



# Synergistic Exploitation of Sentinel-1 in Planet Fusion



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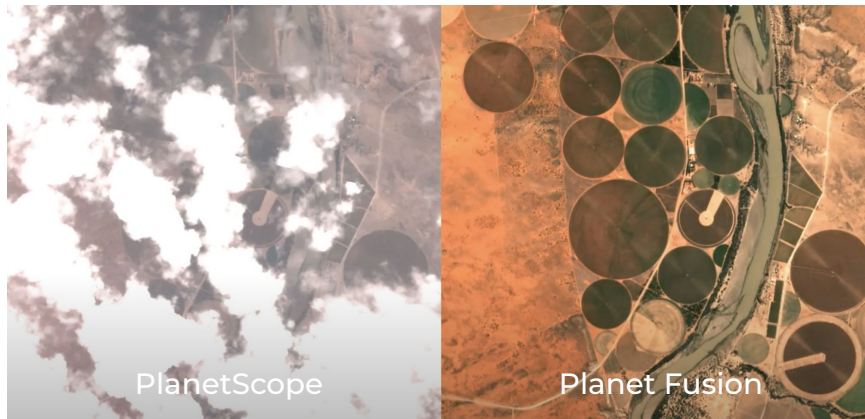
# Planet Fusion

## What is Planet Fusion?

**Planet Fusion Surface Reflectance** (PF-SR) product is a daily, 3 meter, gap-free, ARD product in four spectral bands (blue, green, red, NIR).

Uses **rigorous methodology** to enhance, harmonize, inter-calibrate, and **fuse optical data** from:

- PlanetScope
- Landsat-8/9
- Sentinel-2
- MODIS
- VIIRS





# Planet Fusion

## Why are we looking at SAR?

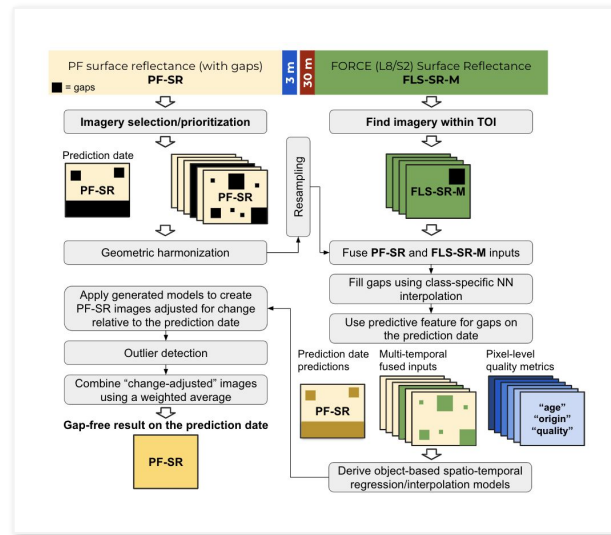
An integral part of the Planet Fusion methodology is **gap-filling**.

- Use FORCE (Landsat-8/Sentinel-2) surface reflectance to fill gaps in PF-SR.
- Ensures a **spatially complete** and **temporally continuous** product.

We are incorporating **Sentinel-1 data** into the Planet Fusion gap-filling process in order to:

- *Update uncertainty estimates* of gap-filled pixel values.
  - Closely related to the temporal gap between *actual observation data*.
- *Inform gap-filled pixel values*.
  - Capture outlier events (e.g., floods, early harvest, fires, deforestation, ...)

\* For more details on Planet Fusion, see poster session “B1.07 Analysis Ready Data: are we there yet?” on Friday (Rasmus Houborg).





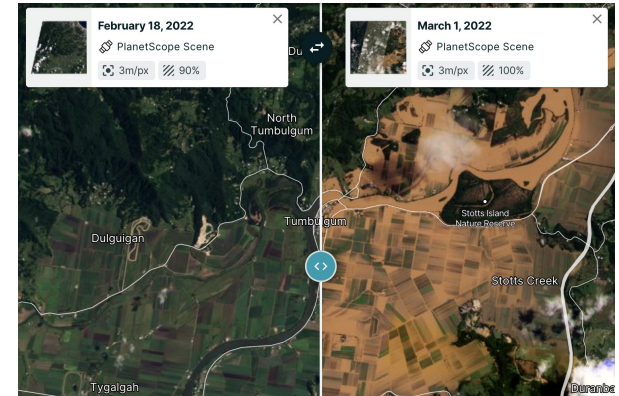
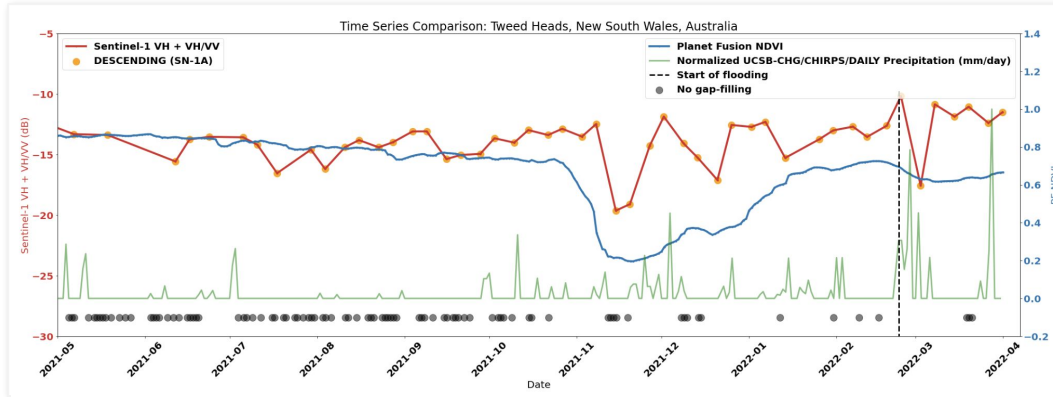
# Planet Fusion + Sentinel-1

## Time Series Analysis for Flood Event

**AOI:** Tweed Heads, New South Wales, Australia

**TOI:** Late February - early March 2022

- Only Sentinel-1A coverage.
- Sentinel-1 time series captures flooding event, Planet Fusion *maybe* does.





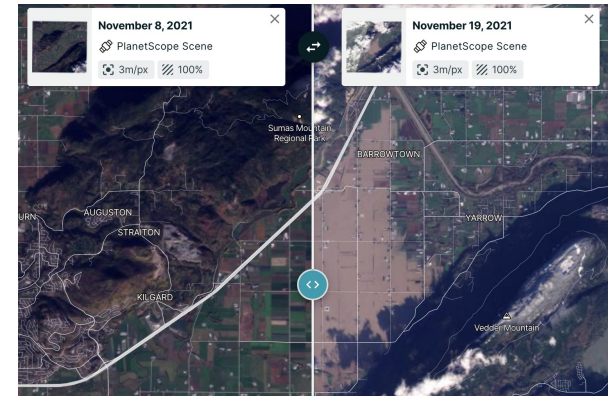
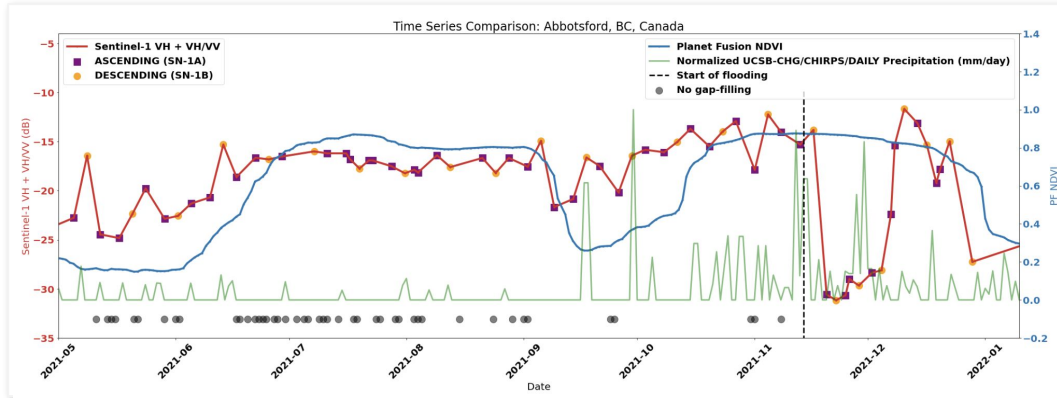
# Planet Fusion + Sentinel-1

## Time Series Analysis for Flood Event

**AOI:** Abbotsford, British Columbia, Canada

**TOI:** Mid-November 2021

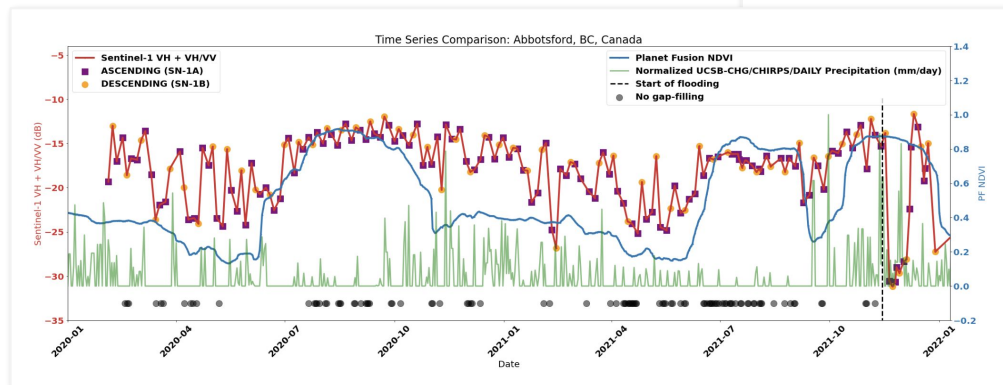
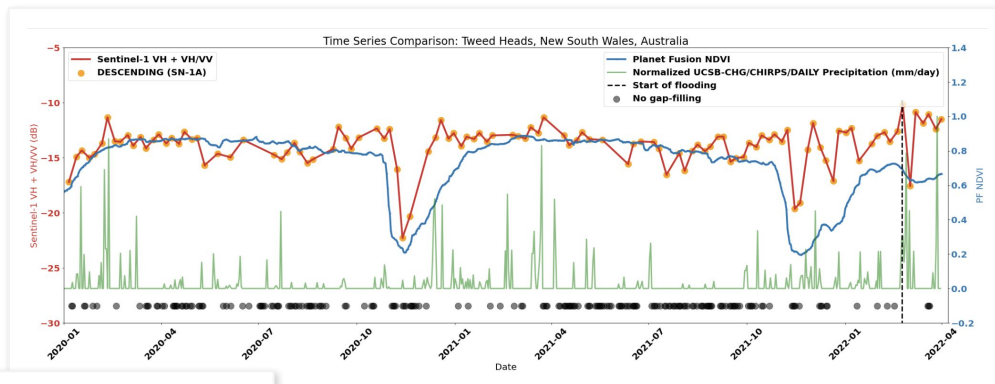
- Both Sentinel-1A and -1B coverage.
- Sentinel-1 time series captures flooding event, Planet Fusion time series *does not*.



# + Planet Fusion + Sentinel-1

## Time Series Analysis for Flood Event

Sentinel-1 time series are a little noisy...



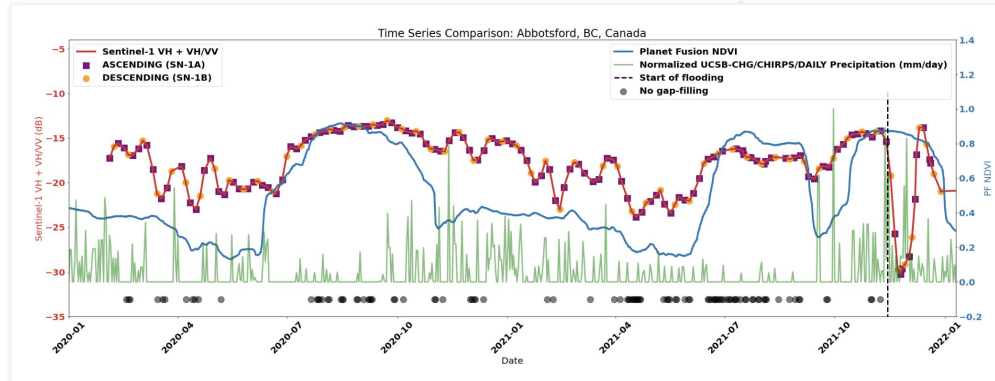
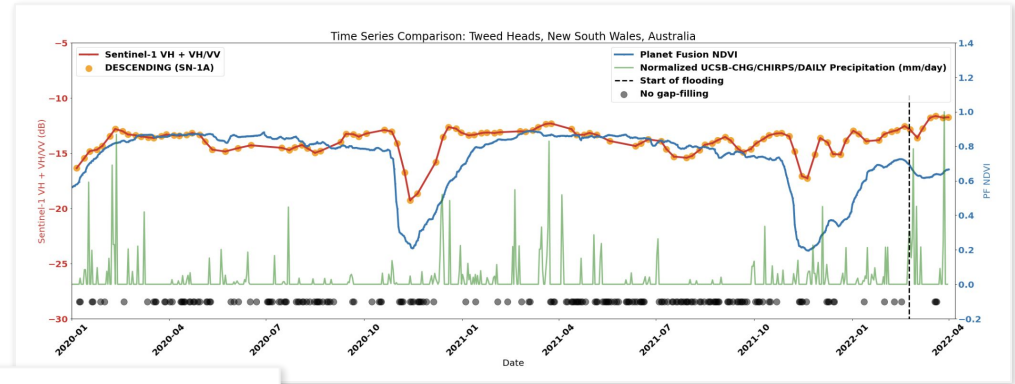
...but smoothing out that noise isn't always the best approach.



# Planet Fusion + Sentinel-1

## Time Series Analysis for Flood Event

Sentinel-1 time series are a little noisy...



...but smoothing out that noise isn't always the best approach.

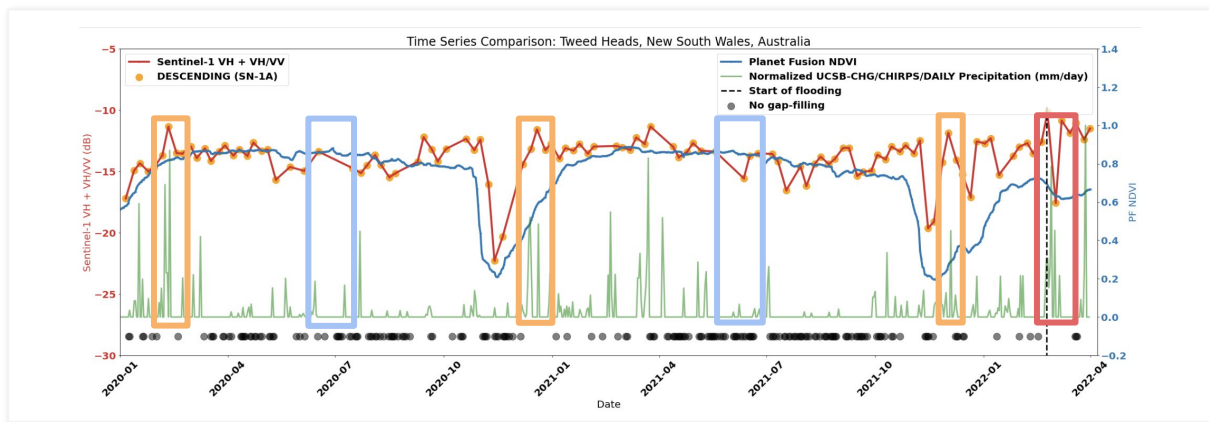




# Planet Fusion + Sentinel-1

## Time Series Analysis for Flood Event - Australia AOI

Some of the “noise” in SAR time series is related to (lack of) precipitation events.



- Increased soil saturation (rain) → higher dielectric → increased SAR backscatter
- Decreased soil saturation (dry-down) → lower dielectric → decreased SAR backscatter
- Saturated soil (flood) → smooth surface → decreased SAR backscatter



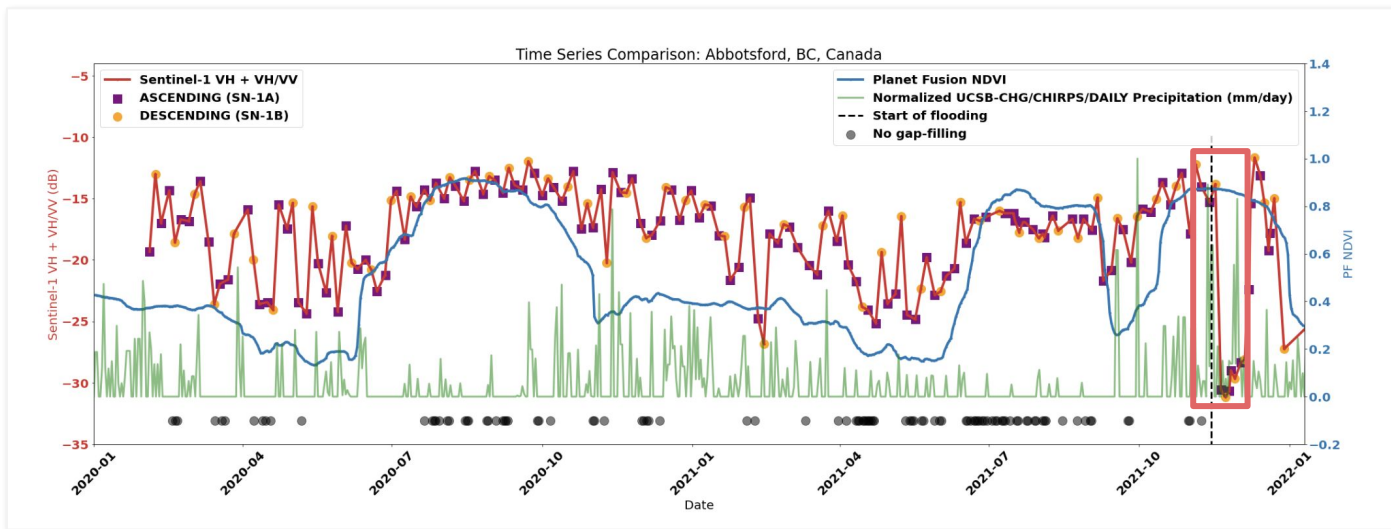


# Planet Fusion + Sentinel-1

## Time Series Analysis for Flood Event - Abbotsford AOI

For wetter climates, it's more difficult to separate these influences/events.

- The amplitude of the oscillations in the time series tends to decrease during high NDVI/dry-down events, and increase during low NDVI/rain events.

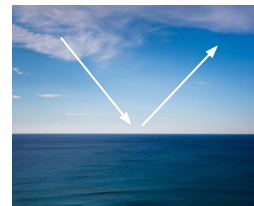
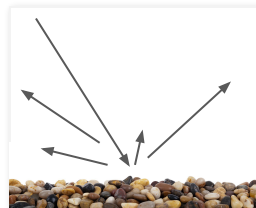




# Modeling SAR Scattering

Biggest contributors to differences in SAR backscatter:

1. **Topography:** Affects local incidence angle.
2. **Roughness:** Alters direction of scatter.
3. **Composition:** Changes in dielectric constant.  
- e.g., soil moisture, sucrose accumulation, ...



In order to **parse out vegetation information from SAR signal**, we need to account for other contributors to changes in SAR backscatter.

- **Physical models:** parametric, make assumptions, struggle to generalize for different land cover types/stages.
- **Machine learning models:** non-parametric, black box, generalize well for different land cover types/stages.



# Planet Fusion + Sentinel-1

## Random Forest Model - Setup

**Goal:** Train random forest model to **generate SAR derived NDVI time series** that can be used to flag **undetected outlier events** in Planet Fusion during extended periods of cloud.

**AOI:** Abbotsford, British Columbia, Canada (UTM 10N, 23E-226N)

**TOI:** January 2020 - April 2022

**Ground Truth:** NDVI derived from Planet Fusion (non-gap-filled)

**Features** (field-based):

- Sentinel-1 (processed to CARD4L using SNAP)
  - VV, VH, RVI, RFDI, VV-VH, VH + VH/VV, VV/(VH+VV)
  - incidence angle, platform (1A or 1B), orbit (ascend or descend)
- Static features:
  - Field segment
  - Date
  - DEM, slope, aspect
  - SoilGrids (0-5cm depth, 250m resolution), 6 features (sand, silt, clay, coarse fragments, bulk density, carbon density)
- Soil water content Planetary Variable (100m resolution)

**Model Details:**

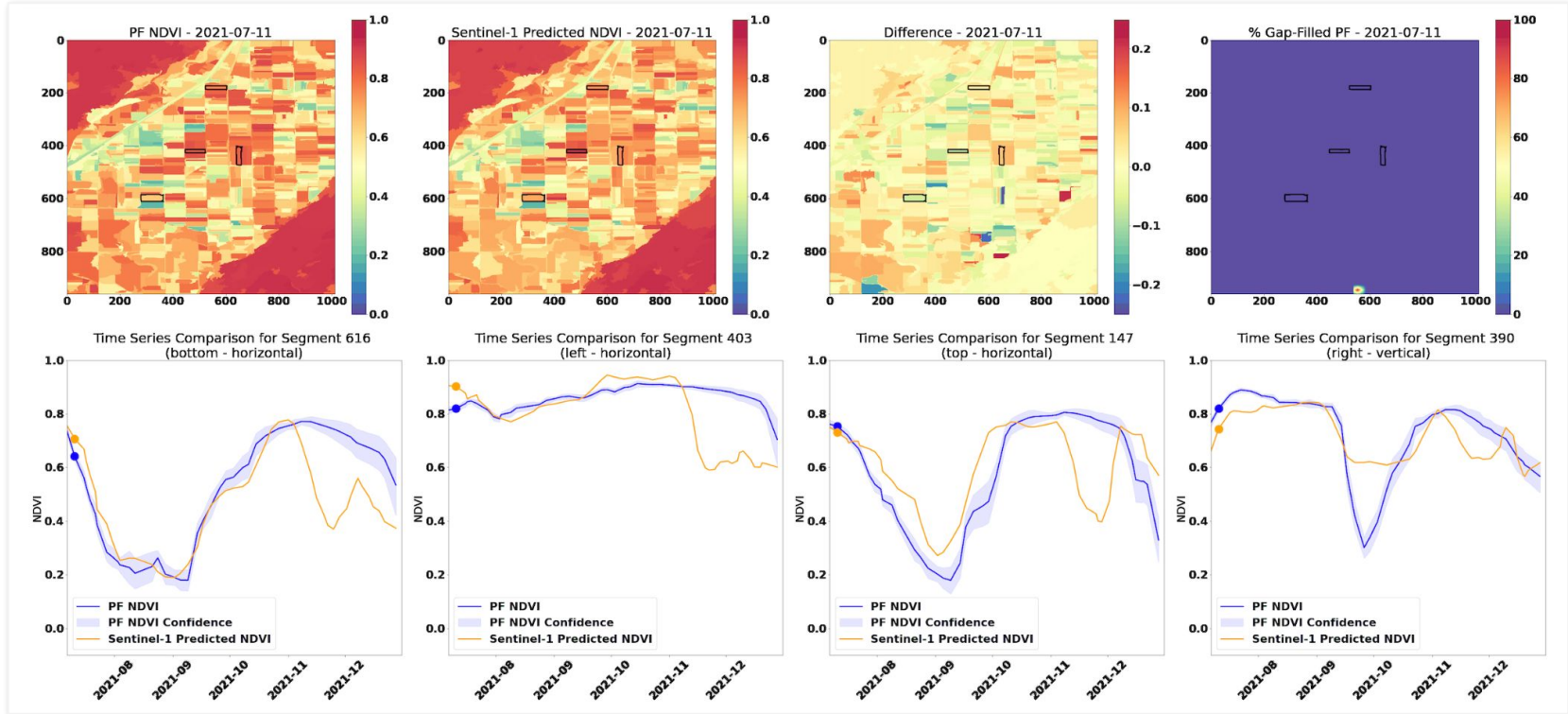
- XGBoost regressor,  $\frac{2}{3}$  data used for training,  $\frac{1}{3}$  used for testing
- 50 iterations of 3-fold cross-validation to select some model parameters (n\_estimators, max\_depth)





# Planet Fusion + Sentinel-1

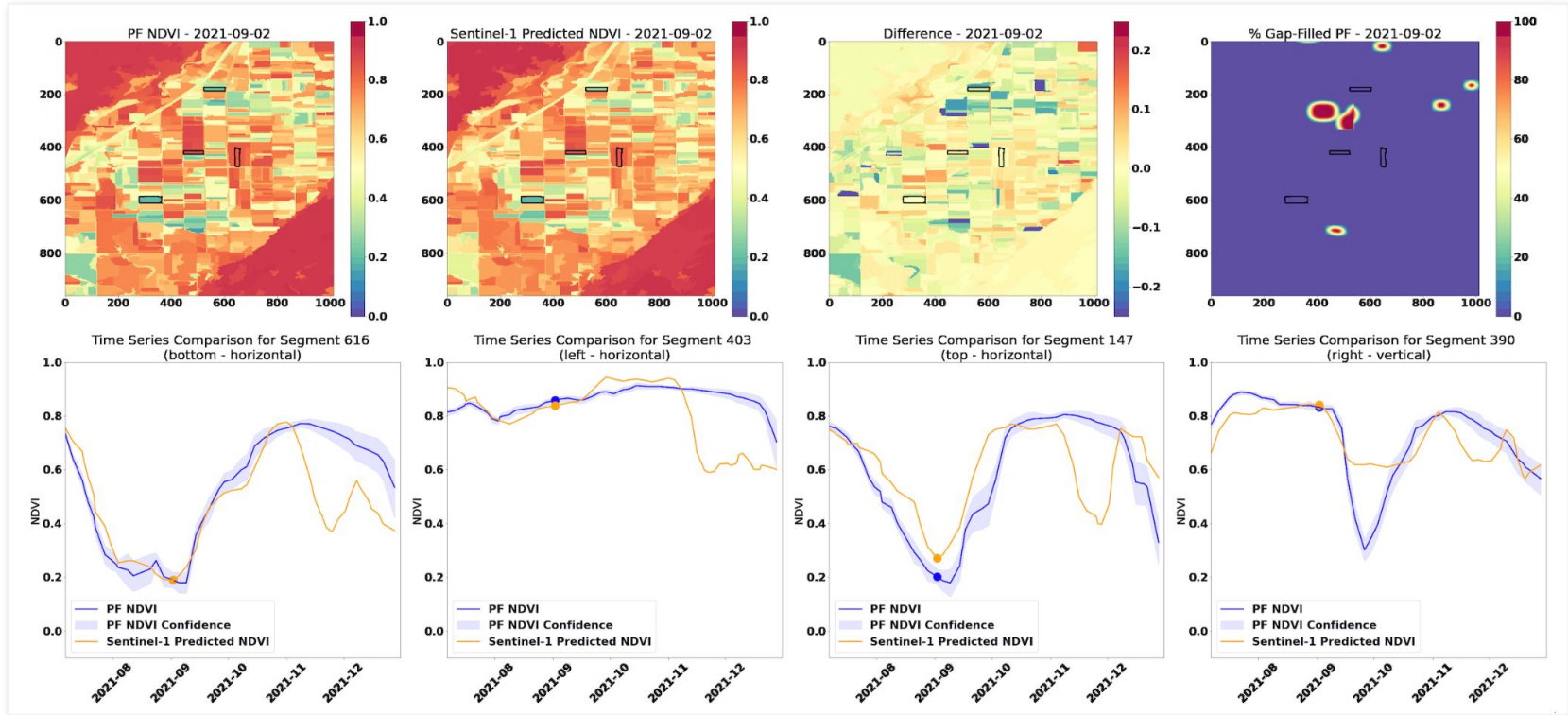
## Random Forest Results - Abbotsford AOI





# Planet Fusion + Sentinel-1

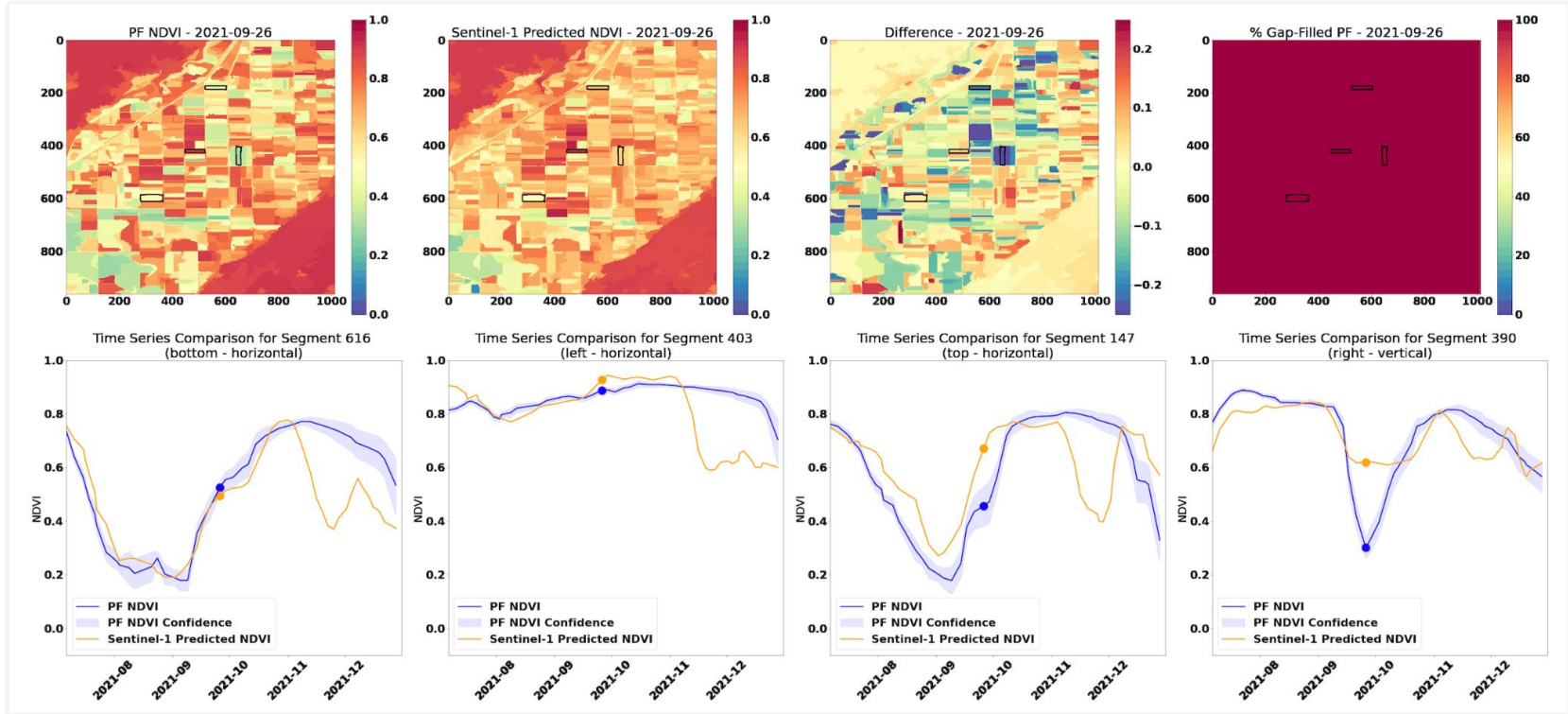
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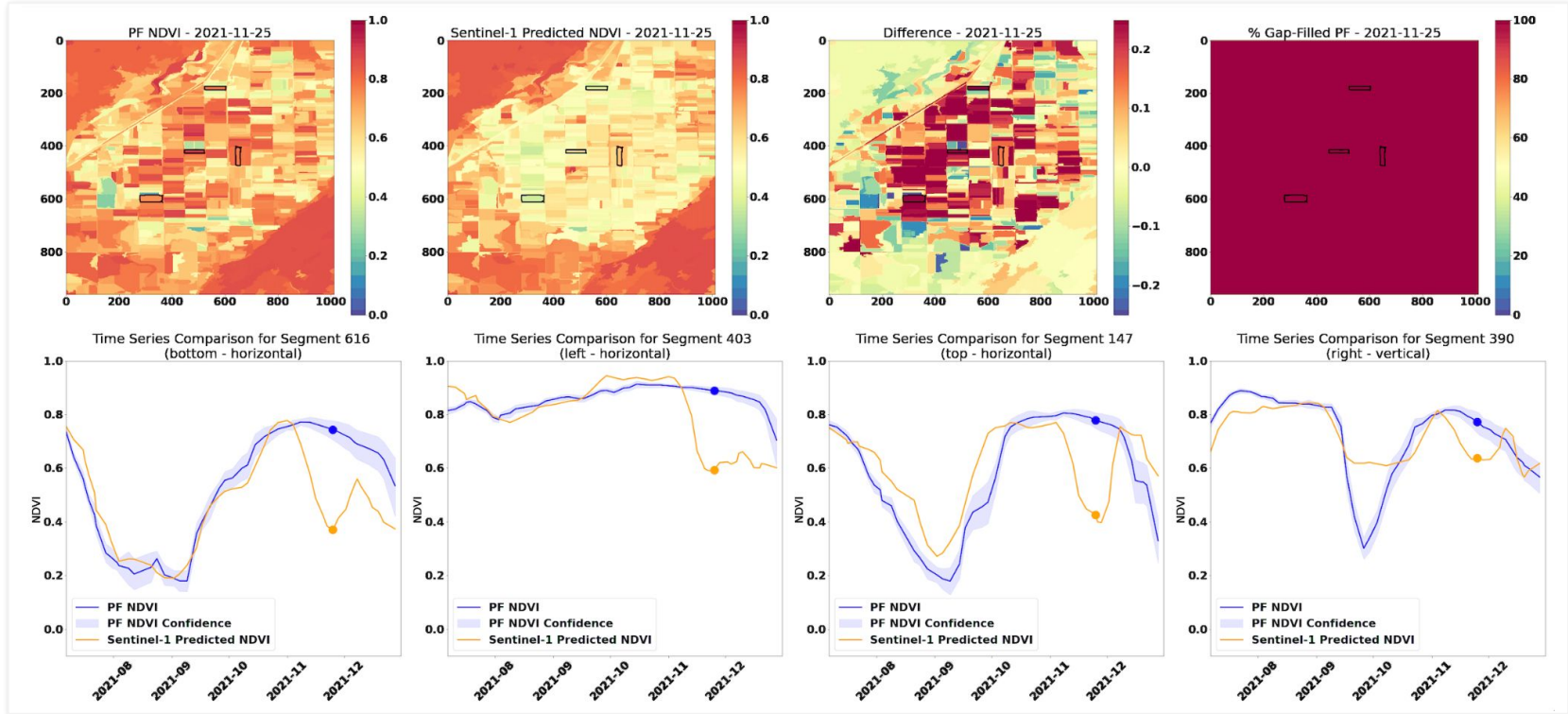
## Random Forest Results - Abbotsford AOI





# Planet Fusion + Sentinel-1

## Random Forest Results - Abbotsford AOI





# Planet Fusion + Sentinel-1

## Random Forest Results - Abbotsford AOI

Number of training samples: 18632

Train R2: 0.9779

Train RMSE: 0.0287

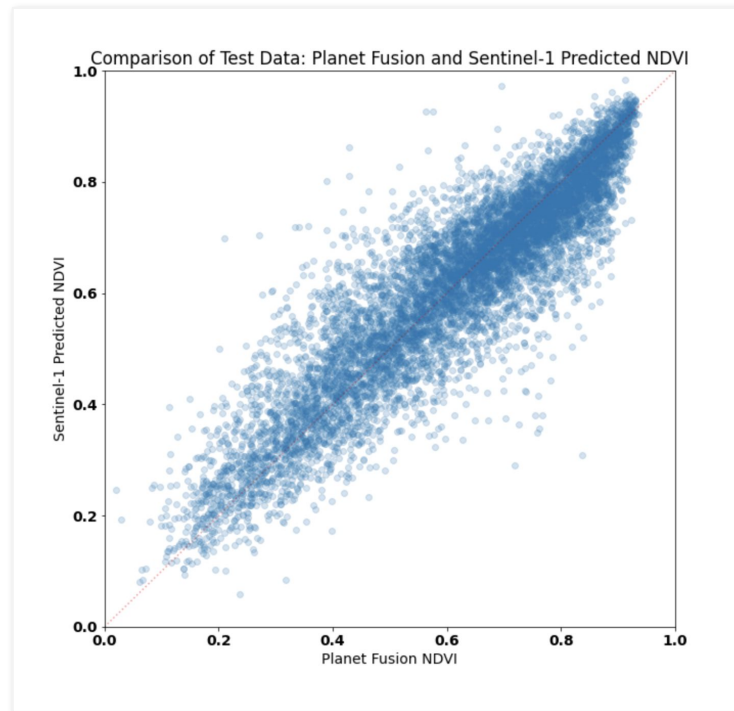
Number of testing samples: 9178

Test R2: 0.8248

Test RMSE: 0.0812

### Top 10 features used by random forest model:

1. **vv - vh (dB):** 0.4035
2. **vh (dB):** 0.0785
3. **date:** 0.0628
4. **segment:** 0.0614
5. **silt:** 0.0389
6. **vh + vh/vv (dB):** 0.0360
7. **coarse fragments:** 0.0345
8. **sand:** 0.0303
9. **vv (dB):** 0.0245
10. **bulk\_density:** 0.0237

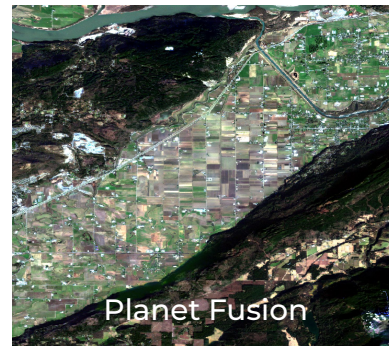
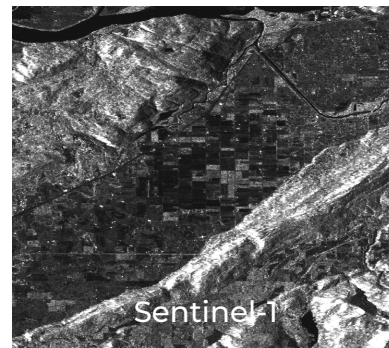




# + Planet Fusion + Sentinel-1

## How do we get to surface reflectance?

- How can we use Sentinel-1 data to **inform pixel values in gap-filling?**
- Several recent studies have looked at the **translation of SAR to optical surface reflectance** using deep learning.
  - E.g., GANs models have shown to be quite powerful
- Points of note for these types of models:
  - Rigorous validation process is required to generate ARD quality.
  - Training is computationally expensive and time consuming.
    - Planet Fusion is already a computationally expensive product.
  - Black-box nature.
    - How much is the SAR data being used, or is it a complicated interpolation technique for optical data?





# Next Steps

## Planet Fusion + SAR

- Continue working out **how to best exploit** the **temporal cadence** of Sentinel-1 data and fuse it into the gap-filling process.
- Exploit SAR in **various steps** within Planet Fusion:
  - Integrate geometric alignment techniques for SAR + optical data.
  - Explore the use of a SAR derived vegetation index time series to assist with cloud masking.
  - SAR change detection to flag areas of concern.

SAR is an **information rich data source** – there is so much potential when integrating with a **powerful product like Planet Fusion!**





# Thank You.



Engage with Planet's Science Programs and apply here for Planet Data via ESA Earthnet  
[go.planet.com/lps22](https://go.planet.com/lps22)



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