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Assessment of spatio-temporal fusion and super-resolution algorithms between the proposed Sentinel-HR and Sentinel-2 (NG) missions

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What is Sentinel-HR ? A phase-0 mission study

Sentinel-HR would be a VHR and 3D Sentinel mission complementary to Sentinel-2 (NG)

Coverage	All land and coasts (similar to S2)
Ground Sampling Distance	≤ 2.5 meters
Revisit time	20 days
Spectral bands	Blue, Green, Red, Near Infra Red (similar to S2 10m bands)
Viewing angles	Constant Nadir (at center of swath)
Stereoscopic capability	Systematic with height accuracy better than 4m CE90
Orbit	Sun-synchronous
Tasking	no tasking, instrument always on over lands
Mission lifetime	7 years or more
Proposed launch date	2028
Products	Analysis Ready, free and open data

Aim: gather multi-temporal, high resolution observations for land surface change detection

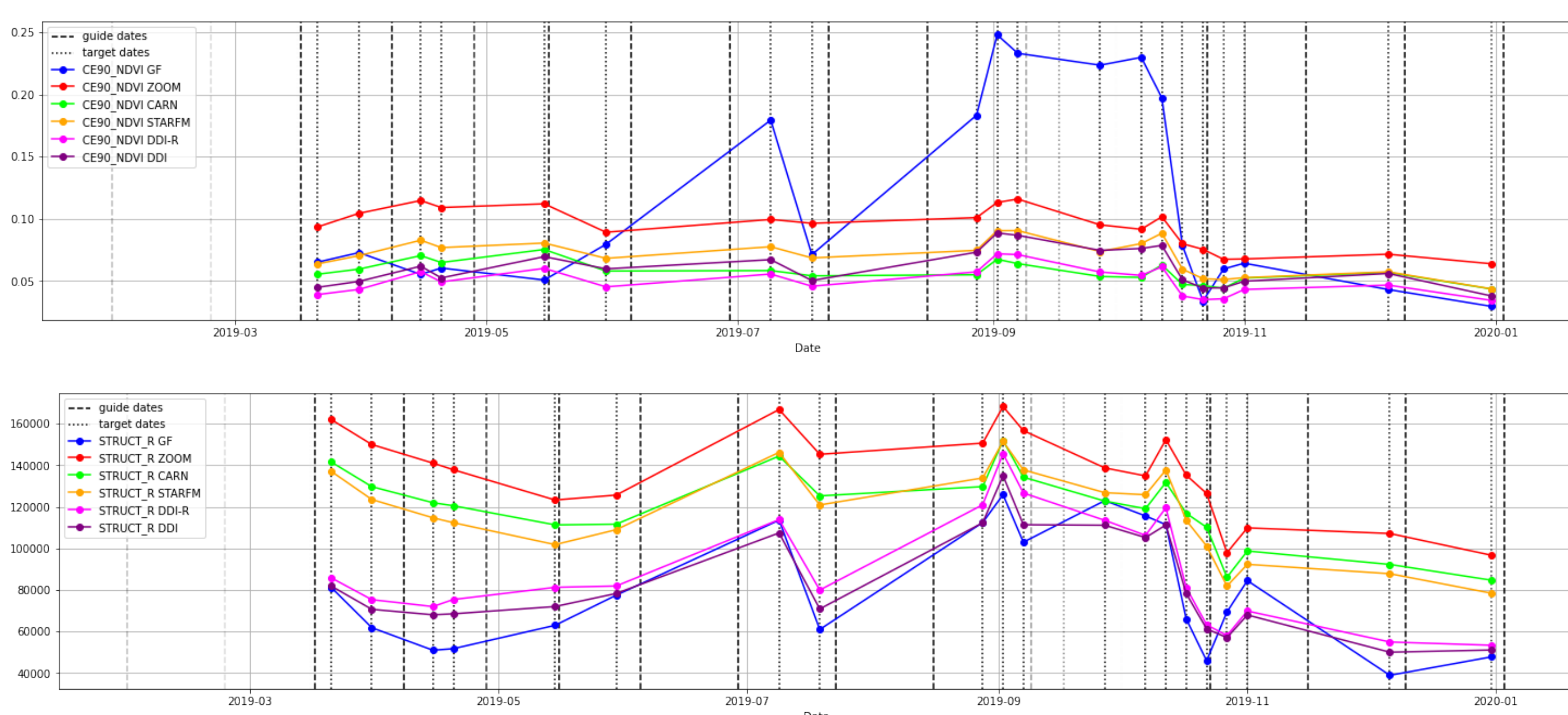
Hybridation: Dataset

- Use Venüs and Sentinel-2 L2A products from Theia archives
- Search for Venüs 5m "guide" series with ≈ 20 days revisit (will act as Sentinel-HR)
- Cross-search "target" series of Sentinel-2 and Venüs less than 1 day apart (will act as S2 with its high resolution reference)
- Downsample Sentinel-2 to 25m (ratio of 5 SHR+S2) or 12.5m (ratio of 2.5 for SHR+S2NG)
- Spatial registration and radiometric harmonization by linear regression

Site Name	Location	Landscape	Guide	Target	Time range
SUDOE-4	France	Mountains	10	14	2019.07 - 2020.01
MAD-AMBO	Madagascar	Desert	17	39	2018.11 - 2020.01
FR-LQ1	France	Mixed	9	27	2020.04 - 2020.10
FR-BIL	France	Agricultural, urban	12	16	2020.03 - 2020.11
ARM	USA	Agricultural	16	23	2019.03 - 2020.01
ESGISB-2	France	Agricultural, urban	10	14	2018.11 - 2019.05

Benchmark results for resolution factor $\times 5$

CE90 NDVI metric (\approx radiometry) and STRUCT R metric (\approx edges) on ARM site



Hybridation: Problem statement

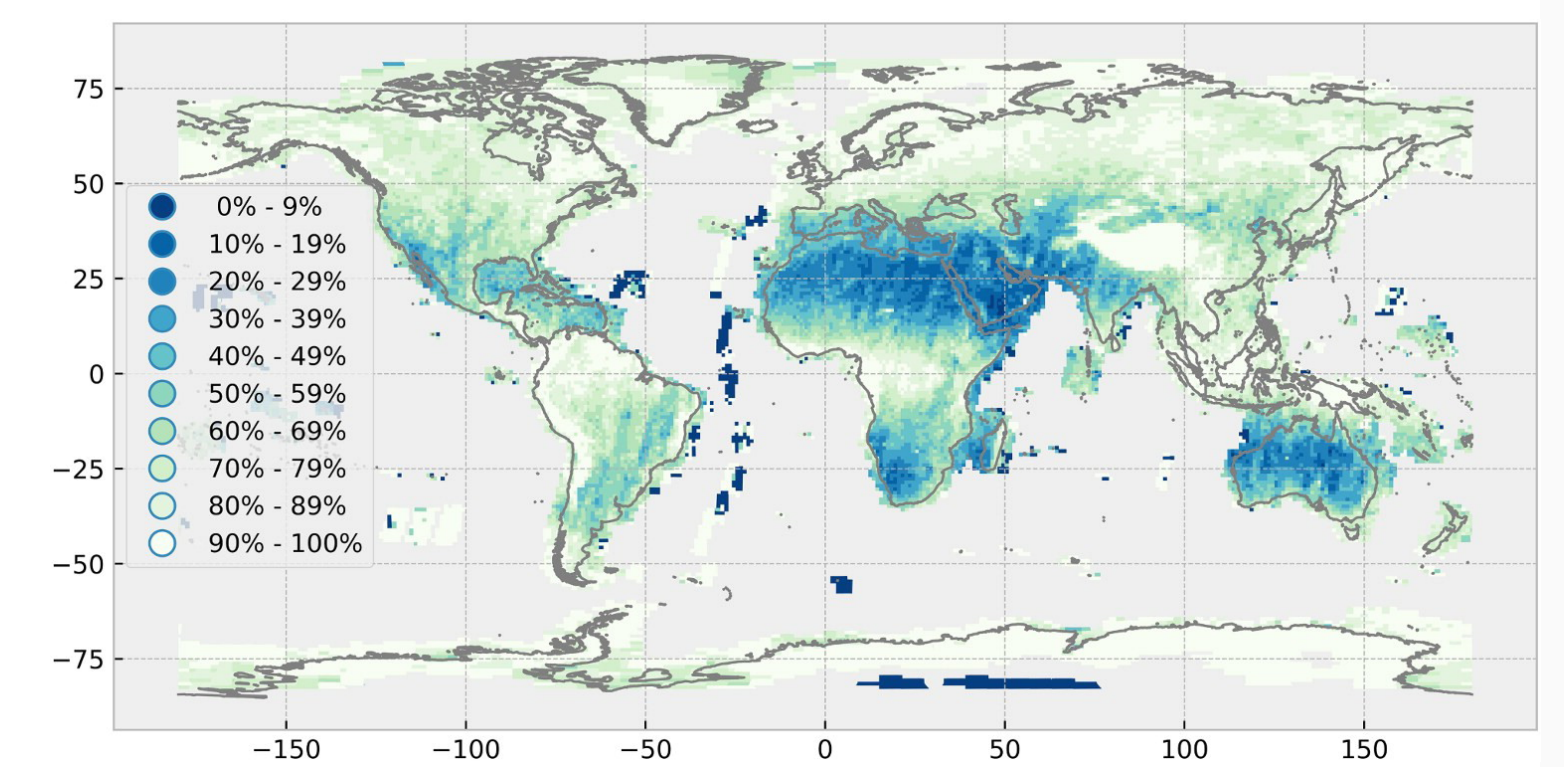
Problem

- Some use-cases require both 2m resolution and revisit better than 20 days
- Cloud cover will impair the 20 days revisit in most locations

Idea

- Combine Sentinel-HR images (2m, 20 days) with:
 - Sentinel-2 (10m, 5 days)
 - Sentinel-2 NG (5m, 2 days)
- To make 2 meters prediction with revisit < 20 days

Percentage of S2 cloud contaminated scenes in 2017



Phase 0 Objective

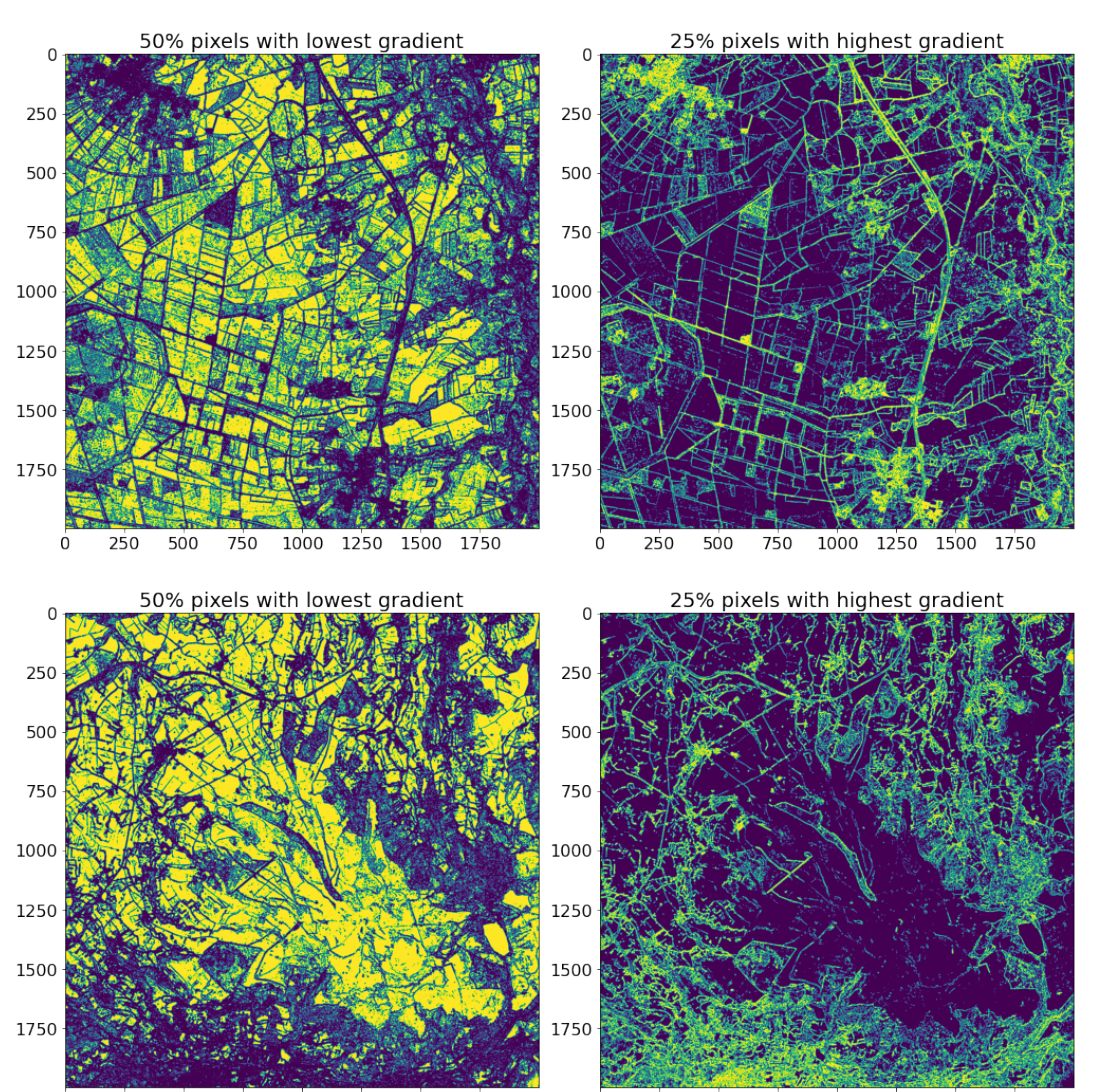
Demonstrate feasibility of hybrid products and assess expected performances

Hybridation: Benchmark

Principle

- Predict all target dates at 5m using 5m guide dates and 25m or 12.5m target dates
- Derive different metrics (RMSE, MAE, PSNR, UIQI, CE90, CE99, SAM, Structural, ERGAS ...)
- Computed on bands + NDVI, for whole image, 50% of lowest gradient pixels, 25% of highest gradient pixels

Low / High gradient magnitude stratas

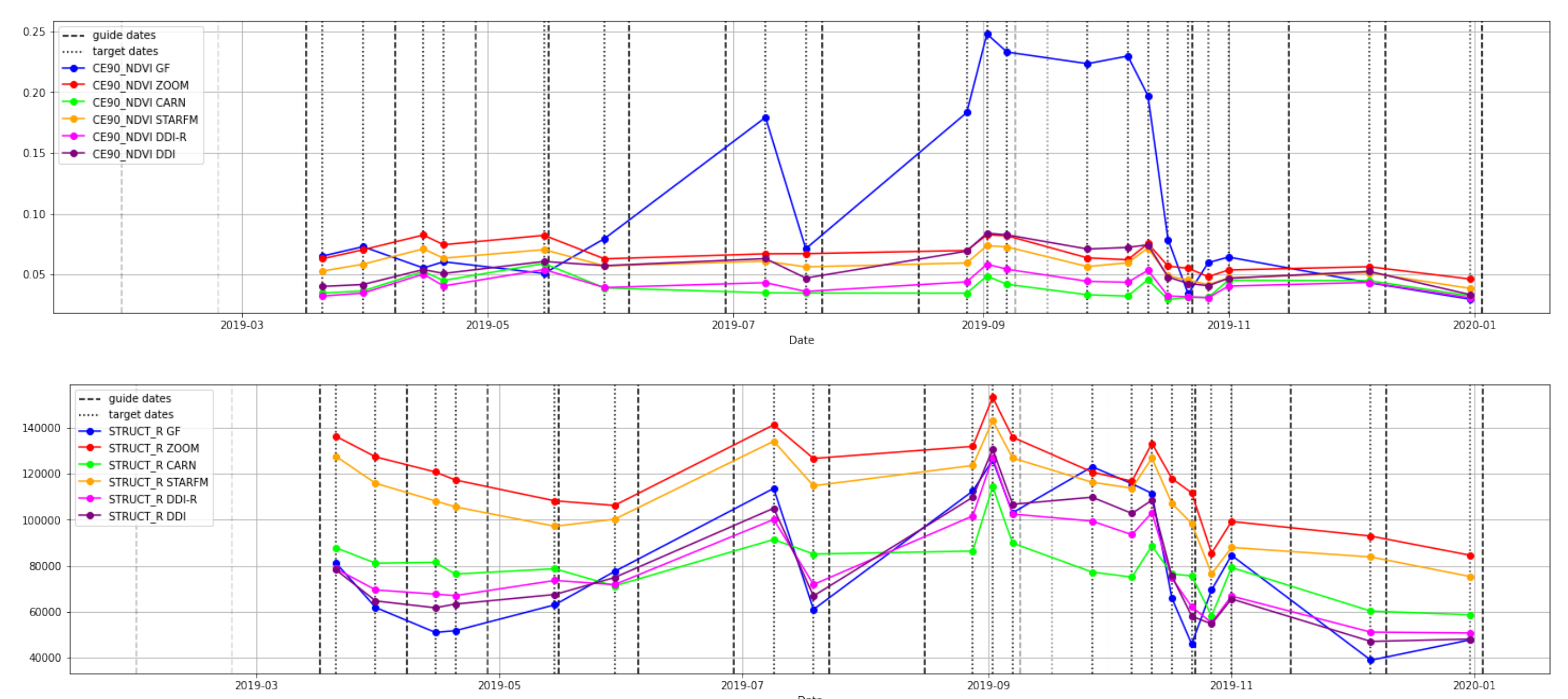


Methods overview

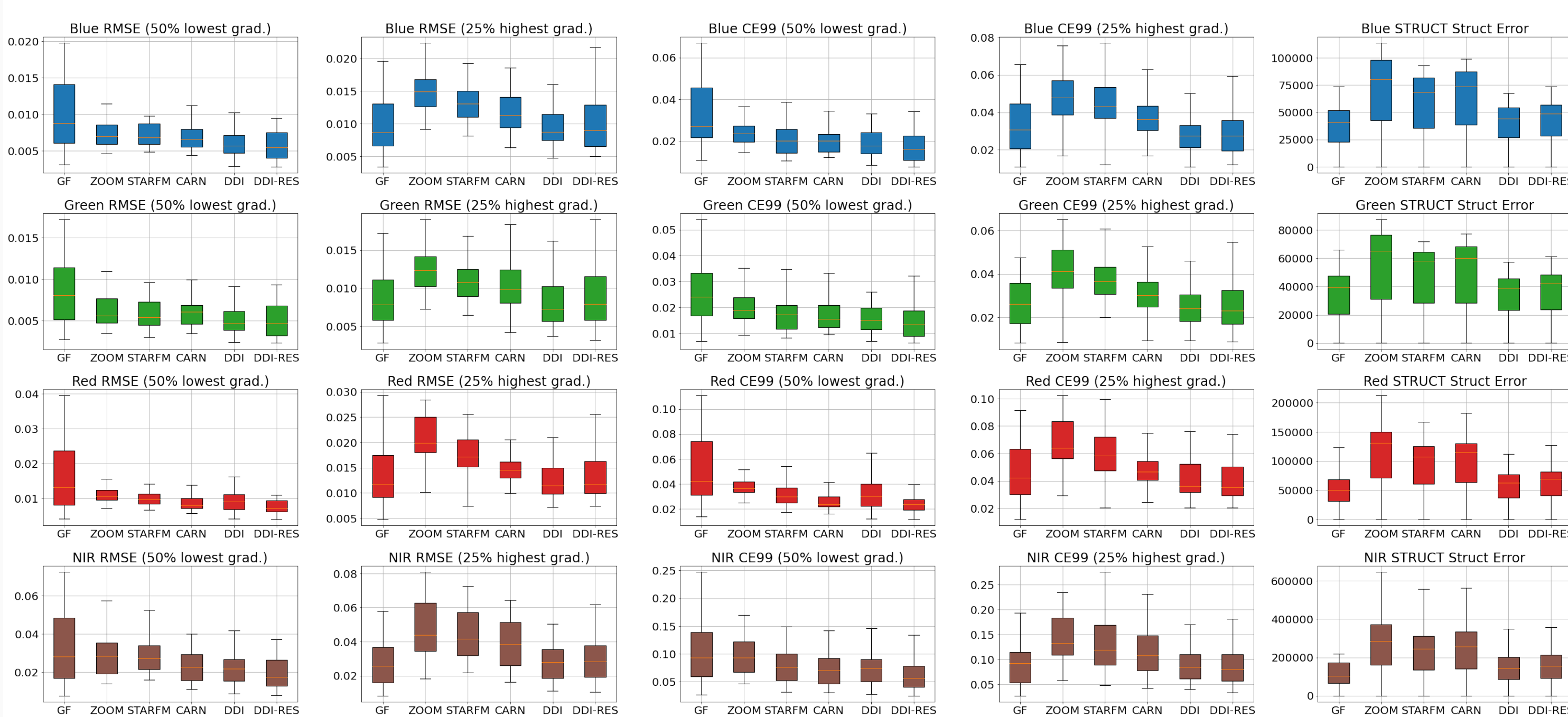
Method	Use HR images	Use LR images
Temporal interpolation	yes	no
Spatial interpolation	no	yes
SISR (CARN)	training	inference
Data Driven Interpolation (ours)	inference	training*
STARFM / ESTARFM	yes	yes

Benchmark results for resolution factor $\times 2.5$

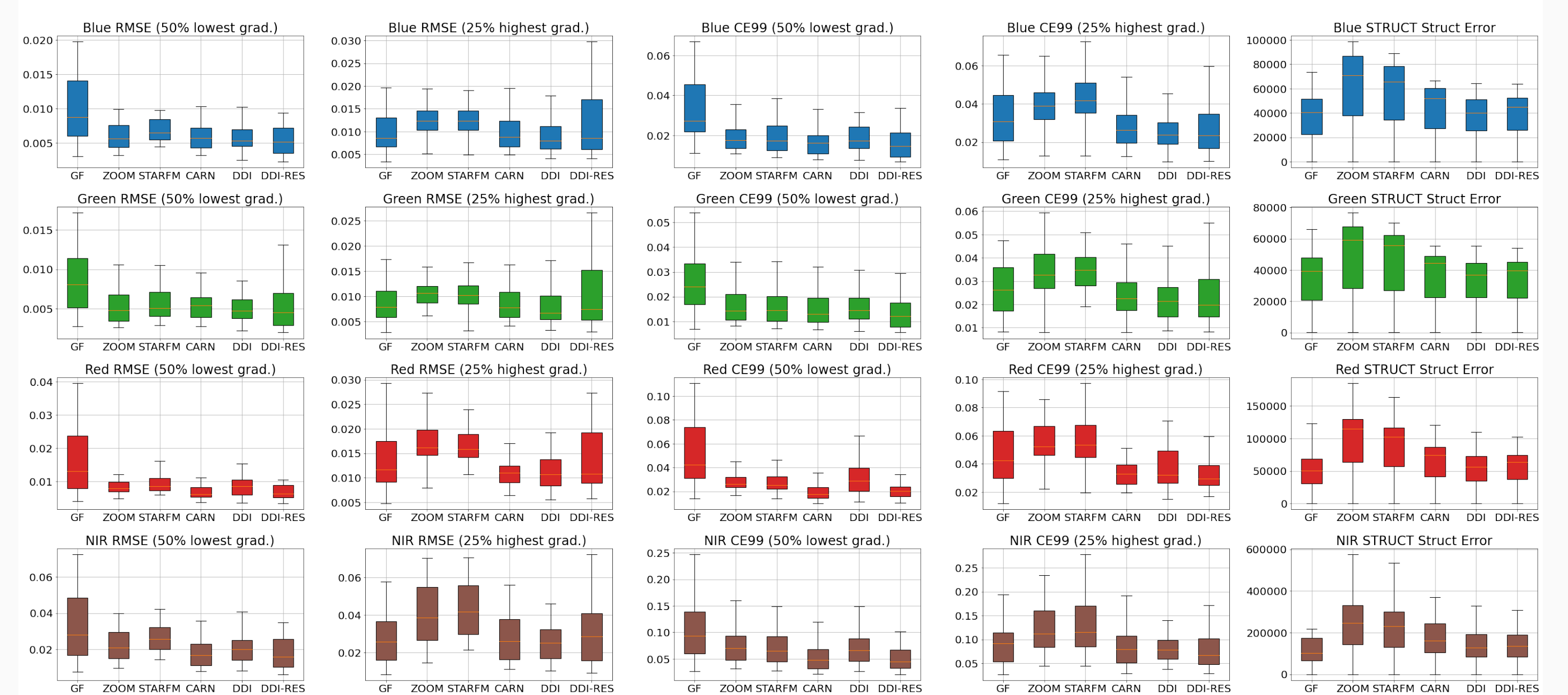
CE90 NDVI metric (\approx radiometry) and STRUCT R metric (\approx edges) on ARM site



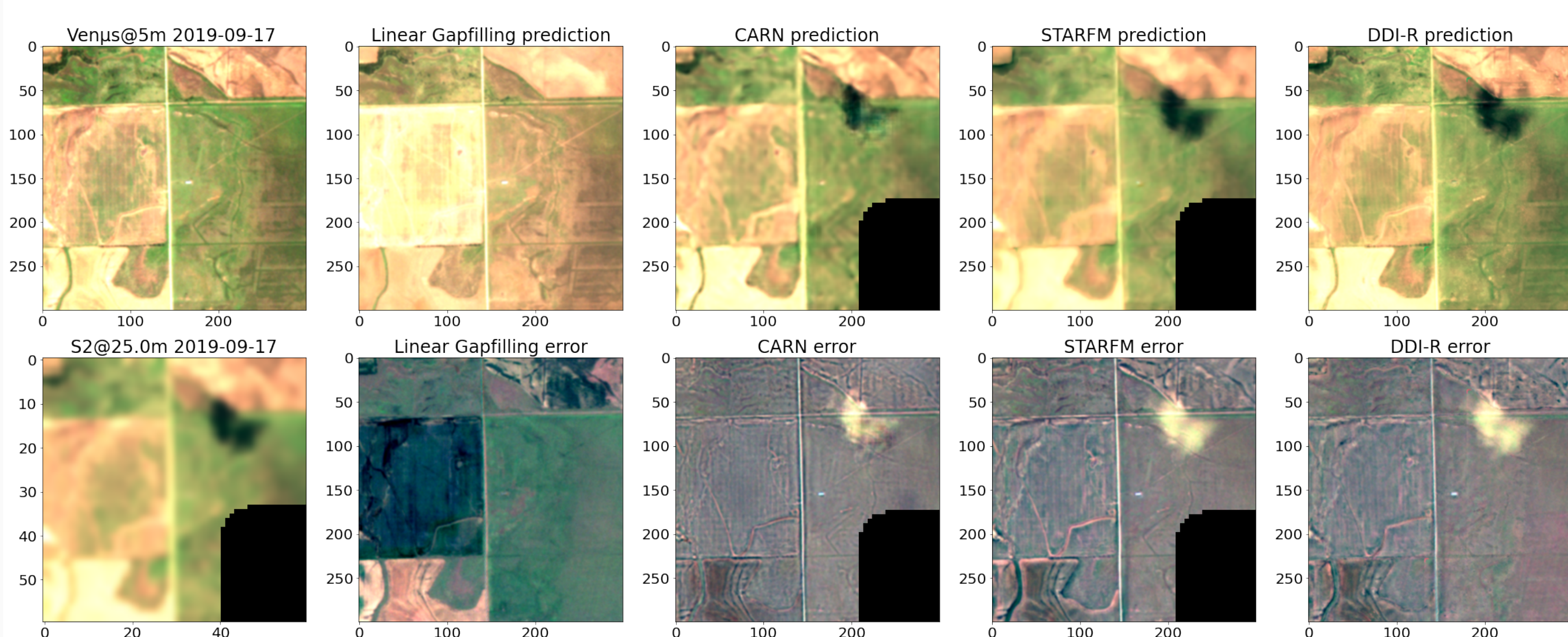
Metrics on all sites, reference and prediction on same day (54 images)



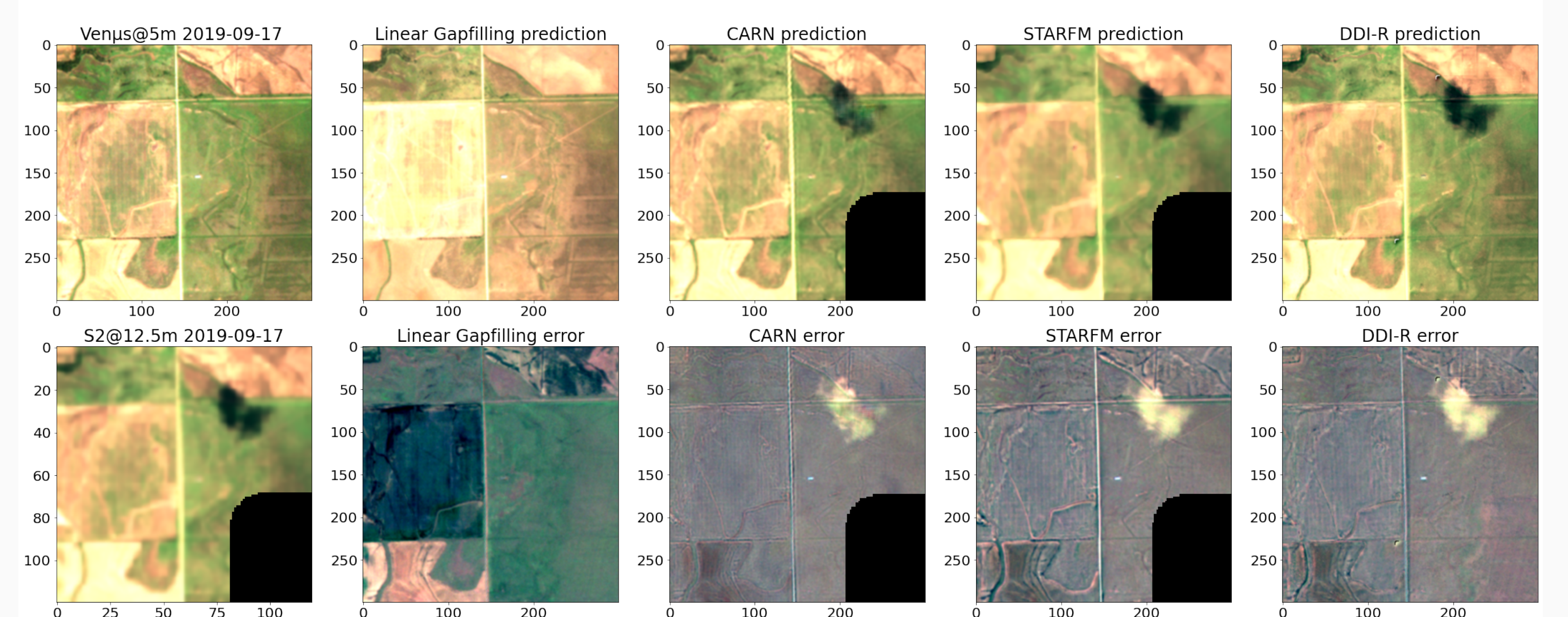
Metrics on all sites, reference and prediction on same day (54 images)



Example of prediction for ARM site



Example of prediction for ARM site



Conclusion

- Super Resolution seems competitive for a ratio of 2.5 (provided that training data are available). Also very simple to use after offline training (only requires the low resolution S2 date)
- DDI more interesting for higher ratios, and provides gap-filling as well, but requires (fast) training for each date and SHR dates buffering
- Clear interest on mixing SHR with S2(NG) with any method (instead of temporal interpolation)

Full report of Sentinel-HR phase-0 available on HAL



Covers hybridation study but also user requirements and mission design
 Julien Michel, Olivier Hagolle, Anne Puissant, Pierre-Alexis Herrault, Thomas Corpetti, et al.
 Sentinel-HR Phase 0 Report. [Research Report] CNES - Centre national d'études spatiales; CESBIO. 2022. (hal-03643411)