Agenda

Ministry of Environment
National Institute of Environmental Research

<u>Science Team Telecon</u>

AOGS 2018

Second KORUS-AQ Science Team Meeting

KORUS-AQ publications

Science Presentations

- Dejian Fu
- Younha Kim

March Contest Question

KORUS-AQ

Ministry of Environment
National Institute of Environmental Research

NASA

Session AS40: Results from the 2016 KORUS-AQ and Related Field Studies in Asia

Oral/Poster assignments have been completed, but the program has not yet been announced on the website.

Oral Session 1

AS40-A028	Factors Influencing Ozone Variability in Major Cities in Korea	Limseok Chang (*National Institute of Environmental Research, Korea)*
AS40-A013	Observation-based Modelling and Analysis of Ozone Production in the Seoul Metropolitan Area During KORUS-AQ	Jason Schroeder (*NASA)*
AS40-A007	Evaluation of Simulated VOCs During the KORUS-AQ Campaign and Their Effect on Ozone Production in Korea	Yujin Ok (*Seoul National University)*
AS40-A024	Urban and Industrial VOC Signatures in the Seoul Region during KORUS-AQ	Isobel Simpson (*University of California, Irvine)*
AS40-A017	Airborne Glyoxal Measurements and Its Contribution to Secondary Organic Aerosol Foramtion Over the Korea Pennisula	Kyung-Eun Min (*Gwangju Institute of Science and Technology)*
AS40-A021	Contribution of Local Emissions of Aromatic Compounds to Secondary Organic Aerosol Formation Over the Korean Peninsula	Christoph Knote (*Ludwig-Maximilians-Universität München)*
AS40-A008	Air Chemistry Modeling Issues That We Have Learned from the KORUS-AQ Campaign	Prof. Rokjin J. Park (*Seoul National University)*

Oral Session 2

AS40-A020	Evaluation of the Large Point Source Emissions in the KORUS-AQ Version 2.0 Emissions Inventory	Jung-Hun Woo (*Konkuk University*
AS40-A004	CO Source Contributions and Combustion Characteristics During KORUS-AQ	Wenfu Tang (*University of Arizona)*
AS40-A019	Integrated Assessment of Air Quality Improvement Plan for Korea and China	Younha Kim (*Konkuk University)*
AS40-A018	Analyzing Ozone Production Sensitiveness in South Korea Using Air-monitoring Network Measurements from 2001 to 2016	SuKyong Yun (*Gwangju Institute of Science and Technology)*
AS40-A022	Long-range Transport and Vertical Structure of Air Pollutants During the 2016 KORUS-AQ Field Study : Meteorological Controls on Transport Pathway and Air Quality in Downwind Regions	Hyo-Jung Lee (*Pusan National University)*
AS40-A001	Production and Loss of Sulfate on the Sea Surface During Its Transport from Eastern China to South Korea	Wonbae Jeon (*Pusan National University)*
AS40-A010	Chemistry of New Particle Growth During Spring Time in the Seoul Metropolitan Area, Korea	Hwajin Kim (*KIST)*
AS40-A027	Tropospheric Ozone Profile Maps from the Synergic Observation of AIRS and OMI: Updates on Validation and Science Application for KORUS-AQ	Dejian Fu (*Jet Propulsion Laboratory, California Institute of Technology)*

Poster Session

AS40-A002	Characterization of the NO2 Artifact Associated with the Chemiluminescence Technique Equipped with Molybdenum Converter During KORUS-AQ Campaign	Jinsang Jung, (*Korea Research Institute of Standards and Science)*
AS40-A005	Assessing How Aerosols Effect OMI NO2 Retrievals During KORUS-AQ	Michal Segal Rozenhaimer (*Bay Area Environmental Research Institute/NASA Ames Research Center)*
AS40-A006	Introduction of Stray Light Correction Algorithm with the Characterization of Point Spread Functions for Better Improvement of GeoTASO Measurements	Mina Kang (*Ewha Womans University)*
AS40-A009	Effect of Nitryl Chloride Chemistry on Oxidation Capacity in East Asia	Hyeonmin Kim (*Seoul National University)*
AS40-A011	Investigating the Contributions of Trans-boundary Transport and Local Emissions to Air Quality in South Korea During KORUS-AQ	Seoyoung Lee (*Yonsei University)*
AS40-A012	Surface NO2 Volume Mixing Ratio Estimated from Total Column Observations of Pandora Spectrometer during KORUS-AQ	Heesung Chong (*Yonsei University)*
AS40-A023	Evaluation of a multi-constituent chemical reanalysis during KORUS-AQ: role of dynamics and emissions	Kazuyuki Miyazaki (*Japan Agency for Marine-Earth Science and Technology)*
AS40-A016	Developing a Procedure for Estimating Aerosol Number Density Trend Based on Routine Measurements of Meteorological Parameters in Seoul, Korea from 1980 to 2017	Youngwoo Ji (*Gwangju Institute of Science and Technology)*

Second KORUS-AQ Science Team Meeting

27-31 August 2018 (Save the dates on your calendar)

The Beckman Center at UC-Irvine:
www.thebeckmancenter.org

Similar to the discussion at the first meeting, we will need to assess progress and establish important findings for the Final Science Synthesis Report to the Korean Ministry of the Environment scheduled for release in early 2019.

Publications

Going forward, here are a few requirements that will help us to keep track of science team progress and ensure consistency among the published findings:

1) Anyone in the draft stage of manuscript writing should email their title and full author list to Jim Crawford. We will keep the list updated and shared at each monthly webex.
2) Authors are highly encouraged to present a summary of their analysis and findings during a monthly webex before submitting the paper.
3) Authors should also identify the target journal for their paper. We have not yet decided on whether a special issue will be commissioned, but this information may help us to decide whether to have a special issue or allow our papers to span many journals.
4) Double check to be sure that the most recent data is being used in your analysis (e.g., LARGE-APS size distribution data for DC-8 was updated today).
5) KORUS-AQ data doi's will become available in the near future. Please these doi's to reference the data used in your paper.
6) Intercomparison analyses of measurements are underway and will be presented in a future webex. If you are using variables measured by multiple groups, please be aware of and prepare to cite intercomparison results.

Publications (1)

Authors	Title	Journal	Status
Hwajin Kim, Qi Zhang, Jongbae Heo	Influence of Intense secondary aerosol formation and long range transport on aerosol chemistry and properties in the Seoul Metropolitan Area during spring time: Results from KORUS-AQ	Atmospheric Chemistry and Physics	Under Review
Najin Kim, Minsu Park, Seong Soo Yum, Jong Sung Park, Hye Jung Shin, Joon Young Ahn	Impact of urban aerosol properties on cloud condensation nuclei (CCN) activity during the KORUS-AQ field campaign	Atmospheric Environment	Under Review
W. Hu, D.A. Day, P. Campuzano-Jost, B.A. Nault, T. Park, T. Lee, P. Croteau, M.R. Canagaratna, J.T. Jayne, D.R. Worsnop, J.L. Jimenez	Evaluation of the new capture vaporizer for Aerosol Mass Spectrometers (AMS): Elemental composition and source apportionment of organic aerosols (OA).	ACS Earth Space Chemistry	Under Review
W. Hu, D.A. Day, P. Campuzano-Jost, B.A. Nault, T. Park, T. Lee, P. Croteau, M.R. Canagaratna, J.T. Jayne, D.R. Worsnop, J.L. Jimenez	Evaluation of the new capture vaporizer for Aerosol Mass Spectrometers: characterization of organic aerosol mass spectra	Aerosol Science and Technology	Under Review
Wenfu Tang, A. F. Arellano, J. P. DiGangi, Yonghoon Choi, G. S. Diskin, A. Agustí-Panareda, M. Parrington, S. Massart, B. Gaubert, Youngjae Lee, Dan-bee Kim, Jinsang Jung, Hong Jinkyu, Yugo Kanaya, Mindo Lee, A. M. Thompson, J. H. Flynn, and Jung-Hun Woo	Evaluating High-Resolution Forecasts of Atmospheric CO and CO2 from a Global Prediction System during KORUS-AQ Field Campaign	Atmospheric Chemistry and Physics	In prep
Wenfu Tang, L. K. Emmons, A. F. Arellano Jr., B. Gaubert, C. Knote, S. Tilmes, R. R. Buchholz, G. G. Pfister, D. R. Blake, N. J. Blake, J. P. DiGangi, Yonghoon Choi, G. S. Diskin, Jung-Hun Woo	Source Contribution to Carbon Monoxide during KORUS-AQ Using CAM-chem Tagged Tracers	Atmospheric Chemistry and Physics	In prep

Publications (2)

Authors	Title	Journal	Status
Eric Heim, et al.	Asian Dust Observed during KORUS-AQ Facilitates the Uptake and Incorporation of Soluble Pollutants during Transport to S. Korea; The Hwangsa Anthropogenic Model	TBD	In prep
Dan Goldberg, et al.	A high-resolution OMI NO2 product for Korea during KORUS-AQ and using it to derive NOx emissions in Seoul	TBD	In prep
Myungie Choi et al.	Assessment of aerosol optical properties from GOCI, MODIS, VIIRS, and MISR measurements over East Asia during 2016 KORUS-AQ campaign	TBD	In prep
Myungje Choi, Seoyoung Lee, et al.	Assessment of 3-D aerosol distribution for long-range transport and local emission using GOCI and ground, airborne, and satellite lidar measurement during 2016 KORUS-AQ	TBD	In prep
Heesung Chong, Seoyoung Lee, et al.	PCA-based trace gas retrievals from GeoTASO airborne measurements during KORUS-AQ	TBD	In prep
Heesung Chong, et al.	Surface NO2 volume mixing ratio estimated from total column observations of Pandora spectrometer during KORUS-AQ	TBD	In prep
Seoyoung Lee, Ja-Ho Koo, et al.	Regional transport effect to explain the aerosol concentration and variation in the Korean peninsula	TBD	In prep
Sujung Go, et al.	Imaginary part of refractive index derived from UV-MFRSR in Seoul, and implications for retrieving UV Aerosol Optical Properties for GEMS measurements	TBD	In prep
Hyungkwan Lim, et al.	Aerosol loading height retrieval from AHI using spatiotemporal variability during KORUS AQ	TBD	In prep

Publications (3)

Authors	Title	Journal	Status
Hyungkwan Lim, et al.	Intercomparison of aerosol optical depth data using AHI, GOCI and MI from Yonsei AErosol Retrieval (YAER) algorithm	TBD	In prep
Yeseul Cho, Ja-Ho Koo, et al.	Spatiotemporal properties of O3 and NO2 in the Seoul Metropolitan Area: comparison among total column, vertical profile, and surface patterns	TBD	In prep
Sang Seo Park, et al.	Temporal variation of total ozone without its variations at surface and stratosphere	TBD	In prep
Paul Romer, Ron Cohen, et al.	Constraints on aerosol nitrate photolysis as a potential source of HONO and NOx	TBD	In prep
W. Hu, P. Campuzano-Jost, D. A. Day, B. A. Nault, T. Park, T. Lee, A. Pajunoja, A. Virtanen, P. Croteau, M. R. Canagaratna, J. T. Jayne, D. R. Worsnop, J. L. Jimenez	Size distributions and ambient quantifications for organic aerosol (OA) in aerosol mass spectrometer (AMS) instruments with the new capture vaporizer (CV)	Journal of Aerosol Science	In prep
B. A. Nault, P. Campuzano-Jost, D. A. Day, J. C. Schroder, B. Anderson, A. Beyersdorf, D. R. Blake, W. H. Brune, J. D. Crounse, R. C. Cohen, Y. Choi, C. Corr, J. A. de Gouw, J. Dibb, J. P. DiGangi, G. Diskin, A. Fried, L. G. Huey, M. J. Kim, C. J. Knote, K. D. Lamb, T. Lee, D. D. Montzka, T. Park, A. E. Perring, S. E. Pusede, P. S. Romer, E. Scheuer, J. P. Schwarz, K. L. Thornhill, P. O. Wennberg, A. J. Weinheimer, A. Wisthaler, J. H. Woo, P. J. Wooldridge, and J. L. Jimenez	Secondary Organic Aerosol Production over Seoul, South Korea, during KORUS-AQ	Atmospheric Chemistry and Physics	In prep

Publications (4)

Authors	Title	Journal	Status
B. A. Nault, P. Campuzano-Jost, D. A. Day, J. C. Schroder, D. R. Blake, M. R. Canagaratna, J. A. de Gouw, F. Flocke, A. Fried, J. B. Gilman, T. F. Hanisco, L. G. Huey, B. T. Jobson, W. C. Kuster, B. Lefer, J. Liao, D. D. Montzka, I. B. Pollack, J. Peischl, B. Rappenglueck, J. M. Roberts, T. B. Ryerson, J. Stutz, P. Weibring, A. J. Weinheimer, E. C. Wood, and J. L. Jimenez	Quantification of the Rapid Photochemical Secondary Organic Aerosol Production Observed across Megacities around the World	Nature Geosciences or PNAS	In prep
B. A. Nault, P. Campuzano-Jost, D.A. Day, W. W. Hu, B. B. Palm, J. C. Schroder, R. Bahreini, H. Bian, M. Chin, S. L. Clegg, P. Colarco, J. Crounse, J. A. de Gouw, J. Dibb, M. J. Kim, J. Kodros, F. D. Lopez-Hilfiker, E. A. Marais, A. Middlebrook, J. A. Neuman, J. B. Nowak, J. Pierce, J. M. Roberts, E. Scheuer, J. A. Thornton, P. R. Veres, P. O. Wennberg, and J. L. Jimenez	Global Survey of Submicron Aerosol Acidity (pH)	Nature Geosciences or PNAS	In prep
D. Jeong, R. Seco, D. Gu, Y. Lee, B. Nault, C. Knote, T. Mcgee, J. Sullivan, J. L. Jimenez, P. Campuzano-Jost, D. Blake, D. Sanchez, A. Guenther, D. Tanner, G. Huey, R. Long, B. E. Anderson, S. R. Hall, Y.-J. Lee, D. Kim, J.-Y. Ahn, A. Wisthaler, and S. Kim	Integration of Airborne and Ground Observations of Nitryl Chloride in the Seoul Metropolitan Area and Its Impact on the Regional Oxidation Capacity During the KORUS-AQ 2016 Field Campaign	TBD	In prep
D. Sanchez, R. Seco, D. Gu, A. Guenther, D. Jeong, J. Mak, Y.-J. Lee, D. Kim, D. Blake, S. Herndon, D. Jeong, T. Mcgee, and S. Kim	OH Reactivity Budget Analysis at the Taehwa Research Forest During KORUS-AQ 2016	TBD	In prep

Publications (5)

Authors	Title	Journal	Status
Isobel Simpson, et al.	Characterization and source apportionment of VOCs in the Seoul Metropolitan Area	TBD	In prep
Kara Lamb, et al.	Regional influences on the direct radiative forcing from black carbon observed over S. Korea	JGR-Atmospheres	In prep
Jinkyul Choi, Rokjin J. Park, Hyung-Min Lee, Seungun Lee, Duseong S. Jo, Jaein I. Jeong, Daven Henze, Jung-Hun Woo, Soo-Jin Ban, Min-Do Lee, Cheol-Soo Lim, Mi-Kyung Park, Hye J. Shin, Seogju Cho, and David Peterson	Source attribution of PM2.5 for Korea during the KORUS-AQ campaign using GOES-Chem adjoint model	TBD	In prep
Yujin Ok, Rokjin J. Park, Donald R. Blake, William H. Brune, Andrew J. Weinheimer, Alan Fried, James Crawford, and Jason Schroeder	Evaluation of simulated VOCs during the KORUS-AQ campaign and their effect on ozone production in Korea	TBD	In prep
Hyeonmin M. Kim, Rokjin J. Park, Jaein I. Jeong, Daun Jeong, Saewung Kim, and Seogju Cho	Effect of nitryl chloride chemistry on oxidation capacity in East Asia	TBD	In prep
Hyung-Min Lee, Rokjin Park, Hyeong-Ahn Kwon	Top-down estimate of isoprene emissions in East Asia using inverse modeling: implication of satellite retrievals from GOME-2 and OMI formaldehyde with KORUS-AQ aircraft observations	TBD	In prep
David Peterson, et al.	Meteorology Influencing Pollution Regimes and Transport during KORUS-AQ	TBD	In prep

Publications (6)

Authors	Title	Journal	Status
K. Miyazaki, T. Sekiya, D. Fu, K. W. Bowman, S. S. Kulawik, K. Sudo, T. Walker, Y. Kanaya, M. Takigawa, K. Ogochi, H. Eskes, F. Boersam, B. Gaubert, J. Barre, and L. Emmons, and the KORUS-AQ team	Evaluation of a multi-constituent chemical reanalysis during KORUS-AQ: Role of dynamics and emissions	JGR-Atmospheres	In prep

KORUS-AQ CONTEST QUESTION FOR MARCH

By the end of the NCAA Men's Basketball Tournament, how many teams will lose to a lower seed?

Tiebreaker question: What will be total combined score for the championship game.

Hint: There will be 63 games played, and knowledge of basketball will not help you win. Koreans should not be afraid to take a guess.

To enter the contest, answers must be emailed to James.H.Crawford@nasa.gov before noon (eastern time) on Thursday (15 March)

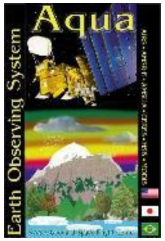
If you are in another time zone, do the math…

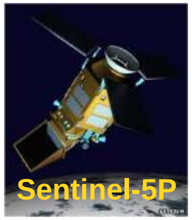
Joint AIRS+OMI Ozone Profile data for KORUS-AQ:

Updates on Validation and Science Applications

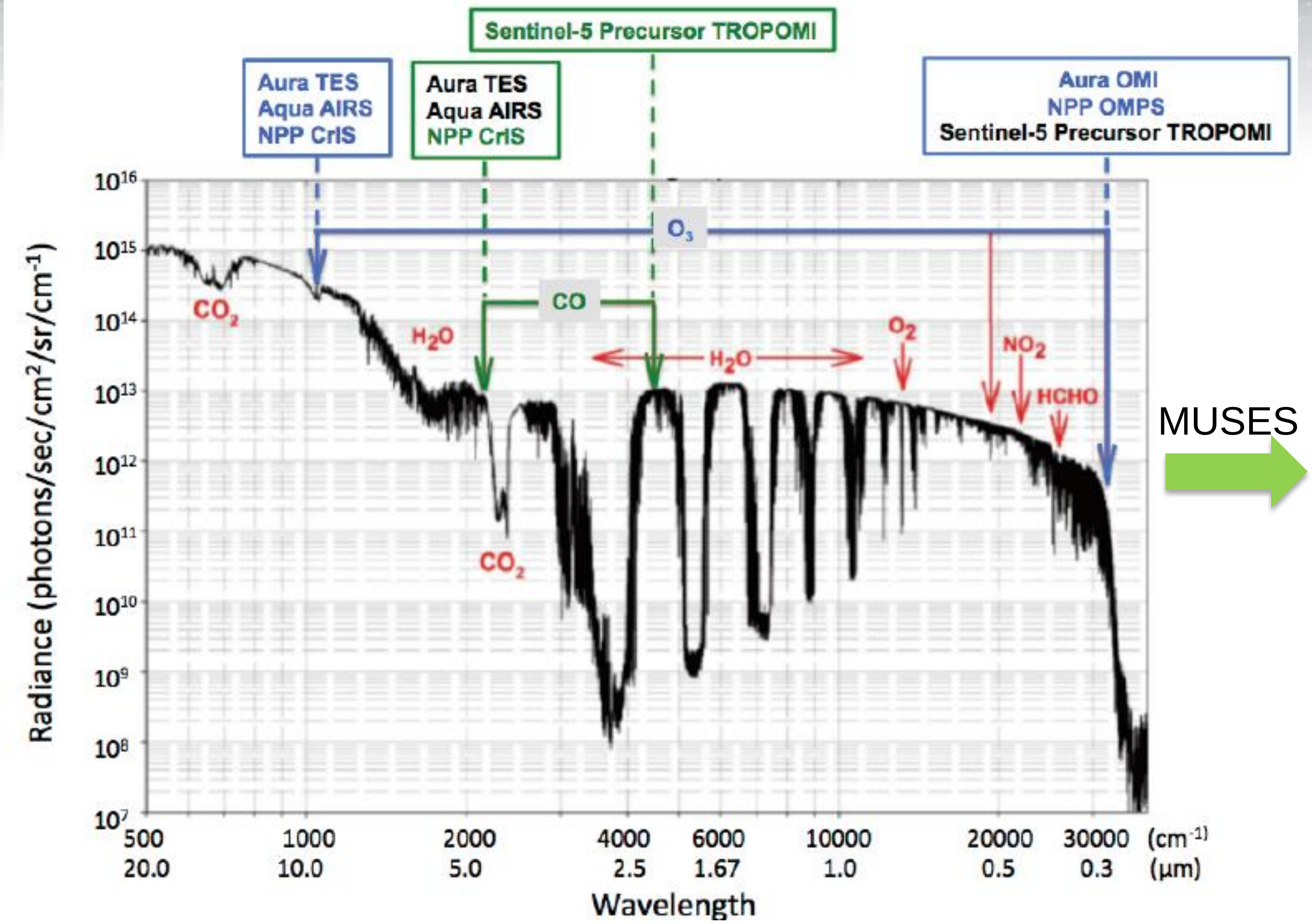
Dejian Fu[1], Kevin W. Bowman[1], Kazuyuki Miyazaki[2], Susan S. Kulawik[1,3], John R. Worden[1], Bradley R. Pierce[4], Robert L. Herman[1], Gregory B. Osterman[1], Fredrick W. Irion[1], with thanks to KORUS-AQ, TES, AIRS, OMI, and CrIS teams

[01] NASA Jet Propulsion Laboratory, California Institute of Technology, USA
[02] Japan Agency for Marine-Earth Science and Technology, Japan
[03] NASA Ames Research Center, USA
[04] NOAA/NESDIS Center for Saellite Applications and Research, USA



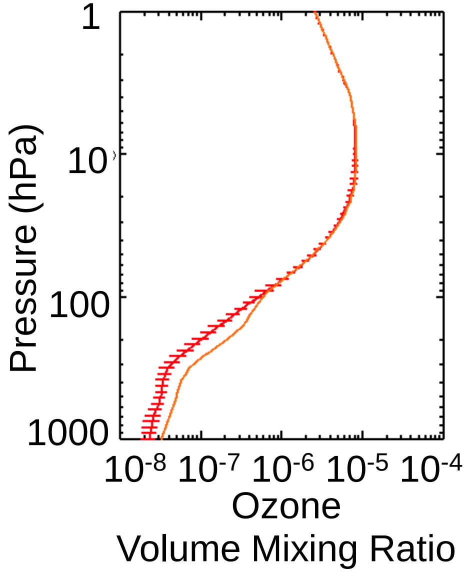


Spectral Regions Used in JPL MUSES Algorithm



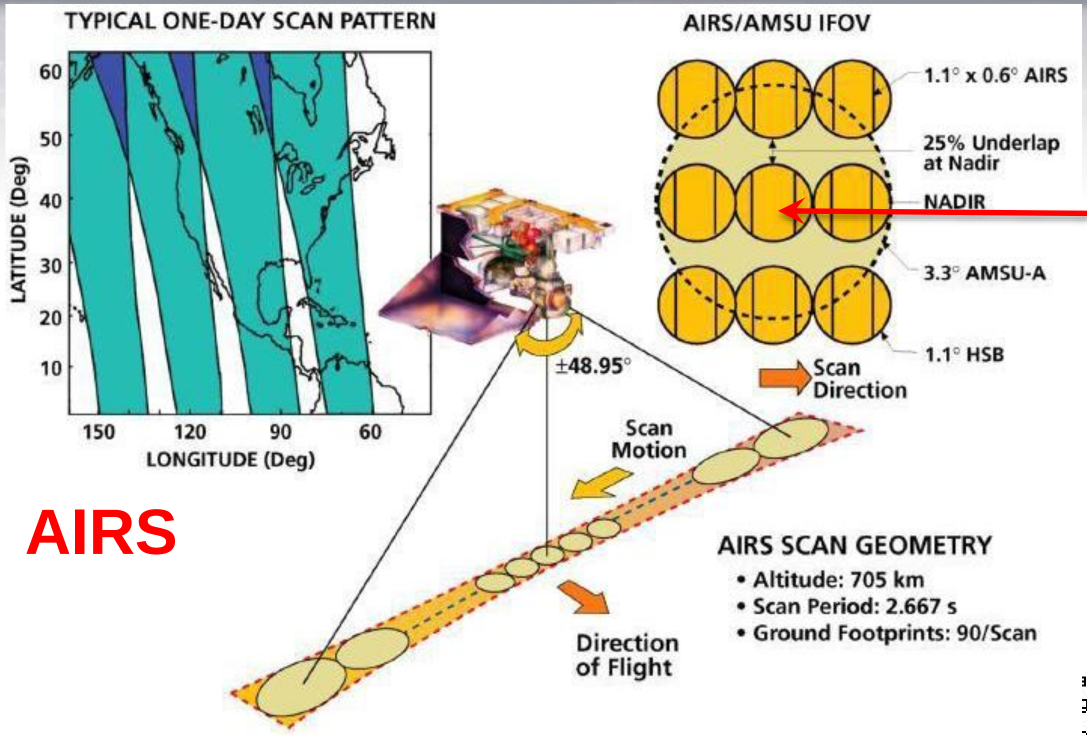
MUlti-SpEctra, MUlti-SpEcies, MUlti-SEnsors (MUSES)

MUSES



Measurements from TIR (LW) are sensitive to the free-tropospheric trace gases.
Measurements from UV-Vis-NIR (SW) are sensitive to the column abundances of trace gases.
Joint LW/SW or ultra-high spectral resolution measurements can distinguish upper/lower troposphere.

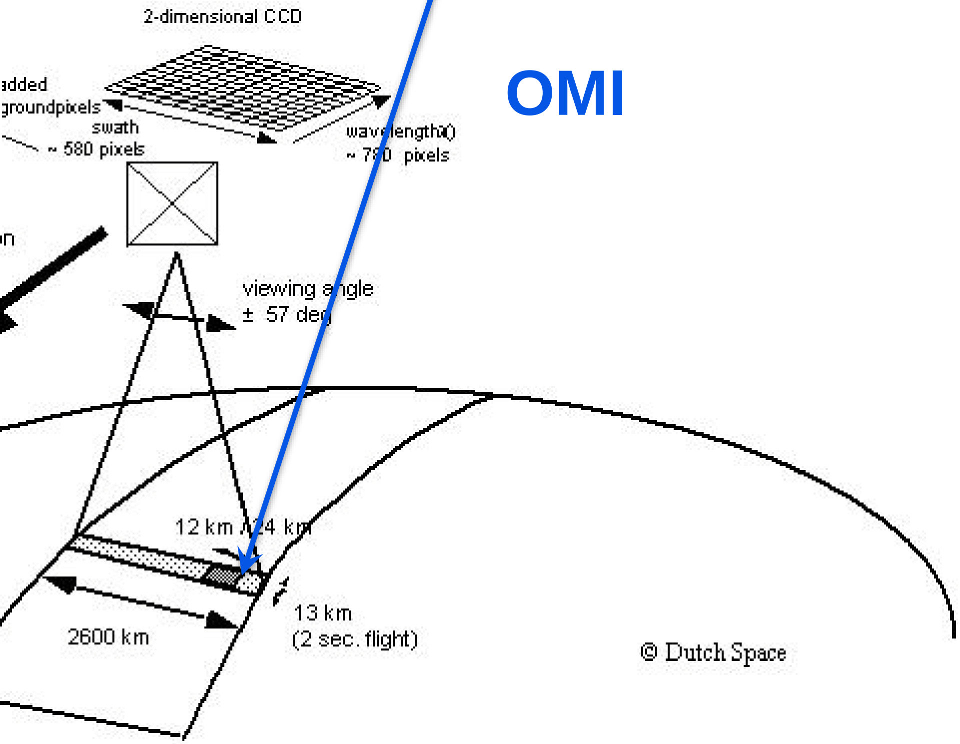
Combined AIRS single footprint to OMI measurements



AIRS

This work combines **AIRS single footprint L1B radiances** to **OMI measured radiances** for retrieving O_3 profiles.

OMI



Characteristics and Diagnostics of O_3 data

JPL MUSES algorithm delivers both retrieved trace gas concentration profiles and observation operators needed for trend analysis, climate model evaluation, and data assimilation.

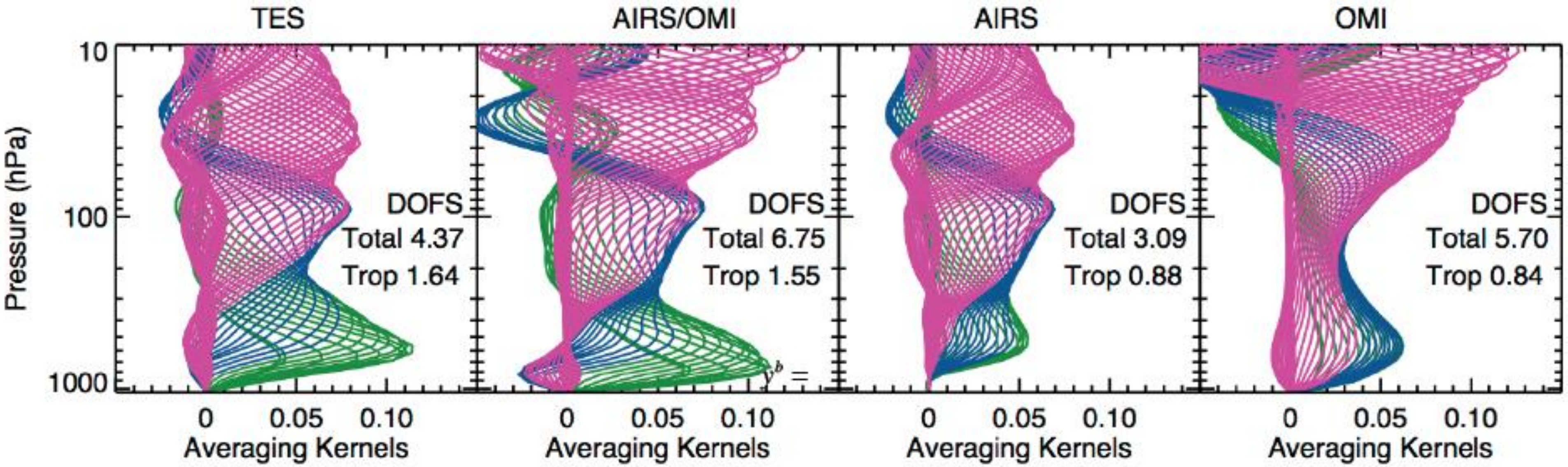
E.g., a data assimilation system applies an observation operator (**H**)

$$\mathbf{y}^s = \mathbf{H}(\mathbf{x}) = \mathbf{x}_a + \mathbf{A}(\mathbf{x}_{model} - \mathbf{x}_a)$$

$\mathbf{y}^s$ is the model profiles; $\mathbf{x}_a$ is *a priori* profiles used in the retrievals; **A** is the averaging kernels of satellite observations.

After applying observation operator to model profiles, the satellite-model differences ($\mathbf{y}^o$- $\mathbf{y}^s$) is not biased by the *a priori* used in the retrievals.

$$\Delta\mathbf{y} = \mathbf{y}^o - \mathbf{y}^s = \mathbf{A}(\mathbf{x}_{true} - \mathbf{x}_{model}) + \varepsilon$$



Joint AIRS/OMI O_3 Retrievals

The AIRS/OMI O_3 retrievals have been configured in two modes.

- Global survey (GS) mode
  - Provides profile data with a spatial sampling similar to TES global survey
    - 28-month data have been processed including
    - **2006 Jan – Dec**
    - **2016 Mar – Jun**
    - 2007 Jan – Dec
  - **Year 2006** and **Mar-June 2016** GS data are available via the link (AIRS-OMI combined products) at https://tes.jpl.nasa.gov/data/
- Regional mapping (RE) mode
  - Processes all available measurements for flight campaigns including
    - **KORUS-AQ, Apr – Jun 2016**
    - ORACLES, Aug, Sept 2016
    - POSIDON, Sept, Oct 2016
  - **KORUS-AQ (Apr-June 2016) RE** data are available via the link (AIRS-OMI combined products) at https://tes.jpl.nasa.gov/data/

Data products have been saved in Hierarchical Data Format, a common format used in the NASA Earth Observation System level 2 products

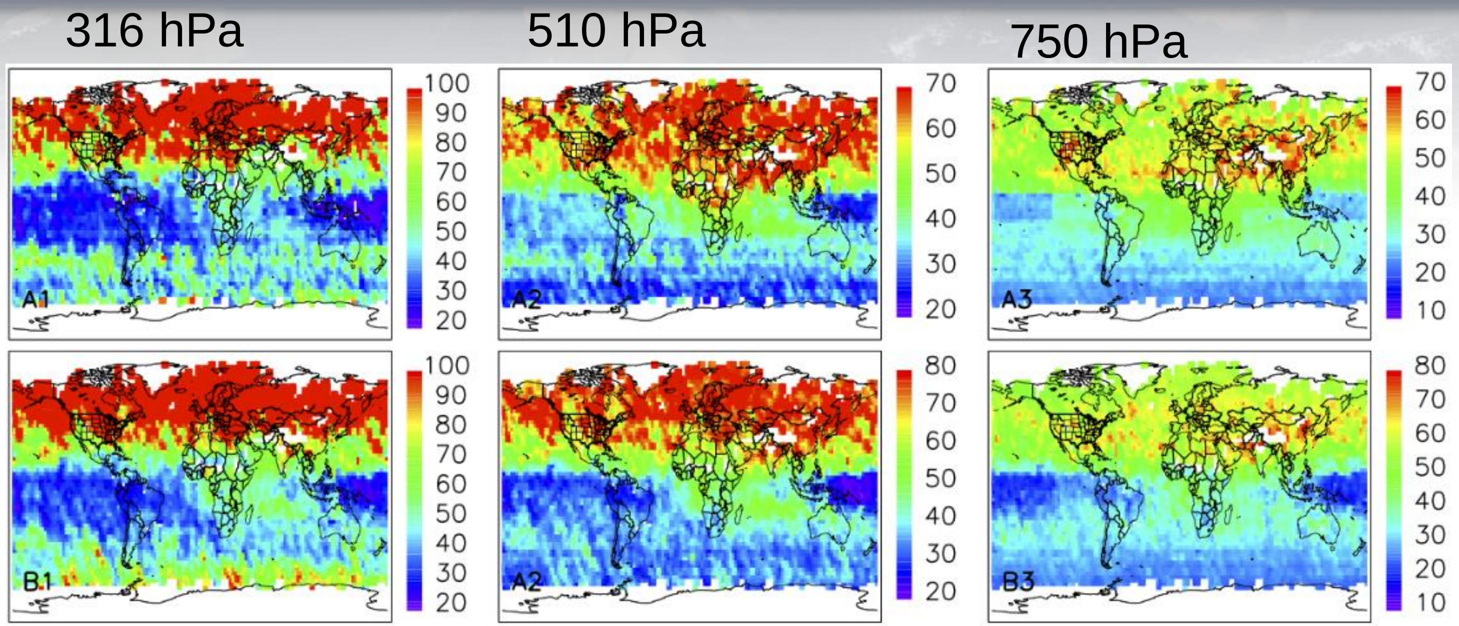
AIRS/OMI O_3 Profile Data from Global Survey Mode

Fu et al., Submit to AMT 2018.

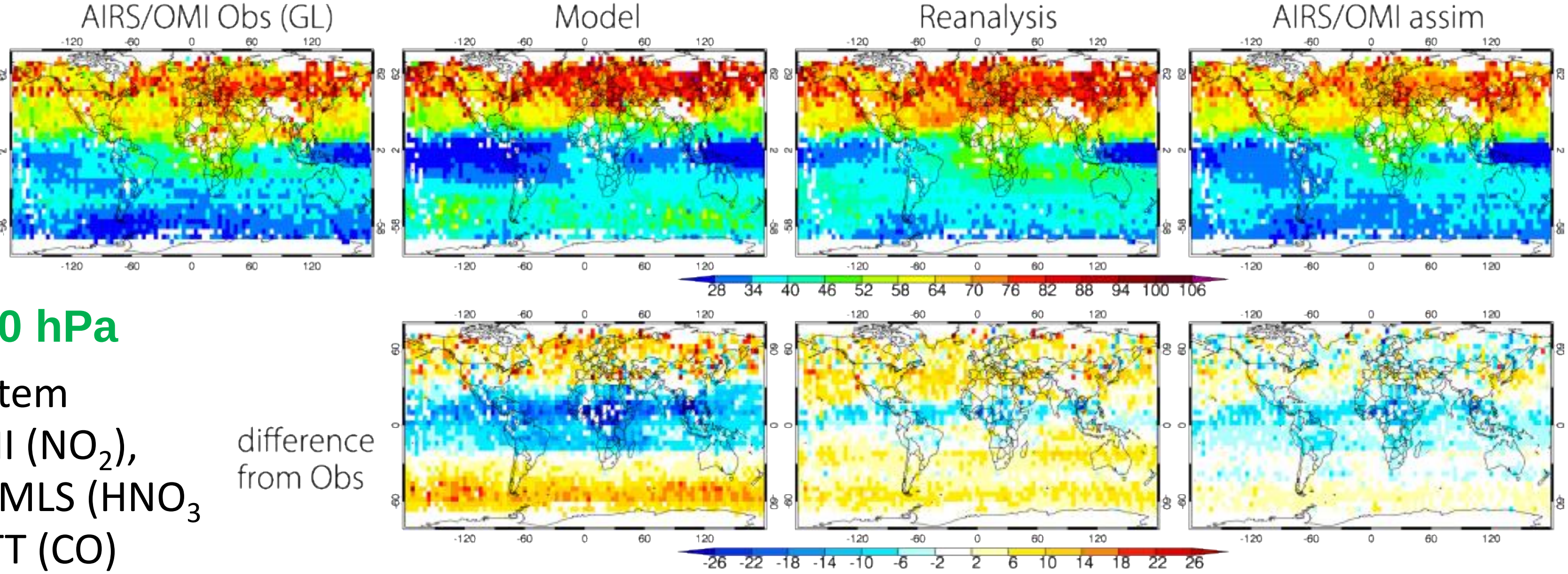
Joint AIRS+OMI

May 2006

TES v6



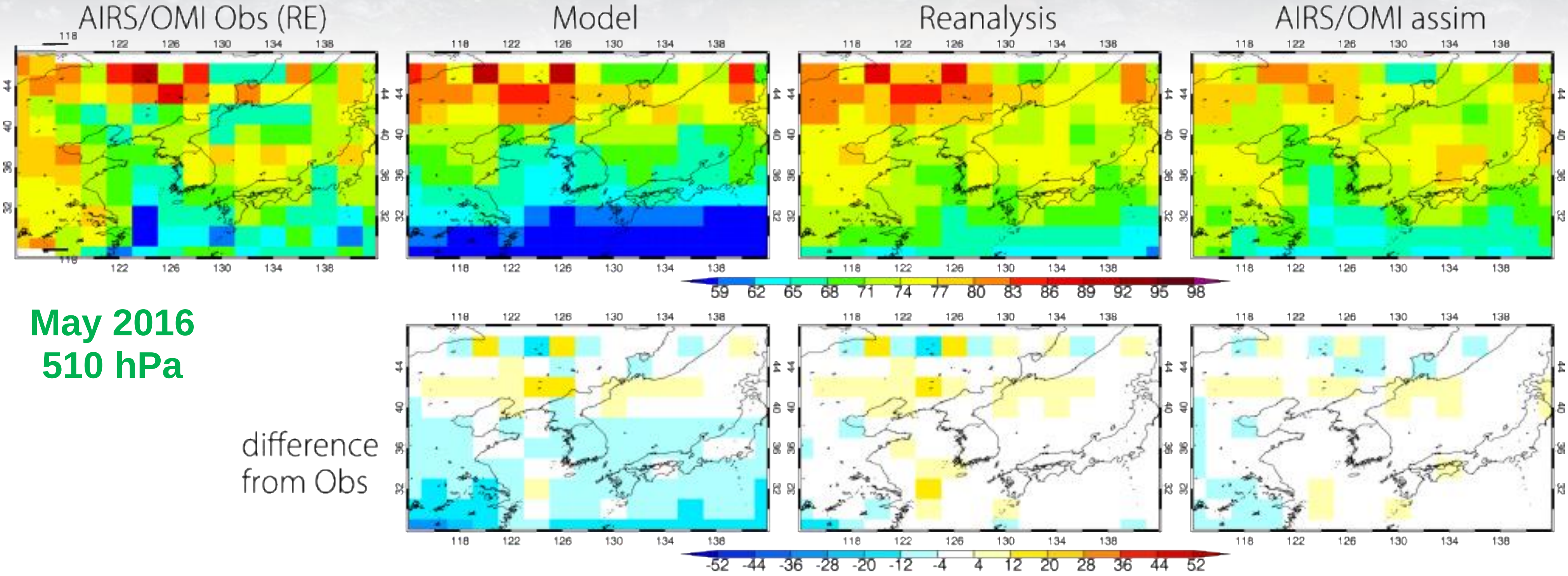
Miyazaki et al., Submit to JGR 2018



- **May 2016; 510 hPa**
- CHASER-DA system assimilated OMI (NO_2), GOME-2 (NO_2) MLS (HNO_3 and O_3), MOPITT (CO)

AIRS/OMI O_3 Profile Data from Regional Mapping Mode

Miyazaki et al., Submit to JGR 2018



Performances of GS and RE mode joint AIRS/OMI data

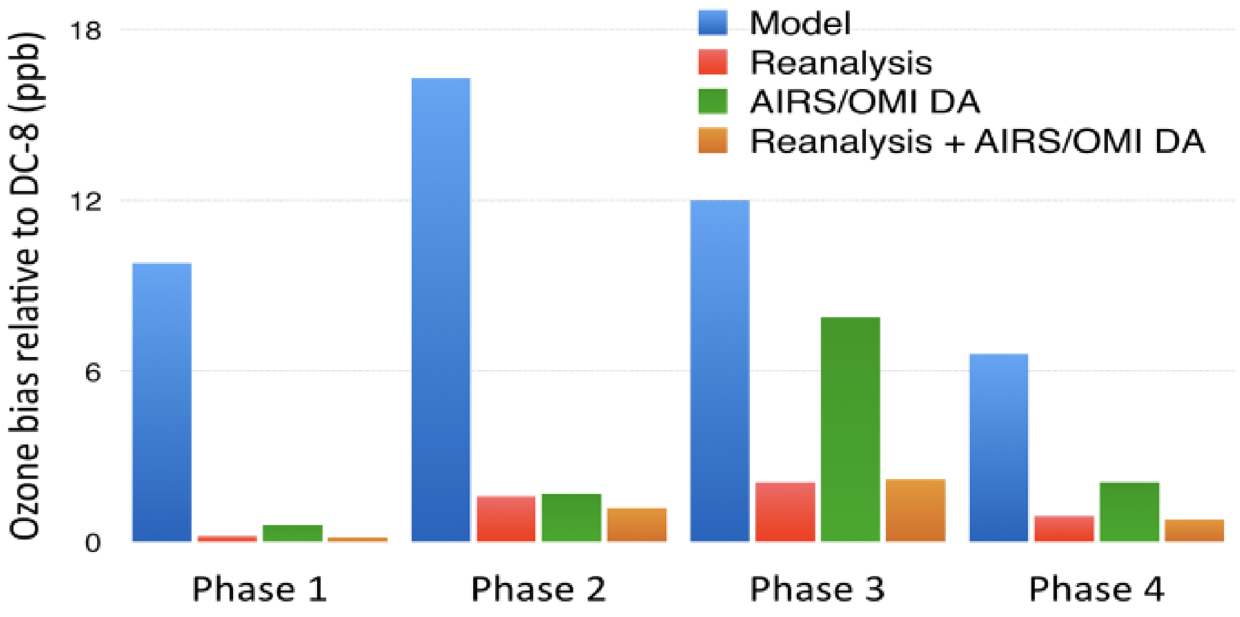
- Diff. (Reanalysis without Joint AIRS+OMI – Joint AIRS+OMI Obs.) **<** (Model - Joint AIRS+OMI Obs.)
- Reanalysis without Joint AIRS+OMI closely agree to joint AIRS+OMI ozone with a mean bias of
  - 0.9 ppbv for RE mode
  - 4.2 ppbv in the northern extratropics
  - -1.8 ppbv in the tropics
  - 4.5 ppbv in the southern hemisphere

Comparisons of O_3 Profile Data among Data Sets

Miyazaki et al., Submit to JGR 2018

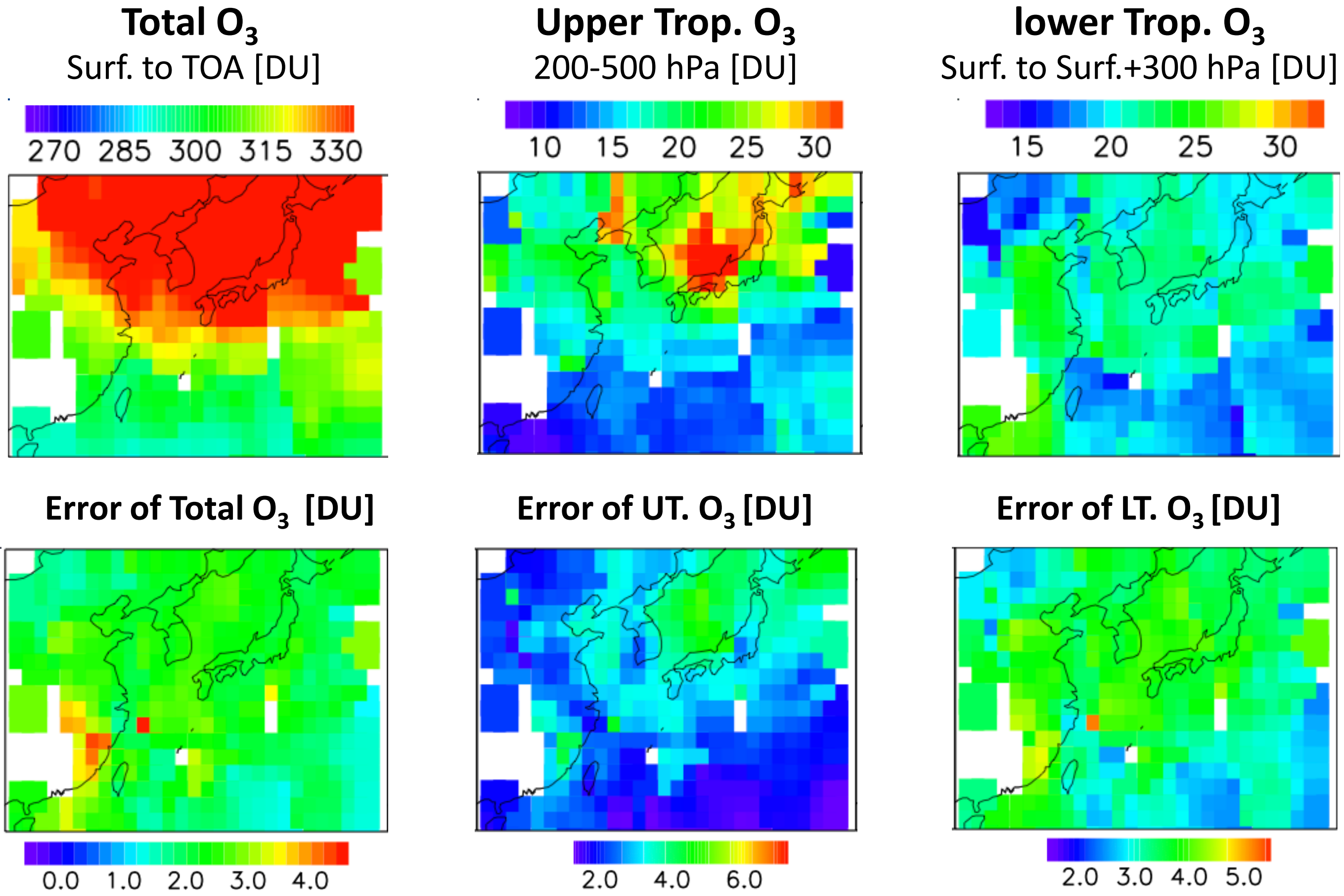
Differences in comparison to AIRS+OMI Obs. (ppb)		GL SH: 55°-15°S		GL TR: 15°S-15°N		GL NH: 15°-55°S		RE	
		Bias	RMSE	Bias	RMSE	Bias	RMSE	Bias	RMSE
510 HPa	Model	4.0	8.3	-12.2	14.4	-1.3	12.0	-5.2	14.5
	Reanalysis	4.5	6.0	-1.8	6.5	4.2	9.2	0.9	10.5
	AIRS/OMI assim	-0.2	3.7	-5.3	7.1	-0.4	7.2	0.1	8.3

Phase 1: May 1-16
Phase 2: May 17-22
Phase 3: May 25-31 (OMI instrument issue)
Phase 4: June 1-6 (OMI instrument issue)



Joint AIRS/OMI O_3 Maps for KORUS-AQ Campaign

- Korea-US Air Quality study (KORUS-AQ) - International Cooperative Air Quality Field Study
- Joint AIRS/OMI O_3 profile data
  - Total ozone shows strong latitudinal dependence, dominated by stratospheric ozone.
  - The pattern of enhancement (Upper tropospheric > Lower tropospheric) over Korean peninsula <-> Japan suggests either lofting and transport of pollution from the surface or the influence of stratosphere-troposphere exchange.



Total O_3
Surf. to TOA [DU]

Upper Trop. O_3
200-500 hPa [DU]

lower Trop. O_3
Surf. to Surf.+300 hPa [DU]

Error of Total O_3 [DU]

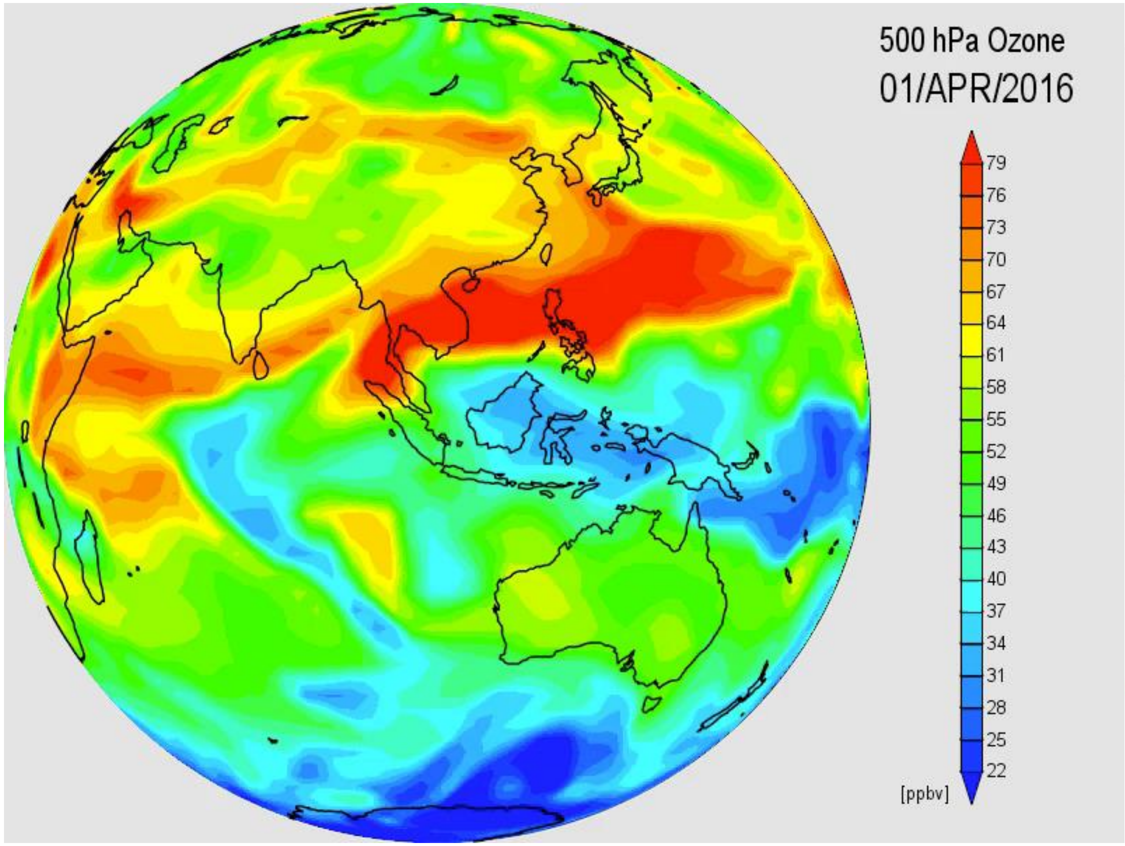
Error of UT. O_3 [DU]

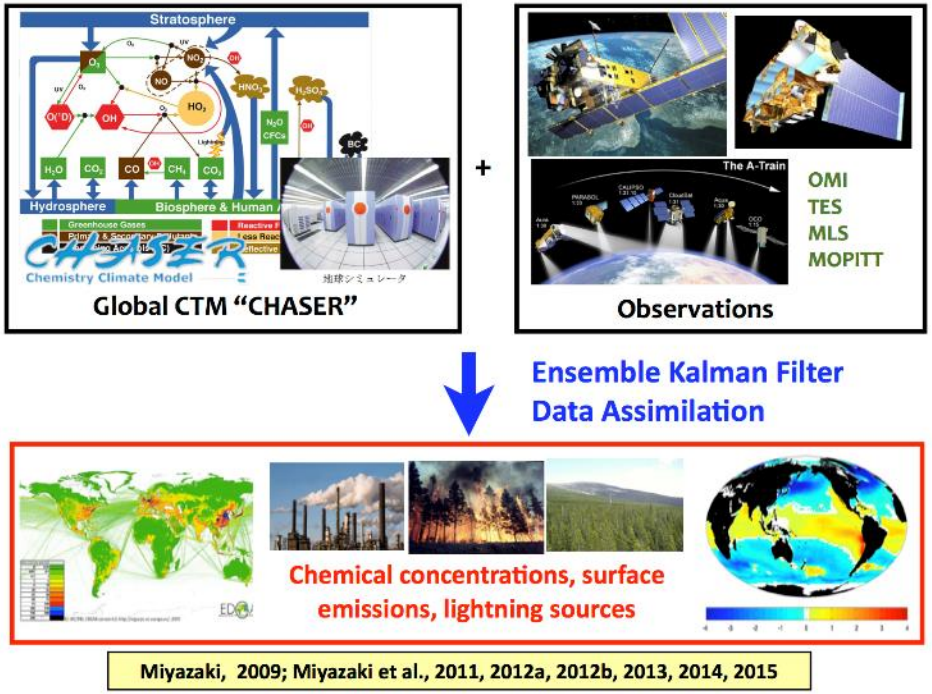
Error of LT. O_3 [DU]

Three-day averaged
May 18-20, 2016.

Assimilated Global Ozone Fields

- Joint AIRS/OMI ozone profiles have been assimilated into CHASER system.
- CHASER system assimilated the OMI (NO_2), GOME-2 (NO_2) MLS (HNO_3 and O_3), MOPITT (CO) for KORUS-AQ ,recently assimilated AIRS/OMI ozone profile data


500 hPa Ozone
01/APR/2016



Global CTM "CHASER"

+

Observations

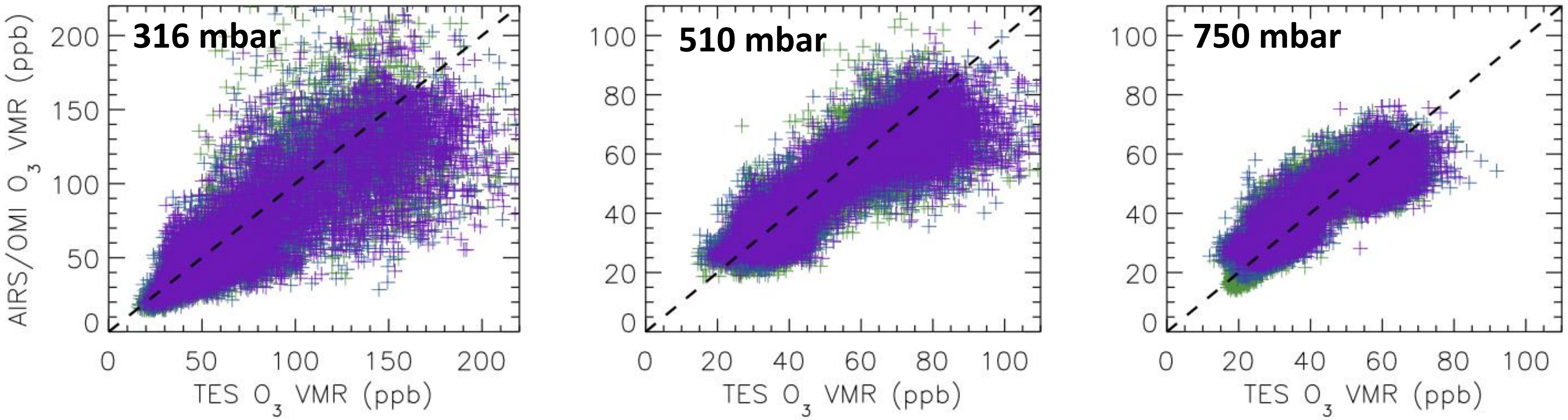
OMI
TES
MLS
MOPITT

Ensemble Kalman Filter
Data Assimilation

Chemical concentrations, surface emissions, lightning sources

Miyazaki, 2009; Miyazaki et al., 2011, 2012a, 2012b, 2013, 2014, 2015

Joint AIRS/OMI vs. TES Global Survey O_3 March to June 2006



- The differences are within the estimated uncertainty.

316 hPa		Mar	Apr	May	Jun
Pearson Correlation Coefficient		0.85	0.84	0.84	0.84
Differences (AIRS+OMI – TES)	Mean (ppb)	-7.3	-6.9	-8.1	-6.0
	RMS (ppb)	21.5	21.6	22.6	19.8
	Mean (%)	9.8	7.3	7.3	-5.0
	RMS (%)	24.2	25.7	24.7	23.8
Total Uncertainty	AIRS+OMI O_3 (%)	28.6	28.9	28.5	28.0
	TES V6 O_3 (%)	22.5	23.0	22.9	22.1

510 hPa	Mar	Apr	May	Jun
	0.87	0.88	0.89	0.86
	-2.9	-3.3	-3.6	-4.1
	8.6	8.9	9.2	9.5
	4.9	4.2	4.2	-4.5
	17.3	18.2	16.4	17.0
	22.5	22.8	23.0	22.8
	20.1	20.1	20.1	19.5

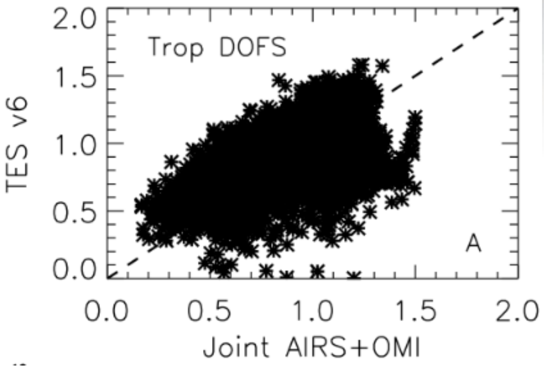
750 hPa	Mar	Apr	May	Jun
	0.90	0.90	0.90	0.83
	-0.4	-1.2	-1.6	-2.2
	6.7	7.0	6.4	7.1
	-0.6	0.3	1.3	-2.3
	19.3	19.8	15.9	17.4
	22.4	22.9	24.1	24.7
	23.1	23.3	24.0	24.0

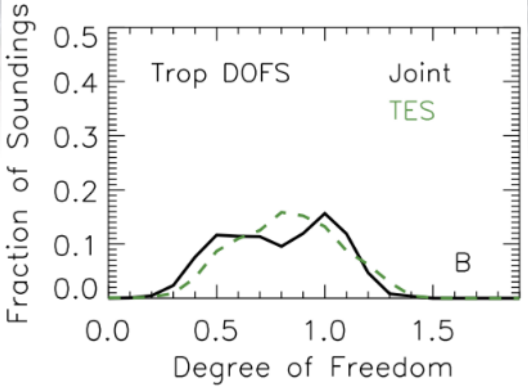
Fu et al., Submit to AMT 2018.

Number of Global Survey	AIRS+OMI	14	15	16	15
	TES	16	14	15	15

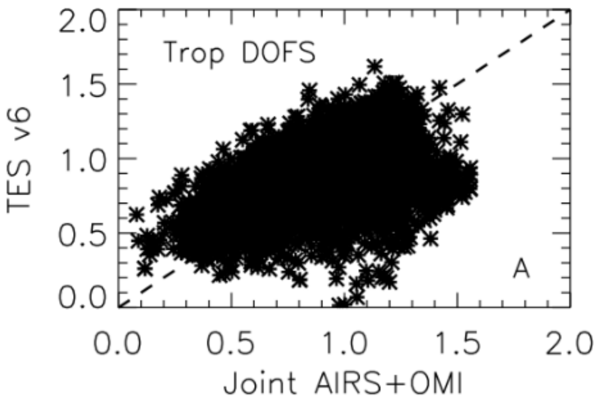
AIRS/OMI vs. TES v6 GS Trop DOFS

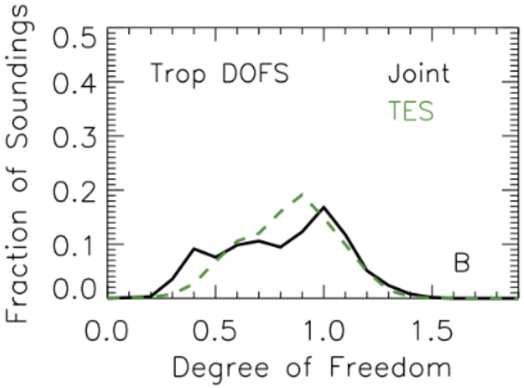
April 2006
Corr. R = 0.65;
Mean(TES/Joint) = 1.10
Mean(TES-Joint) = 0.04



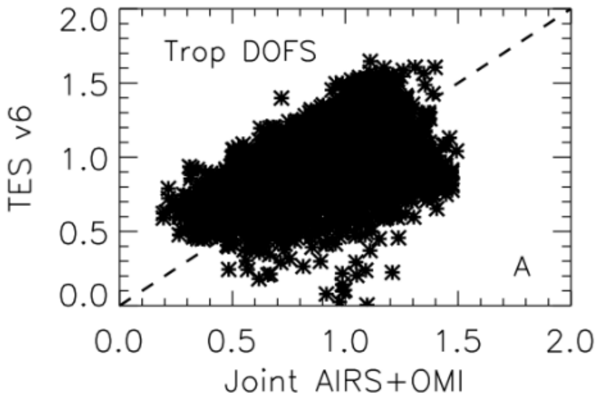


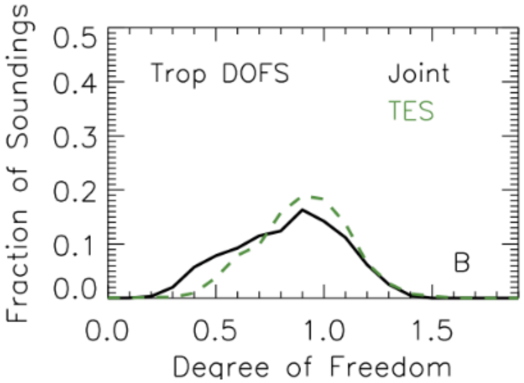
May 2006
Corr. R = 0.58;
Mean(TES/Joint) = 1.10
Mean(TES-Joint) = 0.03





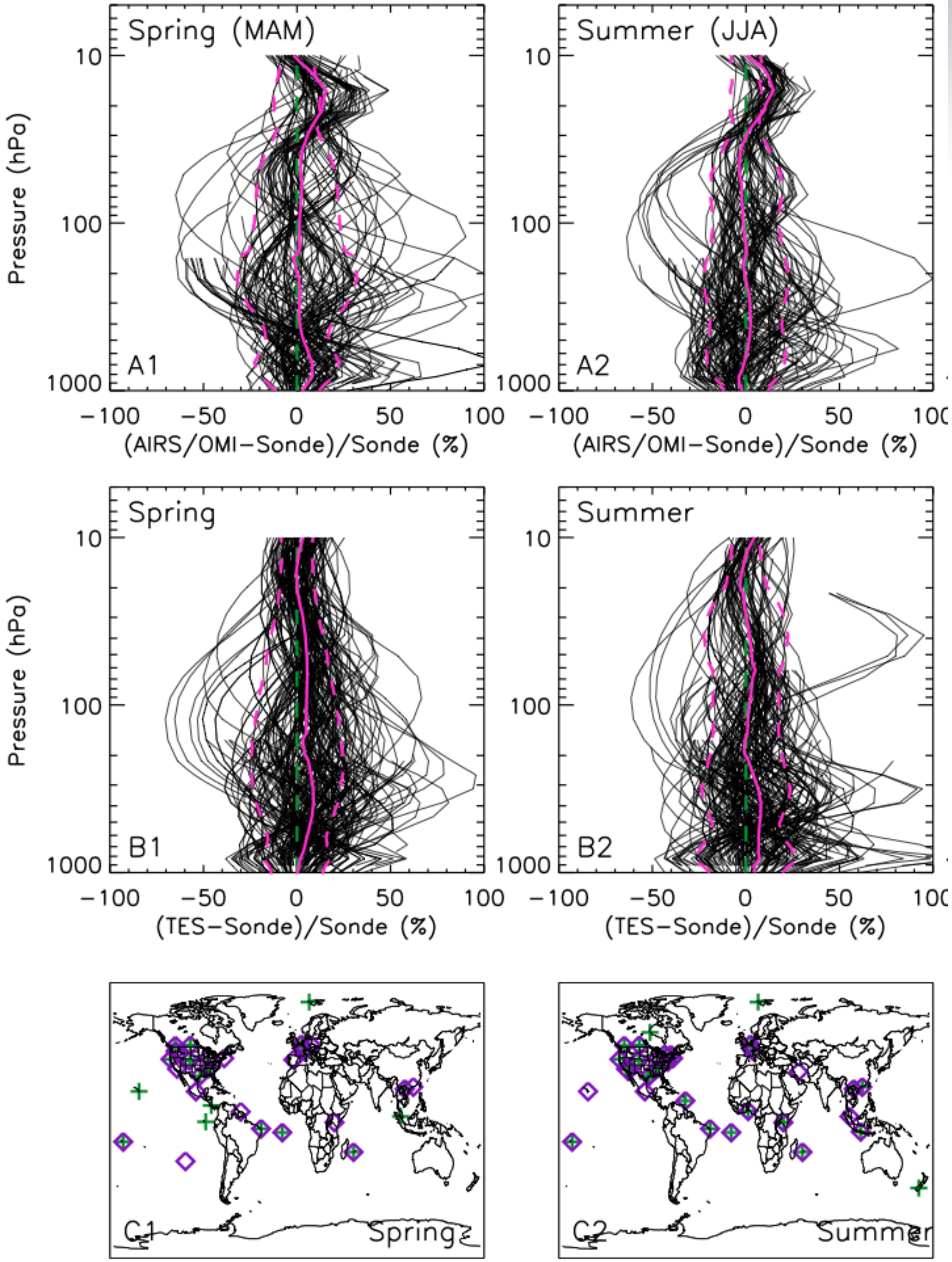
June 2006
Corr. R = 0.51;
Mean(TES/Joint) = 1.14
Mean(TES-Joint) = 0.07





Fu et al., Submit to AMT 2018.

Comparisons to WOUDC Ozonesondes



		Spring		Summer	
Differences (Satellite – WOUC Sonde with Satellite Observation Operator Applied)	316 hPa	AIRS+OMI	TES	AIRS+OMI	TES
	Mean (ppb)	2.8	6.1	0.7	4.2
	Mean (%)	1.3	8.6	2.2	6.6
	RMS (ppb)	17.1	19.2	13.4	17.0
	RMS (%)	25.6	23.7	20.4	23.8
	510 hPa	Spring		Summer	
		AIRS+OMI	TES	AIRS+OMI	TES
	Mean (ppb)	1.3	3.6	-0.8	3.5
	Mean (%)	3.8	7.0	1.6	7.3
	RMS (ppb)	7.6	9.2	10.9	10.6
	RMS (%)	17.2	17.4	20.4	17.9
	750 hPa	Spring		Summer	
		AIRS+OMI	TES	AIRS+OMI	TES
	Mean (ppb)	2.4	1.7	-2.2	2.6
	Mean (%)	8.0	3.4	-2.0	6.6
	RMS (ppb)	7.6	6.9	8.6	12.5
	RMS (%)	21.1	16.2	18.8	25.3
Number of WOUDC Sonde Sites		20	25	27	30
Number of Satellite/Sonde Coincident		131	197	134	171

Coincident criteria

- Passed retrieval quality check
- Distance within 300 km
- Time diff. within 4 hours
- Day Time; March, April, May (MAM) 2006
- Day Time; June, July, August (JJA) 2006

Fu et al., Submit to AMT 2018.

JPL/UW-Madison Team for NOAA FIREX

Fire Influence on Regional and Global Environments Experiment (FIREX) is to study the impact of biomass burning of western north America fires on climate and air quality.

JPL/UW-Madison team will combine high vertical/spatial resolution O_3 and CO data with chemical data assimilation to provide a critical synoptic context for quantifying the role of fires on atmospheric composition and air quality.

JPL MUSES algorithm will provide

- CrIS CO profile data
  - nine times higher spatial resolution vs. the CrIS operational data products
- Joint CrIS/OMPS O_3 profile data
  - could distinguish upper/lower troposphere, similar to AIRS/OMI $O_{3,}$ but 3X spatial coverage
- Both CO and O_3 profile data products provide full observation operators readily for data assimilation/model evaluation

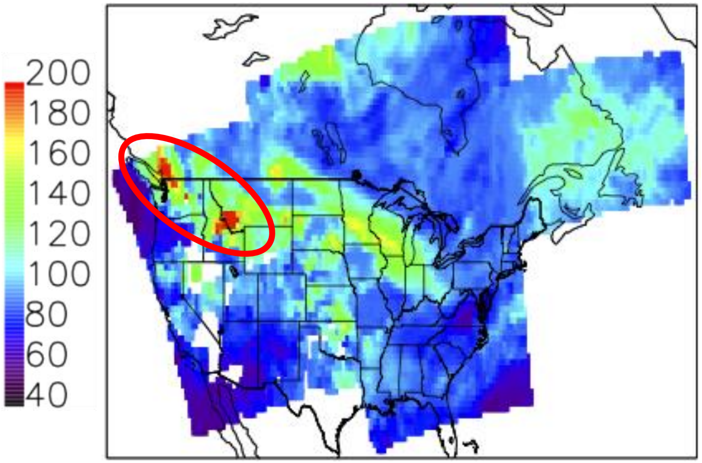
UW-Madison Real time Air Quality Modeling System (RAQMS) will provide

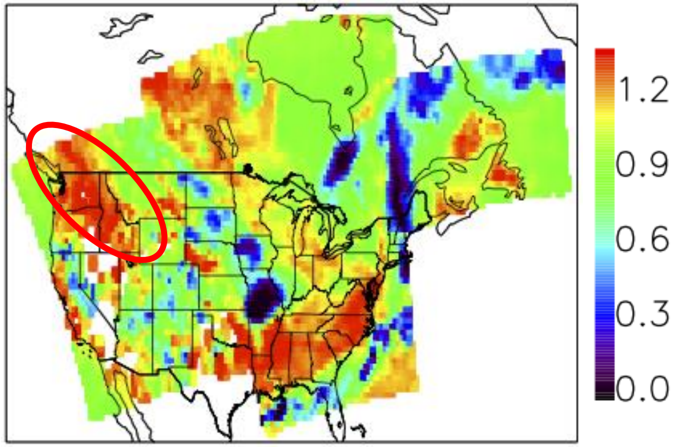
- Real-time assimilation
  - Aura-MLS stratospheric ozone profiles (>50mb)
  - Aura-OMI total ozone column (cloud cleared)
  - MODIS aerosol optical depth
- Real-time fire detection via MODIS data
- Will assimilate JPL CrIS CO and joint CrIS/OMPS O_3 profile data

MUSES-CrIS CO Maps for NOAA FIREX

- Plume of biomass burning observed on August 5, 2017
- CrIS CO profiles were retrieved using single footprint CrIS full spectral resolution data.
- MUSES algorithm retrieves trace gases profiles, cloud optical depths, surface properties and temperature profiles.

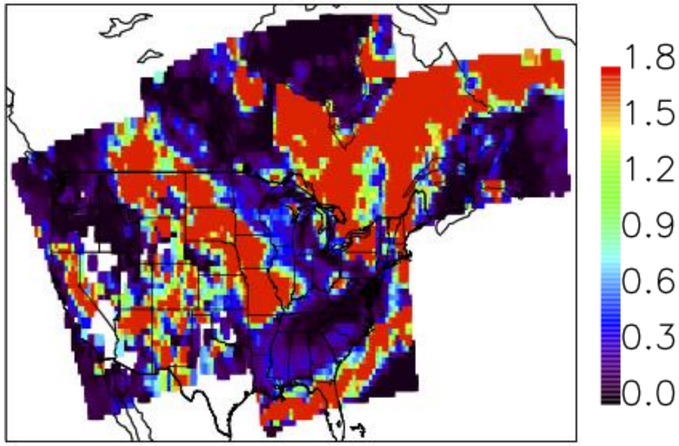
CO VMR
@510 mbar
ppb





CrIS Trop.
CO DOFS

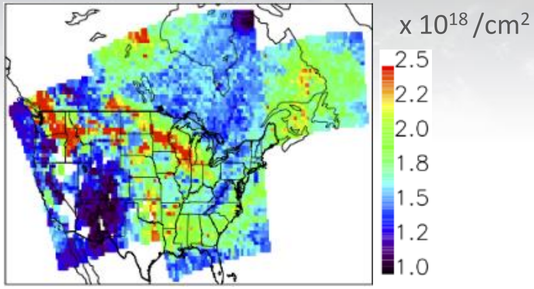
MODIS
Image



CrIS Cloud
OD

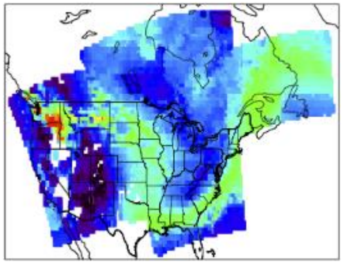
Comparisons of MUSES-CrIS and RAQMS CO Data

CrIS CO Tropospheric Column

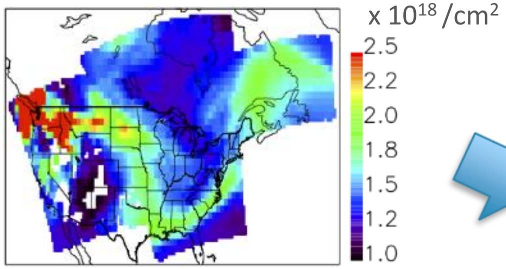


- Used CrIS single footprint full spectral resolution L1B radiances in the retrievals
- MUSES CrIS CO data show agreement to the RAQMS model fields that were applied the observation operators of CrIS CO.
- Collaborating with Dr. Pierce at UW-Madison for assimilating CrIS CO data into the RAQMS model

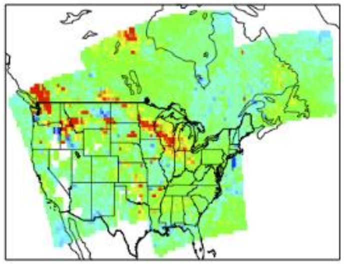
RAQMS after applying CrIS Ak



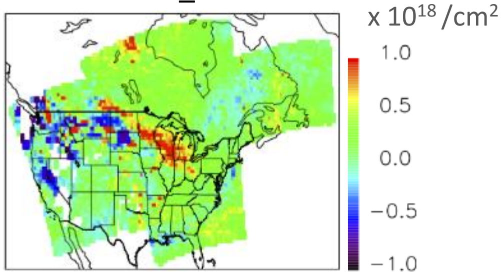
RAQMS without applied CrIS Ak

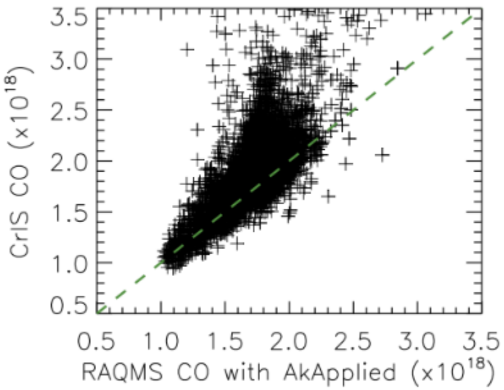


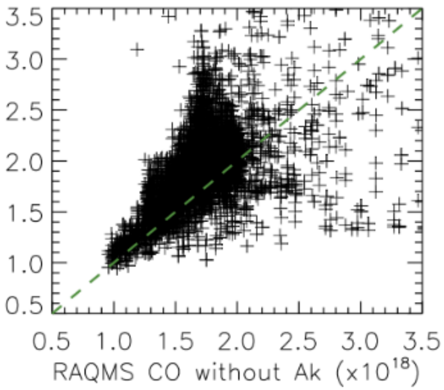
CrIS - RAQMS_AkApplied



CrIS - RAQMS_withoutAk







Applying MUSES CrIS CO Observation Operator to RAQMS Predicted CO Fields	Correlation Coefficient	Mean Diff		RMS	
		x10^{18}	%	x10^{18}	%
With	0.68	-0.15	6.9	0.27	11.1
Without	0.40	-0.15	6.6	0.45	25.7

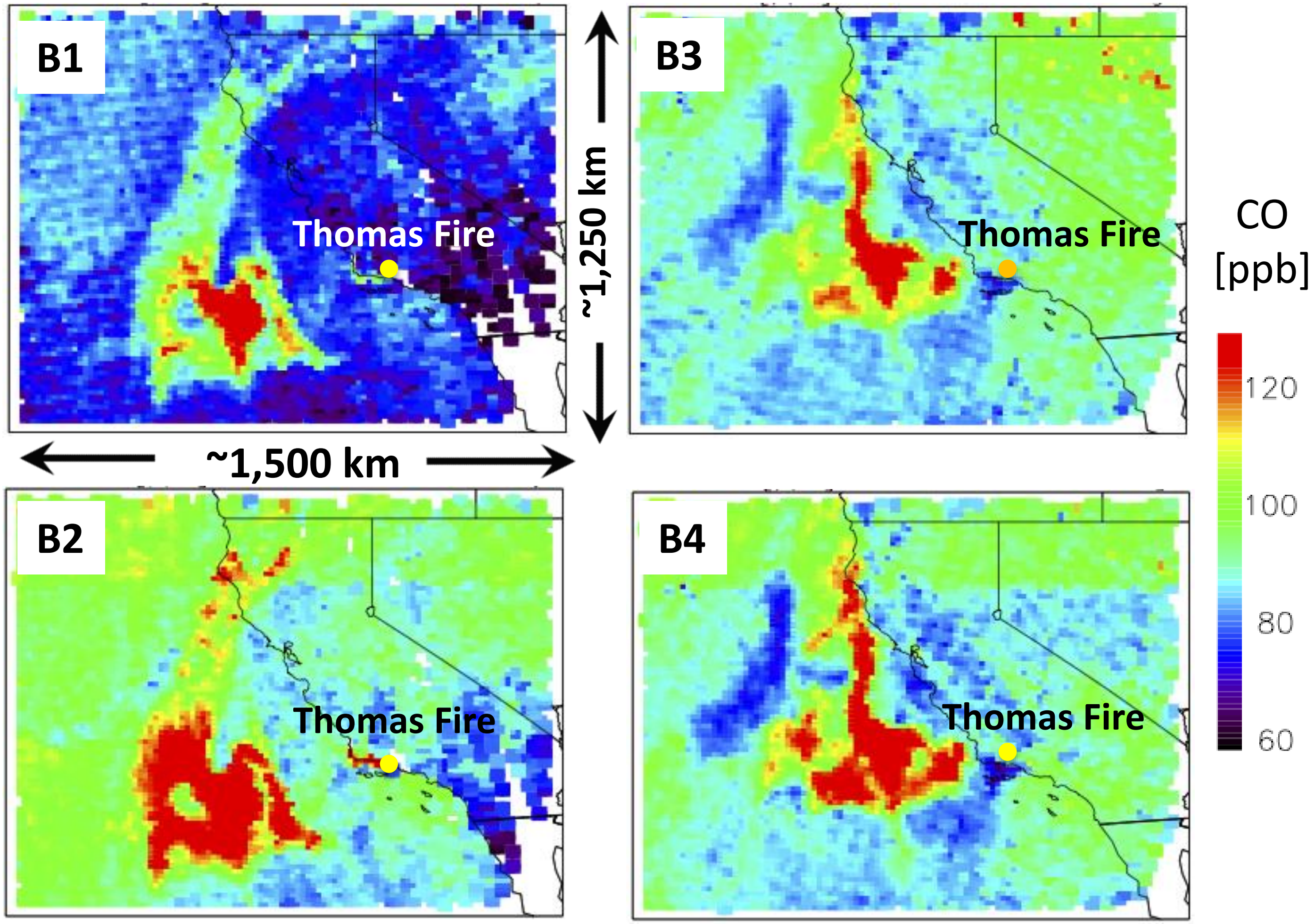
CrIS Carbon Monoxide Observations for Thomas Fire

Email Contact: dejian.fu@jpl.nasa.gov

Hazard of Thomas Fire

Location: near Los Angels, California, USA
Date: Dec 4, 2017 - Jan 12, 2018
Burn Area: 281,893 acres; ~1,140 km^2
Buildings Destroyed: 1,063
Fatalities: 1 firefighter, 1 civilian (20 indirectly)

- CO volume mixing ratio profiles (VMR) retrieved using JPL multi-spectra, multi-Species, multi-sensors (MUSES) [Fu et al, 2013, 2016]
- Provides retrieved profiles and observation operators
- 9X finer spatial resolution than the operational AIRS/CrIS products
- Algorithm heritage of TES, OMI, OCO-2, have been applied to TES, AIRS, CrIS, TROPOMI, OMI, OMPS, OCO2 for a suite of species including CO, O3, CH4, H2O, HDO, CH3OH, PAN, NH3, CO2



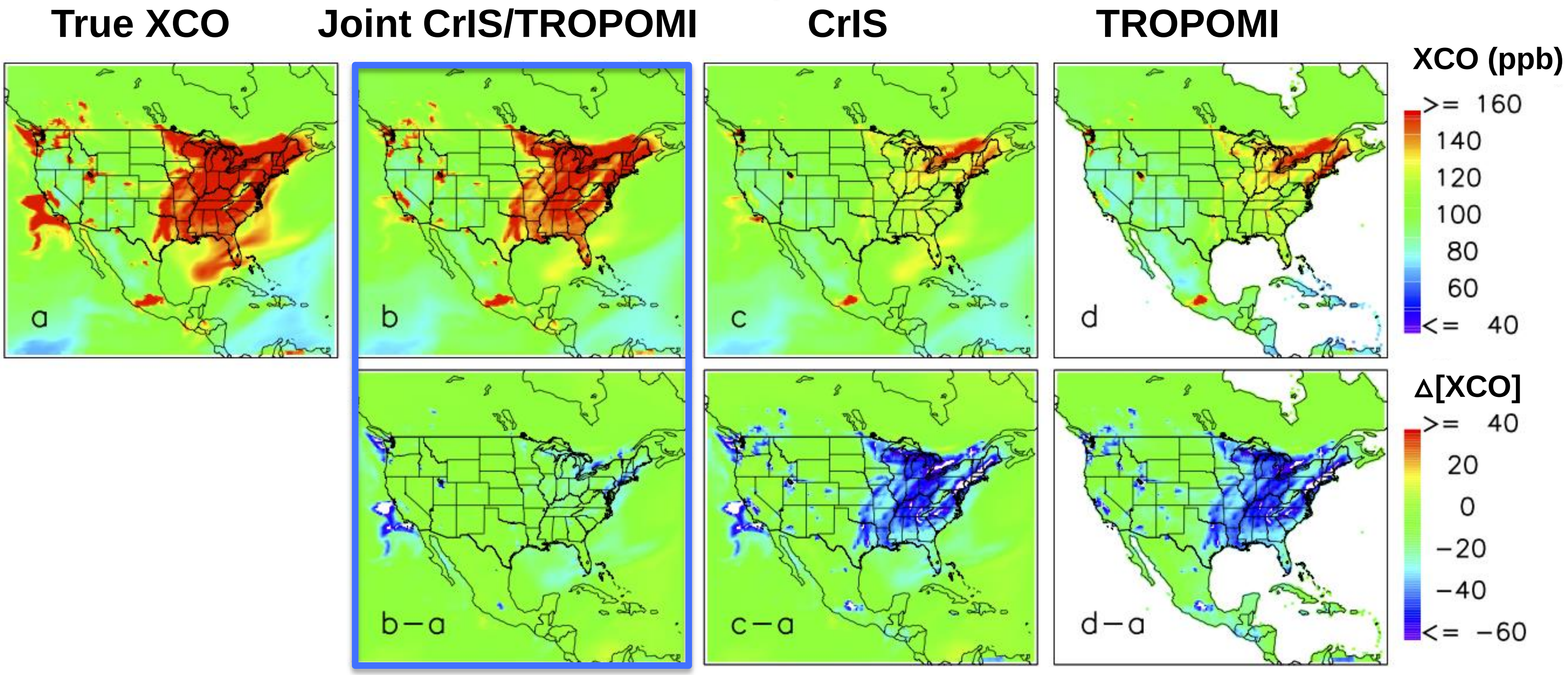
SNPP Synergic Observations

December 12, 2017

[A] VIIRS image of fire plume
[B1-4] CrIS Carbon monoxide VMR
[B1] Day time; 316 hPa
[B2] Day time; 510 hPa
[B3] Night time; 316 hPa
[B4] Night time; 510 hPa

High Resolution Near Surface CO Data via Combining CrIS/TROPOMI Measurements

- In October 13, 2017, ESA Sentinel 5 Precursor (S5P) launched successfully, forming a satellite constellation with Suomi-NPP satellite.
- It provides an unique opportunity to extend and improve the MOPITT joint TIR/NIR CO data, via combining CrIS/TROPOMI measurements [Fu *et al.*, AMT, 2016]
- **XCO maps:** near surface partial column averaged VMR [surface to ~750 hPa]



Summary

- MUSES retrieval algorithm can combine radiances measured from long wavelength (TES, AIRS, CrIS) and short wavelength (OMI, OMPS, TROPOMI) space sensors to retrieve the vertical concentration profiles of primary gaseous pollutants including O_3 and CO.
  - Joint AIRS/OMI and CrIS/OMPS retrieved O_3 profiles can distinguish the abundances in the upper troposphere from the lower troposphere.
  - Joint CrIS/TROPOMI would help in extending the MOPITT CO profile data.

- The observation operators of joint AIRS/OMI data products enable data assimilation, e.g., “CHASER-DA”, demonstrating the significant impacts on ozone distributions.

- The O_3 and CO data products from MUSES algorithm could help in the quantitative attribution of anthropogenic emissions and natural influences of pollutants for NASA KORUS-AQ and NOAA FIREX.

Thank you for attention!

Questions?

KORUS-AQ Monthly Tag-up, Mon/Tue, 12/13 March, 7p/9a (US/KOR)

Evaluation of Large Point Source Emissions over South Korea using NASA KORUS-AQ Aircraft Field Campaign

Jung-Hun Woo et al.,

Konkuk University

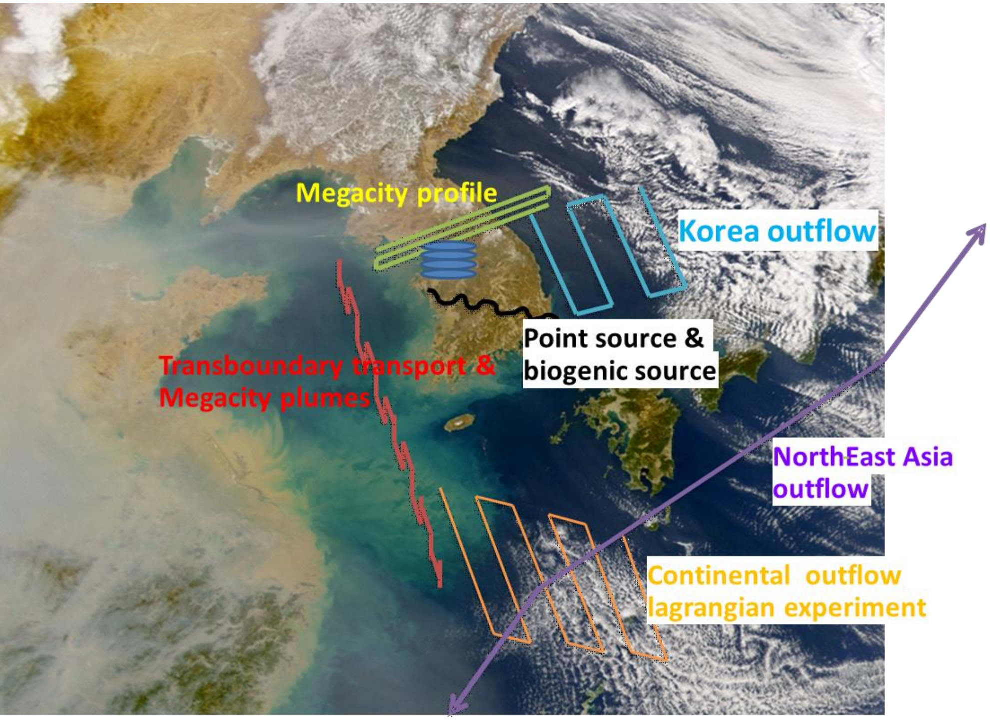
KORUS-AQ

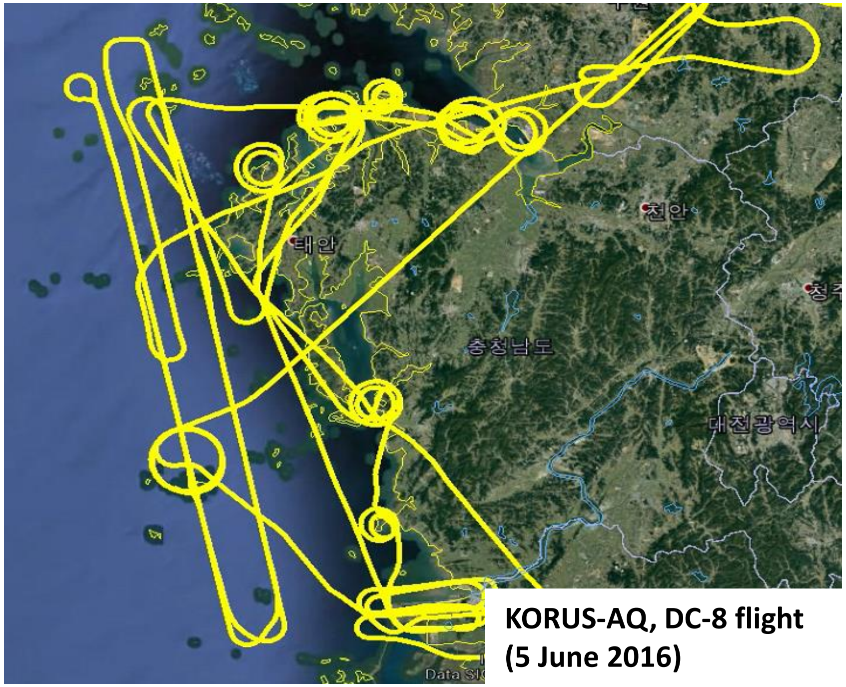
Science

- Better understanding of the factors controlling air quality
- Test and improve model simulations of air quality

Societal Impact

- Provide guidance on measures to improve air quality in Korea



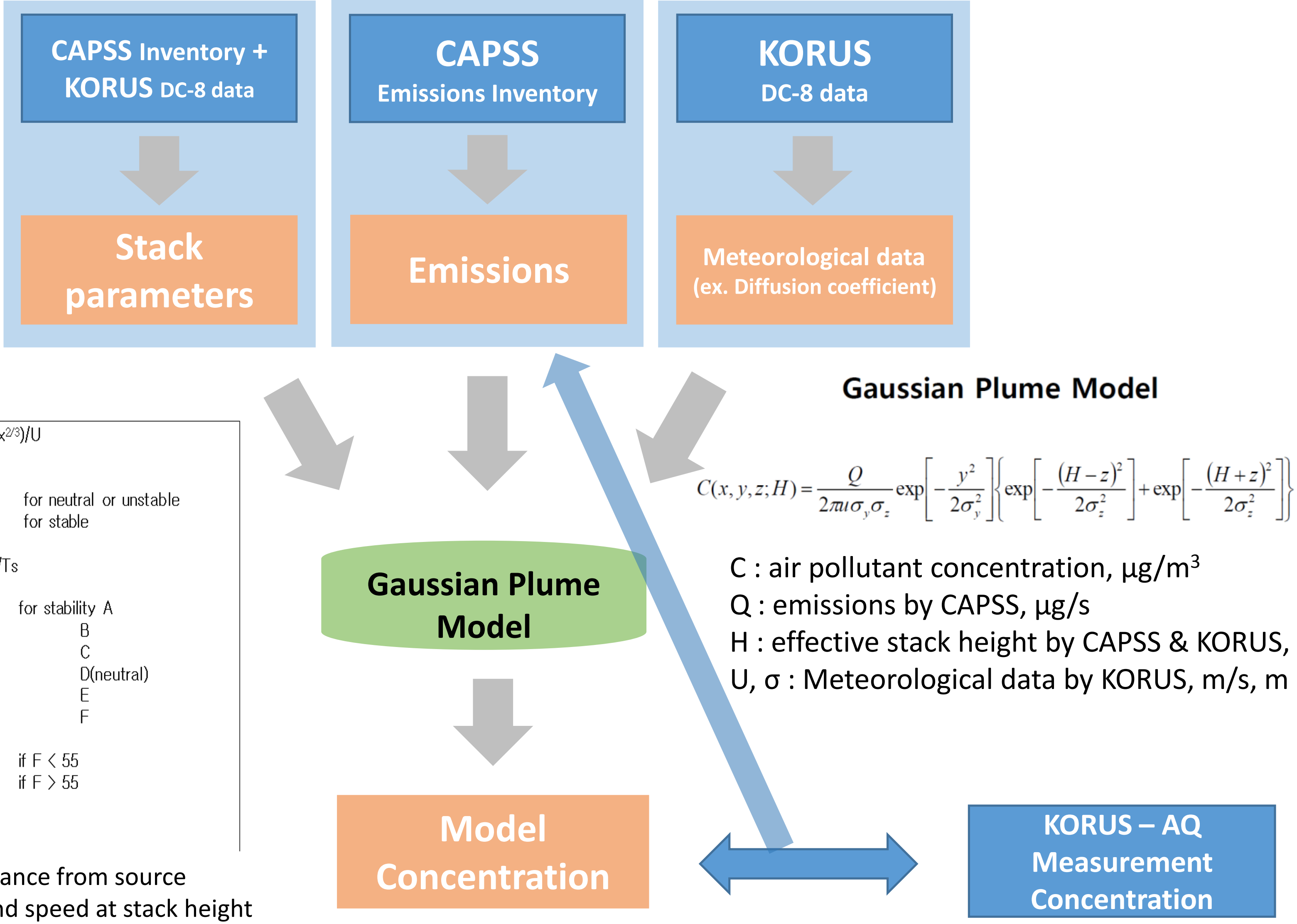


KORUS-AQ, DC-8 flight
(5 June 2016)

Evaluate LPS Emissions using the DC-8 flight (June 5, 2016)

- **LPS Emissions from KORUS Ver 2.0(CAPSS) data**
- **Measured concentrations of SO_2 and NO_x using DC-8 flight (Circular flight around stacks)**
- **SO_2 and NO_x concentrations were estimated using measurement-driven Gaussian plume model**
- **Inter-comparison of modeled and measured concentration would reveal validity of large point source emissions**

Methodology


CAPSS Inventory + KORUS DC-8 data → **Stack parameters**

CAPSS Emissions Inventory → **Emissions**

KORUS DC-8 data → **Meteorological data (ex. Diffusion coefficient)**

Gaussian Plume Model

Model Concentration

KORUS – AQ Measurement Concentration

Validation of emissions through comparison with measurements

Briggs Formular

1) If $x \le 3.5\,X$, $\triangle H = (1.6\,F^{1/3}\,x^{2/3})/U$
2) If $x > 3.5\,X$

(1) $\triangle H = (1.6F^{1/3}(3.5X)^{2/3})/U$ for neutral or unstable
(2) $\triangle H = 2.6(F/US)^{1/3}$ for stable

Where, $F = 2.45 V_s * d^2\,(T_s - T_a)/T_s$
$G = (9.8/T_a)(dT/dZ + 0.98)$

$dT/dZ \le -1.9$	for stability A
$-1.9 \sim -1.7$	B
$-1.7 \sim -1.5$	C
$-1.5 \sim -0.5$	D(neutral)
$-0.5 \sim 1.5$	E
> 1.5	F

$X = 14\,F^{5/8}$ if $F < 55$
$X = 34\,F^{2/5}$ if $F > 55$
X : distance from source (m)
$S = 0.02\,g/T_a$
$G = 9.81\ m/s^2$
$U/U0 = (Z/Z_0)^{0.25}$

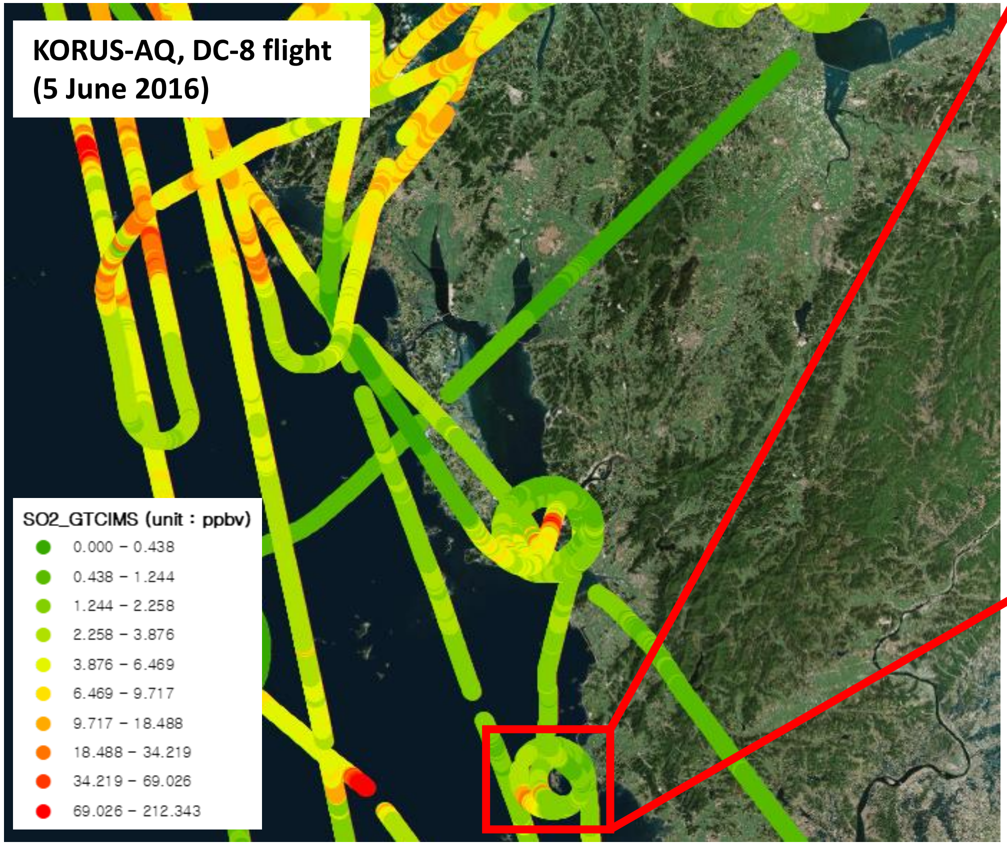
x : distance from source
U : wind speed at stack height
Vs : exhaust velocity
Ts : exhaust temperature
Ta : atmosphere temperature
d : stack inner diameter

Gaussian Plume Model

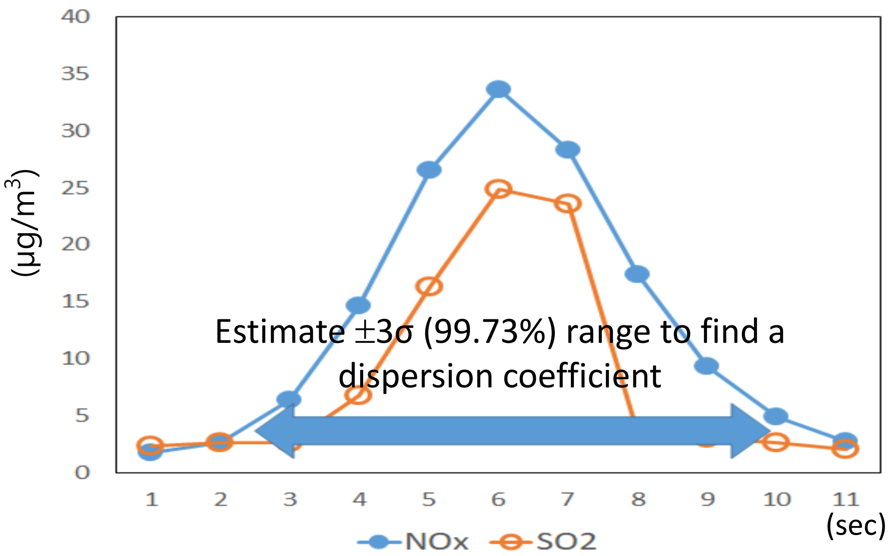
$$C(x,y,z;H) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left[-\frac{y^2}{2\sigma_y^2}\right]\left\{\exp\left[-\frac{(H-z)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(H+z)^2}{2\sigma_z^2}\right]\right\}$$

C : air pollutant concentration, $\mu g/m^3$
Q : emissions by CAPSS, $\mu g/s$
H : effective stack height by CAPSS & KORUS, m
U, σ : Meteorological data by KORUS, m/s, m

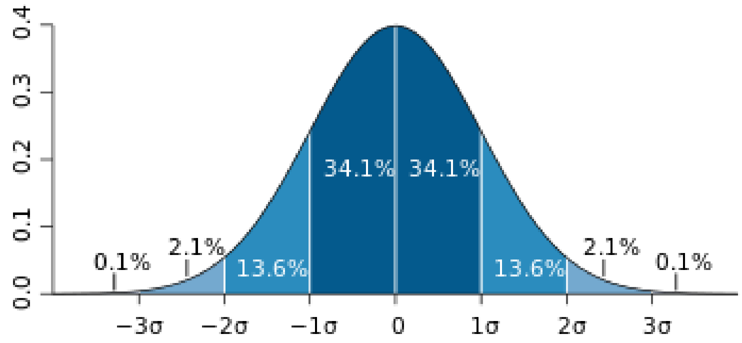
Dispersion coefficient



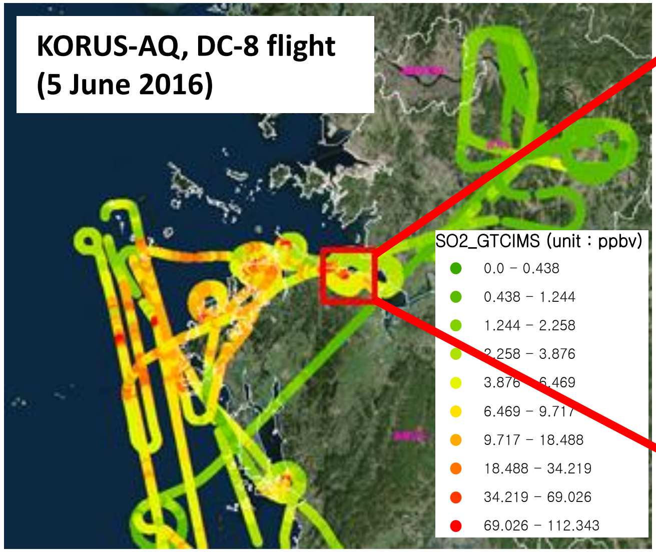
Source : In-situ CIMS measurements of PANs, SO2, and HCL



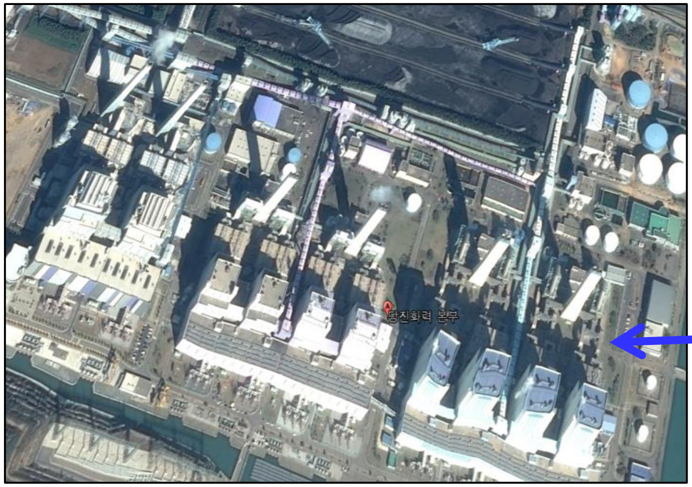
Estimate ±3σ (99.73%) range to find a dispersion coefficient

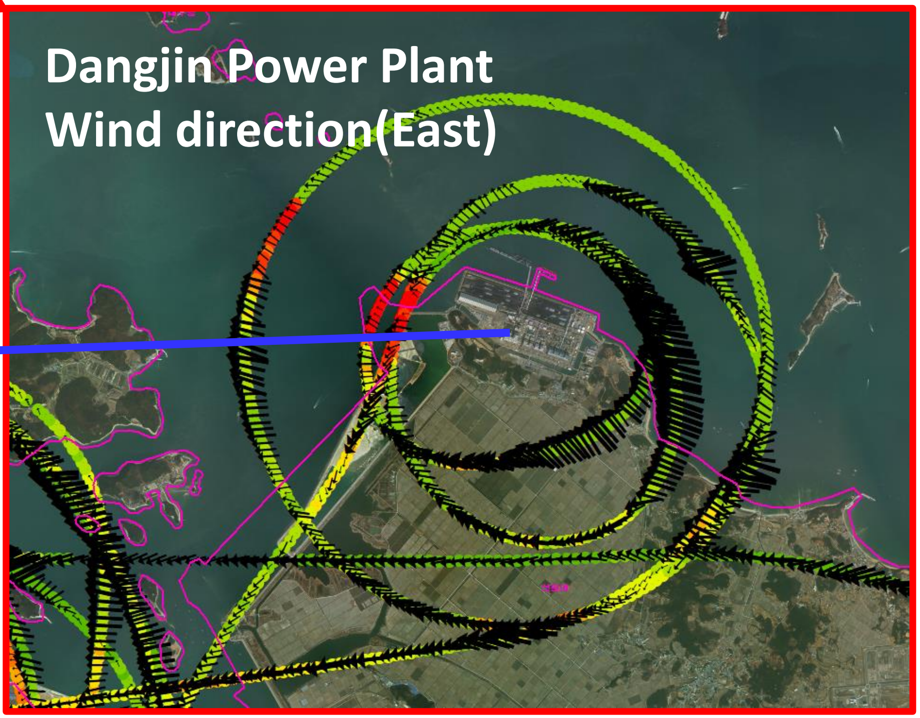


Emissions Evaluation



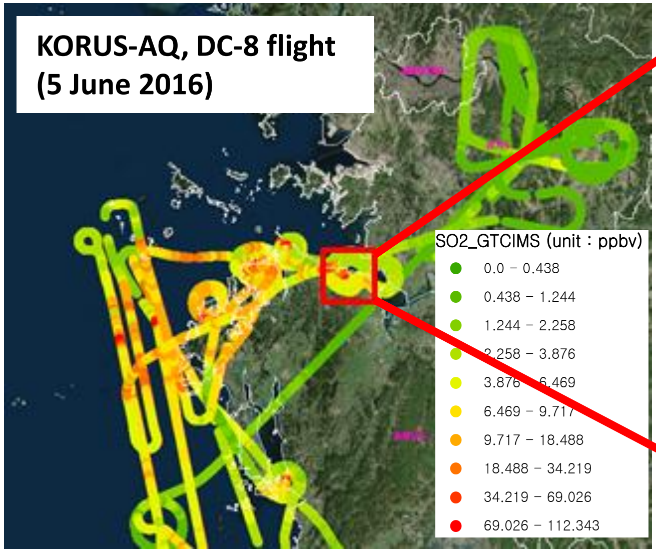
Source : In-situ CIMS measurements of PANs, SO2, and HCl



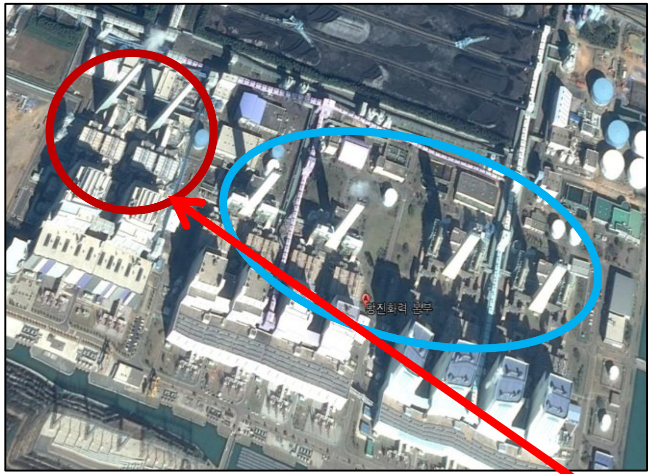


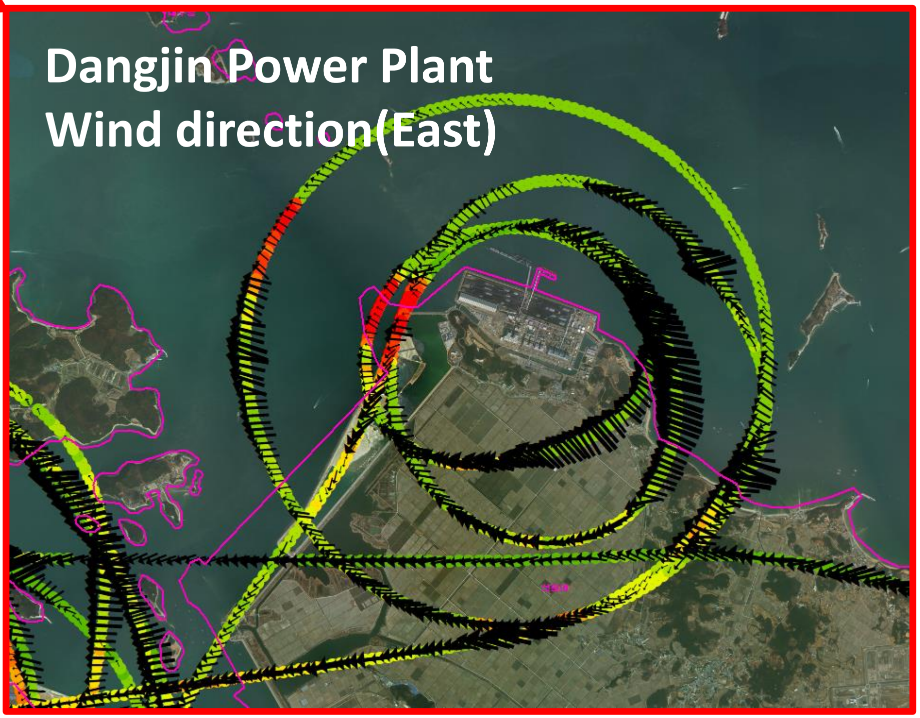
Ratio ($\frac{\text{Model}}{\text{Measurement}}$)	CAPSS 2013
SO_2	0.37

Emissions Re-evaulation



Source : In-situ CIMS measurements of PANs, SO2, and HCl



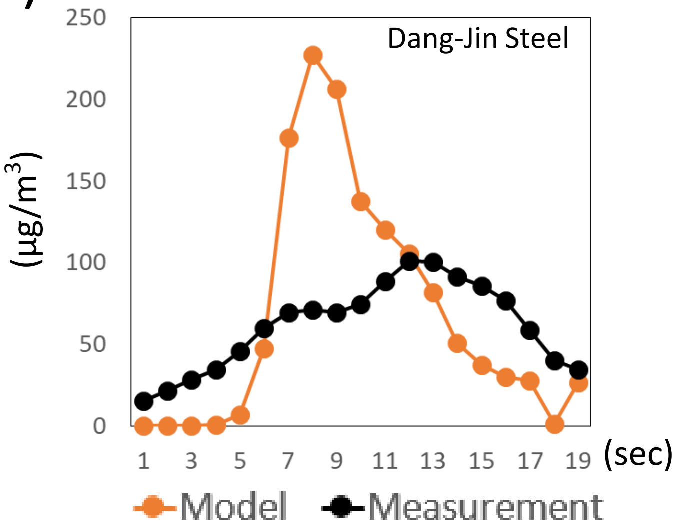


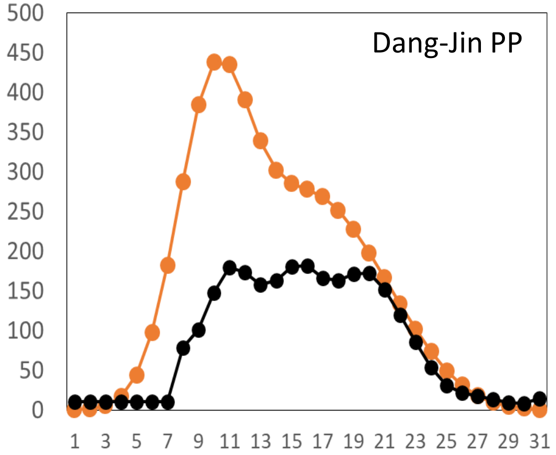
CAPSS 2013 : 4 Large Point Source Stacks

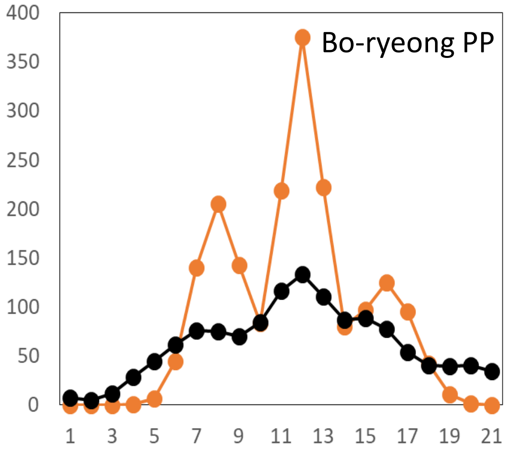
Updated CAPSS : 4 stacks plus 2 New Stacks

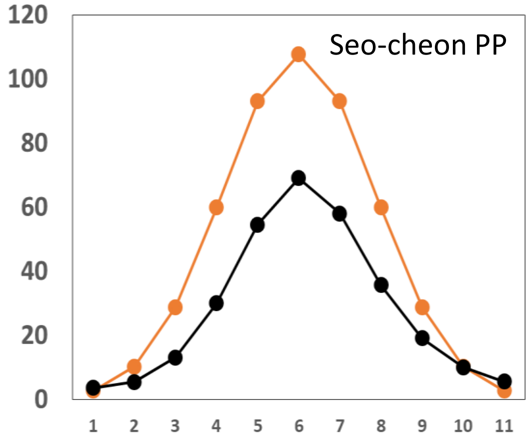
Ratio ($\frac{\text{Model}}{\text{Measurement}}$)	CAPSS 2013	Updated CAPSS
SO_2	0.37	0.71

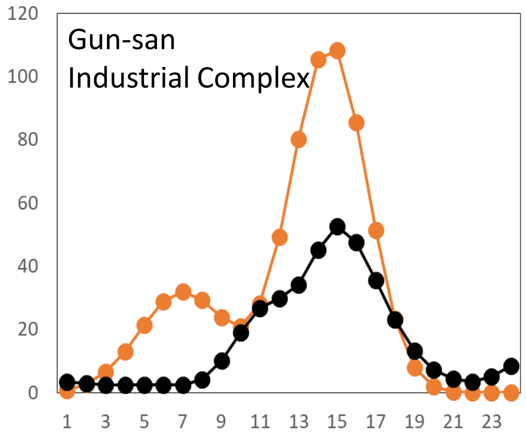
Result(NOx)





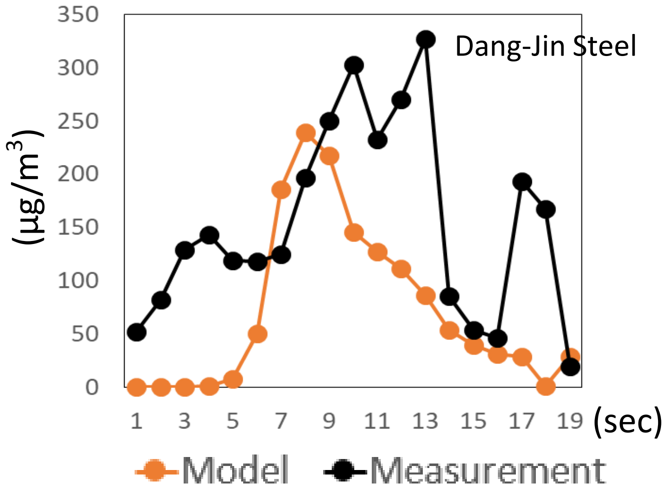


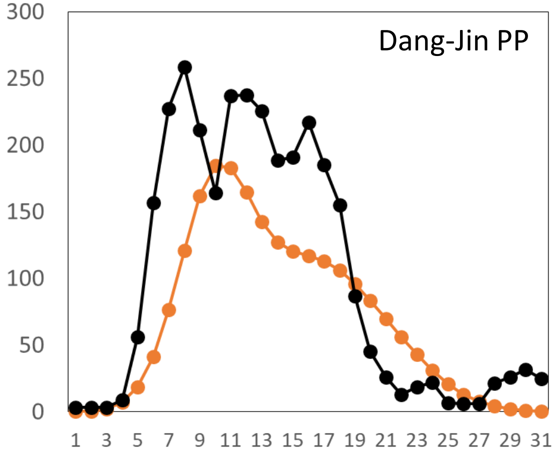


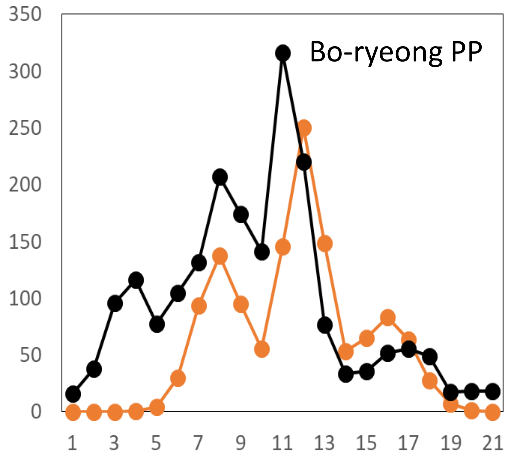


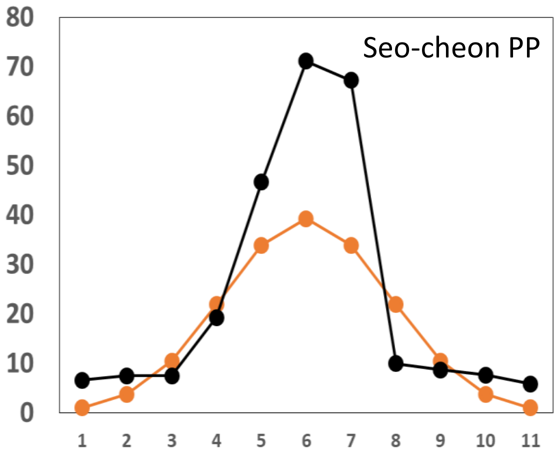
Concentration ratio (NOx)	Dang-jin steel	Dang-jin PP	Bo-ryeong PP	Seo-cheon PP	Gun-san Industrial Complex
Model/Measurement	1.57	1.52	1.66	1.64	1.77

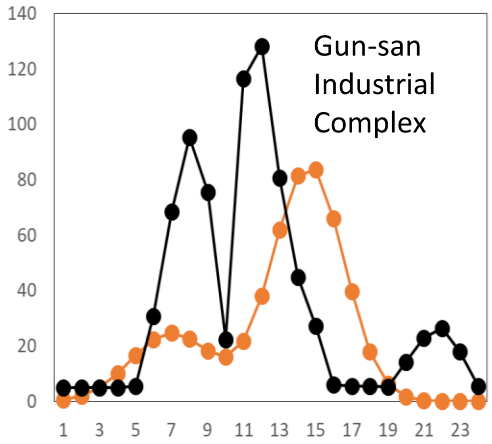
Result(SO_2)











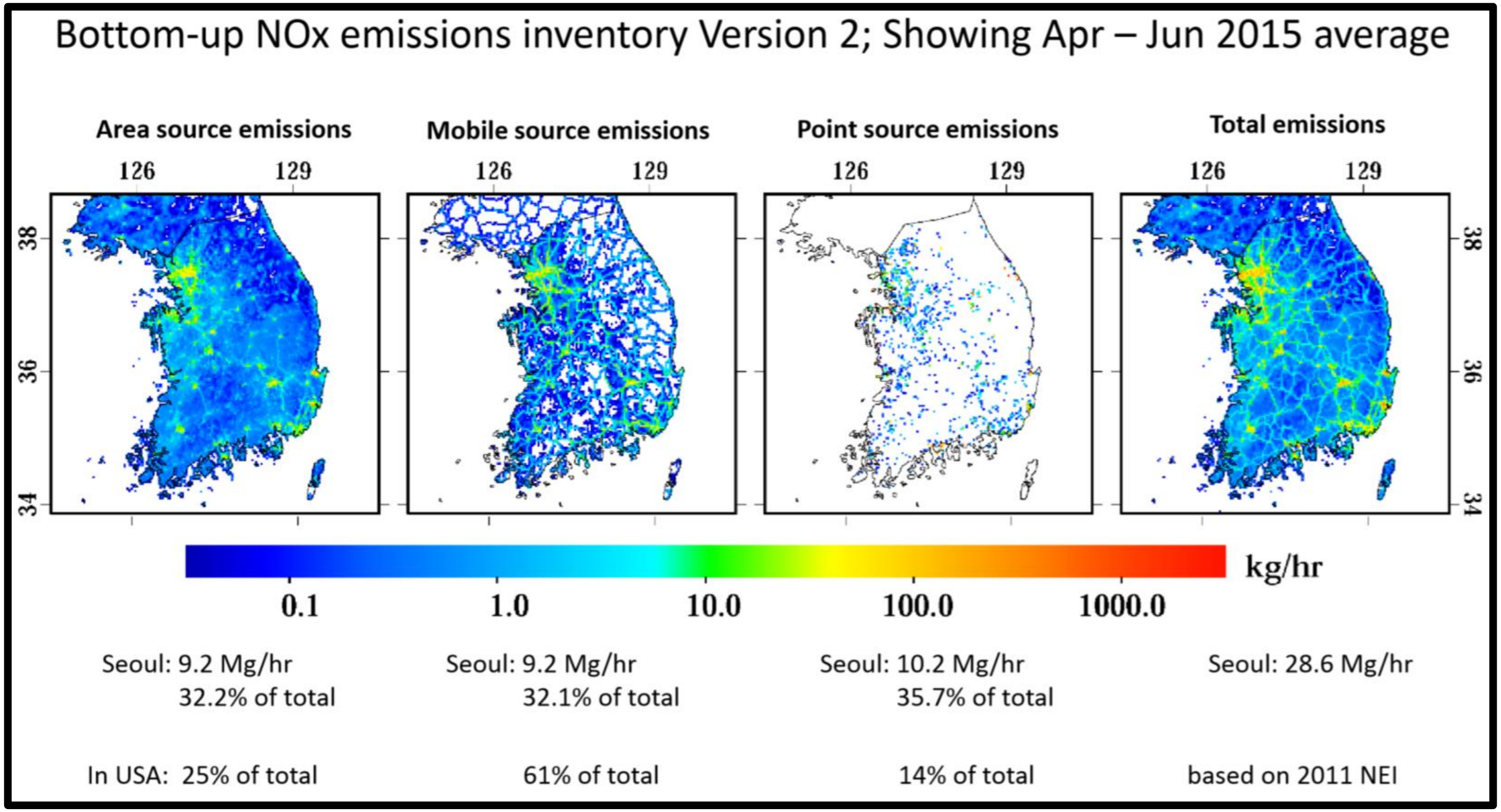
Concentration ratio (SO_2)	Dang-jin steel	Dang-jin PP	Bo-ryeong PP	Seo-cheon PP	Gun-san Industrial Complex
Model/Measurement	0.64	0.71	0.78	0.5	0.56

Summary

- We have evaluated NOx and SO2 Emissions from 5 LPSs over that western part of South Korea using the DC-8 June 5th flight
- SO2 and NOx concentrations were estimated using the KORUS Ver 2.0(CAPSS) LPS emissions data and measurement-driven Gaussian plume model
- Inter-comparison of modeled and measured concentration were conducted to understand validity of large point source emissions
- At 5 sites, NOx emissions seem to be overestimated (ratio from 1.52 to 1.77) and SO_2 seem to be underestimated(ratio from 0.5 to 0.78)
- Evaluation of the model-measurement ratio helped improving emissions information in case of the Dangjin Power Plant

Re-validation of KORUS v2.0 Emissions

From the last WebEx (Dan's presentation) : A high-resolution OMI NO2 product for Korea during KORUS-AQ and using it to derive NOx emissions in Seoul



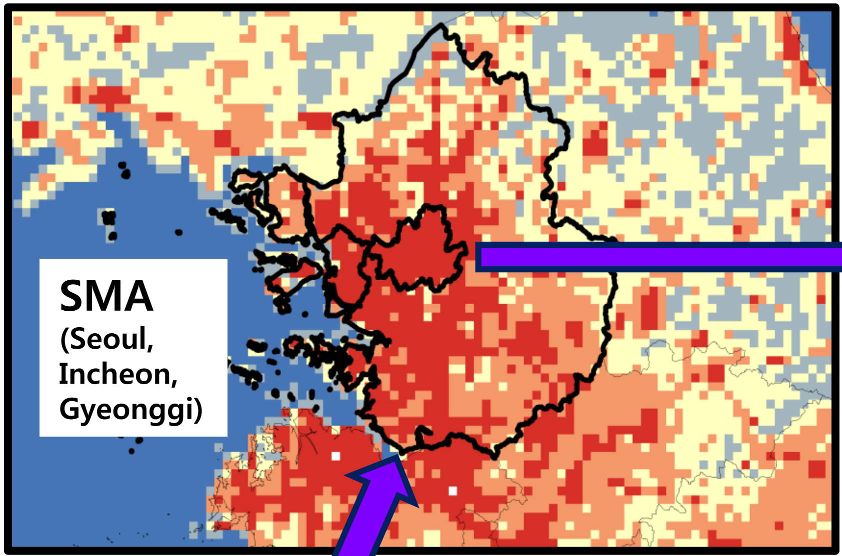
Bottom-up NOx emissions inventory Version 2; Showing Apr – Jun 2015 average

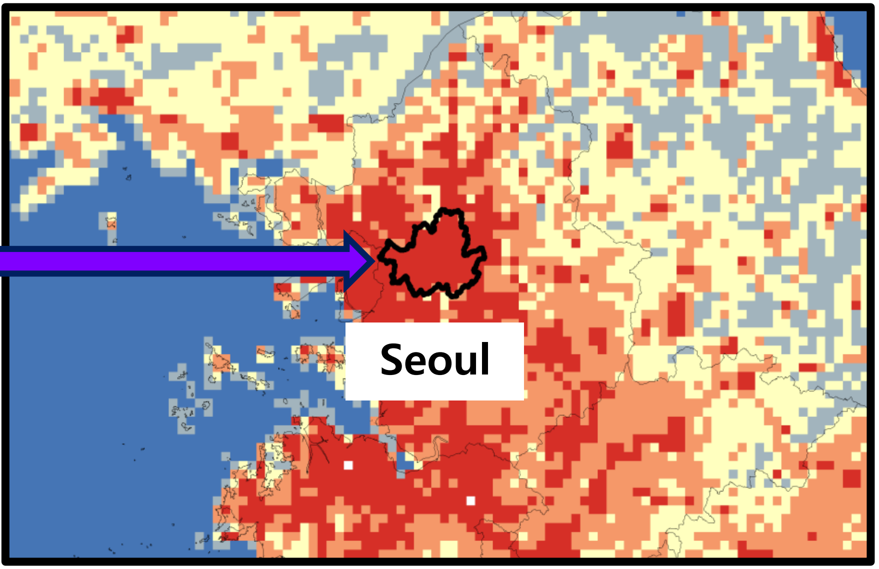
Area source emissions	Mobile source emissions	Point source emissions	Total emissions
Seoul: 9.2 Mg/hr 32.2% of total	Seoul: 9.2 Mg/hr 32.1% of total	Seoul: 10.2 Mg/hr 35.7% of total	Seoul: 28.6 Mg/hr
In USA: 25% of total	61% of total	14% of total	based on 2011 NEI

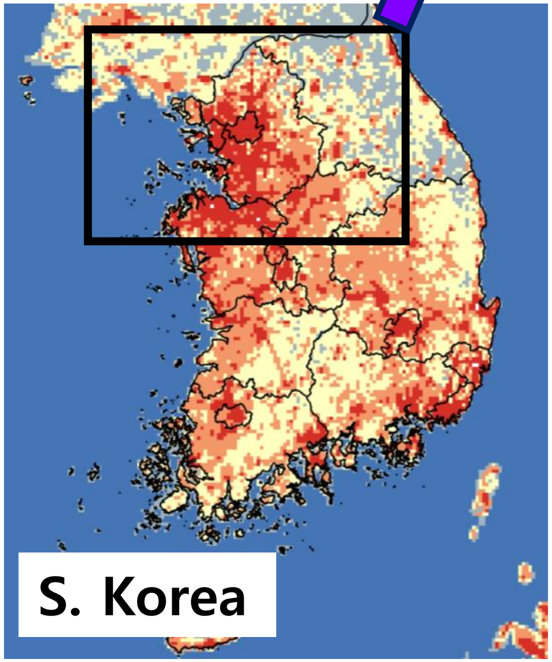
We have double-checked the emission of KORUS v2.0 over these domains. Just to make sure…

Double-checking KORUS v2.0 Emissions

NO_x Emissions(May 2015)







Region	Type	KORUS ver 2.0	
		NOx (kton/yr)	Ratio
S. Korea	Area	311.5	31.5%
	Mobile	304.9	30.8%
	Point	372.9	37.7%
	Total	989.4	100.0%
SMA	Area	90.4	32.4%
	Mobile	114.9	41.2%
	Point	73.7	26.4%
	Total	279.0	100.0%
Seoul	Area	33.4	50.7%
	Mobile	30.0	45.6%
	Point	2.4	3.7%
	Total	65.9	100.0%

ANL (Dan)		
NOx(kton/yr)	Ratio_Seoul	Ratio_USA
80.6	32.2%	25%
80.6	32.2%	61%
89.4	35.7%	14%
250.5	100.0%	100%

Dan's emission amounts are similar to SMA's, not Seoul's. The ratios are similar to those of South Korea. So, we may need to check domain definition

For KORUS emissions, nonroad mobile emissions were included in the area source. If we add them to the mobile source, we have pretty similar ratio to USA's (SMA A:M:P is 13: 61: 26).

Another Issue in NOx Emissions

- We've used SMOKE to process emissions inventory. The SMOKE and CMAQ use the molecular weight of 46 for both NO and NO_2 because they use EPA's "NO_2 equivalency" concept. The users of KORUS emissions dataset should use MW of 46 (not 30 for NO) for both species. It may cause NO_x emissions underestimation otherwise. FYI, the default emissions speciation ratio we have used for NO : NO_2 is 90 : 10.

```
0000  NO                 NO                               1            30          1
0000  NOX                NO                            0.90            46       0.90
0000  NOX                NO2                           0.10            46       0.10
0000  OVOC               ALK2                          0.85           148       0.85
0000  OVOC               OLE2                           0.1           148        0.1
0000  PM                 AERO                             1             1          1
0000  PM2_5              PM2_5                            1             1          1
0000  PM10               PM10                             1             1          1
```

Thank you!