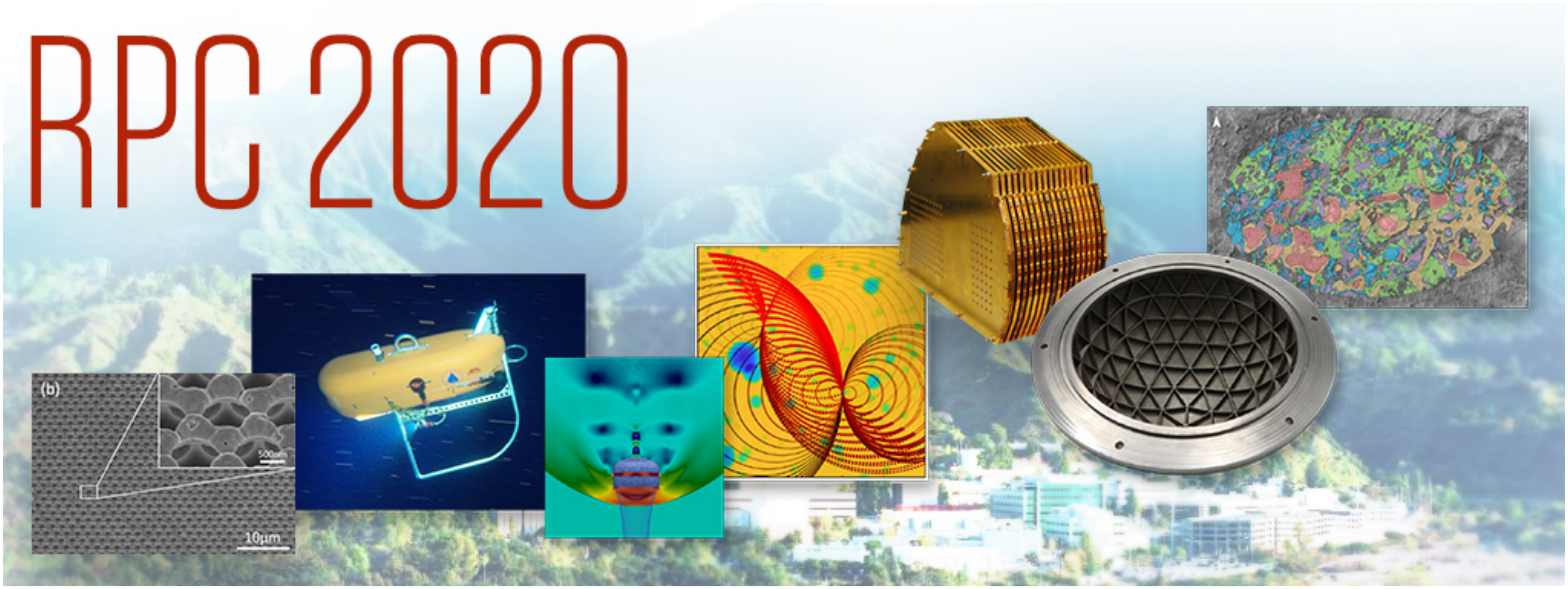

Virtual Research Presentation Conference

Maturing HiMAP (High-resolution Imaging Multiple-species Atmospheric Profiler) System to TRL 6

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Program: Strategic Initiative

Jet Propulsion Laboratory
California Institute of Technology

Assigned Presentation # RPC-037

HiMAP

– Towards enabling new measurement capabilities for air quality science

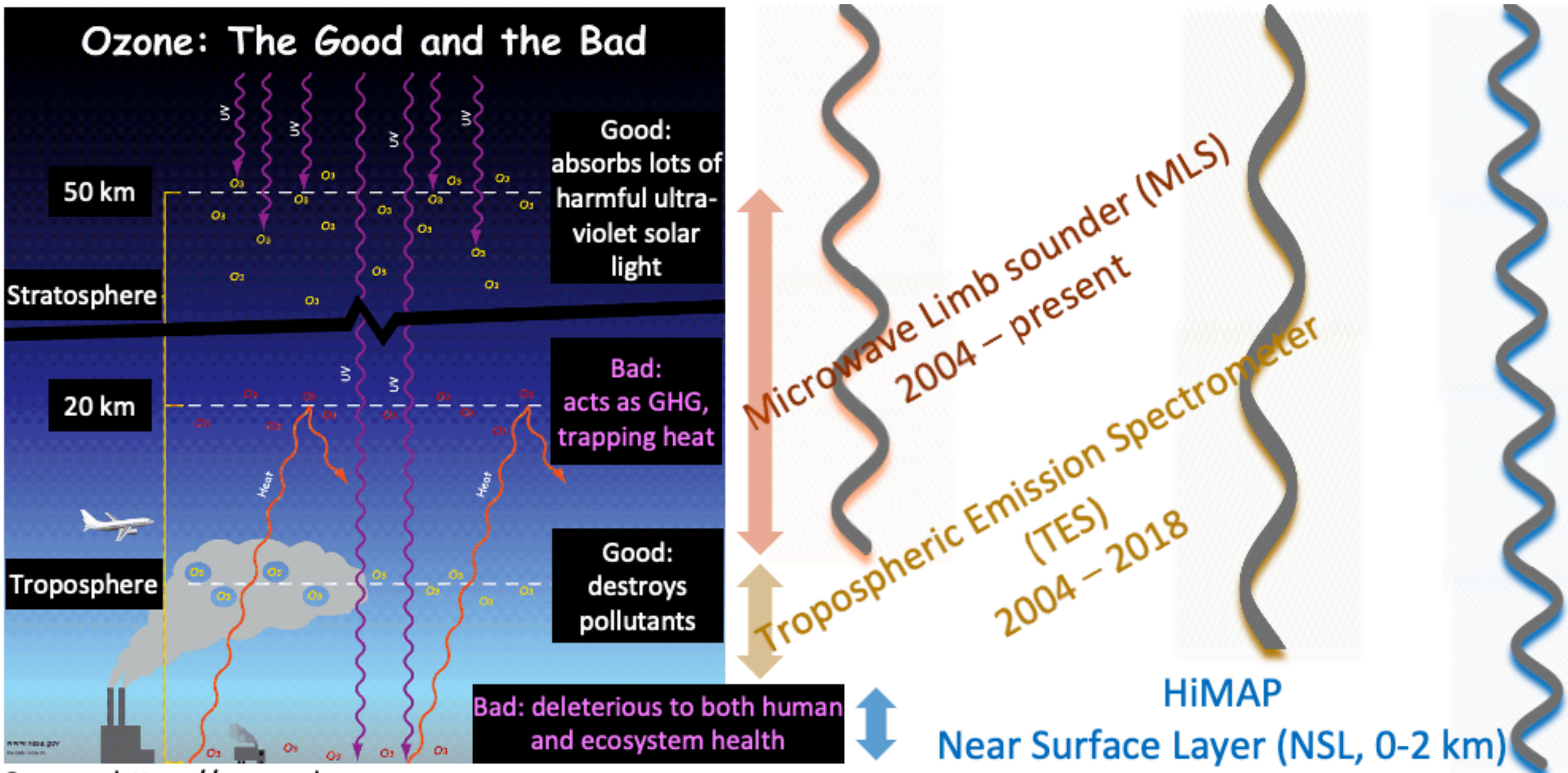
Abstract

Global, high-resolution, vertical profile measurements of aerosols and gaseous pollutants (O_3 and NO_2) are identified as NASA priorities by the 2017 Earth Sciences Decadal Survey. These three observables are currently available in the form of tropospheric columns (i.e., the amount of pollutants from surface to tropopause). However, quantification of their global health and environmental impacts requires a major advance in measurement technology that enables quantification of their concentrations in the near-surface layer (0–2 km), where air quality is strongly influencing the human health and economic prosperity.

In this presentation, we will review the science, technology backgrounds, and the simulation work that links the new air quality measurement needs to instrument requirements for next generation of satellite missions. We will explain the HiMAP instrument concept, and report the development of the key technology named Metagrating, followed by the performance evaluation and demonstration of this new technology. In the end, we will provide the plan regarding the path to the future missions for JPL community.

2017-2027 Earth science decadal survey

– requires new measurement capabilities for air quality[1, 2, 3]

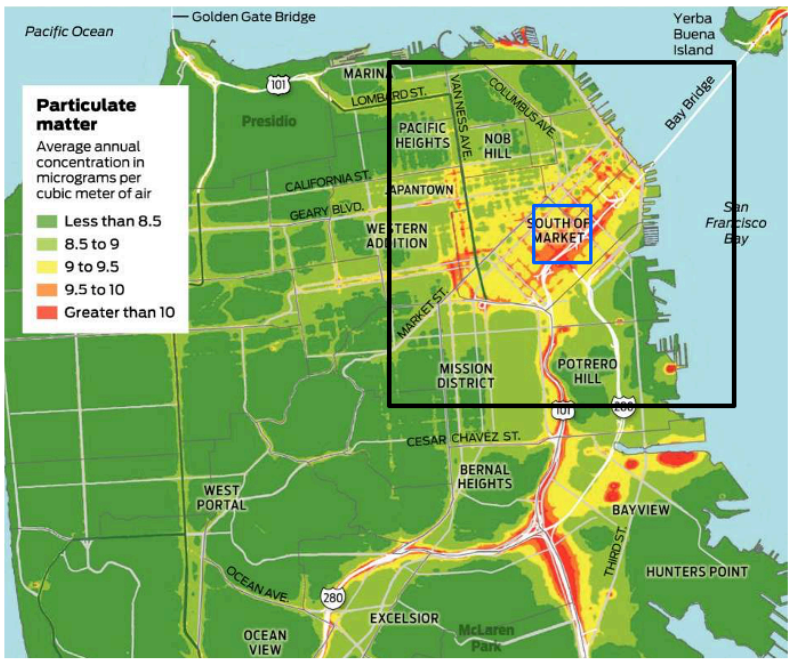


Source: https://spaceplace.nasa.gov

Air pollution: horizontal view

– new intra-urban scale measurements for new science and application

Improvement in spatial resolution to map both gaseous pollutants (O_3 and NO_2) and aerosols at the neighborhood (intra-urban) scale and better quantify the health impacts of air pollution[1, 2, 3]



horizontal resolution

TROPOMI 7 x 7 km² → HiMAP
- 1 x 1 km² (megacities)
- 4 x 4 km² (global survey)

Source: San Francisco Department of Public Health, Bay Area Air Quality Management District

JPL

Observing System Simulation
– define the instrument requirements

Climatology

- Vertical distribution of pollutants, surface-cloud properties
- Long term, in-situ and remote sensing measurements

Radiative transfer modeling

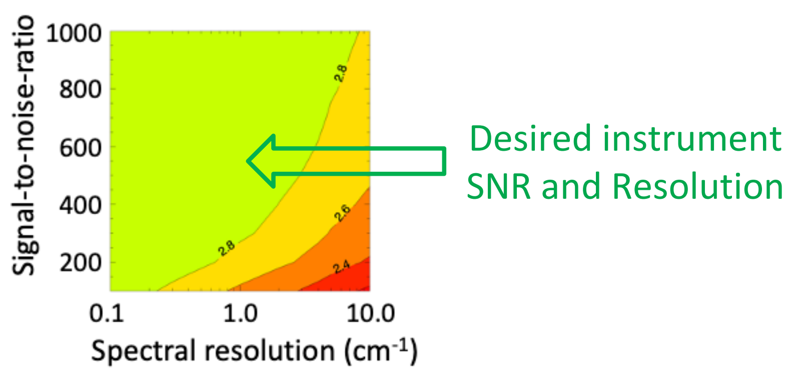
- VLIDORT (Spurr 2016)
  - Radiance spectra (I)
  - Polarization spectra (Q, U)
  - Jacobian $\partial y / \partial x$
  - Multispectral simulation

Simulated observation

- Instrument model
  - Instrument line shape function
  - Signal-to-noise ratio
  - Calibration uncertainty

Information contents, measurement uncertainty analysis

- Optimal estimation method (Rodgers 2000)
  - Degree of freedom for signals
  - *a posteriori* uncertainty



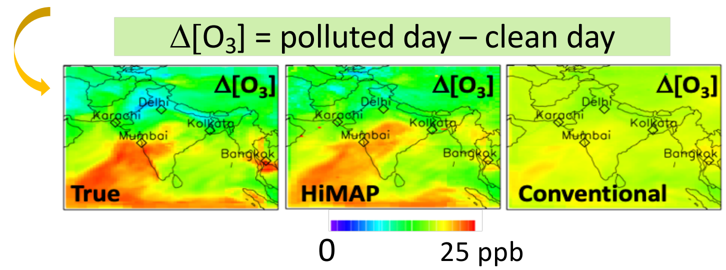
Choi *et al.*, in press, (2020)[4].

HiMAP instrument concept

– new measurement capabilities enabled by metamaterials

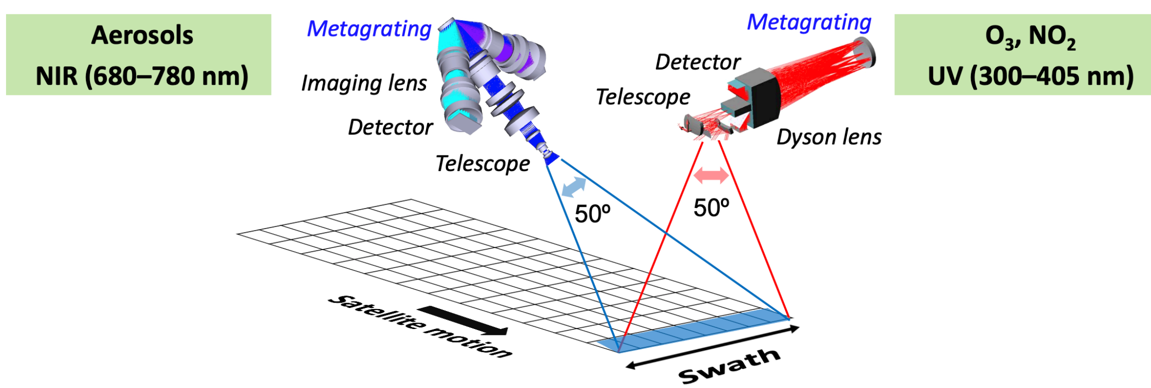
Unique capability on quantifying the change of pollutants in the NSL (0 – 2 km) via combining

- Simultaneous radiometric, polarimetric measurements[4, 5]
- High spectral resolution and signal-to-noise ratio[4, 5]
- Multiple spectral bands[4]



Compact form factor (5U)

- Broad-band, high efficiency, imaging metagrating – key technology to enable new measurements
- Two independent modules – provide flexibility on the satellite constellation strategy



Optics design: James McGuire, Mayer Rud (383)

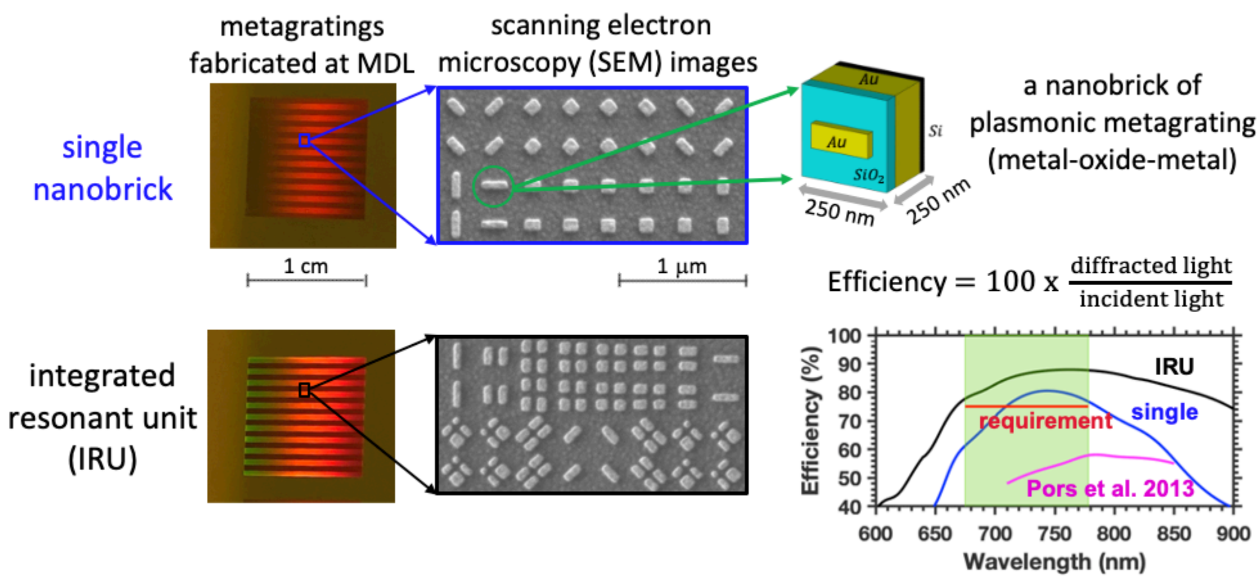
Focal Plane Array: William Johnson (389)

Metagrating technology

– a joint venture with MDL and NTNU

A single device that simultaneously provides three functionalities: polarization analysis, spectral light dispersion, and spatial mapping.

Efficiency > 80% across a broad spectral region



Richard Muller, Daniel Wilson (389), Hui-Hsin Hsiao (NTNU)

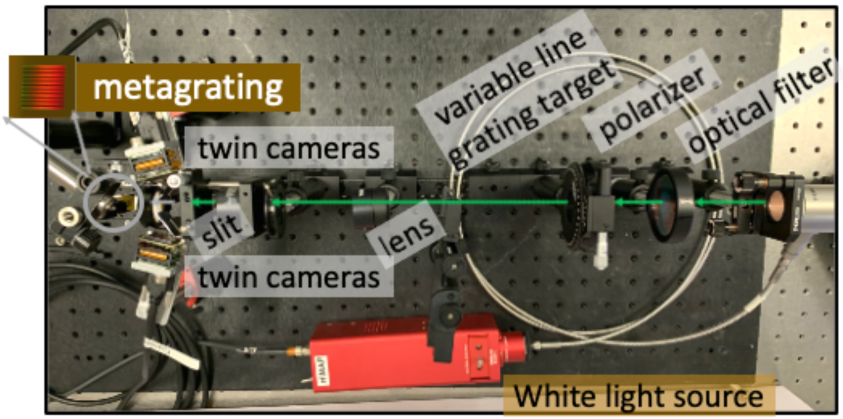
Hsiao *et al.*, in preparation, (2020).

Optical characterization of metagrating

– evaluate performance and demonstrate concept

Config. #1: using white light source

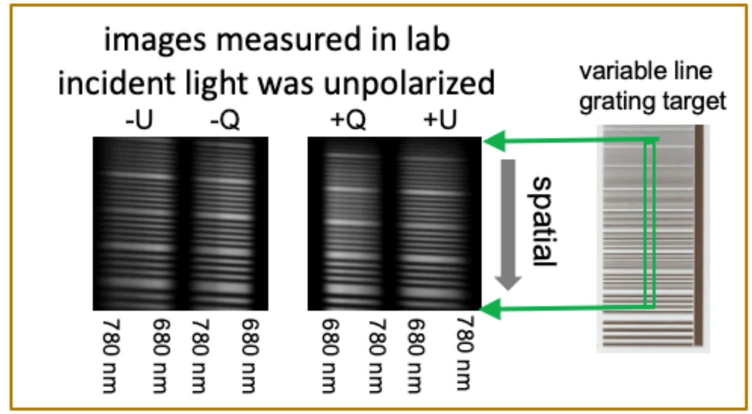
Config. #2: using UV-Vis-NIR continuous, tunable laser system as light source

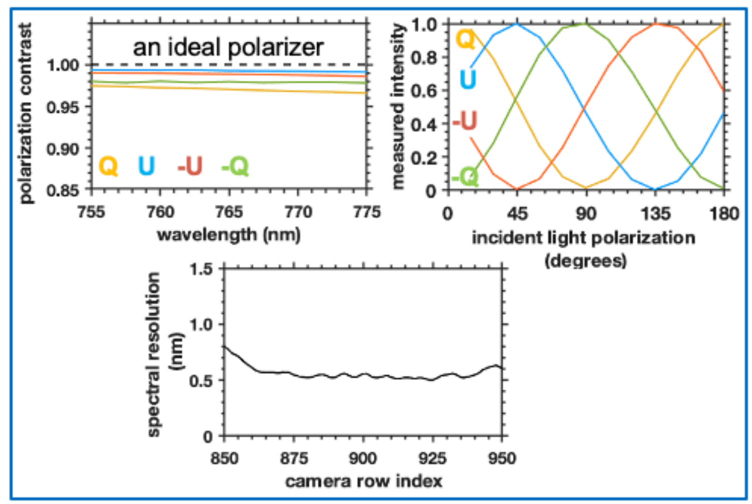


Config. #1: delivers spatially, spectrally, polarimetrically, resolved images

Config. #2: the measured polarization contrast, polarimetric modulation, and spectral resolution agree to the theoretical prediction

Gerard Van Harten, Deacon Nemchick, Timothy Crawford (329)





Next steps
– towards future missions

Instrument Development

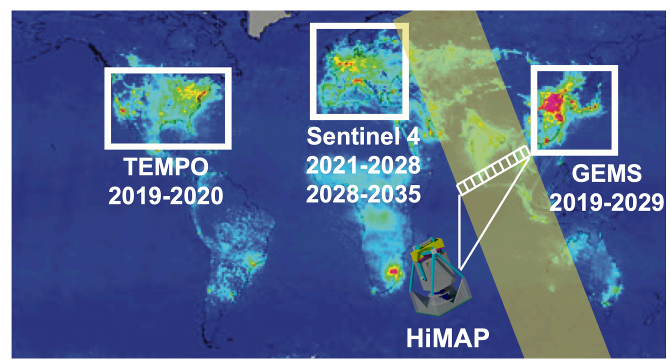
- ESTO IIP FY21 for building whole instrument

Future missions to address the class of "MOST IMPORTANT" science objectives associated with air quality (page 7-3, 7-4 of the 2017 ESDS report) via

- enable new measurements of pollutants in the NSL (0 – 2km), where air quality affects the health and economic prosperity of billions of people
- fill the spatial gaps of three GEO instruments, thus helping in the attribution of air quality to local/nonlocal pollutants through global measurements
- constrain the process-based air quality models thus providing improved mechanistic understanding of air pollution and its impacts on health and economic prosperity

Candidate opportunities

- Ozone and Trace Gas Earth Explorer
- Planetary Boundary Layer Incubator
- Earth Venture



Jessica Neu (DPM, 329)

Reference and Publication

[1] "2017-2027 Decadal Survey for Earth Science and Applications from Space: Thriving on Our Changing Planet A Decadal Strategy for Earth Observation from Space," available at: http://sites.nationalacademies.org/DEPS/ESAS2017/index.htm

[2] "Burden of disease from the joint effects of Household and Ambient Air Pollution for 2012," World Health Organization (WHO), technical report, 2014, available at: http://www.who.int/phe/health_topics/outdoorair/databases/HAP_BoD_results_March2014.pdf

[3] "WHO methods and data sources for global causes of death 2000–2012," WHO, Global Health Estimates Technical Paper WHO/HIS/HSI/GHE/2014.7, 2014, available at: http://www.who.int/entity/healthinfo/global_burden_disease/GlobalCOD_method_2000_2012.pdf.

[4]* Choi M., Sander S.P., Spurr RJ.D., Pongetti T.J., van Harten G., Drouin B.J., Diner D.J., Crisp D., Eldering A., Kalashnikova O.V., Jiang J.H., Hyon J.J., Fu D.: Aerosol profiling using radiometric and polarimetric spectral measurements in the O_2 near infrared bands: Estimation of information content and measurement uncertainties, *Remote Sensing of Environment*, in press, (2020).

[5] Hasekamp O.P., Landgraf J., van Oss R.: The need of polarization modeling for ozone profile retrieval from backscattered sunlight. *J. Geophys. Res.*107(D23), 4692. (2002).

[6]* Richter J., Chipman R., Daugherty B., Diner D.J., Eldering A., Hyon J., Kupisnki M., Neu J.L., Fu D.: Specifying Polarimetric Tolerances of a High-resolution Imaging Multiple-species Atmospheric Profiler (HiMAP), *Proc. SPIE. 10925*, *Photonic Instrumentation Engineering VI*, (2019).

*This SRTD project supported the publication of [4] and [6].