Distribution: General

Technical note

PROBA-V C2 AOT masking

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LIST OF ACRONYMS

AM	AOT Map
AOT	Aerosol optical thickness
C1	Collection 1
C2	Collection 2
MERRA	Modern-Era Retrospective analysis for Research and Applications
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
PROBA-V	Program for On-board Autonomy – Vegetation instrument
PV	Proba-V
RGB	False colour composite with Red-Green-Blue channels
SM	Status Map
SWIR	Short wave Infrared
TOC	Top of Canopy

CHAPTER 1 PROBLEM STATEMENT

The PROBA-V Collection 2 (PV C2) was atmospherically corrected using the Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA-2) data from NASA as input for water vapour, ozone and aerosol optical thickness (AOT) (Ramon et al., 2021). When very high AOT occurs, this results in very high Top-of-Canopy (TOC) reflectance. The impact is the strongest for Blue channel (B0) and decreases with increasing wavelength (Red (B2), NIR (B3) and SWIR). Most often, when the AOT values are very high, the TOC reflectance is then masked as saturated in the Status Map (SM).

Yet, since the MERRA-2 data is at lower resolution than the PV data, it is interpolated to the same resolution as the PV C2 data. Such very high AOT values are then interpolated to neighbouring pixels, resulting in a gradient from very high to lower AOT values. When using these inputs in the atmospheric correction, the bordering area around the saturated TOC reflectance values is also too high, although these are within the range of valid TOC reflectances, and are therefore not masked out in the SM. The result is then a bright 'halo' around masked values as demonstrated in Figure 1.

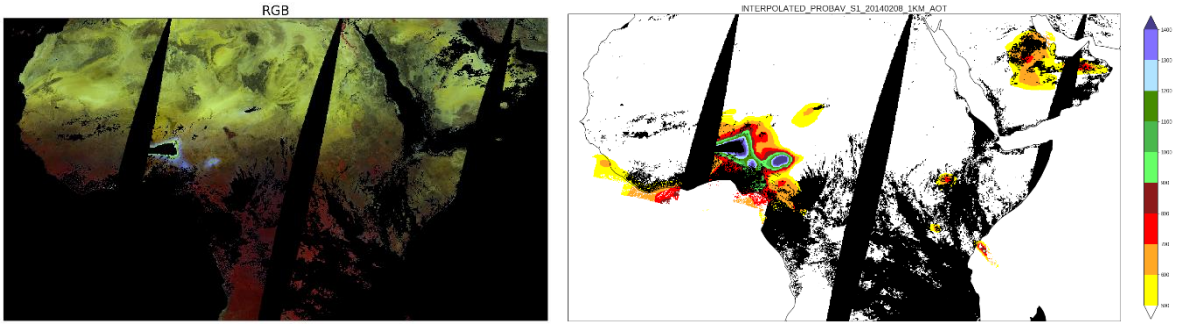


Figure 1: RGB (Blue, Red, NIR) image of S1 TOC 1 km image of 08/02/2014 (left), and the corresponding resampled AOT image used in the atmospheric correction.

The impact is the largest for the Blue band, but it also impacts Red and NIR images and it is therefore also visible in the NDVI. The impact is very small in the SWIR band as can be seen in Figure 2. Most of the area with high AOT is already masked out because the Blue TOC reflectance saturates. This is less the case for Red and for NIR and SWIR, there is no saturation, but the effect of the high AOT is still visible in the images.

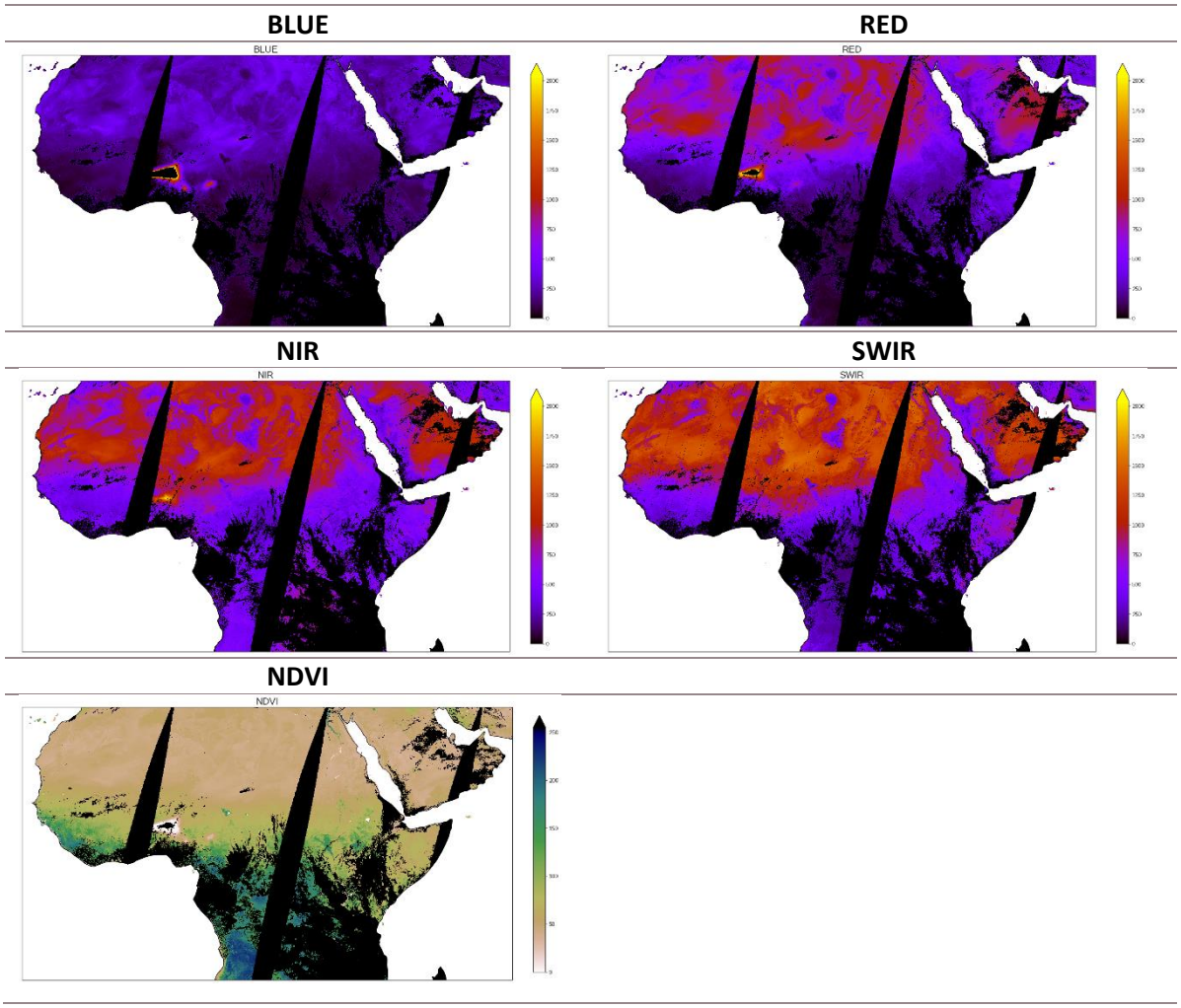


Figure 2: Blue, Red, NIR, SWIR and NDVI of S1_TOC 1 KM for 08/02/2014

CHAPTER 2 ANALYSIS

A large set of images were visually analysed by applying different AOT thresholds on the images and evaluating the result. Not only the area in the vicinity of the high AOT event was evaluated, to be able to identify the impact on other areas as well. Figure 3 shows two examples of this analysis.

In addition, several more detailed plots with AOT overlaid as contours and line plots were generated through the high AOT events and compared with the PV C1 data to evaluate from which AOT value the TOC reflectance values start to deviate. Yet, in the PV C1 TOC reflectance data, these areas were often masked as cloud covered. An example of this analysis is shown in Figure 4, Figure 5 and Figure 6.

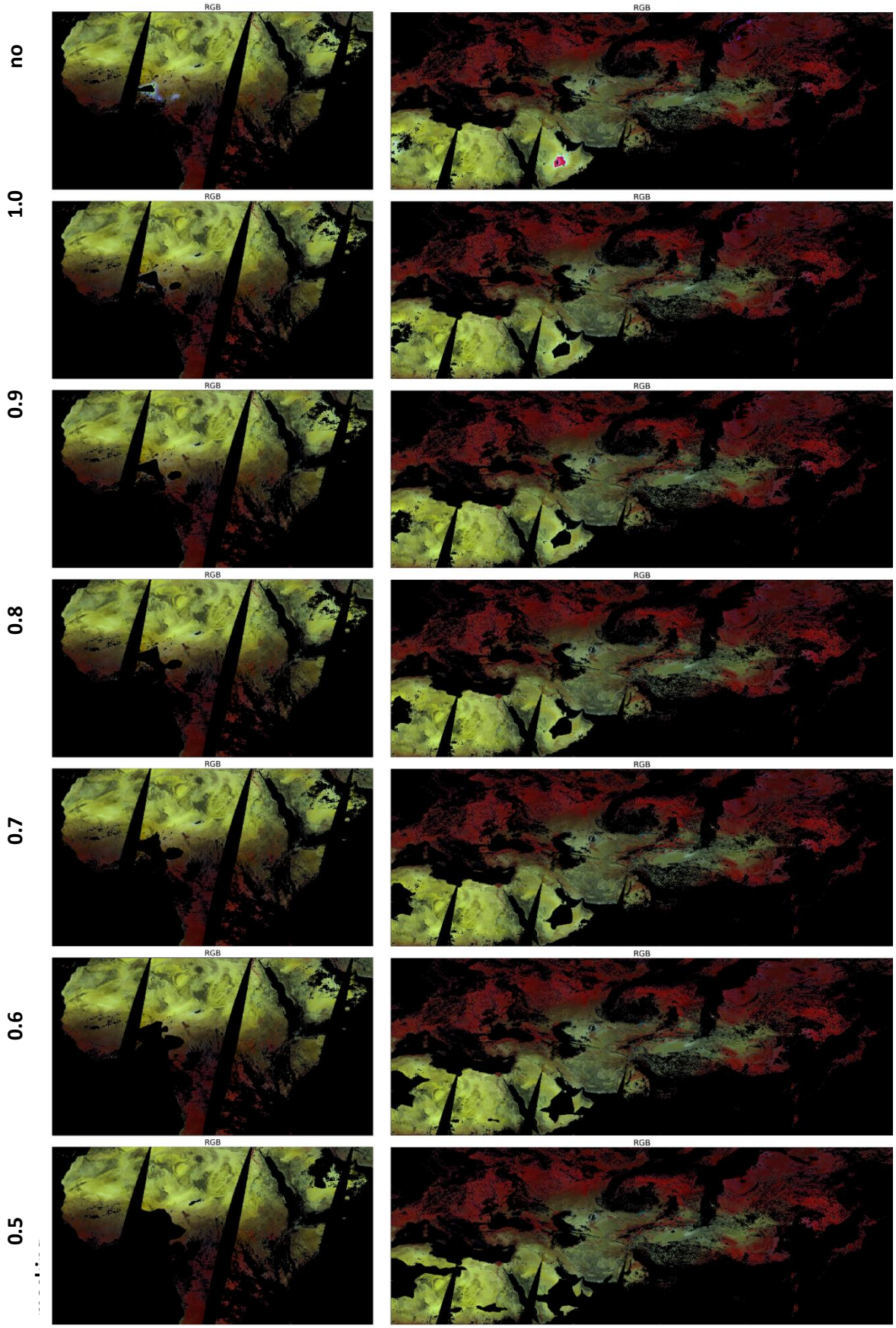


Figure 3: Examples of masking at different levels of AOT (from >0.5 to >1.0) of the RGB images for S1_TOC 1 KM 08/02/2014 (left) and 15/07/2014 (right).

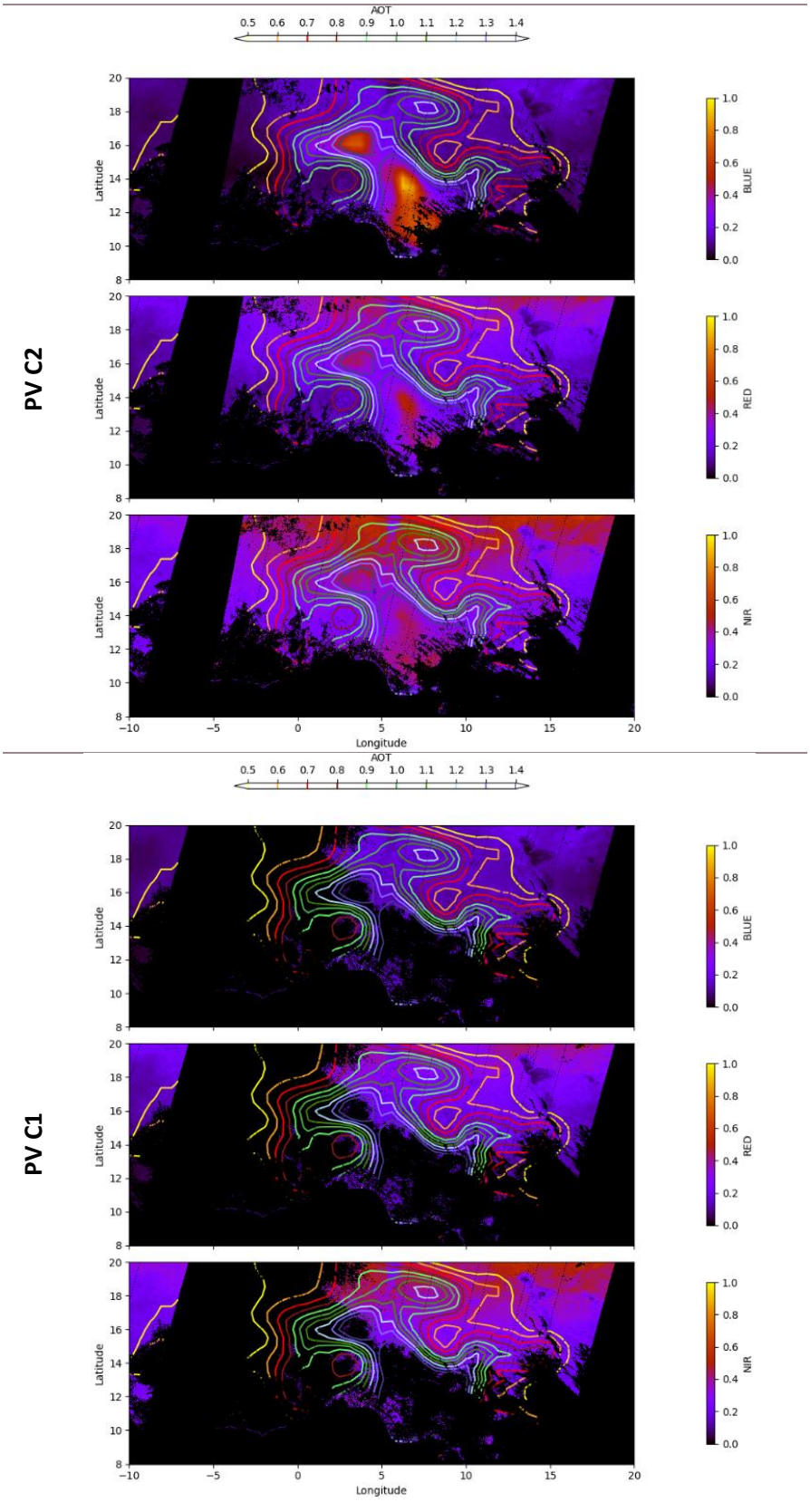


Figure 4: S1_TOC 1KM of 16/02/2014. Zoom in on problem region for Blue, Red and NIR with AOT thresholds overlaid as contour plot for PV C2 (top) and C1 (bottom). In C1 the areas with high AOT were masked as clouds.

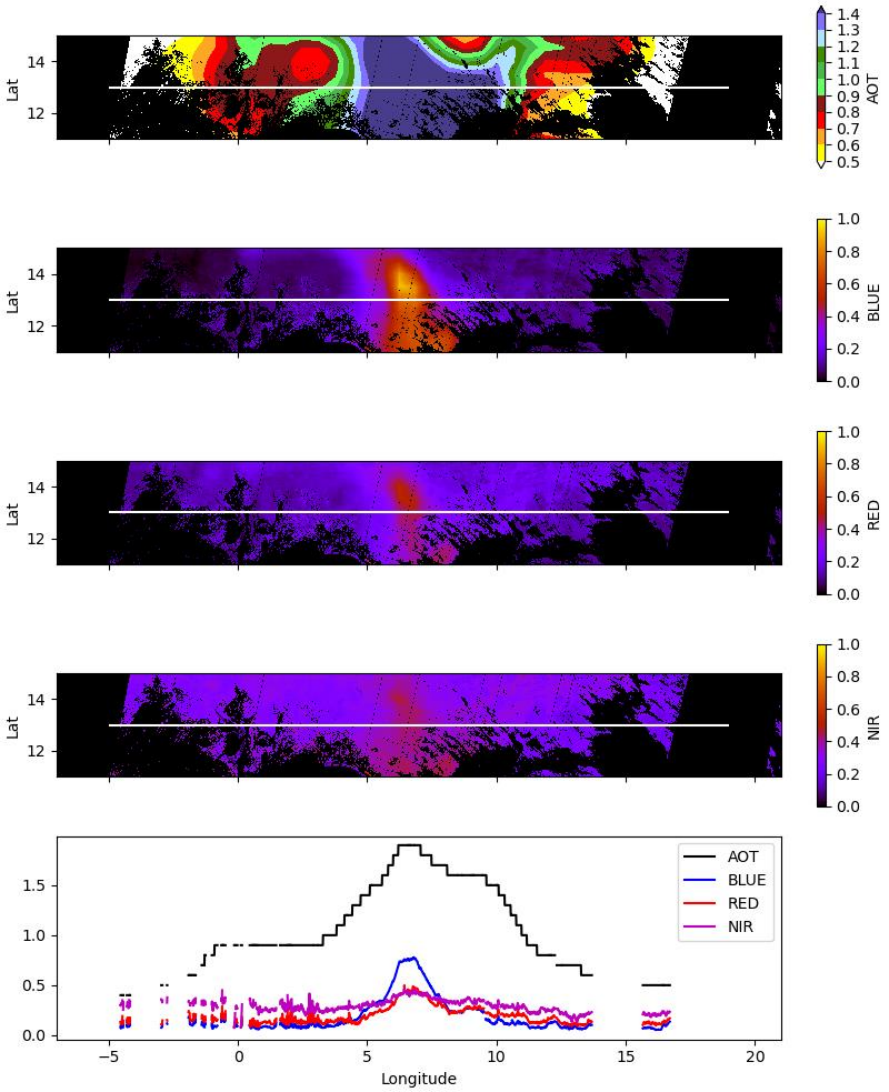


Figure 5: S1_TOC 1KM of 16/02/2014. Line plot of AOT and Blue, Red, NIR TOC reflectances for PV C2.

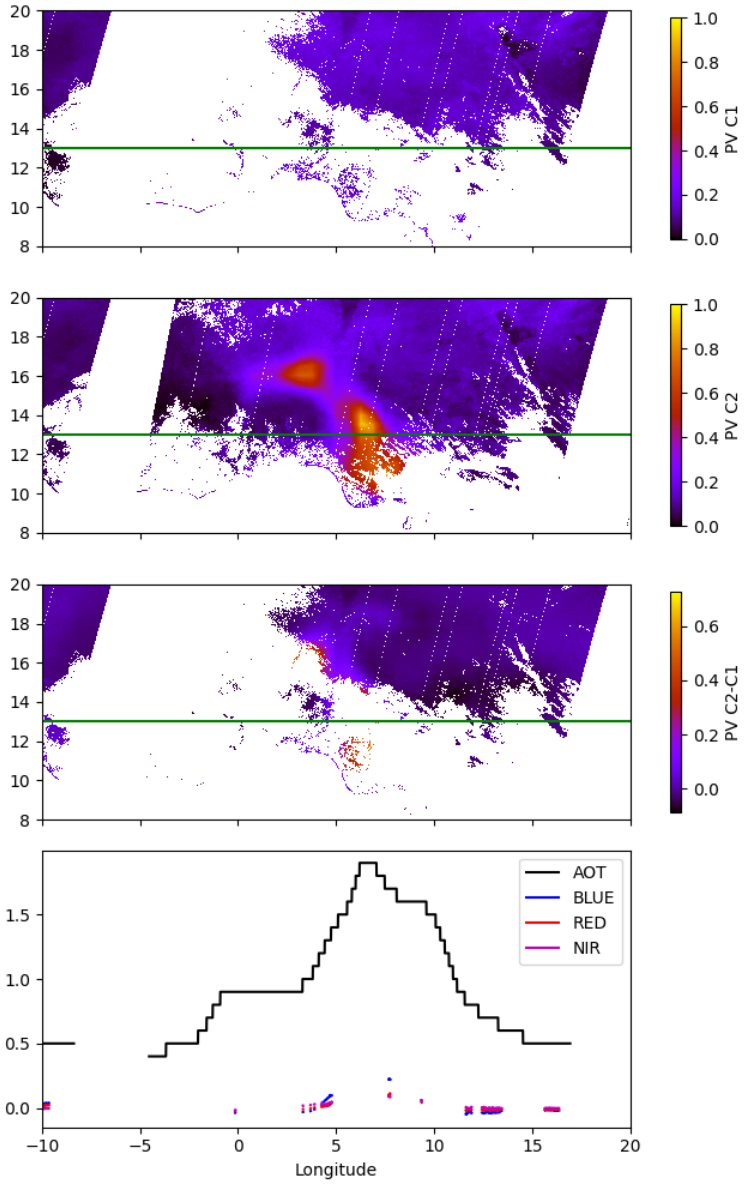


Figure 6: S1_TOC 1KM of 16/02/2014. From top to bottom: (1) PV C2 Blue, (2) PV C1 Blue and (3) difference between C2-C1 for the Blue band, (4) line plot of Blue, Red, NIR and AOT for the green line indicated in the images.

CHAPTER 3 PROPOSED SOLUTION

3.1. AOT MASKING

Additional AOT masks (AM) based on the AOT data that is interpolated to the PV resolution are provided. These masks are additional to the existing SM and should be used to mask out the areas in the TOC reflectance and NDVI that are impacted by these large AOT values. The masks are provided in all three resolutions (100 m, 300 m and 1 km), and for all compositing steps: S1 for all resolutions, S5 for 100 m and S10 for 300 m and 1 km.

The masks are provided as a separate byte layer per tile. The naming of the AOT masks is similar to the naming of the PV C2 products.

PROBAV_<synthesis type>_TOC_<tile id>_YYYYMMDD_<resolution>_AM_V201.tif

With:

- Synthesis type: S1, S5 or S10
- Tile id: tile identification in the format XxxYyy, with xx the column and yy the row of the tile
- Resolution: 100M, 333M or 1KM

The values in the masks are provided in Table 1.

Table 1: Values of the AOT masks

Value	Meaning
0	Resampled AOT < 0.5
5	Resampled AOT ≥ 0.5 AND Resampled AOT < 0.6
6	Resampled AOT ≥ 0.6 AND Resampled AOT < 0.7
7	Resampled AOT ≥ 0.7 AND Resampled AOT < 0.8
8	Resampled AOT ≥ 0.8 AND Resampled AOT < 0.9
9	Resampled AOT ≥ 0.8 AND Resampled AOT < 1.0
10	Resampled AOT ≥ 1.0

3.2. RECOMMENDED THRESHOLDS

The magnitude of the impact decreases with increasing wavelength (Blue < Red < NIR < SWIR). Therefore, we advise different thresholds to be used depending on the layer(s) that is (are) used. When using Red, NIR, SWIR or NDVI, the recommendation is to mask out all AOT values equal to and above 0.8. This means that the values 0, 5, 6 and 7 in the mask indicate the good values, and all values of 8 and larger are to be masked out.

When using the Blue TOC reflectance, the recommended threshold is reduced to 0.6, meaning that all pixels with AM > 6 should be masked out.

For some applications, it might be necessary to perform a more rigorous masking or even a less constraining masking (e.g. if an outlier detection method is used). Since the masks provide different values of AOT, this is possible. For AOT values above 1.0, the TOC reflectances and the resulting NDVI are certainly negatively impacted and should not be used, therefore no more detail is provided above this value.

In the following chapter, the impact on the completeness of the data is assessed for the use of different thresholds.

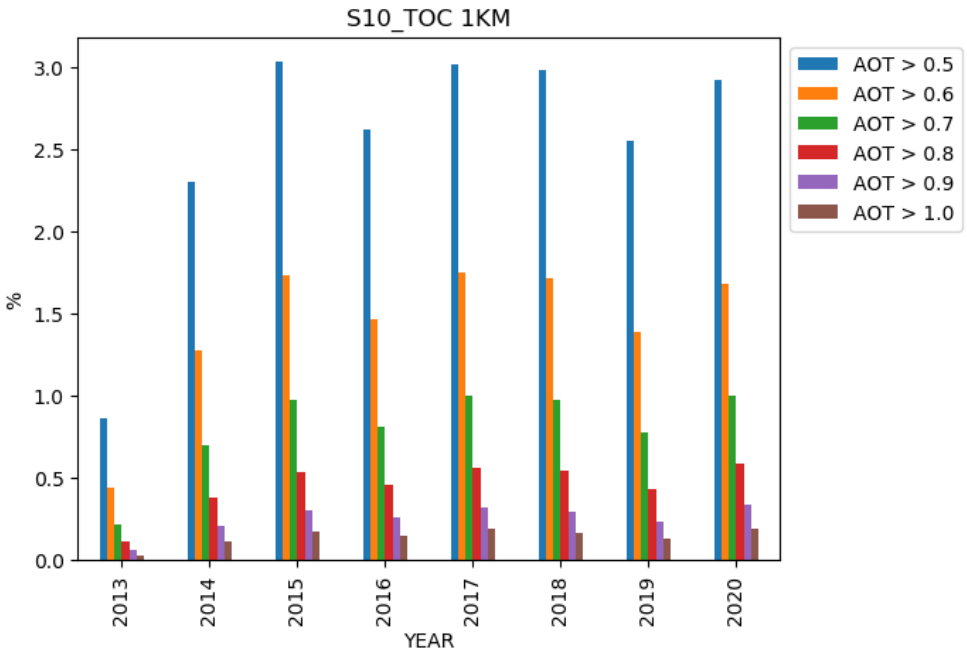
CHAPTER 4 IMPACT ASSESSMENT: % CLEAR LAND OBSERVATIONS AFFECTED

The impact of using different thresholds on the completeness of the data is evaluated in this chapter.

The percentage of clear and good land pixels that is affected above certain thresholds were analysed for S1 and S10 data. This result reflects the additional loss of data after filtering for bad quality observations, cloud and cloud shadow. The analysis is performed on the 1 km dataset, but the results are also valid for the 100 m and 300 m datasets.

4.1. OVERALL PER YEAR

Figure 7 shows the percentage clear land pixels that is lost when applying different thresholds on the AOT mask. When masking the PV C2 TOC reflectance data with the most severe constraint (AOT > 0.5 is masked), up to 3% of the S10 data and between 6 and 7% of the S1 is additionally masked. This amount is reduced by half when applying a slightly higher constraint of 0.6. This is the recommended threshold when using the Blue band (B0). For the other reflectance bands, the threshold of 0.8 is advised, resulting in a loss of about 0.5% of the S10 data and less than 1.5% of the S1 data. The results are similar for the other resolutions.



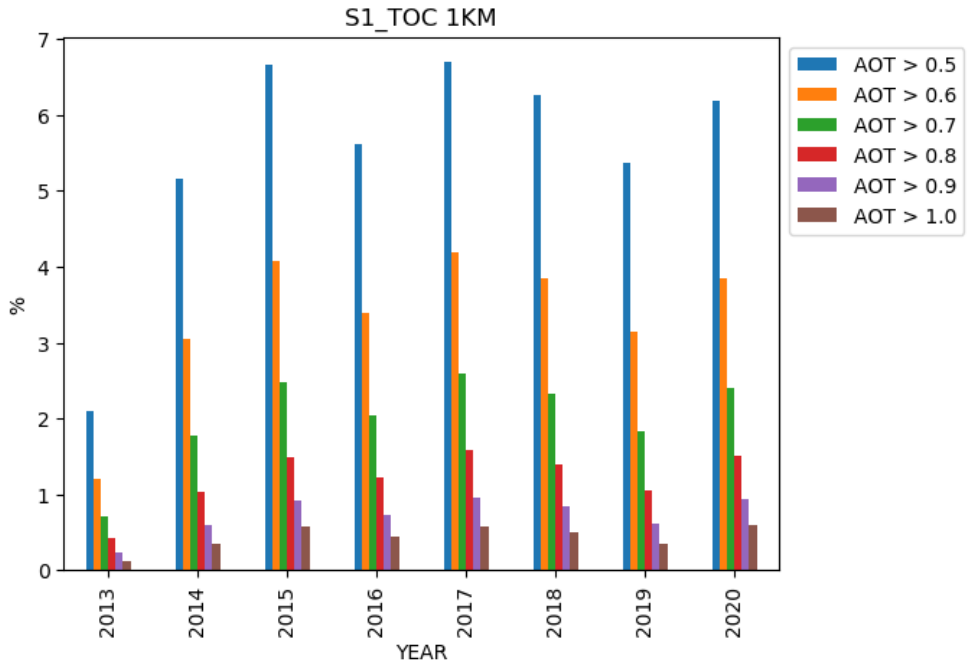


Figure 7: % clear land pixels affected on S10 (top) and S1 (bottom) TOC 1 KM data for different thresholds on the AOT mask. Note that there are PROBA-V observations from Oct/2013 until June/2020.

4.2. SPATIAL PATTERN OF IMPACT PER YEAR

Maps were calculated per year to assess how often pixels are affected when using a specific AOT mask threshold. Histograms show for these affected pixels how many observations (in %) are affected.

Examples are provided for the recommended thresholds for the year 2014 (Figure 8 to Figure 11). All other thresholds and years are provided in Annex B for S10 and Annex C for S1. The results are similar for the other resolutions.

Figure 8 shows the % observations per pixel that are affected by applying the thresholds 0.6 and 0.8 to the S10 TOC data at 1 KM. The impact is mostly concentrated in the desert areas (e.g. the Sahara), areas with high air pollution (e.g. China) and dense forest areas (e.g. mid-Africa). Some areas at high latitudes are also affected. Much less data is affected with the threshold of 0.8 (recommended for use for Red, NIR, SWIR and NDVI) compared to 0.6 (recommended for Blue).

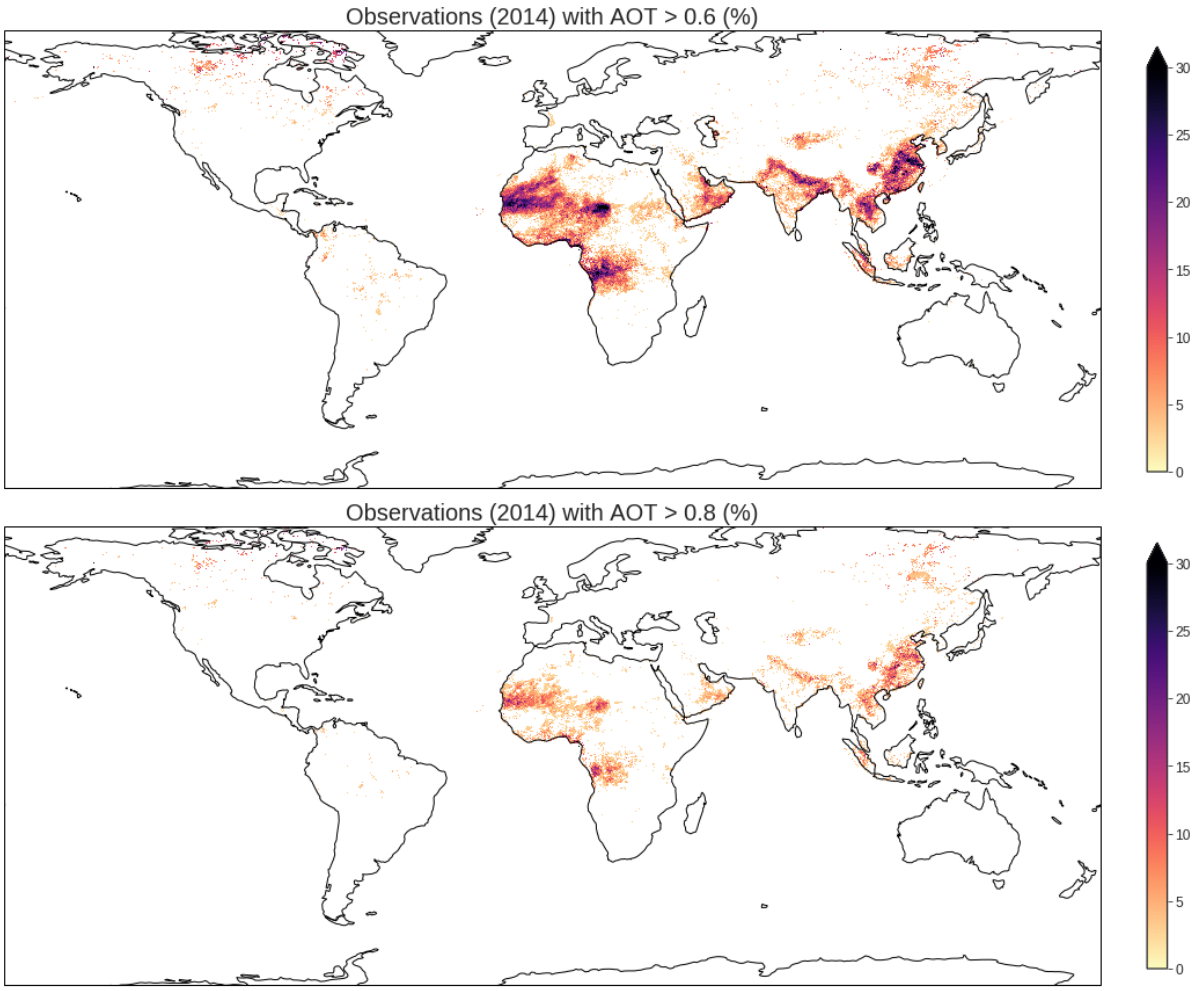


Figure 8: % observations with AOT mask > 0.6 (top) and > 0.8 (bottom) for S10 TOC 1 KM data from 2014.

The histograms of the observations affected per pixel are shown in Figure 9. Again here, the amount of affected observations per pixels is less with a threshold of 0.8.

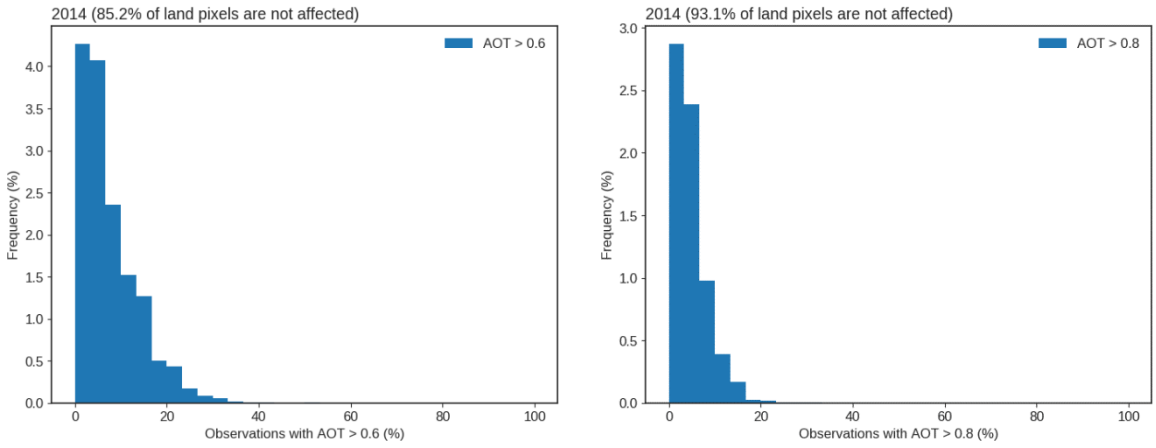


Figure 9: Histograms of the frequency (in %) of affected pixels over time for S10 TOC 1 KM data from 2014 for the thresholds AOT mask > 0.6 (left) and > 0.8 (right).

Figure 10 and Figure 11 show the same results but for the S1 TOC data of 2014. To generate these graphs, only every 5th day was selected of the time series. It is obvious that the impact is larger in the S1 dataset.

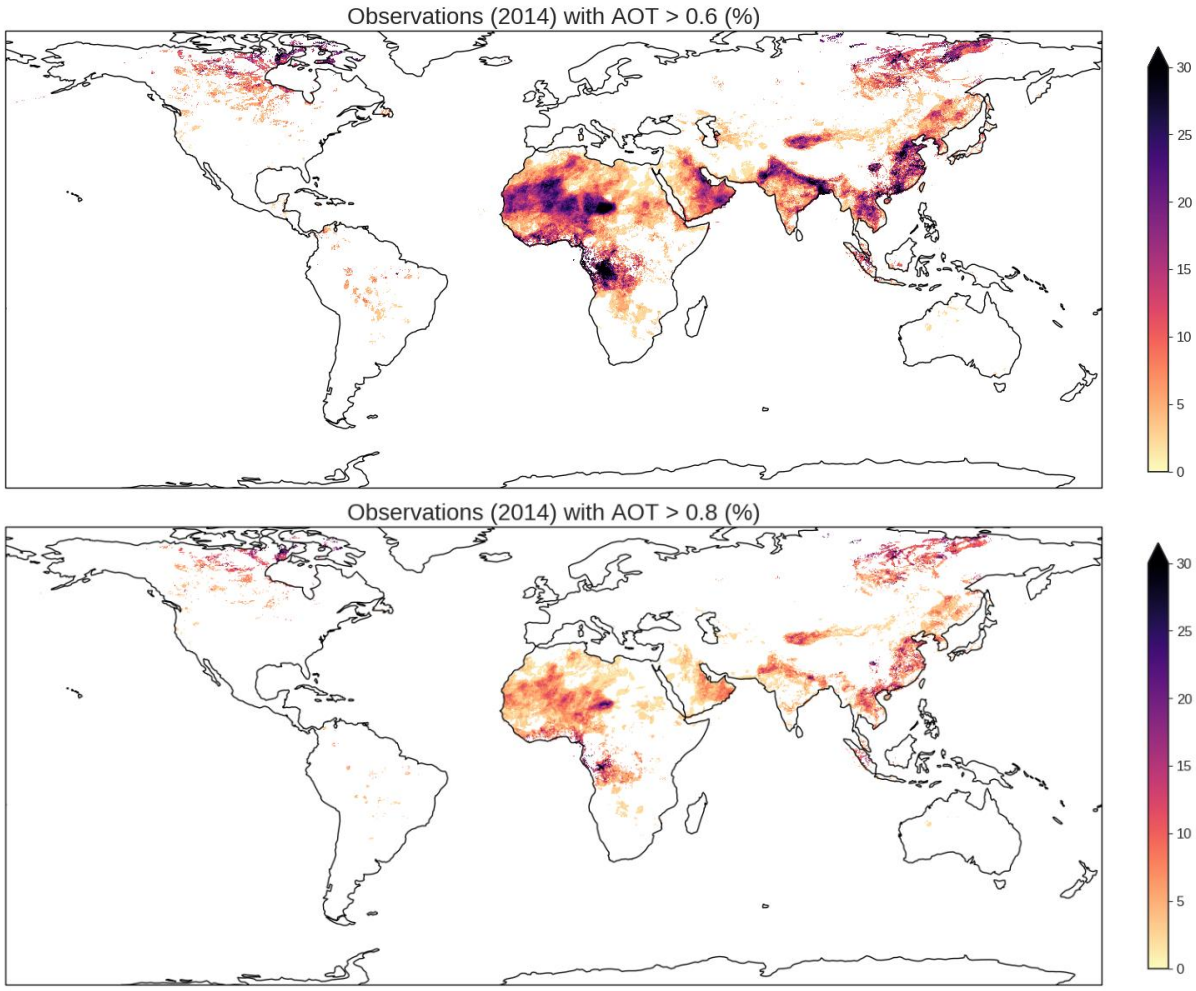


Figure 10: % observations with AOT mask > 0.6 (top) and > 0.8 (bottom) for S1 TOC 1 KM data of 2014.

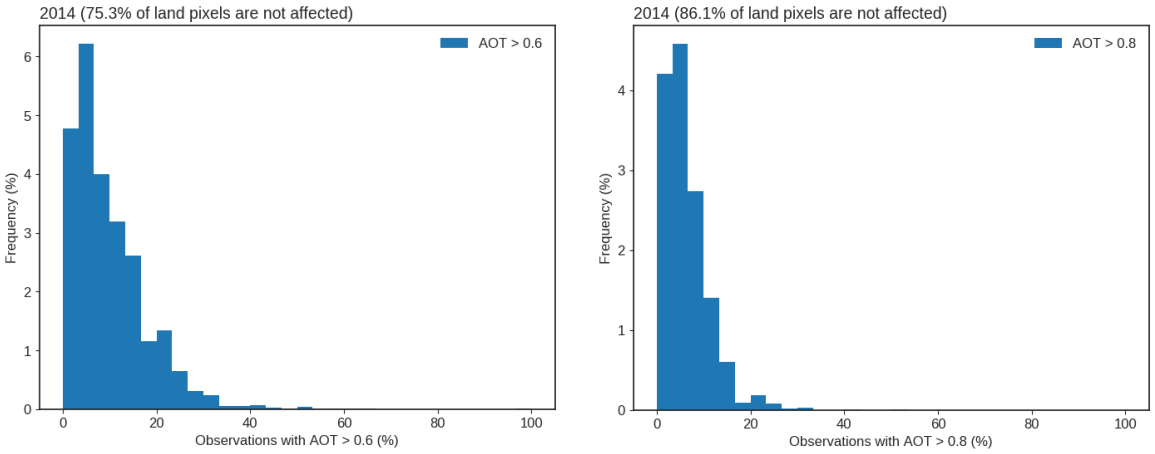


Figure 11: Histograms of the frequency (in %) of affected pixels over time for S1 TOC 1 KM data of 2014 for the thresholds AOT mask > 0.6 (left) and > 0.8 (right).

CHAPTER 5 SUMMARY AND CONCLUSION

The Proba-V Collection 2 archive is affected by artefacts where very high AOT values occur. When this occurs, the Top-Of-Canopy reflectance values are high. The impact is the largest in the Blue (B0), lower in Red and NIR (B2 and B3) and almost negligible in the SWIR. The Status Map (SM) of the products does not allow to remove these areas.

Therefore, an additional mask, the AOT Mask (AM), is provided to enable filtering out these areas. The AOT Mask contains several values to allow users to define their own filtering thresholds. The impact of the different thresholds was analysed and is summarized in this document.

Based on the analysis, we recommend the following thresholds:

- When using Red, NIR, SWIR or NDVI, the recommendation is to mask out all AOT values equal to and above 0.8. This means that the values 0, 5, 6 and 7 in the mask indicate the good values, and all values of 8 and larger are to be masked out.
- When using the Blue TOC reflectance, the recommended threshold is reduced to 0.6, meaning that all values of 6 or larger in the mask should be masked out.

The masks are provided per tile for each resolution and each composite product.

ANNEX A: EXAMPLES OF IMPACT OF THRESHOLDS ON S1

S1_TOC 1 KM 03/06/2014

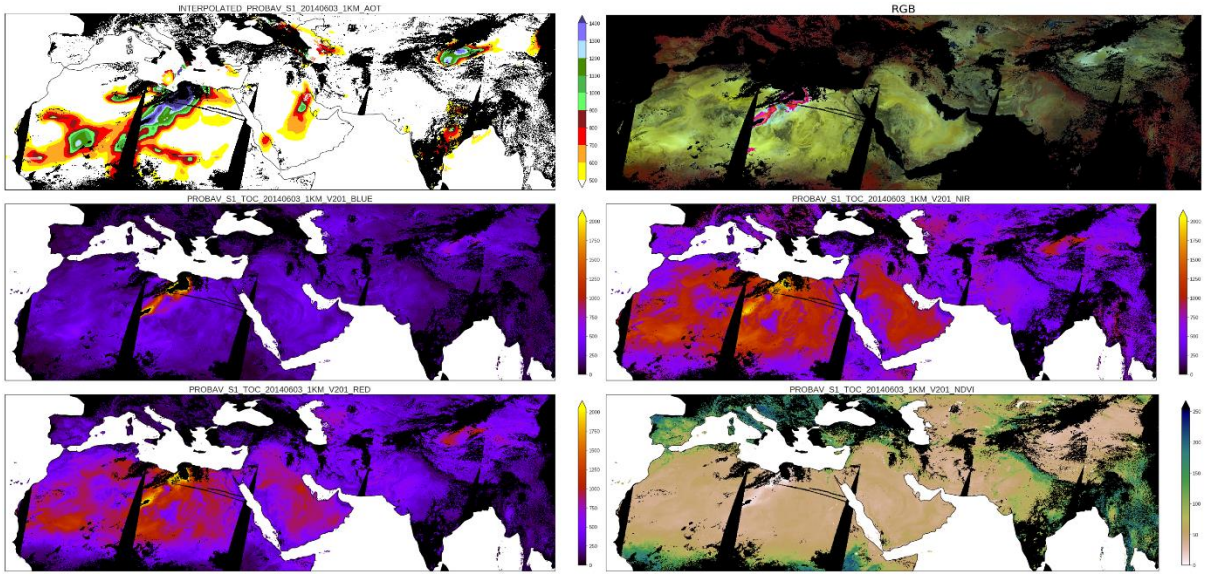


Figure 12: AOT (top left) and original RGB image (top right), TOC reflectance data Blue (middle left), Red (middle right), SWIR (bottom left) and NDVI (bottom right).

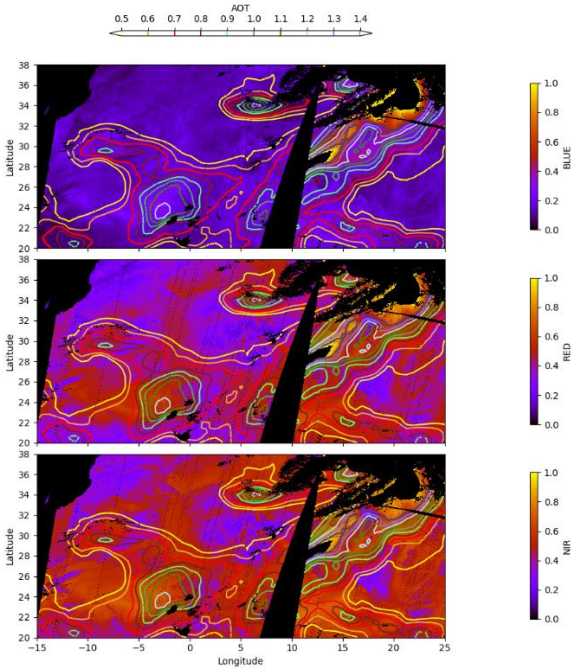


Figure 13: PROBA-V C2 zoom in on problem region for blue (top), red (middle), and NIR (bottom) bands. AOT contours are overplotted.

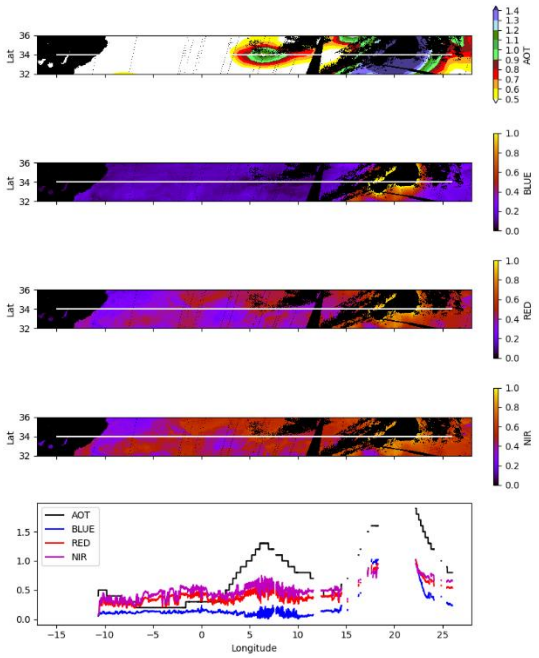


Figure 14: Line extracts.

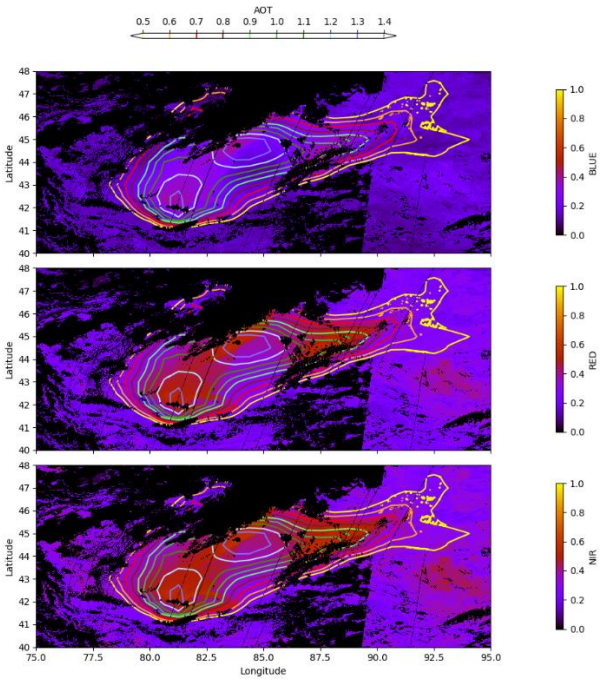


Figure 15: PROBA-V C2 zoom in on problem region for blue (top), red (middle), and NIR (bottom) bands. AOT contours are overplotted.

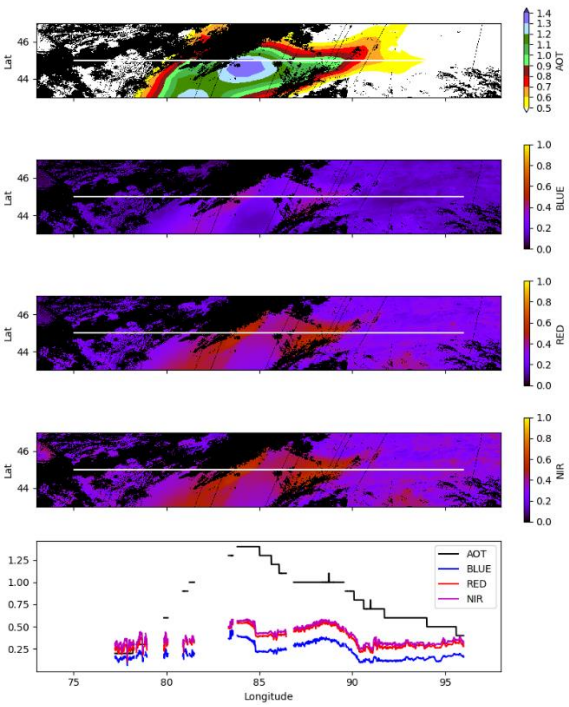


Figure 16: Line extracts.

S1_TOC 1 KM 07/06/2014

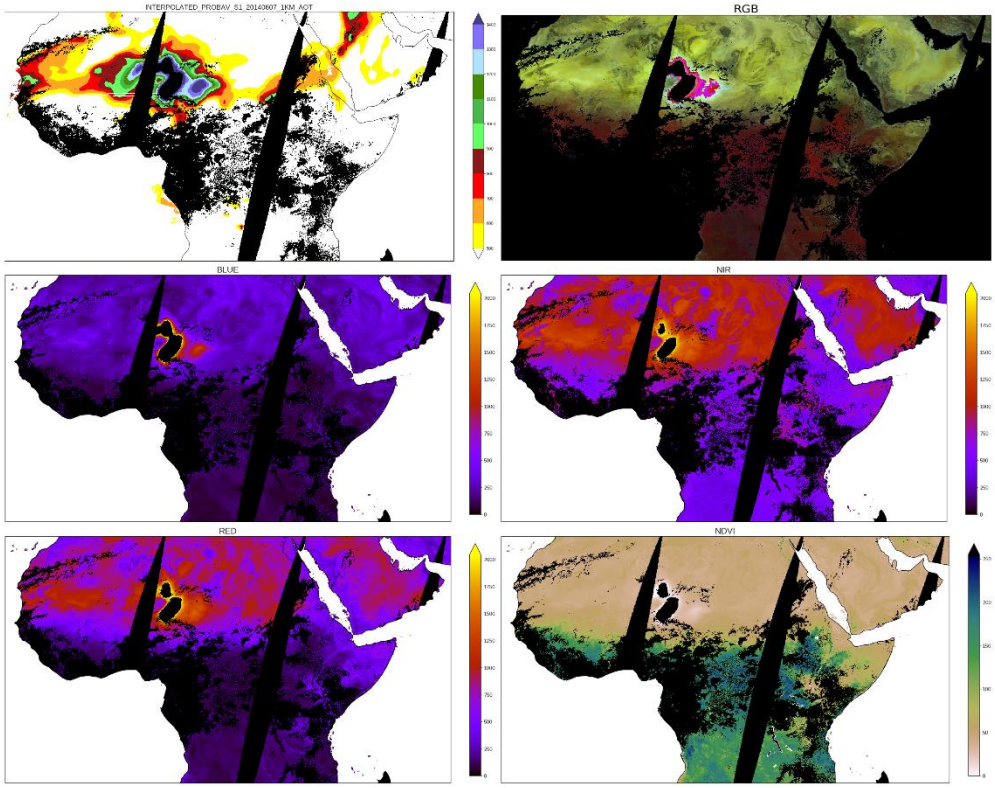


Figure 17: AOT (top left) and original RGB image (top right), TOC reflectance data Blue (middle left), Red (middle right), SWIR (bottom left) and NDVI (bottom right).

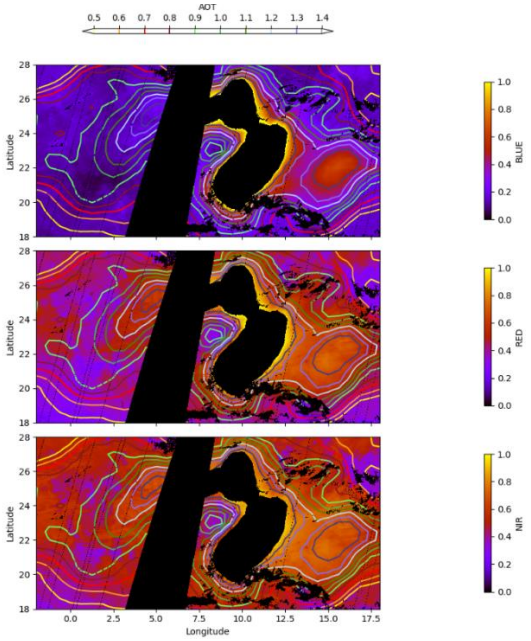


Figure 18: PROBA-V C2 zoom in on problem region for blue (top), red (middle), and NIR (bottom) bands. AOT contours are overplotted.

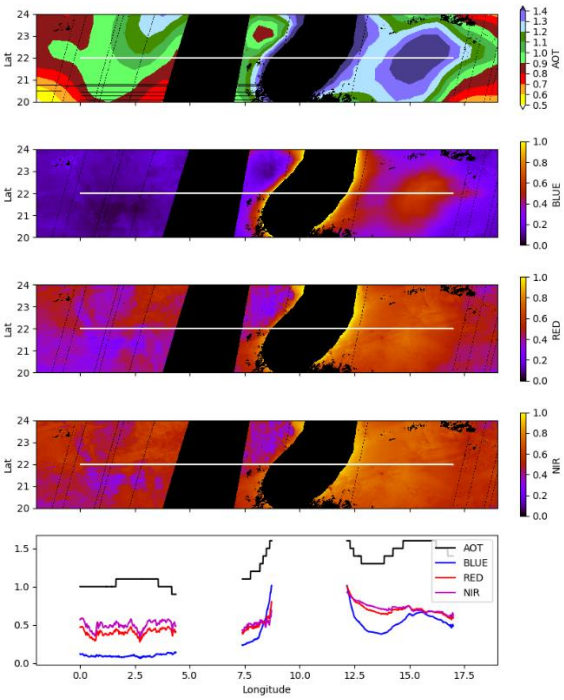


Figure 19: Line extracts.

S1_TOC 1 KM 14/06/2014

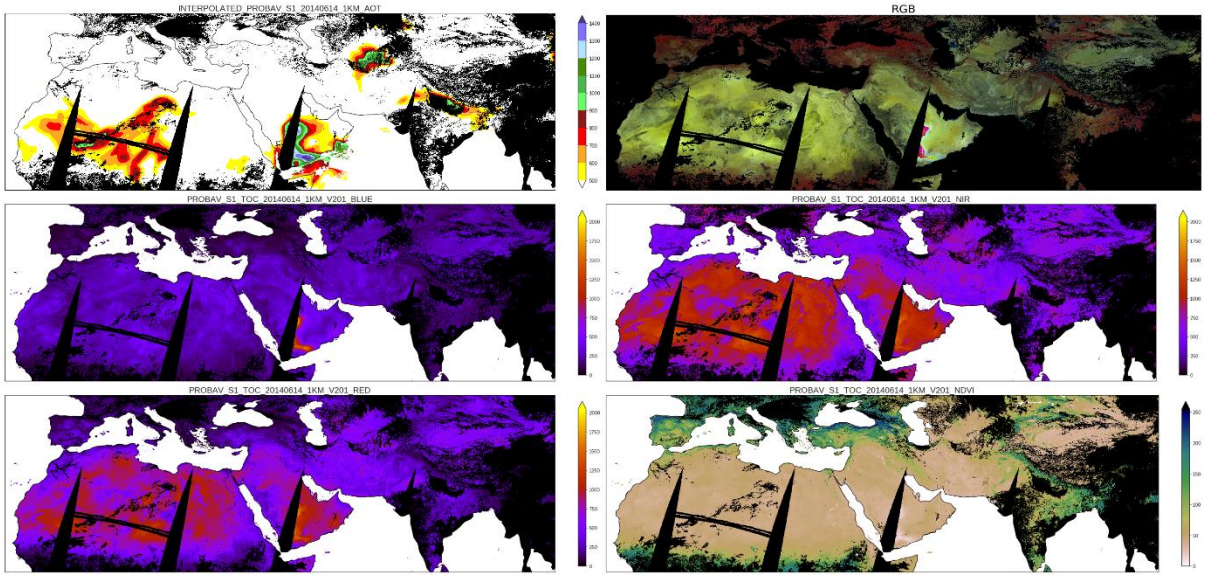


Figure 20: AOT (top left) and original RGB image (top right), TOC reflectance data Blue (middle left), Red (middle right), SWIR (bottom left) and NDVI (bottom right).

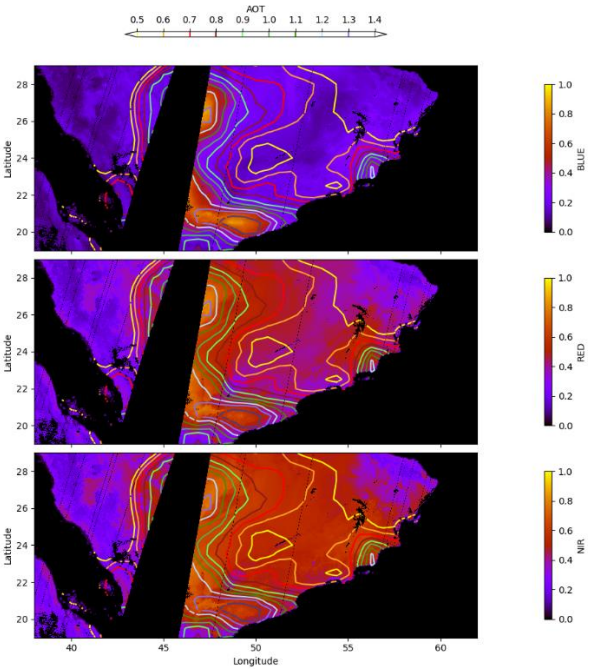


Figure 21: PROBA-V C2 zoom in on problem region for blue (top), red (middle), and NIR (bottom) bands. AOT contours are overplotted.

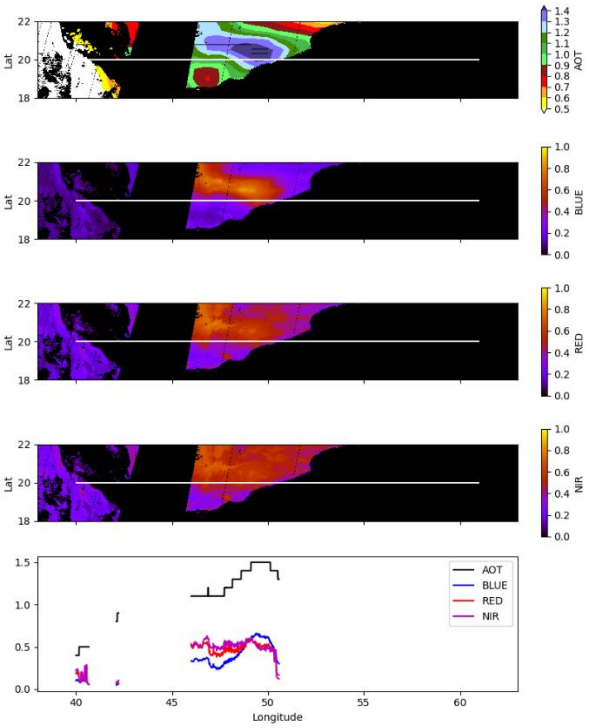


Figure 22: Line extracts.

S1_TOC 1 KM 15/07/2014

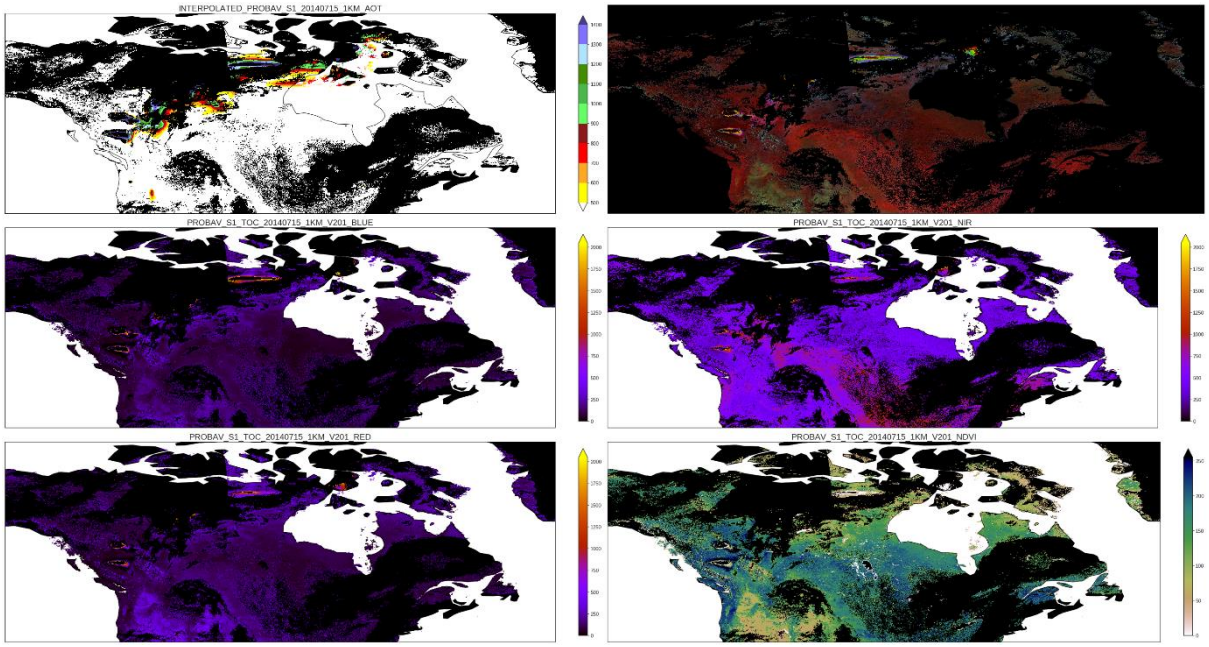


Figure 23: AOT (top left) and original RGB image (top right), TOC reflectance data Blue (middle left), Red (middle right), SWIR (bottom left) and NDVI (bottom right).

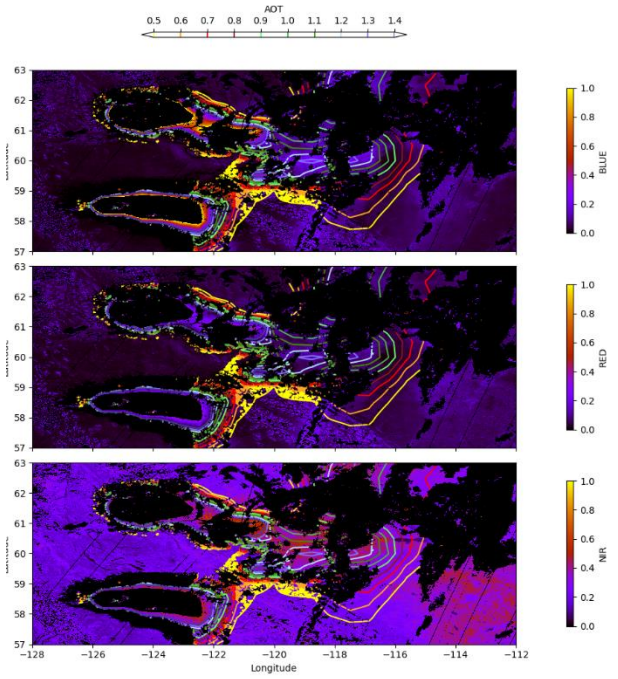


Figure 24: PROBA-V C2 zoom in on problem region for blue (top), red (middle), and NIR (bottom) bands. AOT contours are overplotted.

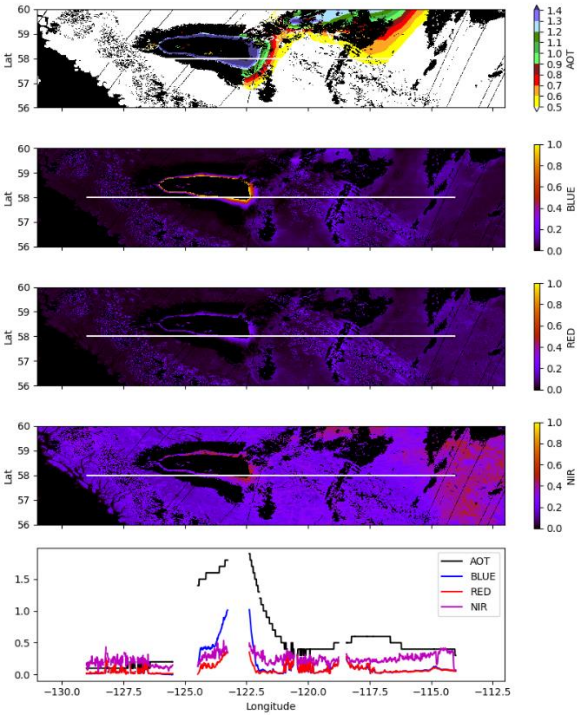


Figure 25: Line extracts.

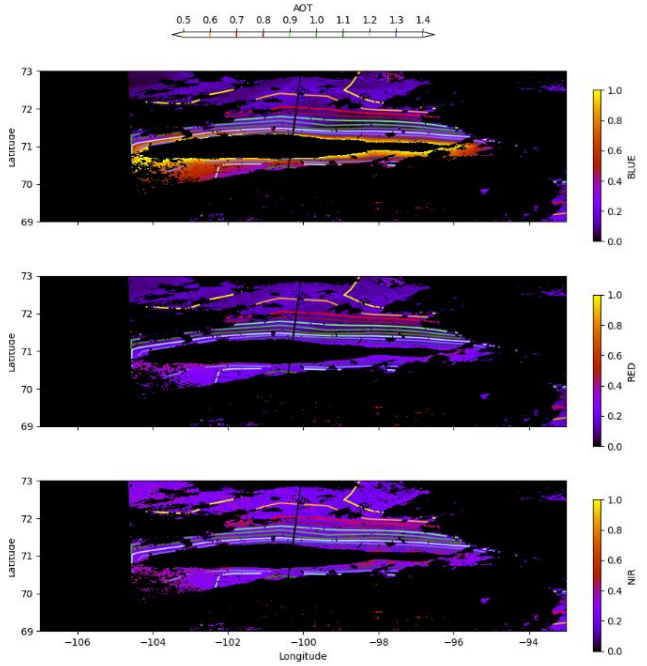


Figure 26: PROBA-V C2 zoom in on problem region for blue (top), red (middle), and NIR (bottom) bands. AOT contours are overplotted.

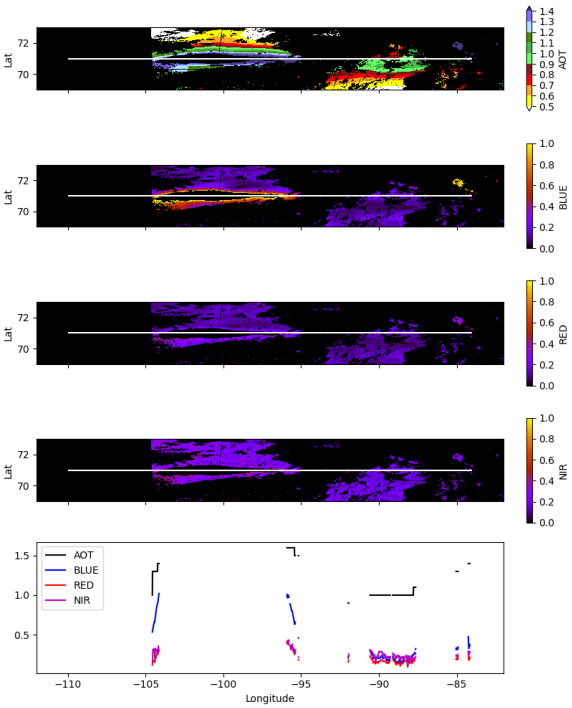


Figure 27: Line extracts.

S1_TOC 1 KM 16/07/2014

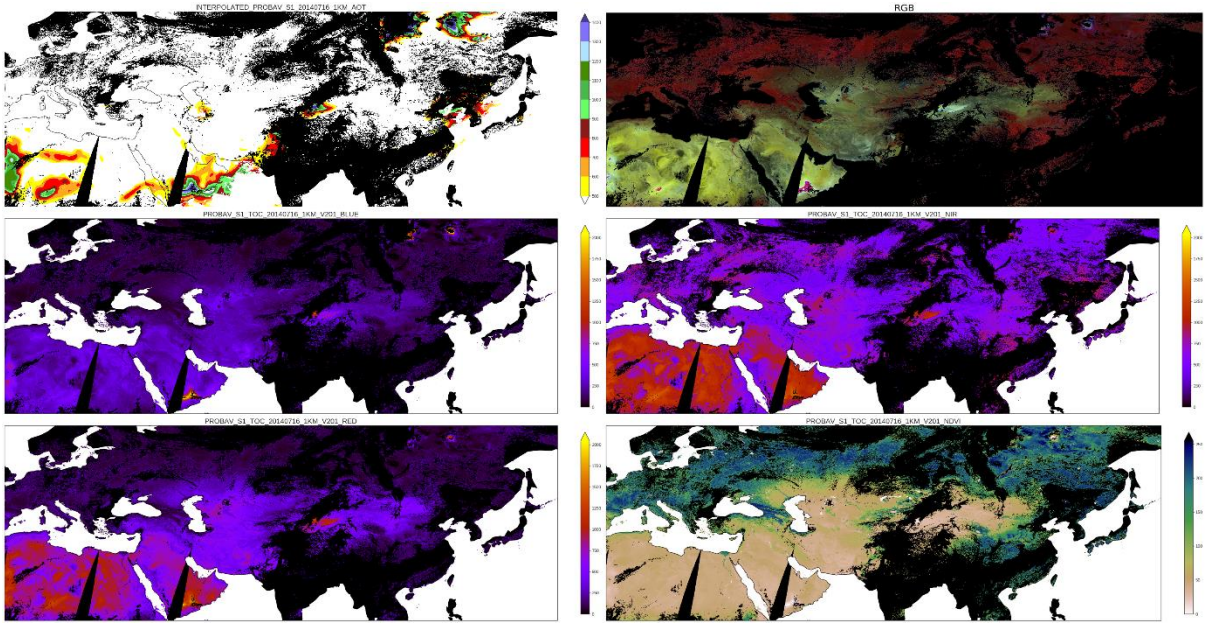


Figure 28: AOT (top left) and original RGB image (top right), TOC reflectance data Blue (middle left), Red (middle right), SWIR (bottom left) and NDVI (bottom right).

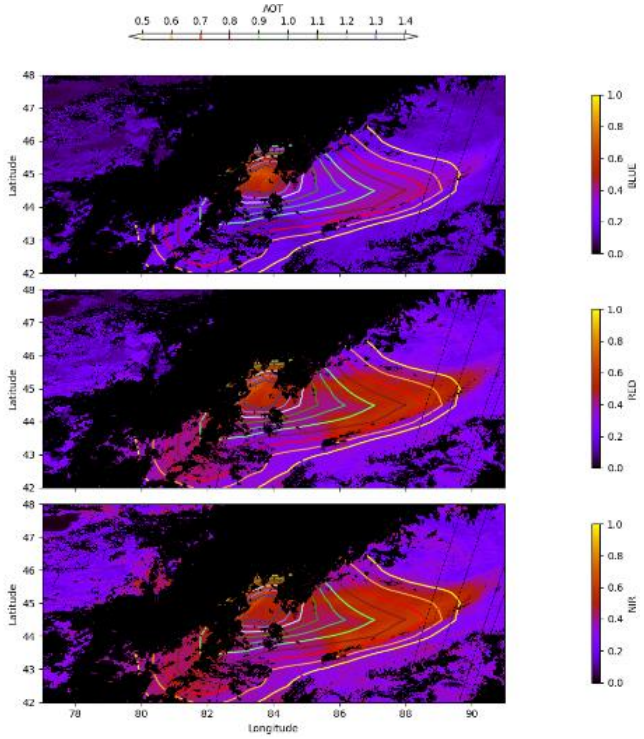


Figure 29: PROBA-V C2 zoom in on problem region for blue (top), red (middle), and NIR (bottom) bands. AOT contours are overplotted.

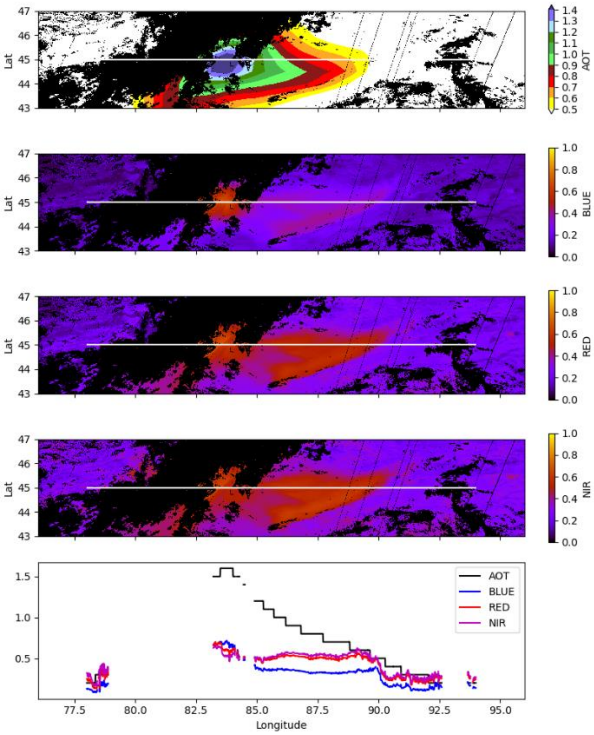


Figure 30: Line extracts.

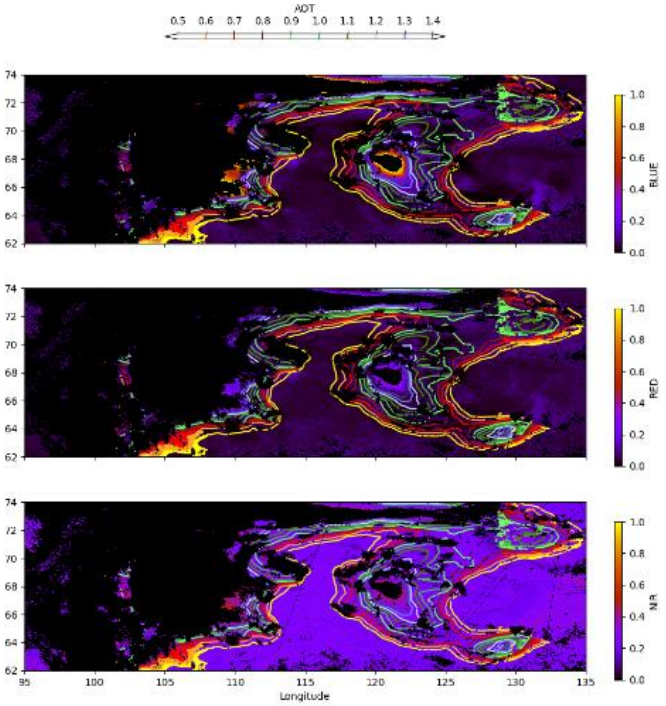


Figure 31: PROBA-V C2 zoom in on problem region for blue (top), red (middle), and NIR (bottom) bands. AOT contours are overplotted.

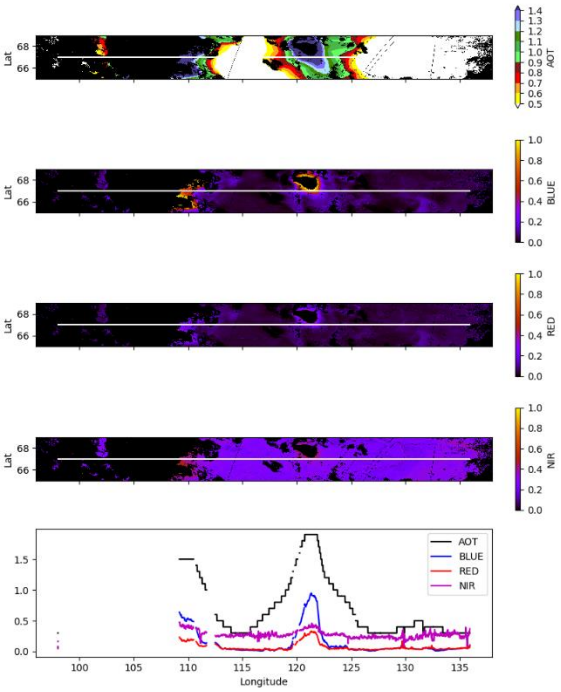


Figure 32: Line extracts.

S1_TOC 1 KM 19/07/2014

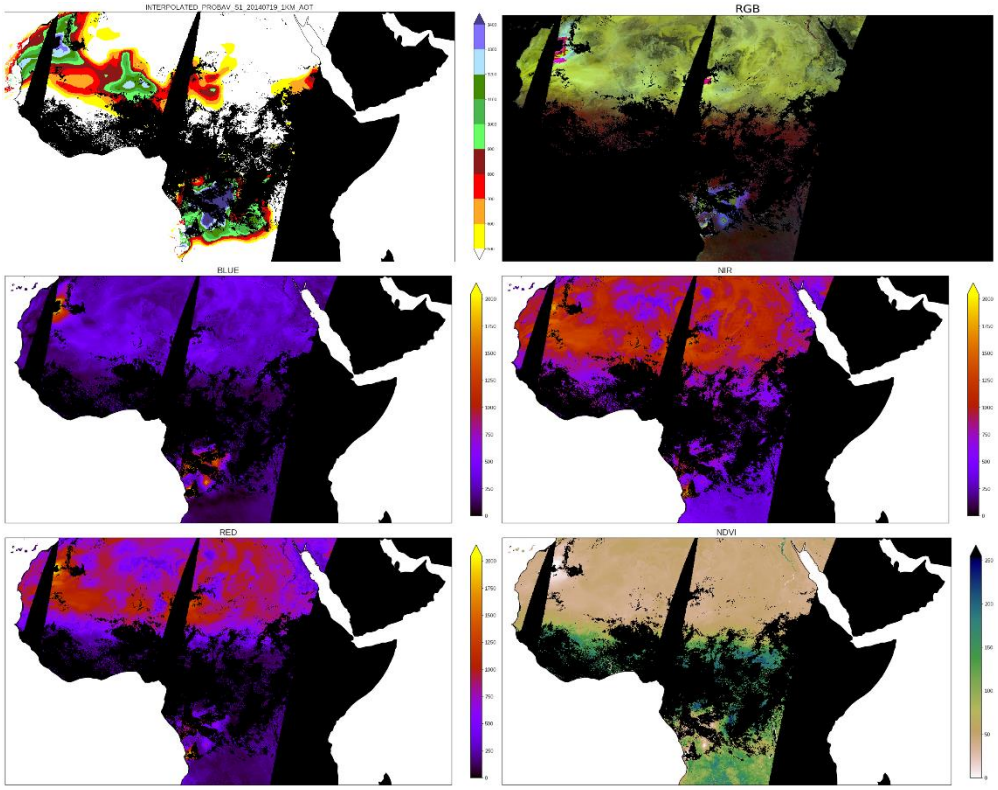


Figure 33: AOT (top left) and original RGB image (top right), TOC reflectance data Blue (middle left), Red (middle right), SWIR (bottom left) and NDVI (bottom right).

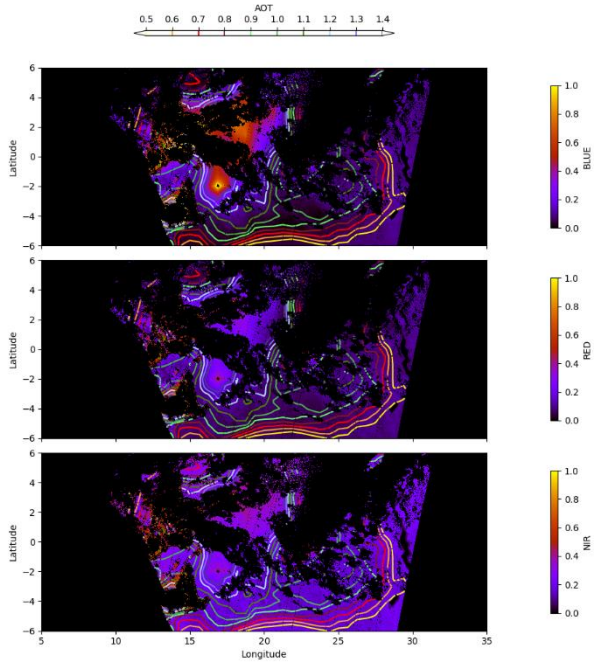


Figure 34: PROBA-V C2 zoom in on problem region for blue (top), red (middle), and NIR (bottom) bands. AOT contours are overplotted.

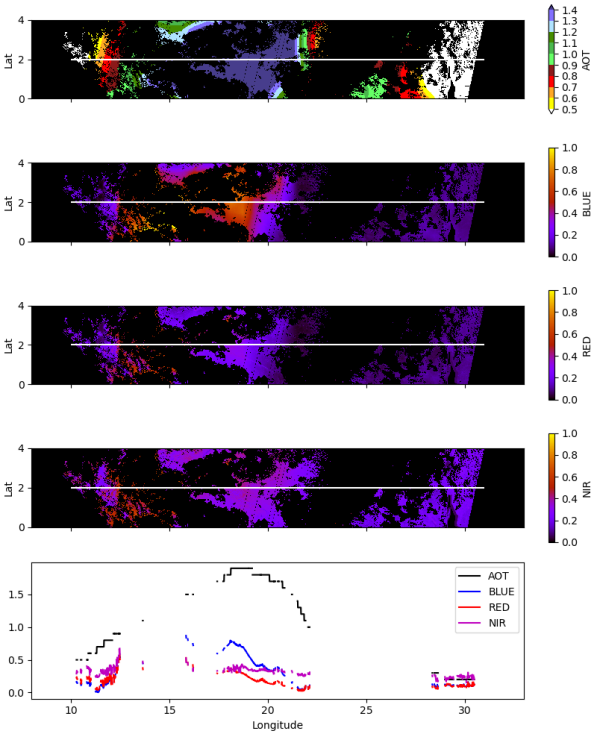


Figure 35: Line extracts.

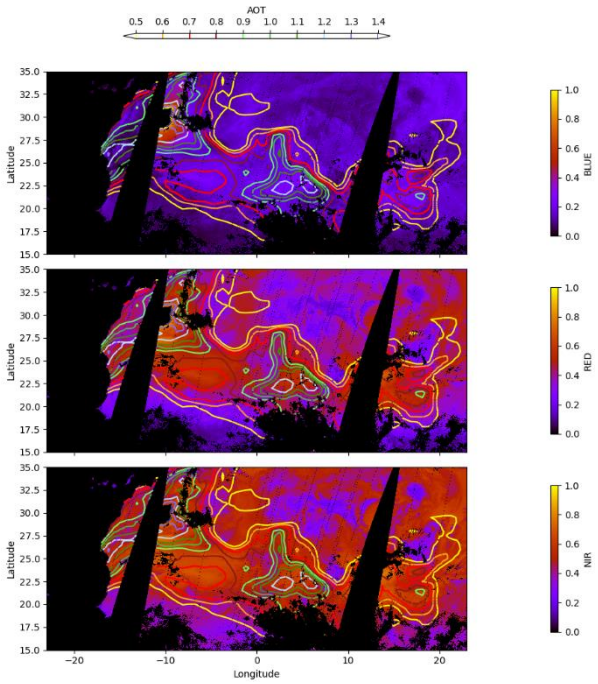


Figure 36: PROBA-V C2 zoom in on problem region for blue (top), red (middle), and NIR (bottom) bands. AOT contours are overplotted.

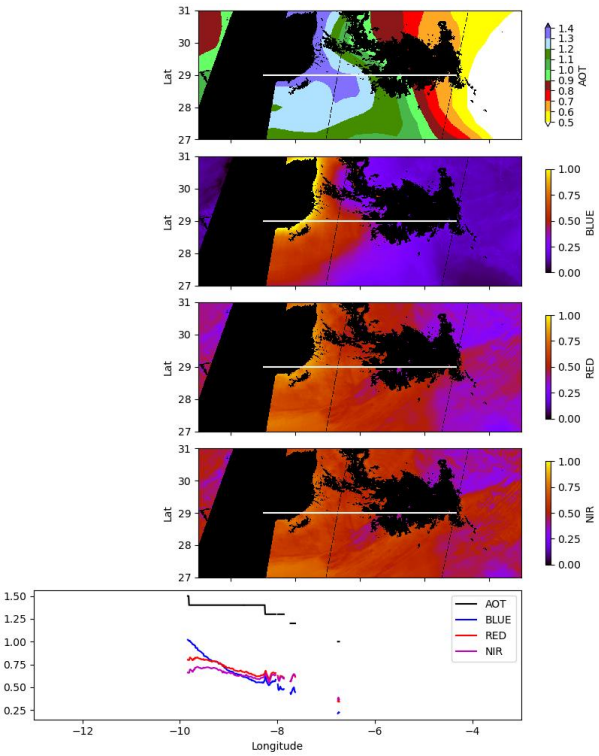
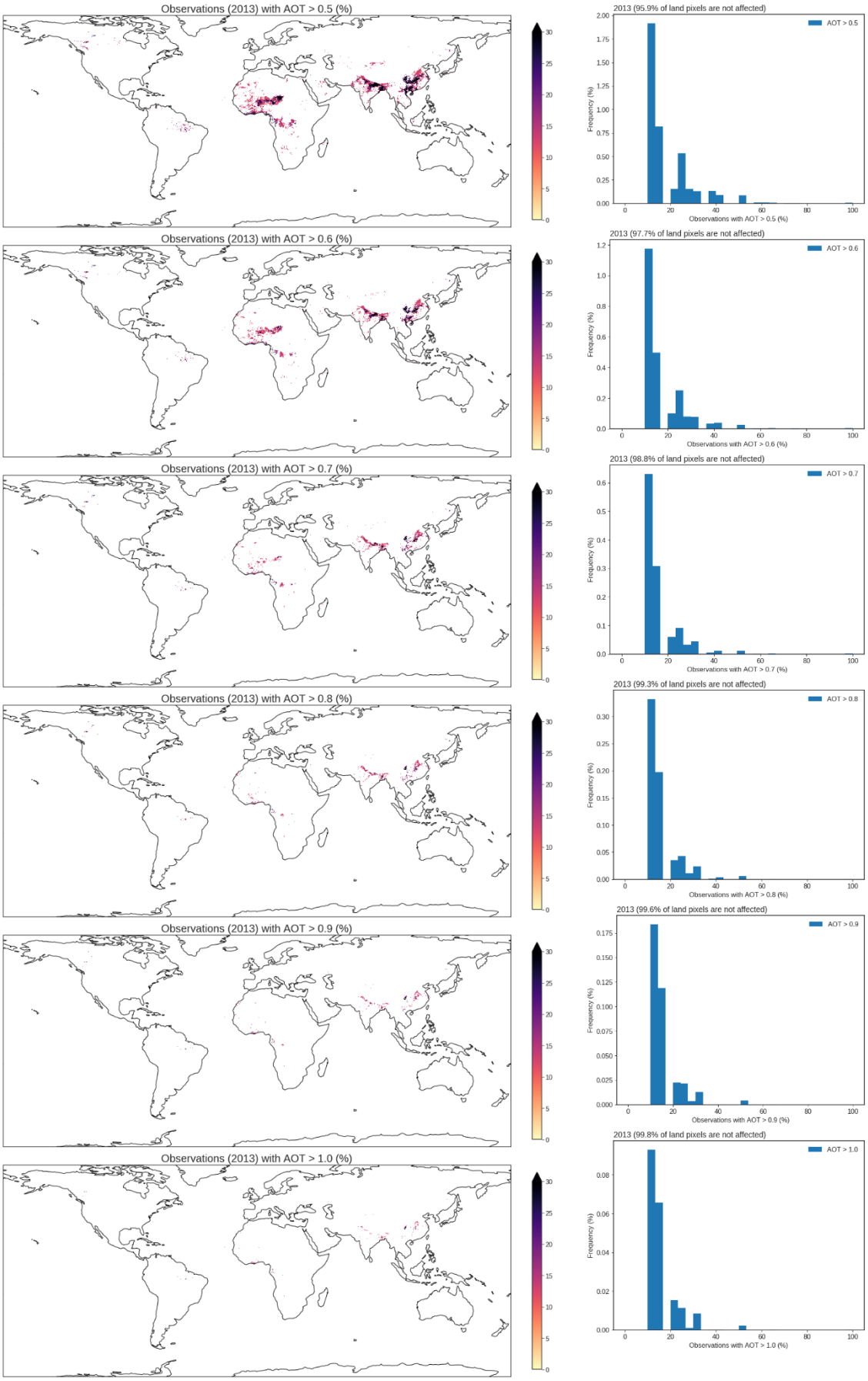


Figure 37: Line extracts.

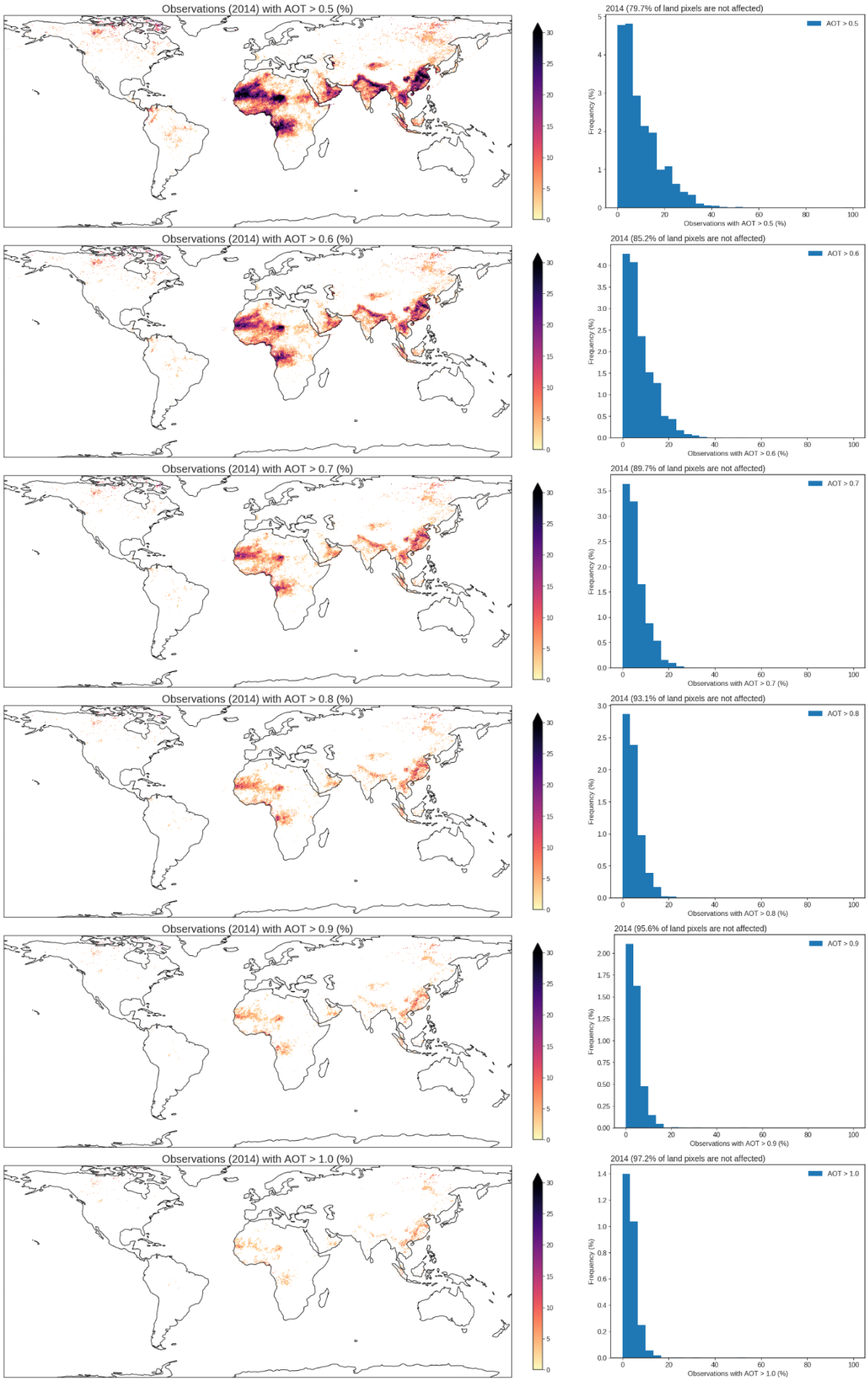
ANNEX B: SPATIAL PATTERN OF IMPACT PER YEAR FOR S10 TOC – 1 KM

The following maps show how often a certain pixel is affected (in %) after applying a specific AOT threshold. It is the percentage of clear land observations that are affected.
Histograms show for these affected pixels how many observations (in %) are affected.

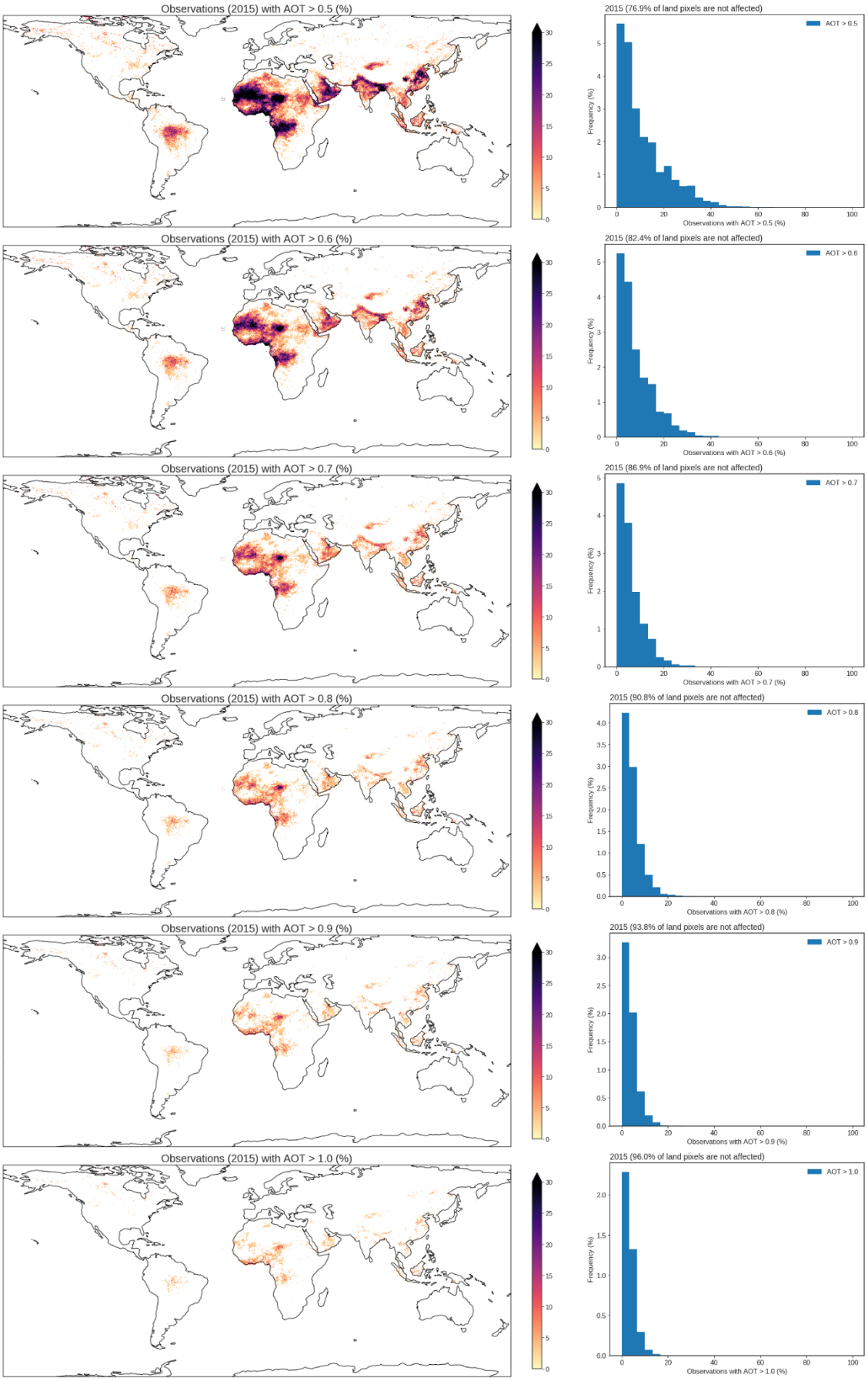
2013


Observations (2013) with AOT > 0.5 (%)
2013 (95.9% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2013) with AOT > 0.6 (%)
2013 (97.7% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2013) with AOT > 0.7 (%)
2013 (98.8% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2013) with AOT > 0.8 (%)
2013 (99.3% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2013) with AOT > 0.9 (%)
2013 (99.6% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2013) with AOT > 1.0 (%)
2013 (99.8% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

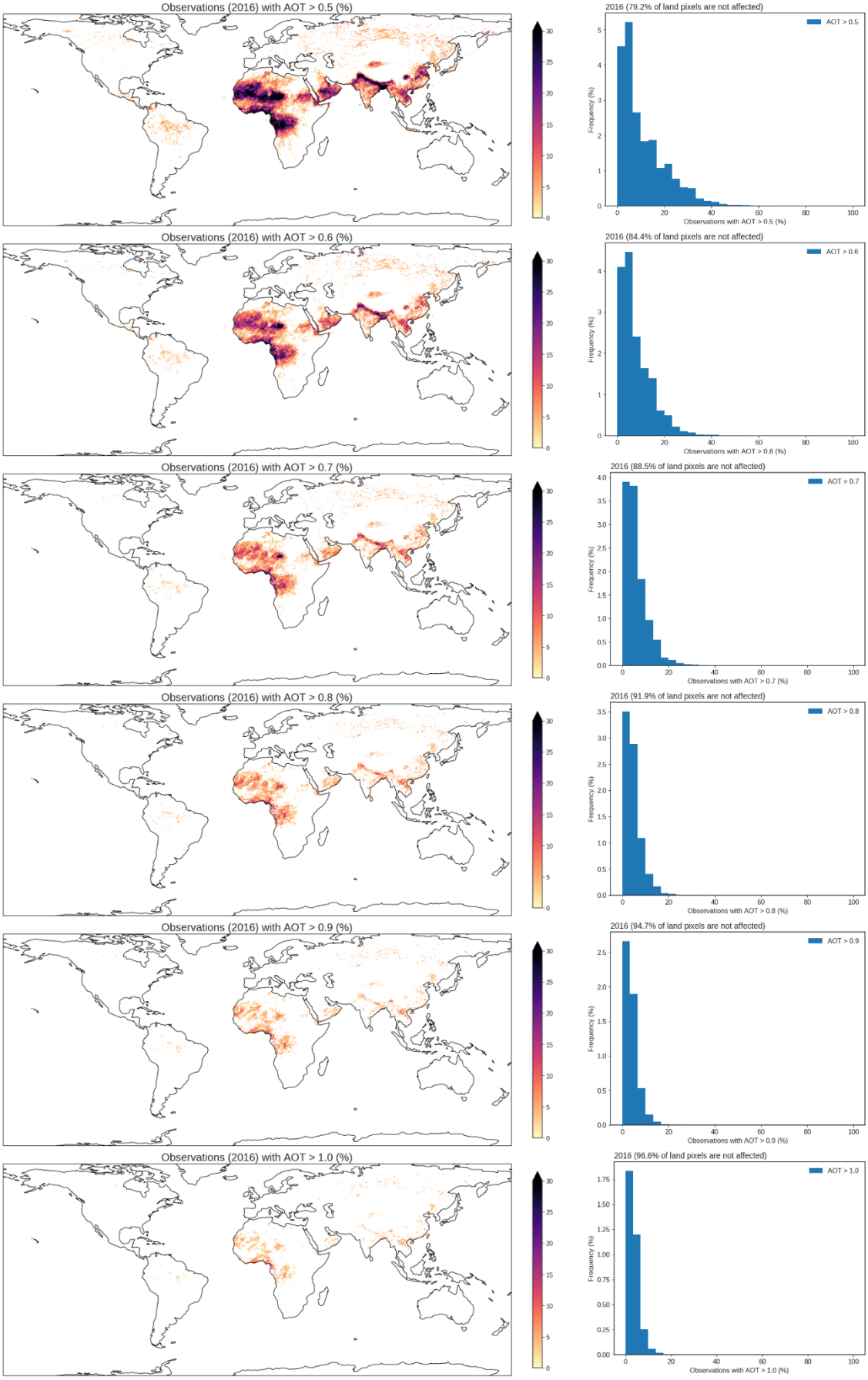
2014


Observations (2014) with AOT > 0.5 (%)
2014 (79.7% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2014) with AOT > 0.6 (%)
2014 (85.2% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2014) with AOT > 0.7 (%)
2014 (89.7% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2014) with AOT > 0.8 (%)
2014 (93.1% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2014) with AOT > 0.9 (%)
2014 (95.6% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2014) with AOT > 1.0 (%)
2014 (97.2% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

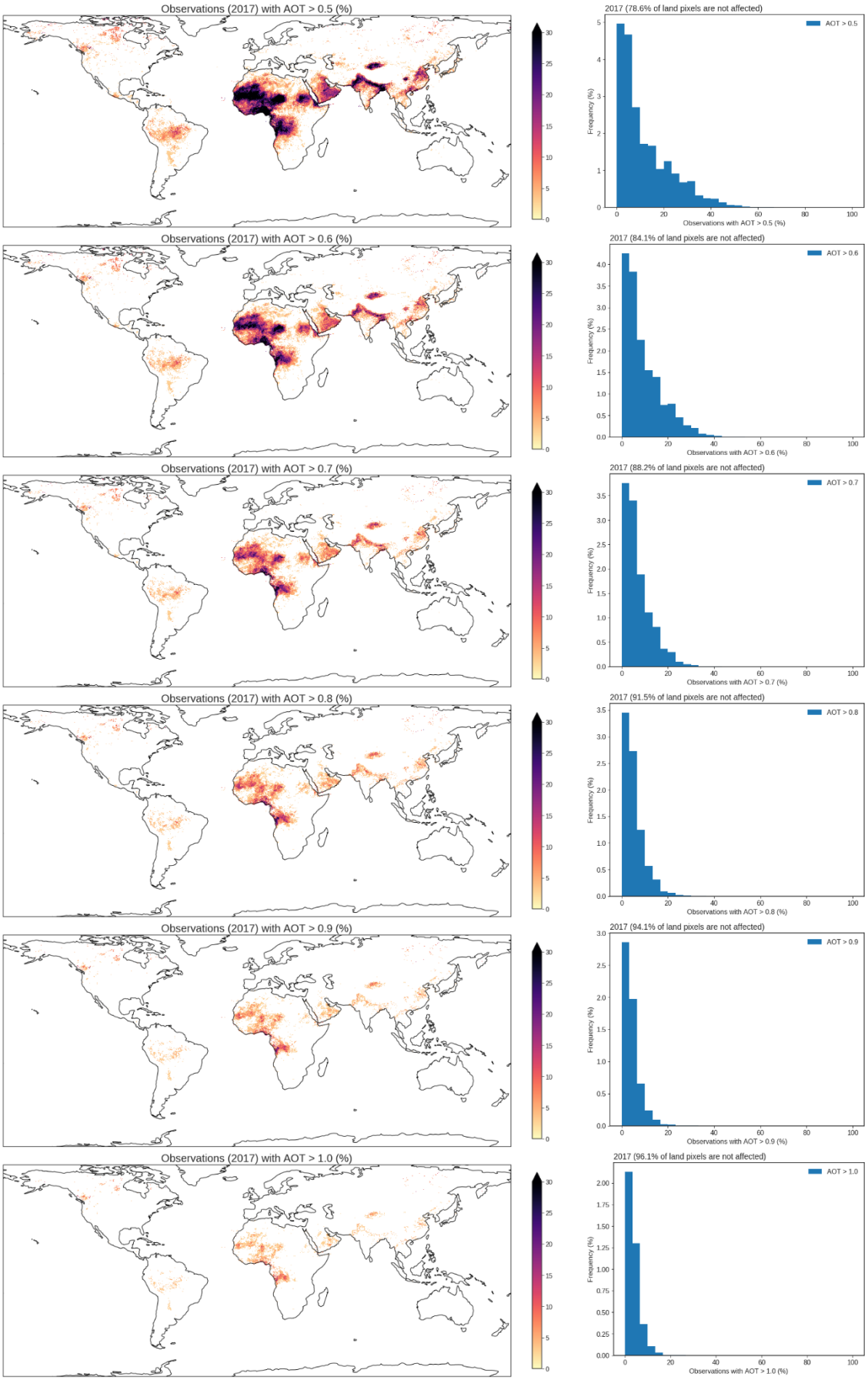
2015


Observations (2015) with AOT > 0.5 (%)
2015 (76.9% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2015) with AOT > 0.6 (%)
2015 (82.4% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2015) with AOT > 0.7 (%)
2015 (86.9% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2015) with AOT > 0.8 (%)
2015 (90.8% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2015) with AOT > 0.9 (%)
2015 (93.8% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2015) with AOT > 1.0 (%)
2015 (96.0% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

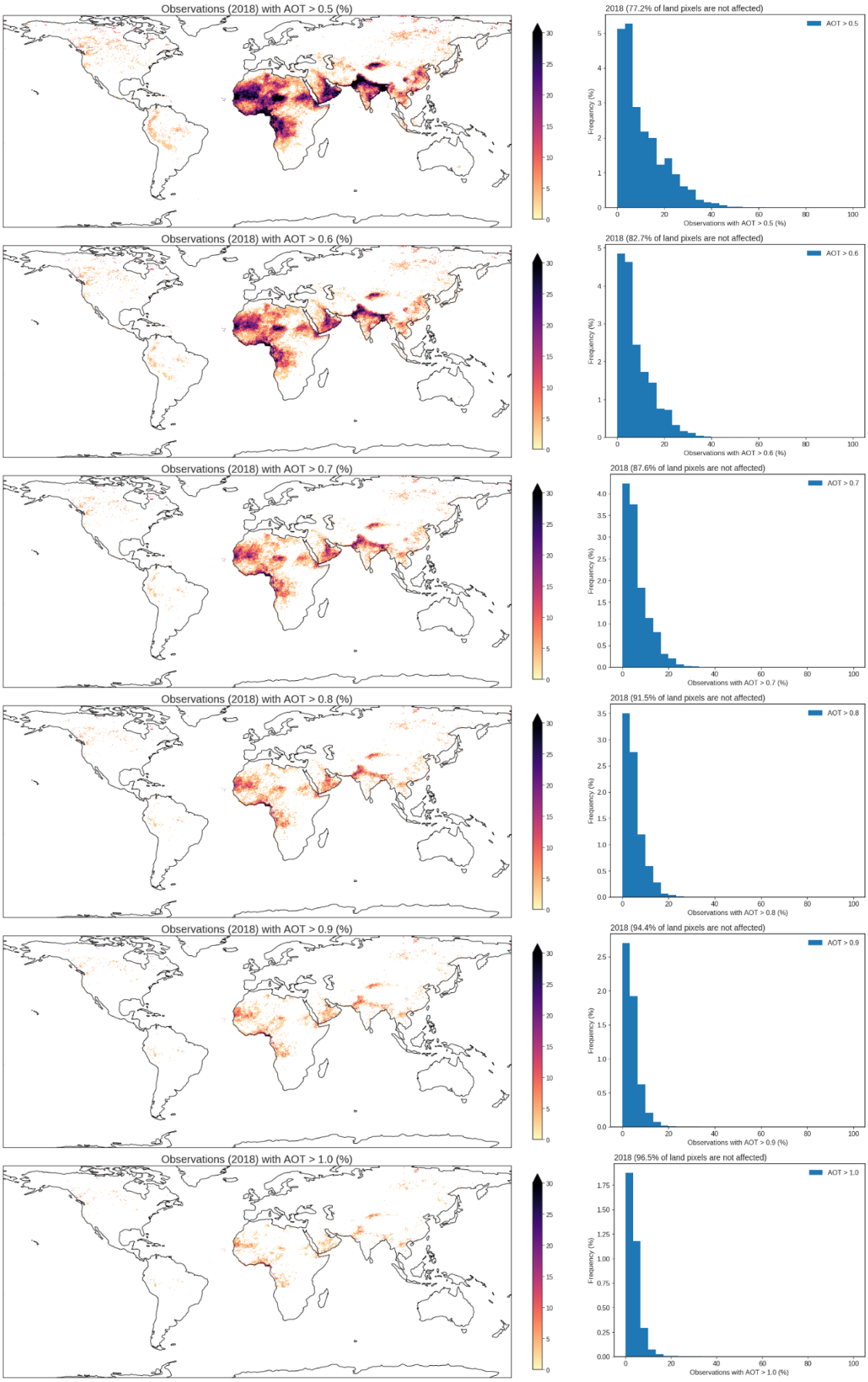
2016


Observations (2016) with AOT > 0.5 (%)
2016 (79.2% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2016) with AOT > 0.6 (%)
2016 (84.4% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2016) with AOT > 0.7 (%)
2016 (88.5% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2016) with AOT > 0.8 (%)
2016 (91.9% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2016) with AOT > 0.9 (%)
2016 (94.7% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2016) with AOT > 1.0 (%)
2016 (96.6% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

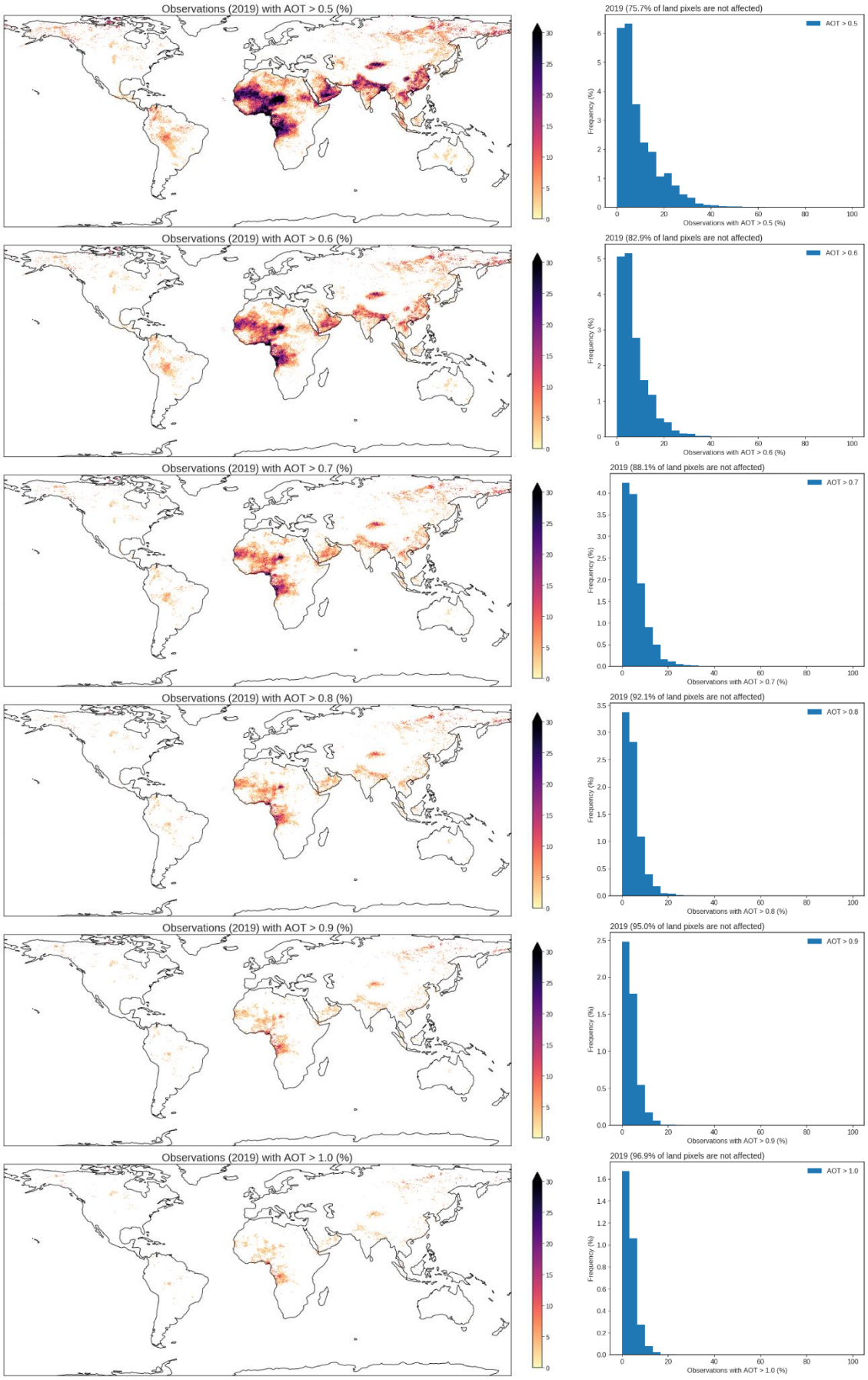
2017


Observations (2017) with AOT > 0.5 (%)
2017 (78.6% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2017) with AOT > 0.6 (%)
2017 (84.1% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2017) with AOT > 0.7 (%)
2017 (88.2% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2017) with AOT > 0.8 (%)
2017 (91.5% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2017) with AOT > 0.9 (%)
2017 (94.1% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2017) with AOT > 1.0 (%)
2017 (96.1% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

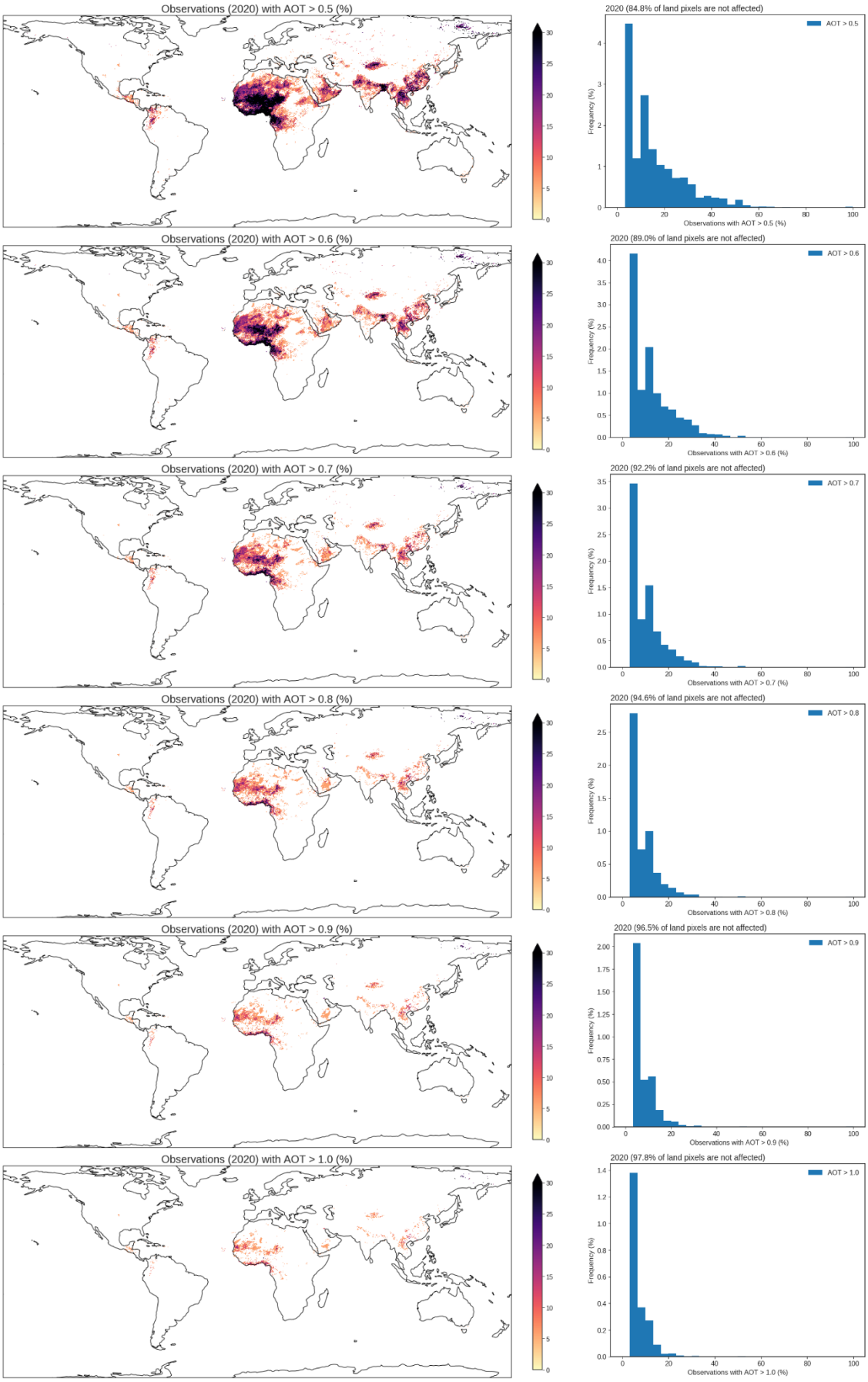
2018


Observations (2018) with AOT > 0.5 (%)
2018 (77.2% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2018) with AOT > 0.6 (%)
2018 (82.7% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2018) with AOT > 0.7 (%)
2018 (87.6% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2018) with AOT > 0.8 (%)
2018 (91.5% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2018) with AOT > 0.9 (%)
2018 (94.4% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2018) with AOT > 1.0 (%)
2018 (96.5% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

2019


Observations (2019) with AOT > 0.5 (%)
2019 (75.7% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2019) with AOT > 0.6 (%)
2019 (82.9% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2019) with AOT > 0.7 (%)
2019 (88.1% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2019) with AOT > 0.8 (%)
2019 (92.1% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2019) with AOT > 0.9 (%)
2019 (95.0% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2019) with AOT > 1.0 (%)
2019 (96.9% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

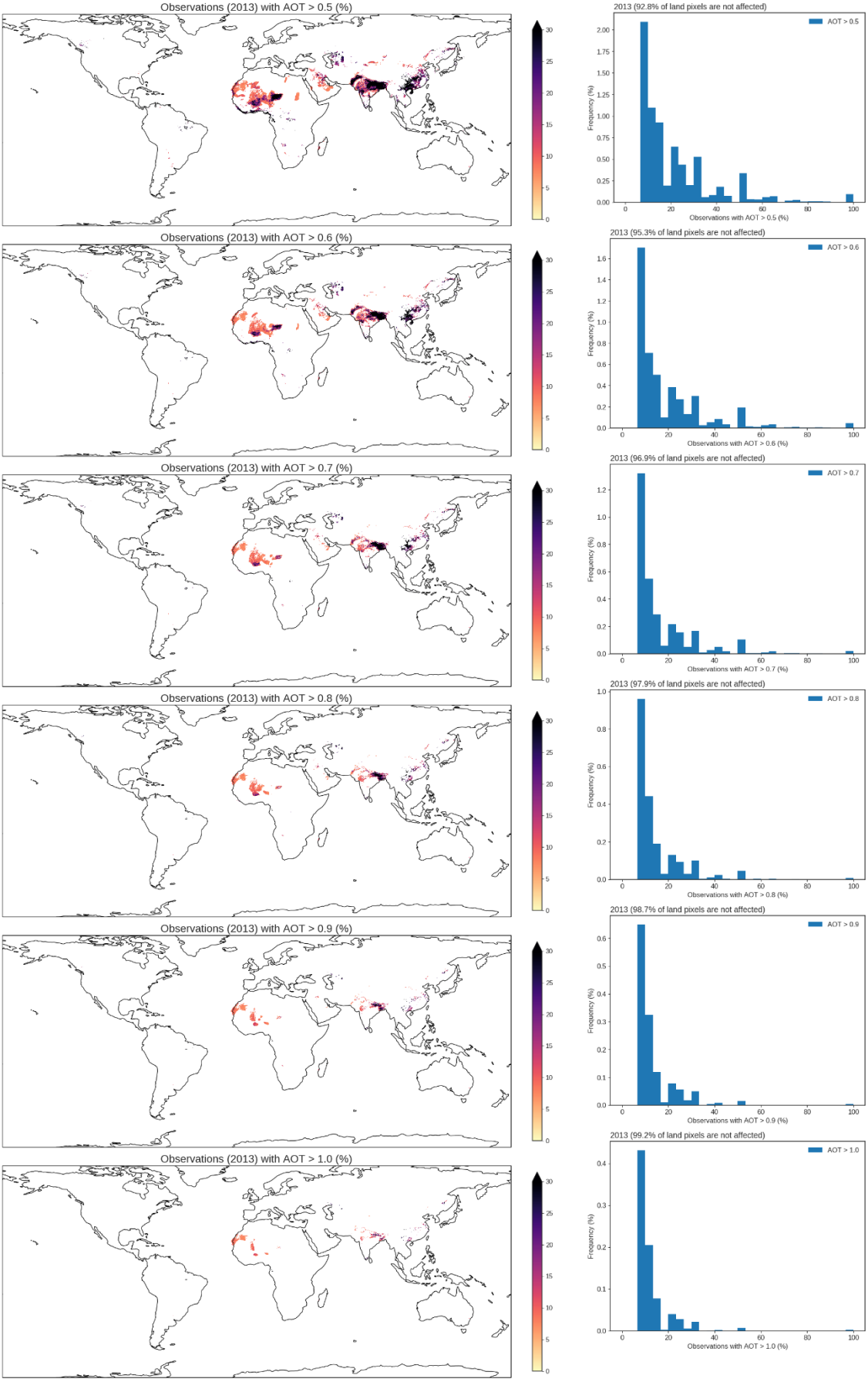
2020


Observations (2020) with AOT > 0.5 (%)
2020 (84.8% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2020) with AOT > 0.6 (%)
2020 (89.0% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2020) with AOT > 0.7 (%)
2020 (92.2% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2020) with AOT > 0.8 (%)
2020 (94.6% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2020) with AOT > 0.9 (%)
2020 (96.5% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2020) with AOT > 1.0 (%)
2020 (97.8% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

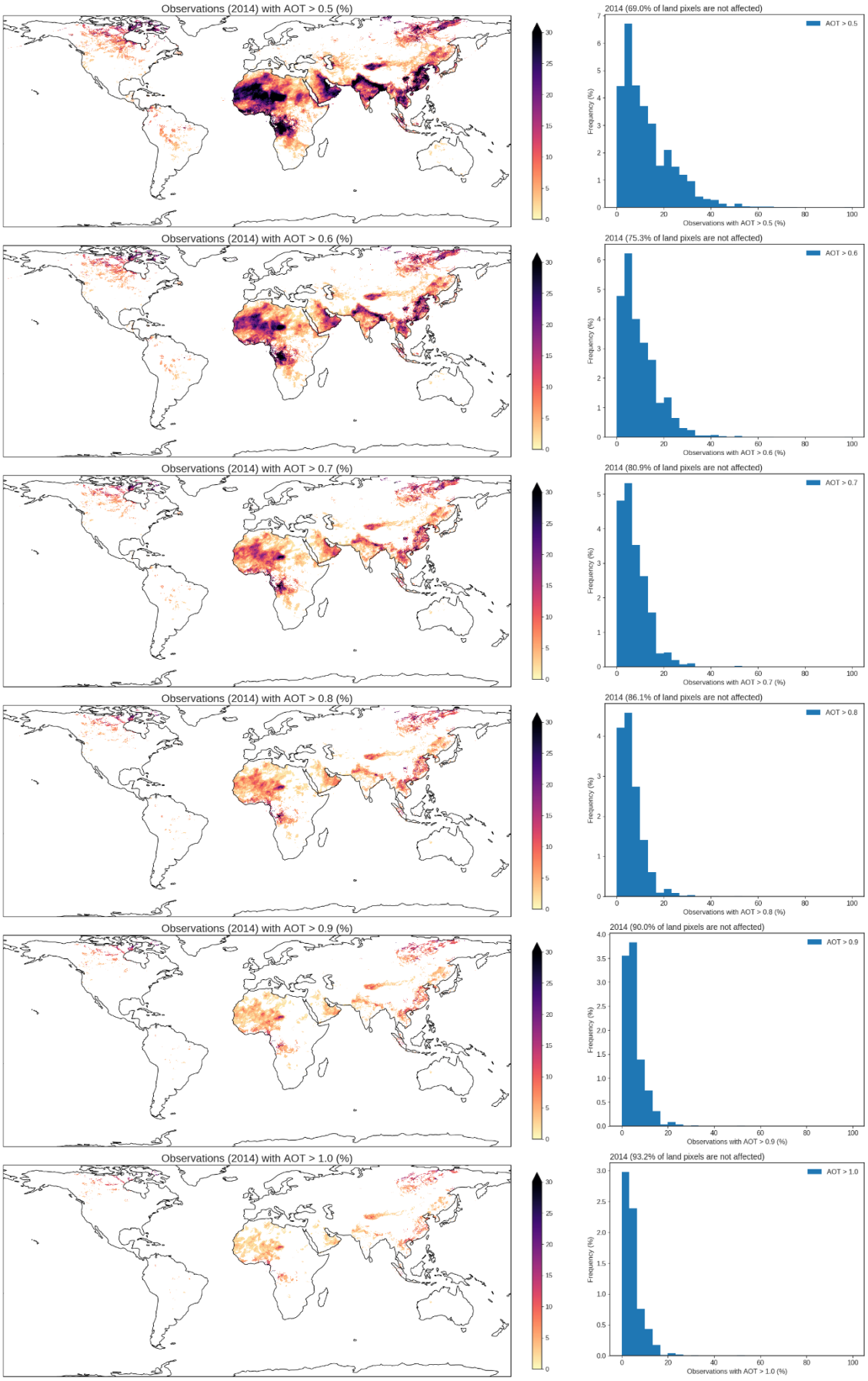
ANNEX C: SPATIAL PATTERN OF IMPACT PER YEAR FOR S1 TOC - 1 KM

The following maps show how often a certain pixel is affected (in %) after applying a specific AOT threshold. It is the percentage of clear land observations that are affected.
Histograms show for these affected pixels how many observations (in %) are affected.
The S1-TOC dataset is subsampled to every 5th day to reduce processing time.

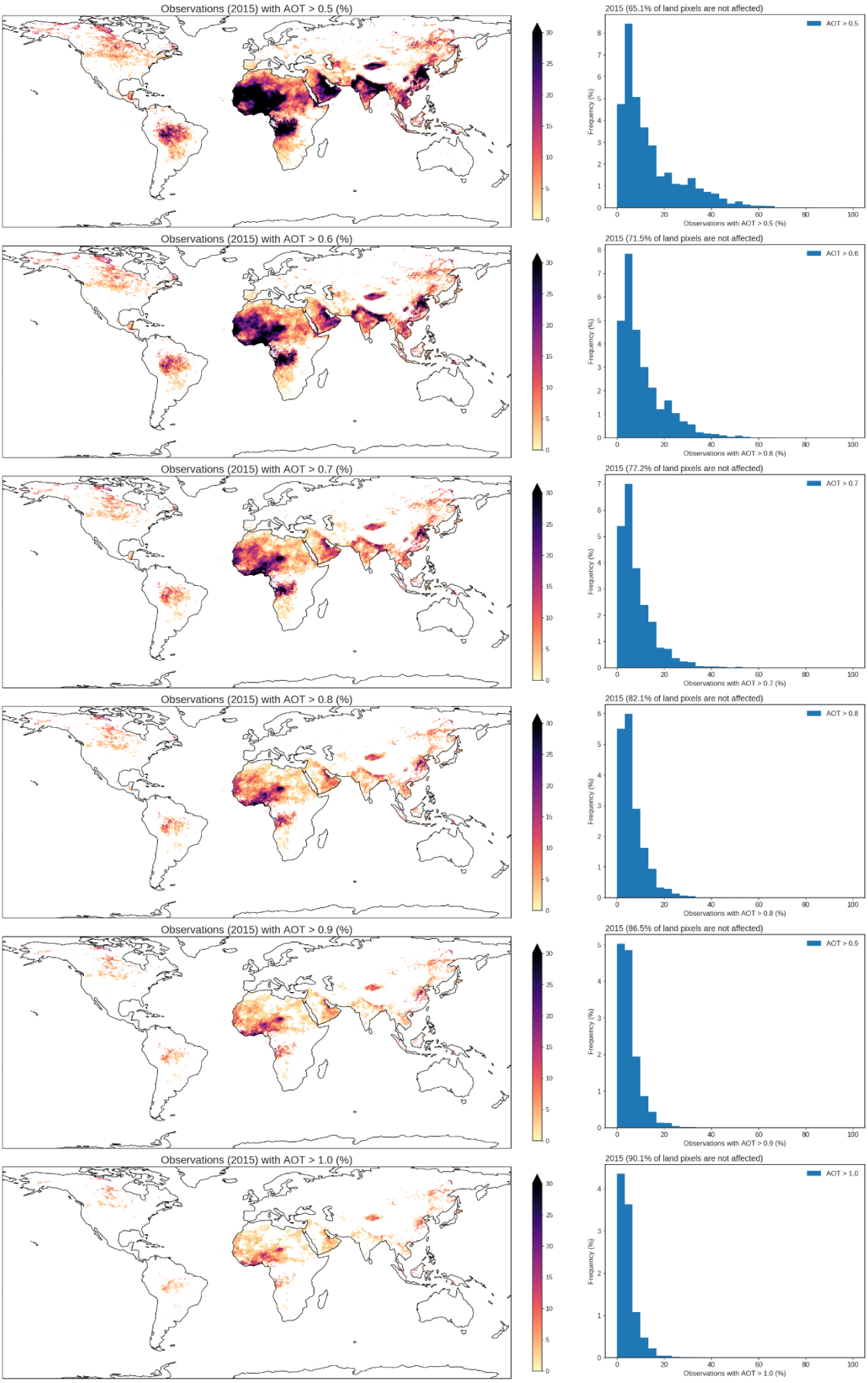
2013


Observations (2013) with AOT > 0.5 (%)
2013 (92.8% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2013) with AOT > 0.6 (%)
2013 (95.3% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2013) with AOT > 0.7 (%)
2013 (96.9% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2013) with AOT > 0.8 (%)
2013 (97.9% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2013) with AOT > 0.9 (%)
2013 (98.7% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2013) with AOT > 1.0 (%)
2013 (99.2% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

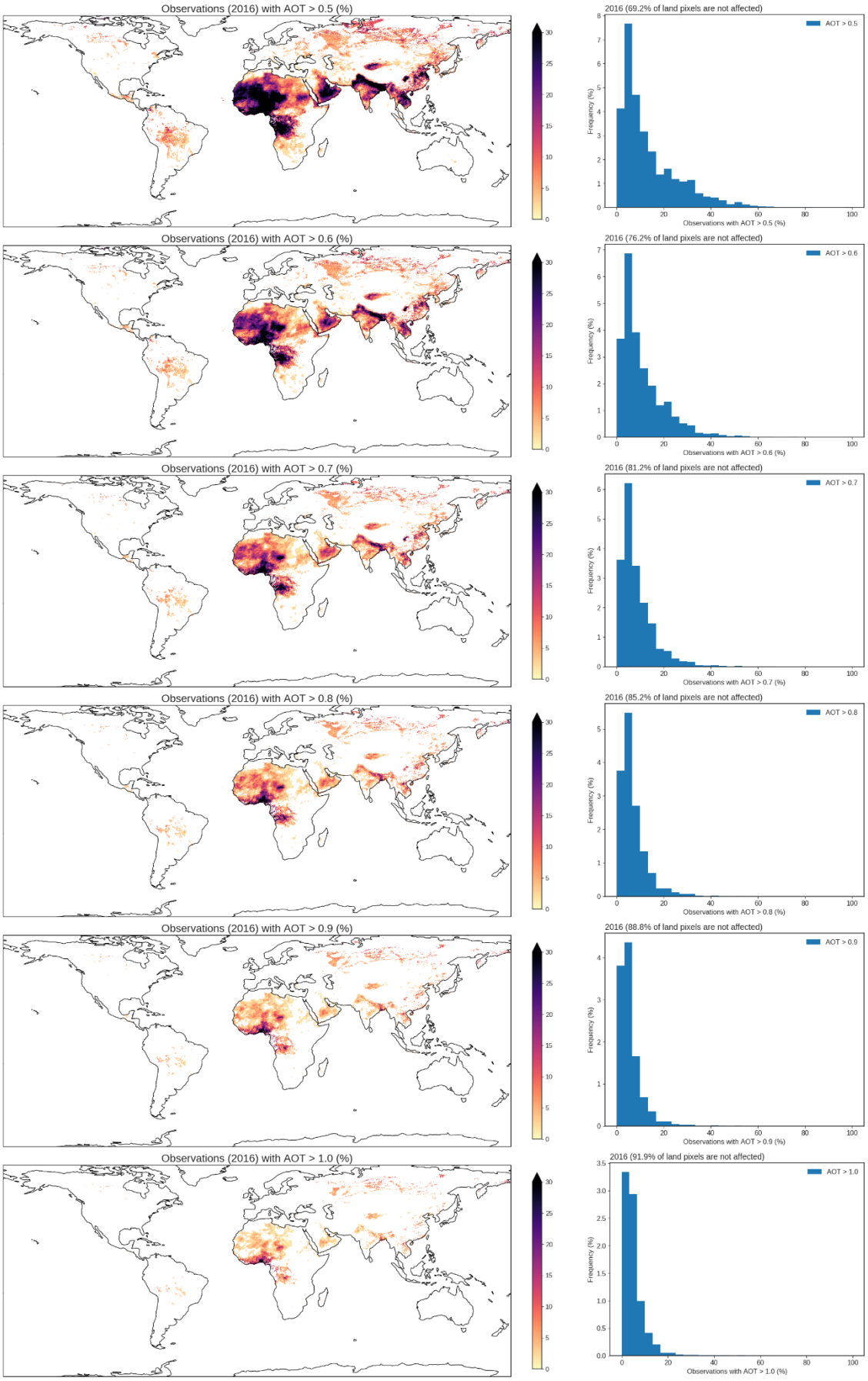
2014


Observations (2014) with AOT > 0.5 (%)
2014 (69.0% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2014) with AOT > 0.6 (%)
2014 (75.3% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2014) with AOT > 0.7 (%)
2014 (80.9% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2014) with AOT > 0.8 (%)
2014 (86.1% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2014) with AOT > 0.9 (%)
2014 (90.0% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2014) with AOT > 1.0 (%)
2014 (93.2% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

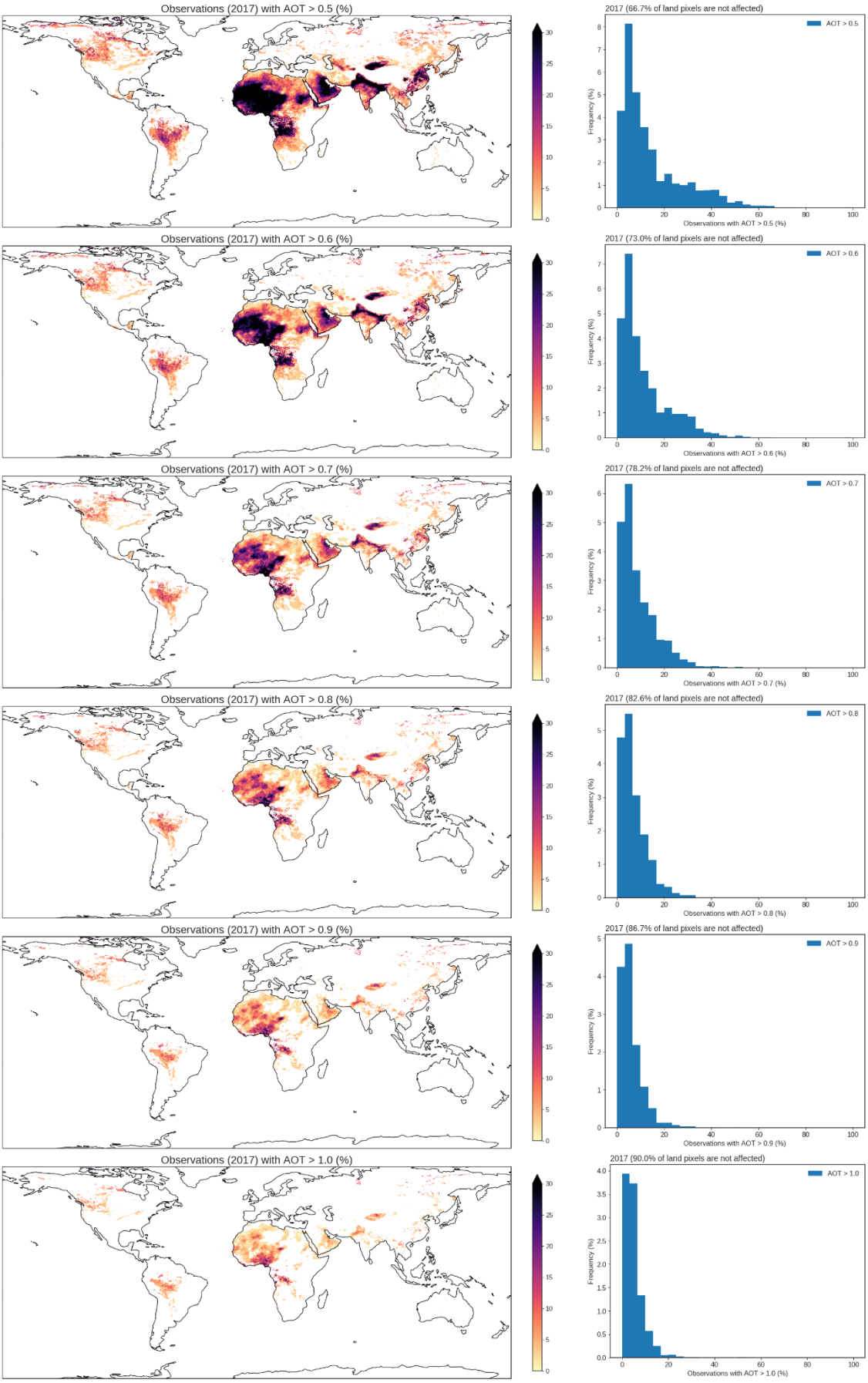
2015


Observations (2015) with AOT > 0.5 (%)
2015 (65.1% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2015) with AOT > 0.6 (%)
2015 (71.5% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2015) with AOT > 0.7 (%)
2015 (77.2% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2015) with AOT > 0.8 (%)
2015 (82.1% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2015) with AOT > 0.9 (%)
2015 (86.5% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2015) with AOT > 1.0 (%)
2015 (90.1% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

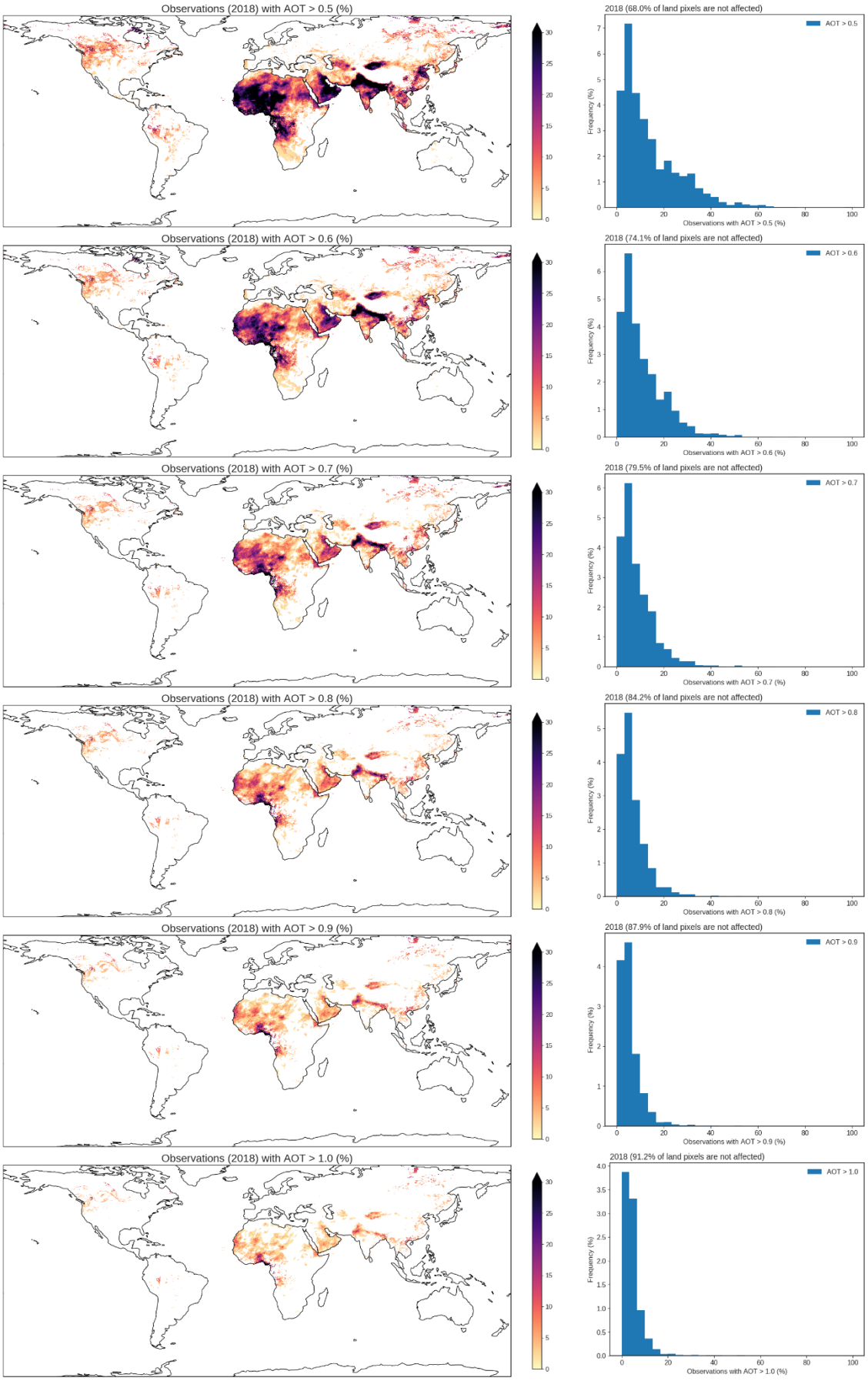
2016


Observations (2016) with AOT > 0.5 (%)
2016 (69.2% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2016) with AOT > 0.6 (%)
2016 (76.2% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2016) with AOT > 0.7 (%)
2016 (81.2% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2016) with AOT > 0.8 (%)
2016 (85.2% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2016) with AOT > 0.9 (%)
2016 (88.8% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2016) with AOT > 1.0 (%)
2016 (91.9% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

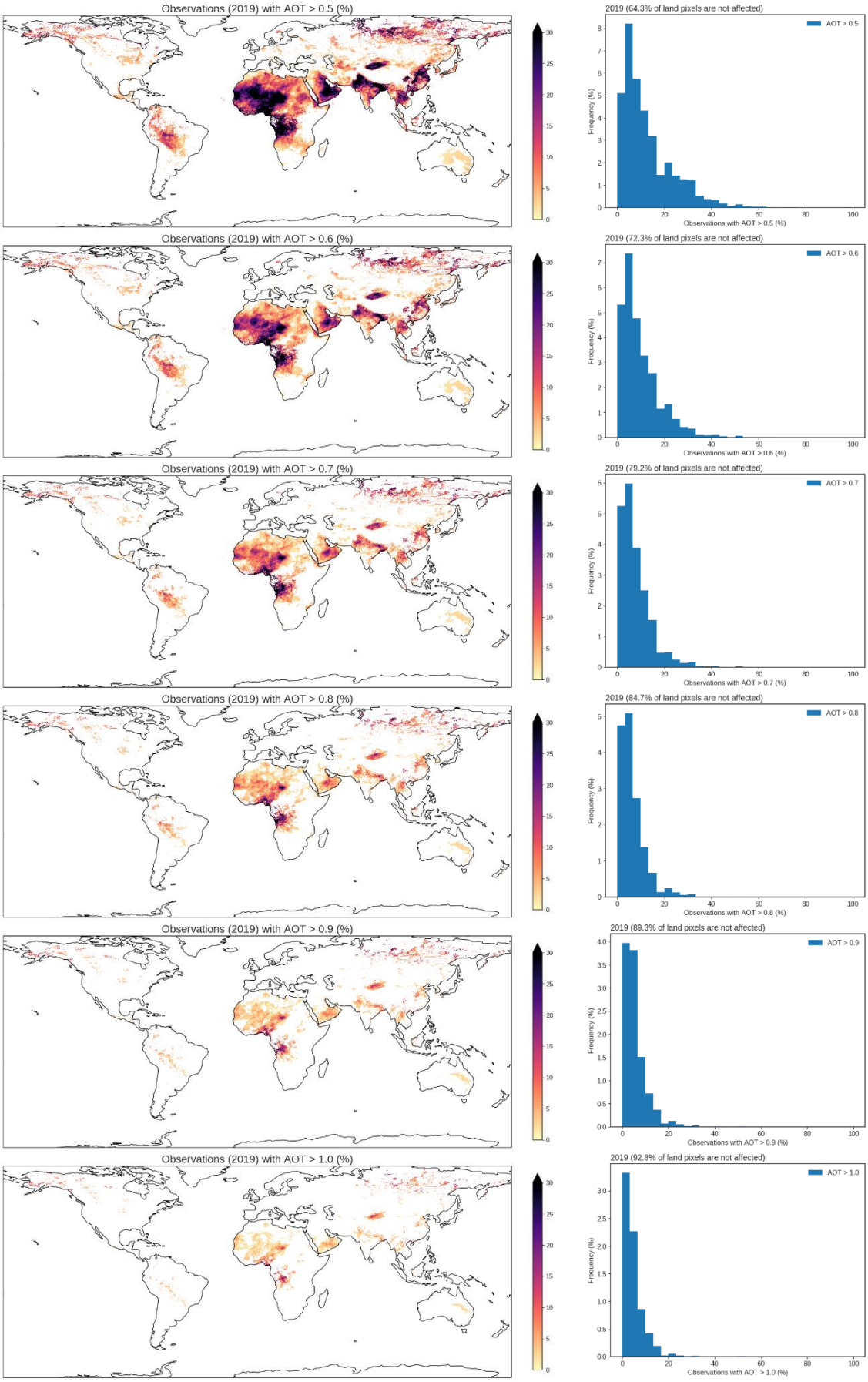
2017


Observations (2017) with AOT > 0.5 (%)
2017 (66.7% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2017) with AOT > 0.6 (%)
2017 (73.0% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2017) with AOT > 0.7 (%)
2017 (78.2% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2017) with AOT > 0.8 (%)
2017 (82.6% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2017) with AOT > 0.9 (%)
2017 (86.7% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2017) with AOT > 1.0 (%)
2017 (90.0% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

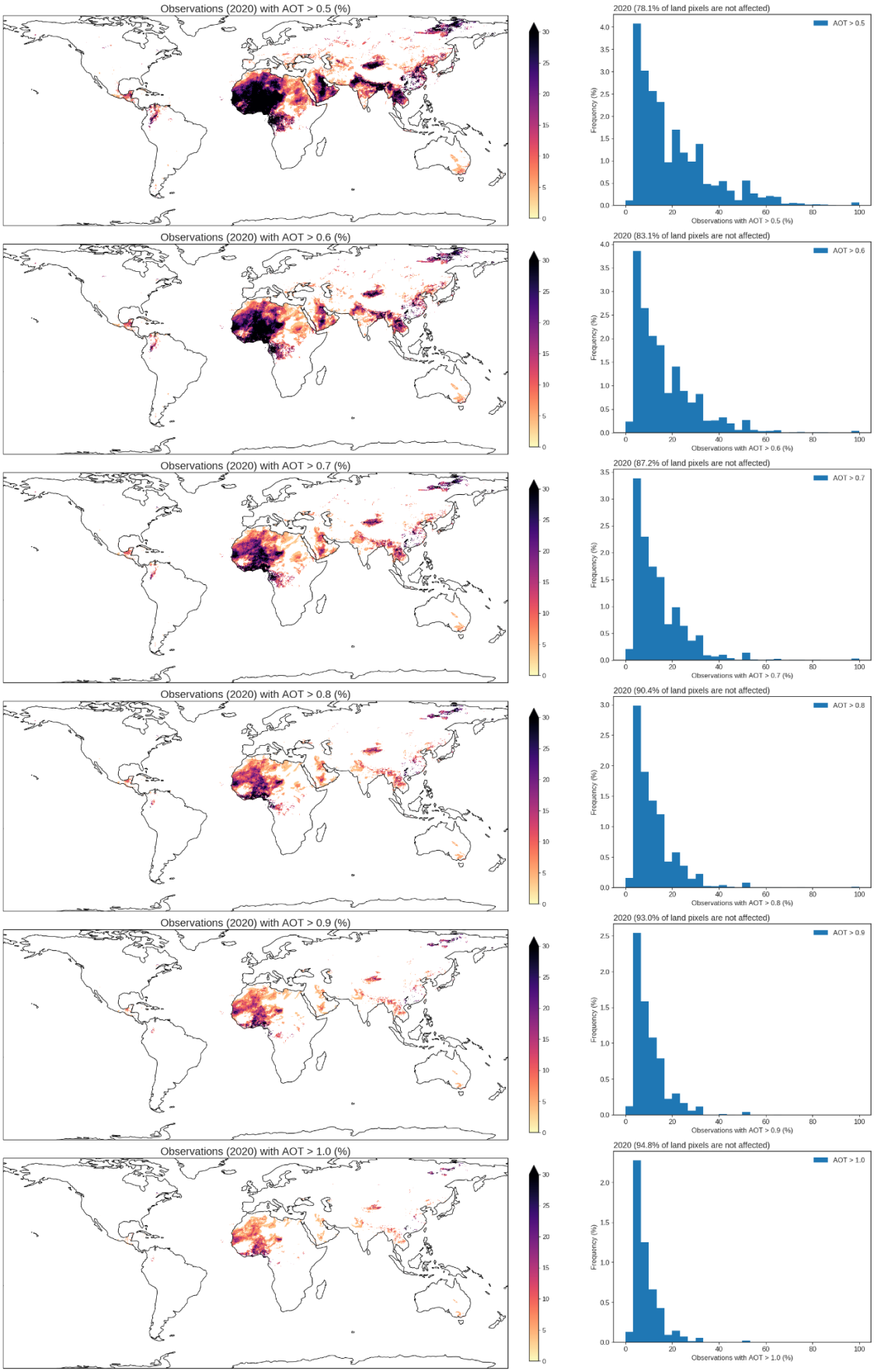
2018


Observations (2018) with AOT > 0.5 (%)
2018 (68.0% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2018) with AOT > 0.6 (%)
2018 (74.1% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2018) with AOT > 0.7 (%)
2018 (79.5% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2018) with AOT > 0.8 (%)
2018 (84.2% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2018) with AOT > 0.9 (%)
2018 (87.9% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2018) with AOT > 1.0 (%)
2018 (91.2% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

2019


Observations (2019) with AOT > 0.5 (%)
2019 (64.3% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2019) with AOT > 0.6 (%)
2019 (72.3% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2019) with AOT > 0.7 (%)
2019 (79.2% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2019) with AOT > 0.8 (%)
2019 (84.7% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2019) with AOT > 0.9 (%)
2019 (89.3% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2019) with AOT > 1.0 (%)
2019 (92.8% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)

2020


Observations (2020) with AOT > 0.5 (%)
2020 (78.1% of land pixels are not affected)
AOT > 0.5
Frequency (%)
Observations with AOT > 0.5 (%)
Observations (2020) with AOT > 0.6 (%)
2020 (83.1% of land pixels are not affected)
AOT > 0.6
Frequency (%)
Observations with AOT > 0.6 (%)
Observations (2020) with AOT > 0.7 (%)
2020 (87.2% of land pixels are not affected)
AOT > 0.7
Frequency (%)
Observations with AOT > 0.7 (%)
Observations (2020) with AOT > 0.8 (%)
2020 (90.4% of land pixels are not affected)
AOT > 0.8
Frequency (%)
Observations with AOT > 0.8 (%)
Observations (2020) with AOT > 0.9 (%)
2020 (93.0% of land pixels are not affected)
AOT > 0.9
Frequency (%)
Observations with AOT > 0.9 (%)
Observations (2020) with AOT > 1.0 (%)
2020 (94.8% of land pixels are not affected)
AOT > 1.0
Frequency (%)
Observations with AOT > 1.0 (%)