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SUBJECT: Assessment of Solution-Agnostic Observational Needs for Stratospheric Composition

1. Scope:
   This memo provides background information and recommendations and guidance for solution-agnostic observational needs for Stratospheric Composition.

2. Background:
   NESDIS has to regularly assess the user mission needs for environmental observations. This is important in order to (1) remain cognizant with the evolution of these needs and to (2) better plan for the next-generation architecture, and in particular, the space-based architecture. To achieve this goal, these needs have to be collected from a broad community, in a solution-agnostic fashion, in order to provide a reference for multiple observing systems solutions that will be able (1) to meet these needs now and in the future, (2) to look at innovative ways to meet all needs cost-effectively, and (3) to potentially fill or reduce existing observation gaps. It is important to note that these needs are expressed from a relatively wide community of observational users, but it is important to highlight they do not constitute requirements for NOAA. An internal NOAA process exists to define observational requirements. This effort is one part of the overall NESDIS user engagement process.

   Understanding stratospheric composition is important due to potential impacts on human and ecosystem health and climate. The SAT subcommittee on atmospheric composition (see List of Contributors) focused on several application areas where satellite data are a main source of observational data. A panel of expert reviewers (see List of Contributors) reviewed the needs, attributes, and their priorities, following which observational needs for these applications were briefed to the SAT. Representatives were in attendance from academia, private sector, NASA, DoD, and in NOAA, from the line offices, and the

OSAAP Analysis Team (TPIO) in charge of stewarding and updating the COURL, as well as representatives from the major programs, who ultimately will be charged with developing the components of the space architecture (LEO, GEO, and SWO). All were given opportunities to provide comments and feedback on the observational needs.

It is the purpose of this memo, compiled by the SAT subcommittee on atmospheric composition and reviewed by the Government-only Core-SAT team, to document and establish the needs for stratospheric composition by assessing the users' needs from many sources. It is important to note that the information captured is in geophysical space which is consistent with the international standard established by the WMO (e.g., the OSCAR database). This means that what is captured here is the information content needed for the observations. It does not mean that the user systems will assimilate those products. This exercise captured user needs in a solution-agnostic fashion.

3. Facts and Findings:
   a. Facts
      (1) Atmospheric chemistry species were selected from a subset of chemical species that are included in state-of-the-art global atmospheric chemical transport models, such as the Real-time Air Quality Modeling System (RAQMS).
      (2) Reductions in stratospheric ozone concentration allow more damaging radiation to reach the Earth's surface, potentially harming plants and animals and impacting human health and, notably, agriculture.
      (3) The distribution of stratospheric ozone has been shown to affect tropospheric conditions, including weather, on seasonal to sub-seasonal time scales, as well as impacting large scale circulation patterns.
      (4) Continual monitoring of stratospheric ozone with good global coverage on weekly to monthly time scales will feed into improved understanding of radiative and dynamical processes and improve near-term as well as seasonal to sub-seasonal forecasts.
      (5) Maintaining vertically and spatially resolved satellite measurements of both ozone, water vapor, and aerosols is critical, as are measurements of other chemically and radiatively active species in the stratosphere.
      (6) The US Clean Air Act mandates that NOAA and NASA regularly report on the state of the stratospheric ozone layer to Congress.
      (7) Stakeholders of NOAA's stratospheric ozone monitoring include numerous Federal agencies (e.g., NOAA, NASA, EPA, USDA, etc.), the private sector (agricultural interests), and a variety of international bodies.
   b. Findings
      (1) The SAT developed a list of solution-agnostic stratospheric composition observational needs and assembled them into several tables. The tables summarize those observational needs and were determined as part of the overall NESDIS user engagement process that consisted of deliberations with experts, established expert groups, published documentation, and

NOAA Line Office experts. The list was consolidated, reviewed, and approved by the Government-only Core-SAT committee.

4. Recommendation:

The SAT recommends that NOAA use the following solution-agnostic stratospheric composition observational needs, as shown in the tables below, as an input to the establishment of the NOAA observational requirements for stratospheric composition needs. These tables include variable names, attributes' ranges of these variables, as well as associated prioritizations. These recommendations should be considered as part of the planning and development of next-generation space architecture and product development.

Table Descriptions

Table 1. Describes the list of variables needed for the stratospheric composition applications, why they are important for the application, and whether they are already identified as an existing variable in the TPIO databases.

Table 2. Identifies geophysical variable priorities for the stratospheric composition application as reviewed by the Core-SAT using the inputs from the subcommittee for atmospheric composition as an input. The recommendations from other user needs activities (TPIO, NASA-NOAA, XORWG, etc.) were considered, and included by OSAAP/TPIO.

Table 3. Shows the variable performance ranges for the stratospheric composition application, as determined by the Core-SAT. These data are based on the input from the subcommittee for atmospheric composition as well as input from the OSAAP Analysis Team, and other sources, as mentioned previously. The data ranges, shown as triplets, are defined as "minimally useful or Threshold," "Expected [performance in the 2030-time frame]," and "Maximum Effective." The current geophysical variable performance ranges are listed as well.

Table 4. Includes stratospheric composition application attribute priorities, per variable, including horizontal and vertical resolution, temporal resolution, error standard deviation, and data latency. This table was provided by the OSAAP/TPIO Team based on "differential attribute change per unit time" in the vertical and horizontal dimensions. Current attribute weights, per geophysical variable, are listed.

<u>Conclusions:</u>

This is the first comprehensive catalog of observational needs for stratospheric composition that has been collected by NOAA. This observational needs list is designed to consolidate the set of needs, defined in a way that helps the design and evaluation of the next-generation space architecture, but also to serve as a reference for all those interested in these needs in the near future. As stated previously, the collection of user needs was developed and reviewed by a variety of different sources that included representatives from the OSAAP/TPIO, the LEO and GEO programs, and representatives from the NOAA Line Offices and Centers (OAR/CSL, OAR/GML, OAR/ARL, NWS/EMC, NESDIS/STAR, OAR/CPO), NASA, DoD, and academia. The final determination of the list of user needs and attributes was assembled and confirmed by the Core-SAT. The collection of observational user needs is part of the on-going user engagement process and should be refreshed regularly in order to maintain an up-to-date list of users' observational needs.

Table 1. Stratospheric Composition Variable Needs: Table 1 is a list of the variables needed by the stratospheric composition application, the importance of these variables, and a notation about the variable status in the TPIO databases.

Geophysical Variable	Variable Importance	TPIO Database (Existing/ New)
O3 – Ozone	Key constituent of the stratosphere protecting human and ecosystem health and climate	E
N2O – Nitrous Oxide	Ozone depleting substance, tracer for chemical and dynamical processes	N
CH4 – Methane	Tracer for chemical and dynamical processes	E
CO2 – Carbon Dioxide	Tracer for chemical and dynamical processes	E
CFCl3 (F11) – Trichlorofluoromethane	Ozone depleting substance	N
CF2Cl2 (F12) – Dichlorodifluoromethane	Ozone depleting substance	N
CH3Br – Bromomethane	Ozone depleting substance	N
CF3Br (H1301) – Bromotrifluoromethane	Ozone depleting substance	N
CF2ClBr (H1211) – Bromochlorodifluoromethane	Ozone depleting substance	N
HNO3 - Nitric Acid	Tracer for chemical and dynamical processes	E
N2O5 – Dinitrogen Pentoxide	Tracer for chemical and dynamical processes	N
H2O2 – Hydrogen Peroxide	Tracer for chemical and dynamical processes	N
HCl – Hydrogen Chloride	Tracer for chemical and dynamical processes	N
ClONO2 – Chlorine Nitrate	Tracer for chemical and dynamical processes	N
ClO - Chlorine Monoxide	Tracer for chemical and dynamical processes	N
OClO – Chlorine Dioxide	Tracer for chemical and dynamical processes	N
HF - Hydrogen Fluoride	Tracer for chemical and dynamical processes	N
HNO4 – Peroxynitric Acid	Tracer for chemical and dynamical processes	N
HOCl – Hypochlorous Acid	Tracer for chemical and dynamical processes	N
NO3 – Nitrate	Tracer for chemical and dynamical processes	N
NO2 – Nitrogen Dioxide	Tracer for chemical and dynamical processes	E
NO – Nitrogen Oxide	Tracer for chemical and dynamical processes	N
CH3OOH – Methyl Hydroperoxide	Tracer for chemical and dynamical processes	N
CO – Carbon Monoxide	Tracer for chemical and dynamical processes	E
HBr – Hydrogen Bromide	Tracer for chemical and dynamical processes	N
BrO – Bromine	Tracer for chemical and dynamical processes	N
BrONO2 – Bromine Nitrate	Tracer for chemical and dynamical processes	N
HOBr – Hypobromous Acid	Tracer for chemical and dynamical processes	N

Geophysical Variable	Variable Importance	TPIO Database (Existing/ New)
BrCl – Bromine Chloride	Tracer for chemical and dynamical processes	N
Cl2 – Chlorine	Tracer for chemical and dynamical processes	N
Aerosol Optical Depth	Proxy for climate forcing by particles	E
Aerosol Layer Height	Informs climate forcing by particles	E
Aerosol Single Scattering Albedo	Informs climate forcing by particles	N
Aerosol Refractive Index	Informs climate forcing by particles	E
Aerosol Particle Size	Informs climate forcing by particles	E
Aerosol Particle Shape	Informs climate forcing by particles	N
Speciated Aerosol Mass	Informs climate forcing by particles	N
Volcanic Ash	Informs climate forcing by particles and aircraft hazard	E
H2O - Water Vapor	Driver for climate forcing and tracer for chemical and dynamical processes	N
SO2 - Sulfur Dioxide	Informs climate forcing by particles	E
SF6 - Sulphur Hexafluoride	Tracer for chemical and dynamical processes	N
OH - Hydroxyl Radical	Tracer for chemical and dynamical processes	N
HO2 - Hydroperoxy Radical	Tracer for chemical and dynamical processes	N

Table 2. Geophysical Variable Priorities for Stratospheric Composition: This table includes the list of the geophysical information and their prioritization, based on a scale from 0 (non-important) to 1 (critically important), needed for stratospheric composition as determined by the Systems performance Assessment team (SAT). This list was consolidated using a multitude of sources and follows the variables definition and units used in the Advanced Systems Performance Evaluation tool for NOAA (ASPEN) tool.

Geophysical Variable	Short Name	Units	Priority
O3 – Ozone	O3	ppmv	1.0
N2O – Nitrous Oxide	N2O	ppbv	0.8
CH4 – Methane	CH4	ppbv	0.8
CO2 – Carbon Dioxide	CO2	ppmv	0.5
CFCl3 (F11) – Trichlorofluoromethane	CFCl3	pptv	0.5
CF2Cl2 (F12) – Dichlorodifluoromethane	CF2Cl2	pptv	0.5
CH3Br – Bromomethane	CH3Br	pptv	0.3
CF3Br (H1301) – Bromotrifluoromethane	CF3Br	pptv	0.5
CF2ClBr (H1211) – Bromochlorodifluoromethane	CF2ClBr	pptv	0.5
HNO3 - Nitric Acid	HNO3	ppbv	1.0
N2O5 – Dinitrogen Pentoxide	N2O5	pptv	1.0
H2O2 – Hydrogen Peroxide	H2O2	ppbv	1.0
HCl – Hydrogen Chloride	HCl	ppbv	1.0*
ClONO2 – Chlorine Nitrate	ClONO2	ppbv	0.8
ClO - Chlorine Monoxide	ClO	pptv	0.8
OClO – Chlorine Dioxide	OClO	pptv	0.8
HF - Hydrogen Fluoride	HF	pptv	0.5
HNO4 – Peroxynitric Acid	HNO4	ppbv	0.8
HOCl – Hypochlorous Acid	HOCl	ppbv	0.8
NO3 – Nitrate	NO3	ppbv	1.0
NO2 – Nitrogen Dioxide	NO2	ppbv	1.0
NO – Nitrogen Oxide	NO	ppbv	1.0
CH3OOH – Methyl Hydroperoxide	CH3OOH	ppbv	0.3
CO – Carbon Monoxide	CO	ppmv	0.8
HBr – Hydrogen Bromide	HBr	pptv	1.0*
BrO – Bromine	BrO	pptv	0.8
BrONO2 – Bromine Nitrate	BrONO2	pptv	0.8
HOBr – Hypobromous Acid	HOBr	pptv	0.8

Geophysical Variable	Short Name	Units	Priority
BrCl – Bromine Chloride	BrCl	pptv	0.8
Cl2 – Chlorine	Cl2	pptv	0.8
Aerosol Optical Depth	AOD	unitless	1.0
Aerosol Layer Height	Aerosol Height	km	0.8
Aerosol Single Scattering Albedo	Aerosol Albedo	unitless	0.8
Aerosol Refractive Index	Aerosol Scattering	unitless	0.5
Aerosol Particle Size	Aerosol Size	microns	0.8
Aerosol Particle Shape	Aerosol Shape	unitless	0.5
Speciated Aerosol Mass	Speciated Aer Mass	ug/m3	1.0
Volcanic Ash	Vol Ash	mg/m3	1.0
H2O - Water Vapor	H2O	ppmv	1.0
SO2 - Sulfur Dioxide	SO2	pptv	1.0
SF6 - Sulphur Hexafluoride	SF6	ppmv	0.5
OH – Hydroxyl Radical	OH	pptv	0.8
HO2 – Hydroperoxy Radical	HO2	pptv	0.8

Table 3. Stratospheric Composition Observational Need Attribute Performance Ranges: List of observational needs of the current systems for stratospheric composition in NOAA. These needs are expressed in terms of ranges between minimally useful (Threshold), expected level of performance in 2030 (Expected) and the maximum effective usefulness level beyond which there is no incentive to improve performance (Maximum Effective). These are written as [Threshold, Expected, Maximum Effective]. The attributes include the spatial coverage, the horizontal resolution, the temporal refresh, the precision, and latency. When appropriate, the vertical resolution is listed.

- Geographic Coverage: The geographic region needed for observations.
- Horizontal resolution: The ground projected instantaneous field of view.
- Temporal refresh: Time between observations at a location, i.e, time to observe the geographic coverage region.
- Data Latency: Time from 'image taken' to full relay of data to a ground station.
- Vertical Resolution (when appropriate): The average vertical distance between observations in degrees of freedom.
- Precision: Error standard deviation under clear/cloudy conditions and over land/ocean.
- Accuracy: Mean absolute non-random error.
- Validity Range: The low and high values that can be observed.
- Long term stability of the measurement: Long term changes in precision (noise).
- Robustness: The number of sources needed to make the observation.
- Continuity: Period in years for which the observations are required.

Geophysical Variable	Geophysical Variable Units	Geographic Coverage (dimensionless)	Horizontal Resolution (km)	Temporal Refresh (h)	Data Latency (h)	Vertical Resolution (dof)	Precision: Clear/ Cloudy, Land/ Ocean (%)	Accuracy (%)	Validity Range (Same Units as Variable)	Long- term Stability (%)	Robustness (unitless)	Continuity (yr)
O3 – Ozone	ppmv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1**, 5, 120]	[20, 5, 1] %	0.001+[10, 5, 1] %	[0.001- 15]	[5, 2, 1] %/Decade	[2, 3, 6]	1 year
N2O – Nitrous Oxide	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[30, 15, 5] %	1+[30, 15, 5] %	[1-400]	[10, 5, 1] %/Decade	[2, 3, 6]	1 year
CH4 – Methane	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[50, 20, 5] %	1+[25, 10, 5] %	[1-2500]	[25, 10, 5] %/Decade	[2, 3, 6]	1 year
CO2 – Carbon Dioxide	ppmv	Network, CONUS, Global	[200, 100, 20]	[72, 24, 12]	[36, 12, 6]	[1, 5, 120]	[40, 10, 5] %	[40, 10, 5] %	[250-2000]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
CFCl3 (F11) – Trichlorofluoromethane	pptv	Network, CONUS, Global	[200, 100, 20]	[72, 24, 12]	[36, 12, 6]	[1, 5, 120]	[20, 10, 1] %	1+[10, 5, 1] %	[1-300]	[10, 5, 1] %/Decade	[2, 3, 6]	1 year

Geophysical Variable	Geophysical Variable Units	Geographic Coverage (dimensionless)	Horizontal Resolution (km)	Temporal Refresh (h)	Data Latency (h)	Vertical Resolution (dof)	Precision: Clear/ Cloudy, Land/ Ocean (%)	Accuracy (%)	Validity Range (Same Units as Variable)	Long- term Stability (%)	Robustness (unitless)	Continuity (yr)
CF2Cl2 (F12) – Dichlorodifluoromethane	pptv	Network, CONUS, Global	[200, 100, 20]	[72, 24, 12]	[36, 12, 6]	[1, 5, 120]	[20, 10, 1] %%	1+[10, 5, 1] %	[1-600]	[10, 5, 1] %/Decade	[2, 3, 6]	1 year
CH3Br – Bromomethane	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[40, 10, 5] %	[40, 10, 5] %	[1-20]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
CF3Br (H1301) – Bromotrifluoromethane	pptv	Network, CONUS, Global	[200, 100, 20]	[72, 24, 12]	[36, 12, 6]	[1, 5, 120]	[20, 10, 1] %	[10, 5, 1] %	[1-10]	[10, 5, 1] %/Decade	[2, 3, 6]	1 year
CF2ClBr (H1211) – Bromochlorodifluoromethane	pptv	Network, CONUS, Global	[200, 100, 20]	[72, 24, 12]	[36, 12, 6]	[1, 5, 120]	[20, 10, 1] %	[10, 5, 1] %	[1-10]	[10, 5, 1] %/Decade	[2, 3, 6]	1 year
HNO3 - Nitric Acid	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[40, 20, 5] %	[20, 10, 5] %	[1-30]	[20, 10, 5] %/Decade	[2, 3, 6]	1 year
N2O5 – Dinitrogen Pentoxide	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[50, 20, 5] %	1+[25, 10, 5] %	[1-1000]	[25, 10, 5] %/Decade	[2, 3, 6]	1 year
H2O2 – Hydrogen Peroxide	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	0.001+[40, 10, 5] %	[0.001-10]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
HCl – Hydrogen Chloride	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[20, 10, 1] %	0.001+[10, 5, 1] %	[0.001-10]	[10, 5, 1] %/Decade	[2, 3, 6]	1 year
ClONO2 – Chlorine Nitrate	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[30, 20, 5] %	0.001+[15, 10, 5] %	[0.001-10]	[15, 10, 5] %/Decade	[2, 3, 6]	1 year
ClO - Chlorine Monoxide	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 40, 10] %	0.1+[40, 20, 10] %	[0.1-10]	[40, 20, 10] %/Decade	[2, 3, 6]	1 year
OClO – Chlorine Dioxide	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	[40, 10, 5] %	[0.1-5]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
HF - Hydrogen Fluoride	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[40, 20, 5] %	1+[20, 10, 5] %	[1-2500]	[20, 10, 5] %/Decade	[2, 3, 6]	1 year
HNO4 – Peroxynitric Acid	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	0.1+[40, 10, 5] %	[0.1-50]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
HOCl – Hypochlorous Acid	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	0.001+[40, 10, 5] %	[0.001-50]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year

Geophysical Variable	Geophysical Variable Units	Geographic Coverage (dimensionless)	Horizontal Resolution (km)	Temporal Refresh (h)	Data Latency (h)	Vertical Resolution (dof)	Precision: Clear/ Cloudy, Land/ Ocean (%)	Accuracy (%)	Validity Range (Same Units as Variable)	Long- term Stability (%)	Robustness (unitless)	Continuity (yr)
NO3 – Nitrate	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	0.001+[40, 10, 5]	[0.001-50]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
NO2 – Nitrogen Dioxide	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	1+[40, 10, 5] %	[1-100]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
NO – Nitrogen Oxide	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[20, 10, 1] %	0.001+[10, 5, 1] %	[0.001-100]	[10, 5, 1] %/Decade	[2, 3, 6]	1 year
CH3OOH – Methyl Hydroperoxide	ppbv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	0.001+[40, 10, 5] %	[0.001-10]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
CO – Carbon Monoxide	ppmv	Network, CONUS, Global	[200, 100, 20]	[72, 24, 12]	[36, 12, 6]	[1, 5, 120]	[80, 40, 10] %	0.001+[40, 20, 10] %	[0.001-10]	[40, 20, 10] %/Decade	[2, 3, 6]	1 year
HBr – Hydrogen Bromide	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	1+[40, 10, 5] %	[1-50]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
BrO – Bromine	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[60, 20, 10] %	[30, 20, 10] %	[1-50]	[30, 20, 10] %/Decade	[2, 3, 6]	1 year
BrONO2 – Bromine Nitrate	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	[40, 10, 5] %	[1-50]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
HOBr – Hypobromous Acid	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	[40, 10, 5] %	[1-50]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
BrCl – Bromine Chloride	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	0.01+[40, 10, 5] %	[0.01-10]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
Cl2 – Chlorine	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[1, 5, 120]	[80, 20, 5] %	1.0+[40, 10, 5] %	[1.0-20,000]	[40, 10, 5] %/Decade	[2, 3, 6]	1 year
Aerosol Optical Depth	unitless	Network, CONUS, Global	[50, 5, 1]	[1440, 60, 5] min	[180, 30, 5] min	[1, 5, 120]	[20, 10, 1] %	0.001+[10, 5, 1] %	0 - 50	[10, 5, 1] %/Decade	[2, 3, 6]	1 year
Aerosol Layer Height	km	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5]	[5, 60, 120]	[20, 10, 1] %	0.1+[10, 5, 1] %	0 - 60	NA	[2, 3, 6]	1 year
Aerosol Single Scattering Albedo	unitless	Network, CONUS, Global	[10, 2, 0.1]	[24, 12, 1]	[3, 1, 0.5]	[1,5,120]	[80, 40, 5] %	0.01+[40, 20, 5]	0 - 1	[40, 20, 5] %/Decade	[2, 3, 6]	1 year
Aerosol Refractive	unitless	Network, CONUS, Global	[10, 2, 0.1]	[24, 12, 1]	[3, 1, 0.5]	[1,5,120]	NA	NA	0.0001-2	NA	[2, 3, 6]	1 year

Geophysical Variable	Geophysical Variable Units	Geographic Coverage (dimensionless)	Horizontal Resolution (km)	Temporal Refresh (h)	Data Latency (h)	Vertical Resolution (dof)	Precision: Clear/ Cloudy, Land/ Ocean (%)	Accuracy (%)	Validity Range (Same Units as Variable)	Long- term Stability (%)	Robustness (unitless)	Continuity (yr)
Index												
Aerosol Particle Size	microns	Network, CONUS, Global	[10, 2, 0.1]	[24, 12, 1]	[3, 1, 0.5]	[1,5,120]	[80, 40, 5] %	0.1+[40, 20, 5] %	0 - 100	[40, 20, 5] %/Decade	[2, 3, 6]	1 year
Aerosol Particle Shape	unitless	Network, CONUS, Global	[10, 2, 0.1]	[24, 12, 1]	[3, 1, 0.5]	[1,5,120]	NA	NA	NA	NA	[2, 3, 6]	1 year
Speciated Aerosol Mass	ug/m3	Network, CONUS, Global	[10, 2, 0.1]	[1440, 60, 5] min	[180, 30, 5] min	[1,5,120]	[80, 40, 5] %	2+[40, 20, 5] %	0-1000	[40, 20, 5] %/Decade	[2, 3, 6]	1 year
Volcanic Ash	mg/m3	Network, CONUS, Global	[4, 2, 1]	[720, 10, 1] min	[60, 10, 1 min]	[1,5,120]	[80, 40, 5] %	0.01+[40, 20, 5] %	0.01-1000	[40, 20, 5] %/Decade	[2, 3, 6]	1 year
H2O - Water Vapor	ppmv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5] min	[1, 5, 60]	[20, 10, 5]%	[20, 10, 5]%	1-20	[5, 2, 1] %/Decade	[2, 3, 6]	1 year
SO2 - Sulfur Dioxide	pptv	Network, CONUS, Global	[4, 2, 1]	[720, 10, 1] min	[60, 10, 1] min	[1,5,120]	40, 20, 5] %	0.001+[40, 10, 5] %	[1- 5000]	[5, 2, 1] %/Decade	[2, 3, 6]	1 year
SF6 - Sulphur hexafluoride	pptv	Network, CONUS, Global	[200, 100, 20]	[72, 24, 12]	[36, 12, 6] min	[1, 5, 120]	[20, 10, 1] %	[10, 5, 1] %	[0-10]	[10, 5, 1] %/Decade	[2, 3, 6]	1 year
OH – Hydroxyl Radical	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1]	[3, 1, 0.5] min	[1, 5, 120]	[80, 40, 10] %	0.01+[40, 20, 10] %	[0.01-10]	[40, 20, 10] %/Decade	[2, 3, 6]	1 year
HO2 – Hydroperoxy radical	pptv	Network, CONUS, Global	[50, 5, 1]	[24, 12, 1] min	[3, 1, 0.5] min	[1, 5, 120]	[80, 40, 10] %	0.01+[40, 20, 10] %	[0.01-10]	[40, 20, 10] %/Decade	[2, 3, 6]	1 year

* Surface to 60 km

** Must include surface

<u>Table 4. Stratospheric Composition Observational Need Attribute Priority</u>: List of the stratospheric composition variables as prioritized in Table 1. This table contains the relative importance of the attributes for each of the variables. This provides engineers and designers of sensors and constellations the ability to assess where emphasis should be put when performing trade studies. For each row (variable), the weights between 0 (no importance) and 1 (highest importance) is assigned to the individual attributes described in the columns. NA indicates not applicable.

Geophysical Variable	Images	Geographic Coverage	Horizontal Resolution	Temporal Refresh	Data Latency	Vertical Resolution	Precision: Clear/ Cloudy, Land/ Ocean	Accuracy	Validity Range	Long-term Stability	Robustness	Continuity
O3 – Ozone	1	1	1	1	0.8	1	0.8	1	1	1	1	1
N2O – Nitrous Oxide	0.75	1	0.5	0.5	0.5	0.75	0.8	1	1	1	1	1
CH4 – Methane	0.75	1	0.5	0.5	0.5	1	0.8	1	1	1	1	1
CO2 – Carbon Dioxide	0.5	1	0.5	0.5	0.5	0.5	1	1	1	1	1	1
CFCl3 (F11) – Trichlorofluoromethane	0.5	1	0.5	0.5	0.5	0.5	0.8	1	1	1	1	1
CF2Cl2 (F12) – Dichlorodifluoromethane	0.5	1	0.5	0.5	0.5	0.5	0.8	1	1	1	1	1
CH3Br – Bromomethane	0.5	1	0.5	0.5	0.5	0.5	1	1	1	1	1	1
CF3Br (H1301) – Bromotrifluoromethane	0.5	1	0.5	0.5	0.5	0.5	0.8	1	1	1	1	1
CF2ClBr (H1211) – Bromochlorodifluoromethane	0.5	1	0.5	0.5	0.5	0.5	0.8	1	1	1	1	1
HNO3 - Nitric Acid	1	1	1	1	1	1	0.8	1	1	1	1	1

Geophysical Variable	Images	Geographic Coverage	Horizontal Resolution	Temporal Refresh	Data Latency	Vertical Resolution	Precision: Clear/ Cloudy, Land/ Ocean	Accuracy	Validity Range	Long-term Stability	Robustness	Continuity
N2O5 – Dinitrogen Pentoxide	0.5	1	1	1	1	1	0.8	1	1	1	1	1
H2O2 – Hydrogen Peroxide	0.5	1	1	1	1	1	1	1	1	1	1	1
HCl – Hydrogen Chloride	1	1	1	1	1	1	0.8	1	1	1	1	1
ClONO2 – Chlorine Nitrate	1	1	1	1	1	1	0.8	1	1	1	1	1
ClO - Chlorine Monoxide	0.5	1	1	1	1	1	1	1	1	1	1	1
OClO – Chlorine Dioxide	0.5	1	1	1	1	1	0.8	1	1	1	1	1
HF - Hydrogen Fluoride	0.5	1	0.5	0.5	0.5	0.5	0.8	1	1	1	1	1
HNO4 – Peroxynitric Acid	0.5	1	1	1	1	1	0.8	1	1	1	1	1
HOCl – Hypochlorous Acid	0.5	1	1	1	1	1	1	1	1	1	1	1
NO3 – Nitrate	0.5	1	1	1	1	1	0.8	1	1	1	1	1
NO2 – Nitrogen Dioxide	0.5	1	1	1	1	1	0.8	1	1	1	1	1
NO – Nitrogen Oxide	0.5	1	1	1	1	1	0.8	1	1	1	1	1
CH3OOH – Methyl Hydroperoxide	0.5	1	1	1	1	1	0.8	1	1	1	1	1
CO – Carbon	0.5	1	0.5	0.5	0.5	0.5	0.8	1	1	1	1	1

Geophysical Variable	Images	Geographic Coverage	Horizontal Resolution	Temporal Refresh	Data Latency	Vertical Resolution	Precision: Clear/ Cloudy, Land/ Ocean	Accuracy	Validity Range	Long-term Stability	Robustness	Continuity
Monoxide												
HBr – Hydrogen Bromide	1	1	1	1	1	1	0.8	1	1	1	1	1
BrO – Bromine	0.5	1	1	1	1	1	0.8	1	1	1	1	1
BrONO2 – Bromine Nitrate	1	1	1	1	1	1	1	1	1	1	1	1
HOBr – Hypobromous Acid	0.5	1	1	1	1	1	0.8	1	1	1	1	1
BrCl – Bromine Chloride	0.5	1	1	1	1	1	1	1	1	1	1	1
Cl2 – Chlorine	0.5	1	1	1	1	1	1	1	1	1	1	1
Aerosol Optical Depth	1	1	1	1	1	1	0.8	1	1	1	1	1
Aerosol Layer Height	1	1	1	1	1	1	0.8	1	1	1	1	1
Aerosol Single Scattering Albedo	0.2	1	1	0.5	0.5	1	0.8	1	1	1	1	1
Aerosol Refractive Index	0.2	1	1	0.5	0.5	1	0.8	1	1	1	1	1
Aerosol Particle Size	0.2	1	1	0.7	0.7	1	0.8	1	1	1	1	1
Aerosol Particle Shape	0.2	1	1	0.5	0.5	1	1	1	1	1	1	1
Speciated Aerosol Mass	1	1	1	1	1	1	0.8	1	1	1	1	1

Geophysical Variable	Images	Geographic Coverage	Horizontal Resolution	Temporal Refresh	Data Latency	Vertical Resolution	Precision: Clear/ Cloudy, Land/ Ocean	Accuracy	Validity Range	Long-term Stability	Robustness	Continuity
Volcanic Ash	1	1	1	1	1	1	0.8	1	1	1	1	1
H2O - Water Vapor	1	1	1	1	0.8		0.8	1	1	1	1	1
SO2 - Sulfur Dioxide	1	1	1	1	1	1	0.8	1	1	1	1	1
SF6 - Sulphur Hexafluoride	0.5	1	0.5	0.5	0.5	0.5	0.8	1	1	1	1	1
OH – Hydroxyl Radical	0.5	1	1	1	1	1	0.8	1	1	1	1	1
HO2 – Hydroperoxy Radical	0.5	1	1	1	1	1	0.8	1	1	1	1	1

Sources of Stratospheric Composition Observational Needs:

The Core-SAT team, composed of federal employees from NOAA (including representatives from the NWS, NOAA OSAAP Analysis Team, and the NOAA LEO and GEO Programs), reviewed the air quality monitoring and forecasting observational needs by assessing the users' needs as developed by the SAT air quality subgroup, but also with the findings from other sources including:

- "A Value Assessment of an Atmospheric Composition Capability on the NOAA Next-Generation Geostationary and Extended Orbits (GEO-XO) Missions." DOI: https://doi.org/10.25923/1s4s-t405, https://repository.library.noaa.gov/view/noaa/27224
- "Chemical data assimilation estimates of continental U.S. ozone and nitrogen budgets during the Intercontinental Chemical Transport Experiment–North America." DOI: https://doi.org/10.1029/2006JD007722
- "A revised linear ozone photochemistry parameterization for use in transport and general circulation models: multi-annual simulations." DOI: https://doi.org/10.5194/acp-7-2183-2007
- "Tropospheric chemistry in the Integrated Forecasting System of ECMWF." https://doi.org/10.5194/gmd-8-975-2015
- Community of Practice, product baseline, and user value chain coordination through the User Engagement Council
- "Global Atmospheric Composition Needs from Future Ultraviolet–Visible–Near-Infrared (UV–Vis–NIR) NOAA Satellite Instruments" https://journals.ametsoc.org/view/journals/bams/104/3/BAMS-D-22-0266.1.xml

All these user needs were incorporated into this document, using a prioritized, vetted list of variables, with an agreed upon format (e.g., choice of units, etc.). This will allow for a better understanding of the overall needs for the air quality monitoring and forecasting application, a streamlining of the process to collect observational needs, and minimizing the outreach to users. The requirements' ranges, and their associated priorities, will also serve as an input to the ASPEN tool, which is used to assess potential future architecture solutions and their abilities to meet users' needs.

Important note: This memo was developed by the Subcommittee and approved after deliberations and discussions among the core-SAT, which consist of federal employees only. These recommendations were made following extensive scientific fact-finding, review of the scientific literature, and SAT discussions with scientific experts and others knowledgeable in the field.

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List of Acronyms

Abbreviation	Definition
ARL	Air Resources Laboratory
ASPEN	Advanced Systems Performance Evaluation tool for NOAA
BAMS	Bulletin of the American Meteorological Society
COURL	Consolidated Observational Users Requirements List
CPO	Climate Program Office
CSL	Chemical Sciences Laboratory
DAAS	Deputy Assistant Administrator for Systems
DoD	Department of Defense
ECMWF	European Centre for Medium-Range Weather Forecasts
EMC	Environmental Monitoring Center
EPA	[U.S.] Environmental Protection Agency
GEO	Geosynchronous Earth Orbit
GeoXO	Geostationary Extended Observations (Previously GEO-XO)
GML	Global Monitoring Laboratory
IR	Infrared
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OBS	NWS Office of Observations
OSAAP	Office of System Architecture and Advanced Planning (NOAA/NESDIS)
OSCAR	Observing Systems Capability Analysis and Review tool
RAQMS	Real-time Air Quality Modeling System
SAT	System performance Assessment Team
STAR	Center for Satellite Applications and Research
SWO	Space Weather Office
TPIO	Technology, Planning and Integration for Observation
UV	Ultraviolet
Vis	Visible
WMO	World Meteorological Organization
XORWG	GeoXO Requirements Working Group