Part 1 Question & Answer Session A

Please type your questions in the Slido/Question & Answer Box. We will try our best to get to all your questions. If we don't, feel free to email Caterina Mogno (caterina.mogno@nasa.gov) or Amy Huff (amy.huff@noaa.gov). This document will be shared to the training webpage within one week.

1. **Question: Why will TEMPO end in a few years?**
   The TEMPO mission will be reviewed again in a few years to determine whether it will continue operations beyond September 2029. This is a typical NASA mission review cycle process. TEMPO is capable of a 15 year lifespan in space as long as it continues to be extended via the review process.

2. **Question: Does TEMPO cover both day and night data of America?**
   TEMPO collects aerosol data only during daylight hours. Because TEMPO is a passive sensor that measures scattered UV and visible wavelengths of sunlight, it requires daylight to operate. More of the distinction between passive and active sensors can be found in the recommended "Fundamentals of Remote sensing Training''. There are certain TEMPO 'twilight' data products which use emitted light during nighttime (city lights, auroras), but these are not related to aerosols (or trace gases).

3. **Question: Since instruments like TEMPO and GOES-R are limited primarily to North America and the Western Hemisphere, how can we achieve similar hourly monitoring of complex aerosol pollution (such as dust storms, biomass burning, and urban emissions) in other major regions of the world? Specifically, what satellite options are available for monitoring places like India, and what is the extent of coverage over the African continent?**

   To achieve hourly and sub-hourly monitoring of aerosols, fires, and trace gases in regions beyond the reach of TEMPO and GOES-R, it is possible to rely on an

international constellation of geostationary satellite instruments that serve as their counterparts:

- For Asia: GEMS mission (the East Asian counterpart to TEMPO) alongside the Advanced Meteorological Imager (AMI). Furthermore, the Himawari AHI (positioned at about 140 degrees East) acts as a counterpart to the GOES-R ABI, providing full disk daytime monitoring over East Asia, the western Pacific, and India.
- For Europe and Africa: Sentinel-4 acts as the European and North African counterpart to TEMPO. For broader, full-disk meteorological coverage of these regions, Meteosat FCI is positioned above the prime meridian to cover all of Europe and the African continent. In addition GOES-East can be used to monitor most of the Atlantic Ocean as well as the westernmost tip of the African coast.

4. **Question: Do we still use TEMPO for Alaska data readings, given its larger pixels, or do we utilize other satellites for this region?**
   The Field of Regard (FoR) of TEMPO only covers a very small portion of southeastern Alaska. GOES-West ABI does cover all of Alaska, but at a very oblique satellite view zenith angle (VZA), so Level 2 products like ABI AOD and Smoke/Dust Mask are not recommended because they have a lot of uncertainty. The best choice for satellite observations of Alaska is polar-orbiting satellites, such as NOAA-21 and NOAA-20. VIIRS RGB and aerosol L2 product imagery are available for Alaska on AerosolWatch.

5. **Question: For El Salvador, Central America, do you recommend the use of GOES ABI, for monitoring Saharan dust and PM2.5? As I understood, the coverage area includes the Caribbean.**
   Yes, GOES-R ABI covers the Americas, including El Salvador. AerosolWatch displays GOES-East Full Disk ABI GeoColor, dust RGB, AOD, AOD 3-hour composite, smoke/dust mask, and fire detections imagery. To access the Full Disk imagery, click on the small green button that says “Full Disk”, located at the top right side of the AerosolWatch website.

6. **Question: Is there any plan to make TEMPO cover all around the globe? Or just in North America?**

TEMPO coverage is limited to its field of regard. Current operational instruments similar to TEMPO provide coverage over East Asia, Europe, and North Africa. You can see the White Paper "Expanding the Geostationary Atmospheric Composition Constellation: Towards Global Coverage" for a discussion on opportunities to expand this constellation further.

7. **Question: Does TEMPO continue to maintain the hourly full scan of the FOV during rapid observation mode?**
   During rapid or special observation mode, TEMPO targets only a portion of the TEMPO Field of Regard at high temporal frequency (e.g., < 10 minutes). However, TEMPO does not conduct special operations the entire day. The goal is to limit special operations to no more than 50% of TEMPO's observing time each day so TEMPO will provide 'normal or standard' observations over the complete Field of Regard. However, for example, during a 1-hour long special observation mode over a portion of the U.S. West region, TEMPO will only cover that selected portion of the Field of Regard.

8. **Question: What is the difference between a granule and a scan?**
   A "scan" is a complete cycle of collecting measurements across TEMPO's entire Field of Regard; for example, during TEMPO standard operations, a "scan" takes an hour to cover the complete Field of Regard from east to west. A "granule" is a set of data collected during a scan. During TEMPO standard operations, data from one "scan" is divided into "granules" (to keep the data sizes more manageable and to provide data with lower latency especially for the near real-time NO2 and HCHO data). One scan typically contains nine granules, but there are fewer in the mornings and evenings when sunlight only covers a portion of the TEMPO FOR.

9. **Question: How do scientists combine data from two satellites when one takes much sharper, more detailed pictures than the other?**
   To combine data from two satellite sensors, the observations have to be matched spatially and temporally. Measurements from one sensor must be mapped to the grid of the other sensor; typically, the higher-resolution data are remapped to the coarser-resolution grid. This regridding process is done using observations from the two sensors that are closest in time to each other. The NOAA NESDIS Aerosol Science Team developed this type spatial and temporal matching method to combine data from ABI and TEMPO. We have a journal

article in review that describes this process in detail. We can share the link to the paper when it is published.

10. **Question: How is the accuracy of TEMPO aerosol products evaluated, what ground-based measurements are commonly used for validation, and how significant are the differences between them? For PM2.5 estimates, how reliable are these estimates in regions with very few air-quality monitoring stations?**
    AERONET sun photometer measurements, including AOD and Angstrom Exponent, and atmospheric lidar data from the EarthCARE satellite are used to validate the Level 2 aerosol products: Smoke/Dust Mask (AERONET AOD/AE and EarthCARE), AOD (AERONET AOD), and ALH (EarthCARE). Details of the initial validation of TEMPO AOD and ALH are given in the paper by Zhang et al.

    For PM2.5, AirNow regulatory monitors are used for validation. Estimates of PM2.5 in the Caribbean and Mexico are less accurate because there are no PM2.5 regulatory monitor data input into the GWR model for these regions. You can find the details of the 10-fold cross validation of the PM2.5 estimates in the paper by Zhang et al.

11. **Question: So the surface air quality is being confirmed by low cost sensors on the ground and shown on TEMPO's data layers?**
    Low-cost sensor data are not included in the PM2.5 algorithm currently; only data from US EPA and Canadian regulatory air quality monitoring sites are used.

12. **Question: In PM2.5 estimate product for Mexico, is there any flag for knowing if there is any AirNow data used?**
    No PM2.5 monitor data from Mexico are reported to AirNow. As a result, there are no surface PM2.5 monitor data from Mexico input to the TEMPO PM2.5 algorithm.

13. **Question: As the atmosphere between sensors and ground can itself have different concentrations, how can we know the data we got of that specific area is accurate?**
    AOD and Smoke/Dust Mask do not convey information about where aerosols are vertically in the atmosphere. Aerosol Layer Height (ALH) is an estimate of the altitude (height above ground) where most of the aerosols are located. You can

use TEMPO ALH in conjunction with AOD and Smoke/Dust Mask to get a 3-dimensional picture of aerosols in the atmosphere. The TEMPO hourly PM2.5 product uses TEMPO AOD, ALH and observations from AirNow surface PM2.5 monitors in a Geographic Weighted Regression (GWR) model to derive a near-surface estimate of PM2.5 concentrations at the surface.

14. **Question: How does TEMPO distinguish wildfire smoke from other aerosols while ensuring accurate hourly measurements?**
    The TEMPO Aerosol Detection product (ADP) algorithm uses the UV AAI to identify absorbing aerosols, then a Dust Smoke Discrimination Index (DSDI) to separate smoke from dust. We have a journal article in review that describes this process in detail, along with the Smoke/Dust Mask validation. We can share the link to the paper when it is published.

15. **Question: Why don't you just remove the low and medium quality for tempo? Why do you include them in the output product?**
    There are some applications for which medium and low quality data can be used, such as qualitative assessments of where aerosols and smoke are and where they might be going. NOAA decided to include all the data qualities in the data files, so users have the choice of what quality data to use for their specific applications.

16. **Question: How can we determine whether an apparent rapid increase in aerosol optical depth represents a genuine increase in aerosol loading, rather than a change in aerosol vertical distribution, relative humidity-driven particle growth, or changing cloud contamination—and how can we disentangle these effects when multiple processes occur simultaneously within the same pixel?**
    Additional data products, such as TEMPO Aerosol Layer Height (ALH) and Smoke/Dust Mask available from ABI or TEMPO, can address some of these other explanatory factors.

    In addition, the product documentation can provide additional details on how these factors are handled during the retrieval process, and which confidence thresholds or flags need to be applied to get the highest quality and confidence data. For example, for TEMPO AOD, only high quality AOD and ALH are recommended. For ABI AOD, high quality AOD is recommended for quantitative

applications, such as validation, while high + medium qualities AOD are recommended for qualitative applications, such as imagery shown on the AerosolWatch website.

Finally, aerosol optical depth is a quantitative measure of aerosol loading. It is not dependent on aerosol vertical distribution, like UV AAI is. Cloud contamination is a known issue that causes anomalously high AOD adjacent to clouds. If you suspect cloud contamination, you can confirm by overlaying the AOD product (TEMPO or ABI) on the corresponding true color (TEMPO) or GeoColor (ABI) imagery.

17. **Question: When analyzing complex mixed-plume scenarios involving simultaneous wildfire smoke and urban anthropogenic emissions, how reliably do the TEMPO/ABI level 2 smoke/dust masks distinguish aerosol types at an hourly temporal scale to support accurate health risk assessments?**
    TEMPO and ABI Smoke/Dust Mask products currently do not have the capability to identify mixed plumes, or aerosol types other than smoke and dust. The algorithm only retrieves smoke or dust for a given pixel, not a mixture of types. The Smoke/Dust Mask product is validated using aerosol classification based on AOD and Angstrom Exponent (AE) measurements from AERONET sun photometer stations. Smoke and smog/haze have overlapping ranges of AE values, making it difficult to differentiate haze from smoke. This overlap introduces uncertainty into the validation of satellite smoke detection, as haze and smoke aerosols may be classified together. In addition, the Smoke/Dust Mask is a qualitative indicator of smoke or dust aerosols, with no indication of where vertically the aerosols are in the atmosphere. For that reason, the Smoke/Dust Mask is not recommended for health risk assessments. Instead, use the TEMPO estimated surface PM2.5 product, which incorporates the TEMPO ALH product, and therefore is a more accurate estimate of aerosol health impacts at the surface.

18. **Question: How can we distinguish between smoke aerosols transported at high altitudes and smoke near the surface that directly affects human health, using TEMPO's Aerosol Layer Height and PM2.5 products?**
    TEMPO ALH is an estimate of the altitude (height above ground) where most of the aerosols are located, including smoke. TEMPO PM2.5 incorporates ALH and

information about observed surface PM2.5 from AirNow regulatory monitors, so the product is an estimate of the PM2.5 concentrations at the surface.

19. **Question: In complex scenes featuring mixed cloud cover and heavy absorbing aerosols (such as biomass burning smoke plumes), how does the retrieval algorithm handle cloud-fraction contamination in the UV-visible spectra? and what are the primary error sources in separating Aerosol Optical Depth (AOD) from Aerosol Layer Height (ALH)?**
The Aerosol Detection product (ADP) algorithm first retrieves UV AAI to identify absorbing aerosols, including smoke, and then uses the DSDI to separate smoke from dust. The UV AAI identifies absorbing aerosols, including aerosols over (on top of) clouds. Smoke or dust underneath clouds are not detected by the UV AAI. The ADP algorithm inputs the ABI L2 Cloud Mask product to identify pixels that are partially or completely covered by clouds. In addition, the algorithm uses a series of "internal tests" as a double check of cloud contamination. We have a journal article in review that describes this process in detail, along with the Smoke/Dust Mask validation. We can share the link to the paper when it is published.

    TEMPO AOD and ALH are generated from the same algorithm, but using different convolved TEMPO spectral bands. So the AOD and ALH are not "separated", rather, they are retrieved separately. Details about the AOD-ALH algorithm are given in the paper by Zhang et al.

20. **Question: Why does false smoke detection occur during the morning period?**
We can see higher probability of false smoke detection during dusk (and dawn) because the sun is low at the horizon (high solar zenith angle, SZA), which determines more complex viewing geometry and environmental conditions for the sensor: the light has to travel a longer path to the sensor, there may be longer surface shadows or morning/evening fog. In these conditions the retrieval is more challenging and can lead to false detections, such as detecting a smoke plume where there is not.

    Specific reasons for false TEMPO smoke detections include:
    - Tests for clouds failed due to the higher SZAs in the morning

- The bidirectional reflectance distribution function (BRDF) of the surface reflectance is assumed to be Lambertian in the current version of the algorithm. The assumption can fail in this situation. To address this issue, a Directorial Lambertian Equivalent surface Reflectance (DLER) database, derived from TEMPO and ABI, will be implemented in the next update to the TEMPO ADP algorithm.

In these conditions it is recommended to cross-check with available true color imagery or look at fire hotspot detection products to assess if a fire is really present. In addition the technical product documentation can provide additional details on which confidence thresholds or flags need to be applied to get the highest quality and confidence data.

21. **Question: What is the vertical resolution and maximum altitude at which ALH can be measured? In cases where an atmospheric scene is complex with thin multilayers existing, the ALH is labeled as a "mean value" of the scene? Is there any significant difference regarding ALH retrieval over land versus sea? How well does the Height of Aerosols work when analyzed through an urban environment? Is there (or planning) a distinction within ALH between the boundary layer height contribution and the lower troposphere?**
TEMPO ALH is the height at which the aerosol extinction (from scattering and absorption of 550 nm light) is a maximum. So there is only one “layer” retrieved, the layer (altitude above the surface) at which aerosol extinction is greatest. ALH is an optical property based on an assumed aerosol vertical profile. In reality, the actual profile may differ—such as having multiple layers, varying shapes, or different thicknesses—which can introduce uncertainty into the ALH retrieval.

In the initial product validation reported by Zhang et al., 2025, ALH retrievals were compared to measurements from the High Spectral Resolution Lidar 2, and showed ALH had a bias of 0.14 km and an RMSE of 1.19 km over land, and a bias of –1.12 km and an RMSE of 1.25 km over water.

22. **Question: Is it possible to process the algorithm based on the ABI higher resolution pixel size rather than TEMPO lower resolution? If not, is it possible to upsample the ADP product to higher resolutions?**

When measurements from one sensor must be mapped to the grid of the other sensor, such as with ABI and TEMPO, the higher-resolution data are typically remapped to the coarser-resolution grid. It is certainly possible to upsample the TEMPO Smoke/Dust Mask or UV AAI using standard techniques, but this is something that would need to be done by the user. There are no plans to implement upsampling in the TEMPO ADP algorithm.

23. **Question: If someone wants to work with the TEMPO UV AAI, not the Scaled AAI, what are the appropriate quality filters that should be applied? Are they similar to the ones applied to the Scaled AAI, as it is described on the respective documentation?**
    Please read the TEMPO-ABI ADP User's Guide before working with the data files. All the TEMPO aerosol product User's Guides are available here. To answer your specific question, no, you should not use the same processing for UV AAI as for the SAAI. No quality or diagnostic flags need to be used for UV AAI. However, we recommend plotting UV AAI in the range of [0,12], as shown on AerosolWatch.

24. **Question: From slide 16, the ABI AOD data, is there a reason the data is not available to the public?**
    ABI AOD data are available to the public. NOAA has public-private partnerships with the three major cloud data providers to host NOAA data free to users. You can access ABI AOD data via AWS (Amazon) and GCS (Google); no registration or cloud accounts are needed.
25. **Question: How do you look up the TEMPO and ABI data on the Earthdata website?**
    TEMPO and ABI aerosol data files are not available from NASA Earthdata. When the TEMPO aerosol product algorithms become operational in 2027, data files will be available to download through NASA Earthdata. You can access ABI data for free on the cloud: see the answer to Question 24 for links to the GOES-R data cloud archives.