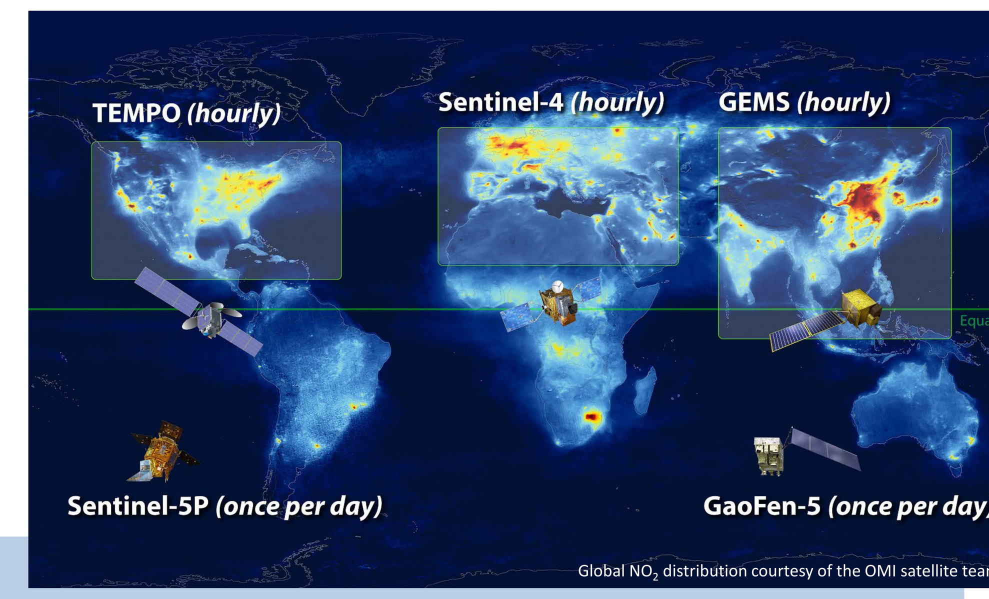
Hemispheric Airborne Measurements of Air Quality (HAMAQ)
A proposal to NASA's Earth Venture Suborbital-3 program

Science Overview

An unprecedented view of air quality from space will be coming to fruition in the next several years, including the first trace gas observations from geostationary orbit. These satellites will provide once per day global coverage and hourly coverage over the major population centers of the Northern Hemisphere. With contributions from the United States, European Union, South Korea, and China, this constellation of satellites demands strong international collaboration and contextual support from surface and airborne measurements to exploit its full potential. NASA's Earth Venture program provides an ideal opportunity for making such a contribution.

Hemispheric Airborne Measurements of Air Quality (HAMAQ, pronounced "hammock") proposes to conduct targeted airborne field studies that will bridge satellite observations with regulatory surface air quality networks and models, creating an integrated observing system that brings satellite data into the decision-making process.



HAMAQ Goal: Evaluate and exercise the integrated observing system for air quality

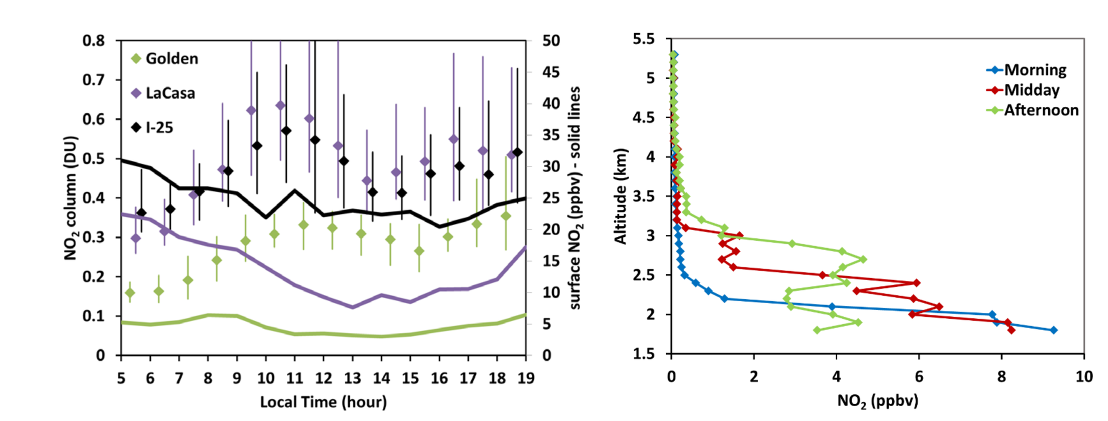
Question: How can observations from the international air quality constellation be effectively integrated into assessments of air quality in the Northern Hemisphere?

Expected Outcome: Infusion of satellite information to improve air quality ground monitoring, spatial coverage, forecasting, and decision making.

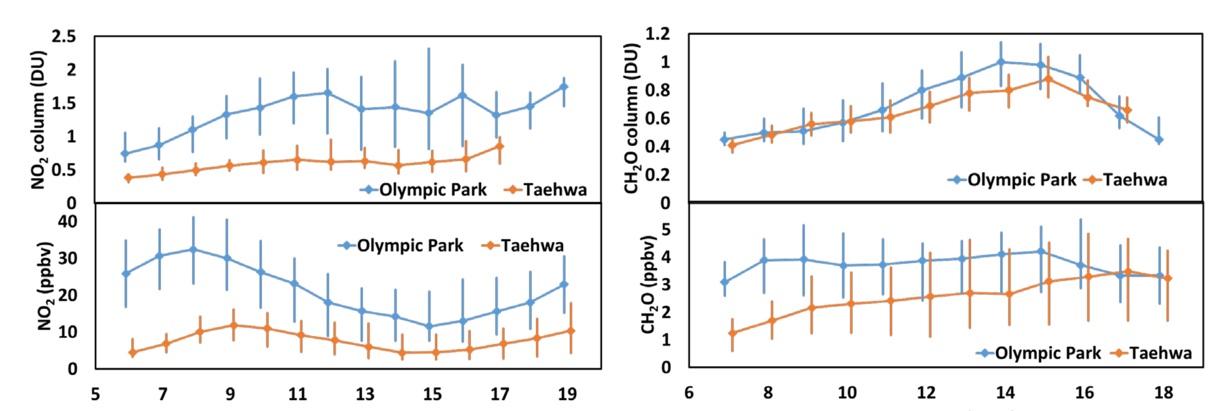
Objective 1: Improve connections between satellites and surface networks for air quality assessment

Question: What are the factors most affecting the integration of satellite and ground-based observations (e.g., vertical distribution, spatial gradients, aerosol shielding, aerosol composition and size, relative humidity, etc.)?

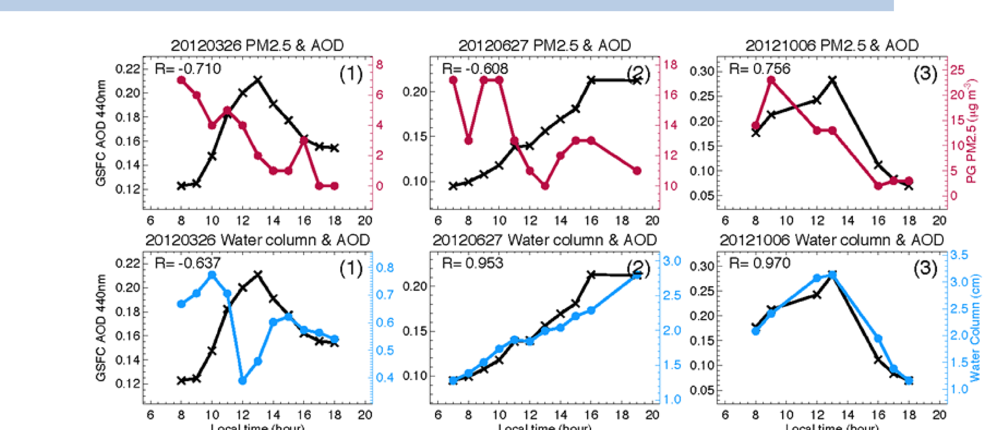
Expected Outcome: Improved quality and interpretation of satellite observations, spatial context for ground-based networks, and recommendations for optimizing ground monitoring locations.



Left: DISCOVER-AQ Colorado observations of diurnal trends for NO_2 column density (median values and interquartile range) contrasted with average in situ NO_2 (lines) at the surface for three sites. **Right:** Average airborne in situ profiles over the LaCasa site demonstrating diurnal changes in column density and NO_2 gradients within the boundary layer



Diurnal statistics (median and interquartile range) for column and surface NO_2 (left) and CH_2O (right) from Pandora spectrometer and in situ observations at Olympic Park in Seoul and Taehwa Research Forest downwind of Seoul observed during KORUS-AQ.

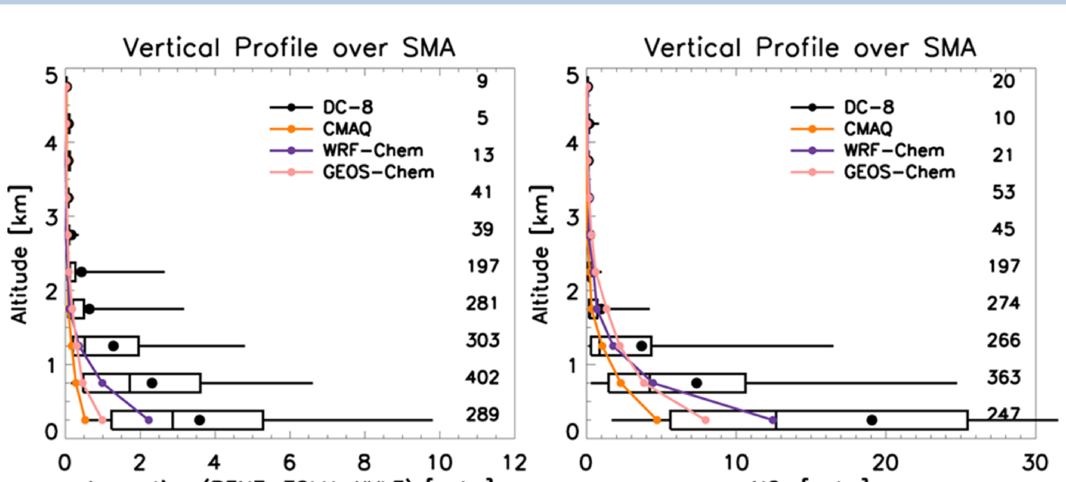


Examples of different daytime variations of AOD, $PM_{2.5}$, and column water vapor at a location near Washington, DC in 2012. AOD and column water vapor data are from AERONET and $PM_{2.5}$ data are from EPA sites located within 4 km.

Objective 2: Evaluate emission inventories

Question: Are emission inventories adequate to explain observed distributions of precursors (e.g., NOx, CH_2O, SO_2) and resulting impacts on O_3 and $PM_{2.5}$?

Expected Outcome: Improved emissions inventories and methods for using satellite observations to diagnose emissions

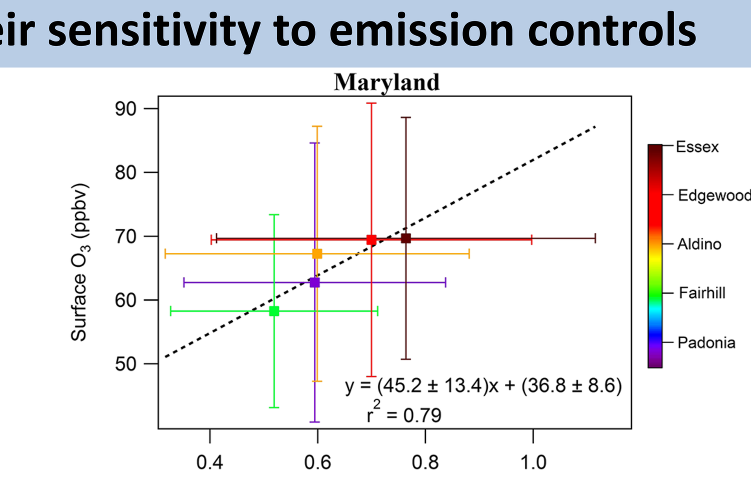


Comparison of NASA DC-8 observations with three independent model simulations for aromatic VOCs (left) and NOx (right) over Seoul during KORUS-AQ.

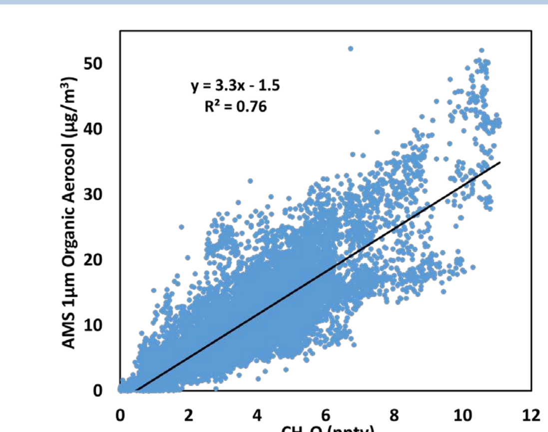
Objective 3: Further develop satellite proxies for air quality

Question: Are satellite data providing useful information on ozone, $PM_{2.5}$, and the relative importance of precursor gases?

Expected Outcome: Improved diagnosis of exposure to ozone, $PM_{2.5}$, and their sensitivity to emission controls



Correlation of surface ozone with CH_2O column densities from airborne in situ profiles over five sites during DISCOVER-AQ Maryland.



Correlation of organic aerosol with CH_2O observed over Seoul during KORUS-AQ.

Objective 4: Investigate the diversity of factors controlling air quality across multiple urban settings

Question: What are the differences in air quality across various North American and Asian locations observed by satellite?

Expected Outcome: Improved understanding of similarities and differences in air quality and approaches to mitigation

Phase 1: Establish an Asian component of the Hemispheric Pandora Network

Phase 2: Conduct 4 airborne deployments with NASA's DC-8

Deployment 1: Northeastern United States, July 2020 (NASA LaRC) to observe ozone nonattainment areas extending from the Mid-Atlantic to New England states.

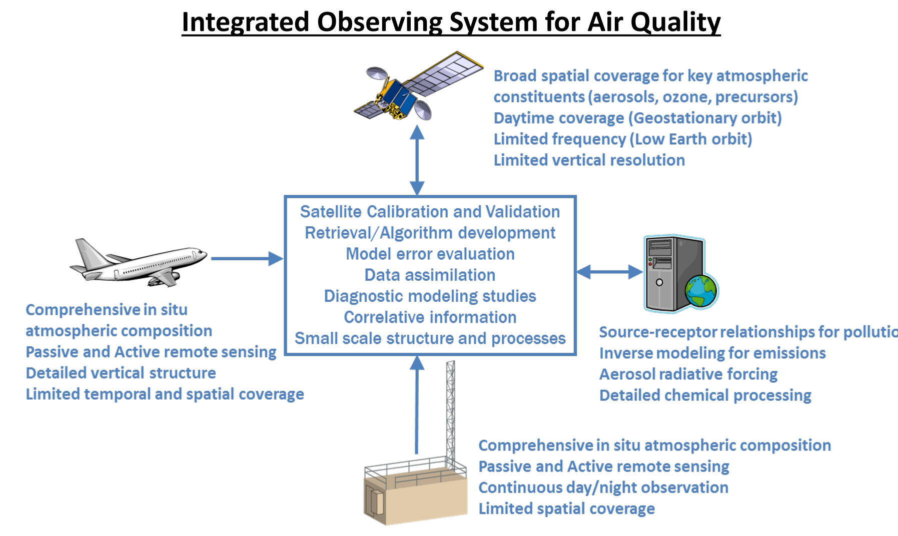
Deployment 2: South Korea, Jan-Feb 2021 (Osan Air Base) to observe peak conditions for wintertime fine particle pollution and assess the relative contributions of local and transboundary emissions.

Deployment 3: North America, July 2021 (TBD) nominally planned from NASA's Palmdale facility providing access to west coast areas plagued by both ozone and fine particle pollution. This deployment may be shifted if Pandora and satellite observations reveal areas where attention is more urgent.

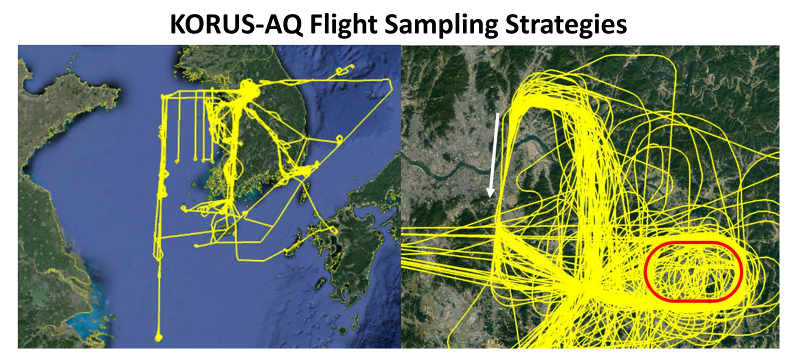
Deployment 4: South Korea, May-June 2022 (Osan Air Base) during the pre-monsoon pollution season to examine response to emission control policies implemented after the KORUS-AQ field study targeting a 30% reduction in fine particle pollution by 2022.

Modeling and Analysis: **A suite of models will be applied across global-to-regional-to-in situ scales to understand the chemical and physical processes controlling the spatio-temporal distributions of pollutants and precursors as they relate to the *multi-perspective observations of the integrated observing system.***

Integrated Observing System for Air Quality



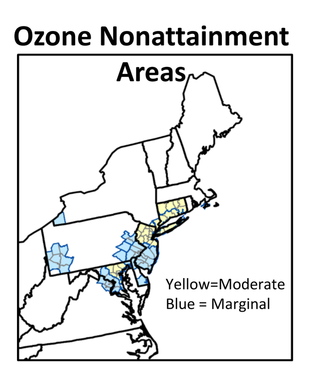
KORUS-AQ Flight Sampling Strategies



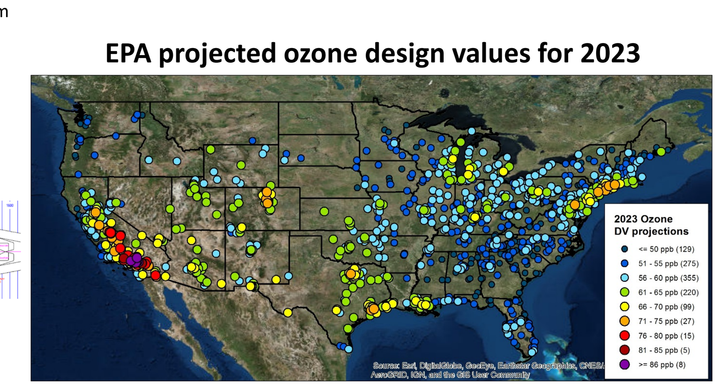
Above: Regional air quality sampling strategy employed during KORUS-AQ. Yellow lines show DC-8 sampling routes across the domain (left) and the Seoul Metropolitan Area (right). The descent profile over Seoul is indicated by a white arrow and the red circle shows the spiral ascent profile to the southeast. Both regional and vertical sampling are required to evaluate the integrated observing system

Asian Pandora Network

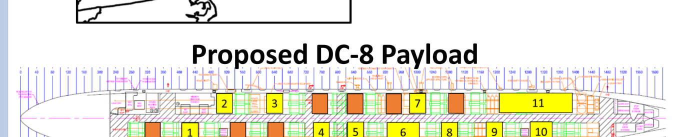
Ozone Nonattainment Areas



EPA projected ozone design values for 2023



Proposed DC-8 Payload



1-DACOM/DLH, 2-Chemiluminescence/CAFS, 3-LARGE/SP2, 4-CAMS, 5-AMS, 6-WAS, 7-ToF-CIMS, 8-DLR-CIMS, 9-PTR-ToF-MS, 10-PTR-MS, 11-DIAL/HSRL

HAMAQ Science Team

Leadership	
James Crawford, NASA LaRC	Principal Investigator
Qing Liang, NASA GSFC	Science and Data Analysis Lead
Luke Ziemba, NASA LaRC	DC-8 Platform Scientist
DC-8 Airborne Measurements	
Donald Blake, UC-Irvine	Non-methane hydrocarbons and halocarbons (WAS)
Joshua DiGangi, NASA LaRC	In situ water vapor (DLH)
Glenn Diskin, NASA LaRC	In situ CO, CH_4, CO_2 (DACOM)
Alan Fried, CU-Boulder	In situ CH_2O, C_2H_6, C_2H_4 (CAMS)
Johnathan Hair, NASA LaRC	Active remote sensing of ozone and aerosols (DIAL/HSRL)
Samuel Hall, NCAR	Spectral actinic flux and photolysis frequencies (CAFS)
Taehyoung Lee, HUFS, South Korea	In situ aerosol chemical composition (AMS)
John Nowak, NASA LaRC	In situ NH_3 (PTR-MS)
Hans Schlager, DLR, Germany	In situ SO_2, HNO_3 (CIMS)
Andrew Weinheimer, NCAR	In situ O_3, NO, NO_2, NOy (Chemiluminescence)
Armin Wisthaler, University of Oslo, Norway	Non-methane hydrocarbons (PTR-ToF-MS)
Bin Yuan, Jinan University, China	In situ oxygenated organic compounds (Iodide ToF-CIMS)
Luke Ziemba, NASA LaRC	In situ aerosol properties (LARGE) and black carbon (SP2)
Surface Remote Sensing	
Robert Swap, NASA GSFC	Pandora spectrometers
Brent Holben, NASA GSFC	AERONET sunphotometers
Modeling	
Greg Carmichael, University of Iowa	WRF-Chem regional model
Mian Chin, NASA GSFC	GEOS-5 global model and NU-WRF regional model
Louisa Emmons, NCAR	CAM-chem global model
Pablo Saide, UCLA	Satellite data assimilation
James Crawford, NASA LaRC	0-D photochemical box model

Asian Pandora Site Hosts			
Country	**City**	**Investigator Name**	**Investigator Institution**
Bangladesh	Dhaka	Abdus Salam	Dhaka University
Bangladesh	Bhola	Abdus Salam	Dhaka University
China	Nanjing	Aijun Ding	Nanjing University
China	Guangzhou	Min Shao	Jinan University
China	Beijing	Liangfu Chen	Institute of Remote Sensing and Digital Earth (RADI)
China	Kunming	Wu Jian	Yunnan University
China	Chengdu	Jinyuan Xin	Chengdu University of Information Technology
China	Wuhan	Minghui Tao	China University of Geoscience
India	Delhi	Tuhin Kumar Mandal	National Physical Laboratory, Delhi
India	Kanpur	S. N. Tripathi	Indian Institute of Technology, Kanpur (IITK)
India	Varanasi	Kirpa Ram	Banaras Hindu University
India	Pantnagar	Manish Naja	ARIES, Nainital
India	Nainital	Manish Naja	ARIES, Nainital
Korea	Seoul	Jhoon Kim	Yonsei University
Korea	Busan	Jae H. Kim	Pusan National University
Korea	Ulsan	Chang-Keun Song	Ulsan Institute of Science and Technology
Korea	Incheon	Joon-Young Ahn	National Institute of Environmental Research
Japan	Tokyo	Hitoshi Irie	Chiba University
Japan	Fukue Island	Yugo Kanaya	Japan Agency for Marine-Earth Science Technology
Malaysia	Kuala Lumpur	Mohd Talib Latif	Malaysian Meteorological Department
Pakistan	Islamabad	Fahim Khokhar	National University of Sciences and Technology
Philippines	Manila	James B. B. Simpas	Manila Observatory
Thailand	Chiang Mai	Ronald Macatangay	Nat'l. Astronomical Research Inst. of Thailand (NARIT)
Thailand	Bangkok	Nguyen Thi Kim Oanh	Asian Institute of Technology
Vietnam	Hanoi	Ly Bich Thuy	Hanoi University of Science and Technology
Vietnam	Ho Chi Minh City	To Thi Hien	Vietnam National University

Collaborators	
Pieternel Levelt and Pepijn Veefind, KNMI, Netherlands	TROPOMI
Kelly Chance, Harvard SAO, USA	TEMPO
Jhoon Kim, Yonsei University, South Korea	GEMS
Liangfu Chen, RADI, China	GaoFen-5
Timothy Watkins and James Szykman, US EPA	Collaborative measurements and modeling
Paul Miller, NESCAUM, USA	Collaborative measurements and modeling
Jeongsoo Kim, NIER, South Korea	Country host; broad collaboration (air/ground/model)
Alexander Cede, Luftblick, Austria	Pandonia and hemispheric Pandora observations
Randall Martin, Dalhousie University, Canada	SPARTAN (Surface PARTiculate mAtter Network)
Bojan Bojkov, EUMETSAT, Germany	EUMETSAT validation activities

We expect to engage many more collaborators if funded.

Copies of the proposal with many more details are available on request from Jim Crawford (James.H.Crawford@nasa.gov)