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).

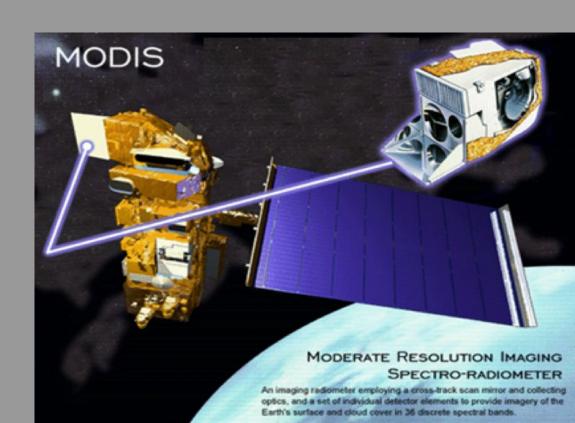
Specifications

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)



Data

- Target variables MODIS Monthly Level 3 Data (hdf4) 1 x 1 degree grid, Monthly mean of daily Cloud Top Height (CTH)
- Input Variables NOAA-NCEP v4 Reanalysis:
- Surface Temperature and Mean Sea Level Pressure Wind Speeds and Direction at surface 500 hPa and 250 hPa

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)

3.438710

2.889516

1.977419

1.090323

0.675806

-3.023387

-2.716129

-2.749194

-2.901613

-2.970161

476.62903

476.59677

476.58066

476.60483

476.60483

9331195

9331196

9331197

9331198

9331199

-89 175

-89 176

-89 178

-89 179

177

Lat/long, month of the year.

468.77420

469.58066

470.79030

470.30646

469.17743

	Rolative trailinaity and reimperature at 600 file
•	Estimates of Upwelling LW flux at the surface and Downwelling SW flux at TOA.
•	500 hPa omega

20.120163

20.648386

20.944353

21.108065

21.191936

5.246775

4.380645

3.638710

2.981452

2.326613

SpecHum 850mb(*1/1000

-0.039468

-0.034266

-0.032315

-0.034589

-0.039895

kg/kg)

0.002896

0.002895

0.002853

0.002805

0.002770

Sfc Temp(K)

301.49033

301.68710

301.88870

301.90643

301.53387

MSLP(mb)

993.21130

993.02260

993.14343

993.46860

994.06445

12

12

	wind Speeds and Direction at Sunace, 500 nPa and 250 nPa.
•	Relative Humidity and Temperature at 850 hPa
•	Estimates of Upwelling LW flux at the surface and Downwelling SW flux at TOA.
	FOO hDa amaga

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

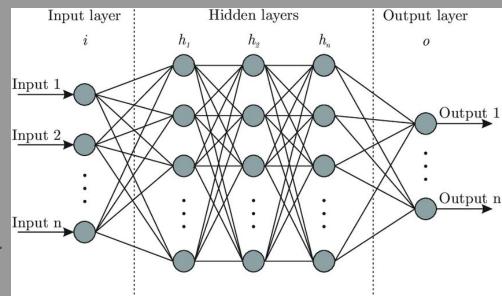
(Excluding 2007, 2013, 2015)

Training set is 70% of the data volume.

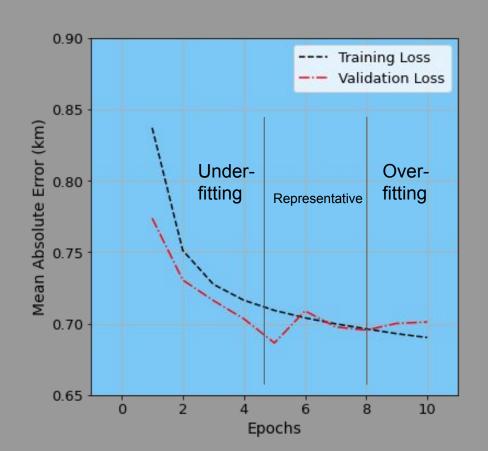
Remaining 30% for validation/optimisation.

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

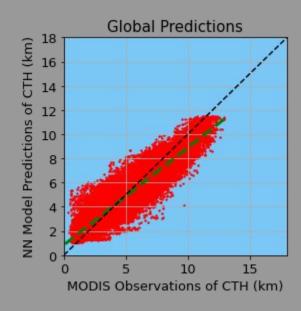
First local minima of validation loss reached on 5th epoch.

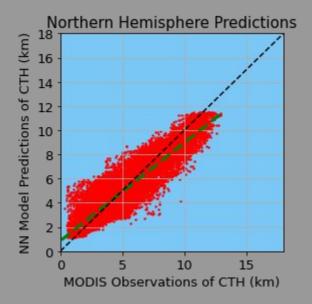
Model Mean Errors:

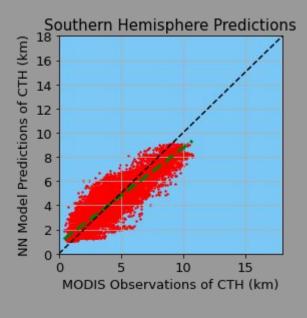
mean_absolute_error: 0.7092 (training)

val_mean_absolute_error: 0.6864 (validation)

Predictions for August 2007







Mean error = - 43 m

Standard error = 834 m

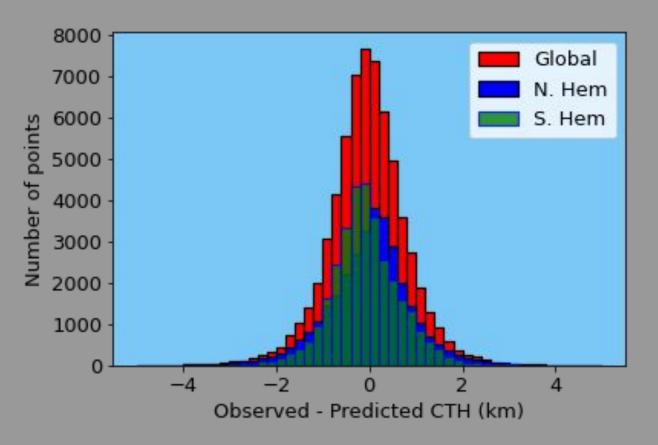
Mean error = - 13 m

Standard error = 914 m

Mean error = -75 m

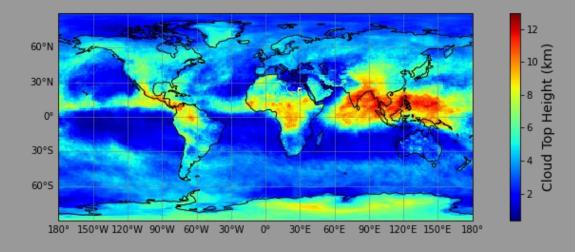
Standard error = 744 m

Histogram of Differences

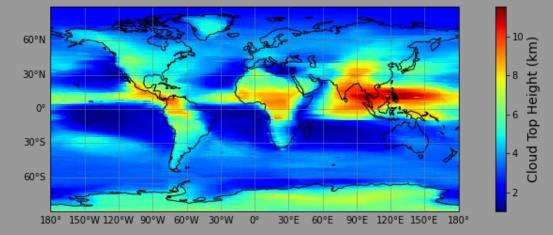


MODIS mean CTH for Aug 2007 vs. NN predicted mean CTH

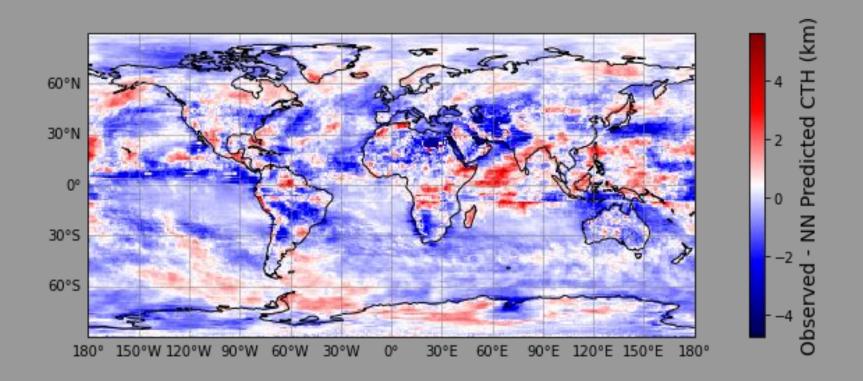
MODIS CTH mean August 2007



NN CTH mean August 2007

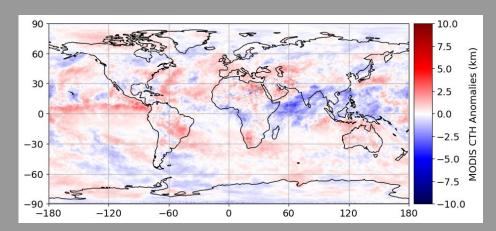


Difference between MODIS CTH mean vs. NN predicted CTH mean

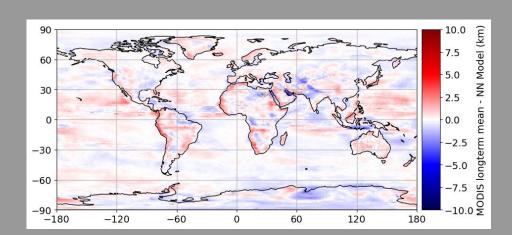


CTH mean August anomalies (MODIS) vs. NN predicted anomalies

MODIS CTH mean August anomalies



NN predicted CTH mean August anomalies



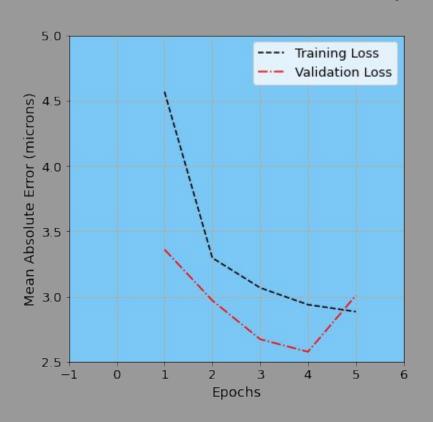
Conclusions

- 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

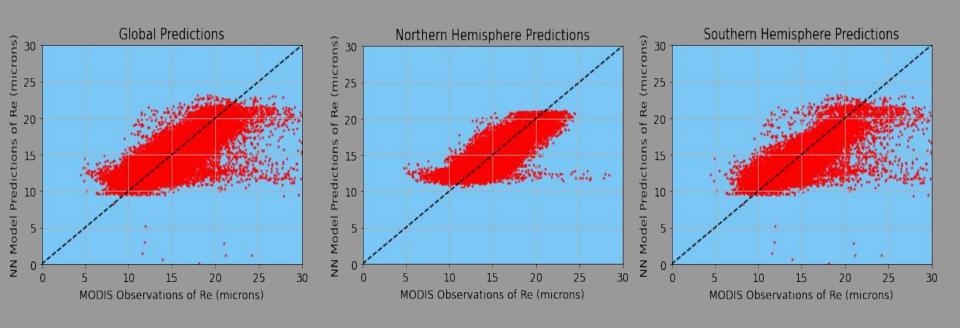
First local minima reached on 4th epoch.

Model Mean Errors :

mean_absolute_error: 2.9372 microns(training)

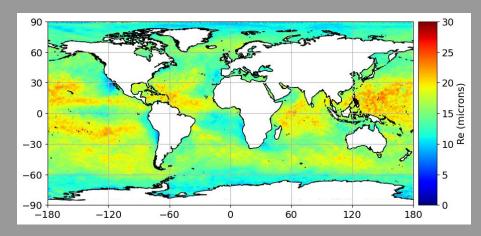
val_mean_absolute_error: 2.5763 microns(validation)

Re mean for August 2007

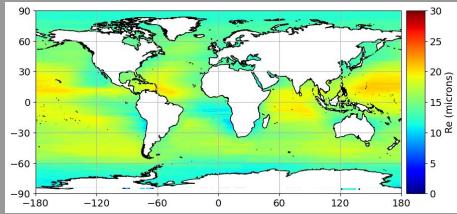


MODIS Re mean vs. NN predicted Re mean

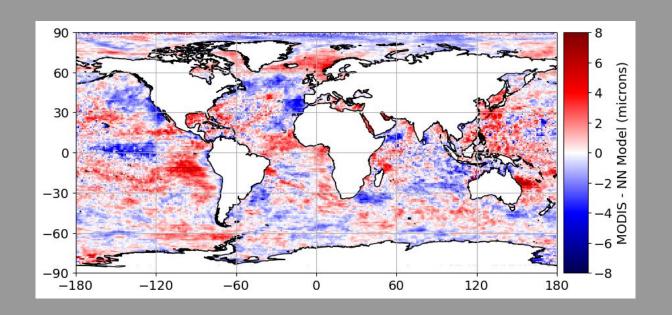
MODIS Re mean August 2007



NN Re August 2007



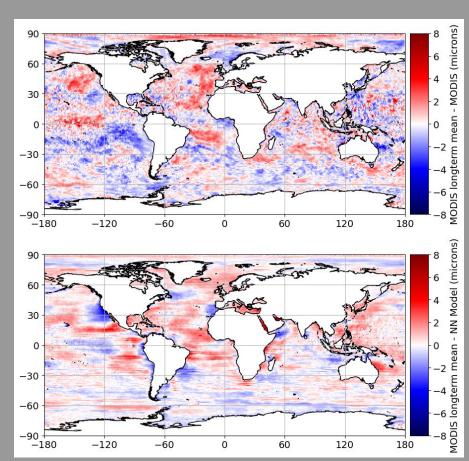
Difference between MODIS Re mean vs. NN predicted Re mean



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

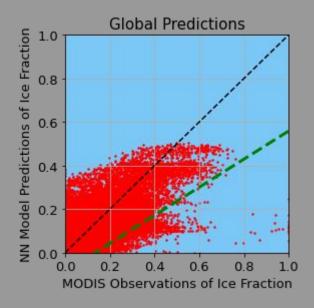
MODIS Re mean August anomalies

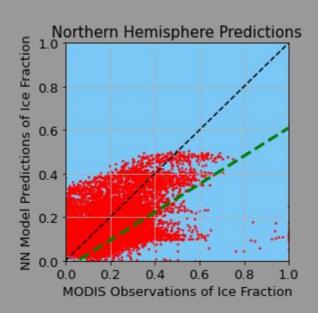
NN predicted Re mean August anomalies

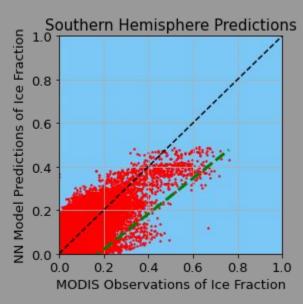


Similar Analysis for Ice Fraction

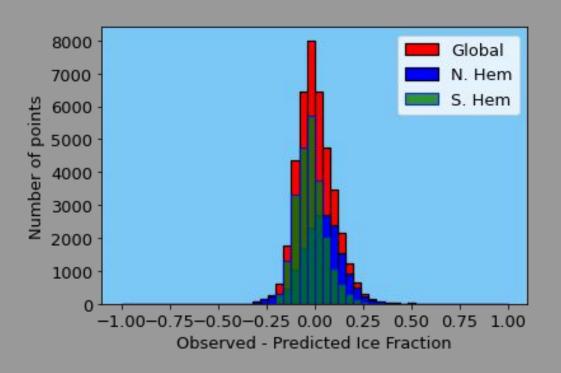
Predictions for August 2007







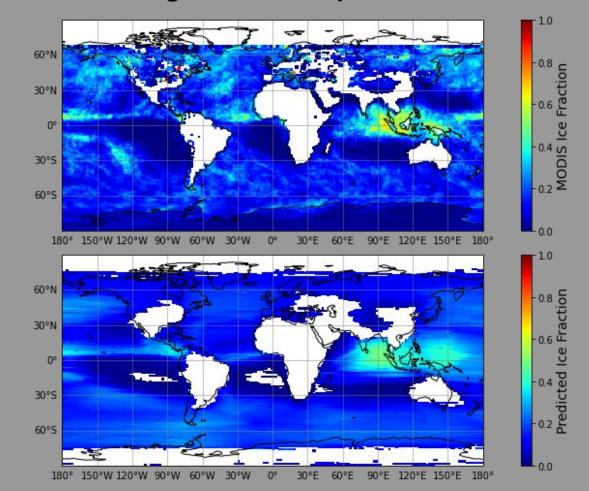
Histogram of Differences



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

