Prediction of Global Cloud Properties from Monthly MODIS data and Reanalysis

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Motivation

Clouds are a very important component of the global climate system.

Can we predict MODIS cloud properties using a Neural Network Regression Model - Cloud Top Height, Cloud Droplet Effective Radius and Cloud Ice Fraction - using Reanalysis Data as Input?

The Moderate Resolution Imaging Spectroradiometer(MODIS), one of the key instruments for NASA's Earth Observing System (EOS).

Specifications

750 km polar orbit

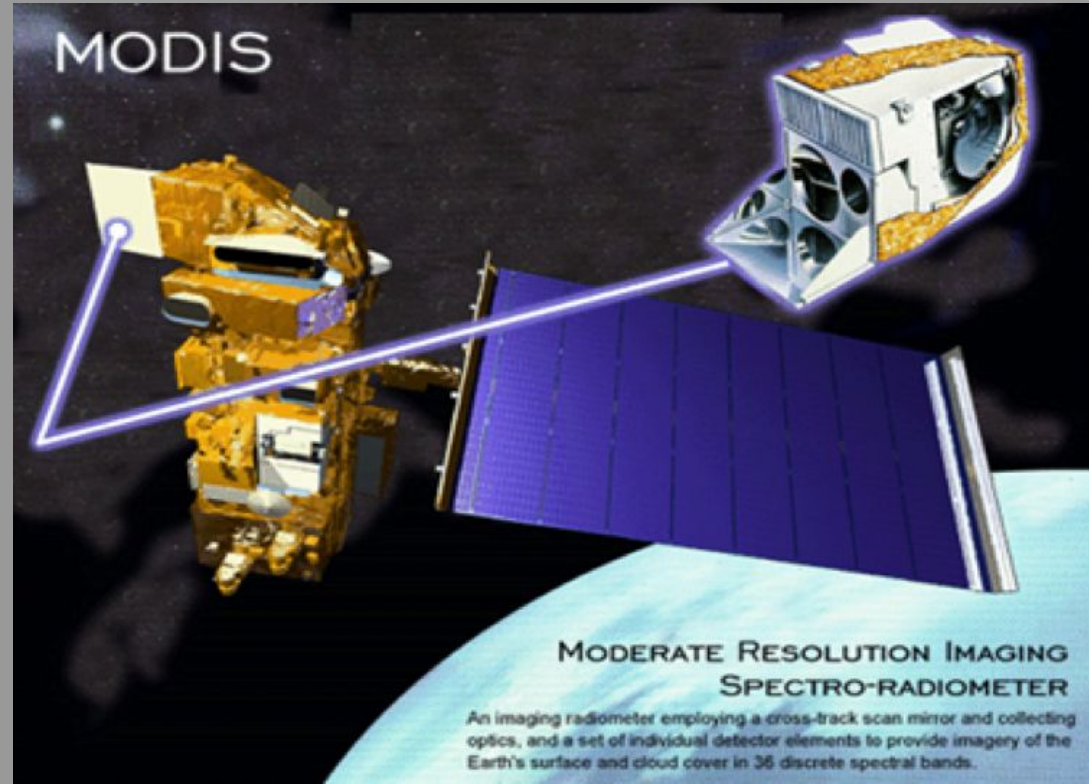Whisk-broom scanner with 2330 km cross-track swath

36 spectral bands ranging from 0.41 to 14.385μm

Resolutions:

250 m (bands 1 - 2)

500 m (bands 3 - 7)

1000 m (bands 8 - 36)

MODIS

MODERATE RESOLUTION IMAGING SPECTRO-RADIOMETER

An imaging radiometer employing a cross-track scan mirror and collecting optics, and a set of individual detector elements to provide imagery of the Earth's surface and cloud cover in 36 discrete spectral bands.

Data

1) **Target variables - MODIS** Monthly Level 3 Data (hdf4) - 1 x 1 degree grid, Monthly mean of daily Cloud Top Height (CTH)

2) **Input Variables - NOAA-NCEP v4 Reanalysis**:

- *Surface Temperature and Mean Sea Level Pressure*
- *Wind Speeds and Direction at surface, 500 hPa and 250 hPa.*
- *Relative Humidity and Temperature at 850 hPa*
- *Estimates of Upwelling LW flux at the surface and Downwelling SW flux at TOA.*
- *500 hPa omega*
- *Lat/long, month of the year.*

	lat	lon	SWflux(W/m2)	LWflux(W/m2)	Uwnd_sfc(m/s)	Vwnd_sfc(m/s)	Uwnd_250mb(m/s)	Vwnd_250mb(m/s)	Omega_500mb(mb/day)	SpecHum_850mb(*1/1000 kg/kg)	Sfc_Temp(K)	MSLP(mb)	month
9331195	-89	175	476.62903	468.77420	-3.023387	3.438710	20.120163	5.246775	-0.039468	0.002896	301.49033	993.21130	12
9331196	-89	176	476.59677	469.58066	-2.716129	2.889516	20.648386	4.380645	-0.034266	0.002895	301.68710	993.02260	12
9331197	-89	177	476.58066	470.79030	-2.749194	1.977419	20.944353	3.638710	-0.032315	0.002853	301.88870	993.14343	12
9331198	-89	178	476.60483	470.30646	-2.901613	1.090323	21.108065	2.981452	-0.034589	0.002805	301.90643	993.46860	12
9331199	-89	179	476.60483	469.17743	-2.970161	0.675806	21.191936	2.326613	-0.039895	0.002770	301.53387	994.06445	12

Neural Network Model

5 'dense' layers:

1) **Input Layer** - 256 nodes
2) **3 Hidden Layers** - each with 256 nodes
3) **Output Layer**
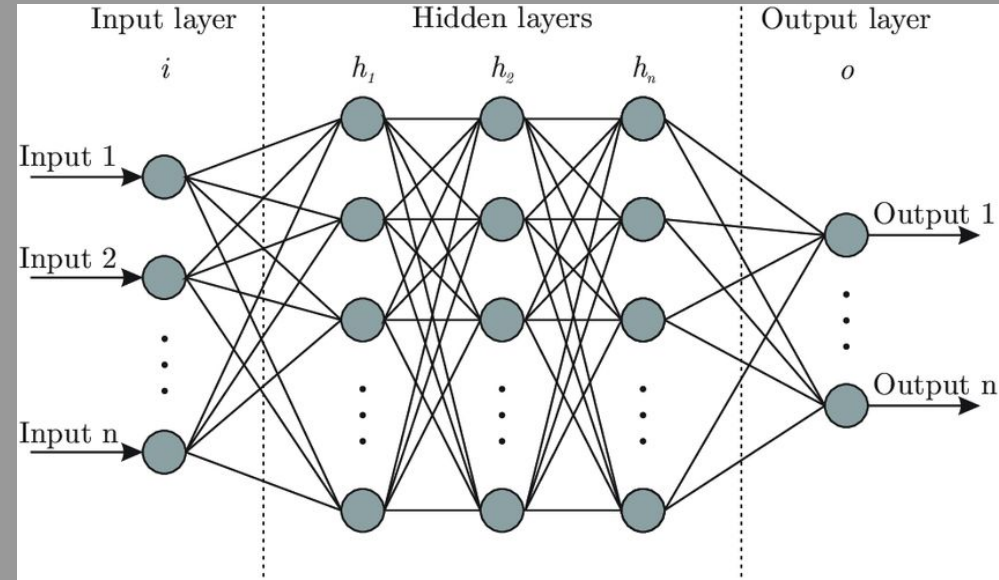
Input Layer:

Training dataset - All data from 2005-19

 (Excluding 2007, 2013, 2015)

Training set is 70% of the data volume.
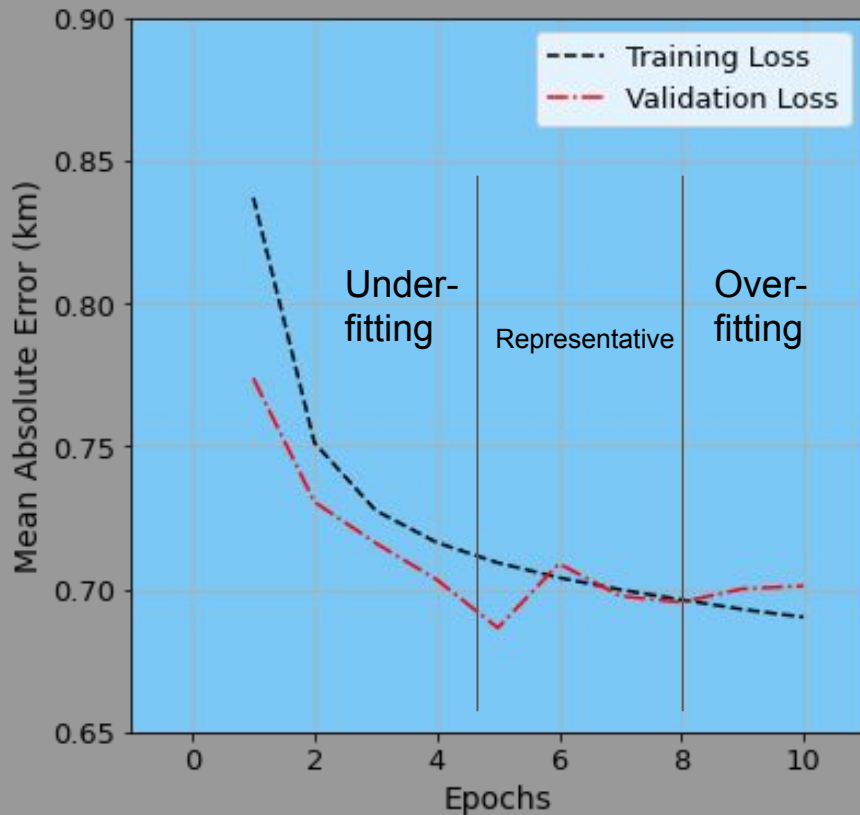
Remaining 30% for validation/optimisation.

Multivariate regression through NN:

CTH = *f (Lat, Long, Month of Year, Radiation, Winds, Surface Properties)*

The Training of the Model

We chose, for time and computational restrictions, to restrict training to when the first local-minima of validation loss is reached.

Number of epochs = 10, Batch size = 64

Average time per epoch = 434 s = 7.23 min

First local minima of validation loss reached on 5th epoch.

Model Mean Errors :

mean_absolute_error: 0.7092 (training)

val_mean_absolute_error: 0.6864 (validation)

Predictions for August 2007

Global Predictions

NN Model Predictions of CTH (km) — MODIS Observations of CTH (km)

Northern Hemisphere Predictions

NN Model Predictions of CTH (km) — MODIS Observations of CTH (km)

Southern Hemisphere Predictions

NN Model Predictions of CTH (km) — MODIS Observations of CTH (km)
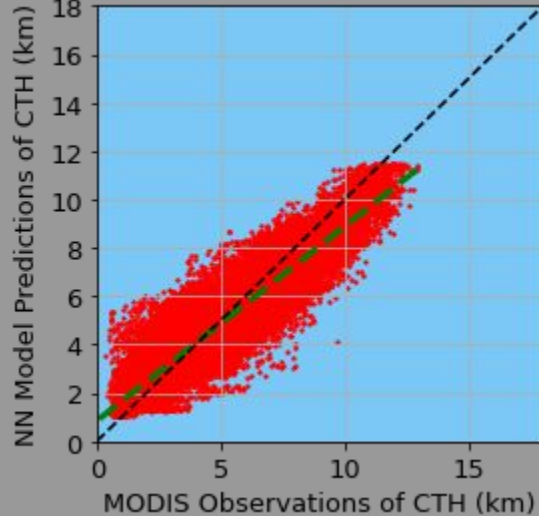
Mean error = - 43 m

Standard error = 834 m
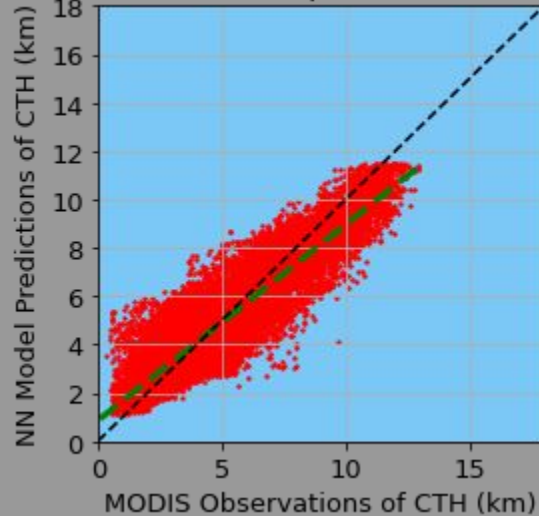
Mean error = - 13 m

Standard error = 914 m
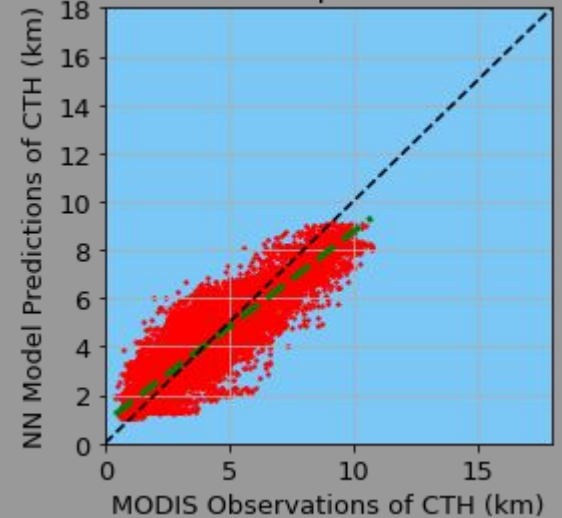
Mean error = -75 m

Standard error = 744 m

Histogram of Differences
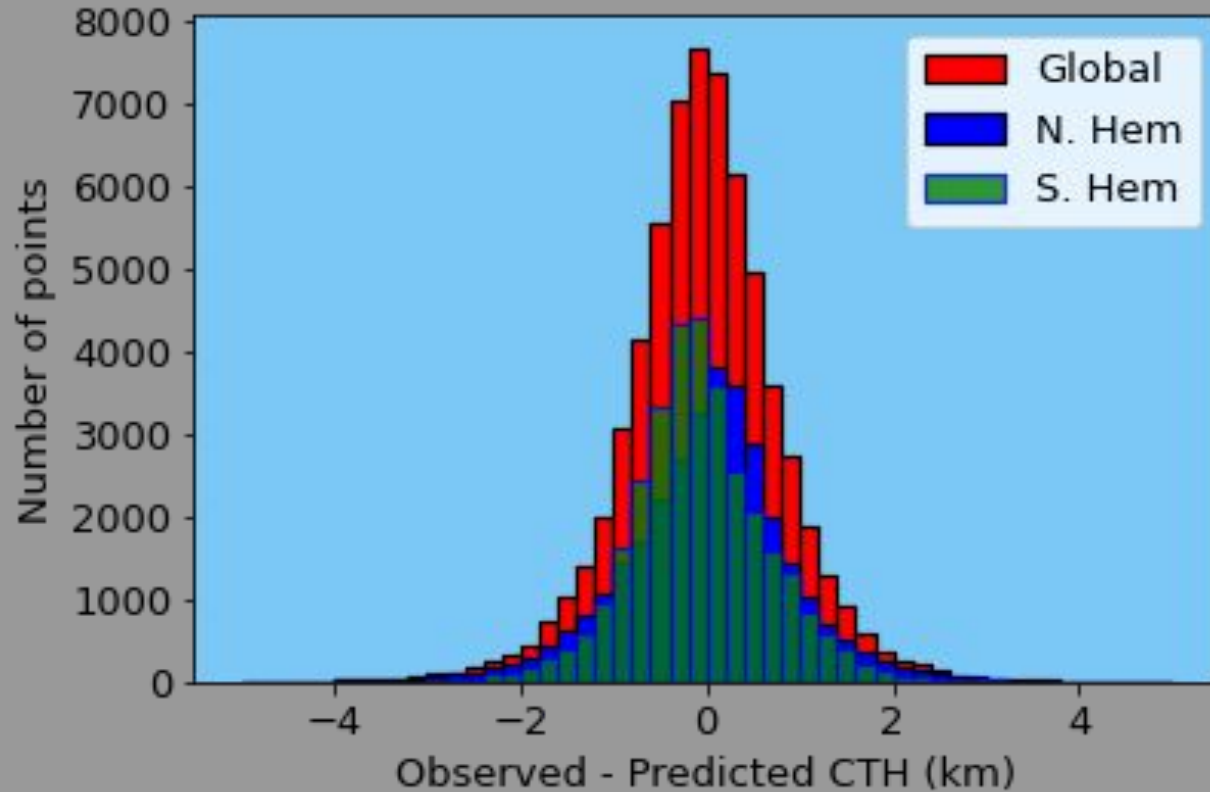
MODIS mean CTH for Aug 2007 vs. NN predicted mean CTH

MODIS CTH
mean August
2007
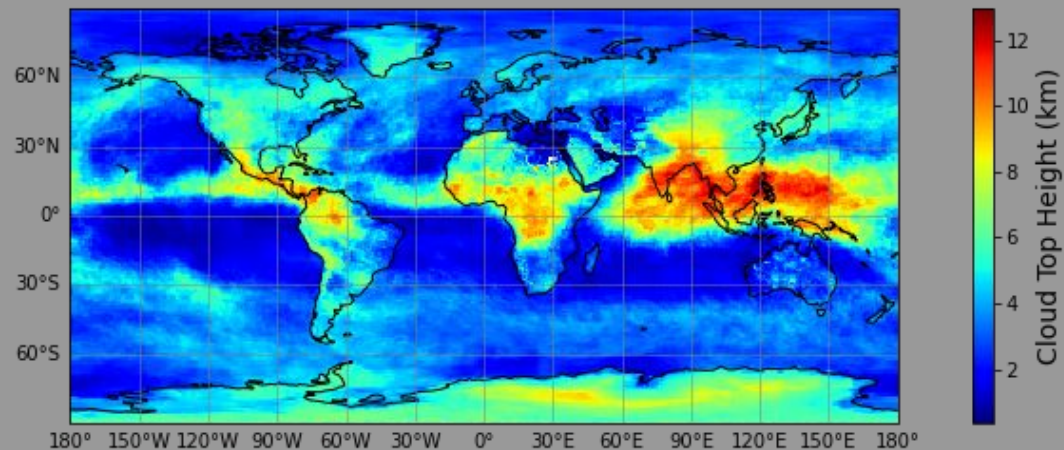
NN CTH
mean August
2007
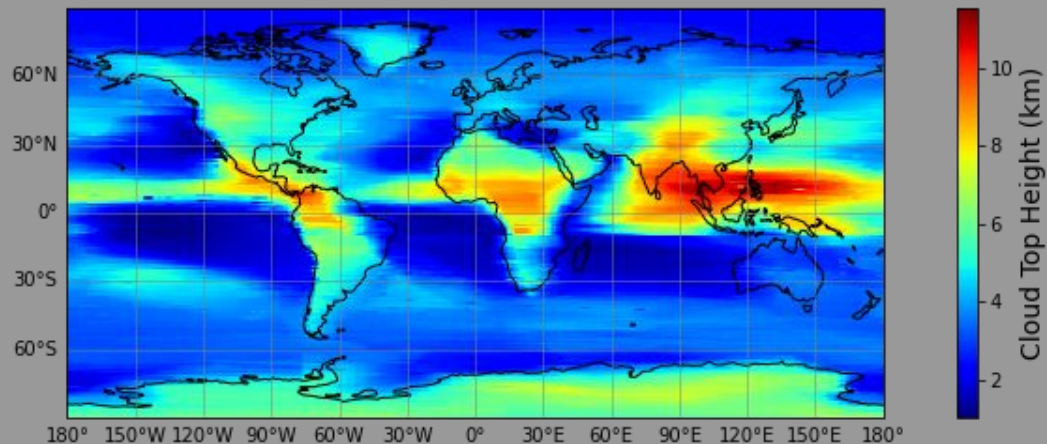
Difference between MODIS CTH mean vs. NN predicted CTH mean
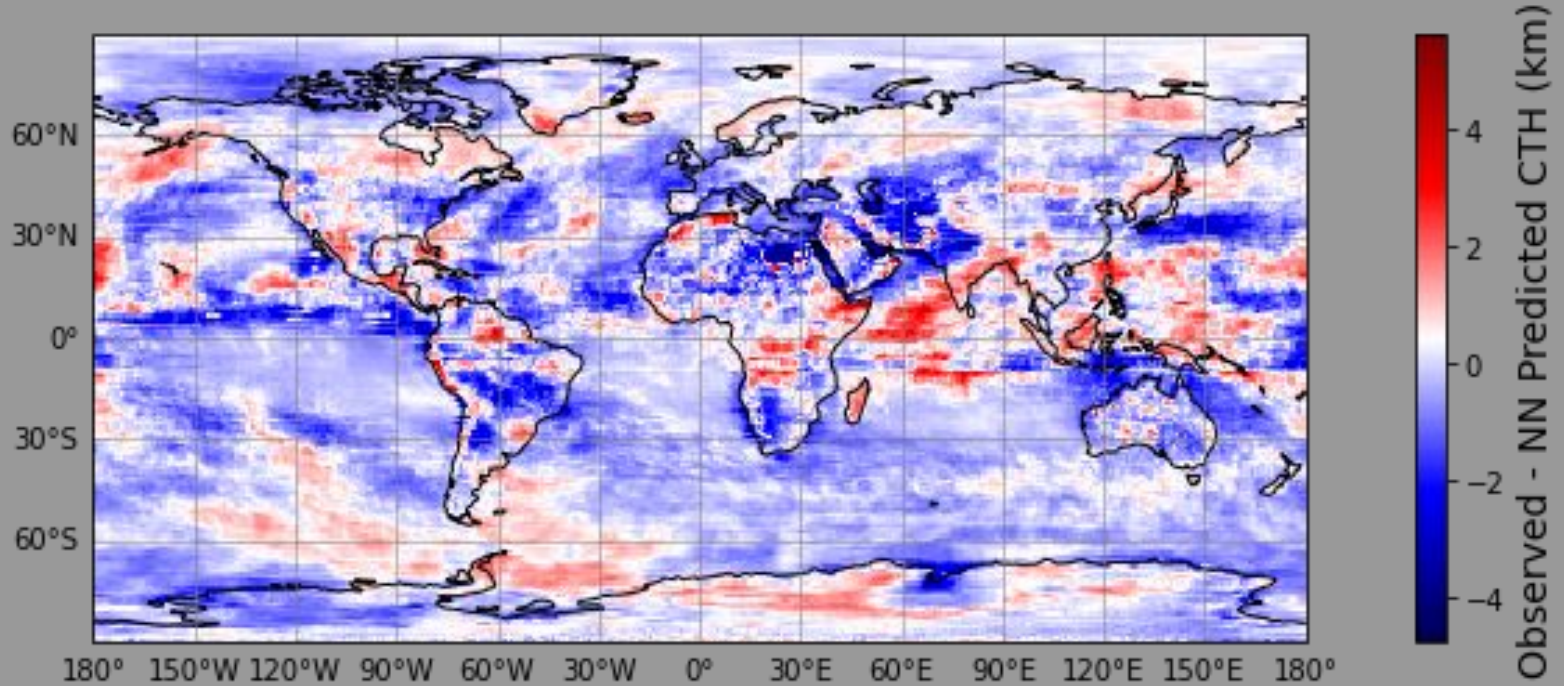
CTH mean August anomalies (MODIS) vs. NN predicted anomalies

MODIS CTH
mean August
anomalies
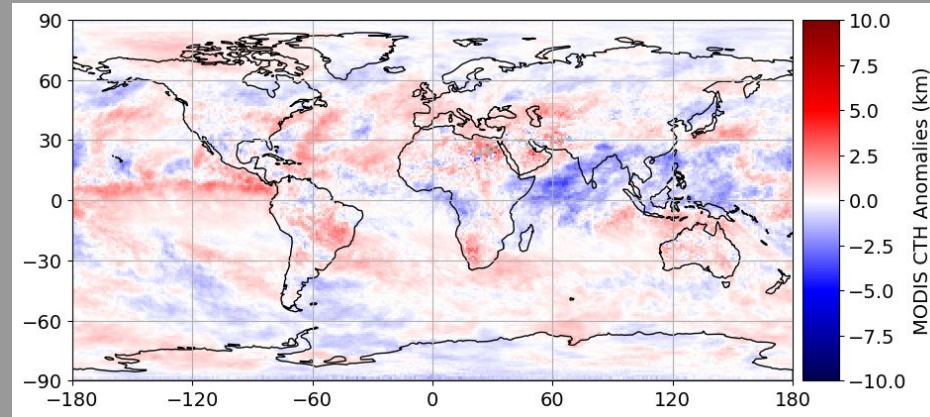
NN predicted
CTH mean
August
anomalies
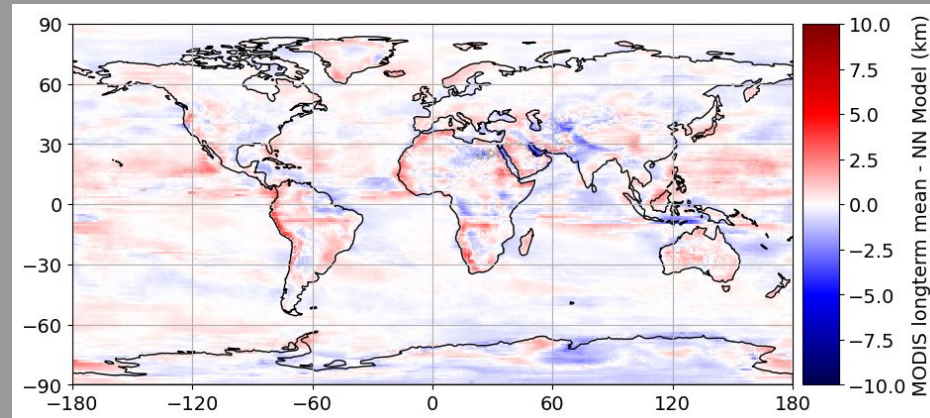
Conclusions

1. The agreement between the observed MODIS CTH and predicted CTH for training/validation and for August 2007 is usually pretty good.

2. The model didn't capture the geographical variabilities very well, especially with respect to cloud anomalies.

3. Although the overall mean and standard errors were small enough, errors were larger wherever there was high CTH (greater variability in CTH). Max , min and STD need to be figured in, for a more robust prediction.

4. Low training period was an obvious source of much of these disagreements.

5. Similar analyses were carried out for cloud effective radius and cloud ice fraction.

THANK You!
Questions?

Similar analysis for Re (effective radius)

For Effective Radius (Re) mean
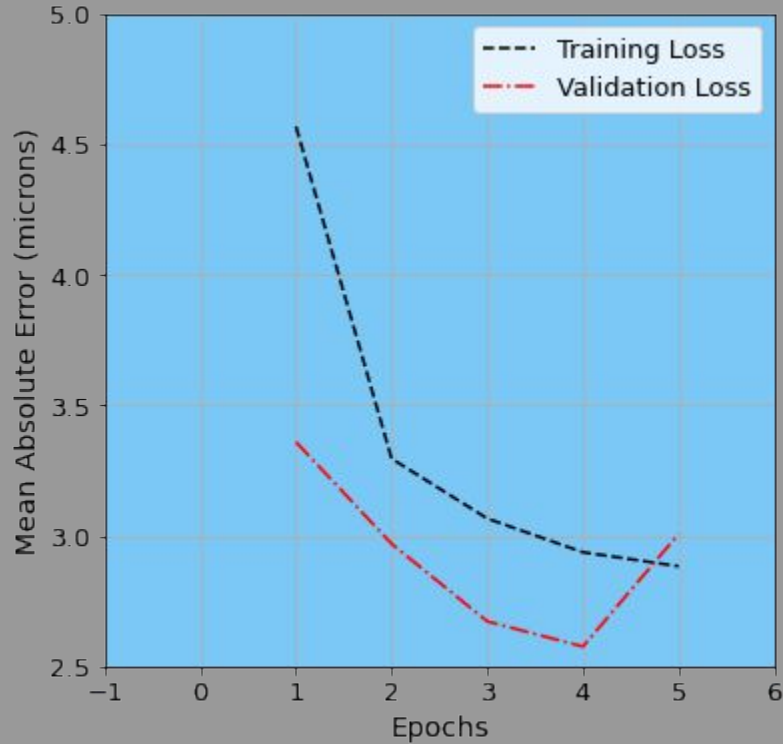
Number of epochs = 5

Average time per epoch = 255 s = 4.25 mins

First local minima reached on 4th epoch.

Model Mean Errors :
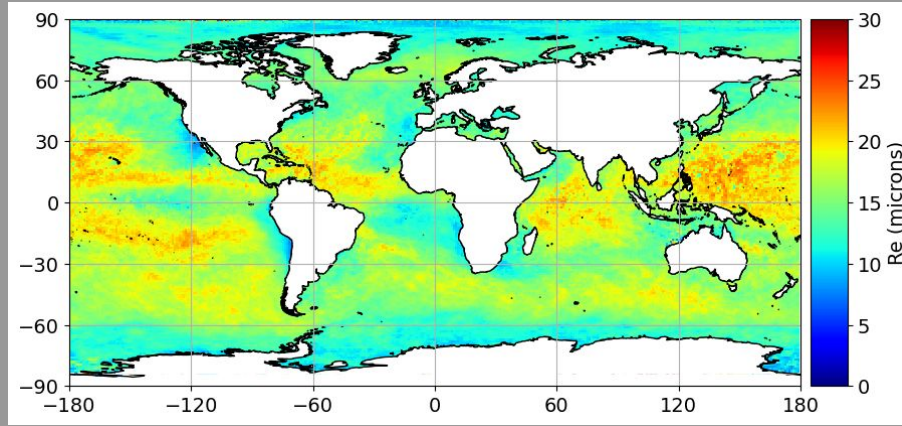
mean_absolute_error: 2.9372 microns(training)

val_mean_absolute_error: 2.5763 microns(validation)
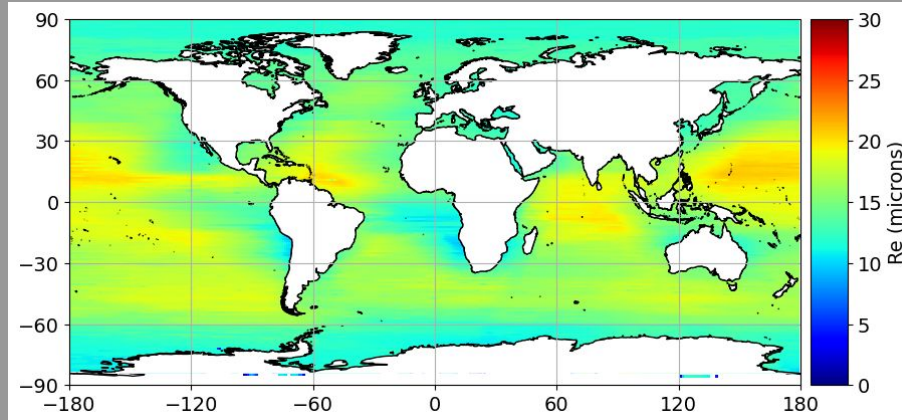
Re mean for August 2007
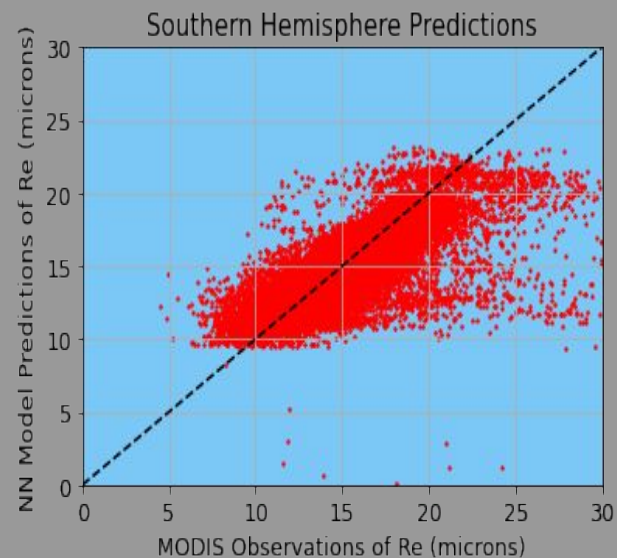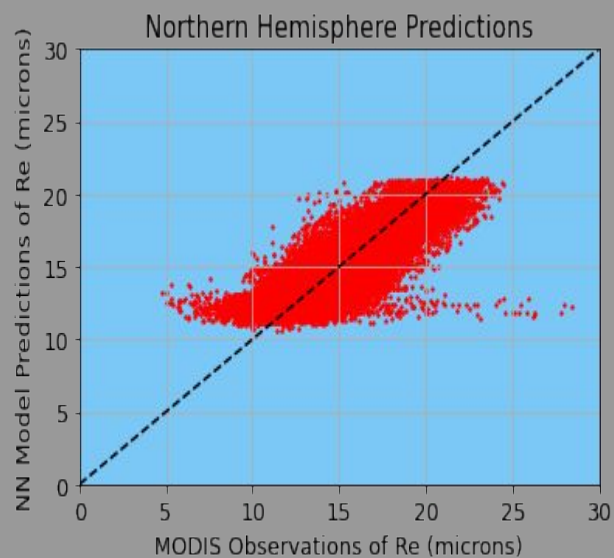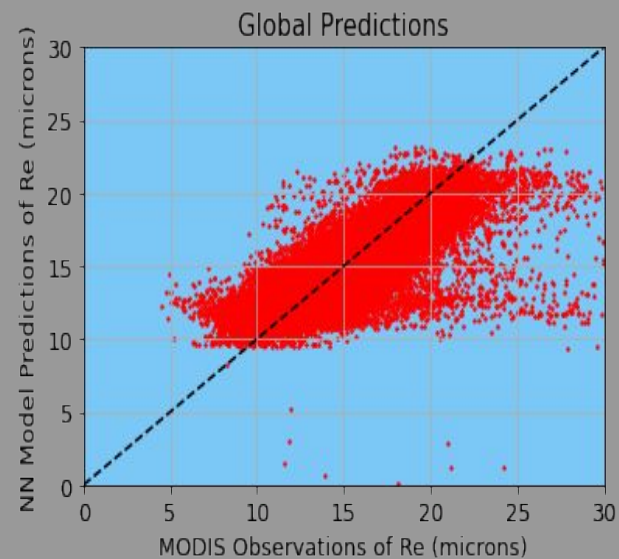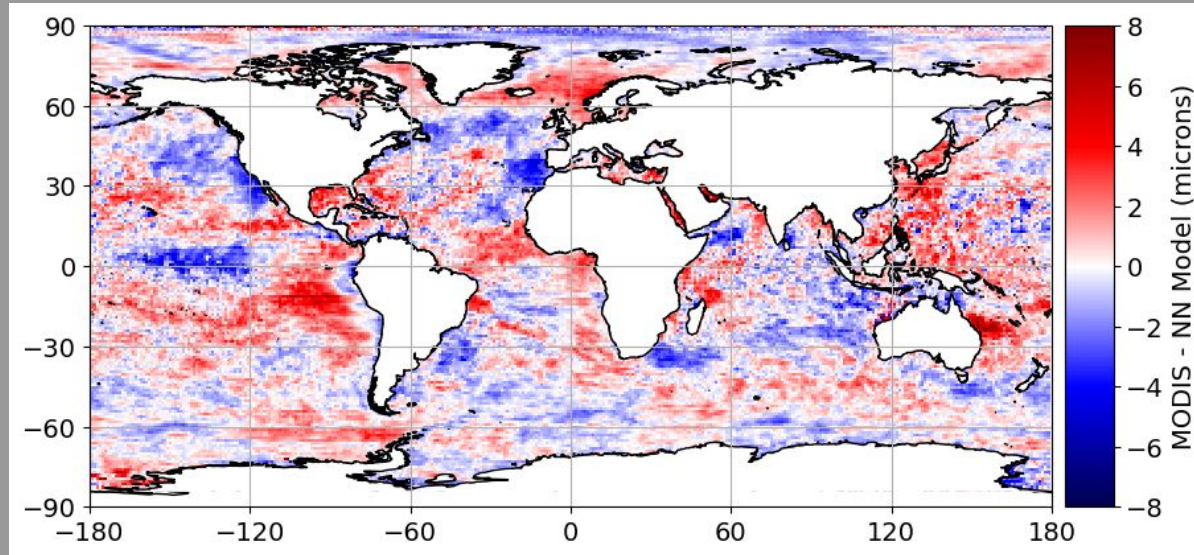
MODIS Re mean vs. NN predicted Re mean
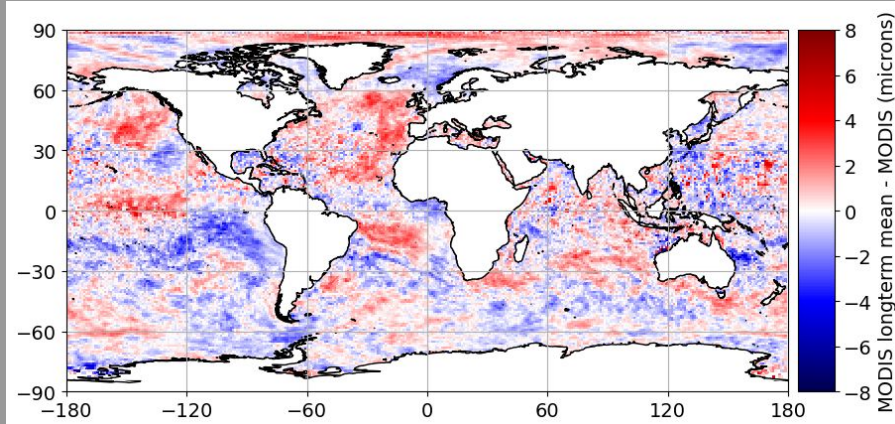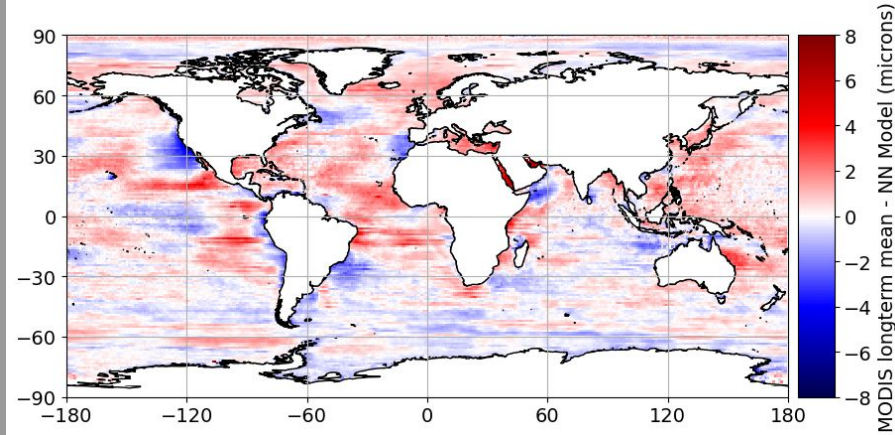
MODIS Re mean
August 2007

NN Re
August 2007

Difference between MODIS Re mean vs. NN predicted Re mean

Re mean August anomalies (MODIS) vs. NN predicted anomalies
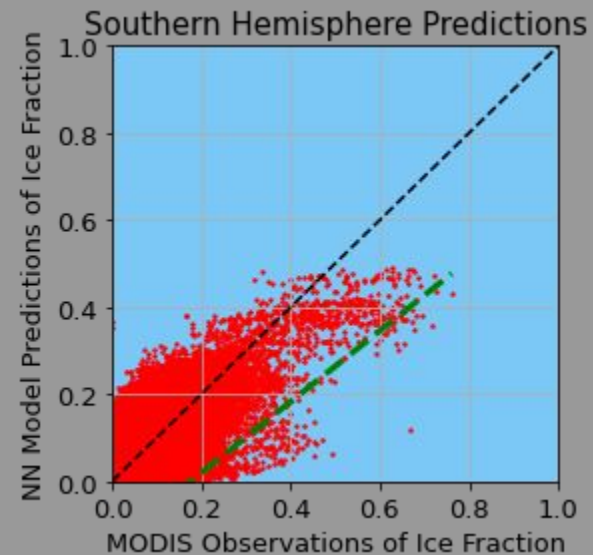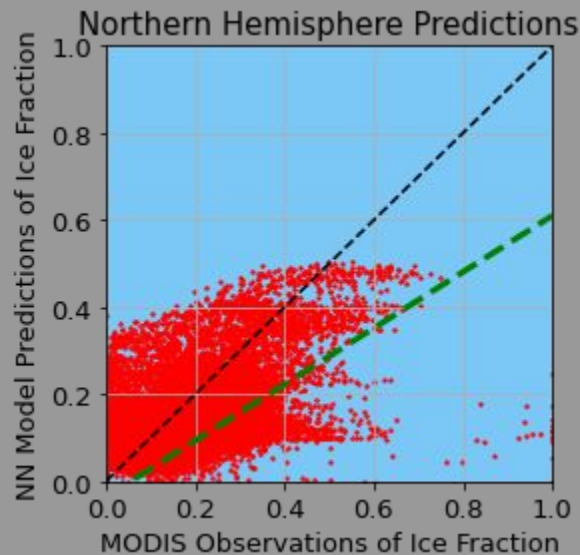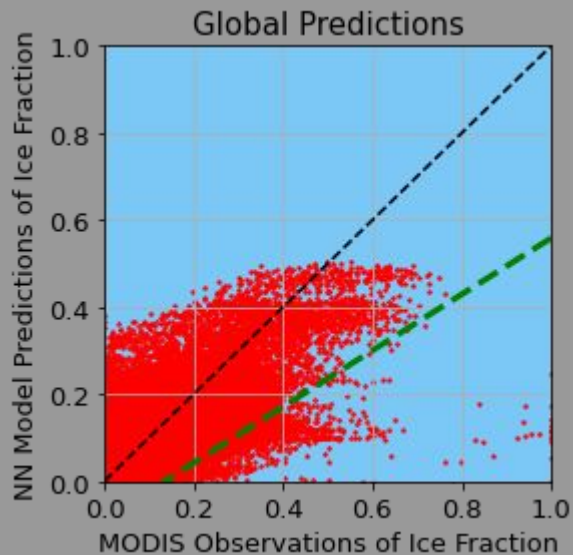
MODIS Re
mean August
anomalies

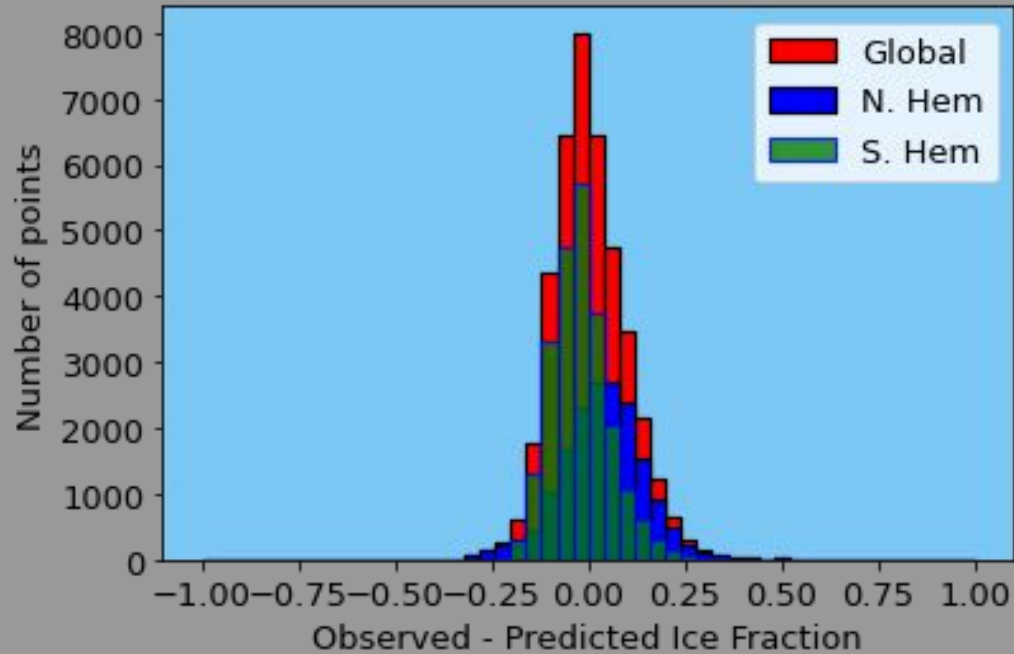NN predicted
Re mean
August
anomalies

Similar Analysis for Ice Fraction

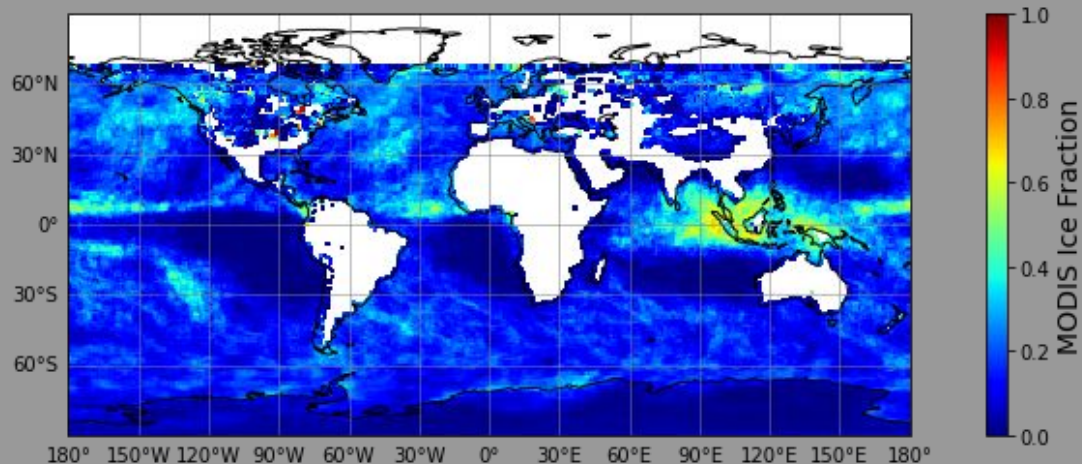# Predictions for August 2007
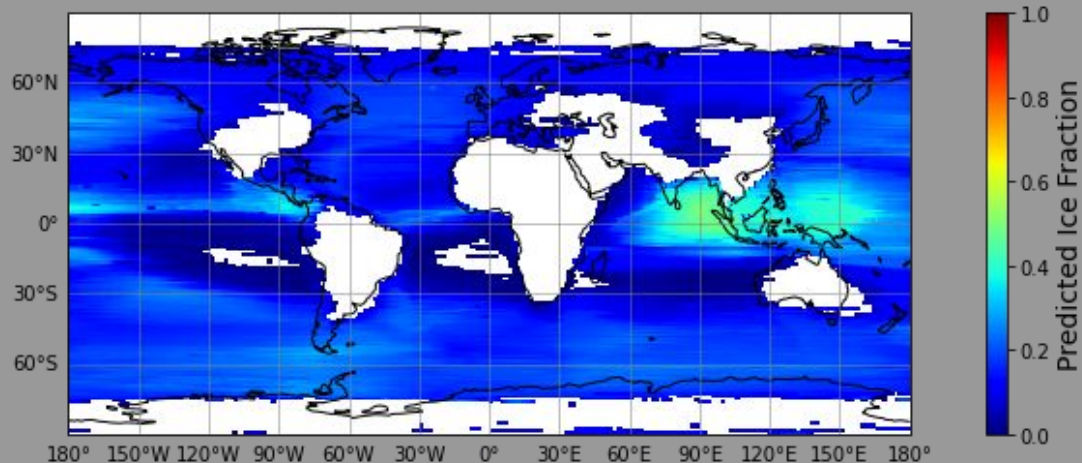
Histogram of Differences

MODIS mean Ice Fraction for Aug 2007 vs. NN predicted mean Ice Fraction

MODIS Ice Fraction mean August 2007

NN Ice Fraction mean August 2007

Difference between MODIS Ice Fraction mean vs. NN predicted mean Ice Fraction