A Model Facility for Attribution Science

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CU-CIRES and NOAA/ESRL/PSD

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Attribution of Weather and Climate Extremes Workshop
September 9-11, 2014

Just the FACTS, Ma'am

- FAcility for Climate AssessmenTS (FACTS)
  - http://www.esrl.noaa.gov/psd/repository/alias/facts
- A new NOAA facility for assessment of recent weather and climate events
- Provides access to and analysis of climate model output
- Based on RAMADDA
  - Designed to be portable

Why do we need FACTS?

- Climate Model Intercomparison Projects (CMIP3 and CMIP5) provide a useful basis for studying how extremes change due to increasing greenhouse gases
- However, they are only of very limited usefulness to study the effects of real-time evolving modes of natural variability (e.g. ENSO, PDO, AMO) on observed weather/climate extremes.
- Scientists need to easily share and compare datasets.

Current FACTS Datasets

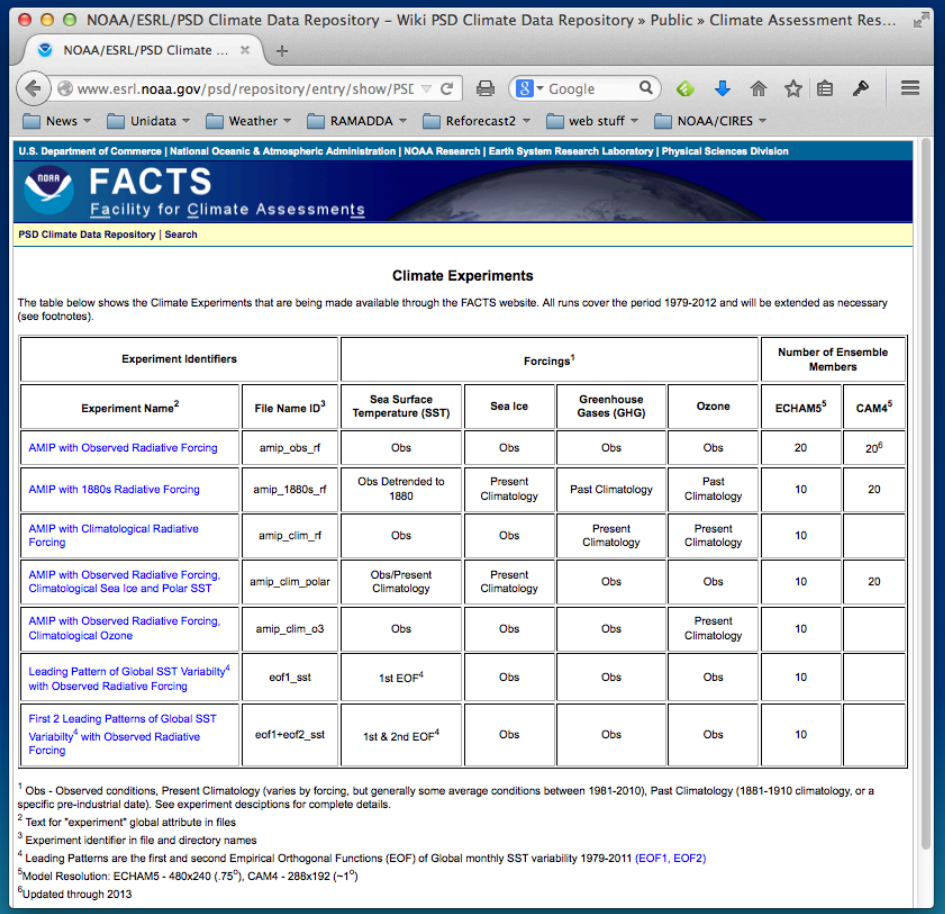
- AMIP experiments using CAM4 (.94 x 1.25 degree/L26) and ECHAM5 (T159/L31)
- 10-20 ensemble members for each experiment
- Experiments vary one or more of:
  - Greenhouse gases (GHG)
  - Sea Surface Temperature (SST)
  - Sea Ice (SIC)
  - Ozone (O3)
- All runs cover 1979-"present"

Input Forcing Sources

- Greenhouse Gases (GHG)
  - CMIP5 recommended values (Meinshausen, et al)
- SST and Sea Ice
  - Derived from CAM dataset (Hurrell, et al)
- Ozone
  - ECHAM5: Based on data from the AC&C/SPARC ozone database
  - CAM4: CAM-Chem (Lamarque, et al)
- Aerosols
  - Model dependent

Available Datasets

- PSD AMIP Experiments (monthly)
  - Observed Radiative Forcing (RF)
  - 1880s RF
  - Climatological Sea Ice & Polar SST
  - Climatological RF
  - Climatological Ozone
  - SST EOF 1
  - SST EOF 1&2



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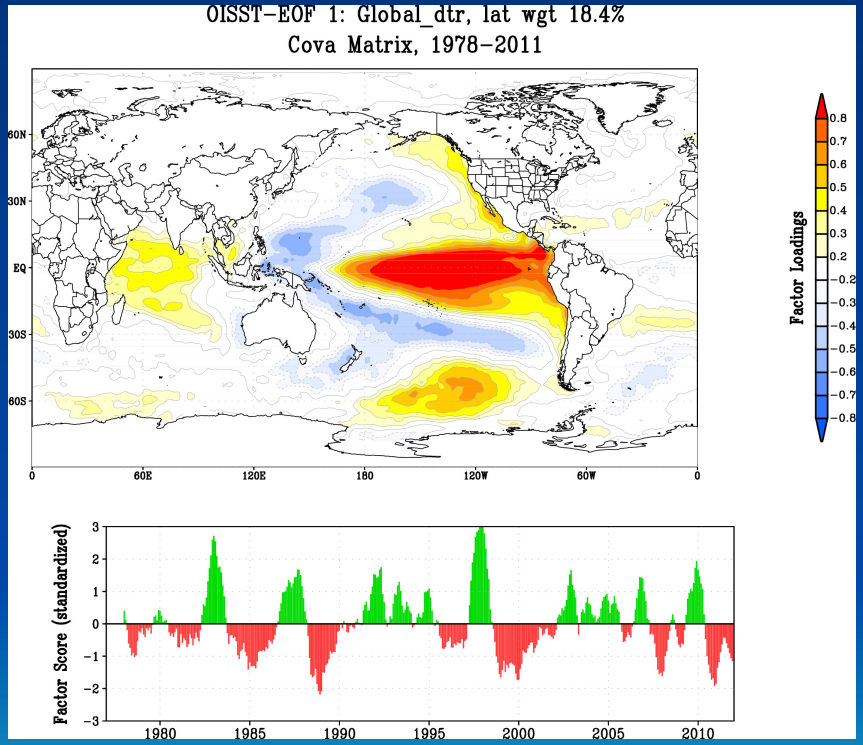
Climate Experiments

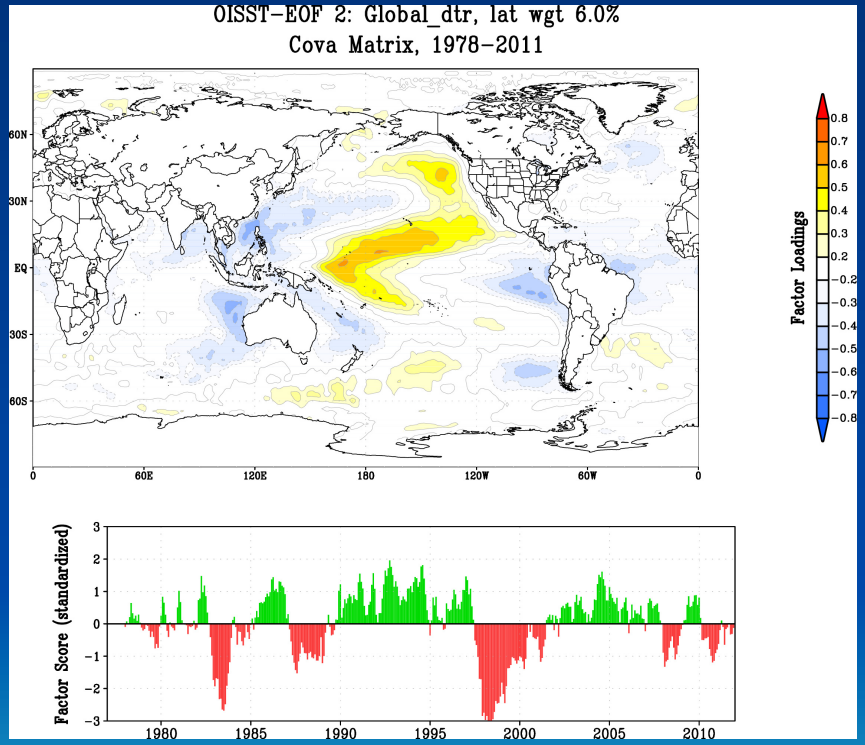
The table below shows the Climate Experiments that are being made available through the FACTS website. All runs cover the period 1979-2012 and will be extended as necessary (see footnotes).

Experiment Identifiers		Forcings[1]				Number of Ensemble Members	
Experiment Name[2]	File Name ID[3]	Sea Surface Temperature (SST)	Sea Ice	Greenhouse Gases (GHG)	Ozone	ECHAM5[5]	CAM4[5]
AMIP with Observed Radiative Forcing	amip_obs_rf	Obs	Obs	Obs	Obs	20	20[6]
AMIP with 1880s Radiative Forcing	amip_1880s_rf	Obs Detrended to 1880	Present Climatology	Past Climatology	Past Climatology	10	20
AMIP with Climatological Radiative Forcing	amip_clim_rf	Obs	Obs	Present Climatology	Present Climatology	10	
AMIP with Observed Radiative Forcing, Climatological Sea Ice and Polar SST	amip_clim_polar	Obs/Present Climatology	Present Climatology	Obs	Obs	10	20
AMIP with Observed Radiative Forcing, Climatological Ozone	amip_clim_o3	Obs	Obs	Obs	Present Climatology	10	
Leading Pattern of Global SST Variabilty[4] with Observed Radiative Forcing	eof1_sst	1st EOF[4]	Obs	Obs	Obs	10	
First 2 Leading Patterns of Global SST Variabilty[4] with Observed Radiative Forcing	eof1+eof2_sst	1st & 2nd EOF[4]	Obs	Obs	Obs	10	

[1] Obs - Observed conditions, Present Climatology (varies by forcing, but generally some average conditions between 1981-2010), Past Climatology (1881-1910 climatology, or a specific pre-industrial date). See experiment descriptions for complete details.
[2] Text for "experiment" global attribute in files
[3] Experiment identifier in file and directory names
[4] Leading Patterns are the first and second Empirical Orthogonal Functions (EOF) of Global monthly SST variability 1979-2011 (EOF1, EOF2)
[5] Model Resolution: ECHAM5 - 480x240 (.75°), CAM4 - 288x192 (~1°)
[6] Updated through 2013

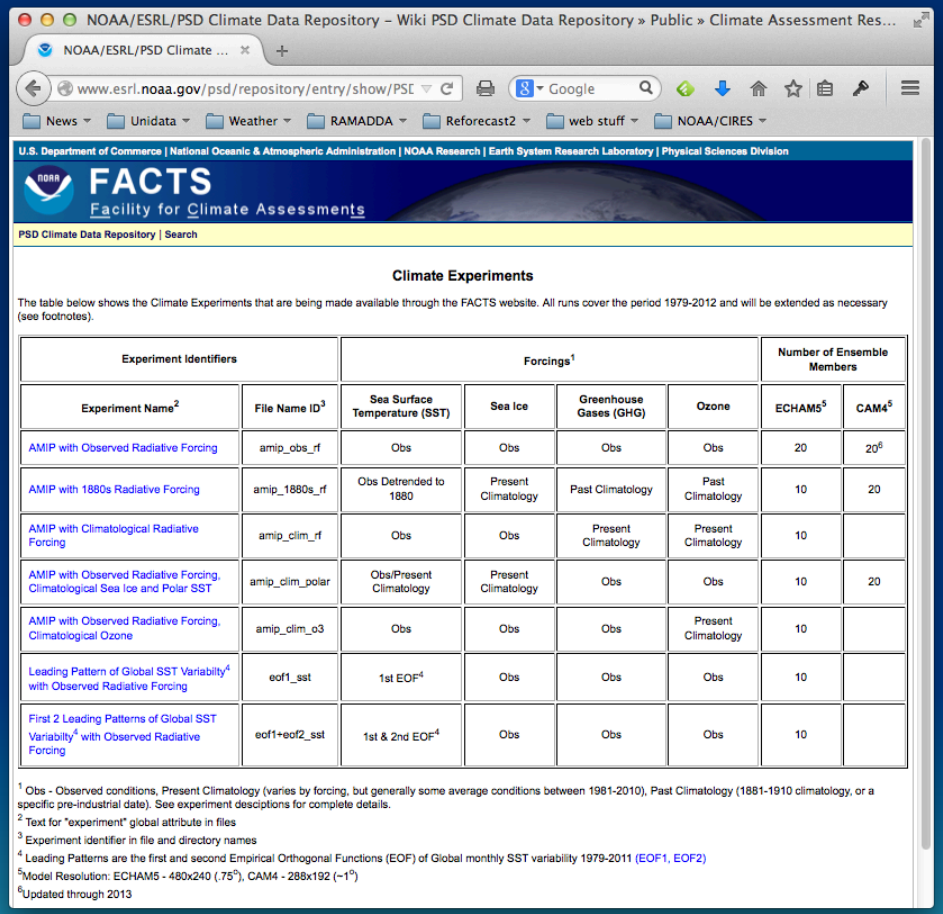
EOF Experiment Forcing





Available Datasets

- Reanalyses (monthly)
  - 20th Century V2
  - ERA-Interim
  - MERRA
  - NCAR/NCEP R1



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AMIP with Observed Radiative Forcing, Climatological Sea Ice and Polar SST	amip_clim_polar	Obs/Present Climatology	Present Climatology	Obs	Obs	10	20
AMIP with Observed Radiative Forcing, Climatological Ozone	amip_clim_o3	Obs	Obs	Obs	Present Climatology	10	
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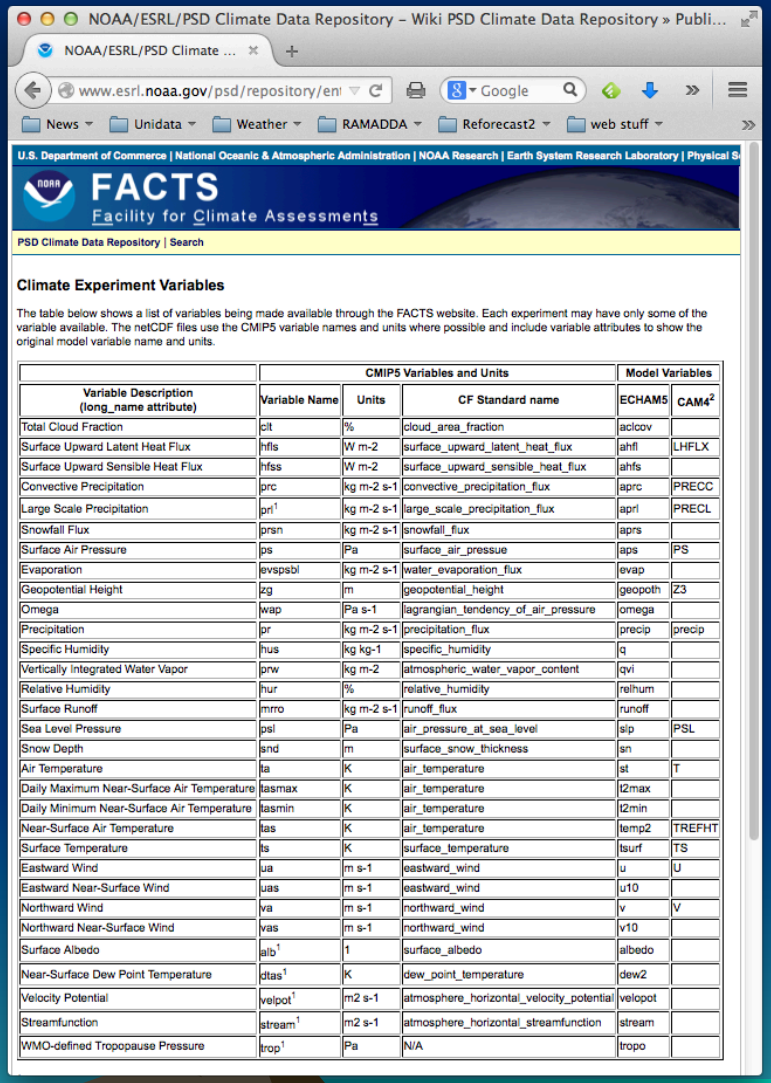
Variables

- Surface:
  - Temperature (surface, 2m)
  - Precipitation (total, convective, large scale)
  - Pressure (surface, sea level)
  - Surface upward latent heat flux
- Pressure (17 levels)
  - Temperature
  - U&V Wind Components
  - Geopotential Height



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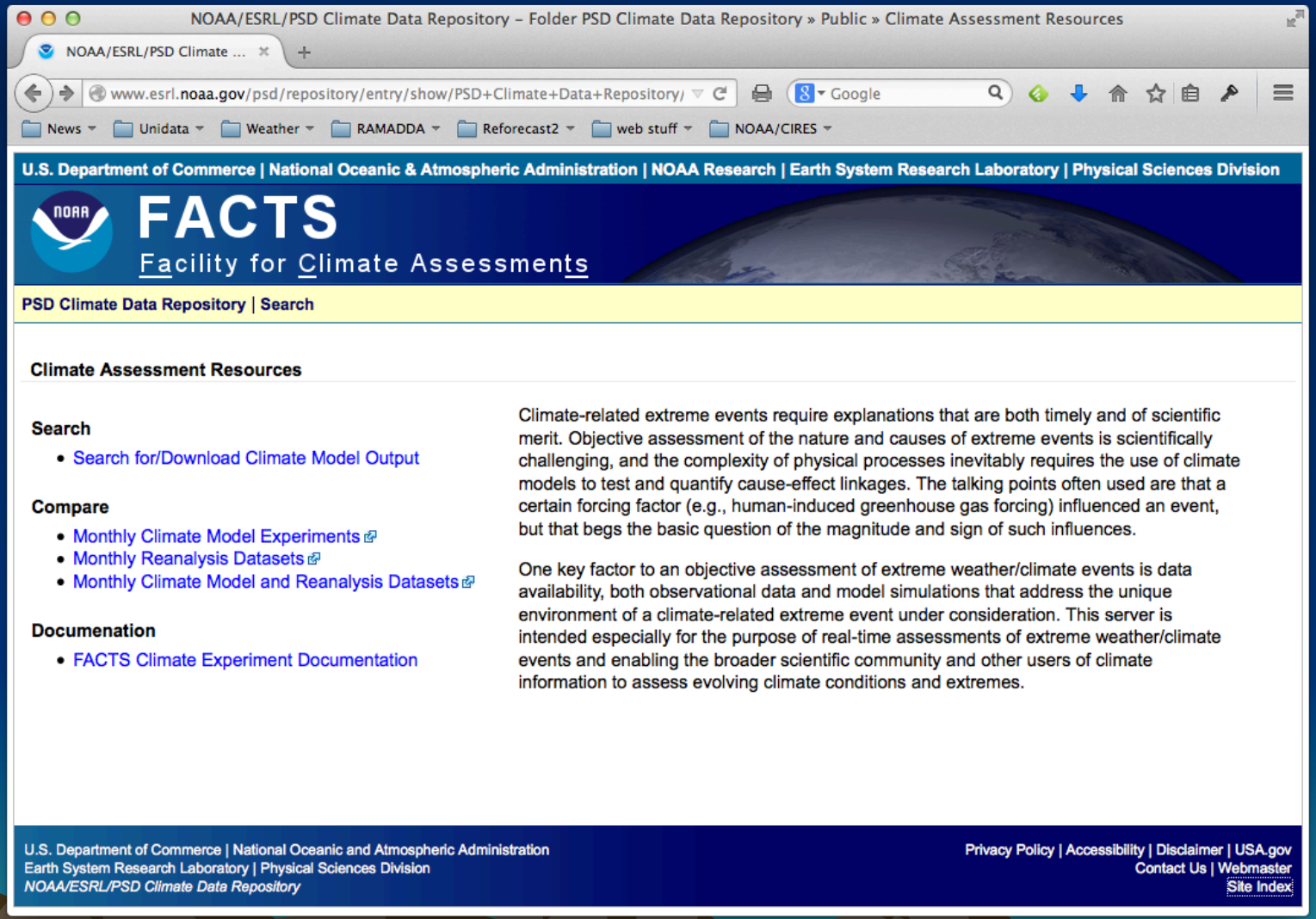
Climate Experiment Variables

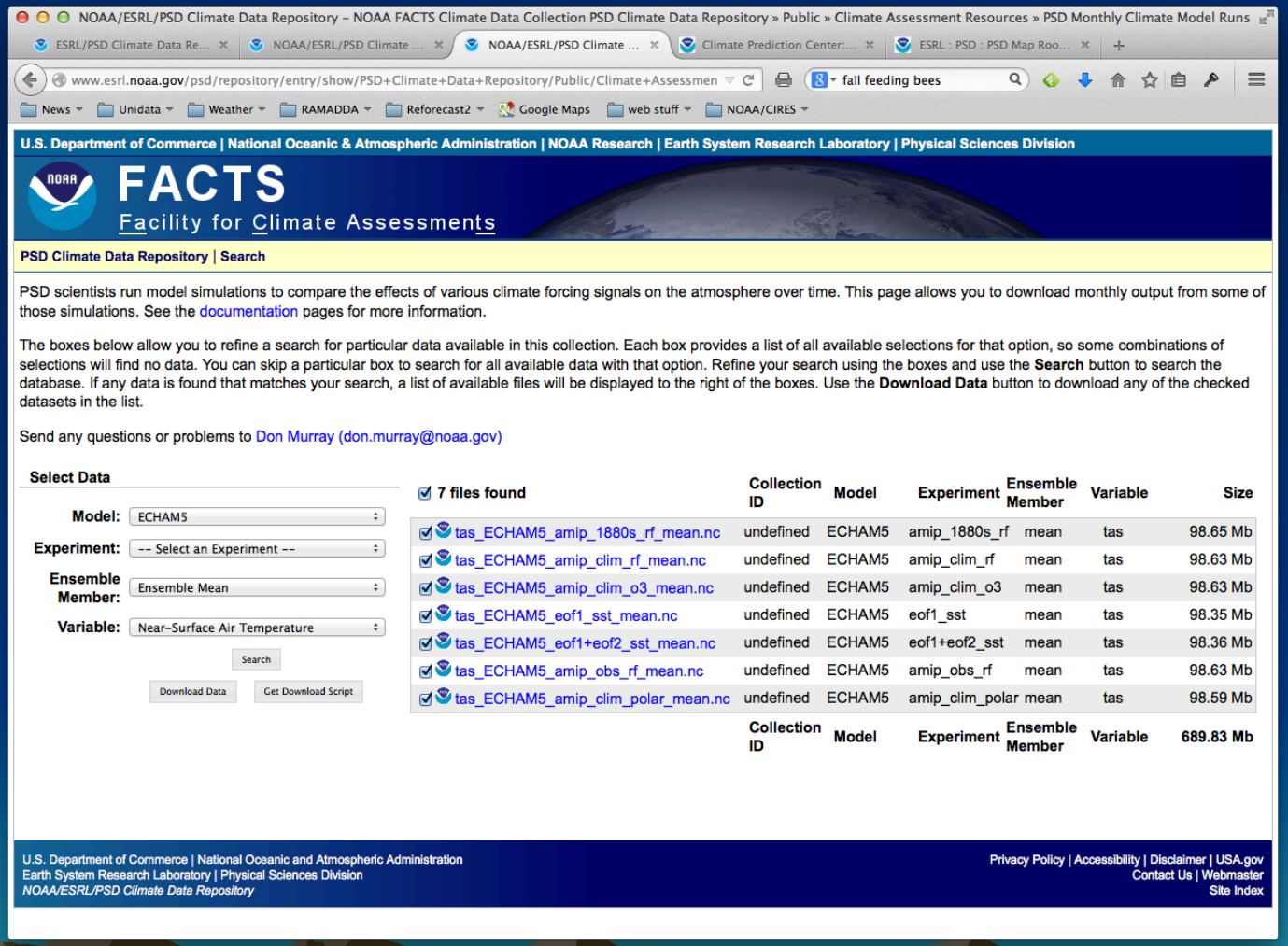
The table below shows a list of variables being made available through the FACTS website. Each experiment may have only some of the variable available. The netCDF files use the CMIP5 variable names and units where possible and include variable attributes to show the original model variable name and units.

	CMIP5 Variables and Units			Model Variables	
Variable Description (long_name attribute)	Variable Name	Units	CF Standard name	ECHAM5	CAM4[2]
Total Cloud Fraction	clt	%	cloud_area_fraction	aclcov	
Surface Upward Latent Heat Flux	hfls	W m-2	surface_upward_latent_heat_flux	ahfl	LHFLX
Surface Upward Sensible Heat Flux	hfss	W m-2	surface_upward_sensible_heat_flux	ahfs	
Convective Precipitation	prc	kg m-2 s-1	convective_precipitation_flux	aprc	PRECC
Large Scale Precipitation	prl[1]	kg m-2 s-1	large_scale_precipitation_flux	aprl	PRECL
Snowfall Flux	prsn	kg m-2 s-1	snowfall_flux	aprs	
Surface Air Pressure	ps	Pa	surface_air_pressue	aps	PS
Evaporation	evspsbl	kg m-2 s-1	water_evaporation_flux	evap	
Geopotential Height	zg	m	geopotential_height	geopoth	Z3
Omega	wap	Pa s-1	lagrangian_tendency_of_air_pressure	omega	
Precipitation	pr	kg m-2 s-1	precipitation_flux	precip	precip
Specific Humidity	hus	kg kg-1	specific_humidity	q	
Vertically Integrated Water Vapor	prw	kg m-2	atmospheric_water_vapor_content	qvi	
Relative Humidity	hur	%	relative_humidity	relhum	
Surface Runoff	mrro	kg m-2 s-1	runoff_flux	runoff	
Sea Level Pressure	psl	Pa	air_pressure_at_sea_level	slp	PSL
Snow Depth	snd	m	surface_snow_thickness	sn	
Air Temperature	ta	K	air_temperature	st	T
Daily Maximum Near-Surface Air Temperature	tasmax	K	air_temperature	t2max	
Daily Minimum Near-Surface Air Temperature	tasmin	K	air_temperature	t2min	
Near-Surface Air Temperature	tas	K	air_temperature	temp2	TREFHT
Surface Temperature	ts	K	surface_temperature	tsurf	TS
Eastward Wind	ua	m s-1	eastward_wind	u	U
Eastward Near-Surface Wind	uas	m s-1	eastward_wind	u10	
Northward Wind	va	m s-1	northward_wind	v	V
Northward Near-Surface Wind	vas	m s-1	northward_wind	v10	
Surface Albedo	alb[1]	1	surface_albedo	albedo	
Near-Surface Dew Point Temperature	dtas[1]	K	dew_point_temperature	dew2	
Velocity Potential	velpot[1]	m2 s-1	atmosphere_horizontal_velocity_potential	velopot	
Streamfunction	stream[1]	m2 s-1	atmosphere_horizontal_streamfunction	stream	
WMO-defined Tropopause Pressure	trop[1]	Pa	N/A	tropo	

FACTS Website



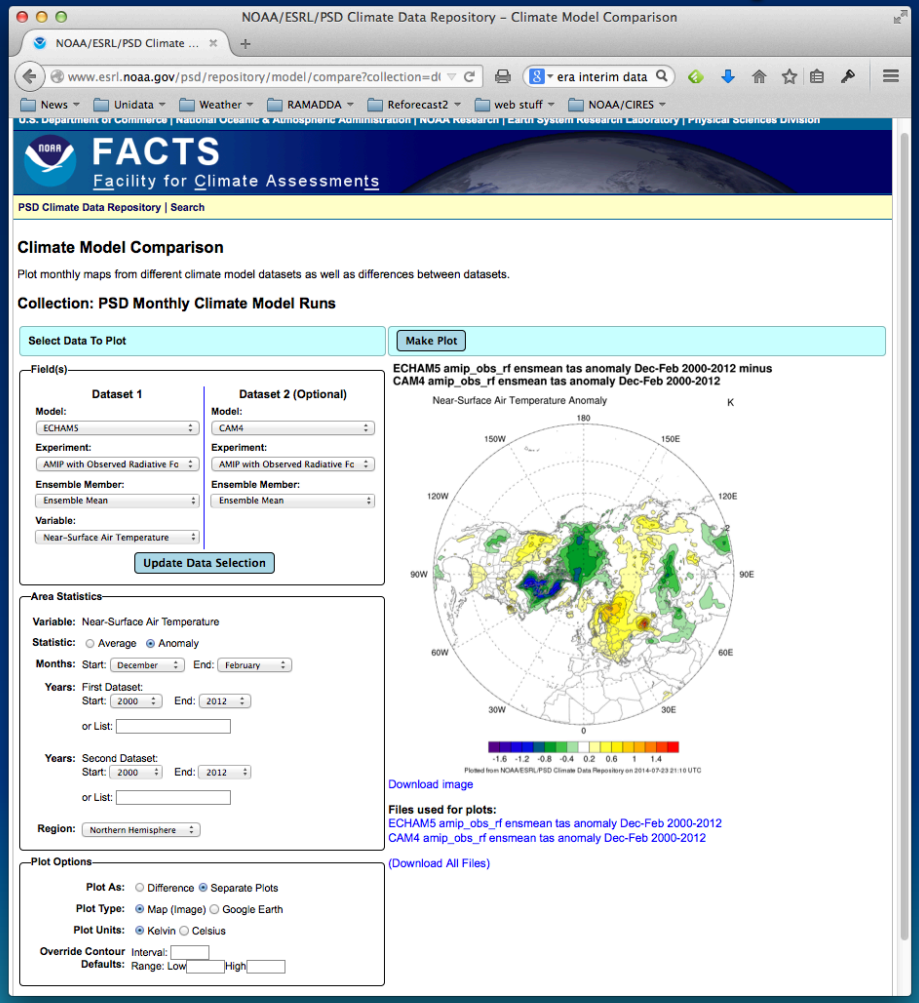
Search for/Download Data

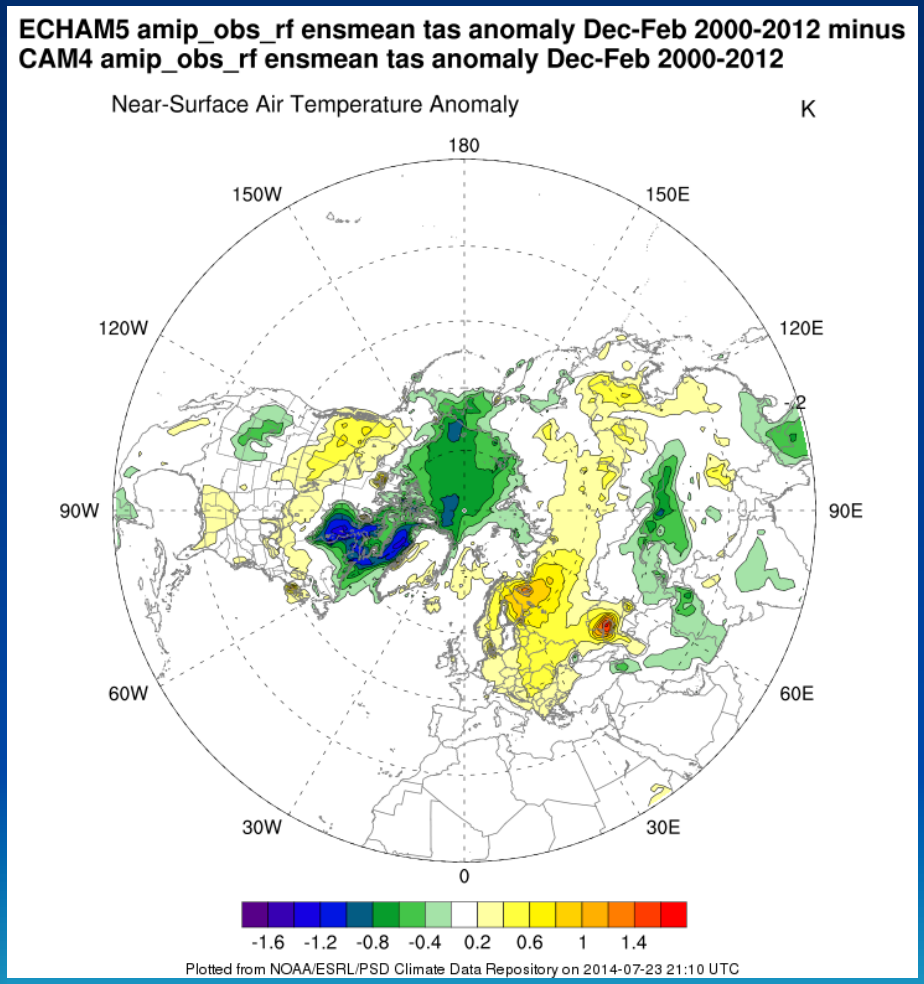


Compare Models

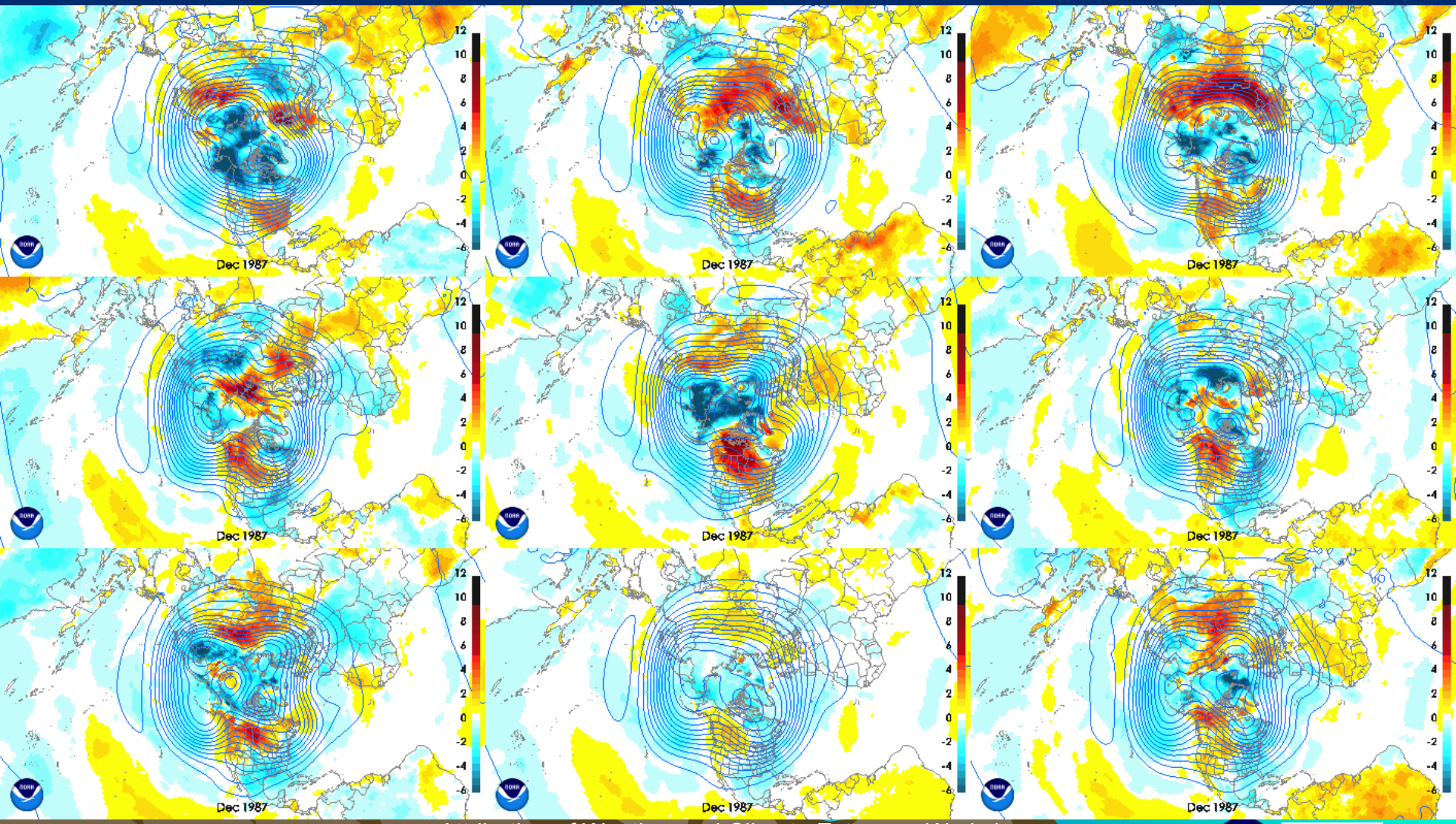
- Interactive plotting – Monthly Data
  - Plot single model/experiment/ensemble member
  - Compare same model over different time periods
  - Compare two different model experiments
  - Compare model experiments and reanalyses
- Uses CDO and NCL for analysis and plotting

Compare Models



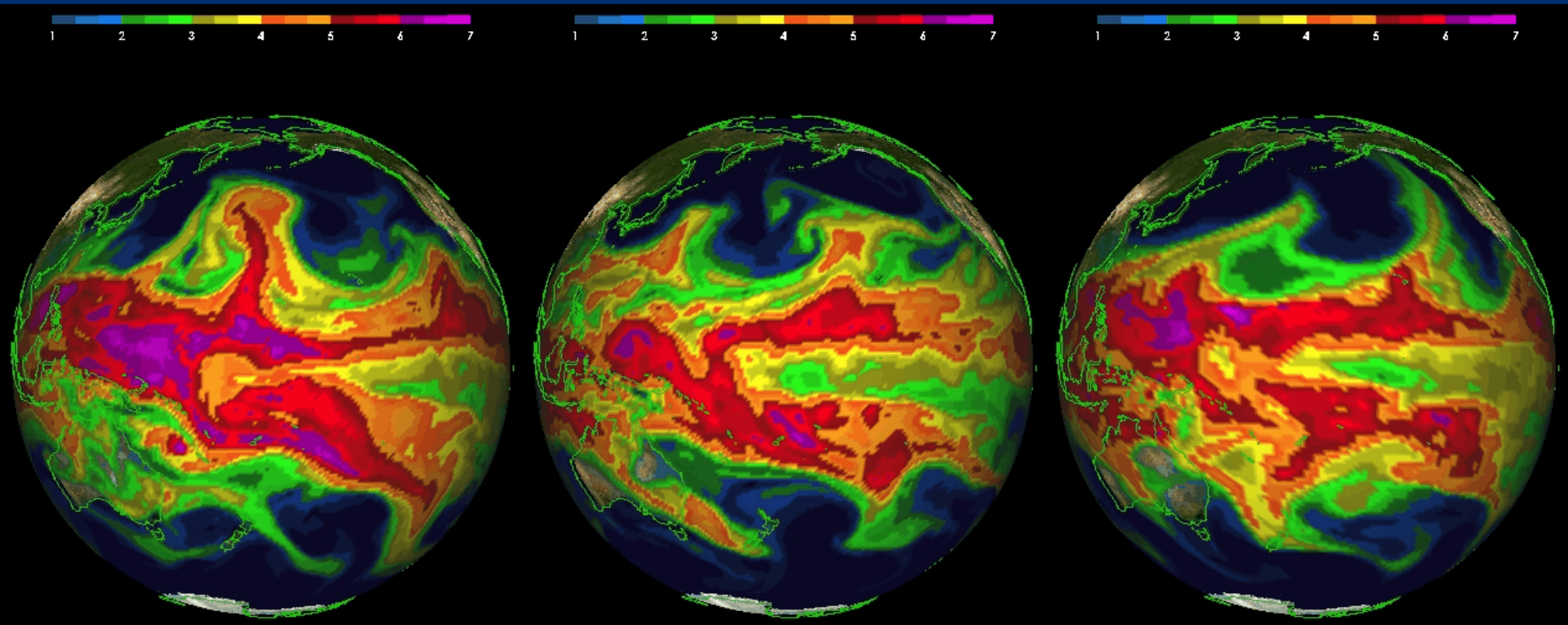


Examples



2m Temperature anomalies and 500 hPa heights – 1981-1990

Examples

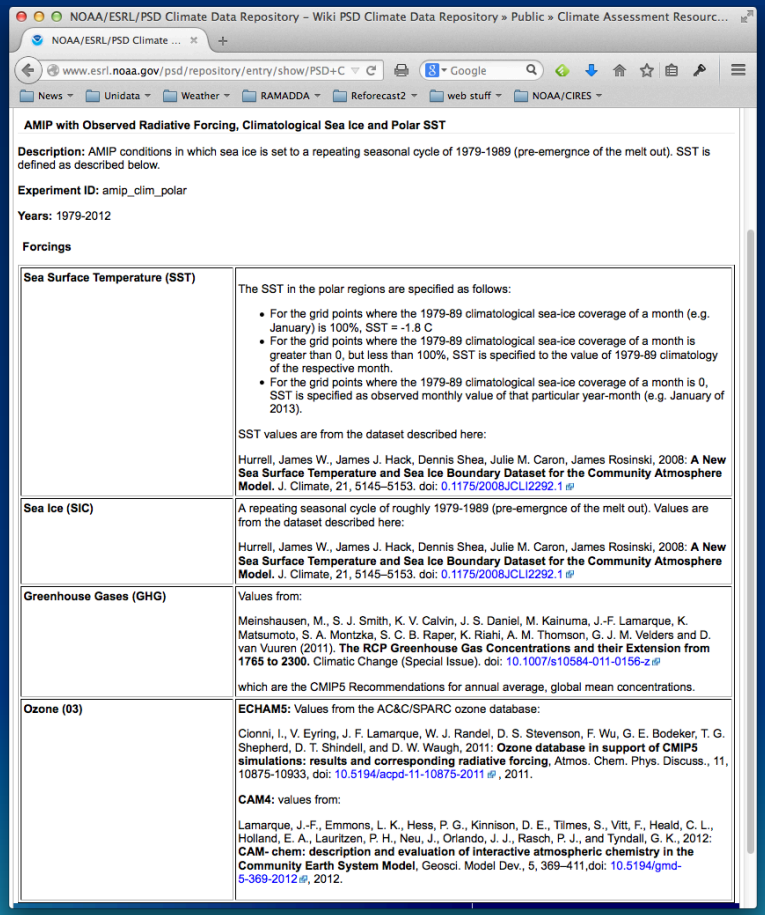


Which is Which?

Daily Precipitable Water for December

FACTS Documentation

- **Experiments** page lists the experiments, the forcings used and the number of ensembles
  - Each experiment has a detailed page listing the input datasets used.
- **Variables** page shows the original model variable names
  - Files use CMIP5 variable names
- File Format
  - All files use CF Conventions
  - CMIP5-like naming
  - netCDF4 w/ compression



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AMIP with Observed Radiative Forcing, Climatological Sea Ice and Polar SST

Description: AMIP conditions in which sea ice is set to a repeating seasonal cycle of 1979-1989 (pre-emergnce of the melt out). SST is defined as described below.

Experiment ID: amip_clim_polar

Years: 1979-2012

Forcings

Sea Surface Temperature (SST)	The SST in the polar regions are specified as follows: • For the grid points where the 1979-89 climatological sea-ice coverage of a month (e.g. January) is 100%, SST = -1.8 C • For the grid points where the 1979-89 climatological sea-ice coverage of a month is greater than 0, but less than 100%, SST is specified to the value of 1979-89 climatology of the respective month. • For the grid points where the 1979-89 climatological sea-ice coverage of a month is 0, SST is specified as observed monthly value of that particular year-month (e.g. January of 2013). SST values are from the dataset described here: Hurrell, James W., James J. Hack, Dennis Shea, Julie M. Caron, James Rosinski, 2008: **A New Sea Surface Temperature and Sea Ice Boundary Dataset for the Community Atmosphere Model.** J. Climate, 21, 5145–5153. doi: 0.1175/2008JCLI2292.1
Sea Ice (SIC)	A repeating seasonal cycle of roughly 1979-1989 (pre-emergnce of the melt out). Values are from the dataset described here: Hurrell, James W., James J. Hack, Dennis Shea, Julie M. Caron, James Rosinski, 2008: **A New Sea Surface Temperature and Sea Ice Boundary Dataset for the Community Atmosphere Model.** J. Climate, 21, 5145–5153. doi: 0.1175/2008JCLI2292.1
Greenhouse Gases (GHG)	Values from: Meinshausen, M., S. J. Smith, K. V. Calvin, J. S. Daniel, M. Kainuma, J.-F. Lamarque, K. Matsumoto, S. A. Montzka, S. C. B. Raper, K. Riahi, A. M. Thomson, G. J. M. Velders and D. van Vuuren (2011). **The RCP Greenhouse Gas Concentrations and their Extension from 1765 to 2300.** Climatic Change (Special Issue). doi: 10.1007/s10584-011-0156-z which are the CMIP5 Recommendations for annual average, global mean concentrations.
Ozone (03)	**ECHAM5:** Values from the AC&C/SPARC ozone database: Cionni, I., V. Eyring, J. F. Lamarque, W. J. Randel, D. S. Stevenson, F. Wu, G. E. Bodeker, T. G. Shepherd, D. T. Shindell, and D. W. Waugh, 2011: **Ozone database in support of CMIP5 simulations: results and corresponding radiative forcing,** Atmos. Chem. Phys. Discuss., 11, 10875-10933, doi: 10.5194/acpd-11-10875-2011, 2011. **CAM4:** values from: Lamarque, J.-F., Emmons, L. K., Hess, P. G., Kinnison, D. E., Tilmes, S., Vitt, F., Heald, C. L., Holland, E. A., Lauritzen, P. H., Neu, J., Orlando, J. J., Rasch, P. J., and Tyndall, G. K., 2012: **CAM- chem: description and evaluation of interactive atmospheric chemistry in the Community Earth System Model**, Geosci. Model Dev., 5, 369–411,doi: 10.5194/gmd-5-369-2012, 2012.

Examples of Usage

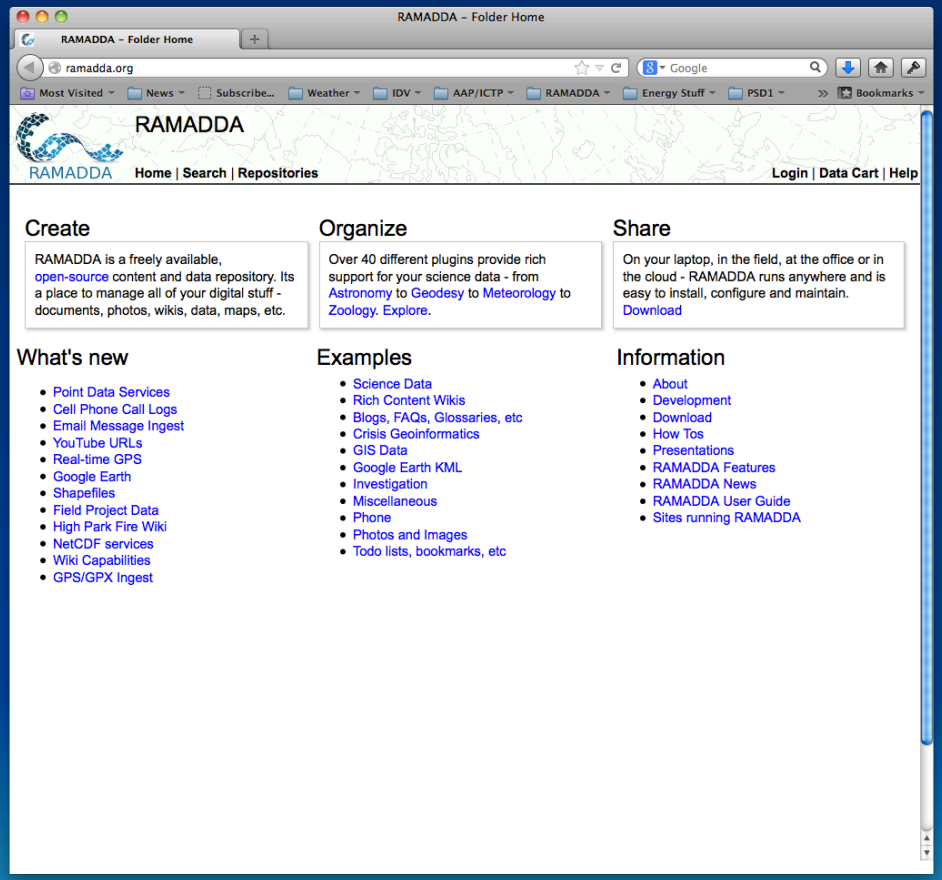
- Investigate the effects of sea ice on arctic amplification (Perlwitz et al. 2013)
  - Sea ice effect limited to lower portion of troposphere
  - Small part of overall arctic warming
- Inform stakeholders on causes of the 2012 Missouri River Basin flooding

More features coming soon

- Additional models and experiments
- Time series
- Animations
- Ensemble analysis
- Access to observational datasets
- Daily Data

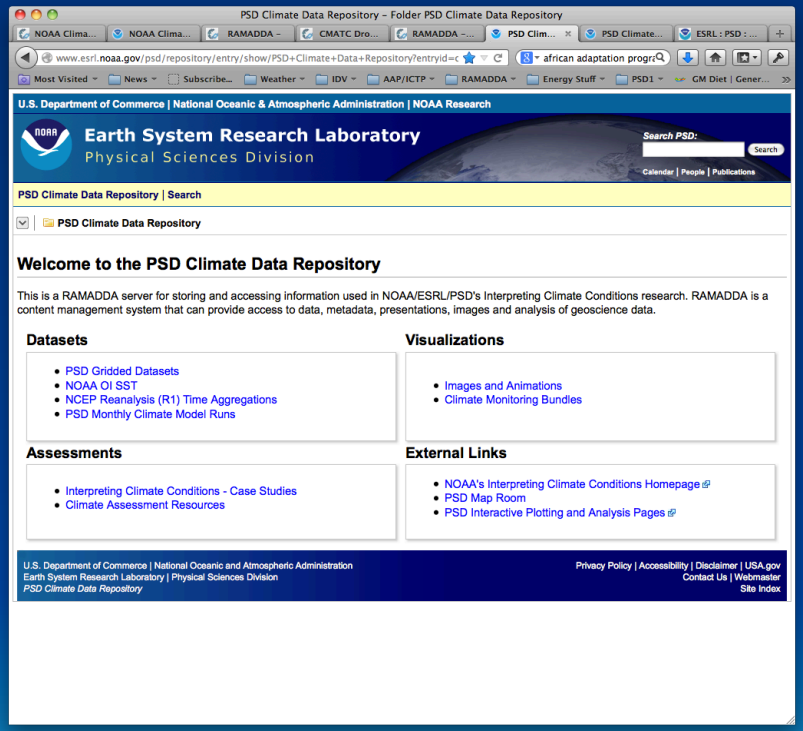
What is RAMADDA?

- Basis for FACTS website
- Repository for Archiving, Managing and Accessing Diverse Data
- Freely available, open source publishing platform and content management system for earth science data
  - Java-based web system
  - Supports query, access and download of data
  - Provides facilities for publishing
  - Plug-in architecture allows others to add new functionality.



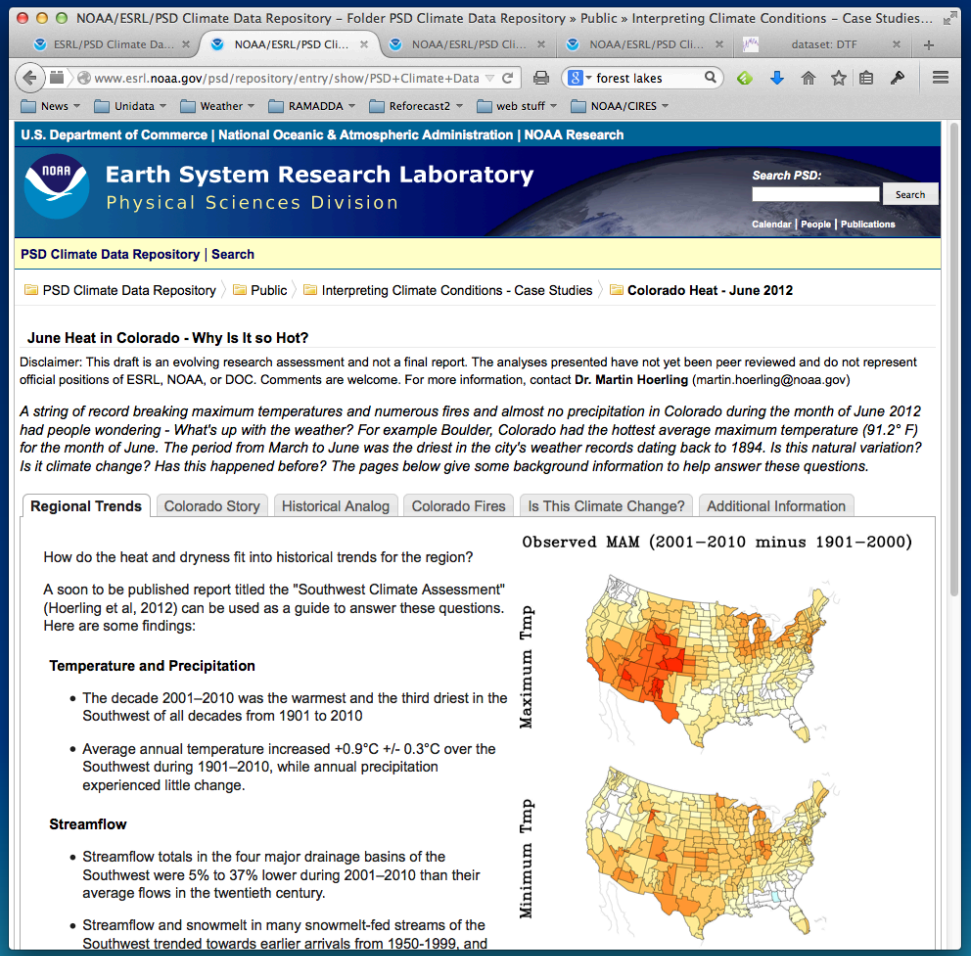
PSD RAMADDA Server

- NOAA/ESRL/PSD Climate Data Repository
  - Access to climate-related gridded data
  - Home of the FACTS website for climate attribution
  - Publishing platform for PSD climate assessments



Publishing Platform

- The RAMADDA wiki facility can be used to publish climate assessments
  - Allows integration of images, maps, data access
  - Example – June 2012 Colorado Heat Wave

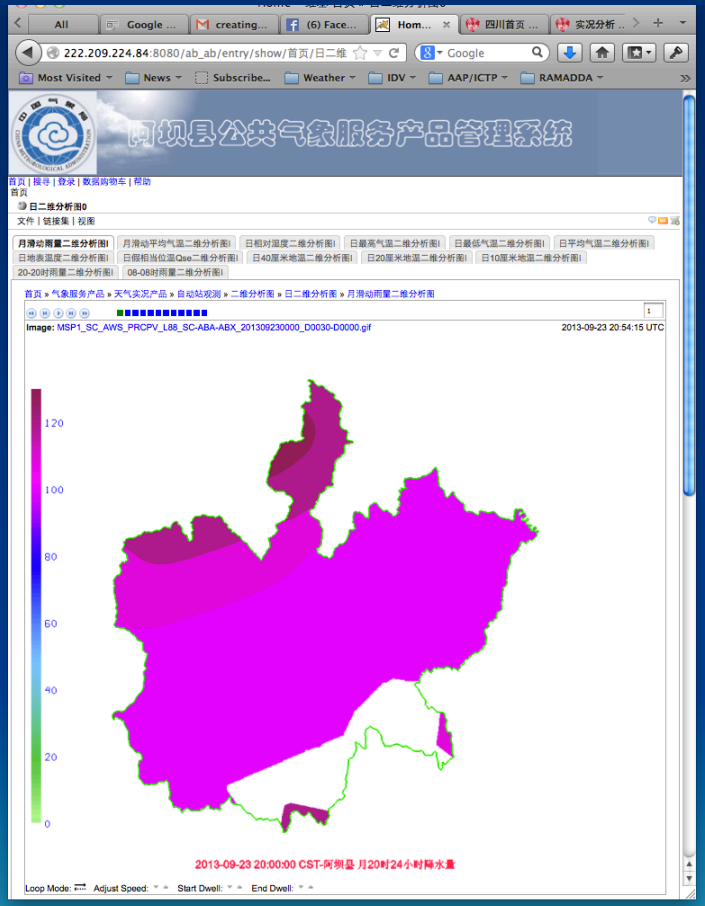


RAMADDA Features

- Easy to install, runs on most machines, even your laptop
- Supports access to and services for climate data
  - FACTS code available as a plugin
- Publishing facilities allow rapid creation of rich content that includes both the analysis and access to the underlying data without knowing much about web page creation.

Example RAMADDA Servers

- China Meteorological Administration – Chengdu
  - Store weather information and maps of current weather
  - Maps generated by IDV accessed outside RAMADDA on public site
  - Uses language translation facility



Example RAMADDA Servers

- African Adaptation Program
  - Designed to assist 20 countries across Africa to incorporate climate change risks and opportunities into their national development processes
  - Used RAMADDA to facilitate access to climate data and share climate related materials.
  - Program concluded in June, 2012, but servers are still running.

Summary

- NOAA's FACTS repository provides freely available climate model experiment output for use in climate assessments
- The underlying RAMADDA framework can be implemented at other sites to provide a similar interface to other model experiments (e.g. CMIP5, CFSR)

More Information

- FACTS website
  - http://www.esrl.noaa.gov/psd/repository/alias/facts
- RAMADDA web site with examples:
  - http://ramadda.org