KORUS-AQ Assets

These slides outline the major Korean and US assets available for May – June 2016 Field Campaign focused on the Korean Peninsula and surrounding waters.

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Overview of KORUS-AQ Assets

Aircraft
- NASA DC-8
- NASA King Air
- Hanseo Univ. King Air
- KMA King Air

Ship
- KMA R/V Kisang I
- KIOST R/V Onnuri

Ground
- MoE National Network
- Research Sites (Univ., NIER, KMA)
- CIMEL/Pandora

Model Forecast Support

Satellite Observations

NASA Contributions to KORUS-AQ: An International Cooperative Air Quality Field Study in Korea

US Steering Group: Jassim Al-Saadi, Gregory Carmichael, James Crawford, Louisa Emmons, and Saewung Kim

Korean Steering Group: Chang-Keun Song, Lim-Seok Chang, Gangwoong Lee, Jhoon Kim, and Rokjin Park

NASA KORUS-AQ Panel Review 13-15 July 2015 (Washington, DC)

Funding will be applied primarily to instrument the DC-8 Aircraft with limited funds for additional ground measurements and modeling support.

DC-8 Priorities for measurements outlined in the whitepaper.

- Priority 1 – Mission essential
- Priority 2 – Highly desirable
- Priority 3 – Useful

DC-8 Trace Gas Priority List

Gas Phase In Situ	Priority	Detection Limit	Resolution
O3	1	1 ppbv	1 s
H2O	1	10 ppmv	1 s
CO	1	5 ppbv	1 s
CH4	1	10 ppbv	1 s
CO2	1	0.1 ppm	1 s
NMHCs	1	<10%	1 min
NO	1	10 pptv	1 s
NO2	1	20 pptv	1 s
HCHO	1	50 pptv	1 s
OH, HO2, RO2	2	0.01/0.1/0.1 pptv	30 s
OH reactivity	2	1 s^{-1}	10 s
H2O2	2	50 pptv	10 s
ROOH	2	50 pptv	10 s
HNO3	2	50 pptv	10 s
PANs	2	50 pptv	10 s
RONO2	2	50 pptv	10 s
SO2	2	10 pptv	1 s
CH3CN	2	10 pptv	1 min
NOy	3	50 pptv	1 s
Halocarbons	3	variable	1 min
HCN	3	10 pptv	1 min
NH3	3	30 pptv	1 min
N2O	3	1 ppbv	10 s
Organic Acids	3	10 pptv	1 min

DC-8 Aerosol Priority List

Aerosol In Situ	Priority	Detection Limit	Resolution
Size Distribution/Number	1	NA	10 s
Volatility	1	NA	1 s
Scattering	1	1 Mm-1	1 s
Absorption	1	0.2 Mm-1	10 s
Hygroscopicity	1	NA	10 s
Ionic composition	1	50 ng m^{-3}	5 min
Organic composition	1	100 ng m^{-3}	1 min
Black carbon	1	50 ng m^{-3}	1 s
Size-resolved composition	2	100 ng m^{-3}	1 min
Single particle composition	2	<4 µm dia.	5 min
CCN	2	<4 µm dia.	1 s
Cloud particle size dist.	2	0.05-1000 µm	1 s
Radionuclides (^{222}Rn, ^{7}Be, ^{210}Pb)	3	1/100/1 fCi m^{-3}	5 min

DC-8 Remote Sensing, Radiation, Meteorology Priority List

Remote Sensing, Radiation, and Met	Priority	Detection Limit	Resolution
UV spectral actinic flux (4π sr)	1	80° SZA equivalent	5 s
Ozone lidar (nadir/zenith)	1	5 ppbv or 10%	300 m
Trace Gas Columns (O_3, NO_2, C_2HO)	1	variable	variable
Multi-spectral optical depth	1	0.01	1 s
Aerosol profiles of extinction	1	10 Mm^{-1} or 10%	300 m
Aerosol profiles of backscatter	1	3%	30 m
Aerosol profiles of depolarization	1	3%	30 m
High Resolution Met (T, P, winds)	2	0.3K, 0.3 mb, 1 ms^{-1}	1 s
Hyperspectral solar flux	3	4%	1 s
Broadband flux	3	5%	1 s

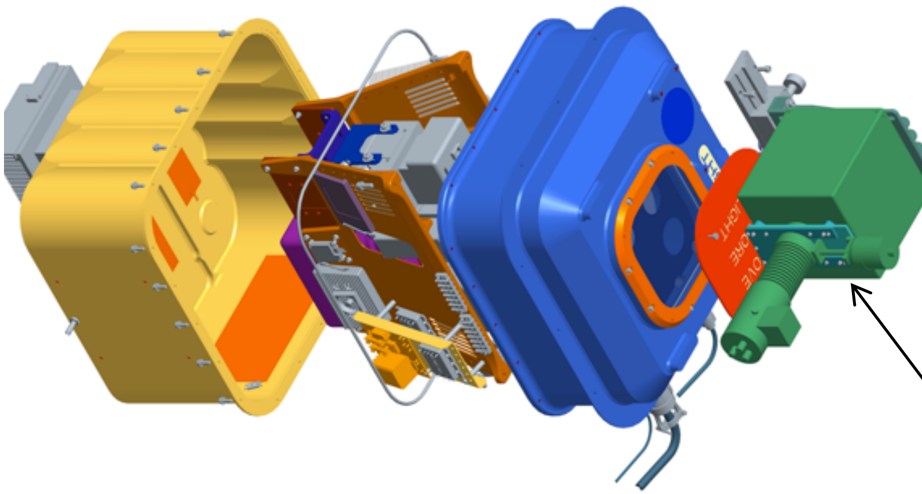
Korean Contributions to DC-8 Payload

- SP-2
- CIMS - Reactive Nitrogen, ClNO2, etc.
- AMS (HIAPER rack)
- CCN
- PTR-MS
- CEAS (HONO, CH2O, NO2)

- NO3 and N2O5 would be more effective from the ship?

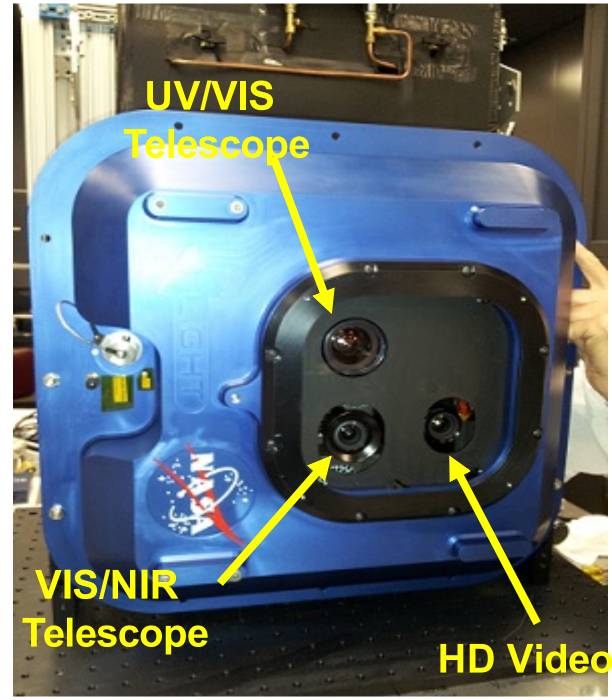
Overview of GCAS (GEO-CAPE Airborne Simulator)

Exploded view



Field Radiometric Calibration Fixture

Telescopes map vertical slit extent to a 7.5 km cross-track FOV. Images captured at 2 Hz and co-added along track.



Spectral coverage and sampling

- **300-490 nm @0.2 nm/pixel**
- **480-890 nm @0.4 nm/pixel**

Slant column product precision for NO_2

- Minimum retrieved resolution 250 m x 500 m: 1.5e15 molecules cm^{-2}
- Typical retrieved resolution 1 km x 1.5 km: 0.4e14 molecules cm-2

Retrievals for total O3 and HCHO have also been demonstrated

Overview of GeoTASO (TEMPO/GEMS Airborne Simulator)

Geostationary Trace gas and Aerosol Sensor Optimization

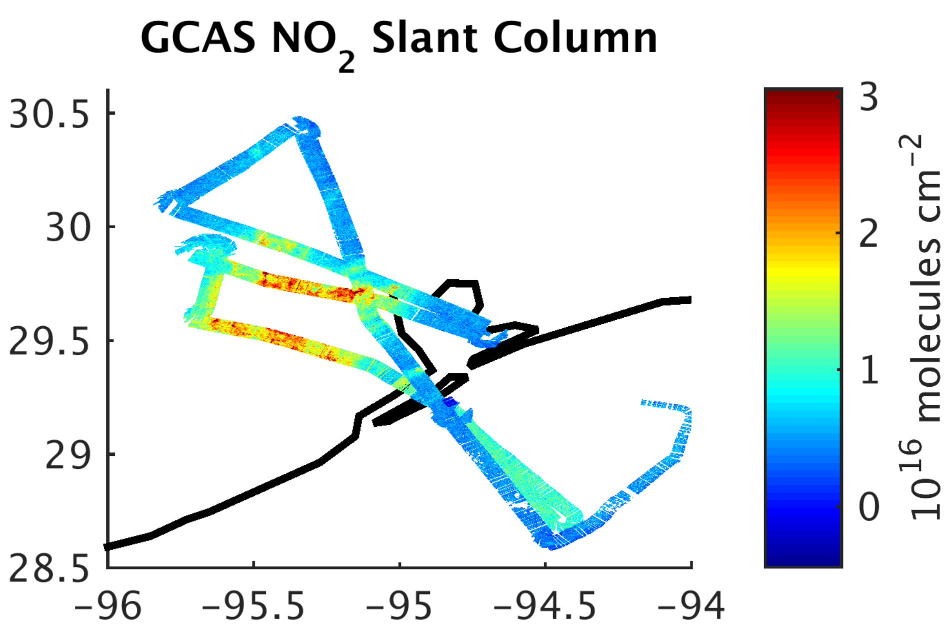
- NASA-funded airborne sensor and trace gas/aerosol retrieval project to advance mission readiness of sensor/algorithms for GEO-CAPE/TEMPO missions
  - UV-Vis spectrometer with 2 2-D detector arrays covering 290-390 nm (O_3, SO_2, HCHO) and 415-695 nm (NO_2, O_3, aerosol)
    - Imaging spectrometer covers ~8 km swath with 50 m x 80 m ground patch resolution
    - Spectral passbands of ~ 0.4 nm in UV, ~0.8 nm in Vis with 3x oversampling spectrally
    - Signal to noise of ~ 50 for individual samples
  - Project status
    - Sensor built and demonstrated on HU-25C Falcon aircraft during 2 DISCOVER-AQ deployments
    - Retrievals using flight data underway
    - Sensor calibration at GSFC before and after deployments

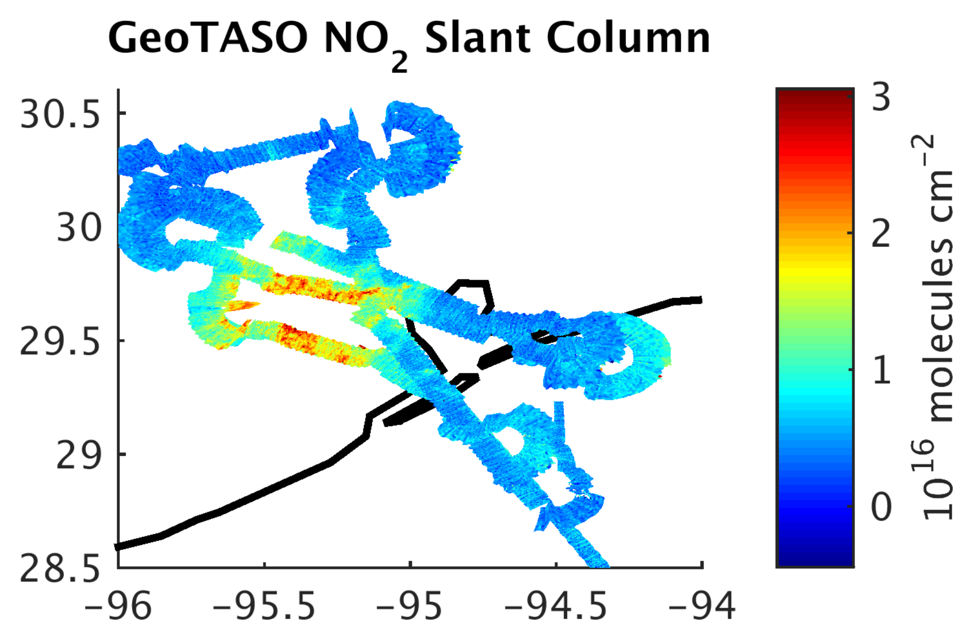
- DISCOVER-AQ flights
  - 20 flight hours during Sep. 2013 Houston deployment
  - 50 flight hours during July-Aug 2014 Denver deployment
  - Most flights at ~35 kft altitude and overfly DISCOVER-AQ sites
  - Retrievals of atmospheric pollutants from flight data
    - Trace gas retrievals typically use binned up samples at 0.5 to 1 km square cells
    - NO2, SO2, AOD and total O3 retrievals demonstrated
    - CHCO, profile O3, CHOCHO retrieval products in development
    - Ozone retrieval using both UV and Vis absorption bands in development

GeoTASO NO_2 on Falcon (500x500 m^2) and GCAS NO_2 on B-200 (250x500 m^2)

Caroline Nowlan, SAO

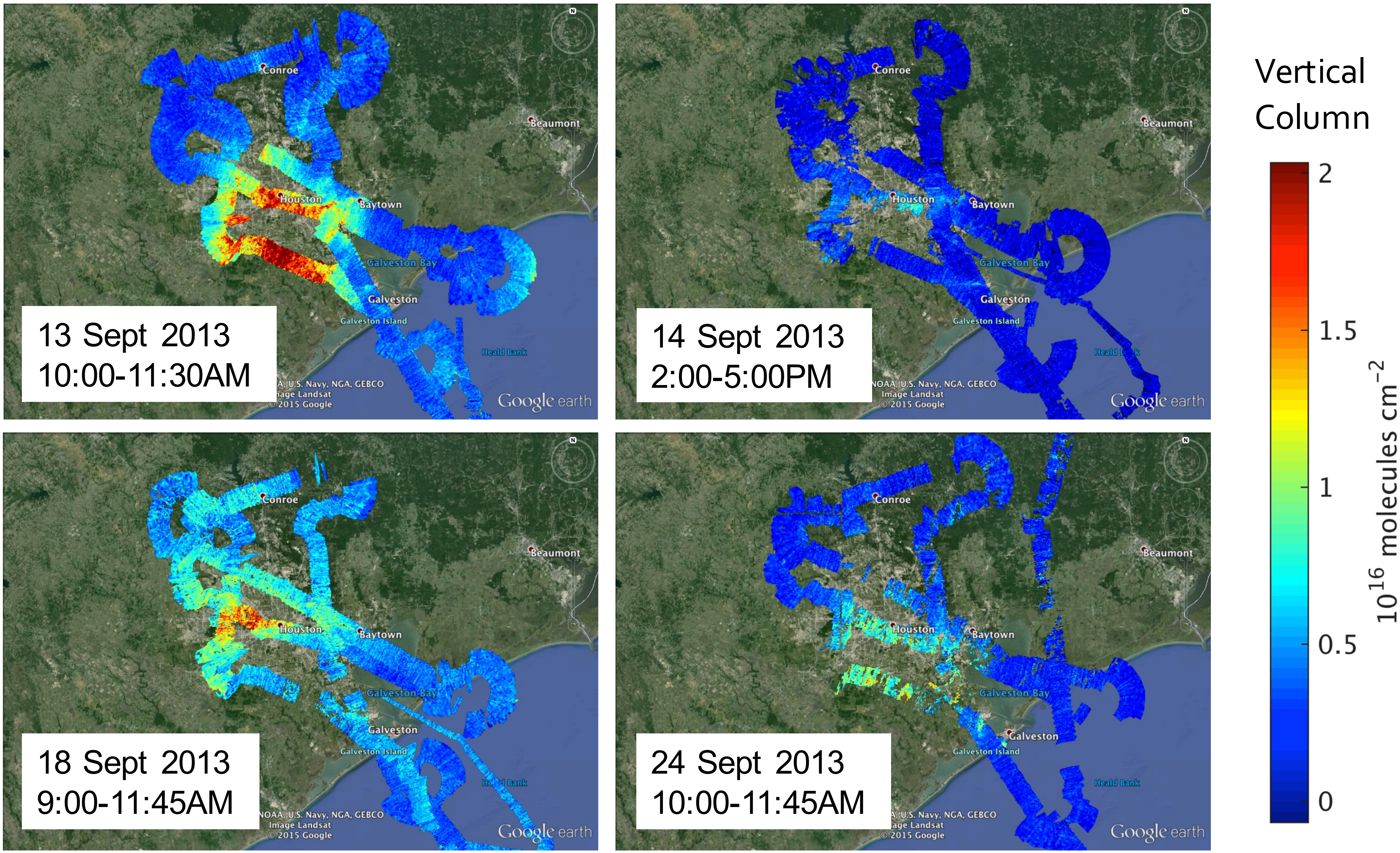
- Close flights in Houston, TX, on 13 September 2013 show very similar NO_2
- Both analyzed with GeoTASO algorithm





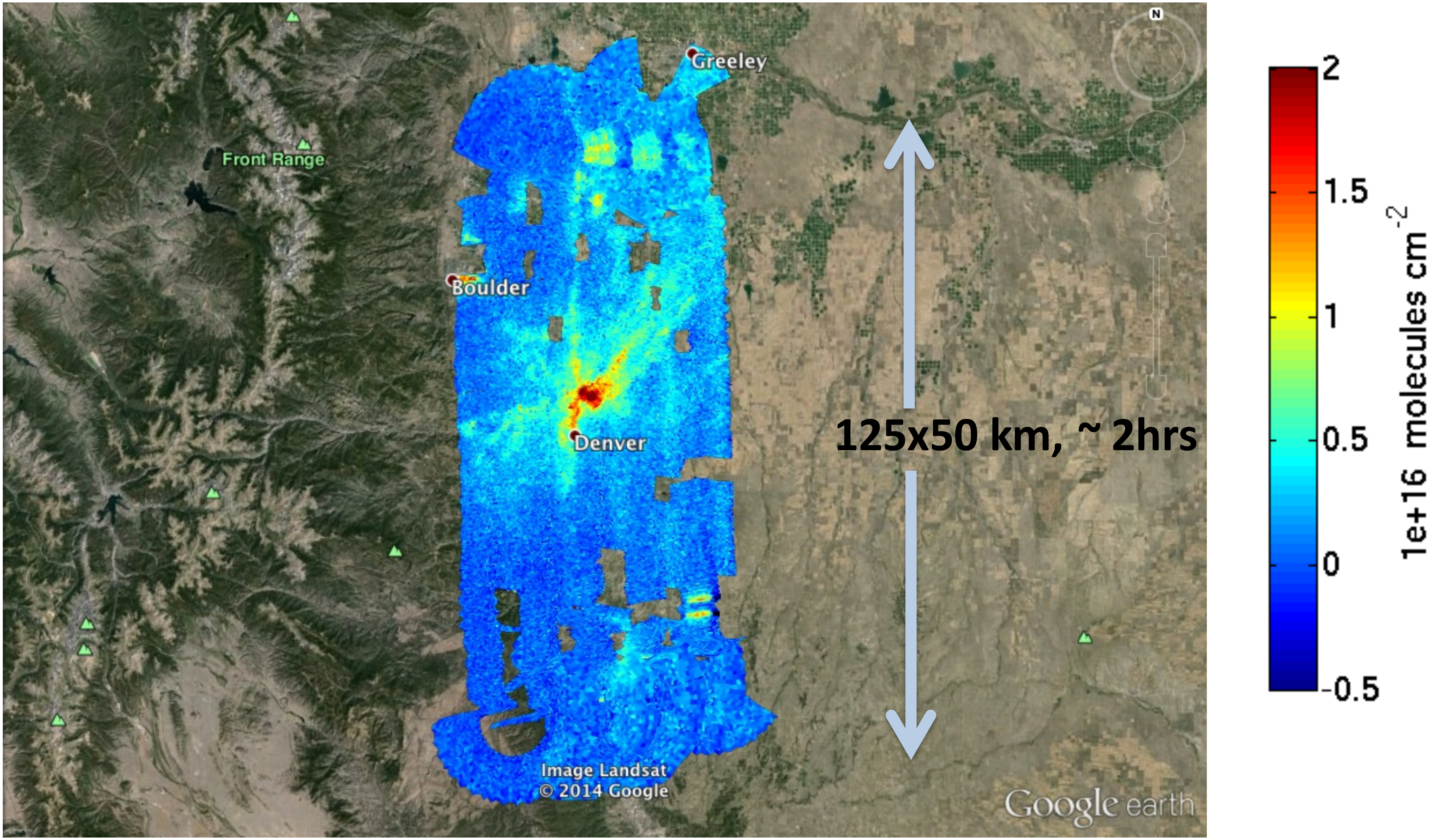
GeoTASO NO_2 over Houston (Cloud-free ground pixels)

Caroline Nowlan, SAO



GeoTASO NO_2 Slant Column, 02 August 2014

Morning



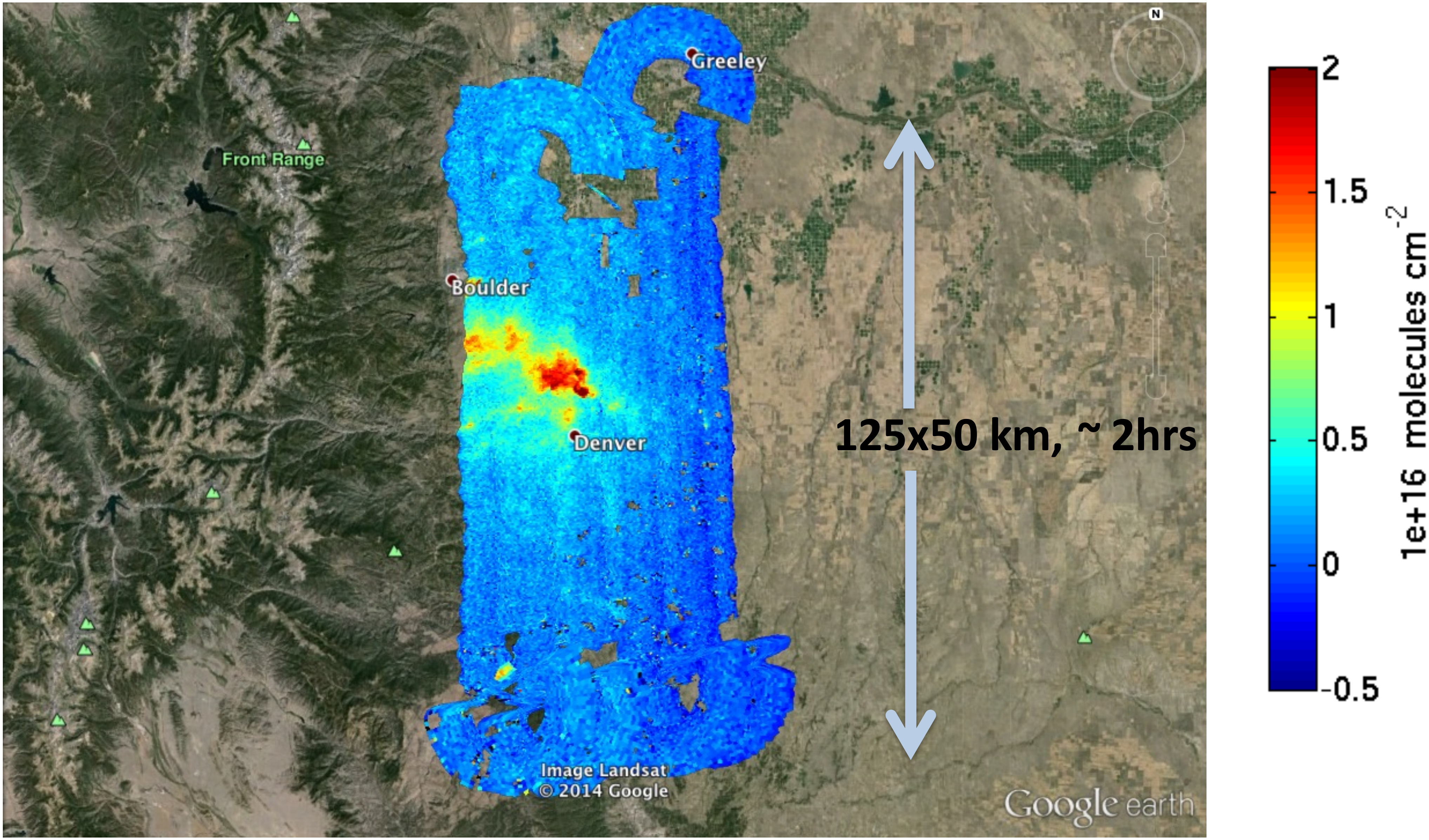
Co-added to approx. 500m x 450m

Morning vs. Afternoon

From Caroline Nowlan, SAO
Preliminary data

GeoTASO NO_2 Slant Column, 02 August 2014

Afternoon



Co-added to approx. 500m x 450m

Morning vs. Afternoon

From Caroline Nowlan, SAO
Preliminary data

TEMPO/GEMS Airborne Simulator Options for KORUS-AQ

- **GeoTASO instrument is available**
- **GCAS instrument is occupied with another field campaign**
- **GeoTASO can operate from either King Air or Falcon aircraft**
- **Logistically, King-Air is the preferred aircraft**
    - Less complex
    - 70% less expensive
    - Operating envelope can meet KORUS-AQ objectives
- **Recommendation: proceed with planning for GeoTASO operation on a NASA King Air aircraft**
- ***UV Calibration for Geo-TASO is an open question…should be possible in time for the KORUS-AQ campaign***
- ***This platform will allow remote sensing measurements to be independent of the DC-8, not affected by changes in altitude that the DC-8 would create.***
- ***Would it help to fly along a satellite track? Need to examine opportunities in terms of overpass, meteorology, and airspace restrictions.***

Information for NASA King Air Flight Planning in KORUS-AQ

- **King Air typical flight characteristics**
  - 28,000 ft optimum cruise (approximately 8.5 km)
    => 7 km swath width with GeoTASO/GCAS mapping instruments
  - Typical flight speed 100m/s = 6km/min = 60km/10min = 360km/hr
    - 1 flight can cover 800 nautical miles = 1400km
    - For comparison: DC-8 typical flight speed 180m/s
  - Up to 4.5 hr flight duration (approximately 4 hr science operations)

- **For 2-D gapless mapping, assume:**
  - Lateral track spacing of 5km (9-10 parallel lines per 50km wide box)
  - 100km length per 20 min (including turn times)
    => 3 hr flight can map a 100km x 50km box

- **Budgeting for 120 local flight hours => approximately 30 flights**

- **Can do 2 4-hour flights in the same day**

King Air vs Falcon differences

Altitude and influence on swath width

- tan(22.5)=halfwidth/alt; width=2*tan(22.5)*alt = .83*alt
- King Air: 28000ft approx 8.5 km => 7 km swath width
- Falcon: 35000ft approx 10.7 km => 8.9 km swath width

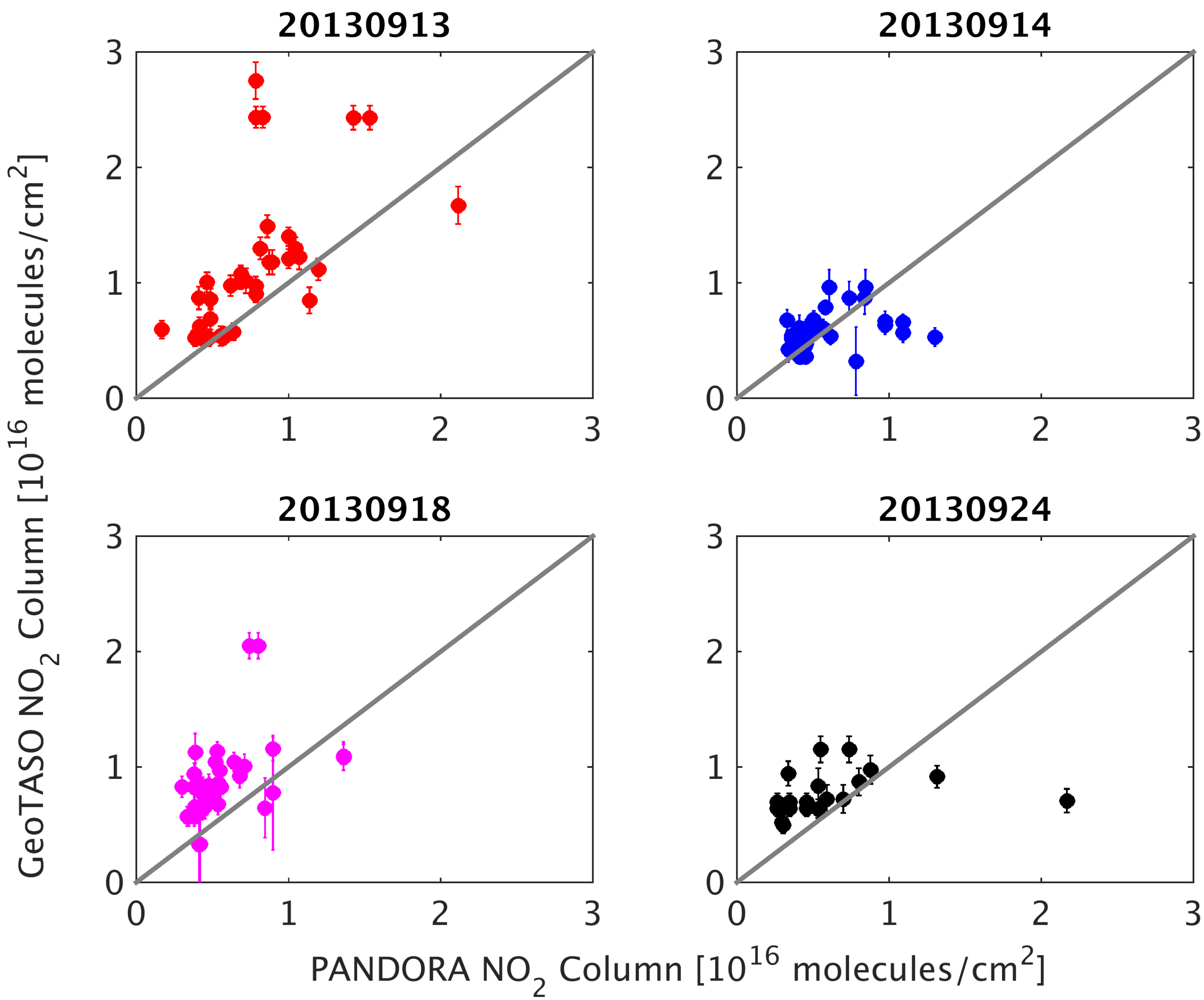
Falcon can fly approx. 50% faster but also burns fuel 3x faster

Falcon total operating cost is 50% larger than King Air

King Air is more reliable, easier access to spares

GeoTASO NO_2 vs PANDORA NO_2 Houston Urban Flights

Caroline Nowlan, SAO



- Cloud-free observations

Small bias, possible causes to be investigated:

- Aerosols not currently included in radiative transfer model for air mass factor calculation
- Effects from zenith sky observations or background offset removal using clean observations over water

GeoTASO Measurements

- Measures with 2 detector arrays
  - UV: 280 – 410 nm (**O_3, HCHO, SO_2**)
  - Visible: 416 – 690 nm (**NO_2, O_3, aerosols**)
- 2-D CCD array detector
  - One dimension across flight track and one in wavelength dimension
- Resolution at surface:
  - ~500x500 m^2 (NO_2, HCHO, O_3)
  - ~1x1 km^2 (SO_2)
- We retrieve slant columns using nearby zenith-sky reference spectra, then convert to vertical columns with air mass factor from a radiative transfer code (VLIDORT, Spurr et al., 2006) using CMAQ at 4x4 km^2 resolution

Hanseo Univ. King Air

The actual payload is not yet determined.

If AMS goes on the DC-8, other instruments would go on the King Air.

Ozone -important
PM2.5 (chemical composition) – moved to DC-8
VOCs Speciation – canisters might be possible, but are bulky, other options from U.S. researchers?
NO2 – CAPS – useful for validation, chemistry, emissions, etc.
CO
SO_2
Meteorology (?)

Small formaldehyde from NASA might be possible

KMA King Air

CCN
Cloud droplet distribution
SP2
OPC
O3
NO,NOx,NOy
SO2
CH4
CO
CO2
N2O
H2O, LWC, Total water
Dropsonde
Nephelometer
AIMMS 20 (Winds)
Microwave radiometers (SFMR, GVR)
T, Dew Point, winds

Flight duration up to 6 hours
Shorter flight if reaching higher altitudes (20 kft)
Number of flight hours TBD)

KMA R/V Kisang I

Ozone
PM2.5 (mass and chemical composition) - PILS
Aerosol number and size distribution
NO/NOx/NOy
PAN
HONO
C14 content of PM2.5
Viscosity
CO
SO_2
BVOCs and OH Reactivity (PTRMS)
Aerosol Scattering and Absorption
Meteorology – AWS and radiosonde

Dates and Areas of Operations?

Can MBL structure be measured? Twice a day radiosonde launches provide this.

Can NASA add Pandora and Aeronet instruments? Need to discuss how well those instruments can be stabilized for the ship motions.

KIOST R/V Onnuri

Pandora (NO_2 and O_3 Column)
MicroTOPs
Insitu Trace Gases (e.g., NO_2, O_3, etc)
Aerosol Composition
Aerosol Size Distribution
Aerosol Optical Properties

Areas of Operations?

Research Sites (Univ., NIER, KMA)

Pre-campaign Sites:

- Baengnyeong Island
- Yonsei University
- HUFS
- GIST
- Anmyeon
- Busan University

Other Operational Sites:

- LIDAR Network
- MoE National Network

CIMEL/Pandora

Initial Deployment to Pre-Campaign sites

Do we need to expand this for KORUS-AQ?

Model Forecast Support

NIER National Air Quality Forecast System

Need for Regional vs. Global Models

Satellite Observations

Near real-time availability for which satellites?

What else?