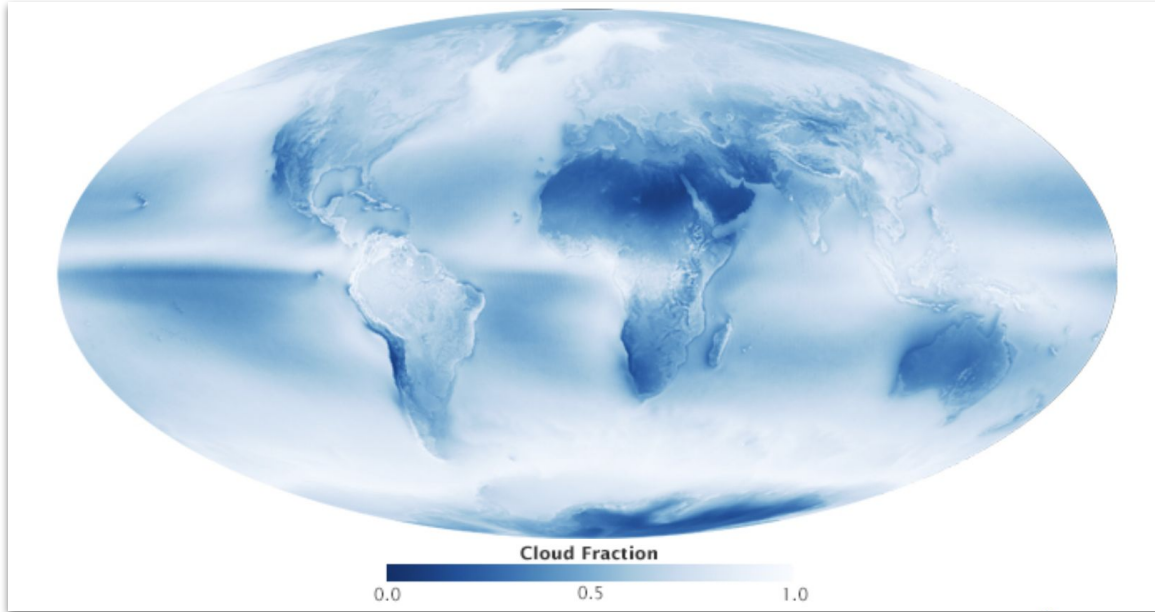


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¹Computer Science, Cornell University

²Computer Science, Columbia University

General Problem Setup



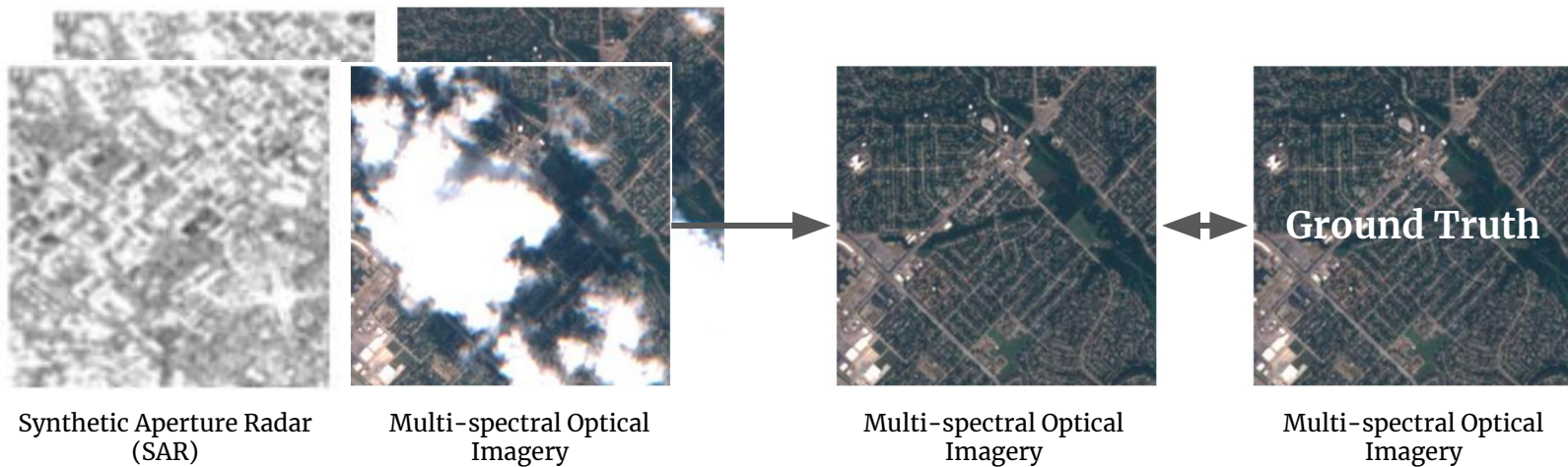
Remote-sensing imagery is promising for Earth observation and environmental monitoring.

But ...

70% of land areas are not completely **cloud-free**

The averaged **cloud fraction** over land is **55%**

Cloud Removal

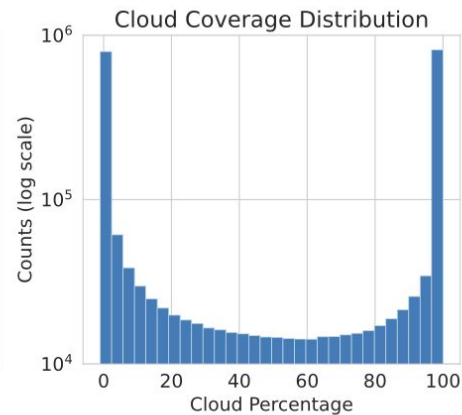
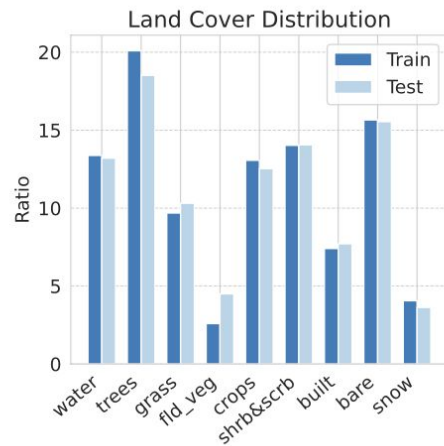
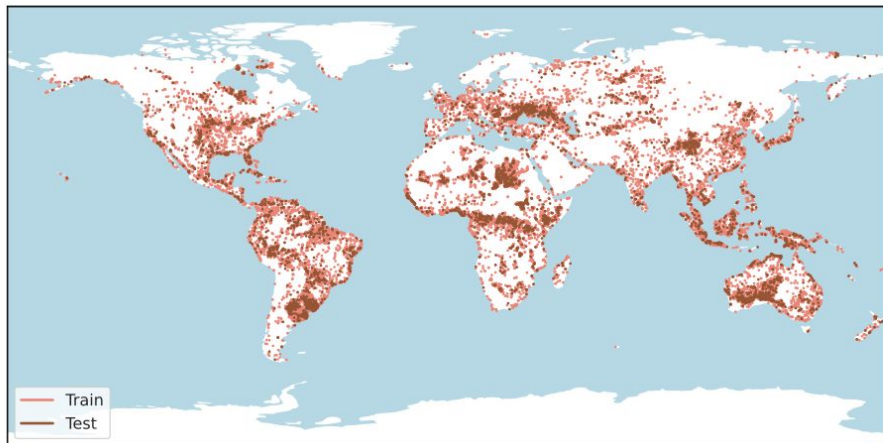


Problems with Existing Datasets and Benchmarks

1. **Small Scale**
 - a. Cannot capture the rich spatial-temporal variations on Earth.
2. **Biased in Land Cover and Cloud Percentage**
 - a. No balancing on land cover distribution.
 - b. Some only consider scenarios with cloud coverage $< 30\%$.
3. **Ill-defined due to Temporal misalignment**
 - a. In some cases, the input and target (GT) satellite images were months apart.

AllClear Highlights

Key Features: 1) Large-scale (largest to-date); 2) sufficient sampling for all land cover types; 3) no filtering on cloud coverage distribution; 4) small temporal misalignment; 5) stratified evaluation.



SoTA Cloud Removal Models Fail on AllClear Benchmark

Model	Training Dataset	PSNR (\uparrow)	SSIM (\uparrow)	SAM (\downarrow)	MAE (\downarrow)
Least Cloudy	-	28.864	0.836	<u>6.982</u>	0.078
Mosaicing	-	29.824	0.754	23.58	0.045
UnCRtainTS [Ebel et al., 2023]	SEN12MS-CR-TS	<u>29.009</u>	0.898	5.972	0.039
U-TILISE [Stucker et al., 2023]	SEN12MS-CR-TS	24.660	0.807	7.765	0.083
CTGAN [Huang and Wu, 2022]	Sen2_MTC	27.783	<u>0.840</u>	8.800	<u>0.041</u>
PMAA [Zou et al., 2023a]	STGAN	12.455	0.460	8.072	0.240
	Sen2_MTC	24.328	0.768	8.680	0.078
DiffCR [Zou et al., 2023b]	STGAN	17.998	0.642	9.512	0.117
	Sen2_MTC	25.220	0.744	9.382	0.060

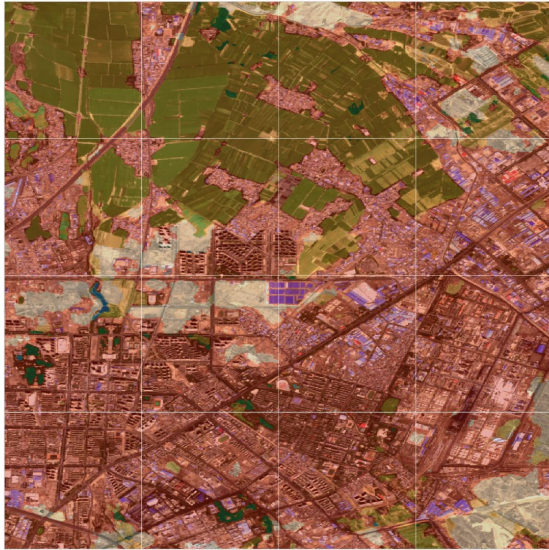
SoTA Model Benefits from Scaling up

Fraction of Data	# data point	PSNR (\uparrow)	SSIM (\uparrow)	SAM (\downarrow)	MAE (\downarrow)
1%	2,786	27.035	0.898	5.972	0.039
3.4%	10,167	28.474	0.906	6.373	0.036
10%	27,861	32.997	0.923	6.038	0.023
100%	278,613	33.868	0.936	5.232	0.021

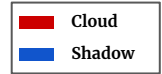
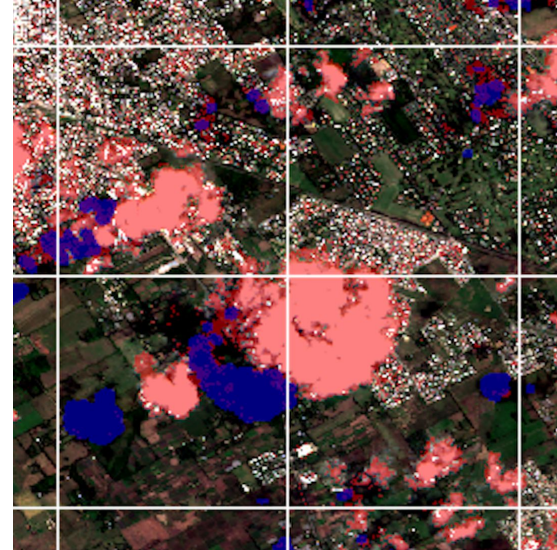
SoTA Model Benefits from Longer Time Sequence Inputs

# Consecutive Frame as Input	PSNR (\uparrow)	SSIM (\uparrow)	SAM (\downarrow)	MAE (\downarrow)
3	28.474	0.906	6.373	0.036
12	30.399	0.919	5.920	0.028

Stratified Evaluation: Land Cover and Cloud Coverage

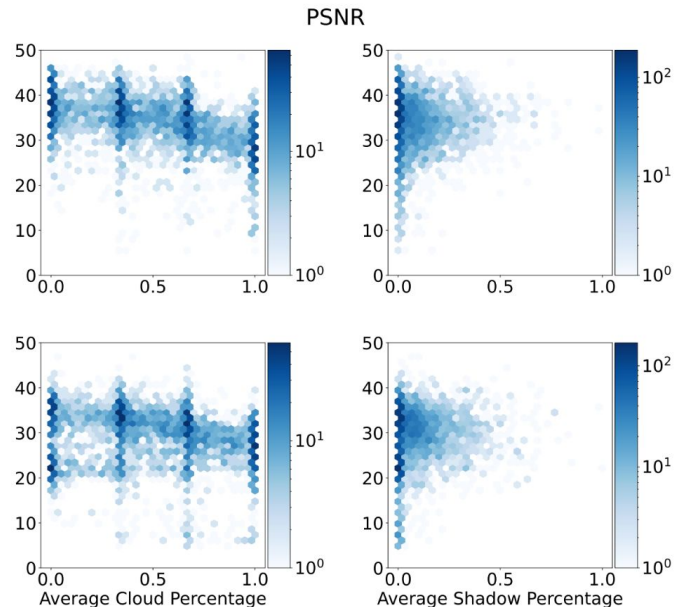
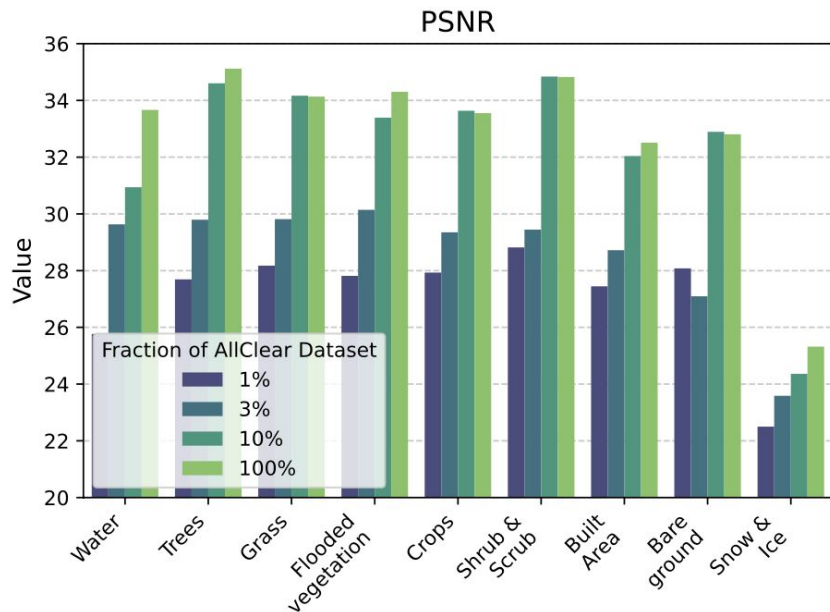


Land Use / Land Cover (LULC) Maps
(Source: Dynamic World V1)



Cloud and Shadow Masks
(Source: s2cloudless)

Stratified Evaluation: Land Cover and Cloud Coverage



Input images

Target

Pretrained Model

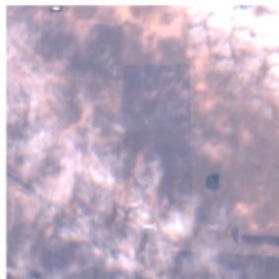
2022-08-12

2022-08-17

2022-08-27

2022-08-22

PSNR: 29.77, SSIM: 0.97



Fail to refer to clear inputs

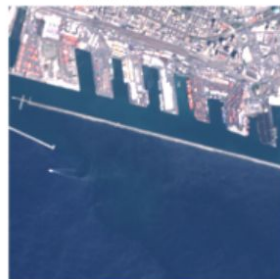
2022-06-20

2022-06-30

2022-07-05

2022-06-25

PSNR: 29.15, SSIM: 0.87



Fail to recover true color

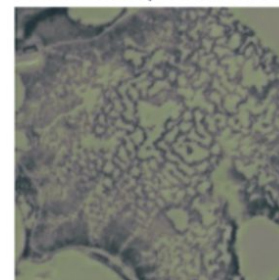
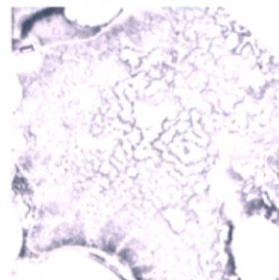
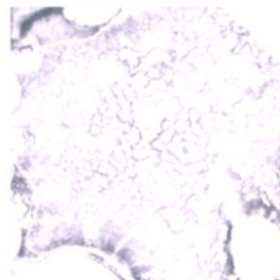
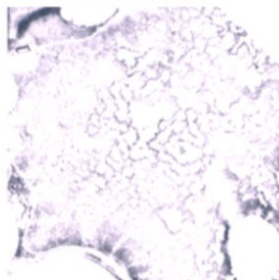
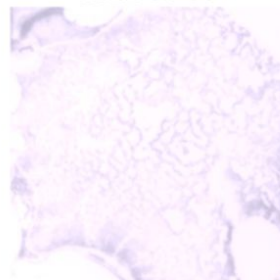
2022-03-08

2022-03-11

2022-03-13

2022-03-09

PSNR: 9.55, SSIM: 0.67



Fail to tell snow from cloud

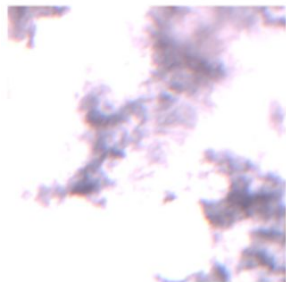
Input images

Target

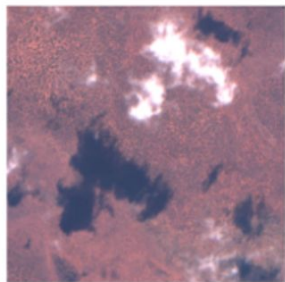
Model trained on 10% AllClear

Model trained on full AllClear

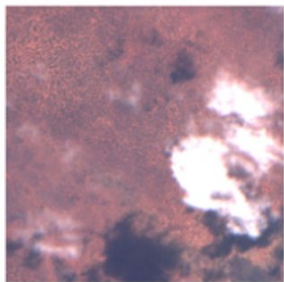
2022-07-21



2022-07-31



2022-08-05



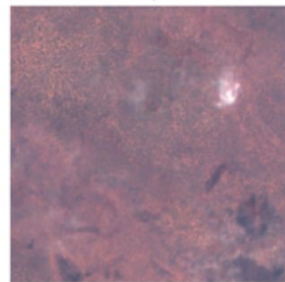
2022-07-26



PSNR: 28.66, SSIM: 0.95



PSNR: 38.56, SSIM: 0.98



2022-01-06



2022-01-11



2022-01-21



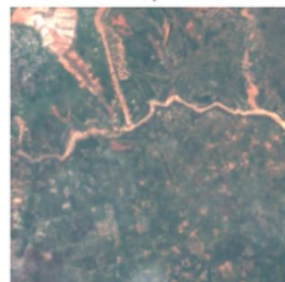
2022-01-16



PSNR: 27.77, SSIM: 0.93



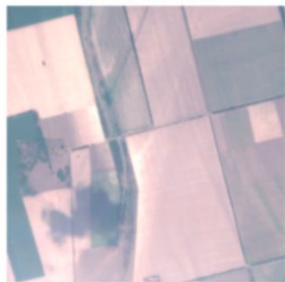
PSNR: 34.53, SSIM: 0.97



2022-07-21



2022-07-31



2022-08-05



2022-07-26

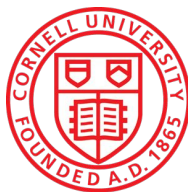


PSNR: 29.05, SSIM: 0.96



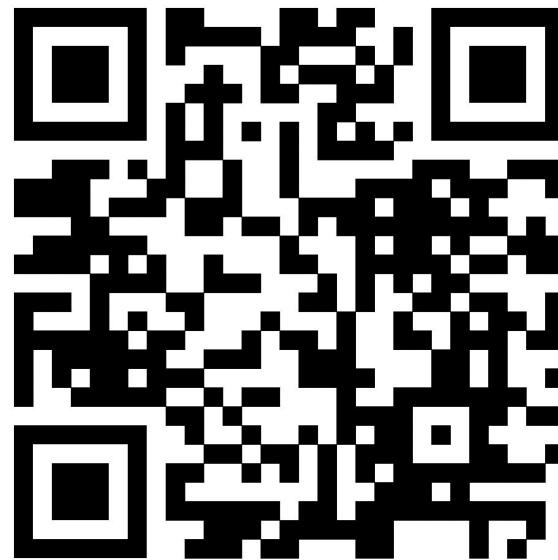
PSNR: 34.89, SSIM: 0.98





Thank you!

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<https://allclear.cs.cornell.edu/>