climate change initiative

LAKES

# Towards the Development of Global Gap-Filled Lake Surface Water Temperature and Ice Cover Products

L. Carrea, C.R. Duguay, S.J. Johnston, C.J. Merchant, J. Murfitt, S. Shaetar, N. McCarroll

**7th LAKES workshop on**
**Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling**
**20-22 November 2024 – Milano**

lakes cci

CLS · National Research Council of Italy · LEGOS · Sertit ICUBE · University of Reading · H2O Geomatics · PML Plymouth Marine Laboratory · Brockmann Consult · eawag aquatic research · NORCE · University of Stirling

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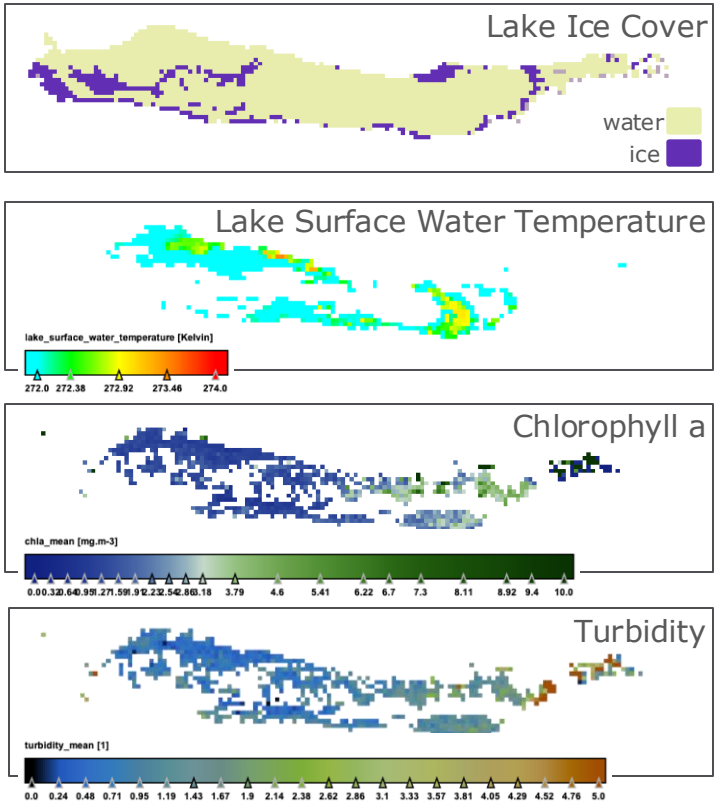
- ESA CCI LAKES v2.1 dataset – Lakes Surface Water Temperature and Ice Cover observations
- Demand for gap filled data from users and ARCLake experience
- Overview and objective of the project and lake selection
- LSWT/LIC gap filling techniques to explore on lake selection
- Final dataset characteristics and timing

# ESA CCI LAKES v2.1 dataset

Kaptchagayskoye - Kazakhstan



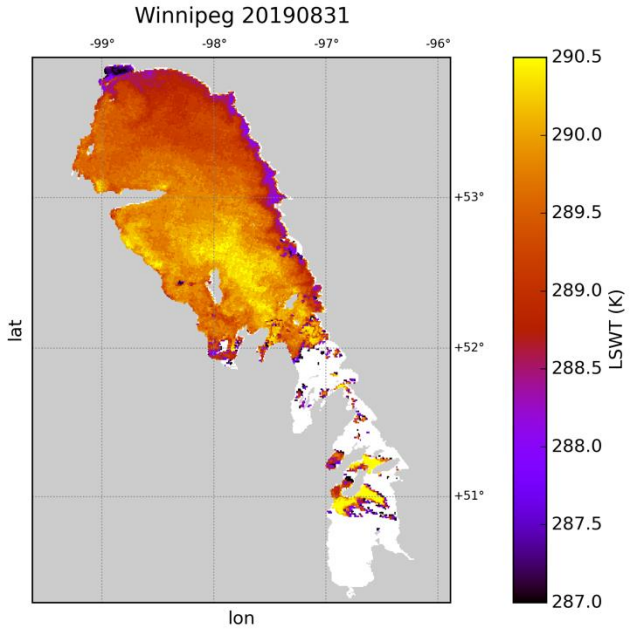

Lake Surface Water Temperature
Lake Ice Cover
Lake Ice Thickness
Lake Water Leaving Reflectance
Lake Water Extent
Lake Water Level

| | |
|---|---|
| Spatial resolution | 1/120° |
| Temporal resolution | Daily (best) |
| Spatial coverage | 2024 lakes (best) |
| Temporal coverage | 1992-2022 (best) |

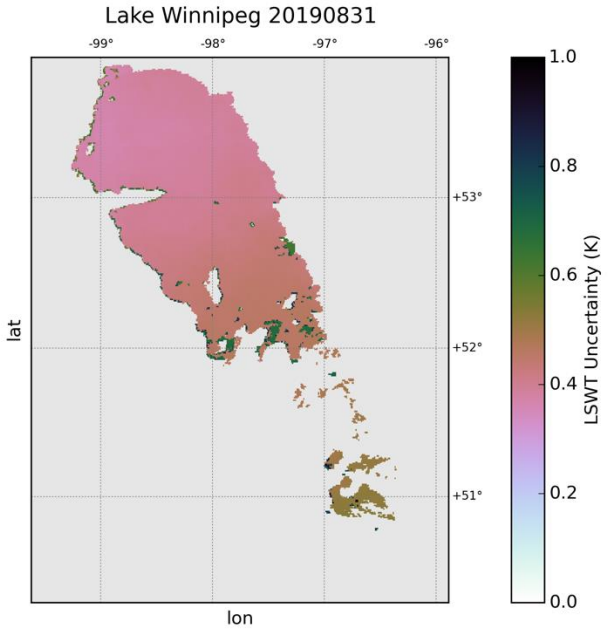
Carrea, L., Crétaux, JF., Liu, X. *et al.* Satellite-derived multivariate world-wide lake physical variable timeseries for climate studies. *Sci Data* **10**, 30 (2023)

# ESA CCI LSWT and LIC observations

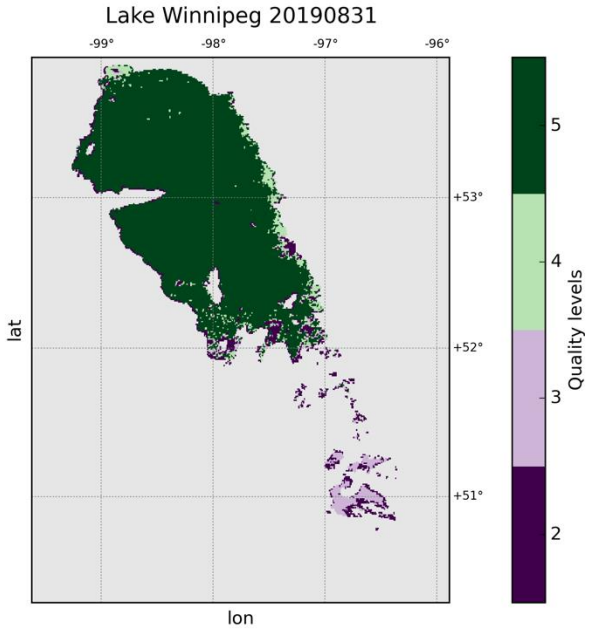
## LSWT @1/120° resolution




LSWT



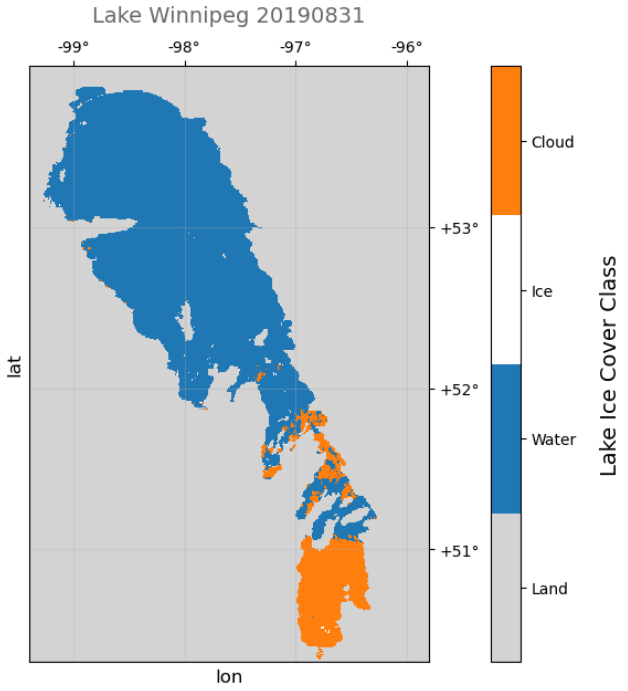

LSWT uncertainty

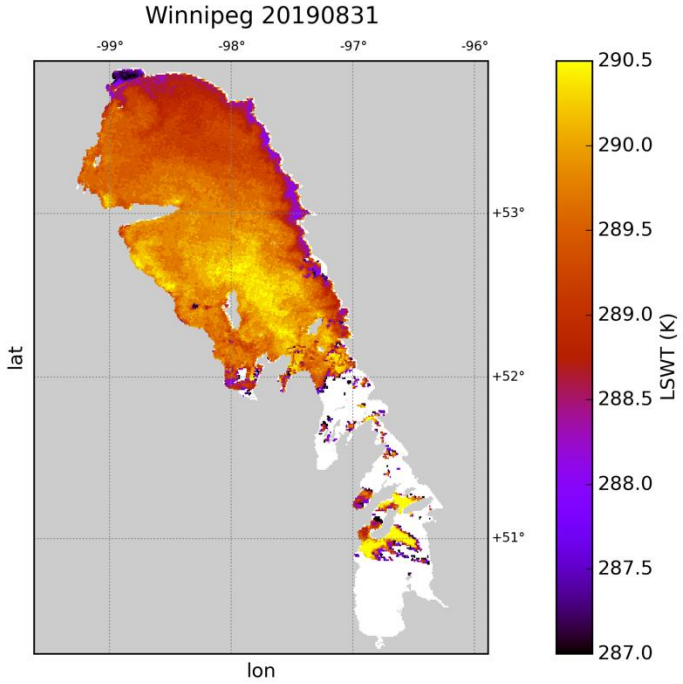



LSWT quality levels

# ESA CCI LSWT and LIC observations

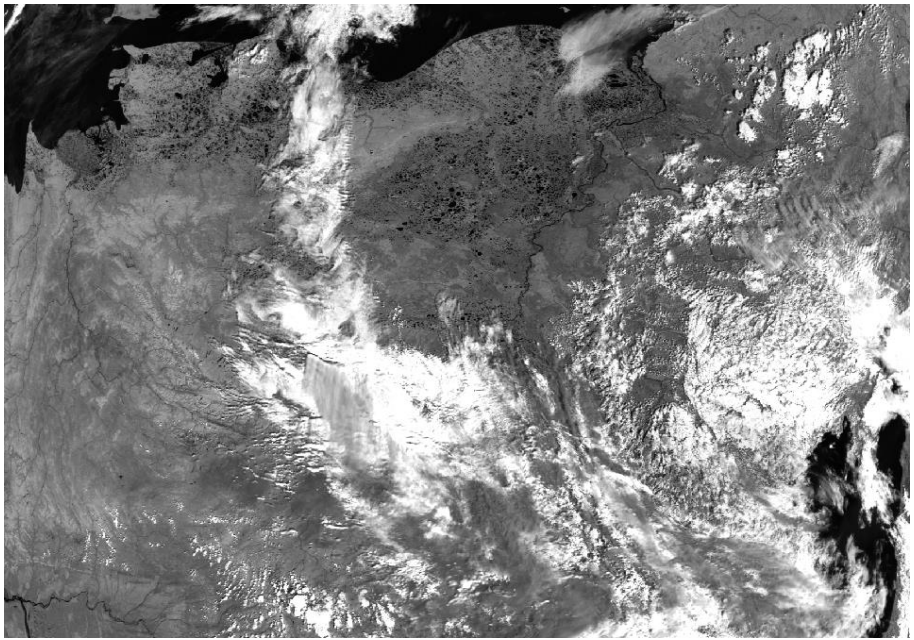
## LIC @1/120° resolution



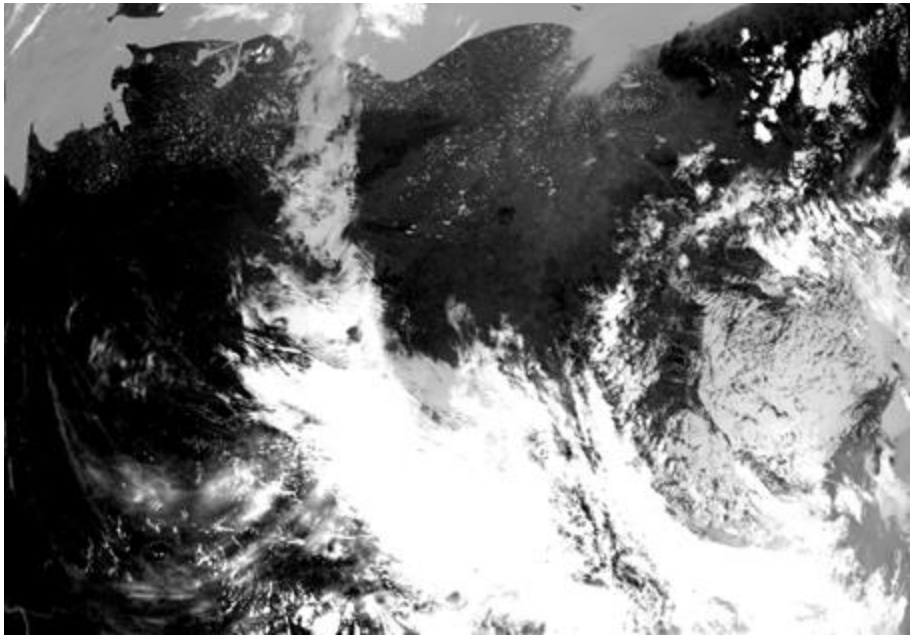



# ESA CCI LSWT and LIC observations

AVHRRA 2012-06-15



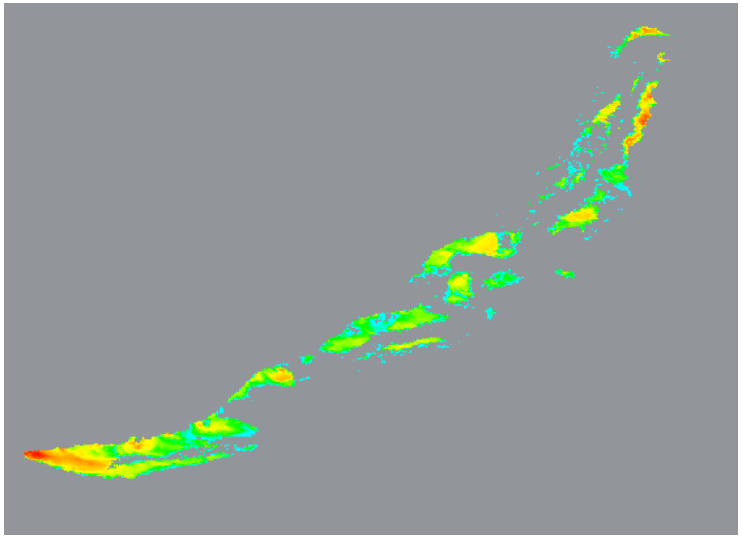
Reflectance 1610 nm

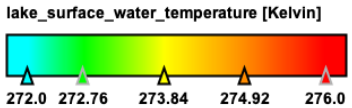


Brightness temperature 10800 nm

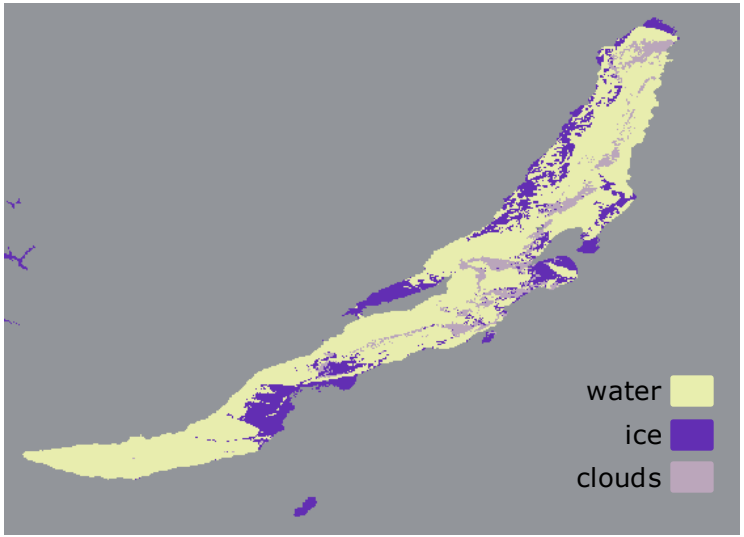
# ESA CCI LSWT and LIC observations

## LSWT






## LIC



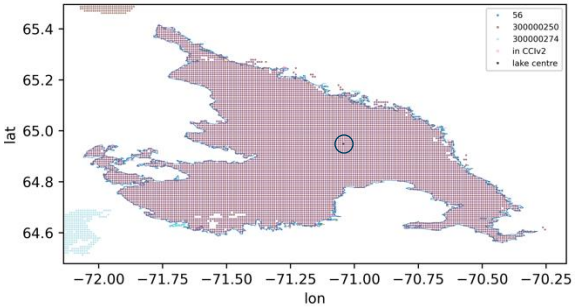

2022-12-27

# Scientific context and ARCLake dataset

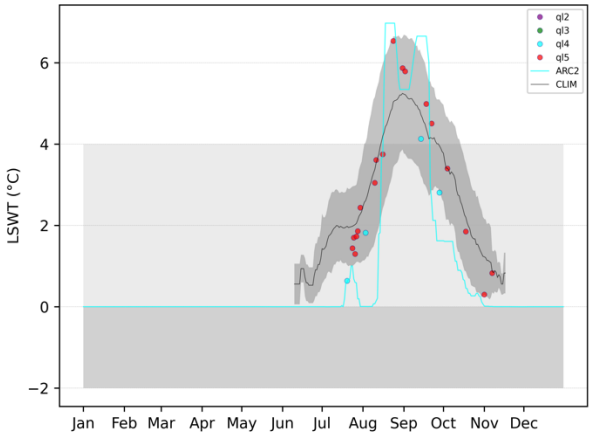
## Context

- Strong user demand for a gap-filled LSWT+LIC dataset (climate studies, weather forecast,…)
- ESA ARCLake (2010-2013) LSWT+LIC gap-filled data usage exceeded the filled data users
- ARClake work highlighted that per-lake optimisation of gap-filling procedures is required
- Dataset contained 1628 lakes

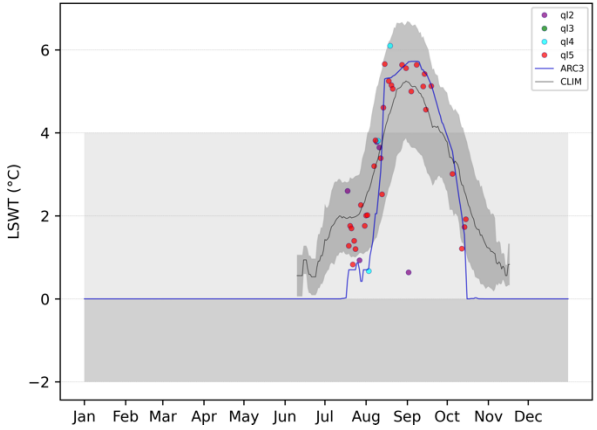
Amadjuak lake - Canada




LSWT comparison at lake CENTRE lake 56 year 2001




LSWT comparison at lake CENTRE lake 56 year 2011




**CCI v2.1 LSWT and ARCLake reconstructed LSWT**

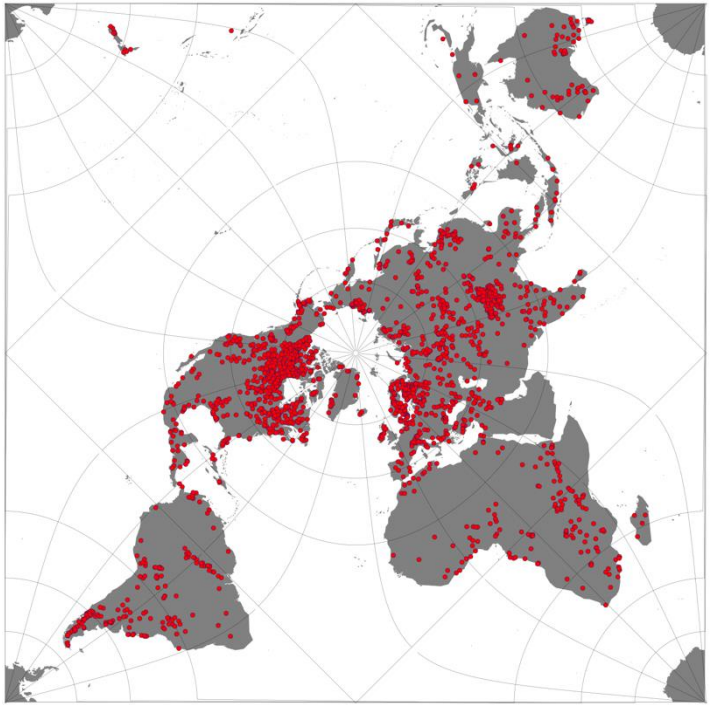
# Objectives of the project

## Objectives

- Create a gap-filled LSWT and LIC dataset
- Verify/apply the consistency between LSWT and the LIC
- Validate the results also through manual inspection
- Create an automated process for LSWT+LIC L4 dataset for future versions

**Attempt for the 2024 ESA CCI lakes during 2000-2023**

**2024 CCI lakes**



# Overview of the project

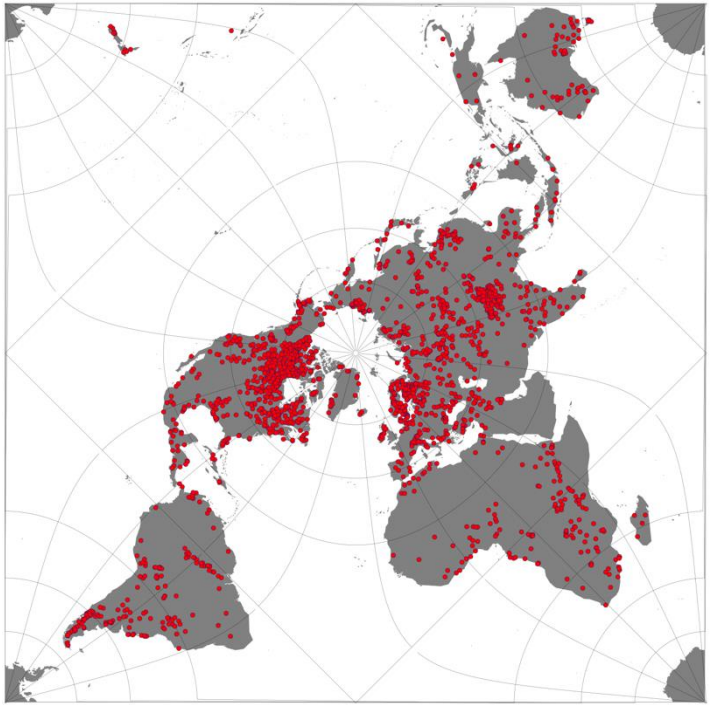
**Phase 1**

- Establish gap-filling methodology on a selection of lakes.
- Detailed verification of the gap filled LSWT+LIC product for the selected lakes.
- Devise strategies for unsuccessful lakes

**Phase 2**

- Verify the consistency of LSWT and LIC
- Create the product for the 2000 lakes
- Verify/validate and automatization

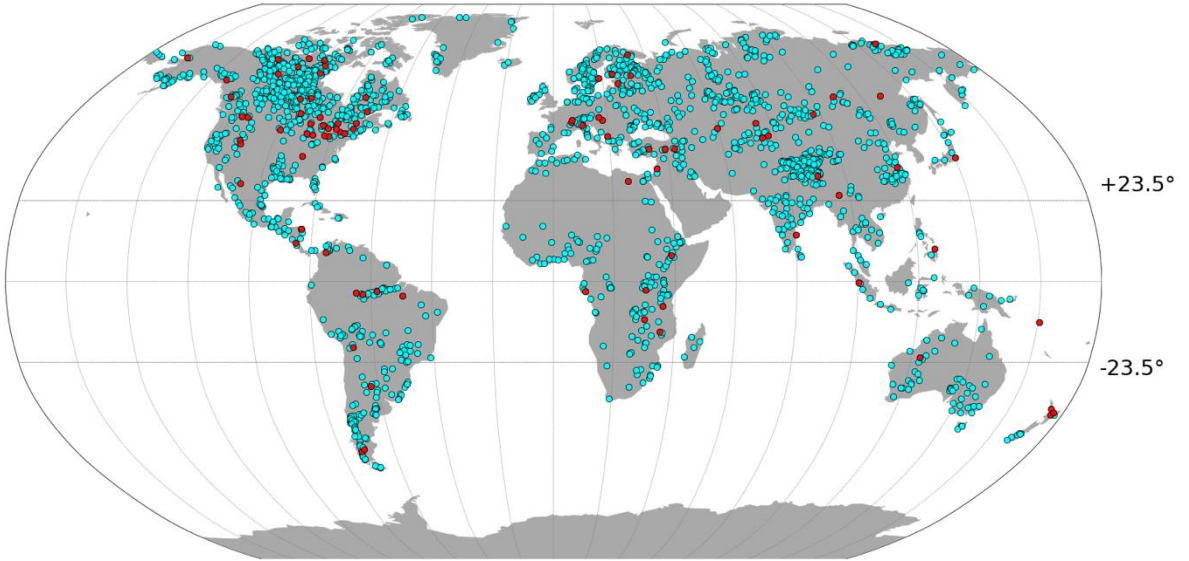
**2024 CCI lakes**



# LSWT + LIC gap filling – Lake selection

- The ~100 lakes are selected to be representative of the ~2000 lakes full dataset.
- Selected on the base of metrics such as **percentage of pixels with observations**, **number of day with observations**, **spatial LSWT variation**, **size**, **ice phenology**, **reflectance (color)**
- Lakes with LSWT insitu data

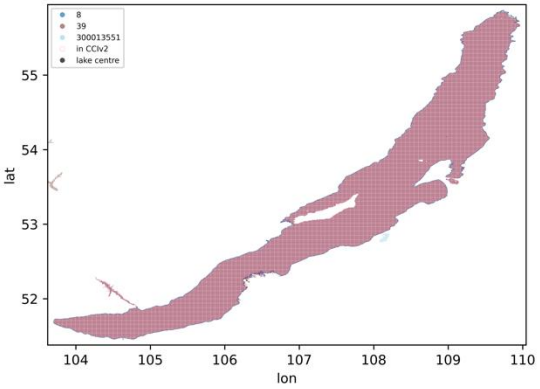
Lake selection geographical distribution

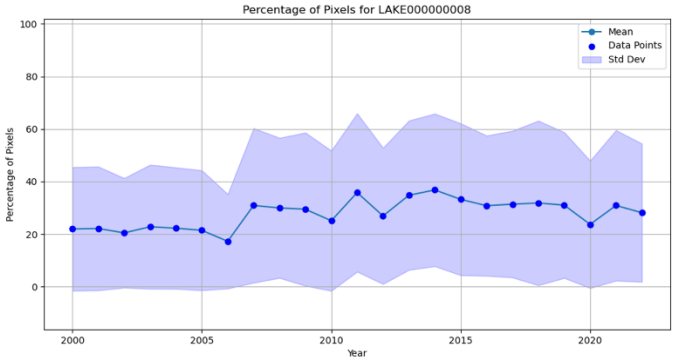


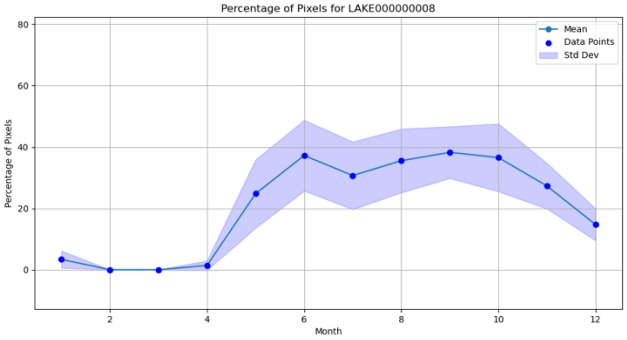
# LSWT metrics

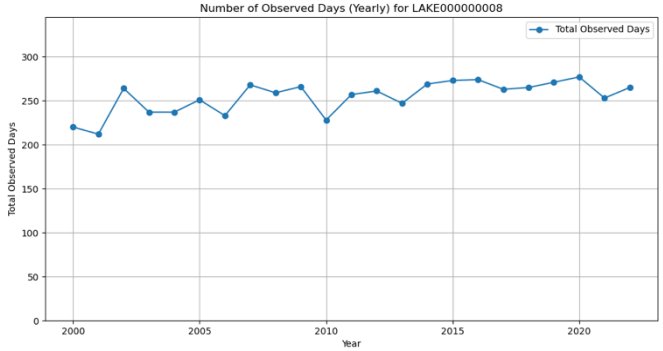
## How many pixels/days do we have to fill?

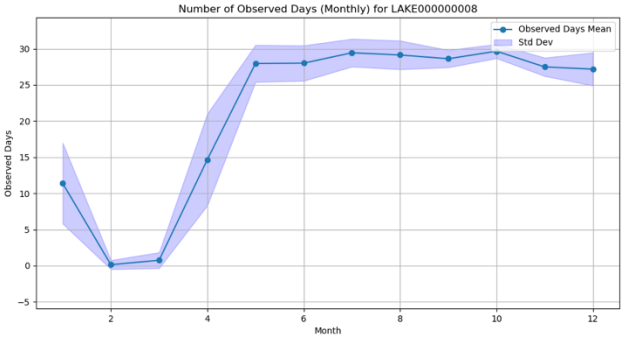
Lake Baikal - Russia



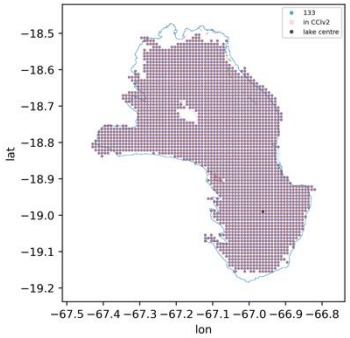



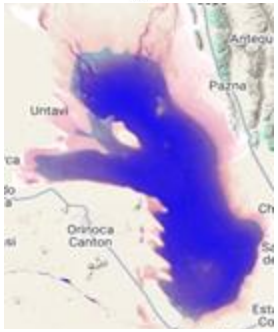



# LSWT metrics

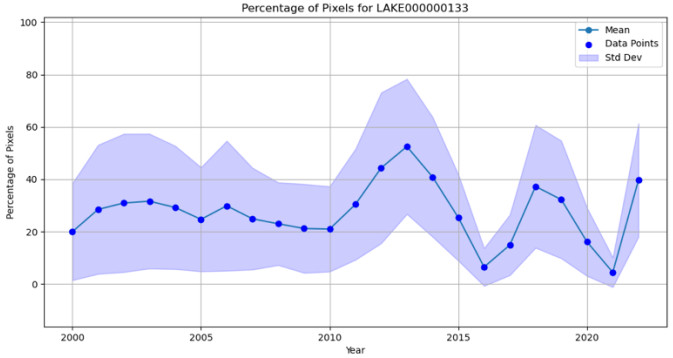
## How many pixels/days do we have to fill?

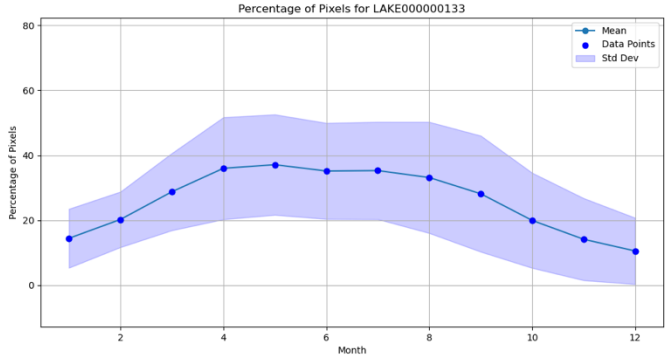
Poopo lake - Bolivia

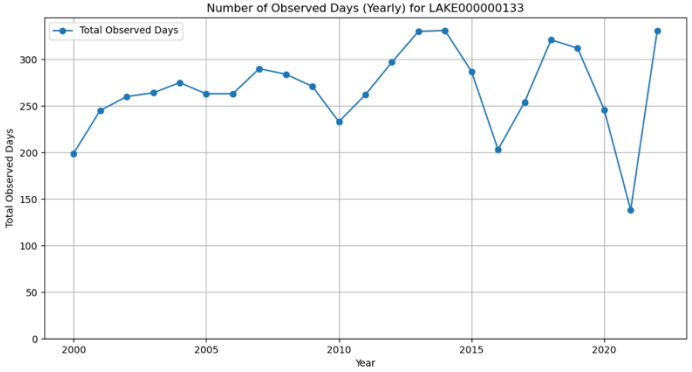


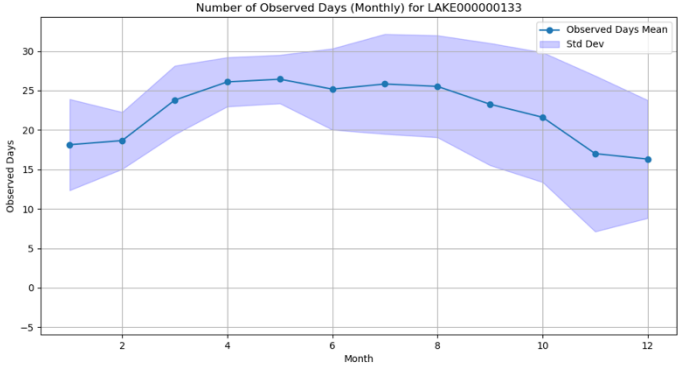




[Pekel, 2016]



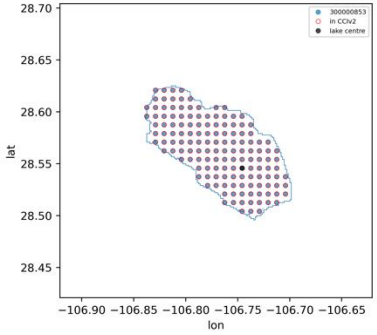



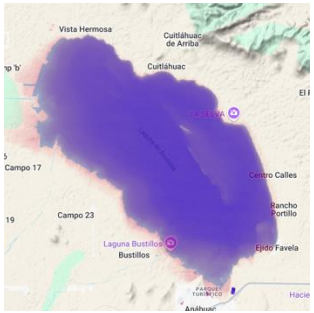
# LSWT metrics

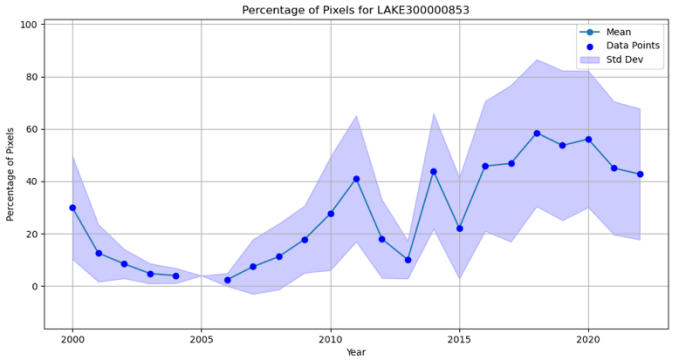
## How many pixels/days do we have to fill?

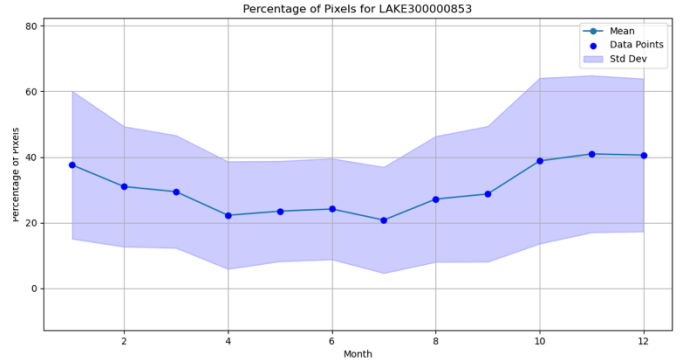
Bustillos lake - Mexico

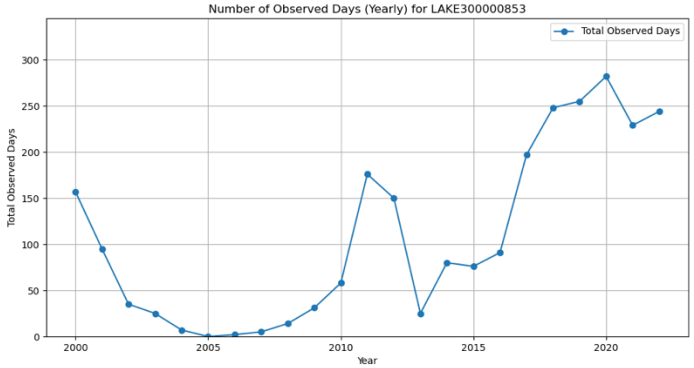


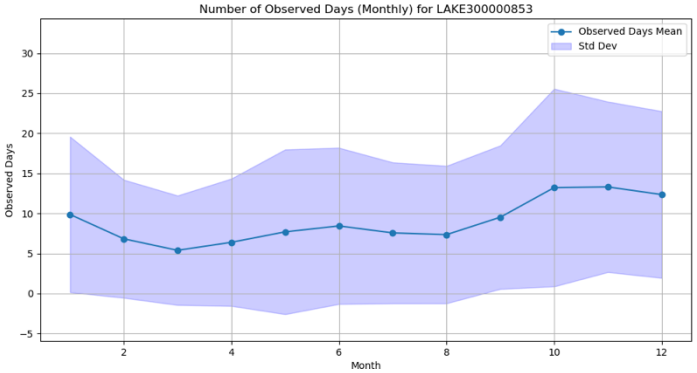

[Pekel, 2016]



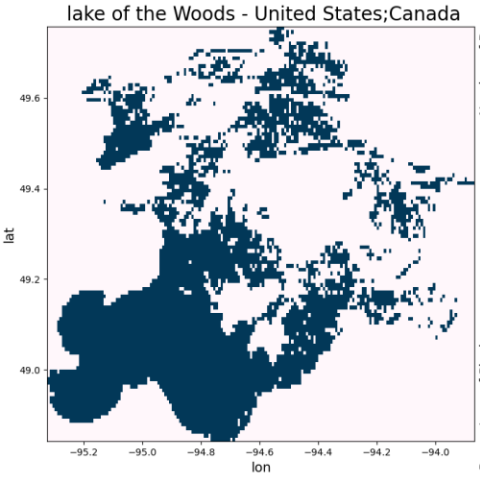



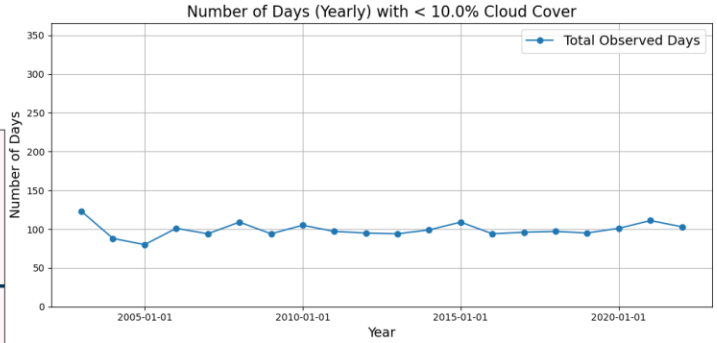



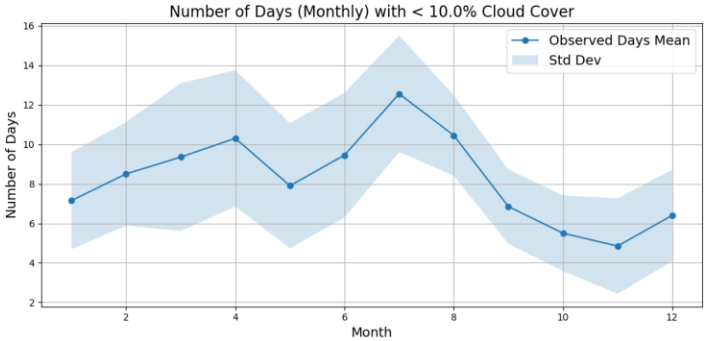



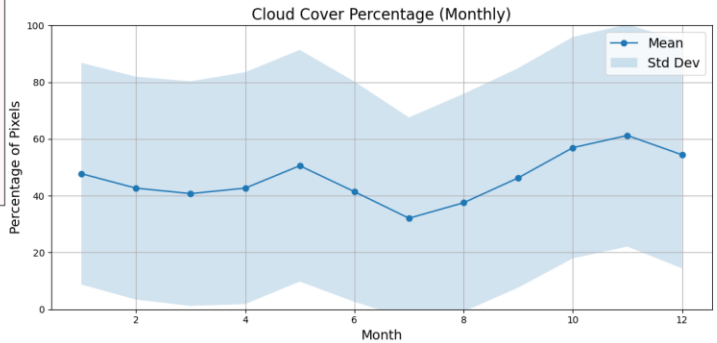



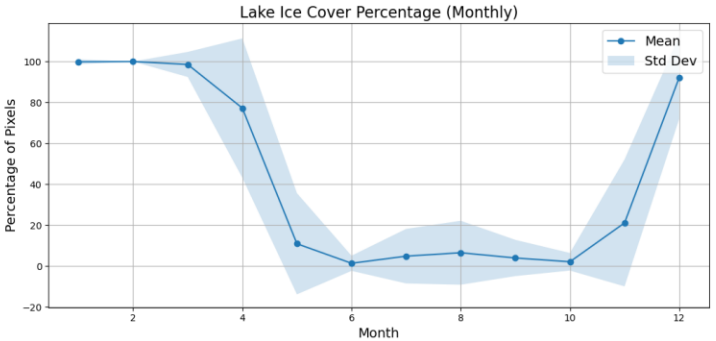
# LIC metrics



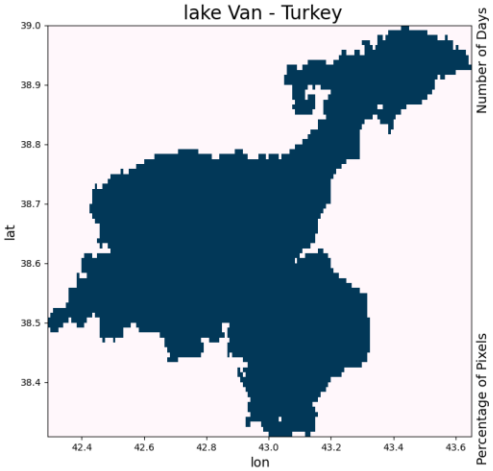



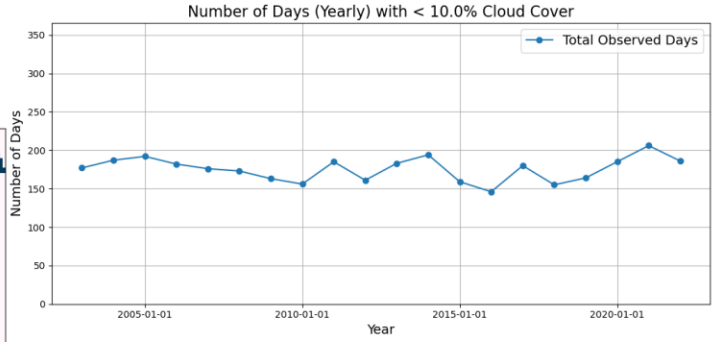



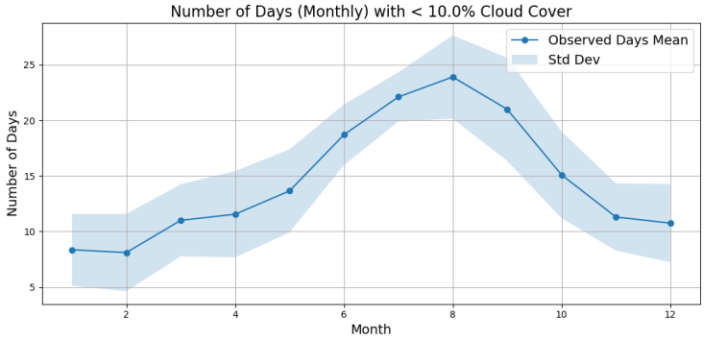



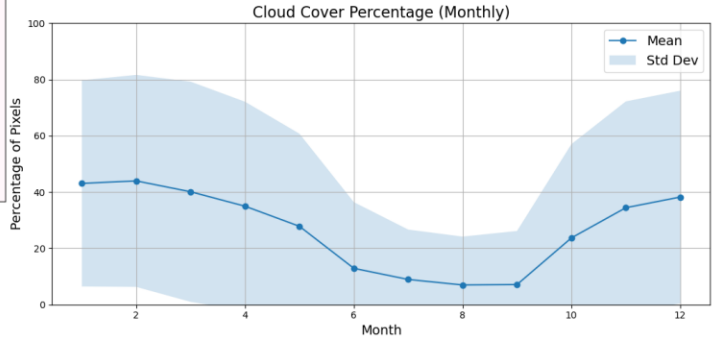



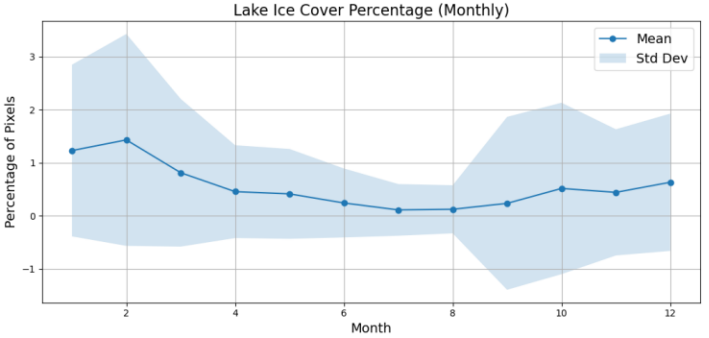
# LIC metrics



# LSWT gap filling

Two algorithms to be evaluated:

- **DINEOF** (Data Interpolating Empirical Orthogonal Function): optimized **EOF** through iteration of cross validation. It was used for the ARCLake dataset and has been used to reconstruct surface temperature and chlorophyll-a.
- **DINCAE** (Data Interpolating Convolutional Auto-Encoder): a **machine learning algorithm** which allow modelling of non-linear spatial and temporal relationships. Based on a training phase and a reconstruction phase.

Both, can be used to **reconstruct multivariate datasets**.

For both the algorithm, **preprocessing** of the data is necessary to

- exclude inaccurate observations that could negatively influence the reconstructions
- ensure that sufficient observations are present

For lakes with **low number** of observations different strategies will be explored

# LIC gap filling

## Proposed work logic for LIC

1. **Model Exploration**(Complete):

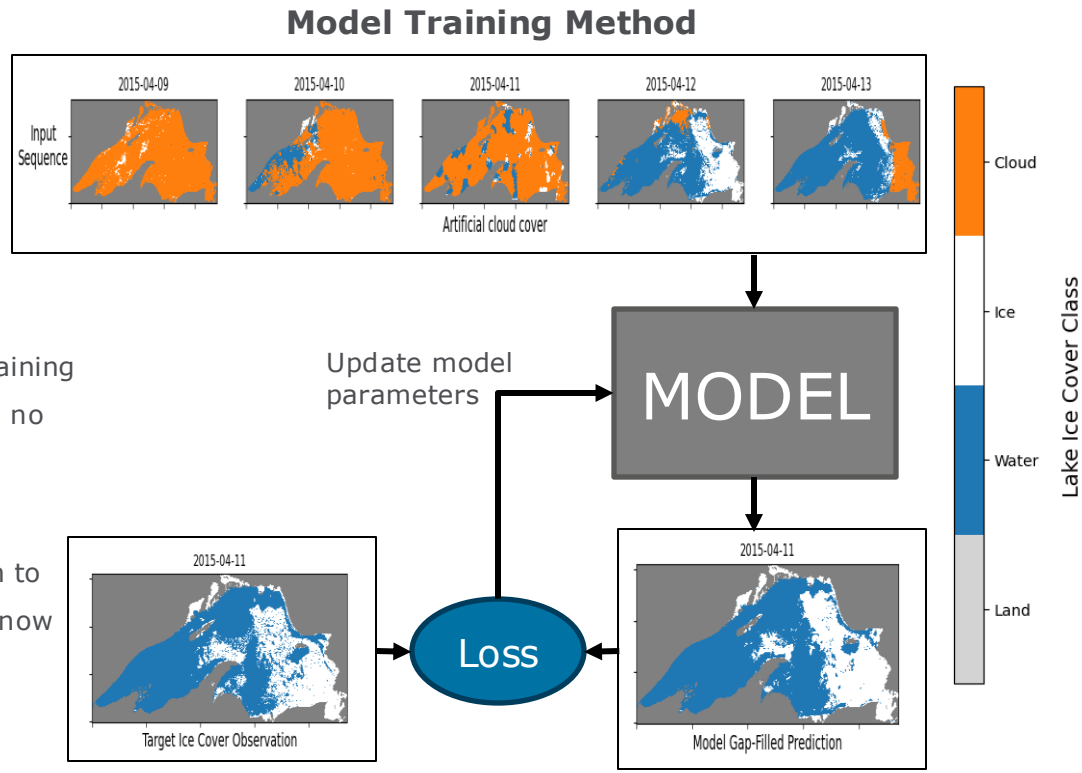
- Explored models including 3-D CNN, U-Net, and vision transformer – best results seen with the U-Net

2. **Model Training** (Current Phase):

- Development of training and validation datasets for training the U-Net, using artificial cloud cover on samples with no obstructions.

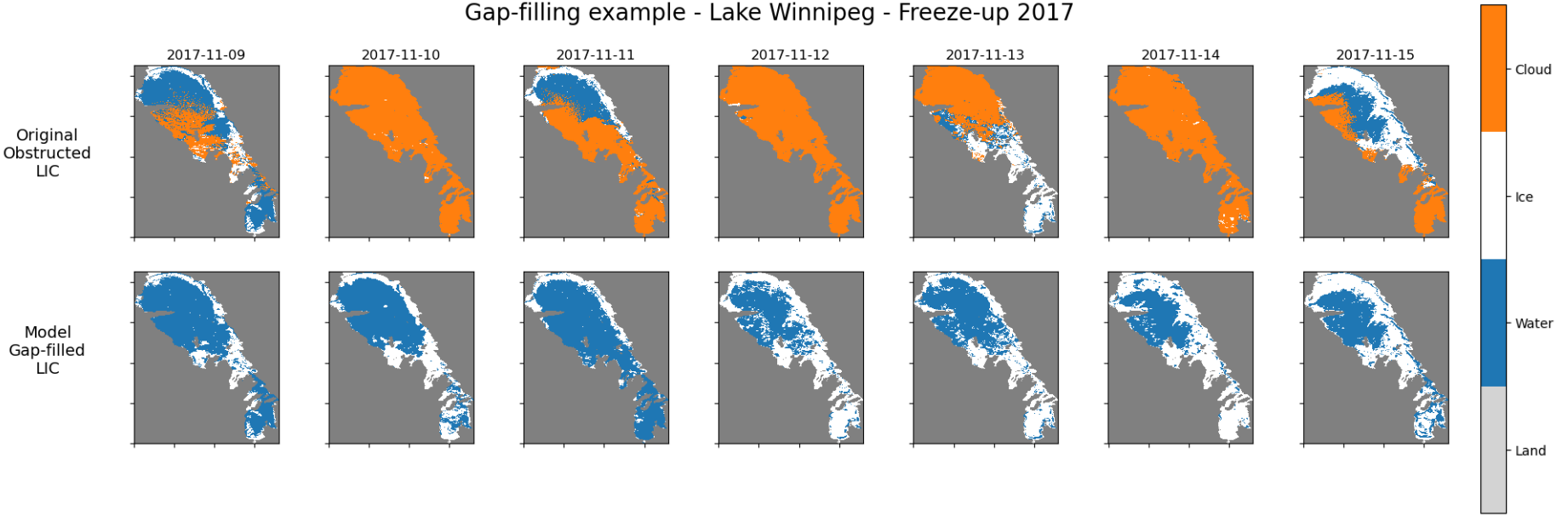
3. **Deployment and Gap-filled evaluation** (Next):

- Evaluation of global gap filled dataset with comparison to existing gap filled products such as the Multi-sensor Snow and Ice Mapping System



# LIC gap filling

**Early Results:** Deploying trained model to fill cloud cover



# Final dataset and timing

- The full dataset will be available from **May 2026**
- For each lake the gap-filled mask of **LSWT** and **LIC** will be **consistent**
- An estimation of the LIC and LSWT **uncertainty** will be attempted
- The **spatial resolution** will be finalised at the end of the project
- The temporal coverage will be from **2000-2023**