Nature-based infrastructure for enhancing climate resiliency of groundwater resources in South Florida: An integrated modeling approach

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Outline

- Overview
- Objectives
- General Approach
- Available climate model data

Overview

- **South Florida hydrologic system is complex, often called "*ground-zero*" for climate change impact**

Sea-level rise

Changing precipitation patterns

Higher temperatures

Rapid socioeconomic development

Population increase

[population to rise 30.5% by 2045 relative to 2018 (Rayer & Wang, 2019)]

[27% increase in population by 2035 will growth water demand by 18% (FDEP, 2019)]

decision-makers aware of climate change

little evidence on its impact in the current ***water supply***

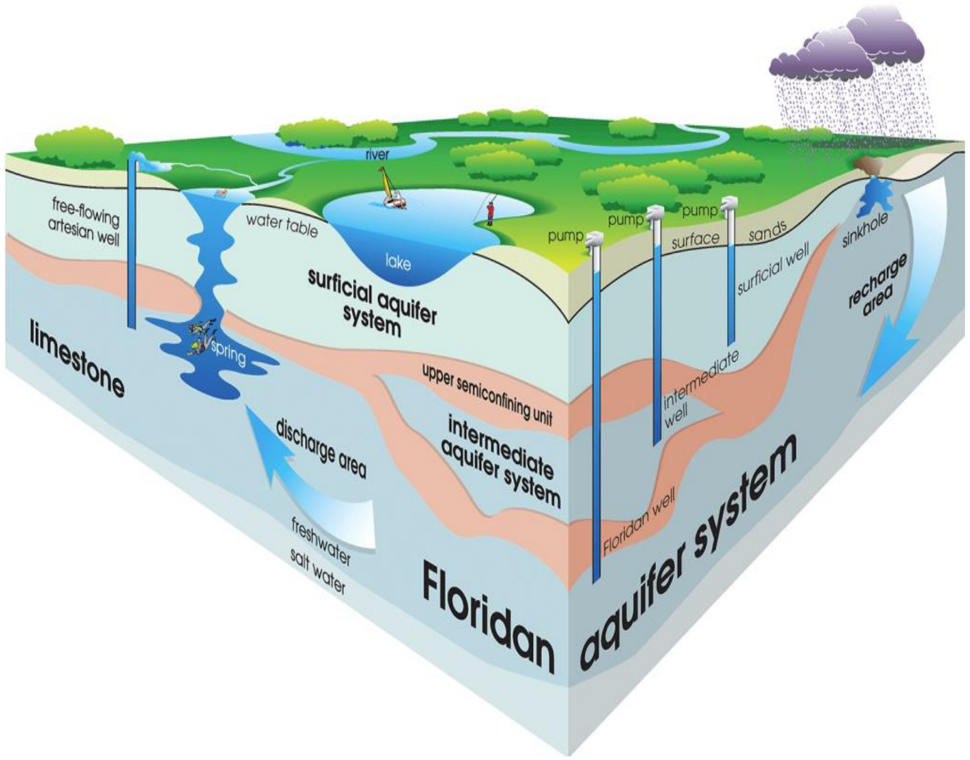
[Maliva et al., 2021]

Overview

- Groundwater is the main source of freshwater supply

- **Developing an integrated modeling for evaluating and enhancing the climate resilience of groundwater resources is not well investigated**

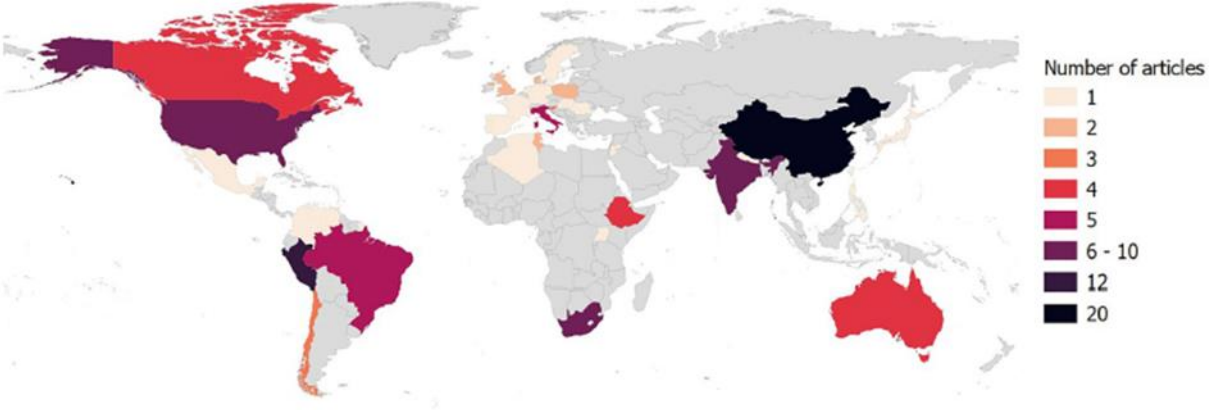
- Quantifying its availability under current and future climate scenarios and management strategies is crucial
  - Such a study can be helpful for applying **proper NBIs** to be more compatible with the impacts at variety of spatial and temporal scales.

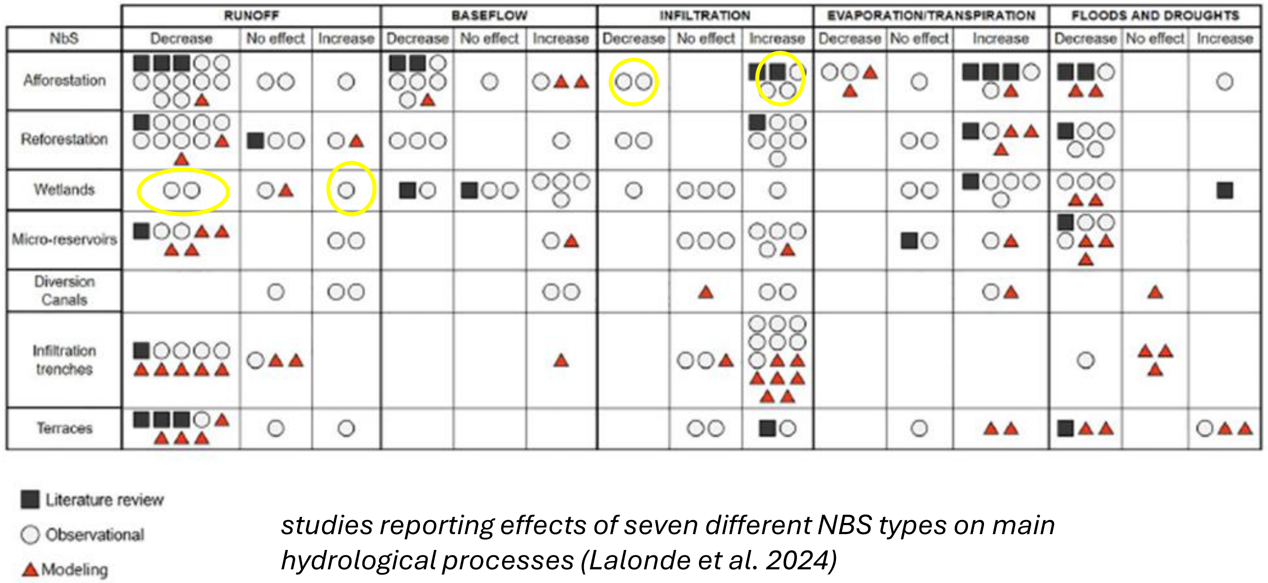


https://www.sjrwmd.com/water-supply/aquifer/

Overview

Effectiveness of NBIs on different hydrological responses is inconsistence

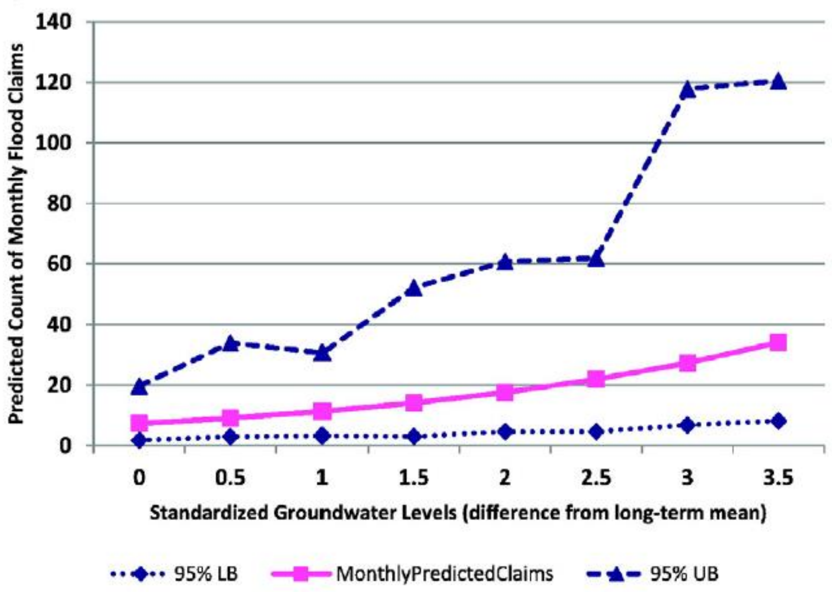




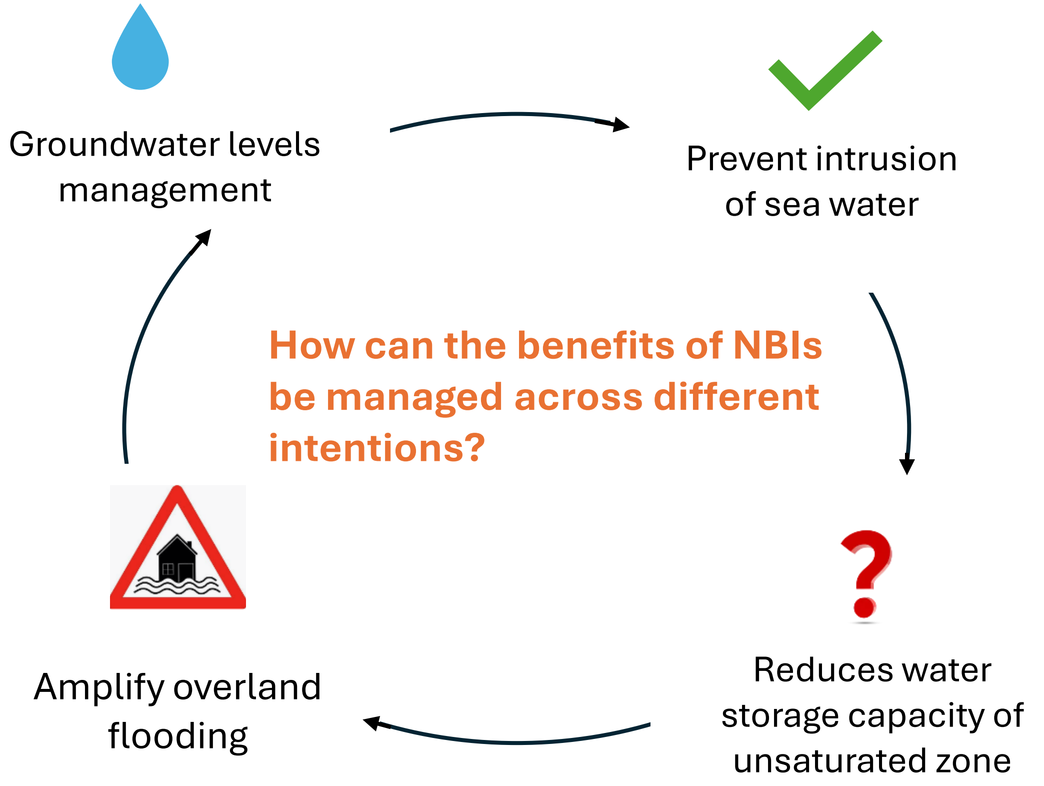
studies reporting effects of seven different NBS types on main hydrological processes (Lalonde et al. 2024)

Overview

Example: in South Florida



Predicted count of monthly flood claims for high-claim watershed in Miami dade (Czajkowski et al, 2018)



It is crucial to evaluate the NBIs effectiveness for the intended objective, following an integrated modeling approach.

- agriculture, flooding, protect wetland

Objectives

Obj-1: Assess the impacts of multiple climate factors on various groundwater related hydrological and ecological features under future climate and management scenarios

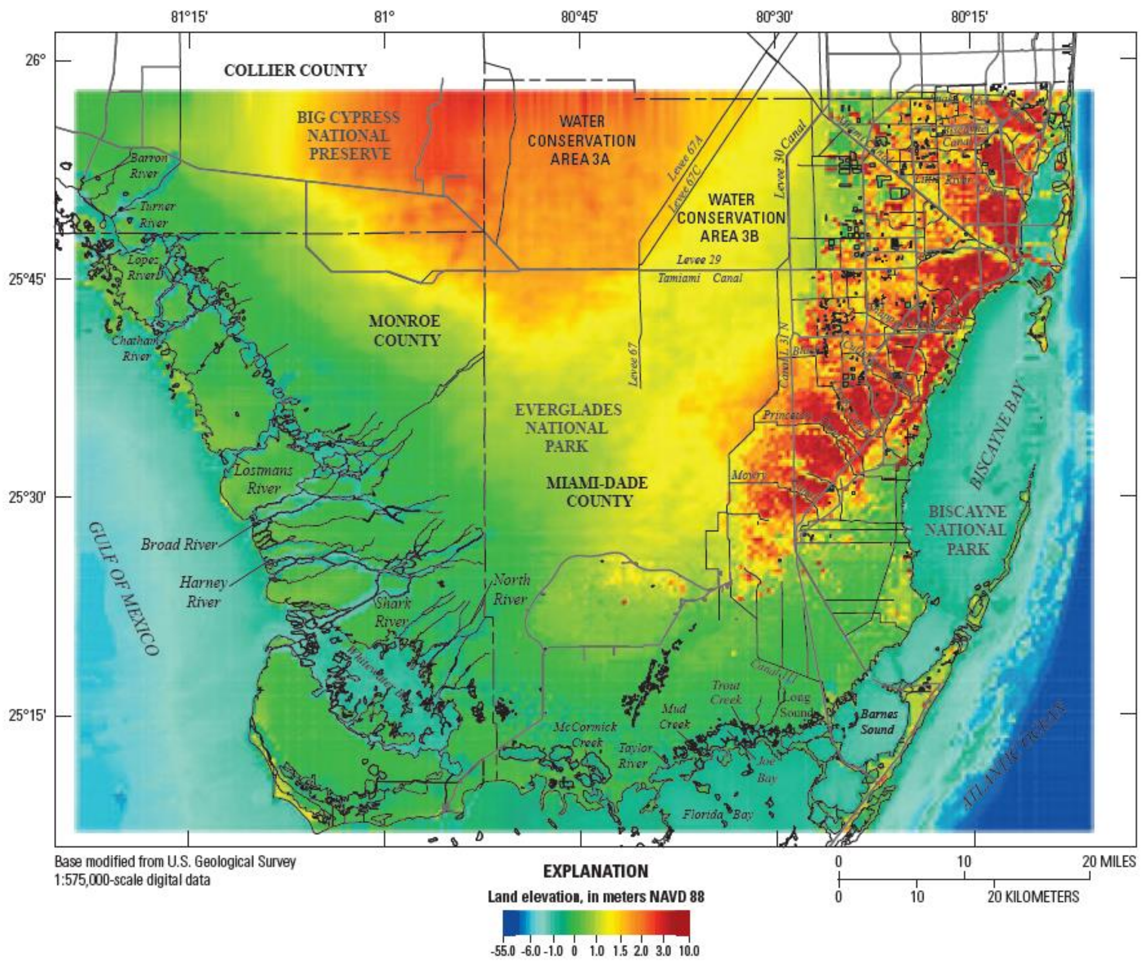
- How will projected changes in temperature and precipitation patterns affect groundwater recharge rates and aquifer levels?
- What is the impact of sea-level rise on the salinity and availability of groundwater resources under different climate and management scenarios?
- How do hydrological, ecological, and anthropogenic factors interact to influence future groundwater dynamics in South Florida?

Obj-2: Evaluate nature-based infrastructures (NBIs) to mitigate climate change impact on water resources in south Florida

- Which specific NBI strategies provide the most significant benefits for groundwater recharge enhancement and water quality improvement under varying climate scenarios?
- What are the perceptions and insights of stakeholders regarding the implementation of NBI?
- How NBIs be effectively integrated into existing water management practices to enhance groundwater resiliency for climate change?

Study area

The same boundary to the Biscayne and Southern Everglades Coastal Transport (BISECT) domain



Swain et al. 2019

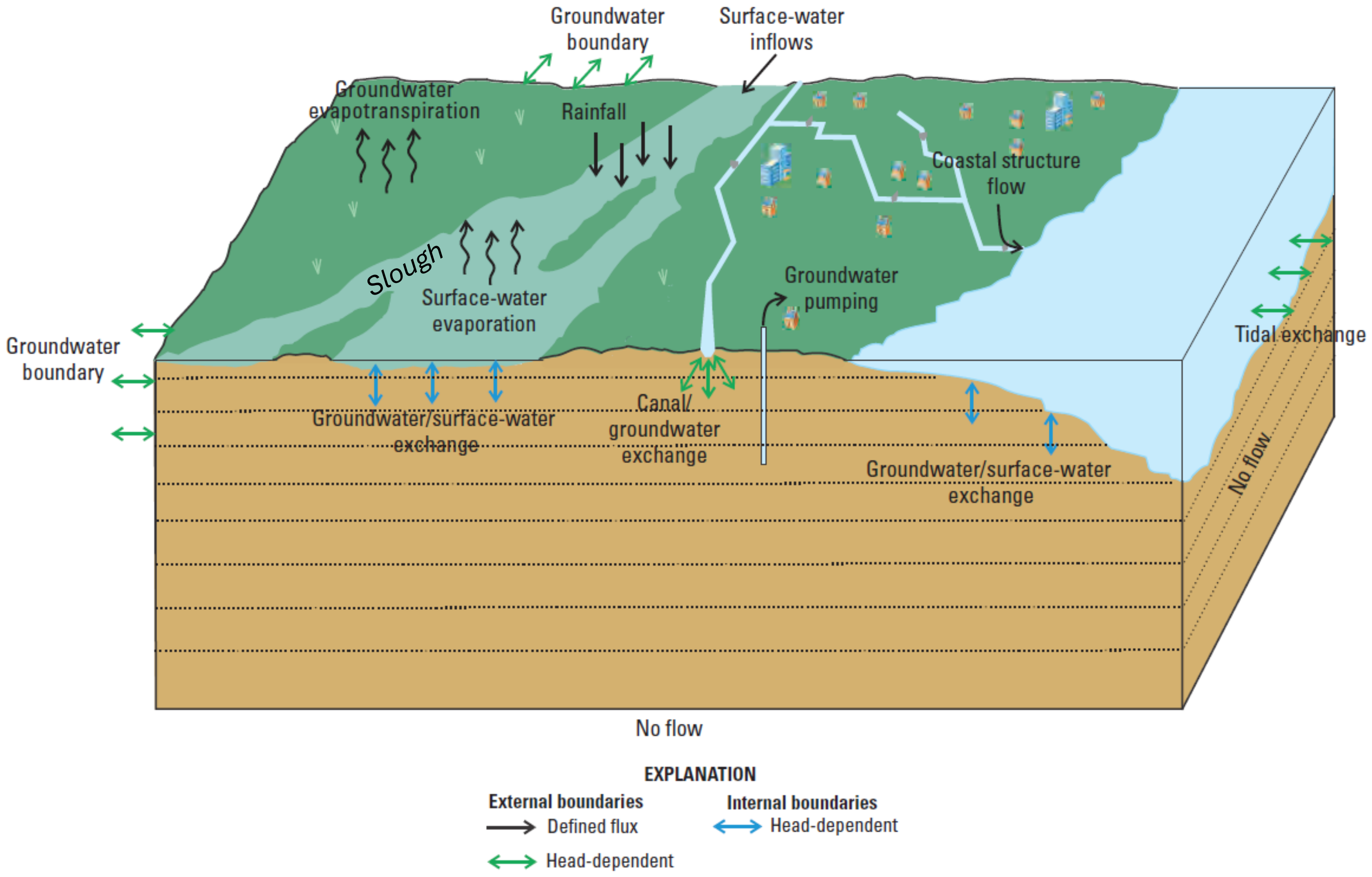
Approaches: Integrated hydrological model

Modeling

- BISECT model will be updated to quantify future groundwater availably
- Coupled SW-GW density-dependent flow model

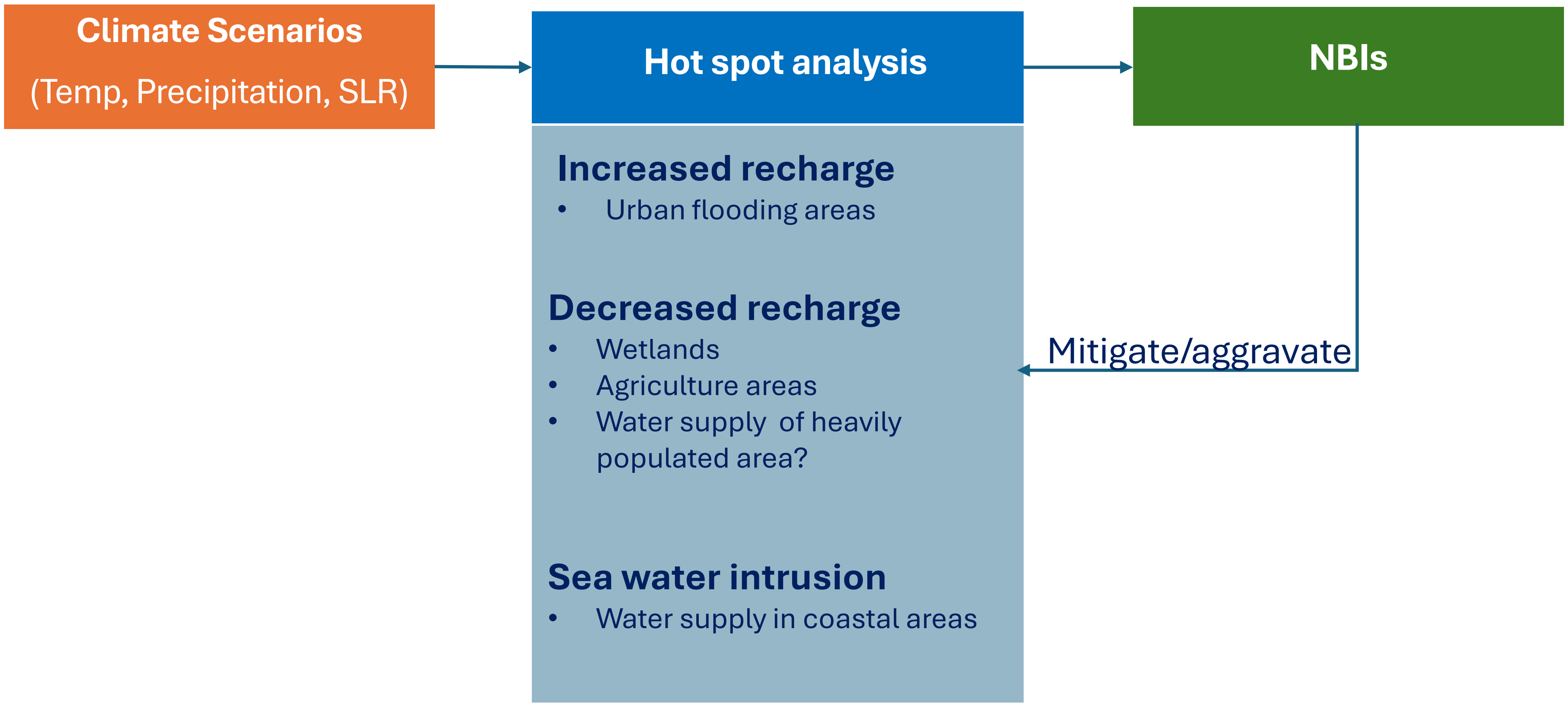
- Baseline (up to 2015)

- Future climate scenarios (2015-2065)

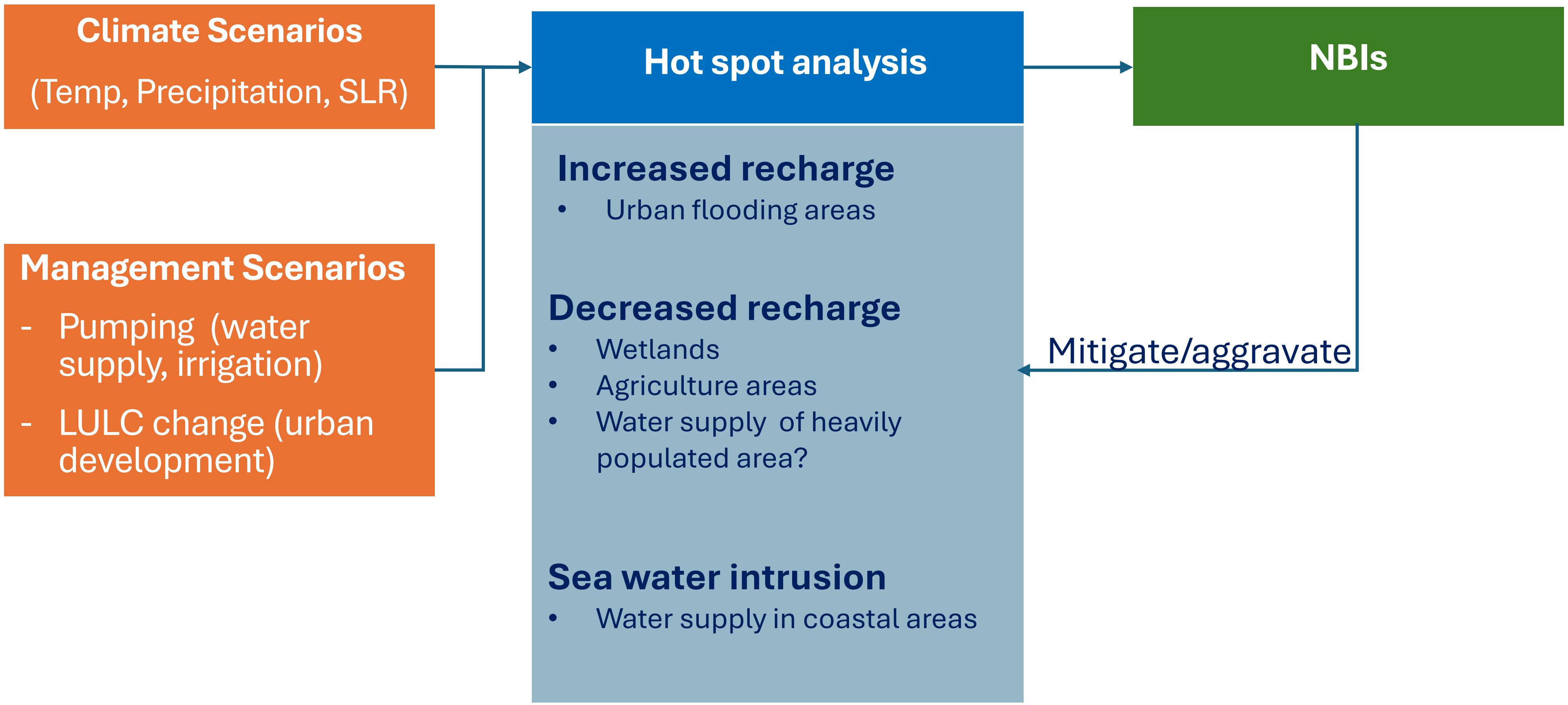


Conceptual model of the hydrologic system of the BISECT model (Swain et al., 20219)

Approaches: Climate impacts and NBI for mitigation



Approaches: Climate and human impacts and NBI for mitigation



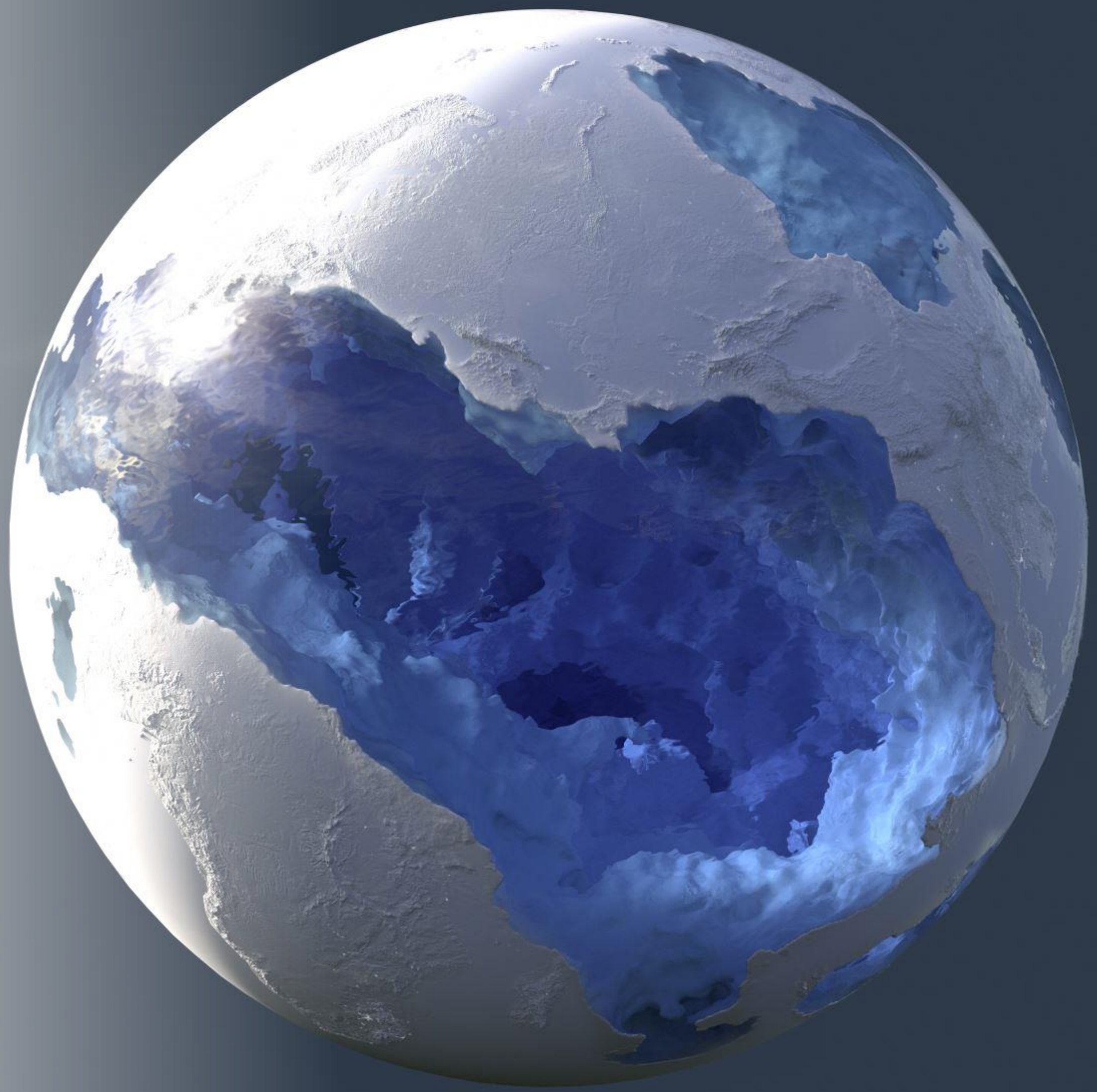
Approach for Next Phase

Hydrological and management criteria → Weight the criteria [expert and stakeholder] → Suitability of NBIs [spatial]

A framework for suitability of the NBIs on mitigating the climate change impact will be developed using multi-criteria decision-making approach

Global climate models (GCMs)

- The are many portals to access the climate model data
- coarse for local-scale applications
- required the use of downscaling and bias correction methods
  - CMIP6 data under the Shared Socioeconomic Pathways (SSPs)
  - Dynamically downscaled spatio-temporal climate data will be employed



NASA Global Daily Downscaled Projections, CMIP6 (NEX-GDDP) https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp-cmip6

Variable	Description	Units
hurs	Near-surface relative humidity	percentage
huss	Near-surface specific humidity	kg/kg
pr	Precipitation (including both liquid and solid phases)	$kg/m^2/s$
rlds	Surface downwelling longwave radiation	W/m^2
rsds	Surface downwelling shortwave radiation	W/m^2
sfcWind	Surface wind speed	m/s
tas*	Near-surface air temperature	degrees K
tasmax*	Maximum near-surface air temperature	degrees K
tasmin*	Minimum near-surface air temperature	degrees K

- **originally released in 2015 for CMIP5**
- **provide a set of global bias-corrected climate change projections (25km resolution)**
- **used to evaluate climate change impacts on processes that are sensitive to finer-scale climate gradients and the effects of local topography on climate conditions.**

CMIP6-based Multi-model Hydroclimate Projection over the Conterminous US (CONUS)

V1:
https://hydrosource.ornl.gov/data/datasets/9505v3_1/

V1.1:
https://doi.ccs.ornl.gov/dataset/9d3ff396-992d-5bd7-ab02-d21ec6193147

https://hydrosource.ornl.gov/data/datasets/9505v3-1/

- **Downscaled using dynamical and statistical techniques**
- **Meteorological reference observations (Daymet and Livneh)**
  - high-resolution (~ 4 km)

- **V1 data included six selected CMIP6 GCMs**
  - baseline (1980 – 2019)
  - near-future (2020-2059) under the high-end (SSP585)

- **V1.1: extended period and added GCM**
  - far-future (2060-2099) across SSP370, SSP245, and SSP126
  - EC-Earth3 is added

**additional variables and scenarios may be available upon request*

List of CMIP6 GCMs Used for Downscaling

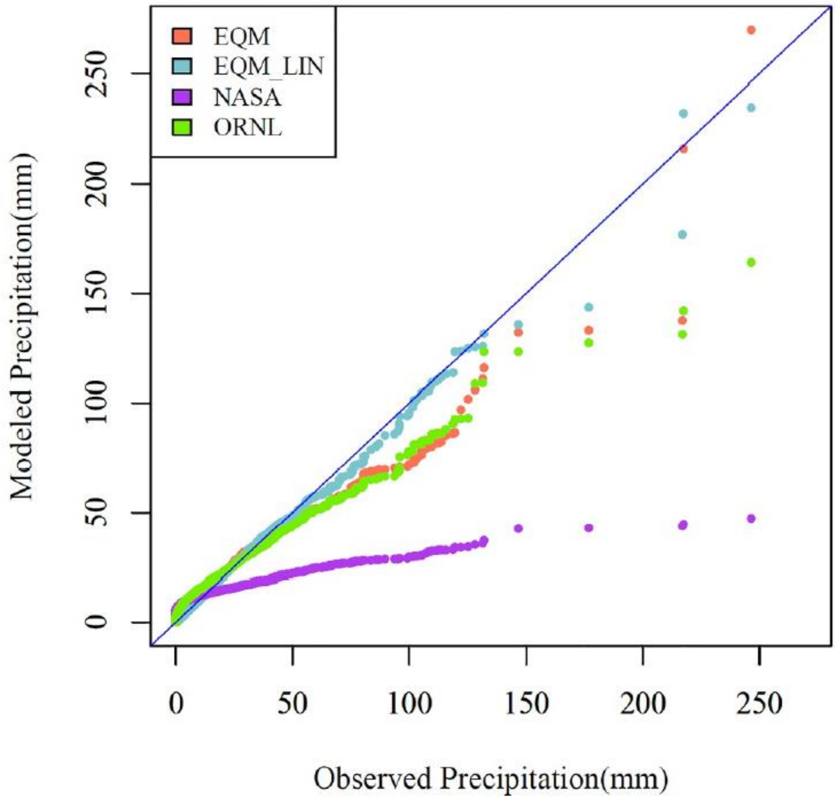
CMIP6 GCM name	Spatial resolution	Ensemble member	GCM institute	References
ACCESS-CM2	144 × 192	r1i1p1f1	The commonwealth Scientific and Industrial Research Organization, Australia	Dix et al. (2019)
BCC-CSM2-MR	160 × 320	r1i1p1f1	Beijing Climate Center	Wu et al. (2018)
CNRM-ESM2-1	256 × 128	r1i1p1f2	French Center National de la Recherche Scientifique	Seferian (2018)
MRI-ESM2-0	160 × 320	r1i1p1f1	Meteorological Research Institute Japan	Yukimoto et al. (2019)
MPI-ESM1-2-HR	192 × 384	r1i1p1f1	The German Climate Computing Center	von Storch et al. (2017)
NorESM2-MM	192 × 288	r1i1p1f1	Multi-institutional, coordinated climate research project in Norway	Bentsen et al. (2019)

Climate Projections for South Florida

Recent study

- GCM data tend to underestimate high quantiles of precipitation and are inappropriate for extreme precipitation values

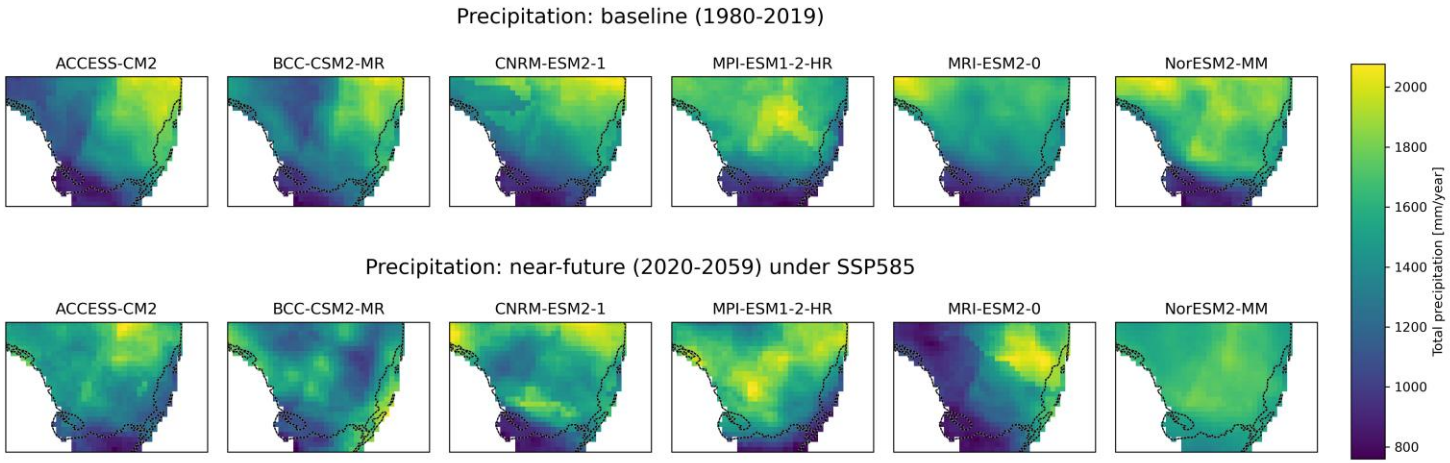
Developing institute	GCM	Horizontal resolution	Reference
Commonwealth Scientific and Industrial Research Organization & Australian Research Council Centre of Excellence for Climate System Science	ACCESS-CM2	1.9° × 1.3°	Dix et al. (2019)
Beijing Climate Center	BCC-CSM2-MR	1.1° × 1.1°	Wu et al. (2018)
Canadian Centre for Climate Modeling and Analysis	CanESM5	2.8° × 2.8°	Swart et al. (2019)
National Center for Meteorological Research, Météo-France and CNRS	CNRM-ESM2-1	1.4° × 1.4°	Seferian (2018)
European community Earth-System Model	EC-Earth3-Veg	0.7° × 0.7°	EC-Earth Consortium (EC-Earth) (2019)
Max Plank Institute	MPI-ESMI-2-LR	1.9° × 1.9°	Mauritsen et al. (2019)
Meteorological Research Institute	MRI-ESM2-0	1.1° × 1.1°	Yukimoto et al. (2019)
Norwegian Climate Center	NorESM2-MM	0.9° × 1.3°	Seland et al. (2020)
National Center for Atmospheric Research, USA	CESM2	2.8° × 2.8°	Danabasoglu (2019)

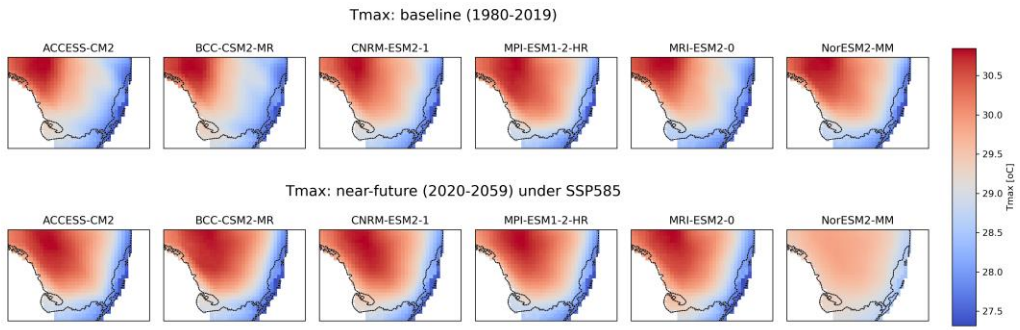


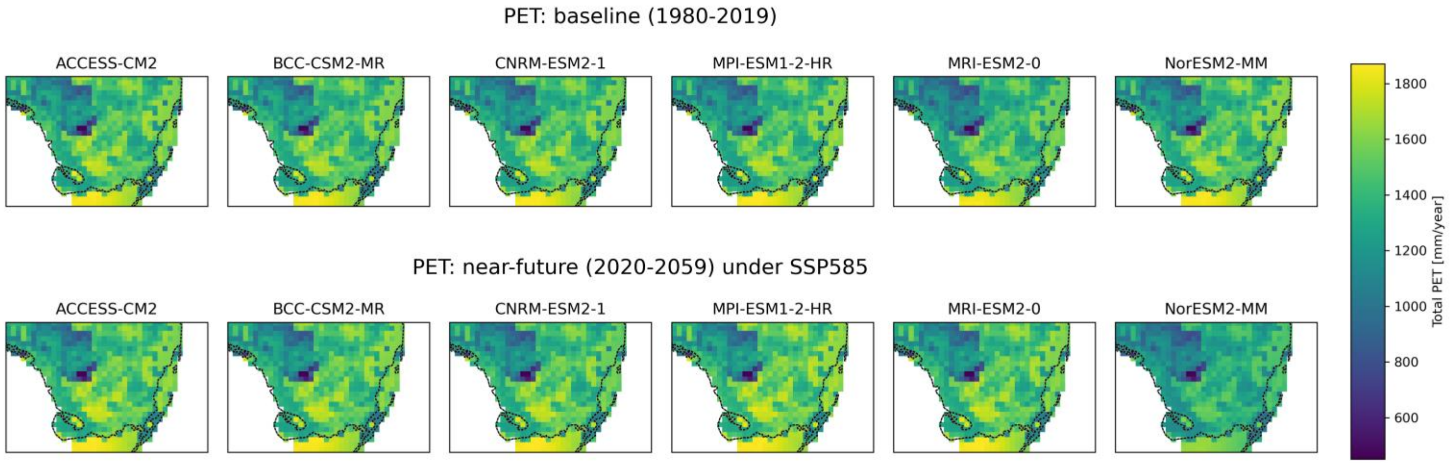
Rahimi et al. 2024

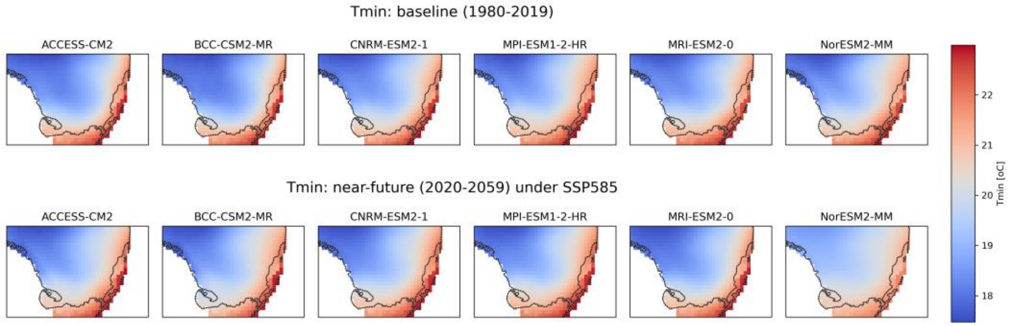
Dynamically downscaled climate variables

South Florida | Data Accessed from Globus platform

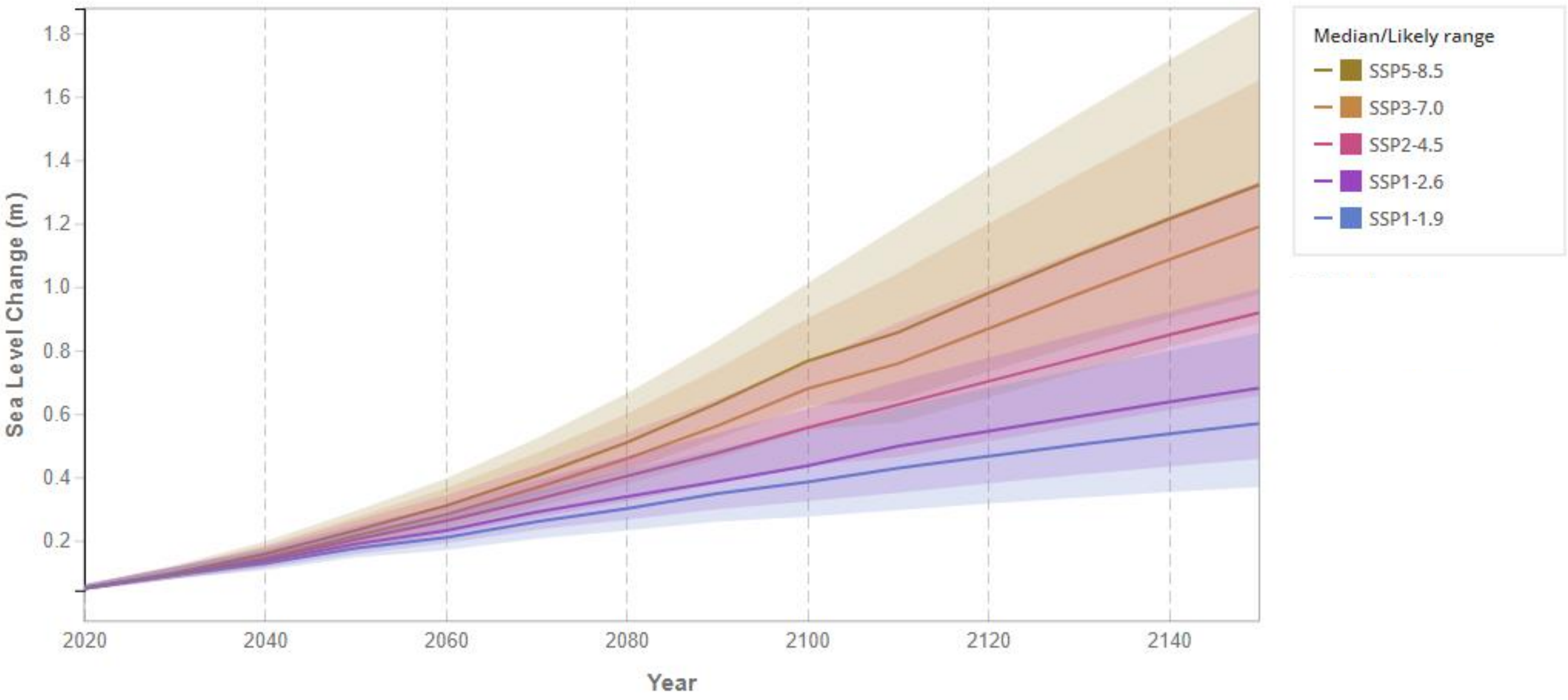








Projected Sea Level Rise



https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool?type=global

Thank you!

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