A Deep Learning-based Technique for Long-term Prediction of Sea Surface Temperature: over the Aegean, Ionian and Cretan Seas (NE Mediterranean Sea)

Marios Krestenitis, Yannis Androulidakis, Yannis Krestenitis
COSS-TT , Montréal 2023

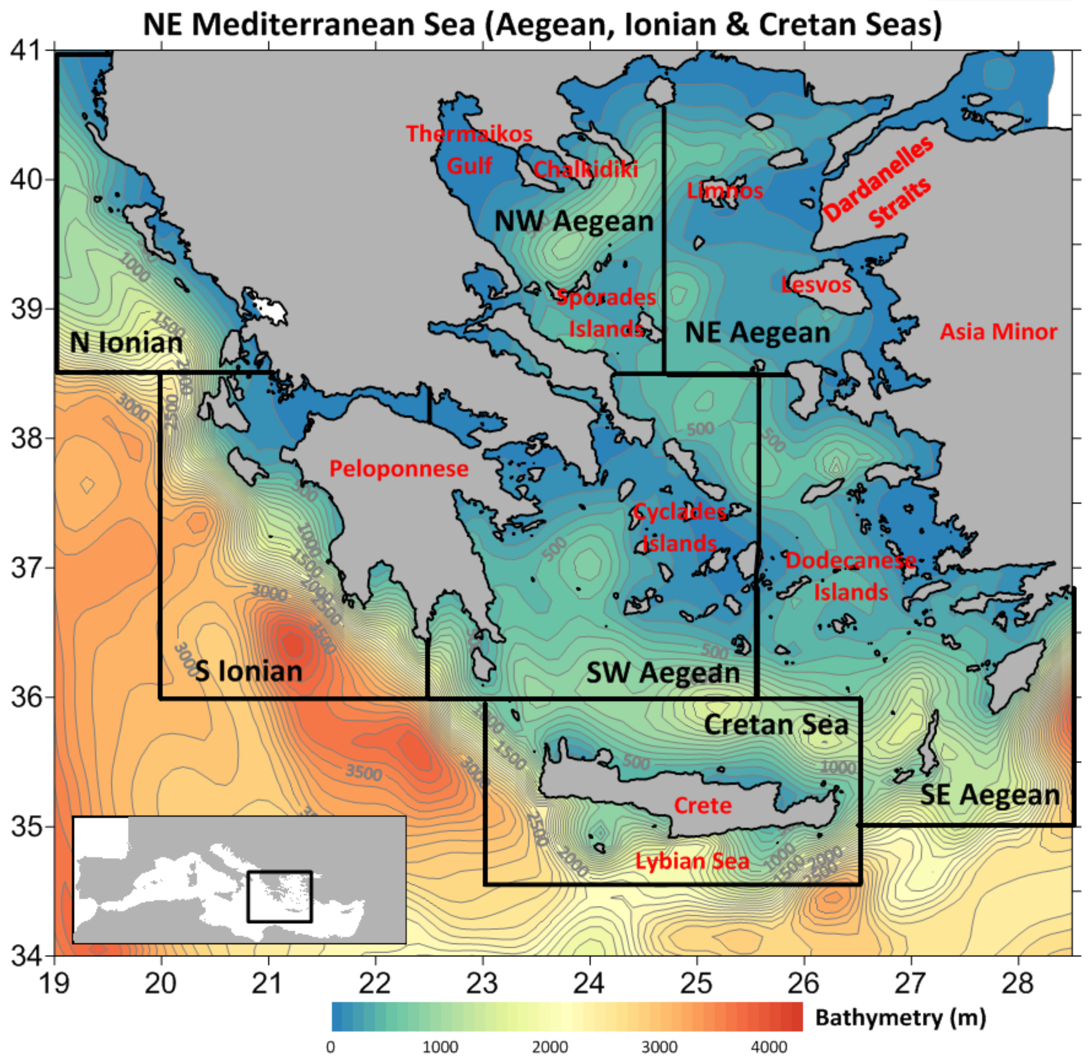
Contents

Introduction

- **Sea Surface Temperature** (SST) is a main indicator of **global warming**
- **Extreme** events of prolonged high SST levels are named **Marine Heat Waves** (MHWs)
- MHWs affect natural and urban **coastal enviroment**
- **Accurate** prediction of MHWs in the distant-future (from years to decades) is a **challenging** task and a **considerable need**

Study Area

- Northeastern Mediterranean Sea
  - Aegean, Ionian, and Cretan (AIC) Seas
  - environmental **protected** areas
  - **fishery** and **aquaculture** zones
  - **large** urban areas
- Significant **increasing** trends of SST during the last decades
- MHWs occurrence:
  - **strong** spatial variability over the AIC basin
  - stronger positive trends in the **northern** Aegean Sea
  - "**hot spots**" of MHW formation
  - vital need of the **accurate prediction** of SST
- Summer 2021:
  - prolonged **extreme** sea temperature conditions in Thermaikos Gulf
  - **damaged** mussels production of both **2021** and **2022**

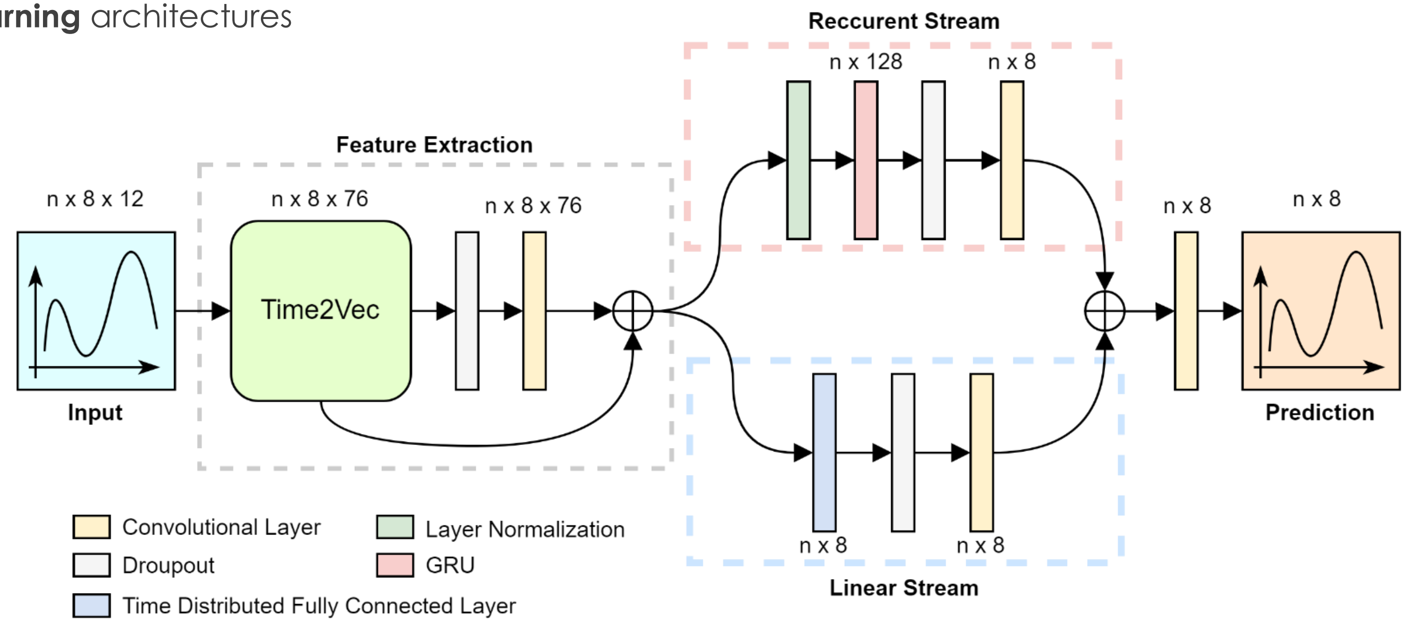


Dataset

- **Satellite** Observations
  - SST satellite-deried fields; E.U. Copernicus Marine Service
  - SST fields averaged over 7 sub-basins of the AIC domain
- **Atmoshperic** data
  - ERA5 hourly data; Copernicus Climate Change Service
  - Air temperature, wind speed, air pressure, shortwave radiation, longwave radiation
- Study period (2008-2022; latest access on 23/04/23)
- Seasonal decomposition
  - Utilize **original** values & **residual**
  - Exploit the residual noise to learn **small-scale** SST variations

Methodology

- Utilize the effectiveness of well-known **deep learning** architectures
- Long-term **multiregional** SST forecasting
- **Variable** temporal (*n*) & spatial (*k*=8) resolution
- **Feature extraction** module:
  - **enhance** the features quality
  - fuse the **spatial** information
- **Reccurent** Stream
  - Analyze **temporal dependencies** of SST
  - Capture **short-term** flunctuations
  - Capture **complex** patterns
- **Linear** Stream
  - Capture the **long-term** trends
  - Provide a **baseline** prediction

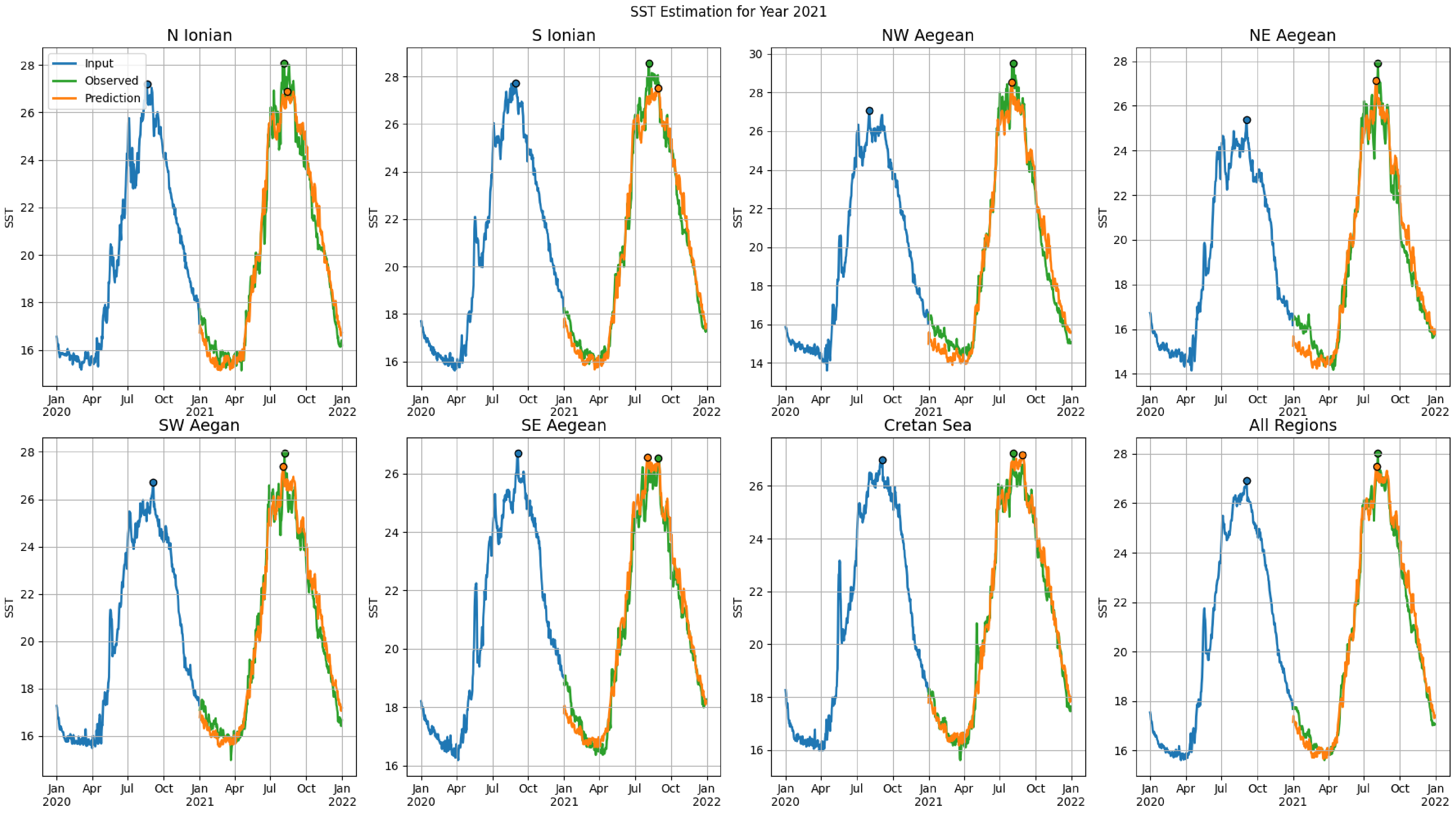


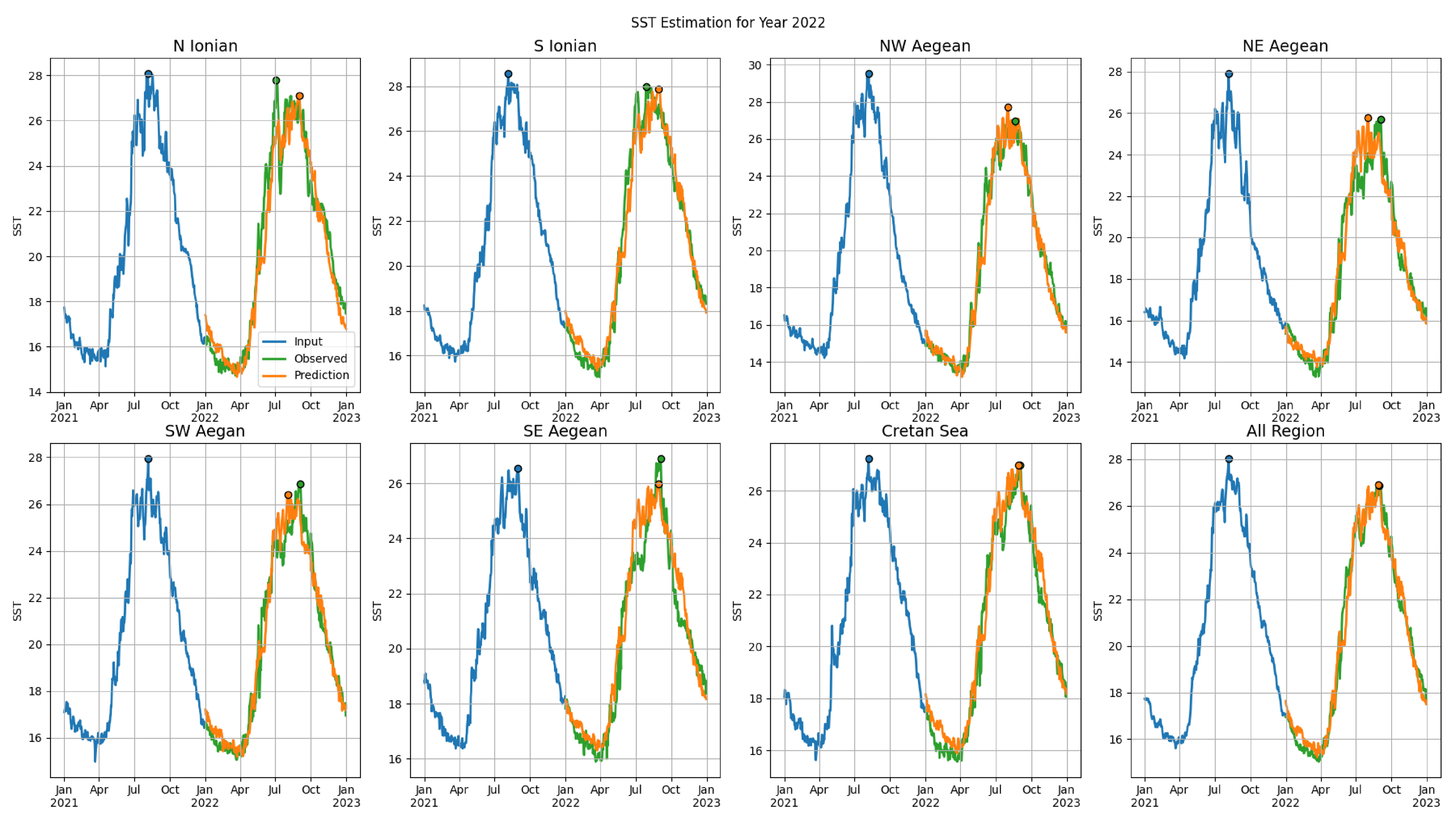
Train & Evaluation

- Training set: **01/01/2008** to **31/12/2020**
- Evaluation set: **01/01/2021** to **31/12/2021**
- Testing set: **01/01/2022** to **31/12/2022**
- Length *n* of time-series: **365** days
- Trained for **200** epochs with batch size **128**
- Weighted Mean Squared Error (wMSE)
  - Higher penalty of **wrong predictions** especially during **summer period**
  - **Force** the model to forecast extreme SST levels instead of **naively fit** to the trend

Ablation Study

Model			2021			2022		
TimeVec	Linear	Recurrent	wMSE	MSE(<15)	MSE(>24)	wMSE	MSE(<15)	MSE(>24)
✓	✓	✗	0,7712	0,1690	0,5896	1,1357	0,8273	0,6452
✓	✗	✓	0,7764	0,4048	0,4098	1,1201	0,2118	0,9733
✗	✓	✓	0,5996	0,1671	0,4355	1,5639	0,9305	1,0540
✓	✓	✓	0,5601	0,1642	0,3768	0,9621	0,1650	0,6919

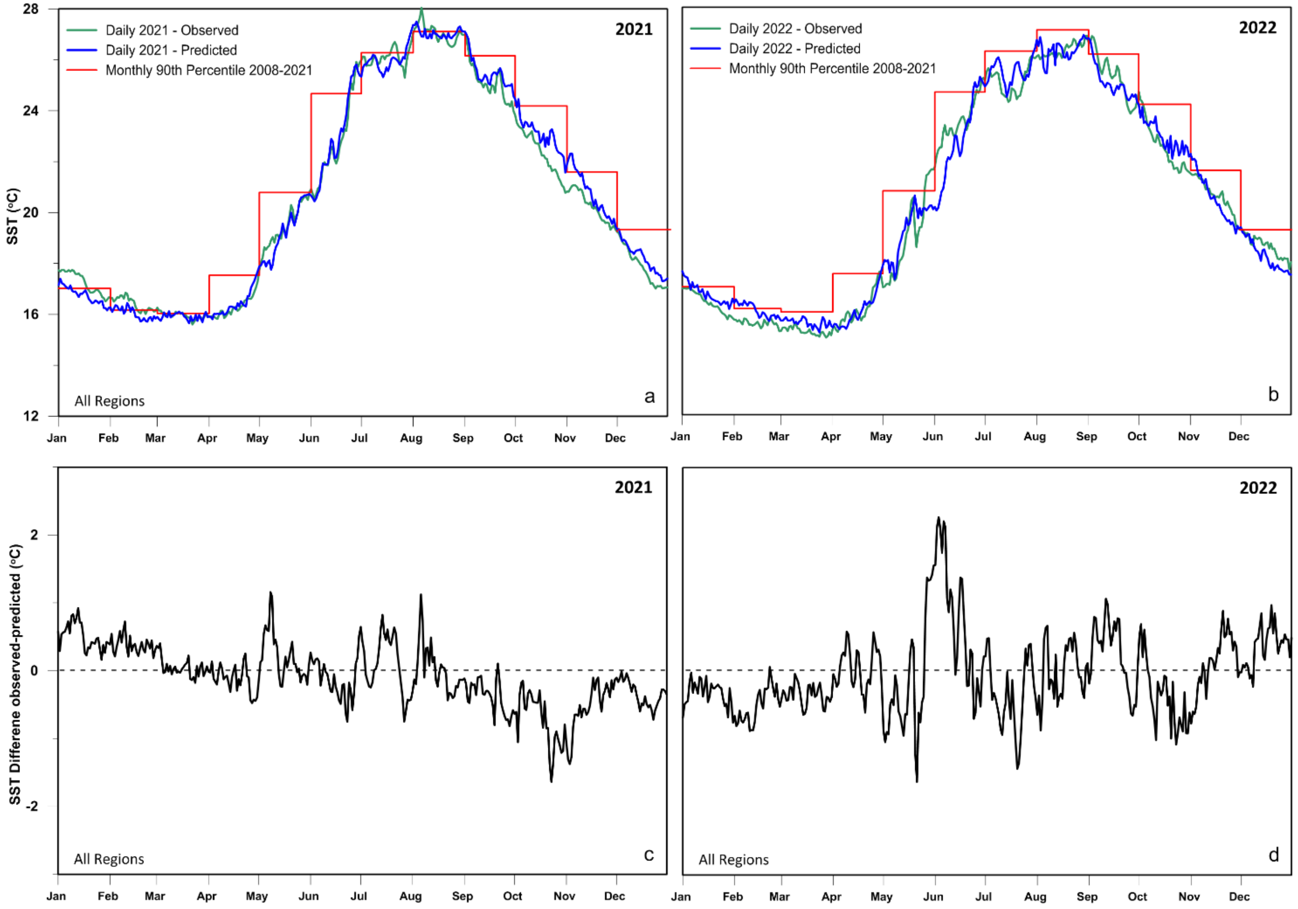

SST Estimation for Year 2021
N Ionian
S Ionian
NW Aegean
NE Aegean
SW Aegan
SE Aegean
Cretan Sea
All Regions
Input
Observed
Prediction
SST
Jan 2020
Apr
Jul
Oct
Jan 2021
Jan 2022

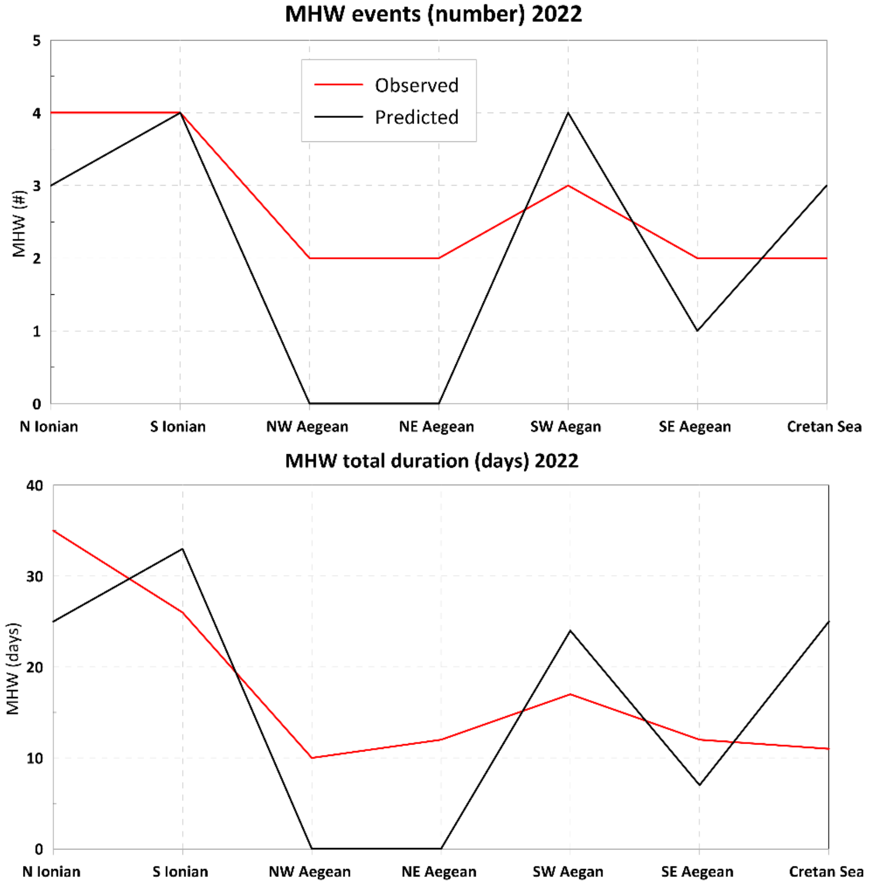

SST Estimation for Year 2022
N Ionian
S Ionian
NW Aegean
NE Aegean
SW Aegan
SE Aegean
Cretan Sea
All Region
SST
Input
Observed
Prediction
Jan 2021
Apr
Jul
Oct
Jan 2022
Apr
Jul
Oct
Jan 2023

Forecasting: Practical Cases

- Predict MHWs events
- Forecast SST values for 2023

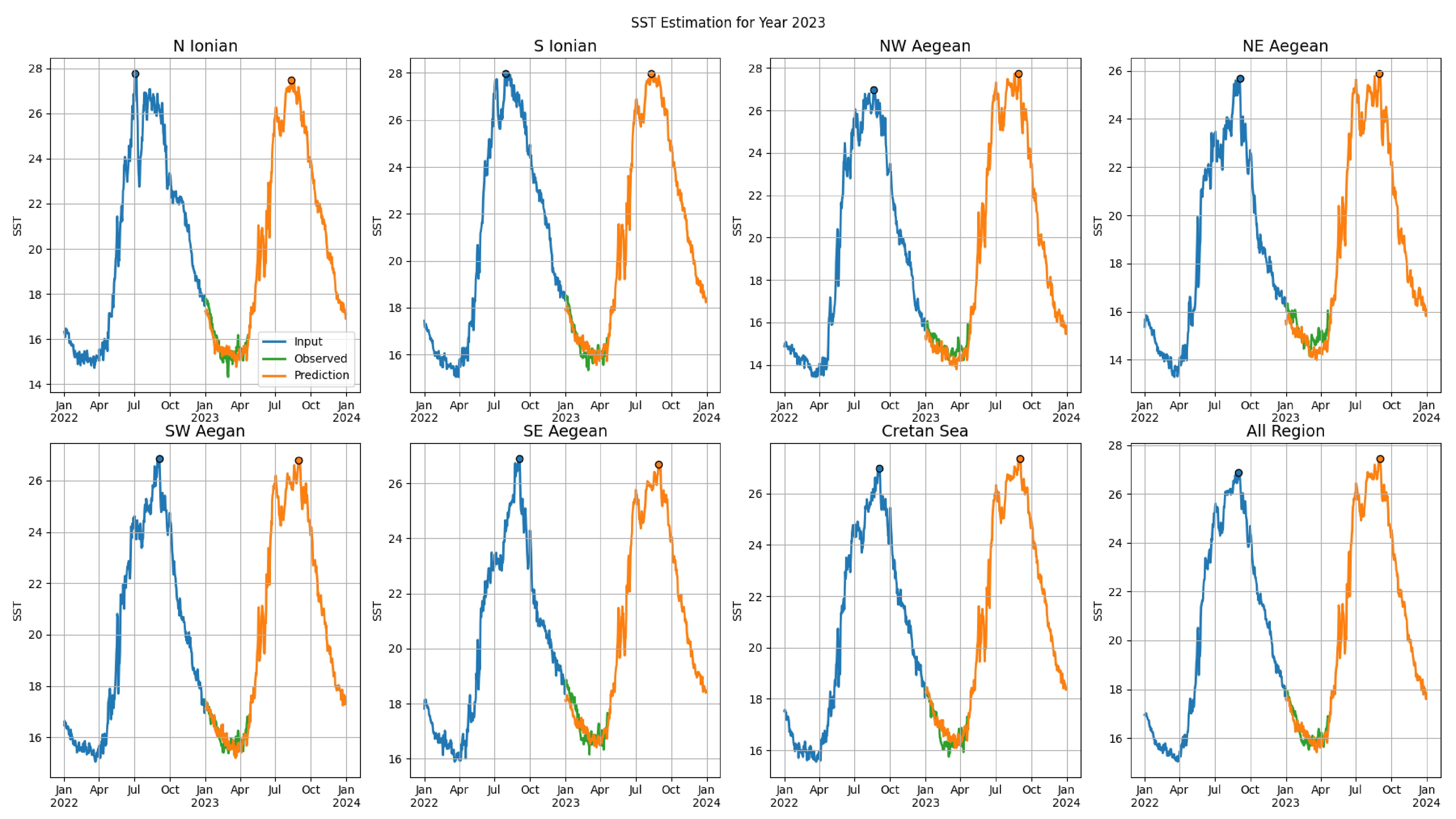
Predicting MHWs





- Marine Heat Waves (MHW) detection on predicted and observed SST timeseries
- Based on methodology by Hobday et al. (2016)
- Mean monthly 90th percentile baseline (red line)

- Predicted number of events (upper)
- Predicted duration of events (lower)
- Agreement (high in Ionian and SW Aegean)
- Weaker for Northern Aegean areas


SST Estimation for Year 2023
N Ionian
S Ionian
NW Aegean
NE Aegean
SW Aegan
SE Aegean
Cretan Sea
All Region
SST
Input
Observed
Prediction
Jan 2022
Apr
Jul
Oct
Jan 2023
Apr
Jul
Oct
Jan 2024

Conclusions

- Necessity for **accurate** prediction of SST
- **Novel** & **efficient** deep-learning based method to forecast SST
- **Multiregional** forecasting
- Variable **spatial** & **temporal** resolution
- **Adaptive** learning
- Future work:
  - **increase** spatial resolution
  - **computer vision** approaches

Thank you ☺