

Orchestrating a Climate Modeling Data Pipeline using Python and RAM Disk

A Brief Overview of the WRF Tools Package

Andre R. Erler

PyCon Canada

November 7th, 2015

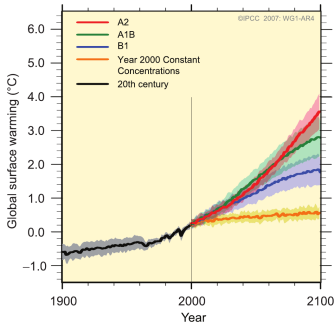
Outline

Introduction: Climate Modeling
Regional Models

The Pre-processing Pipeline
The WRF Pre-processing System (WPS)

Using Python to Drive the Pipeline
The Tool Chain
The Class Structure

Concluding Remarks



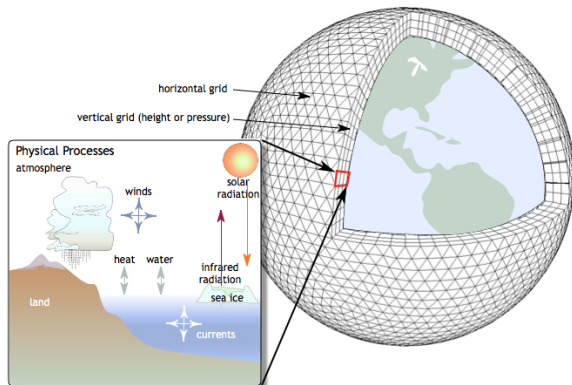
IPCC AR4 (2007) projections for global surface temperature under different scenarios.

Global Climate Models are the main tool to predict climate change.

Global Climate Models

Climate models compute energy, mass, and momentum fluxes on a relatively coarse grid.

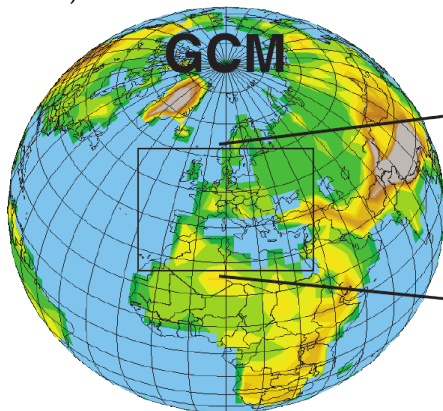
Schematic of a Global Climate Model (GCM):



Center for Multiscale Modeling of Atmospheric Processes, CSU

Regional Climate Models

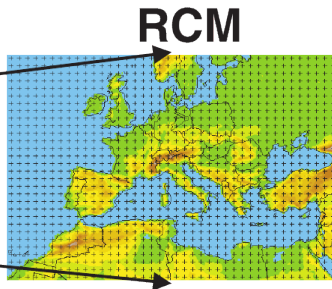
GCM resolution is coarse and many regional details are not resolved (e.g. the Rocky Mountains and the Great Lakes).



Giorgi (2006)

Regional Impacts

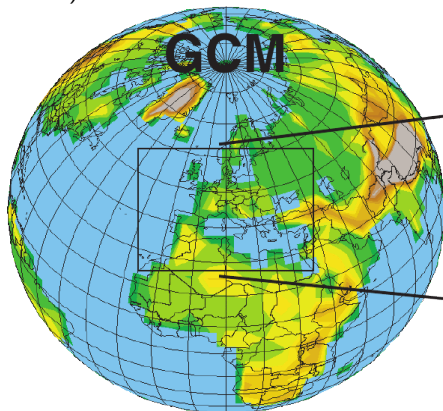
Regional impacts of Climate Change are modeled with high-resolution regional climate models (RCM).



Regional models simulate a small area at much higher resolution ($\times 10$).

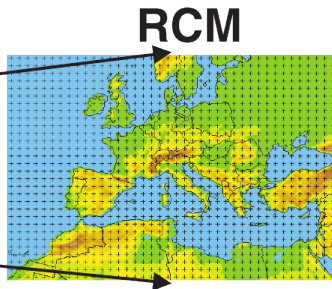
Regional Climate Models

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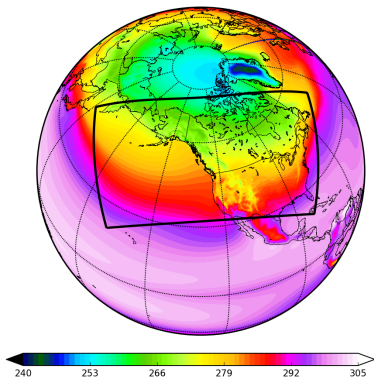
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Global Model: CESM

The Community Earth System Model is used as driving model.

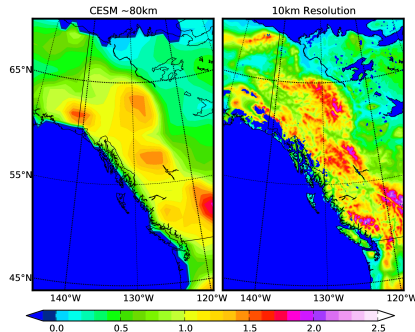
Annual Average Skin Temperature [K]



Average Surface Temperature and
Outline of the WRF Domain

Andre R. Erler (A.R.Erler@gmail.com)

Terrain Height [km]



Topography of Western Canada.

Left: CESM at ~ 80 km

Right: WRF (inner domain) at 10 km

Regional Model: WRF

The Weather Research and Forecast
model is the regional model.



WRF is actually pronounced “Worf”, like Lt. Worf in *Star Trek: The Next Generation* (left)

The WRF model is a limited-area numerical weather prediction model developed by the National Center for Atmospheric Research

Running the Regional Climate Model

- ▶ The coupling process between GCM and RCM is “off-line”
- ▶ A pre-processing system converts GCM output into RCM input files
- ▶ An RCM simulation is split into ~ 200 separate jobs
- ▶ The RCM runs continuously, each job submitting the next

The WRF Tools Package

Python

- ▶ Run pre-processing tool chain (WPS)
- ▶ Initialize RCM jobs
- ▶ Run post-processing

Shell Script

- ▶ Submit pre-processing
- ▶ Run the RCM job, submit next job
- ▶ Archiving to tape

WRF Tools enables continuous and autonomous operation

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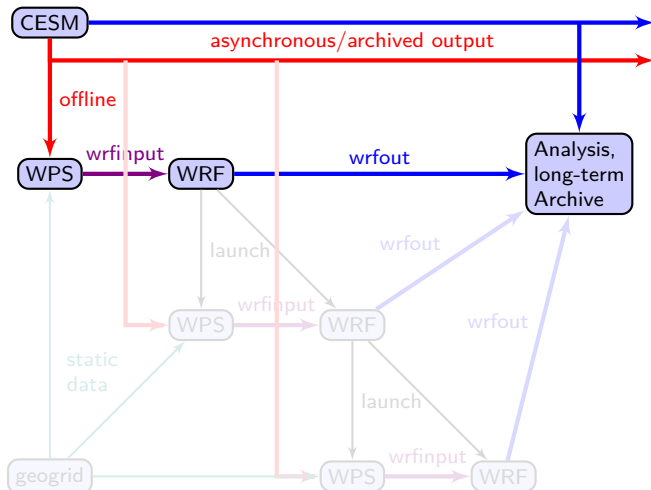
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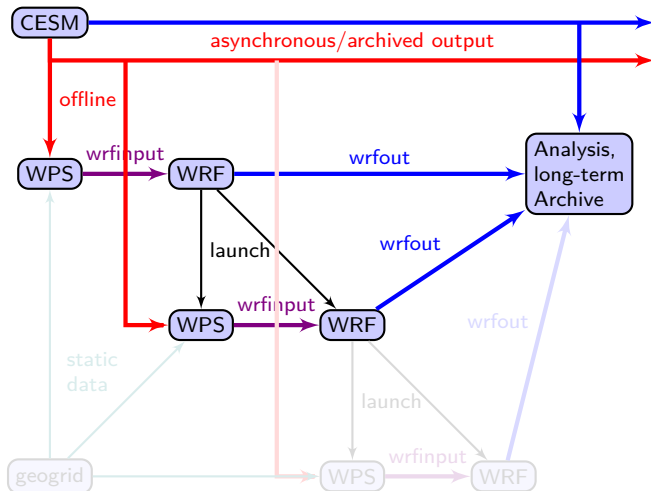
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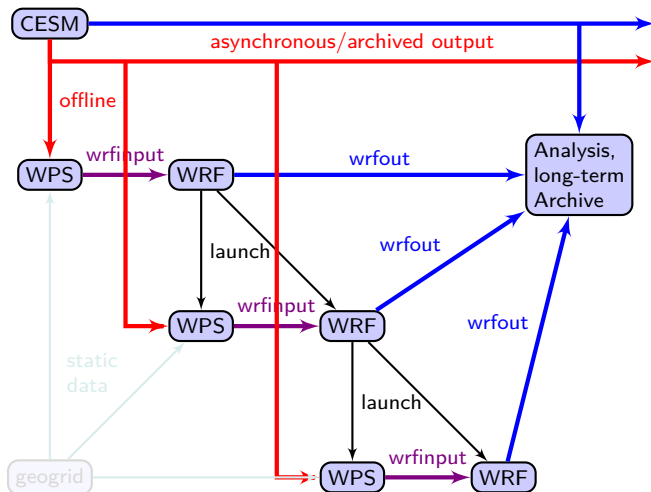
The Data Pipeline



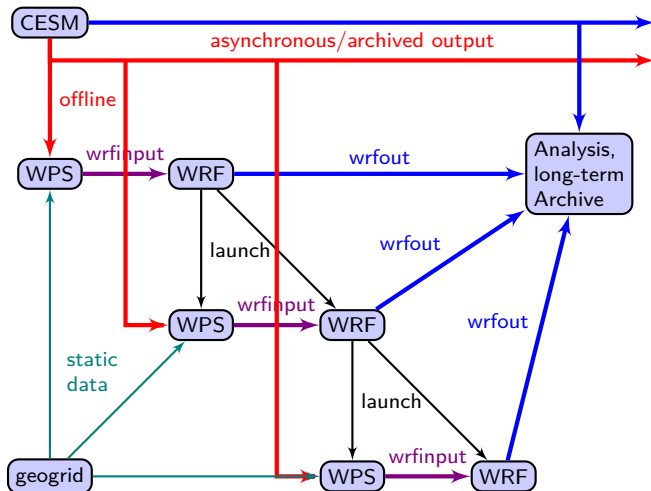
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The Data Pipeline



WPS: A Collection of **FORTRAN** Legacy Tools

WPS Components

1. `geogrid.exe`
static / geographic data
2. `ungrib.exe` / `unccsm.exe`
convert driving data to
WRF IM Format
3. `metgrid.exe`
interpolate to WRF grid
4. `real.exe`
generate boundary
condition files

FORTRAN legacy tools read from and write to temporary files:

- ▶ Strongly I/O limited in a HPC cluster environment

The Solution (on Linux)

Run on RAM-disk!

- ▶ speedup $\sim \times 10$
- ▶ requires 64 GB RAM

Using Python driver script

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Using Python driver script

PyWPS: A Driver Module for WPS

- ▶ Collect required input data from GCM archive
- ▶ Run applicable pre-processing tools on RAM disk
- ▶ Assemble WRF input files

Why Python?

- ▶ Easy parallelization
- ▶ Classes for different datasets/GCMs

PyWPS Imports

- ▶ multiprocessing for parallelization
- ▶ re to find input files
- ▶ fileinput, sys to edit configurations files
- ▶ subprocess to launch FORTRAN tools
- ▶ shutil, os to handle temporary files

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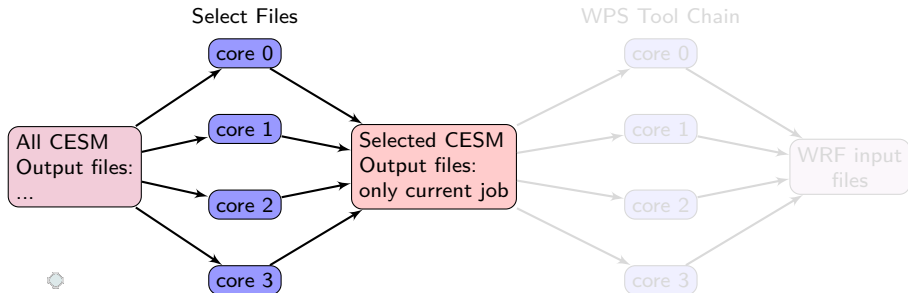
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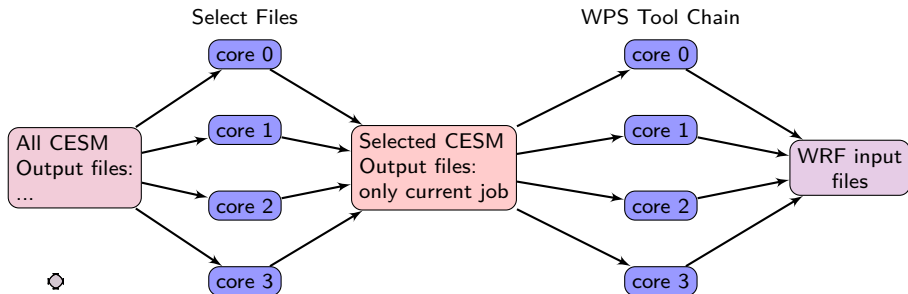
PyWPS: The Program Flow



The WPS Tool Chain:



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The WPS Tool Chain:



The Class Structure

Dataset/GCM specific parameters:

- ▶ Input file types/names
- ▶ Interpolation tables/grid
- ▶ Variables / frequency

Multiple Datasets

- ▶ *Inheritance* for common procedures
- ▶ *Polymorphism* for different procedures

```
class Dataset(object):
    prefix = '' # file prefix
    vtable = 'Vtable'
    gribname = 'GRIBFILE' # input
    ungrib_exe = 'ungrib.exe'
    ungrib_log = 'ungrib.exe.log'
    ...
    def __init__(self, ...):
        # type checking
        ...
    def setup(self, src, ...):
        ...
    def cleanup(self, tgt):
        ...
    def extractDate(self, fname):
        # match valid filenames
        ...
    def ungrib(self, date, mytag):
        # generate file for metgrid
        ...
```

Summary & Conclusion

Python

- ▶ Use Python for flow control (manage legacy tools)
- ▶ Parallelization relatively easy (on node)
- ▶ Class structure is versatile and makes maintenance easier

RAM-disk

- ▶ Scientific Programming: dealing with legacy tools
Often in FORTRAN, often relying on disk I/O
- ▶ Use RAM-disk to avoid unnecessary disk I/O

Thank You!

~

Questions?

List of Publications using WRF Tools

- ▶ **Erler, Andre R.**, W. Richard Peltier, Marc d'Orgeville (submitted), Projected Changes in Hydro-Climatic Extremes for Western Canada, Journal of Climate.
- ▶ Marc d'Orgeville, W. Richard Peltier, **Andre R. Erler** (under review), Uncertainty in Future Summer Precipitation on the Great Lakes Basin due to Drought in the South-Western US, Journal of Geophysical Research.
- ▶ **Erler, Andre R.**, W. Richard Peltier, Marc d'Orgeville, 2015, Dynamically Downscaled High Resolution Hydro-Climate Projections for Western Canada, Journal of Climate.
- ▶ Marc d'Orgeville, W. Richard Peltier, **Andre R. Erler**, Jonathan Gula, 2014, Climate change impacts on Great Lakes Basin precipitation extremes, Journal of Geophysical Research.