Parameterization of Vertical Cloud Distribution With CCCM and MERRA Data Using Machine Learning Method

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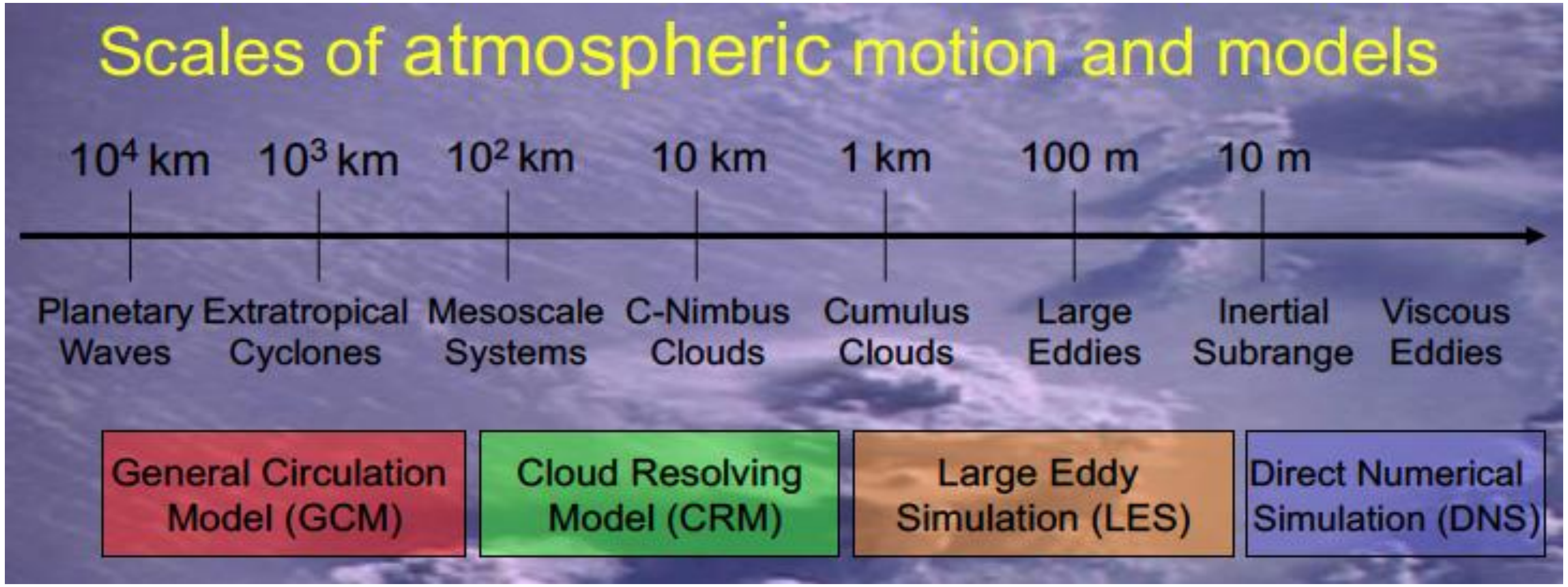
Introduction (Motivation)

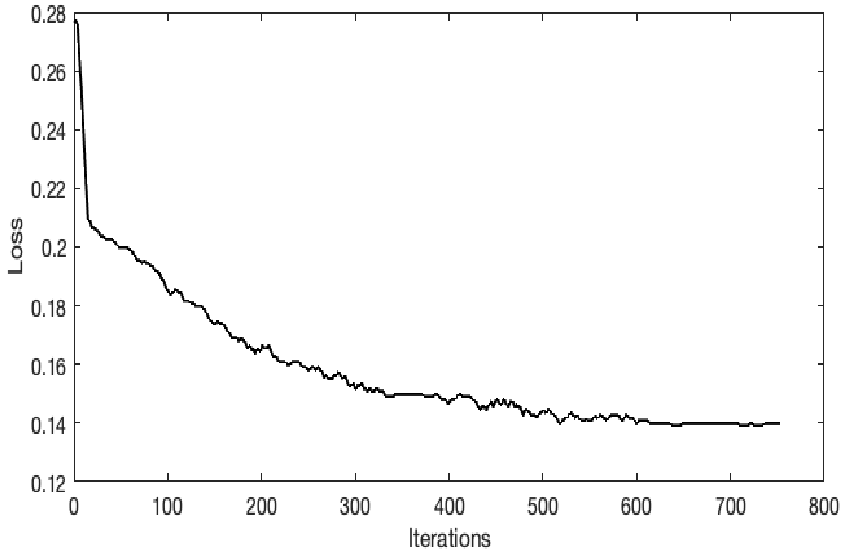


- General circulation models (GCMs) and numerical weather prediction (NWP) models are unable to resolve many important sub-grid scale physical processes
- One of the critical uncertainties in GCMs raises from clouds, where simple physical parameterization algorithms fail to capture the complex nature of the associated physical processes.
- Machine Learning algorithms offer innovative approach to study cloud parameterization problems and speed up simulations

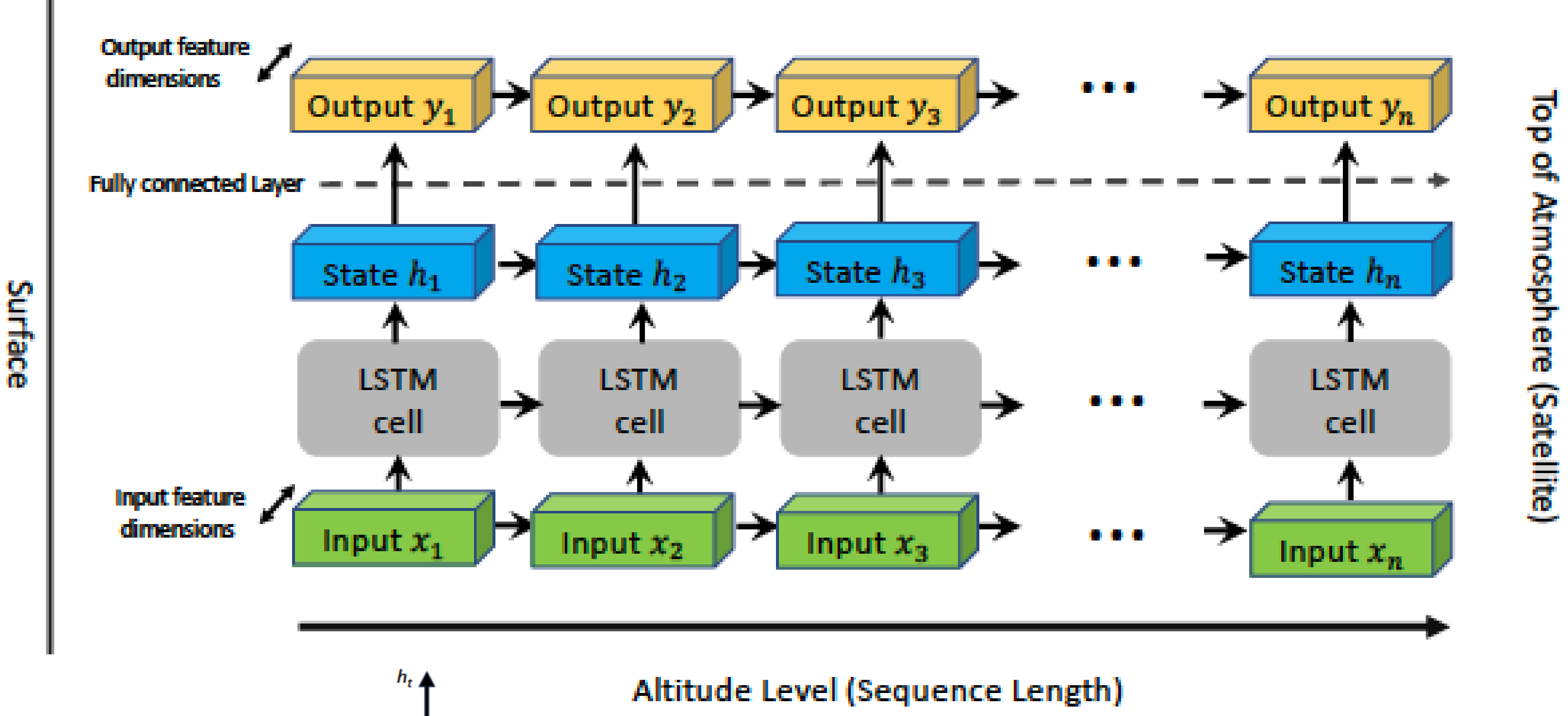
ML Setups (Data)

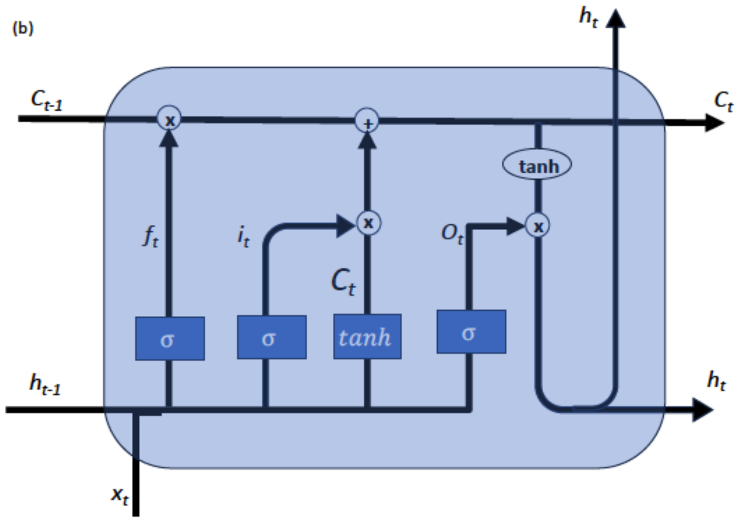
Inputs (MERRA)	Outputs (CCCM)
U Profiles	CCCM Volumetric Cloud Fraction Profiles
V Profiles	
ω Profiles	
T Profiles	
RH Profiles	
P Profiles	
Latent Heat Flux	
Sensitive Heat Flux from Turbulence	
Surface T, RH, P	

Training data	(2008-01) 90%
Validation data	(2008-01) 10%
Test data	(2008-02)



ML Setups (Model)

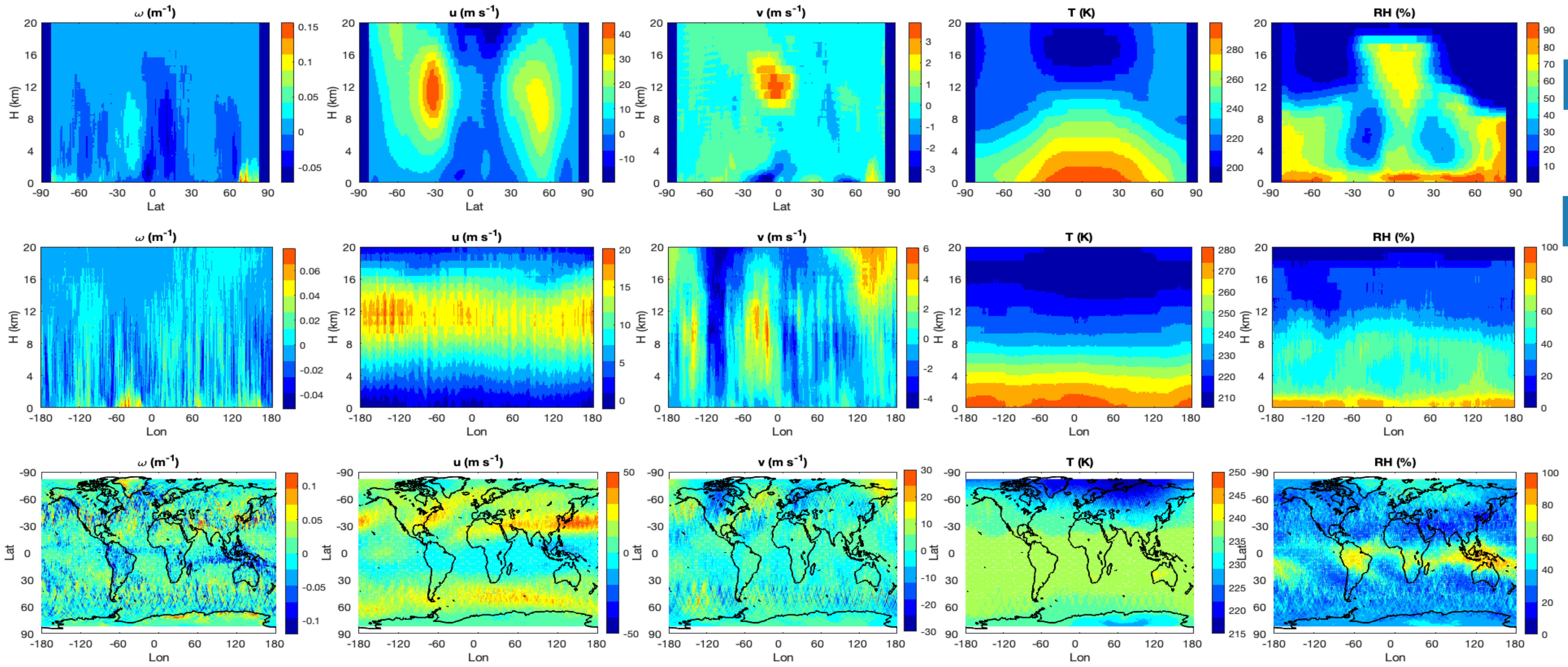




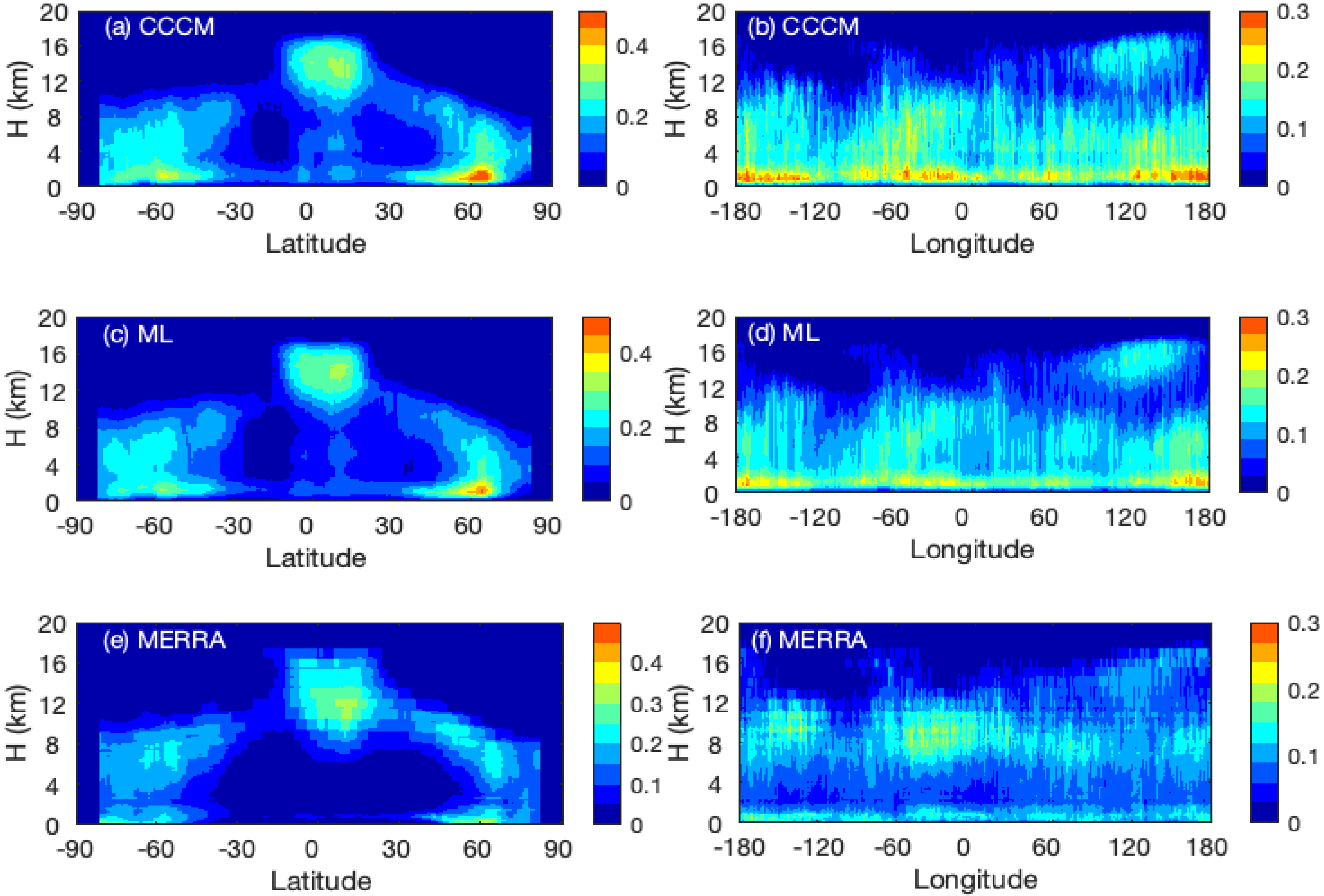
LSTM seq-to-Seq Regression Model

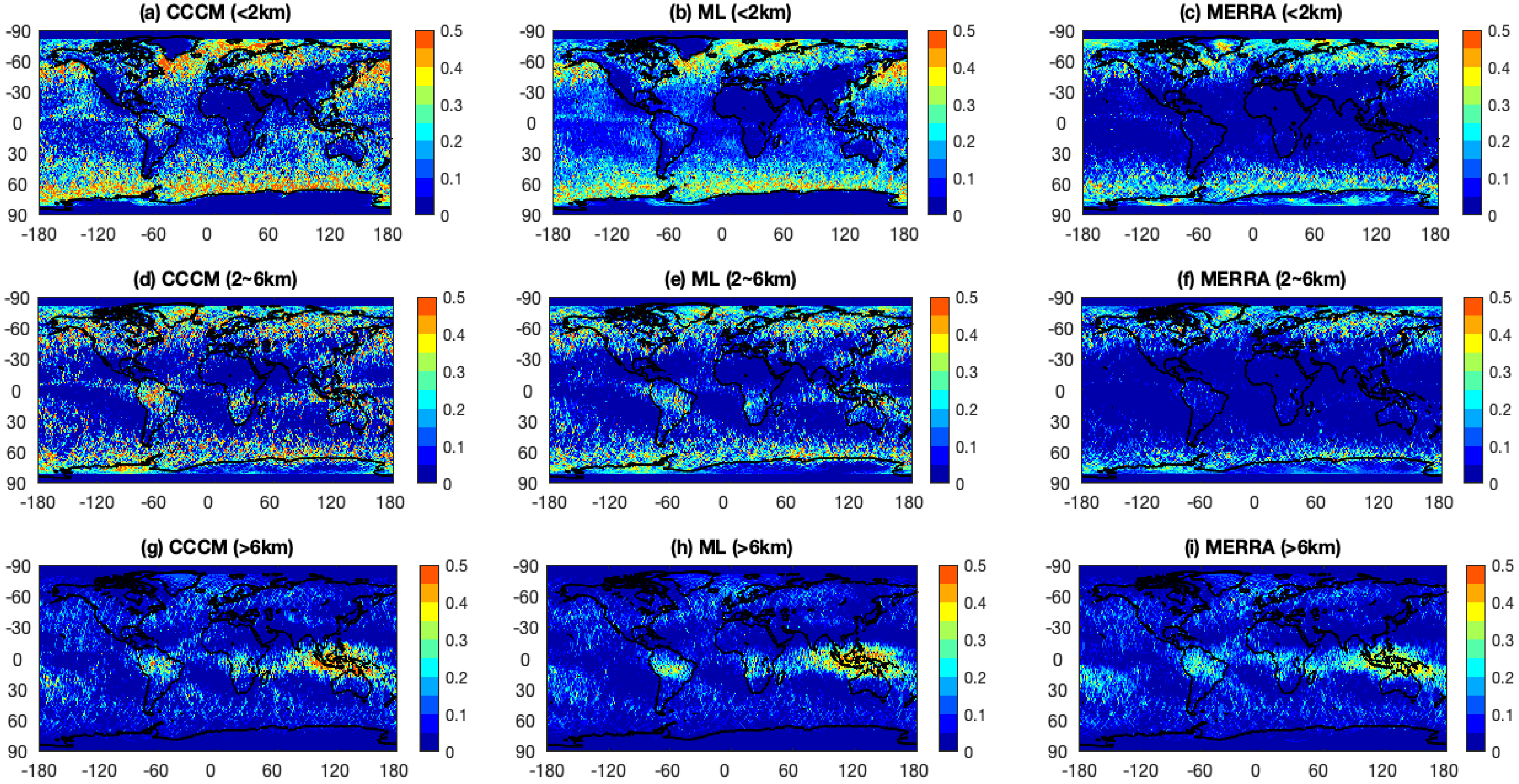
Sequence Input Layer
LSTM Layers
Dropout Layers
Fully connected Layers
ReLu Layer
Regression Layers

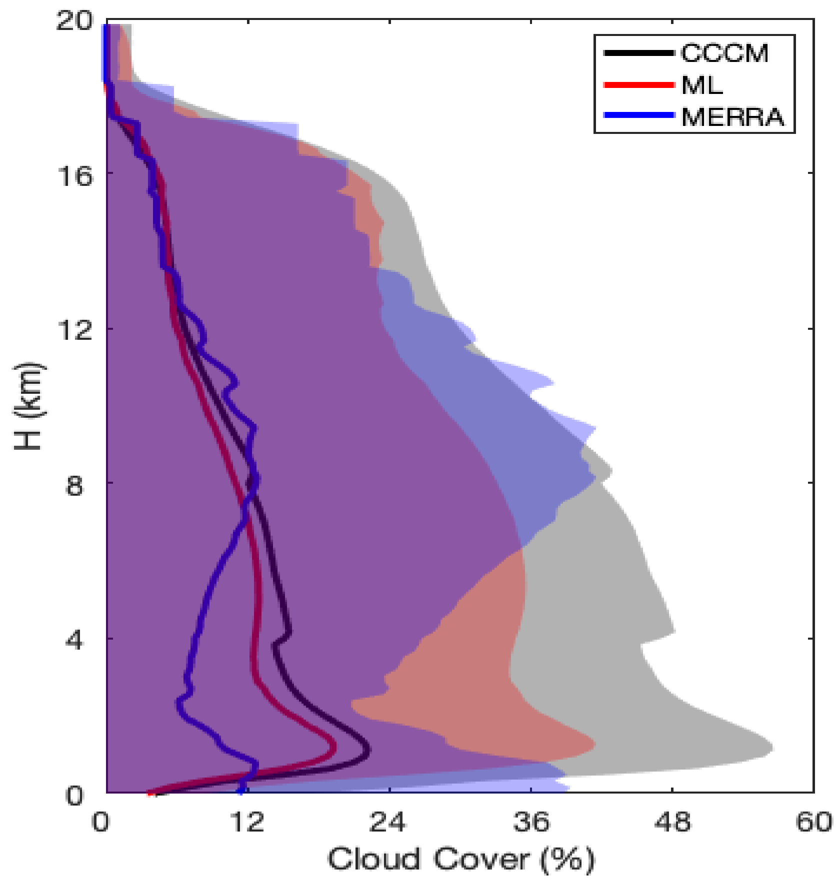
ML Inputs

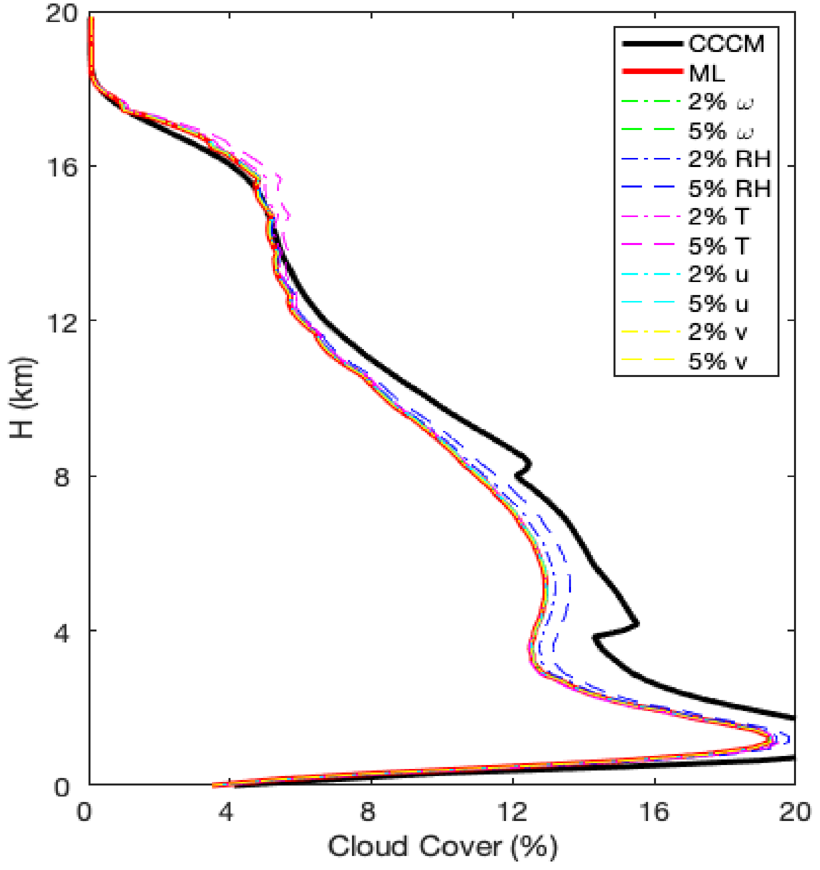


Results




(a) CCCM (<2km)
(b) ML (<2km)
(c) MERRA (<2km)
(d) CCCM (2~6km)
(e) ML (2~6km)
(f) MERRA (2~6km)
(g) CCCM (>6km)
(h) ML (>6km)
(i) MERRA (>6km)


20
16
12
8
4
0
H (km)
0
12
24
36
48
60
Cloud Cover (%)
CCCM
ML
MERRA


20
16
12
8
4
0
H (km)
0
4
8
12
16
20
Cloud Cover (%)
CCCM
ML
2% ω
5% ω
2% RH
5% RH
2% T
5% T
2% u
5% u
2% v
5% v

Summary

- By using an appropriate machine learning model, we are able to learn, understand and represent the complex physical processes related to vertical moisture transport and cloud formation/deformation

  - There are consistent agreements on cloud volumetric fraction, in both geographical and vertical distributions
  - The parameters driving the formation of low clouds are relative humidity (RH), while for high clouds, temperatures play a crucial role

- Observations from the space Lidar/Radar are valuable to understand the global cloud and climate systems

Perspectives

- Machine Learning (ML) can assist in reconstructing vertical cloud distributions from meteorological data, leveraging its capability to grasp cloud physics through the "ML surrogate relationship". In the future, further exploration is essential to design our own ML models that aligns more closely with the underlying physics and physical constraints.

- The work holds the potential to improve our traditional cloud/climate models

- Through ML, we can continue to reconstruct satellite measurements