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NPOESS Community Collaborative Calibration/Validation Plan for the NPOESS Preparatory Project OMPS EDRs

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ELECTRONIC APPROVAL SIGNATURES:

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1.0 INTRODUCTION

This calibration/validation (cal/val) plan describes our approach for validating the Environmental Data Records (EDRs) for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) Ozone Mapping and Profiler Suite (OMPS). The validation products covered in this plan are the OMPS Nadir Mapper (NM) Total Column Ozone (TOZ) EDR, the OMPS Nadir Profiler (NP) Ozone Profile Delivered Intermediate Product (DIP), and the Cross-track Infrared Scanner (CrIS) infrared (IR) Ozone DIP. The OMPS products will require global validation. Details of task activities, actors, resources, and their relation to existing programs are provided.

1.1 Building on the Heritage

The main thrust of the work is to replicate and expand what has already been done for data products from the second-generation Solar Backscatter Ultraviolet instrument (SBUV/2) and the Global Ozone Monitoring Experiment-2 (GOME-2), and to perform similar analysis and evaluation for the OMPS products.

This plan has considerable redundancy in validation assets. There are multiple BUV instruments in operation. It is unlikely that all these resources would fail. While comparisons to other satellite instrument products is not direct validation, it does allow the transfer of characterization obtained for an instrument over longer times to a newer one through the dense sampling of both. Ground-based validation assets have also been selected with redundancy in both number and types of stations. The plan also will generate results from heritage algorithms. These serve two purposes: one is to check on the performance of new algorithms relative to older ones; the second is to allow direct comparison of new results with satellites products generated with older algorithms.

1.2 Distribution of Effort

The principal activities will be performed by researchers at the National Oceanic and Atmospheric Administration’s (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS), NOAA’s National Weather Service (NWS) and the National Centers for Environmental Prediction (NCEP), NOAA’s Office of Oceanic and Atmospheric Research (OAR) and Earth Systems Research Laboratory (ESRL), the National Aeronautics and Space Administration’s (NASA) Goddard Space Flight Center (GSFC), and members of the Northrop Grumman Aerospace Systems (NGAS) calibration/validation team—especially those working on the OMPS Sensor Data Records (SDRs)—and the NPP on-orbit verification team.

These participants will use computing resources at their respective home institutions and the NPOESS Government Resource for Algorithm Verification, Independent Testing, and Evaluation (GRAVITE), the Algorithm Development Area (ADA), the ESS Science Investigator-led Processing System (NSIPS), and the NASA Science Data Segment (SDS) (via the OMPS Product and Evaluation and Test Element (PEATE)). The participants will make comparisons to their own data sets as well as others from the World Ozone and Ultraviolet

Radiation Data Centre (WOUDC), the Aura Validation Data Center (AVDC), and the Network for the Detection of Atmospheric Composition Change (NDACC).

1.3 Key Participants

Key personnel and organizations supporting the activities described in this plan are provided in the following tables.

1.3.1 Lead Responsibilities

Table 1. Division of Lead Responsibilities

Team Lead and Ozone Operational Algorithm Team (O3OAT) Chair	Lawrence.E.Flynn@noaa.gov
NESDIS Tasks	Early orbit analysis Internal consistency Satellite comparisons Monitoring and trending
Ground-based Comparisons Lead	Irina.Petro@noaa.gov
ESRL Tasks	Ground-based processing and operations Ground-based comparisons
Product User Lead	Craig.Long@noaa.gov
NCEP Tasks	Product application evaluation

The lead for the OMPS EDR and IP calibration and validation team is L. Flynn. He is currently the co-chair of the NESDIS Atmospheric Chemistry Product Oversight Panel, the chair of the IPO Ozone Operational Algorithm Team, and the NESDIS SBUV/2 calibration scientist. He is responsible for developing the content of the NESDIS Integrated Calibration/Validation System (ICVS) for UV instruments.

The lead for the OMPS suborbital data component is Irina Petropavlovskikh. She is the developer of the current Umkehr ozone profile retrieval algorithm. Among her colleagues at the ESRL are the NOAA experts on Dobson instruments, Brewer instruments, and ozone balloonsondes.

The lead for the OMPS product evaluation component is Craig Long of NCEP. He is in charge of producing the UV index forecasts, conducting NOAA's satellite-based ozone layer monitoring, and creating NOAA's Northern and Southern Hemisphere Winter Stratospheric Summaries.

1.3.2 Other Key Participant Individuals and Organizations

Other key participants include: NASA-affiliated personnel in the Earth Observing System (EOS) Aura Mission, the NPOESS Preparatory Project (NPP), and the Measures Ozone Program; NOAA-affiliated personnel in the NPOESS Data Exploitation (NDE) project, the Product Oversight Panels, and the cooperative research centers, e.g., the Joint Center for Satellite Data Assimilations (JCSDA); and other national and international members of the ozone research community. The participants include the following: (See Appendix IV for expansions of abbreviations and acronyms)

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NPOESS has responsibility for organizing and running the Ozone Operational Algorithm Team (O3OAT), Data Analysis Working Group (DAWG), NGAS Algorithm Team, and the OMPS SDR and EDR Validation Teams.

2.0 OBJECTIVES AND EXIT CRITERIA

The primary objectives for the OMPS product cal/val plan are to validate products during the Intensive Calibration and Validation (ICV) phase. Activities in earlier phases are mainly preparation for the tasks in this phase. See Section 3.2 for a discussion of cal/val phases and related OMPS activities.

There are few hard pre-launch (PL) phase objectives. The goals are to have tools, readers, and algorithms ready and tested for application to the tasks post-launch. If tools are not completed, then work will continue during later phases. There are also goals for maintaining and improving the ground-based assets. There are related actions elsewhere in the OMPS program that need to finished prior to launch including the creation of the Integrated Mission Timeline (IMT), completion of SDR and EDR algorithms data tasks, delivery of instrument characterizations and test results, and creation of correction modules. These are integral to the performance of the tasks in this plan, and the timing of some development and testing is dependent upon their completion.

2.1 Ozone Total Column EDR and Profile DIP Requirements for Mission Success

The OMPS NM TOZ EDR has two levels of performance requirements: operational requirements and long-term stability (LTS) (climate; LTS-(C)) requirements. The latter involve trending of instrument performance over the life of the mission, and will require reprocessing to meet the desired levels of accuracy. (Reprocessing is the creation of products from SDRs that have been improved by retrospective characterization and analysis. These are by definition not the operational EDRs and DIPs of the NPOESS program.) The EDR requirements are in Table 2, below, based on the NGAS-generated NPOESS system specification document (York 2007).

Table 2. OMPS Total Ozone EDR performance requirement attributes

EDR/Attribute	Appendix D Specification
Horizontal Cell Size (HCS)	50 km @ nadir
Horizontal Reporting Interval	50 km @ nadir
Vertical Cell Size	60 km
Solar Zenith Angle (SZA) coverage	SZA < 80 deg
Vertical Coverage	0 to 60 km
Measurement Range	50 to 650 DU[1]
Measurement Accuracy	
TOZ > 450 DU	16 DU
250 DU < TOZ < 450 DU	13 DU
TOZ < 250 DU	9.5 DU
Measurement Precision	
TOZ > 450 DU	7.75 DU + 1.1% of ozone over 450 DU
250 DU < TOZ < 450 DU	7.7 DU
TOZ < 250 DU	6.0 DU
Mapping uncertainty, 1 Sigma	5 km
Maximum Local Average Revisit Time	24 hrs
Latency	NPP - 140 min; NPOESS - 28 min
Measurement Degradation Conditions	
Total Column Accuracy SO_2 Index (SOI) > 6 DU	15 DU + 3 SOI
Total Column Precision SO_2 Index > 6 DU	6 DU + 1.5 SOI

[1] DU = Dobson Unit, 1 milli-atmosphere centimeter

It has been agreed that—like heritage sensors—the OMPS will continue to make measurements and products beyond the 80-degree solar zenith angle (SZA) limit, but that the products will not have to meet these requirements there. However, we will evaluate the performance everywhere. The OMPS total ozone EDR has a long-term stability requirement of 1% over seven years, but reprocessing will be required to reach this performance level.

Concern over the cloud top pressure information that is used in the TOZ algorithm has grown as it has become clear that there are significant differences between cloud top pressures estimated for IR radiances compared to those for UV radiances. Current and alternative algorithm performance in this area will be an area of key interest. We will work with the Version 8.5 and Version 9 Total Ozone Mapping Spectrometer (TOMS)-heritage total ozone algorithms, which contain better information on UV-cloud top pressures, as part of OMPS EDR validation activities. We are investigating the use of a new effective UV cloud top pressure climatology derived from Ozone Monitoring Instrument (OMI) measurements for use with the heritage Version 8 TOMS algorithm as applied to the GOME-2 instrument.

The OMPS Nadir Profiler DIP product has been given the role of continuing the heritage performance of the NOAA Polar-orbiting Operational Environmental Satellite (POES) SBUV/2 mission. Thus, its requirements are to continue the performance of that series both for operational and climate applications. The measurements will be processed with heritage algorithms; therefore, the SDR performance becomes the key requirement. The OMPS NP SDR performance requirements and comparisons to the SBUV/2 measurements are given in the following table from Ball Aerospace & Technology Corporation (BATC), which is building the OMPS.

Table 3. OMPS Ozone Profile SDR performance requirements

Sensor Parameter	Baseline Algorithm Needs	Baseline Sensor Allocation	Comments
Wavelength Range	252-380 nm min. (252-306 for profile)	250-310 nm min. (310-380 nm from NM)	Ozone profile, column, reflectivity
Bandwidth (FWHM)	1.1 nm	1 nm	
Samples/FWHM	1 (minimum)	2.4	λ shift, Ring effect
Number of Channels	13 discrete channels* (8 below 310 nm)	Hyperspectral coverage: 250-380 nm	Triplets, over-sampling, aerosols
Horizontal Cell Size (HCS)	250 km @ nadir	250 km @ nadir	Heritage sampling
Signal-to-Noise Ratio (SNR)	From SBUV/2 spec 35 to 400, short to long	SBUV/2 spec values for NP channels, 1000 for TOZ channels	Precision
Polarization sensitivity	<5%	<5%	Accuracy
λ registration	< 0.01 nm	< 0.01 nm	Ozone cross-section
Albedo calibration	2%	2%	Accuracy and stability
Pixel to pixel calibration and linearity	1% max	1% max	Accuracy
Stray light, out-of-field	1% max (integrated)	1% max	Accuracy and stability
Stray light, out-of-band	1% max (all wavelengths)	1% max	Accuracy and stability

* The 8 profiling wavelengths are: 252.00, 273.61, 283.10, 287.70, 292.29, 297.59, 301.97, and 305.87 nm. The wavelength channels from the total column focal plane are 312.6, 317.6, 331.3, 339.9, and 379.6 nm.

There is a known deficiency in the OMPS NP, namely, its performance in the South Atlantic Anomaly (SAA). The charge-coupled device (CCD) array detectors will be susceptible to measurement errors from charged particles in the region, with a frequency and size large enough to alter and corrupt the retrieved profiles. Therefore, we will lose coverage in this region relative to current performance. The extent of the loss will be evaluated, as will flagging and mitigation options.

The NPOESS system will also provide a Cross-track Infrared Sounder (CrIS)-based ozone IP. This product is provided without performance requirements. We will refer to this product as the IR ozone IP. We expect it will have similar quality to the existing Earth Observing System (EOS) Atmospheric Infrared Sounder (AIRS) ozone products as described and validated in a recent publication (Divakarla *et al.* 2008).

2.2 Attaining Compatibility of Products with User Expectations

For the ozone profile DIP, current Interface Data Processing Segment (IDPS) plans are to use the Version 6 ozone profile algorithm developed for the SBUV/2 program; NOAA's operational SBUV/2 program uses a newer version, Version 8. As part of other work for the IPO, we are adapting this latter algorithm for use with OMPS measurements, and we will evaluate and validate the products from this algorithm as part of this plan. As we explain later, the Version 8 algorithm has some good properties for intercomparisons and internal checks. If the IPO decides that this algorithm should progress to implementation on the IDPS, we will implement/test it in the Algorithm Development Area (ADA) or Government Resource for Algorithm Verification, Independent Testing, and Evaluation (GRAVITE) environments.

The total ozone EDR products will meet the expectations of users for near-real-time (NRT) applications if they meet the performance requirements, and extend the products to 84º SZA or higher. Note that the creation of Climate Data Record (CDR) products for ozone assessment and long-term trend studies will require reprocessing. We will not validate CDRs directly as a part of this work, but we will evaluate trending to begin tracking the long-term stability of the measurements. In addition, we will implement alternative algorithms that are consistent with those used in heritage programs for CDR creation.

2.3 Integrating with Current Operational Capabilities

GOME-2

The GOME-2 is a new operational UV instrument on the European Meteorological Satellite (EUMETSAT) program's polar-orbiting MetOp-A satellite. It uses linear arrays of detectors to get simultaneous hyperspectral coverage from 240 nm to 790 nm. It produces close to full global coverage by using a mirror to scan cross-track. The fields-of-view (FOVs) for the total ozone wavelengths are 40 x 80 km^2. It has a solar diffuser to monitor instrument throughput degradation and on-board lamps for etalon and spectral scale measurements. The primary NOAA operational ozone products are total column ozone estimates with near-global coverage from the Version 8 TOMS-heritage retrieval algorithm. We expect to upgrade this to the Version 8.5 algorithm to make use of better cloud top pressure information contained within the GOME-2 measurements. This Version 8 algorithm is the best that is available for the historical TOMS record, so record consistency concerns are present for CDR—as opposed to EDR—use. Work is being done in parallel to examine the use of the improved cloud pressure climatology from the OMI record with the heritage algorithm. GOME-2 ozone profile products are currently under development.

2.3.2 OMI

NASA's Earth Observing System (EOS)-era Aura platform Ozone Mapping Instrument (OMI) has two-dimensional array detectors that make hyperspectral measurements from 270 nm to 500 nm, with 12 x 24 km^2 FOVs for total ozone at nadir. It uses solar diffusers and an on-board lamp for calibration measurements. We are in the process of accessing and assessing both total column ozone and ozone profiles as products-of-opportunity from the NRT OMI processing system at GSFC. These assets mean that comparisons of the OMPS EDR to current capabilities should be made with consideration of non-NOAA ozone products.

2.3.3 SBUV/2

There are four currently operating SBUV/2 instruments, the final instrument having been launched on NOAA-19 in February 2009. Their principal earth-view measurement mode is 12 sequential measurements made over 24 seconds, with approximately 200 x 200 km^2 FOVs. The 12 wavelengths are distributed from 253 nm to 340 nm; an additional sensor component makes measurements at 380 nm coincident with each of these. In a second mode, called continuous-scan mode, full spectral measurements are made from 180 nm to 400 nm, sweeping through 1500 wavelengths over a two-minute span. Corresponding discrete and continuous solar irradiance spectral measurements are made by deploying a diffuser into the FOV. There is an on-board Hg lamp for calibration diffuser degradation measurements. The instrument uses three gain ranges with factors of approximately 100 in the gain changes, to cover the full measurement range. The primary operational products are ozone profiles from the Version 8 SBUV/2 retrieval algorithm. These are generated operationally at NESDIS for NRT users, and reprocessed—also at NESDIS—with retrospective calibration and characterization into CDRs for long-term studies.

The key measurements for deriving ozone and other atmospheric products are the ratios of Earth radiance to solar irradiance. The systems are designed so that many throughput and sensitivity changes will cancel out for these ratios. The notable exceptions are the solar diffusers, so the principal calibration chore is tracking the solar diffuser degradation/changes. As noted earlier, the SBUV/2 can view an on-board Hg lamp directly or as illumination of the diffuser to help track these changes. The later TOMS instrument used multiple diffusers, similar to the OMPS on-orbit calibration concept.

2.3.4 Applications

Current NRT ozone products are assimilated into numerical weather models, used to make UV index forecasts, to provide boundary conditions for air quality models, and to monitor the presence and extent of the Antarctic ozone hole. The CDRs from existing systems are used to assess the health of the ozone layer and in climate change studies.

A combined product, using High-resolution Infrared Radiation Sounder (HIRS) ozone information in combination with the SBUV/2 Total Ozone Analysis using SBUV/2 and TOVS (TOAST), is currently providing daily maps with coverage into the polar night. Similar combinations and applications should be developed using the CrIS IR ozone IP.

2.4 Satisfying Stratification and Exclusion Conditions

Stratification Conditions

The main discriminator for evaluating the performance of the total ozone EDRs is column amount. This is because there are multiple sources of imprecision in the estimates. There is a limit on the precision imposed by the measurement SNR, which impacts the estimates in a proportional manner. Further, there are errors caused by the scene conditions, *e.g.,* cloud cover, generate absolute errors related to the amount of ozone below the clouds.

The other important division is based on SZA: At high SZA, the path length through the atmosphere becomes longer. The OMPS total ozone algorithm adjusts for this by changing the selection of wavelength triplets (an absorption pair with a longer reflectivity channel) based on ozone absorption cross sections. This is shown in Table 2 from the OMPS TOZ EDR Algorithm Theoretical Basis Document (ATBD), where SΩ is the geometric path length times the column ozone in atmosphere centimeters (1000 DU). We expect good performance well beyond 80 degrees SZA. Notice that SΩ ~ 6 for at 86 degrees SZA for a 400 DU total column ozone amount.

Table 4. Triplet selection as ozone path length varies

λ Pairs \ SΩ	0.75	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00	5.00	6.00
308.5 – 321.0	1.96	2.61	3.26	3.92	4.57	5.22	6.53	7.83	9.14	10.44	13.05	15.66
310.5 – 321.0	1.39	1.85	2.32	2.78	3.24	3.71	4.63	5.56	6.48	7.41	9.26	11.12
312.0 – 321.0	1.06	1.41	1.77	2.12	2.48	2.83	3.54	4.24	[illegible]	[illegible]	7.07	8.49
312.5 – 321.0	0.92	1.23	1.54	1.85	2.16	2.46	3.08	3.70	[illegible]	[illegible]	[illegible]	7.39
314.0 – 321.0	0.79	1.05	1.31	1.57	1.83	2.09	2.62	3.14	[illegible]	[illegible]	5.23	6.28
318.0 – 336.0	0.62	0.83	1.04	1.24	1.45	1.66	2.07	2.49	2.90	3.32	4.15	4.97
315.0 – 321.0	0.54	0.72	0.90	1.09	1.27	1.45	1.81	2.17	2.53	2.90	3.62	4.34
320.0 – 329.0	0.44	0.59	0.73	0.88	1.03	1.17	1.47	1.76	2.05	2.35	2.93	3.52
322.5 – 332.0	0.33	[illegible]	[illegible]	0.65	0.76	0.87	1.09	1.30	1.52	1.74	2.17	2.61
325.0 – 336.0	0.27	[illegible]	[illegible]	0.54	0.63	0.72	0.90	1.08	1.25	1.43	1.79	2.15
328.0 – 336.0	0.19	0.25	0.32	0.38	0.45	0.51	0.64	0.76	0.89	1.02	1.27	1.53
331.0 – 336.0	0.11	0.14	0.18	0.21	0.25	0.28	0.35	0.42	0.49	0.56	0.70	0.84
316.0 – 329.0	0.73	0.98	1.22	1.47	1.71	1.96	2.45	2.94	3.43	3.92	4.90	5.88
317.0 – 321.0	0.35	0.47	0.59	0.71	0.82	0.94	1.18	1.41	1.64	1.88	2.35	2.82

Too Sensitive

Too Insensitive

The total column estimate performance will have variable precision due to competition between the varying signal levels (primarily larger at longer wavelength) and the ozone sensitivity (smaller absorption at longer wavelengths). While the latter is what allows the longer channels to maintain sensitivity to the full column at large SΩ, it also increases the sensitivity of the retrieved amount to noise.

The performance of the ozone profile retrievals from a BUV instrument using a maximum-likelihood algorithm, such as will be implemented for OMPS, have three types of errors which will differ at different heights: For the lowest and highest portions of the retrieval, where the measurements have little information, the retrievals revert to the *a priori* profile information.

The Version 6 algorithm uses total ozone information in constructing a first guess/*a priori* profile; the Version 8 algorithm uses a static set of *a priori* profiles for each latitude and month. In the middle atmosphere, the vertical resolution of the retrievals is limited by the smoothing error, which is a function of the channel SNRs, ozone absorption, and number of channels. The retrievals will have biases that are complicated functions of the measurement errors and biases. The Version 8 algorithm has diagnostic information to determine these patterns in the form of initial and final residuals, averaging kernels, Jacobians, and measurement contribution matrices. In general, the information content of the retrievals shifts upward as either the SZAs or total ozone amounts increase; these retrievals also work better for ozone located higher in the atmosphere. The bulk of the ozone is in the mid- and lower stratosphere; the height of the bottom of the stratosphere (*i.e.,* the top of the troposphere, called the tropopause) varies with latitude. The tropopause height is greatest in the tropics, drops lower in the mid-latitudes, and is lowest in the Polar Regions.

Degradation (Exclusion) Conditions

The OMPS EDR has performance exclusions when extreme levels of stratospheric contaminants are present. The most common sources of these are aerosols from major volcanic eruptions; we will know if these circumstances are present over larger areas of the globe. The OMPS measurements are used to produce an aerosol index that can identify stratospheric incursions of smoke, dust or sulfate aerosols. The OMPS EDR has performance exclusions for high levels of SO_2, as SO_2 absorption features in the UV complicate ozone retrievals directly. The OMPS measurements are used to create an SO_2 Index (SOI), where SOI values define the presence of this exclusion (see the last two lines of Table 2), and we will validate this index. The OMPS Ozone Profile DIP is also affected by stratospheric aerosols (although not as much as the EDR, provided the wavelengths are selected with less sensitivity to tropospheric variations) and by high atmospheric SO_2 amounts.

The OMPS EDR uses information on atmospheric temperatures and other ancillary data in the retrieval algorithm. Performance may suffer if the preferred information sources, e.g., CrIS for temperature profiles, are not available and the algorithm must revert to poorer sources or climatologies.

The OMPS NP measures very weak signals, accumulated over a 38-second period; multiple detector pixels are aggregated onboard. This means that it will be difficult to remove signal contamination from charged particles such as occur in the SAA, where the OMPS NP will not perform well. Whereas current SBUV/2 instruments use the large photomultiplier tube detector area and a count-up/count-down chopper wheel configuration to remove this background signal, handling this for poor OMPS NP performance over the SAA is still under discussion. BATC has provided system engineering reports (SERs) and information at technical interchange meetings (TIMs) addressing the expected measurement performance degradation and profile DIPs over a range of SAA particle levels and the geographic extent of such conditions. Some of the effects can be lessened by dropping the shortest wavelength channel, resulting in reduced information at the top of the profile. The OMPS NP measurements are also affected by polar mesospheric clouds (PMCs); we are testing an algorithm for use with SBUV/2 data to identify measurements contaminated by this source. Further, the developers of the procedure are working on methods for OMI that could be used with OMPS NP. The OMPS NP instrument is flexible in its operations, and could deliver data more frequently with less spatial aggregation.

Since both OMPS measurements use backscattered solar UV to sense the atmosphere, they have difficulty during solar eclipses, and will not generate products for regions that are in the Earth's shadow at the time of the measurements.

2.5 Attaining Exit Criteria

The exit criteria for the OMPS products fall into two broad categories: verification of operational product quality, and evaluation of long-term stability. The former can be established by making comparisons to contemporary space-based and ground-based products and by analysis of internal consistency during the ICV phase, while the latter will not be demonstrated until much later. Potential problems and anomalies along the road to achieving required performance will be need to be identified, studied, mitigated, solved, or eliminated during all phases of the work.

The exit criteria for the PL phase are to obtain the data and parameters defining the instrument calibration and characterization; to test tools to read in, manipulate, and analyze OMPS and other data records; to demonstrate the use of alternative algorithms; and to begin more-rapid creation and dissemination of ozone products from ESRL ground-based assets.

The exit criteria for the Early-orbit and Checkout (EOC) phase are that sufficient testing and analysis are completed to allow adjustment, evaluation, and validation of the OMPS NM and NP SDRs. The OMPS SDR cal/val plan [REF Latest Version of the Plan] provides details on those tests and much of the analysis. This EDR plan concentrates on the exit criteria for the ICV phase for the OMPS EDR and IP products. The focus of the EOC phase is on the adjustment of retrieval algorithms for as-performing SDR measurements; the focus for the ICV phase is the identification of biases and internal inconsistencies in the products. Broadly speaking, the exit criteria are that the products must be shown to meet the performance requirements described in Section 2. This plan also describes tasks designed to show that they meet or exceed the performance of current ozone products from heritage sensors, *e.g.,* SBUV/2, GOME-2, Infrared Atmospheric Sounding Interferometer (IASI), and HIRS, and are of similar quality to NRT products of opportunity from OMI.

2.5.1 OMPS NM Total Ozone EDR

We expect that NRT and/or operational products will not have the required performance at the start of the mission, as the instruments' performance will have changed from laboratory characterization and calibration. The OMPS EDR cal/val team will assist in an iterative process to identify adjustments and changes in instrument calibration and the SDR and EDR algorithms to reduce biases and improve performance.

At the end of the ICV phase, the objectives of the plan are to have established estimates of the biases, absolute accuracy, and precision of the total column ozone EDRs as functions of ozone amount, latitude, season, reflectivity, Aerosol Index, SO_2 Index, and SZA; and to provide a report comparing this performance to the total ozone EDR requirements.

The exception to the above is the long-term stability requirement. While we will begin time-dependent trending of the EDR relative to validation assets, the earliest evaluation of the systems ability to maintain product stability will be evident in the SDR calibration. The working and reference diffuser system will require a year before the repeated observing conditions are present to provide the first evaluation of the in-orbit performance; up to three years may be needed before retrospective instrument/diffuser characterization can be obtained from analysis of the solar measurements.

An implicit exit criterion for the ICV phase is that the OMPS NM total column ozone EDR should be of sufficient quality that the product is moving into applications mode by demonstrable assimilation into numerical weather models, creation of ozone fields for UV forecasts, and monitoring Antarctic ozone hole and atmospheric ozone layer behavior.

2.5.2 OMPS NP Ozone Profile IP

On one level, attaining the desired performance criteria for the OMPS ozone profile is assured if the OMPS NP and NM SDRs meet their performance requirements. Realistically, this assurance will be determined by comparisons of OMPS ozone profile retrievals to other ozone profile data. The same hierarchy of testing and evaluation is present as for the total ozone products, *i.e.,* estimation of persistent biases with validation data as provided by temporal (monthly) and spatial (10-degree latitude) average comparisons to other satellite products; stratified performance of match-up validation with ground-based data; evaluation of system stability and consistency by both internal and external evaluations (including SDR validation); and assessment of system variability and the presence of error sources (*e.g.,* noise, imprecise corrections or characterizations) and complicating geophysics.

At the end of the ICV phase, the objectives of the plan are to have established estimates of the biases, absolute accuracy, and precision of the ozone profile IPs as functions of total ozone amount, layer amounts, latitude, SAA position, season, reflectivity, Aerosol Index, SO_2 Index, and SZA; and to provide a report detailing this performance and comparing it that for the heritage SBUV/2 products.

An implicit exit criterion for the ICV phase is that the OMPS NP profile ozone IP should be of sufficient quality that the product is moving into applications mode by demonstrable use in numerical weather models and ozone layer monitoring.

2.5.3 CrIS Total Ozone IP

While the CrIS IR ozone products do not have performance requirements, there are expectations that they will be as good as the records obtained from AIRS. This evaluation will be conducted by examining the results of comparison to ozone products from AIRS and IASI. The bulk of the validation work will be accomplished by the CrIS SDR cal/val team through simultaneous nadir overpass (SNO) comparisons of CrIS measurements to those from IASI and AIRS. Additional comparisons to ozone balloonsondes will be made, similar to the match-up validation done for AIRS ozone products.

2.5.4 Bundled IPs, Flags, and Indices

While the purpose of this plan is to formulate a path to validation of ozone products, this goal is inherently tied into the evaluation of residuals, intermediate products, error flags, and other algorithm parameters. The reports described in Section 6, below, will include validation of other products including the reflectivity, SO_2 Index, and Aerosol Index, and summaries of measurement residuals and error flags statistics as compared to expectations.

2.5.5 Information Dissemination

A set of Web pages, similar in content to the ICVS and Office of Satellite Data Processing and Distribution (OSDPD) sites monitoring the SBUV/2 measurements and products, will be created and populated with useful graphs and statistical analysis; these will be designed to have automated updates as products move into regular generation. The reference copy of the pages will live at the NESDIS Center for Satellite Applications and Research (STAR) domain, but mirrors can be placed at other locations as desired.

The overpass match-up data sets (See Tasks a.v.2 and c.iii in Appendix I.) containing the OMPS products will be available via anonymous ftp and on the GRAVITE system. These will be kept current with automated weekly updates from the most recent OMPS processing.

Finally, at the end of the ICV phase we will report on feedback obtained from data assimilation users on product performance. This report will include biases in measurements *vs.* forecast fields without the OMPS data sources, and identification of any difficulties in incorporating the products into applications.

3.0 TECHNICAL APPROACH

3.1 Allocation of Technical Responsibility

3.1.1 Integrated Program Office

The Integrated Program Office (IPO) OMPS product validation lead, L. Flynn, will manage the distribution of validation tasks from the task list to the team members described below. He will also coordinate the flow of information from the EDR and IP validation team to and from the OMPS SDR calibration and validation team, the NPOESS change request (CR) and discrepancy report (DR) systems, and the NPP verification and evaluation team. This information will include parameter tuning, calibration adjustments, and product quality concerns that could lead to algorithm modification or test processing.

3.1.2 NESDIS

The NESDIS tasks will be conducted by members of the Atmospheric Chemistry Product Oversight Panel (ACPOP; L. Flynn and D. McNamara, co-chairs). The Total Ozone EDR and the Ozone Profile DIP are bundled products designed to contain a variety of diagnostic parameters—including residuals—similar to current operational products. Much of the internal evaluation can be done by statistical trending and other analysis of these bundled parameters.

Comparisons to satellite data will be distributed as well, but will be concentrated at NESDIS with coordination with NPP Science Team activities. The NOAA activities will parallel those for the SBUV/2 and GOME-2 instruments in the NOAA ICVS. A discussion of SBUV/2 and GOME-2 ICVS activities as they pertain to OMPS validation is found in Appendix II.

3.1.3 NWS

The NWS tasks will be conducted by the users of the operational ozone products. This effort will be led by C. Long of NCEP. His team will evaluate product quality for applications. These activities include the following: tracking assimilation into numerical weather models, generating UV Index forecasts, and monitoring the state of the atmosphere's ozone layer. In addition to work with current operational products, the team members are also participating in activities funded by the Joint Center for Satellite Data Assimilation (JCSDA) to prepare for the OMPS ozone products, including the use of NRT ozone products from the EOS Aura OMI.

3.1.4 NOAA/ESRL

Comparisons to ground-based data will be distributed across the team, but will be led by I. Petropavlovskikh of NOAA/ESRL. The ESRL maintains a network of fifteen Dobson stations (with six stations automated to provide vertical ozone profiles by using the Umkehr technique, and an additional six Brewer stations making Umkehr measurements) and eight ozone balloonsonde stations. Their participation will ensure timely availability of this data and good understanding of its quality. Additional data from NDACC and WOUDC will complement these measurements.

3.1.5 NASA

NASA activities will use resources at the AVDC and products from the EOS Aura Microwave Limb Sounder (MLS) and OMI missions. One major uncertainty is how to classify and plan for interactions with the NPP Science Team. We certainly do not take the NASA contribution for granted, but do not foresee IPO funding for their product evaluation efforts. We have very good working relationships across the NPP Team activities, which involve PEATE, SDR, EDR, and CDR work. We will work with Rich McPeters, who is on the NPP Science Team and is leading a NASA Measures Project for ozone, and P.K. Bhartia, the OMI chief scientist. We will also work with John Hornstein of the Naval Research Laboratory (NRL), who will act to coordinate the interests and analysis for the Department of Defense (DOD) research and applications.

3.1.6 Other Cross-organizational Activities

An important requirement for all EDR and IP work is SDR fidelity. In recognition of this, we are working on this plan in conjunction with the development of the SDR calibration and validation plans and the NGAS-based EDR calibration and validation plans. We have frequent exchanges with the IPO lead, Scott Janz, and the NGAS lead, Bhaswar Sen, to coordinate this work, which includes tracking issues, waivers, and performance as BATC-based instrument calibration and characterization progresses. This is helped by the work of the DAWG, especially in their oversight of the Sensor Characterization Database tasks.

Finally, we expect continuing support in various forms from the ozone research and user communities as OMPS progresses through its lifetime.

3.2 Technical Approach Summary

NPP calibration/validation planning is divided into four phases: pre-launch (PL), early orbit check out (EOC), intensive calibration and validation (ICV), and long-term monitoring and maintenance (LTM).

The following gives a brief division of the activities in each phase. A more detailed discussion of the tasks involved in each phase is found in Appendix I. A description of the resources required to accomplish this work—addressing personnel, funding, coordination, data, and computation—is found in Section 5.

3.2.1 Pre-launch phase

During the PL phase, the team has been participating in the O3OAT and other NPP/NPOESS activities to provide expertise in the sell-off for OMPS delivery from BATC to NGAS, reviewing IDPS algorithm build progress, monitoring the Sensor Characterization Database Task, lobbying successfully for the creation of bundled products containing intermediate parameters (*e.g.,* measurement residuals and sensitivities), and defining and creating calibration and validation tasks in the CasaNOSA task network.

We have also been implementing and testing ozone data product retrieval algorithms and ozone product validation (using SBUV/2, GOME-2, and OMI projects as resources). This work will continue to progress—from development and transfer of analysis and algorithm tools using shell SDR, EDR, and IP files, through sample synthetic data files and realistic proxy data files—in preparation for real SDR, EDR, and IP data after launch.

Progress towards generating validated OMPS EDR and IP products during the PL phase consists of delivering an OMPS that meets measurement performance requirements; implementing and testing SDR and retrieval algorithms; converting instrument characteristics and corrections into algorithm parameters, look-up tables (LUTs) and subroutines; and generating products containing residuals and diagnostic parameters. Validation team members participate in these activities largely through such entities as the O3OAT.

3.2.2 Early-orbit check-out phase

The next phase of the plan addresses EOC activities. We have already helped to define the CasaNOSA task network entries for this phase, and are participating in creating the Integrated Mission Timeline (IMT).

The objectives during this phase are:

- To confirm instrument performance by SDR analysis;
- To ensure that retrieval algorithms have appropriate characterization, LUTs, tuning, and correction modules, through collaboration with the SDR calibration team; and
- To analyze Earth-view SDR data to appraise its information content, SNRs, wavelength scale stability, outliers and spikes, spectral consistency for reflectivity, solar spectra trending, and stray light correlations.

While much of this will be accomplished by looking over the shoulders of the SDR calibration and validation team as they perform their tasks, the OMPS product validation team will conduct our own independent analyses of the Earth-view SDRs, and begin analysis of instrument parameter and performance trends.

3.3.3 Intensive calibration and validation phase

As the first component of ICV phase work, we will conduct a considerable amount of the analysis by using internal product consistency checks and statistical analysis These will be similar to the checks, calculations, and trending for current operational UV measurements and ozone products.

The second component of activities for the ICV phase is to compare OMPS measurements and products to those from other satellite-based sensors. We expect that there will be several instruments with known records of accomplishment in operation at the start of the NPP mission, and we will use their validation and known evaluations to transfer this to the OMPS measurements and products. These matchup comparison analyses can be performed by processing as little as one week's worth of full-coverage data. We expect that there will be iterative passes through this analysis as the results are fed back to the algorithm and SDR teams.

The third activity component of this phase uses data from suborbital systems as the source for comparisons and validations. We will use the full range of ground-based ozone measurements, but will concentrate on NOAA ESRL Dobson, Brewer, and ozone balloonsonde data, as we will have expedited access to them and good information on their quality. In particular, data obtained in the Umkehr mode will be processed with an algorithm similar to the Version 8 ozone profile code but for ground-based measurements with varying SZAs.. See Petropavlovskihk (2005). This algorithm shares the Version 8 *a priori* profile data set, and has averaging kernels similar to those for the OMPS NP retrievals. Analysis of additional data from NDACC, AVDC, and WOUDC will complement these measurements.

The fourth ICV phase activity component will be to evaluate product quality for applications. This will by done by performing test assimilations into numerical weather models, generating UV Index forecasts, and monitoring Earth's ozone layer. The assimilation systems have the capability to recognize biases between data sources.

3.3.4 Transition to regular operations and long-term monitoring

The final stage in cal/val activities is to transition to the LTM phase. LTM activities begin in the ICV phase, but continue for long-term trending, reprocessing, and algorithm maintenance and improvement. A variety of time-series plots for zonal means statistics will be updated and maintained at the ICVS or its NPOESS equivalent as ongoing quality control and quality assurance (QC and QA). Long-term stability performance will not be demonstrated until some time into the regular operations phase of the mission.

4.0 Schedule and Milestones

4.1 Schedule

Tasks are identified by phase in Section 3 and Appendix I. Given the vagaries of funding, dependence on other program elements and possible slips in the launch dates, a definitive schedule within each phase is not provided here. We expect that major results will have been obtained within the first seven months of the ICV phase, so preparation of the reports described in Section 6 will take place at that time.

4.2 Milestones

The PL phase will see the development, implementation, and exchange of tools, readers, and algorithms among the teams, particularly the NGAS/Raytheon algorithm Team, the NASA OMPS NPP team, the OMPS SDR cal/val team, and our team. Approximately one year before launch, we will examine the state of the overall effort to make sure that we have sufficient information on instrument and measurement characterization and as-implemented codes to proceed with our algorithm development and implementation tasks. We will also review the list of comparative data sets to make sure that we have documented samples of them and demonstrated access to them as needed in the post-launch activities. Approximately three months before the launch, we will conduct an audit of progress toward preparation of all PL phase programs and tools. The goal will be to demonstrate the use of the readers, statistical analysis tools, and algorithms on sample data sets. There will be ongoing checks on progress as work on individual tasks proceeds (*e.g.,* Do we have sample OMPS SDRs and corresponding readers?); completion of these subtasks will simply be noted in internal reports, and not reported as milestones.

The EOC and ICV phases will be times of dynamic activity and will require adaptive responses as some instrument and product characterizations proceed as expected, while other factors have unexpected behavior, requiring additional attention. As described in Section 6, we will provide reports at the end of these phases; completing and delivering these reports represents the major project milestones. We will also move ICVS OMPS monitoring from a test and development state to regular open dissemination approximately one month after the end of the ICV phase.

Adjustments to and adaptation of the SDR and EDR/IP algorithms to the as-performing instruments will be ongoing, and therefore do not fit well into a milestone formula. Where necessary, suitable changes will be made to the algorithms and documented during all post-launch phases. Similarly, we will document deficiencies and problems uncovered in validation activities generally.

5.0 Resource Requirements

This section gives additional information on the resources necessary to complete the tasks and satisfy the exit criteria described in the preceding two sections, respectively.

5.1 Personnel Requirements

While some of the pre-launch tasks could be performed by mid-level programmers, we expect to use senior-level scientific programmers/analysts for these tasks. There are two related reasons for this: First, the overall workload in each task is small, so separating out the easier parts of the tasks from the more complex ones would lead to fractional support for multiple contractors, which would generate communication and continuity problems. Second, since the tools to be developed will be used for scientific analysis later in the program, it will be more efficient to have the analysts who will use those tools develop them themselves. We would like to note that the contractor pool at NESDIS/STAR already includes four programmer/analysts with experience in retrieval algorithms, validation, and monitoring of operational satellite ozone products.

5.1.1 PL Phase Personnel

The contributions of the STAR and NWS plan leads will be supported by base NOAA funding. The work at ESRL and at NCEP will be performed by the leads and by augmenting existing contracts and adding tasks to the duties of current workers. Some of the ESRL funding will be distributed for station inter-calibration activities and improvements.

The two main new positions required for this phase are within STAR:

> *Position 1.a.i. (STAR Task)* – Full-time contractor senior programmer/analyst on algorithm implementation and model and tool development. Support required: $150K/year, starting FY2009.
>
> > There are three components to the work for this task. The first involves preparing specialized analysis programs for use with OMPS data. These include programs to perform empirical orthogonal function (EOF) covariance analysis, to detect evidence of stray light or wavelength shifts, and to estimate signal and noise content. The second component is continuing the progress on adapting the V8 and V8.5 algorithms for use with OMPS NP and OMPS NM, respectively. The third component is preparing programs to make and use match-up validation data sets, *i.e.,* (read and write and generate statistics).
>
> *Position 1.a.ii. (STAR Task)* – Shared contractor senior programmer/analyst on ICVS development. Support required: Half-time $75K/year, starting FY2009.
>
> > The work for this task will be to adapt the standard monitoring analysis and displays for the SBUV/2 sensor as implemented at

ftp://www.star.nesdis.noaa.gov/smcd/spb/calibration/icvs/
so that they will function with OMPS data, including trending of selected parameters' zonal means. We are adding various monitoring tools for the total ozone products from GOME-2 using other funding; the IPO funding will support adapting these additional statistics and analysis to OMPS total column products. We are using the IPO funds to support the other 0.5 FTE for the same programmer who is already working on similar tasks for the other UV applications at 0.5 FTE.

5.1.2 EOC and ICV Phase Personnel

The first year after launch will be the most intensive and will require an increase in personnel activities at NESDIS. It will require adding the equivalent of one analyst by increasing support for the second position from ½ to full time, and the addition of consulting specialists.

Position 2.a.i will simply be a continuation of Position 1.a.i, with a transition of activities from preparation to execution and reporting.

Position 2.a.ii will be a continuation of Position 1.a.ii, but will become full-time on OMPS analysis and monitoring, representing a net increase of half time support.

Position 2.a.iii will bring in as consultants the experts who conduct the SBUV/2 Activation and Evaluation activities to perform similar duties for OMPS. This will be equivalent to half-time contractor support during this period.

During this period, both ERSL and NWS will have increased activity, leading to a need for two half-time positions.

Position 2.b.i. will be at ERSL, and will employ a half-time programmer/analyst to assist in ground-based product processing, dissemination, and analysis.

Position 2.c.i. will be at the NWS, and employ a half-time programmer/analyst to assist in evaluating the use of products in applications and comparisons to NDACC data sets.

5.2 Funding Requirements

5.2.1 Background and Rationale

The bulk of OMPS cal/val funding will be used to support the work of scientific programmers and analysts at NESDIS STAR, drawing upon experience with SBUV/2 and GOME-2 products. These programmers and analysts will convert the analysis and monitoring procedures used for those systems to perform with OMPS EDRs and IPs. These positions will be filled by contractors, with guidance provided by government research scientists. Federal employee activities will be part of their base duties, thus constituting an agency contribution to the work. The support staff will vary from 1.5 to 2.5 contractors (for a total of \$225K/yr to \$400K/yr) over the course of the work, with the larger numbers applicable to the first year after launch. Also during that period, we expect that support for 0.5 contractors ($75K of the requested support) will be directed through NASA GSFC to reach the most qualified analysts for SDR/EDR interface evaluation and parameter checks. These experts are primarily employed as contractors to NASA working on existing BUV programs.

The second largest segment of the support will go toward validation from suborbital resources. We are concentrating on a key set of high-quality stations and instruments for rapid validation. The funding will go through NOAA ESRL, and will vary from $150K/yr to $200K/yr over the course of the work.

A smaller portion of the funding will be used to determine the adequacy of the products for use in applications. This work will leverage existing funding for using OMPS products operationally. The funding will vary from $25K/yr to $75K/yr. We have been working with NOAA NWS, NCEP, and the JCSDA on preparing their systems to use OMPS products.

Since the main activities are at NOAA offices, we expect that each year's funding will be distributed to the three offices directly by the IPO. The work will be divided up as described previously. The majority of the funds for STAR will go to contractor salaries to perform the tasks specified above. In-house programmers will be hired under an existing Science and Technology Task Order contract, specifying ranges of salaries for different position levels. During the first year after launch, an arrangement would be made with the contractor, employing the expert SBUV/2 calibration scientists to obtain a number of weeks of their expert services as consultants.

Unlike the aircraft or field campaigns that are under consideration by other instrument teams, the ozone products validation efforts will concentrate more on measurements from existing assets with ongoing missions. Accordingly, we are devoting a considerable portion of the budget to improving the quality and timeliness of ground-based ozone data records. The funds for ESRL will be used to support instrument calibration and product delivery improvements as well as the comparisons and analysis, that is, the actual validation work.

We will make extensive use of existing tools used in the SBUV/2 and GOME-2 programs, and will coordinate the development of additional assets (*e.g.,* the ICVS work). We are also tying into ongoing work to prepare applications for the new OMPS products—supported under other projects—so that there will be a good flow of information on the evaluation of its quality to and from the team early in the ICV phase. The limited support for the NWS work will leverage their assimilation applications—tracking observed minus forecast differences—and their existing work in executing comparisons to NDACC data sets. Most of their activities will be in the post-launch phases.

We have not allocated specific assets for anomaly resolution. We will have a small and experienced team that can be directed to concentrate on studying specific factors of interest. The overall OMPS team (*i.e.,* IPO, NASA, NGAS, NOAA, and DoD) has excellent ties to the U.S. ozone science community. If a problem is severe, then a tiger team—with additional government researchers and BATC engineers—would be organized. The funds to obtain BATC support are not included in this plan. Additional funding to allow for contingencies and anomaly resolution in the course of execution of the plan should be allocated at the program level and distributed to individual teams as needed.

5.2.2 FY09 NESDIS Cal/Val Component ($225K to NOAA/NESDIS/STAR)

1.a. Full-time contractor Senior Programmer/Analyst
$150K/year starting FY2009

There are three components to the work for this task. The first involves preparing specialized analysis programs for use with OMPS data. These include programs to perform EOF covariance analysis, to detect evidence of stray light or wavelength shifts, and to estimate signal and noise content. The second component is continuing the progress on adapting the V8 and V8.5 algorithms for use with OMPS NP and OMPS NM, respectively. The third component is preparing programs to make and use (generate statistics for) match-up validation data sets.

1.b. Shared contractor on ICVS development
$75K/year starting FY2009

This task will be to adapt the standard monitoring analysis and displays for the SBUV/2 as implemented at
http://www.star.nesdis.noaa.gov/smcd/spb/calibration/icvs/
so that they will function with the OMPS data. These include trending of selected parameters' zonal mean. We are adding various monitoring for the total ozone products from GOME-2 using other funding. This IPO funding will support the adaptation of these additional statistics and analysis to the OMPS total column products.

5.2.3 FY09 Ground-based Validation Activities ($150K to NOAA/ESRL.GMD)

As part of this plan, we are including support for specific improvements and maintenance of the ground-based systems for FY2009 as follows:

2.a. Development and implementation of a system for near-real-time (next day) delivery of total ozone data
Quick delivery of Dobson and Brewer total ozone data from the ESRL stations will reduce the turn-around in obtaining validation results. This will allow us to evaluate the instrument performance and investigate improvements to the algorithms.

2.b. Contribute to the maintenance and calibration of the world standard Dobson # 83.
This instrument is the foundation for the Dobson Network. The other instruments in the network trace their calibration to it.

2.c. Contribute to activities for propagation of Dobson #83 calibration to the ESRL (and global) Dobson network.

Regular comparisons are necessary to maintain the quality and fidelity of these stations.

2.d. Contribute to support for Brewer network operations.
In addition to the current measurements, this network can provide additional ozone profile information with new measurements and algorithms under development in other projects.

2.e. Upgrading of the Dobson super site in Boulder to the near-real-time operations for Umkehr ozone profile data.
This will give us quick access to ozone profile information. Existing SBUV/2 instruments have been compared to this site for decades. The regular Umkehr Dobson processing (~6 months delay) and ozone balloonsonde profiles (several months delay) will be continued under already available funding.

*2.f. Investigate quick access strategies and resources for ozone balloonsonde data such as are currently provided by the South Pole stat*ion. Support for such activity would be provided in the post-NPP launch time frame.

5.2.4 FY09 application testing and evaluation ($25K to NWS/NCEP)

3.a. Prepare for use of global total ozone in UV Forecasts by using GOME-2 and OMI products.

3.b. Prepare for changes in ozone product formats for ozone layer monitoring applications.

3.c. Monitor Binary Universal Form for the Representation of meteorological data (BUFR) *tasks supported by Product System Development and Implementation (PSDI).*

1. NOAA/NESDIS/STAR
   One full-time contractor Senior Programmer/Analyst $150K/year starting FY2009
   Shared contractor on ICVS development and maintenance $75K/year starting FY2009

2. NOAA/OAR
   Ground-based Instrument calibration and maintenance $150 K/year starting FY2009
   Half-time personnel for quick processing and intercomparisons Senior Programmer/Analyst $75K/year starting FY2010

There is a large range of needs in the overall program; we will restrict our attention to some key inter-calibration activities and instrument operations.

3. NOAA/NWS
   Mainly leverage operational work related to GOME-2 and OMI and JCSDA studies. Provide some support for specific preparations. ($25K in FY2009)

4. NRL Mainly leverage existing ozone work
5. NASA Mainly leverage NPP Mission and Science Team, Measures Program, and Ozone Team activities. There are some key players among the NASA contractors for OMI and NPP.

6. SDR Work Rely on NGAS Algorithm and NASA NPP Team activities. Monitor progress and get parameters and algorithms as progress dictates.

5.2.5 Estimates for Five-Year Funding Horizon, FY10 – FY14:

FY10 Continue with minor increase over this year to $425K
a. $225K STAR Flynn-Cal/Val tool preparation and testing
b. $150K NOAA/ESRL Petropavlovskikh-Comparisons to ground-based distributions
c. $50K NOAA/NCEP Long-Evaluate OMPS products for operational applications

FY11 Ramp up for launch $475K (If Launch is early FY11, then move some FY12 to here.)
2. The IPO currently has funds scheduled to be transferred to other areas in NOAA during January as follows:
a. $250K STAR Flynn-Cal/Val tool and algorithm use
b. $175K NOAA/ESRL Petropavlovskikh-Comparisons to ground-based, quick delivery
c. $50K NOAA/NCEP Long-Evaluate OMPS products for operational applications

FY12 Intensive NPP post-launch $600K
a. $300K STAR Flynn-Cal/Val tool and algorithm use
b. $225K NOAA/ESRL Petropavlovskikh-Comparisons to ground-based, quick delivery
c. $75K NOAA/NCEP Long-Evaluate OMPS products for operational applications

FY13 Assumptions - transition to NPP regular operations, start of NPOESS C1 Pre-launch $450K
a. $250K STAR Flynn-Cal/Val tool and algorithm use
b. $175K NOAA/ESRL Petropavlovskikh-Comparisons to ground-based, quick delivery
c. $25K NOAA/NCEP Long-Evaluate OMPS products for operational applications

FY14 Intensive NPOESS C1 post-launch, less NPP $475K
a. $250K STAR Flynn-Cal/Val tool and algorithm use
b. $175K NOAA/ESRL Petropavlovskikh-Comparisons to ground-based, quick delivery

5.3 Coordination Requirements

Clear communications amongst the several participating teams are critical to successfully validate the OMPS products. These teams are the:

- OMPS SDR Cal/Val Team
- NGAS/Raytheon Algorithm Team
- NASA OMPS NPP Science Team
- Ozone data users
- BATC OMPS team, and the
- OMPS EDR and DIP Cal/Val Team.

L. Flynn will coordinate with the key actors in the program including the:

- IPO OMPS SDR Cal/Val Team, to exchange readers and analysis tools and plan the IMT;

- NGAS/Raytheon algorithm development and implementation teams, to obtain as-implemented algorithms, parameters and tables, and sample input and output;
- NASA OMPS NPP Science Team, to exchange proxy data, algorithms, and analysis tools, and to coordinate OMPS LP activities with those for the nadir instruments; and
- Ozone data users to discuss results for current products and expectations for OMPS. (This will involve reviewing the JCSDA-supported assimilation work for MLS, OMI, and GOME-2 ozone products, and NPOESS Data Exploitation (NDE) facility BUFR conversion team progress. Both of these activities already fall within the team lead's duties as Co-Chair of the NESDIS Atmospheric Chemistry Product Oversight Panel.)
- BATC OMPS Team to review instrument performance issues and consult on operations and calibration.

There will be additional coordination with the CrIS and VIIRS teams related to the IR ozone, temperature profiles, cloud and surface reflectivity, and aerosols. C. Barnet, the lead for the CrIS Product Cal/Val Team, is in the NESDIS/STAR/SMCD/SPB, the same branch as L. Flynn, a circumstance that will help ensure timely communications. This coordination is already involved in the planning for the selection and retention of Golden Days. See subsection 5.4.3 for further discussion.

I. Petropavlovskikh will direct the tasks for the ground-based measurements, and serve as the liaison to the broader ground-based measurement community (*e.g.,* Brewer, Dobson, ozone balloonsonde, etc.).

C. Long will direct the tasks for applications and serve as the NWS, JCSDA, and NDACC contact point. Both he and L. Flynn are members of the NOAA Trends Tiger Team, a key ozone climate data record analysis group.

The contractor-supported work on tasks at NESDIS will by managed by L. Flynn, and he will act to coordinate the tool development and other task scheduling and priorities with the execution of the OMPS SDR Team's plan. Many of the tasks have been entered into the CasaNOSA network. There are additional entities support under other programs that are expected to participate in the validation including the NESDIS Research Centers: The Cooperative Remote Sensing Science and Technology Center (CREST), based at the City University of New York, and the Cooperative Institute for Climate and Satellites (CICS), based at the University of Maryland, College Park.

5.4 Validation Data Requirements

Much of the validation and diagnostic data is automatically retained as part of the bundled OMPS EDR and DIP. A list of some of the more important content in these products is provided in Appendix V**.**.

The principal data required to carry out the OMPS cal/val work is organized into the following categories discussed in subsection 5.4 and 5.5:

- Satellite instrument data regularly processed at or delivered to NESDIS and other satellite instrument data;
- Ground-based data, including field campaign data; and
- Products from OMPS SDRs processed by alternative algorithms
- OMPS SDR, EDR, and IP algorithm parameters, ancillary data, and tables;
- OMPS SDRs, EDRs, IPs and Research Products (RPs), and CrIS Ozone IP;

5.4.1 Satellite Data

The satellite data for validation can be split into two categories: those available from operational NOAA processing, namely, SBUV/2 and GOME-2 for BUV and IASI for IR; and those available from external agencies, *e.g.,* the EOS Aura OMI and Microwave Limb Sounder (MLS) and the ERS-2 Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY). Since NOAA does have regular acquisition of some NRT products from EOS instruments, *e.g.,* AIRS and OMI products, this distinction is not complete. All of these data sets are produced and distributed within a week of measurements, many in NRT. We will acquire these records either through existing arrangements at STAR or from data archives with weekly polling. There may be some adjustments depending on the status of specific missions at the time of NPP's launch.

5.4.1.1 Satellite instrument data regularly processed at or delivered to NESDIS

These data values consist of:

(1) The SBUV/2 and GOME-2 solar irradiance data, Level-1 radiance data, and Version 8 algorithm total column and ozone profile output Product Master Files (PMFs) from NESDIS operational processing and reprocessing;

(2) EOS Aura OMI Level-2 total ozone and ozone profile products from the NASA GSFC near-real-time system; and

(3) NOAA-derived zone products from the IASI and AIRS measurements. Rolling directories of several months' worth of these data sets will be stored at NESDIS/STAR.

These data sets will form the other major storage component (see Section 3.1.4.2), and are expected to be on the order of 3 GB/day. The ICVS has developed programs to identify Simultaneous Nadir Overpass (SNO) events. These will be used to provide subsets for refined comparisons of spectral measurements between OMPS and GOME-2.

5.4.1.2 Other satellite instrument data

We will make use of any available ozone measurements from instruments with sufficient validation to improve our understanding of the OMPS products. We expect that these will include the following: Aura MLS Level 2 ozone products from the Goddard Earth Sciences Data and Information Services Center (GES DISC); the Solar Backscatter Ultraviolet Sounder (SBUS) and Total Ozone Unit (TOU) products from the Chinese Meteorological Agency's Feng Yun (FY)-3 satellite; products from SCIAMACHY on the European Space Agency's (ESA) EnviSat;

and data from the Atmospheric Chemistry Experiment (ACE) and the Optical Spectrograph and Infrared Imager System (OSIRIS) on the Canadian Space Agency's SciSat and the Swedish Space Corporation's ODIN satellites, respectively. In addition to the discrete wavelength total ozone products from TOMS heritage algorithms, we will also make comparisons to OMI and GOME-2 Differential Optical Absorption Spectroscopy (DOAS) algorithm [REF] products.

5.4.2 Ground-based Data

We will have rapid access to data from Dobson, Brewer, and ozone balloonsonde stations maintained by NOAA. These include the world standard Dobson Instrument #83, six Dobson and six Brewer stations making Umkehr ozone profile measurements, and twelve stations with regular launches of ozone balloonsonde.

We already regularly check the WOUDC for newly reported data from other ground-based Dobson, Brewer, and ozone balloonsonde instruments for comparisons with the SBUV/2 and GOME-2 products, and will continue this for our OMPS cal/val activities. The NDACC (collection of ozone retrievals from ground-based LIDAR and Microwave instruments all over the world (See the map at http://www.ndsc.ncep.noaa.gov/.) is housed at NOAA NCEP, and will be used to confirm performance results. The NASA AVDC (http://avdc.gsfc.nasa.gov/) already has agreements in place to receive campaign-generated and other ground-based data. We will make use of these data as it is reported. The NPP Science Team is making arrangements with the Southern Hemisphere Additional Ozonesondes (SHADOZ) network for quick access to their data, and to schedule coordinated launches to validate OMPS LP products.

The satellite data situation has a parallel for ground-based data but the acquisition times are expanded; the team will have regular access to Dobson, Brewer, and ozone balloonsonde data through normal ESRL channels, and expedited access to some components as described in Task c.iii. This includes the Umkehr data taken at six Dobson stations (Boulder, CO; Mauna Loa Observatory (MLO), HI; Fairbanks, AK; Observatoire de Haute-Provence (OHP) France; Perth, Australia; and Lauder, New Zealand), and at six stations in the Brewer network maintained by NOAA (Table Mountain, CO; Houston, TX; Niwot Ridge, CO; Bondville, IL; Raleigh, NC; Fort Peck, MT).

We will regularly (monthly) poll the WOUDC and NDACC to gather new contributions to those data centers. We will share these collections with other members of the NPP community and have access to the additional measurements of the SHADOZ network being arranged by the OMPS NPP Science Team. The use of high-vertical-resolution ozonesonde or LIDAR measurements will require averaging kernel and *a priori* profile information from the OMPS NP retrieval algorithm. The ozonesondes typically do not measure above 10 hPa, so comparisons to total ozone require an adjustment in the column amount.

5.4.3 Golden Days and Field Campaign Data

There have been discussions of cross-EDR validation and comparisons by using specially selected and preserved sets of data for "Golden" days. We can accommodate most CrIS choices of days (assuming that the OMPS SDRs are stable enough). We will just collect corresponding ozone information for that day: OMPS SDRs, IPs and EDRs; GOME-2, OMI and SBUV/2 Level

1, 2 and 3 data products; TOAST and SMOBA ozone assimilation data; and whatever sub-orbital measurements can be found - ozone balloonsondes, Dobson, Brewer, Umkehr, MW, LIDAR, etc.

We have some other interests related to orbit stability and reproducing measurement viewing conditions, and some targets for vicarious calibration, but these just mean that we would have additional collections, e.g., a week of equatorial Pacific data to check cross-track measurement consistency, or a repeated collection of information on the anniversary of a Golden Day.

We also may want to preserve/collect data for days with known phenomenon, e.g., volcanic eruptions, large scale fires, major dust storms, that will pop up from time to time.

Among other key features, field campaigns are important in identifying weaknesses and refining the science in targeted retrievals. While we have identified areas of concern and potential improvement, we are not directing resources toward these areas in this plan.

We believe that the majority of our validation can be accomplished by using existing resources. Ground-based snapshots in space and time will be complemented by global comparisons to other satellite resources with similar performance and algorithms. Expedited processing from ESRL sites can be considered as field campaigns, but we hope that automated systems and improved data flow will become regular features. Similarly, NPP team support for additional balloonsonde launches for OMPS LP cal/val could be considered to fall into that category.

Our philosophy for ground-based comparisons for total ozone range from comparing them to *e.g.,* data from the MLO Dobson instrument, with its benign ozone levels and regular calibration, to comparing to 100 or more Dobson stations and allowing the averages to address any inaccuracies. For this purpose, we will use some portion of the funding to ensure suitable status for a small number of NOAA-operated stations; other agencies around the world will be doing do the same for their best stations. We will also use a "shotgun" approach and compare our data to a large number of stations, some of which may be of poorer quality. Both approaches have advantages and disadvantages. The more often we can intercalibrate more stations with international and regional standards, the better. Indeed, a perpetually underfunded key component of ground networks is propagation of calibration intercomparison standards; some programmatic support will be used in that effort.

5.5 Sensor Data

Initial information on the OMPS SDR, EDR, and IP algorithm parameters, ancillary data, and tables will be available from IDPS and GRAVITE/ CasaNOSA in delivery builds, and from the parameter database development task deliveries. This information includes the full range of values from instrument noise and wavelength scale to surface altitude databases to radiative transfer lookup tables. EOC activities are designed to verify and evaluate the instruments' performance as compared to on-ground characterization. We will receive copies of the full OMPS algorithm build packages as they progress through IDPS.

While the primary users of the sensor calibration and characterization data are the SDR algorithm developers/implementers and the SDR Cal/Val Team, the ozone product algorithms require information on wavelength scales and bandpasses, measurement SNRs, and satellite view angles. The EDR and IP algorithms have LUTs that are created from master tables by using specifics for the instruments, *e.g.,* channel bandpasses and sensor view angles. The OMPS uses sample tables to determine pixel selection and aggregation; while this makes instrument operations very flexible, most Earth-view data will be taken in a standard configuration.

As mentioned above, the instrument characterization information will be obtained from the sensor parameter database task deliveries. Information on these data sets is provided in Appendix III; we will obtain these from CasaNOSA. An additional task requires that requires BATC to provide details on the spatial and spectral transfer point-spread functions to NGAS to create a stray light correction. We will also request both the basic data and the derived correction from NGAS for this stray light model and correction. Some of the databases will be static, *e.g.*, bandpass shapes, while others will be updated in-flight, *e.g.*, wavelength scale. SDR validation will provide information on dynamic characterizations. EDR validation tasks will overlap with this work, as we will evaluate wavelength scales and SNRs with our own methods.

In the PL phase, we will obtain sample OMPS SDR, EDR, and IP data from NGAS as it works to implement the algorithms. We will also create proxy data, and make use of those created by other program elements. For example, the NASA OMPS NPP Science Team has recently completed a study of SAA effects by using OMI data as proxy for OMPS measurements. After launch, we will follow evaluation and trending of the solar diffuser degradation, instrument throughput, pixel linearity and response uniformity, dark current levels and bad pixels, and wavelength scale, conducted by the OMPS SDR Cal/Val Team.

With the start of processing after launch, the OMPS SDRs, EDRs, IPs and RPs, and CrIS Ozone IP will be delivered to the NESDIS central. Most of the parameters in the EDRs and IPs are described in Appendix VI. These data will make up one of the largest portions of the storage requirements for the cal/val plan; we expect data volumes to be on the order of 2 GB/day. (The OMPS Limb Profiler products will be developed as RPs by the NASA NPP Science Team. We are tracking and shadowing this development for eventual transition to operational processing at the NDE facility. While we will compare the OMPS EDRs and IPs to these products, most of the benefit from these comparisons will be in validating the OMPS LP work.)

We will perform processing tests of the Version 8 total ozone algorithm—used at NOAA with the GOME-2 instrument and at NASA for the long-term TOMS/OMI record—on the OMPS NM SDR. We may also investigate the Version 8.5 algorithm, which includes Rotational Raman scattering (RRS) – Ring Effect – estimates of cloud top pressures. We will also perform demonstration processing of the OMPS NP SDRs with the Version 8 ozone profile algorithm used at NOAA for SBUV/2 (and applied to EOS Aura OMI) with other IPO support.

5.6 Computing Resources and Technology

The main workhorse for OMPS cal/val ozone data product validation is a dedicated Linux workstation at STAR, which has three terabytes of RAID storage and two dual-core 2.8 GHz CPUs); this machine is only used for OMPS tasks. It makes use of the NESDIS site license for IDL, licenses for Fortran and C compilers, and NetCDF and HDF5 libraries. Reports, documents, and presentations will be produced on PCs with Windows operating systems and Microsoft Office applications. Reports and figures will be converted to Web-based or PDF formats, while some small data files will be stored in ASCII format. Delivery packages of the OMPS SDR and EDR/IP algorithms from IDPS builds will be available on this system. The anonymous *ftp* site at STAR and the GRAVITE system will be used to make data sets, programs, and documents available to other NPP researchers. A modest amount of additional storage will be added to the STAR workstation over the course of the project as the existing storage is filled and hard disk drive prices come down.

The tasks to improve data from ground-based assets and use them in validation studies will be conducted on existing ESRL computing resources. Analysis of product performance in applications will take place on NWS systems. Use of the IPO's GRAVITE system as more than a system to report and exchange data, code, and documents and to mirror web and ftp sites, will be determined by ease of access for the team members. We do not expect the OMPS work to be storage- or computationally intensive. Given the planned increase in data volumes with time, we do expect to purchase an additional disk drive (on the order of three TB) at the end of the second year. Interactions with the ADA or the NDE Science Algorithm Development and Integration Environment (SADIE) will depend on the NGAS and NDE approaches to implementing algorithm improvements. We have already identified several areas where work could progress, addressing development of newer versions of both the total column and ozone profiles algorithms and improved intermediate product algorithms which are in use or under development, e.g., Version 8 ozone profile, Version 8 and 8.5 total column ozone, Version 9 full spectral ozone retrieval, Rotation Raman Scattering cloud to pressure, atmospheric SO_2, and tropospheric ozone algorithms.

The GRAVITE system will be used to test adjustments, improvements, and corrections for the IDPS-implemented algorithms. These will be triggered by a range of circumstances, such as changes to parameters as the in-orbit instrument characterization is refined, discovery of minor inaccuracies traced back to code errors or deficiencies, and/or anomaly resolution and response. The system will also be used to reprocess data to redo prior match-ups as changes are made in algorithms or instrument calibration and characterization. The GRAVITE system will be used to log discrepancy reports and track calibration issues. We will also explore the use of the SADIE and PEATE systems.

Part of the initial work is to survey the existing programs and tools used for the SBUV/2 and GOME-2 characterization and validation, and the tools already developed by the NASA NPP Science Team and OMPS SDR Cal/Val team to determine the starting point for tool development as outlined in Tasks a.ii and a.iv. This includes monitoring and trending used for operational GOME-2 and SBUV/2 products on NESDIS websites.

6.0 REPORTING

6.1 Product Validation Reports

The major reports required include:

(1) **Complete product evaluation reports** - These reports will be generated for the OMPS total column ozone product and OMPS ozone profile product approximately seven months into the ICV phase. They will summarize the results of the internal and external investigations, and quantify the product performance relative to the requirements with stratification as described. Reports will identify issues arising in meeting requirements created by measurement complications (*e.g.,* wavelength-scale variations or stray light signal contamination). The components of the studies used in these reports will be archived, *i.e.,* the tools, programs and data, and documentation on the procedures.

(2) **Open access Web pages -** Appropriate information will be provided by creating Web pages for general access. They will be created and populated with graphs and statistical analysis pertinent to the OMPS data products. They will be designed for automated updates as products move into regular generation. The reference copy of the pages will live at the STAR domain, but mirrors can be placed at other locations as desired.

(3) **Overpass match-up data sets –** Data sets containing the OMPS products and the overpass match-up data sets (See tasks a.v.ii and c.ii.1.) will be available via anonymous *ftp* and on the GRAVITE system. These will be kept current with automated weekly updates from the latest OMPS processing.

(4) **User-feedback Reports -** At the end of the ICV phase, we will report on the feedback obtained from assimilation users on the performance of the products, including biases in measurements *vs. forecast* fields without the OMPS data sources, and identification of any difficulties in the applications implementation

Interim validation reports will be provided to other members of the NPOESS team at the end of the EOC phase and as discoveries merit. These informal reports will be used to provide documentation on problems, anomalies, and other expected and unexpected performance issues. These findings will also be logged into a common resource/information area to allow rapid dissemination and easy access for NPP researchers, investigators, and users. They will be made into formal CRs or DRs as the severity and importance of the problems mandates.

The impact of risk conditions identified in Section 7, and suggestions for possible mitigation, will be included in the periodic reports or elevated as appropriate for their impact. In cases where the issue is primarily related to measurements or instrumentation, the findings will be relayed to and discussed with the OMPS SDR Cal/Val Team. We will assist them in reproducing our results and identifying the concern, as well as seeking resolution. Similarly, algorithm-based problems will be communicated to the algorithm group. We expect to participate on any anomaly resolution teams.

6.2 Spending Plans/Expenditures

L. Flynn will generate overall fund distribution and the specific budgets (breakout of contractor support, equipment, travel, etc.) for NESDIS/STAR funds; I. Petropavlovskikh will create the specific budget for OAR; and C. Long for NCEP. Most of the funding for STAR will be committed to the Science and Technology Task Order contract vehicle to fund contractor support. The contractor provides monthly summaries of task activities and the actual hours billed, which can be forwarded to the IPO, if desired.

7.0 AREAS OF CONCERN

Estimates of total column ozone and ozone profiles have been obtained from BUV measurements for over thirty years. Owing to this long heritage, the principal areas of concern are primarily instrument-related factors including the quality of the SDR calibration (*e.g.,* radiometric calibration, dark current, and nonlinearity), the fidelity of the modeling of the measurements (*e.g.,* wavelength spectral scale and bandpass), and measurement errors (*e.g.,* stray light and SNRs). Algorithms are generally without deficiency; however, there are two notable exceptions: Cloud top pressure, for the total ozone algorithm, and the use of the obsolete Version 6 algorithm, for ozone profile retrievals.

These concerns will be discussed in detail below.

7.1 Known Risks for OMPS

Aside from the general risks associated with new instruments on a new platform and specific risks as classified below, one general risk area for OMPS is related to the dual nature of the mission.

The OMPS NP and NM on NPP are expected to progress quickly toward operational status, providing a flow of products to users; however, the OMPS LP is a research instrument, with consequent expectations of increased need for testing and experimental operations. We will need to balance the shared electronic resource demands (*e.g.,* main electronic boxes and data and command paths to the satellite, including data bandwidth), among the three detectors. This will require communication and coordination among the researchers, operators, and users. Such communications challenges are met for heritage systems as user needs are balanced against anomaly resolution, calibration, and other science needs. The first test of cooperation is present in the ongoing formation of the combined OMPS IMT, which will define the testing schedule during the EOC phase.

A second general risk concerns long-term stability verification. Long-term calibration correction and trending will require two years of data retrievals before retrospective analysis and characterization can meet performance requirements. Ozone products will need to be reprocessed to produce a data record that meets the long-term stability requirements; this reprocessing will be provided by elements outside of the regular IDPS operational processing system. The OMPS EDR Cal/Val Lead, L. Flynn, is leading a project, under the NOAA Science Data Stewardship Program, to set up a reprocessing system for the OMPS total ozone EDR and ozone profile IP to produce CDRs to help fill this functional gap.

It is also worth noting that the most complete OMPS instrument models are those developed and kept by BATC. (See McComas *et al.* 2004) It is likely that any anomaly resolution will require exercises to model the instrument with differing scenarios. This will require support from BATC under contract to NGAS or the IPO. The arrangements for such support are under discussion.

7.1.1 Risks for the OMPS NM SDR

7.1.1.1Stray Light

NGAS is developing a spectral stray light correction algorithm derived from the extensive characterization testing of Flight Model # 1 (FM1) conducted by BATC. While this stray light model and correction program will be tested before launch, the SDR will be examined to verify the performance of this correction and to determine the magnitude of the remaining contamination and its effect on products. Tasks a.i.1, a.i.3, a.iv.3, a.iv.4 and b.i.2 contain elements of this work. Recognition and correction of stray light for the UV2 channel on OMI provides a path forward for OMPS, although there is still some concern, as Rotational Raman Scattering (Ring Effect) variations share some characteristics with stray light signal contamination.

7.1.1.2 Intra-orbital spectral scale shifts

BATC optical and thermal models and FM1 testing predict intra-orbital spectral scale shifts, albeit within acceptable levels for the error allocation of this component given OMPS NM algorithm sensitivity. We will conduct analysis of the actual in-orbit performance to confirm these results. Tasks a.i.1, a.iii.1, a.iv.3, and b.i.2 contain elements of this work and analysis to identify the size of these shifts and to provide information for their correction to further improve the products. EOF analysis of GOME-2 data provides estimates of spectral scale shift on a scene-by-scene basis consistent with DOAS algorithm estimates. We expect that these shifts would be correlated with along-orbit optical bench temperature variations; this means that they should vary slowly from orbit to orbit. The OMPS algorithms can adjust for known scale shifts.

7.1.2 Risks for the OMPS NP SDR

7.1.2.1 Stray Light

Spectral stray light signal contamination (out-of-band response) is also a risk for the NP, and its presence will be evaluated in the EOC phase. The analysis to be done in Task a.iv.4 parallels the approaches used for the SBUV/2 and OMI instruments, *i.e.,* to determine variation correlations between reflectivity and profile channels and changes in the Earth view across solar features, *e.g.,* analysis of an Earth-view Mg II Index. For some SBUV/2 instruments, it was necessary to develop empirical corrections. This should not be necessary for the OMPS NP, as BATC testing has produced good estimates of the spectral transfer functions. If corrections are needed, information is available to create corrections using longer channels as source proxies.

7.1.2.2 Intra-orbital spectral scale shifts

BATC estimates of drift are smaller than their allocation; therefore, this risk level is low. Analysis of in-orbit performance will seek to identify the size of these shifts and to provide information for their correction if necessary. The Version 6 algorithms adjusted for 0.07 nm shifts in the SBUV/2 measurements when the wavelength grating drives became problematical; the expected shifts for the OMPS NP are smaller than these.

7.2 Known Sensor Risks

There is some leeway in the classification of an item as a sensor risk or an SDR risk. If the principal solution is in the SDR algorithm, then it has been assigned there. Most sensor risks have been addressed at the design level. The detectors are actively cooled to -40ºC, which reduces their sensitivity to radiation damage and reduces dark current and radiotelegraph signals (RTS). The two diffusers allow tracking of on-orbit optical degradation, and onboard LEDs track non-linearity in the electronics. Hyperspectral measurements can provide internally consistent information on wavelength scale changes. Nevertheless, there are four watch items, one major concern, and several smaller concerns.

7.2.1 Temperature effects on slit width (Watch Item)

The first watch item relates to thermal effects and the stability of the viewing slit aperture.

Variations in the silt width will change the measurement bandpasses, making them broader or narrower. Such changes are difficult to detect in orbit. One can check if the line structure in the solar measurements is consistent with the bandpass and a high-resolution reference solar measurement. Note that FM2 will have will have a more-stable slit than FM1. It will be difficult to identify intra-orbit variations, as the solar lines in the Earth-view data are affected by Ring Effect redistributions, so it will be difficult to attribute ozone retrieval errors to this factor. If unresolved errors are large enough, we will try to make spectral comparisons of Earth-view data with other UV instruments using SNO comparisons; EOF spectral analysis may provide further evidence.

7.2.2 Fine Structure in Diffuser (Watch Item)

The second watch item is the repeatability of fine spectral structure in diffuser measurements and possible complications for identifying wavelength-dependent degradation. The ground aluminum diffusers used for OMPS can act as optical gratings and thereby produce view-angle dependent spectral structures. Note that F2 will have better grinding techniques applied than F1. Special solar measurements with short integration times as the incident solar angles on the diffuser vary will be taken in EOC phase; we will monitor the SDR cal/val team’s analysis of these data. Longer-aggregation solar measurements will smooth some of this structure, but a trade-off may be required between diffuser exposure and minimizing the effects of this structure.

7.2.3 Diffuser contamination and optical degradation (Watch Item)

The third watch item is diffuser degradation. During assembly, there was a diffuser contamination incident followed by a cleaning process and additional testing to confirm its success, but we will want to monitor the diffusers’ reflectivity degradation closely. Previous BUV instruments have had a wide range of diffuser degradation behaviors related to in-orbit contamination and length of exposure. We will check for rapid or wavelength-dependent diffuser degradation as well as instrument throughput changes. For the SBUV/2, some dichroic elements are suspected of transmission changes related to water vapor outgassing. We will also look at the bootstrap methods applied to the SBUV/2 diffuser measurements to validate the goniometric coefficients as the solar incidence angles vary. Over the course of a solar measurement, the sun is stable source, so relative changes in the corrected signals for different channels signify goniometric inaccuracies.

7.2.4 EMI Susceptibility (Watch Item)

The fourth watch item relates to the stability of the CCD temperatures. Control for nominal operations has given results within allocated variations, but we will want to verify this stability, as small variations can push the performance of the shortest UV profiling channels beyond requirements.

7.2.5 SAA Signal Contamination (Concern)

The CCD detectors used in OMPS are known to be susceptible to errors from false signals caused by charged particles striking the detector. The SBUV/2 solution for this problem, a chopper wheel and count-up/count-down strategy for its single detector, will not work for the OMPS LP. BATC has modeled the effects of expected event levels as the satellite passes through different portions of the SAA. The errors will produce some additional noise-like features for the OMPS NM, but should not compromise the total ozone EDR performance.

For the OMPS NP, the longer integration time, greater data aggregation, and weaker signals combine to make this a problem. BATC has proposed exclusions from SDR performance requirements as the satellite moves further into the SAA. Their studies also indicate that one can reduce the expected corruption of the profile retrievals by omitting the shortest profiling wavelength channel. This has the weakest real signal, and is therefore most affected by false signals. Dropping this channel does reduce the information in the retrieval at the top of the profile. Dark current measurements on the night side will be used to map out the affected area and the magnitude of the signal contamination. These measurements will also be used to evaluate the SNR performance, of particular importance for the shortest profiling channels.

The GOME-2 approach to this error source is to recognize that SAA particles usually produce an increase in the measurement. They use a lower envelope of radiance to irradiance ratios as a function of wavelength to recognize and remove deviating values. The OMI instrument, with it shorter integration times (2 s versus 38 s) and reduced cross-track spatial aggregation (24 km *vs*. 250 km), has many more measurements. This means that there is a much larger probability that some measurements are unaffected, and that there are more opportunities for outlier detection through internal comparisons than will be present for OMPS. The OMPS NP does have the flexibility to operate with less onboard spatial and temporal signal aggregation. Just-completed results from the OMPS NPP Science Team using OMI data at varying aggregation levels confirm the improvement in unaffected signals with decreased aggregation; this should be investigated as a mitigation strategy for the SAA difficulties. The OMPS NP should be operated with alternative temporal and spatial aggregation during the EOC phase to provide real data to evaluate the change in lost coverage under different modes.

7.2.6 Additional Concerns

While not expected to be a problem for NPP, recent information on the NPOESS platforms has led to concerns regarding jitter. Depending on the power spectrum, these vibrations produce entrance slit motions that can lead to changes in the wavelength bandpass. Such changes are difficult to detect and characterize in orbit, thus limiting the ability to correct for them. We are tracking this issue and the specifications for jitter for future missions.

The OMPS instruments use scramblers to reduce polarization sensitivity. Residual polarization levels meet requirements, and should have little impact on the products. Nevertheless, we will examine performance as viewing geometry changes the polarization state of incoming radiances.

7.3 Algorithm Risks

This subsection presents an overview of some of the concerns for the total ozone and ozone profile retrieval algorithms.

7.3.1. Multiple Triplet Total Column Ozone EDR Retrieval

The OMPS NM algorithm uses a generalized formulation of the Version 7 TOMS algorithm with multiple triplets. The consistency of the multiple triplets ozone estimates must be checked, but this is viewed more as a test of the SDR wavelength-dependent calibration than as an algorithm risk. Of more concern is the recent recognition of significant errors in the use of IR cloud top pressure estimates for an UV measurement, as discussed below.

7.3.1.1 Cloud top pressure errors

NGAS is tracking cloud top pressure errors as an algorithm risk item.

Experiences with OMI have led to a preference for UV-derived effective cloud top pressures over IR-derived ones [REF]. The IR-derived estimates place the cloud tops higher due to increased absorption in the IR by thin cirrus. The OMI total ozone products, produced at NASA, use estimates of inelastic scattering across solar features in the UV (the Ring Effect) to obtain cloud top pressure estimates for the total column ozone retrievals. The OMI Science Team has also produced a preliminary set of climatological values as a function of month, latitude, and longitude from four years of data. We expect that the initial OMPS total ozone EDR will use baseline VIIRS cloud top pressure estimates.

We are currently following two paths to improve the operational GOME-2 total ozone products: using OMI climatology, or implementing a Ring Effect estimate algorithm; we will implement a similar set of options for the Version 8 total ozone algorithm for OMPS, and the NPP Science Team is working along similar lines as it looks to OMPS to extend heritage TOMS and OMI records. Both of the GOME-2 options can be implemented with the OMPS total ozone EDR algorithm. The algorithm already uses a default climatology when VIIRS data is absent; this could be replaced with the new OMI-derived climatology.

7.3.1.2 Algorithm performance without limb measurements

Before demanifestation of the OMPS LP, the total ozone EDR algorithm used information from the OMPS LP ozone profile EDR to obtain better estimates of the ozone profile shape and improve total ozone estimates. The requirements have been adjusted for the absence of this information. Tropospheric ozone corrections and profile shape correction strategies include using the OMPS NP products to estimate stratospheric ozone amounts, updating tropospheric climatologies with current data. We will examine tropospheric residual estimates, and compare them to ozone balloonsonde and IR ozone estimates as a check on the tropospheric component of the total column ozone.

7.3.1.3 Algorithm tuning for sensor characteristics, parameters, and look-up tables

The EDR Algorithm Team at NGAS is currently investigating approaches to generate LUTs to provide adequate fidelity in representing the cross-track spectral smile and the instrument view angles. These LUTs must account for atmospheric radiative transfer properties, including Ring and Telluric Effects and sensitivities to temperature and ozone profile variations and wavelength scale changes.

As an additional complication, the widely used Bass and Paur (Bass and Paur 1985) UV ozone cross-sections are under scrutiny [REF]; the international ozone community is consider replacing them with newer measurements reported in Daumont *et al.* (1992) and subsequent studies [REFs from White paper.]. The newer measurements show temperature-dependent behavior more in line with theoretical expectations. The OMPS program should be prepared to follow the lead of the other UV sensor programs in this issue. A change in these data would require re-computation of the master tables used to generate the LUTs for the algorithms.

Version 6 Maximum Likelihood NP Ozone Profile Retrievals

As noted earlier, since the use of the Version 6 SBUV ozone profile algorithm is specified for the OMPS NP DIP, one could consider the product requirements to be met if the SDRs have the desired performance and the algorithm is correctly implemented. The main complication in this implementation for OMPS is the need to obtain longer wavelengths at the FOV sampling of the nadir profiler. Simple aggregation of the OMPS NM measurements will be used to achieve this. Accurate knowledge of the characteristics of both the OMPS nadir sensors in the overlapping wavelength region surrounding 305 nm is critical to merging information from the two sensors. This is among the internal consistency checks in the EOC phase tasks b.i.

7.3.1.1 Use of hyperspectral measurements

The algorithm currently uses makes use of 12 (eight for profiles and four for total ozone and reflectivity), with nominal centers at 253, 273, 283, 288, 292, 298, 302, 306, 313, 318, 331 and 340 nm. The performance of the OMPS NP IP can be improved by the use of information at additional wavelengths.

A modification to use additional measurements has been regarded as a mitigation approach for SDR performance issues, *e.g.,* poor SNR at 252 nm, and SAA signal contamination. This approach would require a substantial modification of the Version 6 algorithm code. One option is to implement a preprocessor to remove outliers and to concentrate spectral information at the current Version 6 channels.

7.3.1.2 Version 6 ozone profile retrieval algorithm compared to Version 8

There are other deficiencies in the Version 6 algorithm relative to the Version 8 (V8A) currently used to produce operational SBUV/2 products. The Version 8 SBUV (/2) ozone profile retrieval algorithm combines backscattered UV measurements and *a priori* profile information in a maximum-likelihood retrieval. (See Rodgers (1990) for an analysis of this class of retrievals.) The V8A improves on the Version 6 SBUV (/2) algorithm described in Bhartia *et al*. (1996).

Among the improvements relative to the Version 6 are the following:

- V8A has new set of *a priori* profiles varying by month and latitude, leading to better estimates in the troposphere—where SBUV/2 lacks retrieval information—allowing simplified comparisons of SBUV/2 results to other measurement systems. In particular, these include Umkehr ground-based ozone profile retrievals that use the same *a priori* data set.
- V8a has a true separation of the *a priori* and first guess profiles. This simplifies averaging kernel analysis.
- V8A has improved multiple scattering and cloud and reflectivity modeling. These corrections are updated as the algorithm iteratively converges to a solution.
- V8A reduces some errors present in V6A, including eliminating errors on the order of 0.5% by providing improved fidelity in the bandpass modeling.
- V8A incorporates several *ad hoc* Version 6 algorithm improvements directly. These include better modeling of the effects of the gravity gradient, better representation of atmospheric temperature influences on ozone absorption, and better corrections for wavelength grating position errors.
- V8A uses improved terrain height information and gives profiles relative to a climatological surface pressure.
- V8A is designed to allow the use of more-accurate external and climatological data, and allow simpler adjustments for changes in wavelength selection.
- V8A is designed for expansion to perform retrievals for hyperspectral instruments.

Another improvement is based on the observation that atmospheric ozone absorption decreases by several orders of magnitude over the 252 nm-to-340 nm wavelength range. The standard V8A uses a variable number of backscattered UV measurements, depending on the SZA of the observations to maintain its sensitivity to ozone changes in the lower atmosphere. For small SZA, (*i.e.,* the sun is high in the sky), only six wavelengths are used in the retrievals. They are at

273 nm, 283 nm, 288 nm, 292 nm, 298 nm, and 302 nm. As the SZA increases, the 306-nm, 313-nm and 318-nm channels are successively added to the retrieval.

The IPO recognizes this disconnect between the planned IDPS Version 6 product and the heritage product, and is funding work at STAR to adapt the Version 8 profile retrieval algorithm for use with OMPS in a separate project. We will evaluate the Version 8 ozone profiles, and compare and contrast their performance with the ozone profile IP. The Version 8 algorithm can be easily modified to make use of more wavelengths, which would allow better performance with respect to precision, given waivers on SNR for the shortest wavelengths.

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APPENDIX I – DETAILED PLAN FOR OMPS EDR VALIDATION

While the four phases of NPP, calibration and validation (PL, EOC, ICV, and transition to operations and LTM) are well defined (*see* Section 3.2), the activities and tasks to prepare for and conduct the analysis and comparisons know no such boundaries. Many later tasks depend on or involve continuation of earlier ones. Tasks within any particular period may require modification due to actual instrument or algorithm performance, occurrence and resolution of anomalies, or availability of data or resources. Preparation of analysis programs, collection of data sets, and adaptation and implementation of algorithms for use in a given segment will need to begin before the start of each period. The schedule must consider the following: the time to develop and test programs to process the data, the time to acquire the required data, the time to perform analysis of results, and the time for iterations as analysis provides information for improvements and these turn into revised products. Therefore, the following material, while a detailed guide to the overall work, the specific order of completion is not set in stone.

A1.1 Pre-Launch Phase

This phase of the work is currently underway, and will continue until launch, currently expected in the summer of 2011. The tasks described below include developing tools and readers to manipulate and analyze the OMPS and correlative ozone products, and implementing operational and heritage algorithms. A substantial amount of work is planned to develop analysis and manipulation tools for the OMPS products. The tool development portion will draw upon the many useful procedures in use for existing SBUV/2 and GOME-2 programs, as well as those under development or collected by the OMPS SDR cal/val team. There are existing JCSDA-funded projects to investigate the assimilation and application of products from OMI, the High-resolution Dynamic Limb Sounder (HIRDLS) and MLS, with qualities similar to those of OMPS. During this phase, we will collect and assemble documents on the programs and data sets used in the work, *e.g.*, calibration test reports, ATBDs, users' guides, and data format specifications handbooks.

A1.1.1 – Objective: Obtain and navigate instrument characterization and calibration measurements

While the main tasks related to this area are for the NGAS algorithm development groups and the joint IPO/NGAS cal/val team, there are some specific areas where the EDR and IP cal/val team needs to be involved. The following three tasks have a target completion date of January 2010.

Task a.i.1. Obtain key calibration data

Intercomparisons of OMPS nadir instruments' solar and Earth measurements with those from other sensors require familiarization with and adjustments for the radiance and irradiance calibrations, the wavelength scale and bandpass specifications, instrument FOVs and satellite viewing angles (SVAs), and stray light corrections. Solar observations will be Doppler-shifted due to spacecraft motion. Programs to provide spectral scales (and shifts for Earth- *vs.* solar-view), bandpasses, FOVs, SVAs, and radiance and irradiance calibration for detector pixels for both the OMPS NP and OMPS NM will be developed under this task.

Task a.i.2. Collect parameters and information for alternative algorithms

Alternative algorithms require similar information to that needed for the main algorithms to select channels and generate LUTs. Programs to determine the channel selection and provide tables and parameters for those channels for the Version 8 Total Ozone and Version 8 Ozone Profile retrieval algorithms will be developed under this task.

Task a.i.3. Develop models of and corrections for instrument performance

Corrections for stray light contamination and wavelength shifts are under development by NGAS and BATC. The resulting programs and data—with and without corrections—will be acquired and tested under this task.

A1.1.2 – Objective: Obtain and manipulate sample SDR, EDR, GEO, and IP data sets

To be ready for the expected flow of OMPS data, programs will be developed and tested using increasingly realistic sets of sample data. These data sets progress from simple sets with proper format, to those with data in realistic ranges, to synthetic data with modeled values, to proxy data with values from actual measurements from other instruments. The OMI and GOME-2 instruments will be used for this last data set. The first two data sets will be provided by NGAS, and the latter two will come from NGAS, the NPP science team, and from other tasks in this plan. The progression from basic to more complex data sets has a target of four-month intervals with proper format by 6/2009, realistic ranges by 10/2009, synthetic data by 2/2010, and proxy data by 6/2010. There is a set of related tasks, supported by NESDIS, to convert the data delivered by the IDPS into formats compatible with those currently used by the NWS, *e.g. BUFR*. There are also existing tasks supported by the JCSDA to prepare for the use of the new data in applications and monitoring. The OMPS cal/val team will work with both of these efforts to ensure that the product evaluation activities can proceed smoothly.

Task a.ii.1 Develop readers, writers, and processors for OMPS data sets

The programs to read and write the data must interface with programs to process the data to create match-ups; to compute and display statistics, trending, and gridded data; and to run alternative algorithms. The work in this task will parallel and anticipate the development of analysis and other programs. There is a STAR team funded by PSDI working to put NPP products into BUFR and gridded binary (GRIB) format. Their programs will be used in the evaluation of the products in applications.

*Task a.ii.2. Create synthetic data set*s

By using instrument specifications and radiative transfer forward models, synthetic data sets can be created to test performance, analysis, and processing. Three radiative transfer programs will be used in the creation of OMPS synthetic data in this task. They are the TOMS Radiative Transfer (TOMRAD) code, the Linearized Discrete Ordinate Radiative Transfer (LIDORT) code, and a single-scattering code developed for use with the SBUV/2. These codes will be used to create test input synthetic data for the readers and follow-on processing in the associated tasks as well as tables for alternative algorithms.

*Task a.ii.2. Create proxy data set*s

By using existing measurements from hyperspectral instruments (in this case GOME-2 and OMI), sample OMPS pseudo-measurements can be created. The NPP OMPS Science Team has done this for the OMPS NM with OMI data. This task will produce similar data from both OMI and GOME-2, and extend the proxy values to the OMPS NP wavelengths.

A1.1.3 Objective: Implement test streams of alternative heritage algorithms

The current NOAA operational algorithm for SBUV/2 is the Version 8 ozone profile algorithm; that for GOME-2 is the Version 8 total ozone algorithm. The resultant products have well-known properties, and the performance desired by operational users. Over the next two years, the algorithms will be will adapted to run on OMPS SDRs. This will allow direct comparison to existing products, with close to identical algorithms used in the processing.

Task.a.iii.1. Implement the Version 8 total ozone algorithm

The Version 8 total ozone algorithm was recently adapted to process data from the Chinese FY-3 platform’s Total Ozone-mapping Unit (TOU) instrument at NOAA/NESDIS. This task will follow similar adaptation to prepare for processing OMPS NM data. An additional complication from recent implementations for GOME-2 and TOU will be the need for SVA-varying tables to account for wavelength scale and bandpass variations across the FOV—that is, as a function of pixel column. The target for the algorithm implementation in this task is that it should be ready for testing with the OMPS NM SDR proxy data by 6/2010.

Task a.iii.2. Implement the Version 8 ozone profile algorithm

The algorithm implemented to produce the OMPS NP ozone profile IP is the outdated Version 6 SBUV/2 algorithm. This algorithm has been replaced in NOAA SBUV/2 processing by the improved Version 8 ozone profile algorithm. Since current ozone applications are making use of this newer product, the IPO is providing support to NOAA/NESDIS to adapt the Version 8 algorithm for possible implementation in the operational OMPS NP IP stream. This task will support that work and piggyback on it to develop an alternative processing algorithm for the OMPS NP. In addition to the improved comparisons with the SBUV/2 products, Version 8 will also provide better diagnostic information for instrument performance.

Task a.iii.3. Implement capability to use algorithm sensitivity in testing and experiments

The EDR and IP products contain sensitivity information that allows studies of potential adjustments to the SDR input. This task will create routines to allow rapid generation of products with posited calibration changes without the need for full reprocessing. Similar tools are already in use with SBUV/2 and GOME-2.

A1.1.4 - Objective: Develop ICVS monitoring, internal consistency and information content evaluation

Current analysis and monitoring for the SBUV/2 and GOME-2 products at NOAA include a variety of internal consistency and trending checks. This set of tasks will prepare programming tools and Web sites to duplicate and expand those for use with OMPS.

Task a.iv.1. Prepare programs to monitor diagnostic values in OMPS products

The primary objective of this task is to create programs to generate an automated set of Web-based figures that track a variety of zonal mean and other statistics for initial and final measurement residuals, effective reflectivity, total ozone triplet and pair consistency, and error and quality flags similar to those produced for the SBUV/2. This will be the first line of evaluation of OMPS ozone products. The programs created in this task will update data sets with daily product information, and create graphics to display and track the results after launch.

Task a.iv.2. Prepare programs to examine performance in selected regions

The work in this task is directed toward more-specialized consideration of retrieval performance in selected regions, specifically, latitude/longitude boxes in the Equatorial and Southeastern Pacific, regions of Greenland and Antarctica, and the SAA. Analysis for the Pacific regions will compare weekly means as a function of SVAs for ozone, residuals, and reflectivity; the analysis for Greenland and Antarctica will examine ice radiances; and the SAA study will look at charged particle effects especially for the OMPS NP. Programs to manipulate the results with proposed calibration changes by using the retrieval sensitivities and optimal estimation matrices will also be adapted from those in use for SBUV/2 and GOME-2. While this task is in the internal evaluation area, the results for these regions will be compared to climatological and concurrent values from other sources.

Task a.iv.3. Evaluation of the information and error content of the OMPS SDRs

The work in this task will adapt the EOF covariance analysis used for GOME-2 and OMI to create a tool to apply to OMPS spectra. This analysis can separate out patterns for ozone and other trace gas absorption, the Ring Effect, wavelength scale drift, noise, stray light, and satellite view angle variations. It can also be used as a filter and correction for some signal contamination.

Task a.iv.4. Additional internal checks

This task collects up a variety of miscellaneous items that will provide useful information on the nadir instruments' performance. These are more specialized tests and comparisons and, in general, they will be used less frequently than the previous analyses. The initial task will just involve collecting sample codes and descriptions of the methods as applied to heritage sensors.

The first class of methods is called "spectral discrimination". In one application of this method, differences in effective reflectivity are studied as cloud brightness and SZAs vary. It has been used to check for nonlinearity, hysteresis, and inter-wavelength calibration errors. The analysis is complementary to that obtained by looking at aerosol indices as a function of wavelength selection.

The second class of methods uses the consistency of data across solar lines to check for Ring Effects, stray light, and solar activity. For example, an Earth-view Mg II core-to-wing ratio index can provide information on additive stray light errors, or the adequacy of an applied correction. The solar measurements will also contain information on spatial stray light, as the diffuser only occupies a fraction of the full FOV.

A third class of methods examines overlap in the 300 nm-to-310 nm spectral region to evaluate the consistency of the OMPS NM and OMPS NP calibration and registration and the presence and character of stray light. The dichroic optic element alters the signal dramatically in this interval, while the stray light contribution drops off slowly.

A1.1.5 - Objective: Support ground-based activities and prepare match-up processing tools

During the PL phase, in addition to preparation for manipulating the data to conduct comparisons, the plan also has substantial components to improve the access and quality of the ground-based assets. Both areas are described in the following tasks.

Task a.v.1. Support for the ground-based component

The plan includes support for specific improvements and maintenance of the ground-based systems pre-launch. These activities include developing and implementing a system for NRT (next-day) delivery of total ozone data; contributing to maintenance and calibration of the world standard Dobson # 83; contributing to activities for propagation of Dobson instrument #83 calibration to the ESRL (and global) Dobson network; contributing to support for Brewer network operations; investigating quick-access strategies and resources for ozone balloonsonde data, such as are currently provided by the South Pole station. Support to put this final activity into effect would be provided in the post-NPP-launch time frame. The other activities will proceed from the present.

Task a.v.2. Prepare to generate and analyze overpass data (with Task a.ii.1)

The components of this task include developing programs to: read and write OMPS product and geolocation information and ground-based products (for a collection of Dobson, Brewer and Ozone balloonsondes); devise match-up criteria and create overpass data sets for satellite retrievals; and perform statistical analysis and data smoothing (*e.g.,* applying averaging kernels) to compare the results. These programs and sample data from ground-based and satellite-based systems will be exchanged among the cal/val team members. A set of 200 or more ground sites will be selected for inclusion in the ASCII-format overpass database. Team members currently are comparing SBUV/2 data to Dobson and Umkehr measurements for a collection of ground stations. The OMPS NP DIP will be nadir-only—like the SBUV/2 ozone profile products—so it will require a relaxed criterion for match-ups. The SBUV/2 program uses a criterion of 2° latitude and 20° longitude.

Task a.v.3. Prepare to compare and analyze satellite data (with Task a.ii.1)

The components of this task include developing programs to: read and write OMPS, SBUV/2, OMI, MLS and GOME-2 products; create matched data sets; and perform statistical analysis and displays *vs. other* variables (for example, latitude or SZA) to compare results. Many of these programs are already in use for SBUV/2 and GOME-2 validation work. Tasks include collecting a sample of non-OMPS data sets, generating gridded map products and zonal means for both the original data and differences, and preparing to sub-sample data sets for SNO events.

Task a.v.4. Further specific programs to compare data

The main work of validation is analysis of differences. These analyses include creating histograms, plotting differences or summary statistics over time, producing scatter plots, and performing regression fits to appropriate models. The task will collect and refine tools to perform these analyses.

A1.2 Early-Orbit Check-Out Phase

The EOC phase is tentatively identified as the first 90 days after launch. The primary objective, from the instrument point of view, is to conduct the series of tests defined in the IMT. While the main burden of work during this period lies with the OMPS SDR Cal/Val Team, some key performance areas and analyses will occur in the EDR area. This work will also provide the first real data to check out the alternative algorithms, match-up codes, and other tools. We will examine the results of planned CrIS comparisons with IASI and AIRS radiances, to be performed by the CrIS Cal/Val Team.

Task b.i.1. Evaluate solar spectra and begin Mg II Index

In this task, solar measurements will be compared with those from reference measurements (with adjustments by scale factors for solar activity) and those from the SBUV/2, OMI, and GOME-2 instruments, for absolute calibration, wavelength registration, and bandpass shape assessment. The internal consistency of the measurements will also be examined. The Mg II Index from the OMPS NP will be compared to those from SBUV/2 instruments. These results will provide a baseline for further solar measurements. The principal responsibility to track the instrument calibration lies with the OMPS SDR Cal/Val team but following their progress and results will help us to understand how the instrument behavior is affecting the downstream products.

Task b.i.2. Evaluate Earth spectra (follow-on to Task a.iv.3.)

The EOF analysis can begin with Earth measurements during this phase. The analysis in this task will provide information on the measurement noise, wavelength scale, spectral correlations, and view-angle consistency. The results will be shared with and compared to those from the SDR Cal/Val team to confirm algorithm parameters and tables, and compare day-1 values to laboratory characterization. An initial appraisal of the stray light corrections will also be obtained. The performance of the OMPS NP in the SAA (*e.g.*, SNRs and outlier statistics) will be given particular attention. Basic geolocation information will be confirmed by mapping reflectivity channels over land/water and ice/water boundary regions, and by comparison with co-located VIIRS measurements.

Task b.i.3. Test readers and analysis tools

The first tests of tools to process and manipulate data and to generate initial results with real data will be made in this phase. We expect that there will be some tuning and modifications of the SDR and EDR products during this period, and that coverage may be spotty,

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Task b.i.4. Test and adjust alternative algorithms

Initial Earth SDR data will also be used to test the implementation of alternative algorithms. They will require tuning and adjustment for on-orbit instrument behavior. The need for tuning and adjustments will be identified and shared in consultation with the SDR Cal/Val and Algorithm Teams.

Task b.i.5. Begin enhanced ground-based data processing

In this phase, we will begin providing more rapid access to ground-based ozone estimates from ESRL assets. This access will be supported and continue through the next (ICV) phase.

A1.3 Intensive Calibration and Validation Phase

During the approximately six months following EOC, the products move into regular production, and the OMPS EDR and IP Cal/Val Team gets its turn in the spotlight. As the following tasks progress and trending continues, information will flow back to the SDR Cal/Val and Algorithm Teams, and forward to the product users.

A1.3.1 - Objective: Internal consistency evaluation and trending

Once regular processing of Earth-data begins, internal consistency analysis and trending begin in earnest—that is, application of the tools developed in Tasks a.iv.1-4. Inconsistencies will be identified and their causes will be investigated. The philosophy for the total ozone EDR is to establish the performance of the (316, 329, 364)-nm B-triplet for nadir measurements, and then to extend this to other triplets and view angles.

Task c.i.1. Web-based monitoring graphics (follow-on to Task a.iv.1)

This task begins analysis, monitoring and trending of standard on-orbit data. The work will produce regular updates and populate the Web-based monitoring pages. The OMPS products will be received and processed, and monitoring plots will be updated and evaluated.

Task c.i.2. Performance, statistics and cross-track consistency for selected regions

With as little as one week of full coverage data, the programs and analysis tools developed and prepared in Task a.iv.2 will be used to check instrument and algorithm performance in regions with well-behaved geophysical values. If this task finds inconsistencies, then sensitivity analysis and adjustment testing tools will be used to probe possible sources, and alerts will be distributed to other members of the NPOESS team.

Task c.i.3. Reflectivity statistics and the start of ice reflectivity trending

This task will continue analysis of reflectivity results. Tests will run from generating basic statistics (*e.g.,* maxima, minima, distributions) to characterizing wavelength, signal level, and

SZA dependencies. Depending on the time of year, this task will also include reflectivity analysis for either Greenland or Antarctica, and the start of trending for those quantities. Initial validation will concentrate on the 329-nm channel. Results for this channel will be extended to other reflectivity wavelengths by comparing values for bright scenes.

Task c.i.4. Aerosol Index statistics and consistency

An aerosol index is a measure of the deviation of the reflectivity from the expected wavelength dependence from a simple cloud model; clean regions of the Earth atmosphere should produce near zero indices. Mid-Pacific Equatorial areas with further screening to avoid sun-glint angles are preferred. Validation will concentrate on the 364-nm channel's consistency with the 329-nm channel, and then extend these comparisons to other long-wavelength triplet components.

Task c.i.5. Ozone pairs and triplets

The algorithm obtains ozone estimates from a set of triplets. Initial validation will concentrate on those using the B-pair ozone (316 nm paired with 329 nm, or 318 nm paired with 331 nm). Validation will then be extended to triplets using different short channel pairs (Column 1 of Table 4) by looking at their performance in benign regions, *i.e.*, those with low SZA and low ozone levels.

Task c.i.6. Comparison with results from alternative algorithms

The OMPS products generated with the primary algorithms will be compared to those from the alternative algorithms. The OMPS total ozone EDR will be compared to results for the heritage Version 8 total ozone algorithm applied to OMPS, and the Version 6 OMPS ozone profile IP will be compared to the heritage Version 8 ozone profile results. These comparisons and benchmarks will allow a clean transfer to the OMPS EDR and IP products from the Version 8 products from OMI, GOME-2 and SBUV/2 in the next section. That is, they will help to separate out differences due to algorithmic effects from measurement ones. They are also the first steps toward extension of the heritage SBUV (/2) ozone CDRs. The OMPS total ozone and ozone profile products will also be compared with CrIS IR ozone products under this task.

Task c.i.7. Golden days

The OMPS cal/val team will participate in selecting golden days for use across the NPP platform. The work in this task consists of collecting and preserving data (including match-up data from the next two sections) for those selected days. Some pertinent considerations are discussed in Appendix VI.

A1.3.2 - Objective: Satellite data comparisons

The quickest and most comprehensive evaluation of ozone product performance, after the start of regular processing, will be obtained by comparisons with previously validated products from other satellite sensors. There are several current missions (EOS Aura OMI and MLS, POES SBUV/2, and MetOp GOME-2) that should still have working instruments in the late 2011/early 2012 time frame. NOAA/NESDIS has good access to and experience with manipulating ozone products from all of these sources.

Task c.ii.1. Total column ozone, aerosol index, SO_2, and reflectivity comparisons

This task will make zonal mean, in-phase orbital match-up, and SNO comparisons of total ozone algorithm products from OMPS (both from the standard operational algorithm and from the Version 8 algorithm) with those from the SBUV/2, OMI, and GOME-2 instruments. Given the similar equator crossing times of EOS Aura, NOAA-19, and NPP, orbital match-ups can be made very tight match-up criteria. The breadth of comparisons will be used to evaluate product performance stratified by total ozone amount, SZA, latitude, and reflectivity. There is ongoing activity to develop a UV-based cloud pressure climatology. Depending on progress and implementation, dependence of ozone estimates on various cloud pressure approaches will also be investigated under this task.

Task c.ii.2. Ozone profile comparisons

This task will be performed in parallel with the preceding task to compare OMPS ozone profile products (Version 6 and Version 8 algorithms) with those from SBUV/2, OMI, and MLS. The SBUV/2 and OMI have Version 8 ozone profile products, and the SBUV/2 on NOAA-19 should have equator crossing times close to those for NPP. Definitive calibration offsets between the OMPS NP and those from SBUV/2 will be estimated from equatorial zonal mean differences. Comparing performances for clear and cloudy scenes will help to evaluate stray light corrections. The higher spatial resolution of the OMI products will allow the creation of good match-up scenes. The better vertical resolution of the MLS products will require the use of the Version 8 averaging kernels for direct comparisons. This type of refinement is used in the current SBUV/2 comparisons to MLS. Performance of the OMPS NP in the SAA will be compared to that obtained by the heritage SBUV/2, with its chopper wheel configuration.

A1.3.3 - Objective: Ground-based data comparisons

This plan contains specific support to improve the quality and timeliness of ground-based measurements from Dobson, Brewer, and ozone balloonsonde stations for use in OMPS validation. The team draws upon considerable experience with suborbital ozone measurements and validation. Together, these two sources give reassurance that ozone products can be validated during ICV. The tasks in this section will be repeated regularly over the course of the mission, as new data deliveries warrant.

Task c.iii.1. Match-up data sets

The task will begin by exercising match-up tools to produce overpass data sets for the ground stations. This will not be limited to the NOAA-operated stations, but will include a large set of WOUDC, SHADOZ, and NDACC stations. All products meeting time and distance criteria for each station will be collected into a station data file, which will continue to grow over NPP's mission lifetime.

Task c.iii.2. Total ozone comparisons

In this task, total ozone estimates will be obtained from Dobson and Brewer measurements, and will be compared to OMPS overpasses results. Systematic differences as a function of station, sky conditions, SZA, and ozone amount will be identified. Time-dependent summary plots will be generated and updated. Because of station-to-station biases, the plan provides for a dedicated set of quality stations to provide timely data to allow better tracking of the accuracy of the diffuser and instrument throughput characterization.

Task c.iii.3. Profile ozone comparisons – Umkehr

The Umkehr mode data from selected stations will receive expedited processing during this phase. The data will be compared to the OMPS NP overpass products. Depending on the Version 6 and Version 8 algorithm, relayering will be applied to generate individual station/layer trending plots.

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*Task c.iii.4. Profile ozone and tropospheric comparisons – ozone balloonsond*e

The NOAA ozone balloonsonde stations will have extra measurements and expedited delivery during this phase. The NPP Science Team has arrangements with the SHADOZ stations for additional and rapid processing for comparison to the OMPS LP products. The WOUDC receives deliveries of ozone balloonsonde data from stations worldwide. Overpass data will be created for all three of these sets of stations in Task c.ii.1, and statistical analysis will be provided for the match-up differences. Comparisons to the OMPS NP products will require application of averaging kernels to ozone balloonsonde data before layer comparisons are performed. Unfortunately, much of the ozone balloonsonde data lies below the mid-stratosphere, where the OMPS NP has low vertical information resolution. Ozone balloonsonde data will provide information to check the appropriateness of tropospheric ozone in standard and climatological profiles used in total ozone retrievals and tropospheric ozone estimates from tropospheric ozone residual (TOR) techniques, *i.e.,* tropospheric ozone estimates obtained by subtracting stratospheric ozone estimates from total column ozone estimates. It will also provide validation for the CrIS IR ozone profiles, as they have information for the upper troposphere/lower stratosphere. See Divakarla *et al.* (2008) for a report on validating AIRS ozone profile products *vs. those* from ozone balloonsondes.

Task c.iii.5. Other ground-based ozone profiles

There are a variety of other instruments that can provide ozone profile estimates including LIDAR, FTIR, and microwave instruments. Many of results are reported to the NDACC, which is housed at NOAA NCEP, with a mirror site at the AVDC. The reporting timeliness for these results varies. These measurements will be included in the overpass generation, and comparisons will be updated as data deliveries merit, but probably not more often than once every two months.

A1.3.4 - Objective: Product applications and assimilation

The purpose of the OMPS program is to provide ozone and other products for use in weather, UV index and air quality forecasts, and monitoring the atmospheric ozone layer. The OMPS products will be assimilated into numerical models at the NWS. As part of this plan, during this period NCEP will evaluate product quality and suitability for use in their applications.

Task c.iv.1. Feedback on product quality

This task will evaluate products performance relative to other sources of information used in NWS models. Feedback will be provided on product biases and variability, and the adequacy of algorithm flags for identifying problem retrievals. This type of feedback is being provided as the NWS begins assimilation of the GOME-2 total column ozone products.

A1.4 Transition to regular operations and long-term monitoring

At some point in the first year of operations, sufficient understanding and validation of the OMPS products will be reached, and the products will move into regular production and use. At that point, the activities addressed by this cal/val plan move to a reduced level of effort. Most activities will continue, but with less-frequent updates and less analysis unless anomalies arise or problems identified in the intensive period remain unresolved. It is important to note that a demonstration of long-term stability performance is not possible until two years of measurements have been made, and measurements have been reprocessed with retrospective instrument characterization and calibration.

Task d.i.1. Transition to regular trending and monitoring

The work in this task will consist of automating processing and analysis to produce Web-based evaluation of product performance; performing regular updates of validation comparisons; and periodic analysis of product performance in selected regions.

Task d.i.2 Key long-term trending

This task consists of trending that is conducted on a time scale of years. The variables of interest include ice radiances, ozone pair/triplet differences, ascending/descending profile and measurement differences, initial residuals, diffuser degradation, and instrument throughput.

Task d.i.3 Maintenance of alternative algorithms

This task addresses the alternative algorithms' needs for updates to tables and parameters as understanding of the instrument and its behavior in flight evolve.

APPENDIX II - ICVS MONITORING IN DEVELOPMENT FOR GOME-2 AND SBUV/2

Given the importance of the key heritage instruments GOME-2 and SBUV/2 for OMPS calibration and validation activities, it is important to understand related activities—either planned or underway—for these sensors, and how they tie to OMPS cal/val activities. Key areas of importance are:

- Irradiance comparisons and products
- Earth radiance and products
- Total column ozone and reflectivity
- Ozone vertical profiles

There are other sources of information that can be applied, as discussed at the end of this appendix.

AII.1 Irradiance Comparisons and Products

The instruments have differing spectral resolution and wavelength scales. Consistent solar irradiance comparisons can be made by looking at the differences for each with a properly bandpass-averaged high-resolution solar spectrum. It is also possible to check and track/trend the solar wavelength scale by using the solar Fraunhofer structure. If the measurement includes the region around 280 nm, it is also possible to make a time series of an Mg II Line Core-to-Wing Ratio Index. These have information on real changes in the solar signals.

1. Irradiance Monitoring Figures

1.a. Comparisons of a solar reference to the solar spectral measurements from the different sensors.
1.b. Time series of Mg II Indices.
1.c. Times series of the wavelength scale changes.
1.d. Times series (surface) of diffuser degradation estimates as a function of wavelength.

AII.2 Earth Radiance and Products

In addition to the above factors for the solar data, there are four important considerations for comparing SBUV/2 measurements and products: the FOVs are large, the wavelengths are measured consecutively, changes in the SZA and SVA affect the signals, and ozone does not have large diurnal variations from 9AM to 3PM. These considerations have led us to use zonal mean statistics (especially equatorial) as a means of comparing performance. We can use SNOs, but there is a need to do some development work.

A further complication occurs with the distinction between NRT operational products and reprocessed CDRs: The instrument calibration is refined using retrospective analysis and validation results before reprocessing to products CDRs. Much of the current monitoring is for the operational performance.

2. *Earth Radiance and Instrument Monitoring Figures*
    - 2.a. Time series of zonal mean SNRs for each of the 12 channels.
    - 2.b. Time series for the Inter-Range Ratios.
    - 2.c. Comparisons of the non-linearity estimates in-orbit with those computed in the lab.
    - 2.d. The SBUV/2 Grating Drive errors.
    - 2.e Estimates of SBUV/2 stray light (both In-band and Out-of- Band Stray Light)

AII.3 Total Column Ozone and Reflectivity

The total column ozone estimates we produce at NOAA are from algorithms using discrete measurement pairs (one at an ozone absorbing wavelength, the other at a nearby reflectivity wavelength). Products from algorithms using spectral windows *e.g.,* DOAS methods, are available for comparison for OMI and GOME-2. These two methods have different sensitivities to calibration uncertainties.

We can also make comparisons between estimates with different wavelength pairs as an internal consistency check. Some time series of these comparisons are in plots on the ICVS SBUV pages at http://www.star.nesdis.noaa.gov/smcd/spb/icvs/proSBUV2operation.php. Note that the discrete wavelength algorithm computes residuals at all 12 wavelengths for the retrieval results from a single pair. It also reports the sensitivity of each residual to changes in the total ozone and reflectivity. Ten-day averages of these residuals over the Equatorial Pacific can be used to identify calibration differences and provide estimates for calibration adjustments. Differences between ozone estimates for the total column estimates and the ozone profile estimates are in the fifth set of figures at the listed ICVS page.

Wavelengths with little ozone or other trace gas absorption are used to give estimates of cloud and surface reflectivity. These can be compared among different instruments over specific regions (*e.g.,* Antarctic and Greenland ice sheets, and open ocean in the Equatorial Pacific) and statistically for long-term stability and relative offsets. Models to remove SZA and SVA have been developed. The 1- and 99-percentile values for the cloud reflectivities are shown in the last set of figures on the ICVS page.

3. *Total Ozone and Reflectivity Monitoring Figures*
    - 3.a. Time series of daily zonal mean total ozone estimates
    - 3.b. Time series zonal mean differences among ozone for total column, profile total, pairs, instruments, DOAS
    - 3.c. Trends of Ice Reflectivity for Greenland and Antarctica
    - 3.d. Statistics and distributions of global reflectivity
    - 3.e. Time series of residual for the Equatorial Pacific
    - 3.f. Evolution of empirical radiance adjustments

AII.4 Ozone Vertical Profiles

The SBUV/2 Version 8 Ozone Profile Retrieval Algorithm is used to generate ozone profile estimates. It is a maximum-likelihood retrieval, with a set of climatological profiles stratified by month and latitude. We have released a DVD with the SBUV/2 reprocessed data through 2003. We updated this release with 2004-2007 data in 2009. The DVD contains a variety of documents and figures that we will mirror at the ICVS or GSICS. Operational processing parameters are updated over time, and reprocessing has additional adjustments to the calibration and instrument characterization. DVD data and associated documentation are available at http://macuv.gsfc.nasa.gov/SBUVOzoneProfile.md and http://macuv.gsfc.nasa.gov/documents.md

The initial residuals from the retrieval algorithm give a means of tracking the relative behavior of two instruments viewing similar latitudes, provided that their SZAs are not too different. The algorithm removes some of the differences in viewing conditions, and the *a priori* ozone profile as the first guess removes the first-order seasonal and latitude variations. This works well in the equatorial zones where there is relatively little variation in ozone amounts. There are additional soft calibration techniques; one is the Ascending/Descending Langley analysis. (REF)

4. Ozone Profile and Residual Monitoring Figures

4.a. Time series of initial and final residuals and their absolute totals and standard deviations. These are at the ICVS and on the DVD.

4.b. Samples of the averaging kernels, measurement contribution functions, Jacobians, noise patterns, and retrieval resolution for the retrieval algorithm.

4.c. Monthly plots of the zonal mean profile differences between the different instruments. These are at the ICVS.

4.d. Monthly ascending/descending ozone profile match-ups with selected SZA differences.

4.e. Intercomparisons (scatter plots) for SNO results for instruments – note Early on the NOAA-16 had orbits that were aligned with the EOS Aura satellite about once every two days. This is the case now for NOAA-18. These give very good opportunities for intercomparisons. We will need to make adjustments for FOV and bandpass differences.

AII.5 Other Resources

In addition to the figures presented at the ICVS site, there are other monitoring resources we can draw upon.

These include work we are doing at NCEP and at the Cooperative Institute for Research in Environmental Sciences (CIRES) to validate the products by intercomparisons with ground-based ozone estimates, work done at CREST to compare SBUV/2 and OMI (updated monthly), and the set of operational monitoring figures and information available through links at http://www.osdpd.noaa.gov/ml/air.

Compliance and Calibration White Books are delivered with each instrument, detailing the on-ground testing. After the initial on-orbit verification tests are completed, we receive Activation & Evaluation Reports. Both of these are in the document lists at http://www.orbit2.nesdis.noaa.gov/smcd/spb/calibration/icvs/sbuvdoc.html

We will take some of the figures from them to post directly at the web sites.

5. *Ground-based and non-UV instrument validation and intercomparisons Figures*
    5.a. Dobson Comparisons - Monthly time series (Ground-based total ozone validation).
    5.b. Umkehr Comparisons - Monthly time series (Ground-based ozone profile validation).
    5.c. Profile comparisons to NDACC (formerly NDSC) Microwave, IR FTS, and LIDAR results.
    5.d. Profile comparisons to ozone balloonsondes.
    5.e. Comparison to other satellite instruments' ozone, *e.g.*, NASA's Stratospheric Aerosol and Gas Experiment (SAGE), MLS, and ESA's Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (Maestro). These would most naturally go on the ICVS, but we also include this information with the CDR.

APPENDIX III – DATABASES EXAMPLES FOR OMPS NM

Sensor Characteristic	Size of Matrix	Need	Description
Static Databases (measured on the ground, not updated on-orbit)			
Radiance Calibration Coefficients	700 x 192, 35x192	SDR algorithm	Required for calibration of Earth scene radiances on-orbit.
Irradiance Calibration Coefficients	700x192, 35x192	SDR algorithm	Required for calibration of Solar scene irradiances on-orbit.
Goniometric Calibration Coefficients	2x7x150x192xmxn	SDR algorithm	Required for goniometric correction of solar calibration data on-orbi
Spatial Resolution / Cell Shape / IFOV Shape	35 x 192 x m x n	Geolocation	Database consists of spatial response in angle space that can be p ground during a given geolocation.
Boresight to Sensor Reference Alignment	35x2	Geolocation	Angular pointing of each macropixel required in geolocation.
TC Bandpass	51x35x192, 51x700x192	SDR/EDR algorithm	Spectral response of each individual pixel and each macropixel.
Dynamic Databases (measured and updated on-orbit, pre-launch ground measurement used as initial value, placeholder, and for testing)			
Channel Band Centers	700x192, 35x192	SDR/EDR algorithm	The actual wavelength calibration occurs using on-orbit solar calibra an initial pre-launch database will be constructed for potential SSP
Linearity	4 x 16384 (4 amps, 14-bit)	Flight Software, SDR algorithm	Linearity is updated using on-orbit data. This database will consist measured on the ground. It should be replaced with on-orbit lineari using LED calibration measurements. Here for SSPR algorithm te
Lamp (LED) Signal	n (each integration time)	SDR Algorithm	LED signal is updated using on-orbit data. Here for SSPR algorithn
Zero Input Offset	4	SDR Algorithm	Updated on-orbit. Provided here as the zero input offset as measu Should be replaced on-orbit.
Sample Table (Bad Pixel Table)	780 x 364	Flight Software, SDR algorithm	Contains map of bad pixels. This database represents the initial d updated on-orbit using calibration measurements.
Dark Current	700x192, 35x192	SDR Algorithm	Dark current is measured on-orbit. This database represents a pla ground measured dark currents for use in potential SSPR algorithn

APPENDIX IV - ACRONYMS AND ABBREVIATIONS

ACPOP	Atmospheric Chemistry Product Oversight Panel
ADA	Algorithm Development Area
AIRS	Advanced Infrared Sounder
ATBD	Algorithm Theoretical Basis Socument
AVDC	Aura Validation Data Center
BATC	Ball Aerospace & Technology Corp.
BUFR	Binary Universal Form for the Representation of meteorological data
BUV	Backscattered Ultraviolet
CCD	Charge-coupled Device
CDR	Climate Data Record
CICS	Cooperative Institute for Climate and Satellites
CIRES	Cooperative Institute for Research in Environmental Sciences
CLASS	Comprehensive Large Array-data Stewardship System
CR	Change Request
CREST	Cooperative Remote Sensing Science and Technology Center
CrIS	Cross-track Infrared Sounder
DAWG	Data Analysis Working Group
DIP	Delivered Intermediate Product
DOAS	Differential Optical Absorption Spectroscopy
DOD	Department of Defense
DR	Discrepancy Report
DU	Dobson Unit
EDR	Environmental Data Record
EOC	Early Orbit Checkout
EOF	Empirical Orthogonal Function
EOS	Earth Observing System
ESA	European Space Agency
ESRL	Earth System Research Laboratory
EuMetSat	European Organisation for the Exploitation of Meteorological Satellites
FOV	Field-of-View
FTIR	Fourier Transform Infrared
FY	Feng Yun
GES DISC	Goddard Earth Sciences Data and Information Center
GRIB	Gridded Binary
GOME-2	Global Ozone Monitoring Experiment (second generation)
GRAVITE	Government Resource for Algorithm Verification, Independent Testing, and Evaluation
GSFC	Goddard Space Flight Center
HIRS	High-resolution Infrared Sounder
IASI	Infrared Atmospheric Sounding Interferometer
ICV	Intensive Calibration/Validation
ICVS	Integrated Calibration/Validation System
IDPS	Interface Data Processing Segment
IMT	Integrated Mission Timeline
IP	Intermediate Product
IPO	Integrated Program Office
IR	Infrared

JCSDA	Joint Center for Satellite Data Assimilation
LED	Light-emitting Diode
LIDAR	Light Detection and Ranging
LIDORT	Linearized Discrete Ordinate Radiate Transfer
LP	Limb Profiler
LTS	Long-term Stability
MAESTRO	Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrived by Occulation
MetOp	Meteorological Operational
MLO	Mauna Loa Observatory
MLS	Microwave Limb Sounder
MW	Microwave
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NDACC	Network for the Detection of Atmospheric Composition Change
NDE	NPOESS Data Exploitation
NESDIS	National Environmental Satellite Data and Information Services
NGAS	Northrop Grumman Aerospace Systems
NM	Nadir Mapper
NOAA	National Oceanic and Atmospheric Administration
NP	Nadir Profiler
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NRL	Naval Research Laboratory
NRT	Near-real-time
NSIPS	NPOESS System Investigator-led Processing System
NWS	National Weather Service
O3OAT	Ozone Operational Algorithm Team
OAR	Office of Oceanic and Atmospheric Research
OHP	Observatoire de Haute-Provence
OMI	Ozone Monitoring Instrument
OMPS	Ozone Mapping and Profiler Suite
OSDPD	Office of Satellite Data Processing and Distribution
OSIRIS	Optical Spectrograph and Infrared Imager System
PEATE	Product and Evaluation and Test Element
PL	Pre-launch
PMC	Polar Mesospheric Clouds
PMF	Product Master File
POES	Polar-orbiting Operational Environmental Satellites
PSC	Polar Stratospheric Clouds
PSDI	Product System Development and Implementation
QA	Quality Assurance
QC	Quality Control
RDR	Raw Data Record
RP	Research Products
RRS	Rotational Raman Scattering
SAA	South Atlantic Anomaly
SADIE	Science Algorithm Development and Integration Environment
SAGE	Stratospheric Aerosol and Gas Experiment

SBUS	Solar Backscatter Ultraviolet Sounder
SBUV/2	Solar Backscatter Ultraviolet (second generation instrument)
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography
SDR	Sensor Data Record
SDS	Science Data Segment
SER	System Engineering Report
SHADOZ	Southern Hemisphere Additional Ozonesondes
SMCD	Satellite Meteorology and Climatology Division
SMOBA	Stratosphere Monitoring Ozone Blended Analysis
SNO	Simultaneous Nadir Overpass
SNR	Signal-to-Noise Ratio
SOI	SO_2 Index
SPB	Sensor Physics Branch
STAR	Center for Satellite Applications and Research
SVA	Satellite Viewing Angle
SZA	Solar Zenith Angle
TIM	Technical Interchange Meeting
TOAST	Total Ozone from Assimilation of SBUV/2 and TOVS
TOMRAD	TOMS Radiative Transfer
TOMS	Total Ozone Mapping Spectrometer
TOR	Tropospheric Ozone Residual
TOU	Total Ozone Unit
TOVS	TIROS Operational Vertical Sounder
TOZ	Total Column Ozone
UV	Ultraviolet
VIIRS	Visible/Infrared Imager Radiometer Suite
WOUDC	World Ozone and Ultraviolet Data Center

Appendix V. EDR/TC IP/NP Bundled Content and Use for Cal/Val.

Motivated by following principles:

1. Provide EDR & SDR content as recommended in the ATBDs
2. Bundle retained validation IPs with the EDRs
3. Bundle information on ancillary and algorithm data choices
4. Make specific diagnostic IPs available within the EDR
5. Provide some specified SDR content in the EDR as well
6. Write out the heritage Version 6 Product Master Files as the Nadir Profiler delivered IP
7. Provide key existing algorithm parameters and values to track long-term stability

Bundled Parameters are provided for calibration, validation, tuning, diagnostics, trending, characterization, and QA/QC.

USE P Operational/Science Product F Data Quality Flag
A Algorithm Validation C Calibration and Trending
V Product Validation

Operational Data Products	USE	UNITS	SIZE/EDR
Effective cloud fraction (TC,NP)	PAV	0.1%	1,1
Effective reflectivity (TC,NP)	PACV	0.1%	1,1
Surface reflectivity (TC,NP)	AV	0.1%	1,1
Snow/Ice Coverage Flag (TC,NP)	FPAV		1,1
Cloud reflectivity (TC,NP)	PAV	0.1%	1,1
Cloud Top Pressure (TC,NP)	AV	0.1mb	1,1
Tropospheric ozone estimates (TC,NP)	PAV	0.1DU	1,1
Stratospheric ozone estimates (TC,NP)	PAV	0.1DU	1,1
Version 7 Total Ozone (TC)	PACV	0.1DU	1
Nadir Ozone Profile (NP)	PACV	0.01%	12
D-Pair Total Ozone estimate (NP)	PCV	0.1DU	1

Calibration Information	USE	UNITS	SIZE/EDR
Calibrated measurement albedos (TC,NP)	CAV	0.02N	22,12
Final measurement residuals (TC,NP)	CAVF	0.01%	22,12
Bandpass centers (TC,NP)	CAV	0.01nm	22,12
Solar Zenith Angle (TC,NP)	CAVF	0.01Deg	1,1
Solar Azimuth Angle (TC)	CAV	0.01Deg	1
Satellite View Angle (TC)	CAV	0.01Deg	1
Spacecraft Roll Angle (TC)	CV	0.01Deg	1
Initial measurement residuals (NP)	CAV	0.01%	12
Residuals for other wavelengths (NP)	CAV	0.01%	12

Algorithm and Product Validation	USE	UNITS	SIZE/EDR
Temperature Profile (TC,NP)	AV	0.02K	12,12
EDR Algorithm ID (TC,NP)	AV		1,1
Latitude, Longitude (TC,NP)	AV	0.02Deg	2,2
GMT Time (TC,NP)	AV	1 s	1,1
Ozone profile information (TC)	AV	0.01%	12
Albedo Ozone Sensitivities (TC)	AVC	0.01%/%	8*22
Albedo Refl. Sensitivities (TC)	AVC	0.01%/%	22
A Priori O3 Profile (NP)	AV	0.01%	12,80
Averaging Kernels (NP)	AV	0.01	12*12

Quality Flags	USE	UNITS	SIZE/EDR
Ancillary data use (TC,NP)	FAV		6,6
Eclipse (TC,NP)	FAV		1,1
South Atlantic Anomaly (TC,NP)	FAV		1,1
Ascending/Descending (TC,NP)	FCAV		1

Aerosol Index (TC)	FPACV	0.01	1	
SO_2 Index (TC,NP)	FPAV		1	
Triplet consistency (TC)	FACV	0.01DU	1	
Sun Glint (TC)	FAV		1	
Version 6 Flags (NP)	FACV		1	

Additional Notes on Other products including P3I

PSCs (LP)	FAV	0.01OD	1,1	
CrIS Total Ozone (IR)	PCV	0.1DU	1	
CrIS Ozone Profile (IR)	PCV	0.001	7	I(slant)
CrIS Cloud Fraction (IR)	PAV	0.1%	1	
CrIS Ozone retrieval quality flags	FAV		3	

CrIS IR Ozone (Implemented as intermediate products in the CrIS algorithm)
CrIS Ozone Quality Flags:
Cloud clearing, temperature contrast, information content

New code to identify situations with quality concerns for the Profile
- Polar Mesospheric Clouds (NP,LP)
- Polar Stratospheric Clouds (NP,LP)

New code to provide product quality estimates
- Retrieval error estimates (TC, NP, and CrIS)
  - Use SDRs radiance quality information and sensitivities

Nadir Profiler Values
- Residuals for additional wavelengths (minor change)
- Extension of current calculation for eight wavelengths

Candidates for additional IPs with algorithm development

	USE	UNITS	SIZE/EDR
Mg II Index (NP solar irradiance)	PAC	0.001	1
Mg II central wavelength (NP SDR)	CA	0.01nm	1
PMCs (NP)	FAV	0.01OD	1,1
Aerosol OD and refractive index (TC)	PAV	0.01	3
Cloud top pressure estimate (TC, NP)	PAV	0.1mb	1,1
Better SO_2 estimate (TC, NP)	PAV	0.1DU	1,1
Polar Mesospheric Clouds (NP,LP)	FPV	0.01OD	1

The first three are used in the SBUV/2 program, and the last three are under development for EOS Aura OMI.

The OMPS SDR products as detailed in Table 9.4 of the EDRIR were in good shape with two exceptions. The missing pieces were:

1. Information on the applied stray light correction for the OMPS LP and NP.
2. A field for the sources of ancillary data (i.e., if non-climatological or non-standard data are used to provide better values of the atmospheric state)

The Version 8 ozone profile algorithm includes the Jacobians of measurement partials with respect to ozone layer amounts and the measurement contribution function matrices along with the averaging kernels in its standard bundled product in addition to the content in the Version 6 product.