Mission Overview: Geostationary Environment Monitoring Spectrometer (GEMS)

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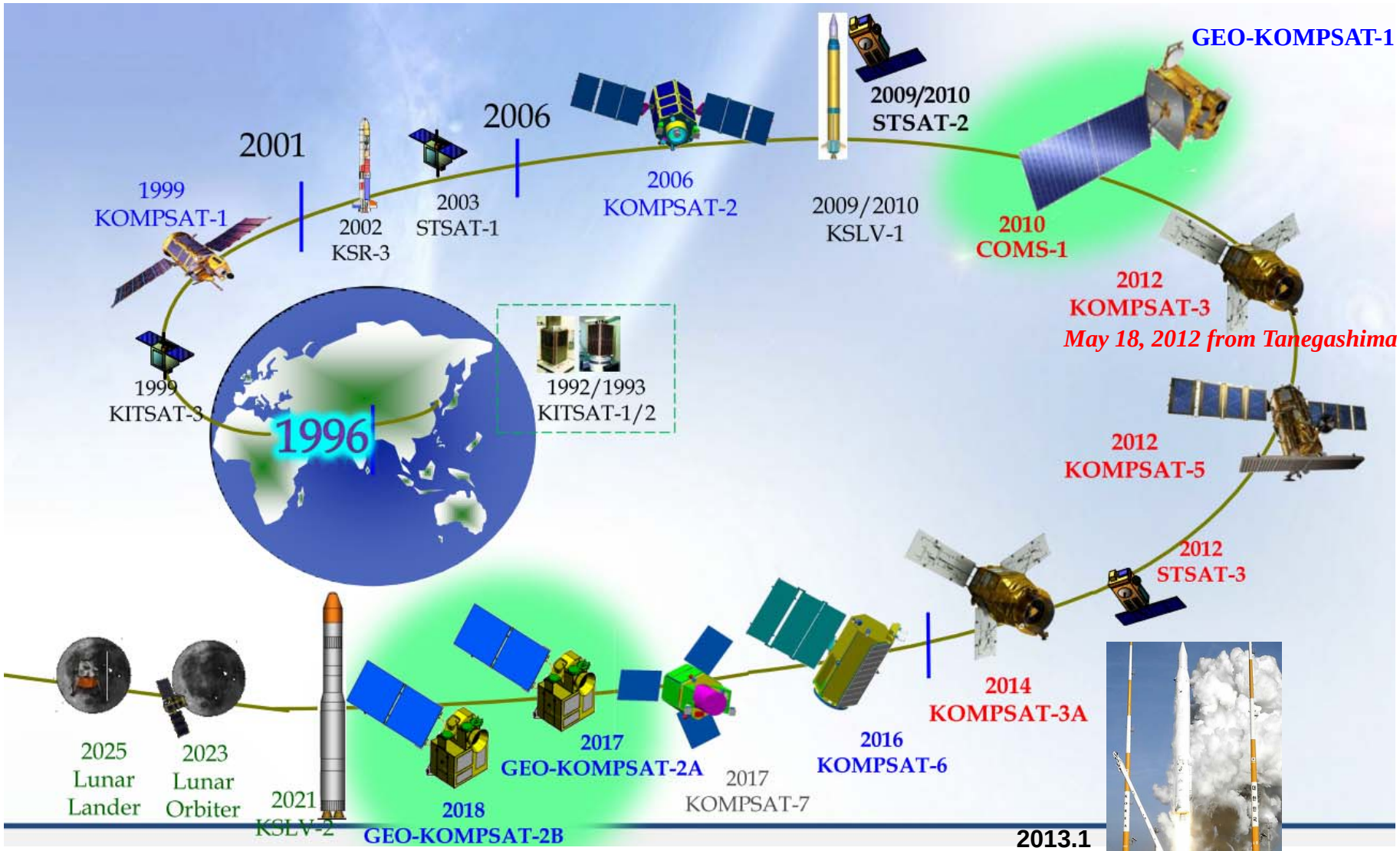
National Space Program of Korea



Geostationary Constellation of UV-Vis spectrometer & Meteorological Payload

Constellation of GEO Mission for Synergistic Products

TEMPO
+ GOES-R
(America)

EPA

UV-Vis
290-690 nm

CfA

KARI

GEMS + AMI + GOCI2
GEO KOMPSAT
(Asia)

UV-Vis 300-500 nm

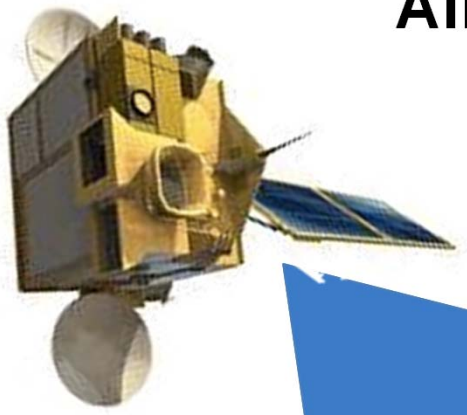
esa

UV-Vis-NIR
305-500, 750-775 nm

GMES S4 UVN
+ FCI + IRS
MTG (Europe)

Constellation synergy
- Improving spatial and temporal coverage
  to monitor globalized pollutants & SLCF
- Sharing basic requirements on data products and
  instrument to maintain data quality
- Consolidating socio-economic benefit analysis
- Supporting QA and CAL/VAL

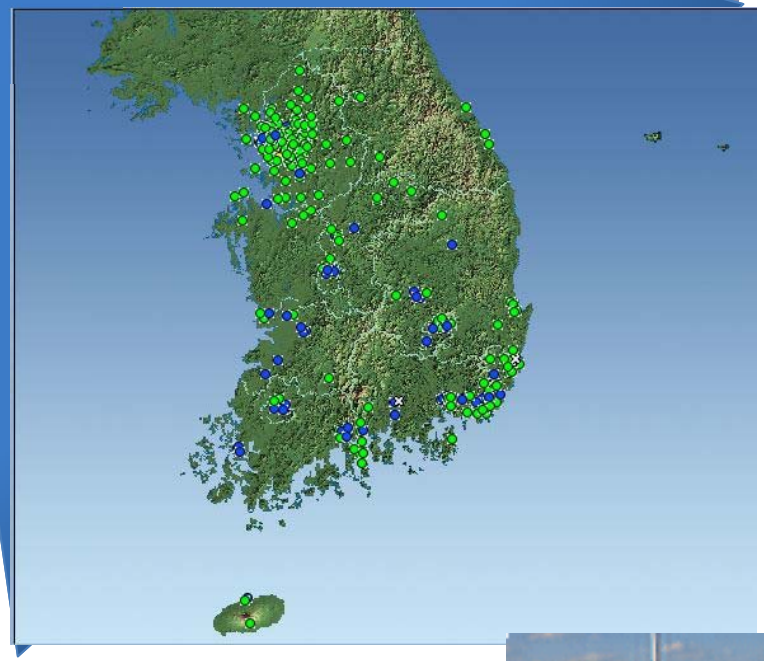
Air Korea Network and Forecast

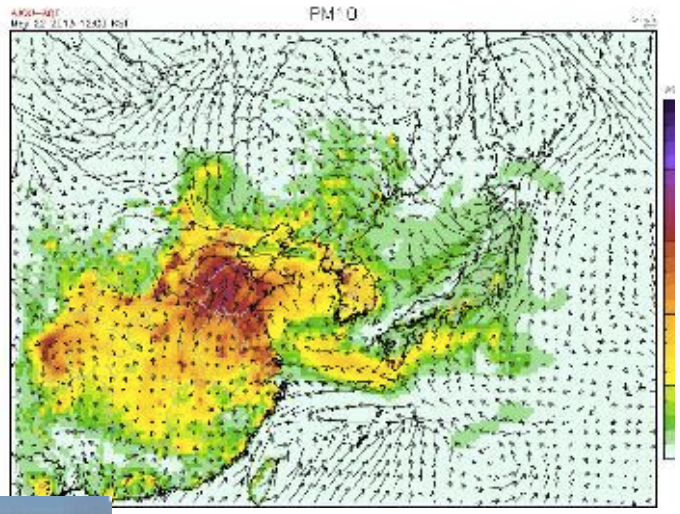


GEMS

Airborne

Air quality forecast





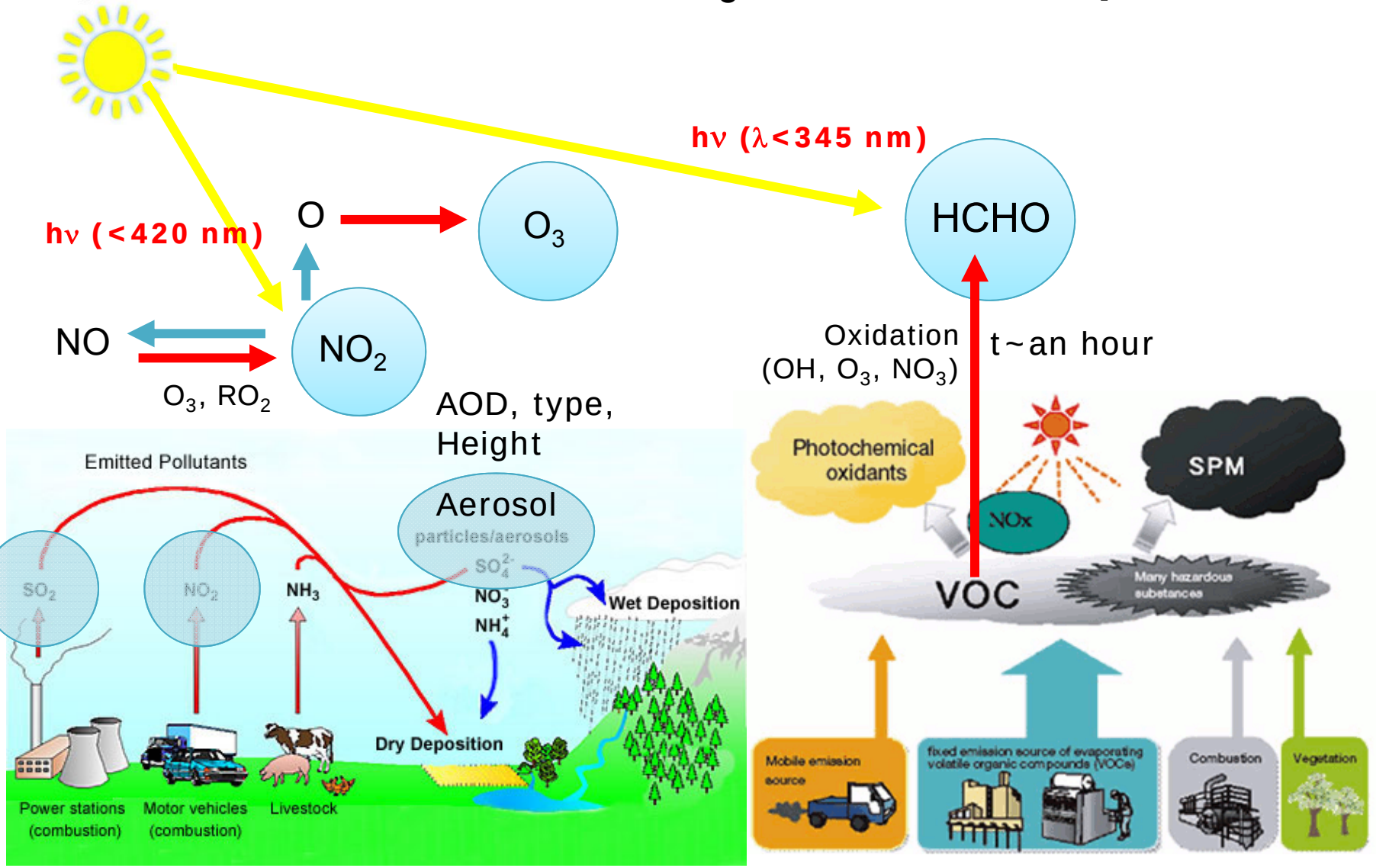
- **Campaigns:**

DRAGON-NE Asia
KORUS AQ

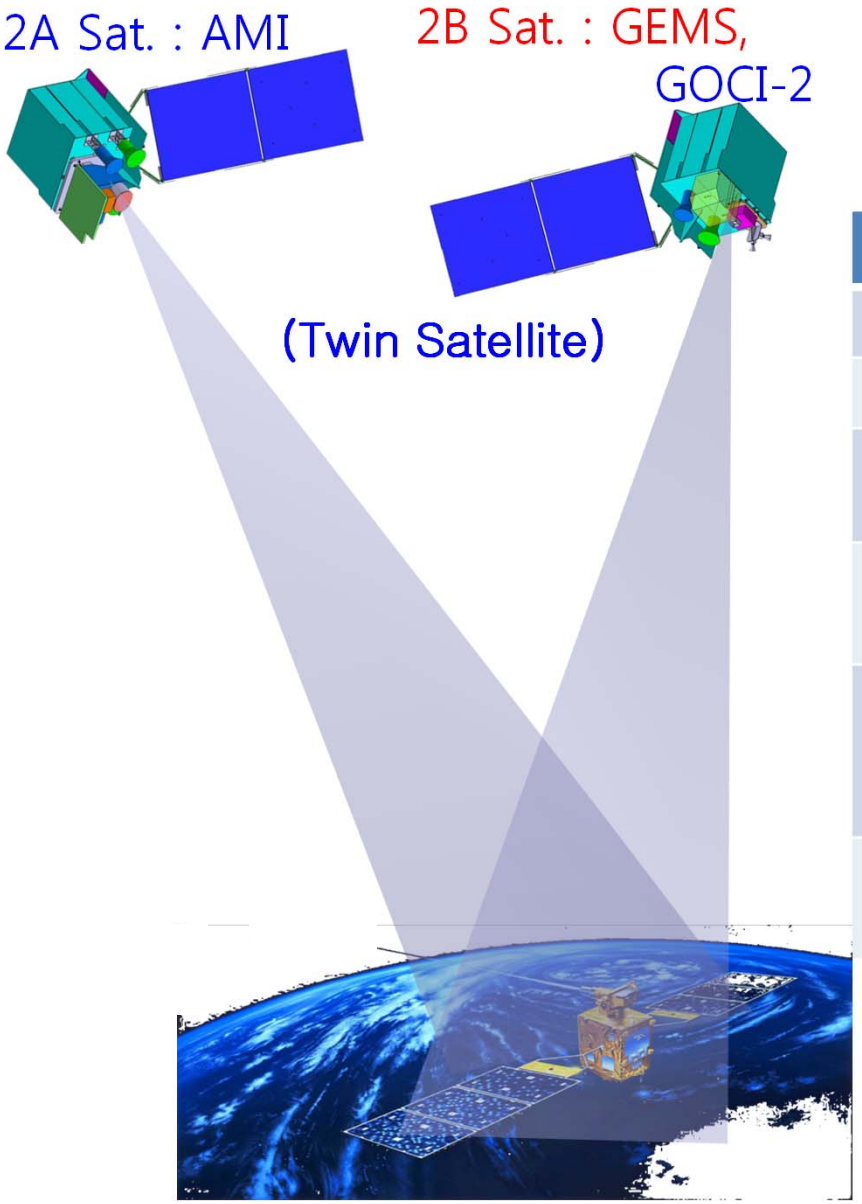
- **Air Korea**

PM10, O_3, NO_2, SO_2, CO
http://www.kaq.or.kr

Objective: Measurements of O_3 & aerosol with precursors



GEO-KOMPSAT 2



- Launch: May 2018(2A), Mar. 2019 (2B)

Specification

	2A	2B	
Payload	AMI	GOCI-2	GEMS
Lifetime		10 years	
Channels	16	13	1000
Wavelength range	0.4 - 13 μm	375 - 860 nm	300-500 nm
Spatial resolution	0.5 / 1 km (Vis) 2 km (IR)	250 m@ eq 1 km (FD)	7 x 8 km^2 @ Seoul
Temporal resolution	10 min (FD)	1 hour	1 hour

Status of GEMS

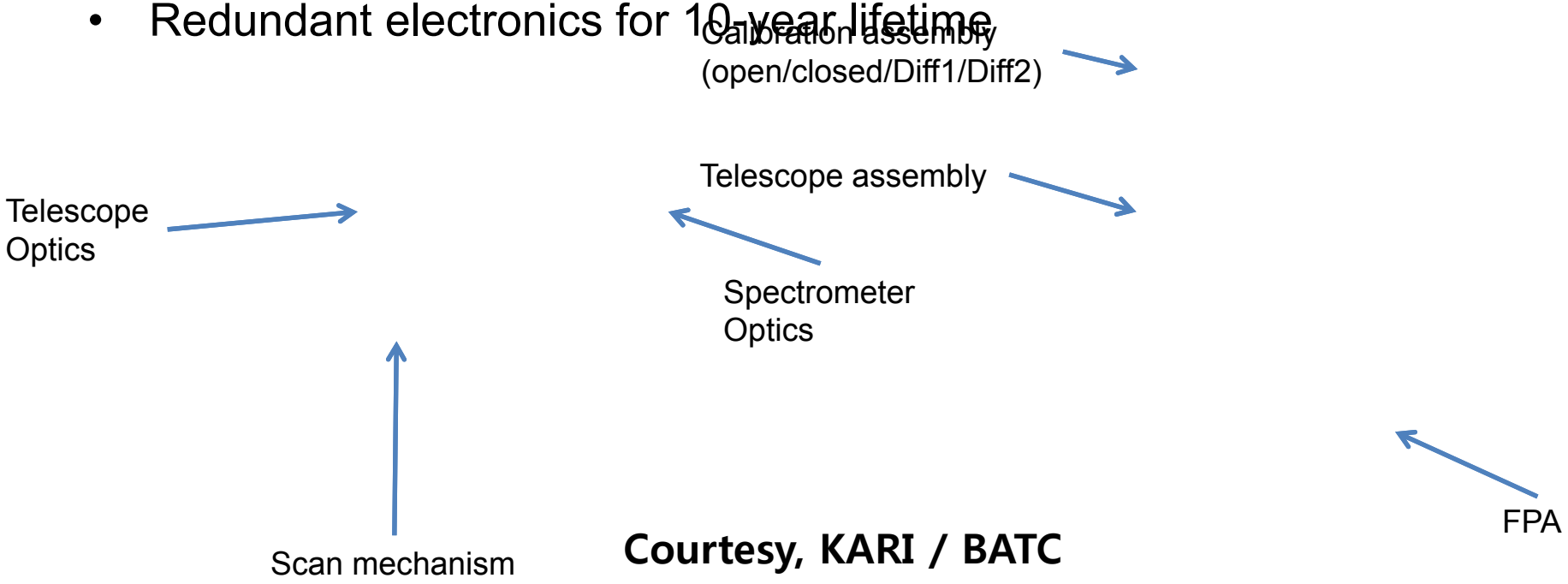
- **GEO-KOMPSAT-2 Program**
  - SRR in Apr., 2012; SDR in Feb. 2014, PDR in Jul., 2014
- **Budget**
  - GEMS Program passed Mid-term review on Dec. 4, 2013, and now is in Main Phase till launch. (* Launch : Mar., 2019)
- **Prime Contractor**
  - Ball Aerospace & Technologies Corp.(selected on May 13th, 2013)

    * AMI contract with ITT; GOCI-2 contract with Astrium
- **GEMS Development**
  - SDR in Oct., 2013, PDR in Mar., 2014, CDR in Feb., 2015
  - GEMS Telescope shall be assembled, aligned, and tested at KARI in 2015 (JDAK)
  - GEMS System integration and test shall be performed in 2016
  - GEMS shall be delivered to KARI from BATC spring of 2017
- **Changes in Environment**
  - Air quality forecast in operation since 2013 by NIER/ME

    → GEMS to be an operational sat. (e.g. data assimilation of model with sat. data)
  - 'KORUS-AQ' airborne campaign planned in 2016 (with GEOTASO)

GEMS Design

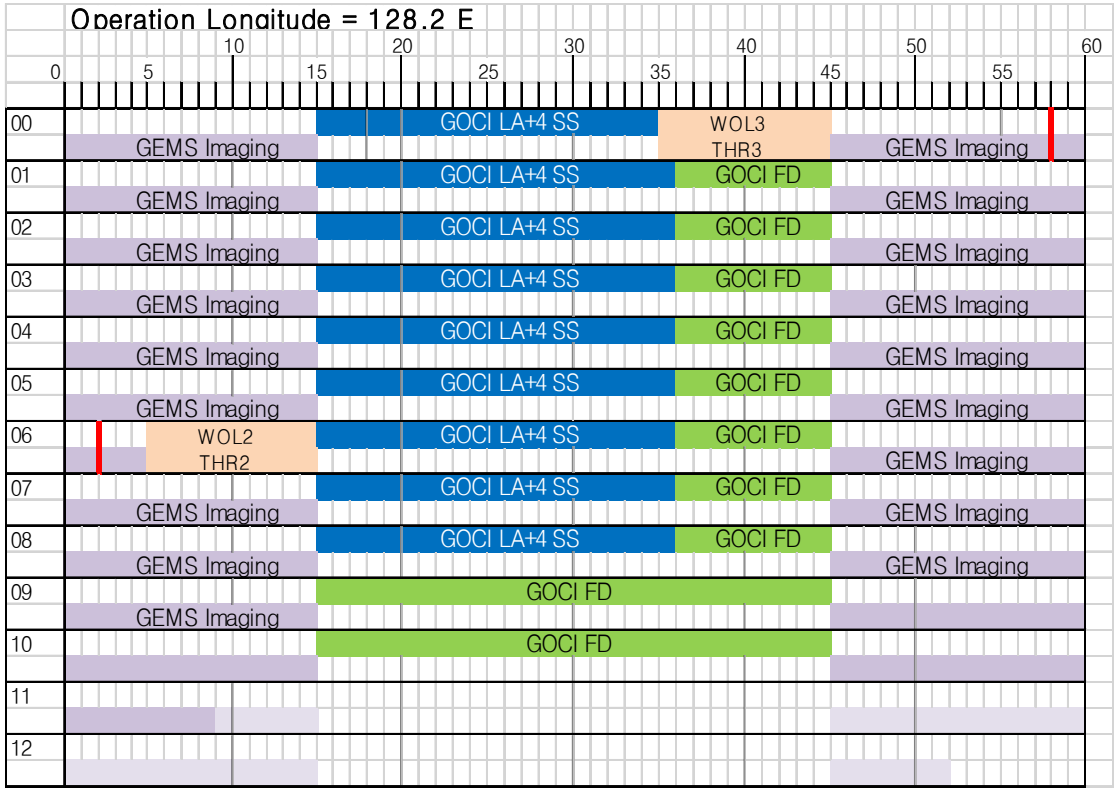
- Step-and-stare UV-Visible imaging spectrometer scanning at least 8 x per day in 30 minutes
- Daily solar and dark calibration
- images coadded at each position + mirror move back < 30 minutes
- Scanning Schmidt telescope and Offner spectrometer
- Diffusers for on-orbit solar calibration and onboard LED light sourc e
- 2-axis scan mechanism with gyro feed capability
- Redundant electronics for 10-year lifetime



Courtesy, KARI / BATC

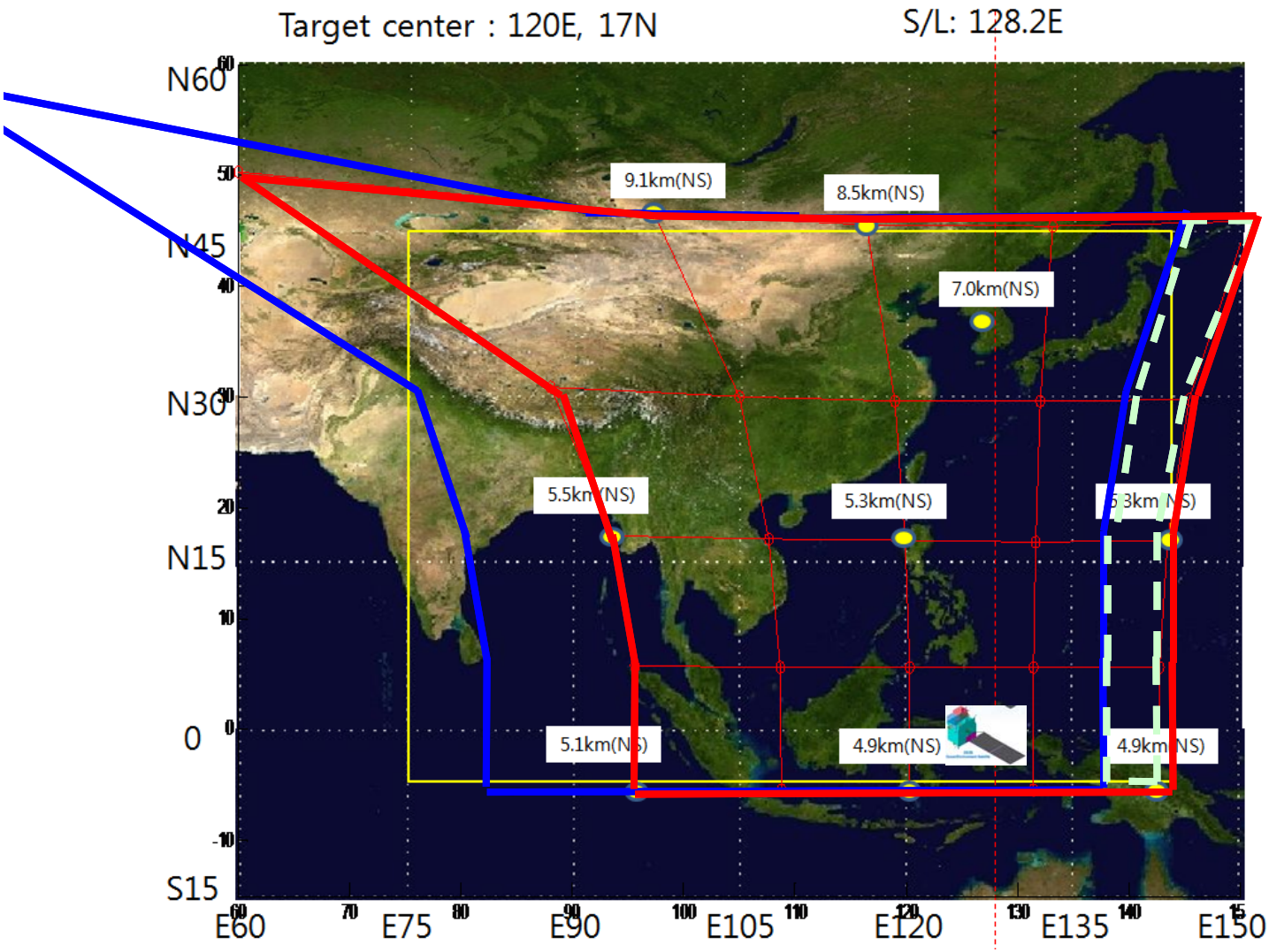
GEMS Concept of Operations

- GEMS Observation Timeline(TBD)



- GEMS/GOCI-II have the same priority.
  - 30minutes for GEMS mission and another 30 minutes for GOCI-II mission
- Wheel offloading will be performed in one of GEMS & GOCI-II imaging slots
  - 4 consecutive months in GEMS slots and another 4 consecutive months in GOCI-II slots

Projected FOV & GSD - NS GSD @ Seoul : 7.0km



Projected FOV

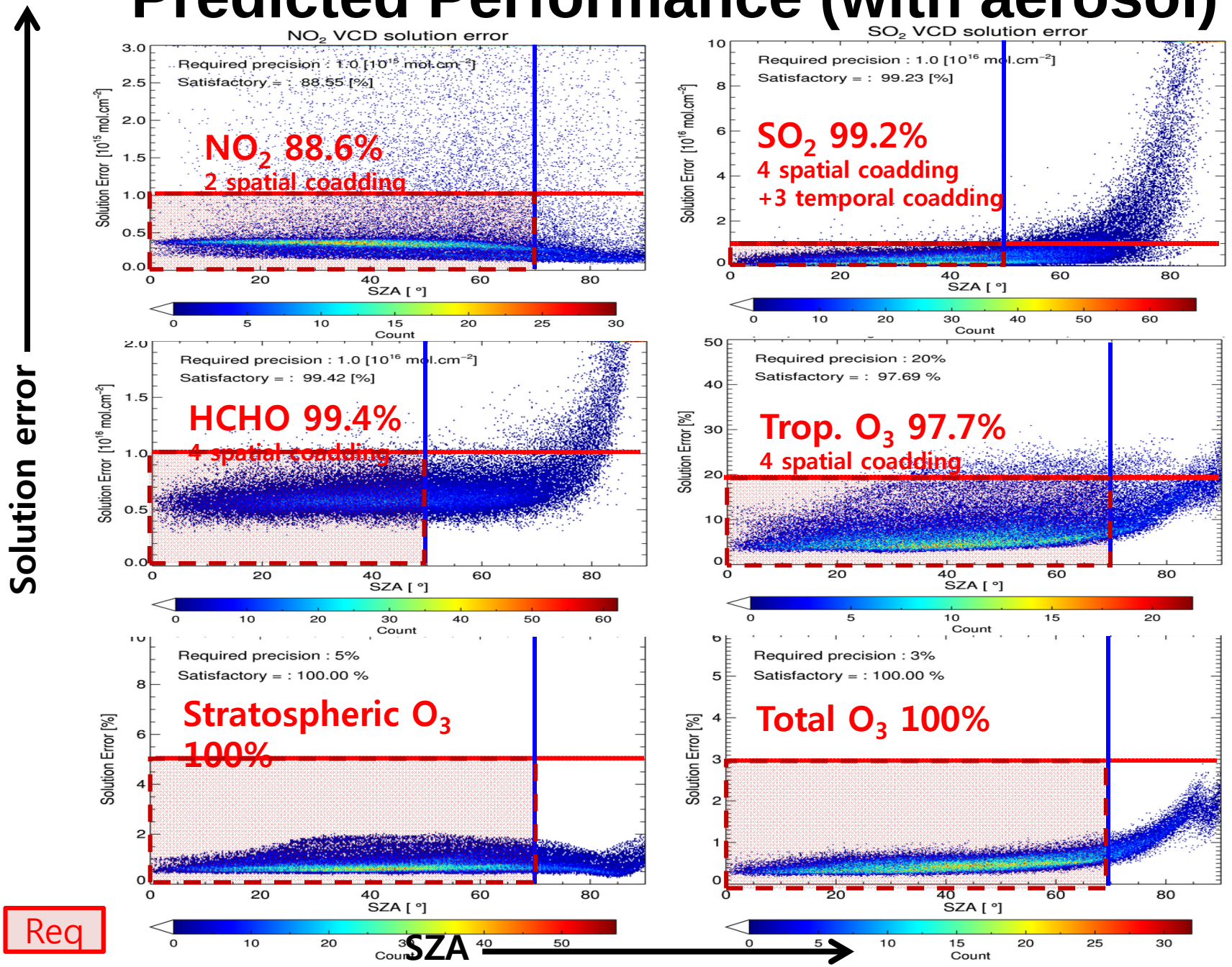
Region of interest

Normal operation **For clear sector method**

Baseline products

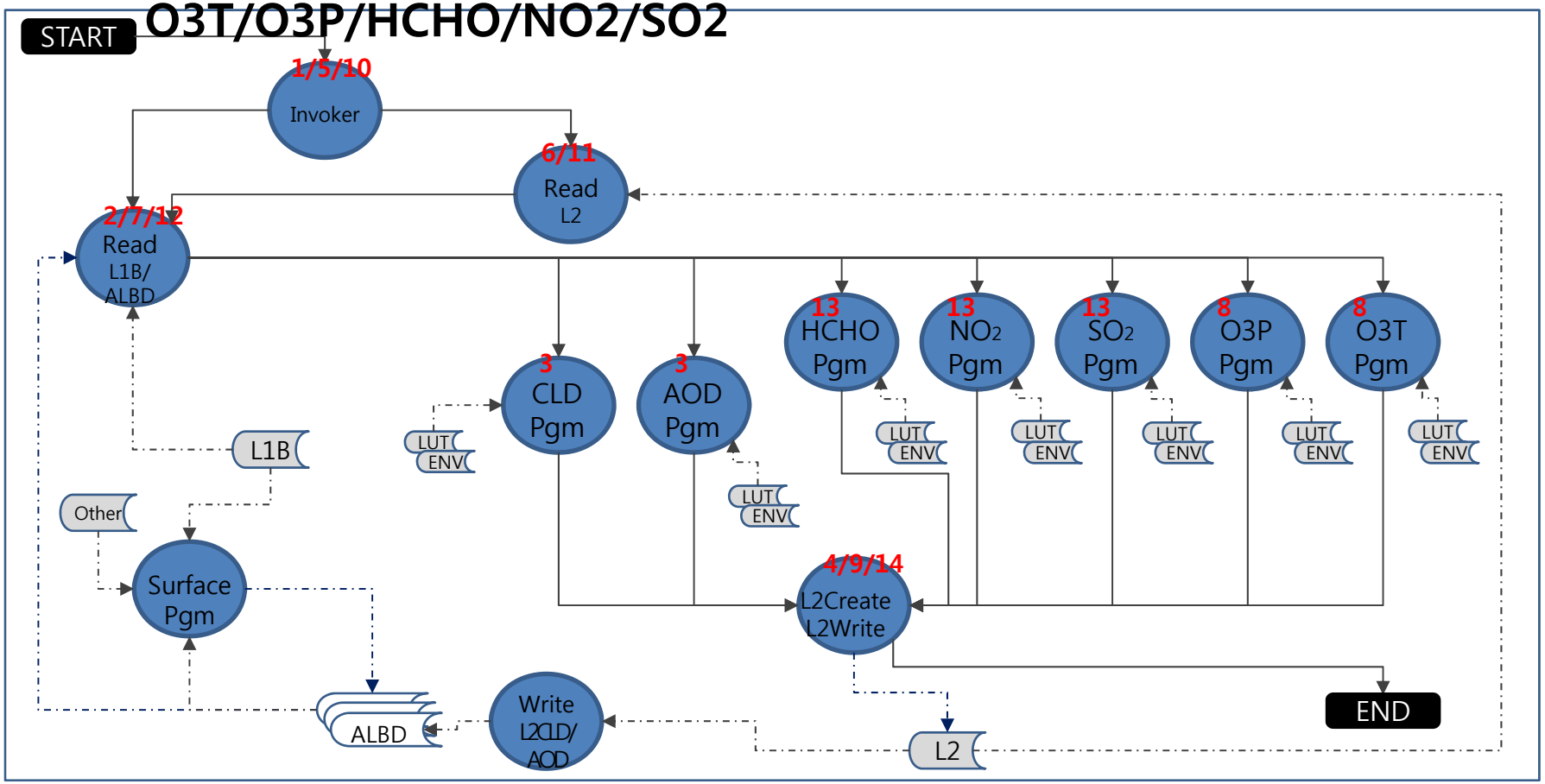
Product	Impor-tance	Min (cm^{-2})	Max (cm^{-2})	Nominal (cm^{-2})	Accuracy	Spectral window (nm)	Spatial Resolution Km^2 @ Seoul	SZA (deg)	Retriev-al
NO_2	Ozone precursor	$3x10^{13}$	$1x10^{17}$	$1x10^{14}$	$1x10^{15}$	425-450	7 x 8 x 2 pixels	< 70	DOAS
SO_2	Aerosol precursor	$6x10^{8}$	$1x10^{17}$	$6x10^{14}$	$1x10^{16}$	310-330	7 x 8 x 4 pixels x 3 hours	< 50 (60*)	
HCHO	Proxy for VOCs	$1x10^{15}$	$3x10^{16}$	$3x10^{15}$	$1x10^{16}$	327-357	7 x 8 x 4 pixels	< 50 (60*)	
O_3	Oxidant, pollutant	$4x10^{17}$	$2x10^{18}$	$1x10^{18}$	3%(TOz) 5%(Strat) 20%(Trop)	300-340	7 x 8	< 70	TOMS, OE
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	OE O_2-O_2
Clouds	Data quality, climate	0 (COD)	50 (COD)	17 (COD)		300-500	7 x 8		Raman, O_2-O_2
Surface Property	Environ-ment	0	1	-		300-500	7 x 8		Multi-spectral

Predicted Performance (with aerosol)

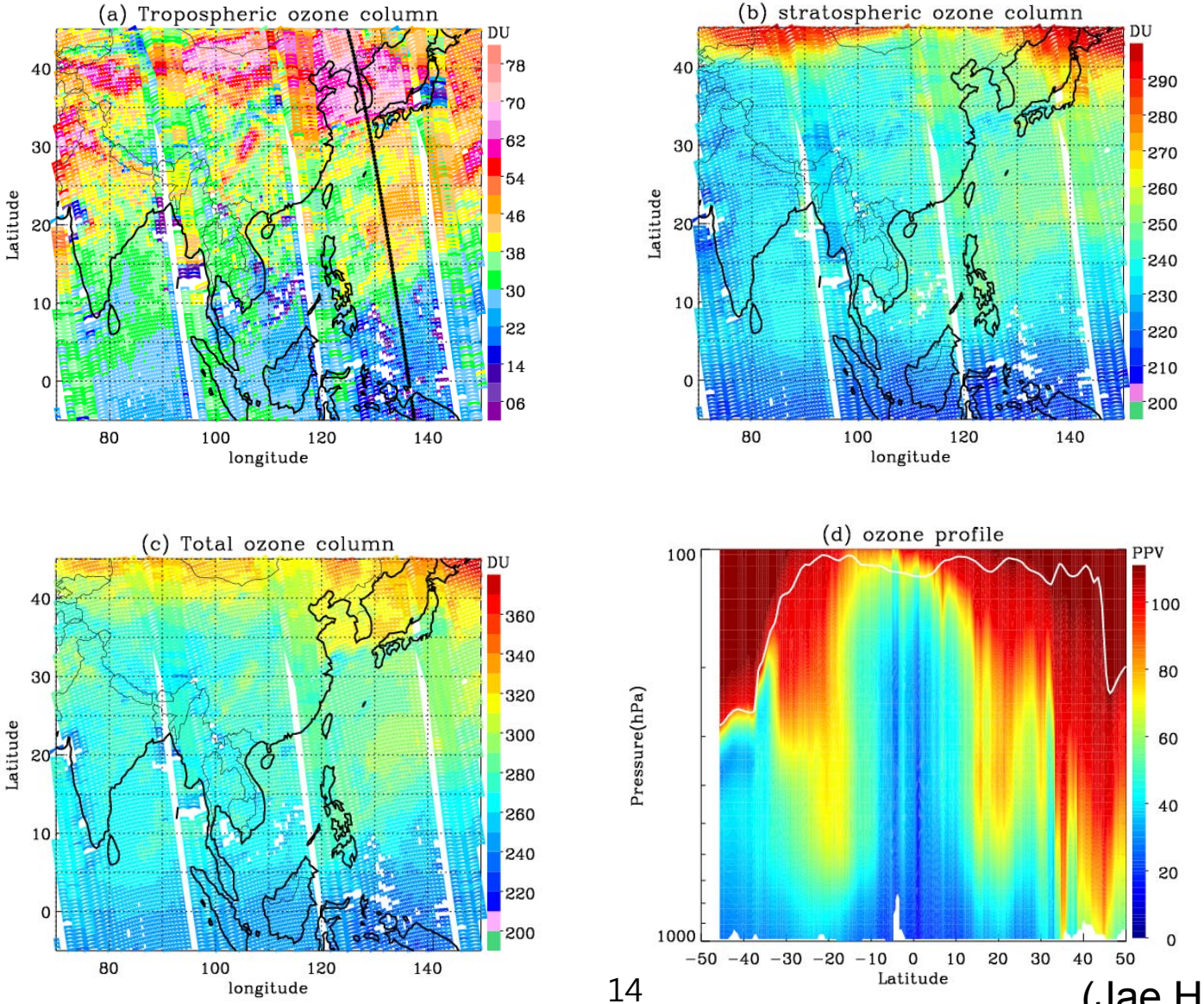


Unified Data Retrieval Algorithm

- Basic design for the unified algorithm to be operated at system level
- In the order of CLD/SFC/AOD, then O3T/O3P/HCHO/NO2/SO2



Example of retrieved ozone using OMI (July 1st, 2007)

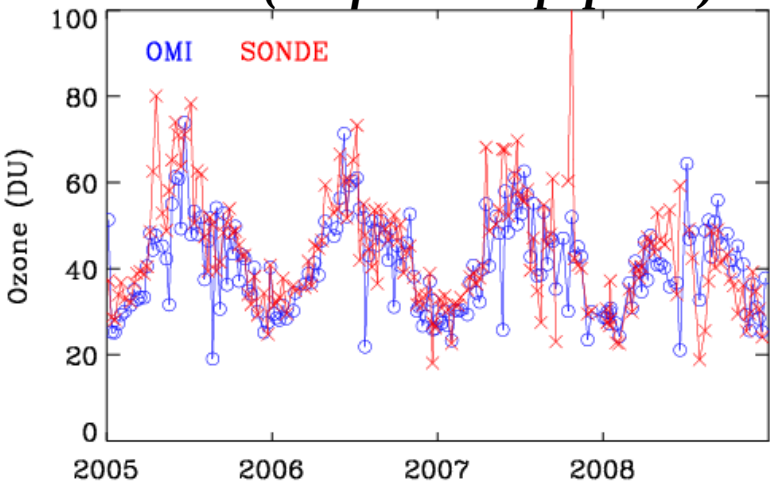


14

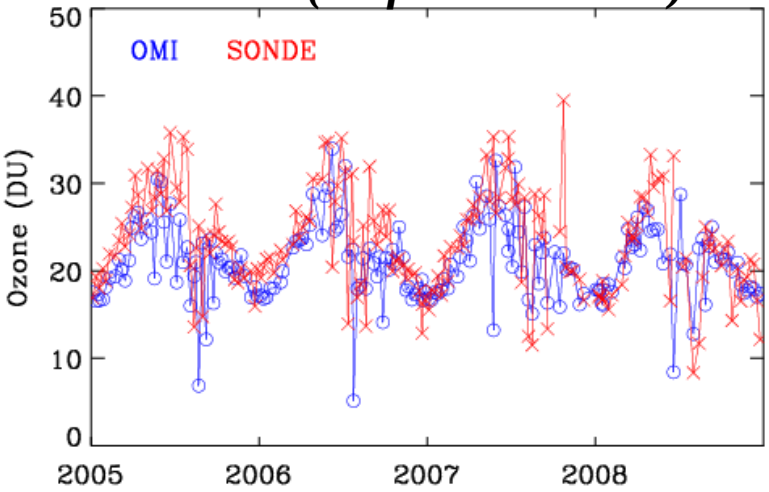
(Jae H. Kim)

Intercomparison of Tropospheric ozone (OMI vs. sonde)

TCO (Surface – tropopause)



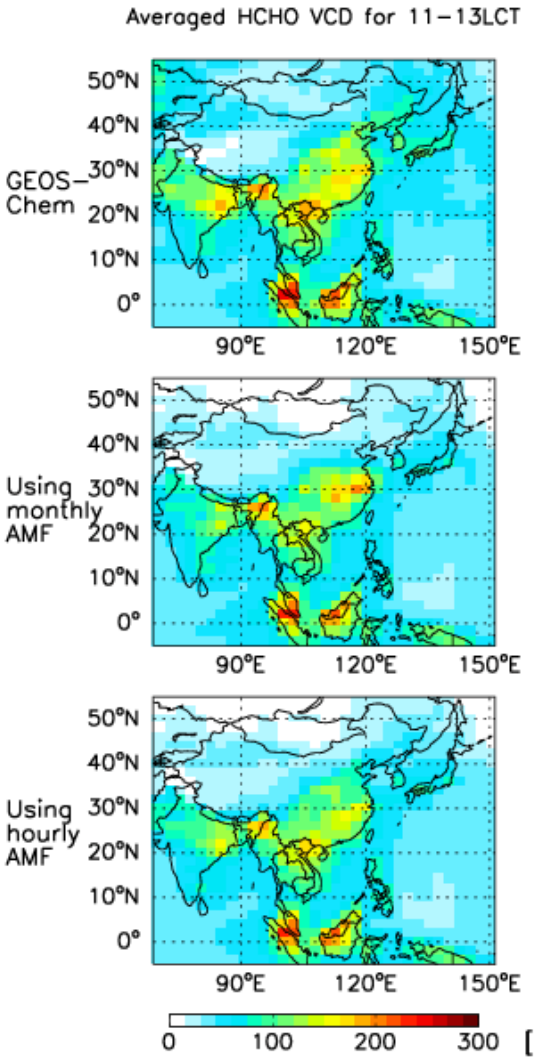
TCO500(surface – 500hPa)

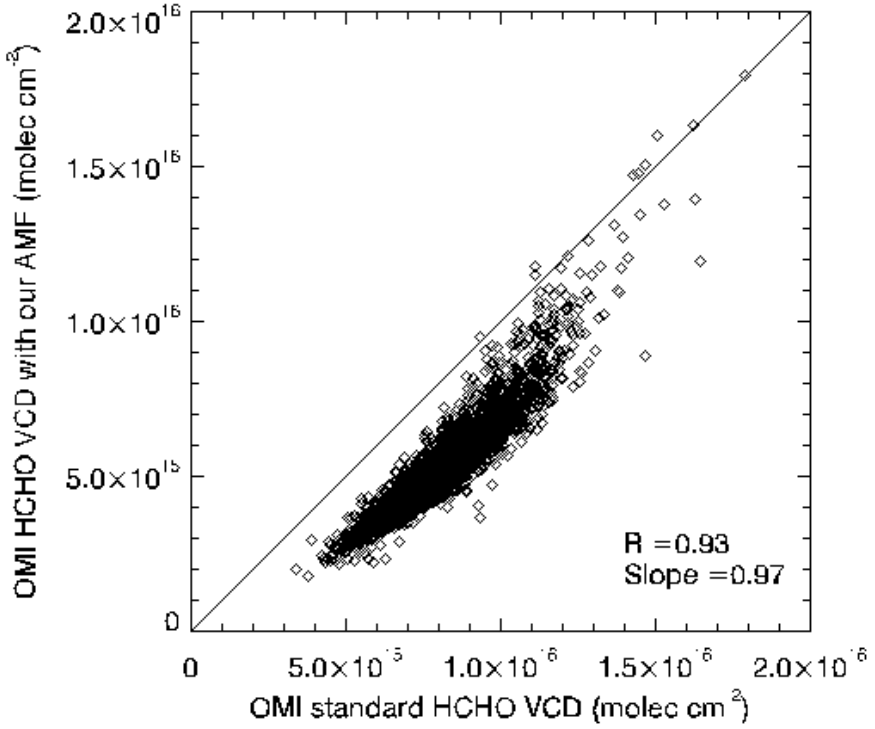


	TCO	TCO500
R	*0.64*	*0.51*
Regression	*y=0.84x+10.7*	*Y=0.67x+9.3*
OMI-SON(DU)	*-3.6±7.6*	*-2.0±4.3*
OMI-SON(%)	*-7.1±18.8*	*-7.0±20.9*

(Jae H. Kim)

Retrieved HCHO using OMI



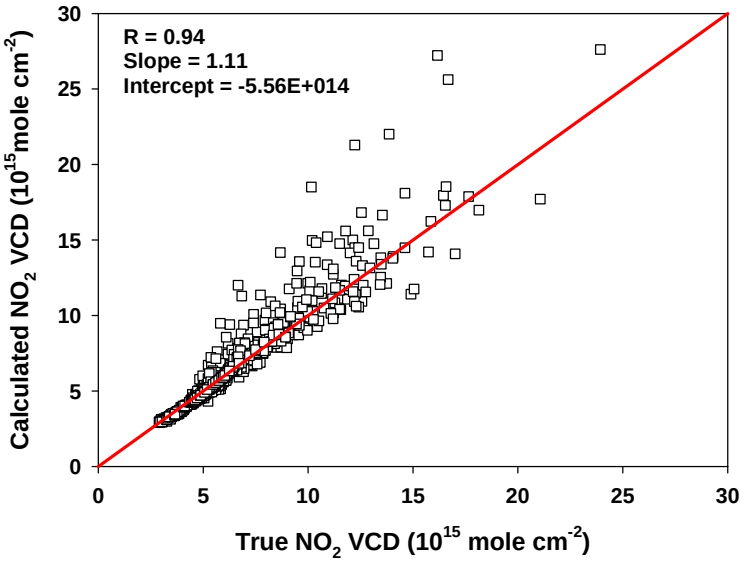


HCHO	**R**	**0.93**
	Regression line slope	**0.97**

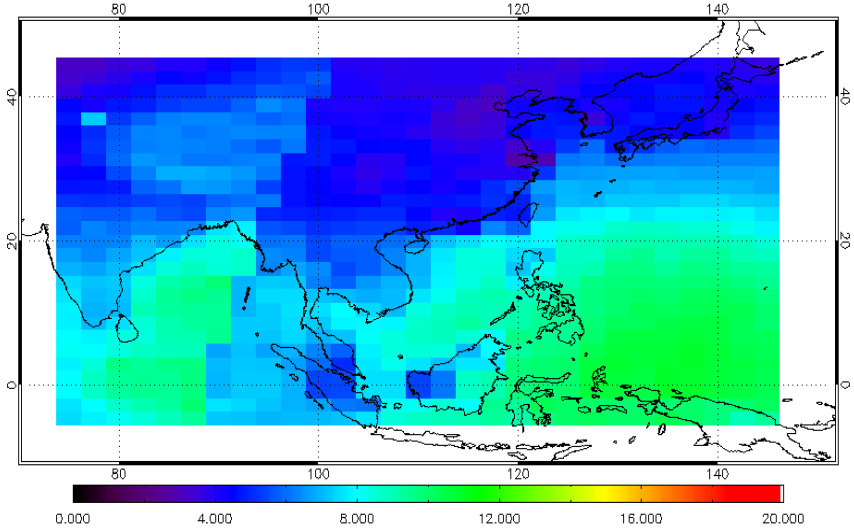
(Rokjin Park)

Retrieved NO_2

◆ Calculated NO_2 VCD vs. true NO_2 VCD



NO_2 SCD error (%)



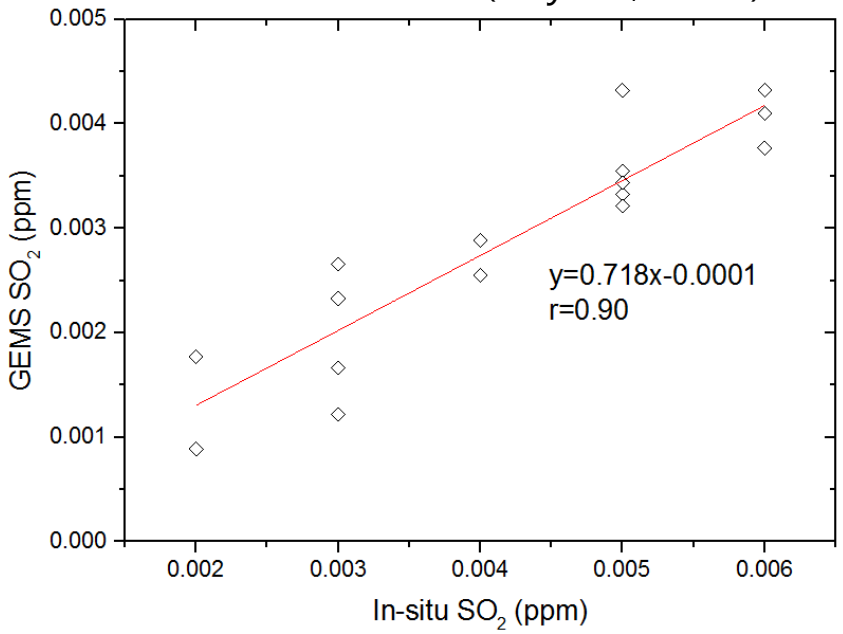
CDR (Q4, 2014)	Correlation coefficient (R)	a, Slope	b, Intercept	RMSE	Error (%)
NO_2 (achieved)	0.94	1.1	0.056 [10^{16}cm^{-2}]	N/A	7%

(Hanlim Lee)

Retrieved SO_2

- **SO_2 intercomparison**
  - SO_2 in urban area

16 Urban site (July 8th, 2007)



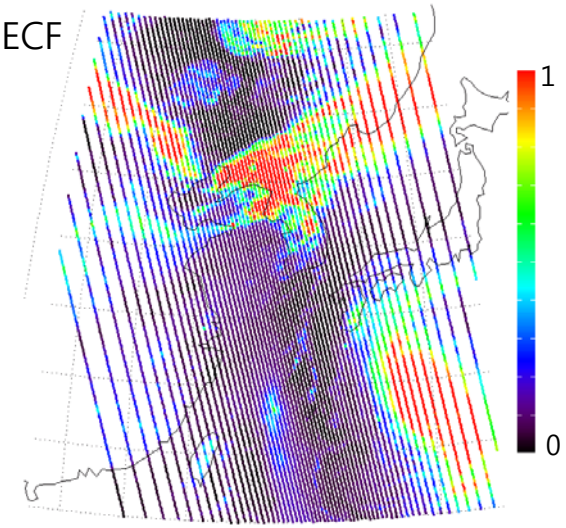
$$SO_2\,(DU)\times 0.029\times\left(\frac{10^6\ \mu g}{1000 m^3}\right)\times\left(\frac{8.314\times 298}{1.013\times 10^5\times 64}\right)$$

Site	Sfc. Obs	GEMS		
	SO_2(ppm)	SO_2(DU)		**SO_2(ppm)**
Seoul	**0.005**	0.30	→	**0.0033**
Busan	**0.005**	0.39	→	**0.0043**
Daegu	**0.005**	0.32	→	**0.0035**
Inchon	**0.006**	0.39	→	**0.0043**
Gwangju	**0.002**	0.16	→	**0.0017**
Daejon	**0.003**	0.11	→	**0.0012**
Ulsan	**0.006**	0.34	→	**0.0037**
Gyeonggi	**0.004**	0.23	→	**0.0025**
Gangwon	**0.003**	0.21	→	**0.0023**
Chungbuk	**0.004**	0.26	→	**0.0028**
Chungnam	**0.003**	0.15	→	**0.0016**
Jeonbook	**0.003**	0.24	→	**0.0026**
Jeonnam	**0.006**	0.37	→	**0.0041**
Gyeongbook	**0.005**	0.29	→	**0.0032**
Gyeongnam	**0.005**	0.31	→	**0.0034**
Jeju	**0.002**	0.08	→	**0.0008**

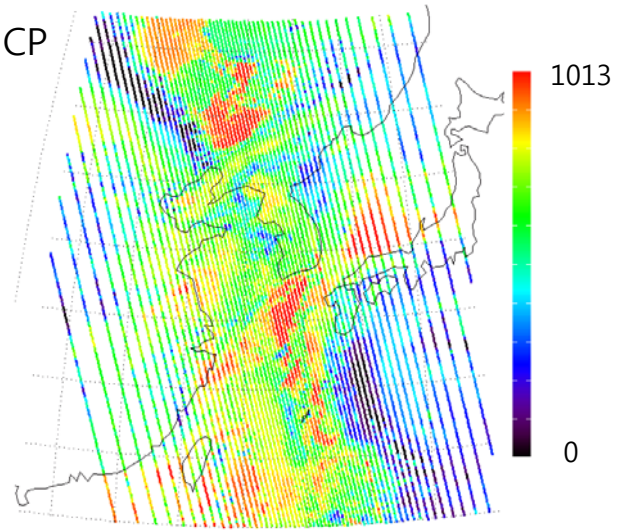
(Young Joon Kim)

Retrieved cloud products

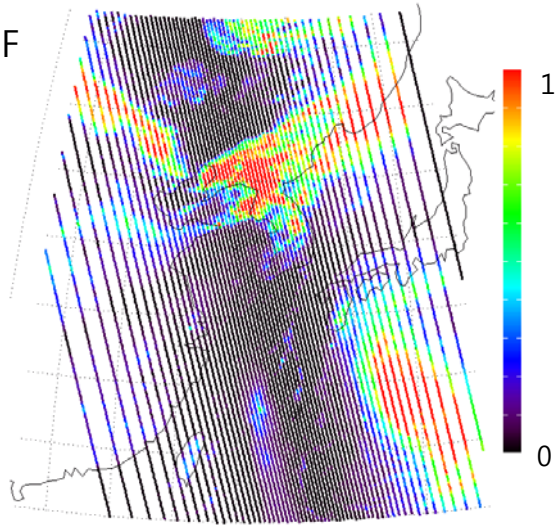
OMIlv2 ECF



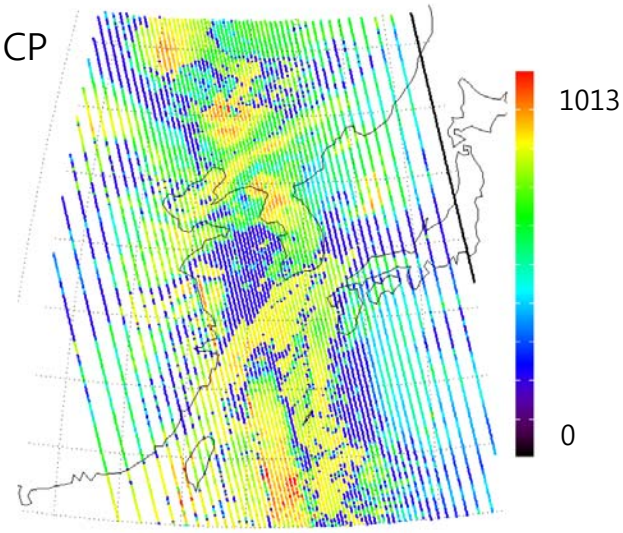
OMIlv2 CP



GCA ECF



GCA CP



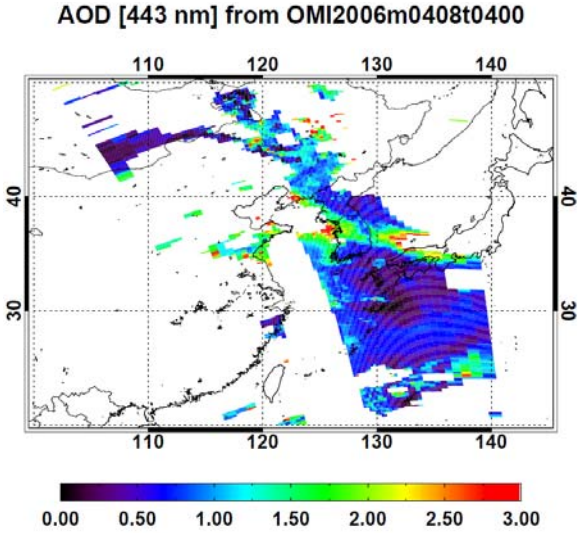
Slope	R	RMSE
0.99	0.98	0.08

Slope	R	RMSE
0.84	0.66	230

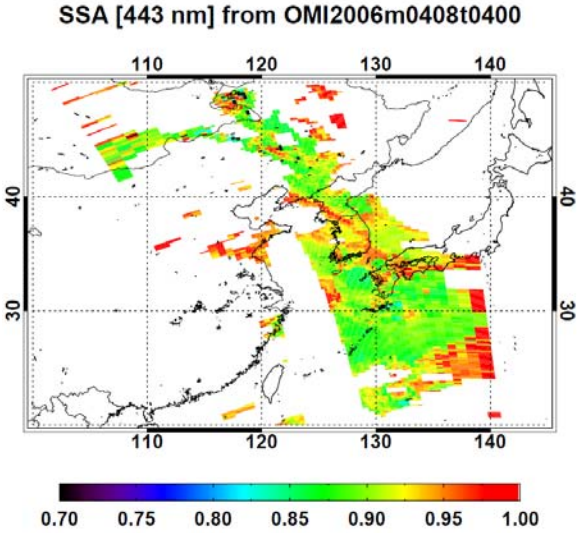
(Yong Sang Choi)

Retrieved Aerosol Properties(AOD, SSA, Height)

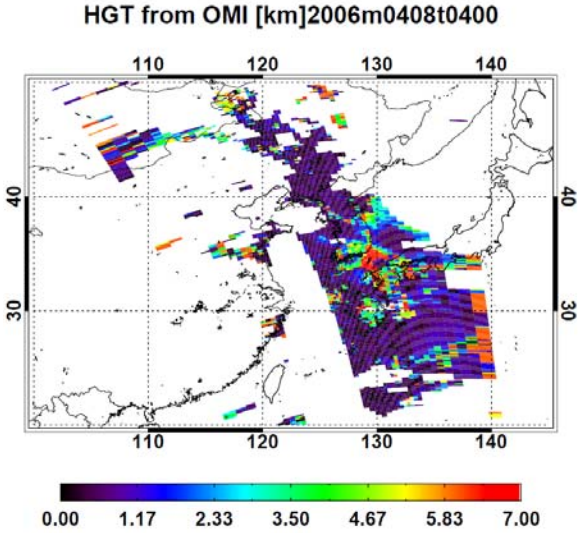
Retrieved AOD [443 nm]

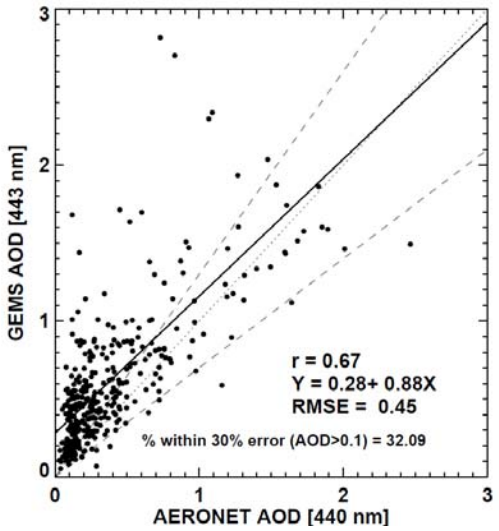


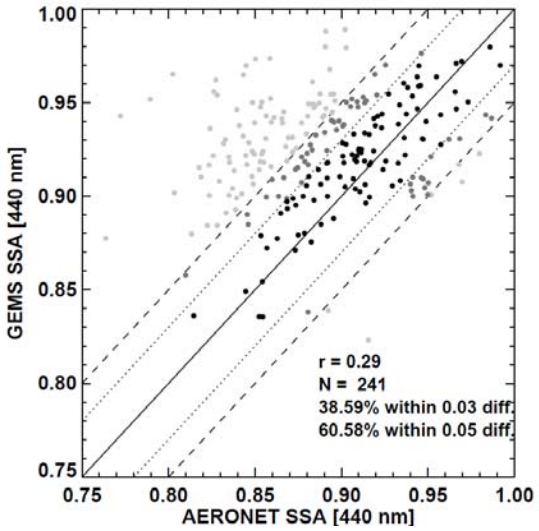
Retrieved SSA [443 nm]



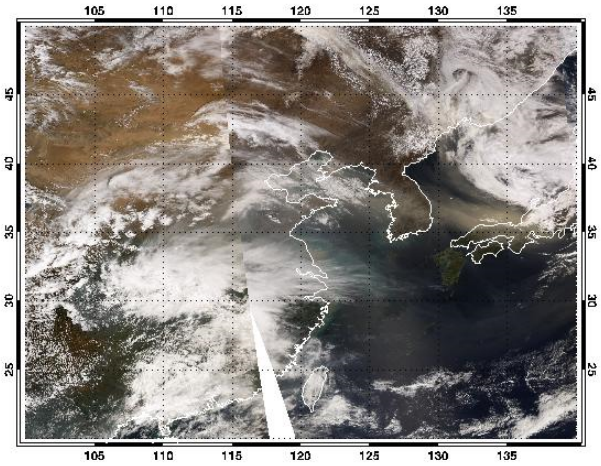
Retrieved HGT [km]







MODIS RGB :2006/04/08



Summary

- CDR of GEMS has been completed successfully and GEMS is now in manufacturing phase to be delivered to KARI by spring, 2017. The launch date for GEMS is now March, 2019.

- GEMS onboard the Geo-KOMPSAT-2B is expected to provide information on aerosol and O_3 together with their precursors in high spatial and temporal resolution
  - O_3 NO_2 HCHO SO_2 AOD/AI/AEH, (possibly CHOCHO, BrO)
  - Clouds, surface reflectance, UV radiation.

- The predicted performance of trace gases from the initial design of GEMS satisfies the product accuracy requirements of NO_2, HCHO, O_3. Meanwhile, the performance is expected to be poor in winter near Korea in particular.

- Collaboration with Team of TROPOMI, Sentinel-4 & TEMPO is valuable in calibration, algorithm development and application.

Acknowledgement

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Ministry of Environment (MoE)
NIER, MoE
KEITI, MoE

Korea Meteorological Administration (KMA)

Korea Ocean R&D Institute (KORDI)

Ministry of Science, ICT & future Planning (MSIP)
KARI

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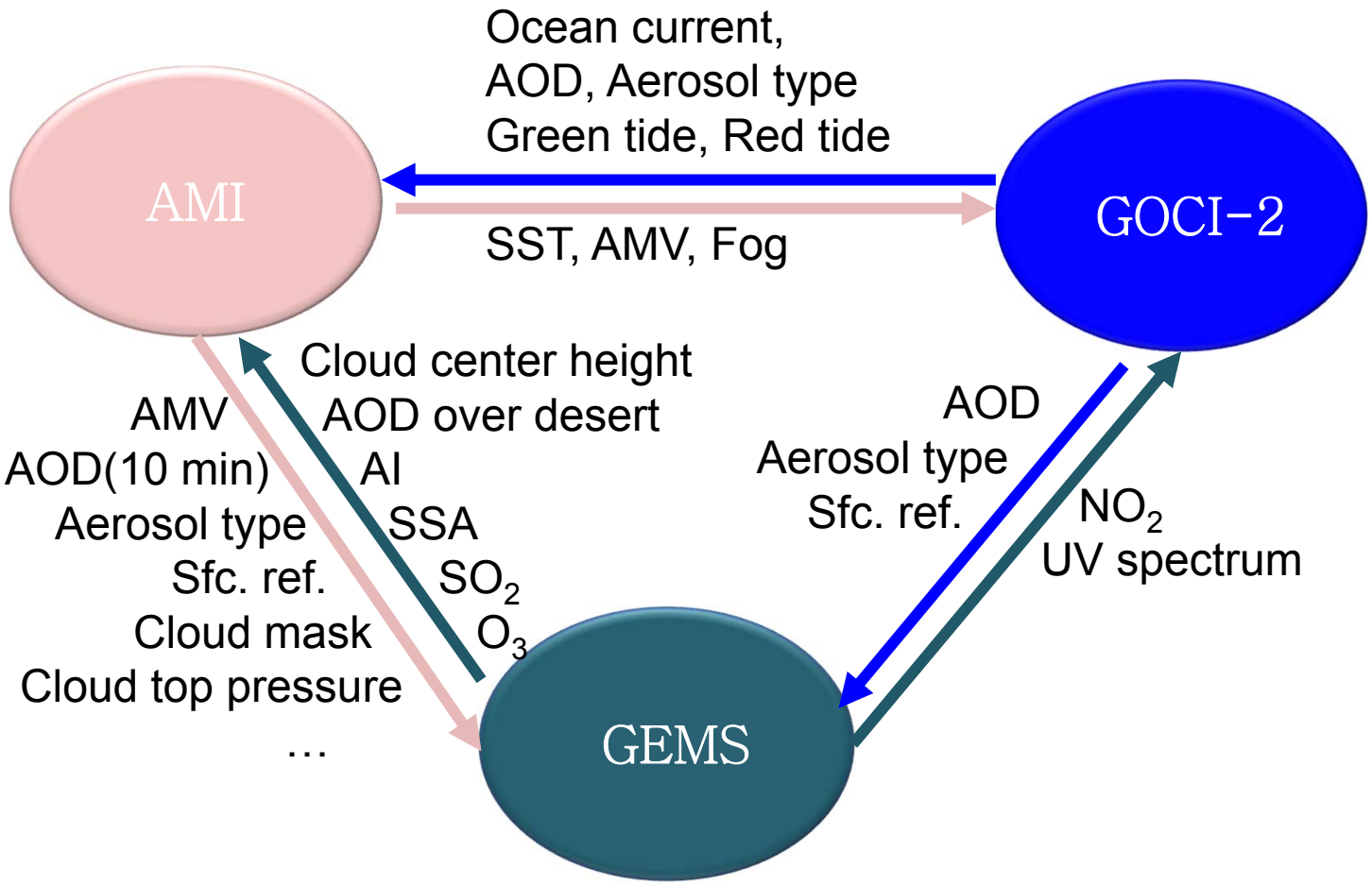
Synergistic products



- ✓ 24 hr Asian dust monitoring over dark and bright surface
- ✓ Cloud morphology (thickness, fraction, type …)

Geostationary Constellation of UV-Vis spectrometer & Meteorological Payload

Constellation of GEO Mission for Synergistic Products

TEMPO
+ GOES-R
(America)

UV-Vis
290-690 nm

GEMS + AMI + GOCI2
GEO KOMPSAT
(Asia)

UV-Vis 300-500 nm

UV-Vis-NIR
305-500, 750-775 nm

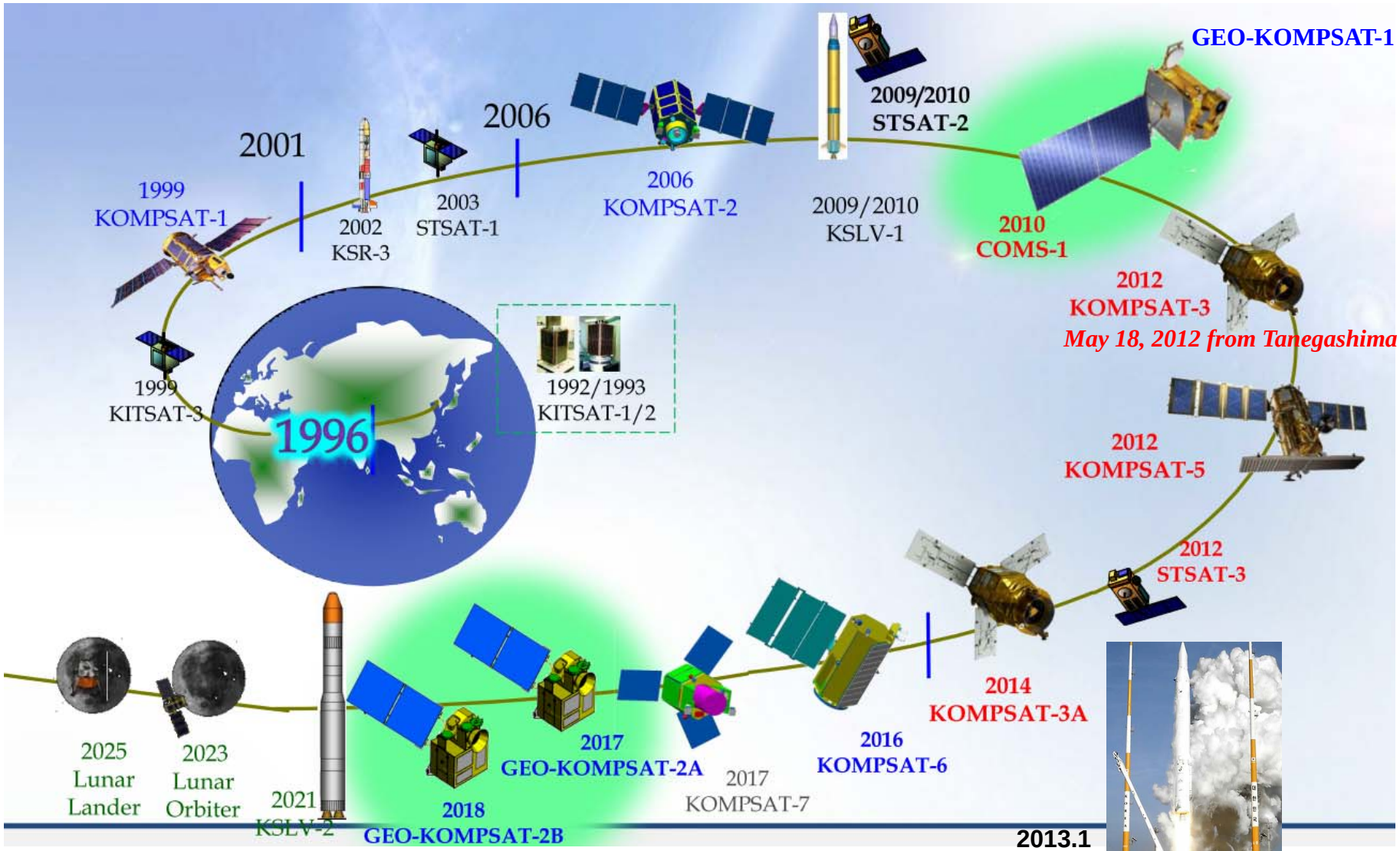
GMES S4 UVN
+ FCI + IRS
MTG (Europe)

Constellation synergy
- Improving spatial and temporal coverage
  to monitor globalized pollutants & SLCF
- Sharing basic requirements on data products and
  instrument to maintain data quality
- Consolidating socio-economic benefit analysis
- Supporting QA and CAL/VAL

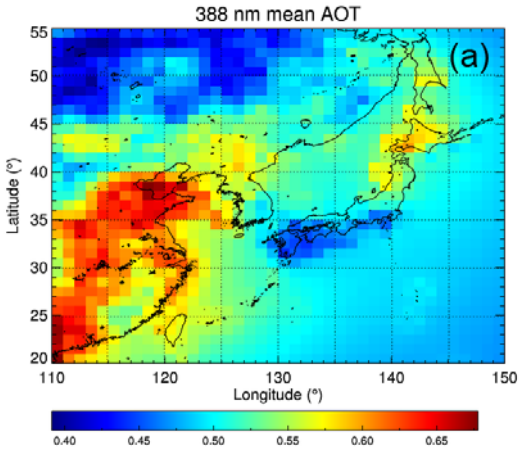
Accuracy of OMI products

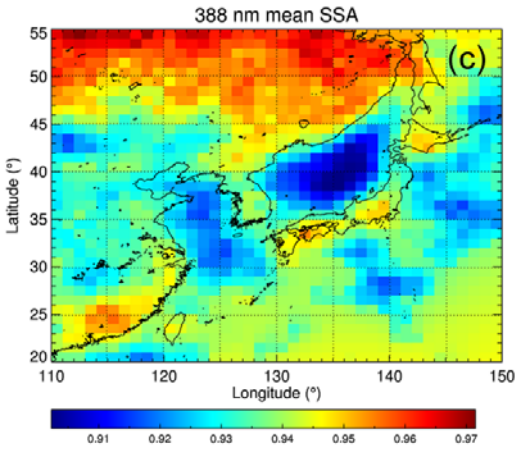
Species	Correlation coefficient (R)	a, Slope	b, Intercept	RMSE	Error (%)
O_3 (Total)	**0.82 – 0.97**	**0.83-0.97**	**35.5DU**	***7%***	
O_3 (Trop)	**0.5-0.8**	**0.5-0.9**	**0-15 DU**	***5-10 DU (10-20%)***	**3-6 DU *(10-20%) [depending on SZA]***
HCHO	**0.81 (0.57-0.77)**	**0.80 (0.75-0.88)**	**0.01×10^{16} (-2.3-$1.8. \times 10^{15}$)**		
NO_2	**0.8**	**0.5**	**3.0 [$10^{15}cm^{-2}$]**	***N/A***	**20%**
SO_2	**0.7**	**1.0**	**0.5 DU**	***N/A***	***50-100%***
CF	**0.90**	**0.9~1.1**	***N/A***	***N/A***	**2% ~ 5%**
CP	**0.80**	**0.9~1.1**	***N/A***	***N/A***	**5% ~ 20%**
Surface Reflectance	**0.70~0.91**	***N/A***	***N/A***	***0.03***	**5~40%**
AOD	**0.7**	**N/A**	**N/A**	**T/V**	**60% at AOD > 0.1**

National Space Program of Korea

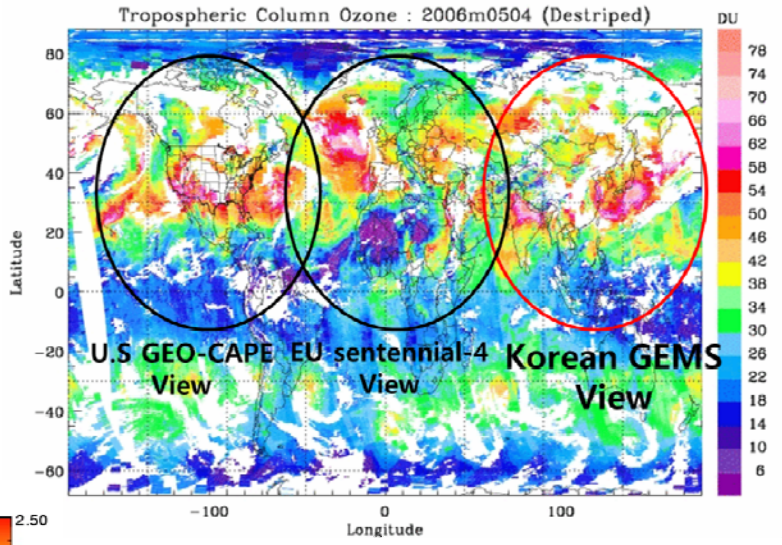


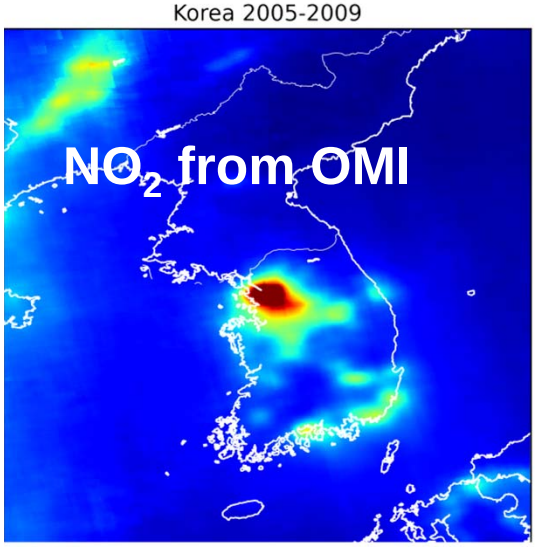
Aerosol, O_3, NO_2, SO_2, HCHO



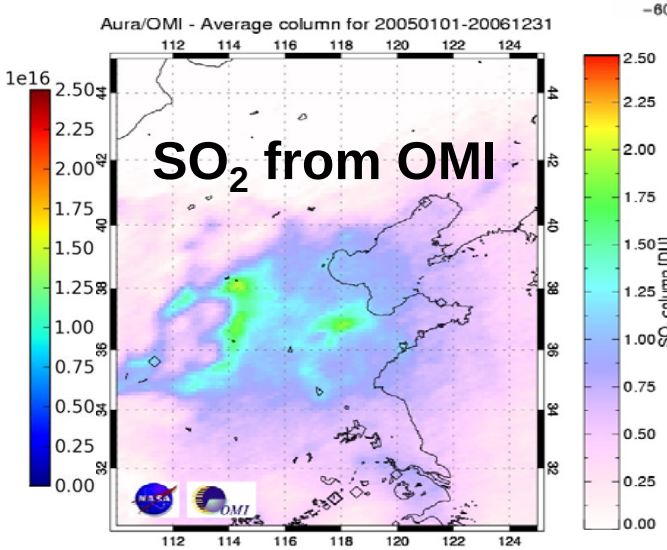


Expected daily tropospheric column ozone map

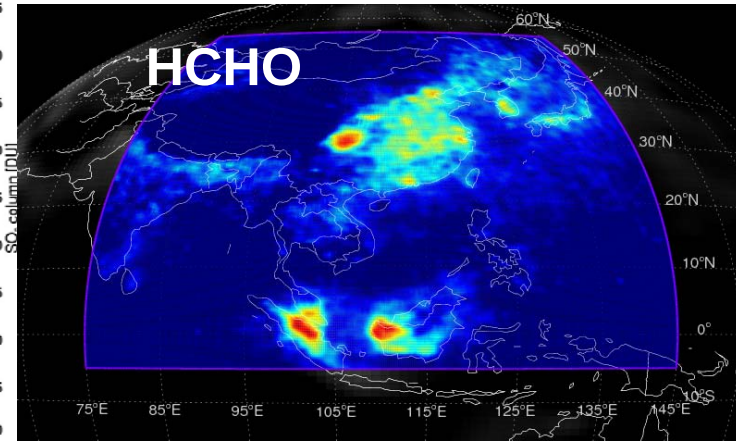




Veefkind (2010)



Krotkov et al.(JGR, 2008)



Kurosu (2010)

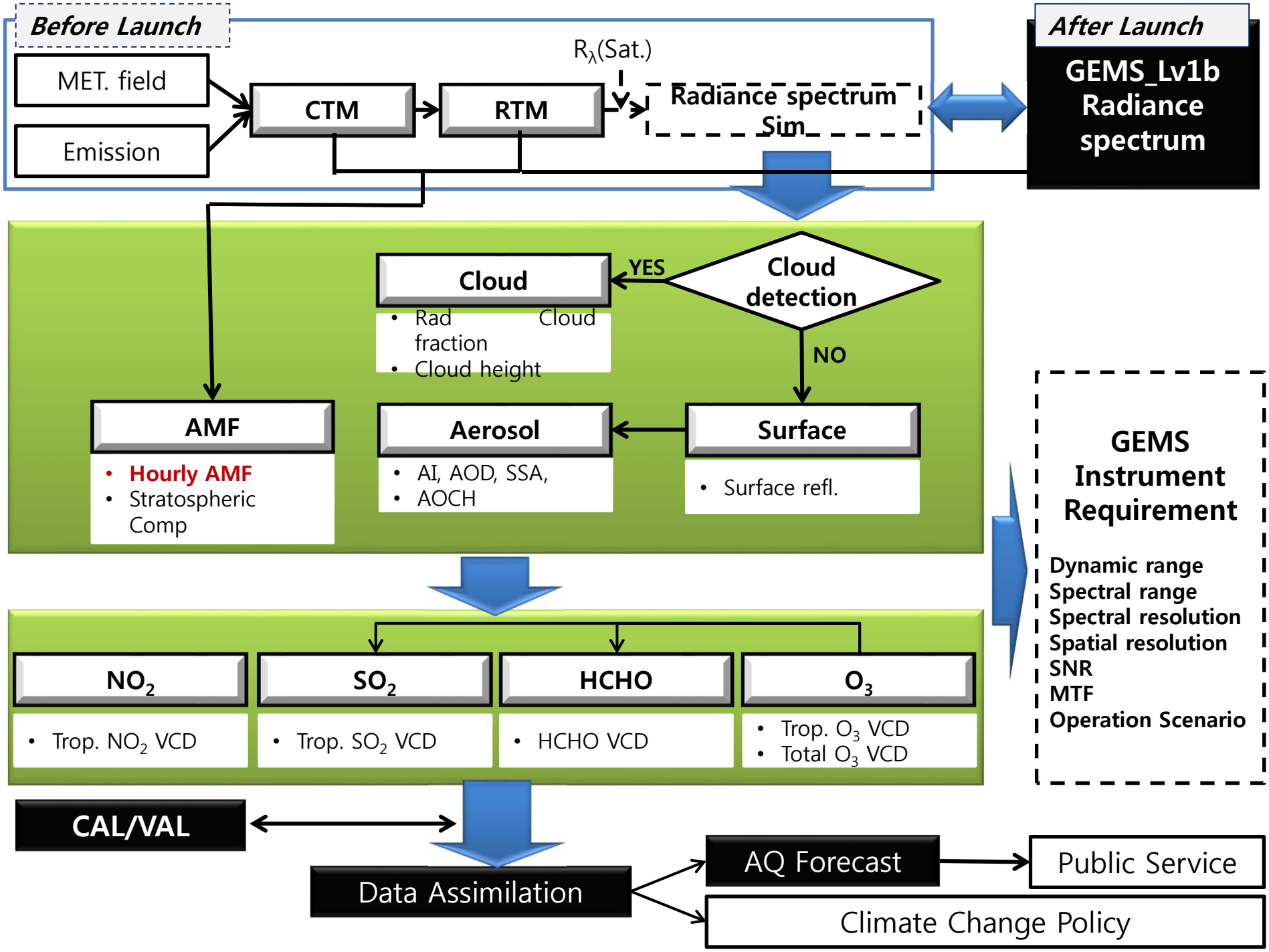
Satellite Remote Sensing of Atmospheric Composition

Satellite		ERS-2	Terra	Envisat		Aura			METOP		GOSAT	S-4, TEMPO G-CAPE GEMS
Sensors	TOMS	GOME	MOPITT	SCIA-MACHY	MIPAS	HRDLS	OMI	TES	IASI	GOME2	TANSO	
Orbit	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	LEO	GEO
Launch	1979	1995	1999	2002	2002	2003	2003	2003	2007	2007	2009	(2018)
O_3	O	O		O	●	O	O	O	O, ●	O		O
H_2O	O	O		O		O		O				
CO			O	O	●				O			
NO				O	●	O						
NO_2		O		O	●	O	O		O	O		O
HNO_3					●	O		O	●			
CH_4			O	O	●	O		O	O		O	
HCHO		O		O								O
SO_2		O		O			O			O		O
BrO		O		O						O		
CO2				O					O		O	
Aerosol	O			O		O	O	O		O		O

O : Column ● : Profile

PS : Polar sun-synchronous GEO : Geostationary

(Courtesy, C.H. Song)


Before Launch
MET. field
Emission
CTM
RTM
R_λ(Sat.)
Radiance spectrum Sim
After Launch
GEMS_Lv1b Radiance spectrum
Cloud
YES
Cloud detection
NO
• Rad Cloud fraction
• Cloud height
AMF
• Hourly AMF
• Stratospheric Comp
Aerosol
• AI, AOD, SSA,
• AOCH
Surface
• Surface refl.
GEMS Instrument Requirement
Dynamic range
Spectral range
Spectral resolution
Spatial resolution
SNR
MTF
Operation Scenario
NO_2
SO_2
HCHO
O_3
• Trop. NO_2 VCD
• Trop. SO_2 VCD
• HCHO VCD
• Trop. O_3 VCD
• Total O_3 VCD
CAL/VAL
Data Assimilation
AQ Forecast
Public Service
Climate Change Policy