NOAA
National Satellite and Information Service

Center for Satellite Applications and Research

Development of Near Real Time TEMPO Aerosol Index/Aerosol Detection Product

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Objective

Credit: Pete Laing/BC Wildfire Service

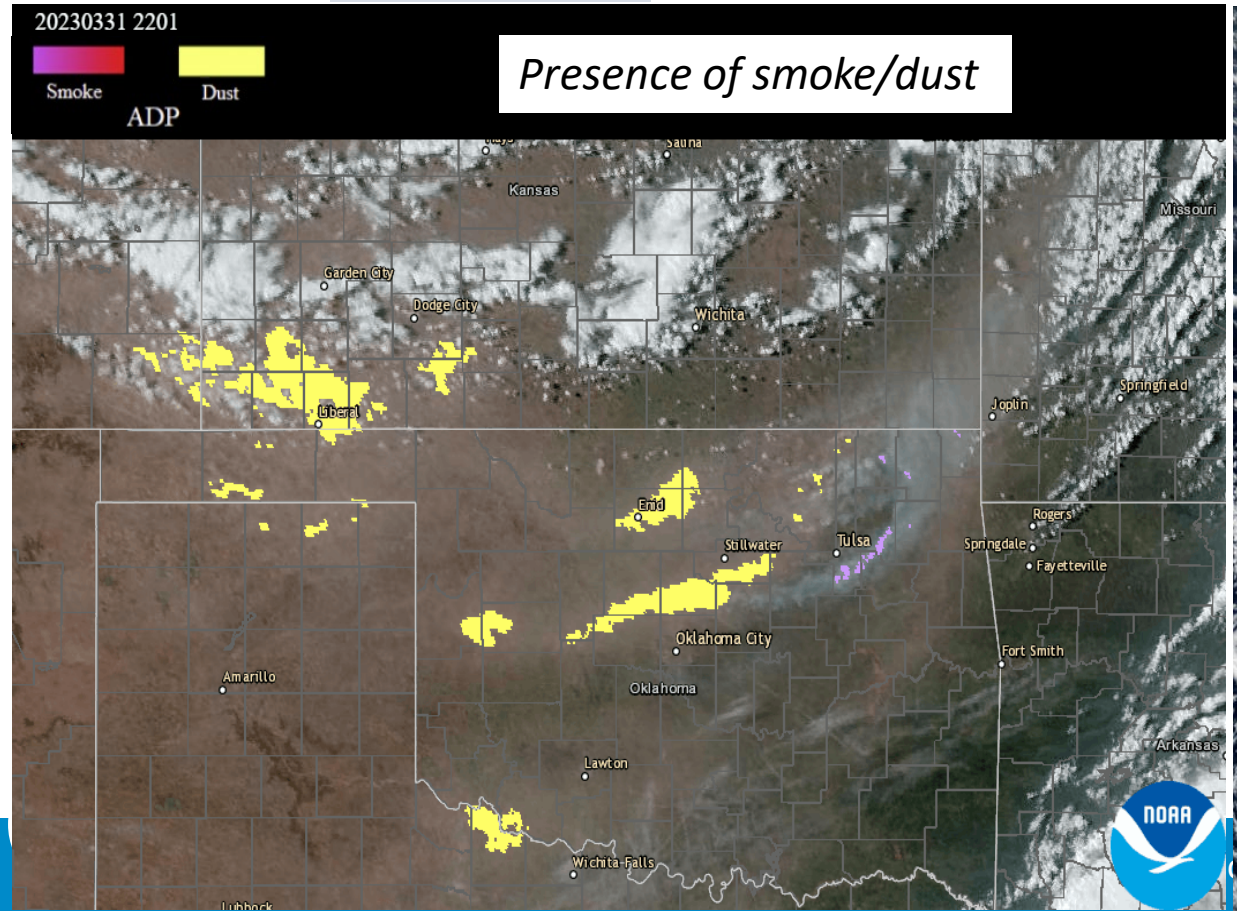
Credit: Roxy Lopez, CC BY-SA 3.0

- Wildfire smoke and blowing dust are becoming more frequent and dominant factors for air pollution.
- The ability to monitor smoke/dust outbreaks from space with both high temporal and spatial resolution provides unique tools for operational and research applications.
- NOAA's operational Enterprise Aerosol Detection Product (ADP), also called smoke/dust mask, provides smoke/dust flags at the pixel level from:
  - VIIRS: S-NPP, NOAA-20 and NOAA-21 (11 yrs. record)
  - ABI: GOES-16, -17 and -18 (~6 yrs. record)
- TEMPO's UV-VIS spectrometer, currently in orbit, has better wavelengths for characterizing absorbing aerosols.
- Hourly smoke/dust mask can be generated by synergistically combining TEMPO with ABI observations & applying NOAA's Enterprise ADP algorithm.

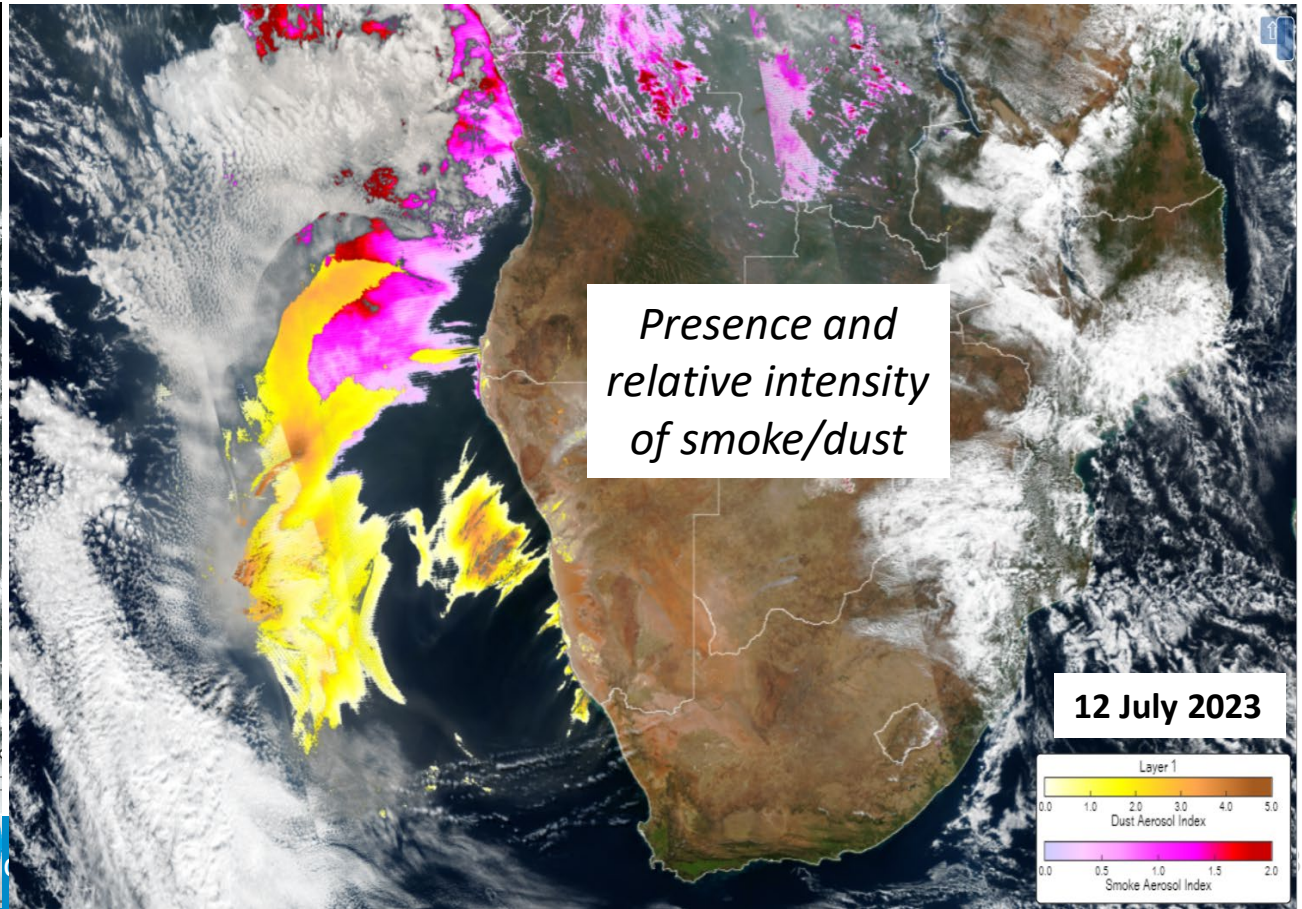
NOAA Enterprise Aerosol Detection Algorithm

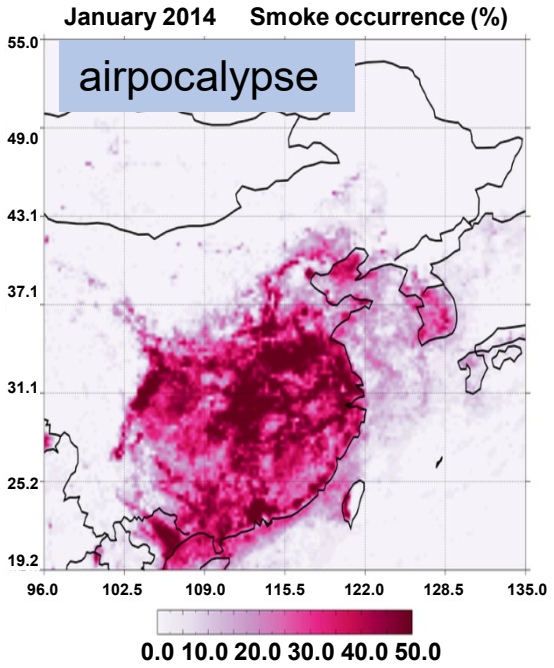
- One algorithm working on observations from multiple sensors including both GEO and LEO platforms.
- Uniform input and output structure.

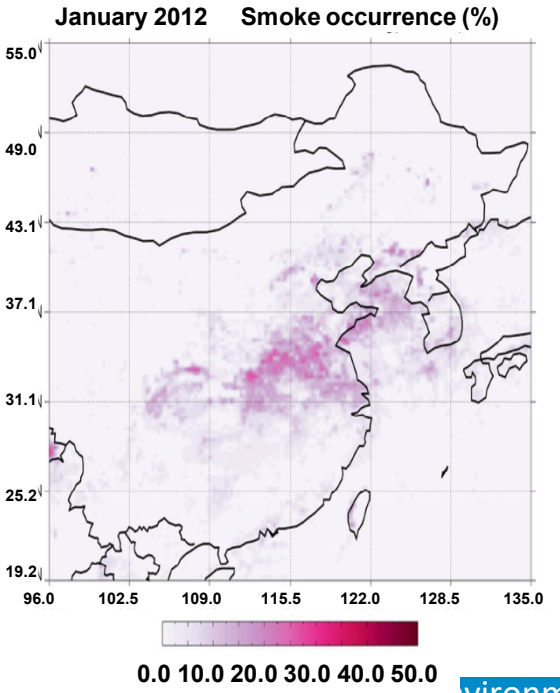
IR-Visible Path **GOES-16/ABI**

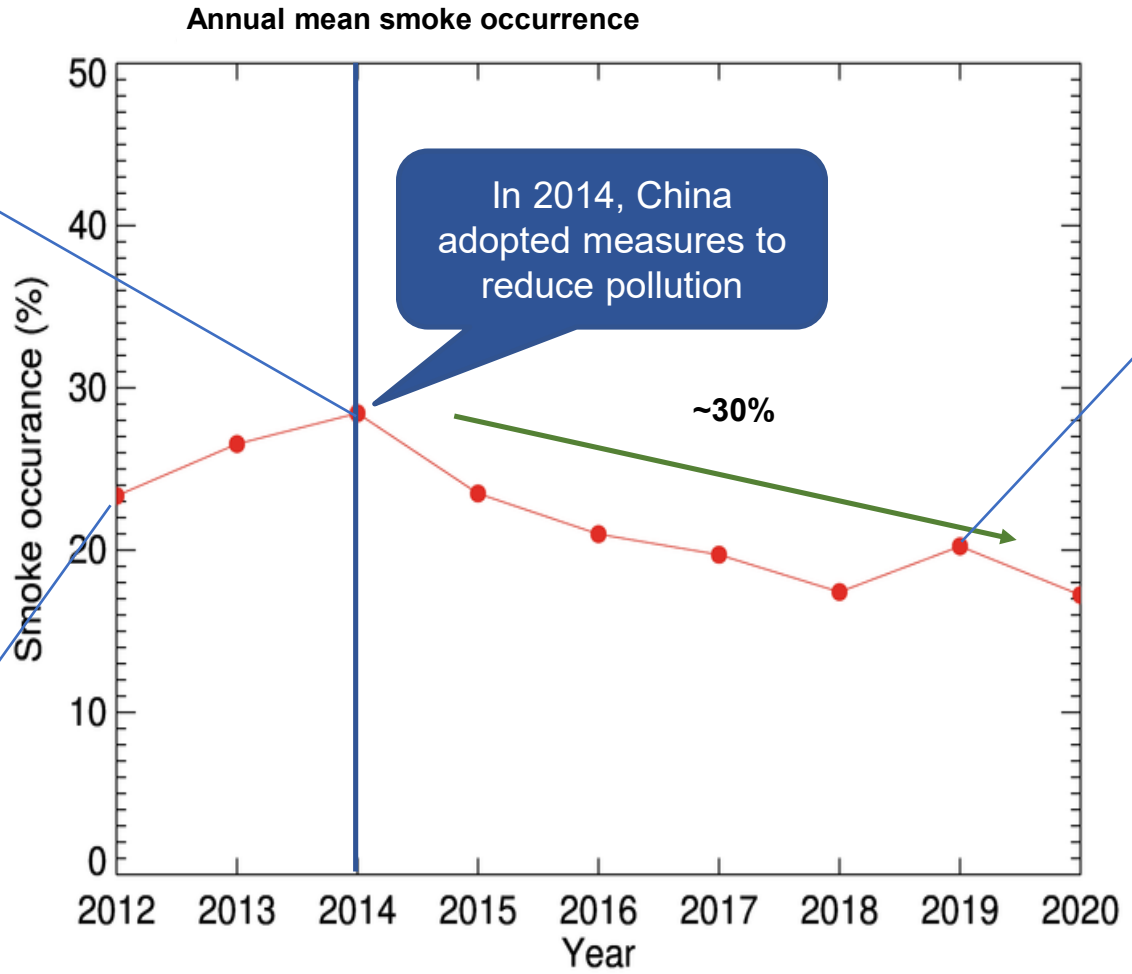


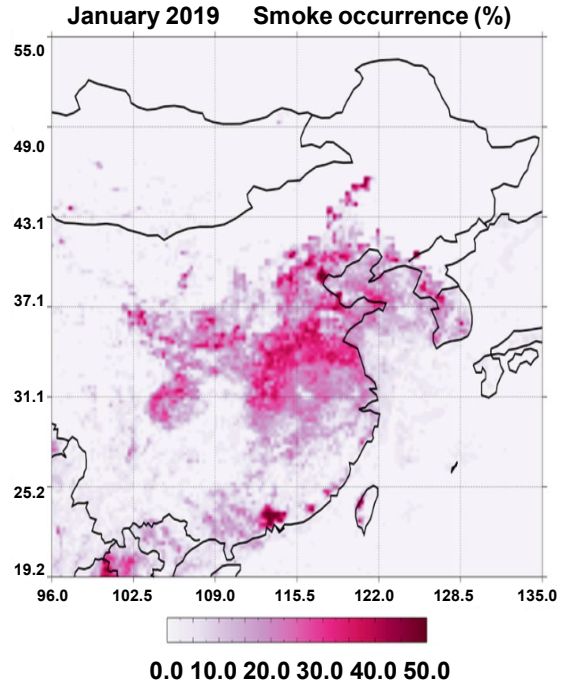
Deep-Blue Path **SNPP/VIIRS**











Greenstone, M., He, G., Li, S., and Zou, E.Y. 2021. "China's War on Pollution: Evidence from the First Five Years," Review of Environmental Economics and Policy 15(2): 281-299.

NOAA TEMPO/ABI Hybrid Aerosol Detection Algorithm

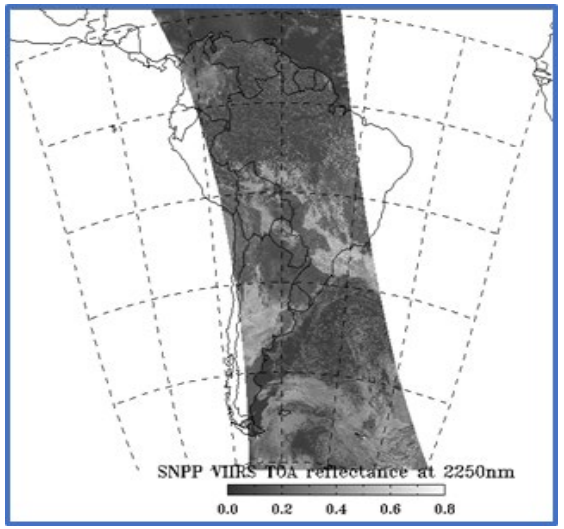
- Hybrid approach taking into account the synergy between an Imager and a spectrometer
  - Temporally coincident
  - Spectrally complementary
  - Spatially overlapping
- Enterprise approach lets the algorithm work on any given imager and spectrometer
  - Imagers: ABI, FCI, AHI, AMI, VIIRS, METImage
  - Spectrometers: TEMPO, Sentinel-4, GEMS, TROPOMI, UVN

TEMPO+ABI

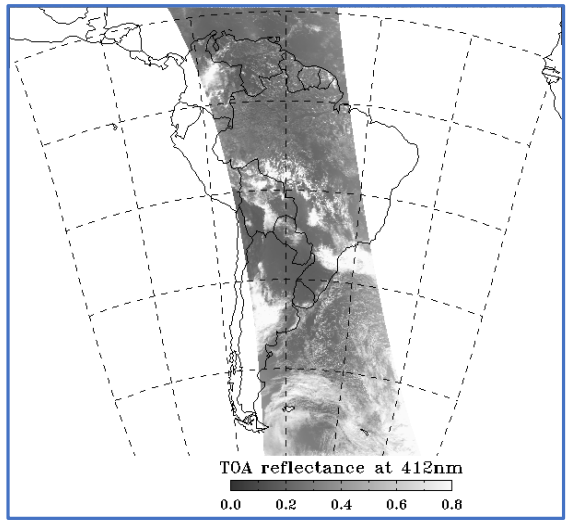
	ABI	TEMPO
Temporal Frequency	10 minutes	Hourly
Spectral Coverage	Vis-IR, 16 bands	UV-VIS 290-490 nm 540-740 nm
Spatial Resolution	0.5/1.0/2.0 km	2.0x4.7 km

TROPOMI+VIIRS

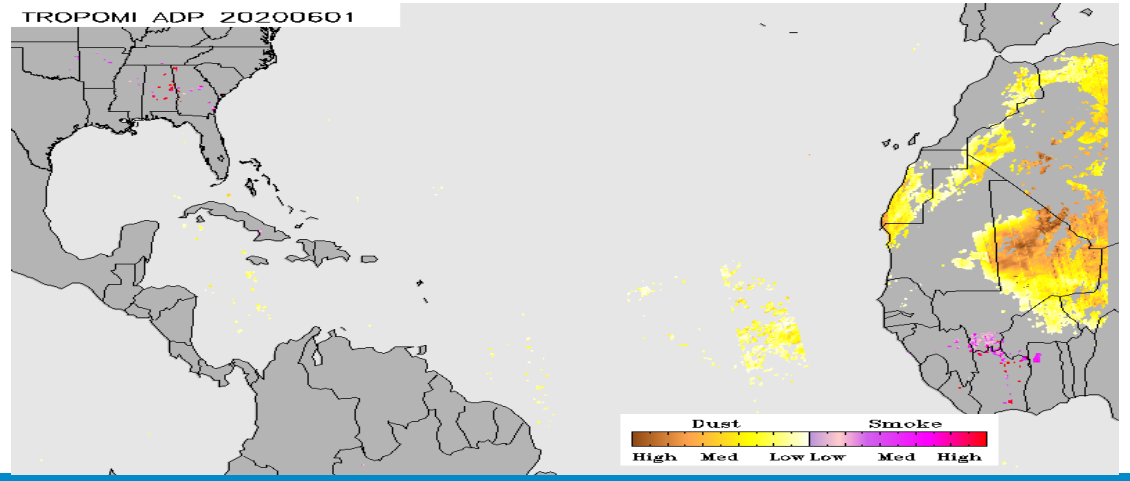
SNPP VIIRS (2250 nm)



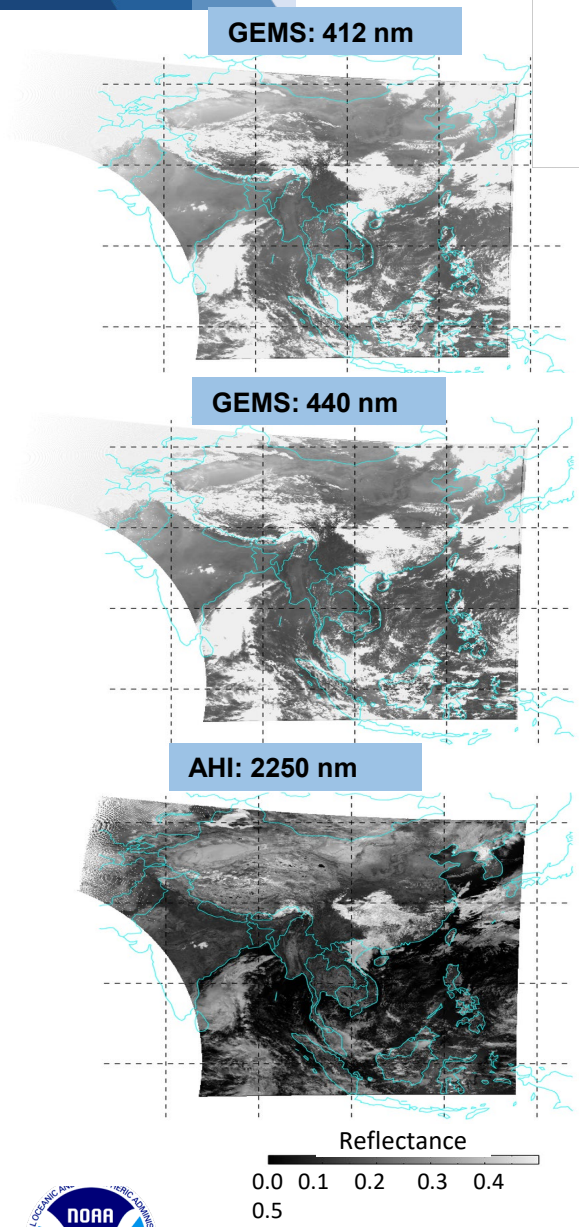
TROPOMI (412 nm)



Trans-Atlantic 'Godzilla' Dust in 2020



TEMPO/ABI Hybrid ADP Algorithm Tested Using GEMS and AHI Data

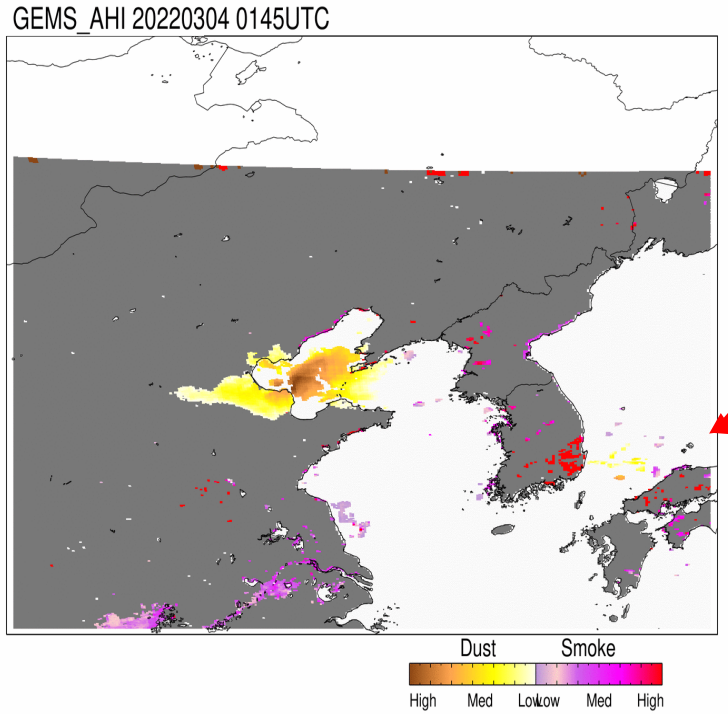


Absorbing Aerosol Index

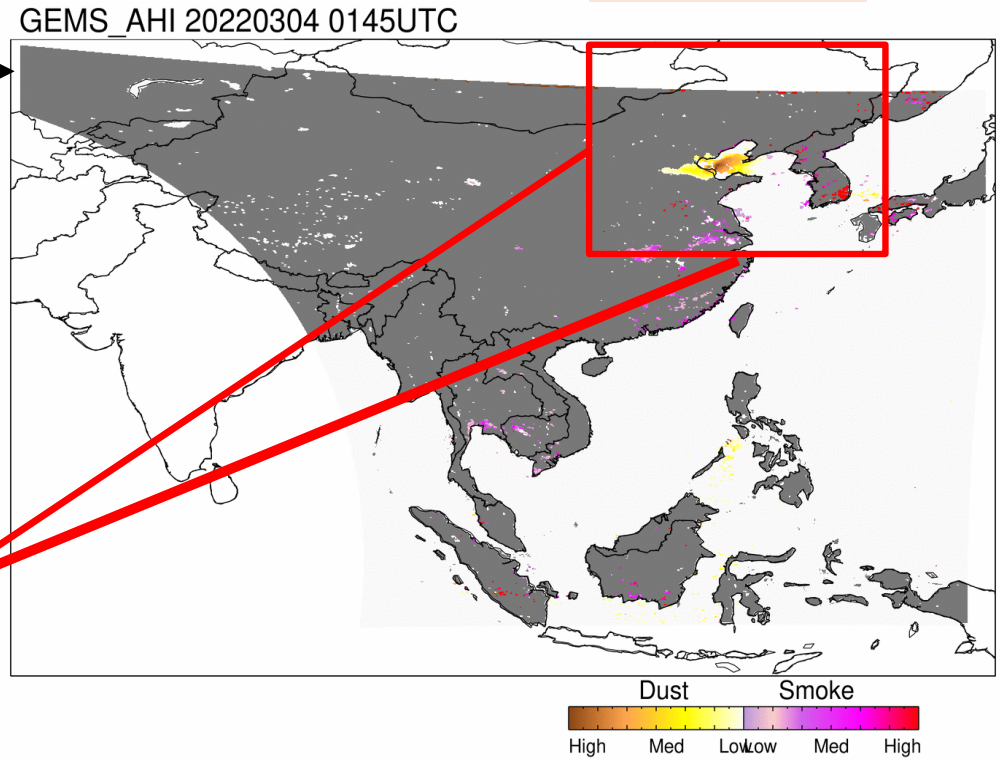
$AAI = -100[1og_{10}(R_{412}/R_{440}) - log_{10}(R'_{412}/R'_{440})]$

Dust Smoke Discrimination Index

$DSDI = -10[1og_{10}(R_{412}/R_{2250})]$

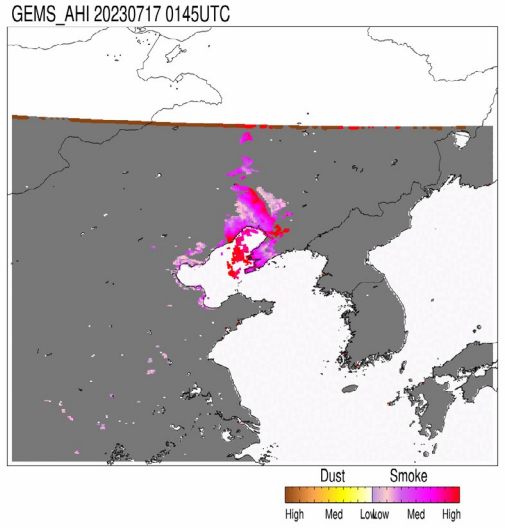


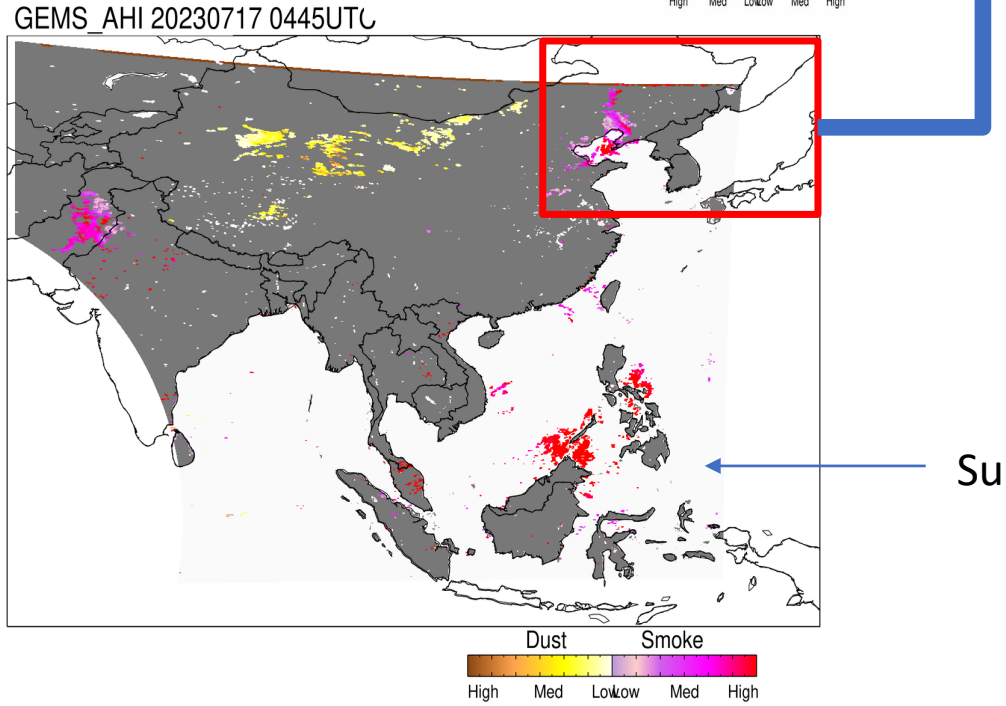
03/04/2022



Hybrid ADP Test Case: - Smoke intrusion from Siberia wildfires (July 17, 2023 04:45 UTC)

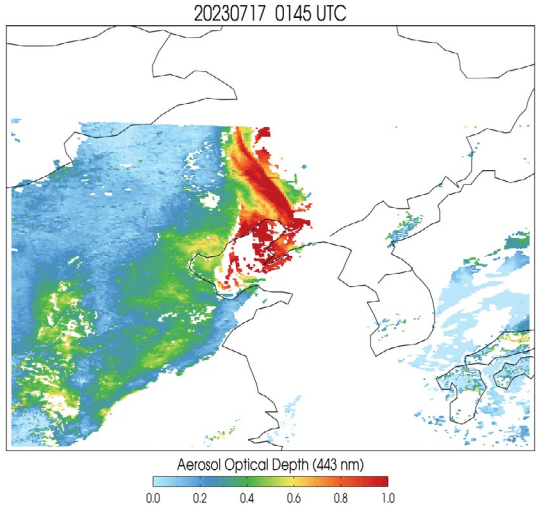
NOAA Hybrid ADP

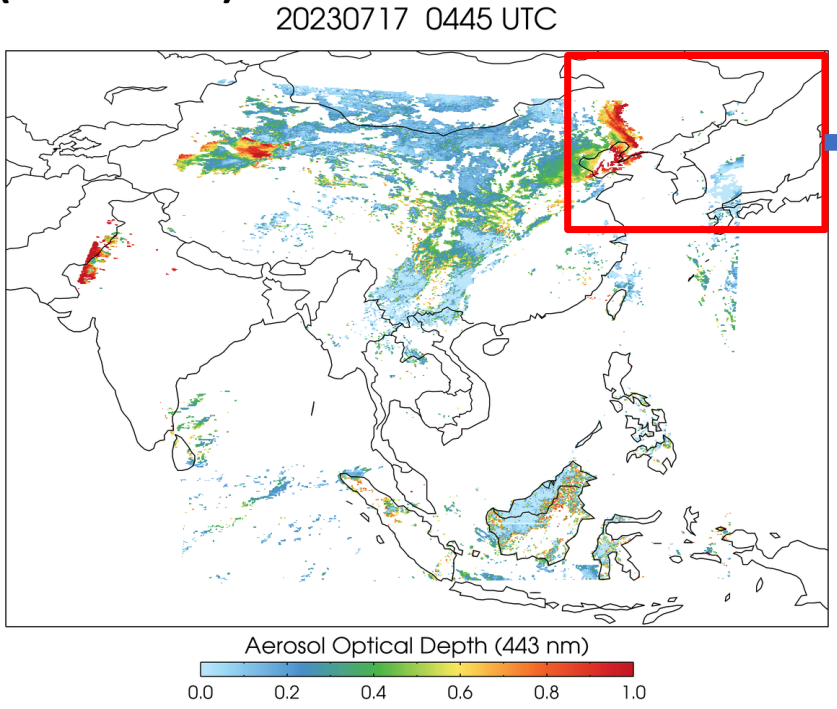




Sun glint

GEMS operational AOD (at 443 nm)



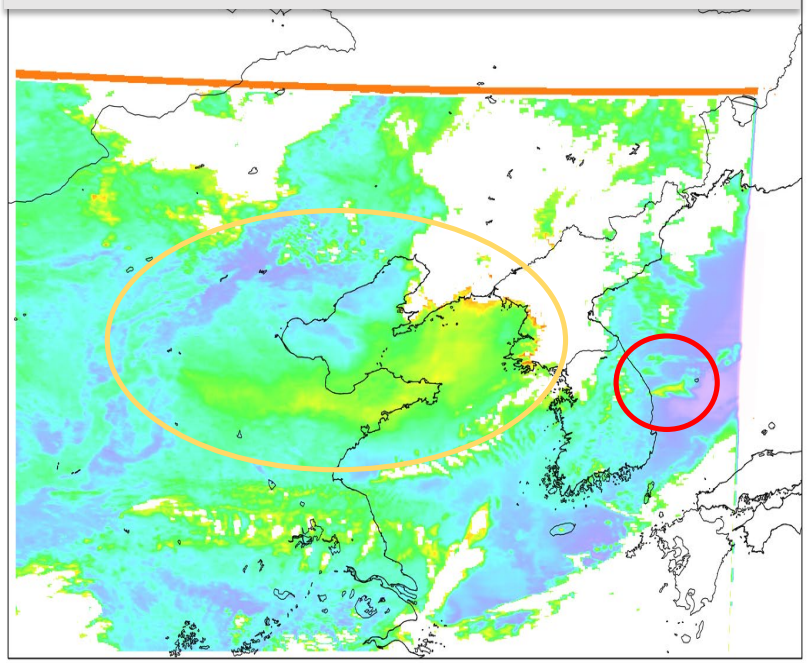


Absorbing Aerosol Index: Deep-Blue vs. UV Wavelengths

20220304 05:45 UTC

Deep-blue Absorbing Aerosol Index

AAI = $-100[1\log_{10}(R_{412}/R_{440}) - \log_{10}(R'_{412}/R'_{440})]$

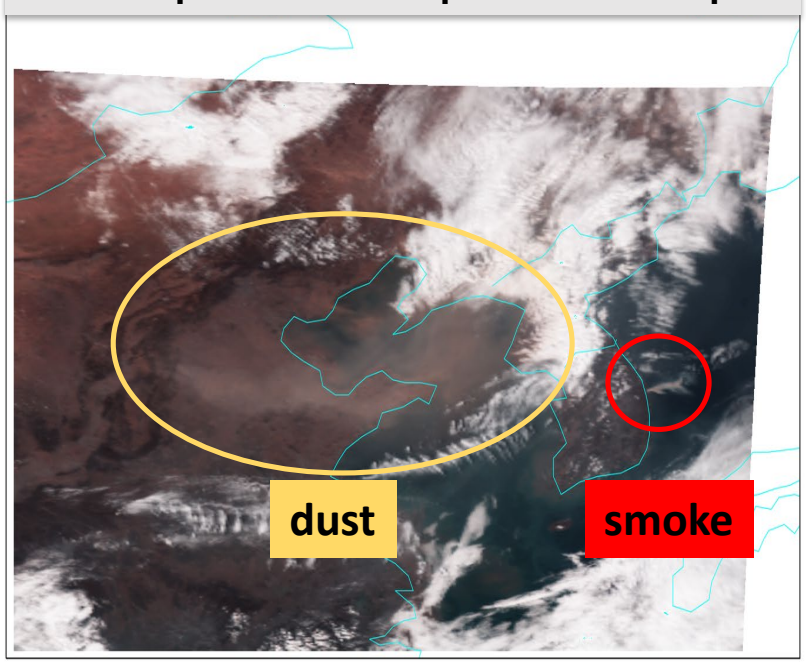


Deep-blue Absorbing Aerosol Index (412/440 nm)

0 2 4 6 8 10 12

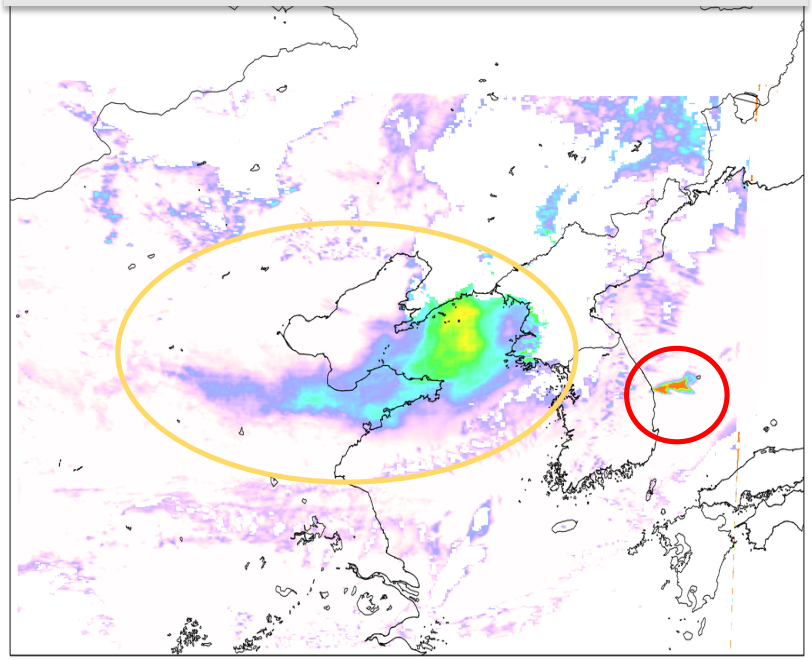
AHI RGB

R=0.64 μm G=0.52 μm B:0.47 μm



UV Absorbing Aerosol Index

AAI = $-100[1\log_{10}(R_{354}/R_{388}) - \log_{10}(R'_{354}/R'_{388})]$

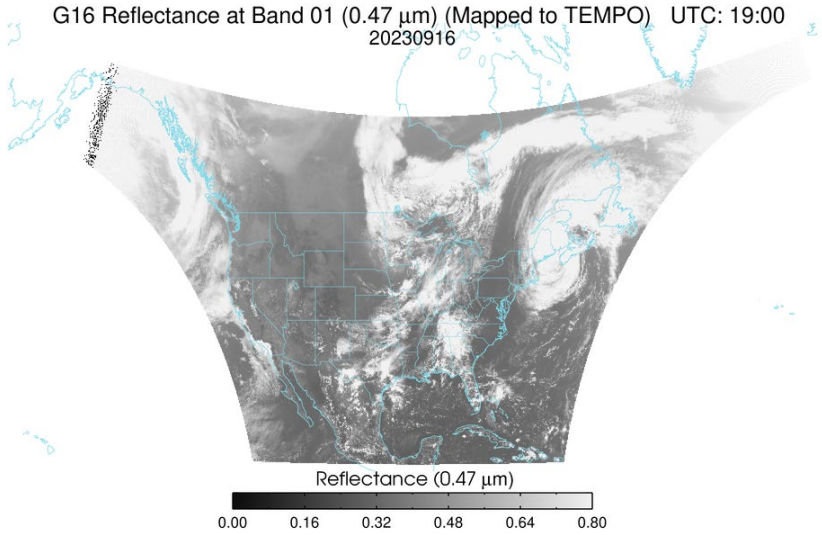


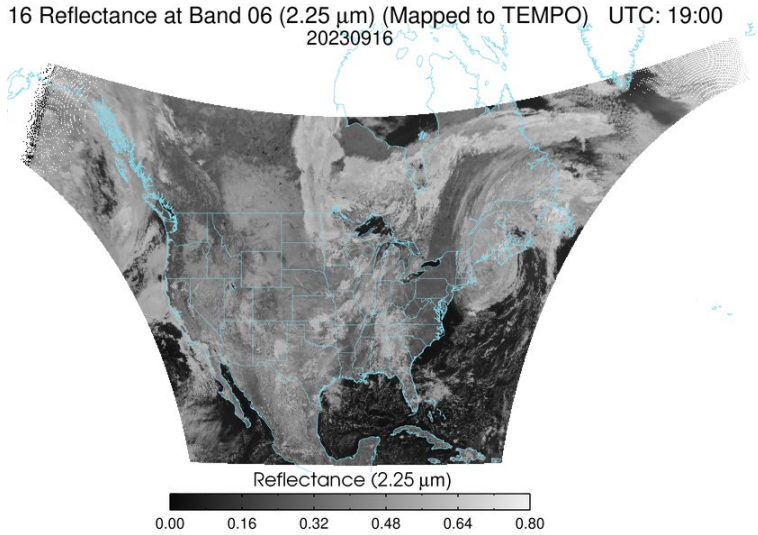
UV Absorbing Aerosol Index (354/388 nm)

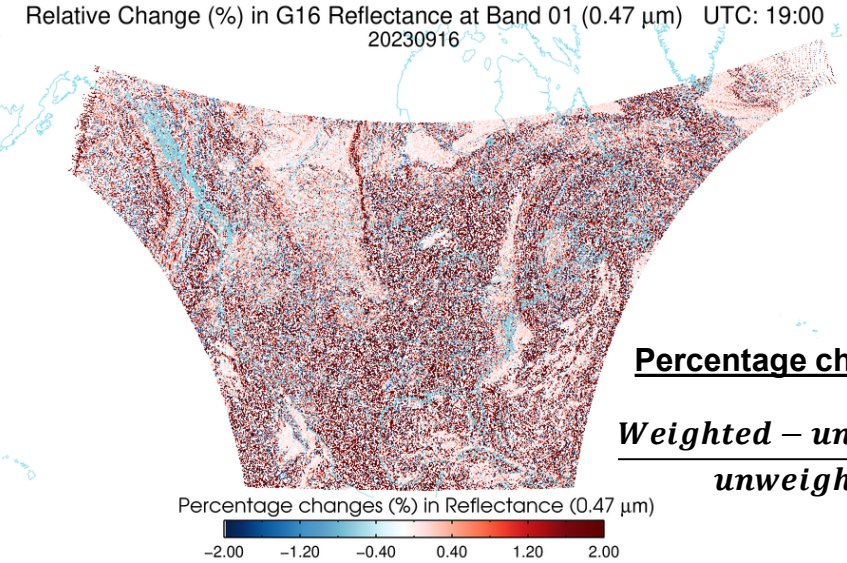
0 2 4 6 8 10 12

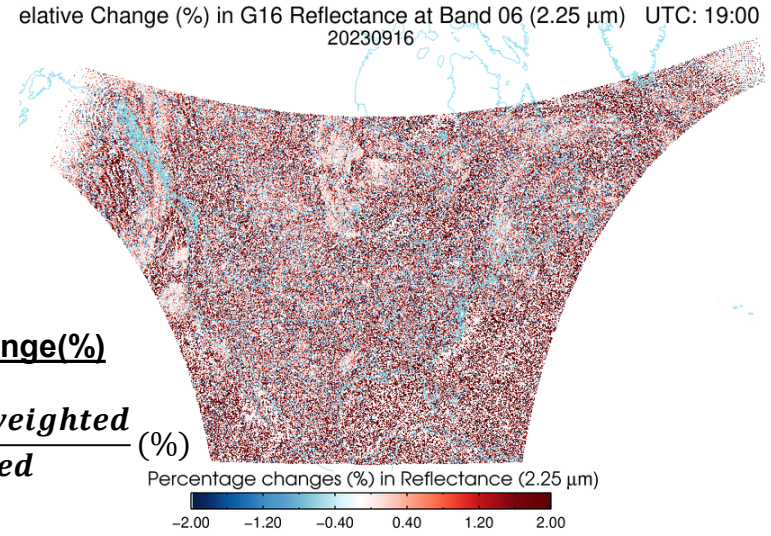
- **For absorbing aerosols, such as smoke and dust, the absorption is larger at UV wavelengths than at longer wavelengths.**
- **By shifting the wavelengths pair from 412/440 nm to 354/388 nm, the absorbing aerosol index shows a stronger contrast between areas with and without smoke/dust.**
- **The advantage of using UV wavelengths for smoke and dust detection will be explored in NOAA TEMPO/ABI hybrid ADP.**

Co-registration Tables for ABI Bands to TEMPO Bands







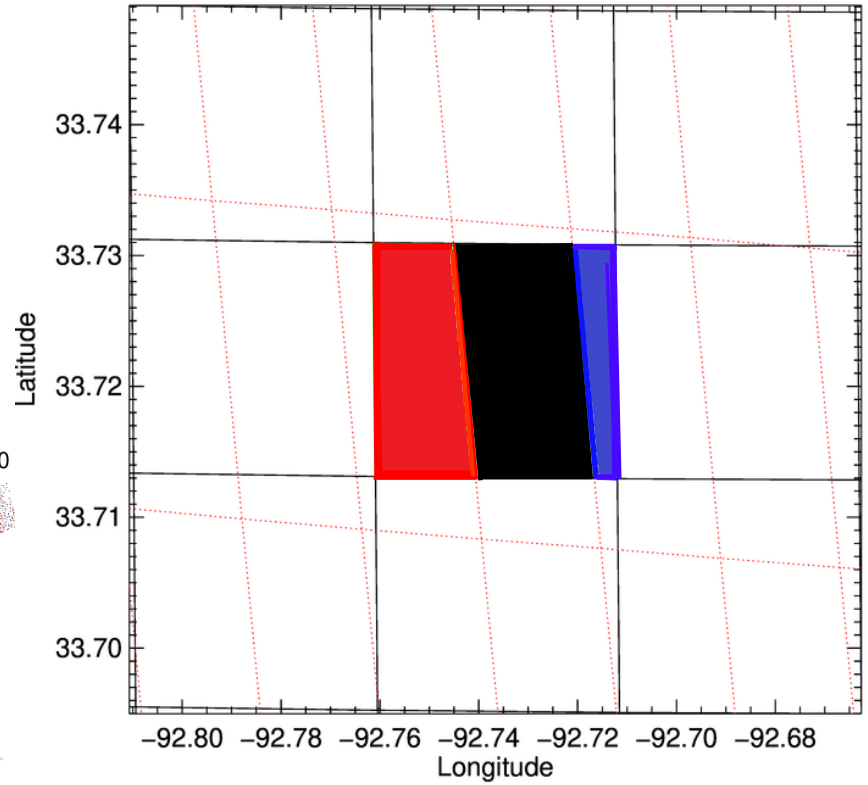


Percentage change(%)

$$\frac{Weighted - unweighted}{unweighted}(\%)$$

Red dotted line grid: GOES-16/ABI 2 km

Black line grid: TEMPO 2.0 x4.7 km



Weight=overlapped area/ABI pixel area

0.55 0.731 0.204

$$R = \frac{\sum_1^n w_i * R_i}{\sum_1^n w_i}$$

R: remapped reflectance n: no. of ABI pixels

w_i : weight at pixel i R_i - ABI reflectance at pixel i

- The difference in the pixel size and orientation requires a weighted average during re-gridding.
- Using TEMPO proxy L1B data, Co-registration tables between ABI and TEMPO bands were created.
- Larger than ~2% difference is seen after applying the weighted average with the co-registration Table.

Summary

- NOAA has developed a TEMPO/ABI hybrid aerosol detection algorithm that is ready to run in near real time, once TEMPO data become operational.
  - The algorithm will run through both the Deep-Blue and IR-Visible paths.
- The TEMPO/ABI hybrid algorithm was tested with GEMS and AHI data.
  - Initial results indicate the hybrid algorithm is capable of identifying both smoke/smog and dust plumes.
- A new UV algorithm path will be explored to take advantage of TEMPO's UV wavelengths.
  - Potential for more accurate smoke/dust detection!
  - Smoke and dust over clouds that is currently not possible with visible AAI.