2022 DRAGON 5 SYMPOSIUM

MID-TERM RESULTS REPORTING

17-21 OCTOBER 2022

PROJECT ID. 58573

THREE DIMENSIONAL CLOUD EFFECTS ON ATMOSPHERIC COMPOSITION AND AEROSOLS FROM NEW GENERATION SATELLITE OBSERVATIONS (3D CLOUD EFFECTS)

Dragon 5 Mid-term Results Project

TUESDAY 18 OCTOBER 2022

ID. 58573

PROJECT TITLE: THREE DIMENSIONAL CLOUD EFFECTS ON ATMOSPHERIC COMPOSITION AND AEROSOLS FROM NEW GENERATION SATELLITE OBSERVATIONS (3D CLOUD EFFECTS)

PRINCIPAL INVESTIGATORS: PING WANG[1], MINZHENG DUAN[2]

CO-AUTHORS: Victor Trees[1], Benjamin Leune[1], Dave Donovan[1], Congcong Qiao[2], Xuehua Fan[2], Juan Huo[2], Piet Stammes[1]

[1] KNMI, [2] IAP

PRESENTED BY: PING WANG

Dragon 5 Mid-term Results Reporting: Overview

- Inform on the project's objectives
- Detail the Copernicus Sentinels, ESA, Chinese and ESA Third Party Mission data utilised after 2 years
- Inform on the results after 2 years of activity
  - -- cloud shadow detection algorithm for TROPOMI
  - -- impacts of cloud shadows on TROPOMI NO_2 products
  - -- aerosol optical thickness retrievals using urban building shadows in GF-2
  - -- aerosol optical thickness retrievals using cloud shadows in Landsat-8
- Inform on the project's schedule, planning & contribution of the partners for the following year
- Report on the level and training of young scientists on the project achievements, including plans for academic exchanges

Project's objectives

Detect the cloud shadows and

Analyze the impact of the 3D cloud effects on trace gas retrievals.

Use the (cloud) shadow and neighbour pixels to derive aerosol optical thickness and surface albedo.

Use 3D radiative transfer model simulations to understand the cloud effects on TROPOMI NO_2 products.

- Detail the Copernicus Sentinels, ESA, Chinese and ESA Third Party Mission data utilised after 2 years

- We have used:

-- S5P L1B, L2 NO_2, AAI, cloud products from November 2020 to June 2021, 8 months of data for all orbits over Europe, Africa, Asia.
-- VIIRS images for 20 scenes
-- GF-2 data for 30 scenes
-- Landsat-8 data for 18 scenes

EO Data Delivery

Data access (list all missions and issues if any).

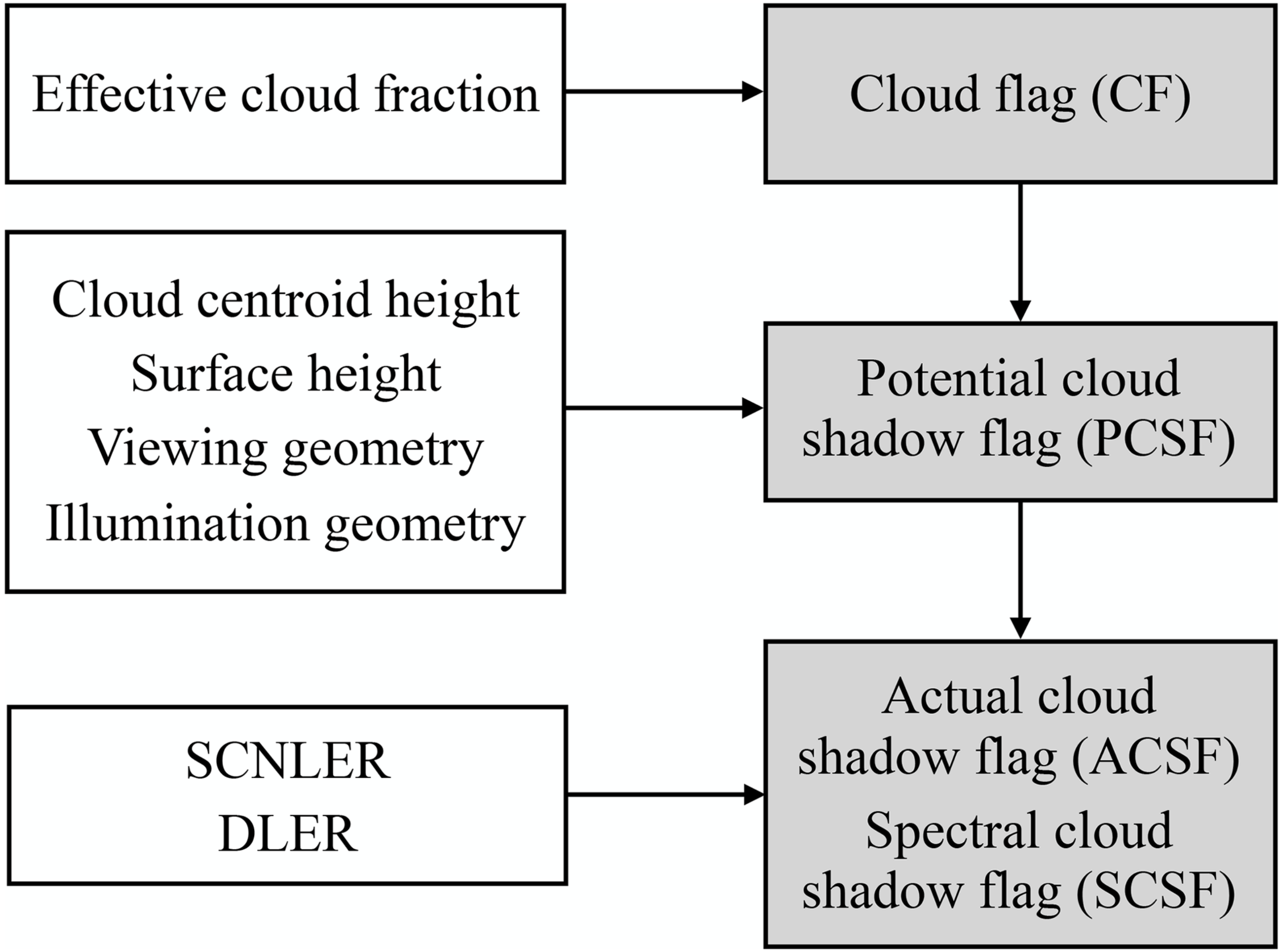
ESA Missions	No. Scenes
1. Sentinel-5P L1B, L2 (NO2, AAI, clouds)	8 months full orbits data
2.	
3.	
4.	
5.	
6.	
Total:	
Issues: No	

ESA Third Party Missions	No. Scenes
1. Landsat-8	18
2.	
3.	
4.	
5.	
6.	
Total:	
Issues: No	

Chinese EO data	No. Scenes
1. GF-2	30
2.	
3.	
4.	
5.	
6.	
Total:	
Issues: No	

Results: cloud shadow detection: methodology

DARCLOS: a cloud shadow detection algorithm for TROPOMI (Trees et al., 2022 AMT)



Features:

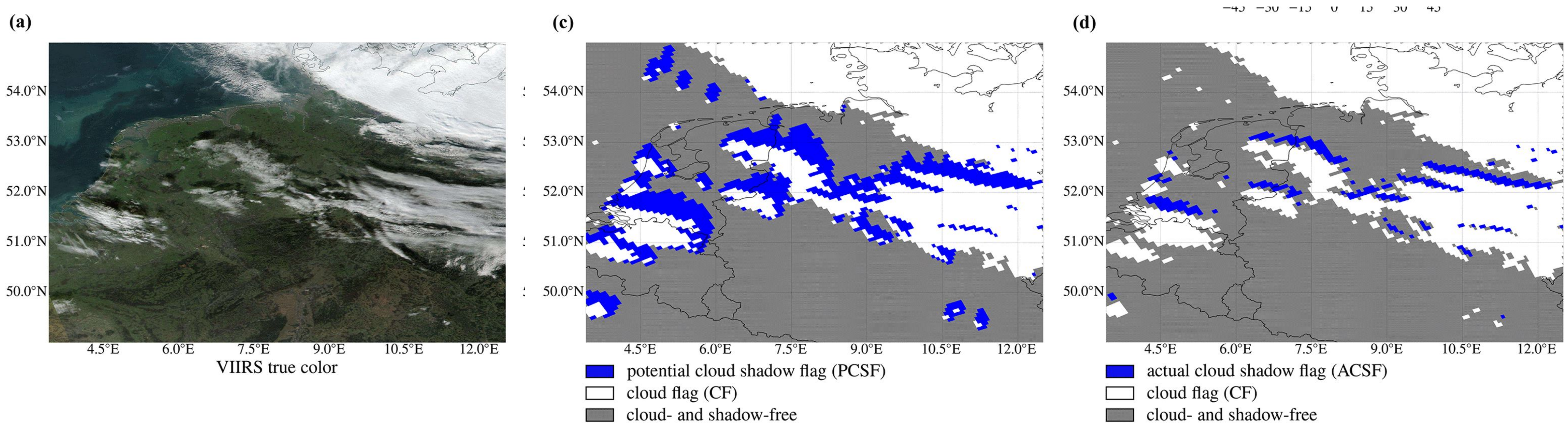
Use TROPOMI existing L2 products

Use reflectance spectra

Three different shadow flags

Suitable for operational processing

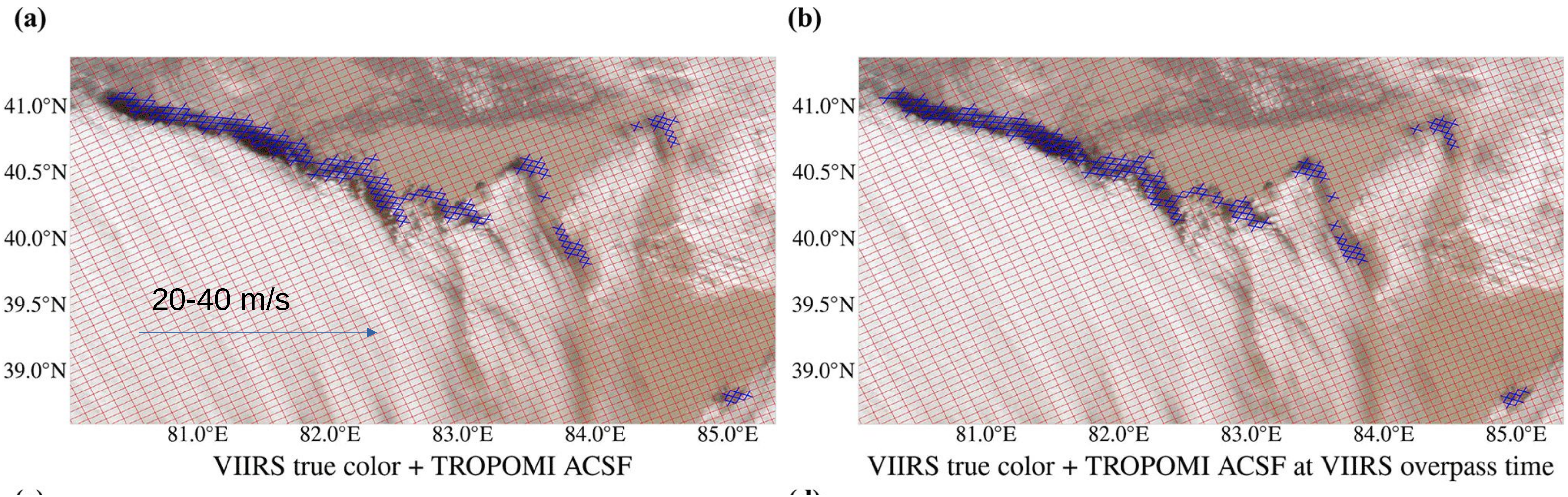
Results: cloud shadow detection: example in Europe



Trees et al., 2022

- Processed 8 months of TROPOMI data for cloud shadow flags
- Cloud shadow flags have been used to reprocess the TROPOMI DLER product

Results: cloud shadow detection: example in China



Trees et al., 2022

- Take into account cloud motion when comparing cloud shadows between TROPOMI and VIIRS (VIIRS measures 4.3 min earlier than TROPOMI)
- Cloud displacement in 5 minutes is about 6-9 km, 1-3 pixels shift of cloud shadows.

Results: cloud shadow detection: validation results

- Validation results

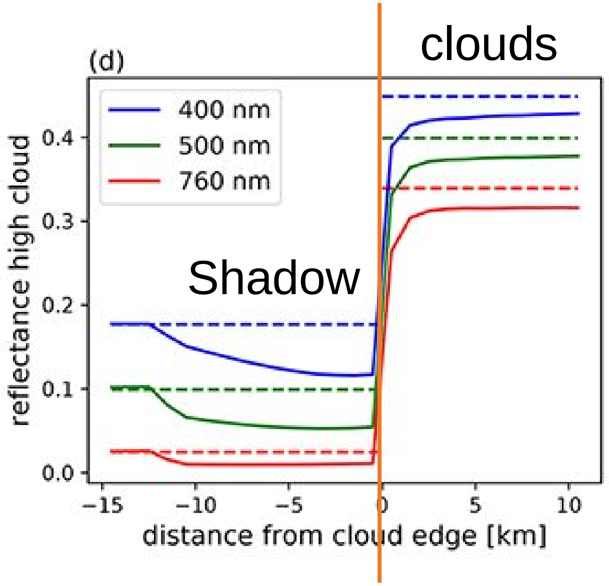
Example	Coordinates	Date	Orbit	Omission error PCSF	Commission error PCSF	Omission error ACSF	Commission error ACSF	F_1 score ACSF
Southern Chile and Argentina	53.528–49.626° S 73.047–62.418° W	3 August 2019	9355	**0.05**	0.48	0.10	0.01	**0.94**
The Netherlands and Germany	49.004–54.991° N 3.4119–12.5062° E	18 November 2018	5690	**0.06**	0.52	0.16	0.04	**0.90**
Sahara, North Africa	24.802–27.400° N 3.506–12.011° E	18 January 2021	16927	**0.14**	0.70	0.18	0.13	**0.84**
Taklamakan Desert, China	36.500–43.000° N 76.000–88.000° E	22 December 2019	11348	**0.02**	0.77	0.08	0.02	**0.95**
The Netherlands, Belgium, and Luxembourg	48.995–55.004° N 2.000–8.000° E	9 October 2018	5123	**0.05**	0.61	0.20	0.07	**0.86**
Taklamakan Desert, China	37.006–42.005° N 80.005–88.007° E	21 December 2020	16527	**0.10**	0.51	0.13	0.11	**0.88**

Results: impacts of shadows on NO2 retrievals: principle

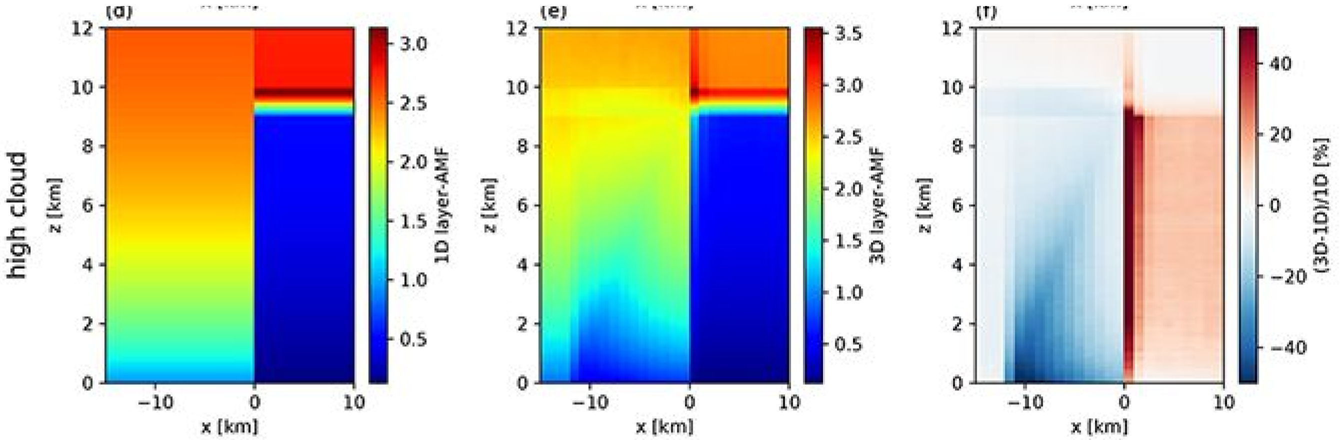
- Steps to retrieve NO2 VCD
  1) fit slant columns (Ns)
  2) separate Tropospheric and Stratospheric columns (Ns_trop)
  3) calculate airmass factors (AMF)
  4) calculate vertical column Ns_trop/AMF_trop

AMF is used to correct light path and is typically calculated using 1D RTM.

- Figures taken from Emde et al., 2022 AMT

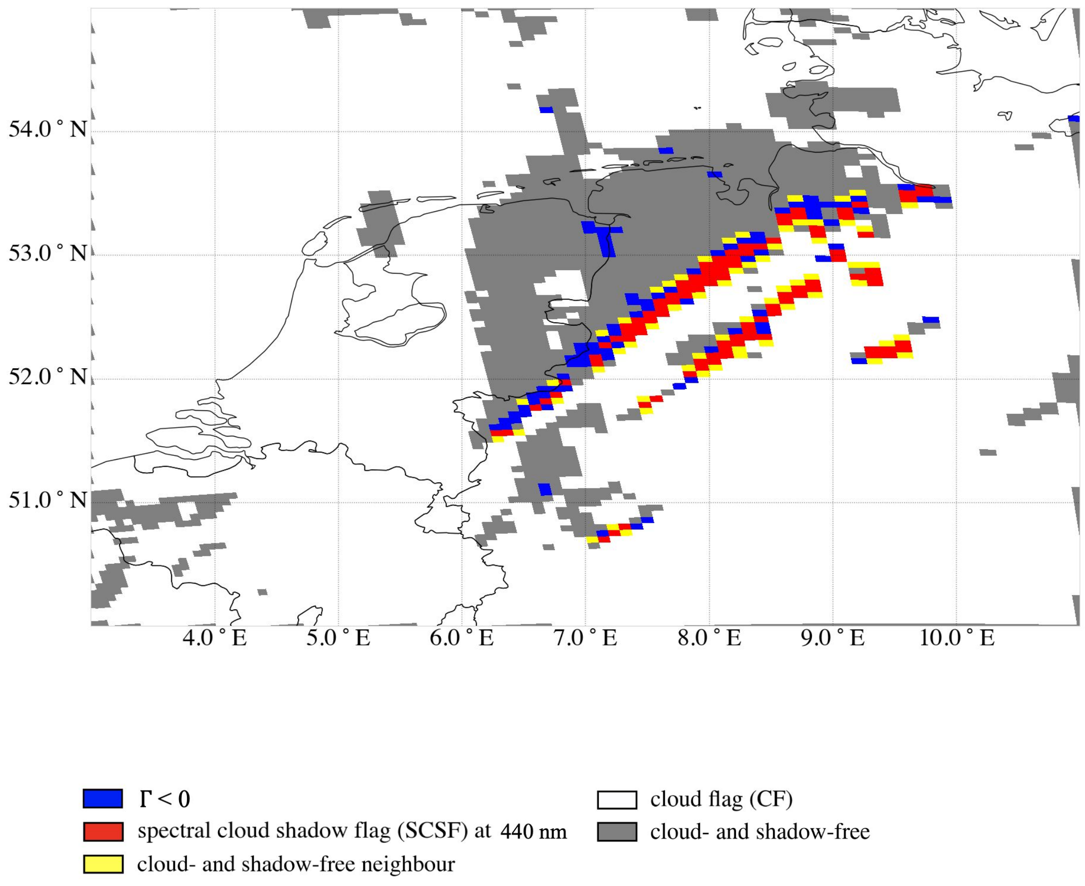


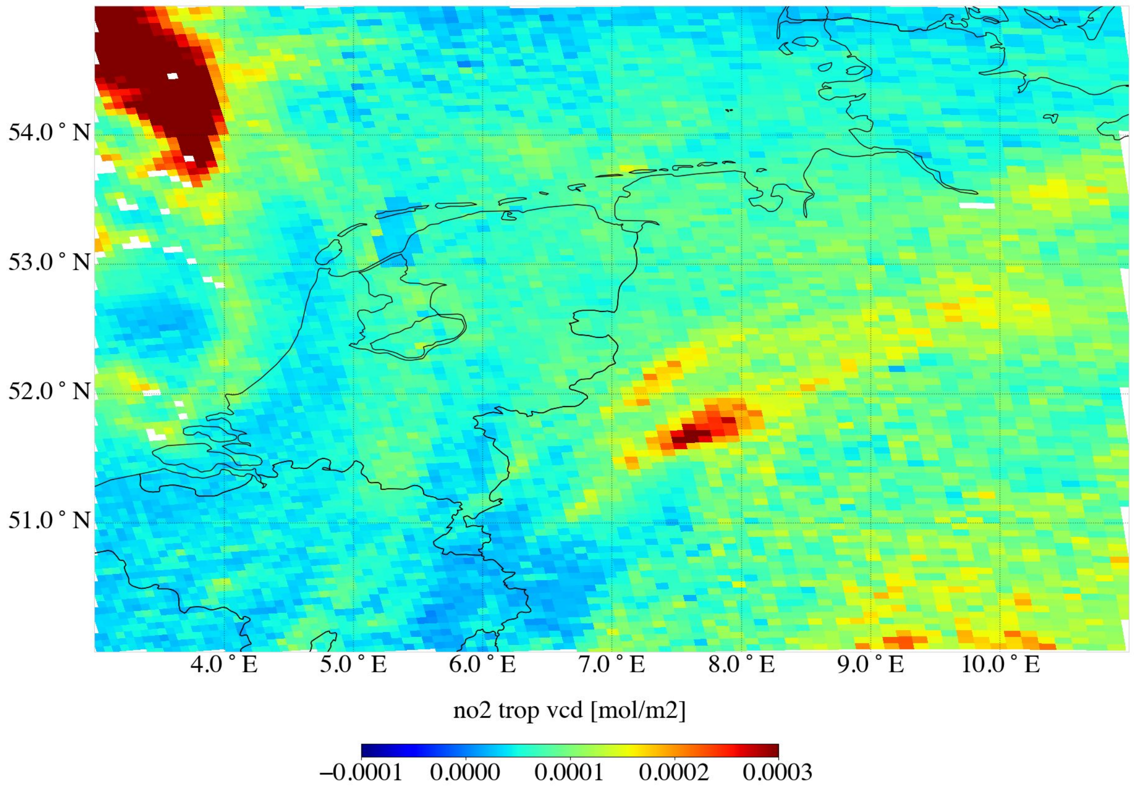
Solid line 3D, dashed line 1D



Results: impacts of shadows on NO2 retrievals (1)

Europe 3 November 2020

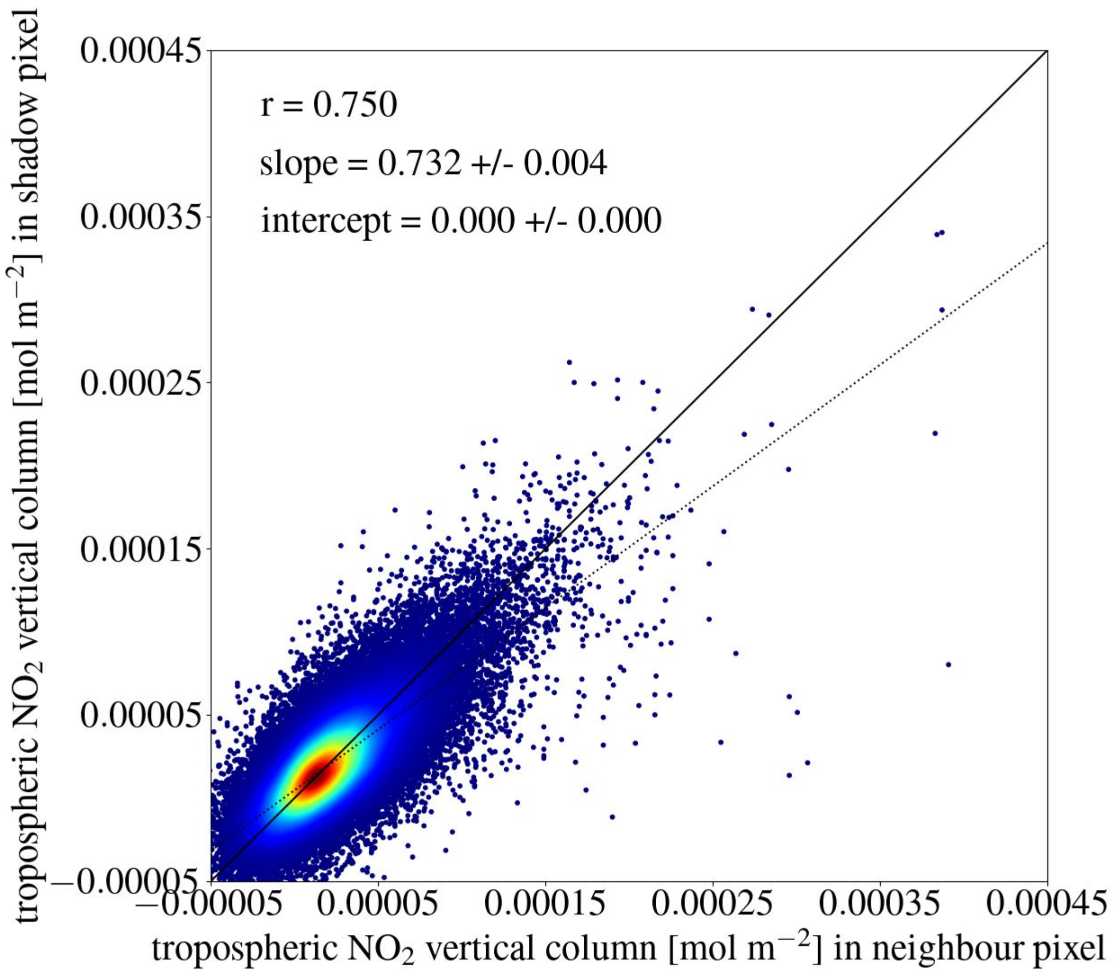




Trees et al., 2022, in preparation

Results: impacts of shadows on NO2 retrievals (2)

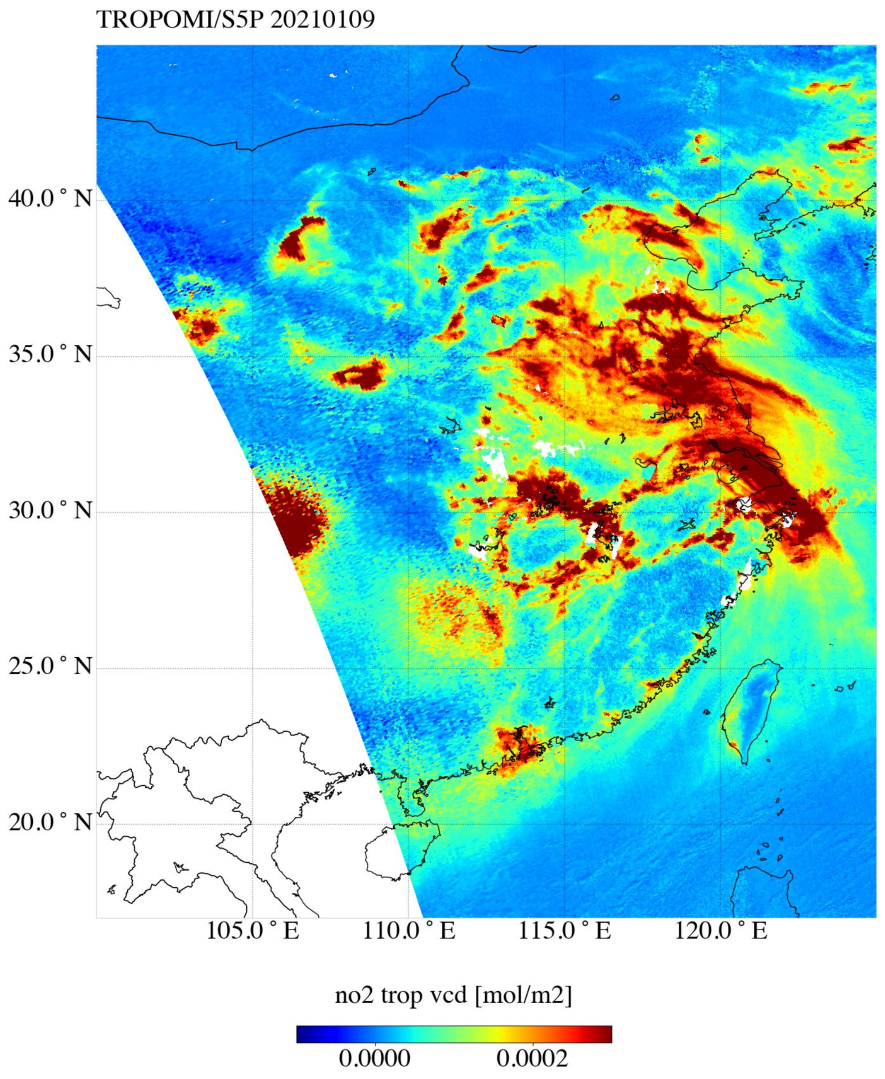
Europe 2020-11 to 2021-06

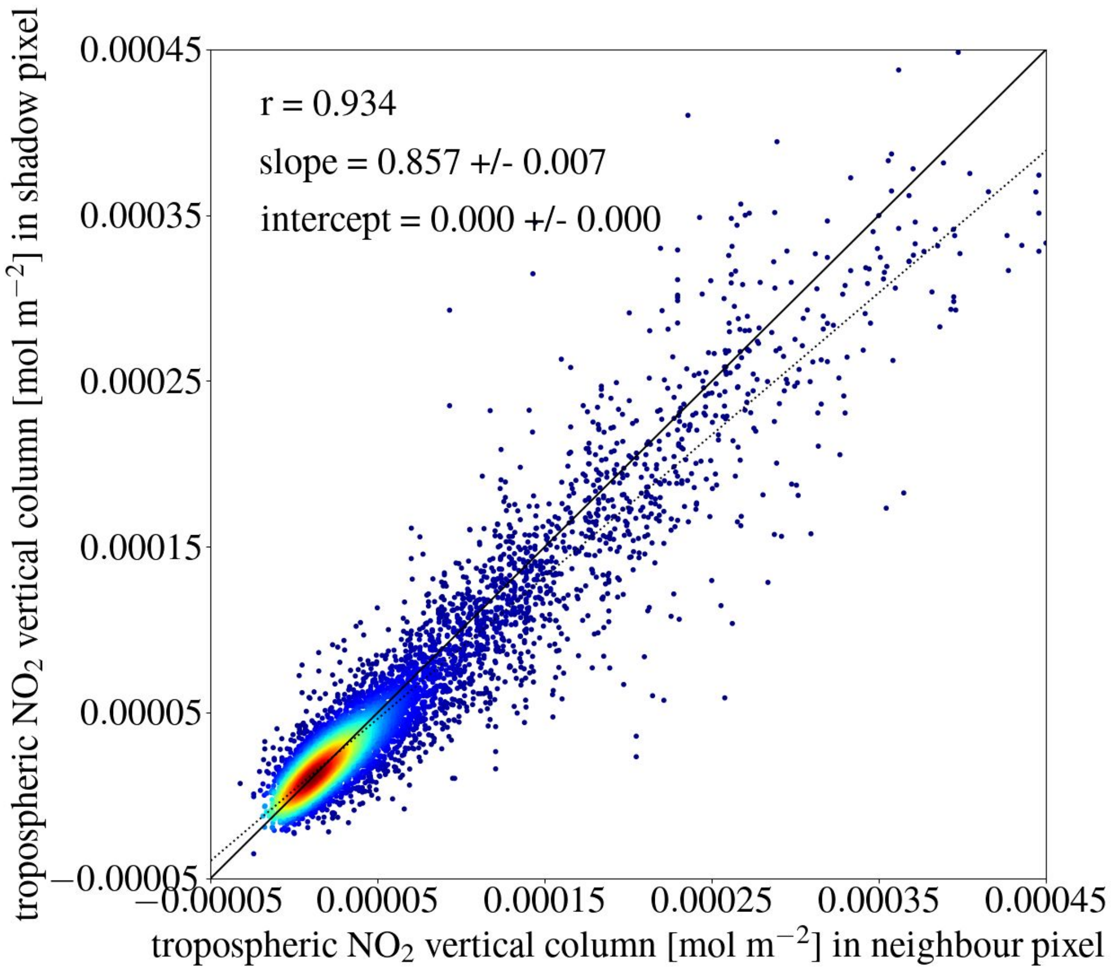


Almost no differences between NO_2 in shadow and in neighbour pixel

Results: impacts of shadows on NO2 retrievals (3)

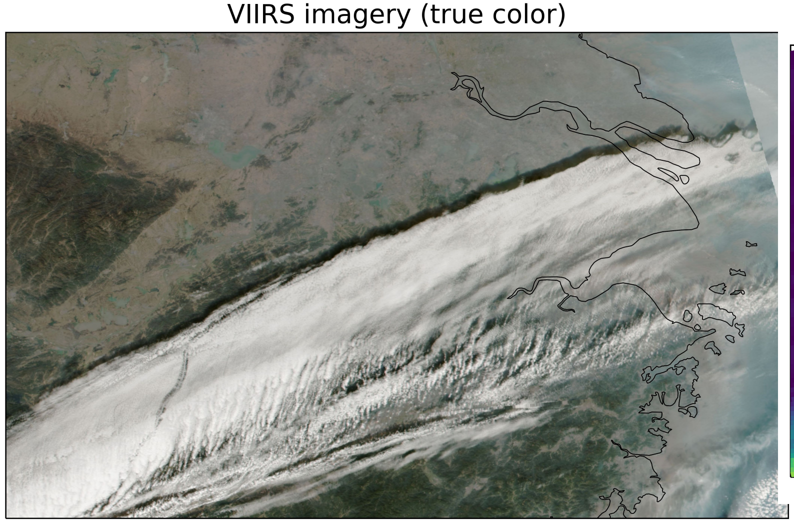
- Eastern Asia 2021-01 – 2021-06

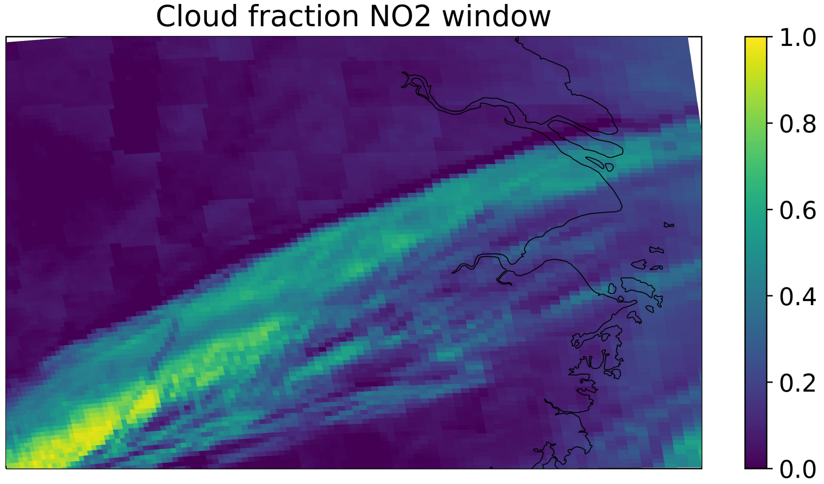


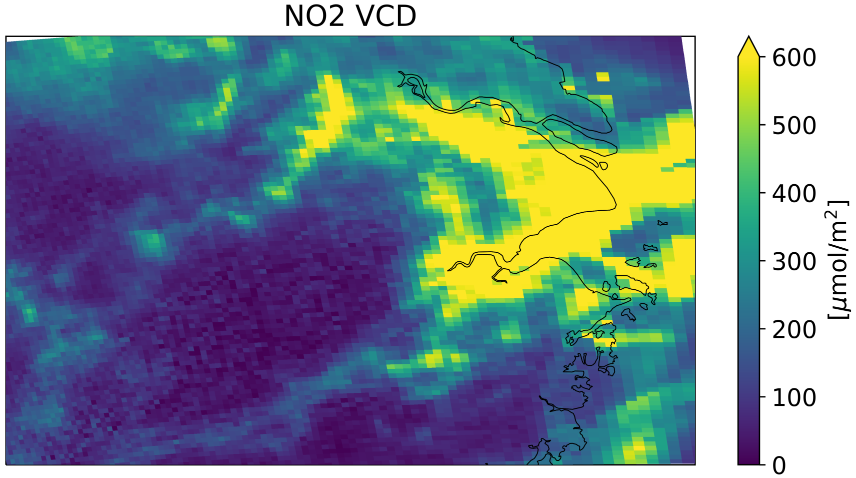


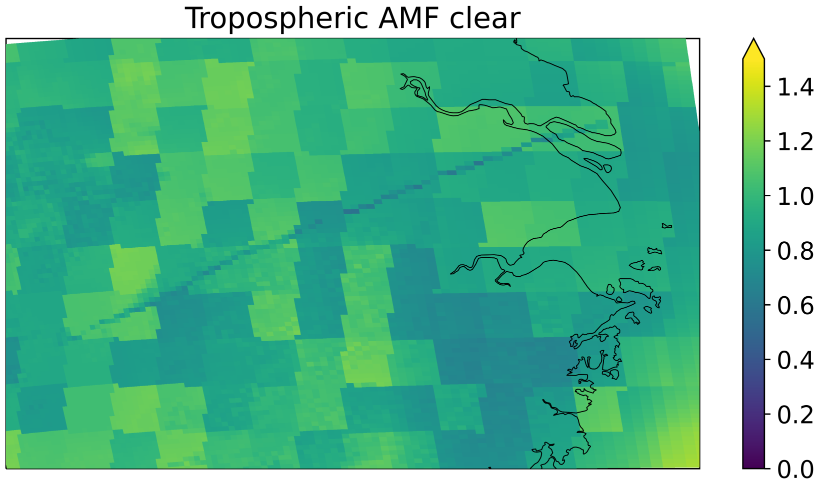
Results: impacts of shadows on NO2 retrievals (4)

- 2019-12-04 VIIRS imagery and TROPOMI cloud, NO2 product, close to Shanghai









Spatial resolution 5.6 km x 3.6 km
Shadow structure is not visible in NO_2 VCD image

AMFs are adjusted in cloud shadows

See poster Leune et al.

Results: AOD retrievals using shadows: principle

- Reflectance for a shadow pixel

$$I_s = I_{path} + \frac{t_{dif}(\mu_0)\,T(\mu_v)\,A}{(1-AS)}$$

- Reflectance for a bright pixel

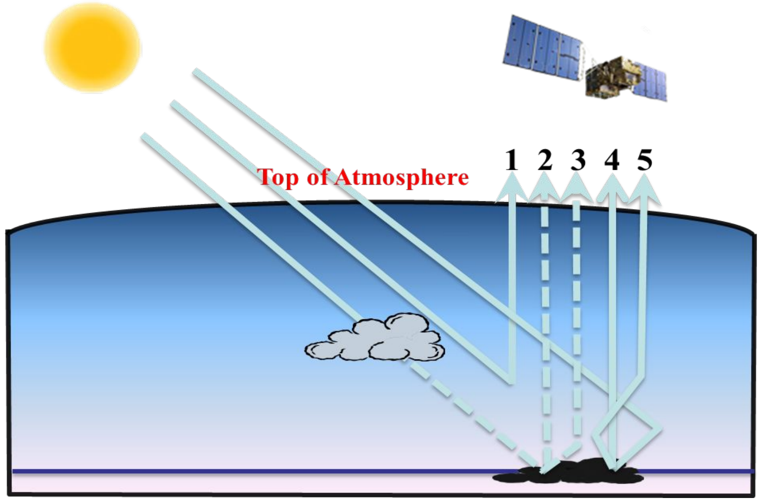
$$I_b = I_{path} + \frac{\left(e^{-\tau/\mu_0} + t_{dif}(\mu_0)\right)T(\mu_v)\,A}{(1-AS)}$$

- Assume same surface albedo at the two pixels

$$\frac{I_b - I_{path}}{I_s - I_{path}} = \frac{e^{-\tau/\mu_0} + t_{dif}(\mu_0)}{t_{dif}(\mu_0)}$$

- Minimize the difference to get AOD

$$\varepsilon = \left| \frac{I_b - I_{path}}{I_s - I_{path}} - \frac{e^{-(\tau_r+\tau_a)/\mu_0} + T_{dif}(\mu_o)}{T_{dif}(\mu_o)} \right|$$



Duan , 2001

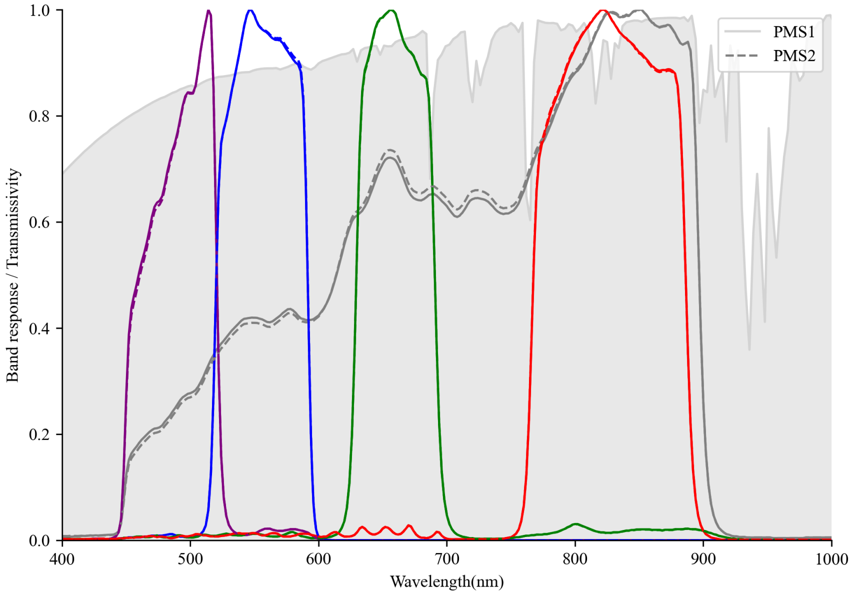
1 atmospheric path

2,4 surface reflection

3,5 inter-action between surface and atmosphere

Results: aerosol retrievals using shadows: GF-2 instrument

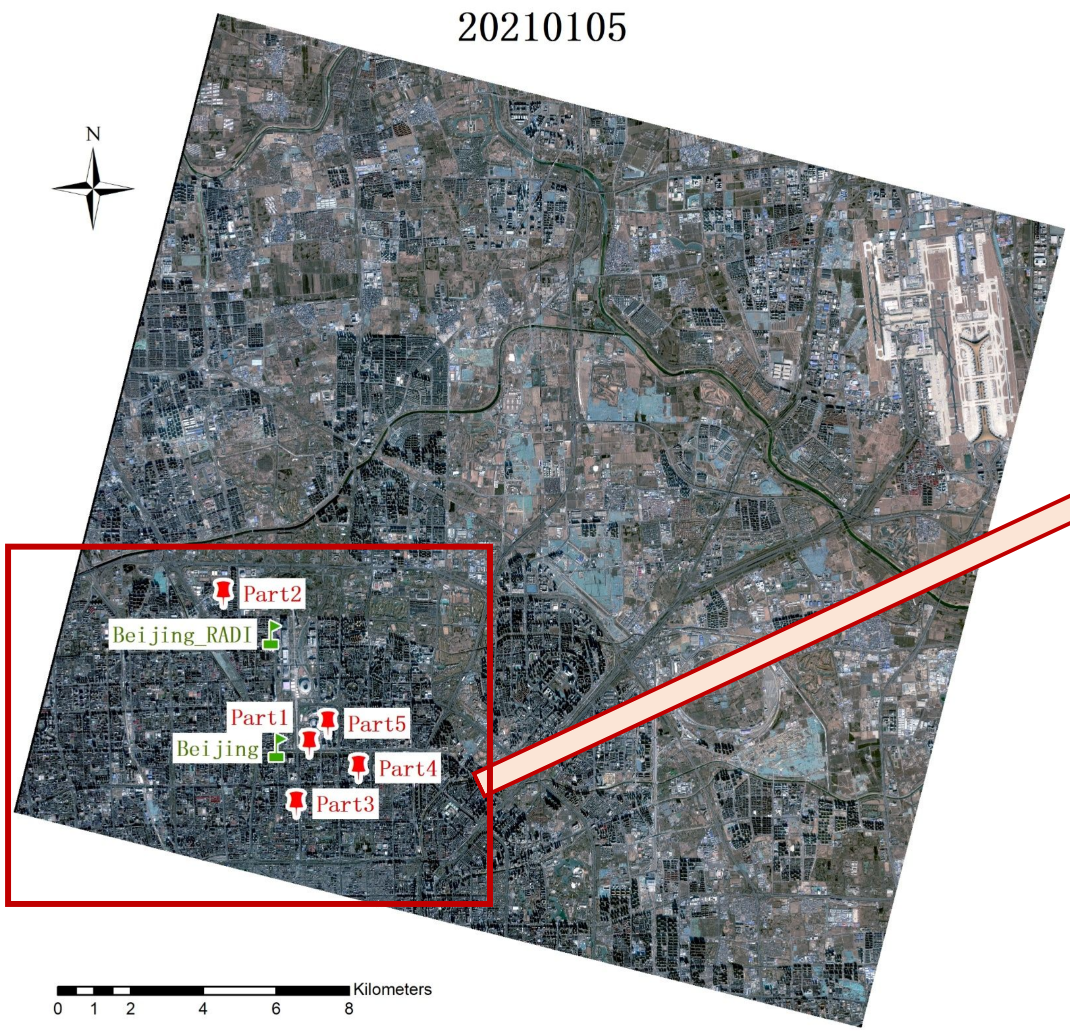
- GF-2 launched in August 2014

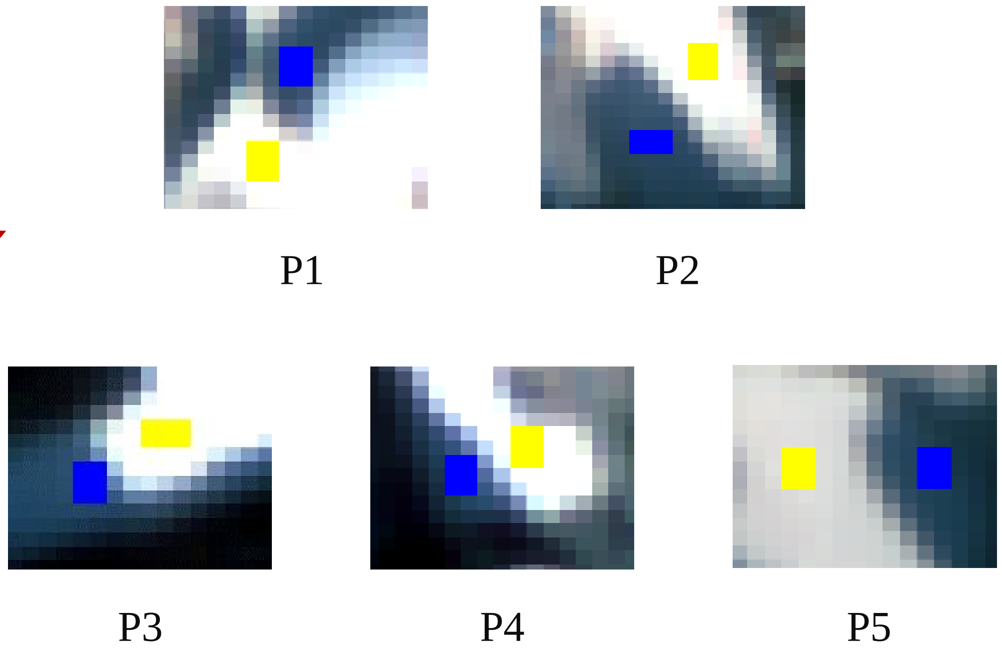


Sensor	Band	Band range (μm)	Spatial resolution(m)	SNR(dB)	Image width (km)	Period （day）
PMS 1/2	1	0.45～0.90	1	23-43	45	5
	2	0.45～0.52	4	25-43		
	3	0.52～0.59				
	4	0.63～0.69				
	5	0.77～0.89				

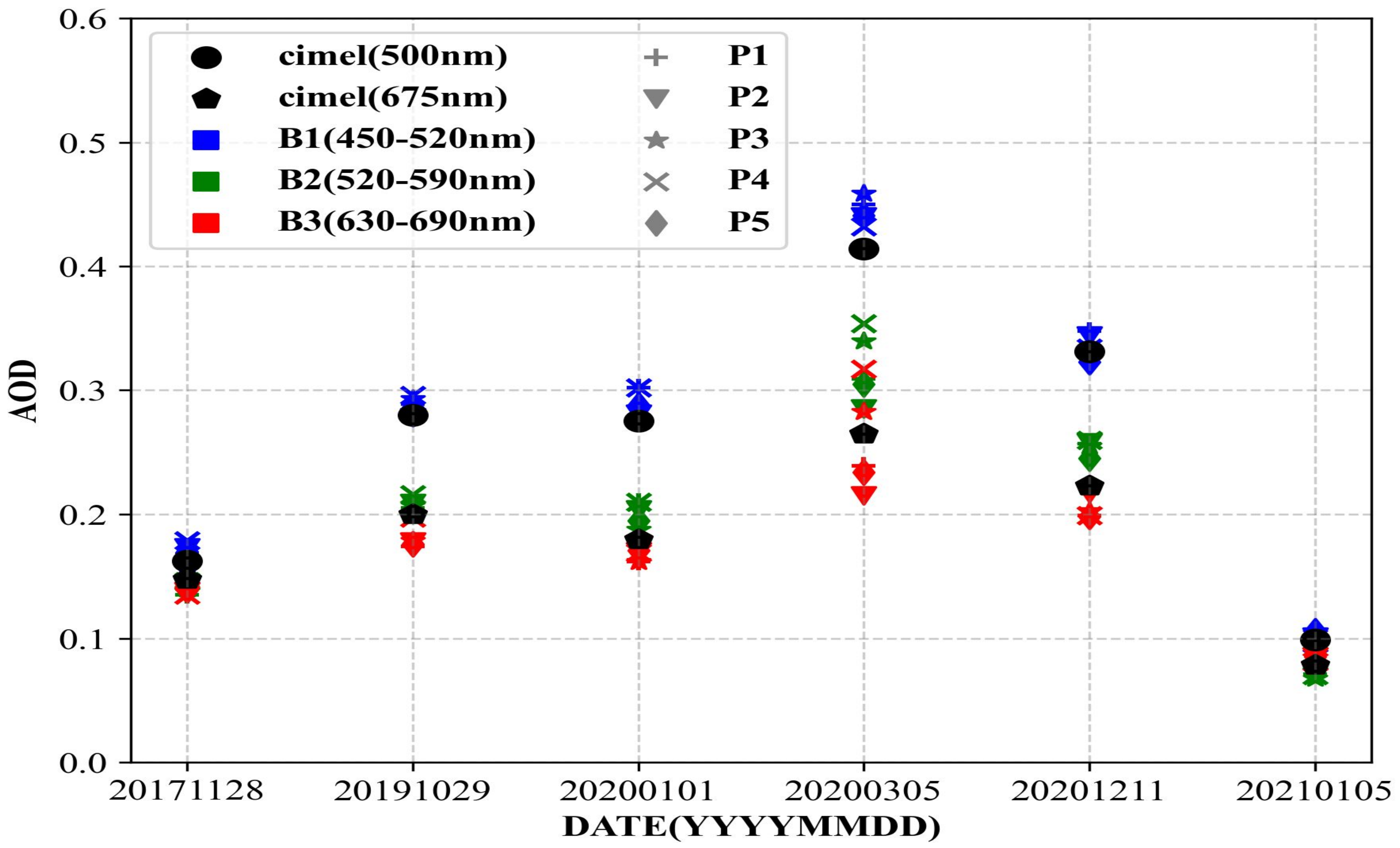
Results: aerosol retrievals using shadows: GF-2 scenes in Beijing

- GF-2 Beijing





Results: aerosol retrievals using shadows: GF-2 AOD

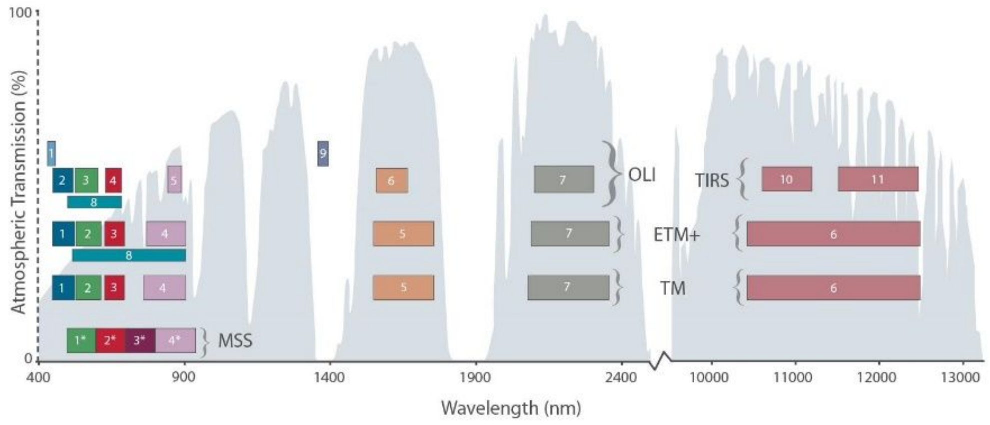


Good agreement with Cimel (Aeronet) AOD

Qiao et al., 2022, manuscript in preparation

Results: aerosol retrievals using cloud shadows: Landsat-8 data

Landsat 8, launch on 11 Feb., 2013

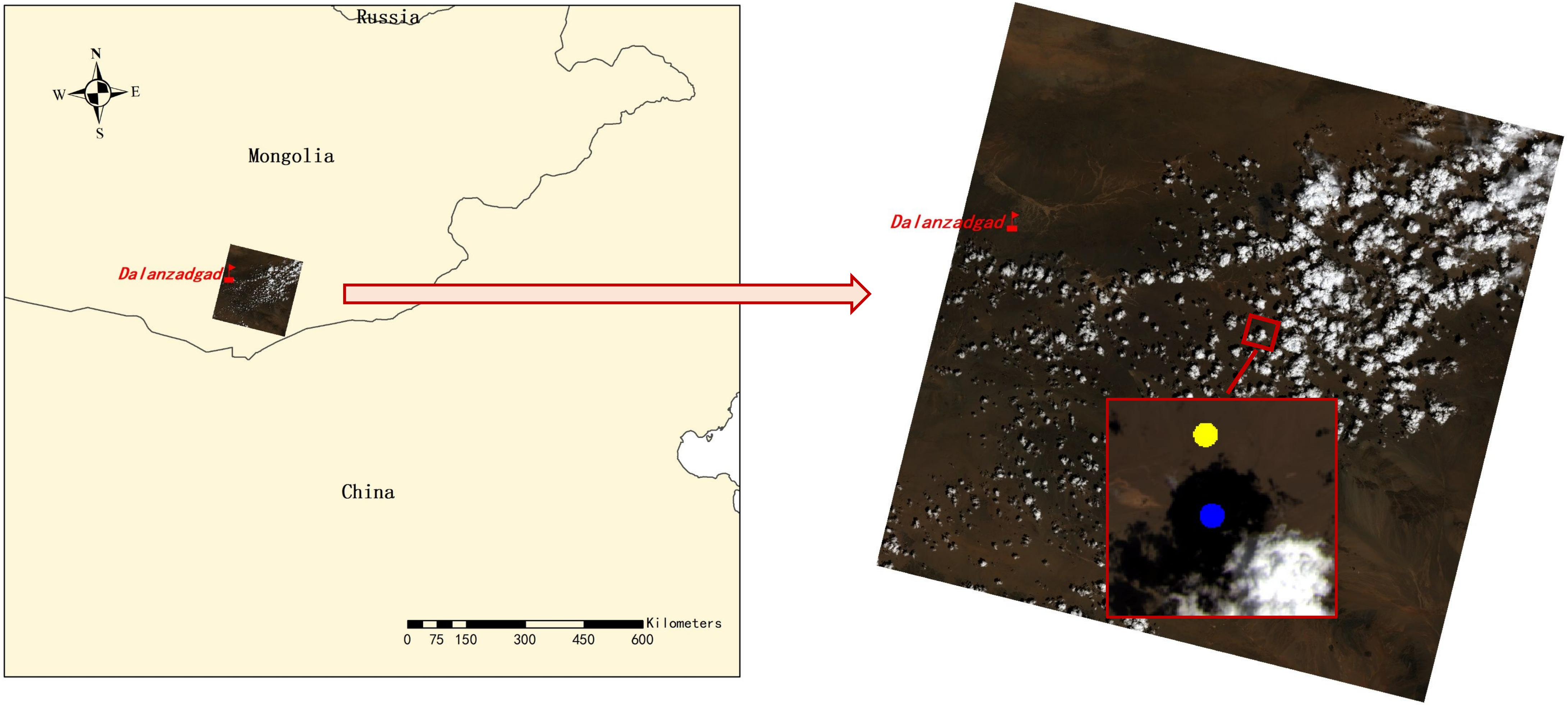


* MSS bands 1–4 were known as bands 4–7, respectively, on Landsats 1–3

Band	Wavelength (um)	Spatial Resolution (m)
B01	0.43 ~ 0.45	30
B02	0.45 ~ 0.51	30
B03	0.53 ~ 0.59	30
B04	0.64 ~ 0.67	30
B05	0.85 ~ 0.88	30
B06	1.57 ~ 1.65	30
B07	2.11 ~ 2.29	30
B08	0.50 ~ 0.68	15
B09	1.36 ~ 1.38	30
B10	10.60 ~ 11.19	100
B11	11.50 ~ 12.51	100

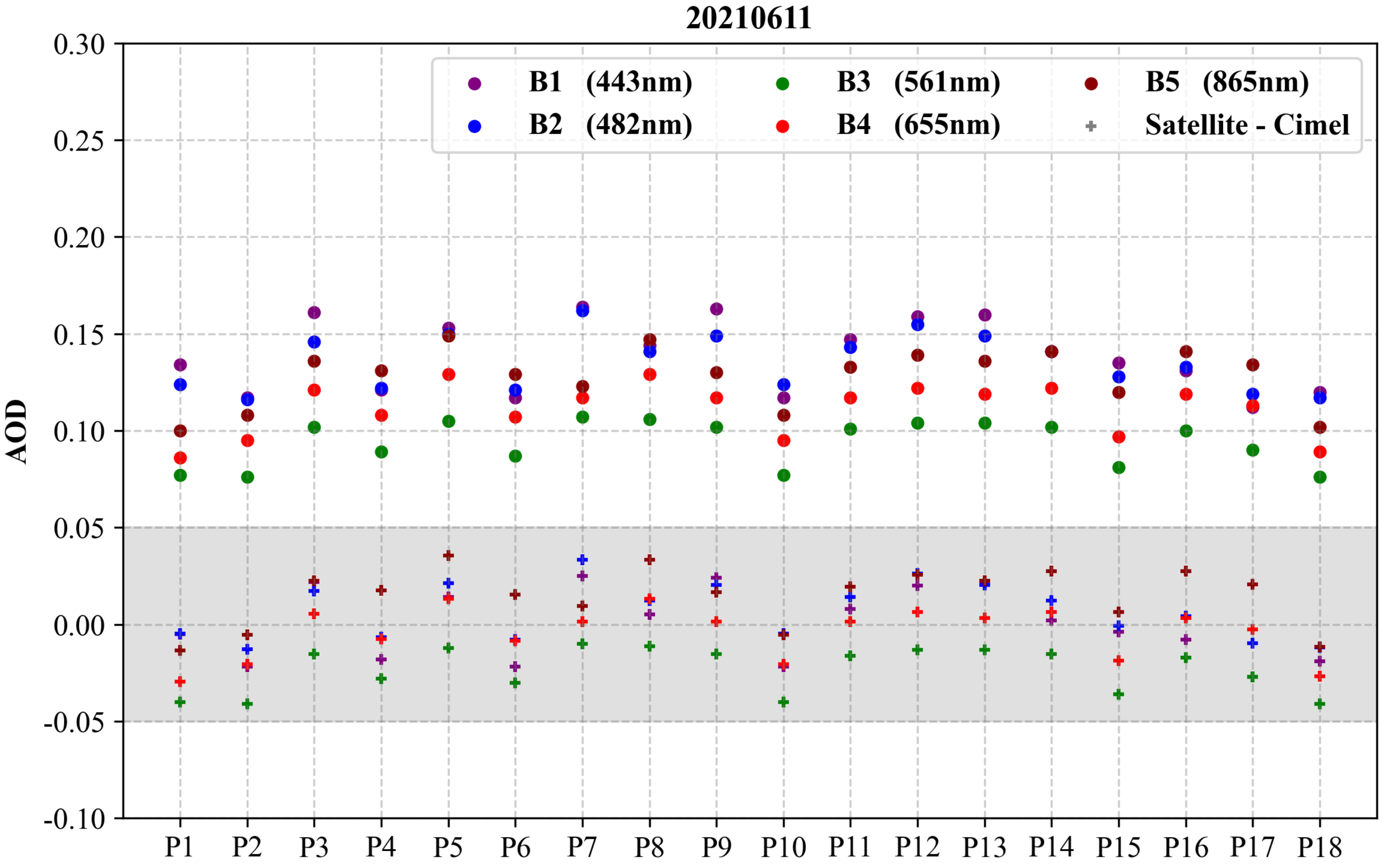
Operational Land Imager (OLI) B01 – B09
Thermal Infrared Sensor (TIRS) B10 - B11

Results: aerosol retrievals using cloud shadows: Landsat-8 image



Results: aerosol retrievals using cloud shadows: Landsat-8 AOD

- Landsat-8



- Selected 18 cloud shadow pixels, retrieved AOD using Landsat8 Band 1~5.
- Good agreement with AERONET AOD.

Qiao et al., 2022, manuscript in preparation

Planning for next two years

- Publish the AOD retrieval paper using GF-2 and Landsat-8 scenes
- Apply automatic shadow detection algorithm on GF-2 and Landsat-8
- Apply AOD retrieval algorithm to TROPOMI

- Publish the analysis of cloud shadows in S5P NO2 products
- Simulate the impacts of shadows on NO_2 and Aerosols using 3D models.
- Improve NO_2 retrievals at high spatial resolution

European Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Benjamin Leune	KNMI	Observing 3D Cloud Shadow Effects in the S5P NO2 product	Analyze the cloud shadow effects on S5P NO2 product. Improve the NO2 products for high spatial resolution satellite measurements
Victor Trees	KNMI/TU-Delft		Develop cloud shadow detection algorithm, analyze cloud shadow effects on NO2 products, simulate impact of cloud shadows on aerosol and NO2 products.

Chinese Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Congcong Qiao	IAP		Aerosol optical thickness retrievals from GF-2 and Landsat-8