Modeling leaf phenology under global climate change

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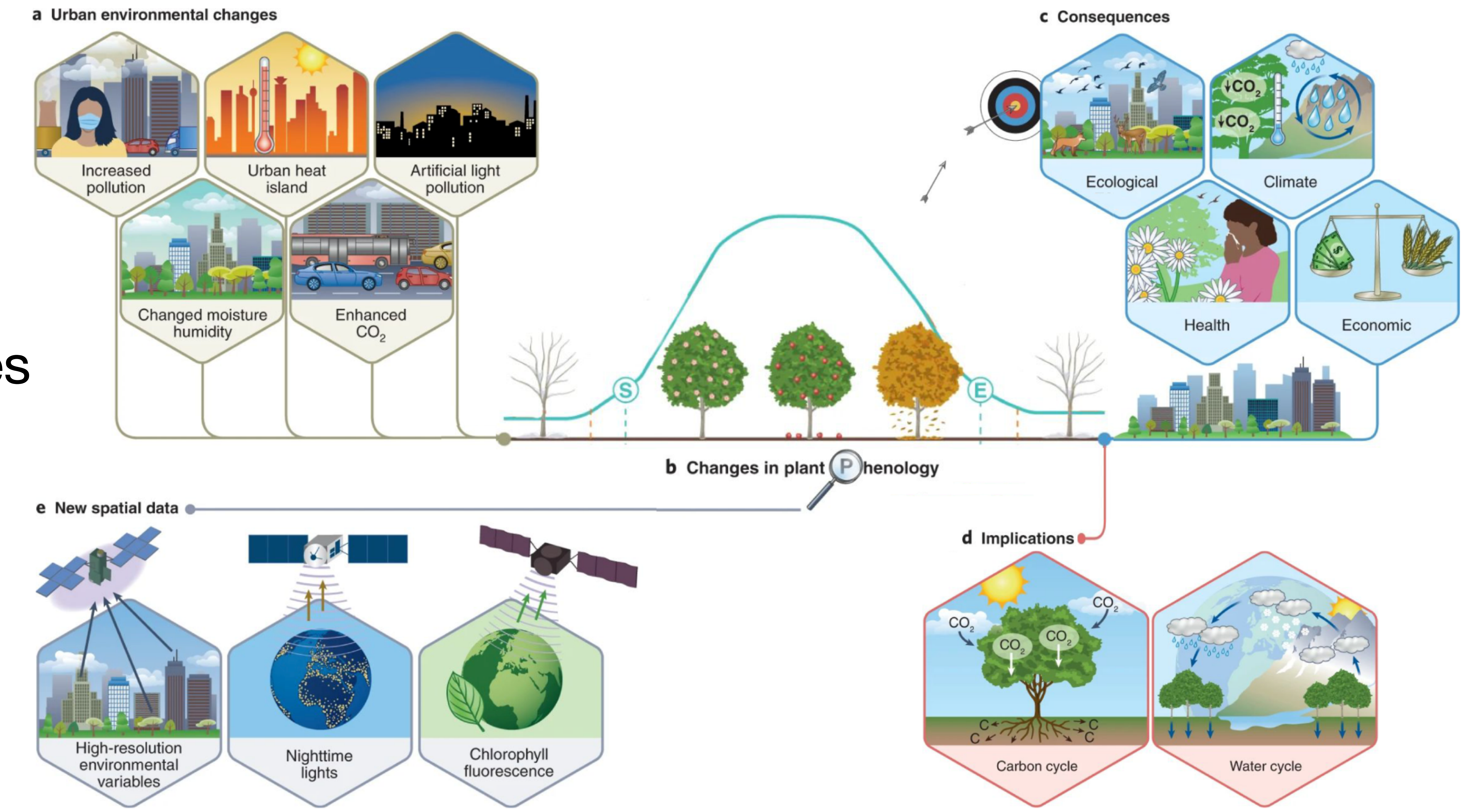
Motivation

Leaf phenology:

- indicator of climate change
- control of carbon uptake
- feedback to water cycle and energy fluxes

Importance of constraining phenology:

- difficult to predict
- informs on climate change response
- economic, health, ecological impact



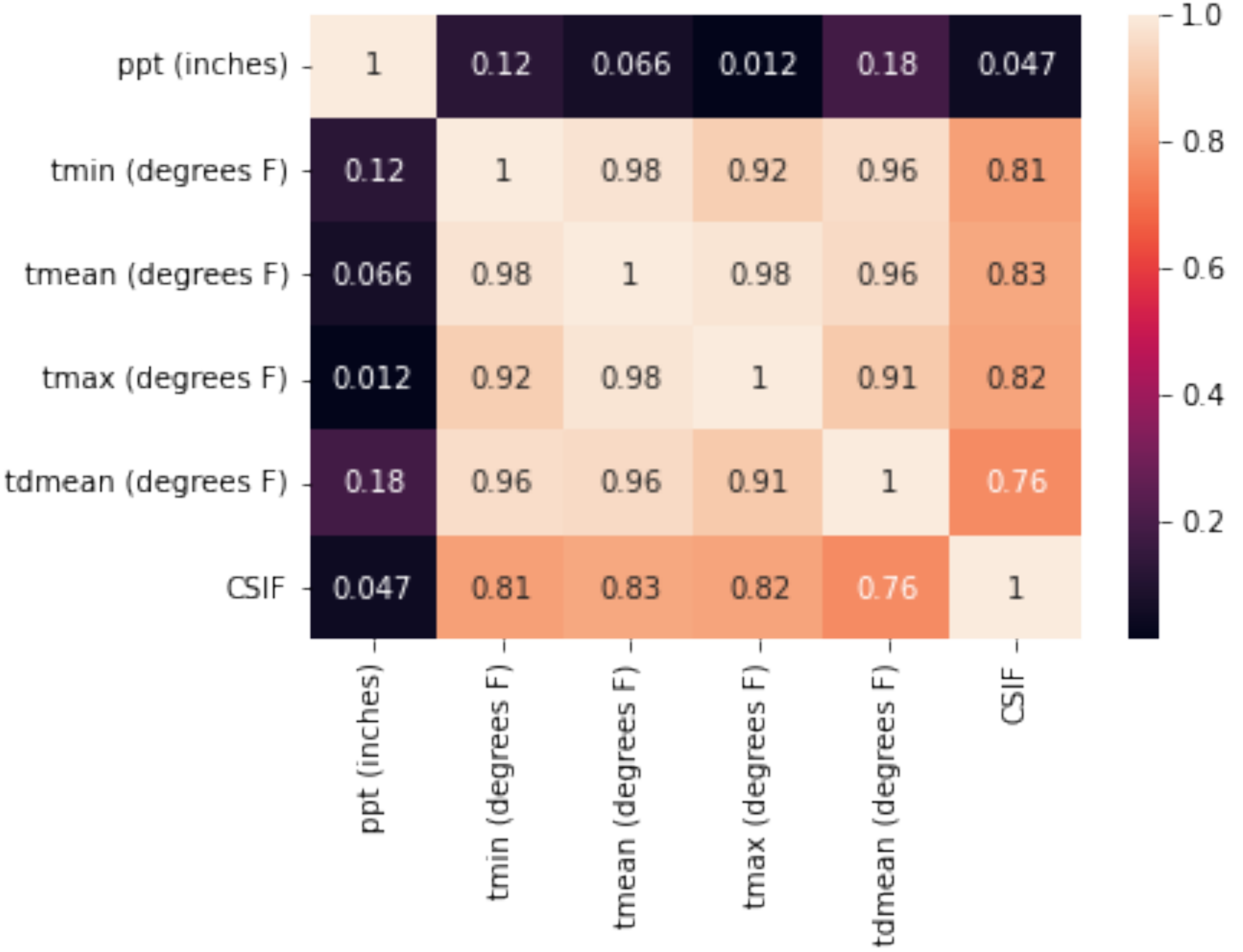
Drivers of leaf phenology

Temperature

Precipitation

Air humidity

Photoperiod



Correlation matrix

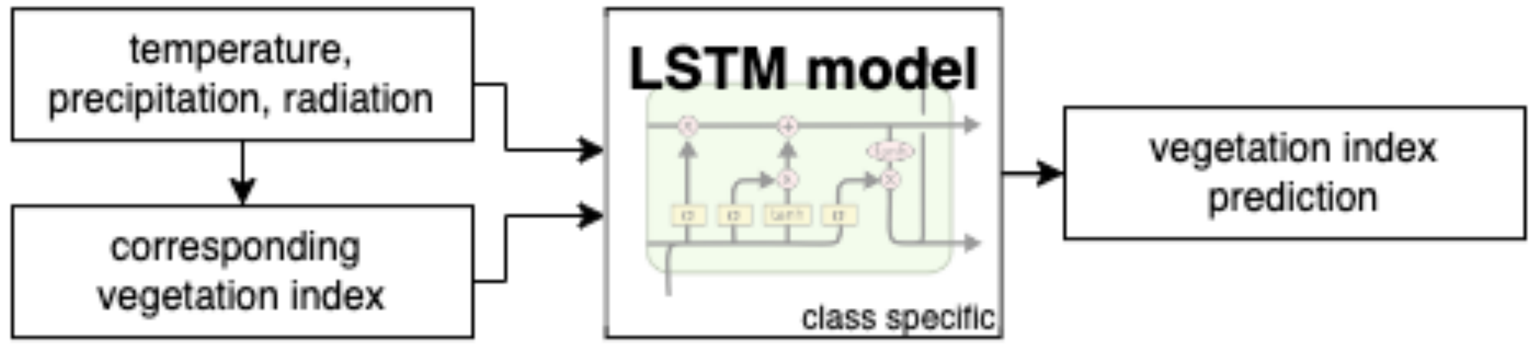
Methods

Data :

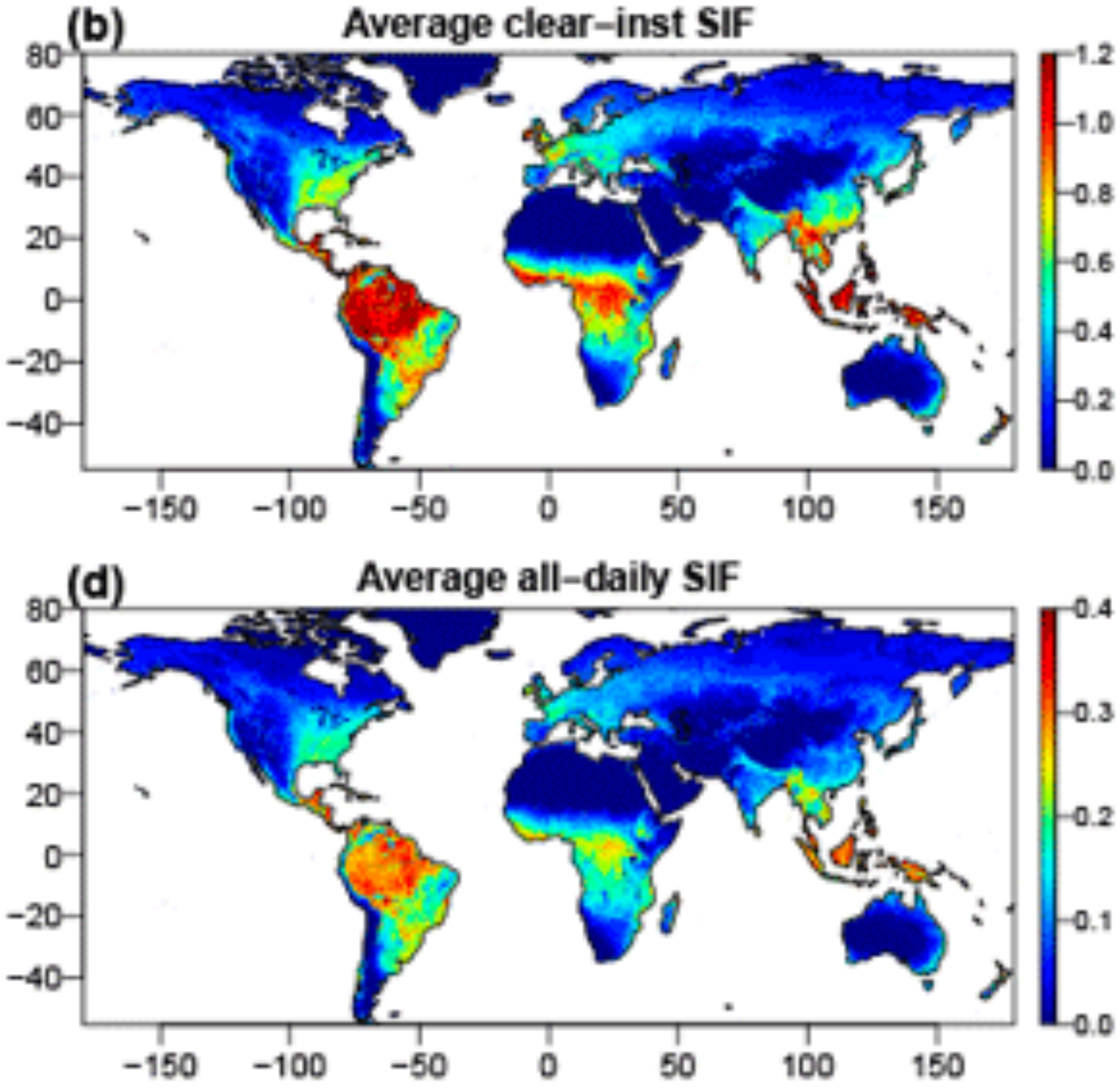
- Satellite observations of vegetation indicator: Contiguous Solar-Induced Fluorescence from MODIS
- Climate data (temperature, precipitation, radiation)

Machine Learning model:

- Models including **time recurrence**
- Long short term memory (LSTM) fitted across plant functional types

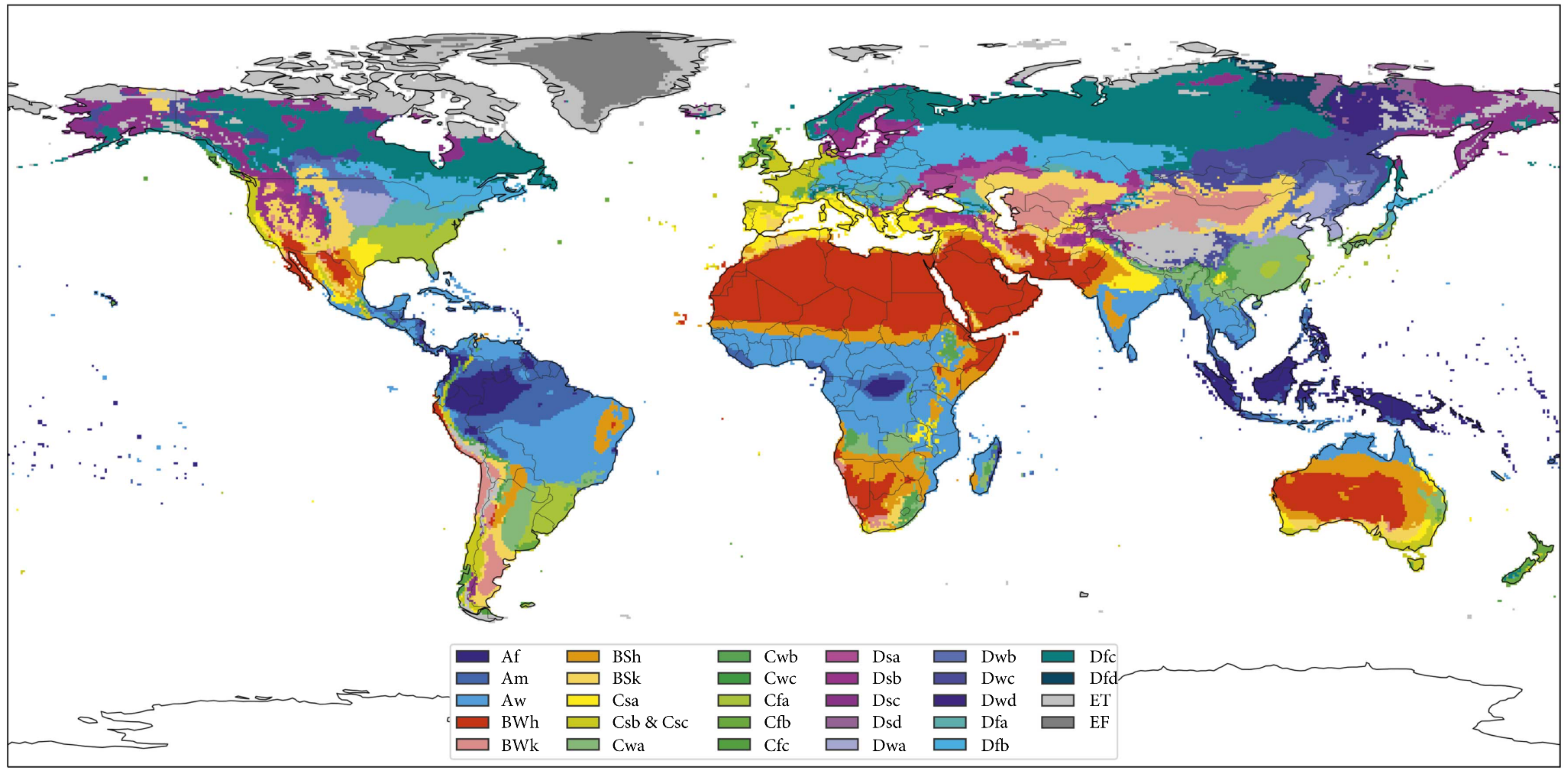


Lstm model pipeline



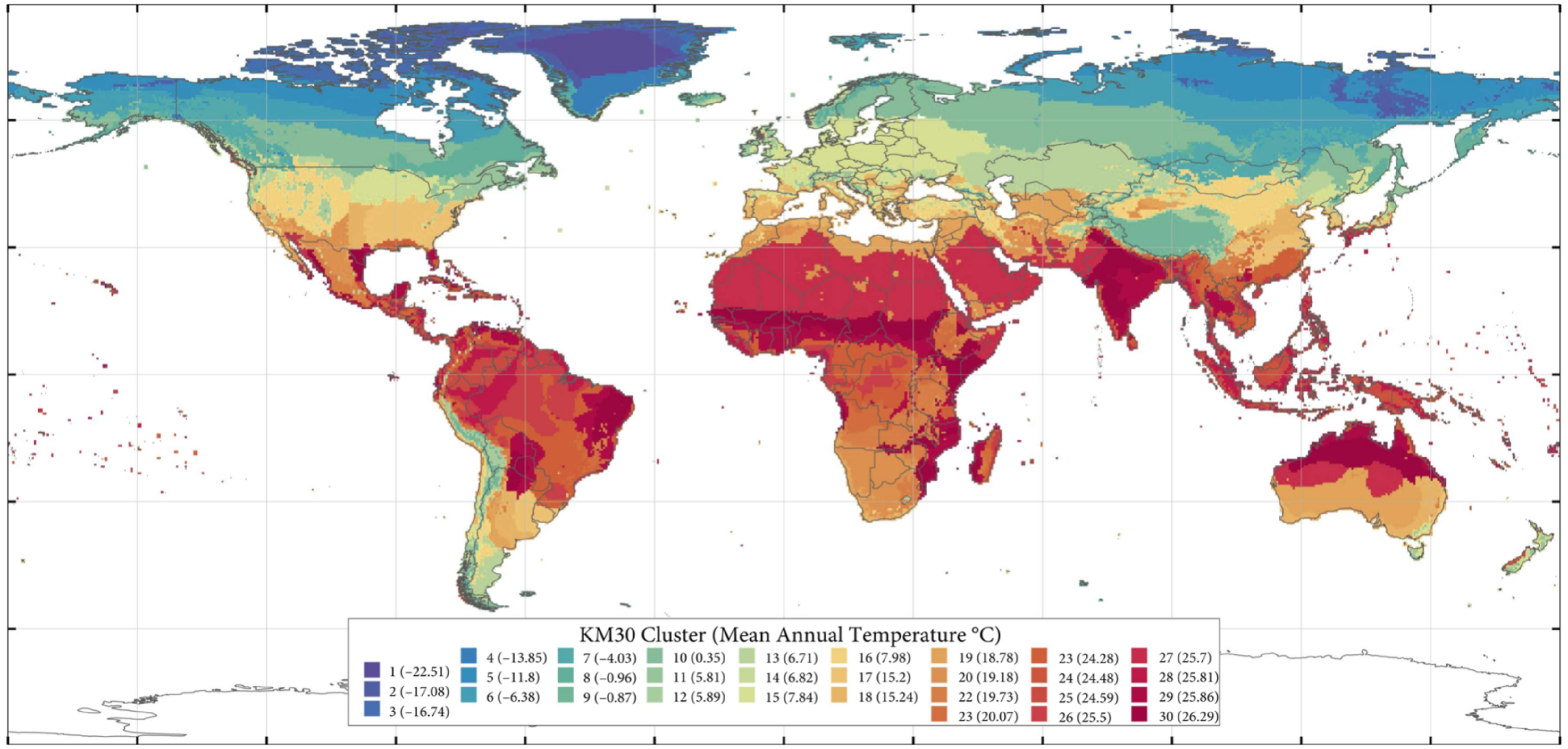
Source: (Yao Zhang et al. 2018)

Clustering for climate classification



Köppen–Geiger classification of the present climate.

- Uses broad empirical averages
- Does not reflect recent climate changes



30 present climate classes after K-means clustering

- Adaptable: CSIF based or climate based

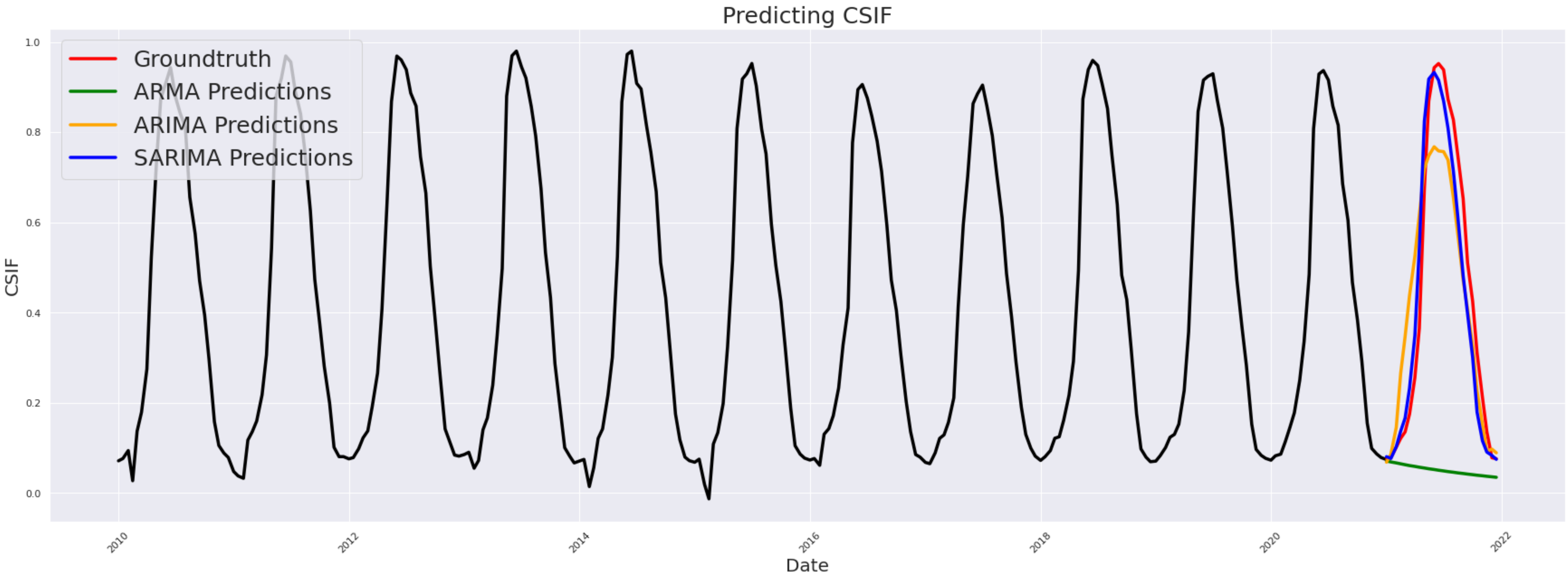
Initial results

Seasonal Autoregressive Integrated Moving Average (SARIMA)

$$y'_t = c + \phi_1 y'_{t-1} + \cdots + \phi_p y'_{t-p} + \theta_1 \varepsilon_{t-1} + \cdots + \theta_q \varepsilon_{t-q} + \varepsilon_t,$$

$p =$ order of the autoregressive part;
$d =$ degree of first differencing involved;
$q =$ order of the moving average part.

$$(1 - \phi_1 B)\ (1 - \Phi_1 B^4)(1 - B)(1 - B^4) y_t = (1 + \theta_1 B)\ (1 + \Theta_1 B^4) \varepsilon_t.$$

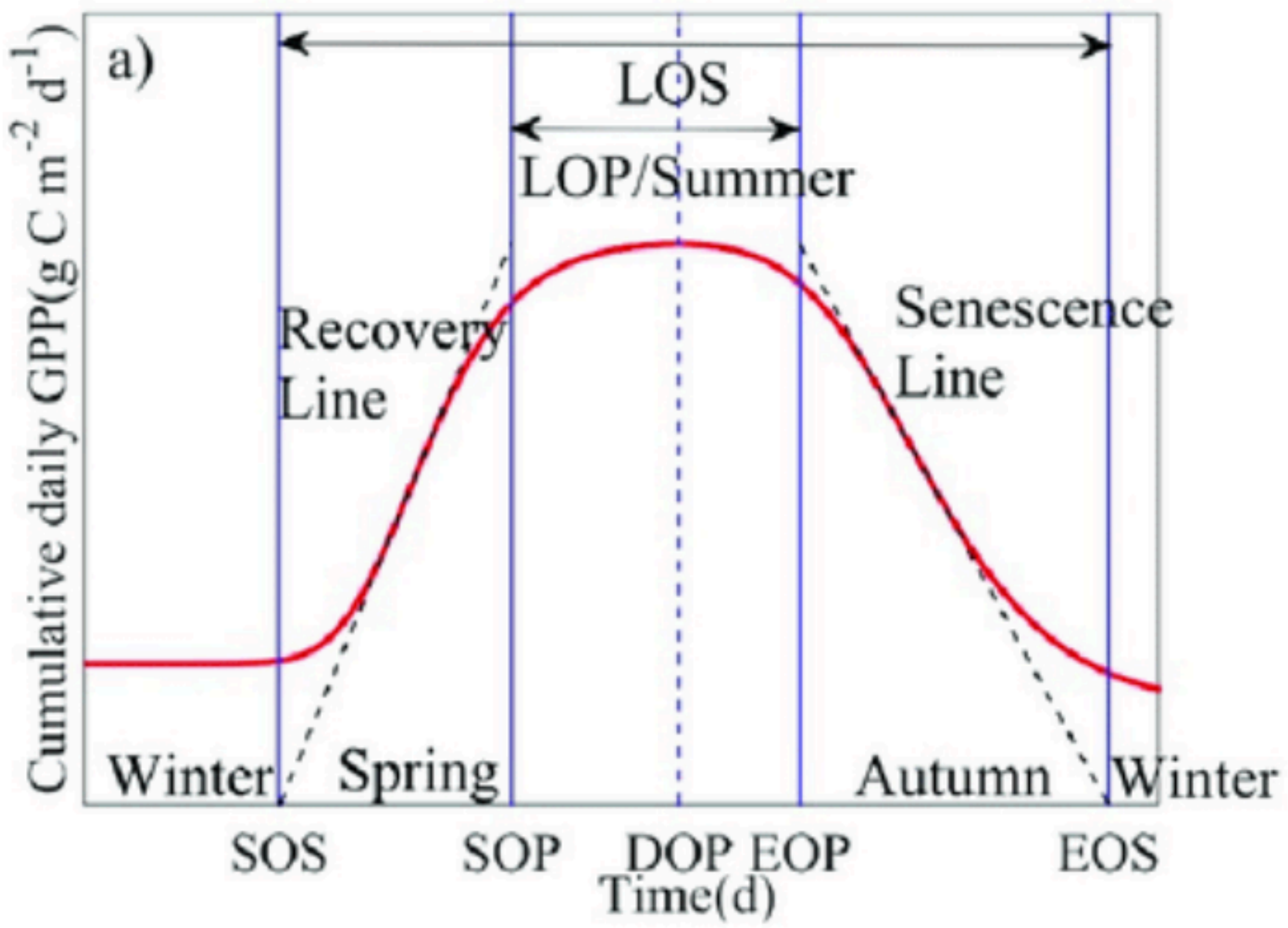


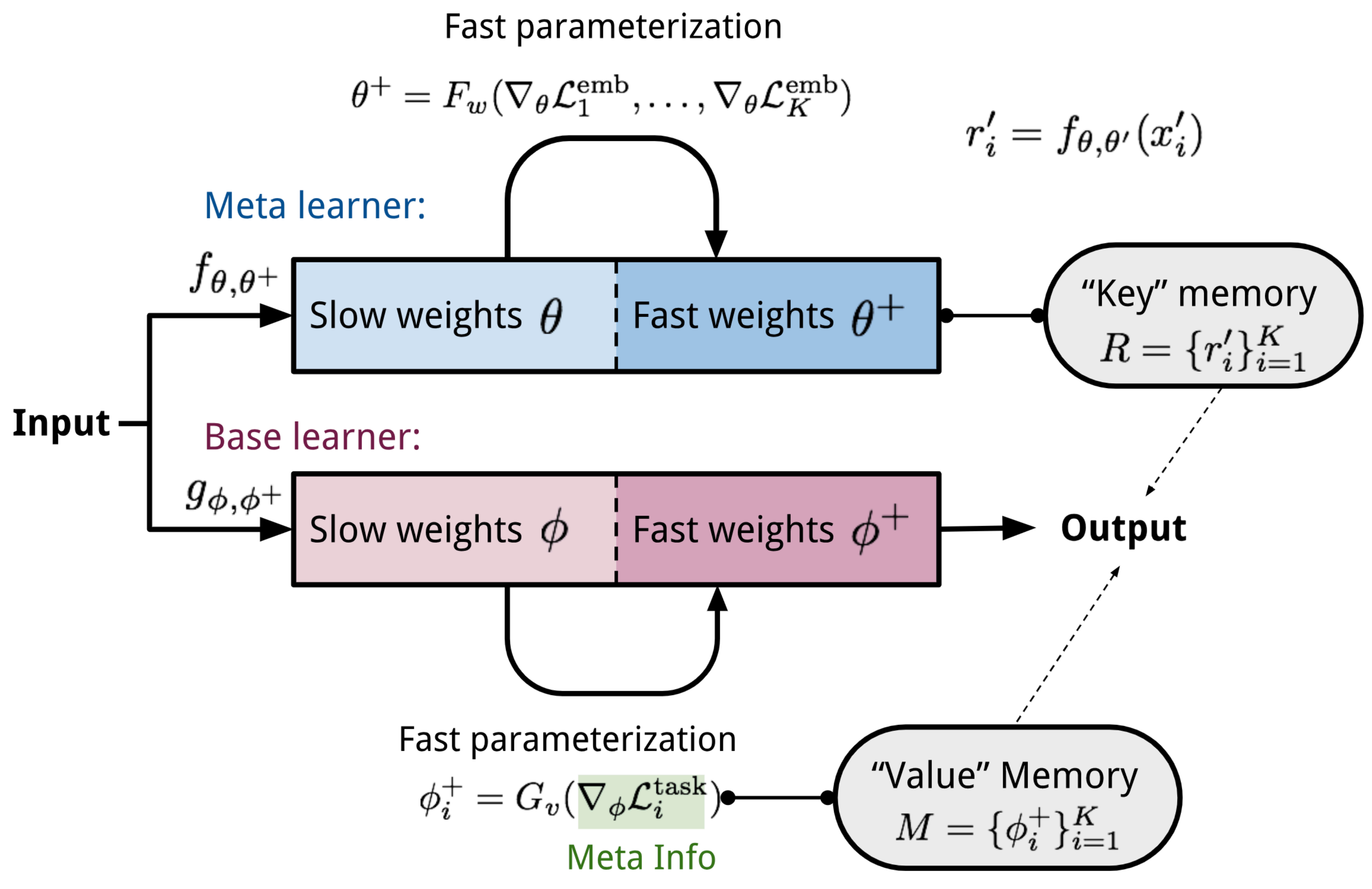
CSIF forecasting for Denver, CO, USA

Model	RMSE
ARMA	0.5099
ARIMA	0.1491
SARIMA	0.0908

Next steps

- Defining metrics
  - for phenological events
  - for model validation
- Model improvements:
  - Meta-learning
  - New attention mechanisms
- Model Testing



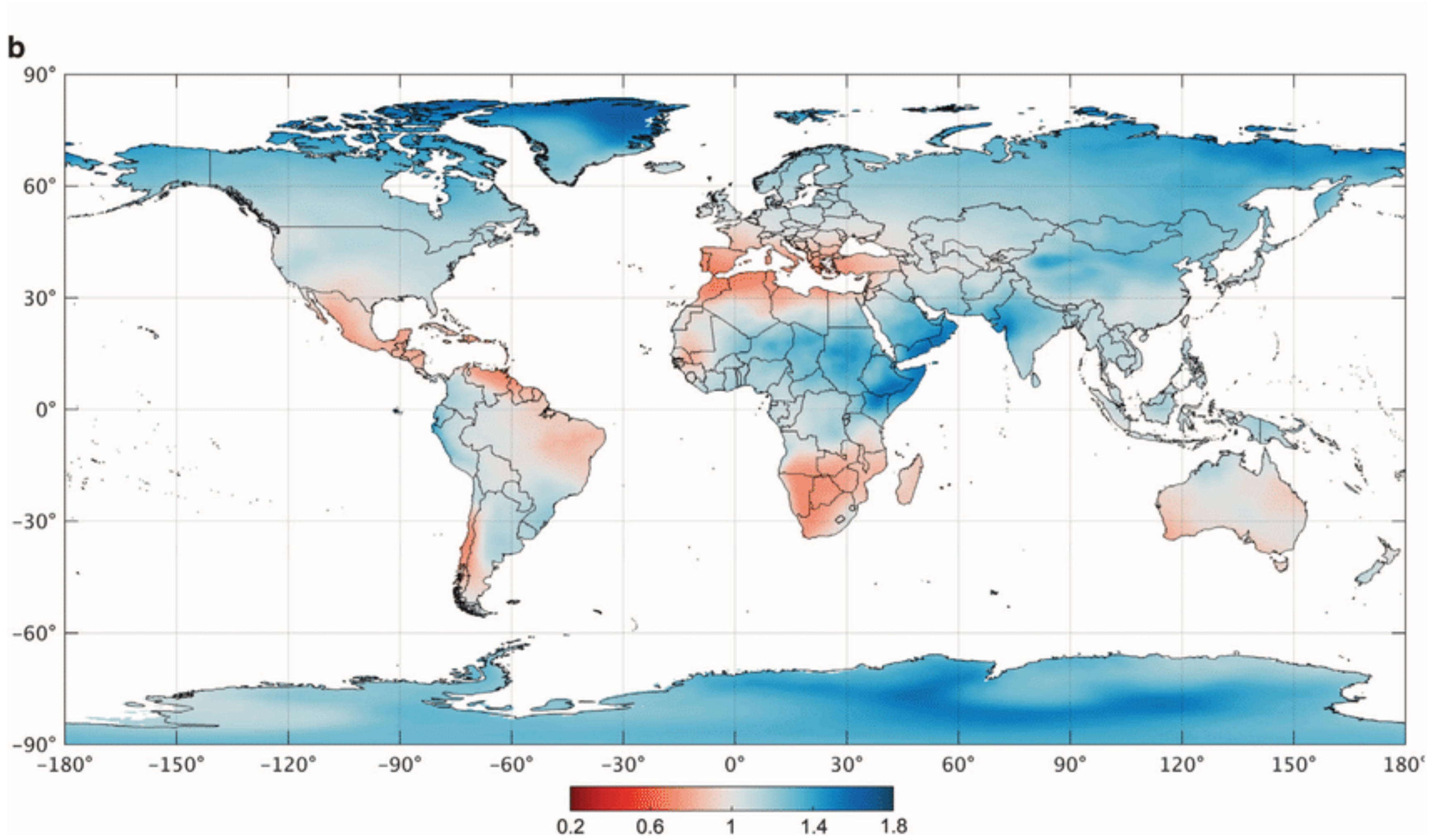


Remaining Challenges

1- Impacts of extreme climates

Less accurate phenology models during extreme climate events

2- Lack of regional diversity



Overrepresentation of boreal and temperate regions

Lack of data from tropical/subtropical regions