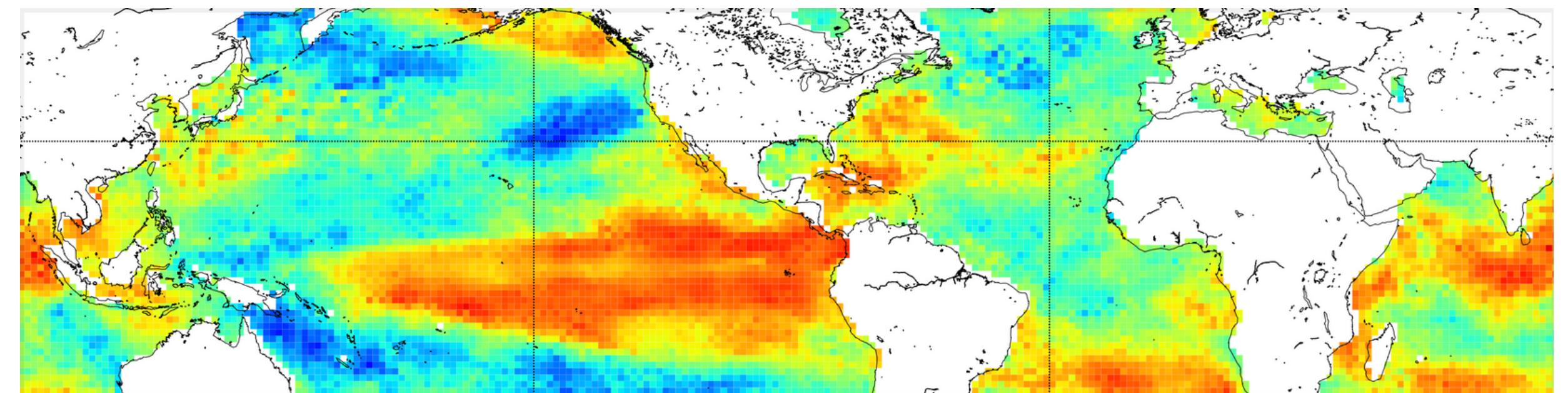


Improving sub-seasonal drought forecasting with machine learning and climate indices

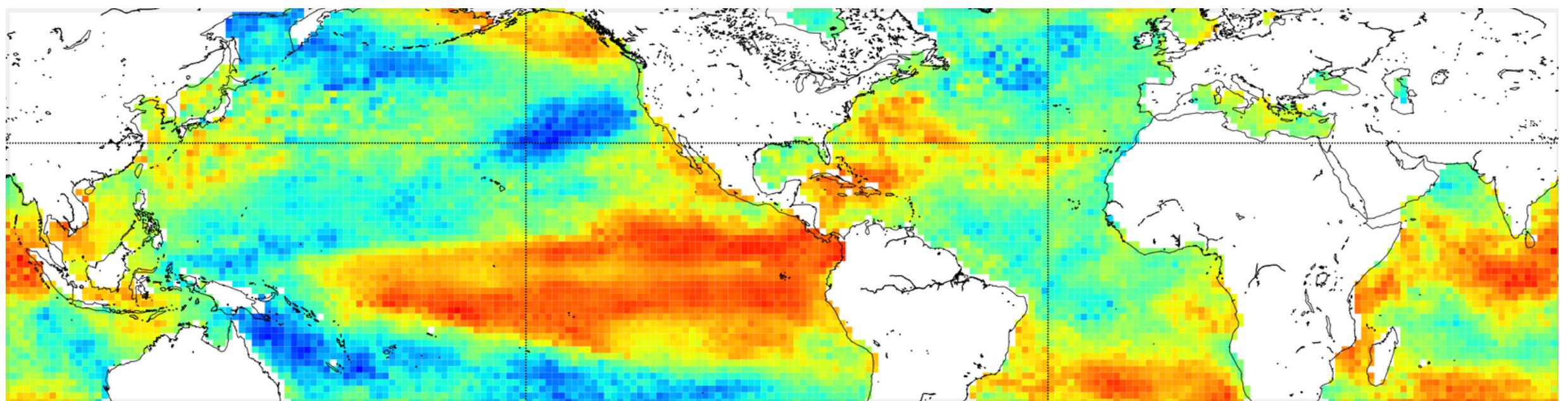
IHE Delft, 03/11/2022





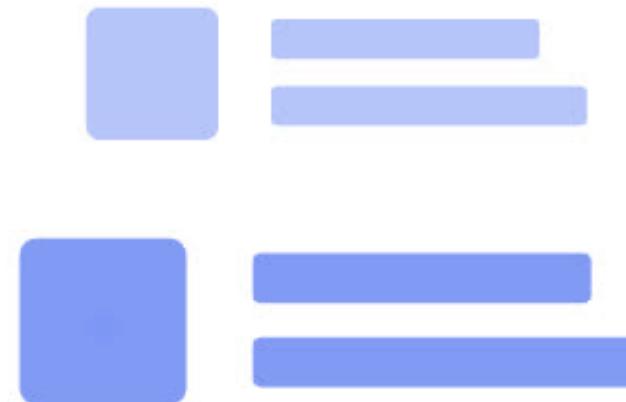
you can find
the slides
here!

IHE Delft, 03/11/2022



Today's Agenda

this presentation will go through the following stages:



01

Intro

02

Context

03

Framework

Intro



- 01 What is drought
- 02 ML for Drought
- 03 The gap

Intro

- 01 What is drought
- 02 ML for Drought
- 03 The gap



Meteorological Drought

a period of time in which a region experiences below-normal precipitation

Reduced soil moisture, Reduced stream flow, Crop damage

Water shortage

Intro



- 01 What is drought
- 02 ML for Drought
- 03 The gap

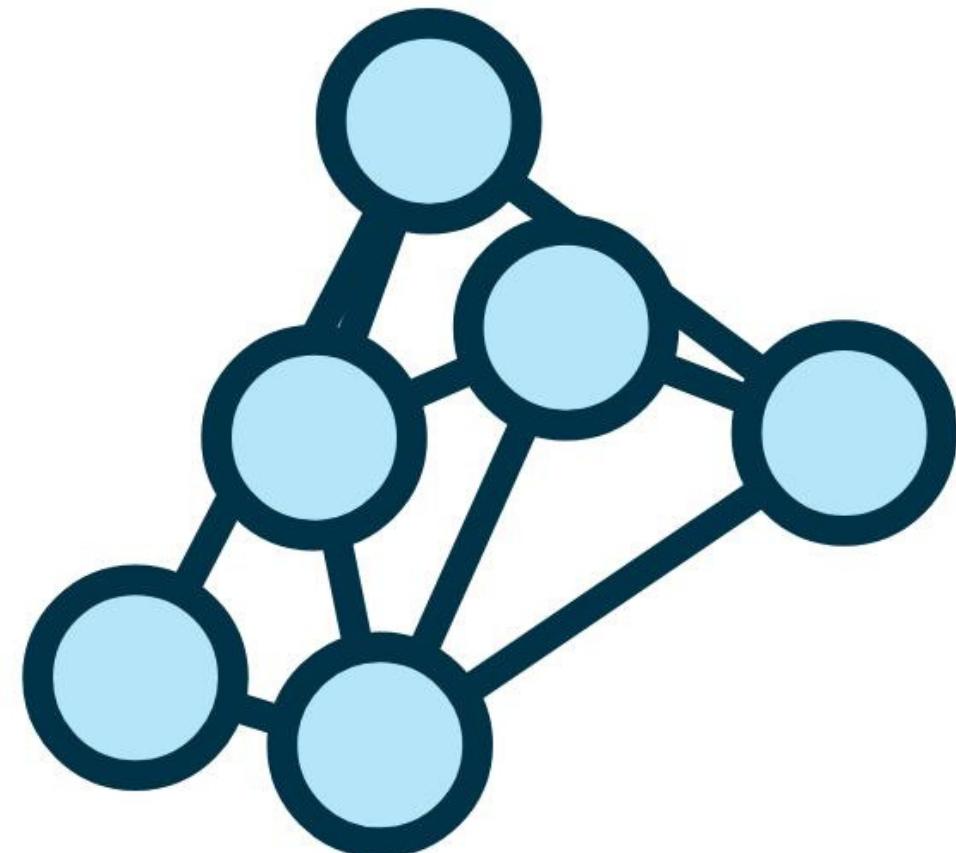
The onset, extent and duration of drought are difficult to define

different stakeholders have varying degrees of tolerance and resilience to these events

(Slette et al., 2019)

Being able to forecast them is crucial

Intro

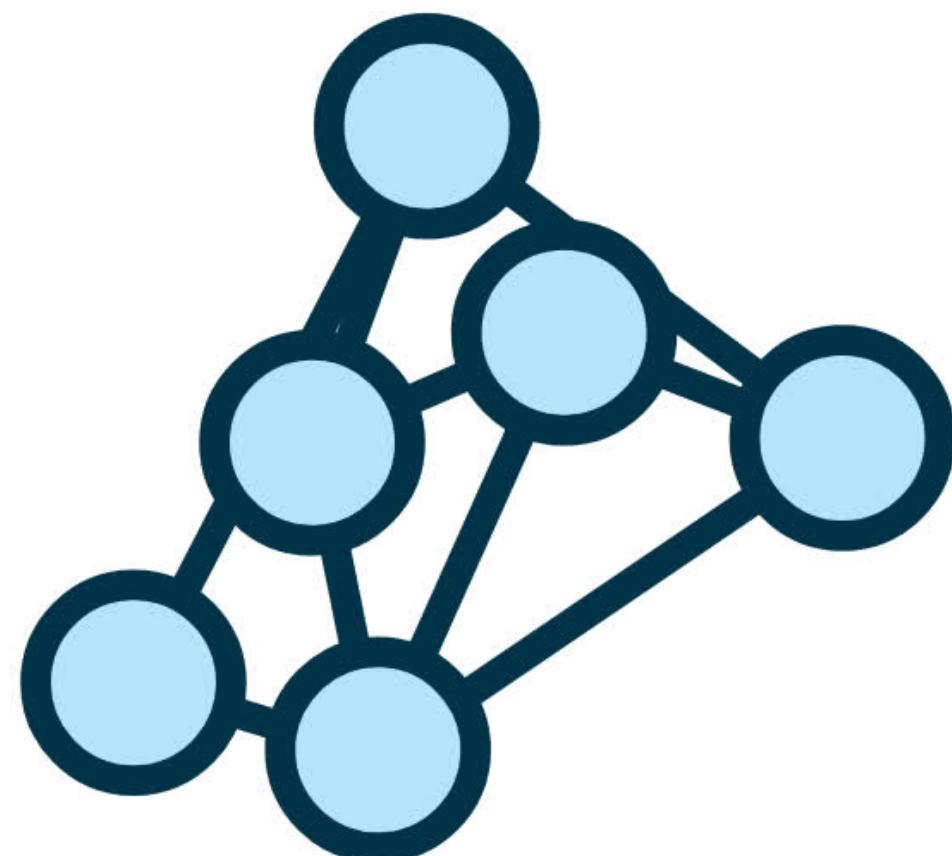


exploitation of *statistic* and *dynamic techniques* for droughts forecasting has been and is widely studied

sub-seasonal forecasting

- 01 What is drought
- 02 ML for Drought
- 03 The gap

Intro



Earth observation data
Artificial Intelligence
Hardware (GPU,TPU)



**AI-based
prediction
models**

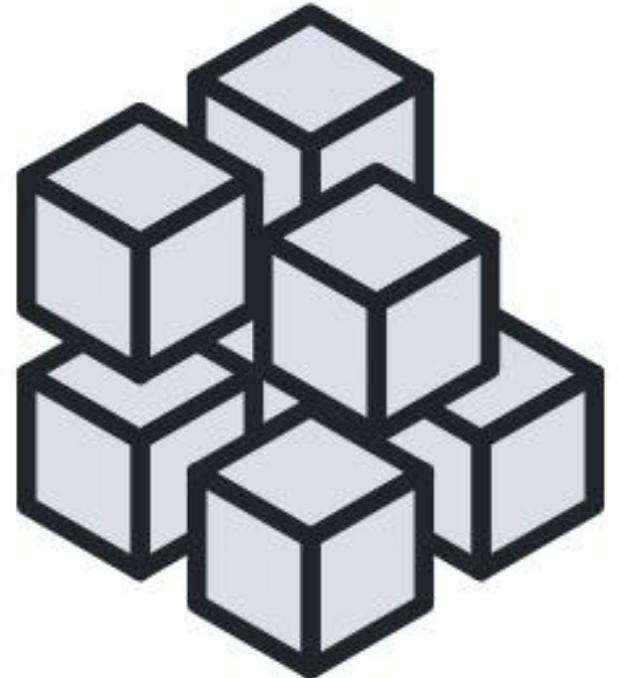
McGovern et al. (2017)

Learn from past data
Integrate physical understanding into the models
Discover additional knowledge from the data
Handle large amounts of input variables

- 01 What is drought
- **02 ML for Drought**
- 03 The gap

Intro

- 01 What is drought
- 02 ML for Drought
- 03 The gap



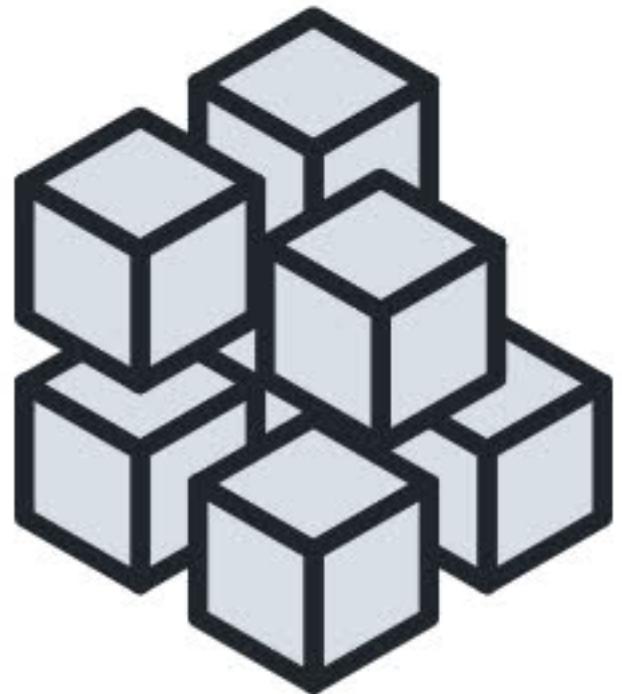
**sub-seasonal
drought forecasting**

↔ AI

**Why to focus on sub-seasonal
lead times?**

Intro

- 01 What is drought
- 02 ML for Drought
- 03 The gap



Informative predictors

seasonal:

climate indices and large scale teleconnection patterns

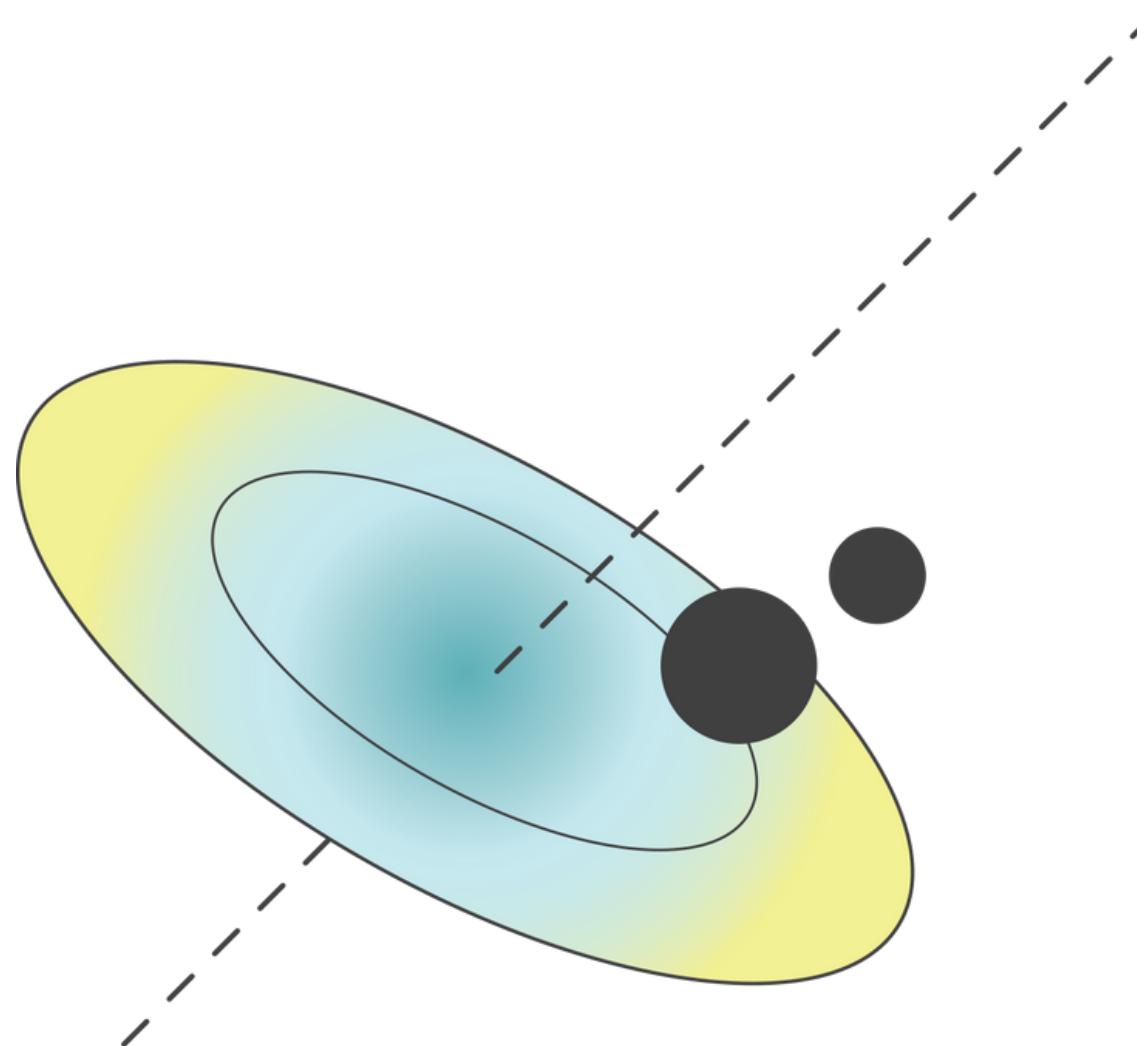
short-medium term:

local variable (precipitation, temperature)

sub-seasonal?

- **short enough** that the atmosphere still has memory of its **initial conditions**
- **long enough** to allow **atmospheric circulation** to affect the evolution of weather conditions

Context



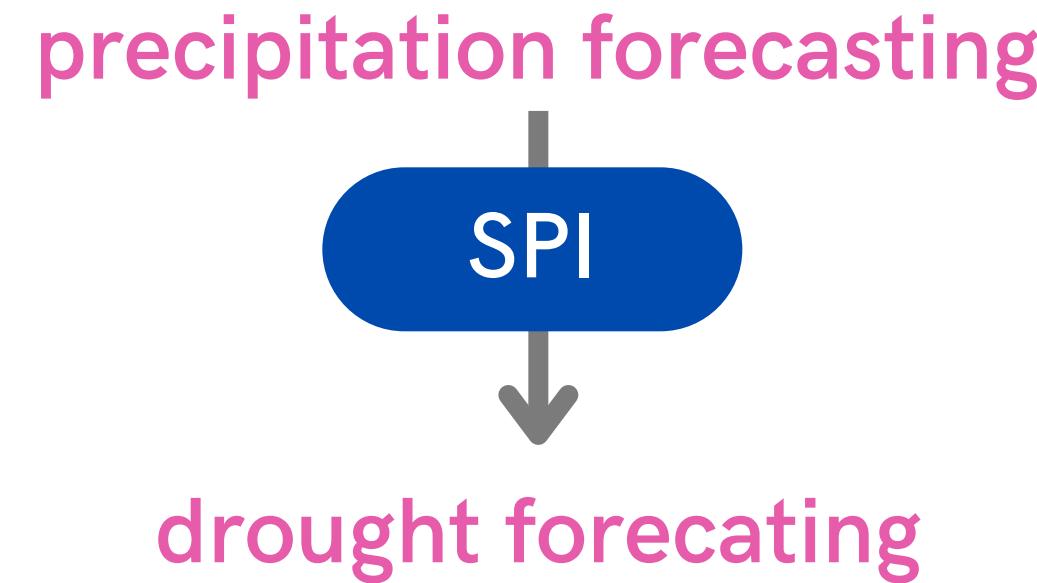
- 01 What (our goal)
- 02 Where (study area)
- 03 How (the framework)

Context

Machine Learning model for
sub-seasonal drought
classification

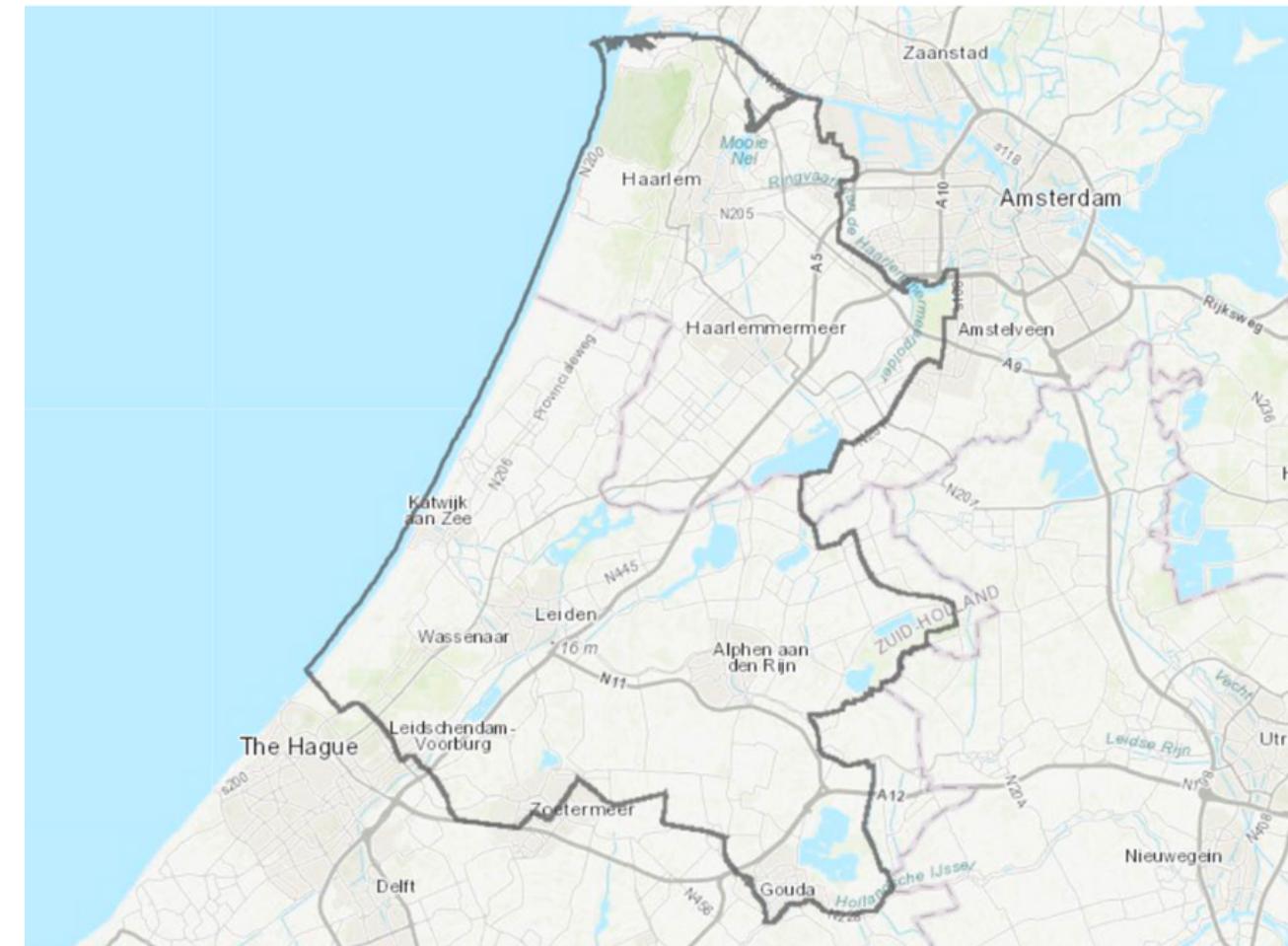
Based on
SPI
classes

Machine Learning model for
sub-seasonal precipitation
forecasting



- 01 What (our goal)
- 02 Where (study area)
- 03 How (the framework)

Context



- 01 What (our goal)
- 02 Where (study area)
- 03 How (the framework)

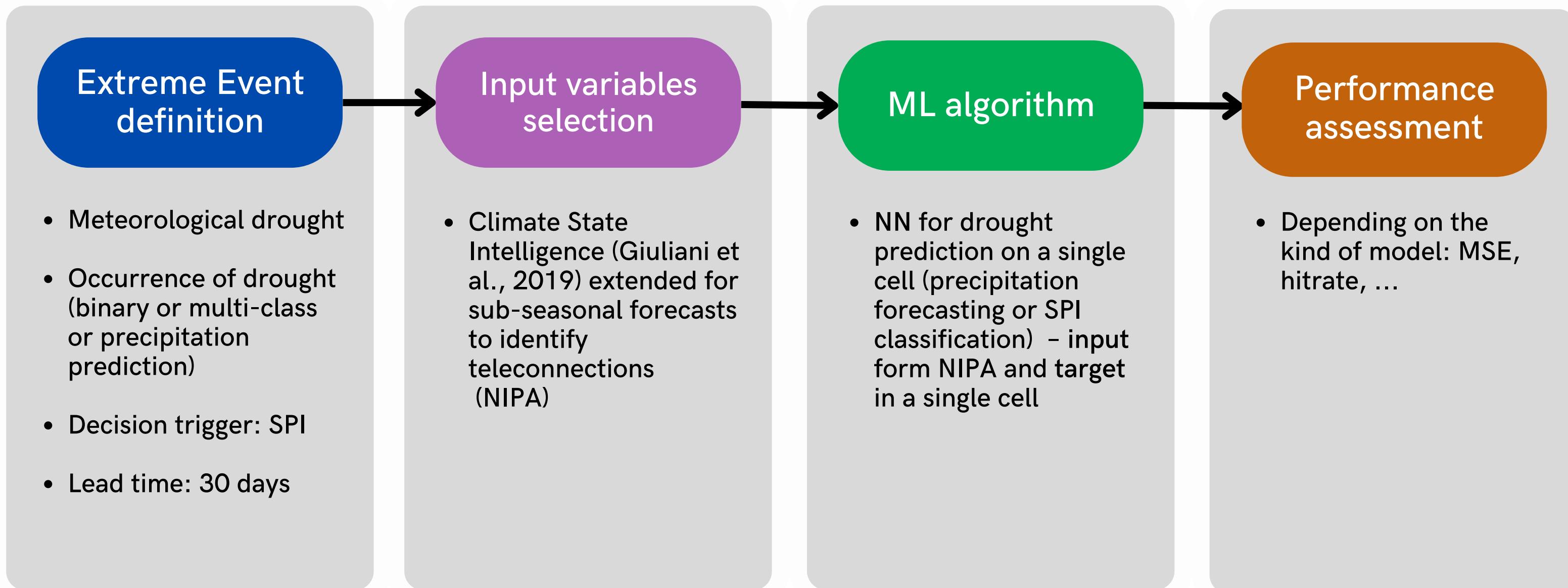
Rijnland

small sub-catchment of 1000 km² at the very end of the Rhine delta in the Netherlands

water board of Rijnland is able to forecast drought at **bi-weekly** lead times. The goal is to extend it to **a month**

Context

- 01 What (our goal)
- 02 Where (study area)
- 03 How (the framework)



Framework

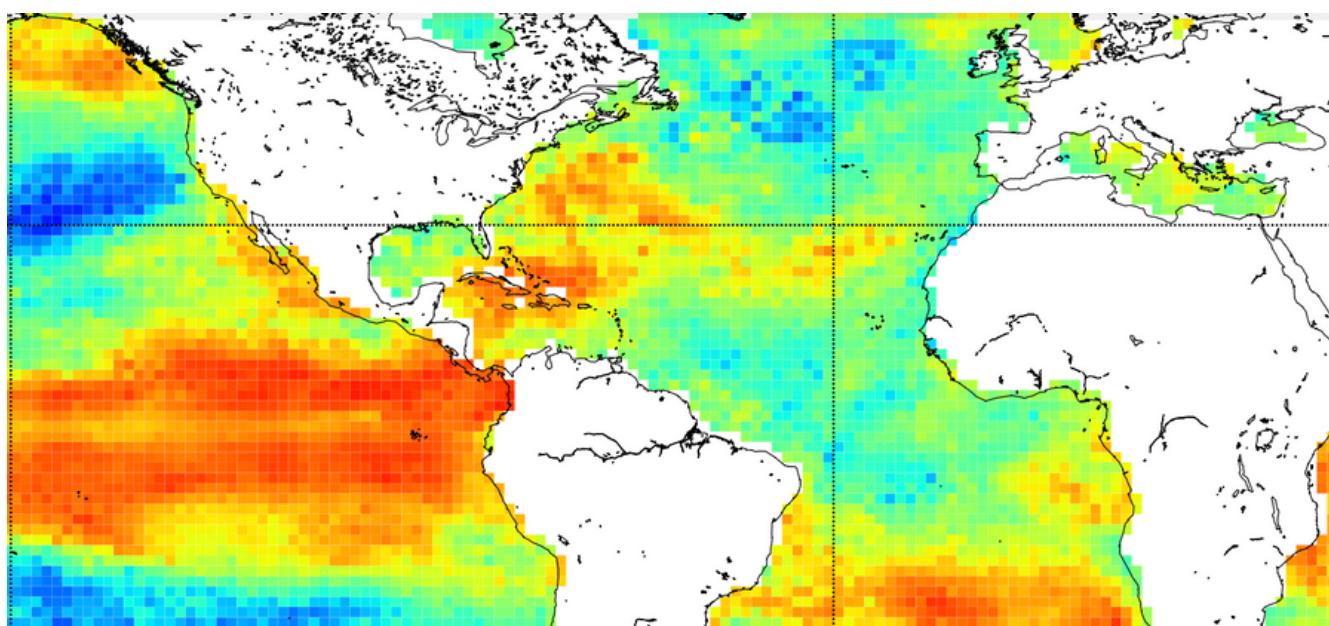
- 01 NIPA
- 02 Neural Network



Framework

- 01 NIPA
- 02 Neural Network

Nino Index Phase Analysis



Zimmerman et al. (2016)



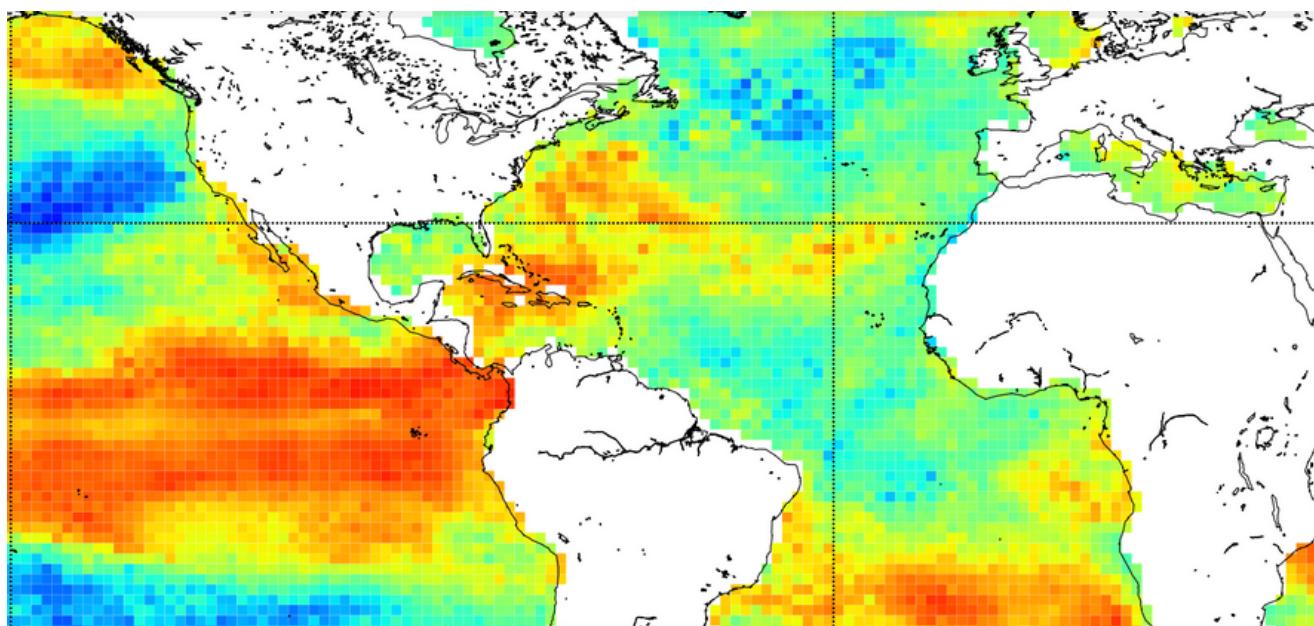
Giuliani et al. (2019)



Our readaptation

Framework

- 01 NIPA
- 02 Neural Network

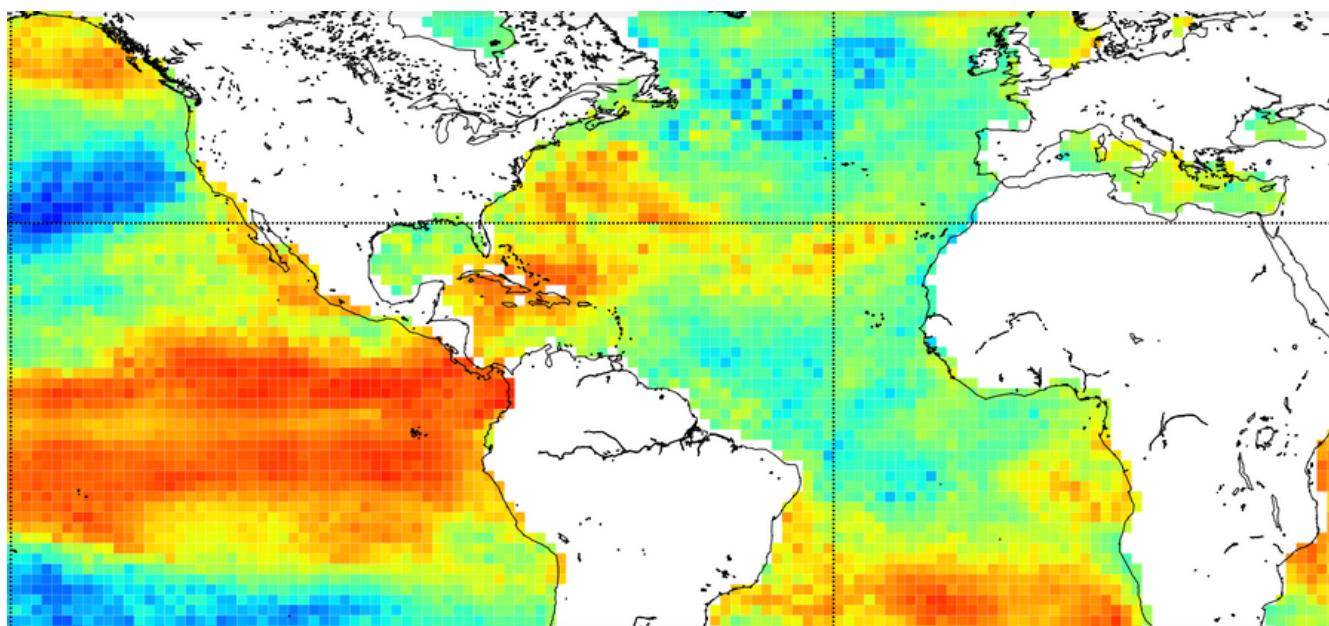


NIPA is a framework that searches for links between **Global** and **Local variables** exploiting the phases of teleconnection patterns materialized by **climate indices**

Framework

- 01 NIPA
- 02 Neural Network

climate indices



El Niño Southern Oscillation (ENSO)

North Atlantic Oscillation (NAO)

SCAndinavian oscillation (SCA)

East Atlantic oscillation (EA)

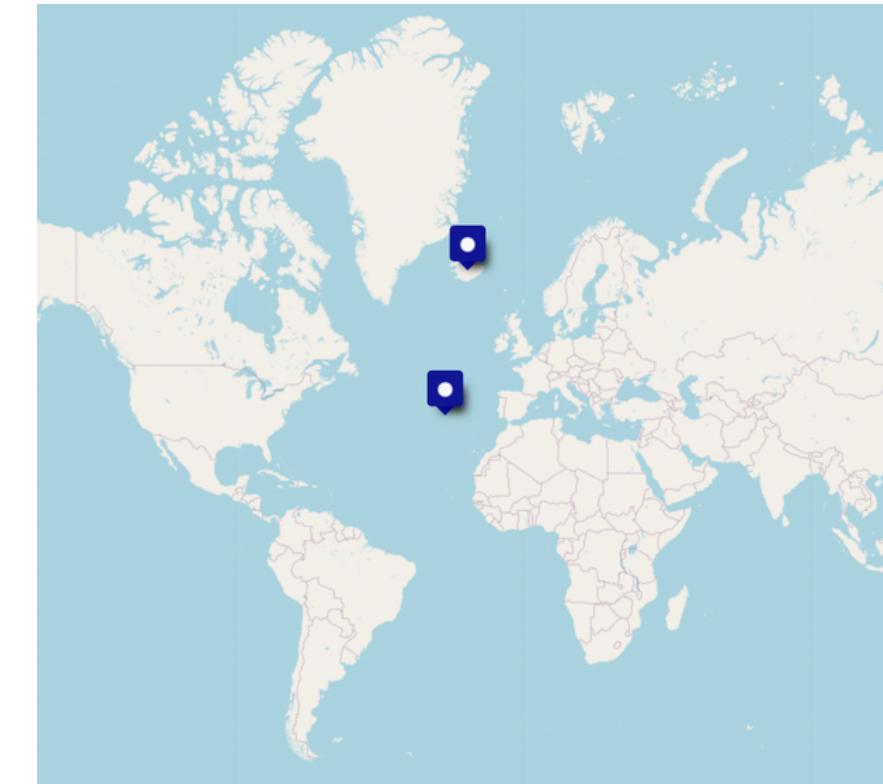
Framework

- 01 NIPA
- 02 Neural Network

- **above/below-normal temperatures** in eastern United States and northern Europe
- **above/below-normal temperatures** in Greenland and southern Europe
- **above/below-normal precipitation** over northern Europe and Scandinavia
- **above/below-normal precipitation** over southern and central Europe

climate indices

North Atlantic Oscillation (NAO)



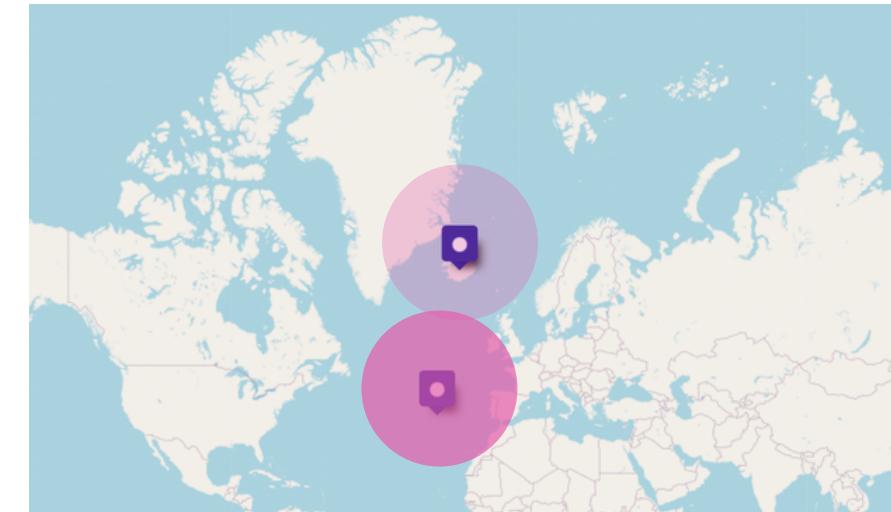
Framework

- 01 NIPA
- 02 Neural Network

- **above/below-normal temperatures** in eastern United States and northern Europe
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climate indices

North Atlantic Oscillation (NAO)



Phase Neg

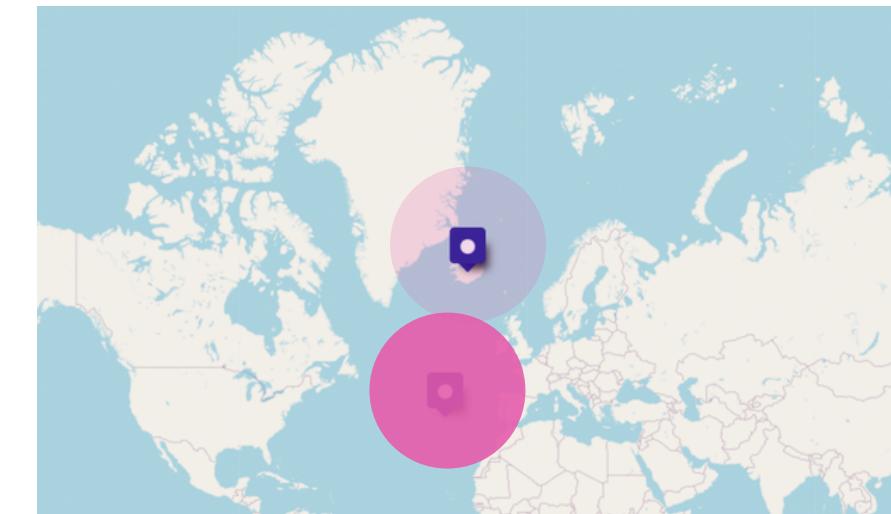
Framework

- above/below-normal temperatures in eastern United States and northern Europe
- above/below-normal temperatures in Greenland and southern Europe
- above/below-normal precipitation over northern Europe and Scandinavia
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- 01 NIPA
- 02 Neural Network

climate indices

North Atlantic Oscillation (NAO)



Phases Pos

Framework

- 01 NIPA
 - 02 Neural Network
-

DATA

- Local precipitation (monthly timeseries) - **cumulative**
- Global variable (monthly timeseries) - **SLP,SST,Z500 - mean**
- Climate Index (monthly timeseries) - **ENSO, NAO, SCA, EA**

Input

Data extraction

Phase segmentation

Correlation

PCA

output

SETTING PARAMETERS

- Month **(of local precipitation)**
- Aggregation level **(of pre-month global data)**

Framework

- 01 NIPA
 - 02 Neural Network
-

SETTING PARAMETERS

- Month **(of local precipitation)**
- Aggregation level **(of pre month global data)**

Example:

- Month **1** local precipitation of **January** and the global variable of **December**
- Month **1** local precipitation of **January** and the global variable of **November + December**

Input

Data extraction

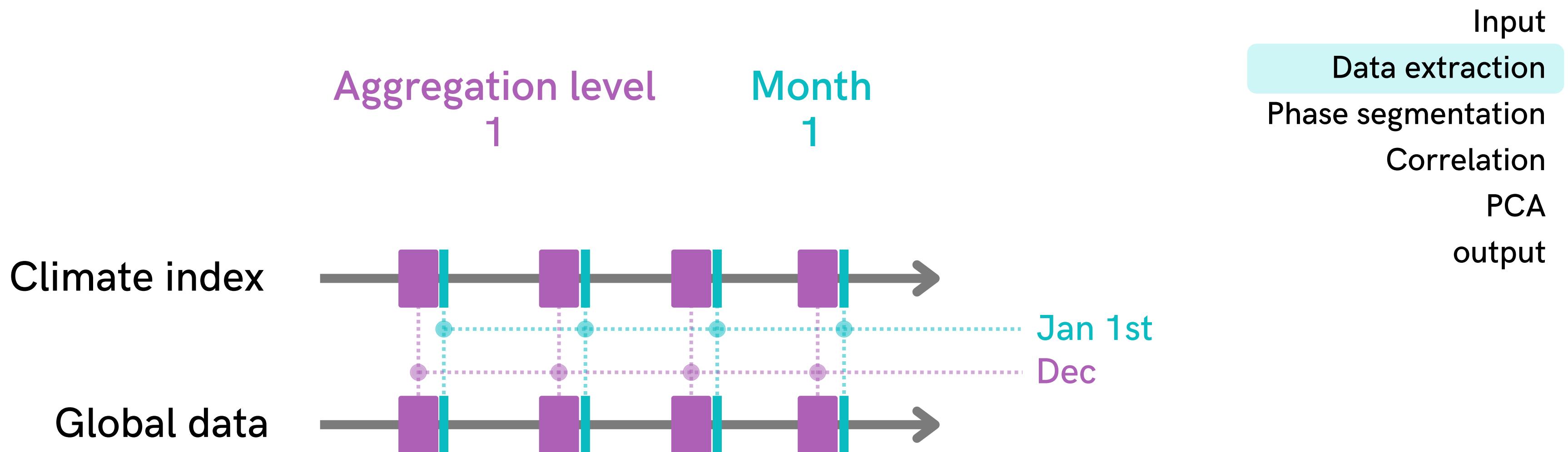
Phase segmentation

Correlation

PCA

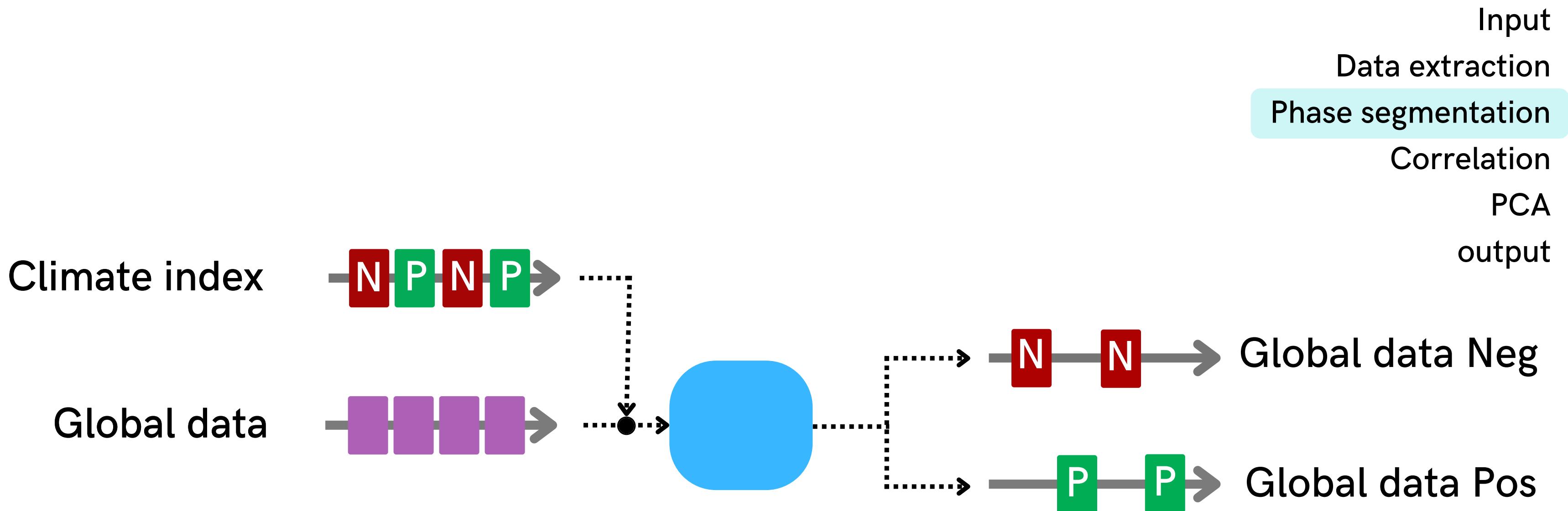
output

Framework



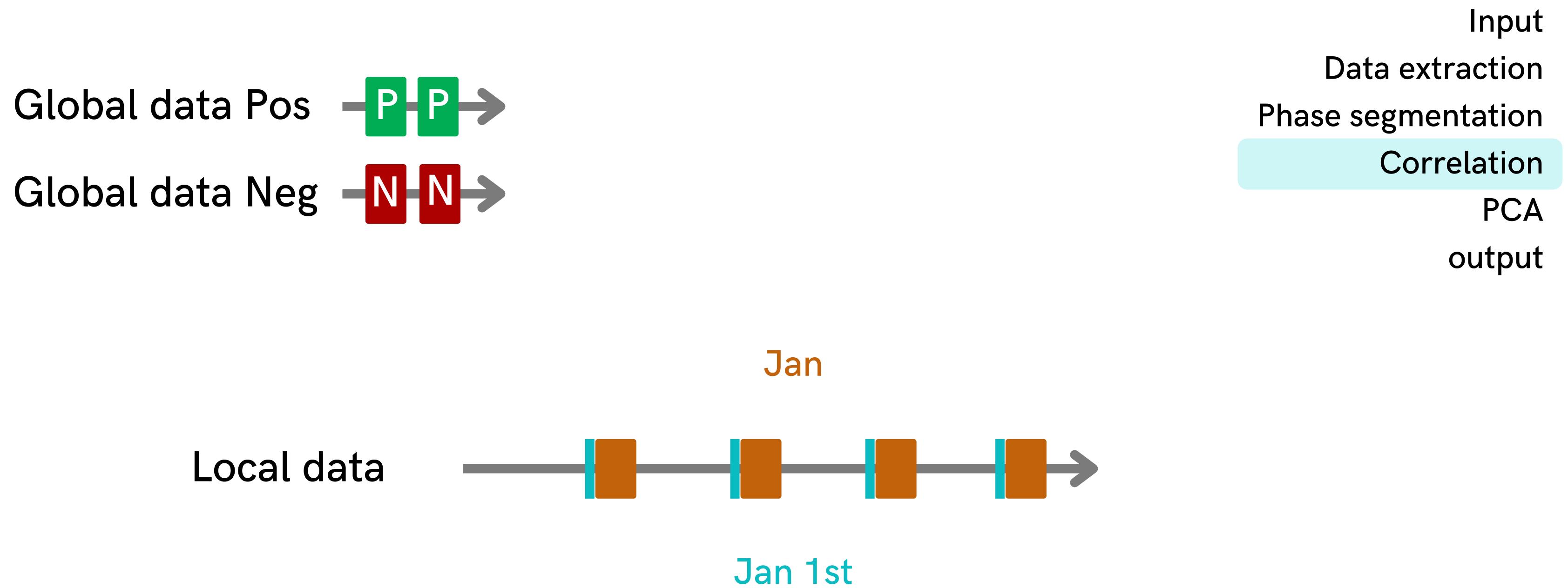
NOTE: this is an year-based operation. NIPA will extract the data for the December of each year

Framework



Framework

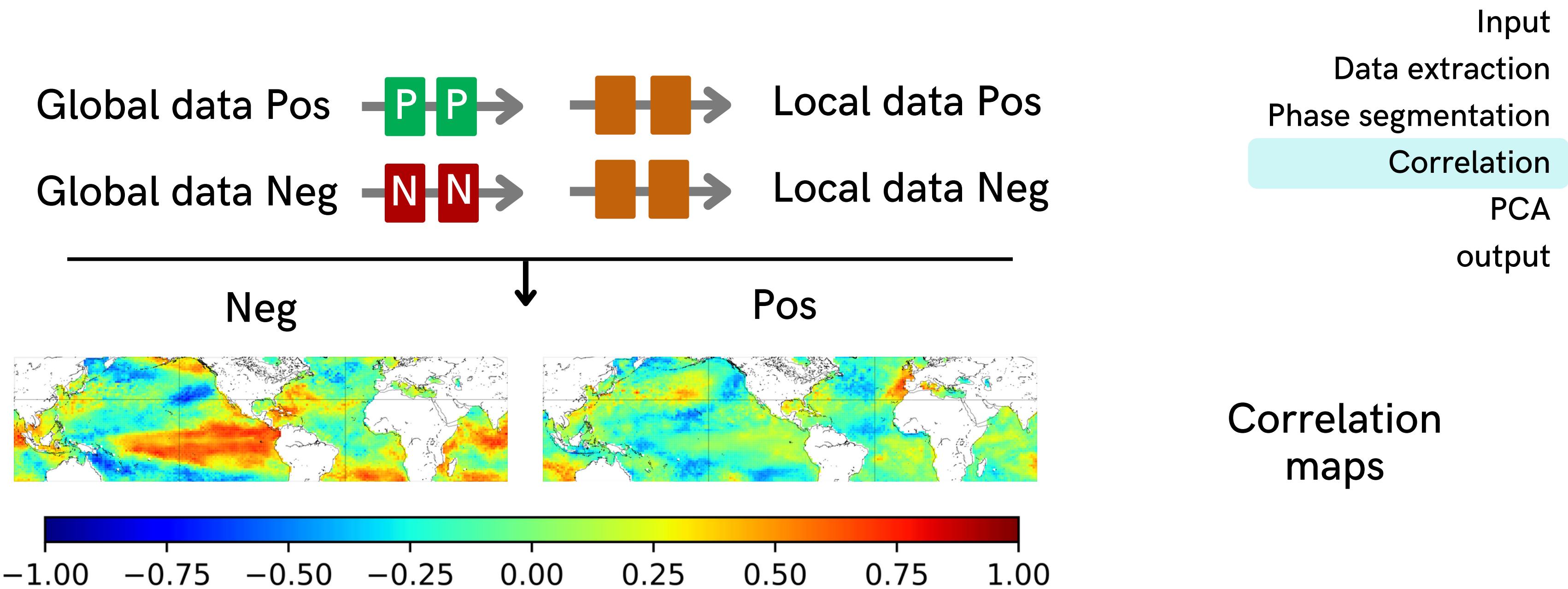
- 01 NIPA
 - 02 Neural Network
-



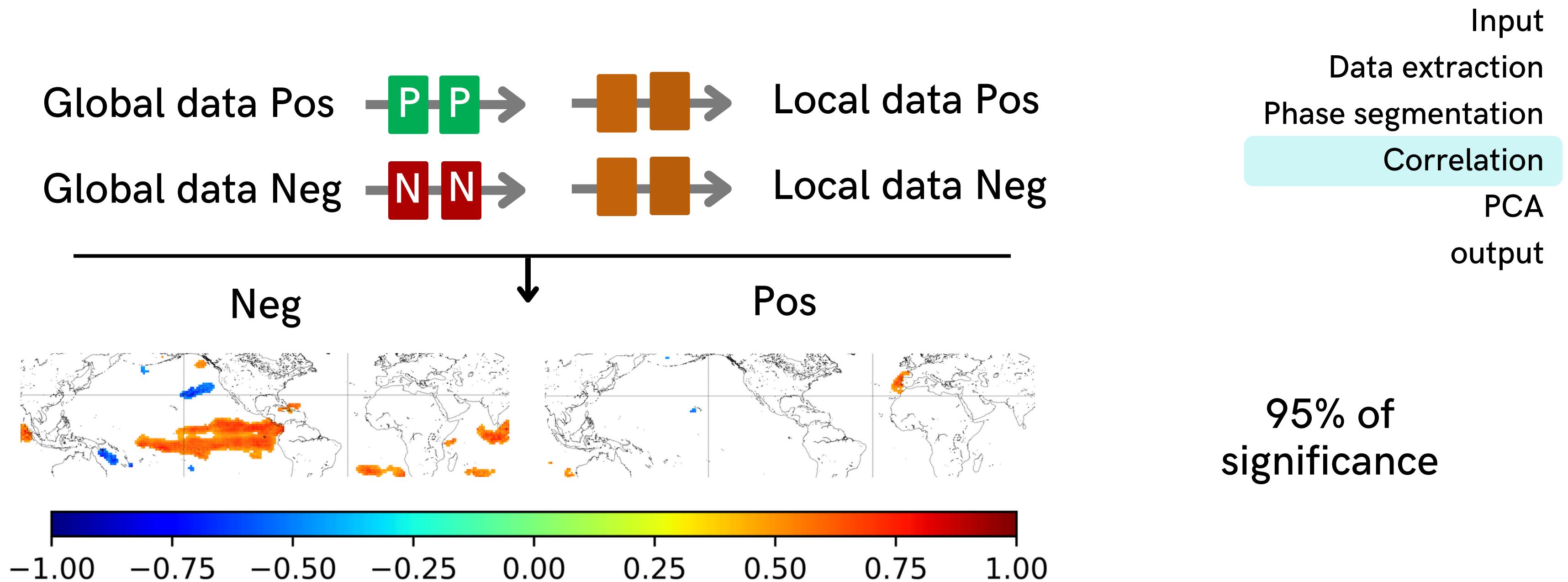
Framework



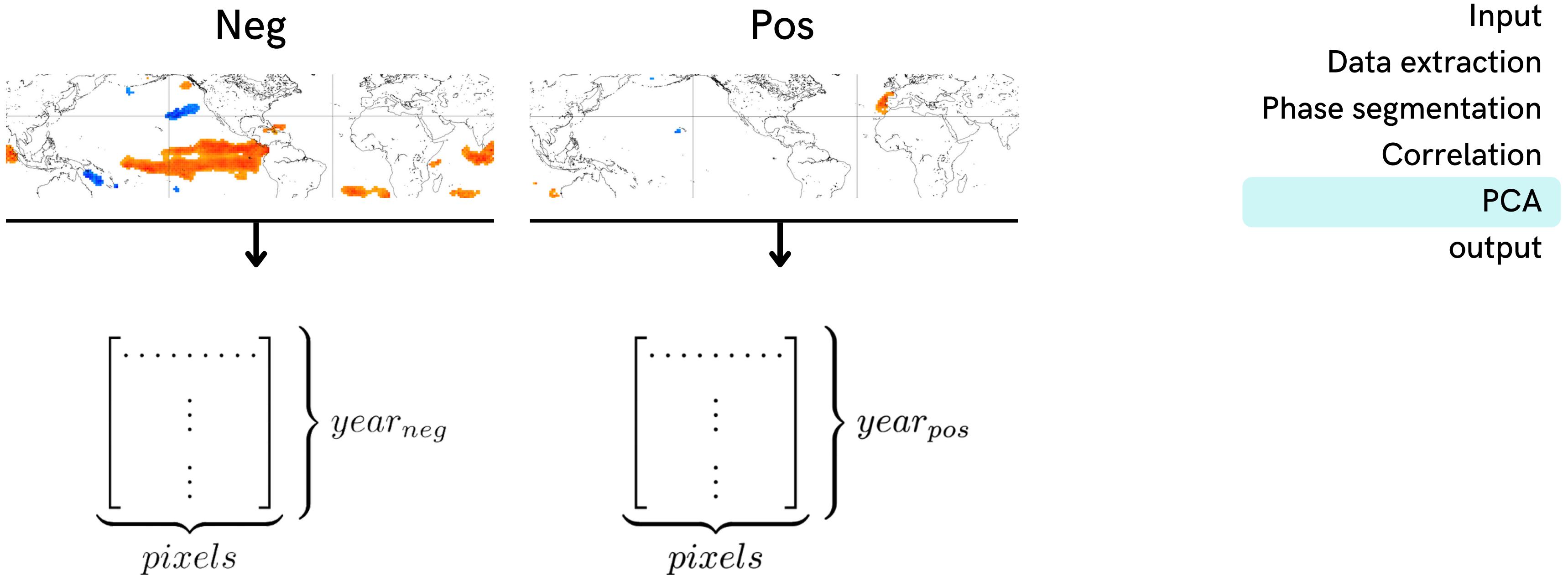
Framework



Framework

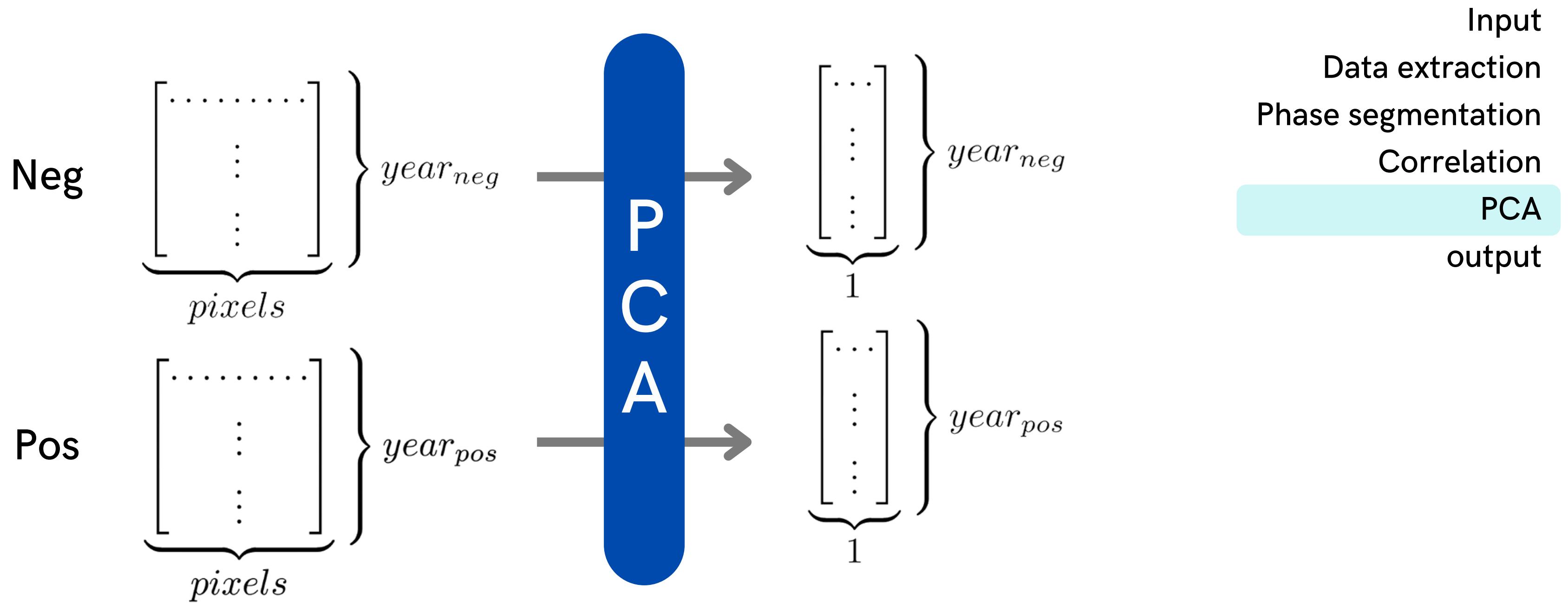


Framework



- 01 NIPA
- 02 Neural Network

Framework

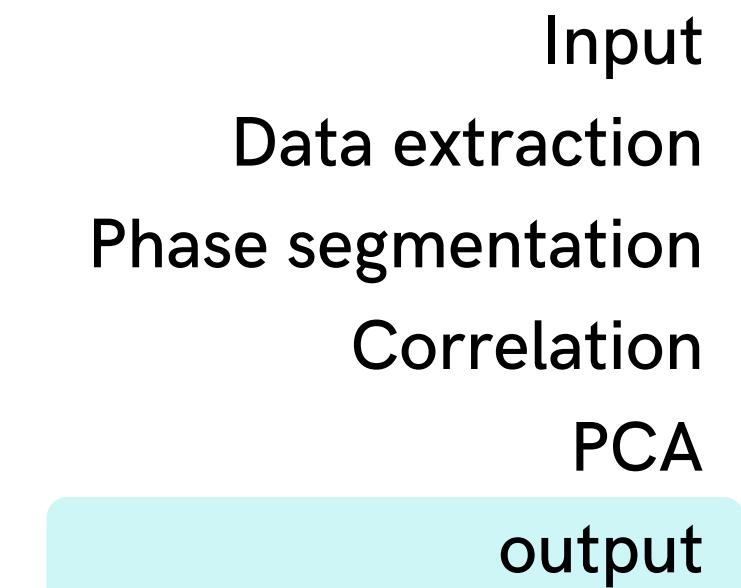


Framework

PC1	phase_label
PC1 1979	1
PC1 1980	2
...	...
...	...
PC1 2021	2

Dataset for 1 month

- 01 NIPA
- 02 Neural Network



Framework

This procedure can be applied

- for each Month
- for each combination of:
 - Local Precipitation
 - Global Variable (SST/SLP/Z500)
- for each aggregation level of SST/SLP/Z500 (1/2/3 month)

● 01 NIPA

● 02 Neural Network

Input

Data extraction

Phase segmentation

Correlation

PCA

output

Framework

- 01 NIPA
 - 02 Neural Network
-

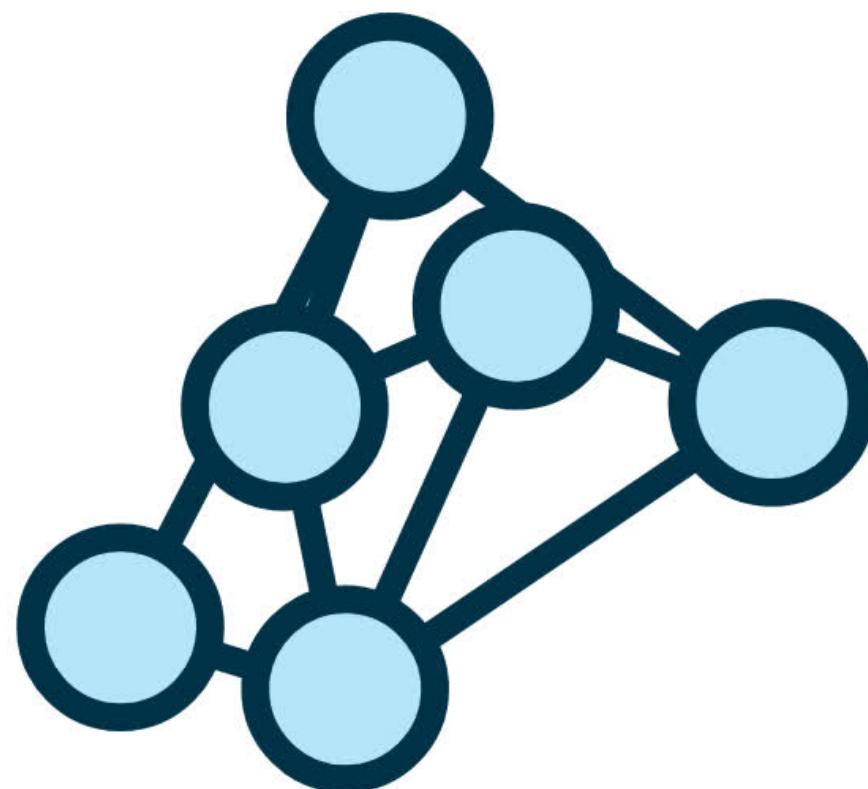
Introduction

Link with NIPA

Our ideas

Model creation

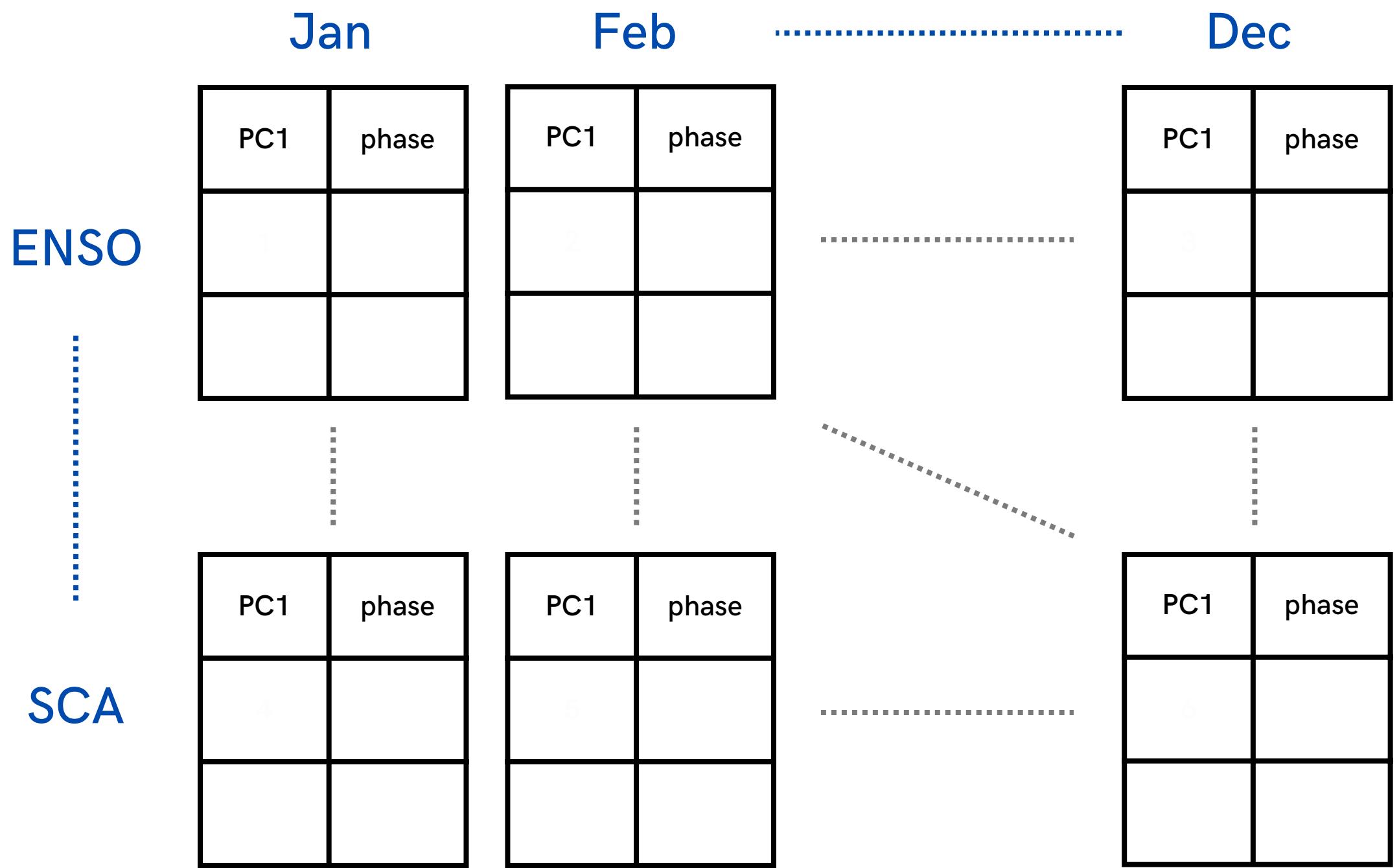
A raw result



Just entered in this step

- which are our thoughts on **how to proceed**
- **what has emerged** from the test

Framework



- 01 NIPA
- 02 Neural Network

Introduction

Link with NIPA

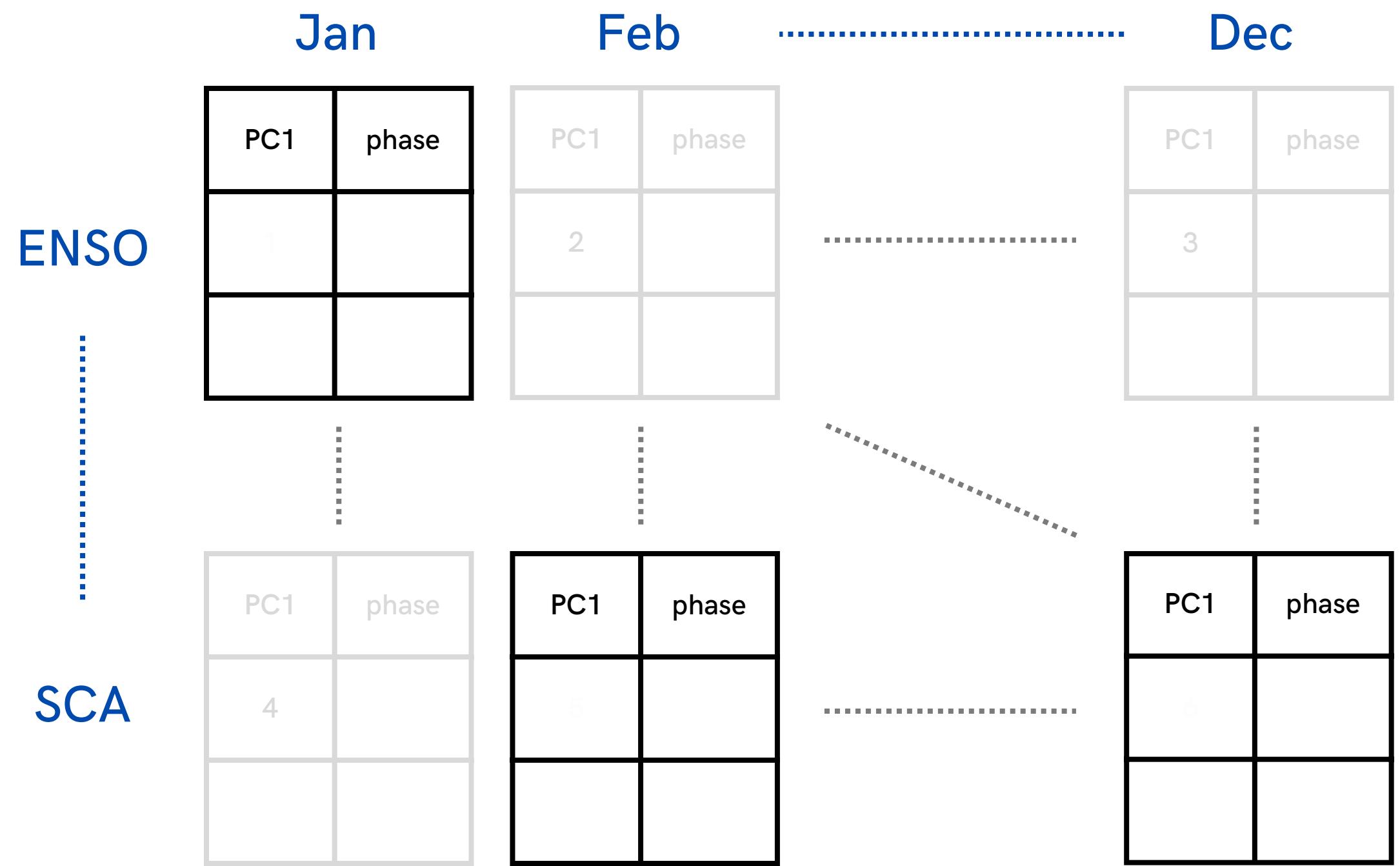
Our ideas

Model creation

A raw result

- 01 NIPA
 - 02 Neural Network
-

Framework



Introduction

Link with NIPA

Our ideas

Model creation

A raw result

Framework

- Skim some of the features based on the **pearson coefficients** of a linear regression between **PC1** and **Local Precipitation**
- Skim some of the features by imposing a **minimum correlation threshold**
- Consider the skimmed set of features and build **N different models for each month** and compare the **N different Leave One Out validation errors** to choose the best one

- 01 NIPA
- 02 Neural Network

Introduction

Link with NIPA

Our ideas

Model creation

A raw result

Framework

- 01 NIPA
 - 02 Neural Network
-

Inputs: (PC1, phase label) **Target:** (Local Precipitation)

Introduction

Link with NIPA

Our ideas

Inputs: (PC1_1, PC1_2, climate state);
Target: (Local Precipitation)

Model creation

A raw result

Climate index 1	Climate index 2	Climate state
1	1	1
1	2	2
2	1	3
2	2	4

Framework

- Input features:
 - SCA-SLP-1-1,
 - EA-SST-1-1,
 - climate state
- Target: Cumulative precipitation
- Hidden layers: 2
- Neurons: (3, 2)
- Activation function: ReLU
- Loss function: MSE

- 01 NIPA
- 02 Neural Network

Introduction

Link with NIPA

Our ideas

Model creation

A raw result

Framework

- 01 NIPA
 - 02 Neural Network
-

- Training set
- △ Validation set

MSE of **319.0494** on the validation set

comparable with giuliani et al with ELM (374.905)

Introduction
Link with NIPA
Our ideas
Model creation
A raw result

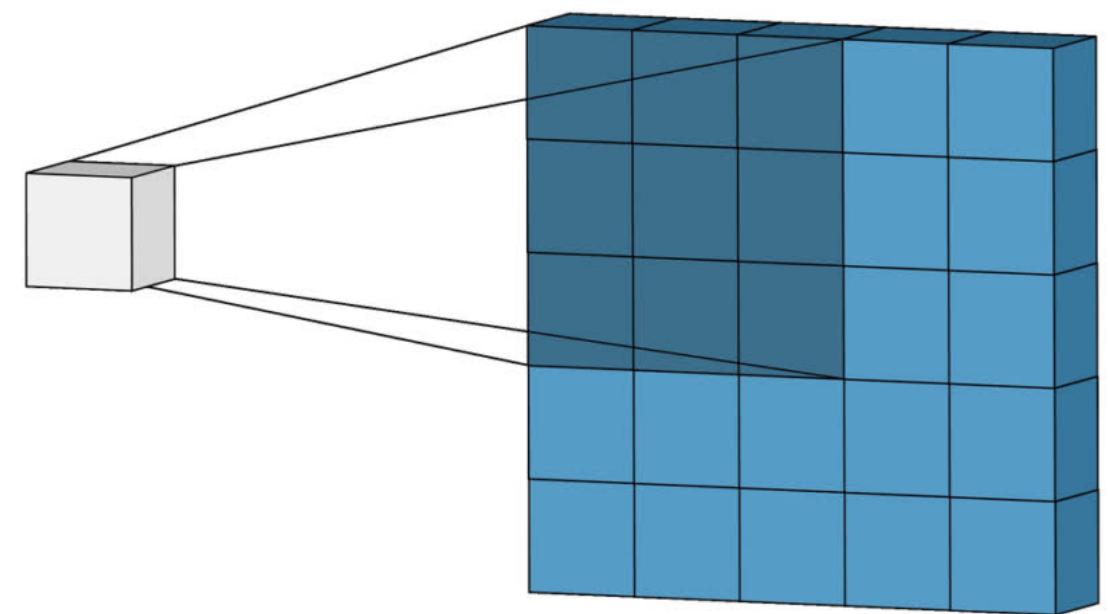
Framework



- 01 NIPA
- 02 Neural Network

Introduction
Link with NIPA
Our ideas
Model creation
A raw result

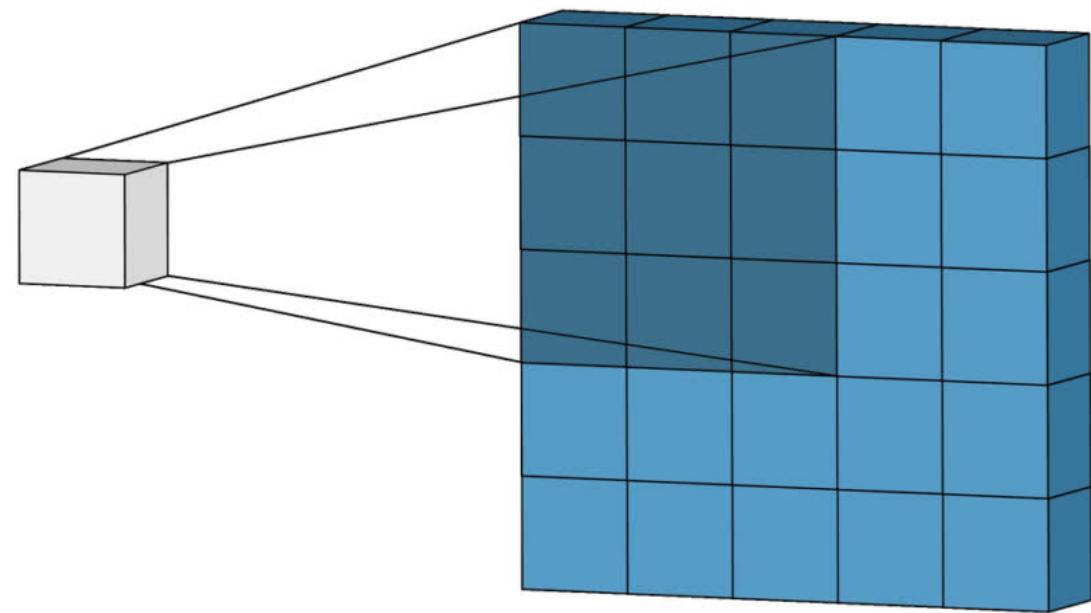
Future ideas



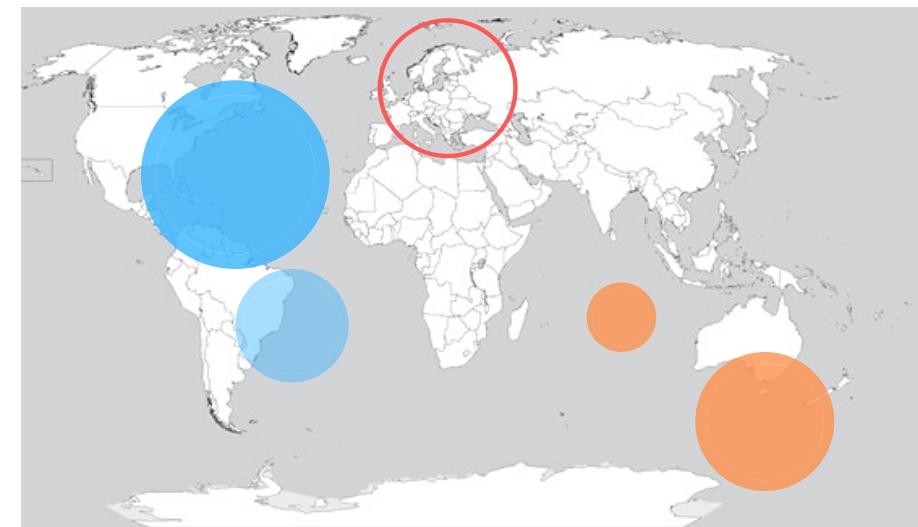
NN
↔
CNN

PC1
↔
**Correlation
Map**

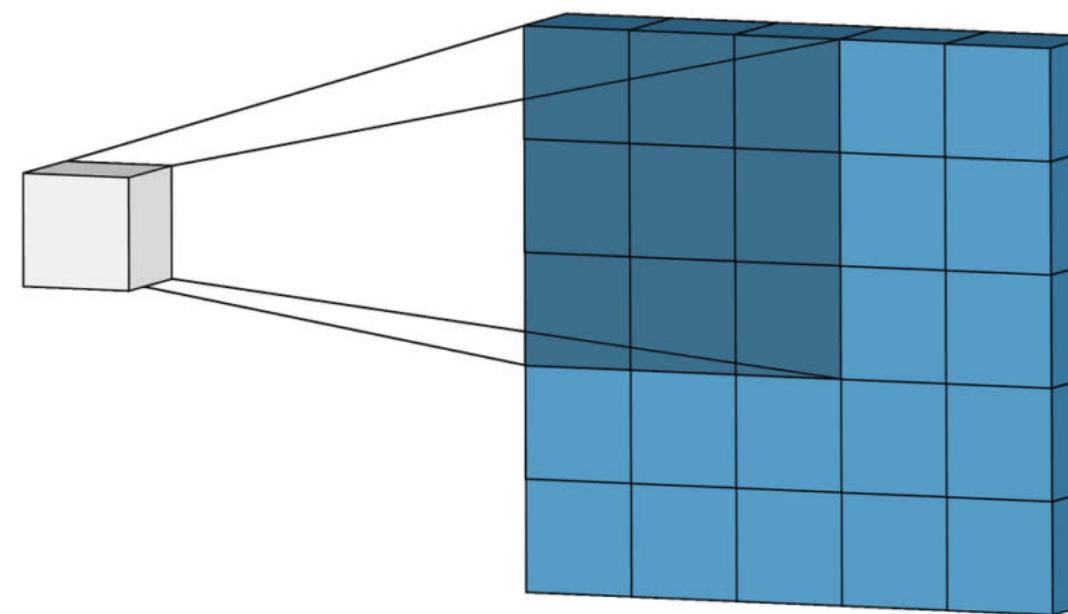
Future ideas



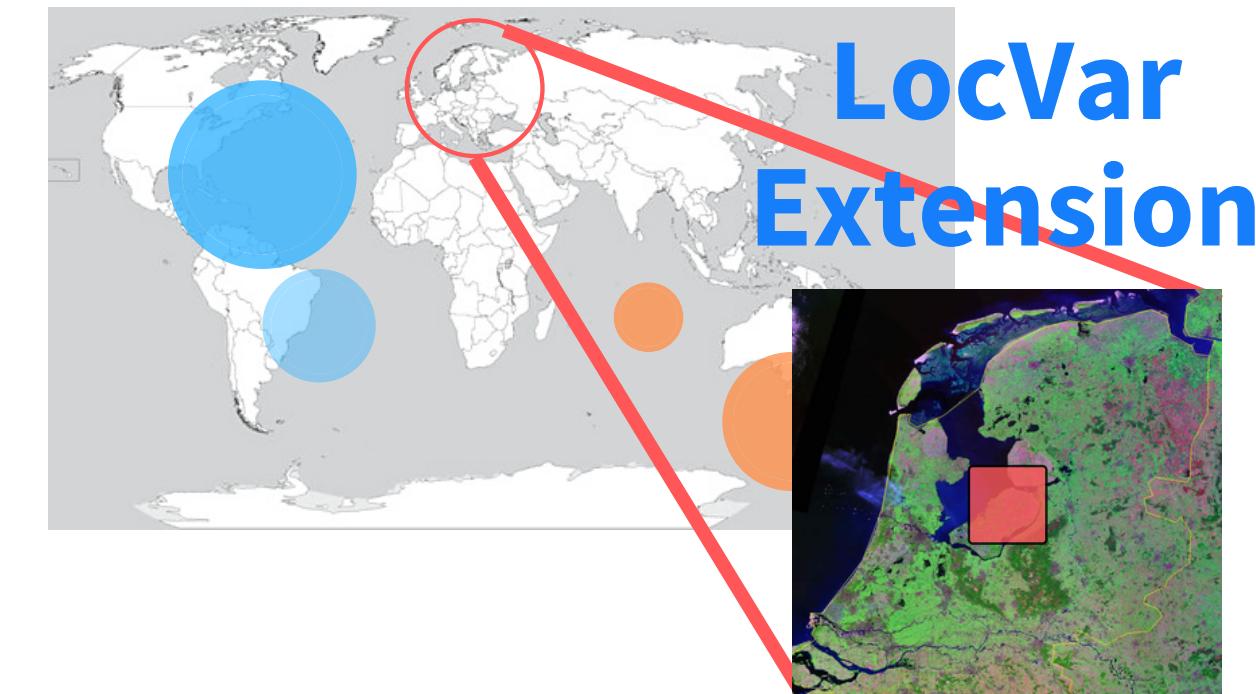
Global CorrMap



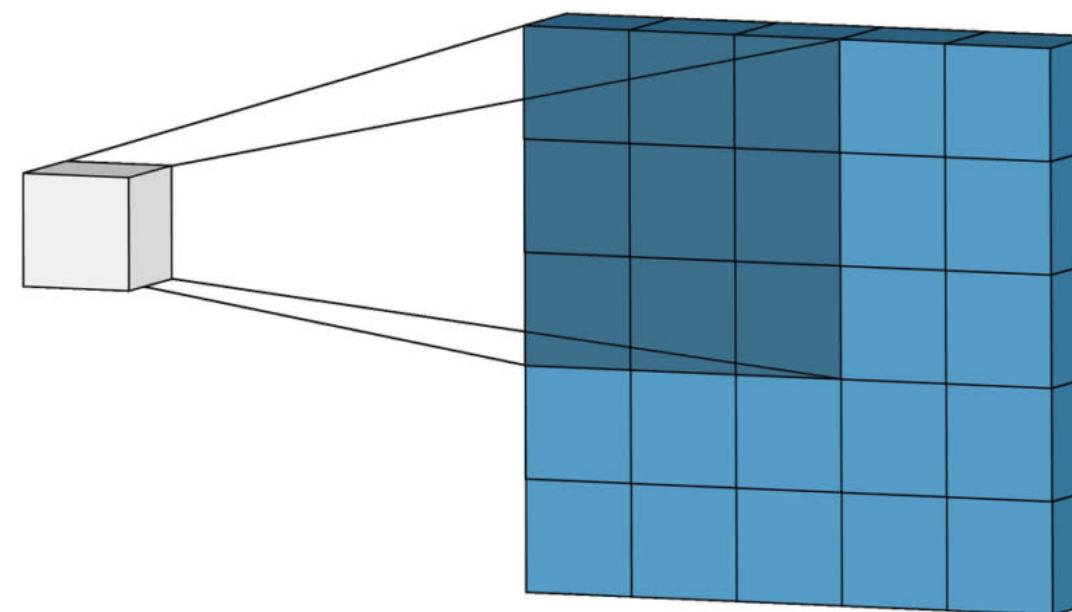
Future ideas



Global CorrMap



Future ideas

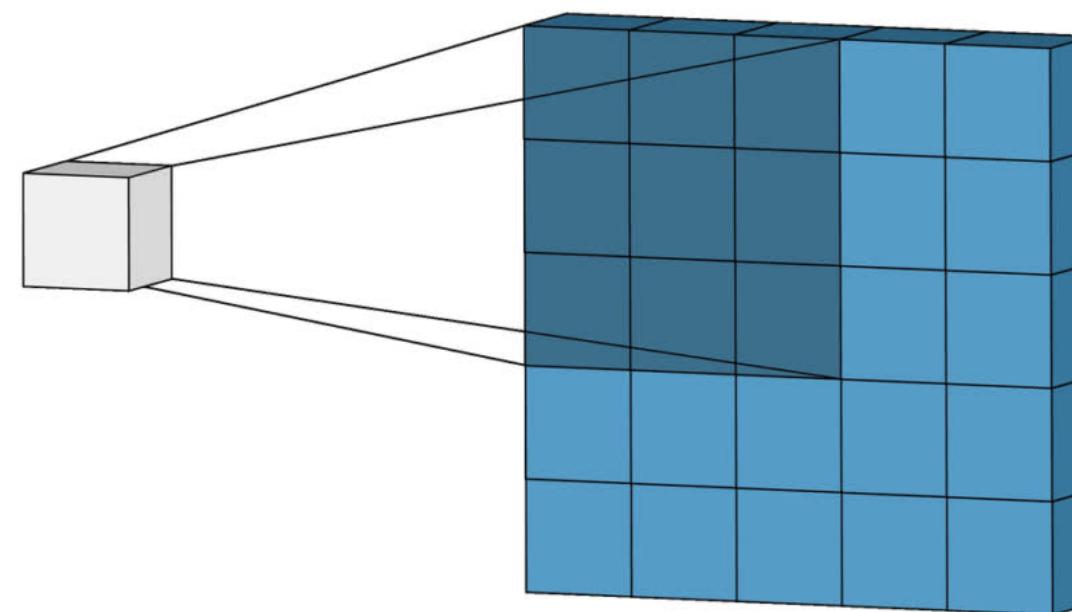


Global CorrMap



**Study
area**

Future ideas



Global CorrMap

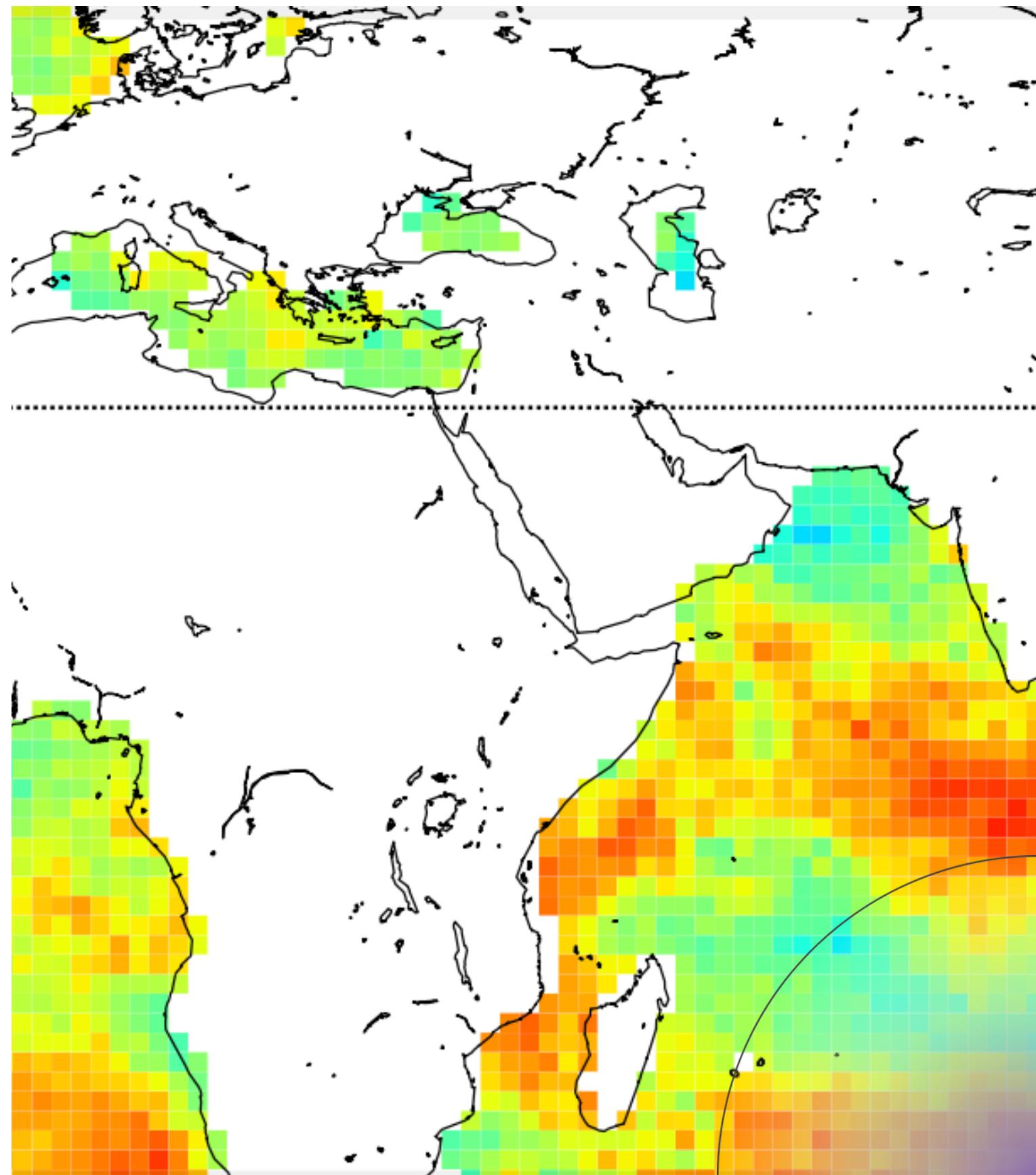


Global scale relevant
information

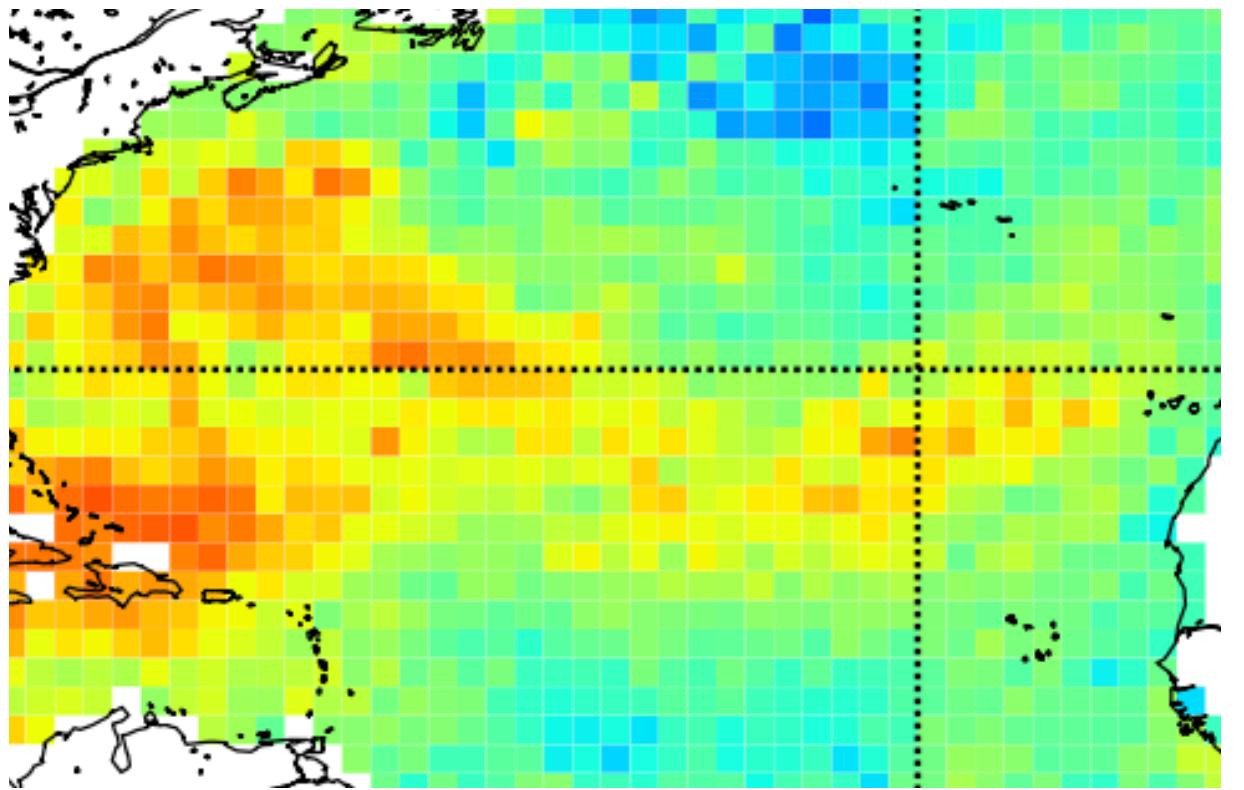
LocVar
Extension

Medium scale
relevant
information

Study
area



**Thank you
for attending!**



Zimmerman et al. (2016)



Giuliani et al. (2019)



you can find
the slides
here!

Our readaptation

