Focal-TSMP: Deep learning for vegetation health prediction and agricultural drought assessment from a regional climate simulation

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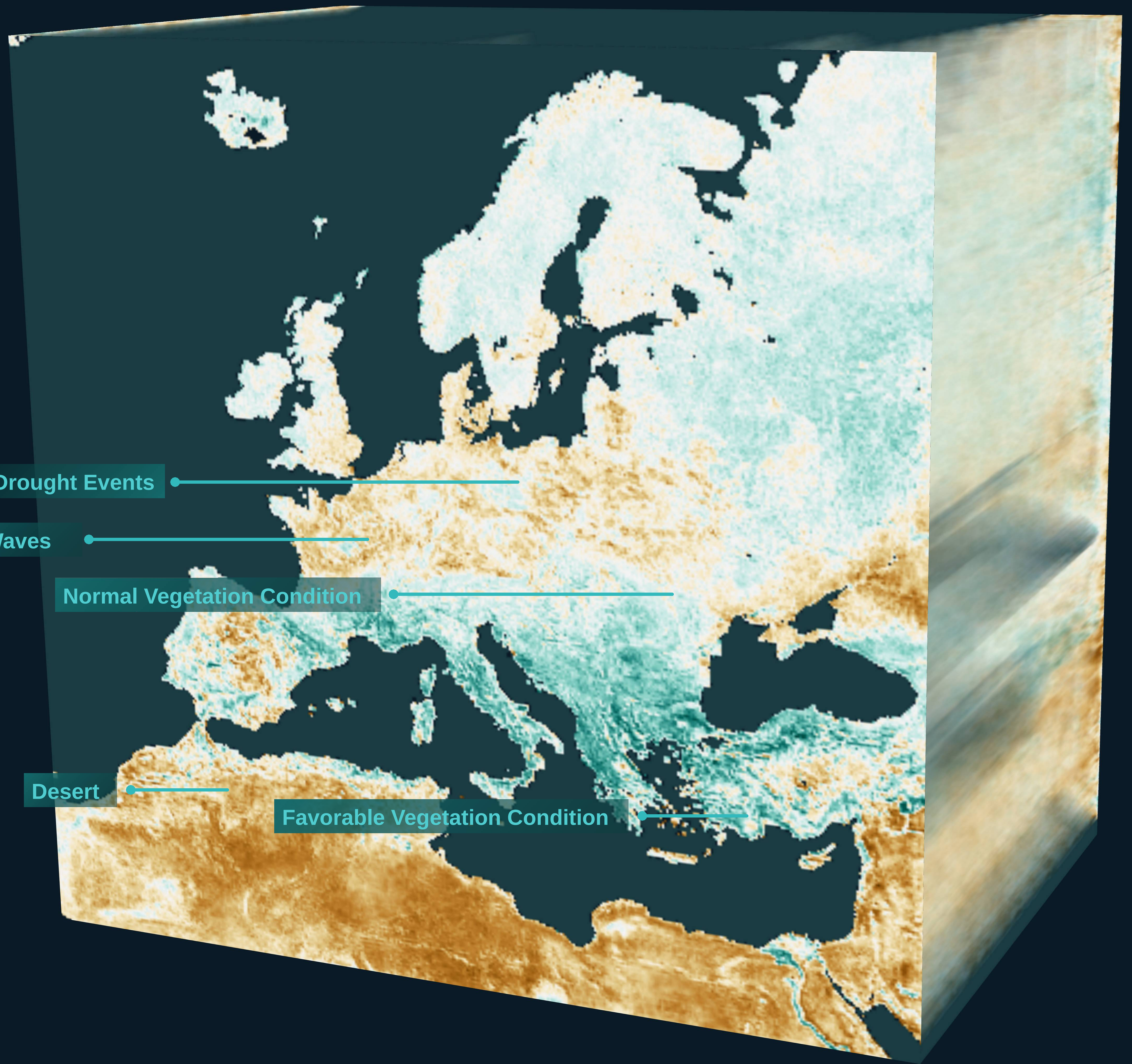


I INTRODUCTION

- We use Earth simulations based on Terrestrial System Modeling Platform (TSMP)[1] to predict remote sensing products such as Normalized Difference Vegetation Index (NDVI) and Brightness Temperature (BT) on a weekly basis:

TSMP → Deep Learning → NDVI, BT

- These predicted satellite images can then be used to derive different agricultural drought indices such as Vegetation Condition Index (VCI), Thermal Condition Index (TCI), and Vegetation Health Index (VHI)[2] based on a pixel-wise long-term climatology:

Normalization

$$\text{VCI} = 100\,\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$$

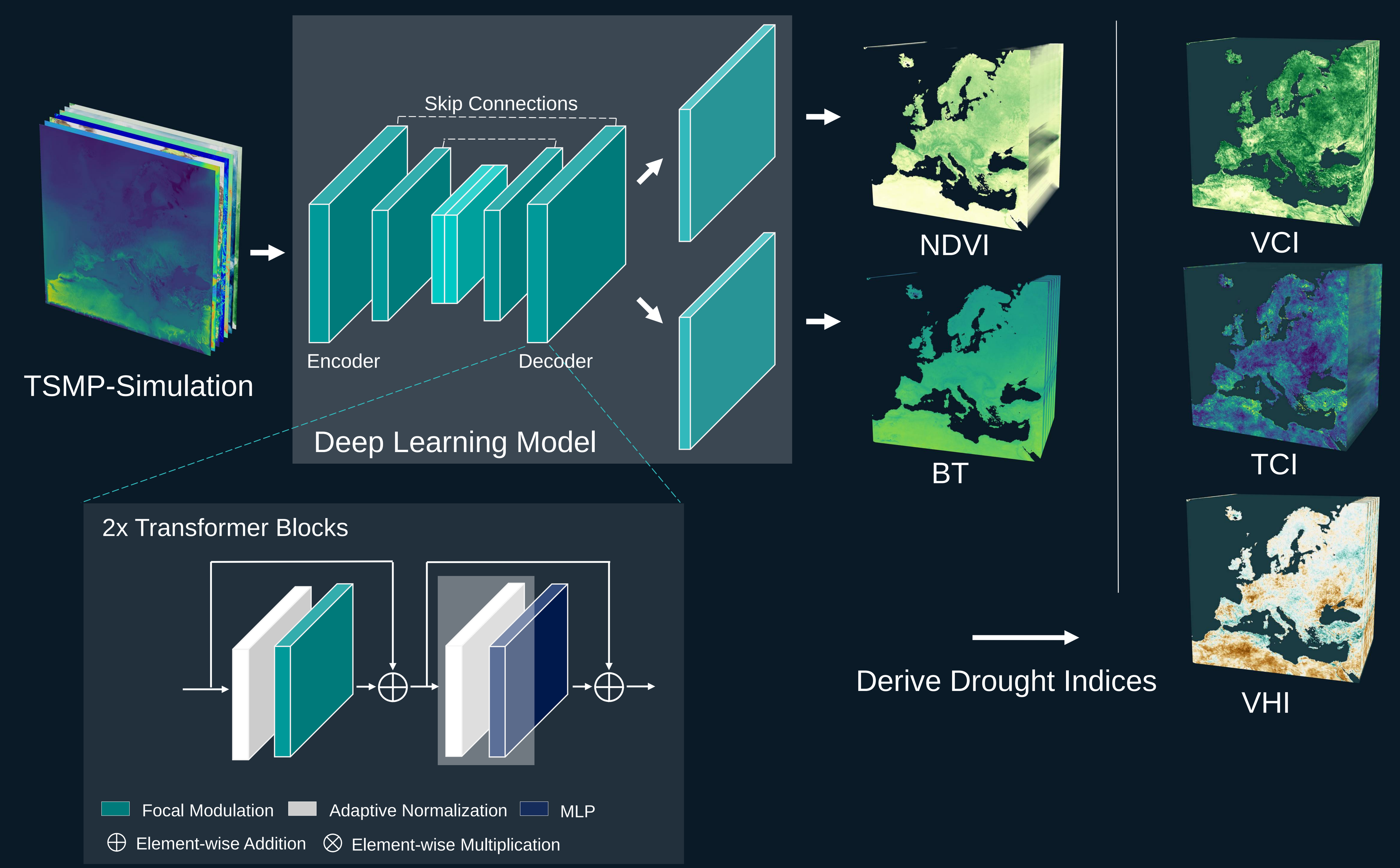
$$\text{TCI} = 100\,\frac{BT_{max} - BT}{BT_{max} - BT_{min}}$$

$$\text{VHI} = \alpha\, VCI + (1-\alpha)\, TCI$$

- We implemented deep neural networks that can be used to automatically identify regions with agricultural droughts in the future based on simulated data
- TSMP constitutes of COSMO, CLM3.5, and ParFlow as a long-term (1989-2019), high-resolution (~12.5km) regional Earth system climatology over Europe

II METHOD

- Input: TSMP Simulation ⟶ Output: Satellite Products (NDVI and BT)
- Deep Learning Model: Encoder-Decoder U-Net with transformer blocks based on Focal Modulation Networks

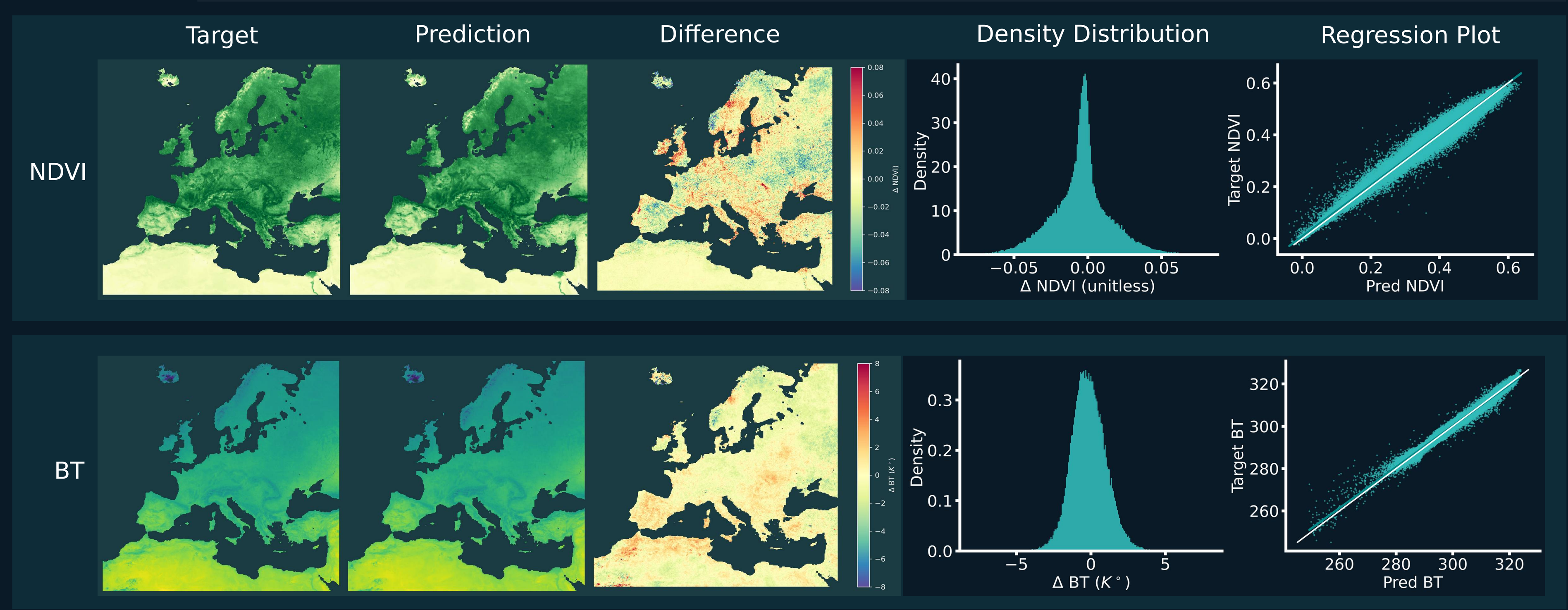


III RESULTS

- Performance of the model on the test set as a seasonal averaged prediction (the shown result is an example for summer 2018)
- The model achieves a good performance to predict the satellite observations
- Most mismatches between the predictions and real observations are over mountains and very cold regions

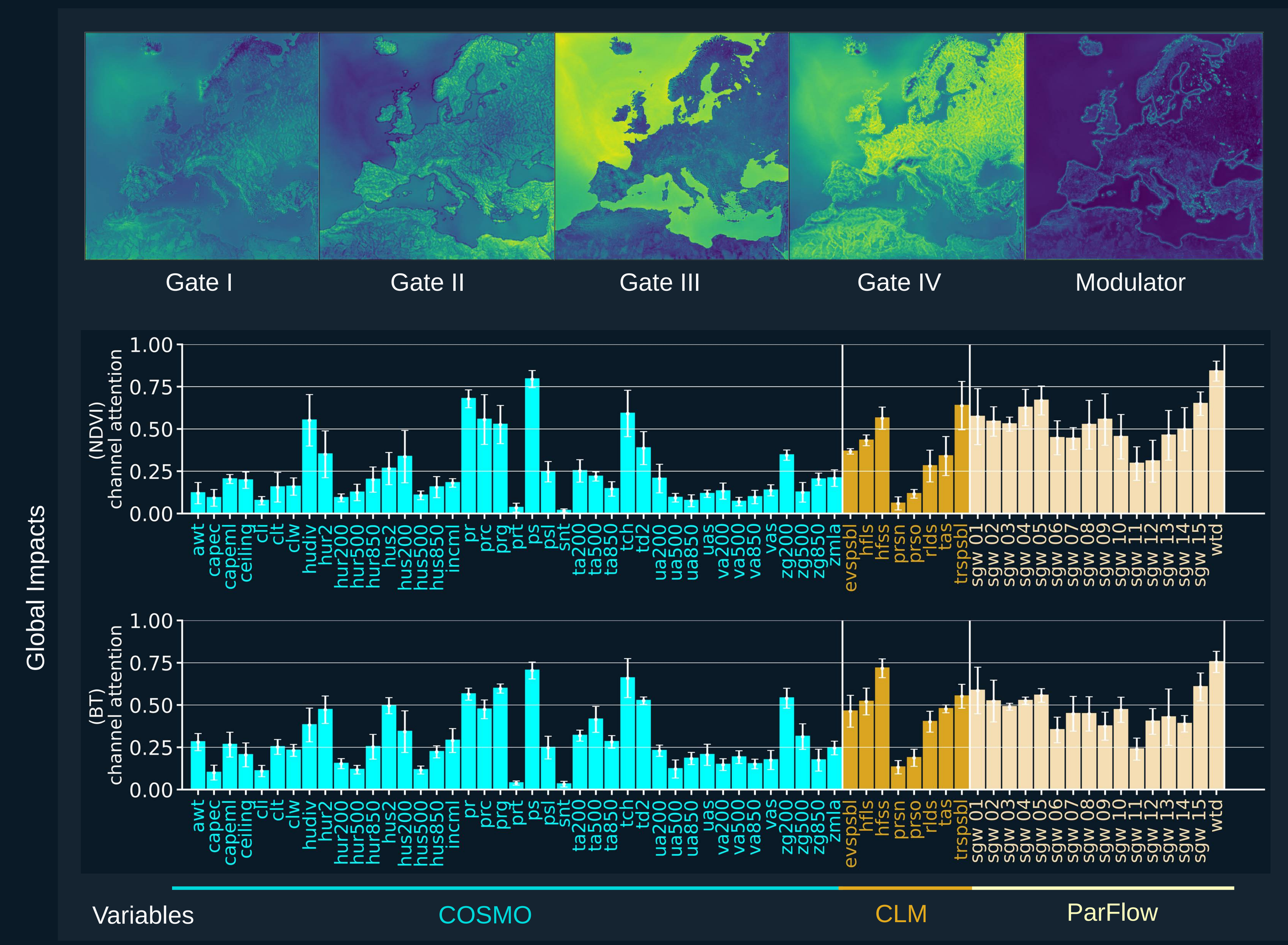
Summer 2018 (Weeks 25 - 38)

Mean Absolute Error (MAE)					Coefficient of determination (R2)				
BT	NDVI	TCI	VCI	VHI	BT	NDVI	TCI	VCI	VHI
0.949	0.016	10.9	12.4	8.5	0.987	0.983	0.547	0.560	0.445



IV Attention Maps

- Visualization of gating and modulator values
- Global impacts of the input variables via Channel Attention



V CONCLUSIONS

- We formulated the problem of simulating satellite-based images as a deep learning problem and demonstrated that deep learning can be used for surface radiation forecasting based on TSMP
- The results provide opportunity to simulate more surface radiations (different bands of electromagnetic spectrum)
- Channel attentions provide insights into the correlations between TSMP and the predicted remote sensing products
- We showed an application to predict vegetation health indices from the predicted satellite products
- Limitations: input simulation is expected to deviate from observations at the local scale. Furthermore, drought indices are not reliable over area without vegetation and very cold surfaces

Acknowledgments
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