ARTIFICIAL NEURAL NETWORK FOR OCEAN SURFACE CURRENT PREDICTION AROUND THE KOREAN PENINSULA

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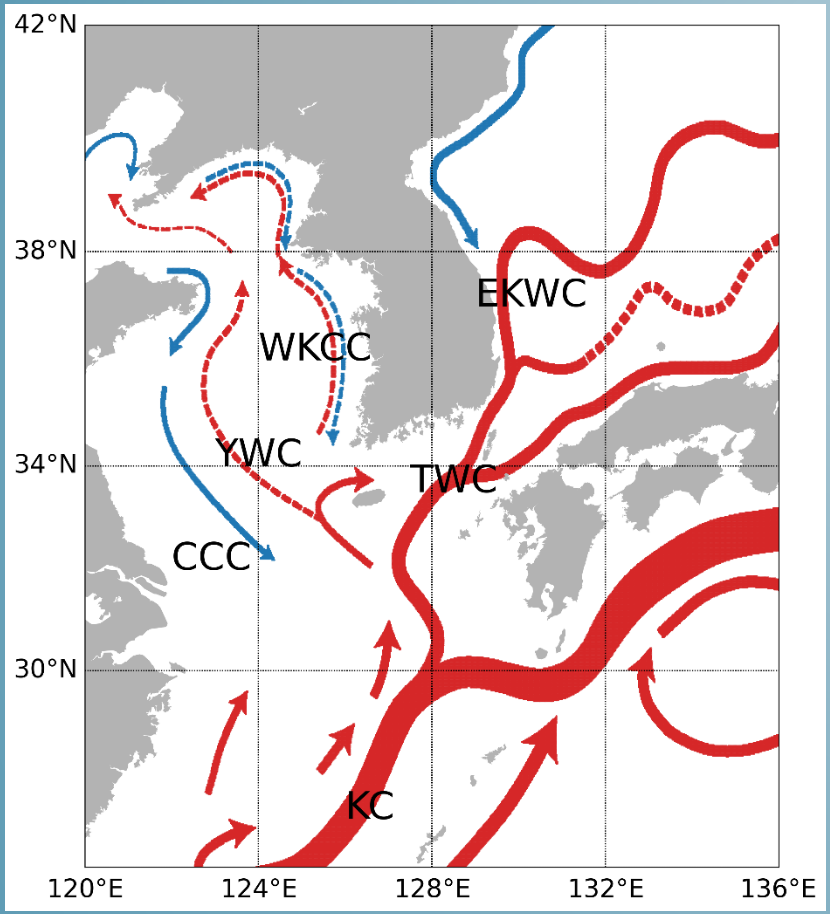
Ocean Physical-process Analysis Laboratory

AI model for surface current prediction?



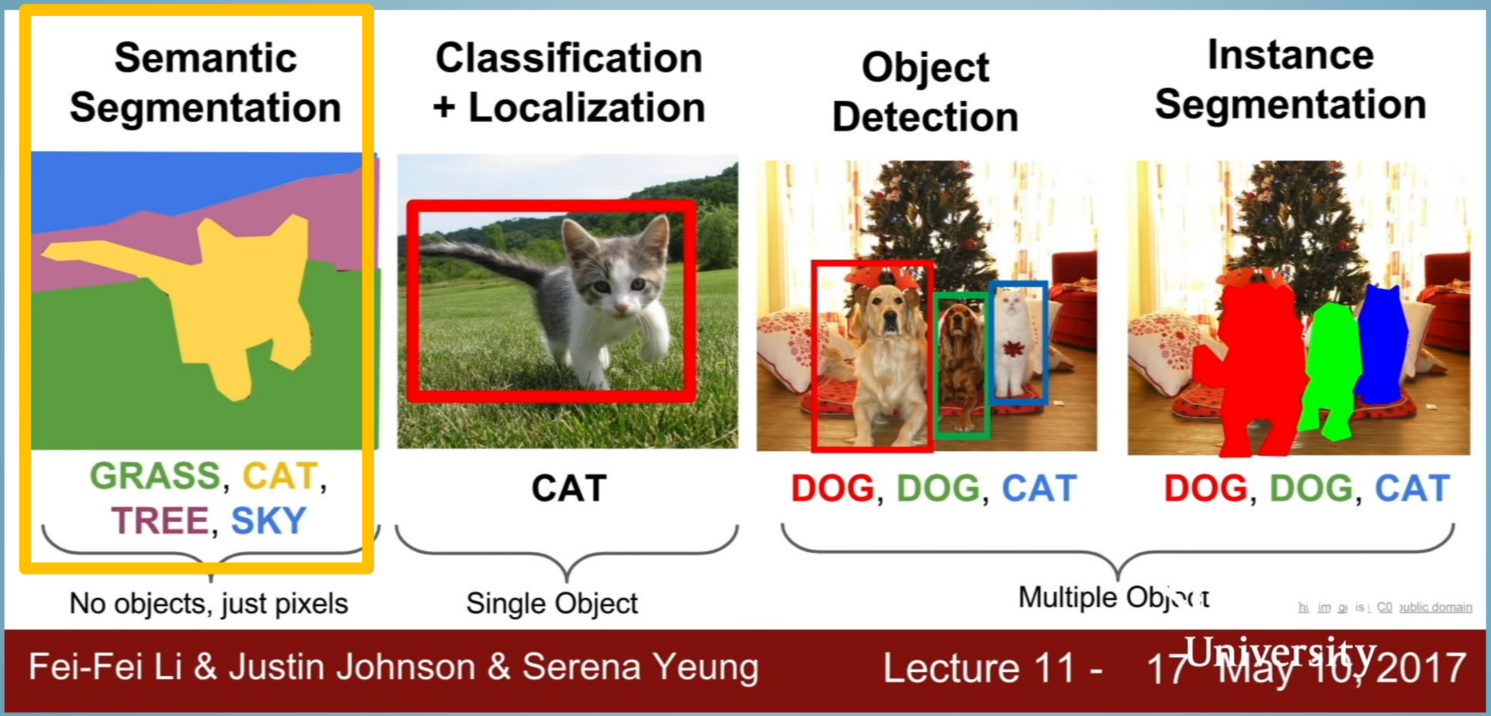
Data from KHOA

- Ocean surface current prediction is essential for various objectives.
- Seas around Korean peninsula show different characteristics:
  Yellow Sea = tides dominant
  East Sea = mesoscale processes
- Numerical model with fine-spatial resolution including is needed for prediction.
- However, it requires high computational power.

- An efficient surface current prediction framework around Korean peninsula using a 3-dimensional convolutional neural network (3-D CNN)

Convolutional Neural Networks (CNN)

– Semantic Segmentation



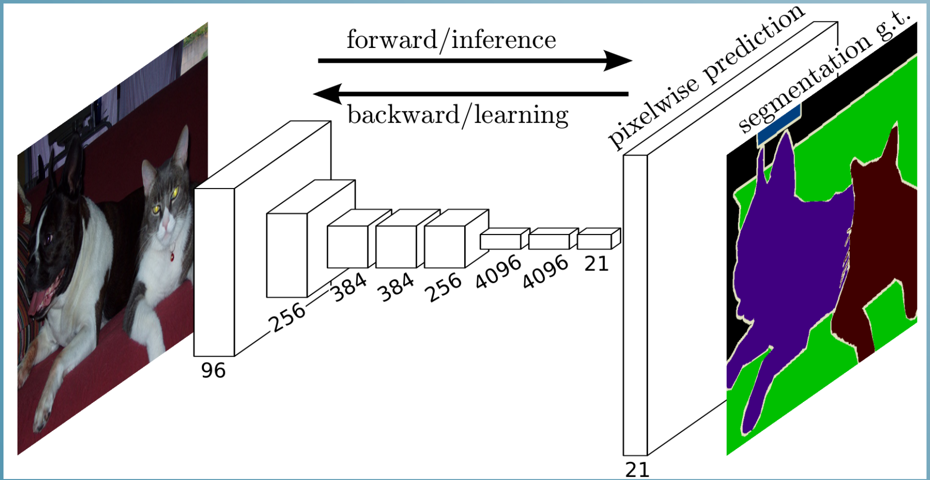
CS231n: Convolutional Neural Networks for Visual Recognition

- In Computer Vision (CV) area, there are many different tasks: Image Classification, **<u>Semantic Segmentation</u>**, Object Localization, Object Detection, Instance Segmentation, etc.

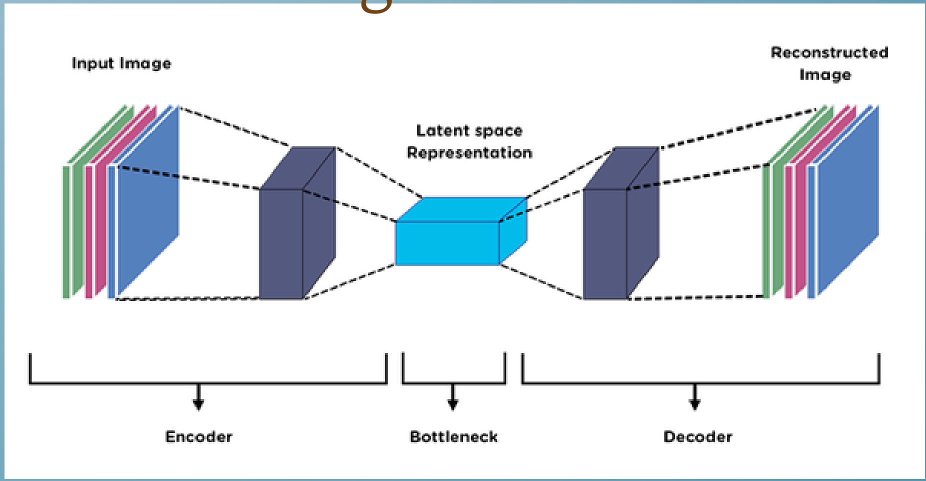
CNN – Semantic Segmentation

- One of computer vision task
- Fully convolutional network (FCN)
- Encoder-Decoder structure
- Pixel-wise classification
- **Pixel-wise regression**

- Encoder:
  Encodes or compresses the input data into a latent-space representation
- Decoder:
  Decodes or reconstructs the encoded data (latent space representation) back to original dimension

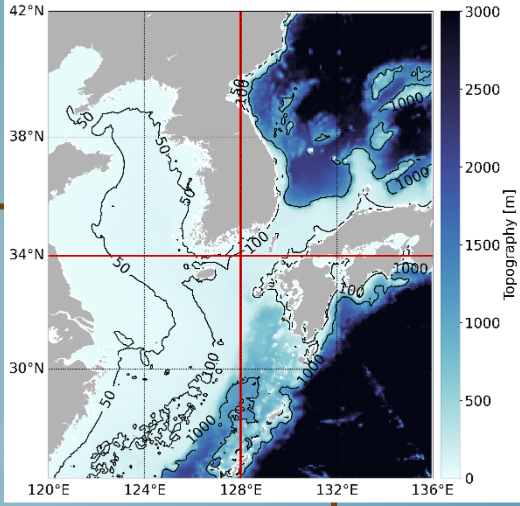


Fully Convolutional Networks for Semantic segmentation (Long et al., 2015)



https://medium.com/@birla.deepak26/

Oceanic & Atmospheric Data



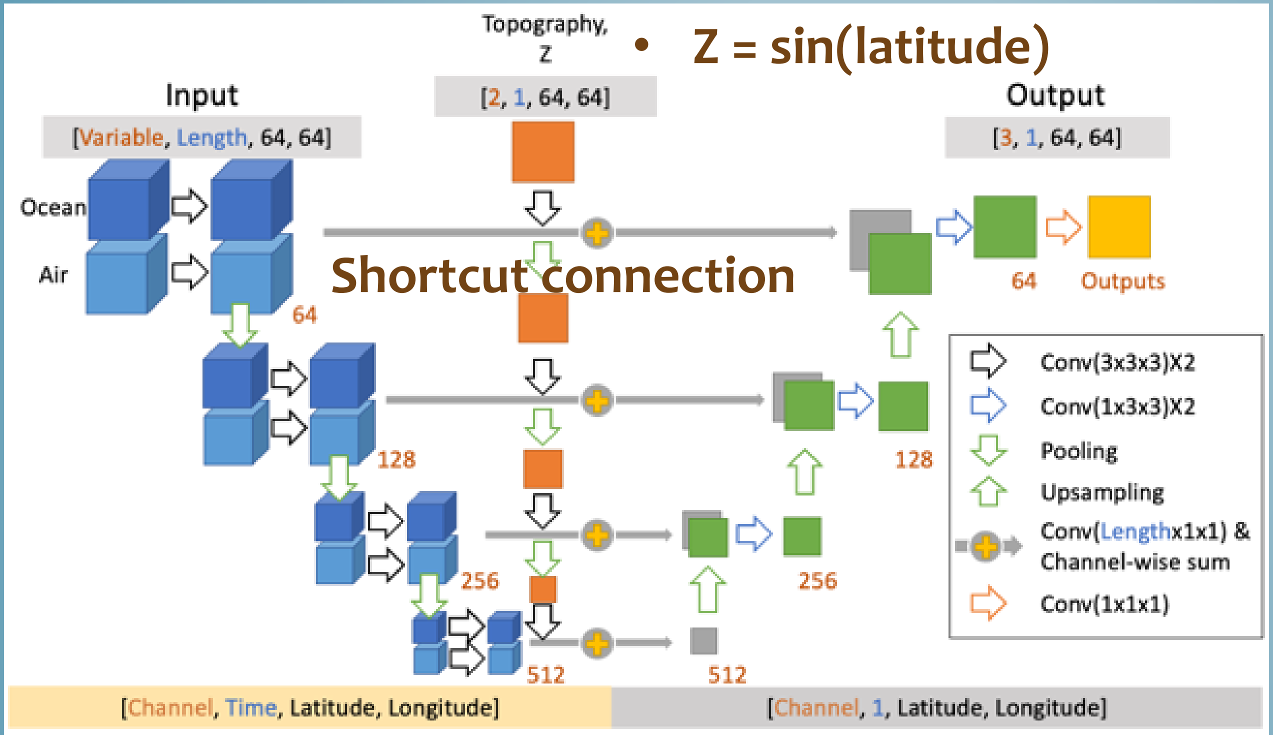
- Oceanic inputs – OPEM reanalysis data
  Time resolution: daily
  Spatial resolution: 1/20° → 1/16°
  Sea surface current (U, V, SSH)

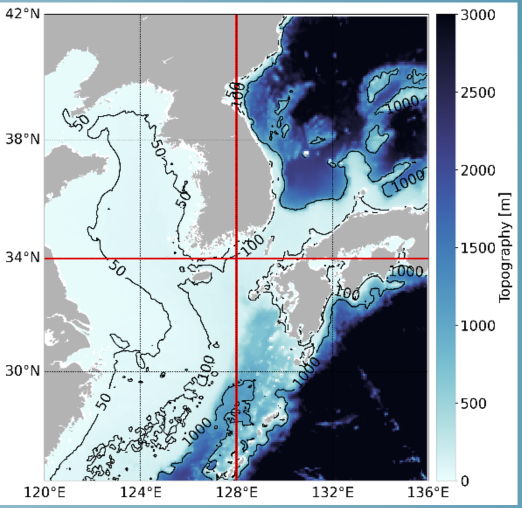
- Atmospheric inputs – ECMWF ERA5 reanalysis data
  Time resolution: hourly → daily
  Spatial resolution: 1/4° → 1/16°
  - Only 10 m above surface wind velocity (U10, V10)

- Train set: 1993–2012 (20 years)

- Test set: 2013-2014 (2 years)

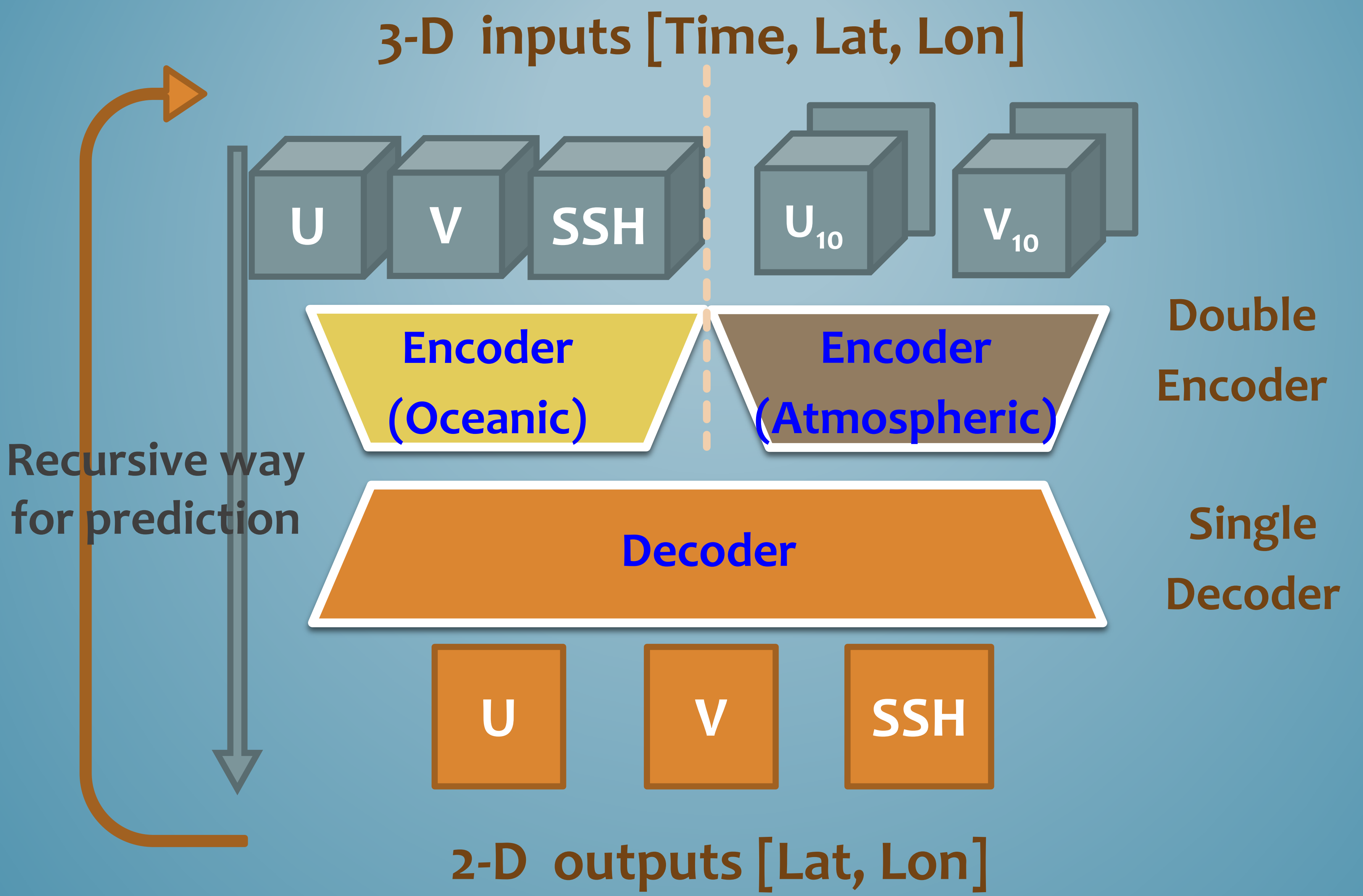
AI Methods





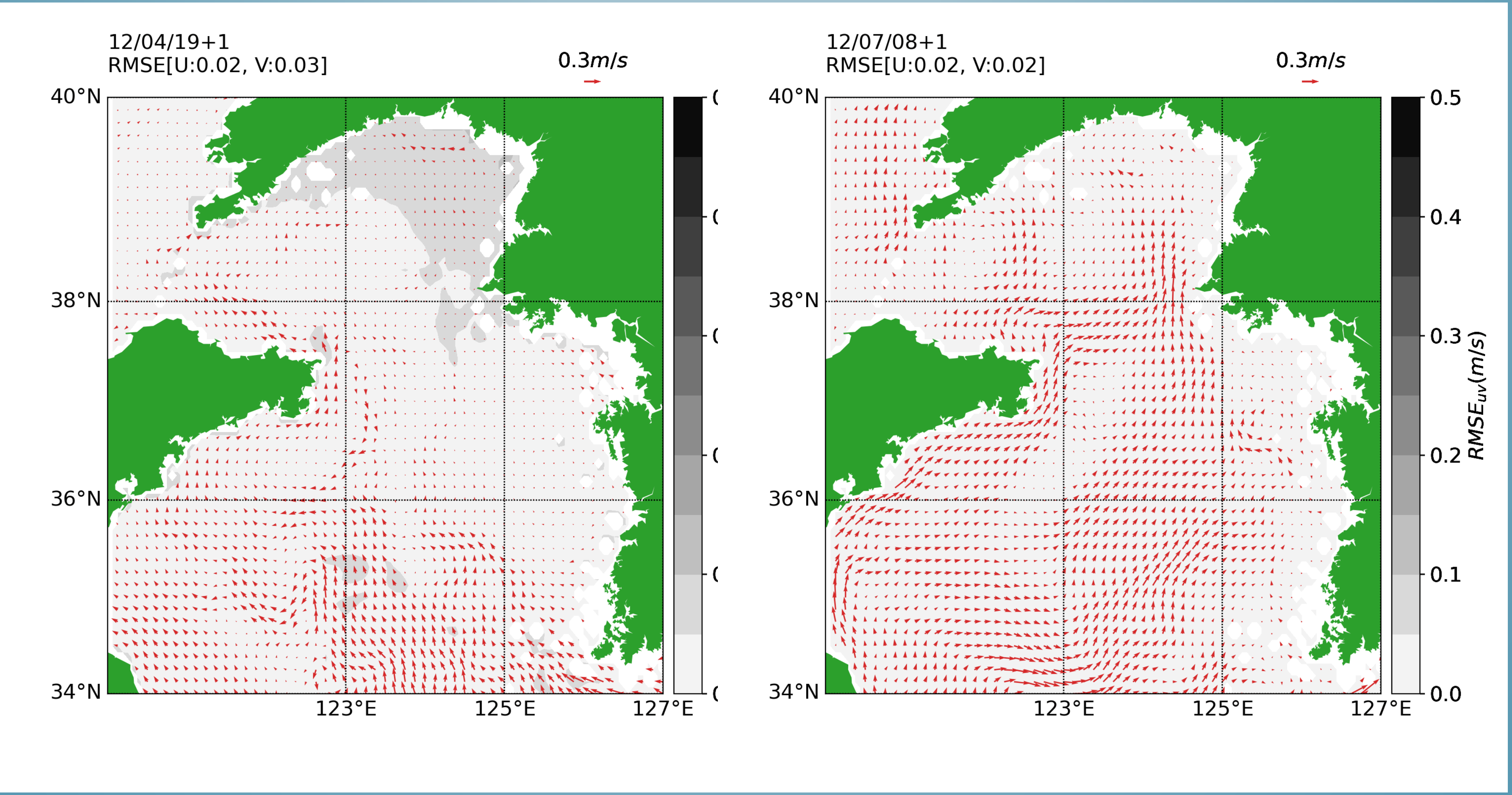
- The U-shaped network:
  Encoder-decoder structure with shortcut connection
- The full domain (256×256) are divided into four patches (128×128) and used in the training processes
- Double encoder for each oceanic and atmospheric data
- Topography data is included in the shortcut connection

AI Methods


3-D inputs [Time, Lat, Lon]
U
V
SSH
U10
V10
Encoder (Oceanic)
Encoder (Atmospheric)
Double Encoder
Decoder
Single Decoder
Recursive way for prediction
U
V
SSH
2-D outputs [Lat, Lon]

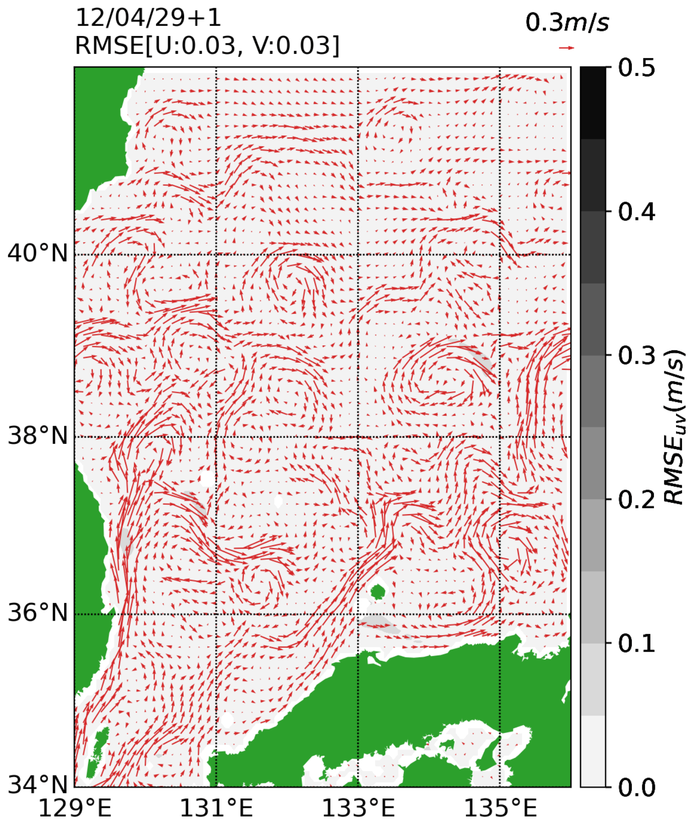
AI model prediction of surface current for 5 days: Yellow Sea

Start date: Apr. 19, 2012 Start date: Jul. 08, 2012

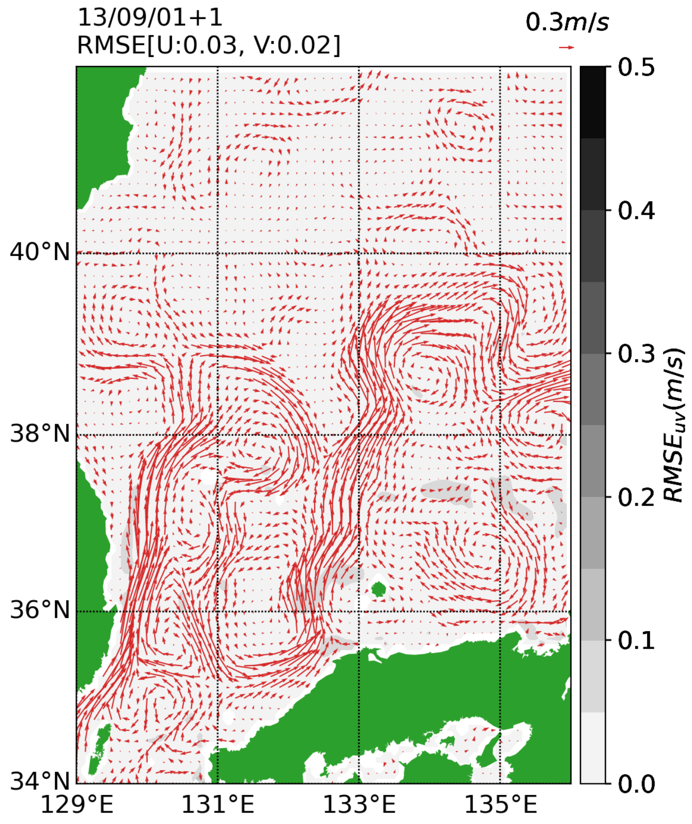


AI model prediction of surface current for 5 days: East Sea

Start date: Apr. 29, 2012

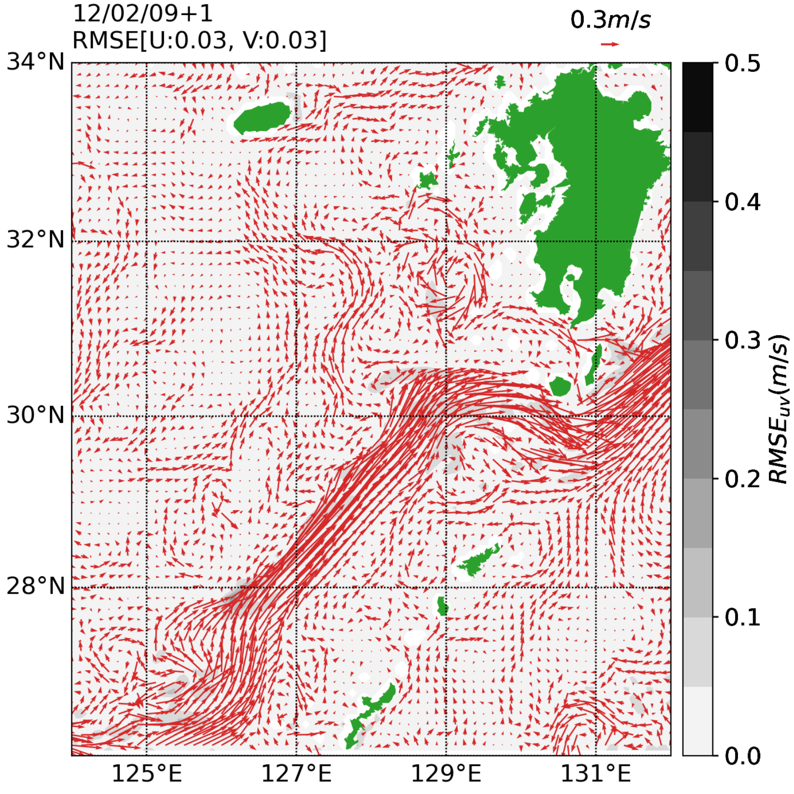


Start date: Sep. 01, 2013

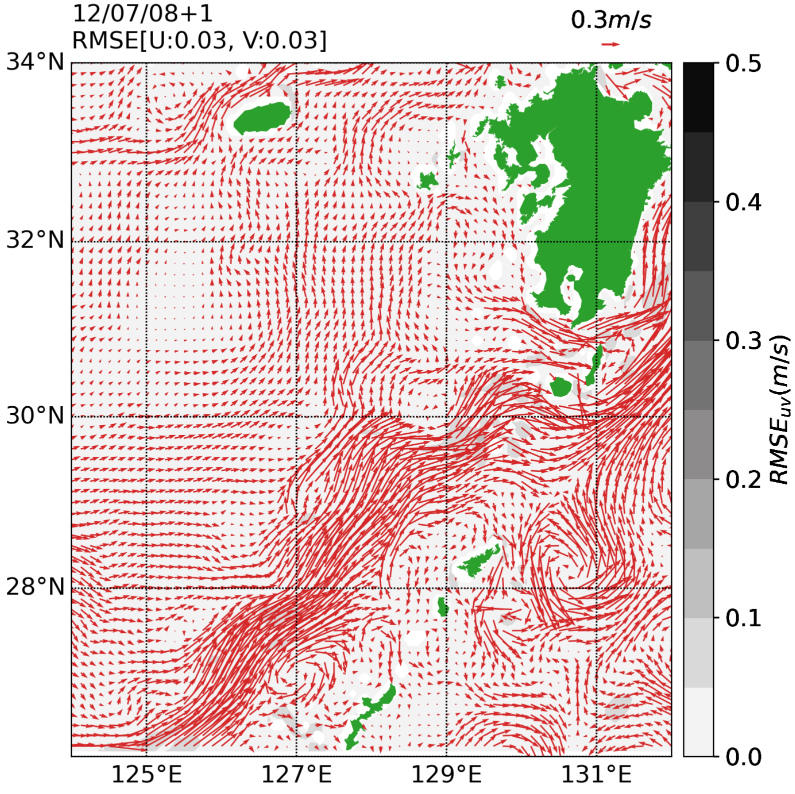


AI model prediction of surface current for 5 days : East China Sea

Start date: Feb. 09, 2012



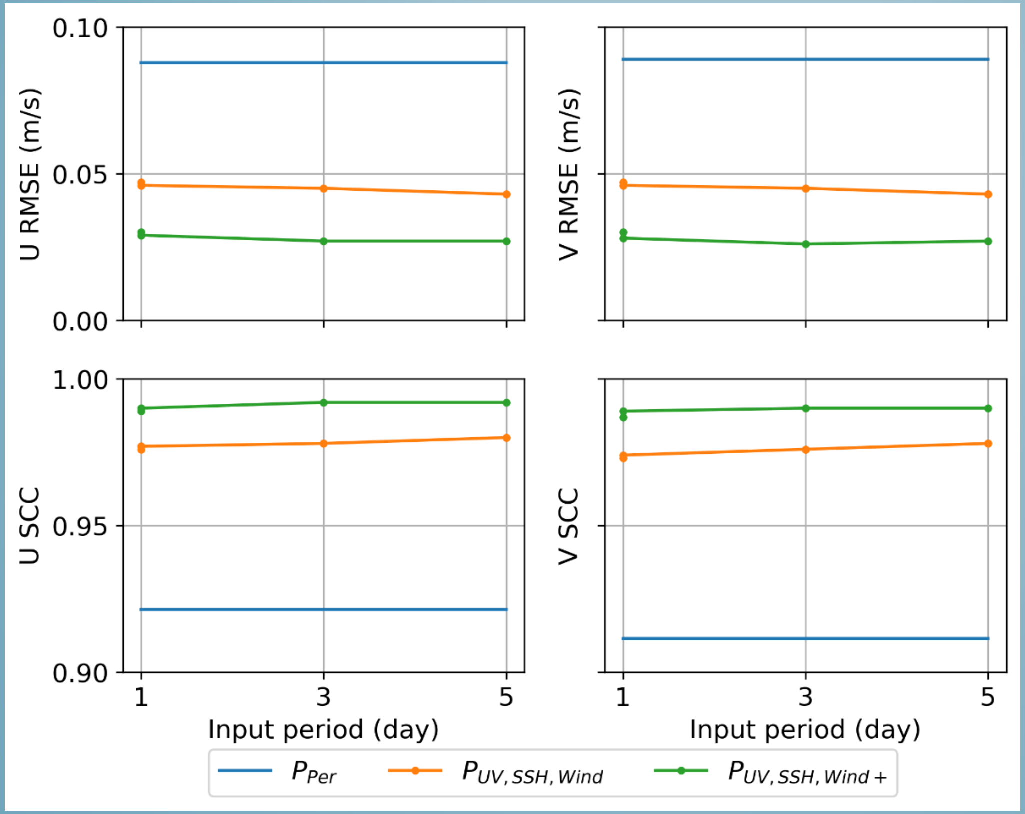
Start date: Jul. 08, 2012

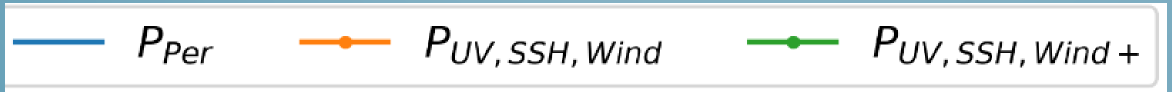


AI model performance depending on input periods and winds

RMSE of U

SCC of U (spatial correlation coefficient)

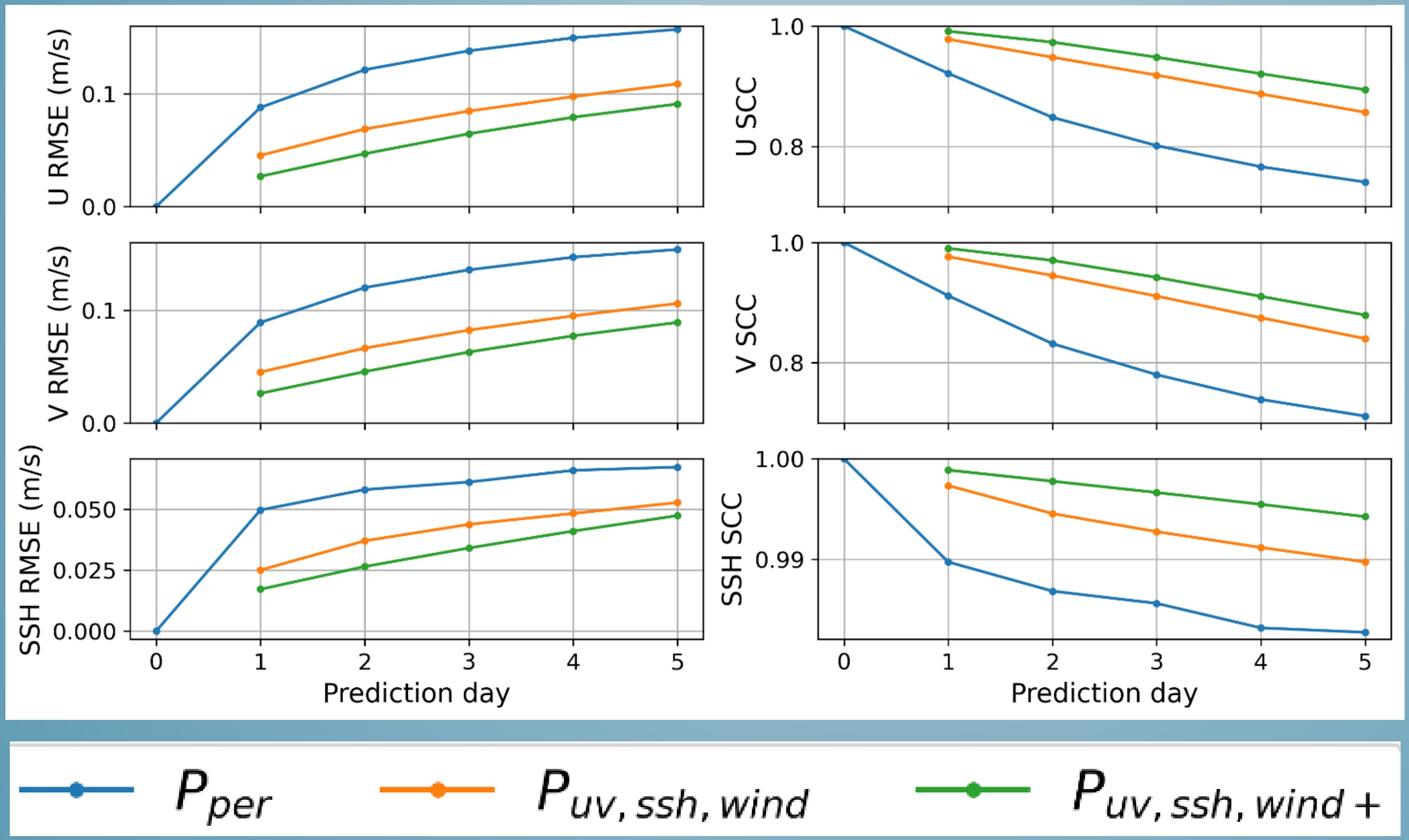




- **Optimal input periods are 3 to 5 days.**
- **The next-day wind input performs the best.**

- P_{per}: Persistence prediction (RMSE between today and tomorrow)
- $P_{UV,SSH,Wind}$: Prediction with surface current, SSH, and 10-m wind
- $P_{UV,SSH,Wind+}$: $P_{UV,SSH,Wind}$ with the next-day wind

AI model errors depending on predicting days
=> RMSE=~0.07 m/s for the prediction on day 3



RMSE of U

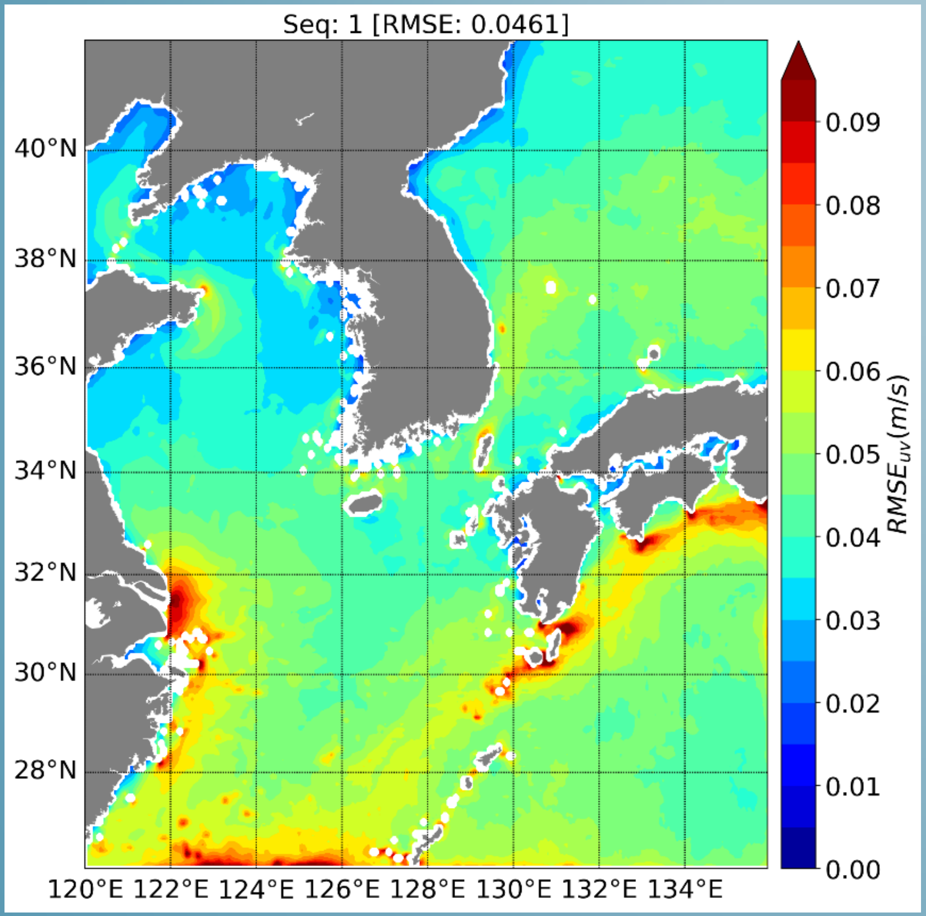
RMSE of V

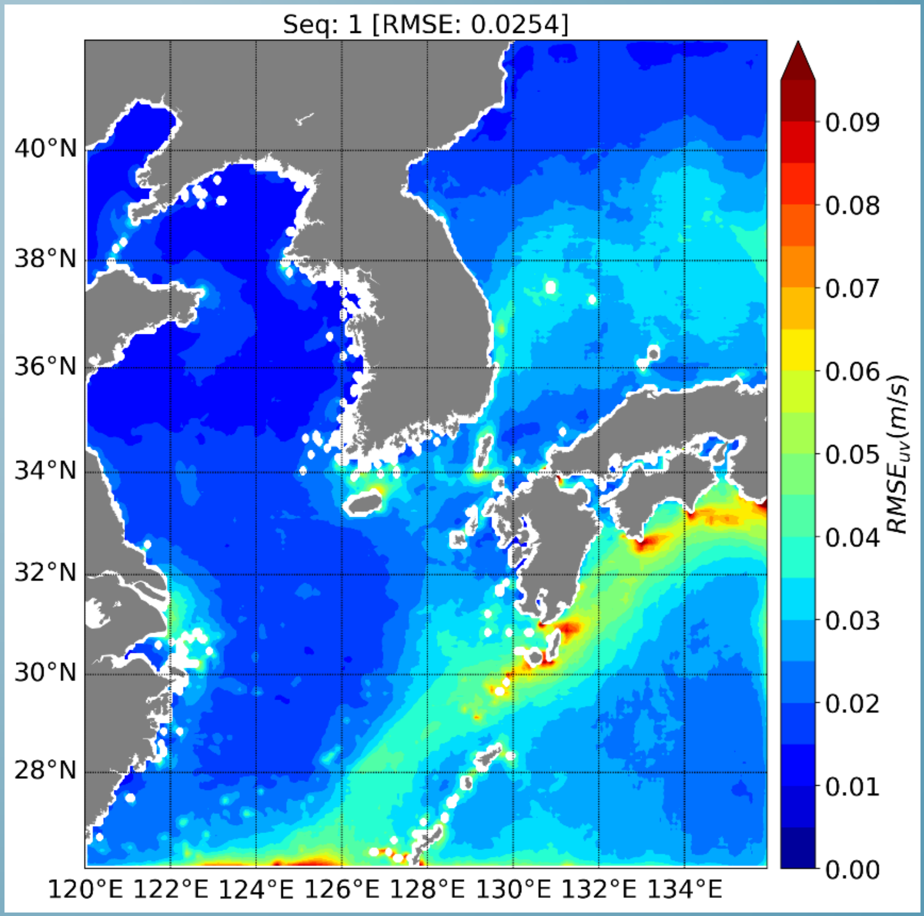
RMSE of SSH

- P_{per}: Persistence prediction (RMSE between today and tomorrow)
- $P_{UV,SSH,Wind}$: Prediction with surface current, SSH, and 10-m wind
- $P_{UV,SSH,Wind+}$: $P_{UV,SSH,Wind}$ with the next day’s wind

Effects of wind+ on the current prediction

Prediction using U, V, SSH, wind | using U, V, SSH, wind+



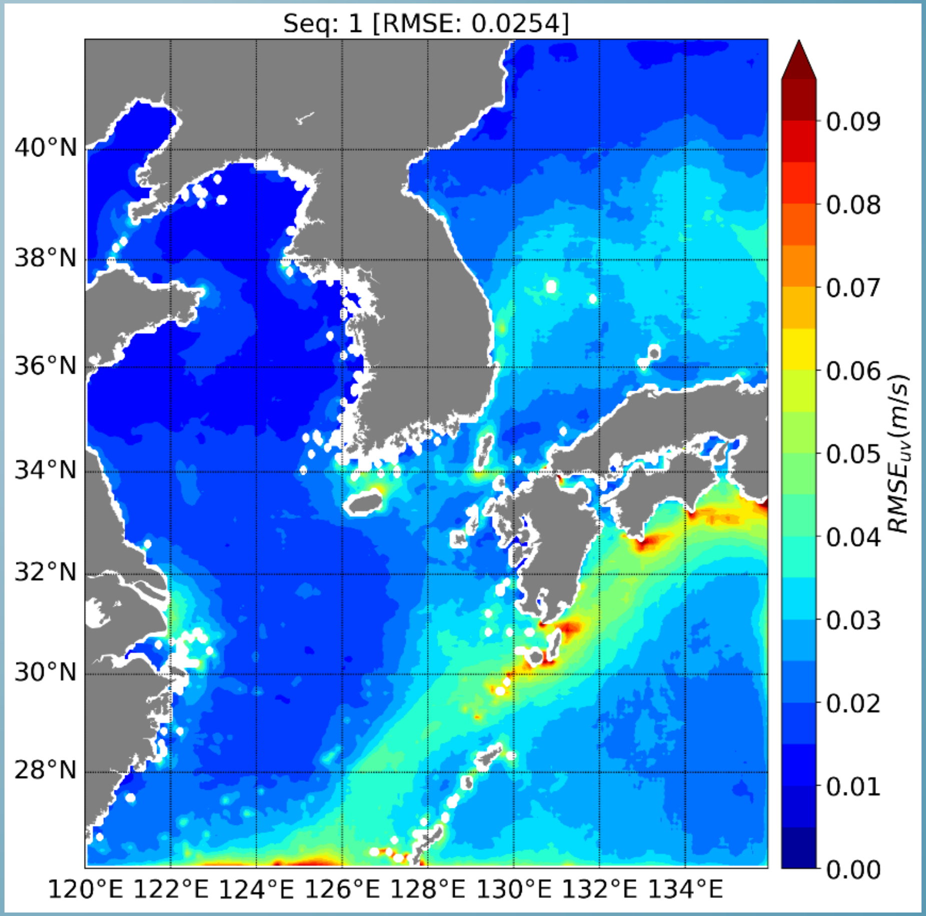


Error distribution of uv-component averaged RMSE ($RMSE_{uv}$) for the 1st prediction day (Input days = 3)

Effects of wind+ on the current prediction

- The input of the next-day wind (wind+) results in a significant improvement in the Yellow Sea as expected. In addition, open sea areas also show some improvement.
- Yangtze River discharge prediction is also improved with wind+
- The effects of wind+ on the strong geostrophic currents such as the Kuroshio and the East Korea Warm Current are rarely seen.

using U, V, SSH, wind+

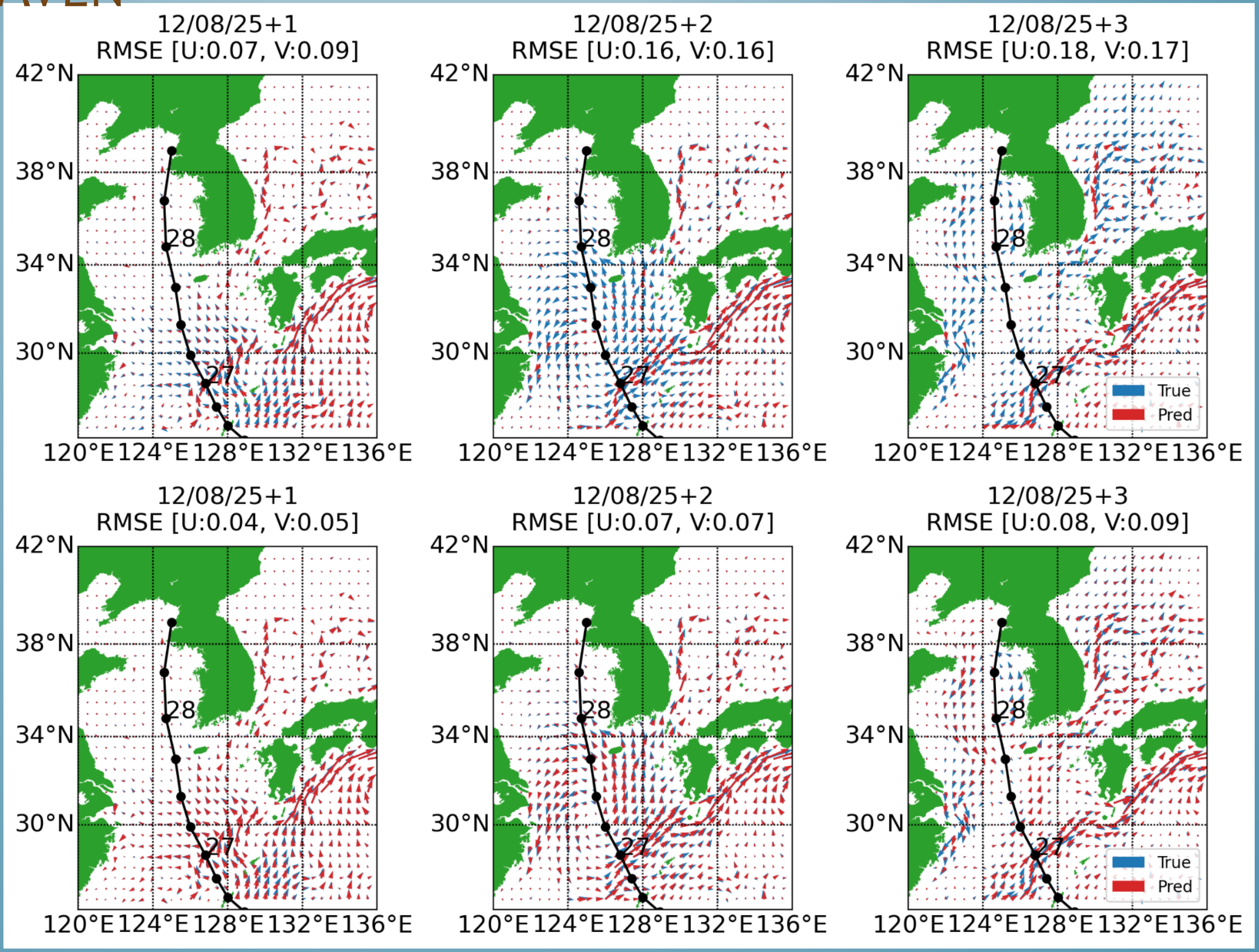


Prediction of typhoon-induced currents improves when the next-day winds (wind+) are used

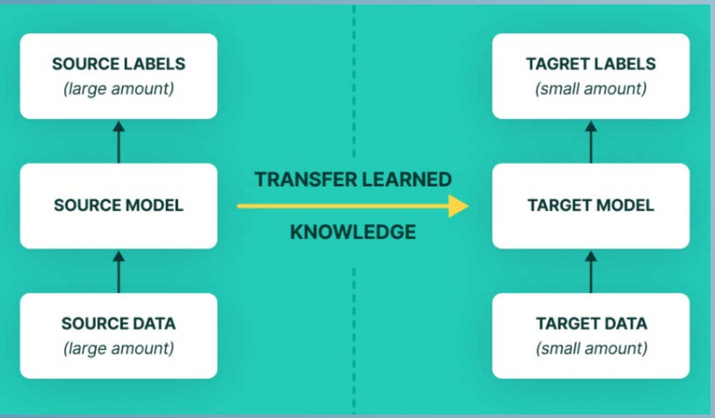
Typhoon: BOLAVEN

$P_{UV,SSH,Wind}$

$P_{UV,SSH,Wind+}$



Transfer learning



https://www.v7labs.com/blog/transfer-learning-guide

Source data

Oceanic input – OPEM reanalysis data

Atmospheric input – ECMWF ERA5 data

- Train set: 1993–2012 (20 years)
- Test set: 2013-2014 (2 years)

$P_{UV,SSH,Wind+}$ Transfer learning

Target data

Oceanic input – OPEM analysis data

Atmospheric input –KMA GDAPS data

- Train set: 2017–2020 (4 years)
- Test set: 2021 (1 year)

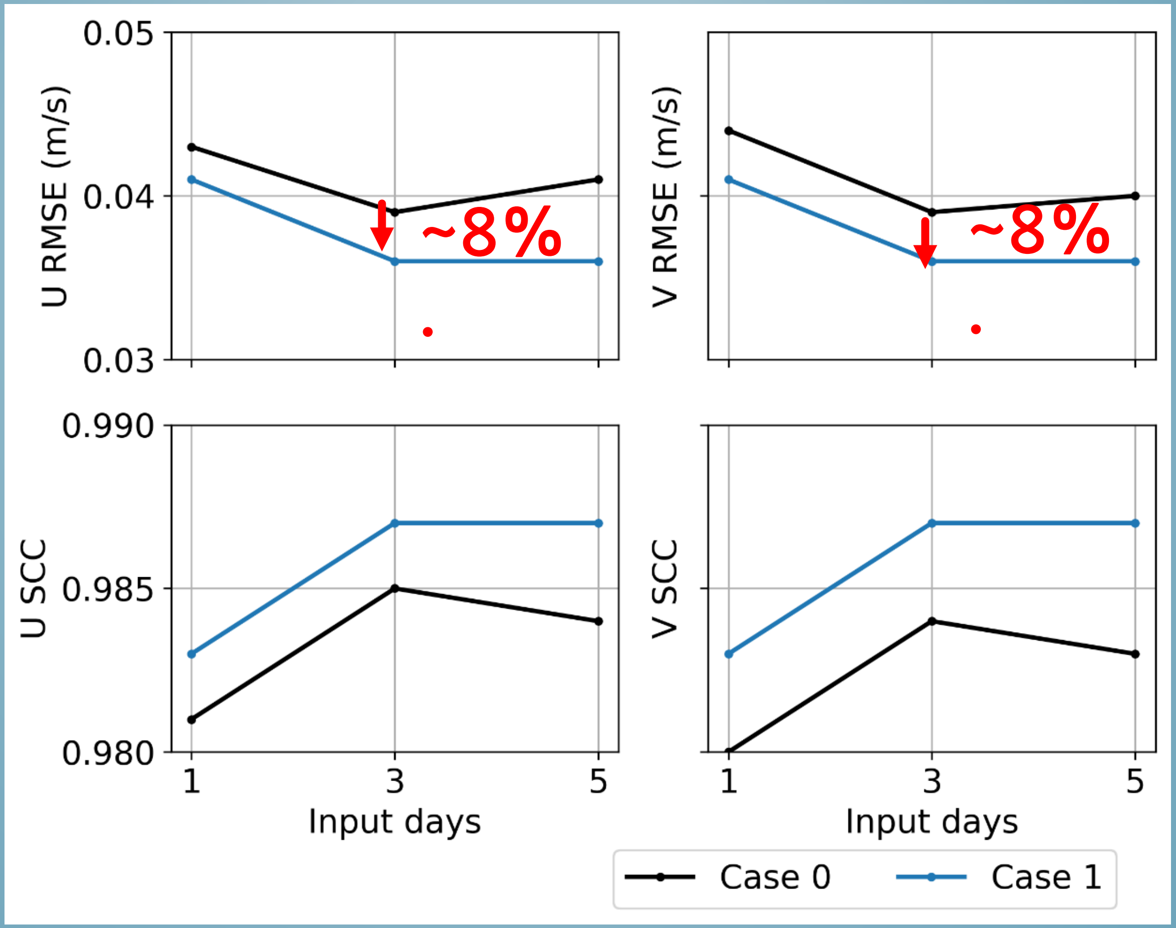
Improvement of current prediction using transfer learning

RMSE:

P_{per}≈0.1

SCC:

P_{per}≈0.89

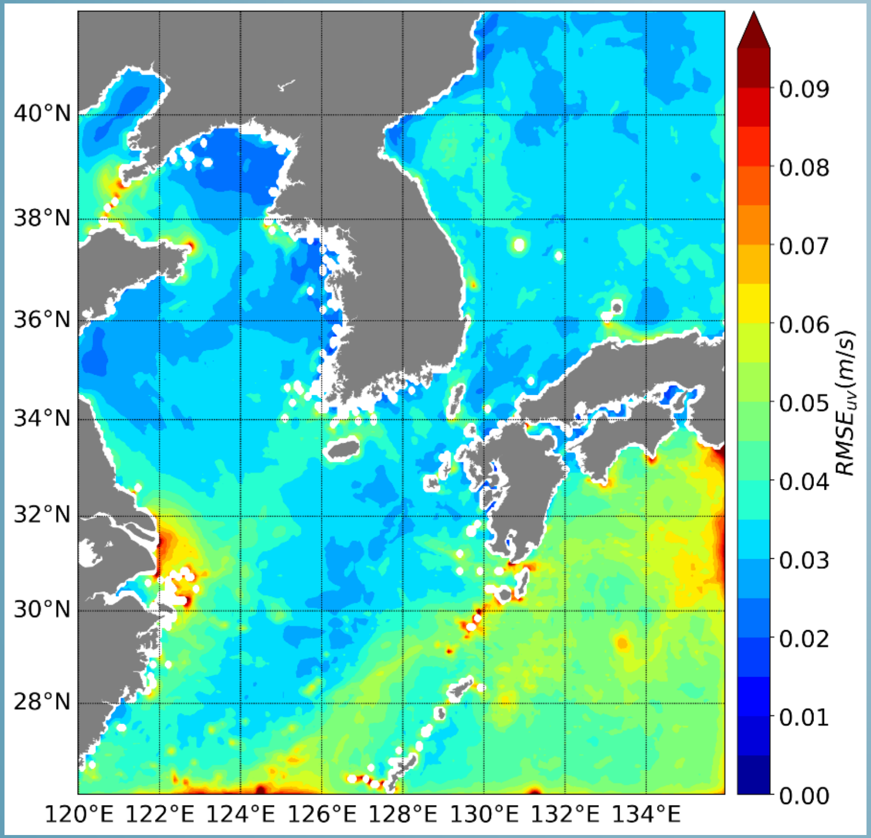


Case0: <u>No</u> transfer learning case

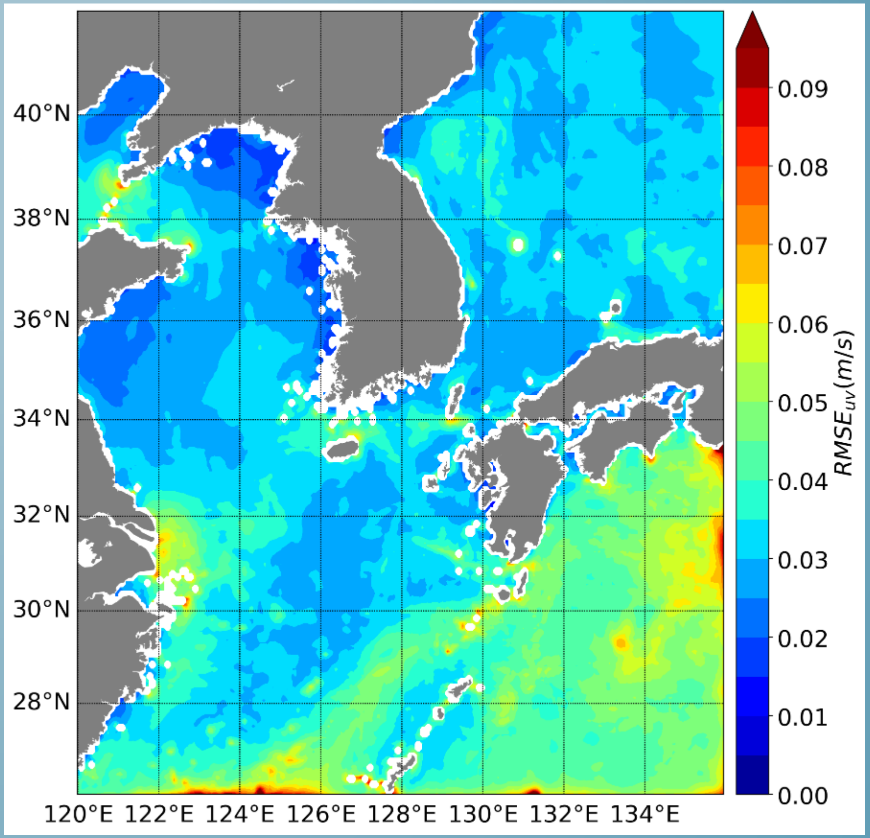
Case1: Transfer learned case

(from 20 years of reanalysis data)

Improvement of current prediction using transfer learning



Case0 (No transfer learning)



Case1 (transfer learning)

Error distribution of uv-component averaged RMSE ($RMSE_{uv}$) for the 1st prediction day (Input days = 3)

Conclusions

- The U-shaped 3-D CNN model is applied to predict the sea surface current around Korean peninsula.
- The AI model including the next-day wind data shows the better performance than the other models. In addition, it could successfully simulate extreme events caused by the typhoon passage.
- Transfer learning can improve the performance of the sea surface current prediction.
- High resolution ocean prediction system using CNNs can be a practical and efficient way with a lightweight computing power.