# KrigR – CLIMATE DATA FOR YOUR SPATIAL STUDY

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# microclimatic processes [...] affect broad-scale ecological processes - LEMBRECHTS & LENOIR, 2019

WorldClim Precipitation Climatology



Data Min = 0.0, Max = 881.4



### → Are we really using the best data available?





# **CLIMATE DATA - WHAT WE HAVE**

#### **Gridded Observations:**

- Single-location measurements
- Aggregated and interpolated to fit grid

#### Shortcomings:

3



WorldClim temperature station data

Examples of datasets for temperature<sup>1</sup> and precipitation<sup>2</sup>

Name	Spatial resolution	Temporal resolution	Period covered
<u>CRUTv4</u> <sup>1</sup>	5° x 5°	Monthly	1850 - present
<u>GHCNv3</u> <sup>1,2</sup>	5° x 5°	Monthly	1880 - 2016
NOAA <sup>1</sup>	5° x 5°	Monthly	1880 - present
<u>GISTEMP</u> <sup>1</sup>	2° x 2°	Monthly	1880 - present
GHCN_CAMS <sup>1</sup>	0.5° x 0.5°	Monthly	1948 - present
UDelaware <sup>1,2</sup>	0.5° x 0.5°	Monthly	1900 - 2017
WorldClim2 <sup>1,2,*</sup>	0.042° x 0.042°	Monthly	1960 - 2018
<u>CPC Global<sup>1,2</sup></u>	0.5° x 0.5°	Daily	1979 - 2010
NOAA_land <sup>2</sup>	0.5° x 0.5°	Monthly	1948 - present
<u>GPCP</u> <sup>2</sup>	2.5° x 2.5°	Monthly	1979 - present
<u>GPCC</u> <sup>2</sup>	0.5° x 0.5°	Monthly	1891 - present





# **CLIMATE DATA - WHAT IS OUT THERE**

#### **Climate Reanalyses:**

- Synthesis of models and observations
- Product of choice for climate scientists
   doing process studies

#### Improvements:

- All climate parameters are available from a single product
- Dynamically consistent
- No spatial or temporal gaps
- Close match to a multitude of observations
- Massive advancement in temporal resolution

#### Examples of global climate reanalyses

Name	Spatial resolution	Observations assimilated	Temporal resolution	Period covered
<u>ERA5-</u> Land	0.1° x 0.1°		Hourly & monthly	1950* – present
ERA5	0.28° x 0.28°			
<u>JRA55</u>	1.25° x 1.25°	Ground-	6 hourly & daily	1958 – 2012
<u>NCEP</u>	2.5° x 2.5°	Satellite-born		1979 - presemt
MERRA-2	0.5° x 0.5°		Hourly & 3 hourly & 6 hourly	1980 - present
ERA-20C	0.25° x 0.25°	Surface pressure	3 hourly & 6 hourly	1900 - 2010

 $^{\ast}$  currently, ERA5 and ERA5-Land data is available going back to  ${\sim}1980$ 

 $\rightarrow$  Higher-resolution climate reanalyses are available for some regions





# **CLIMATE DATA – WHAT'S STOPPING US**

#### **Download specifications:**

- Very complicated
- Not R-based

5

• No processing of data

#### **Spatial resolution:**

- Too coarse for biological use:
  - Era5: ~30km x 30km
  - Era5-Land: ~9km x 9km
- e.g. WorldClim delivers 1km x 1km

#### $\rightarrow$ KrigR solves these issues!

ERA5-Land hourly data from 1981 to present	Geographical area 💿	
Overview Download data Documentation	O Whole available region	
	With this option selected the entire available area will be provided	







ERIK KUSCH



# KrigR - OBTAINING THE DATA

#### **Download Prerequisits**

CDS account & API key (generated <u>here</u>)

#### ecmwfr package:

- Very unintuitive download specification
- No processing of data

#### KrigR package:

- Wrapper functions for ecmwfr package
- More intuitive specification
- Masking according to shapefiles
- Aggregation of hourly/monthly data to desired temporal resolutions







# KrigR - DOWNSCALING THE DATA

#### Kriging

- Geostatistical downscaling method
- Covariates at training & target resolution

#### automap package:

- Kriging functionality in R

#### KrigR package:

- Covariates (USGS GMTED 2010 DEM):
  - Donwload and pre-processing function
- Kriging (automap wrapper):
  - Parallel processing of multilayer rasters
  - Added sanity checks before Kriging



Kriged Air Temperature (1st - 6th January 2014)





7

# KrigR – Workflow I

8



### KrigR – Workflow II



Kriged Air Temperature (1st - 6th January 2014)





277.3

279.0

280.8

275.5

272.1

273.8







# KrigR - CONSIDERATIONS FOR USERS

#### Consider your covariates

- <u>Consistency</u>: Relationship of target variable & covariates across spatial/temporal scales
- <u>Colinearity</u>: Exploit relationships between climate variables for Co-Kriging
   → Not all climate variables can be downscaled the same way

#### **Computational cost**

- Processing time scales close to exponentially with extent and downscaling factor
- Adding covariates only marginally increases computational cost

 $\rightarrow$  Downscale small regional products using many covariates.

#### **Global Kriging**

- Important relationships break down between the hemispheres
- Computational cost prohibits us from doing this in one step

 $\rightarrow$  We can Krig global products in latitude bands or smaller tiles



10



# OUTLOOK

11

What did we gain?

- R-integrated access to state-of-the art climate products
- Complete workflow for advanced statistical downscaling of spatial products within R

#### How can you get it?

- It's on github and ready to use (you'll also find this presentation there)
- Get in touch with us for workshops

#### What's still to come?

- KrigR for use in species distribution modelling  $\rightarrow$  Publication
- Application of KrigR in vegetation dynamics studies  $\rightarrow$  Publication & Poster at ISEC









### **CLIMATE VARIABLES & COVARIATES**

- Surface air temperature (SAT)
  - $\rightarrow$  DEM relationship is very consistent
- Soil temperature
  - $\rightarrow$  SAT & soil type & soil moisture drive this
- Precipitation
  - $\rightarrow$  processes are highly spatially sensitive. Downscaling is not advised.
- Soil moisture
  - $\rightarrow$  driven by precipitation & modified by soil and slope properties
- Wind
  - ightarrow highly spatially sensitive. DEM and slope steepness can be exploited

