Validation challenges for upcoming limb missions

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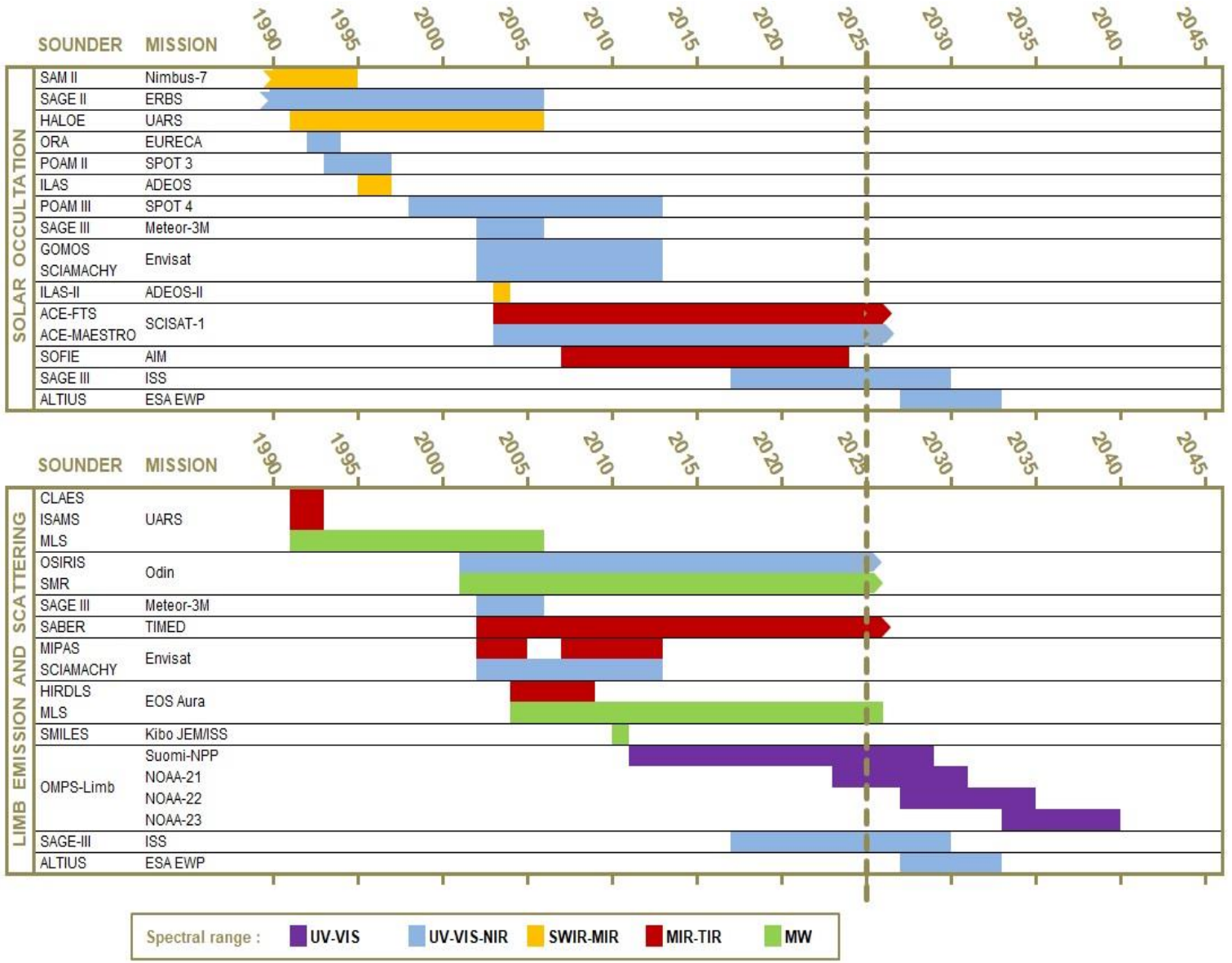
End of the “Golden Era” for Limb Sounding

Over the past decades, there have been multiple limb sounding satellite sensors in the “on-orbit fleet”

- Initial measurement focus on aerosols, ozone and related species
- Then extended to further trace gases for ozone chemistry, air pollutant, and climate studies

As missions ended, replacement limb sensors have narrowed focus to:

- Primarily measuring stratospheric ozone, water vapour, and aerosols
- Using UV-VIS or UV-VIS-NIR solar occultation or limb scattering



Plot: J.-C. Lambert

Limb Sounding Landscape in Next Decade - Current

Heritage (in extended operations) missions that remain are "dwindling"

- OSIRIS (UV/VIS) and SMR (MW) on Odin and Aura-MLS will end in 2026
- Only four remain – one has a potential end date because of the ISS lifetime

Mission / Instrument(s)	launch	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Current limb missions in extended operations															
Odin – SMR & OSIRIS (ends in 2026)	2001														
TIMED – SABER	2001														
SCISAT – ACE-FTS & MAESTRO	2003														
Aura – MLS (ends in 2026)	2004														
Suomi-NPP – OMPS-LP	2011														
SAGE III / ISS (must end by 2030)	2017														
Current in-orbit limb missions in baseline operations															
MATS	2022														
JPSS-2 - OMPS-LP	2022														
AWE / ISS (likely ending by 2026)	2023														

Current missions (in baseline operations) focus on:

- Mainly stratospheric ozone for OMPS-LP on JPSS-2
- Gravity waves in the mesosphere for MATS on INNOSAT and AWE on ISS

Limb Sounding Landscape in Next Decade – Planned

Planned missions and data products – in development

- ALTIUS (UV-VIS-NIR) – stratospheric ozone, aerosol, NO_2, water vapour
- OMPS-LP (UV-VIS) on JPSS-3 and JPSS-4 – mainly stratospheric ozone
- HAWC – ALI (VIS-NIR) – stratospheric aerosols & SHOW (SWIR-MIR) – UTLS water vapour

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Current in-orbit limb missions in baseline operations															
MATS	2022														
JPSS-2 - OMPS-LP	2022														
AWE / ISS (likely ending by 2026)	2023														
Planned limb missions - baseline operations															
ALTIUS	2027														
JPSS-3 / JPSS-4 - OMPS-LP	2027+														
HAWC – ALI & SHOW	2031														

Limb Sounding Landscape in Next Decade – Proposed

So, what is potentially coming:

Candidate missions (under study through ESA and NASA)

- CAIRT (MIR-TIR) – UTLS to lower thermosphere composition (ESA Earth Explorer 11)
  - Focusing on middle atmosphere trace gases, isotopologues, aerosol precursors/aerosols, derived parameters such as age-of-air, gravity wave characteristics in the stratosphere and mesosphere

- STRIVE (MIR-TIR) – UTLS and stratosphere composition (NASA Earth System Explorers Program)
  - Focusing on trace gases, isotopologues, aerosol precursors/aerosols, derived parameters such as age-of-air, gravity wave characteristics

- Keystone (MW) – upper atmosphere composition (ESA Earth Explorer 12)
  - Focusing on winds, temperature, atomic oxygen, ozone, trace gases

Proposed missions (not exhaustive!)

- Solar occultation : SAGE IV cubesat and SOLSTICE (continuing from late CubeMAP)
  - UTLS and stratosphere composition – ozone, trace gases
- Emission : Terahertz /FIR missions focused on water vapour, ice clouds, isotopologues using constellation of instruments

What do we need to start working on now!

Altitude range needed with high vertical resolution
- UTLS, stratosphere, mesosphere and beyond
- Validation for 3-D/tomographic retrievals – higher spatial resolution than current sensors

Suite of trace gases and particles needed
- Transport tracers, ozone depleting substances, pollutants, …
- Water vapour and isotopologues
- Aerosols and clouds

Validation for derived products needed
- Age-of-air from SF_6 and other tracers – requires comparisons for both
- Gravity waves from 3-D temperature fields

Challenges of cross-validation and maintaining consistency across constellations of instruments
- Added considerations with differences in performance, aging, etc.

Overall, what are the on-going instruments/data sets and campaign-based measurements we need?
- Complementary measurements and FRMs we need to do the validation
- Campaigns and other data sets needed to connect to current and heritage measurements for creating climate data records and supporting essential climate variables