Guidance for a Standard Information Gathering Of Performances and Applications Requirements

General Guidance on Gathering Application Requirements and Priority Information: Filling Out ARR and ATP Tables

Templates for an application-dependent requirement ranges (ARR) table and an application-dependent technical priorities (ATP) table are provided. They are meant to offer a standard way to communicate the requirements and priorities of applications. Applications are defined here to encompass models like GFS or HWRF, but also outcomes and mission service areas. This guidance is provided to facilitate this collection of information necessary to get an accurate sense of the requirements and the importance (or priority) of each requirement for applications, both current and future. The ARR and ATP tables standardize the collection of this information by providing a standard way to present these requirements and priorities. These tables will be used by the Government to facilitate the assessment of the trade space of the different solutions to fulfill the application requirements. This assessment is going to be achieved using ASPEN, the Advanced Systems Performance Evaluation tool for NOAA/NESDIS. This in turn will help formulate the optimal solution for NOAA's next-generation space architecture. The requirements are specified in terms of geophysical information content (temperature, moisture, etc. and their associated attributes of temporal refresh, accuracy, spatial coverage, etc.) required by the application to function optimally. The format of the ARR and ATP is consistent with that of the SCP format (Sensor/Constellation Performance table). Indeed, the ARR/ATP tables represent the applications *demands* for the Environmental knowledge, while the SCP represents the capability of the instruments and/or constellation to *offer* knowledge about that same environment. This format consists of a table of observables representing the different components of the Environment (the rows), and their attributes (the columns, including spatial coverage, temporal refresh, etc.). For most of the attributes, the ARR are specified as a triplet—a minimal, middle, and maximal value. It is important to keep in mind that the requirements should be in terms of geophysical variables, and not be technology dependent. For example, requirements from global NWP might call for sounding information (of temperature). In practice, global NWP assimilates radiances not temperature, but those radiances actually are tuned/designed to maximize temperature sounding information and it is in terms of temperature that the requirements should be specified. If tomorrow the same global NWP starts assimilating radiometric counts instead of radiances, the requirement for accurate temperature sounding information (from those counts) would not change. In other words, even though a NWP model assimilates radiances, the ARR should be specified in terms of temperature and moisture profiles because that is what information those radiances will contain. The Application-dependent

Technical priorities (ATP) represent another layer of the application requirements. It represents the relative importance of the requirements for individual observables and their attributes. In other words, it describes how important the variables are to the applications. Is temperature more important than moisture for example? It also represents the relative importance of the different attributes for the same variable. Is vertical resolution more important than spatial coverage for example?

To specify application requirements, we must first list the geophysical variables for which information is needed. For example, a weather forecast model requires information on the wind, temperature, pressure, density, and water vapor in the atmosphere and a number of boundary conditions at the top of the atmosphere (TOA) and at the Earth's surface. For any application within ASPEN, this list of required geophysical variables will be a subset of the (master) list of variables (Table 1) The requirements for each geophysical variable will be described in ASPEN in terms of a subset of the (master) list of attributes (Table 2). The requirements for each attribute of each geophysical variable are given as a triplet of the form [x.min, x.mid, x.max], where x.min is the minimally useful value, x.mid is an intermediate value (not used in the ASPEN prototype), and x.max is the maximally useful value. For example, for temperature error s.d. the ARR could be [3,2,1] indicating that temperature observations with errors 3 K or greater are not useful and that observations with errors less than 1 K are no more useful than those with errors equal to 1 K. In the ASPEN calculations, the ARR is used to normalize the sensor capabilities which are also specified in terms of the same geophysical variables and attributes.

Application requirements will be based on SME inputs and hence will have an element of subjectivity for current applications. ASPEN can also be used to estimate benefits of sensor to planned upgrades of current applications as well as entirely new applications. In these cases the SME inputs will be more subjective. However, for current applications and possibly for applications upgrades currently being tested and evaluated, the degree of subjectivity could be alleviated in part by using OSSE, OSE, and other techniques in order to assess the true application sensitivity to observations and thereby refine the application requirements. Subjectivity will always remain however for the requirements of applications that do not exist in a form that allows quantitative testing. This discussion also applies to the ATP tables discussed next. Note that to apply ASPEN to a planned upgrade or a future application requires new ARR and ATP tables.

For any given application, some variables are more important than others and for a given variable, some attributes are more important than others. The ATP table for an application captures the relative priorities of each cell in the ARR table. The ATP table is used for weights when summarizing the normalized sensor capabilities in a weighted average. This results in a single number representing the relative benefit of the sensor for the application

While the ATP table entries are relative weights for each variable-attribute cell, it is recommended to consider the relative weights between variables and then the relative weights between attributes for that variable. To construct an ATP table, use the "Guide" tab in the ATP file to do this automatically. The ATP sheet will automatically be populated by first normalizing each row of relative attribute weights to sum to 1 and then multiplying by that variable's relative weight. Since the weights are used in a weighted average, so they do not have to sum to 1. It may be useful to choose one important weight, set it to 1 or 100, and then set the other weights relative to that one important weight. Use this approach both to set the Priority for Geophysical Variable weights and the attribute weights separately for each geophysical variable in the Guide sheet. In the Guide sheet (and ARR table), use zero weight for variables and/or attributes that are not relevant to the application.

The information below serves as more detailed guidance, in the form of answers to questions we expect to be asked. More general information can be found in Appendix A.

Specific guidance in the form of Q&As

1. Do I have to fill the ARR and ATP tables?

No, but they are important to fill out if we want a particular application and its requirements to be accounted for in the design of the next-gen space architecture and in routinely assessing the trade space of environmental data optimization (which ones to acquire, to maintain in observations portfolio, to drop, etc.). The ARR and ATP tables are offered as a simplified way to standardize the collection of these application requirements. The ARR and ATP tables will facilitate the assessment of trade space of sensor and/or sensor constellation solutions in a consistent fashion. Without these tables, the application will not be considered in this assessment.

2. What are the ARR and ATP tables?

The ARR table is a way to collect information on the requirements of an application in terms of a description of the Earth environment. First, the ARR table contains the geophysical variables for which the application requires information. Then for each variable, the ARR table contains requirement ranges for different attributes of the variables. Attributes describe the spatial-temporal and vertical coverages and error characteristics that are required. For most of the attributes, the ARR are specified as a triplet—a minimal, middle, and maximal value. The ATP tables have the same columns (attributes) and rows (variables) as the ARR tables. The ATP table entries are the relative importance of each variable-attribute pair.

Each table contains a "Notes" tab that allow adding information deemed needed or missing in the other tabs. The tables also contain an "Uncertainties" tab, to document the uncertainties of the requirements and the technical priorities.

3: What if I don't have geophysical requirements, and instead I have needs in terms of sensors or constellations specific characteristics?

The requirements should be in terms of geophysical information content, not technology solutions. For example, even though a NWP model assimilates radiances that are sensitive to temperature and moisture, the ARR should be specified in terms of temperature and moisture information content (profiles). It should be easier and more straightforward to specify application requirements in terms of geophysical variables.

It is worth noting that, in the process of sensor or constellation design, the aspect of specifying instrument characteristics (specification) is a different step that happens at a later stage. Once the requirements are accounted for and the optimal solution (of sensors and constellations found), then the Government, would be able to start specifying the exact characteristics of the sensors/constellations (bandwidths, frequencies, number of channels/bands, noise level, number of orbits, etc).

4. Why are the ARR and ATP tables needed?

ARR and ATP tables are used to assess the benefits and values of various sensors (or constellations), for both LEO and GEO (as well as GEO-XO) platforms. To allow us to study the trade space of solutions which will lead us to the optimal next-generation space architecture solution. The ARR allows the provision of the geophysical requirements. The ATP tables provide the relative weights applied to the geophysical capability assessments in order to compute the overall benefit of a sensor to an application.

This assessment is done by comparing the requirements of the selected applications against the performances offered by the different technologies/solutions. This will lead to the study of the trade space and the optimization (cost/benefit optimization) of the overall design.

Thus, the presence of ARR/ATP tables for a particular application will allow the application's requirements to influence that trade space assessment, along with many other applications.

5. When I have the ARR and ATP workbooks ready, how should I name the files?

Files should be named ARR_orgID_applicationName_versionNumber and ATP_orgID_applicationName_versionNumber (e.g., ARR_EMC_GDAS_V17.2 and ATP_EMC_GDAS_V17.2). The orgID, applicationName, and versionNumber tokens should match for a pair of ARR and ATP files.

Note that the ARR and ATP are considered to be a pair so their names should be consistent except for the ARR and ATP prefixes.

6. How should I fill the ARR and ATP tables? (Which cells should be filled?)

All the cells without a color background should be filled if possible, except those with gray text. Rows with gray text are not currently used by ASPEN, but are additional variables now being considered for addition to ASPEN. If an application has requirements for these additional variables, then these cells should be filled even if grayed out. The table cells are all initialized either to TBD (to be determined) or 0. Fill the ARR table cell with "NA" and the ATP table cell with zero if the application does not require information on this particular geophysical variable, or if the attribute does not apply to this geophysical variable. It is recommended that both primary (such as model state variables) and secondary variables (such as model boundary conditions) be captured in the ARR and ATP tables. This will allow us to fully assess the benefit of different sensors/constellations to the application. One can consider giving different priorities though to primary and secondary variables if appropriate. For example, in the case that secondary variables are not available, but then can be replaced by climatological information, then their importance is likely less important than variables vital for the execution of the application. See also questions 21-24 and 30.

7. What about filling out descriptive information?

Yes, please fill out the cells (B1:3) labeled ARR and ATP name (B1, give a name to the ARR or ATP table that reflect the application being described here), POC and Organization providing the table (B2, usually the point of contact email address is all that is needed here), version and date (B3, to distinguish several version if need be).

8. What are the different definitions of the variables and their units?

The variables are described in Table 1.

9. What are the attributes and how do I fill them out?

The attributes are described in Table 2. Some specific notes are provided here. In the ARR table, for the "Geographic Coverage" attribute use a descriptive term such as Global, Tropics, CONUS, etc. The list of regions currently recognized by ASPEN are limited and are listed in Table 3. If you suggest additions, please include an unambiguous definition. Add a definition if your term is not standard in the "Notes" tab. For the "Robustness" attribute please report the range of the required number of sources that should provide this geophysical information (variable). For example, if we want the atmospheric temperature to be measured by multiple sources, because the application is an operational application and requires a minimum robustness, then we should report the number of these sources required.

10. What about my imagery requirements?

Imagery is usually used as a stand-in for some geophysical variable(s). That is, the value of imagery is the sensitivity to geophysical information (aerosols, cloud, temperature, moisture, salinity, wave height, fire radiative power, volcanic ash, etc.). If the application requires imagery sensitive to a particular geophysical variable (or a set of them) please set the "imagery" attribute to TRUE for that (those) variable(s). In other words, answer the question "Does the application require an image of (or an image sensitive to) the geophysical variable in this row?" You should also provide additional information about the temporal refresh, horizontal resolution, accuracy, etc. Since not all imagery is the same in terms of these attributes, it is important to specify what requirements are important for the application.

10a. What about sensors data requirements in terms of brightness temperatures and radiances?

As explained above, the requirements are specified in terms of geophysical information content (temperature, moisture, etc. and their associated attributes of temporal refresh, accuracy, spatial coverage, etc.). The requirements should be in terms of geophysical variables, not brightness temperatures or radiances. For example, even though a NWP model assimilates radiances that are sensitive to temperature and moisture, the ARR should be specified in terms of temperature and moisture profiles.

11. What if my requirement does not include a certain geophysical variable or a certain attribute for some geophysical variable? Or if I give no priority to them?

The ASPEN list of variables is meant to describe the entire earth system, from the bottom of the ocean to the sun. Your application probably only requires a subset of these variables, and some of the ASPEN attributes are not relevant to some variables. Anything not applicable should be entered as “NA”. Any not applicable requirement (i.e., ARR table element) should have a zero priority (i.e., ATP table element). If you have a requirement for a variable that is not listed in these templates, please let us know. It is best to document it in the “Notes” tab of the table.

12. What if I have questions or want example ARR and ATP tables?

Please contact Stacy Bunin <stacy.bunin@noaa.gov> or Sid Boukabara <sid.boukabara@noaa.gov>.

13. What is this information going to be used for?

ARR and ATP tables are used by Government in combination with sensor/constellation performance (SCP) tables to assess the trade space of performances. Learned lessons from this exercise will inform our next steps in the next-generation space architecture design. Namely, defining specifics of sensors and constellations that maximize the value to NOAA by best fulfilling the NOAA applications requirements with the best cost for the taxpayers.

14. What if I need to make updates or edits to the ARR and/or ATP table templates?

A tab (i.e., sheet) labeled “Notes” is included in the template files. Please add all your comments or suggested updates in there. Alternatively, please contact Stacy Bunin <stacy.bunin@noaa.gov> or Sid Boukabara <sid.boukabara@noaa.gov>.

15. What if I am uncertain about certain values of the requirements and/or technical priorities?

Please provide a 1-sigma estimate of the uncertainty in the same cell in the ARR “Uncertainties” tab or the ATP “Uncertainties” tab. These tabs are pre-filled with zeros, indicating no uncertainty. The units of these uncertainties are identical to the units of the corresponding variables. These uncertainties will actually be useful for the assessment, since these uncertainties will be used to generate overall uncertainties of the final output from ASPEN.

16. What if I have reservations or concerns about certain things in the ARR and ATP?

Please provide this commentary in the “Notes” tab of either the ARR or ATP file. We will review all notes and either provide clarifications or address the issue(s). Please also provide information on how to contact you to get more information/clarification about the issue or concern.

17. Can I edit the units or names of other "constants" in the table?

The table cells with color fill should not be altered. If you do, those columns or rows will be difficult to use. It is recommended to add a note in the "Notes" tab, to notify us of your belief that we should modify this information.

18. What if I need more information?

Please contact stacy.bunin@noaa.gov or sid.boukabara@noaa.gov for additional information.

19. What about if I have more variables that I would like to highlight in terms of my applications requirements? What if I want to volunteer more information than the tables allow?

Please add geophysical variables as needed. Note however that we will likely not be able to have every single variable. The goal is to be able to represent the entire Earth environment with all its components (atmosphere, ocean, cryosphere, space, etc.) but to avoid duplicate information. For instance, moisture profile should be sufficient to represent moisture in the atmosphere and there should be no need to also include the total precipitable water (TPW). Initial geophysical variables were chosen for the table prototype. These are not grayed out. The grayed-out lines are those that we are considering for future versions. The list of geophysical variables will be expanded in the future as the need arises. Add additional geophysical variables as needed. However, if you add rows (new geophysical variables) or columns (new attributes) these will be reviewed but may not necessarily be used for our assessment. It is suggested that you contact the POCs above to let us know ahead of time as soon as you think of adding new variables or attributes, so we could account for that on our end.

20. What if I would like to provide a pair of ARR and ATP tables for other candidate applications that I believe should also be accounted?

Please do so. There should be a pair of one ARR and one ATP file for each candidate application. Please provide multiple tables for different applications. In addition, there may be several modes of operation or a planned series of revisions for the same application, each with different requirements. Please provide a separate table for each operational mode or version of interest. For example, the global NWP model often runs with two different latency requirements, first say 4 h for the forecast, and second say 9 h for the analysis that precedes the short-term forecast leading up to the next analysis. Another case that might require multiple tables for the same application is when we want to capture the current and future state of the application.

21. Do the ARR and ATP tables need to be consistent?

The ARR and ATP table are used together to normalize sensor capabilities and to sum the normalized results for an overall benefit. Variables or attributes of certain variables that are not applicable and therefore have no priority should be coded as NA in the ARR table and zero in the ATP table. All other cells should have valid ARR table entries and greater than zero ATP entries.

22. How should the ARR and ATP table entries relate to each other?

For a given table entry (i.e., variable-attribute cell) the three entries in the ARR table are used to normalize the sensor/constellation capability as depicted in Figure 1. This normalized value is called the geophysical capability assessment of the attribute of that variable and represents the degree to which this particular requirement is satisfied by the given sensor or constellation for the given application. Each ATP table entry gives the relative weight of the corresponding variable-attribute combination for the application.

23. How do I fill out the uncertainties of the requirements ranges and the technical priorities?

Your estimates of the ARR and ATP table entries, i.e., of the requirement ranges and priorities, may be very well known or educated guesses. In the first case, uncertainties should simply be set to 0. But if that is not the case, please also estimate the uncertainty of your estimates. These uncertainties will be used in Monte Carlo simulations to estimate the uncertainties of the ASPEN outputs.

24. For the ATP, can you explain how to distinguish the relative weights of observables/variables and then the relative weights of the attributes for each observable?

The ATP table entries are relative weights for each variable-attribute cell. It is recommended to consider the relative weights between variables and then for each variable the relative weights between attributes. To construct an ATP table, use the Guide sheet in the ATP file to do this automatically.

25. Are the ATP and ARR sensor and/or constellation dependent?

No. The ARR and ATP tables should depend only on the application and ideally should not consider the technological solutions that might be employed to fulfill the application requirements. This is important, because we want to assess the values of different technology solutions against the same set of requirements. If the requirements are set in terms of a specific solution (e.g., requirement for a 6.9 micron IR channel for instance) this will inevitably lead to a bias toward that technology and will prevent us from performing an unprejudiced trade space and technology value assessment.

26. What if I have requirements in sensor space (bandwidth, bands, noise level, etc)?

See Q3.

27. Do you have an example of ATP and ARR I can use as a template?

Yes. The blank template is provided as a separate .xlsx file. Filled in examples can also be provided.

28. What if my application is changing, and the requirements/priorities I give today might become obsolete in the near future?

See Q20. Please provide different ARR and ATP tables for different application versions. This will allow you, for example, to add new variables that are now not required but that are expected to become requirements in the near- or long-term future. Note that while the requirements are set in terms of ranges, a table for a current application should *not* use the upper end of the range to predict what the future requirements of the application might be. See Q29 for a detailed description of the requirements ranges.

29. What do the requirements ranges correspond to? What is the middle value used for?

The three values in the requirements ranges, denoted x.min, x.mid, and x.max define the shape of the normalization function. The extremes (x.min and x.max) correspond to the minimally and maximally useful values of the parameter. Thus values worse than x.min are normalized to zero (meaning they provide no value to the application), values better than x.max are normalized to one (they provide the maximum information above which there is no added information provided), and in the simplest case the normalization varies linearly in between x.min and x.max. This formulation looks like but is different than other requirement ranges that might be specified by a triplet as in OSCAR (threshold, breakthrough, goal) and SPRWG (study threshold, expected, maximum effective). The OSCAR and SPRWG triplets specify current and future requirements for observing systems. In ASPEN the requirement ranges relate to the usefulness of data to specific applications. . Note that for several attributes smaller is better, so x.max is smaller than x.min. The middle value (x.mid) is usually the x value that corresponds to fulfilling the requirements at the 70% level. If you want to use x.min to correspond to some other level of satisfaction, please do so, but be sure to make a note of this. When x.mid is the midpoint between x.min and x.max, and x.mid corresponds to the 50% level, then the normalization curve is linear. The prototype ASPEN calculations do not make use of the x.mid value. Plans are to use a power law or logistics equation to use the x.mid value in the future.

30. Do the ATP values need to be between 0 and 1? Does the total need to add up to 1?

The scale for the ATP values is arbitrary since they will be used in a weighted average. They do not have to be between 0 and 1. They do not have to sum to 1. They should not be negative. When ASPEN calculates a weighted average, this calculation essentially normalizes all the weights to sum to one.

31. How do I fill the ATP values then?

It is recommended to follow the following process:

- Decide which variable is more important than the others and provide these relative weights in the column E in the “Guide” tab, which is labeled in E4 as the “Priority for Geophysical Variable”. Note that variables that are not applicable, i.e., variables with only NA entries in the corresponding row in the ARR table, should have a column E weight of 0.
- For each variable with a positive column E weight, decide which attributes are more important than the others, and decide on the corresponding relative weights for the

attributes in columns F:S. Column T, labeled “Working Sum” is a calculated column and should not be altered.

32. What if my application is dependent on other applications?

Some of your application requirements may be satisfied by another application. For example, GFS provides boundary conditions to other models. If some requirements are normally met by another application, please add this information to the “Notes” tab.

Specific Guidance and additional info for the requirements ranges and technical priorities

- *Source of requirements.* Requirements are ultimately determined by SMEs. For an initial capability, the ASPEN project determined requirements (and priorities) from existing data bases including NOSIA, SPRWG, and OSCAR.
- *Independence between requirements and technical priorities*. The requirements and priorities are independent but are related in how ASPEN uses them (see Q22) and for every requirement there should be a priority.
- *Independence from sensor-specific and technology-specific performances*. The requirements and priorities should depend only on the application and ideally should not relate to the sensor-specific and technology-specific methods of fulfilling the requirements. The requirements and priorities should describe the information content and relative importance of that content that is required by the application(s).
- *Assumptions.* Any assumptions made in filling out the ARR and ATP tables should be noted, preferably in the “Notes” tab of the ARR or ATP file.

Table 1. Geophysical variables describing the Earth environment.

Environmental Domain	Geophysical Variable	Symbol / Abbreviation	Units (s.d. Units)
Atmosphere	Relative Humidity	RH	%
Atmosphere	Wind Speed Profile: Eastward	u	m/s
Atmosphere	Wind Speed Profile: Northward	v	m/s
Atmosphere	Aerosol Concentration	n_A	/m3
Atmosphere	Cloud Cover	CC	Fraction
Atmosphere	Ozone Concentration (Column)	O_3	DU
Atmosphere	Cloud and Moisture Imagery	CMI	NA
Atmosphere	Incoming Shortwave Radiation: Surface	ISR	W/m2
Atmosphere	Air Temperature: Profiles	T(z)	K
Atmosphere	Water Vapor: Boundary Layer Depth	WV_BLD	km
Atmosphere	Carbon Dioxide/CO2	CO2	ppm
Atmosphere	Total Lightning	TL	**%**
Atmosphere	Specific Humidity	q	g/kg
Atmosphere	Methane CH4	CH4	ppmv
Atmosphere	Carbon Monoxide/CO	CO	ppbv
Atmosphere	Sulfur Dioxide/SO2	SO2	DU
Atmosphere	Total Precipitable Water	TPW	mm
Atmosphere	Layer Precip Water	LayerPW	mm
Atmosphere	Aerosol Optical Depth/Thickness	AOT	unitless
Atmosphere	Ozone profile (Troposphere vs stratosphere)	O3_p	%
Atmosphere	Nitrogen Dioxide/NO2	NO2	ppb
Atmosphere	Smoke (evaluated at night)	Smoke_Night	unitless
Atmosphere	Hydrometer Size and Type (Low Cloud and Fog eval at night)	HST_LCF	%
Atmosphere	Aerosol Refractive Index	ARI	TBD
Atmosphere	Effective reflectivity	ER	%
Atmosphere	Aerosol Layer Height	ALH	km
Atmosphere	UV Aerosol Index	UV_AI	km
Atmosphere	Formaldehyde/CH2O	CH2O	molecules/m2
Atmosphere	Glyoxal/C2H2O2	C2H2O2	molecules/m2
Atmosphere	Isoprene/C5H8	C5H8	ppm
Biosphere	Fire Radiative Power	FRP	MW/km2
Biosphere	Flood standing water: Extent	FI	%
Biosphere	Normalized Difference Vegetation Index	NDVI	unitless
Biosphere	Soil Moisture: Surface Wetness	W	m3/m3
Biosphere	Land Surface Albedo	LSA	unitless

Biosphere	Fires: Location and Size (taking size)	fire_size	km
Biosphere	Land Surface Temperature	LST	K
Biosphere	Surface Type	ST	unitless
Cryosphere	Sea Ice Age	SIA	yr
Cryosphere	Sea Ice Concentration	SIC	%
Cryosphere	Snow Water Equivalent	SWE	cm
Cryosphere	Ice Surface Temperature	IST	K
Cryosphere	Snow Cover	SC	%
Cryosphere	Snow Depth	SD	m
Cryosphere	Snow Grain Size	SGS	mm
Cryosphere	Sea Ice Motion, Local	SIM_Local	m/s
Hydrosphere	Cloud Liquid Water Path	LWC	g/m2
Hydrosphere	Rain Rate	RR	mm/hr
Hydrosphere	Cloud Drop Size (at Cloud Top)	CPS	um
Hydrosphere	Cloud Top Temperature	CTT	K
Hydrosphere	Precipitation Rate/Snowfall Rate	SFR	mm/hr
Hydrosphere	Cloud Base Height	CBH	km
Ocean	Ocean color: Chlorophyll-a Concentration	Chl	mg/m3
Ocean	Salinity	S	PSU
Ocean	Sea Surface Height	eta	cm
Ocean	Sea Surface Temperature	SST	K
Ocean	Bathymetry	B	TBD
Ocean	Wave Height	h	m
Ocean	Global Sea Surface Wind Speed	OSWS	m/s
Ocean	Global Sea Surface Wind Direction	OSWD	deg
Space	Electrons: Medium & High Energy, GEO	e_MedHI_GEO	#/(cm2-s-sr-keV)
Space	Electrons and Protons: Low Energy, GEO	ep_Low_GEO	#/(cm2-s-sr-eV)
Space	Protons: Medium and High Energy, GEO	p_MedHi_GEO	#/(cm2-s-sr-KeV)
Space	Solar and Galactic Protons: GEO	p_SEPGCR_GEO	#/(cm2-s-sr-MeV)
Space	Solar Wind: Low Energy Particle Population, L1	part_Low_L1	#/(cm2-s-sr-keV)
Space	Solar Wind: Plasma Ion Density, L1	rho_L1	#/cm3
Space	Solar Wind: Plasma Ion Temperature, L1	T_L1	K
Space	Solar Wind: Plasma Ion Velocity Vector, L1	Vel_L1	km/s

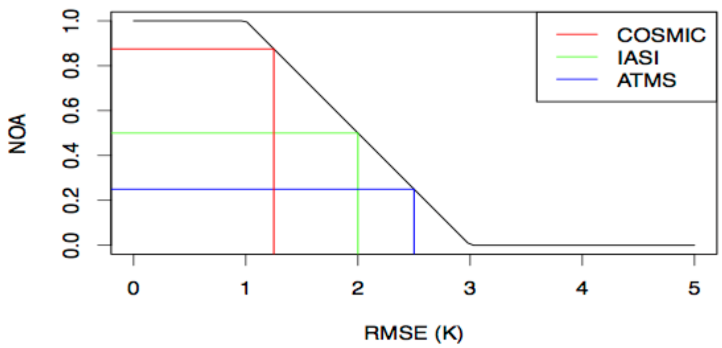
Space	Ionospheric Electron Density Profiles	e_iono	#/cm3
Space	Solar Wind: High Energy Electrons, L1	e_Hi_L1	#/(cm2-s-str-MeV)
Space	Electrons: Medium and High Energy, LEO	e_MedHI_LEO	#/(cm2-s-str-KeV)
Space	Ions: Medium and High Energy, LEO	ion_MedHi_LEO	#/(cm2-s-str-MeV)
Space	Geomagnetic Field: GEO	mag_GEO	nT
Space	Solar Wind: Magnetic Field Vector, L1	mag_L1	nT
Space	Geomagnetic Field: LEO	mag_LEO	nT
Space	Geomagnetic Field: MEO	mag_MEO	nT
Space	Solar Flux: EUV	sun_flux_EUV	W/m2
Space	Solar Flux: X-Ray Irradiance	sun_flux_Xray	W/m2
Space	Solar Imagery: Multi-Spectral X-Ray/EUV Radiance, EarthSun Line	sun_image	W/m2
Space	Solar Imagery: Corona, L1	sun_corona_L1	W/m2
Space	Solar Imagery: Corona, L5	sun_corona_L5	W/m2
Space	Multispectral Auroral Imaging	aurora_image	W/m2
Space	Mesosphere and Lower Thermosphere Atomic Oxygen Vertical Profiles	MT_O	#/cm3
Space	Mesosphere and Lower Thermosphere Winds Vertical Profile	MT_Wind	m/s
Space	Solar Imagery: Heliospheric, L1	Sol_Im_HelioL1	W/m2
Space	Solar Imagery: Heliospheric, L5	Sol_Im_HelioL5	W/m2
Space	Solar Imagery: Magnetogram, L1	Sol_Im_MagL1	nm
Space	Solar Imagery: Magnetogram, L5	Sol_Im_MagL5	nm
Space	Solar Imagery: White Light, L5	Sol_Im_WhiteL5	W/m2
Space	Interplanetary energetic particles	p_SEPGCR_planet	#/(cm2-s-sr-MeV)
Space	Interplanetary Solar wind: L5	part_Low_L5	#/(cm2-s-sr-keV)

Table 2. Attributes of a description of the Earth environment.

Attribute	Symbol	Units	Definition
Imagery Representation	I	logical	This parameter is represented by imagery.
Geographic Coverage	D	dimensionless	Geographic region observed
Horizontal Density	N_A	(100 km)-2	Number of observations within swath per (100 km) square region.
Horizontal Resolution	delta_x	Km	GIFOV or ground-projected instantaneous field of view
Temporal Refresh	T_R	H	Time between observations at a location, i.e, time to observe the geographic coverage region D.
Vertical Extent Bottom	E_b	Km	Bottom of vertical region observed.
Vertical Extent Top	E_t	Km	Top of vertical region observed
Vertical Resolution	N_v	d.o.f	Independent pieces of information in one GIFOV.
Accuracy (Error Standard Deviation)	a	units	Composite accuracy over the vertical layers, over the clear and cloudy conditions, and over different surface backgrounds (when appropriate).
Validity Range Low	V_l	units	Low value that can be observed.
Validity Range High	V_h	units	High value that can be observed.
Robustness	N_S	dimensionless	Number of sources making this observation
Continuity	T_C	Yr	Time for which the observations can be intercalibrated for climate monitoring purposes.
Data Latency	T_L	h	Time from ‘image taken’ to full relay of data to a ground station.

Table 3. Geographic Regions Currently Recognized by ASPEN

Geographic Region	Area	Description	Short Name
Name/Description	km^2		Nickname
Global	5.11E+08	90S to 90N; 0E to 360E	Global
Northern Hemisphere Extratropics	1.28E+08	30N to 90N; 0E to 360E	NHX
Tropics	2.56E+08	30S to 30N; 0E to 360E	Tropics
Southern Hemisphere Extratropics	1.28E+08	90S to 30S; 0E to 360E	SHX
Continental U.S.	8.08E+06	https://en.wikipedia.org/wiki/Contiguous_United_States	CONUS
CONUS East	1.28E+08	NHX centered at 0N; 75W	GEO-75W-60N
CONUS West	1.28E+08	NHX centered at 0N; 135W	GEO-135W-60N
Sun-Earth L1			
Sun-Earth L5			
Insitu MEO			
Insitu LEO			
Insitu GEO			



	RMSE	NOA
ATMS	2.50	0.250
IASI	2.00	0.500
COSMIC	1.25	0.875

Figure 1. The min-max normalization process. In this idealized example, the application requires temperature observations with a useful accuracy range from 1 to 3 K RMSE. The normalized observation accuracy (NOA) is calculated for ATMS, IASI, and COSMIC, using the assumed RMSE values given in the table.