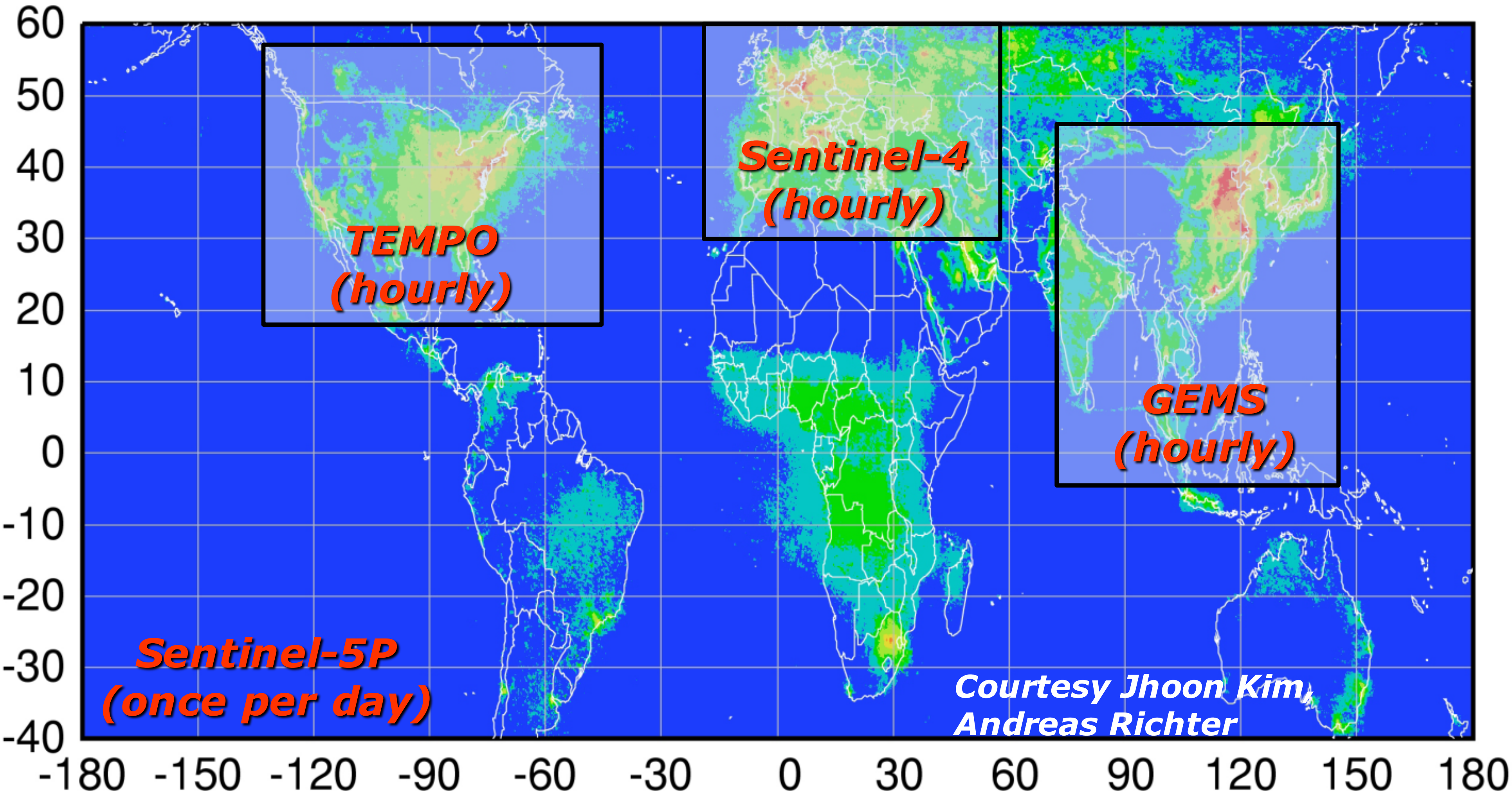
Global pollution monitoring constellation:
Tropospheric chemistry missions funded for launch 2016–2021



Policy-relevant science and environmental services enabled by common observations

- Improved emissions, at common confidence levels, over industrialized Northern Hemisphere
- Improved air quality forecasts and assimilation systems
- Improved assessment, e.g., observations to support United Nations Convention on Long Range Transboundary Air Pollution

Funded tropospheric chemistry mission parameters (as of 4/2015)

	Europe Sentinel 4	USA TEMPO	Korea GEMS	Europe Sentinel 5 Precursor TROPOMI
Orbit	Geostationary	Geostationary	Geostationary	Low-Earth
Domain	Europe and surrounding	North America	Asia-Pacific	Global
Revisit	1 hour	1 hour	1 hour	1 day
Status	Detailed Design, Phase C	Instrument CDR July 2015	Instrument CDR complete	Instrument delivery 2015
Launch	2021 (Flight Acceptance Review first instrument)	No earlier than 11/2018 No later than 11/2021	2019	Early 2016
Payload	UV-Vis-NIR 305-500, 750-775 nm	UV-Vis 290-490, 540-740 nm	UV-Vis 300-500 nm	UV-Vis-NIR-SWIR 270-500, 675-775, 2305-2385 nm
Products	O_3, trop. O_3, NO_2, SO_2, HCHO, AAI, AOD, height-resolved aerosol	O_3, trop. O_3, 0-2km O_3, NO_2, HCHO, SO_2, CHOCHO, AOD, AAI	O_3, NO_2, SO_2, HCHO, AOD	O_3, NO_2, SO_2, HCHO, AAI, AOD, height-resolved aerosol, CO, CH_4
Spatial Sampling	8 km x 8 km at 45N	≤ 2.22 km N/S x 5.15 km E/W @35N	3.5 km N/S x 8 km E/W @38N	7 km x 7 km nadir
Nominal product resolution	8.9 km N/S x 11.7 km E/W @40N	≤ 8.88 km N/S x 5.15 km E/W @35N	7 km N/S x 8 km E/W @38N (gas), 3.5 km N/S x 8 km E/W @38N (aerosol)	7 km x 7 km nadir
Notes	Two instruments in sequence on MTG-S; use TIR sounder on MTG-S (expected sensitivity to O3 and CO). Synergy with imager on MTG-I w.r.t. aerosol and clouds.	GEO-CAPE precursor or initial component of GEO-CAPE. Synergy with GOES-R/S ABI w.r.t. aerosol and clouds.	Synergy with AMI and GOCI-2 instruments w.r.t. aerosol and clouds.	In formation with S-NPP for synergy w.r.t. clouds and O_3.

Air Quality Constellation Targets:
Harmonization to improve data product quality and usage

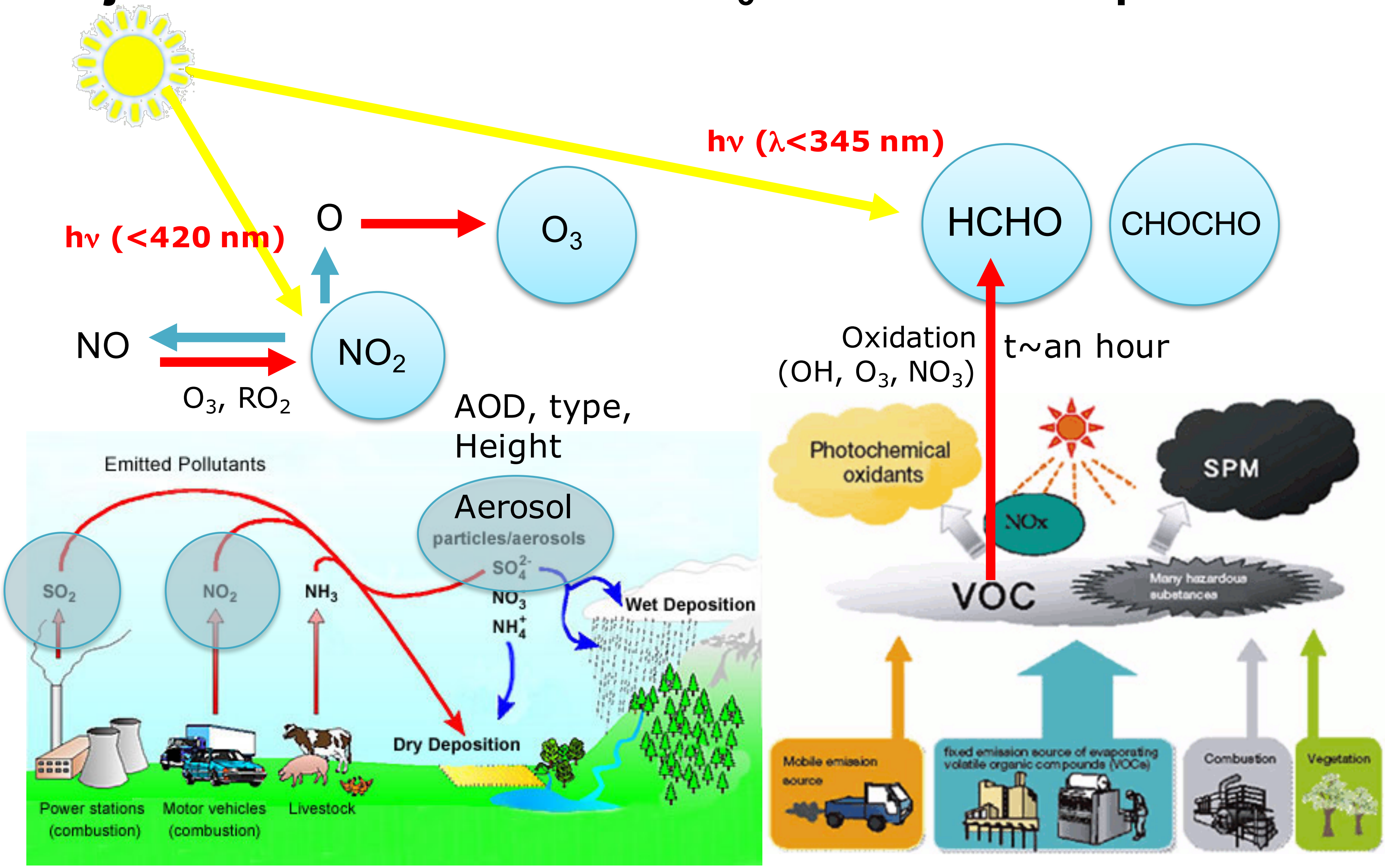
- During 2013, the CEOS* ACC+ AQ Constellation leads developed recommendations for harmonization to mutually improve data quality and facilitate widespread use of the data products
- Includes LEO and GEO: LEO observations are a common transfer standard to link the GEO observations
- Progress to date includes:
  - Sharing of instrument requirements influenced instrument specifications, which may facilitate harmonization of data products
  - Advocating open data policy (including L1B) with common formats to facilitate broad usage
  - Agreed to use NetCDF format to easily exchange data (4/2015 ACC-11)
  - Establishment of new GSICS# UV-Vis subgroup
  - AQ Constellation "Geophysical Validation Needs" document is in preparation

**CEOS = Committee on Earth Observation Satellites*
+ACC = Atmospheric Composition Constellation
#GSICS = Global Space-based Inter-Calibration System

Status of GEMS and TEMPO

- **Ball Aerospace and Technologies Corp (BATC) is building both instruments**
  - NASA selected SAO/LaRC/BATC TEMPO proposal under EV-I 1 November 2012
  - KARI selected BATC as GEMS Prime Contractor May 13th, 2013
  - The instruments have very much in common (e.g., same grating, similar detectors)
- **Instrument developments are on schedule**
  - GEMS CDR Feb. 2015, delivery to KARI from BATC spring 2017
  - TEMPO CDR June 2015, delivery to NASA May 2017
- **Mission implementations are very different**
  - GEMS is an operational mission with 10 year lifetime, scheduled for launch on GEO-KOMPSAT-2B satellite in 2019 (GK2B CDR Jan 2016)
  - TEMPO is a PI-led Earth Venture mission with launch/operation to be arranged by NASA (no earlier than 11/2018, no later than 11/2021)
- **Science teams working together very closely**
  - Science of GEMS and TEMPO is very similar
  - Working together on retrieval algorithms
- **GEMS data will be assimilated into operational air quality forecast models**
  - Air quality forecast in operation since 2013 by NIER/ME

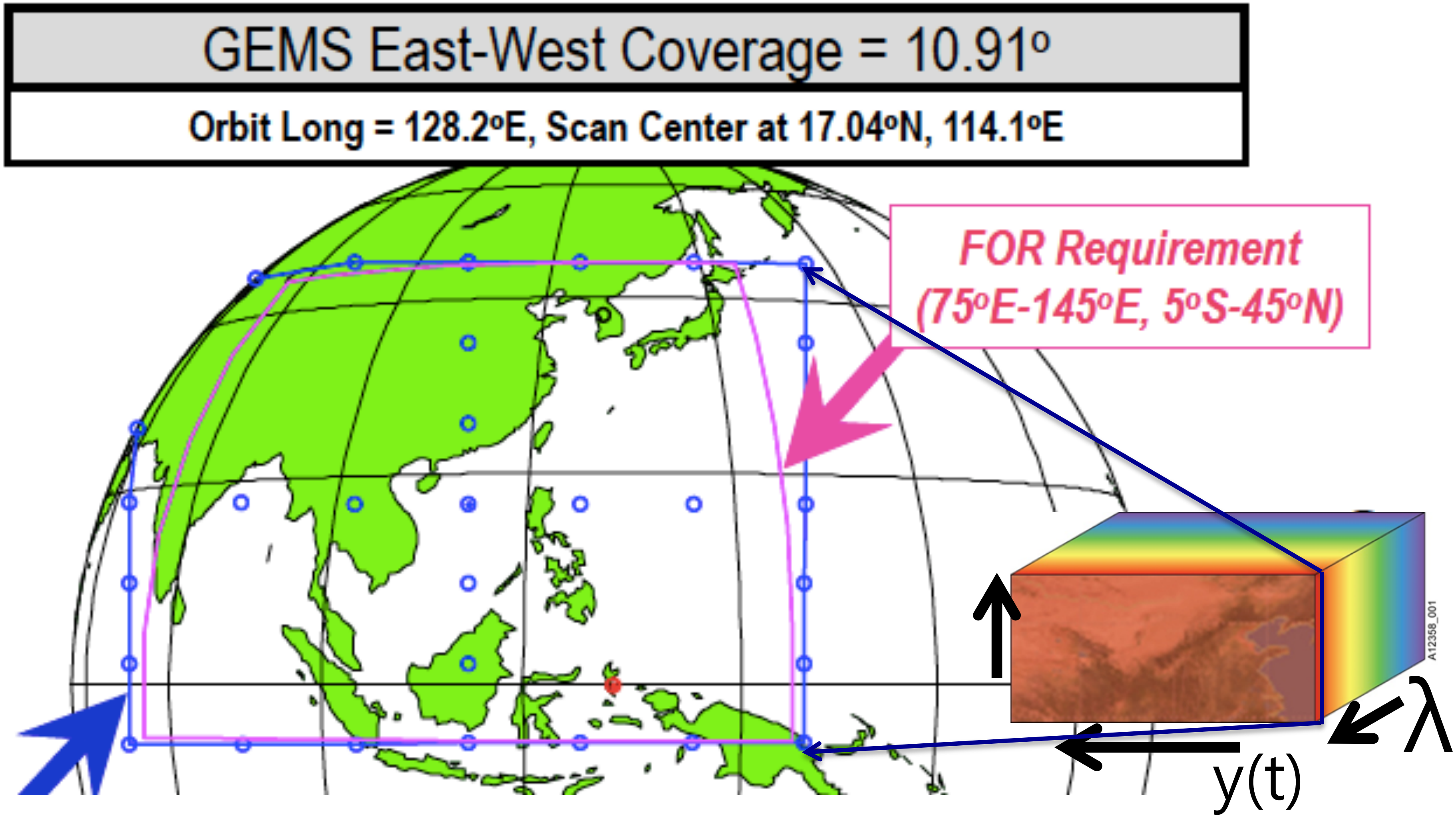
Objective: Measurements of O_3 & aerosol with precursors



Baseline products (16)

Product	Importance	Min (cm^{-2})	Max (cm^{-2})	Nominal (cm^{-2})	Accuracy	Window (nm)	Horiz Resol (km^2)@Seoul	SZA (deg)	Algorithm
NO_2	O3 precursor	3x10^{13}	1x10^{17}	1x10^{14}	1x10^{15} cm^{-2}	425-450	7 x 8 x 2 pixels	< 70	BOAS DOAS
SO_2	Aerosol precursor Volcano	6x10^{8}	1x10^{17}	6x10^{14}	1x10^{16} cm^{-2}	310-330	7 x 8 x 4 pixels x 3 hours	< 50 (60*)	
HCHO	VOC proxy	1x10^{15}	3x10^{16}	3x10^{15}	1x10^{16} cm^{-2}	327-357	7 x 8 x 4 pixels	< 50 (60*)	
CHOCHO	VOC Proxy	TBD	TBD	TBD	TBD	420-260	7 x 8 x 4 px	< 50	
TropLO3 TropUO3 StratO3 TotalO3	Oxidant Pollutant O_3 layer	4x10^{17}	2x10^{18}	1x10^{18}	3%(TOz) 5%(Stra) 20(Trop)	300-340	7 x 8	< 70	OE TOMS
AOD AI SSA AEH	Air quality Climate	0 (AOD)	5 (AOD)	0.2 (AOD)	20% or 0.1@ 400nm	300-500	3.5 x 8	< 70	Multi-λ O_2O_2 Ring
[Clouds] ECF CCP	Retrieval Climate	0 (COD)	50 (COD)	17 (COD)		300-500	7 x 8	< 70	O_2O_2 RRS
Surface Property	Environ- ment	0	1	-		300-500	3.5 x 8	< 70	Multi- λ
UVI Solar Ira	Public health	0	12	-			7 x 8	< 70	

Spatial coverage



Science Questions

- MAPS-Seoul White Paper
  1. Scientific Questions for Atmospheric Chemistry (8)
  2. Air Quality Models and Emission Perspectives (4)
  3. Satellite Application (3)

- NASA KORUS-AQ White Paper
  1. What are the challenges and opportunities for satellite observations of air quality? (4)
  2. What are the most important factors governing ozone photochemistry and aerosol evolution? (2)
  3. How do models perform and what improvements are needed to better represent atmospheric composition over Korea and its connection to the larger global atmosphere? (2)

Integrated KORUS-AQ Science Objectives (1 of 4)

With relation to science questions/objectives of MAPS-Seoul (MS) and NASA KORUS-AQ (NK) white papers

Number	Statement of Objective	White Papers Relation	Measurement Needs	Other Needs
KAQ1	Establish a 'baseline' condition that characterizes O3 and PM air quality relatively free from most local and anthropogenic activities in the SMA	MS1.1, NK2a	Systematic airborne measurements upwind of the SMA	
KAQ2	Segregate the contributions from anthropogenic and natural origins for photochemical oxidants and aerosol species, including biogenic VOC emissions in SMA	MS1.4, MS2.3, NK2a, NK2b, NK3a	Systematic airborne and surface measurements during a range of synoptic regimes, upwind of SMA and within SMA	
KAQ3	Segregate the contributions from different source regions, especially long-range transported vs. local sources: quantify East Asian O3-PM-precursors source-receptor relationships	MS1.4, MS2.2, MS3.1, NK2a, NK2b	Systematic airborne and surface measurements in all synoptic regimes; data from GOCI, OMI/TROPOMI, MODIS, CALIPSO	Models for source/precursor relation
KAQ4	Observe or determine the production and loss rates of oxidants (Ox, H2O2, RO2, HOx) along VOC/ NOX ratios at different parts of the SMA and downwind regions	MS1.2, NK2a, NK3a	Systematic airborne measurements at multiple airmass ages downwind of dominant source regions	

Integrated KORUS-AQ Science Objectives (2 of 4)

With relation to science questions/objectives of MAPS-Seoul (MS) and NASA KORUS-AQ (NK) white papers

Number	Statement of Objective	White Papers Relation	Measurement Needs	Other Needs
KAQ5	Determine the production rates of secondary aerosols during the photochemically active periods and transported events; determine which precursor species are the main drivers for high aerosol loadings	MS1.3, NK2b, NK3a	Systematic airborne and surface measurements of speciated aerosol composition, number, mass	
KAQ6	Determine how much the nighttime NO3 and Cl radicals contribute to the production of aerosol and photochemical species in consecutive daytime periods	MS1.5	Systematic nighttime surface NO3 and Cl concentration, Systematic daytime airborne measurements during stagnant meteorological conditions	
KAQ7	Determine how synoptic conditions (outflow, convection, stagnation, etc.) affect the vertical distribution of trace gases and aerosols, and the extent to which surface ozone and aerosol interact with above-surface levels	MS1.6, NK1a	Systematic vertical profile concentration measurements collocated with surface concentration measurements	
KAQ8	Determine how pollutant distributions relate to cloud cover	MS3.2, NK1b	Systematic airborne measurements in a range of clear-sky and cloudy conditions	

Integrated KORUS-AQ Science Objectives (3 of 4)

With relation to science questions/objectives of MAPS-Seoul (MS) and NASA KORUS-AQ (NK) white papers

Number	Statement of Objective	White Papers Relation	Measurement Needs	Other Needs
KAQ9	Determine the effects of heterogeneous chemistries on aerosol and oxidant productions in the SMA	MS1.7, NK2b, NK3a		
KAQ10	Determine the relationship between aerosol properties and their radiative forcing	MS1.8	Systematic airborne and ground measurements of aerosol physical and radiative properties	
KAQ11	Develop the best-available domestic and foreign anthropogenic emission inventories of O3 and PM precursors and improve them using the field campaign measurements and adjoint inverse modeling.	MS2.1, NK3a, NK3b	Systematic airborne and satellite measurements in all synoptic regimes	Pre-campaign compilation of emission inventories, post-campaign model inversions
KAQ12	Quantitatively evaluate air quality model processes, including analysis of PM10 and PM2.5 mass closure and diagnosis of the most important contributors to systematic model PM underprediction.	MS2.2, NK3a, NK3b	Systematic airborne and surface aerosol measurements in all synoptic regimes	Air quality model forecasts and analyses

Integrated KORUS-AQ Science Objectives (4 of 4)

With relation to science questions/objectives of MAPS-Seoul (MS) and NASA KORUS-AQ (NK) white papers

Number	Statement of Objective	White Papers Relation	Measurement Needs	Other Needs
KAQ13	Assess the impact of the marine boundary layer on O3 and PM.	MS2.4, NK1a, NK2a, NK3a	Vertical profiles of measured air pollutants and meteorological parameters in and around Korea, particularly over ocean	
KAQ14	Test GEMS retrieval algorithms under development, including impacts of vertical distribution of trace gases and aerosols on retrieval accuracy and quantification of the effect of clouds on the retrieval of trace gas concentrations	MS3.2, NK1a	Level-1b data of OMI (and/or TROPOMI and/or GeoTASO), vertical distribution of trace gases and aerosols, cloud identification	Radiative transfer and retrieval calculations
KAQ15	Validate the trace gas products of OMI and OMPS (and/or TROPOMI) and understand the effect of aerosol properties on the retrieval accuracy of NO2	MS3.3, NK1c	Column and vertical profile trace gas and aerosol observations from ground-based and airborne platforms at times and locations of satellite observations, cloud identification	Radiative transfer and retrieval calculations
KAQ16	Validate the aerosol products of GOCI, MODIS, OMI and other relevant satellites and understand how the land/water boundary influences aerosol retrievals	MS3.3, NK1d	Column and vertical profile aerosol observations from ground-based and airborne platforms at times and locations of satellite observations, cloud identification	Radiative transfer and retrieval calculations

Backup