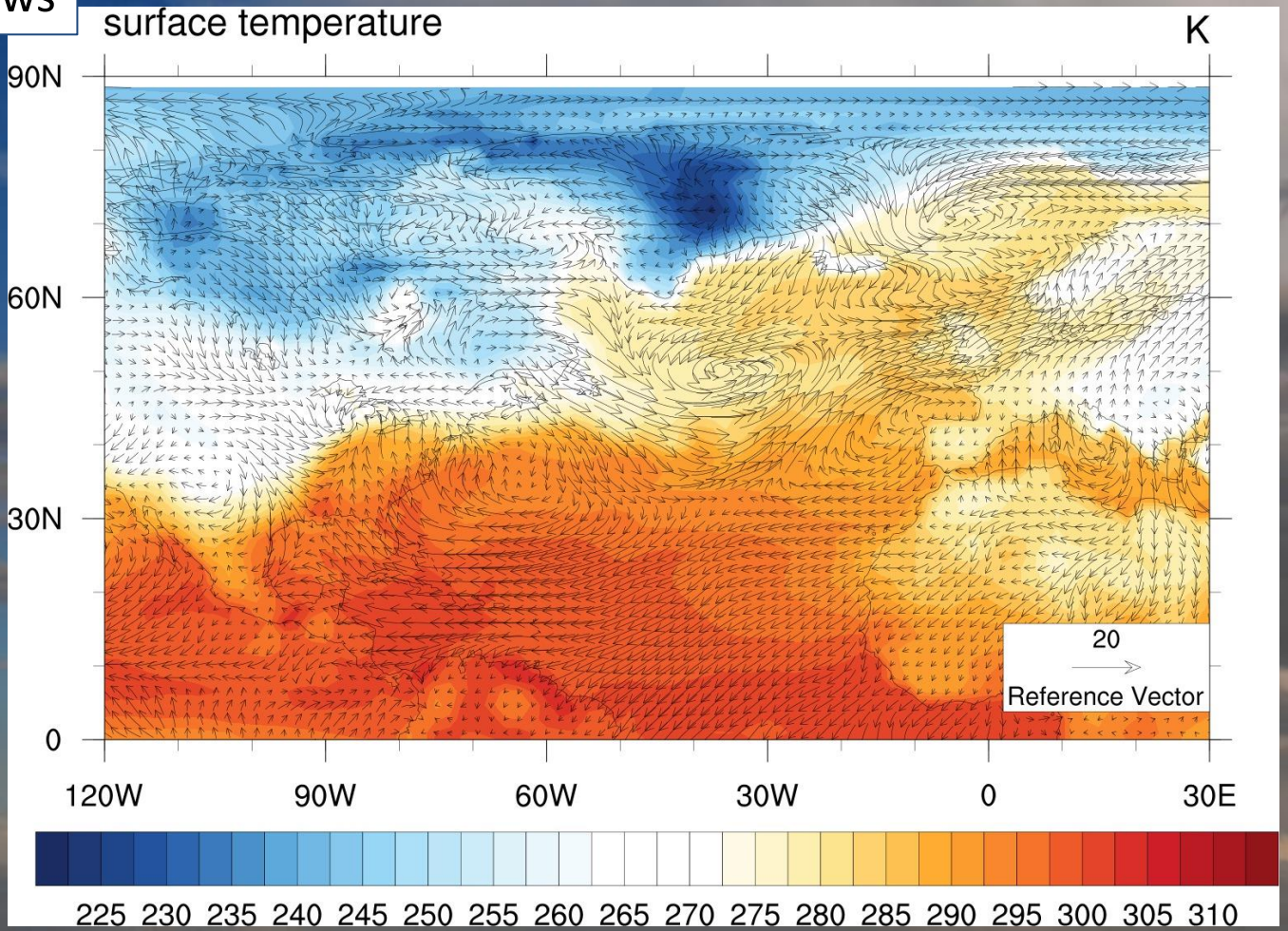
Vector Arrows



Script

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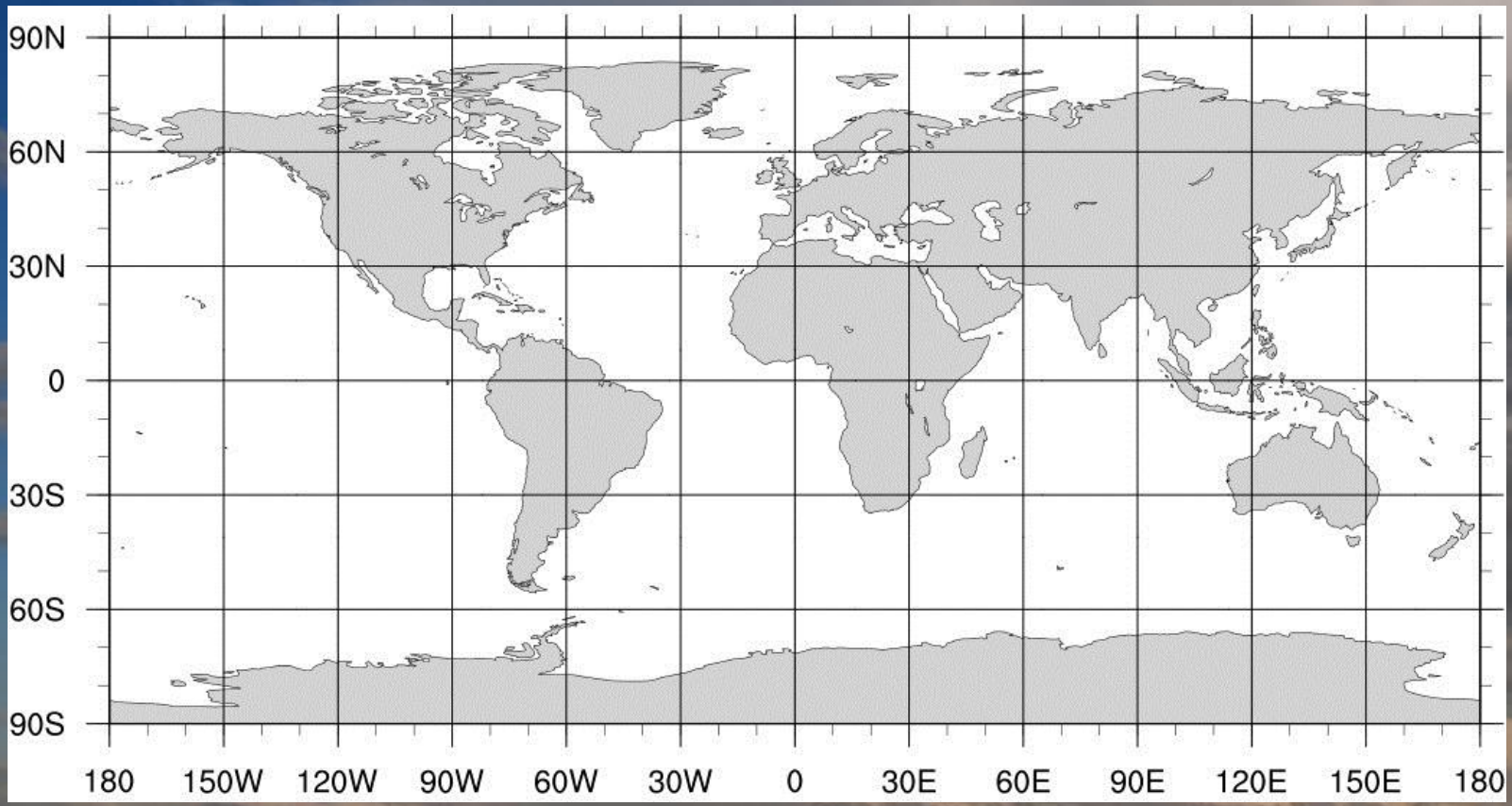
Map



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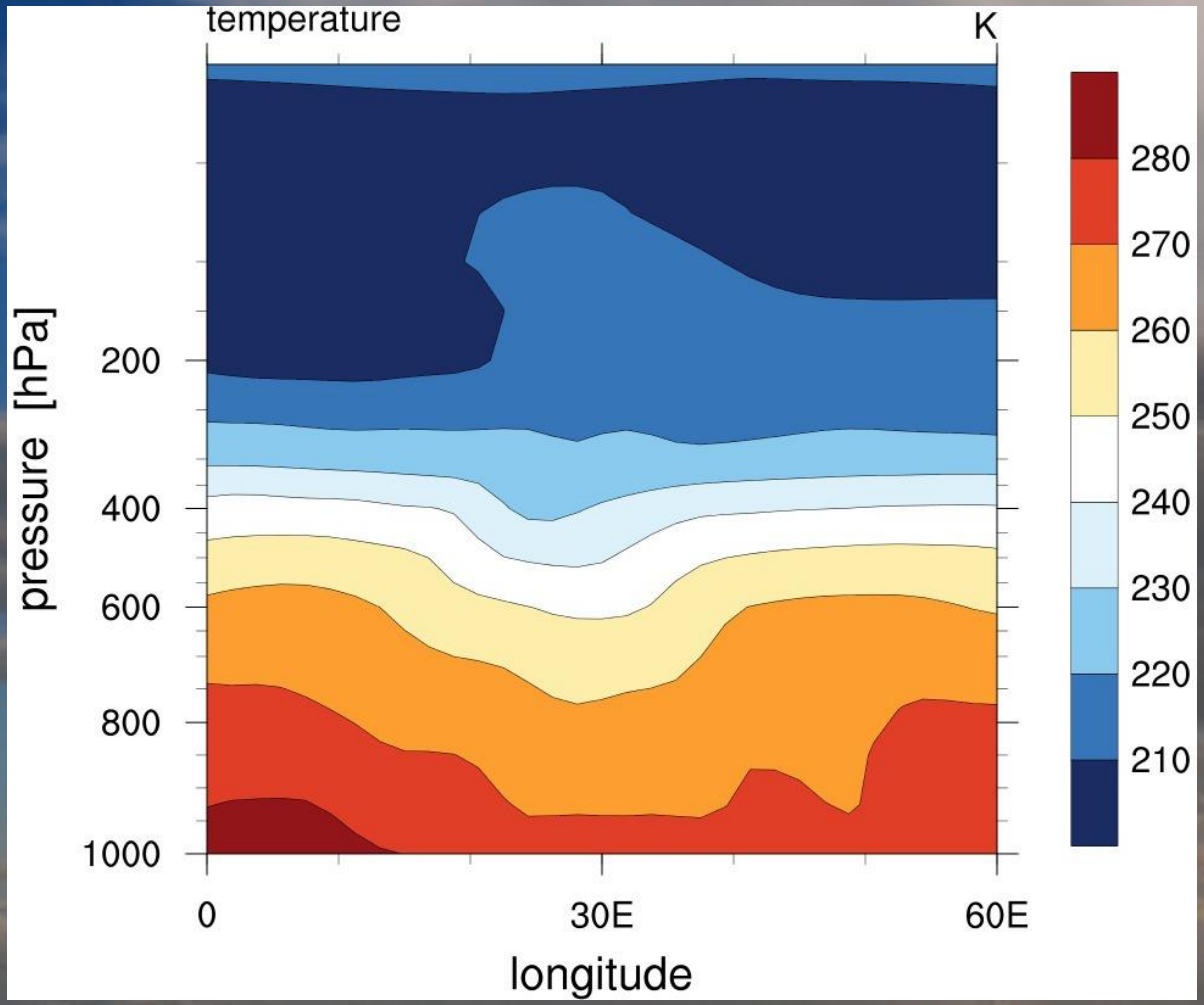
Vertical Slice



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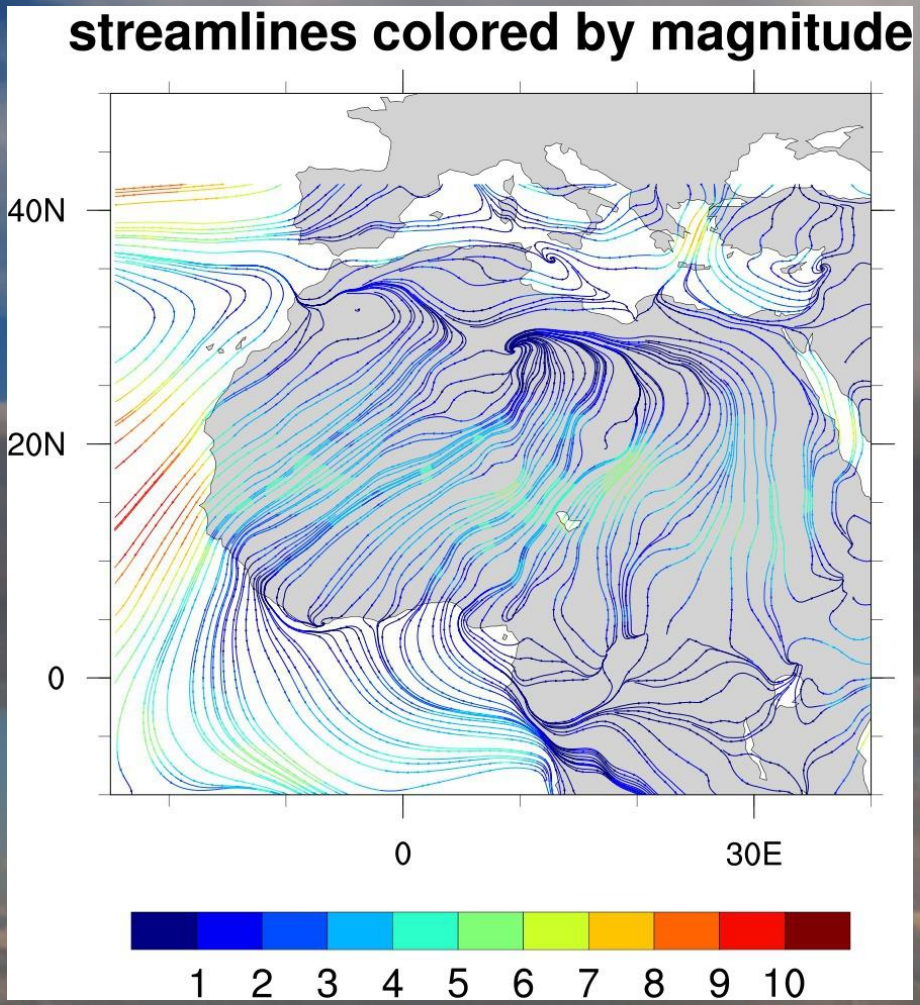
(1) Deutsches Klimarechenzentrum (DKRZ), Hamburg, Germany, (2) NCAR/CISL, Boulder (CO), USA

Streamlines



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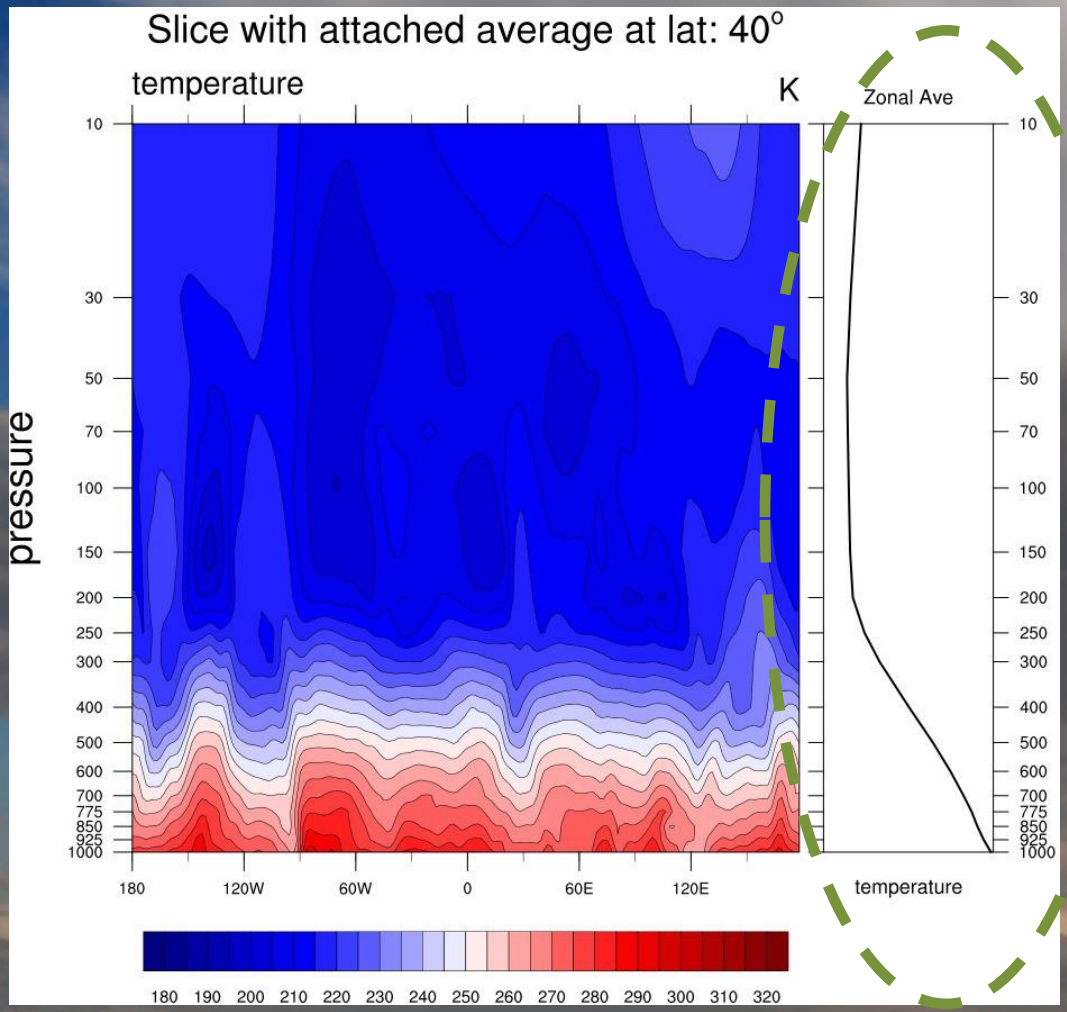

Attached plot

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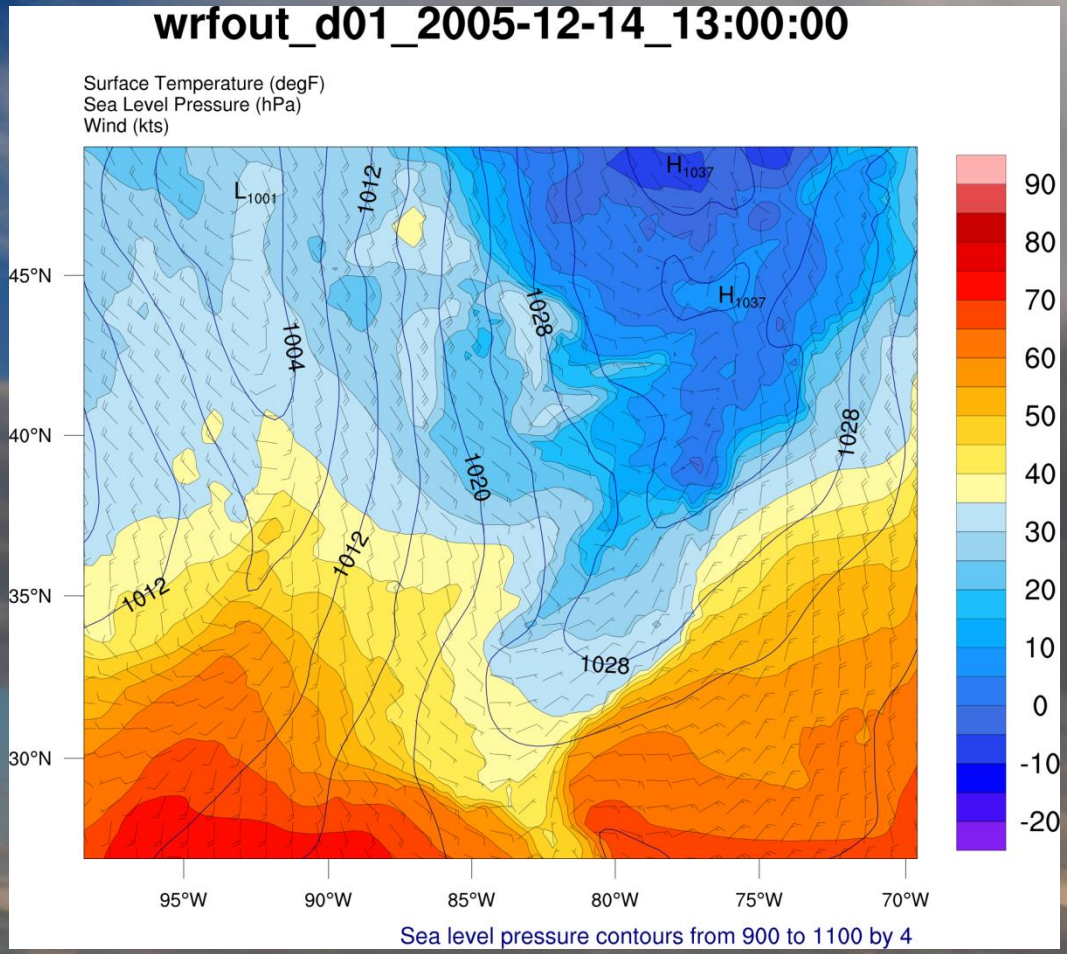
Wind Barbs



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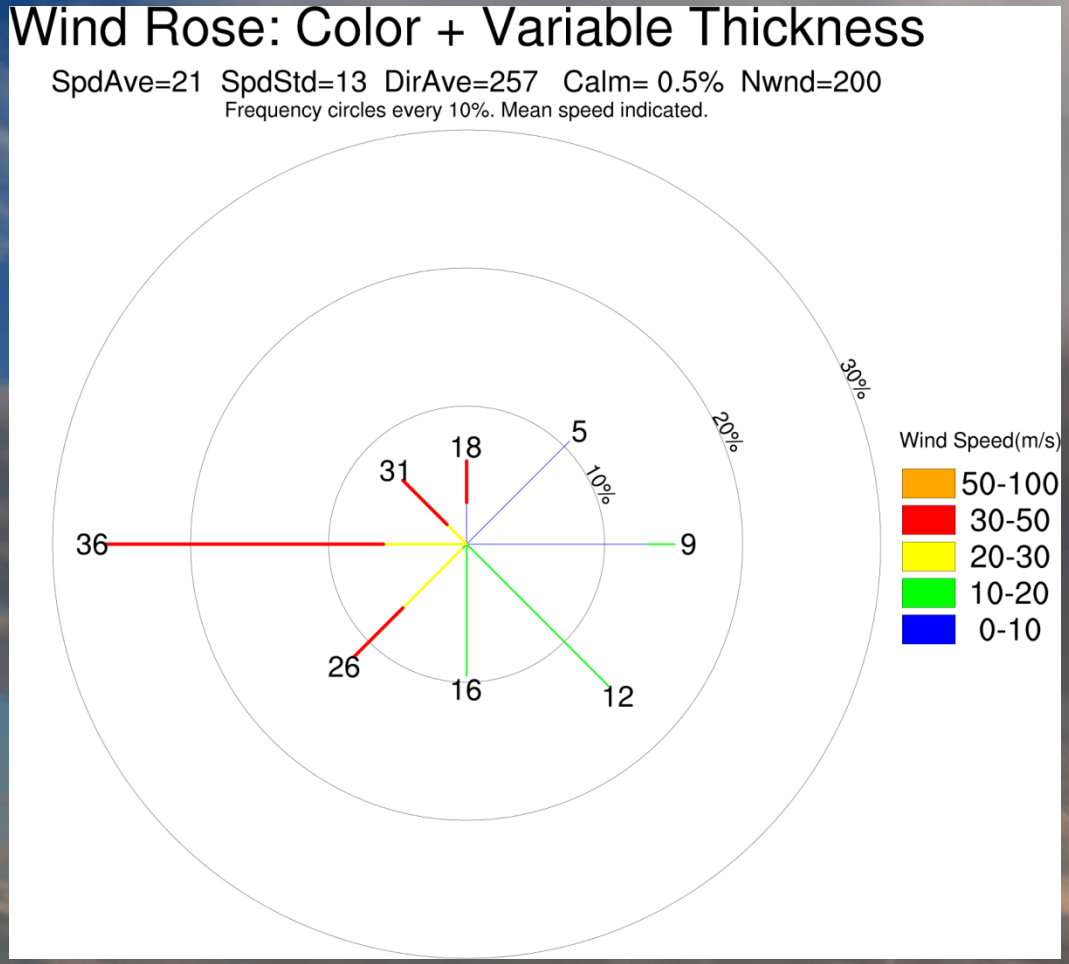
Wind rose



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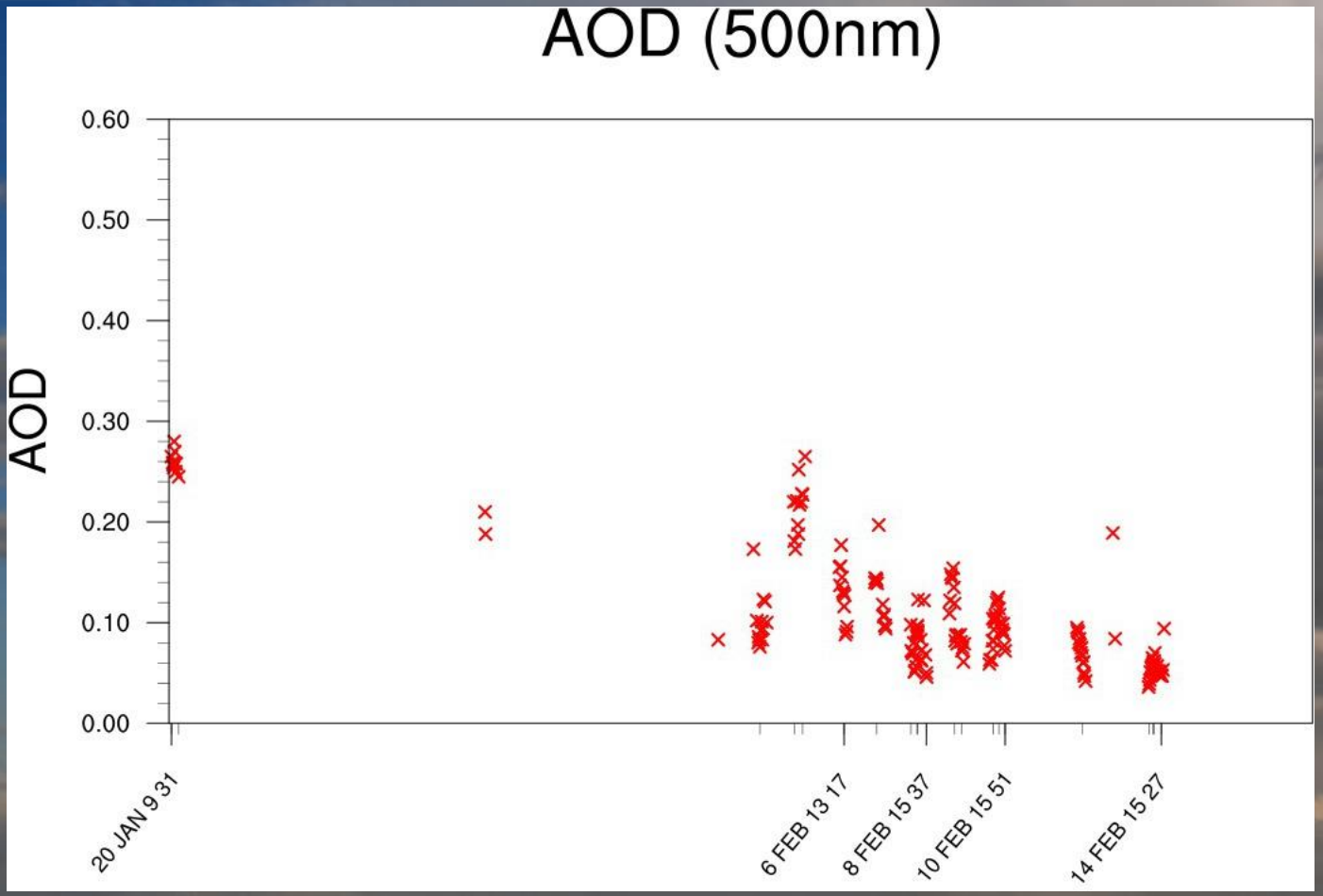
Scatter plot



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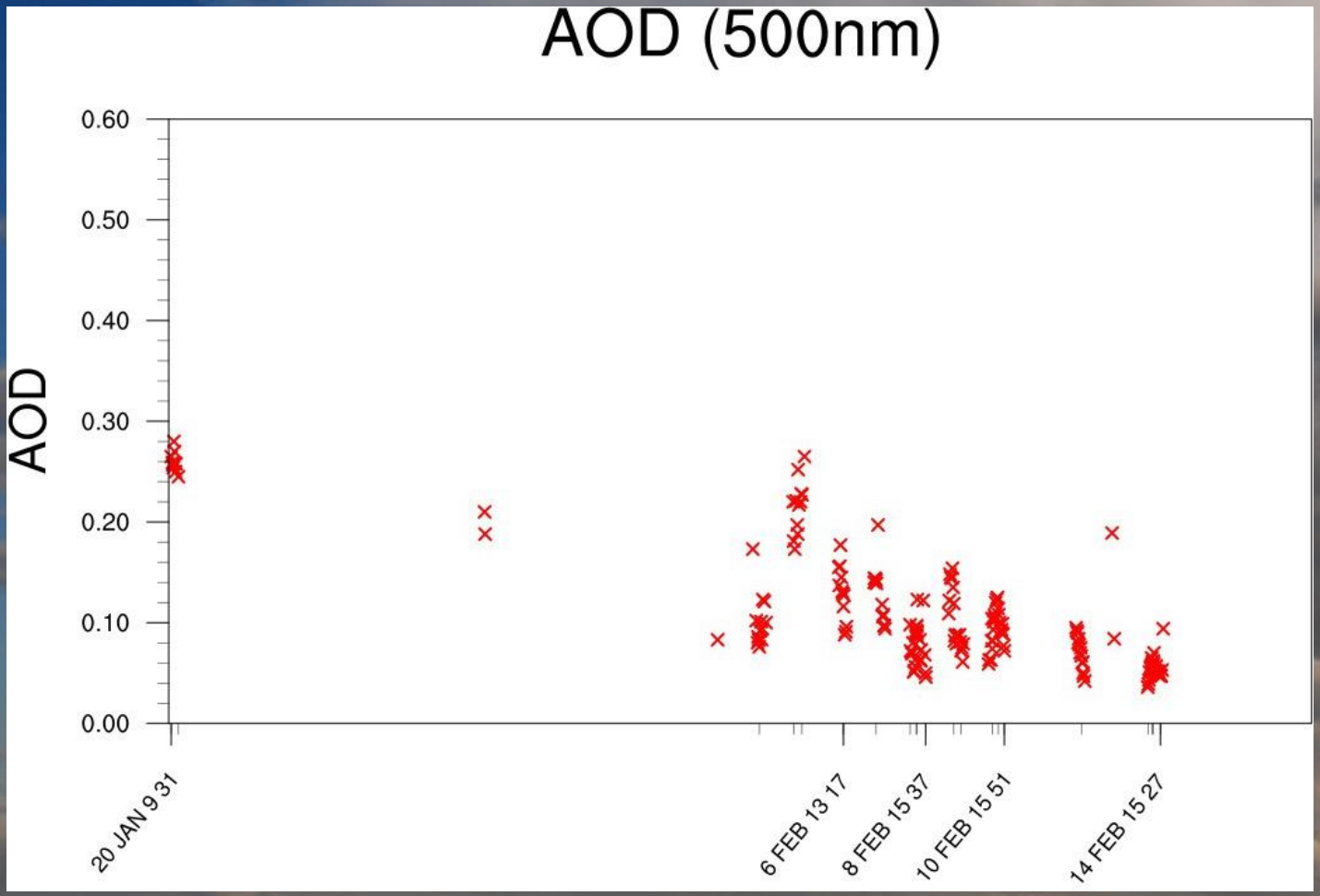

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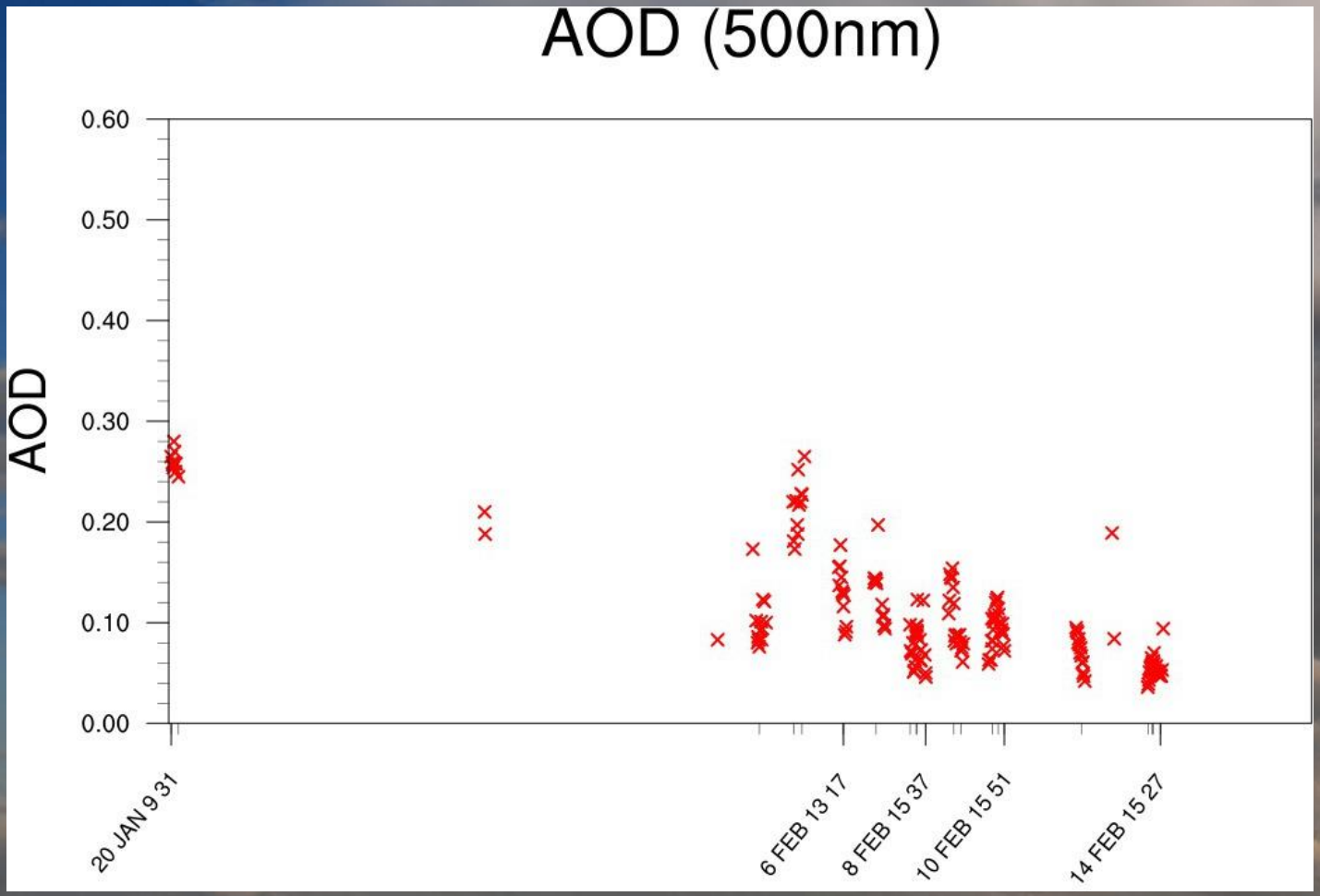

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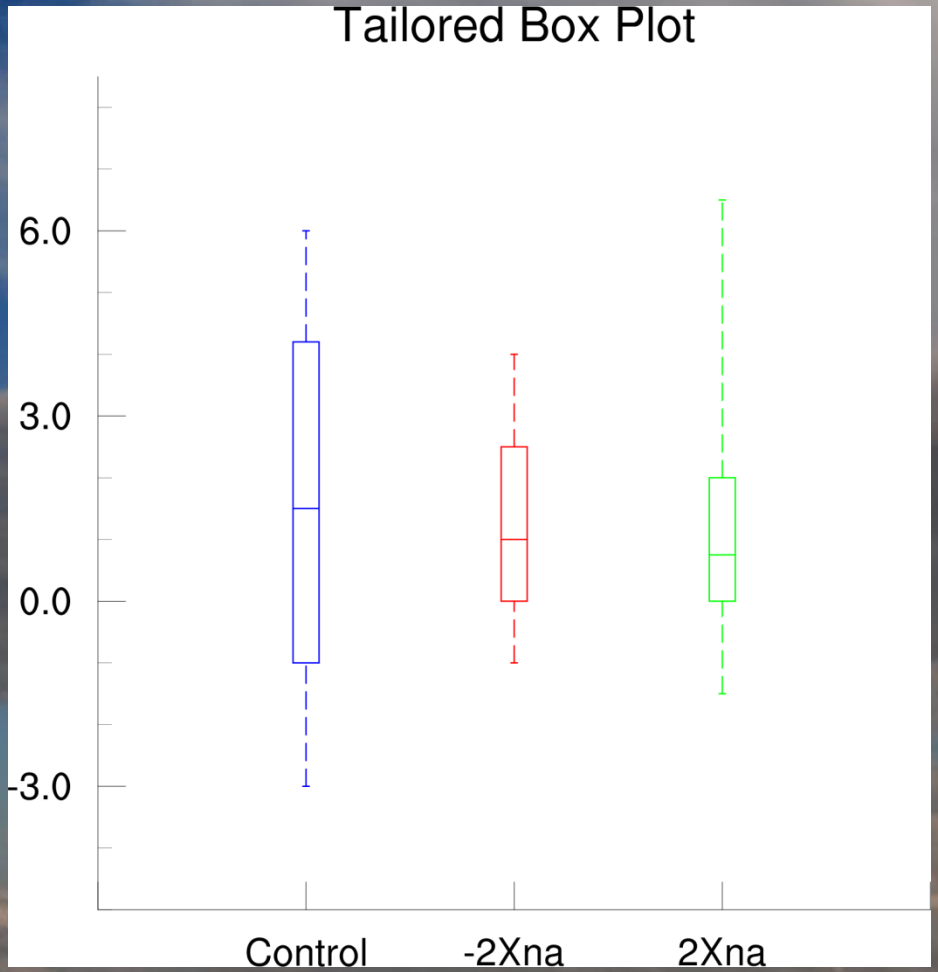
Box plot



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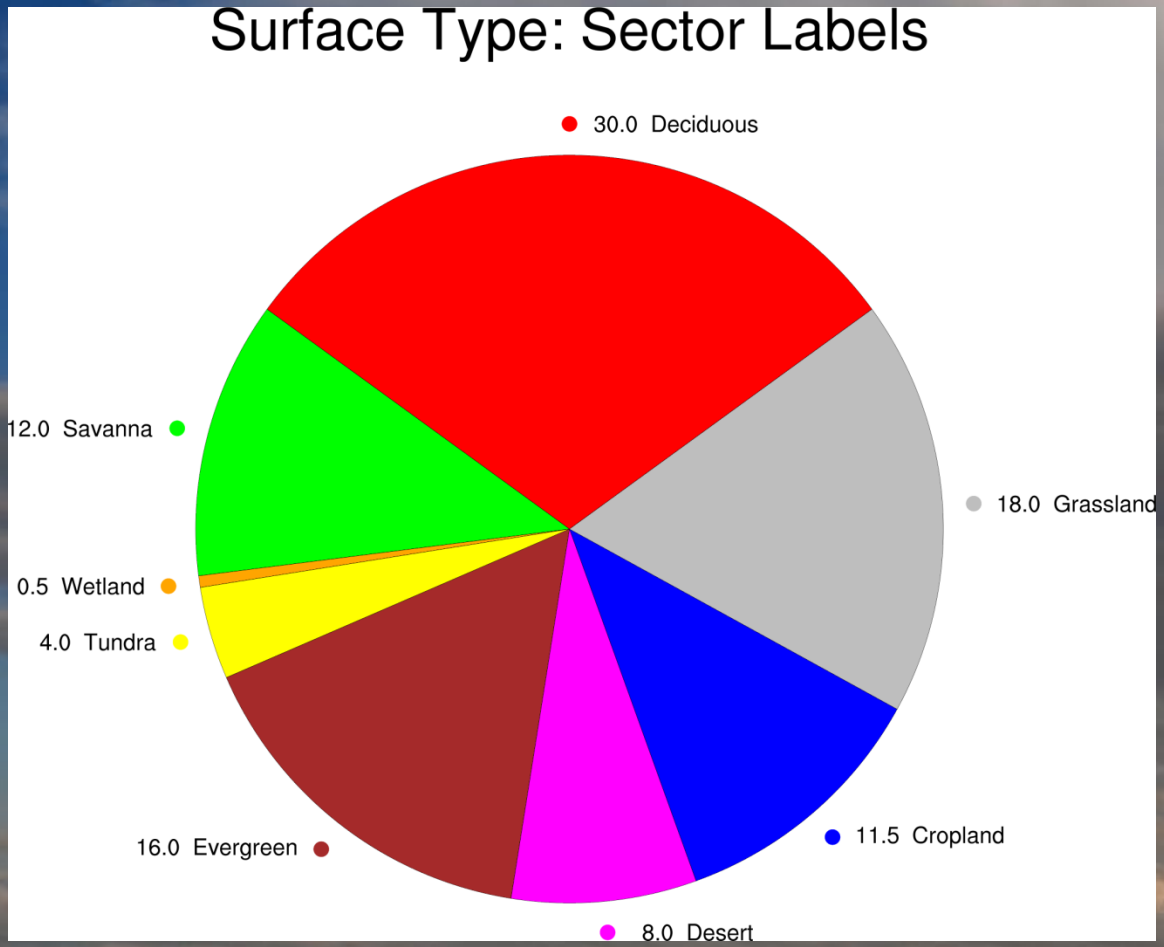
Pie chart



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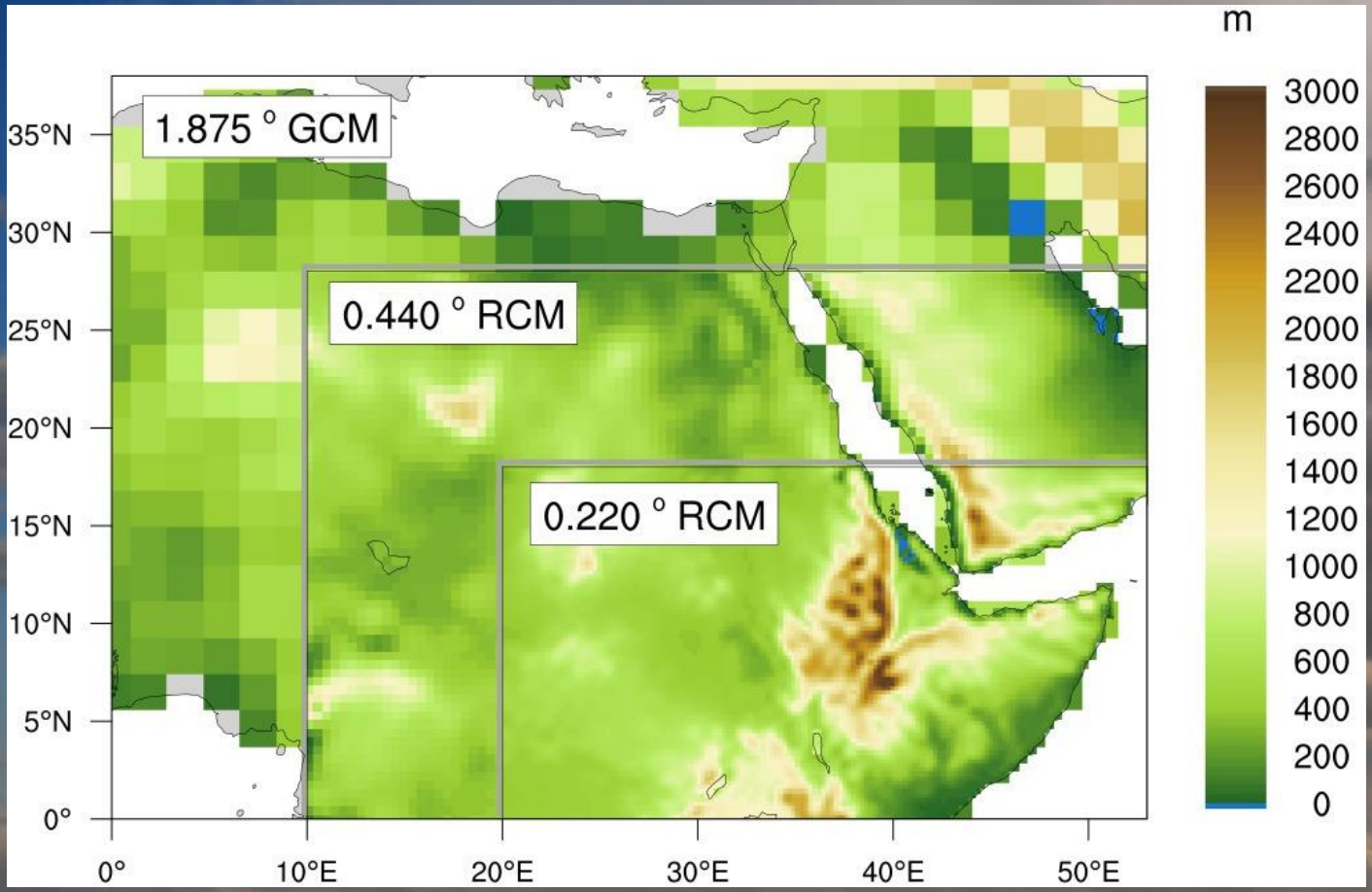
Overlay



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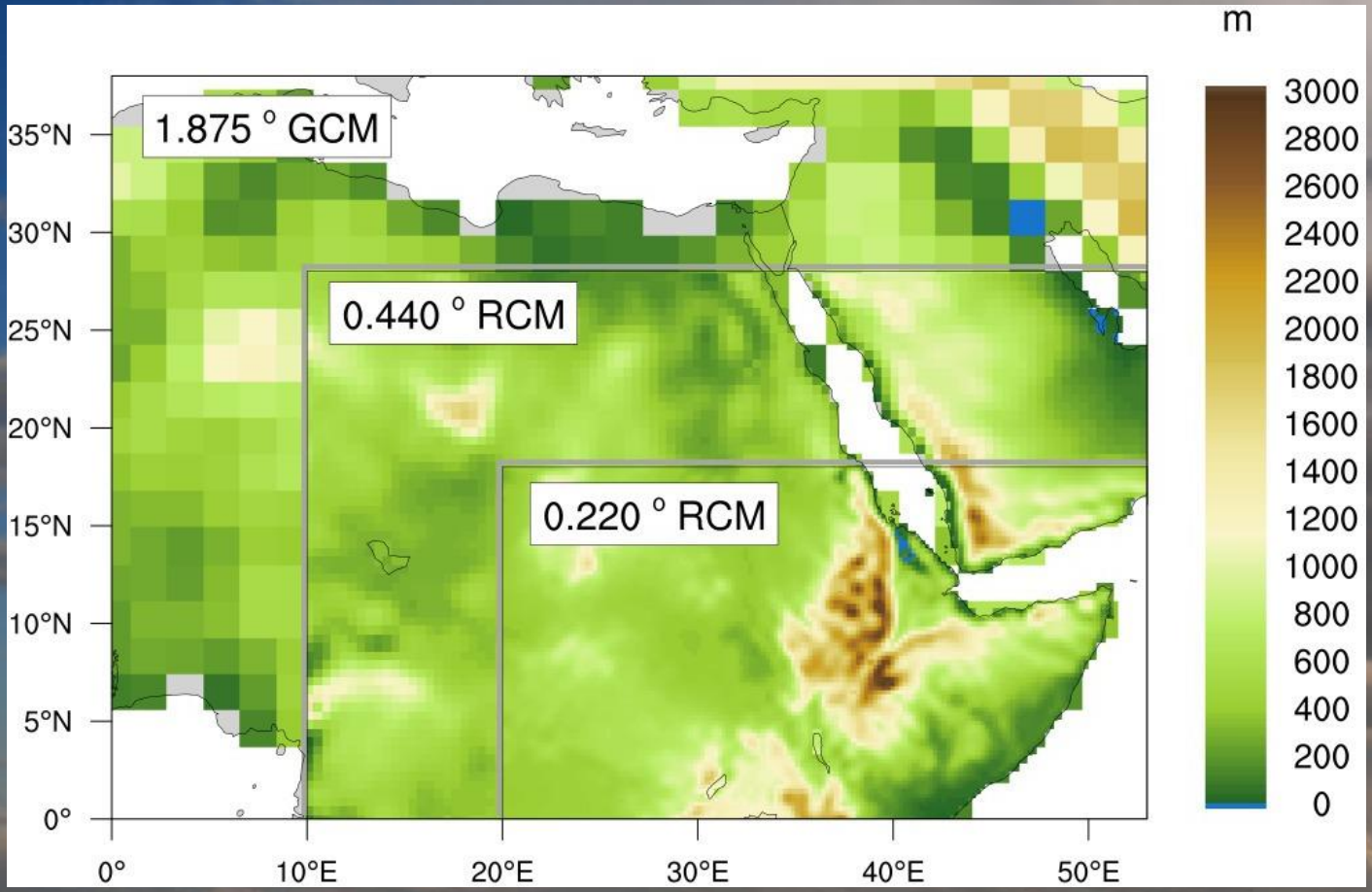
Overlay



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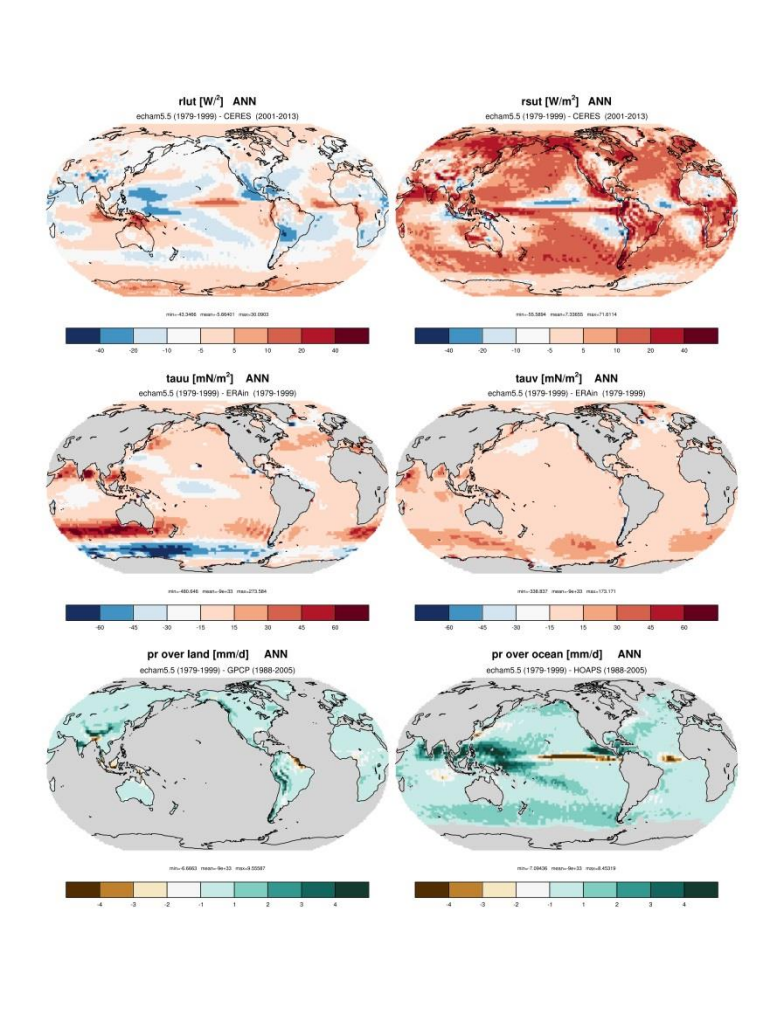
Panel plot



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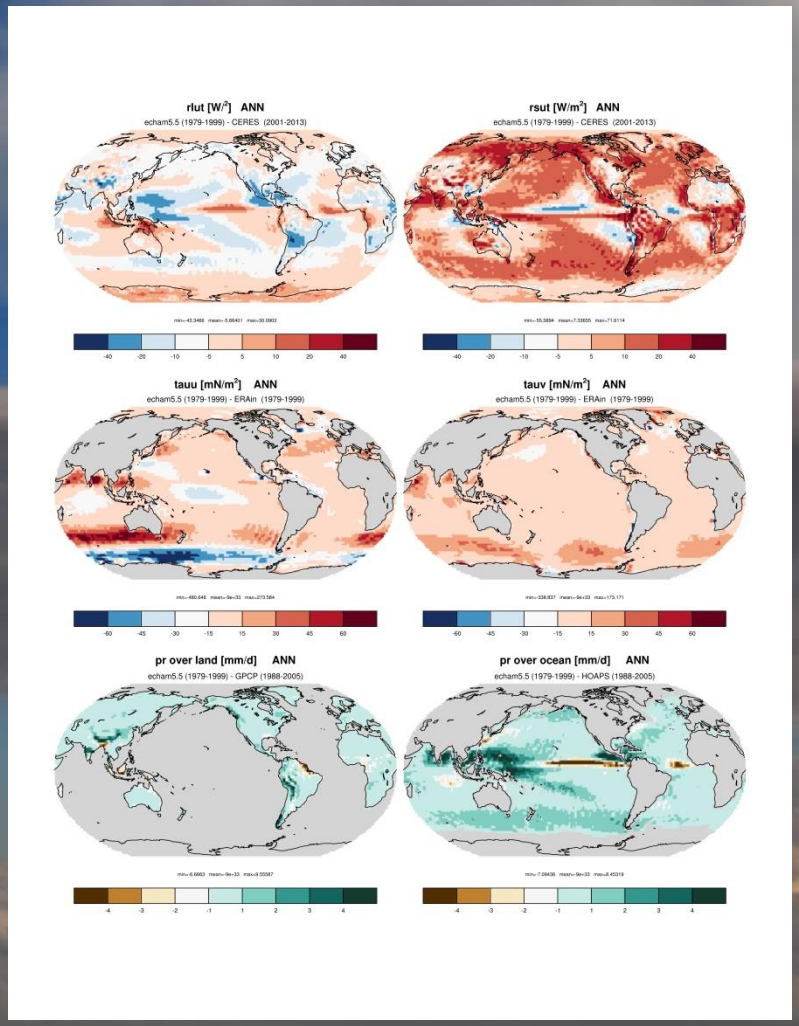

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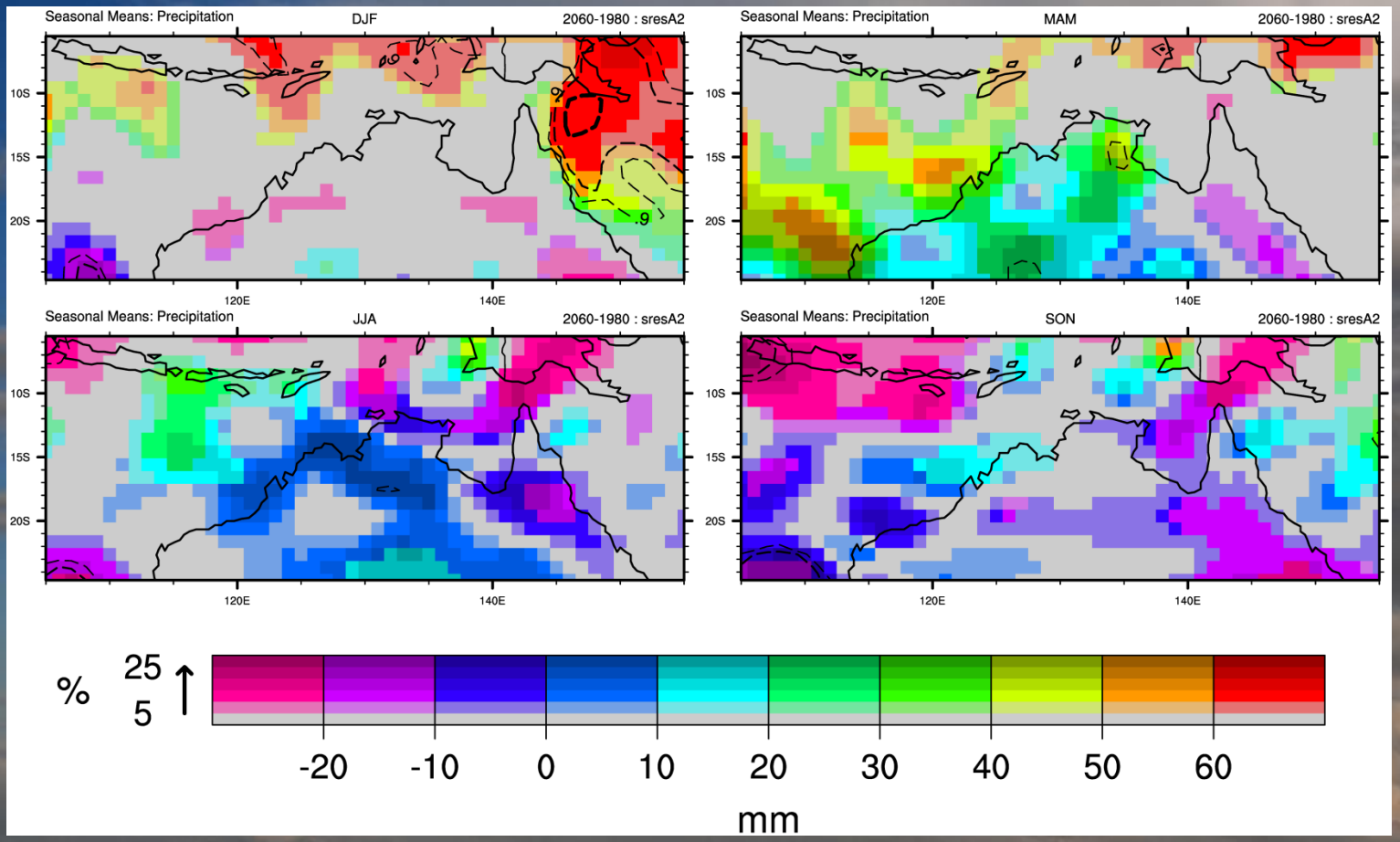
Evans plot



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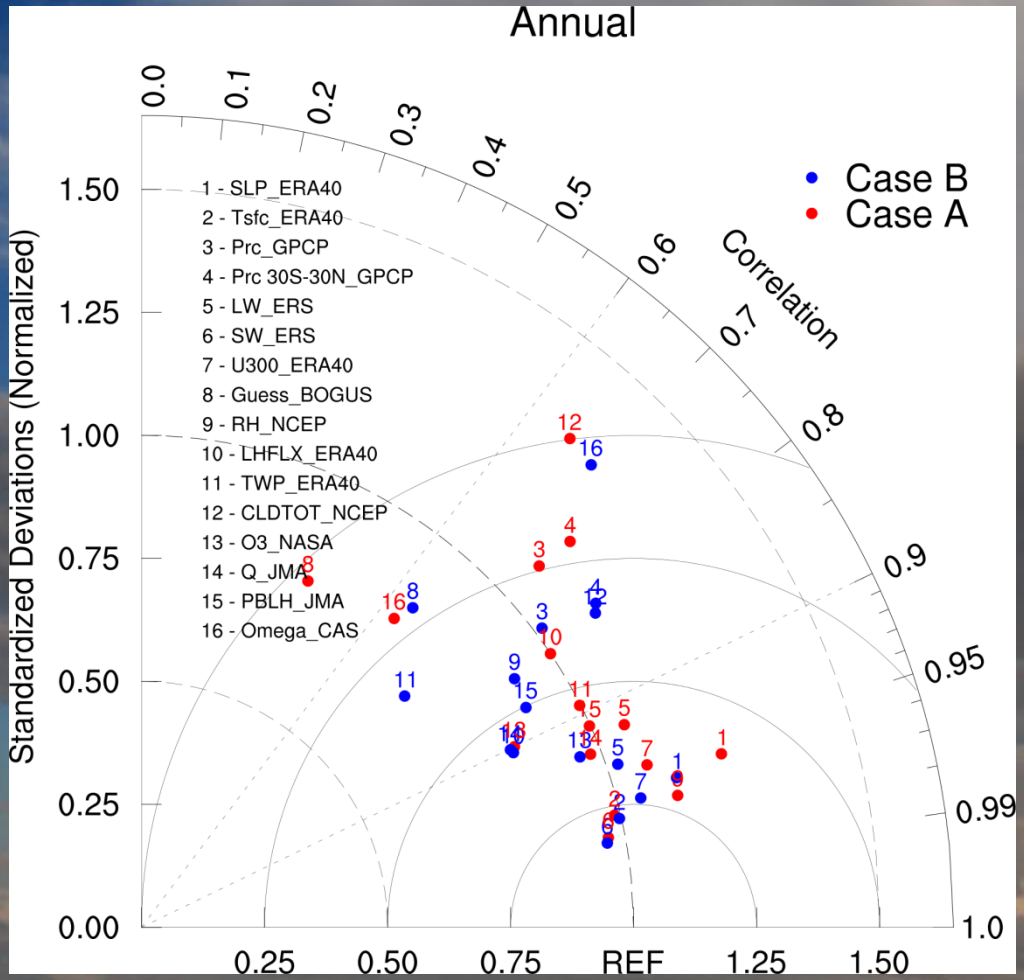
Taylor diagram



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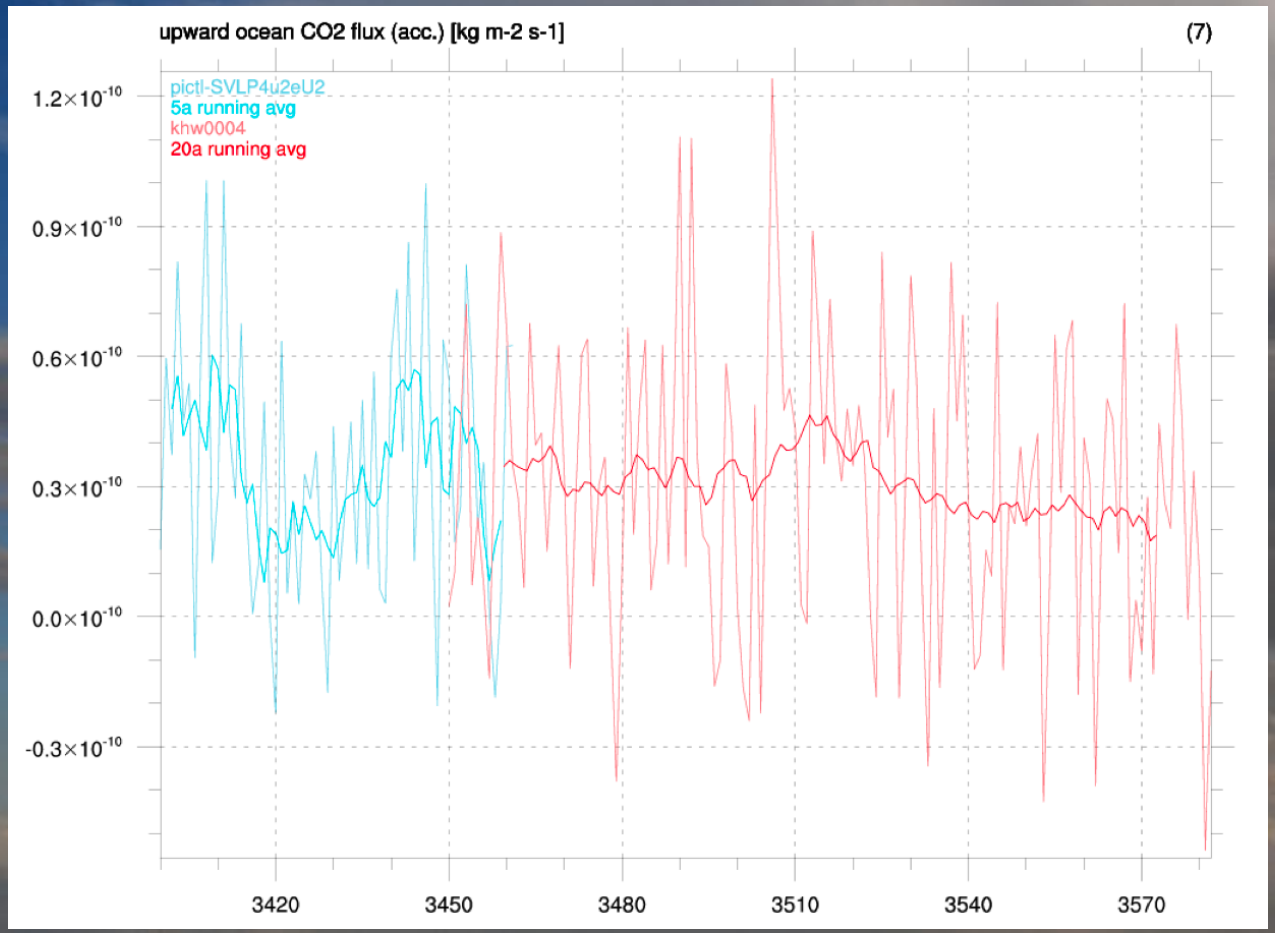
Monitoring for ECHAM6 – upward ocean CO2 flux (acc.)



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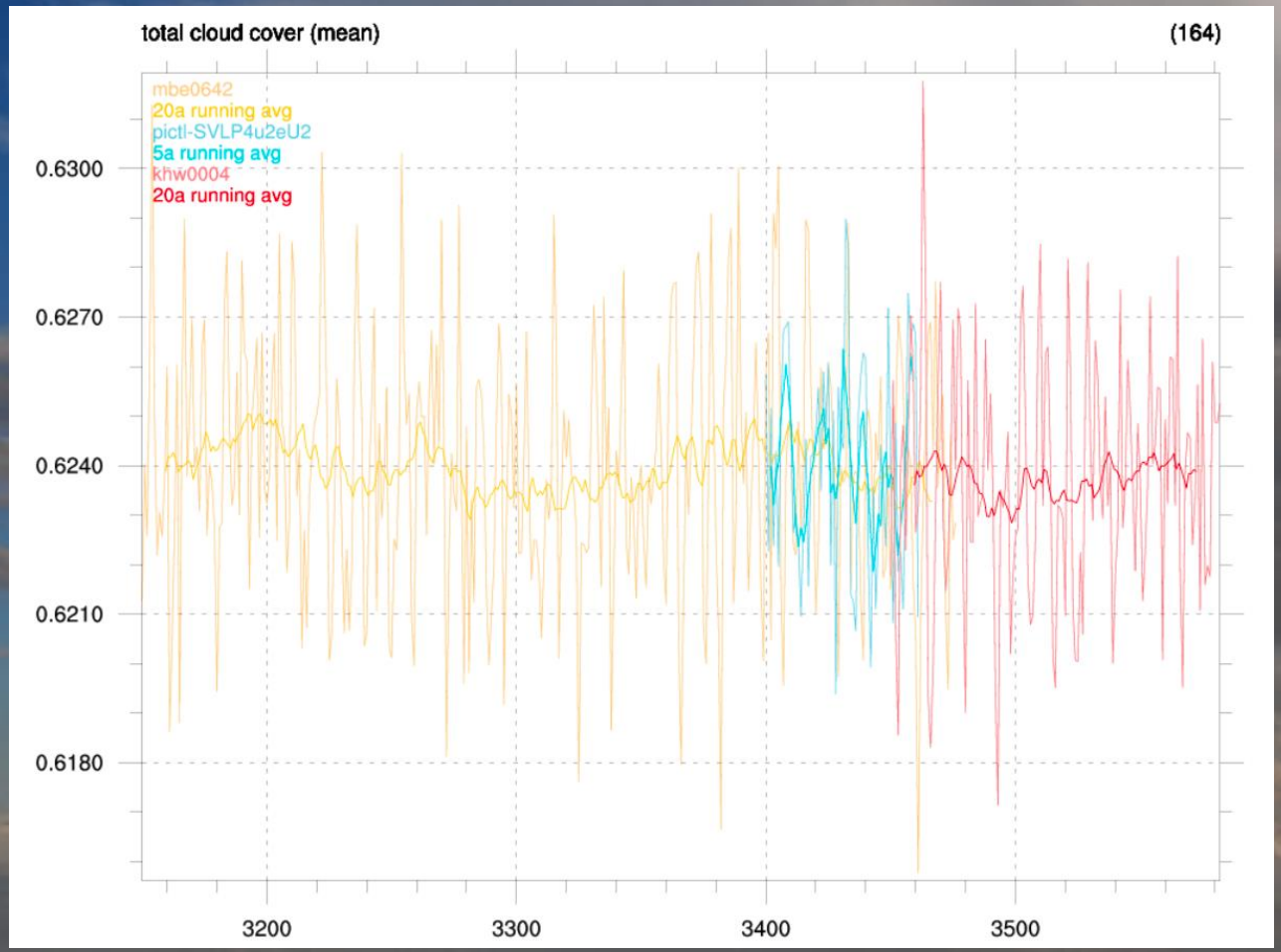
Monitoring for ECHAM6 – total cloud cover (mean)



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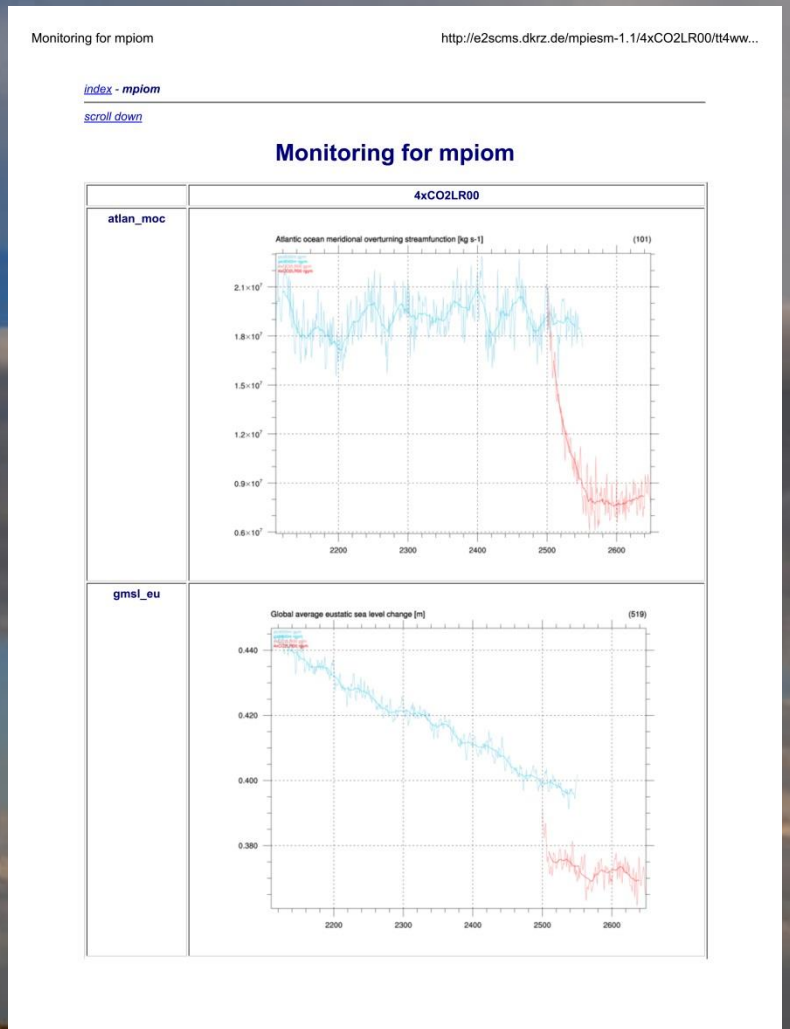
Monitoring for MPIOM



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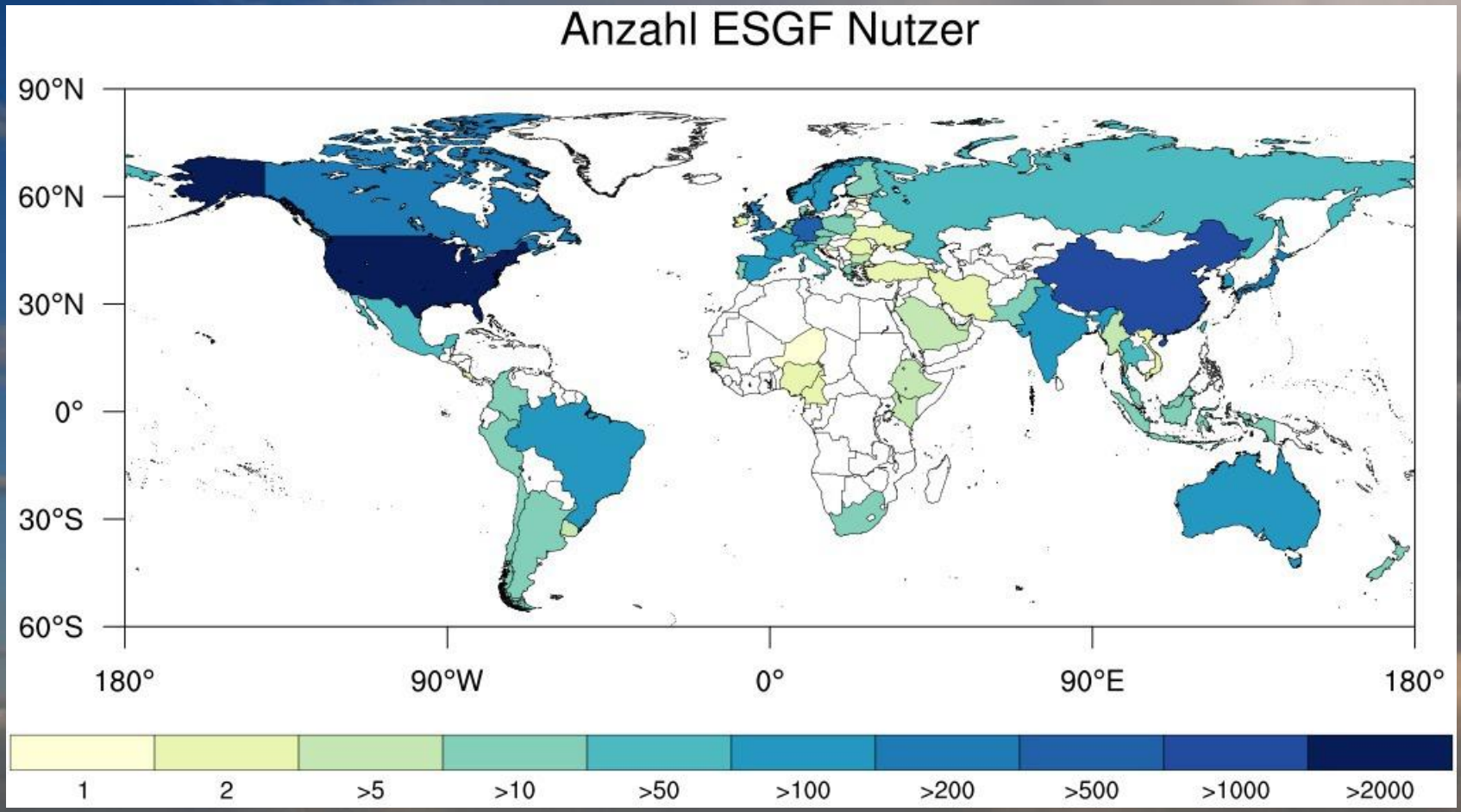
User distribution of DKRZ's ESGF portal



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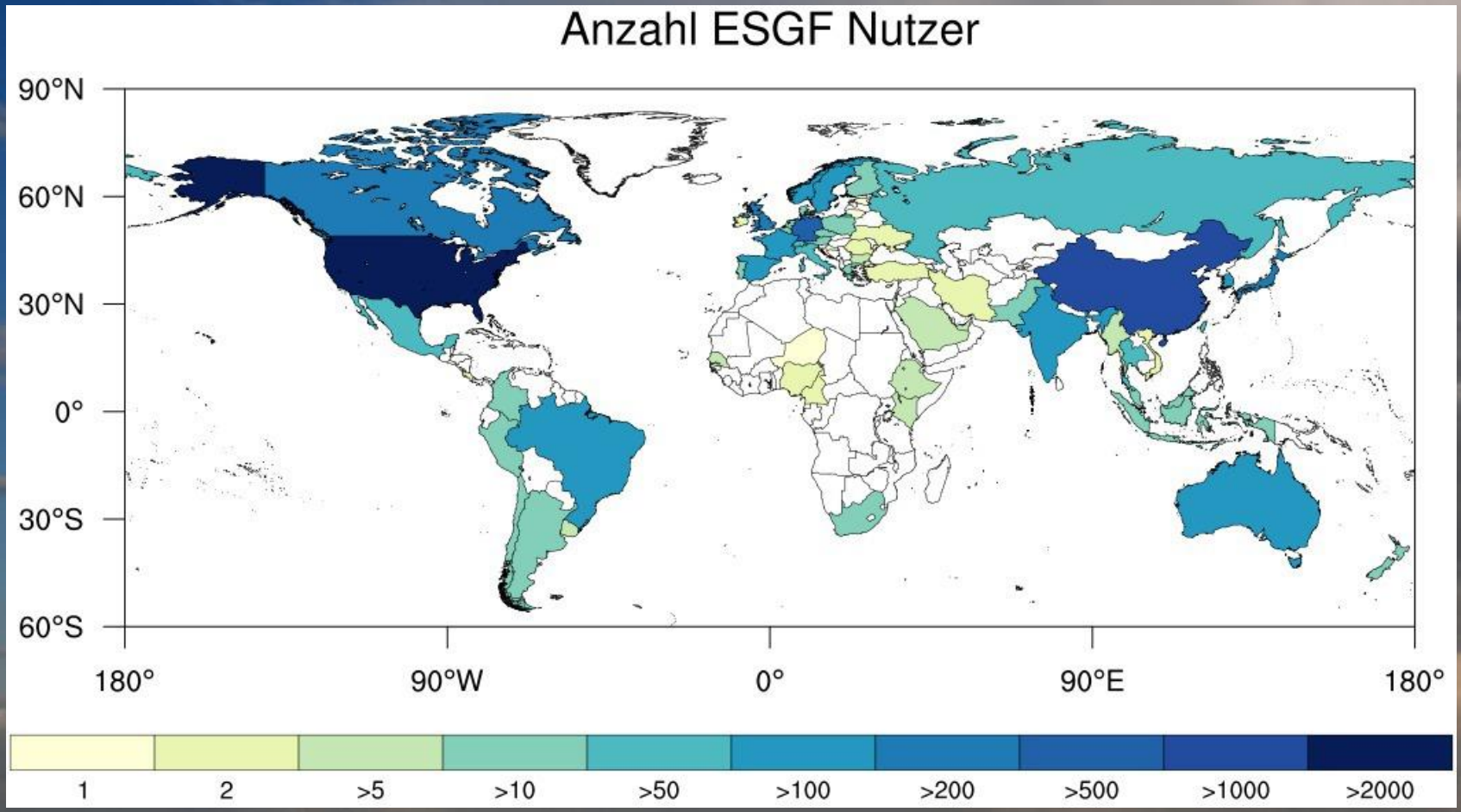

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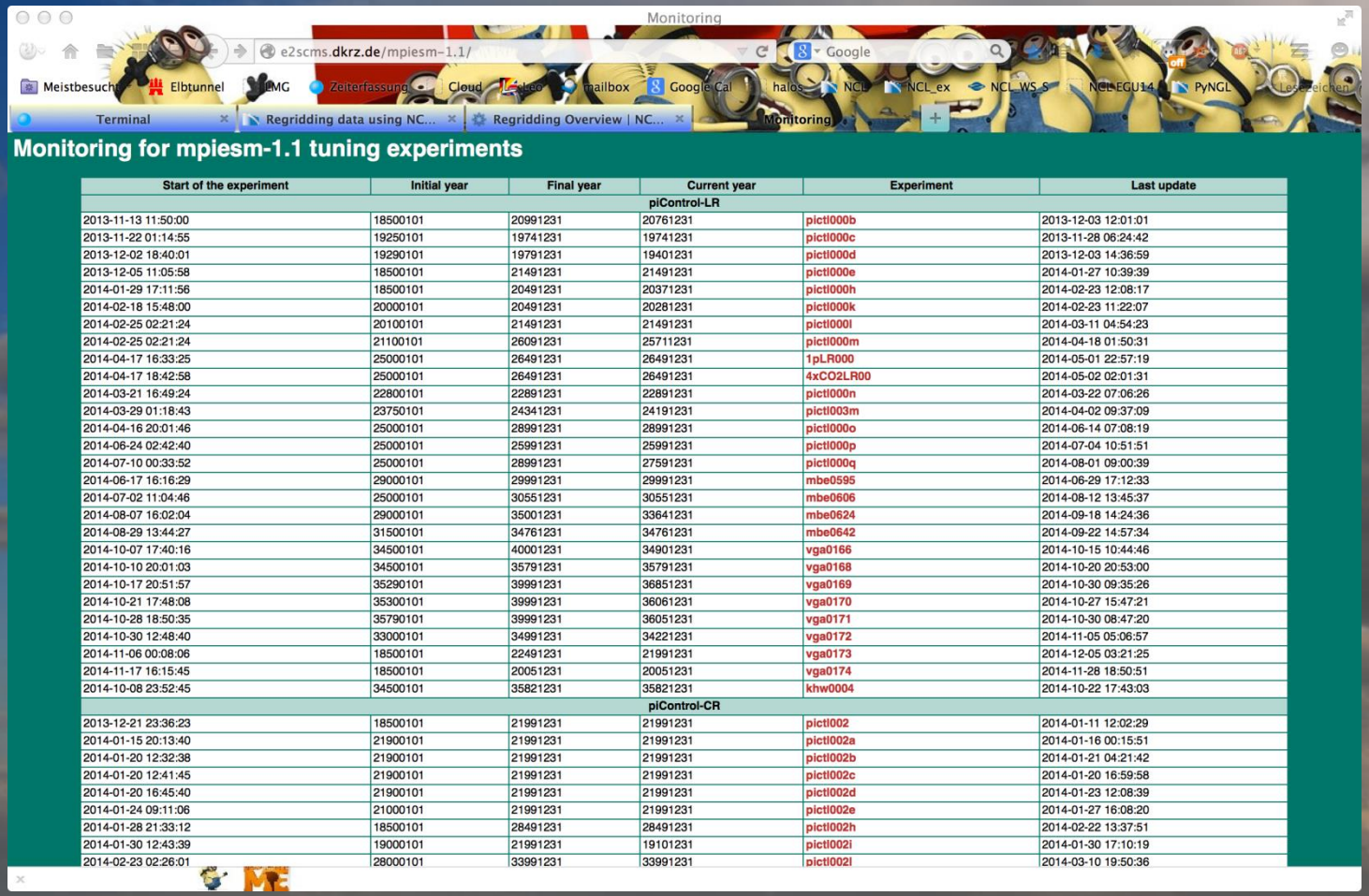
Monitoring web page for MPI-ESM



Monitoring for mpiesm-1.1 tuning experiments

Start of the experiment	Initial year	Final year	Current year	Experiment	Last update
			piControl-LR		
2013-11-13 11:50:00	18500101	20991231	20761231	pictl000b	2013-12-03 12:01:01
2013-11-22 01:14:55	19250101	19741231	19741231	pictl000c	2013-11-28 06:24:42
2013-12-02 18:40:01	19290101	19791231	19401231	pictl000d	2013-12-03 14:36:59
2013-12-05 11:05:58	18500101	21491231	21491231	pictl000e	2014-01-27 10:39:39
2014-01-29 17:11:56	18500101	20491231	20371231	pictl000h	2014-02-23 12:08:17
2014-02-18 15:48:00	20000101	20491231	20281231	pictl000k	2014-02-23 11:22:07
2014-02-25 02:21:24	20100101	21491231	21491231	pictl000l	2014-03-11 04:54:23
2014-02-25 02:21:24	21100101	26091231	25711231	pictl000m	2014-04-18 01:50:31
2014-04-17 16:33:25	25000101	26491231	26491231	1pLR000	2014-05-01 22:57:19
2014-04-17 18:42:58	25000101	26491231	26491231	4xCO2LR00	2014-05-02 02:01:31
2014-03-21 16:49:24	22800101	22891231	22891231	pictl000n	2014-03-22 07:06:26
2014-03-29 01:18:43	23750101	24341231	24191231	pictl003m	2014-04-02 09:37:09
2014-04-16 20:01:46	25000101	28991231	28991231	pictl000o	2014-06-14 07:08:19
2014-06-24 02:42:40	25000101	25991231	25991231	pictl000p	2014-07-04 10:51:51
2014-07-10 00:33:52	25000101	28991231	27591231	pictl000q	2014-08-01 09:00:39
2014-06-17 16:16:29	29000101	29991231	29991231	mbe0595	2014-06-29 17:12:33
2014-07-02 11:04:46	25000101	30551231	30551231	mbe0606	2014-08-12 13:45:37
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2014-08-29 13:44:27	31500101	34761231	34761231	mbe0642	2014-09-22 14:57:34
2014-10-07 17:40:16	34500101	40001231	34901231	vga0166	2014-10-15 10:44:46
2014-10-10 20:01:03	34500101	35791231	35791231	vga0168	2014-10-20 20:53:00
2014-10-17 20:51:57	35290101	39991231	36851231	vga0169	2014-10-30 09:35:26
2014-10-21 17:48:08	35300101	39991231	36061231	vga0170	2014-10-27 15:47:21
2014-10-28 18:50:35	35790101	39991231	36051231	vga0171	2014-10-30 08:47:20
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2014-11-06 00:08:06	18500101	22491231	21991231	vga0173	2014-12-05 03:21:25
2014-11-17 16:15:45	18500101	20051231	20051231	vga0174	2014-11-28 18:50:51
2014-10-08 23:52:45	34500101	35821231	35821231	khw0004	2014-10-22 17:43:03
			piControl-CR		
2013-12-21 23:36:23	18500101	21991231	21991231	pictl002	2014-01-11 12:02:29
2014-01-15 20:13:40	21900101	21991231	21991231	pictl002a	2014-01-16 00:15:51
2014-01-20 12:32:38	21900101	21991231	21991231	pictl002b	2014-01-21 04:21:42
2014-01-20 12:41:45	21900101	21991231	21991231	pictl002c	2014-01-20 16:59:58
2014-01-20 16:45:40	21900101	21991231	21991231	pictl002d	2014-01-23 12:08:39
2014-01-24 09:11:06	21000101	21991231	21991231	pictl002e	2014-01-27 16:08:20
2014-01-28 21:33:12	18500101	28491231	28491231	pictl002h	2014-02-22 13:37:51
2014-01-30 12:43:39	19000101	21991231	19101231	pictl002i	2014-01-30 17:10:19
2014-02-23 02:26:01	28000101	33991231	33991231	pictl002l	2014-03-10 19:50:36

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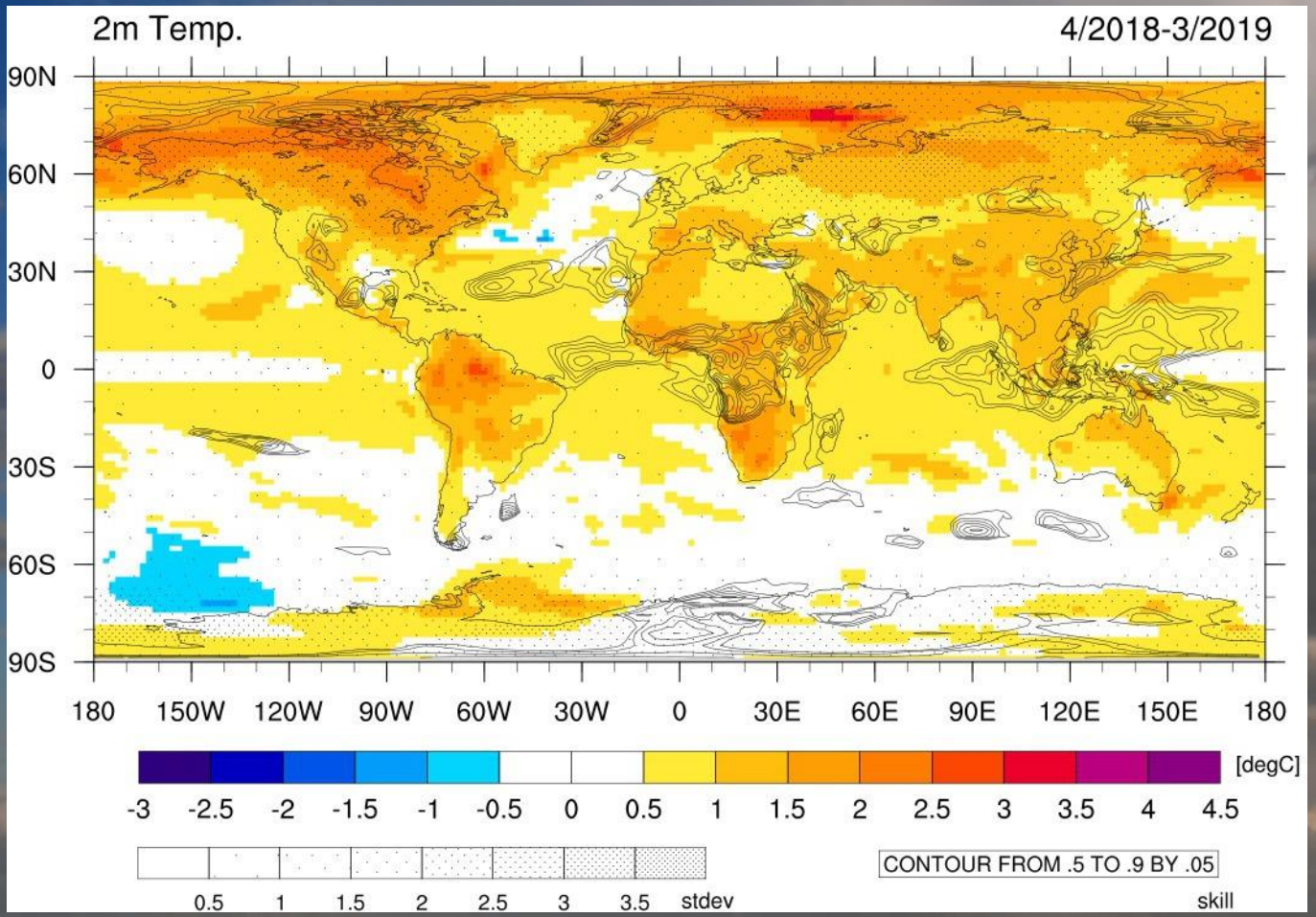
"Visualization of 2D uncertainty in decadal climate predictions" Böttinger et al.



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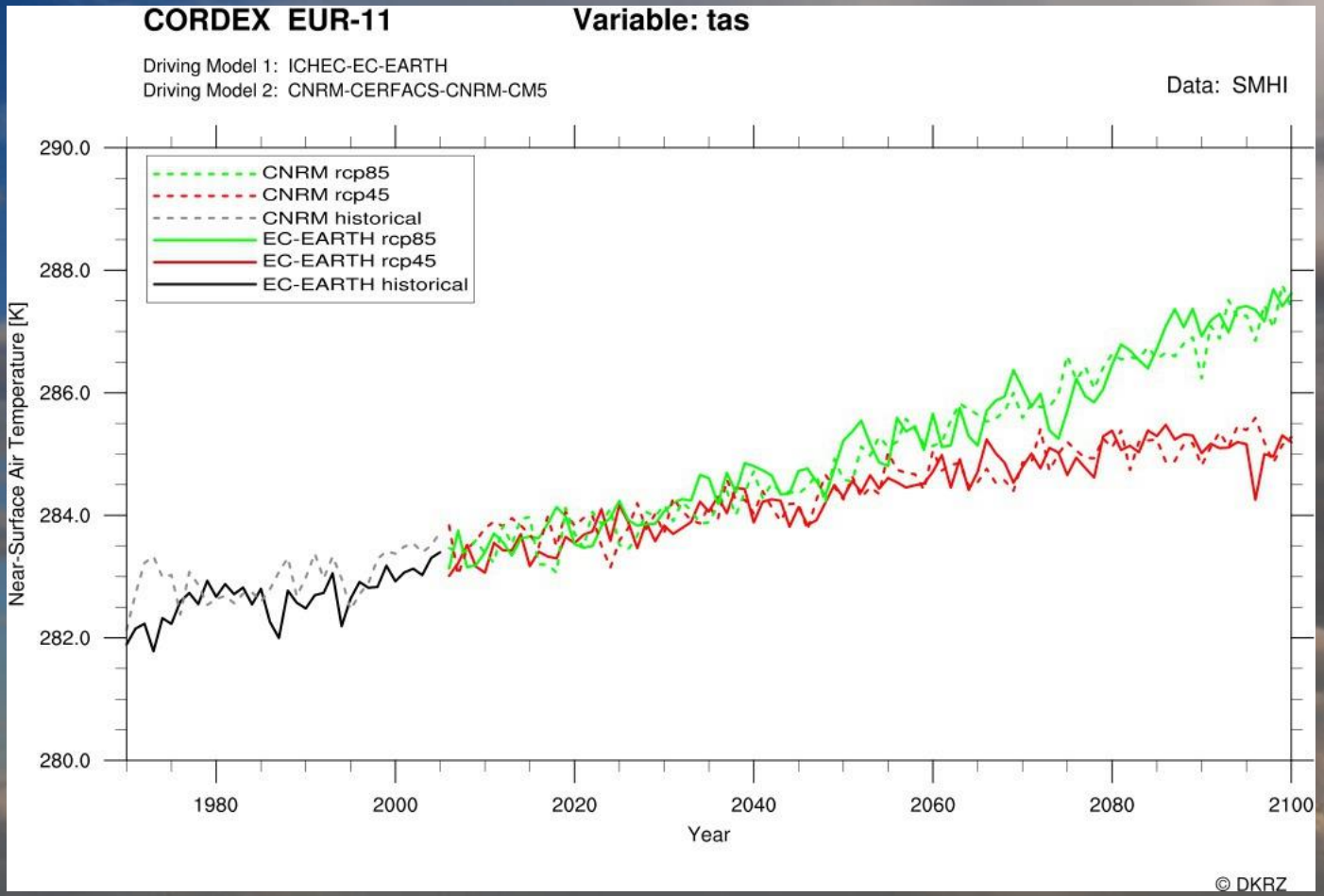
Comparison of CORDEX models



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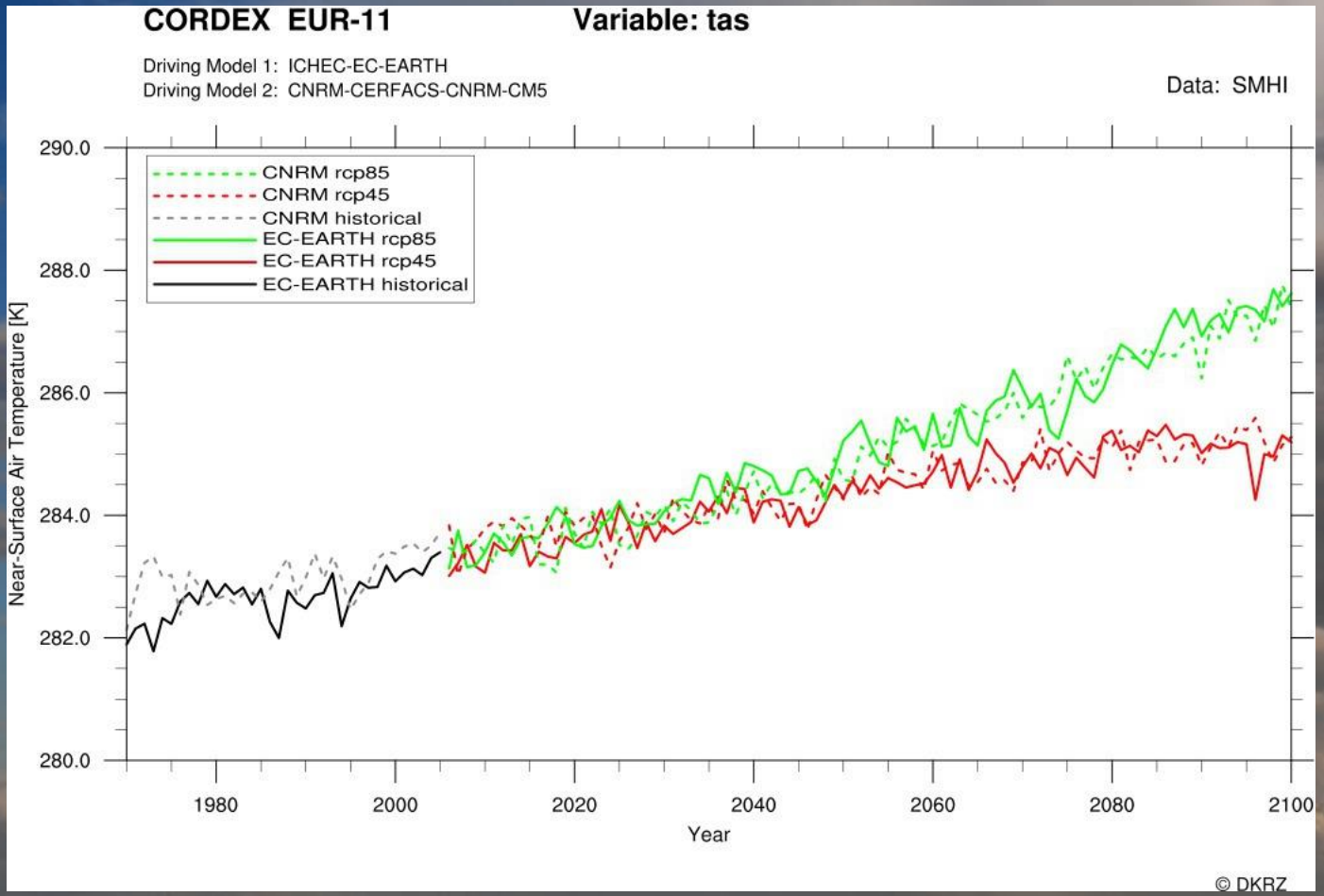

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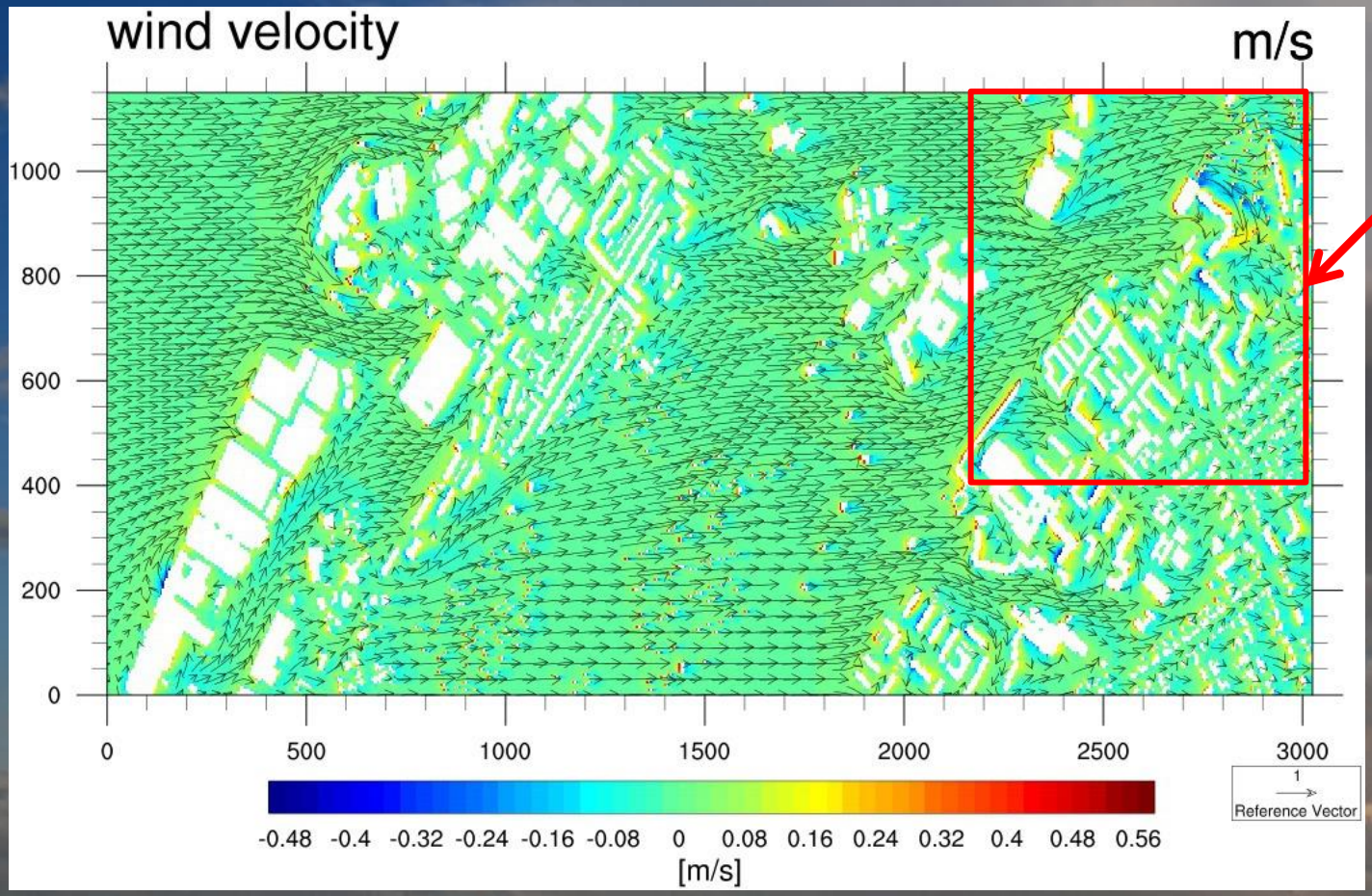
Monitoring web page for MPI-ESM



Zoom in

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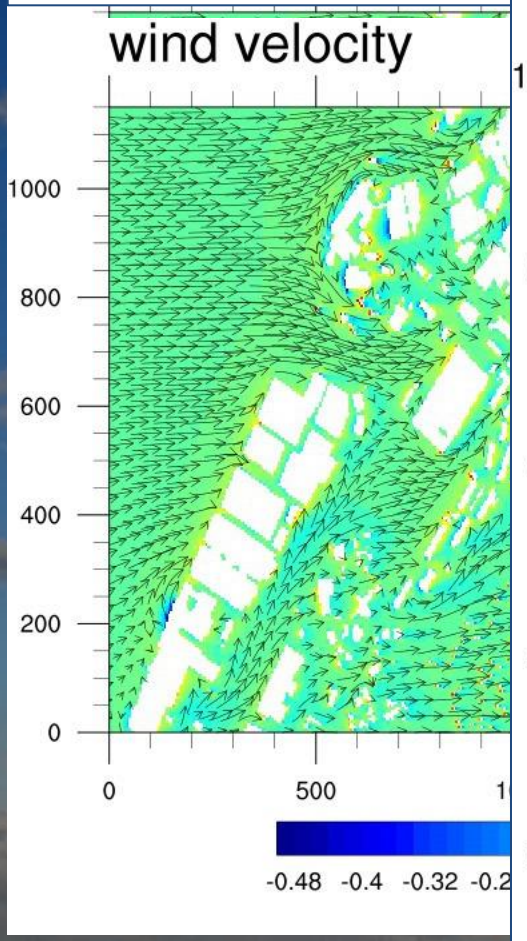
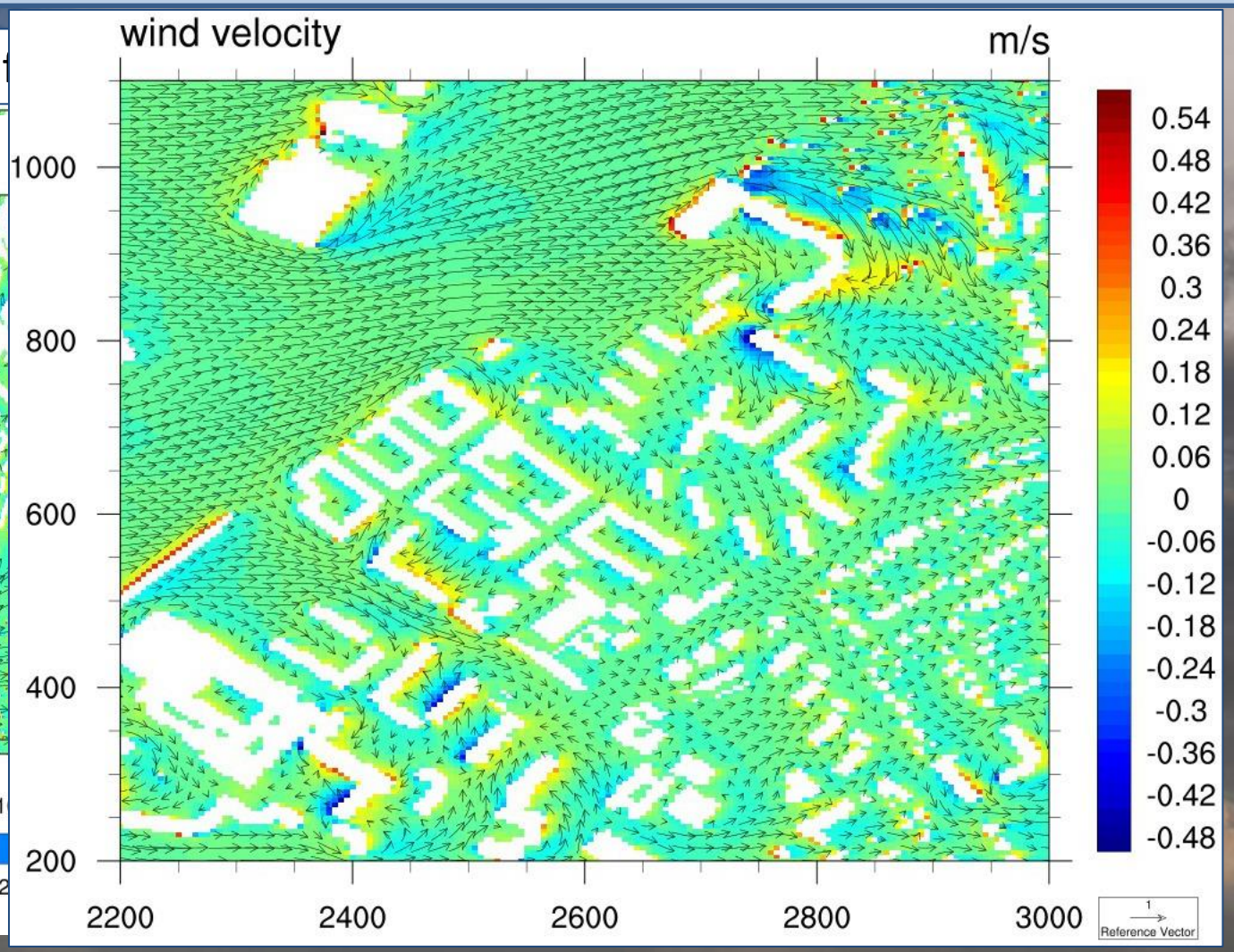
Monitoring web page f





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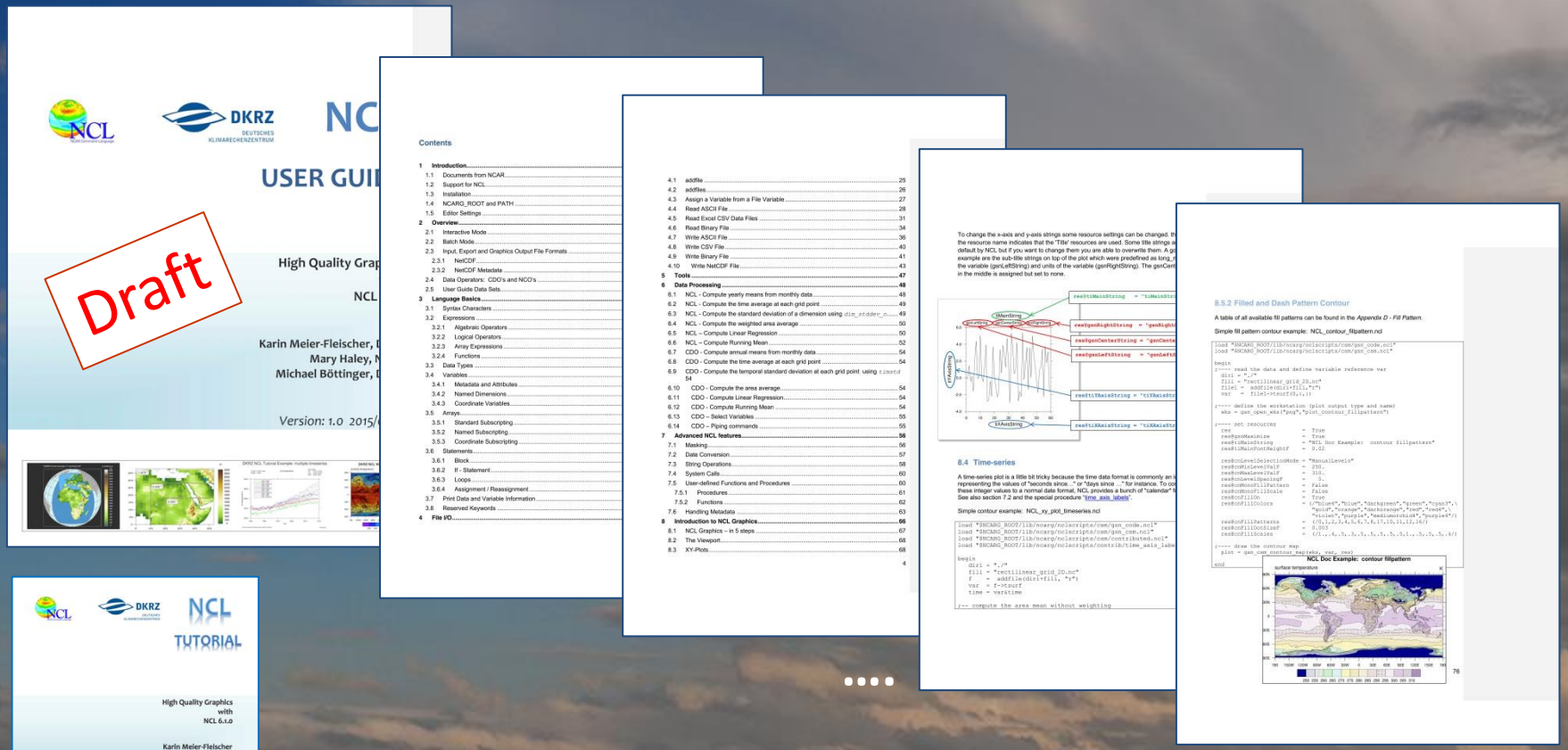
User Guide developed at DKRZ is still in progress (actual 238 pages)



Tutorial developed at DKRZ

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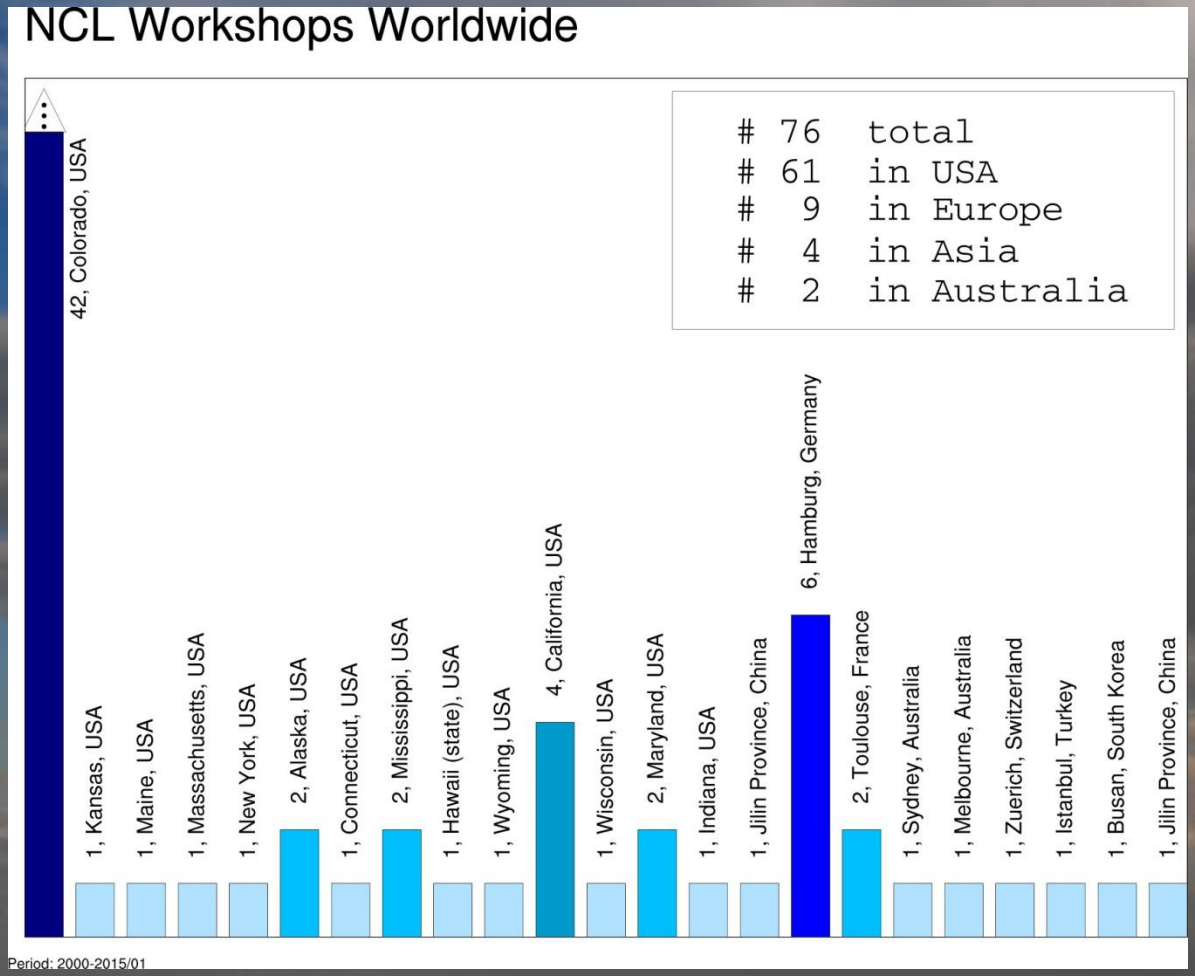
List of NCL workshops at NCAR, universities, and research sites world-wide



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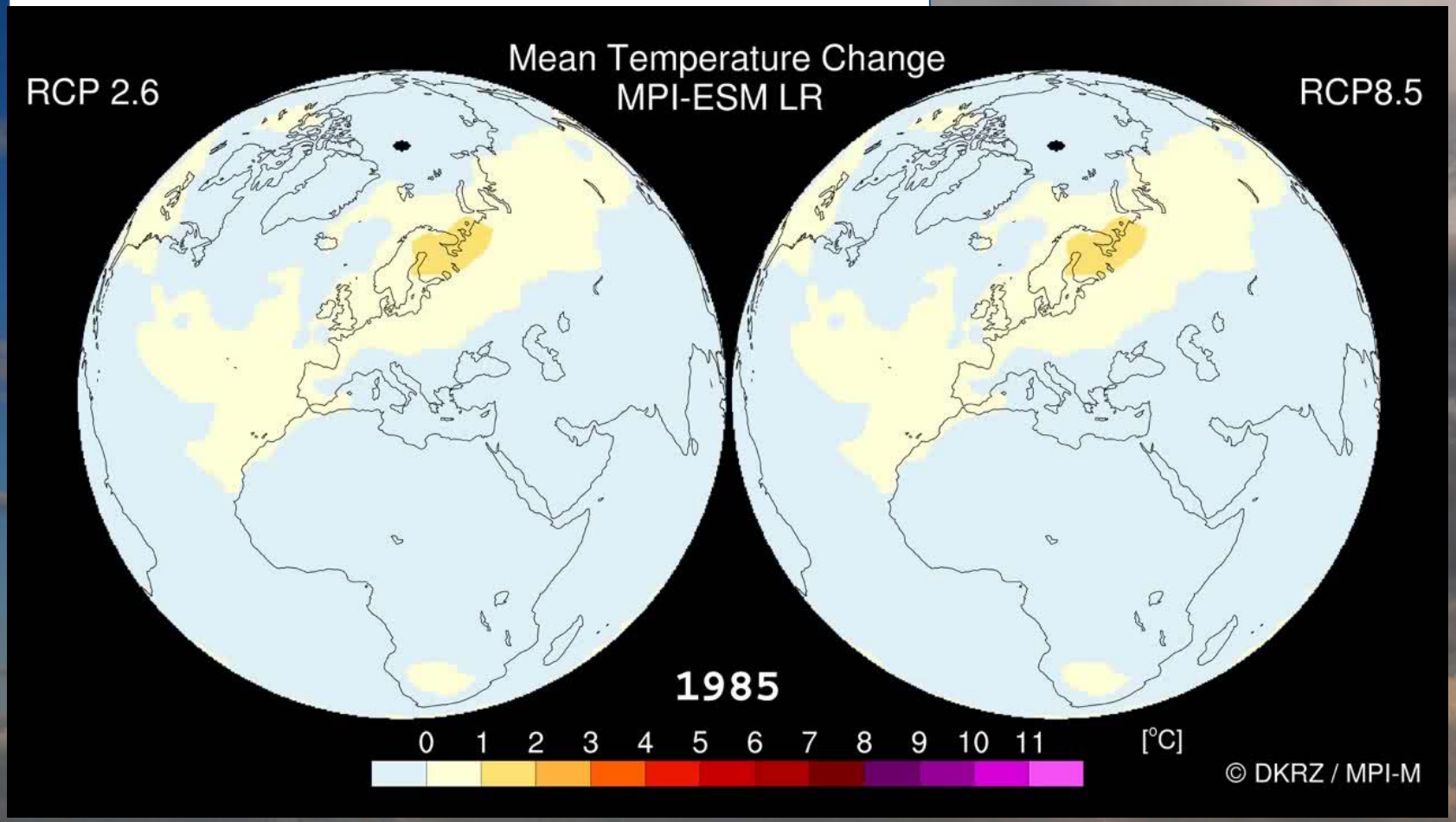
Animation: Mean temperature change (CMIP5)



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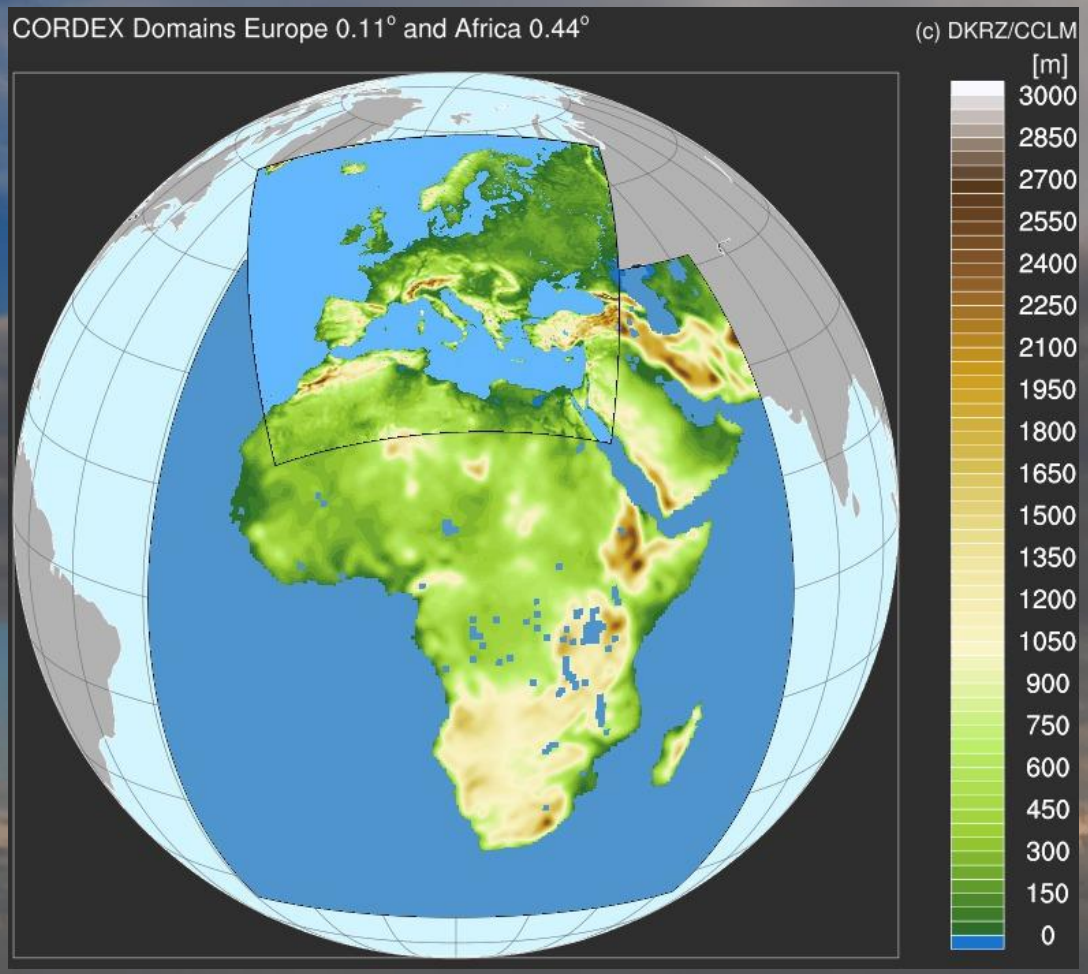
Display different domains and resolutions on Earth globe



NCL - a workhorse for data analysis and visualization in climate research

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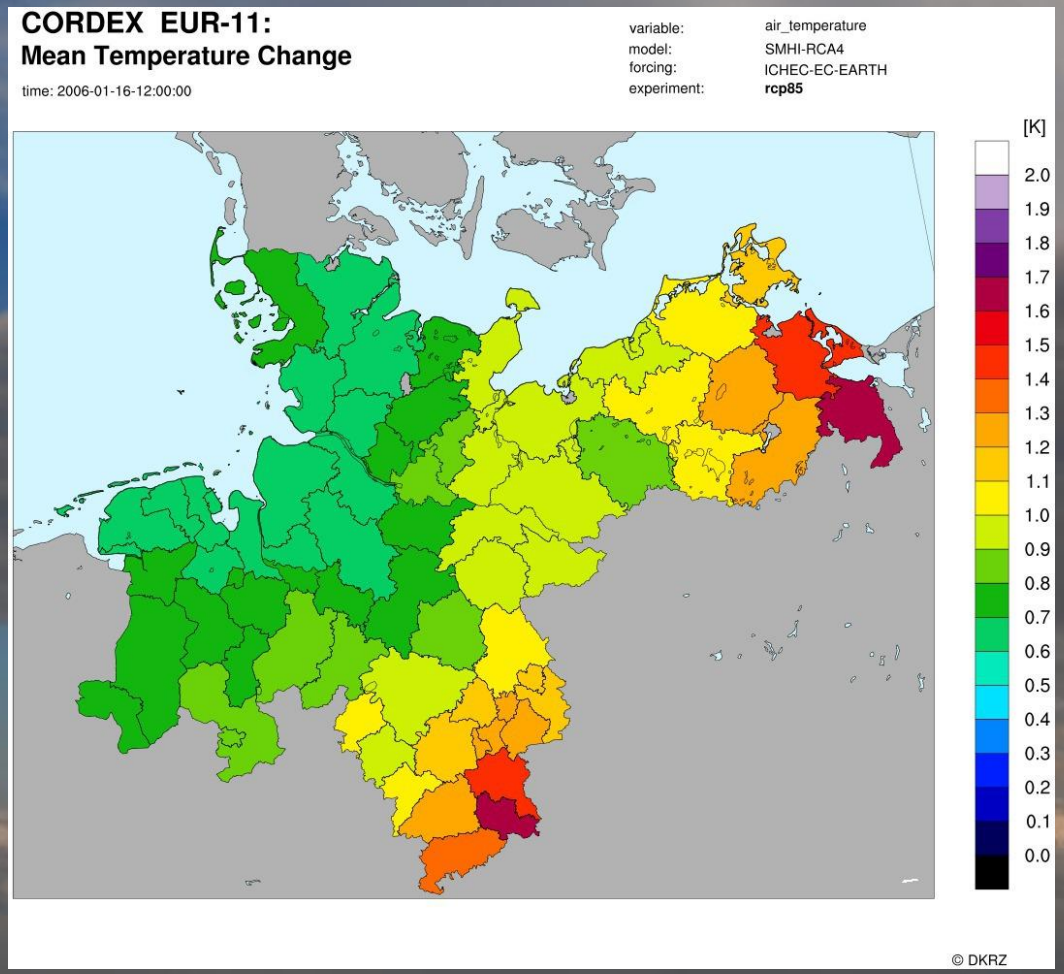
Use of Shapefiles



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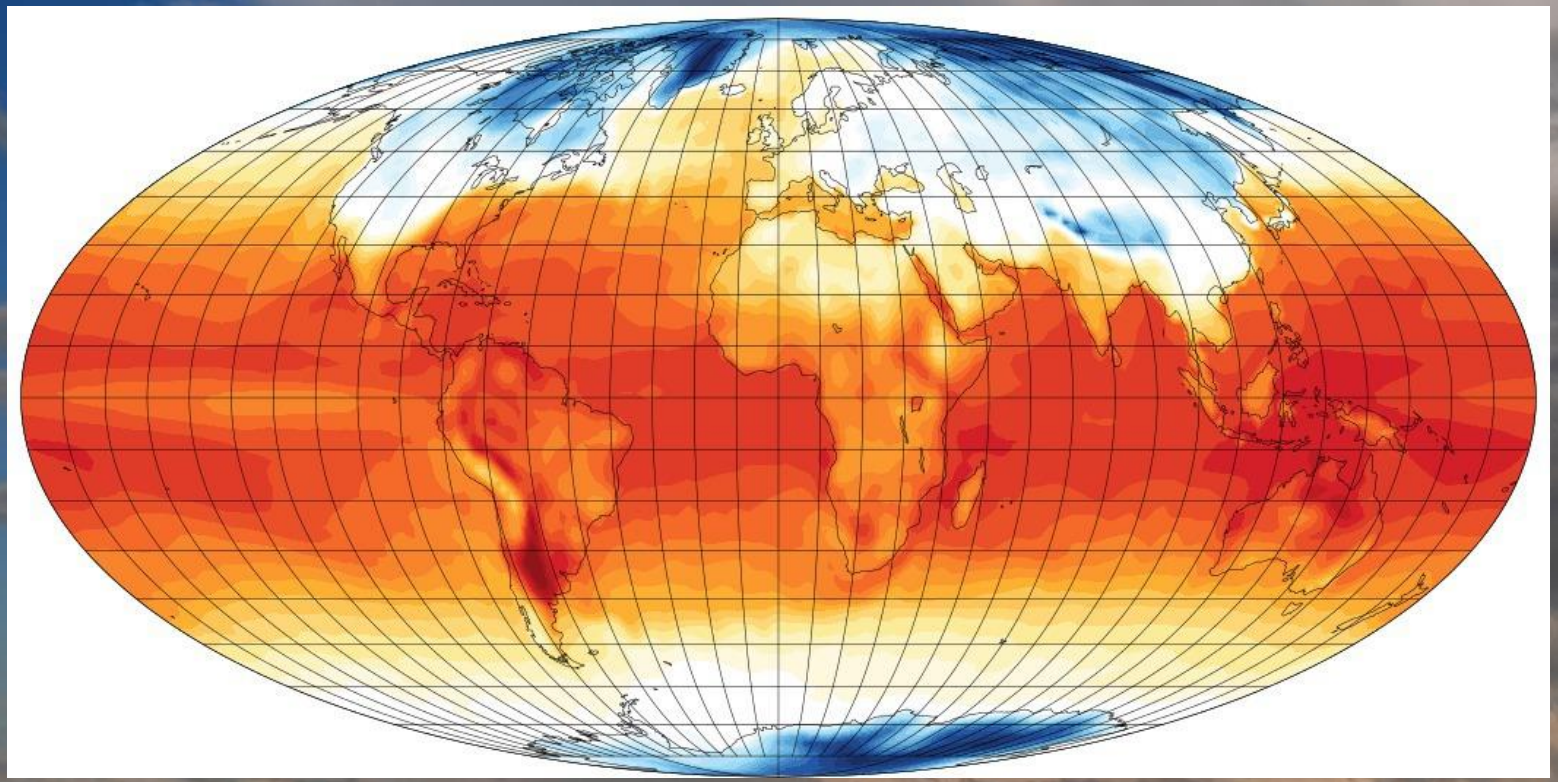
Mollweide projection and filled contours



Script

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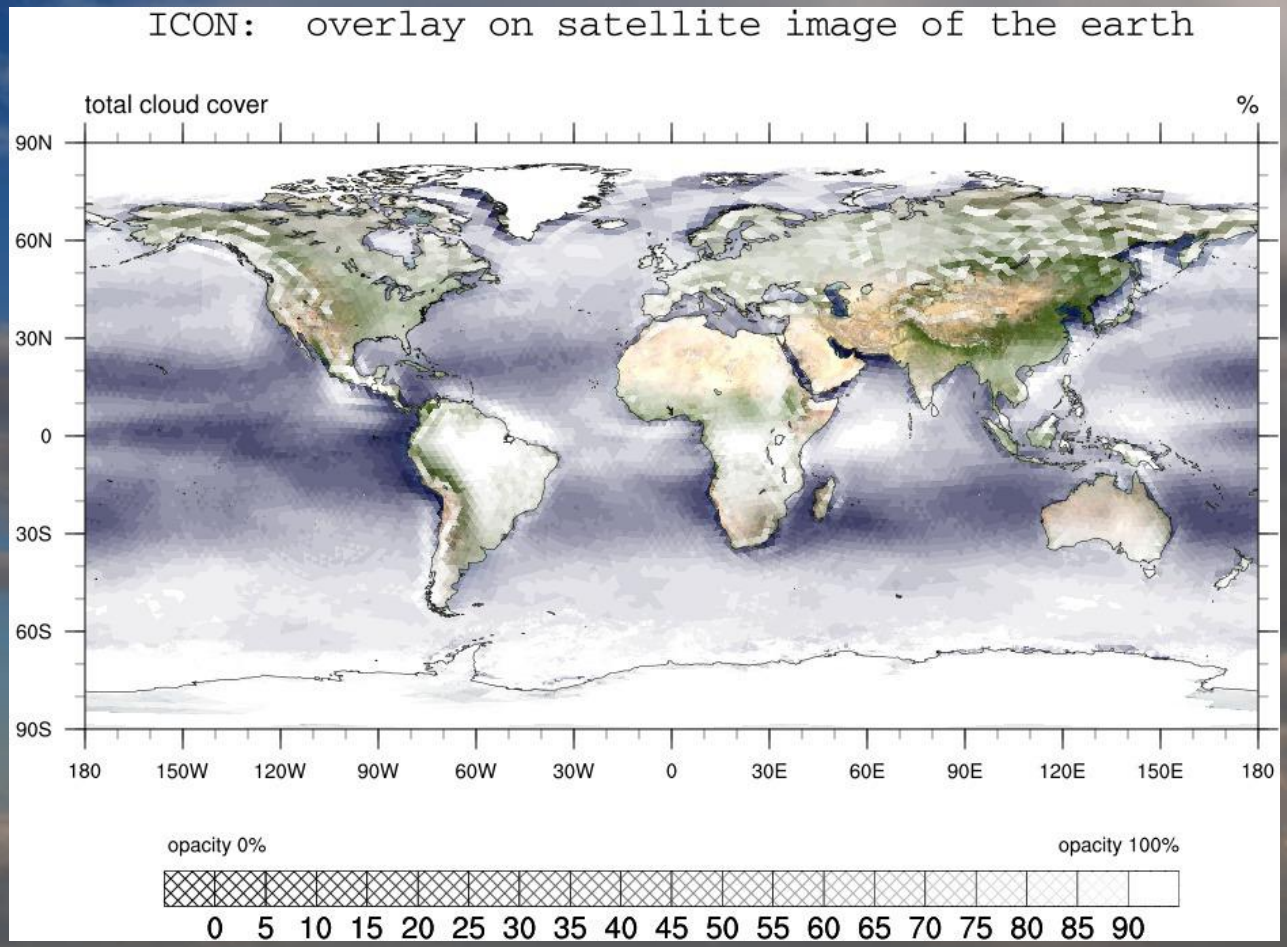
Use transparency to overlay on Earth topography (JPEG file)



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```
;-- load pre-defined functions and procedures
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
   f   =  addfile("$NCL_TUT/data/ECHAM5_OM_A1B_2001_0101-1001_2D.nc","r")
   u   =  f->u10(0,:,:)                      ;-- first time step
   v   =  f->v10(0,:,:)                      ;-- first time step
   t   =  f->tsurf(0,:,:)                    ;-- first time step

;-- define the workstation (graphic will be written to a file)
   wks_type = "png"                           ;-- plot output type
   if(wks_type .eq. "pdf" .or. wks_type .eq."ps") then
      wks_type@wkOrientation = "landscape"    ;-- orientation
   else if (wks_type .eq. "png")
      wks_type@wkWidth      =  1920
      wks_type@wkHeight     =  1920
   end if
   end if
   wks =  gsn_open_wks(wks_type,"plot_vector_overlay")

;-- set plot resources
   cnres                     = True
   cnres@gsnDraw             = False          ; don't draw
   cnres@gsnFrame            = False          ; don't advance frame
   cnres@cnFillOn            = True           ; turn on color
   cnres@cnLinesOn           = False          ; no contour lines
   cnres@mpFillOn            = False          ; no map fill
   cnres@cnMinLevelValF      = 230.0
   cnres@cnMaxLevelValF      = 310.0
   cnres@cnLevelSpacingF     =   2.5

   cnres@lbBoxMinorExtentF   =  0.3
   cnres@pmLabelBarWidthF    =  0.8
   cnres@gsnLeftString       = "surface temperature" ; change left string
   cnres@gsnRightString      =  t@units              ; assign right string
   cnres@tiMainString        = ""

   cnres@mpMinLonF           = -120
   cnres@mpMaxLonF           =   30
   cnres@mpMinLatF           =    0
   cnres@mpMaxLatF           =   90

   vcres                     = True           ; vector only resources
   vcres@gsnDraw             = False          ; don't draw
   vcres@gsnFrame            = False          ; don't advance frame
   vcres@vcGlyphStyle        = "CurlyVector"  ; curly vectors
   vcres@vcRefMagnitudeF     = 20             ; define vector ref mag
   vcres@vcRefLengthF        = 0.045          ; define length of vec ref
   vcres@vcRefAnnoOrthogonalPosF = -.535      ; move ref vector into plot
   vcres@gsnRightString      = " "            ; turn off right string
   vcres@gsnLeftString       = " "            ; turn off left string
   vcres@tiXAxisString       = " "            ; turn off axis label

   cplot  = gsn_csm_contour_map_ce(wks,t,cnres)
   vplot  = gsn_csm_vector(wks,u,v,vcres)
   overlay(cplot,vplot)

   draw(cplot)
   frame(wks)
end
```

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```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;-- read the data and define
  file1 = addfile("$NCL_TUT/data/ECHAM5_OM_A1B_2001_0101-1001_2D.nc","r")
  var   =  file1->tsurf(0,:,:)

;-- define the workstation (plot type and name)
  wks_type = "png"                          ;-- plot output type
  if(wks_type .eq. "pdf" .or. wks_type .eq."ps") then
     wks_type@wkOrientation = "landscape"     ;-- orientation
  else if (wks_type .eq. "png")
     wks_type@wkWidth      =  1920
     wks_type@wkHeight     =  1920
  end if
  end if
  wks = gsn_open_wks(wks_type,"TUT_contour_filled_map")

;-- set resources
  res                       =  True
  res@gsnSpreadColors       =  True
  res@gsnMaximize           =  True

  res@cnFillOn              =  True            ;-- turn on contour fill
  res@cnLinesOn             =  False           ;-- turn off contour lines
  res@cnLineLabelsOn        =  False           ;-- turn off line labels
  res@cnLevelSelectionMode  = "ManualLevels"
                                    ;-- set contour levels manually
  res@cnMinLevelValF        =  250.            ;-- minimum contour level
  res@cnMaxLevelValF        =  310.            ;-- maximum contour level
  res@cnLevelSpacingF       =  1               ;-- contour level spacing

  res@lbLabelStride         =  4
  res@lbBoxMinorExtentF =  0.15    ;-- decrease the height of the labelbar
  res@tiMainString  = ""           ;-- NO title string
;  res@tiMainString = "DKRZ NCL Tutorial Example: filled contour map"
                                   ;-- title string
  res@tiMainFontHeightF =  0.02

;-- draw the contour map
  plot = gsn_csm_contour_map(wks, var, res)

end
```

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```
load "$NCARG_ROOT/lib/ncarg/nclex/gsun/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclex/gsun/gsn_csm.ncl"

begin
  diri = "./"
  fili = "$HOME/NCL/DKRZ_workshop/data/ECHAM5_OM_A1B_2001_0101-1001_2D.nc"

  file1 = addfile(dir+fili,"r")
  var   = file1->tsurf(0,:,:)
  units = var@units

;-- open a workstation
  wks_type = "png"                          ;-- plot output type
  if(wks_type .eq. "pdf" .or. wks_type .eq."ps") then
     wks_type@wkOrientation = "landscape"     ;-- orientation
  else if (wks_type .eq. "png")
     wks_type@wkWidth      =  1920
     wks_type@wkHeight     =  1080
  end if
  end if
  wks = gsn_open_wks(wks_type,"plot_mollweide_projection")

;-- set resources
  res                       =  True
  res@gsnMaximize           =  True
  res@gsnRightString        = ""
  res@gsnLeftString         = ""

  res@cnLevelSelectionMode = "ManualLevels"
  res@cnMinLevelValF        =  230.0
  res@cnMaxLevelValF        =  310.0
  res@cnLevelSpacingF       =    2.5

  res@cnFillOn              =  True
  res@cnLinesOn             =  False
  res@cnLineLabelsOn        =  False

  res@lbLabelBarOn          =  False
;  res@lbBoxLinesOn         =  False
;  res@lbLabelAutoStride    =  True

  res@mpProjection          = "Mollweide"

  res@mpPerimOn             =  False  ;-- don't draw the box around the plot
  res@mpGridAndLimbOn       =  True
  res@mpGridLatSpacingF     =  10.
  res@mpGridLonSpacingF     =  10.
;  res@mpCenterLatF          =  -180.
;  res@mpCenterLonF          =   180.

;  res@tiMainString          = "NCL: Mollweide Projection  (tsurf)"

  plot = gsn_csm_contour_map(wks,var,res)

end
```

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```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin
;-- read the data and define
  diri = "$NCL_TUT/data/"
  fili = "tos_Omon_MPI-ESM-LR_rcp45_r1i1p1_20060101.nc"

   f = addfile(dir+fili,"r")
   tos         =  f->tos
   tos@lat2d   =  f->lat
   tos@lon2d   =  f->lon
   var         =  tos(0,:,:)                ;-- select first time step

;-- define the workstation (plot type and name)
   wks_type = "png"                         ;-- plot output type
   if(wks_type .eq. "pdf" .or. wks_type .eq."ps") then
      wks_type@wkOrientation = "landscape"   ;-- orientation
   else if (wks_type .eq. "png")
      wks_type@wkWidth      =  1920
      wks_type@wkHeight     =  1080
   end if
   end if
   wks = gsn_open_wks(wks_type,"plot_bipolar_grid_MPI-ESM_global")

;-- set resources
   res                       =  True
   res@gsnMaximize           =  True
   res@gsnAddCyclic          =  True
   res@gsnLeftString         = ""
   res@gsnRightString        = ""

   res@cnFillOn              =  True            ;-- turn on contour fill
   res@cnFillMode            = "CellFill"
   res@cnMonoFillColor       =  True
   res@cnFillColor           = "yellow"
   res@cnFillOpacityF        =  0.5
   res@cnLinesOn             =  False           ;-- turn lines off
   res@cnLineLabelsOn        =  False           ;-- turn labels off
   res@cnCellFillEdgeColor   =  1
   res@cnCellFillMissingValEdgeColor = "black"

   res@mpProjection          = "Orthographic"
   res@mpDataBaseVersion     = "MediumRes"
   res@mpFillOn              =  True
   res@mpCenterLonF          =  0
   res@mpPerimOn             =  False
                                   ;-- don't draw the box around the plot
   res@lbLabelBarOn          =  False

   res@tiMainString          = "MPI-ESM grid"

;-- draw the grids
   res@mpCenterLatF = 40
   plot = gsn_csm_contour_map(wks,var,res)

   res@mpCenterLatF =  -40
   plot = gsn_csm_contour_map(wks,var,res)

 end
```

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```
begin
;-- input file
  gridinfofile = "$HOME/data/ICON/grids/r2b4_amip.nc"  ;-- grid info file
  GridInfoFile =  addfile( gridinfofile, "r" )         ;-- add grid file
                                    ;-- (not contained in data file!!!)
;-- define the cell polygon points
  rad2deg =  45./atan(1.)                 ;-- radians to degrees
  vlon =  GridInfoFile->clon_vertices * rad2deg  ;-- cell lon vertices
  vlon =  where(vlon.lt.0, vlon + 360, vlon)     ;-- longitude: 0-360
  vlat =  GridInfoFile->clat_vertices * rad2deg  ;-- cell lat vertices
  nv   =  dimsizes(vlon(0,:))             ;-- number of points in polygon

;-- open workstation
  wks_type         = "png"             ;-- plot output type
  wks_type@wkWidth = 1920              ;-- set workstation width in pixel
  wks_type@wkHeight = 1080             ;-- set workstation height in pixel
  wks = gsn_open_wks(wks_type,"plot_ICON_edges")
                                    ;-- open a workstation
;-- set resources
  mres             =  True
  mres@gsnDraw     =  False            ;-- don't draw the plot
  mres@gsnFrame    =  False            ;-- don't advance the frame
  mres@tiMainString = "ICON grid"
  mres@vpWidthF     =  0.9             ;-- viewport width
  mres@vpHeightF    =  0.85            ;-- viewport height
  mres@vpXF         =  0.08            ;-- start x-position
  mres@vpYF         =  0.9             ;-- start y-position
  mres@mpFillOn     =  True            ;-- fill map grey
  mres@mpOutlineOn  =  True            ;-- outline map
  mres@mpGridLineColor = "grey60"      ;-- grid line color
  mres@mpGridAndLimbOn =  False        ;-- draw grid lines
  mres@mpGeophysicalLineColor  = "black"  ;-- outline color
  mres@mpGeophysicalLineThicknessF = 1.5
                                  ;-- thickness of continental outlines
  mres@mpPerimOn  =  False            ;-- don't draw the box around the plot
  mres@mpDataBaseVersion    = "MediumRes"      ;-- map resolution
  mres@mpGreatCircleLinesOn =  False           ;-- important: v6.2.0 False
  mres@mpProjection         = "Orthographic"   ;-- projection
  mres@mpCenterLonF         =  38              ;-- center at lon
  mres@mpCenterLatF         =  40              ;-- center at lat

  map = gsn_csm_map(wks,mres)                  ;-- create the map

;-- set polygon resources
  pres                      =  True
  pres@gsEdgesOn            =  True            ;-- draw polygon edges
  pres@gsEdgeColor          = "grey20"         ;-- polygon outline color
  pres@gsFillColor          = "yellow"         ;-- polygon fill color
  pres@gsFillOpacityF       =  0.5             ;-- polygon opacity
  pres@gsSegments           = ispan(0,dimsizes(vlon(:,0)) * 3,3)

  gsid = gsn_add_polygon(wks,map,ndtooned(vlon),ndtooned(vlat),pres)

;-- create the plot
  draw(map)                                    ;-- draw the map
  frame(wks)                                   ;-- advance the frame

end
```