Overview of CISESS Stratospheric Projects at the NCEP Climate Prediction Center

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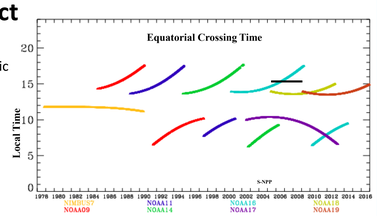
Abstract: **Stratospheric CISESS tasks at the Climate Prediction Center (CPC) span four basic categories including Ozone Mapper and Profiler Suite (OMPS) ozone product validation and use, Stratospheric Aerosol and Gas Experiment (SAGE) III ozone profile validation, Research to Operations transitions, and CFSv2 support of the Copernicus Climate Change Service (C3S). The OMPS on Suomi-NPP (National Polar-Orbiting Partnership), NOAA-20, and future Joint Polar Satellite System (JPSS) satellites provide nadir ozone profiles (NP) and mapped total column (NM) ozone products and replaces the SBUV/2 radiometer. The OMPS Total Column and Profile ozone datasets will be used to extend the ozone Climate Data Records (CDR) in time. These CDRs provide information on ozone decline and recovery. Prior to being fully utilized, the OMPS ozone products need to be evaluated for accuracy and long term stability and validated against other satellite and ground based total column and profile ozone observations. SAGE III began operations on the International Space Station (ISS) in 2017. It is an occultation instrument with ozone profiles measured at every solar and lunar rise and set event per orbit. The SAGE datasets are a backbone to many trend quality CDRs. CPC through CISESS is a member of the SAGE III/ISS Science Team providing validation of the ozone profiles through comparison with OMPS/ SBUV and ground based lidar and microwave instruments. CPC generates many graphics and products on semi-operational systems on Linux boxes or the WCOSS system. CISESS is supporting the identification and transition of products to the NCEP Compute Farm. The CPC has an agreement with the European Centre for Medium-Range Weather Forecasts (ECMWF) to transfer of CFSv2 hindcast/forecast data to ECMWFs Copernicus Climate Change Service (C3S). Twenty-four years of data for 1993 – 2016 are being transferred to be used as a climatology to be followed by real-time transfer of data. An overview of these projects will be presented.**

1- Ozone Mapper and Profiler Suite (OMPS) ozone product

GOALS: Validate OMPS data from Suomi-NPP and NOAA-20, and augment the NOAA Ozone Profile CDR.

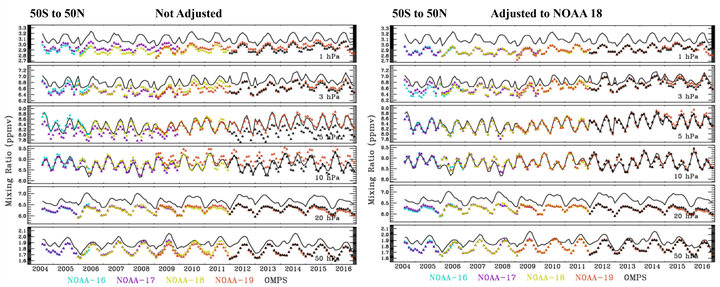
Since the signing of the Montreal Protocol in 1987 and its subsequent agreements banning anthropogenic ozone depleting substances (ODS) the climate community has been anticipating the ability to detect the recovery of the ozone layer.

- The **Solar Backscatter Ultraviolet Radiometers (SBUV and SBUV/2)** have been measuring stratospheric ozone on Nimbus 7 and the NOAA Polar Orbiting Environmental Satellites (POES): NOAA-9, -11, -14, -16, -17, -18 and -19 spanning 40 years from 1978 to present. The last of these SBUV/2 instruments resides on NOAA-19 launched in 2009, and with drifting equatorial crossing time will soon loose latitudinal coverage, and be impacted by an increasing solar zenith angle.
- The **Ozone Mapping and Profiler Suite (OMPS)** instrument has replaced the SBUV/2 as the primary ozone monitoring instrument at NOAA. It is taking observations on the Suomi National Polar-orbiting Partnership (S-NPP) satellite which was launched in 2011 and is on JPSS satellites. JPSS-1 (NOAA-20) was launched on 11/18/2017, and later JPSS satellites will additionally carry the OMPS instrument.



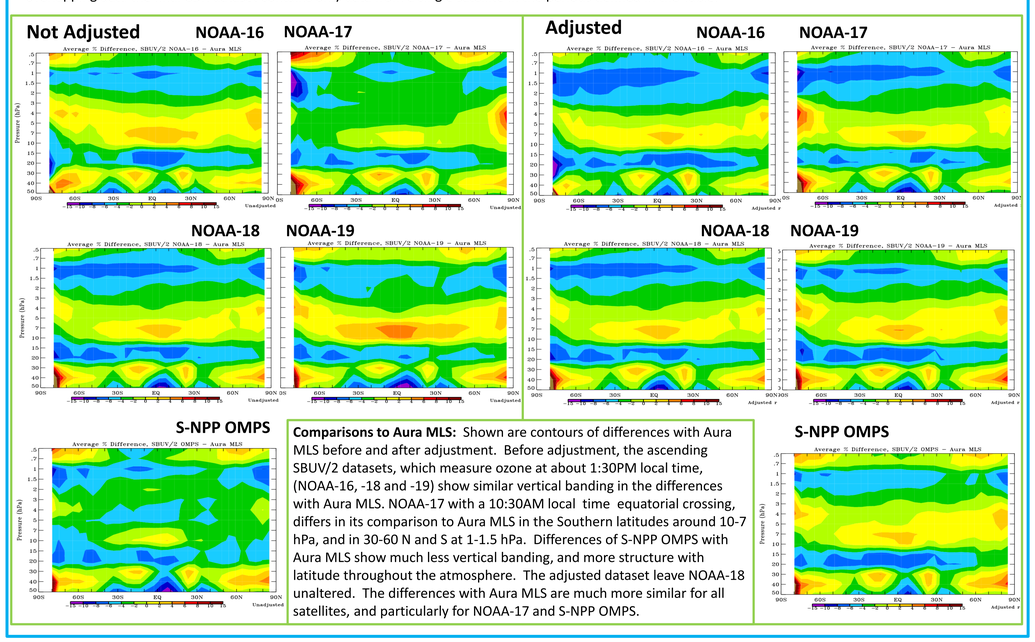
SBUV(/2) & OMPS-NPP	
Satellite	**Period**
Nimbus 7	10/31/78 – 5/31/89
NOAA 11a	6/1/89 – 12/31/93
NOAA 9	1/1/94 – 6/30/97
NOAA 11d	7/15/97 – 12/31/00
NOAA 16	1/1/01 – 12/31/03
NOAA 17	1/1/04 – 12/31/05
NOAA 18	1/1/06 – 12/31/10
NOAA 19	1/1/11 – 12/31/13
OMPS-NPP	1/1/14 – present

The generation of a trend quality dataset depends on meticulous inter-calibration of successive instruments. DeLand [2012] describes the process of SBUV(/2) calibration depending on no-local-time difference comparisons of datasets at the radiance level. OMPS has been calibrated to NOAA 19 SBUV/2 based on chasing orbits in 2013. Nonetheless small latitudinally dependent differences in ozone remain. To create a trend quality CDR and thus be able to discern if a recovery of ozone has been achieved, adjustments are made to the data based on correlations of datasets in the overlap periods.



Dataset Availability: The NOAA Cohesive SBUV(/2) profile ozone dataset is available to the public at ftp://ftp.cpc.ncep.noaa.gov/SBUV_CDR as daily or monthly zonal average datasets.

Shown are time series of the dataset before and after adjustment for the near global (50N to 50 S) dataset. Especially at mid-levels (5 and 10 hPa) the improvement in agreement among the datasets is evident. When adjusted the agreement with Aura Microwave Limb Sounder (MLS) is remarkable, but it is fortuitous that the adjusted results at these levels have little remaining bias with Aura MLS. Differences in line shape between MLS and the SBUV(/2)/OMPS data at 50 hPa are due to the low information content of SBUV2/OMPS resulting in the inability to properly capture and depict the QBO. Though these graphs show overlapping data the final CDR dataset contains only data from a single satellite in the periods defined in the Table.



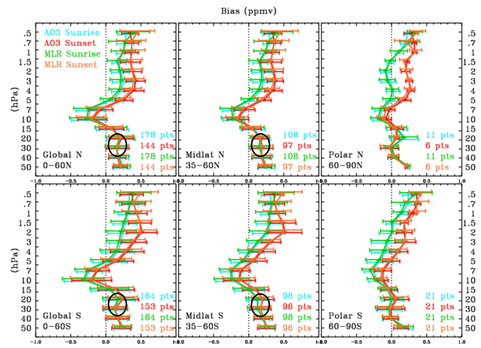
Comparisons to Aura MLS: Shown are contours of differences with Aura MLS before and after adjustment. Before adjustment, the ascending SBUV/2 datasets, which measure ozone at about 1:30PM local time, (NOAA-16, -18 and -19) show similar vertical banding in the differences with Aura MLS. NOAA-17 with a 10:30AM local time equatorial crossing, differs in its comparison to Aura MLS in the Southern latitudes around 10-7 hPa, and in 30-60 N and S at 1-1.5 hPa. Differences of S-NPP OMPS with Aura MLS show much less vertical banding, and more structure with latitude throughout the atmosphere. The adjusted dataset leave NOAA-18 unaltered. The differences with Aura MLS are much more similar for all satellites, and particularly for NOAA-17 and S-NPP OMPS.

2- Validation of SAGE III/ISS ozone profiles to facilitate their inclusion in a long-term Climate Data Record

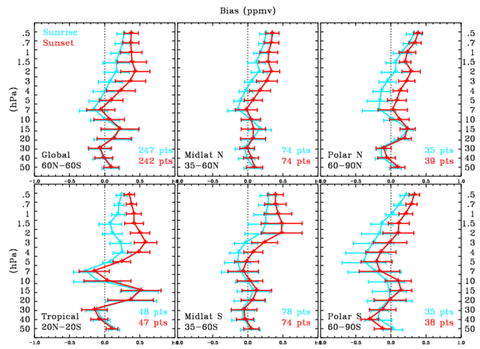
Team includes CU Boulder/CIRES and NOAA/ESRL

GOALS: Compare SAGE III profiles to existing satellite and ground data records to validate the ozone product, and to determine compatibility with data from previous SAGE instruments. Use the SAGE III data to extend the SWOOSH dataset and determine recovery rates of global ozone profiles.

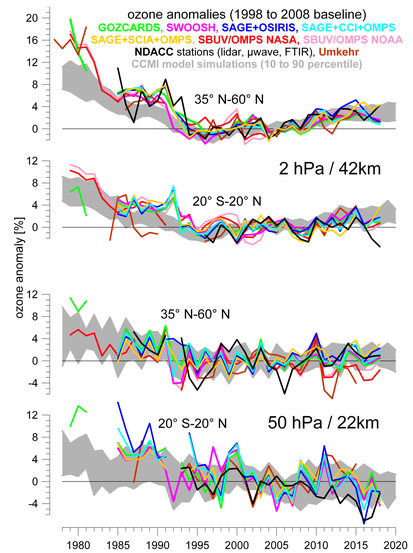
SAGE III is an occultation instrument measuring ozone profiles by examination of the atmosphere during sunrise/sunset and lunar rise/set events. This instrument was added to the suite of instruments on the International Space Station in 2017. Challenges exist with an instrument on the ISS including blockages of the events from physical appendages of the ISS, and gas contamination as payloads/vehicles doc at the ISS and movement of the ISS while the astronauts are awake. Nonetheless the data is of good quality.



Comparisons of SAGE III/ISS to OMPS/SNPP show a small but different diurnal signature in the Northern and Southern hemispheres. This difference is not statistically significant, but still a curiosity.



Comparisons of SAGE II to SBUV2/NOAA-11 exhibit a similar profile to those for SAGE III/ISS. The N/S discrepancies are less apparent.



SAGE II & SAGE III are backbone datasets for several climate data records monitoring ozone recovery. This example from Weber [2018] in the BAMS state of the atmosphere shows reasonable rough agreement among datasets and the CCMI model.

3- Hindcast/ Forecast data to ECMWF Copernicus Climate Change Service (C3S)

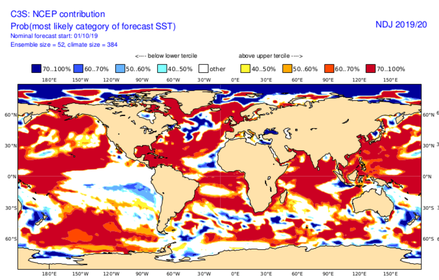
GOAL: transfer CFSv2 hindcast & forecast data to ECMWF C3S in pre-determined format and data frequency.

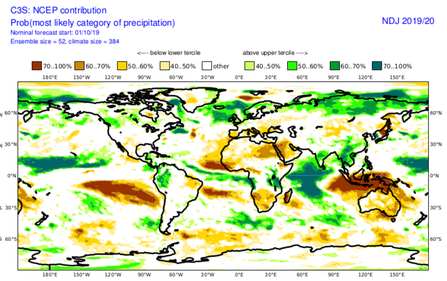
This project is divided into three stages:

- Transfer hindcast data from Jan 1993 - Dec 2016 for use as a climatology. This data is four 6-hourly cycles seasonal forecasts every 5th day.
- Transfer the real-time forecasts from August 2019. This data is four 6-hourly cycles seasonal forecasts available every day.
- Transfer real-time forecasts from Jan. 2017 – Jul. 2017 after all the hindcast data have been transferred. This data is four 6-hourly cycles seasonal forecasts available every day.
- Due to the size of data and network speed between NCEP and ECMWF, also the disk space and processing power of our local computer system, we are only able to transfer total of 7 start dates of data (6 hindcast dates and 1 real-time date) per day.

1. surface altitude
2. land sea mask
3. 2 meter temperature
4. 2 meter dew point temperature
5. 10 meter wind (U and V)
6. mean sea level pressure
7. total cloud cover
8. soil temperature
9. sea-surface temperature
10. sea-ice cover
11. water equivalent of accumulated snow depth
12. soil moisture
13. 2 meter maximum temperature
14. 2 meter minimum temperature
15. precipitation rate
16. sensible heat flux at surface
17. latent heat flux at surface
18. downward short wave radiation at surface
19. downward long wave radiation at surface
20. net short wave radiation at surface
21. net long wave radiation at surface
22. upward long wave radiation at top of atmosphere
23. eastward turbulent surface stress
24. northward turbulent surface stress
25. water runoff
26. geopotential height (850, 700, 500 and 200mb)
27. temperature (850, 700, 500, 200 and 50mb)
28. specific humidity (925, 850, 700 and 500mb)
29. U-V wind (925, 850, 700, 500 and 200mb)

The C3S seasonal monitoring system for NCEP's CFSv2 data **went live** on Oct. 13, 2019 at https://climate.copernicus.eu/charts/c3s_seasonal/.





Participating agencies are:

- European Centre for Medium-Range Weather Forecasts (ECMWF)
- Centro Euro-Mediterraneo sui Cambiamenti Climatici Project – CMCC (Italy)
- Deutscher Wetterdienst – DWD (Germany)
- Meteo France
- NOAA National Centers for Environmental Prediction – NCEP (US)
- UK Met Office

C3S uses supplied data and climatologies to forecast probabilities of:

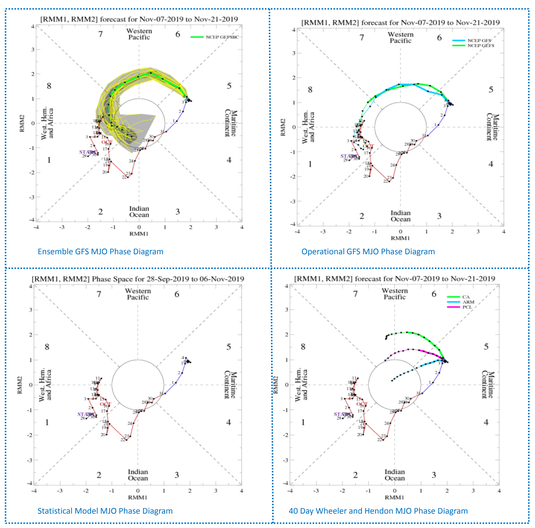
- Mean Sea Level Pressure (MSLP)
- NINO plume
- Sea Surface Temperature (SST)
- Temperature at 2m
- Temperature at 850hPa
- Geopotential Height at 500hPa
- Precipitation

Implemented by ECMWF as Climate Change Service

4- Research to Operations at CPC

GOAL: Move CPC forecasts from the research/semi-operational systems to the NCEP Compute Farm with 24/7 support. Products are publically available on https://cpc.ncep.noaa.gov.

COMPLETE: Implemented daily and monthly MJO index phase processing as an operational job on compute farm system. This job processes observations, forecast models (EGFS, GFS) and statistical models (CA, ARM, PCL) data.



UPCOMING: Implement GODAS Ocean data processing on compute farm system as an operational job by the end of 2019.

Acknowledgements:

- The Aura MLS data were obtained from the NASA GES DISC at http://disc.gsfc.nasa.gov/.
- SAGE III/ISS data were obtained from NASA LARC at https://search.earthdata.nasa.gov/.
- SBUV(/2) version 8.6 data were obtained directly from NASA with the assistance of NOAA/NESDIS. Thanks to Larry Flynn, Eric Beach and L.K. Huang for making this data available.
- S-NPP OMPS Version 8.6 data was obtained from NASA via https://ozoneaq.gsfc.nasa.gov/omps/.
- S-NPP OMPS NESDIS data were obtained directly from NESDIS.

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Conclusions:

- This CISESS project at the Climate Prediction Center is contributing to the understanding of the knowledge of the ozone profile and its response to the provisions of the Montreal Protocol and its successors.
- CISESS is assisting NCEP/CPC with participation in climate initiatives at the international level.
- CISESS is providing service to CPC to reach its goals of secure 24/7 processing and distribution of its product suite.