# An Efficient Workflow Environment to Support the Collaborative Development of Actionable Climate Information

Using the NCAR Climate Risk Management Engine (CRMe)



Jonathan L. Vigh (NCAR), Caspar M. Ammann (NCAR), Jared A. Lee (NCAR)

\* Indicates that CRMe can create composite variables from other primary variables.

Access, evaluation, analysis and translation of complex climate data in efficient, transparent and reproducible ways / for specialized and interdisciplinary science, for applications, and for communication and education.

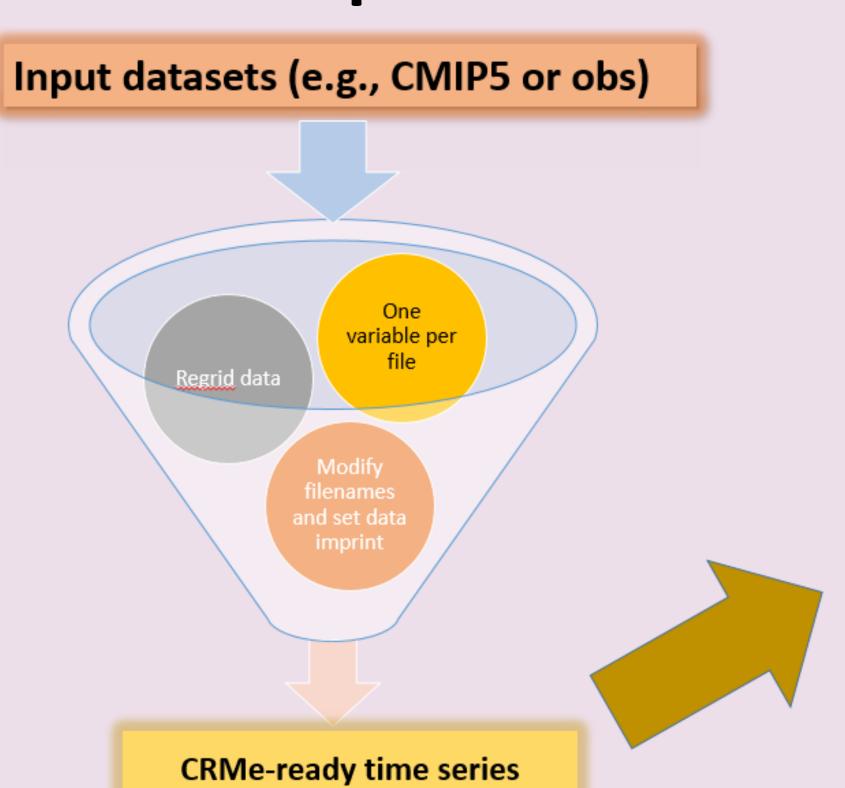
## 1. Overview

The Climate Risk Management engine (CRMe) is an NCL-based code set (with capability to integrate R packages) used to process and analyze large climate data sets (daily or monthly) from a variety of different sources (observations, model output) and on any horizontal resolution (global, regional, local).

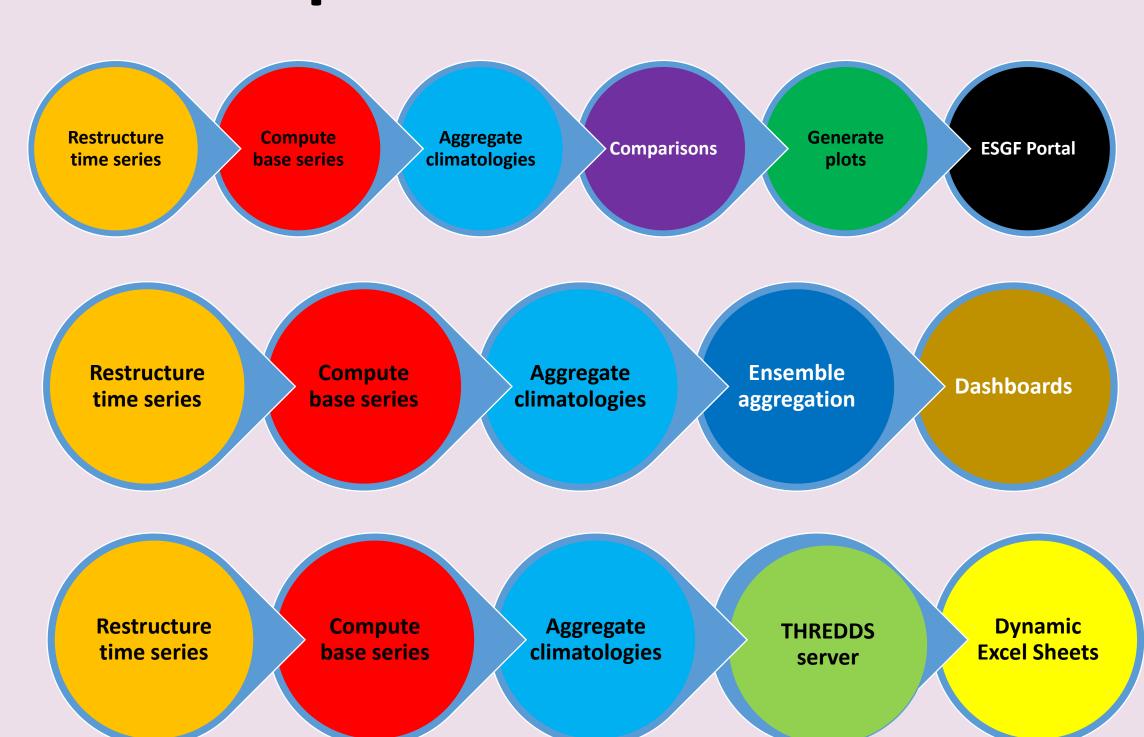
## CRMe provides:

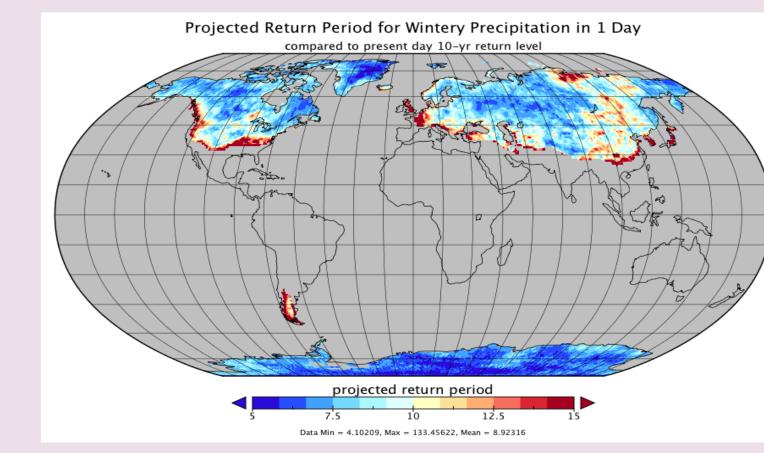
- Consistent data provenance preserves metadata from source data
- Structured metadata schema with controlled vocabulary
- Support for "Big Data"-sized problems (e.g., 100+ years of half degree global data, or 60+ years of quarter degree global data)
- Support data delivery to portals, customized viewers, and other applications such as Microsoft Excel and Open Climate GIS.

# 2. Data Preparation

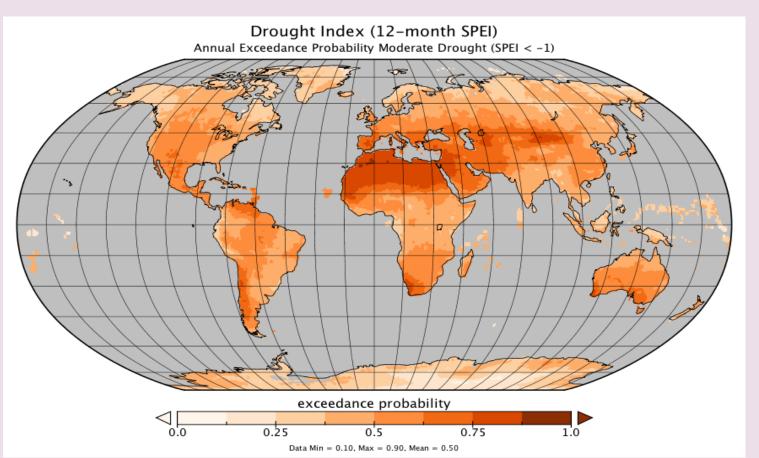


# 3. Example CRMe Workflows





Projected change in 10-y return period for wintery precipitation in



Projected annual exceedance probability of moderate drought in 2036 (12-month *SPEI < -1)* 

# 4. Discrete, efficient workflows

Through thoughtful discretization of computational tasks, CRMe supports highly efficient processing workflows that are flexible enough to be run on a desktop, a server, or a supercomputer.

## Key steps include:

- Preprocess, subset, and regrid input datasets (daily or monthly)
- Standardize data into CF-compliant netCDF
- Restructure daily data to enable very efficient computations
- Calculate base series of various sector- and application-oriented indices at the monthly, seasonal, annual, and decadal time frames
- Aggregate base series data into climatological period statistics.

CRMe can take ~10 TB of CMIP5 data and compute hundreds of complex indices with a turnaround time of a few days.

CRMe employs workflow parallelization by dataset, so scores of climate model datasets can be run simultaneously over multiple climate periods. These capabilities, coupled with the CRMe Viewer, provide powerful new ways to browse and compare large sets of climate data in past and future climates.



# 5. Sector Indices: Extensibility

Diverse application-oriented practitioners have data needs that cannot be fully satisfied using existing indices. Through coordination with experts and practioners from various industry sectors, new indices have been developed to assess climate risks specific to each sector.



**Ports & Water Transport** 

Tropical cyclones

Insurance

River floods

Flash floods

Storm surge

Heat/cold waves

Tropical cyclones

Extratropical cyclones

### Forestry

- Forest fire
- Shift in geographic range
- Droughts
- Floods

Snowfall

- Extreme winds
- Heat/cold stress

## • River levels • Storm surge / waves

- Wind
- Floods

# Heat/cold hazards/costs

# Drought Plantation Tree Climate Suitability Fire

Summary of change in climate suitability for 14 species of plantation tree species for a 30-year future climate period centered on 2085. Areas in red show a complete loss of

climate suitability. Areas in green show a gain of suitability for 2 or more tree species.

# 6. Tailored Data Delivery

In order to be usable, climate data needs to be delivered to end-users in forms that they can work with. Recently, a new data delivery modality was developed to deliver climate data directly from an NCAR-based server to users' Excel spreadsheets. This allows users to dynamically download detailed climate information for a specific location (e.g., user-provided lat/lon coordinates).

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Baseline climate period: 1986-2015 Placename of port: Mazanillo, Mexico			∀eb service updates for p50 ensemble results: <mark>Off</mark>										
racerianie o	i port.	wazanino, mexico				Resul	ts Based o	n an Agg	regation o	of All Ava	ilable CI	MIP5	
Latitude of port: Longitude of port:		19.1138					Ensemble Members: 50th Percentile						
		-104.3385	Data sources:			cmip5_ all-	cmip5_ all-	cmip5_ all-	ll-	all-	all-	_all-	
Interpolation method:		bilinear_interpolation		Future climate period:		none	2010-		2036- 2065	2036-	2071- 2100	2071- 2100	
				Ensemble aggregation m	netric:	p50	p50	p50	p50	p50	p50	p50	
				Scenario:		hist-rep	rcp45	rcp85	rcp45	rcp85	rcp45	rcp85	
Hazards	Summary of Indicator	Technical Description of Indicator	Return Priod /	Metric / Index / Indicator ID	Temporal Aggregation	2000	2025	2025	2050	2050	2100	2100	
Vindspeed	Annual mean wind speed at 10m	Annual mean windspeed at 10 m	Threshold	windspeedaavgann	Period	1.8711702	1.913556	1.96618		1.96784	1.88743	1.96	
	Relative change in annual mean wind	Relative change (normalized by standard deviation) in annual mean wind speed at				1.0711102							
	speed at 10m	10m	·	windspeedaavganndeltarel	period		-5.64382	6.09312	-19.26607	7.09545	-27.545	-8.38	
	Number of very windy days	The average # of days per year with daily mean wind speed >= 10 m/s	10 m/s	windspeed10mpsaavgann	annual	0.0499783	0.044997	0.04499	0.0349976	0.06	0.04	0.0	
	Relative number of high wind days (defined by locale)	The average # of days per year with daily mean wind exceeding the 99th percentile threshold of the baseline climate	99%	windspeed99pbcdp	period	0.01	0.009398	0.01025	0.0089131	0.00974	0.00821	0.008	
Tropical Cyclone ∀ind	Tropical storm risk (gale force)	The annual probability of experiencing a "hit" from a tropical cyclone of at least 34 kt (a hit is defined as having the TC pass through the 1 x 1 deg grid cell of the location; the probabilities have been smoothed by a 3-1 smoother)	34 kt	te34hitap	period	0.1628139	0.162814	0.16887	0.1688719	0.17685	0.16887	0.180	
	Category 1 risk	The annual probability of experiencing a "hit" from a tropical cyclone of at least 64 kt (a hit is defined as having the TC pass through the 1 x 1 deg grid cell of the location; the probabilities have been smoothed by a 9-1 smoother)	64 kt	to64hitap	period	0.0871158	0.092557	0.0932	0.0932035	0.09719	0.09719	0.101	
	Category 3 risk	The annual probability of experiencing a "hit" from a tropical cyclone of at least 96 kt (a hit is defined as having the TC pass through the 1 x 1 deg grid cell of the location; the probabilities have been smoothed by a 9-1 smoother)	96 kt	to96hitap	period	0.0050832	0.015011	0.01501	0.0150107	0.02241	0.01501	0.030	
	Unfavorable conditions in the navigation zone	The # of hours per year with unfavorable conditions in the navigation zone, defined as significant wave height > 2.5 m	2.5 m	ucnavigationzonehours	period	81.043228	81.21308	80.5127	81.445564	80.5621	82.0984	82.	
	Overtopping in a vertical breakwater	The # of hours per year with overtopping > 0.001 l/s/m of a vertical breakwater for a freeboard of 2 m	2 m	overtoppingverticalbreakwaterhours200	period	5388.0928	5943.827	5953.6	6056.4321	6086.63	6134.73	6237.	
	Coastal flooding	The # of hours per year with coastal flooding > 0.1 m in the berth	0.1 m	coastalfloodingabovefreeboardhours010	period	2.9126363	5.210385	0	153.88992	191.806	1383.12	2740.	
Port Conditions	Tidal range	Tidal range (m)	·	tidalrange	period	1.6515614	1.651561	1.65156	1.6515614	1.65156	1.65156	1.651	
Port Conditions	ridarrange			relativesealevelrise	period	0	0.103339	0.11125	0.2442564	0.26885	0.5073	0.658	
Port Conditions	Relative sea level rise	Relative sea level rise (m)	·										
Port Conditions	<u> </u>	Relative sea level rise (m)  Percent change in maximal total water level associated with a 20-year return period, relative to the maximal total water level associated with a 20-year return period in the baseline climate	- 1 in 20	totalwaterlevelreturnievel 20 del tarel	period	(	6.360886	6.84767	15.034821	16.5485	31.2262	40.51	

Example of an Excel spreadsheet using the CRMe Web Data Service.

The CRMe Web Data Service delivers discrete pieces of climate information, called *climatons*, at the rate of 18 per second. A climaton can be a timeaggregated value of a variable (e.g., mean monthly temperature in Jan) or a period index value (e.g., change in 10-year return period of 5-day rainfall). Users can select whether to use the nearest grid point, bilinear interpolation, or country-aggregated results.

# 7. Projects using CRMe

**National Predictions & Projections Project** (NCPP) - evaluation of downscaling methods, supported QED workshop in 2013

World Bank – CRMe has recently been used to provide the data that will populate the next generation Climate Change Knowledge Portal

UAE AGEDI – CRMe was used to provide data for an interactive "climate inspector" tool

A major international development bank – CRMe has recently been used to provide data for climate risk screening tools, adding 100+ new sector-oriented indices

For more information about CRMe, please contact: Jonathan Vigh

jvigh@ucar.edu http://verif.ral.ucar.edu/jntweb/crme/

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