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# NARCCAP Data Tutorial

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# Outline

- Basic concepts of numerical modeling
- The netCDF data format
- NARCCAP project overview
- Finding the data you want
- Fiddly details
- Extracting data

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# The fundamental element of climate simulation is a big box of air

50 x 50 km in NARCCAP

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Each box is represented by 6 numbers

- `hus`: *humidity*
- `ps`: *pressure*
- `ta`: *temperature*
- `ua`: *E-W wind*
- `va`: *N-S wind*
- `zg`: *height*

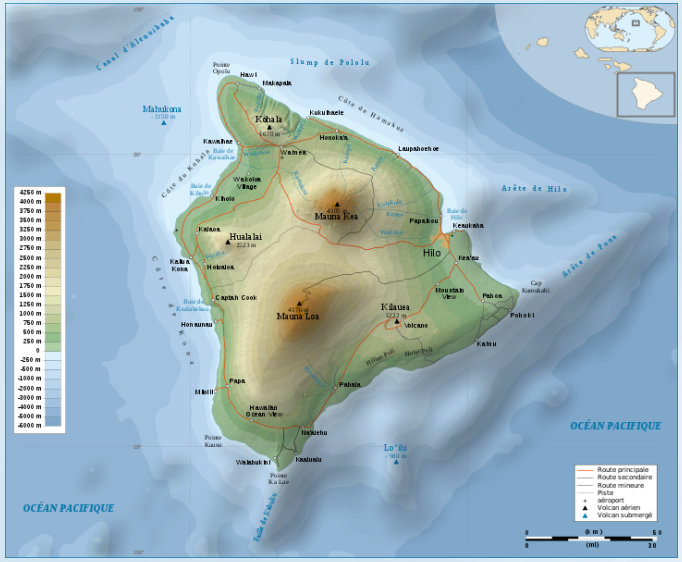
Simulation: apply PDEs for fluid flow to each box to update the 6 numbers and calculate flux between neighboring boxes. (“dynamical core”)

Sub-models for other processes (“physics”)

- radiation transfer
- land surface
- planetary boundary layer
- convection
- microphysics (rain/clouds)

Sub-gridscale processes are handled by parameterization (e.g., thunderstorms)

# Climate models represent reality as big grids of numbers




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| -99 | 0.5 | -99 | -99 | -99 | -99 | -99 | -99 |
| -99 | 0.8 | 1.7 | -99 | -99 | -99 | -99 | -99 |
| -99 | -99 | 0.9 | 0.5 | -99 | -99 | -99 | -99 |
| -99 | 0.7 | 1.1 | 0.9 | 0.3 | -99 | -99 | -99 |
| 0.4 | 1.2 | 1.6 | 1.9 | 2.3 | 1.2 | -99 | -99 |
| 0.9 | 2.5 | 2.2 | 2.8 | 4.1 | 1.8 | 0.2 | -99 |
| -99 | 1.3 | 2.2 | 2.9 | 3.3 | 2.1 | 0.5 | -99 |
| -99 | 0.8 | 2.6 | 3.1 | 2.8 | 2.2 | 0.8 | -99 |
| -99 | 0.1 | 1.9 | 4.2 | 2.4 | 1.6 | 0.9 | 0.1 |
| -99 | -99 | 0.4 | 2.9 | 1.8 | 0.5 | -99 | -99 |
| -99 | -99 | 0.2 | 1.5 | 0.7 | -99 | -99 | -99 |
| -99 | -99 | -99 | 0.3 | -99 | -99 | -99 | -99 |
| -99 | -99 | -99 | -99 | -99 | -99 | -99 | -99 |

("Raster data" in GIS parlance)

# How do you store the data?

- Binary: platform dependent, opaque
- Plain text: huge files, format ambiguity

| | | | |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| 4 | 3 | 2 | 1 |
| 5 | 5 | 5 | 5 |

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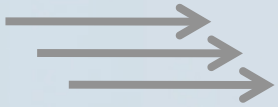

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?

# NetCDF

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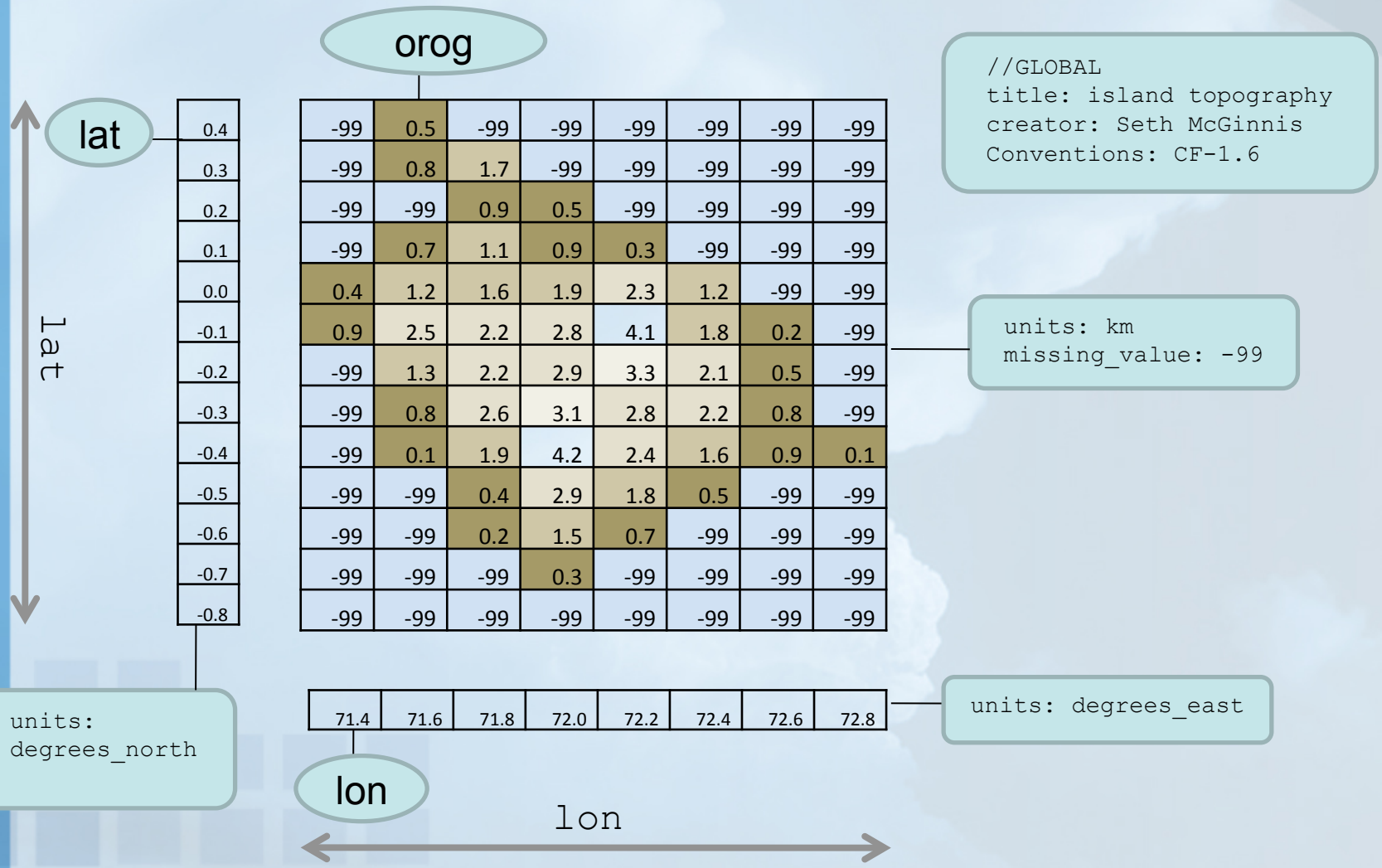
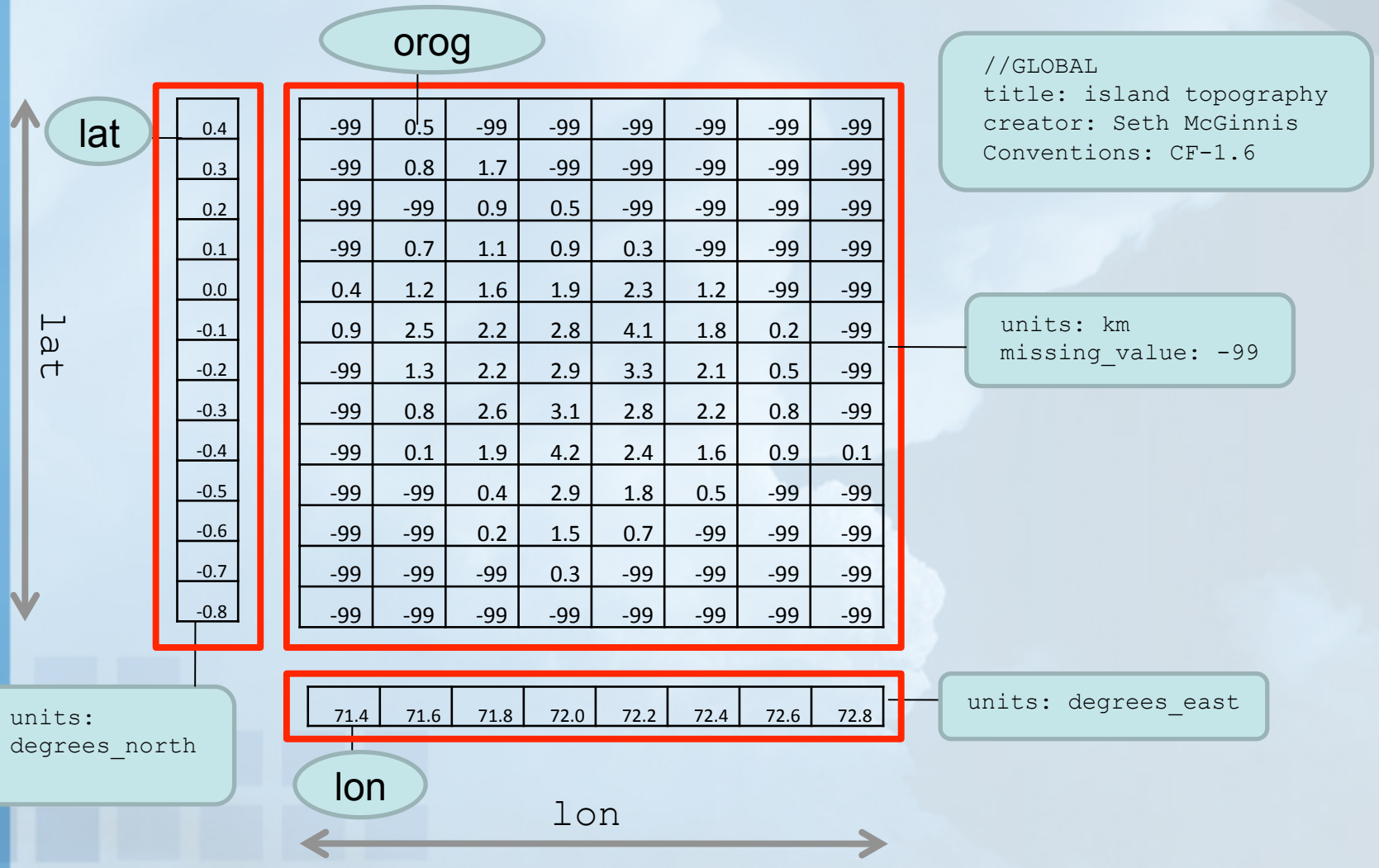
- self-describing
- platform-independent
- array-oriented
- scientific data
- file format

# NetCDF Data Model



# Variables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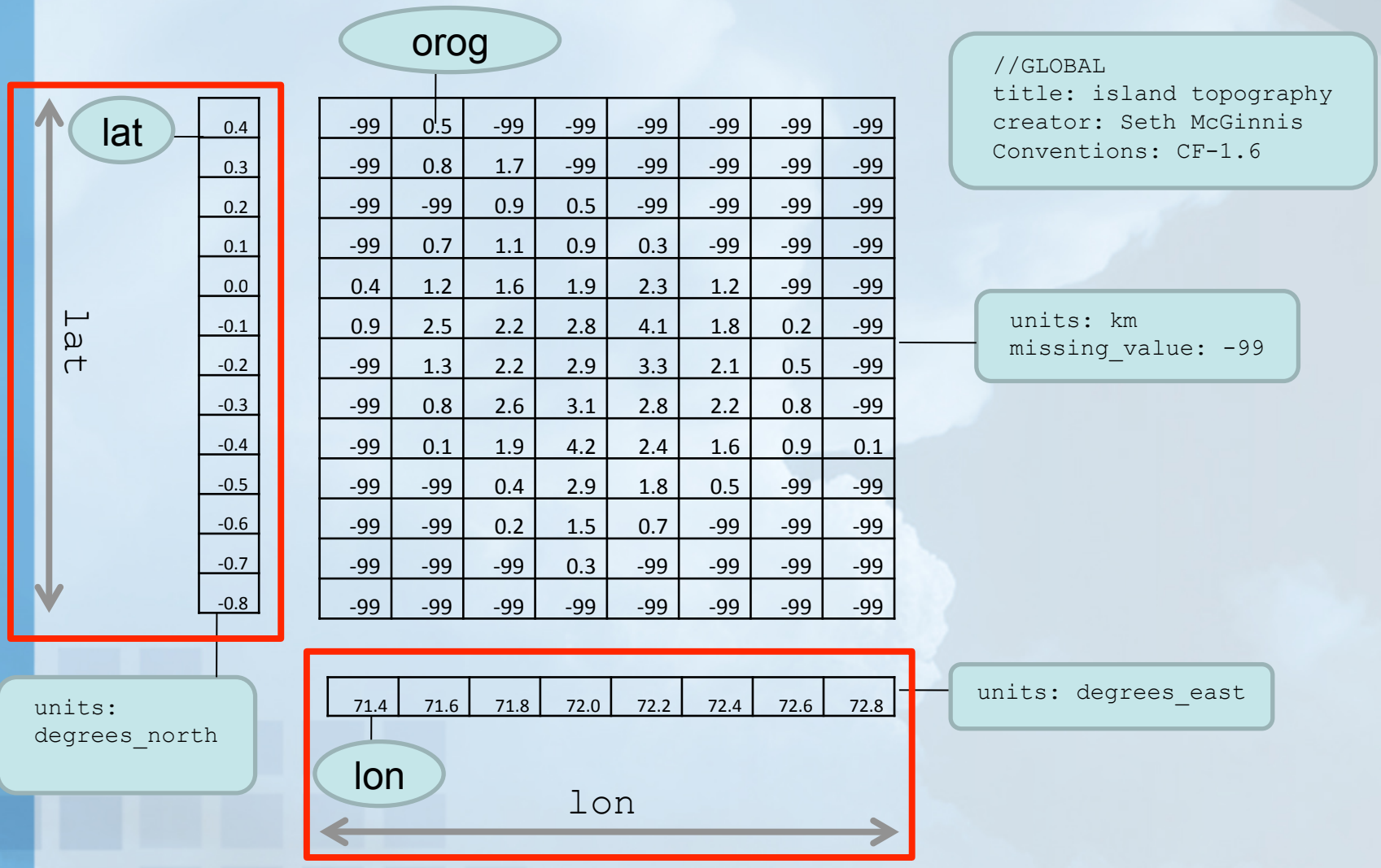
71.4 71.6 71.8 72.0 72.2 72.4 72.6 72.8
lon
lon
//GLOBAL
title: island topography
creator: Seth McGinnis
Conventions: CF-1.6
units: km
missing_value: -99
units: degrees_east
units: degrees_north

# Dimensions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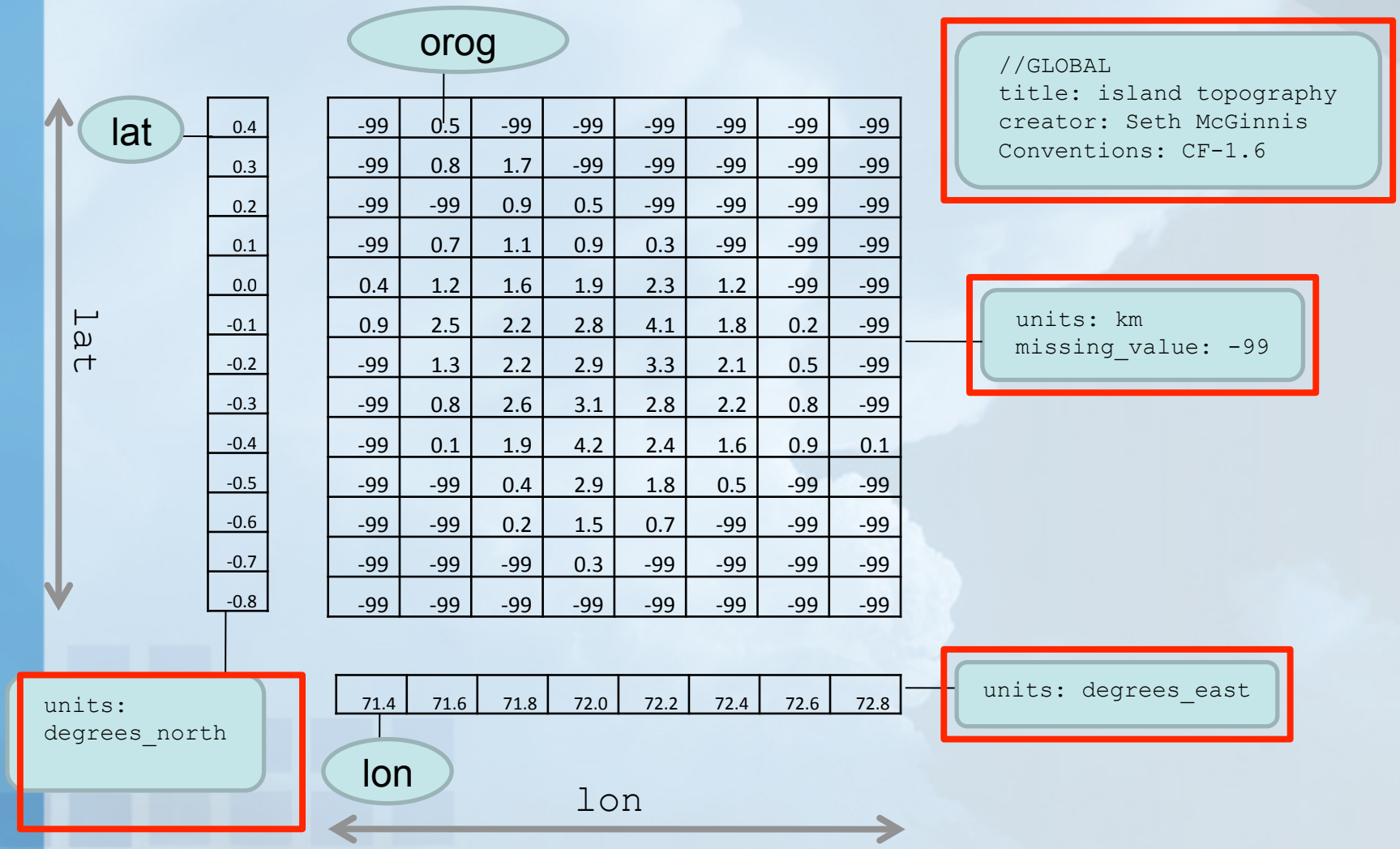
71.4 71.6 71.8 72.0 72.2 72.4 72.6 72.8
lon
lon
units: degrees_east

# Attributes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units: degrees_east
lon
lon

# File Structure

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- Header defines contents, holds metadata; actual data comes after in body of file

```
ncdump -h file.nc
```

- NetCDF: binary. Plain-text equivalent: CDL
- ncdump converts netcdf to CDL
- ncgen converts CDL to netcdf

[demo]

# CF Metadata Standard

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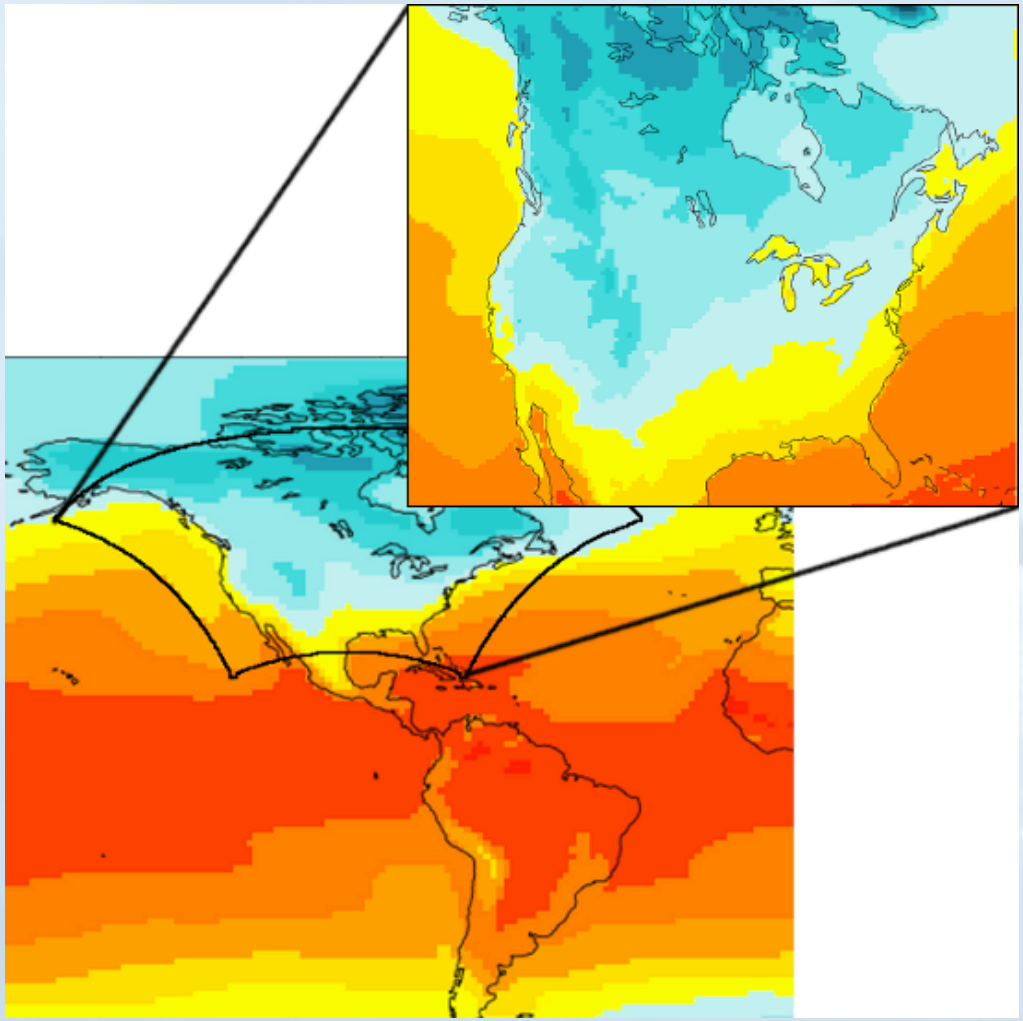
- Set of rules about file naming conventions and metadata contents
- Allows smart tools, GIS compatibility
- standard_name, units attributes
- NARCCAP data follows v 1.0
- CF spec is *extensive*

# NARCCAP: North American Regional Climate Change Assessment Program



Nest high-res* regional models (RCMs) inside coarser global models (GCMs) over N. America

*50 km gridcells

# Goals

- Evaluate model performance and uncertainty
- Generate high-res climate change scenario data for impacts analysis
- Support further dynamical downscaling experiments

# 6 RCM Modeling Teams

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- CRCM - S. Biner, OURANOS
- ECP2 - A. Nunes, Scripps
- HRM3 - R. Jones, et al, Hadley Centre
- MM5I - B. Gutowski, R. Arritt, ISU
- RCM3 - M. Snyder, UC Santa Cruz
- WRFG - R. Leung, PNNL
- Details: narccap.ucar.edu/data/rcm-characteristics.html

# Phase I: NCEP

- Drive RCMs with NCEP-2 Reanalysis
- Reanalysis: NWP with data assimilation estimate of historic state of atmosphere as close as we can come to “observations”
- 25 years: 1980-2004  (1 year of spin-up)

# Phase II: Downscaling GCMs

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- 4 GCMs: CCSM, CGCM3, GFDL, HadCM3
- Two 30-year runs, current (1971-2000) and future (2041-2070). 3 years spin-up
- SRES A2 emissions scenario for future run
- narccap.ucar.edu/about/aogcms.html

# Timeslice Experiments

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- Run GCM globally at ~50 km resolution but without the ocean model.
- Historical run: Use observed SST
- Scenario run: Observed SST + delta based on corresponding coarse AOGCM
- 2 models: GFDL, CCSM (aka CAM3)
- Same time coverage as GCM-driven runs

# Simulations

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| | NCEP | CCSM | CGCM3 | GFDL | HadCM3 |
|---|---|---|---|---|---|
| **CRCM** | done | done | done | | |
| **ECP2** | done | | | done | setup |
| **HRM3** | done | | | done | done |
| **MM5I** | done | done | | | running |
| **RCM3** | done | | done | done | |
| **WRFG** | done | done | done | | |
| **TMSL** | | done | | done | |

# Data Archive

- Data distribution: earthsystemgrid.org
- Organization: RCM → Driver → Table
- 1 variable per file, 5 years per file*

  * (except at beginning of run)
- Filenames:

  `Var_Model_Driver_Time.nc`

  Time = yyyymmddhh of first timestep
- http://narccap.ucar.edu/data/output_archive.html

# Data Tables

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- Table 1: daily values (e.g. Tmin & Tmax)
- Table 2: “big 7” variables for impacts: temp, prec, pressure, wind, sun, humidity
- Table 3: all the other 2-D variables
- Table 4: static (unchanging) variables
  *Not on ESG!* narccap.ucar.edu/data/table4
- Table 5: all 3-D variables

# Acquiring Data

- 1) Register!
- 2) Figure out what variables you want
- 3) Check Data Status Page
- 3) Login to ESG
- 4) Drill down from NARCCAP page
- 5) Authenticate
- 6) Download data

[demo]

# Looking Into the Future

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- No crystal balls
- Scenarios, not forecasts
- Look at current and future
- No “best” model
- Look at multiple models
- Embrace uncertainty

# Fiddly Details

3 main issues:

- Time
- Missing Data
- Map Projections

Also lots and lots of information on the website. Check “About NARCCAP” and “About Data” in particular.

# Time

- GCM runs don't use standard (Gregorian) calendar!  365-day ("noleap") or 360-day
- Don't use spin-up! (It's for model analysis)

| Run | Rec. Start | Rec. End |
|---|---|---|
| NCEP | 1979/12/01 | 2004/11/30 |
| GCM Current | 1970/12/01 | 2000/11/30 |
| GCM Future | 2040/12/01 | 2070/11/30 |

- Check units – "days since"
- If possible, don't count timesteps – use dates
- CCSM-current ends in 1999

# Missing Data

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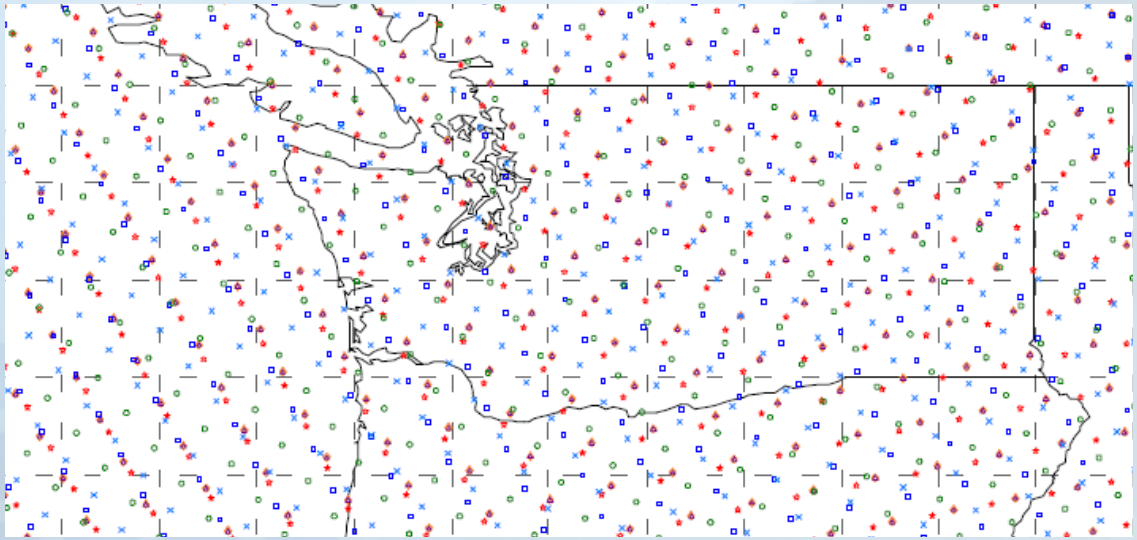
- Variety of causes: late start / early end, problems with model output or postproc
- missing_value or _FillValue = 1e+20f
- Listings of known missing timesteps: http://www.narccap.ucar.edu/data/missing/

# Map Projections

- Earth is round; model arrays are square
- This is *highly inconvenient*
- GCMs use lat-lon grids
- RCMs use projected coordinate systems:



# Map Projections 2

- NARCCAP X/Y dimensions: xc, yc
- 2-D lat & lon arrays in each file

| | |
|---|---|
| CRCM | Polar Stereographic |
| ECP2 | Polar Stereographic |
| HRM3 | Rotated Pole |
| MM5I | Lambert Conformal |
| RCM3 | Transverse Mercator |
| WRFG | Lambert Conformal |

- Projection parameters in each file: see grid_mapping attribute on data variable

# Extracting Data

- Unix/OSX: ncdump, NCO, NCL, CDAT

```
ncks -d xc,22,25 -d yc,45,450 -d
time,"1986-06-01 00:00","1986-09-01 00:00"
in.nc out.nc; ncdump -v tas out.n | sed …
```

- Windows: FAN – see ASCII Howto
- Other options: IDL, Matlab, R, Python...

[demo]

# Citation

- When publishing results using NARCCAP data, please cite the dataset itself, in addition to papers about NARCCAP

Mearns, L.O., et al., 2007, updated 2011. *The North American Regional Climate Change Assessment Program dataset*, National Center for Atmospheric Research Earth System Grid data portal, Boulder, CO. Data downloaded 2012-04-11. [http://www.earthsystemgrid.org/project/NARCCAP.html]

# Other Details

- ECPC→ECP2, WRFP→WRFG
- RCM3 reruns and other caveats
- User Directory
- Papers, Presentations, Software
- Acknowledgements
- Analysis and Results

# Software

- http://nco.sourceforge.net/

- http://www.narccap.ucar.edu/contrib/tools/
- util/: shellscripts using NCO
- ncl/: NCL scripts for plotting, file manip
- R/: interpolation using thin-plate-spline

# GIS

- Import directly into ArcMAP 9+ using the multidimension toolbox
- Instructions on website
- Can’t import HRM3 yet – doesn’t understand map projection
- Datum is ill-defined; use WGS84 probably
- Do averaging, subsetting, etc outside Arc


# array[-1]