NASA Science Mission Directorate
Earth Science Division

NASA Current and Future planning for stratospheric aerosol measurements and such

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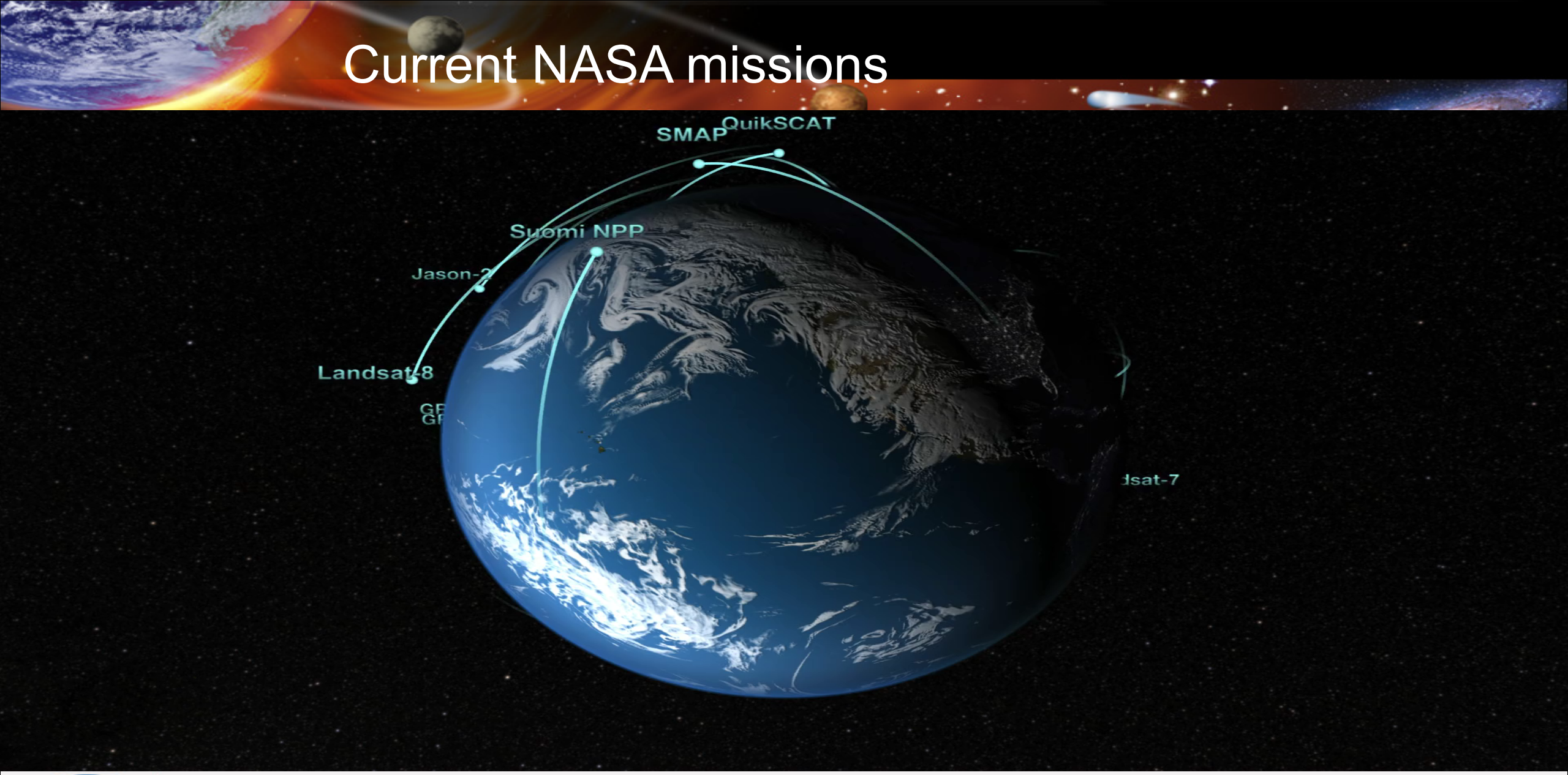
Current NASA missions




Formulation
Implementation
Primary Ops
Extended Ops
SLI-TBD
Formulation in 2015
JPSS-2 (NOAA)
RBI
OMPS-Limb
[[TSIS-2]]
[[Future Altimetry]]
NI-SAR
PACE
SWOT
TEMPO
GRACE-FO (2)
ICESat-2
CYGNSS
RapidScat, CATS, ATS,
LIS, SAGE III (on ISS)
SMAPP
SORCE
TRMM
QuikSCAT
[[TCTE]]
EO-1
Aquarius
Landsat-7
(USGS)
Terra
Suomi NPP
(NOAA)
Aqua
Landsat-8
(USGS)
CloudSat
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2

Overall FY2016 Budget Summary

- ESD budget increases significantly

	FY15	FY16	FY17	FY18	FY19	FY20
FY16	**1.730**	**1.894**	**1.913**	**1.932**	**1.952**	**1.971**
FY15		1.762	1.784	1.805	1.829	---

- NASA now has mandate for additional long-term measurements for the nation:
  - Altimetry after Jason-3
  - Solar Irradiance, Ozone Profile, Earth Radiation Budget all starting in FY16

- Sustainable Land Imaging Program (w/USGS; NASA funds flight hardware):
  - TIR-FFD (2019)
  - Upgraded Landsat-9 (2023)
  - Focused technology development to inform designs of Landsat-10+

- Continued development and launch of: SAGE-III/ISS, ECOSTRESS/ISS, GEDI/ISS, CYGNSS, TEMPO, GRACE-FO, ICESat-2, SWOT, NISAR, PACE

- Continue Venture Class on schedule with full funding

- OCO-3 completion and flight to ISS in late 2017

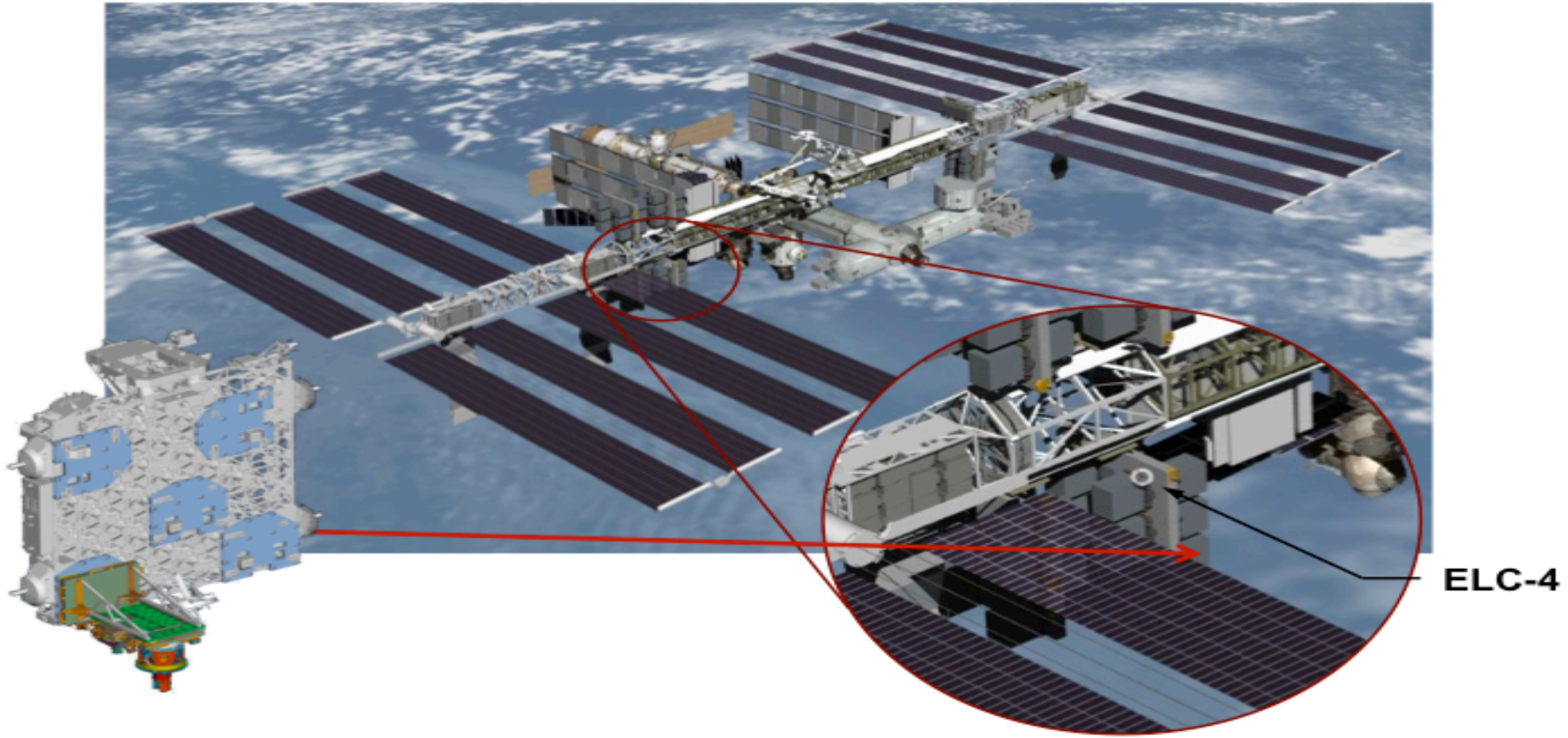
- CLARREO Technology Demonstration instruments on ISS - development and flight in late 2019 (2 instruments, Reflected Solar/HySICS and IR Pathfinder)

“Stratospheric” space missions at NASA!

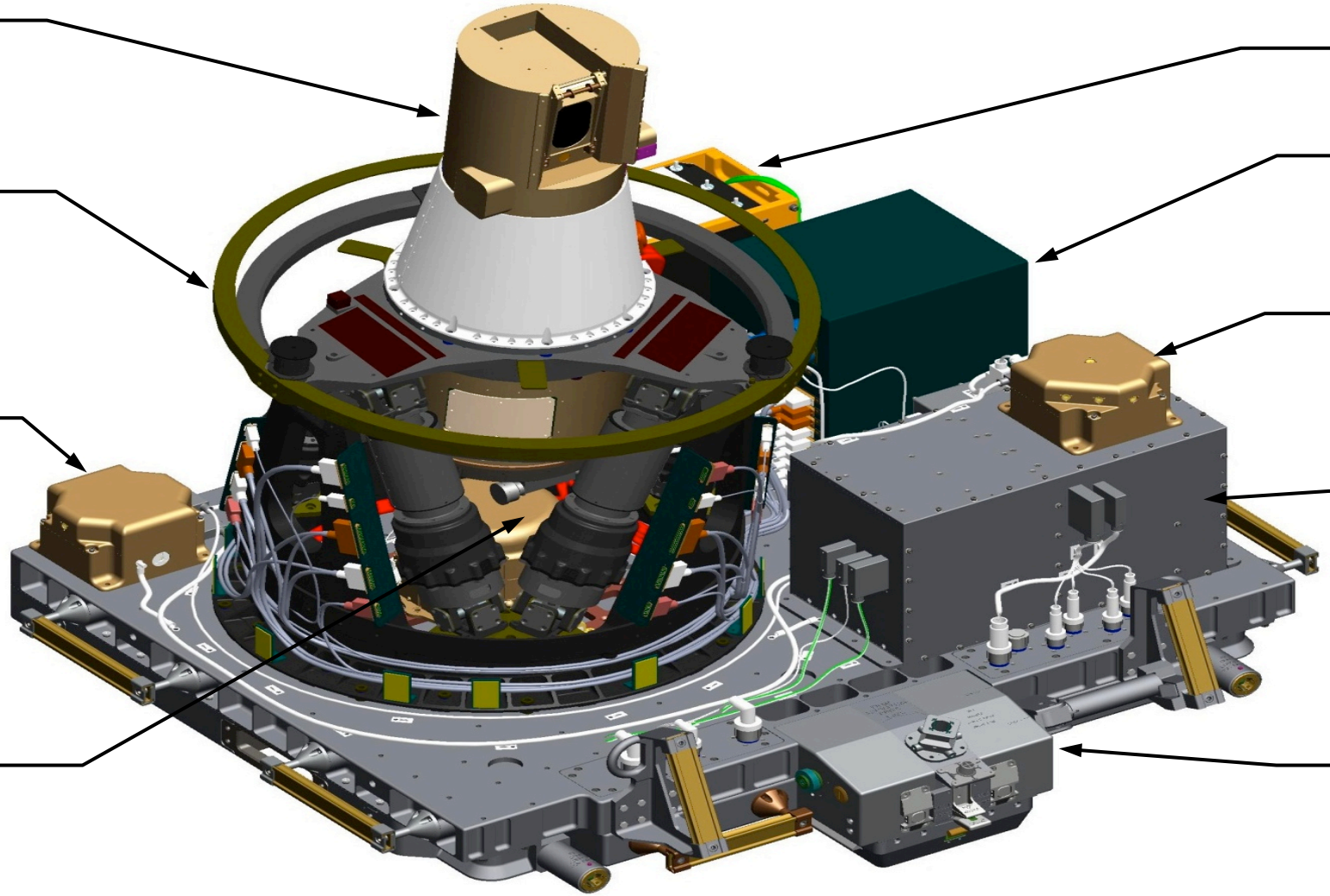
- Aura has been operating since 2004, and should for up to 10 more years.
- OMPS (nadir and limb) on Suomi-NPP is joint with NOAA, NASA produces the only Limb products. Late 2011 - ???
- SAGE-III on ISS will launch some time late 2016 (launch manifest pending.
- OMPS nadir continues on US operational weather satellites (JPSS). Limb is NOT on JPSS-1 (early next year), but NASA will pay for one on JPSS-2 (~2021).
- CALIPSO will continue as long as it produces useful science.
- CATS on ISS will continue until ~2018, when it gets replaced by OCO-3 on JEM.

SAGE III on ISS

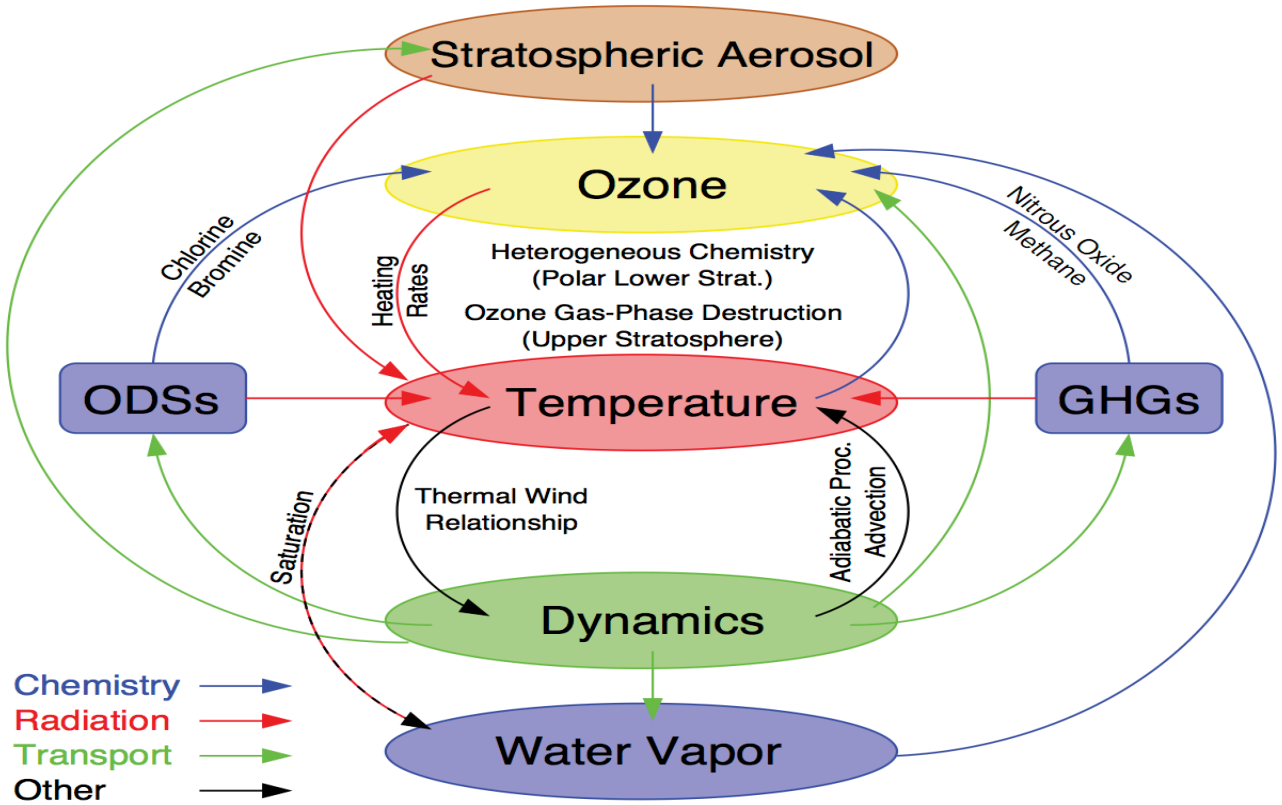
SAGE III on ISS will extend the long-term SAGE Earth Science data record by making climate quality measurements from the ISS



Instrument Payload



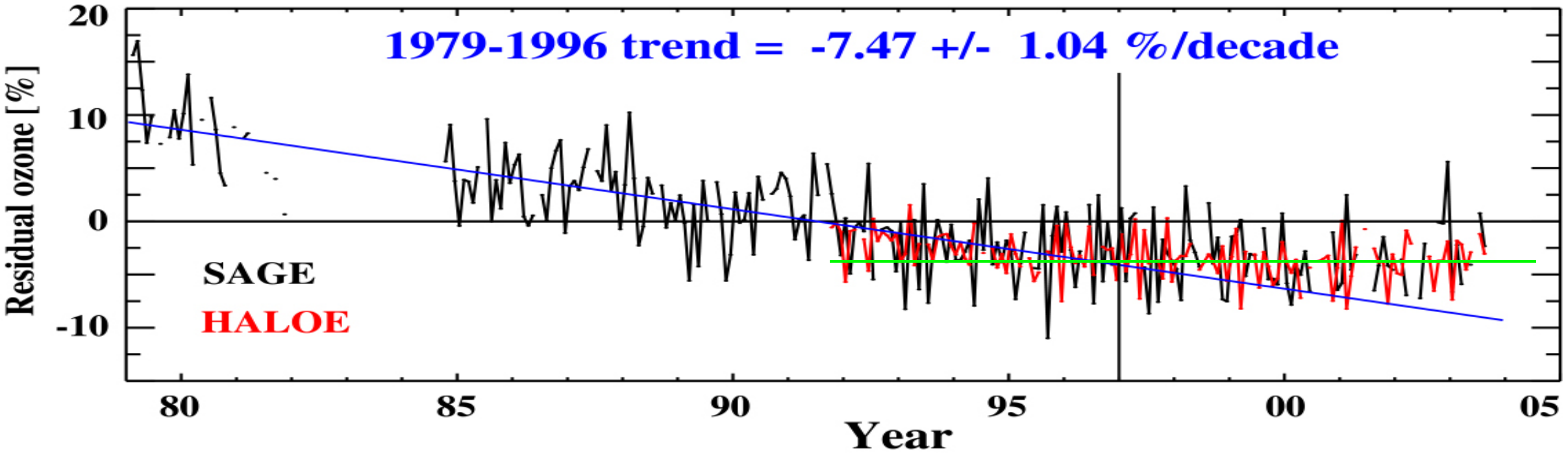
Science Needs



- This simplified schematic illustrates the parameters and process that control ozone
- ODS and GHG can be measured from the ground as long as the dynamics can be modeled
- O_3 and Aerosol Profiles need to be measured
- Trends in Temperature and Water Vapor are inadequately measured

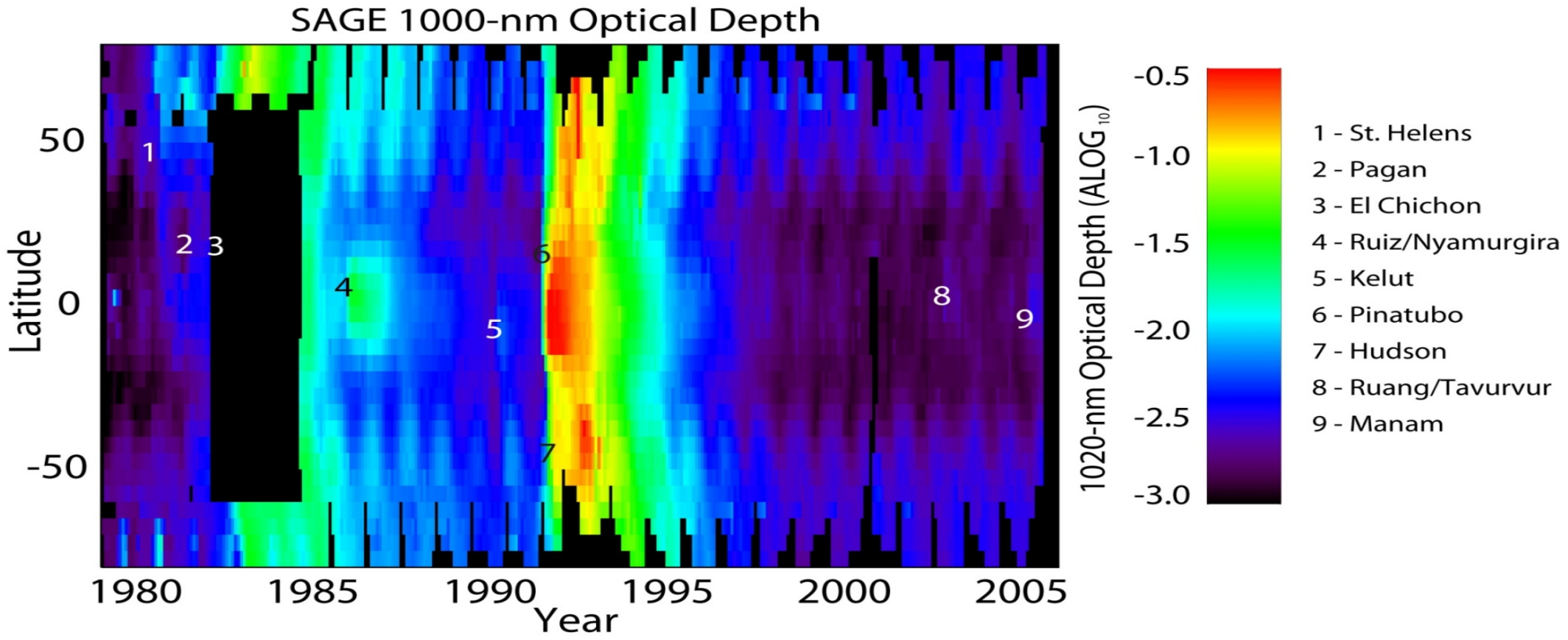
SAGE Science Results

- SAGE produces vertical profiles of aerosols and gases in the stratosphere and upper troposphere
- The multi-decadal SAGE ozone and aerosol data sets have undergone intense scrutiny and are the international standard for accuracy and stability.
- SAGE data has been used to monitor the effectiveness of the Montreal Protocol

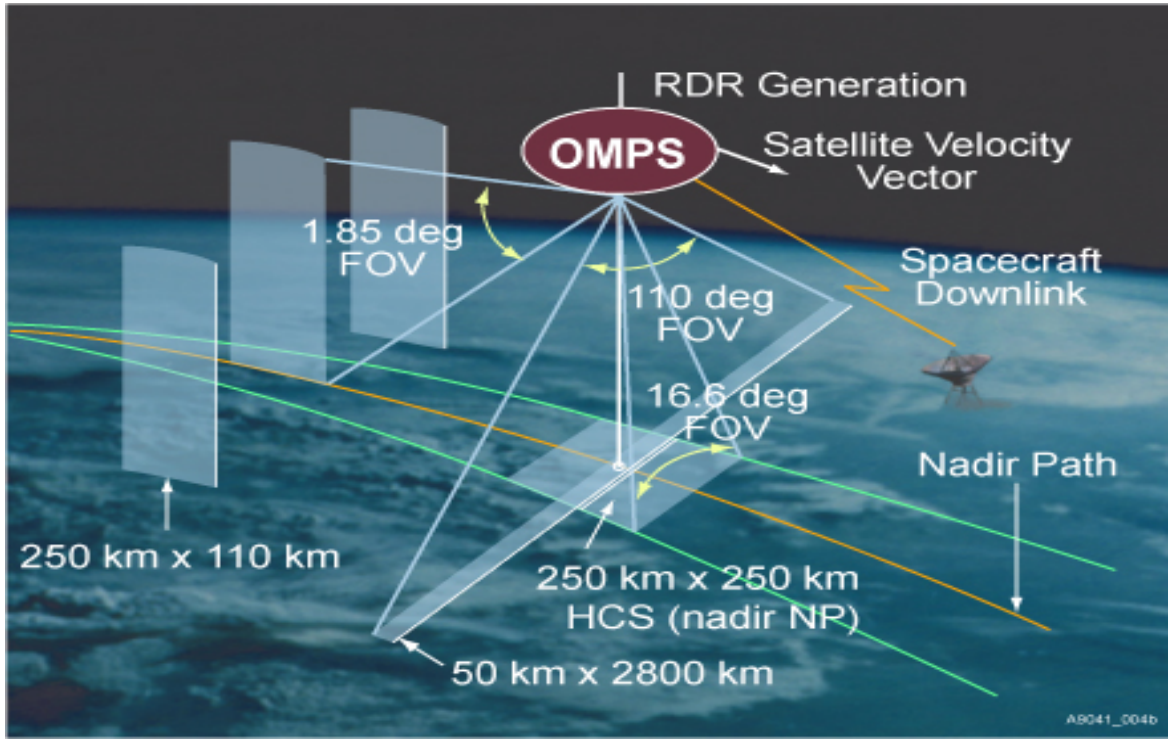


Stratospheric Aerosols

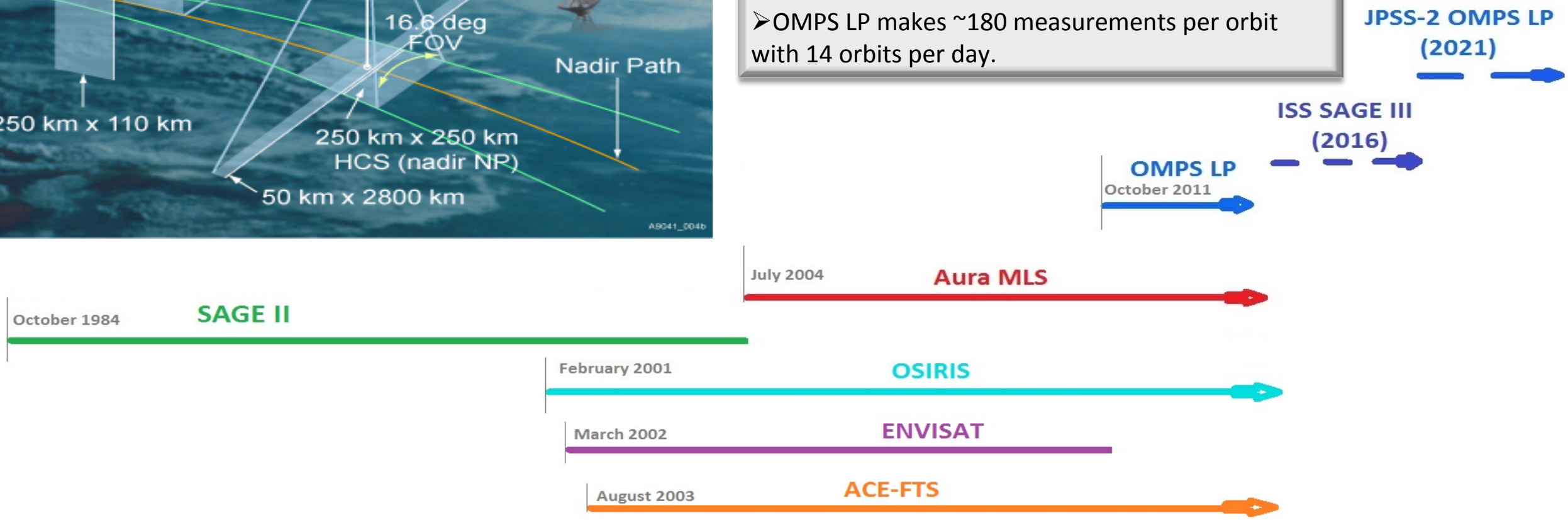
- **SAGE aerosol data is recognized as *The Source* necessary for:**
  - Understanding O_3 trends (Montreal Protocol Scientific Assessment Panel)
  - Interpreting Global Warming (Hansen, 2008 AGU Bjerknes Lecture)



OMPS Limb Profiler continues NASA ozone profile record



- Spectral range 290-1000 nm, with variable resolution (1-25 nm);
- Three slits separated by 4.25 to expand the cross-track coverage;
- Altitude range = 0-80 km, 1.8-2 km vertical resolution;
- OMPS LP makes ~180 measurements per orbit with 14 orbits per day.



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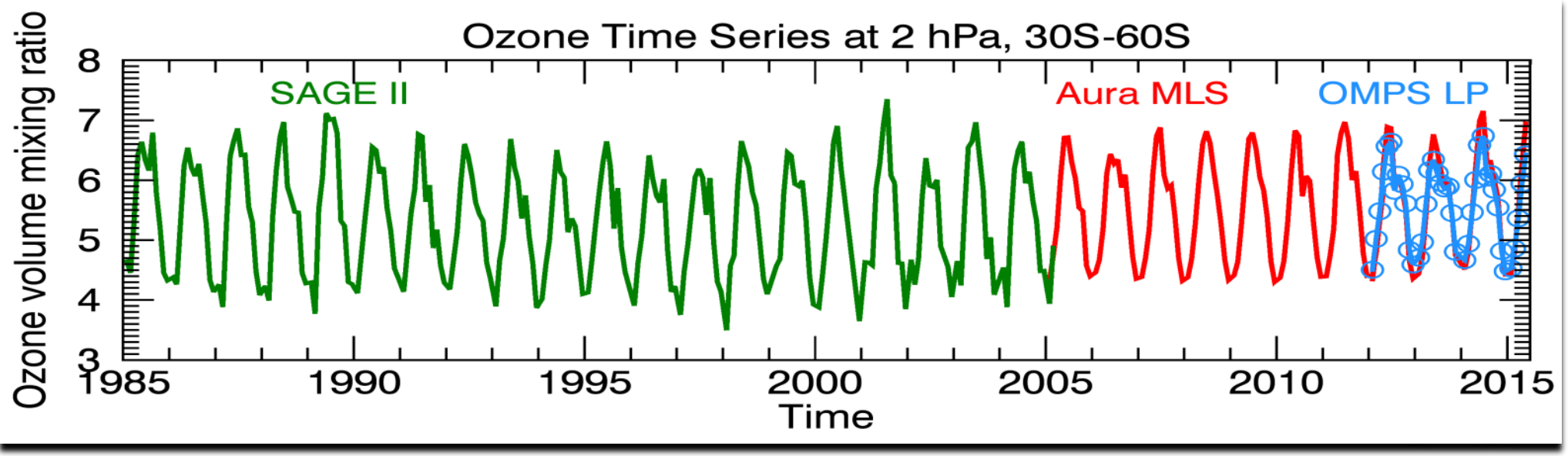
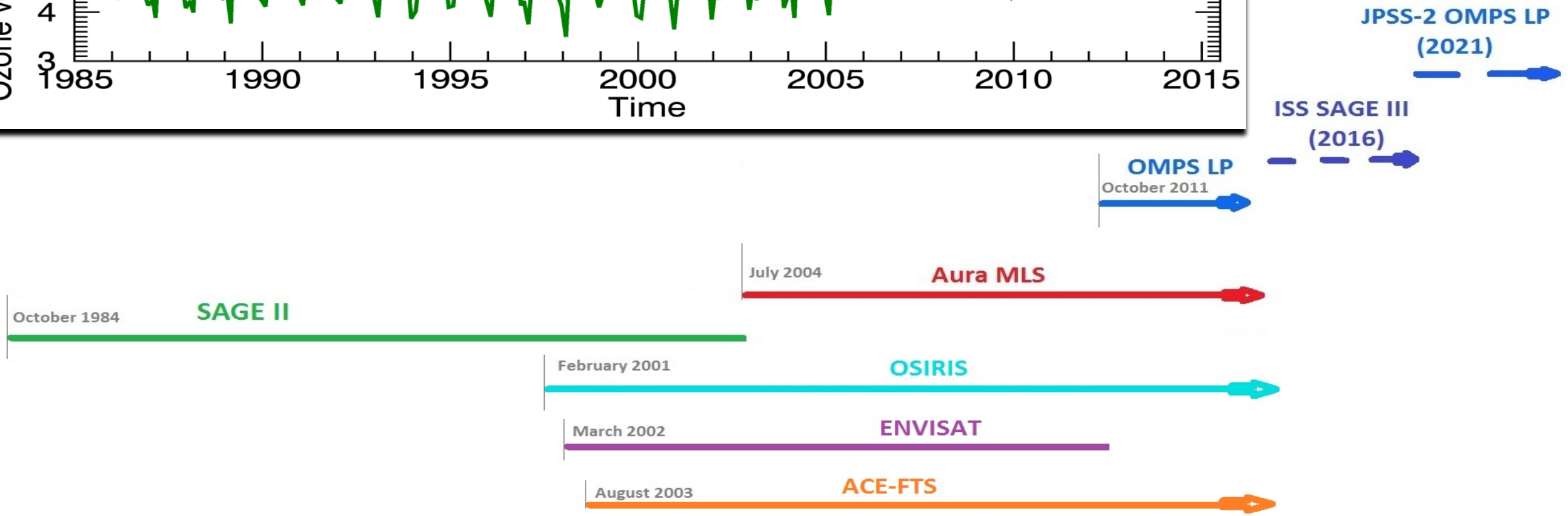




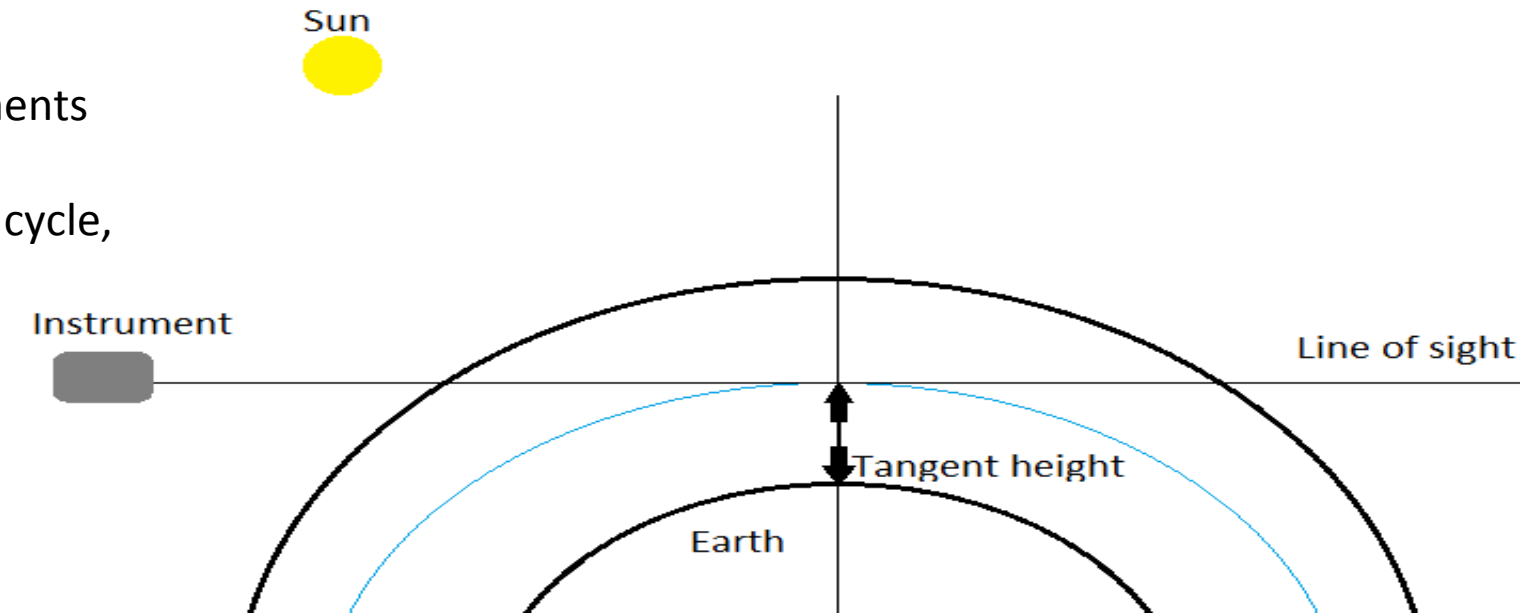
Suitability of OMPS OMPS LP to continue the ozone climate record

Altitude registration error - main source of uncertainties in limb measurements:

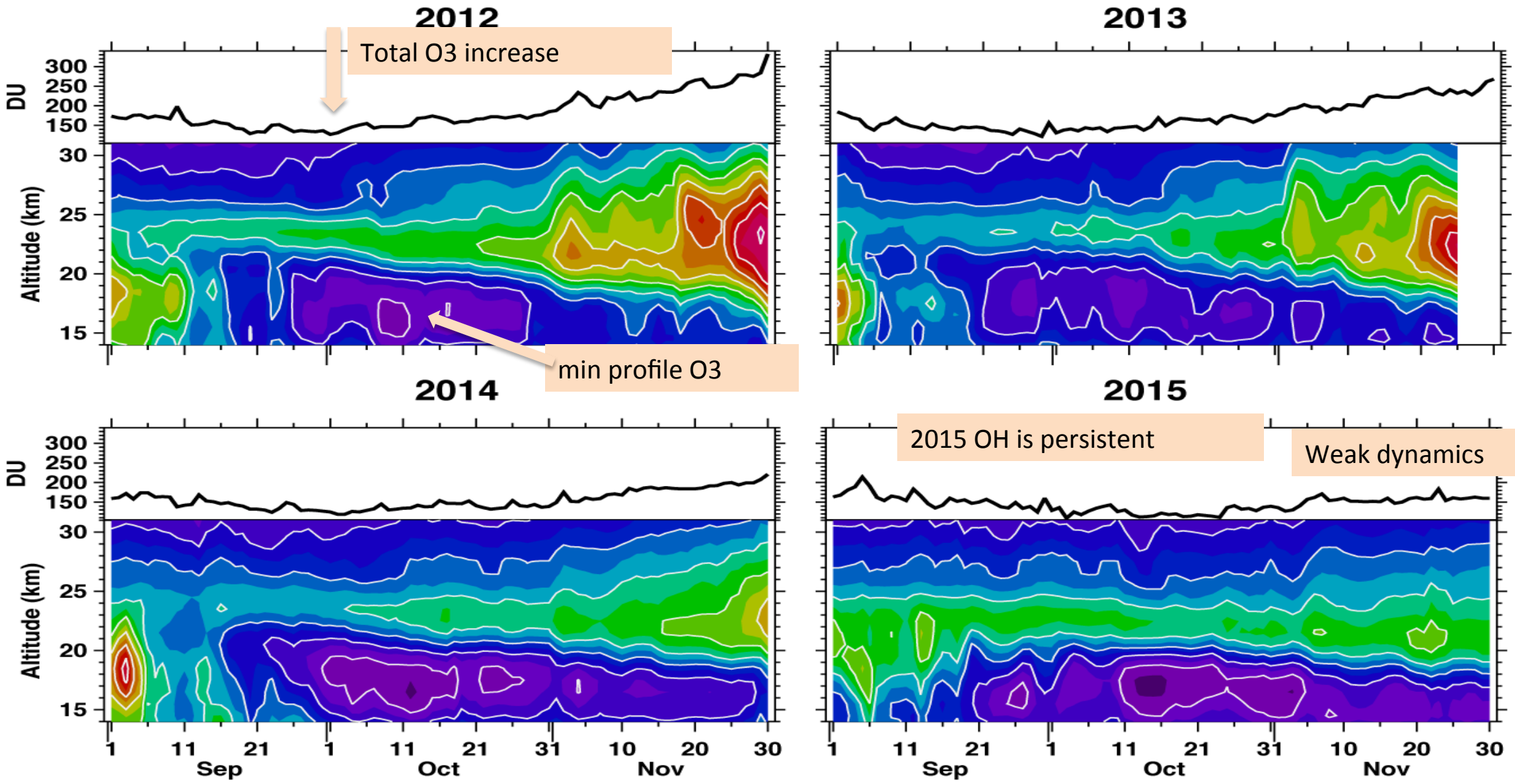
- Characterize sources of errors in Tangent Height registration;
- Develop independent methods for TH registration;
- Estimate sources of uncertainties for each method;
- Develop approaches to validate TH registration.

Validation of ozone retrievals:

- Ensure that OMPS LP retrievals meet requirements for biases and drifts;
- Focus on time-dependent variability (seasonal cycle, QBO, Antarctic ozone hole etc.)



OMPS observations of the Antarctic Ozone Hole



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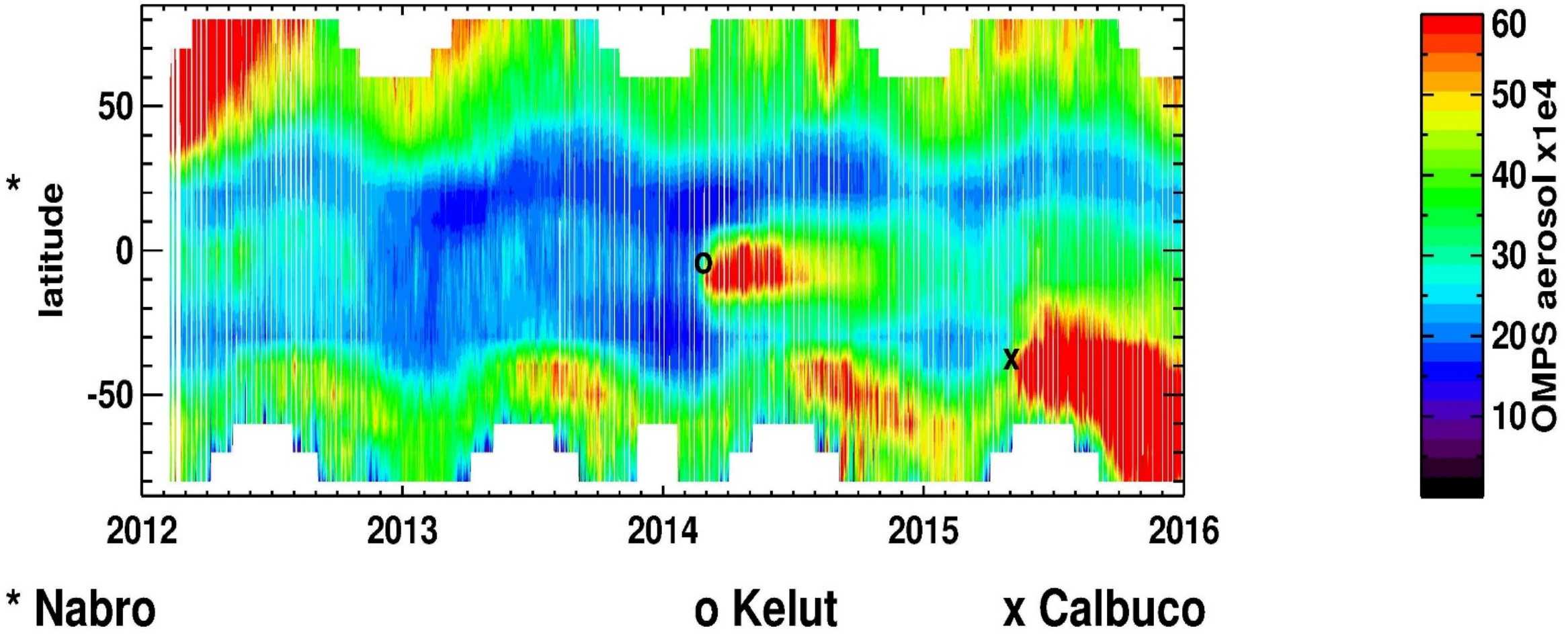
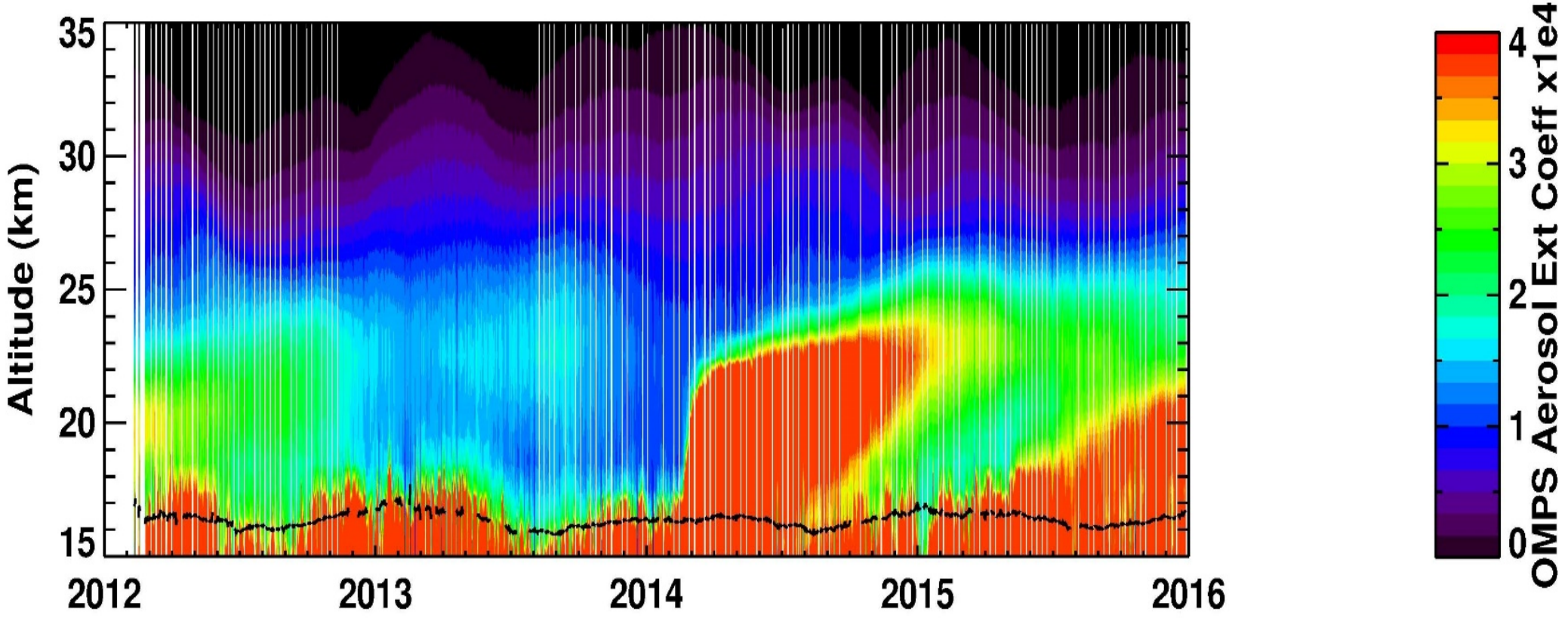
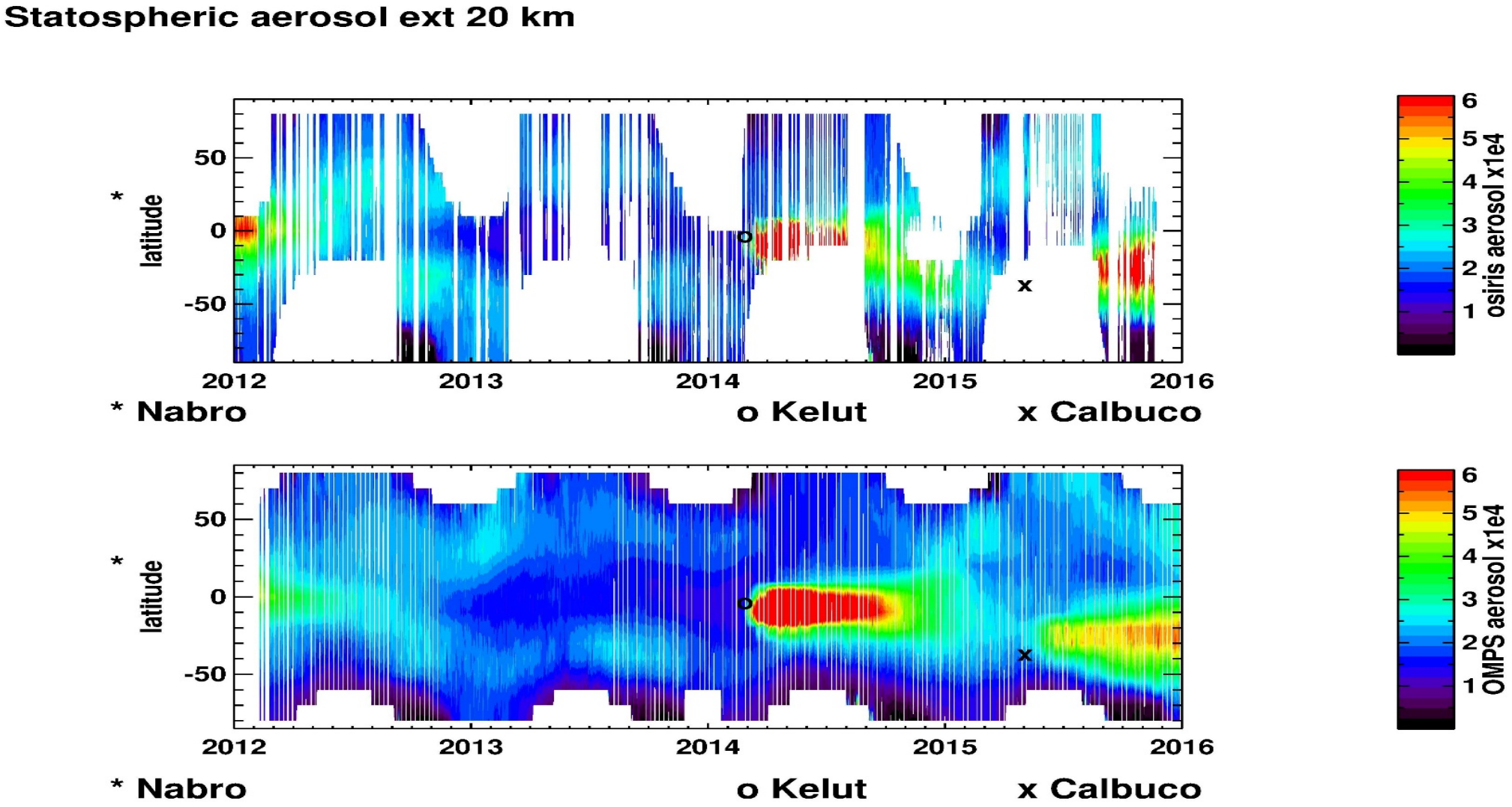
OMPS Limb Aerosol Column Optical Depth



OMPS-Limb Zonally averaged (10S-0 lat) aerosol vertical extinction/km



Comparison of extinction retrieved from OMPS-Limb and OSIRIS



Potential for Science flights from Guam on WB-57

- NASA is negotiating with other US partners to take advantage of the WB-57 being in the Western Pacific in October 2016.
  - Yes, this is very short notice!!!
- If successful, a small payload would fly out of Guam for 2-3 weeks (desired) in order to get both follow-on observations from ATTREX in a season when the Global Hawk was not available for ATTREX and to obtain SO_2 observations in a very clean part of the atmosphere.
- Observations would be mostly in situ (Ozone, water, air canisters, a tracer like CO2/CH4, ice particles). As of now, no appropriate aerosol observations are readily available to be incorporated.
- These data would be too early to correspond to SAGE-III flights, but they will provide good reference data sets.

NASA workshop to plan a response to a Pinatubo-scale volcanic eruption

Purpose: Develop an observation strategy to characterize the changes to atmospheric (especially stratospheric) composition that can be quickly implemented and utilized in response to a major volcanic eruption.

When: 17-18 May, 2016

Where: NASA GSFC

Who: Key, but limited (invited) individuals in satellites remote sensing, aircraft remote and in situ observations, modelers, and leaders of campaigns held during El Chichon and Pinatubo.

Output: Document with a plan to be used as a reference **IF** a large scale volcano goes off that warrants relatively fast action.

Caveats: **NO** funding line exists for such a plan right now. This is **ONLY** to avoid having to make such plans after such an eruption that results missing key observations.

Volcano workshop info…continued

Actions:

- Identify key satellite and surface-based remote sensing data to be collected for detailing the evolving morphology and composition of the volcanic plume and understand potential limitations (e.g., saturation effects) that may arise from large eruptions
- Analyze existing modeling runs that simulate the evolution of plumes resulting from large volcanic eruptions, with detailed consideration of the observables that would be most important to constrain models for future evolution of large scale atmospheric (e.g., climate, chemistry) impacts
- Develop a deployment plan for any needed sub-orbital campaign by specifying key/prioritized measurement requirements that can be used to characterize the eruption's near-term impacts on the atmosphere and to constrain the models that would be used to answer questions about the future impact and evolution of this major eruption. These requirements would in turn be used to identify appropriate sub-orbital platform(s), sensor payload(s), generic flight plans, and generic deployment location(s)
- Develop the synergy and gap-filling between the satellite and sub-orbital plans, including both calibration/ validation of the satellite observations and complementary measurements that may allow for synthesis and/ or development of integrated products e.g., enhanced in-situ sampling when satellite signals are saturated
- Identify a set of existing surface-based remote and in-situ data for which data collection should be augmented

Volcano workshop info…continued…

Actions:

- Develop a deployment plan for additional surface-based remote and in-situ sensors, especially those that may be able to be deployed over relatively short time periods
  - Identify predictive models that can be used for flight planning and then to simulate future evolution of the eruption, to compare with observations to assess the models' ability to represent the atmosphere, and to guide the observational strategy for future study of the eruption's global impacts
  - Assess the state of current early warning tools provided by geological community to understand the potential warning(s) that may be available to the atmospheric science community to help prepare for a potential eruption
  - Assess the ability of the atmospheric science and geological communities to provide integrated knowledge about the eruptions based on the combined data
  - Provide clear guidance as to what information could be made publicly available on what time scale given NASA data policies (e.g., no proprietary period for investigators) and need for adequate calibration/ validation
  - Provide clear guidance as to the nature and type of procurement vehicles and/or stockpiling of materiel that may be needed (and potentially put into place ahead of time) to enable the implementation of post-eruption response activity

NOTE: No funds exist currently to implement such a plan!

Existing NASA supported ground based observations for the stratosphere

- MPLNet
  - Supported through NASA GSFC.
- NDACC lidars
  - Supported through JPL for high powered lidars at Mauna Loa and Table Mountain.
  - Traveling lidar at GSFC for intercomparisons.
- NDACC FTIRs and Microwave radiometers
  - Supported through NCAR, JPL, NRL in numerous locations.
- Aeronet
  - Supported through GSFC, more for troposphere than stratosphere.
- SHADOZ ozone sonde network
  - Supported through GSFC and NOAA GMD.
- Occasional high altitude balloon flights from MkIV and SLS.

Slides from the National Academy of Science regarding the next NASA Earth Science Decadal Survey

Backdrop: In Addition to Tight Budgets…

- **NASA**: Has a backlog of missions recommended in the inaugural survey and increased responsibility—without commensurate budget increases— starting after the JPSS-1 era for vertical profiles of stratospheric and upper tropospheric ozone, solar irradiance, Earth radiation budget measurements, and altimetry (beyond Jason-3).

- **NOAA**: Stabilizing the weather satellite portfolio and avoiding a potential gap between the NPP spacecraft and the first of the next-generation POES systems, JPSS-1, is a top priority. "Climate"-related instruments moving to NASA.

- **USGS**: Interest in survey focuses on future capabilities, including hyperspectral, for a sustained land-imaging imaging program and options for Landsat follow-ons. However, L-9 is projected to be a near-rebuild of L-8 for launch in in 2023. (TIRS on L-8 only has 3-year design life; NASA looking at Class-D TIR free-flyer for 2019 launch.)

Primary Elements of the SOT

- Assess progress in addressing the major scientific and application challenges outlined in the 2007 Earth Science Decadal Survey.
- Develop a prioritized list of top-level science and application objectives to guide space-based Earth observations over a 10-year period commencing approximately at the start of fiscal year 2018 (October 1, 2017).
- Identify gaps and opportunities in the programs of record at NASA, NOAA, and USGS in pursuit of the top-level science and application challenges—including space-based opportunities that provide both sustained and experimental observations.
- Recommend approaches to facilitate the development of a robust, resilient, and appropriately balanced U.S. program of Earth observations from space. Consider: Science priorities, implementation costs, new technologies and platforms, interagency partnerships, international partners, and the *in situ* and other complementary programs carried out at NSF, DoE, DoA, DoD.

Agency-Specific Tasks

NASA

•Recommend NASA research activities to advance Earth system science and applications by means of a set of prioritized strategic "science targets" for the space-based observation opportunities in the decade 2018-2027. (A science target in this instance comprises a set of science objectives that could be pursued and significantly advanced by means of a space- based observation.) …… For each science target, the committee will identify a set of objectives and measurement requirements/capabilities for space-based data acquisitions.

If appropriate and usually only for recommendations associated with major investments, the committee will (via a "CATE" process) assemble notional proof-of-concept missions with the recommended capabilities in order to better understand the top-level scientific performance and technical risk options associated with mission development and execution.

•Other NASA tasks include: The committee will pay particular attention to prioritizing and recommending balances among the full suite of Earth system science research, technology development, flight mission development and operation, and applications/capacity building development conducted in the Earth Science Division (ESD) of the Science Mission Directorate.

What Happens to Missions Recommended in the Previous Survey?

TBD, but:

- In developing its recommendations, survey to "include reconsideration of the scientific priorities associated with the named missions from the 2007 decadal survey."
  - The 2007 survey did not prioritize among the 15 missions for NASA; placement in 1 of 3 time periods (Tiers I, II, III: 2010-13, 2013-2016, 2016-2020) was based on factors including technical readiness; cost; synergy with existing, planned, or recommended missions; and consideration of int'l activities.
- ESD has expressed an interest in having the survey provide guidance on technology investments that will be needed to address recommended science targets.
- Previous surveys have assumed missions in formulation to be considered part of the baseline program of record.

Other Questions

- Why is this survey different from all other NRC surveys?
  - Systems Approach—Advances require study of the Earth as an integrated system
  - Research driven by user needs
  - Science informs policy
  - Inherently multiagency; R2O and continuity are perennial issues
- How will this survey differ from the inaugural survey?
  - No longer appropriate to recommend based on an aspirational budget
  - Congressionally-mandated independent cost appraisal and technical evaluation (CATE) for big ticket items
  - Likely that the science will be "valued" to avoid having one recommended activity grow at expense of all others
  - Increased opportunities to consider "new space" ideas—new players, smaller and less costly platforms, constellations, hosted payloads etc.
  - Improved consideration of international partners

STATUS

- NRC Approval, May 6, 2015
- Chairs and steering committee have been named.
- 1st round of white papers for science topics were submitted, which helped define committees.
- 2nd round of white papers are due in less than 1 month (extended to May 15).
- NASA HQ are not to be part of this process.
- NRC Boards covering atmospheric sciences, polar research, ocean science, hydrology, and the solid Earth will be collaborating partners with the Space Studies Board.
  - Includes membership, execution, staffing, etc.
- Final report due ~ 2 years from survey start (Mid 2017).
- Info @ http://sites.nationalacademies.org/DEPS/ESAS2017/index.htm

Concluding remarks

- NASA still has significant space assets to observing the evolving stratosphere.
  - Aura, SAGE-III, OMPS (especially the limb observations).
- NASA supports, and/or is a lead contributor to, a number of ground based networks for atmospheric observations.
- NASA supports global chemistry/climate models that are state of the art, and see the stratosphere as a key focus.
- NASA is still planning on stratospheric aircraft missions, but at a lower level (mostly funding driven).

- What we are NOT doing!
- Planning on a follow up to Aura. Was not a high priority from the LAST decadal survey. Whether it is in the next Decadal Survey is not clear.
- Funding large scale stratospheric aircraft campaigns outside of the Earth Venture Suborbital solicitation. This is where the funds are now! ATTREX did get funded in the first round of this call. AToM was funded in round 2, focused more on troposphere than stratosphere.
- Most likely NOT getting a funding line for Geo-Engineering. Talk in US Congress is for that to go to DOE.