Implementing a new suite of remapping functions within NCL

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Numerical Modeling of The Environment
Understanding the Environment

- Once the environment is described by numbers and equations, further mathematical operations can help us to understand our environment and predict how it may (re)act.

  - Measurements
  - Satellite based measurements
  - Numerical models

“The purpose of computing is insight, not numbers”.
(Richard Hamming)
Different parameters affect the performance of a numerical model.

Selecting a coordinate system (grid) is one of the most important steps while developing a numerical model (Griffies et al., 2000).

Different models use different grids with different types and resolutions.
Take your pick

• Grid Types:
  – Structured:
    • Rectangular
    • Rectilinear
    • Curvilinear...
  – Hybrids:
    • Cube-Sphere
    • Blocks
    • Adaptive...
  – Unstructured:
    • Triangular
    • Quadrilateral
    • Hexagonal...

Each model claims to be the best model ever,

Therefore, there exists more than one best grid ever.
Sample Structured Grids

Variational Method: Abouali

gridgen.c

http://code.google.com/p/gridgen-c/
Sample Structured Grid

Tripolar Grid, using SCRIP2KML (NCL):
Sample Unstructured Grid

MPAS Grid, Using Unstruct2KML (NCL)
Comparison and Interaction

• To compare the results of different models and data sets quantitatively, the data must be in the same grid.

• Some models rely on the output of one or more models for their input, such as Surface Energy Balance System (SEBS) (Su, 2002).

An Easy procedure to interpolate data from one grid to another is needed.
Interpolation as a Transform Operator

• Interpolation can be considered to be a transform operator, matrix $A$.

$$\text{Data}_{\text{destination grid}} = A \ast \text{Data}_{\text{source grid}}$$

• The interpolation scheme defines the entries of $A$.

• The majority of interpolation schemes only examine how the nodes in the destination and source grids are located relative to each other.

As long as the source and destination grids are not changed, matrix $A$ remains the same.
NCL Remapping Tools

• Is a suite of functions and command line operators that facilitate the remapping capabilities within the NCAR Command Language (NCL)

• Uses a software package from the Earth System Modeling Framework (ESMF) to generate interpolation weights, matrix $A$

• Available interpolation methods are:
  – Bilinear
  – Conservative
  – Patch

www.ncl.ucar.edu

www.earthsystemmodeling.org
Remapping Procedure

Step 1: Converting to SCRIP or ESMF

Step 2: Generating interpolation weights

Step 3: Applying the interpolation weights and remapping
Converting to SCRIP or ESMF

• Several functions and procedures have been developed to facilitate this step:
  – SCRIP Convention Files:
    • GenBox_with_LLURCorner
    • GenBox_with_Center_Dim
    • Rectilinear2SCRIP
    • Curvilinear2SCRIP
    • Auto2SCRIP
  – ESMF Convention Files:
    • Unstructured2ESMF

Sample interface:
function Auto2SCRIP (sourceFileName [1] : string,
                      varName [1] : string,
                      SCRIPFileName [1] : string,
                      fileTitle [1] : string,
                      options [1] : logical
                   ) return_val [1] : integer
Generating Interpolation Weights

• Calls “ESMF_RegridWeightGen” application within NCL
• ESMF must be compiled with NetCDF and LAPACK.
• If ESMF is compiled for multiprocessors, this step would be in parallel (requires mpirun).

NCL interface:
function esmf_remap_weights ( 
  sourceGrid [1] : string, 
  destinationGrid [1] : string, 
  weightFile [1] : string, 
  options [1] : logical 
)
return_val [1] : integer

Options:
• OverWrite
• ForceOverWrite
• method
• pole
• bothRegional
• srcGridRegional
• dstGridRegional
• isBothESMF
• isSrcESMF
• isDstESMF
• showCMD

NOTE: All the interpolation weights are generated using ESMF software package; SCRIP weight generator is not used.
Remapping

• Using “sparse matrix multiplier” of NCL to apply previously generated interpolation weights to perform the actual remapping/regridding

NCL remapping interface:
function esmf_remap ( 
    sourceData : numeric,
    weightFile [1] : string,
    Err [1] : integer
)
return_val : numeric
Sample Code: Step 1

```ncl
load "$/ESMFRegridToolsPATH/ESMFRegridTools.ncl"
begin
  sourceFile="iceh.0070-01.nc"
  SCRIPFileName="TGrid.nc"
  VarName="sst"
  fileTitle="A curvilinear Tripolar grid."
  Opt=True

  Err=Auto2SCRIP(sourceFile,VarName,SCRIPFileName,fileTitle,Opt)

  if (Err.ne.0) then
    print("Not Successful!")
    exit
  end if

end
```
Sample Code: Step 2

```ncl
load "'$ESMFRegridToolsPATH/ESMFRegriddingTools.ncl"
begin
    srcGrid="HRM3_SCRIP.nc"
    dstGrid="CRCM_SCRIP.nc"
    weightFile="HRM3_2_CRCM.nc"
    Opt=True
    Opt@method="conserve"
    Err=esmf_remap_weights(srcGrid,dstGrid, \\
                           weightFile,Opt)
    if (Err.ne.0) then
        print("Not successful!")
        exit
    end if
end
```

- Loading the Library
- Initializing
- Setting Options
- Generating Weights
- Checking for Error
load "$/ESMFRegridToolsPATH/ESMFRegriddingTools.ncl"
begin

    WFile="WRF_2_Rect.nc"

    fid=addfile("../data/WRF.grb","r")
    GH=todouble( fid->HGT_GDS5_ISBL_10 )

    Err=0;
    dstGH=esmf_remap(GH(1,:,:,:),WFile,Err)
    if (Err.ne.0) then
        print("Not Successful!")
        exit
    end if

end
Sample Interpolation Results

- Temperature – HRM3 to CRCM
Sample Interpolation Results

- Surface Pressure - MPAS to 15arcmin World
Sample Interpolation Results

- Surface Pressure - MPAS to 15arcmin World
  Surface Pressure (MPAS to World)
Sample Interpolation Results

- Surface Pressure - MPAS to Tripolar
Sample Interpolation Results

- Geopotential Height – WRF to Rectilinear

Geopotential height (WRF to Rect)

Purple Color shows the coverage of the rectilinear grid.
Sample Interpolation Results

- Sea Surface Temperature – Tripolar to MPAS

Sea Surface Temperature (Tripolar_ESMF to MPAS)
Sample Interpolation Results

- **SWE – EASE to NH**

Snow Water Equivalent - EASE to NH - Patch
Sample Interpolation Results

- SLP – CCSM4 to EASE

Sea Level Pressure - CCSM4 to EASE - patch
Command-Line Tools

- Some of the functions are also accessible from the command-line (Terminal).
- These commands can be used to convert grids to either SCRIP or ESMF convention files.
- Once ESMF is compiled, the user gets a command-line operator that generates weights.
- The user can apply the remapping weights within the command-line or a bash script on one or multiple data files.
Want to Learn More?

• If you are interested in learning how to use the package, please refer to the NCL Remapping Tools User Guide.
• Only a subset of functions were discussed in this presentation.
• The command line tools along with some extra useful functions are described in the manual.
• 21+ Examples
• 5+ Comprehensive Examples
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Thanks For Your Attention

Questions