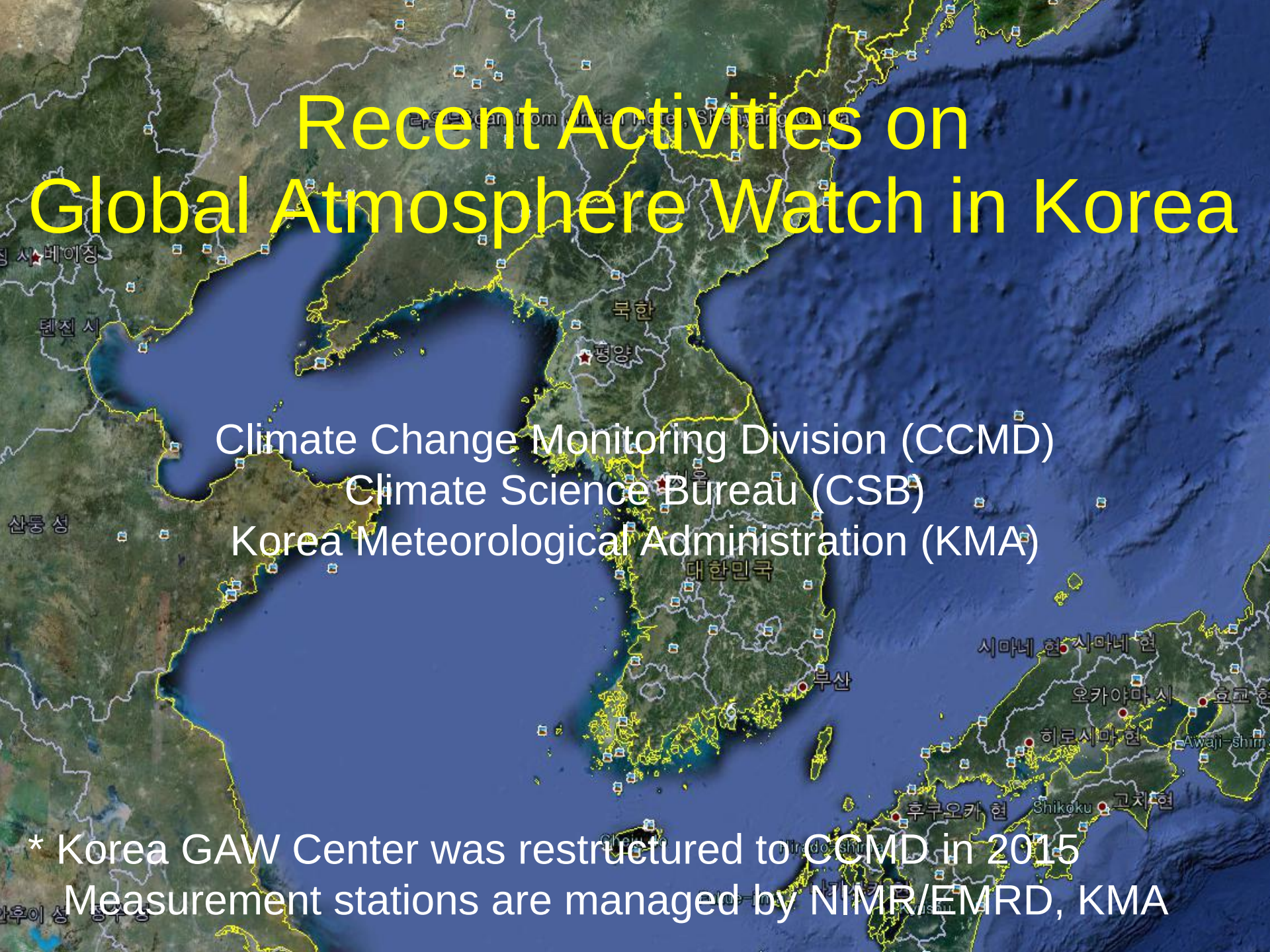
Recent Activities on Global Atmosphere Watch in Korea

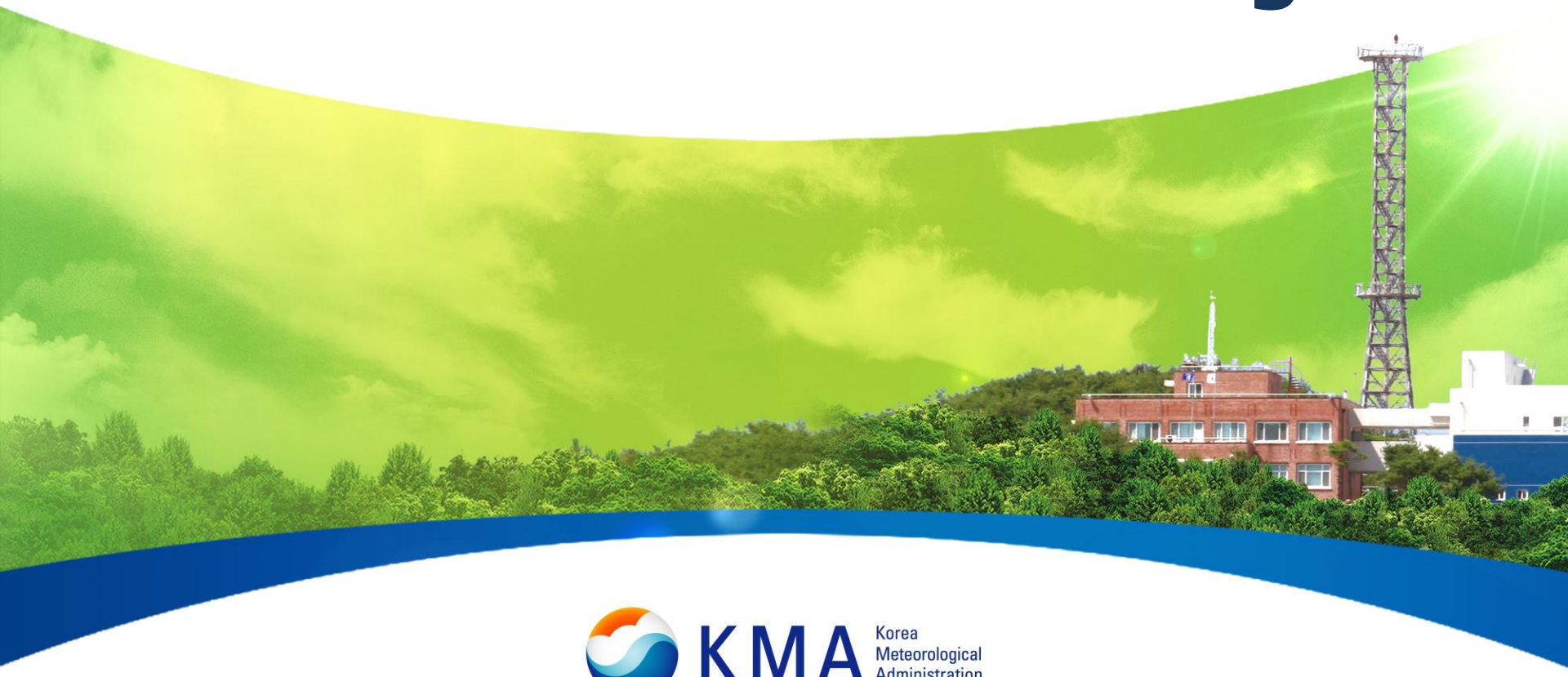


Climate Change Monitoring Division (CCMD)
Climate Science Bureau (CSB)
Korea Meteorological Administration (KMA)

* Korea GAW Center was restructured to CCMD in 2015
Measurement stations are managed by NIMR/EMRD, KMA

Climate Change Monitoring Division

Measurement Stations & Programs



KMA Korea Meteorological Administration

Main and Auxiliary Stations of KMA

H. Antarctica (King Sejong)

Main stations (KMA)

- AMY, JGS, ULL
- GHGs, Reactive gases, Aerosols, Strat. O_3, Radiation, Precip. Chem.

Auxiliary stations (KMA)

- B : Strat. Ozone, UV
- C : Precip. Chem.
- D : Ozone-sonde, UV
- F : UV

Auxiliary stations (Univ.)

- A : CO_2 flux, Strat. H_2O, Strat. O_3, UV
- E : Aerosol LIDAR, AOD
- G : Radon
- H : CO_2, Strat. O_3

(Main stations are run by EMRD, NIMR)

Measurement Programs

Greenhouse Gases

CO_2, CH_4, N_2O,
$CFC_{11, 12, 113}$, SF_6

Reactive Gases

SO_2, CO, NOx, O_3

Aerosols

Physical, chemical,
optical properties

Ozone & UV

UV-A, UV-B
Stratospheric Ozone

Precipitation Chemistry

Acidity, Conductivity
F^-, Cl^-, NO_3^-, SO_4^{2-},
Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}

Atmospheric Radiation

Direct/diffuse sunlight
Solar/terrestrial radiation
Net radiation

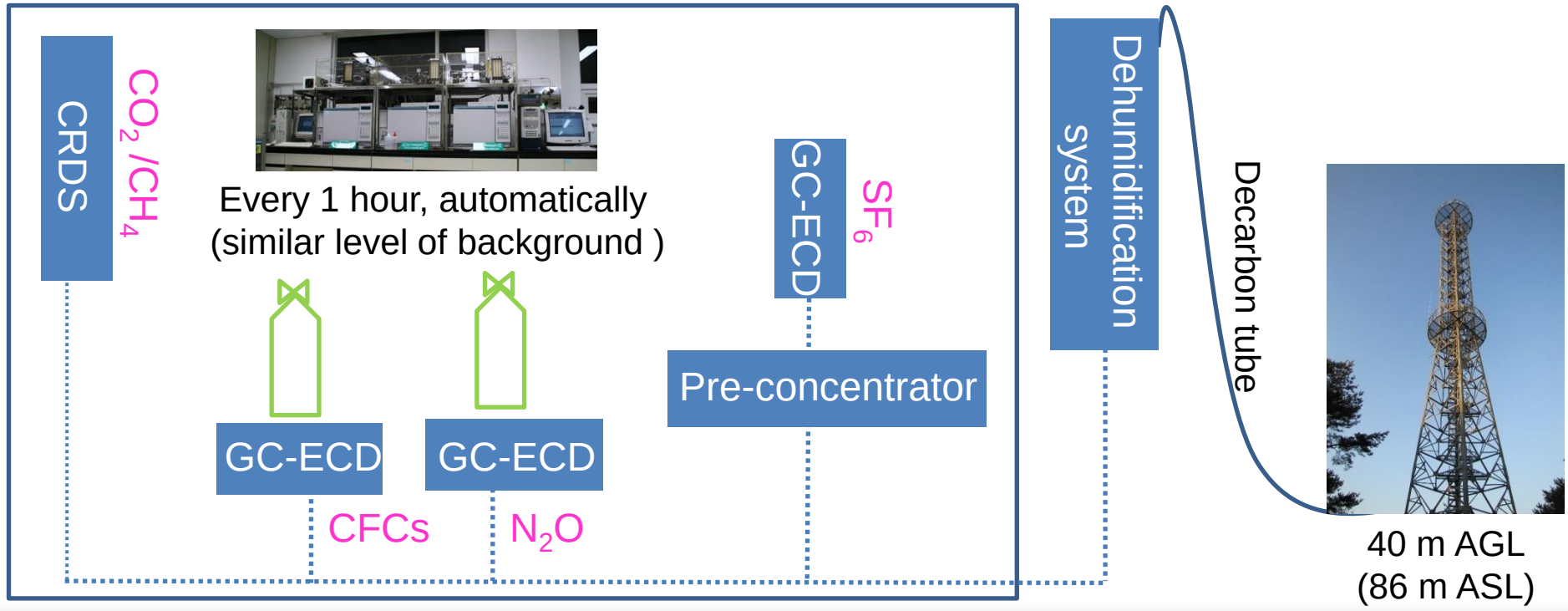
Greenhouse Gases (GHGs)

CO_2, CH_4

❖ CRDS (Cavity Ring Down Spectroscopy)
- Piccaro G2301 (with H_2O), Resol. 5 sec

N_2O, SF_6, CFCs

❖ GC-ECD (Gas Chromatography – Electron Capture Detector)
- Agilent 7890A etc., Resol. 1 hr



Reactive Gases

NOx

❖ Gas-phase Chemiluminescence
- Resol. 5 min (42i-TL, Thermo Sci.)

SO_2

❖ Ultraviolet Flourescence
- Resol. 5 min (43i-TLE, Thermo Sci.)

O_3

❖ Ultraviolet Photometer
- Resol. 5 min (49i, Thermo Sci.)

CO

❖ Nondispersive Infrared Photometer (NDIR)
- Resol. 5 min (48i-TLE, Thermo Sci.)

→ changing to

CRDS (G2401, $CO/CO_2/CH_4/H_2O$)

Aerosols – Instruments

Size Distribution
Resol. 3 min

- Scanning Mobility Particle Sizer : 0.01-0.5 ㎛, 54 Ch.
- Aerodynamic Particle Sizer: 0.5-20 ㎛, 52 Ch.
- Grimm Dust-monitor : 0.25-32 ㎛, 31 Ch.

Scattering/ Absorption
Resol. 5 min

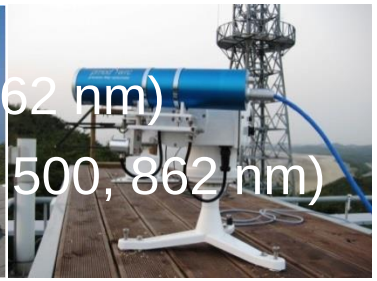
- Nephelometer: 3 wavelengths (RGB)
- Aethelometer

Mass Conc.
Resol. 5 min

- ß-ray PM_{10}, $PM_{1, 2.5, 10}$ (Grimm Dust-monitor)
- High Volume Sampler (TSP, PM10, PM2.5, 1 day/week)

AOD
Resol. 1 min

- Sunphotometer: 5 Ch. (368, 500, 675, 778, 862 nm)
- Precision Filter Radiometer: 4 Ch. (368, 412, 500, 862 nm)

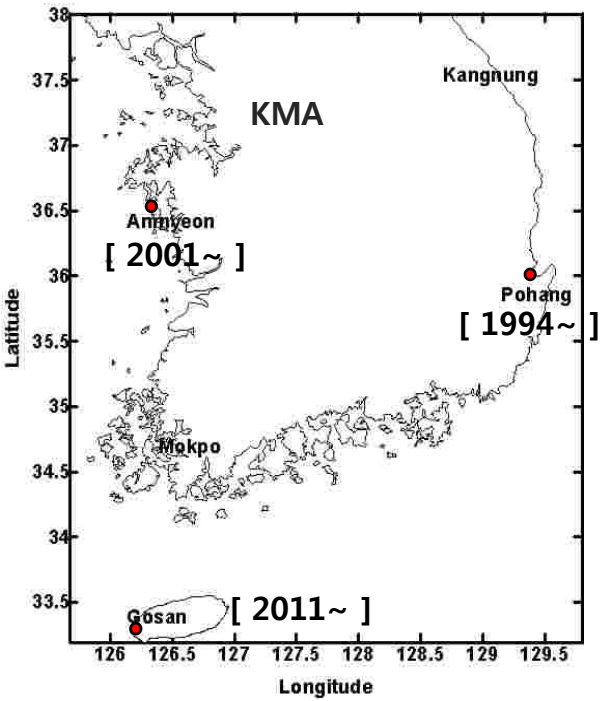


Vertical Distribution
Resol. 20 min

- Aerosol LIDAR (1064, 532 nm)
  - Backscattering coeff., Depolarization ratio, Color ratio

Stratospheric Ozone

Brewer #213 Anmyeon, KMA



Brewer #161
WMO/GO3OS Stn No. 332.
Pohang, KMA

Brewer #196 Jeju Gosan, KMA

Ozonesonde Model 5A ECC
Pohang, KMA

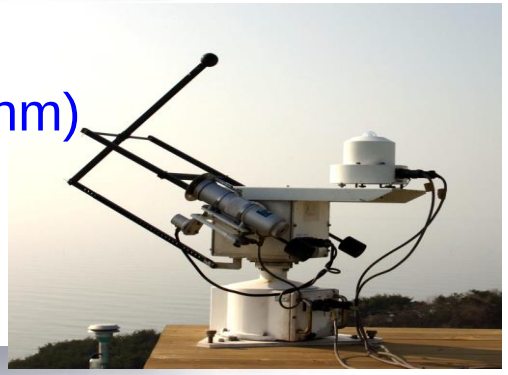
Atmospheric Radiation & UV

UV-A
UV-B
Resol. 10 min

- UV-Radiometer (320-400 nm)
- UV-Biometer (280-320 nm)

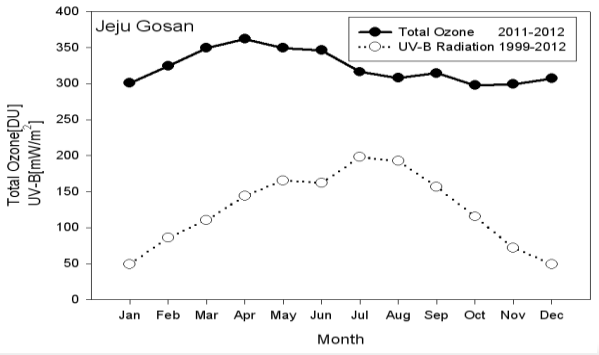
Direct / Diffuse Solar
Resol. 1 min

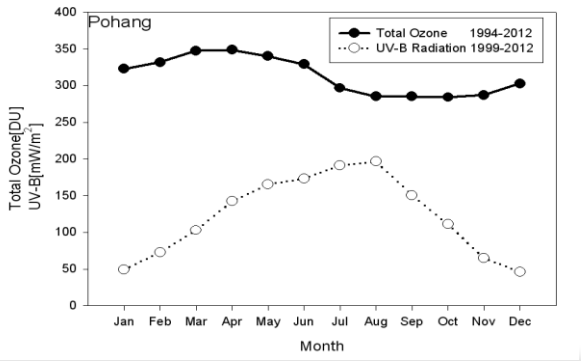
- Pyheliometer (200-2800 nm)
- Shadow band Pyranometer (305-2800 nm)



Radiation balance
Resol. 1 min

- Pyranomter, Pyrgeometer (3-50 ㎛)
- Net Pyradiometer (0.3-50 ㎛)

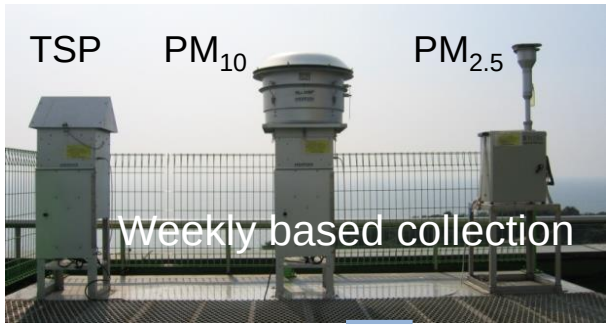




Integrated surface radiation system for upward/downward radiation measurements

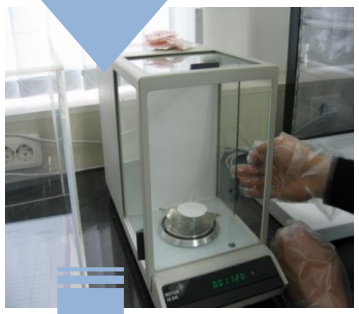
Precipitation Chemistry

Automatic Dry & Wet Sampler
- wet (at precipitation), dry (monthly)



Acidity Conductivity

- ❖ pH meter
- ❖ Conductivity meter



Ions

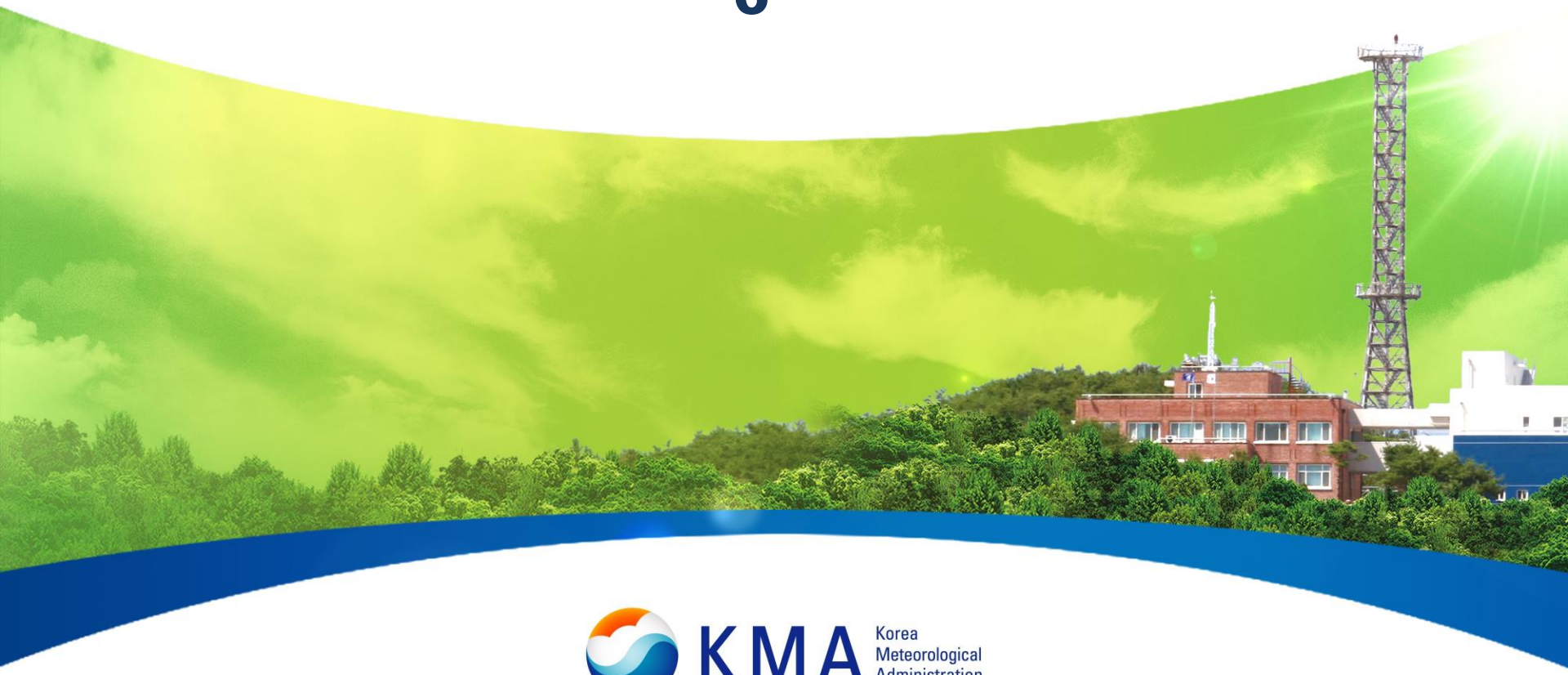
- ❖ Ion Chromatography
- ❖ F^-, Cl^-, NO_3^-, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}

Heavy metals

- ❖ Al, Ca, Fe, K, Mg, Na, S, Ti, Mn, Zn, Cu, V, Cr, Co, Ba, Pb, U

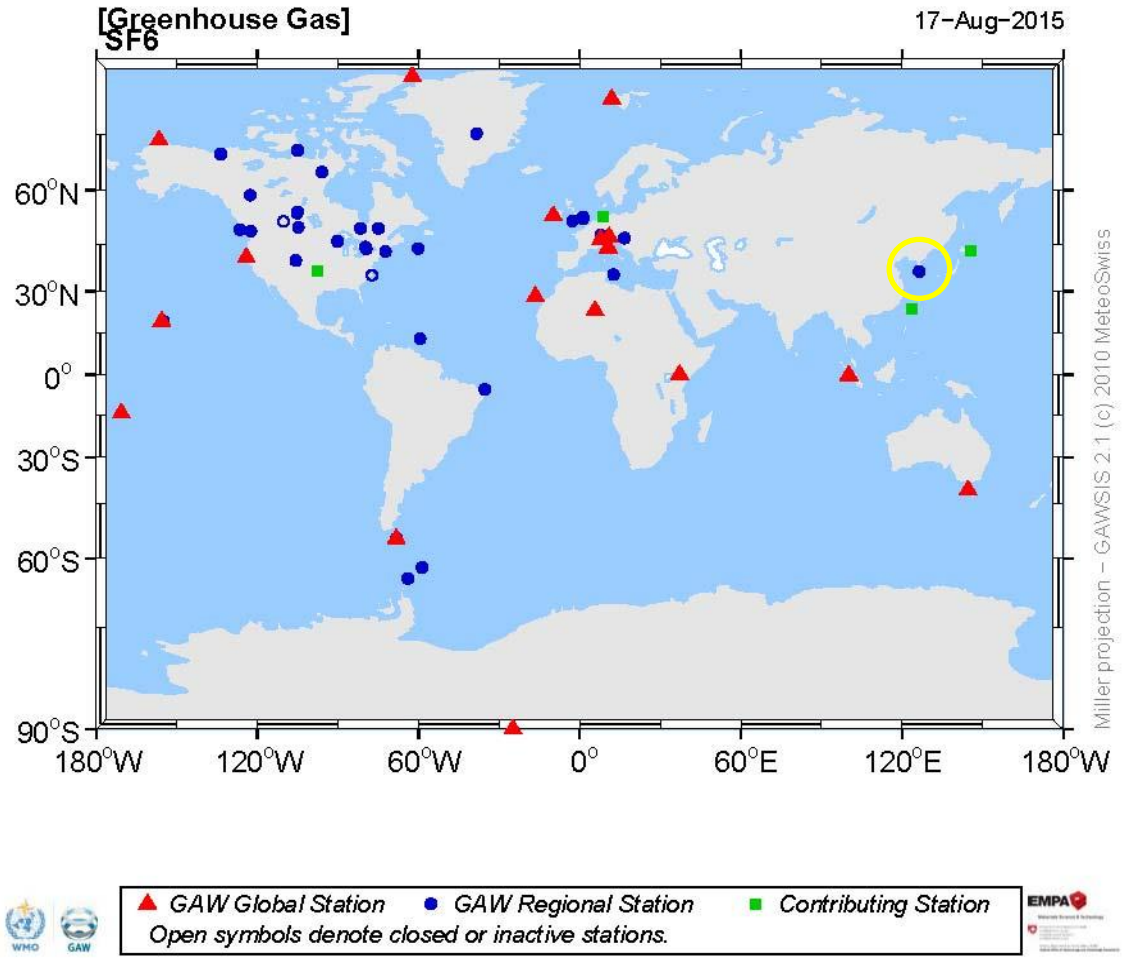
Climate Change Monitoring Division

WCC-SF_6 Activities



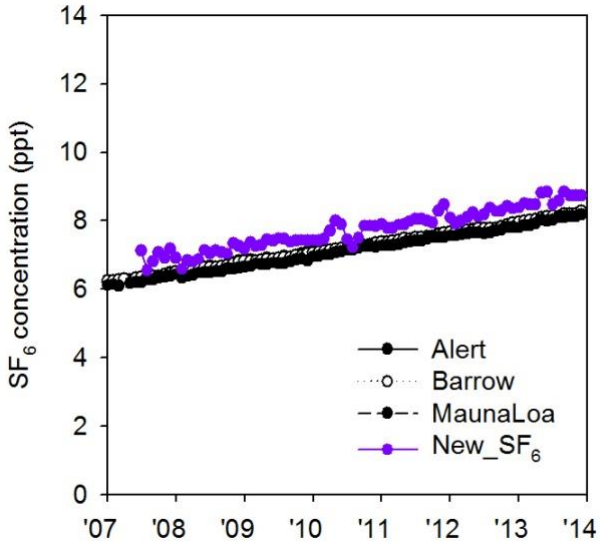
KMA Korea Meteorological Administration

World Calibration Centre for SF_6 (WCC-SF_6)



55 stations

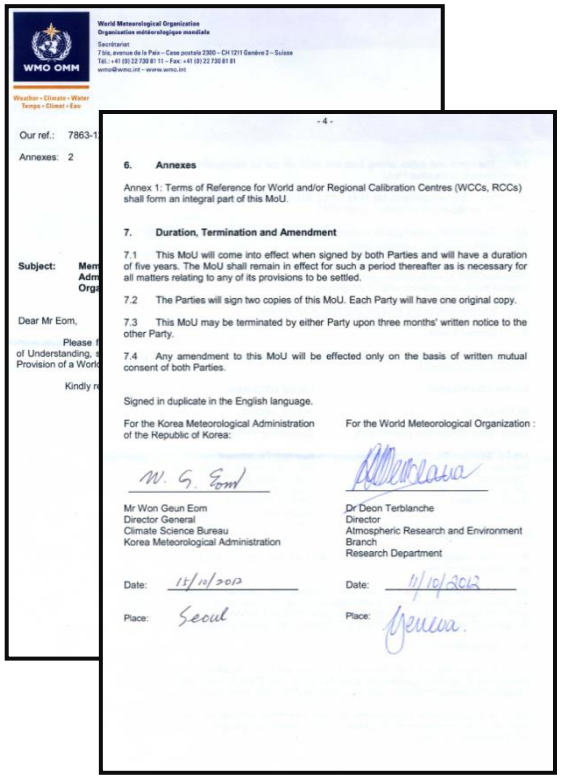
Global 17, Regional 33,
Contributing 4, Non-GAW 1



SF_6 is a very potent and long lived greenhouse gas, now it is not great menace to climate change though due to its small amounts in atmosphere

KMA has measured SF_6 since 2007, was designated as the WCC-SF_6 in 2012, and has run it since 2013.

World Calibration Centre for SF_6 ($WCC\text{-}SF_6$)



- 4 -

6. Annexes

Annex 1: Terms of Reference for World and/or Regional Calibration Centres (WCCs, RCCs) shall form an integral part of this MoU.

7. Duration, Termination and Amendment

7.1 This MoU will come into effect when signed by both Parties and will have a duration of five years. The MoU shall remain in effect for such a period thereafter as is necessary for all matters relating to any of its provisions to be settled.

7.2 The Parties will sign two copies of this MoU. Each Party will have one original copy.

7.3 This MoU may be terminated by either Party upon three months' written notice to the other Party.

7.4 Any amendment to this MoU will be effected only on the basis of written mutual consent of both Parties.

Signed in duplicate in the English language.

For the Korea Meteorological Administration of the Republic of Korea:

Mr Won Geun Eom
Director General
Climate Science Bureau
Korea Meteorological Administration

Date: 15/10/2012
Place: Seoul

For the World Meteorological Organization :

Dr Deon Terblanche
Director
Atmospheric Research and Environment Branch
Research Department

Date: 11/10/2012
Place: Geneva

(Agreed on 11 Oct. 2012)

1.2. The KMA/KGAWC will perform, within the framework of this MoU, the following activities:

a) assist WMO Members operating WMO/GAW stations to link their sulphur hexafluoride (SF_6) observations to the WMO/GAW Reference Scale through comparisons with standards calibrated against the primary/secondary standards maintained by the Central Calibration Laboratory for SF_6;

b) assist the WMO/GAW Scientific Advisory Group (SAG) on Greenhouse Gases in the development of the quality control procedures required to support the quality assurance of SF_6 measurements and ensure the traceability of these measurements to the corresponding primary standard;

c) maintain laboratory and transfer SF_6 gas standards that are traceable to their respective primary standard(s);

d) perform regular calibrations and inter-comparison campaigns involving the WMO/GAW stations/laboratories;

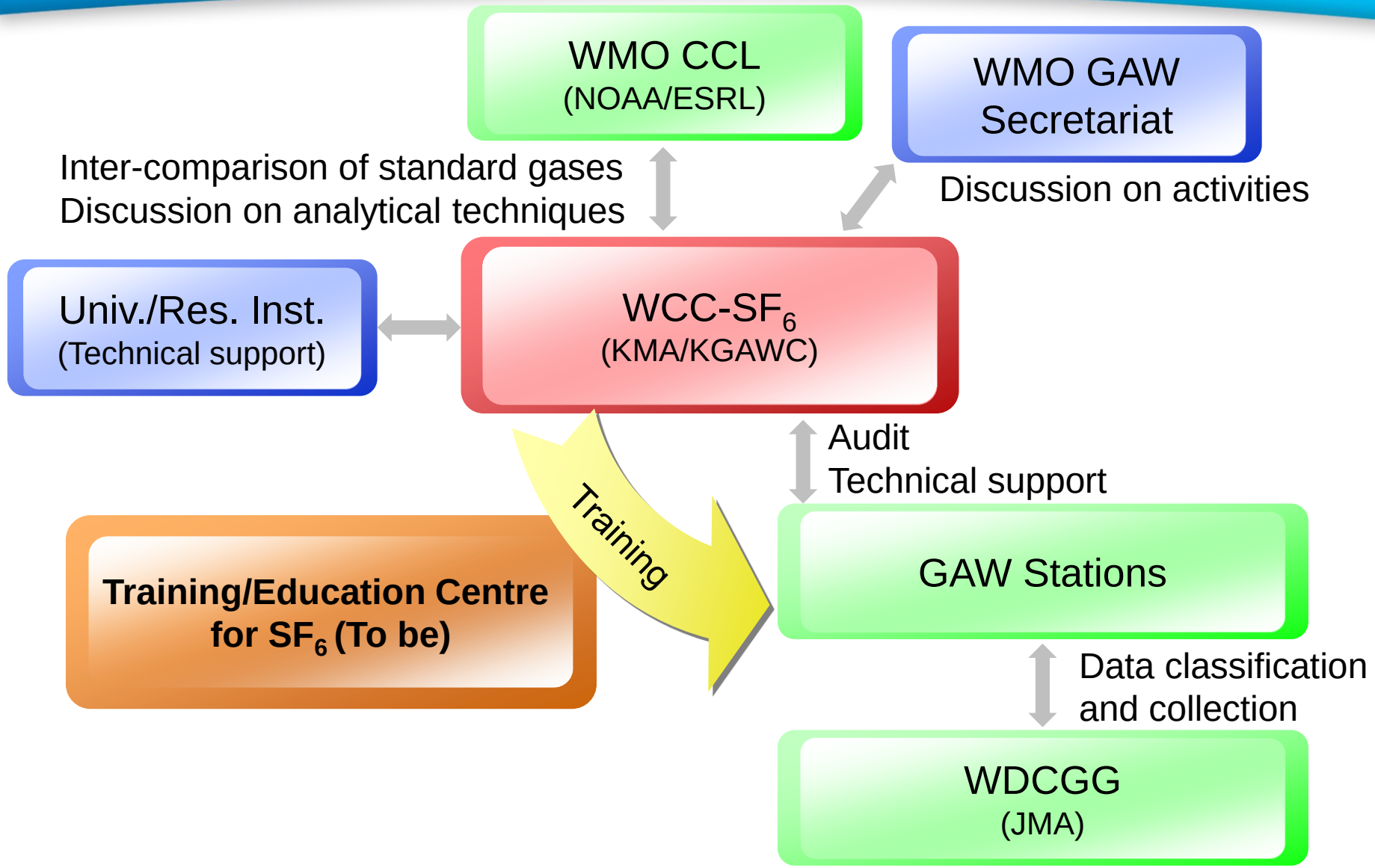
e) assist in provision of training and long-term technical help for WMO/GAW stations; and

f) make public its involvement in the WMO/GAW Programme (e.g. on its websites, in its newsletters).

a) → Distribution of the tertiary standards
Audit
b) → Development of the Q/C procedures
c) → Development of the tertiary standards

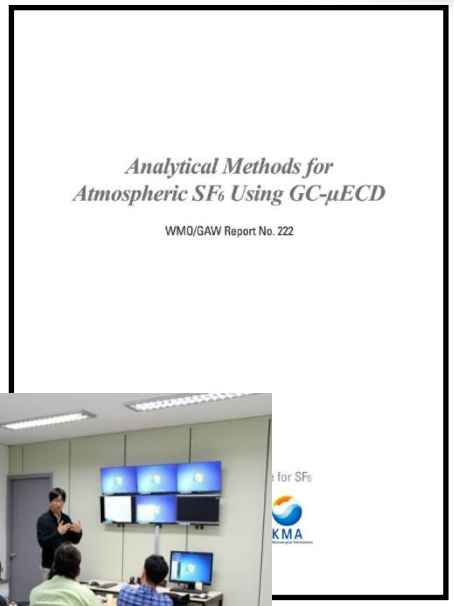
d) → Round-robin comparison experiments
e) → Training and education course,
Technical support
f) → Publications, e.g., newsletters

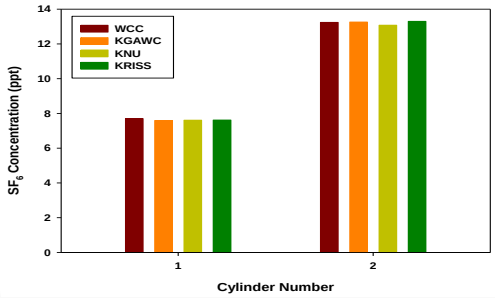
Operation of WCC-SF_6



What WCC-SF_6 has done

- Development of SOP
  - Posted on WMO GAW website
- Distribution of tertiary SF_6 standard gases
  - in connection with audit and technical support
- Audit & technical support
  - Diagnose the measurement system
  - Help build up and improve methodologies
  - IITM in Sep. 2015, Cape Point in Feb. 2016
- Round Robin Comparison
  - Start in Dec. 2015
- Training and education course
  - Annually hold the course linked with APGG





Multi-point calibration (4 standard gases ranged 6~12 ppt)

(unit: ppt)

# of meas. Sample	1	2	3	4	5	SF_6 from WCC [SD]	SF_6 from CCL [SD]	Difference (WCC-CCL)
FB03054	6.651	6.649	6.629	6.636	6.612	6.635 [0.016]	6.633 [0.012]	+0.002
FB03560	7.841	7.833	7.851	7.828	7.901	7.851 [0.029]	7.885 [0.019]	-0.034

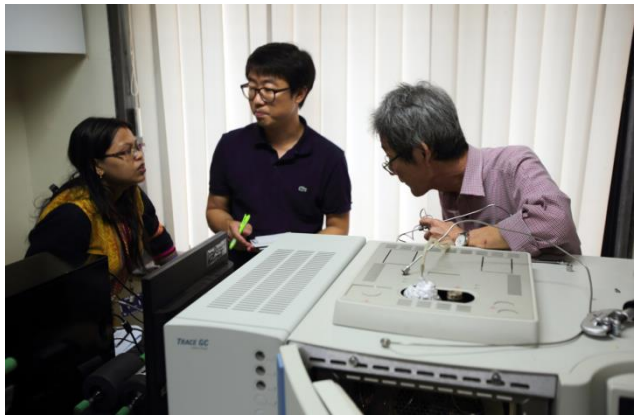
WMO recommended measurement target for SF_6: 0.02 ppt

Two-point calibration (6, 8 ppt)

Collaboration with IITM via WCC-SF_6

- Collaborate on greenhouse gas monitoring activities at IITM's stations with technical assistances of the WCC-SF_6
  - Improve a GC-ECD instrument for simultaneous measurements of atmospheric N_2O and SF_6
  - Provide SF_6 standard gases
  - Share know-how for trace gas measurements using a GC instruments

Done in Sep. 2015



Asia-Pacific GAW Workshop on GHGs (APGG)

1st Asian GAW workshop in 2009

4th Asian GAW workshop in 2012

2nd Asian GAW workshop in 2010

5th Asia-Pacific GAW workshop in 2013

3rd Asian GAW workshop in 2011

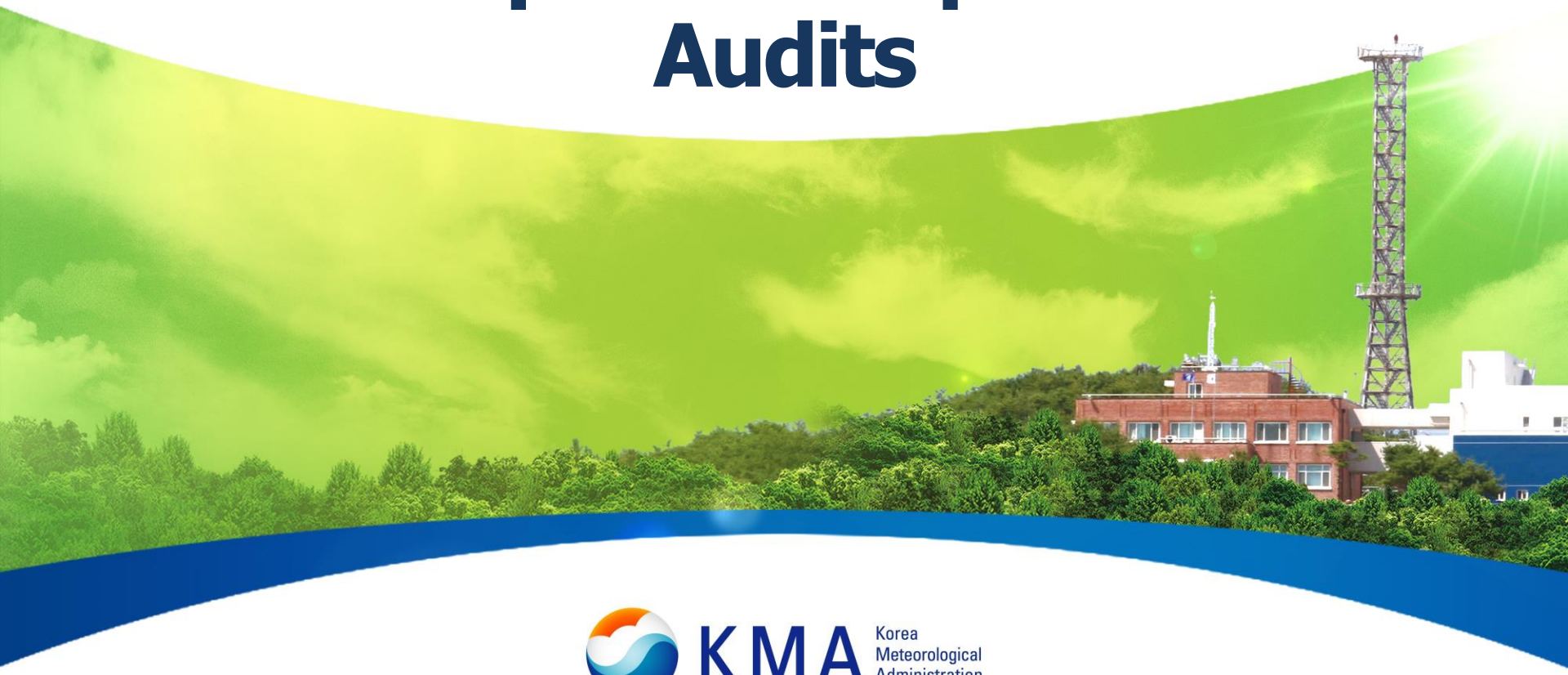
6th Asia-Pacific GAW workshop in 2014

http://www.wmo.int/pages/prog/arep/gaw_home_en.html

- ✓ In connection with WCC-SF_6 Training & Education Course

Climate Change Monitoring Division

Int'l Comparison Experiments & Audits



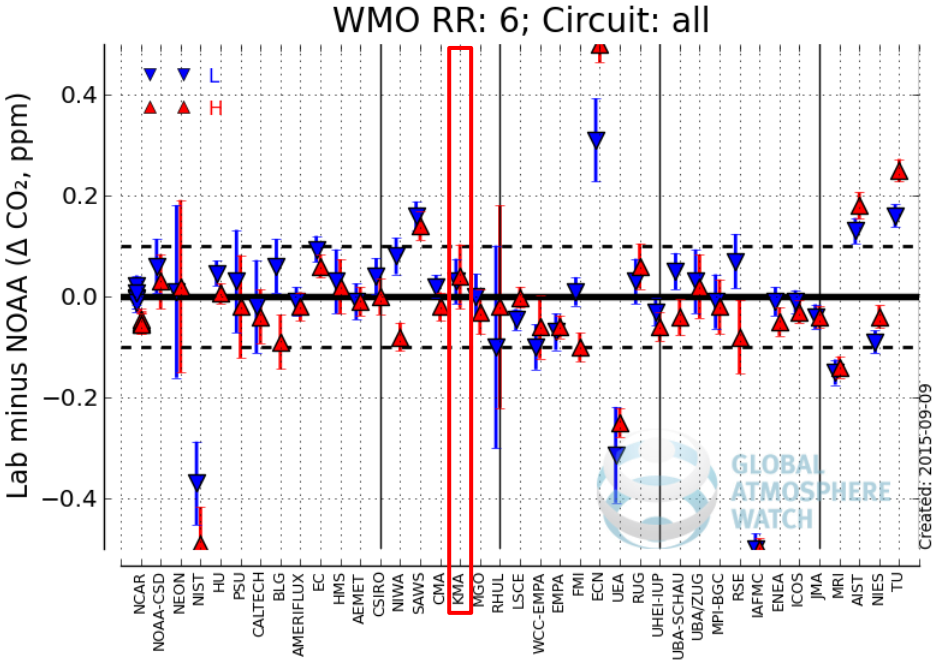
KMA Korea Meteorological Administration

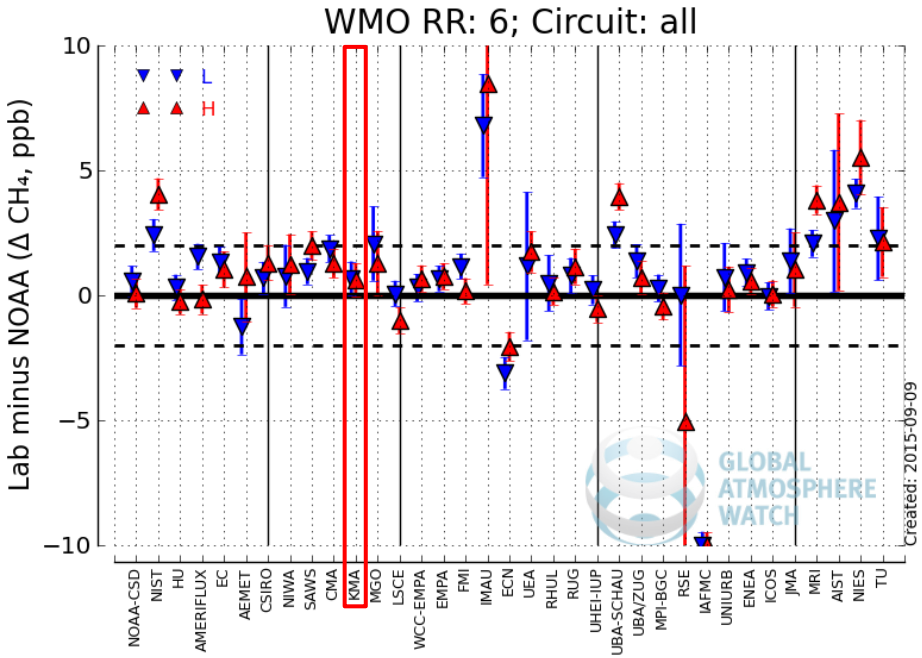
Participation in Round-Robin Comparisons

ΔCO_2, ΔCH_4, ΔN_2O, ΔSF_6, ΔCO

in RR6 (2014-2015) organized by WMO-CCL in NOAA

(Sample analysis by KMA/KGAWC was done in Dec. 2014)





(Source: http://www.esrl.noaa.gov/gmd/ccgg/wmorr/)

Participation in Methane Inter-comparisons

Methane Reference Gas Inter-comparisons

Organized by WMO WCC-CH_4 in JMA

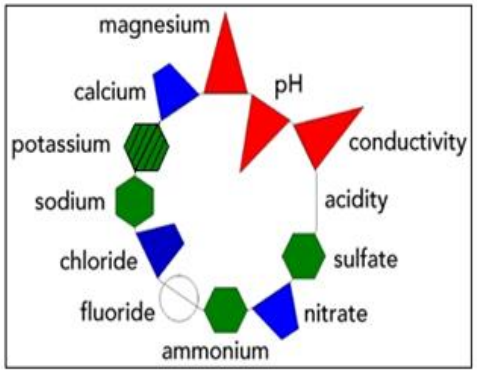
Number of Round	Region	Period of Intercomparison	Participating Laboratory	Cylinder No.
1st	Asia	Apr. 2001 - Nov. 2001	JMA, CMA, KMA	CPB13002 CPB13003
	South-West Pacific	Apr. 2002 - Dec. 2003	JMA, CSIRO, NIWA	
	Japan	Sep. 2004 - Mar. 2005	JMA, TU, NIES	
2nd	Asia	Jul. 2005 - Aug. 2006	JMA, CMA, KMA, KRISS	CPB31289 CPB31288
	South-West Pacific	Dec. 2006 - Aug. 2008	JMA, CSIRO, NIWA	
	Japan	Jun. 2009 - Jan. 2010	JMA, NIES, TU	
3rd	Asia	May 2008 - Jul. 2009	JMA, KRISS, KMA, CMA	CPB13002 CPB13003
	South-West Pacific	Apr. 2010 - Feb.2011	JMA, CSIRO, NIWA	
	Japan	Oct. 2012 - Feb. 2013	JMA, NiPR, AIST, MRI, NIES, TU	
4th	Asia	Jun. 2011 - Mar. 2012	JMA, CMA, KMA	CPB31288 CPB31289
	South-West Pacific	Jun. 2013 - Apr. 2014	JMA, CSIRO, NIWA, NOAA/ESRL	
	Japan	2015 - (In the planning)		
5th	Asia	2014 - (Ongoing)	… KMA ….	CPB13002 CPB13003
	South-West Pacific	2016 - (In the planning)		

(Source: http://ds.data.jma.go.jp/gmd/wcc/wcc.html)

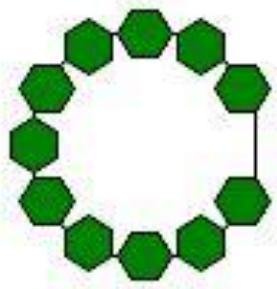
Participation in Precip. Chem. Inter-comparisons

Inter-comparison in Precipitation Chemistry

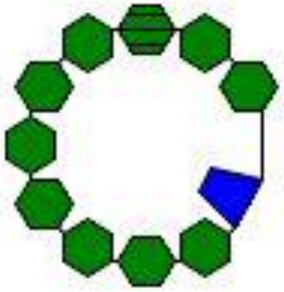
Organized by WDC-PC



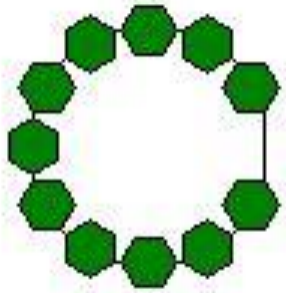
Sample 1



Sample 1



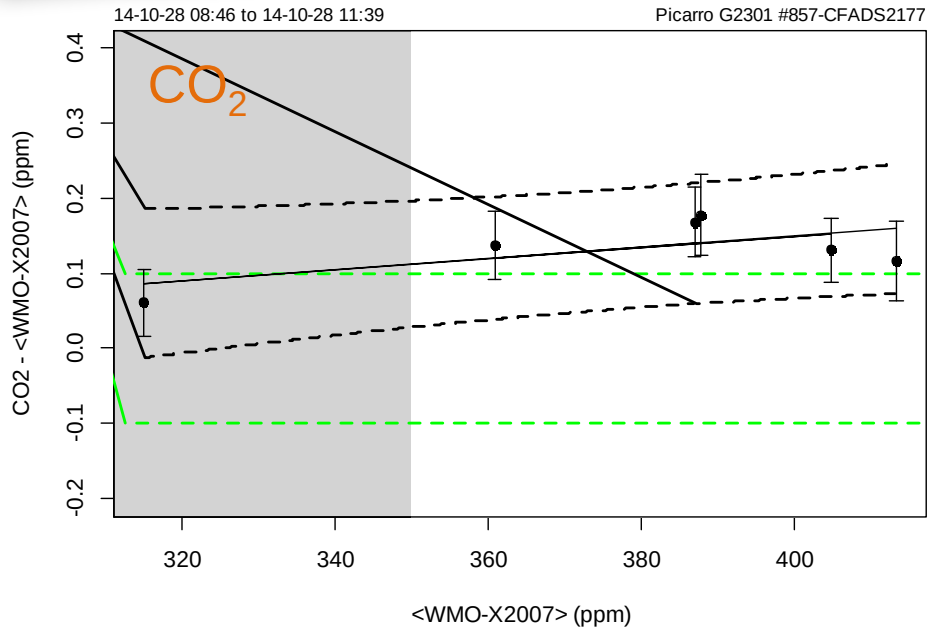
Sample 3

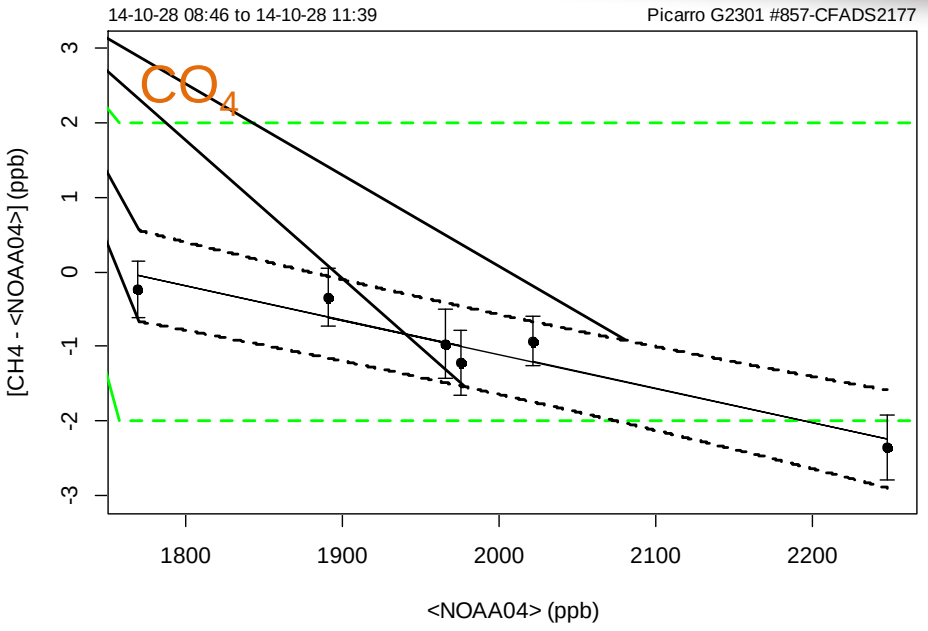


<Results of Inter-comparisons held in May 2015>

- ✓ Good: IQR (Interquartile Range, 25th～75th)
- ✓ Satisfactory: within Median ± IQR/1.349
- ✓ Unsatisfactory: out of Median ±IQR/1.349
- ✓ Out of Detection Limit

Audit by WCC-CO_2,CH_4 (EMPA)





- Small offset of about 0.1 ppm, probably due to differences in the NOAA standards.

- Good agreement within the WMO/GAW DQOs
- Small overestimation expected at <1600 ppb, underestimation at >2200 ppb

<Recommendations>

- The good results showed that the whole measurement set-up is appropriate, and no immediate change of the current praxis is needed.
- It should be considered to use an automated system for calibrations, which would allow the measurements of target and WS.

Audit by WCC-CO_2,CH_4 (EMPA)

Summary Ranking of the Anmyeon-do GAW Station

System Audit Aspect	Adequacy[#]	Comment
Access	(5)	All year access possible
Facilities		
Laboratory and office space	(5)	Large laboratory facilities
Internet access	(5)	Reliable, sufficient bandwidth
Air Conditioning	(5)	Fully adequate
Power supply	(5)	Reliable
General Management and Operation		
Organisation	(5)	Well organised, clear responsibilities
Competence of staff	(4)	Good technical and scientific knowledge, international collaboration encouraged
Air Inlet System	(5)	Adequate system
Instrumentation		
CO_2/CH_4 (Picarro G2301)	(5)	Adequate instrumentation
Standards		
CO_2, CH_4	(4)	NOAA standards, additional working standards recommended
Data Management		
Data acquisition	(5)	Fully adequate
Data processing (CO_2, CH_4)	(4)	Current praxis of weekly instrument calibration results in small jumps.
Data submission (CO_2, CH_4)	(5)	Timely, regular submission

[#]0: inadequate thru 5: adequate.

Dübendorf, August 2015

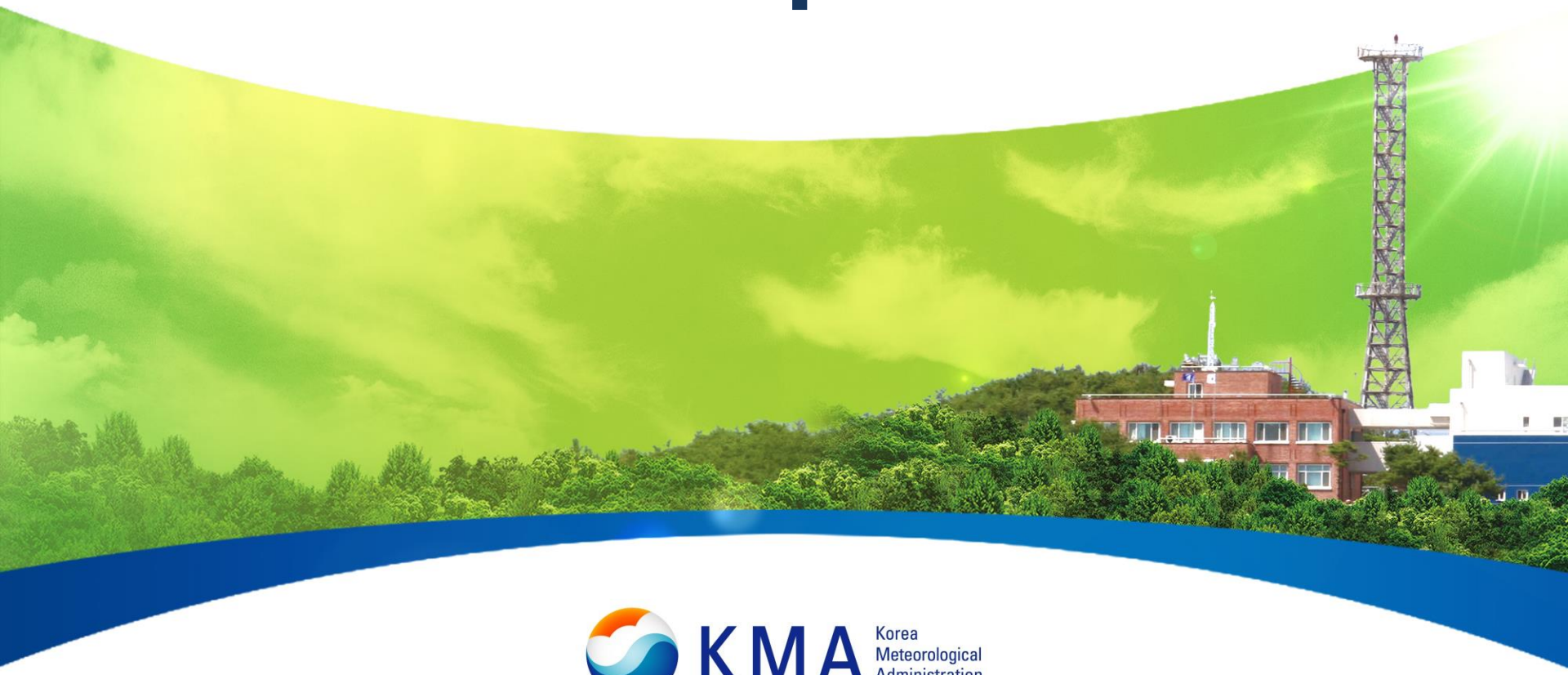
Dr. C. Zellweger	Dr. M. Steinbacher	Dr. B. Buchmann
WCC-Empa	QA/SAC Switzerland	Head of Department

Conclusion of the report

- ✓ The Regional GAW station Anmyeon-do comprises a very comprehensive set of measurements.
- ✓ The combination of long-term measurements, the large number of measured parameters and the location of the site make the AMY station a very important contribution to the GAW programme.
- ✓ The assessed GHG measurements were of high quality.
- ✓ WCC-Empa strongly encourages this process, since the available data would be a very valuable contribution to GAW.
- ✓ The continuation of the Anmyeon-do measurement series as well as the inclusion of the reactive gases measurement programme as GAW parameters is highly recommended.

Climate Change Monitoring Division

Int'l Cooperation



KMA Korea Meteorological Administration

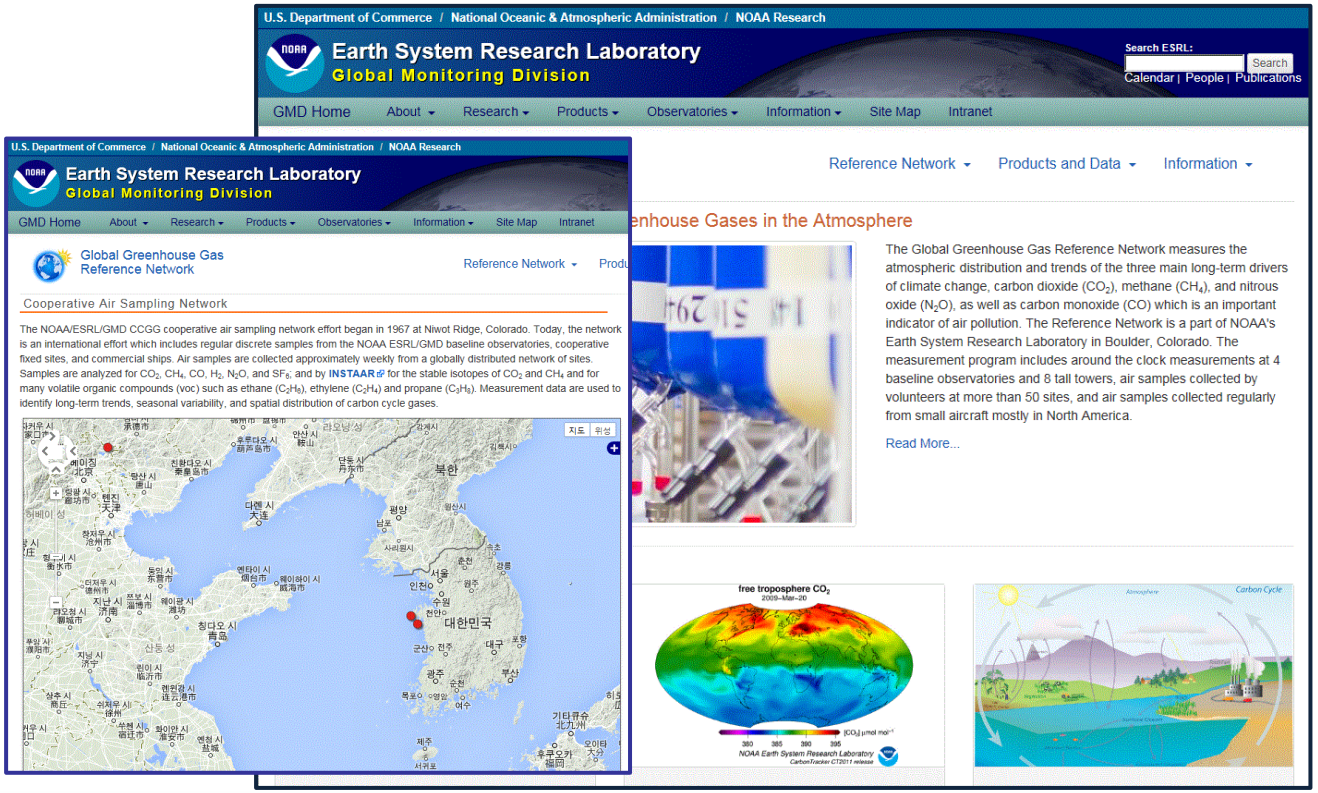
International Cooperation

- Canada/ EC
  - Ozone, UV
- China/ CMA
  - GHGs
- Germany/ DWD
  - Aerosols
  - precipitation chemistry
- India/ IITM
  - GHGs
- Japan/ JMA
  - GHGs
- Vietnam/ NHMS
  - GHGs

- ✓ Share the measurement data and techniques
- ✓ Improve the QA/QC and data quality

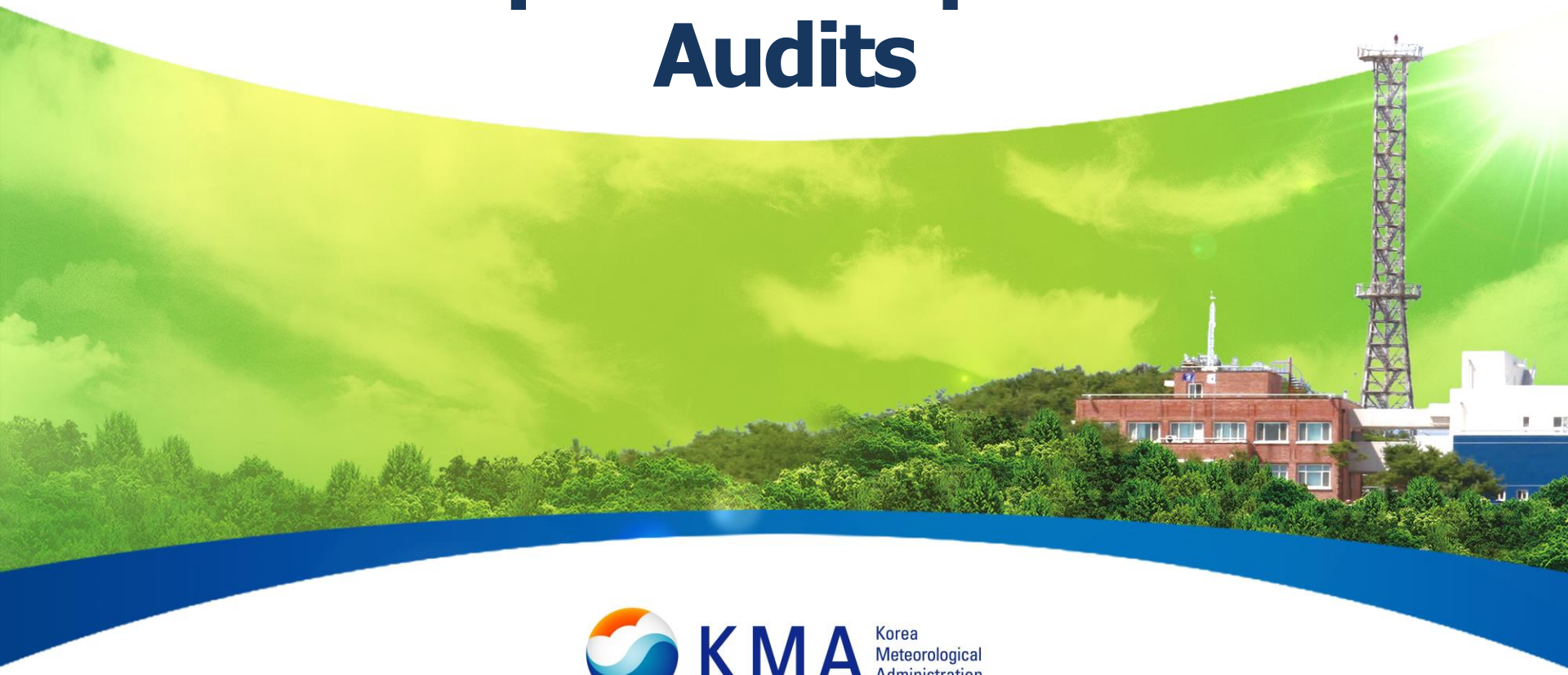
Cooperation with NOAA

- Comparison of real-time measurements of CO_2 & CH_4 with a flask sampling since Dec. 2013.
  - KMA: CO_2, CH_4 from CRDS at rate of 5 sec.
  - NOAA: ~20 species from a flask sampling once a week



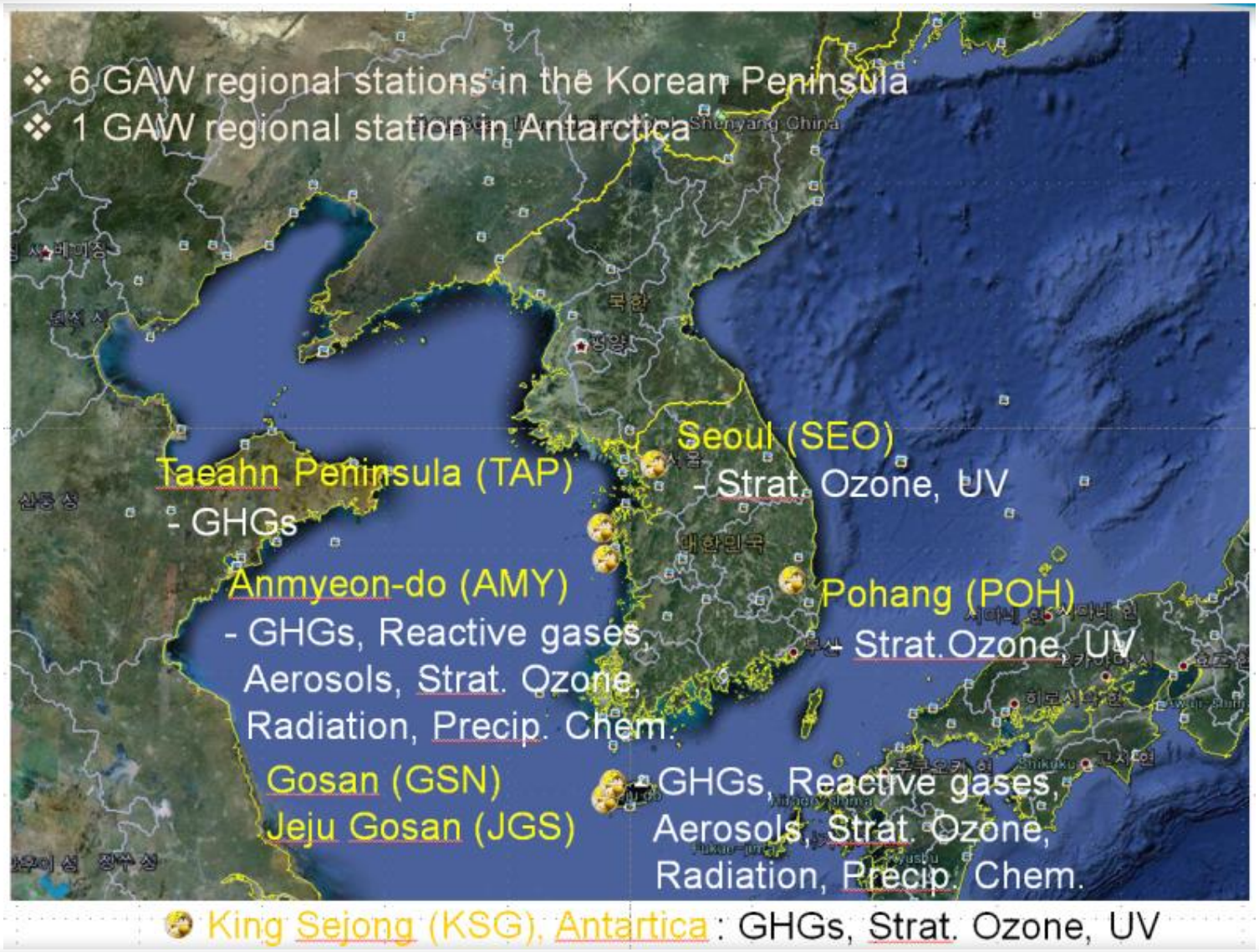
Climate Change Monitoring Division

Int'l Comparison Experiments & Audits



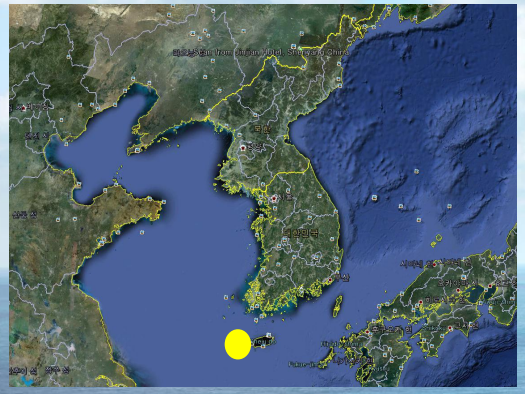
KMA Korea Meteorological Administration

Integration of GAW-related Observations in Korea



- ✓ Share the techniques & data in fields of GAW

Gosan (GSN), Supersite (SNU, KNU, JNU, KMA, etc.)



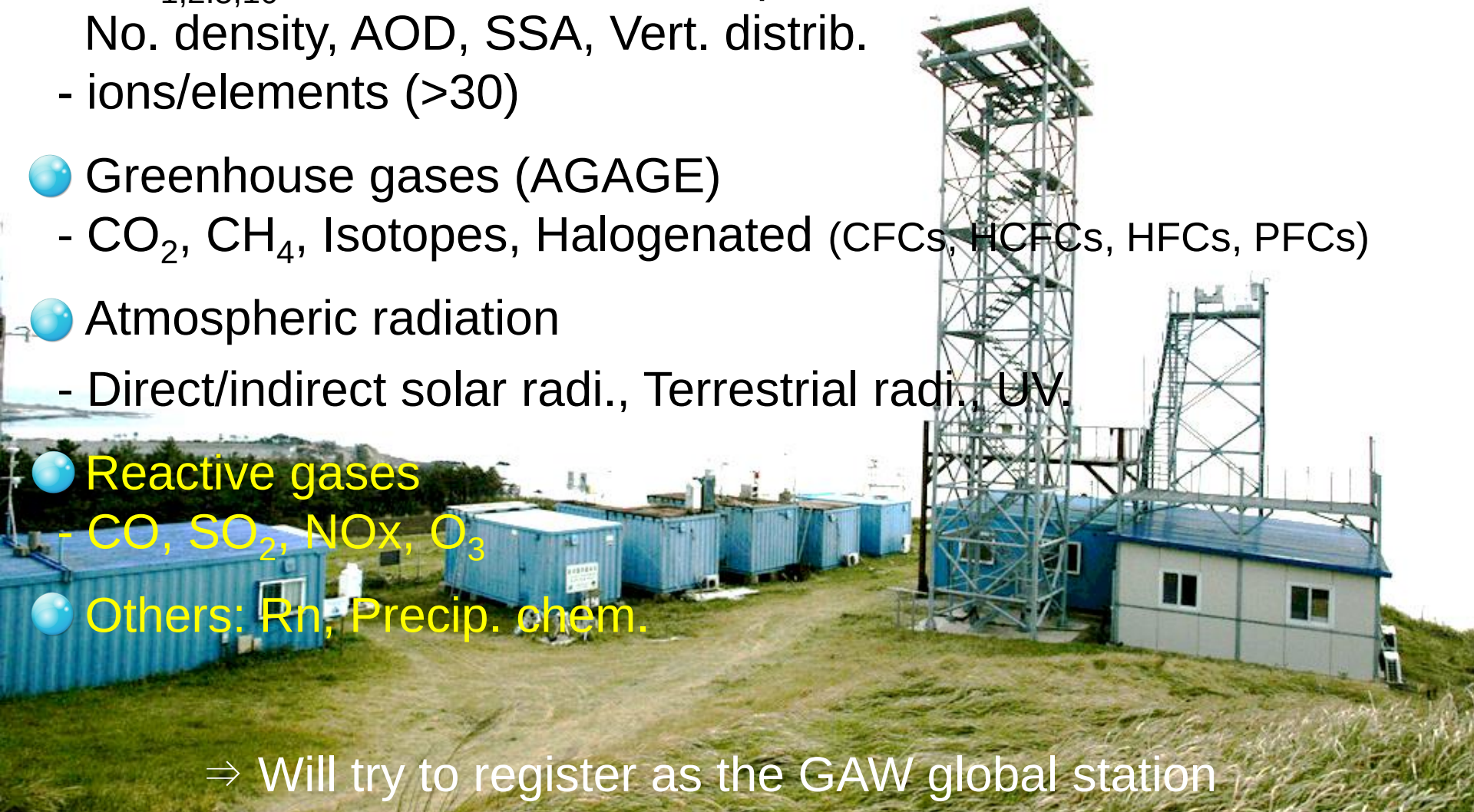
KMA station

Super site

항공촬영일 2013.12.14.

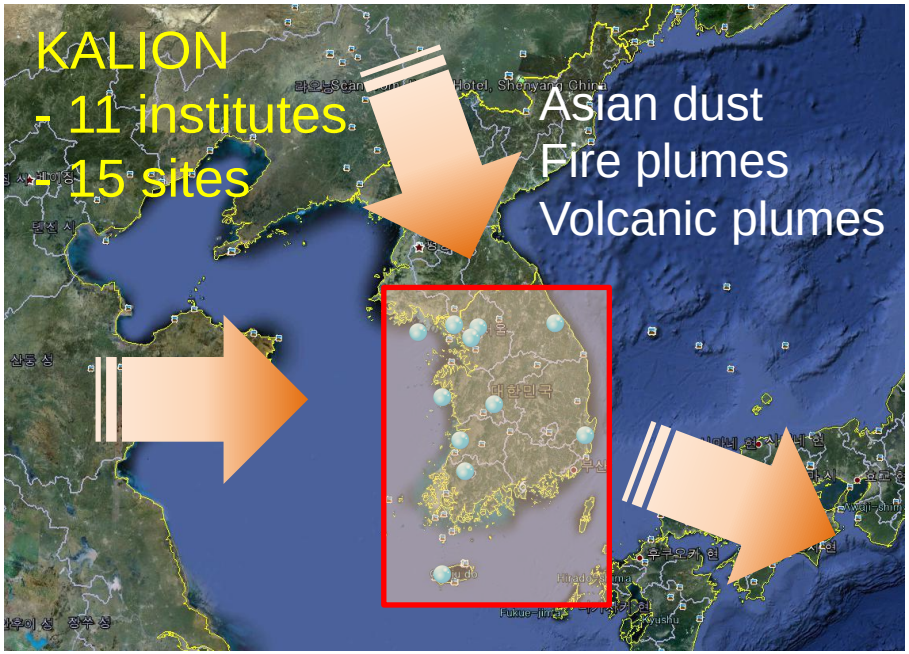
Gosan (GSN), Supersite (SNU, KNU, JNU, KMA, etc.)

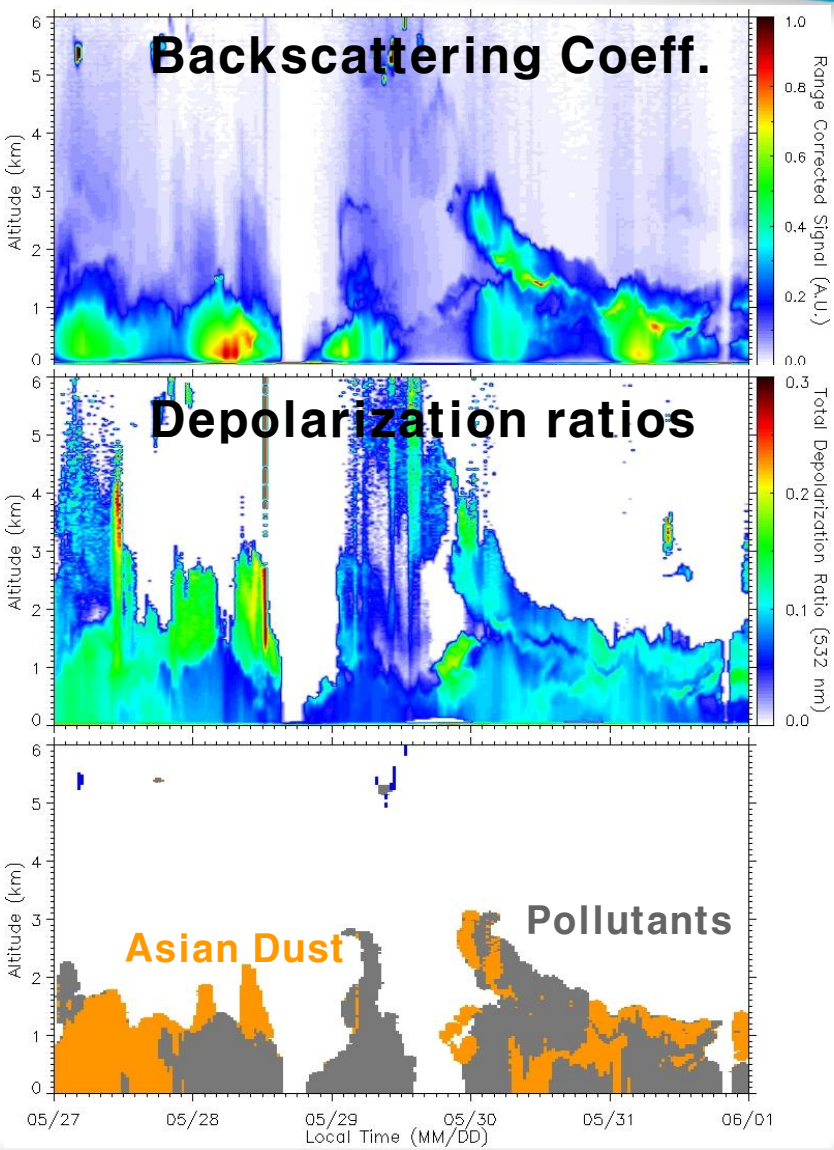
- Aerosols
  - $PM_{1,2.5,10}$, EC/OC, Scatt./Absorp. coeff., Size distrib., No. density, AOD, SSA, Vert. distrib.
  - ions/elements (>30)
- Greenhouse gases (AGAGE)
  - CO_2, CH_4, Isotopes, Halogenated (CFCs, HCFCs, HFCs, PFCs)
- Atmospheric radiation
  - Direct/indirect solar radi., Terrestrial radi., UV.
- Reactive gases
  - CO, SO_2, NOx, O_3
- Others: Rn, Precip. chem.



⇒ Will try to register as the GAW global station

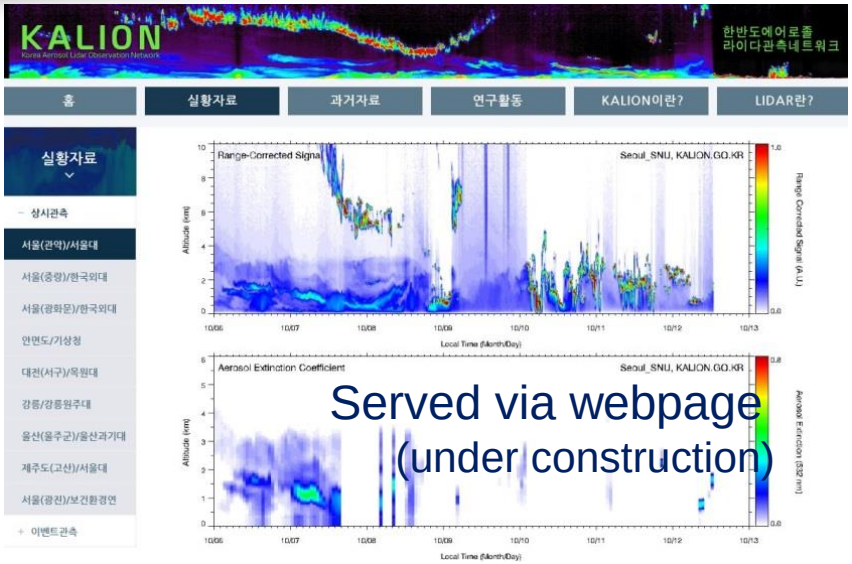
Korea Aerosol LIDAR Observation Network

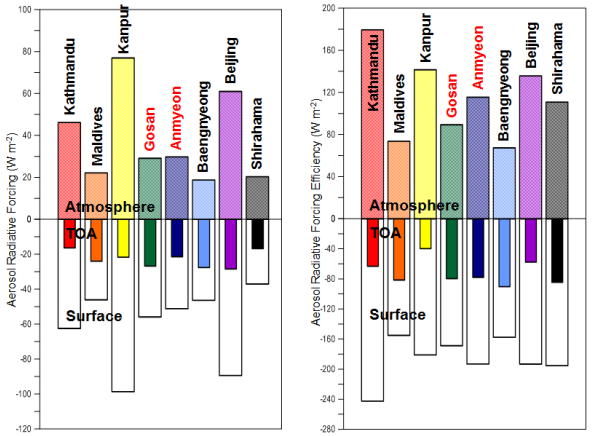




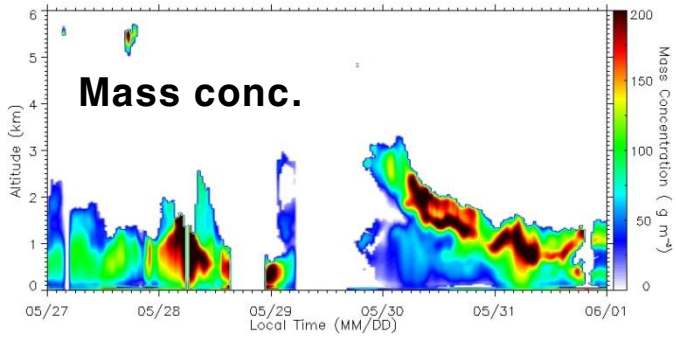
⇒ Plan to join GALION

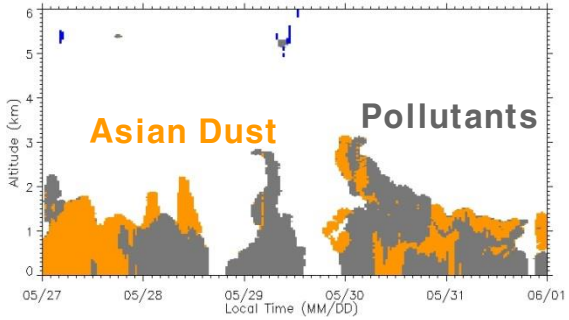
Data Sharing & Output from KALION



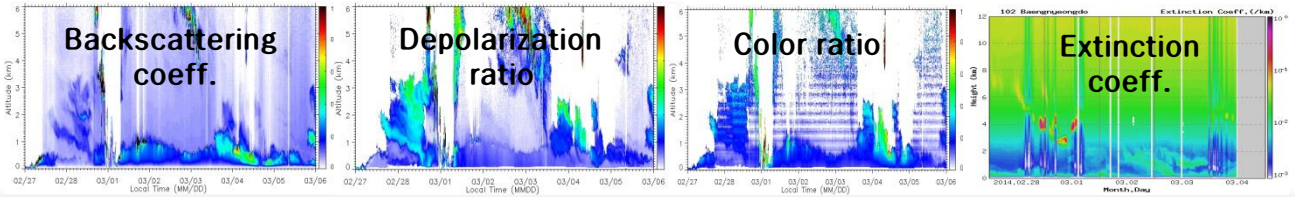


Aerosol Radiative Forcing





Asian Dust Monitoring



Aerosol Properties

KOICA : Training & Education Programme

❖ Title : Capacity building on Climate Change Driver Monitoring Techniques: Greenhouse Gases

* Beneficiaries : technicians or researchers with bachelor's degree of countries which have been monitoring and have a plan to monitor greenhouse gases in the atmosphere

❖ Implementation Agency: Korea Meteorological Administration

❖ Program module: Theorectical lecture (30%), Practice (70%)

❖ Duration: 14 days (once a year)

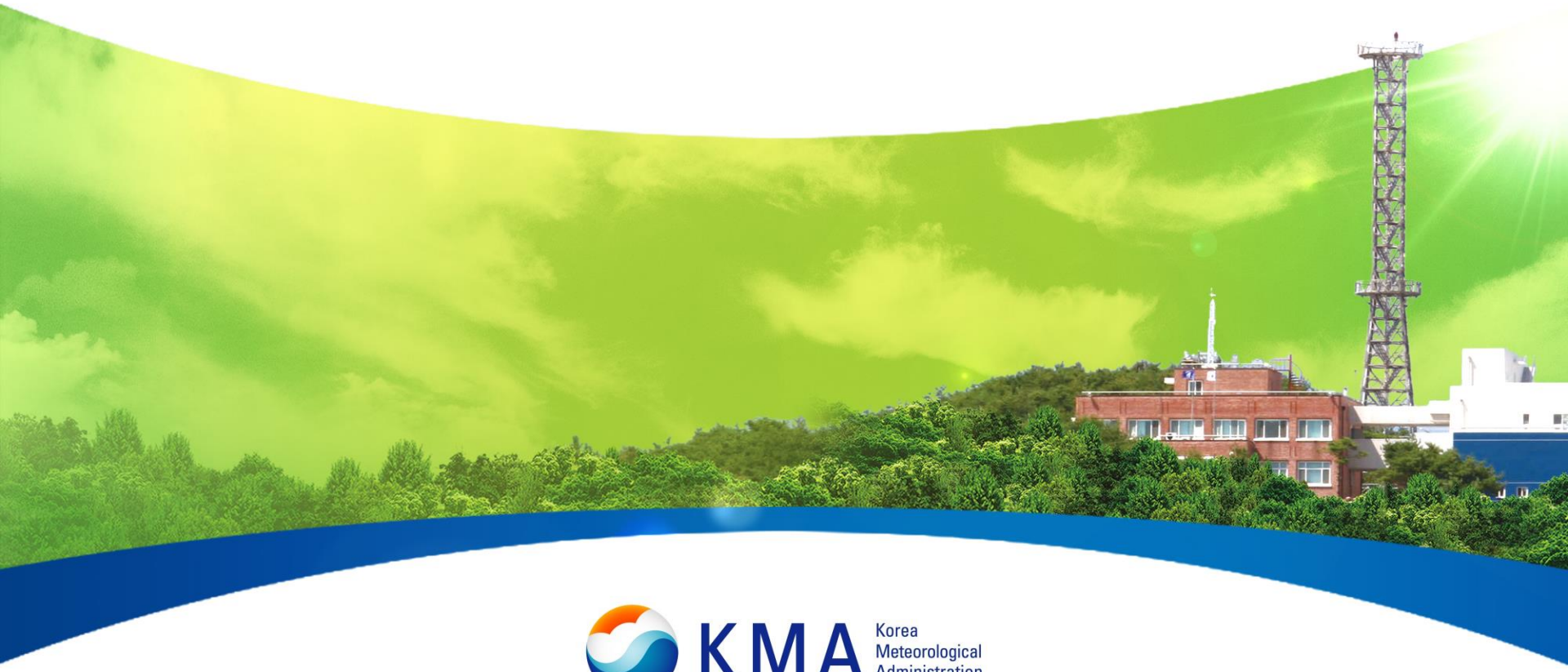
❖ Start: 2017

** Election campaign pledges for an IPCC Chair, done in Oct. 6, 2015

(KOICA: Korea International Cooperation Agency)

Climate Change Monitoring Division

Public Service



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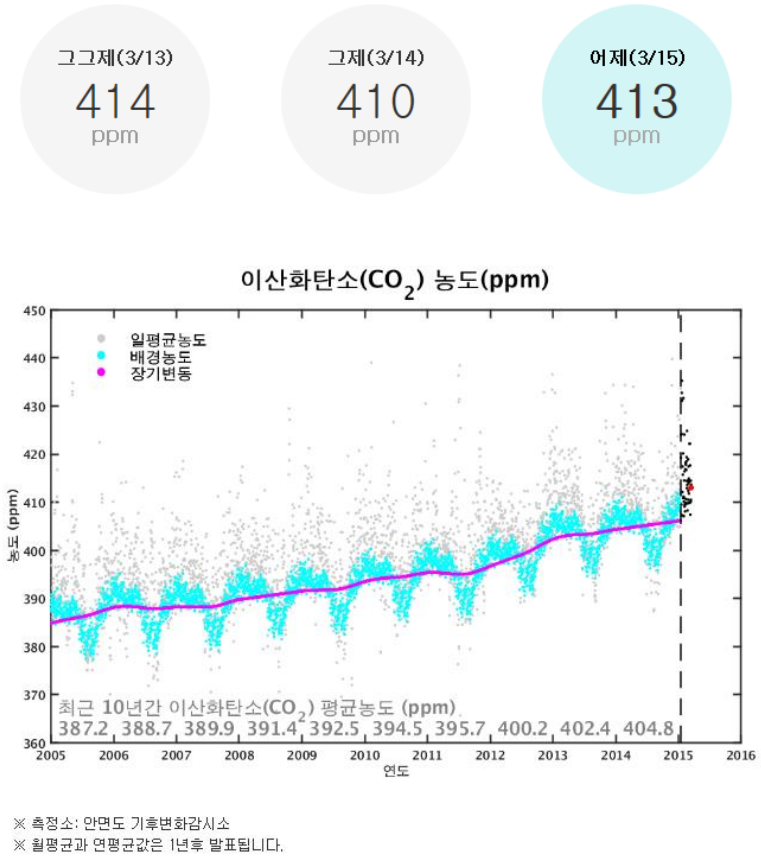
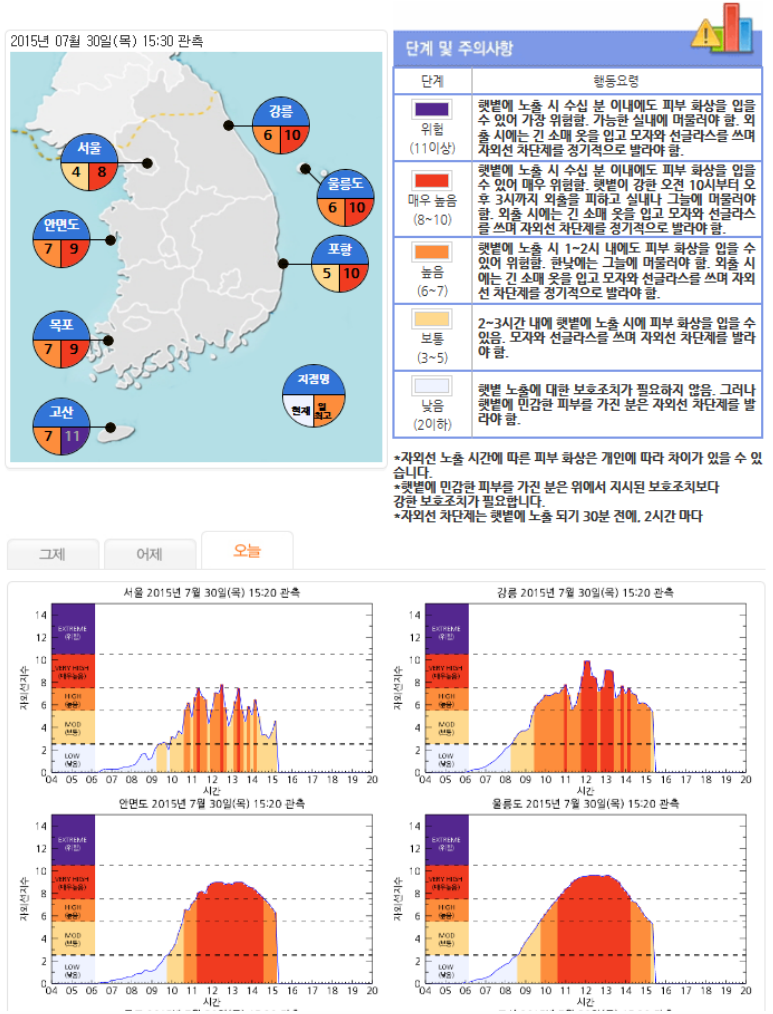
On-line Public Service via KMA Webpage

CO_2 concentrations

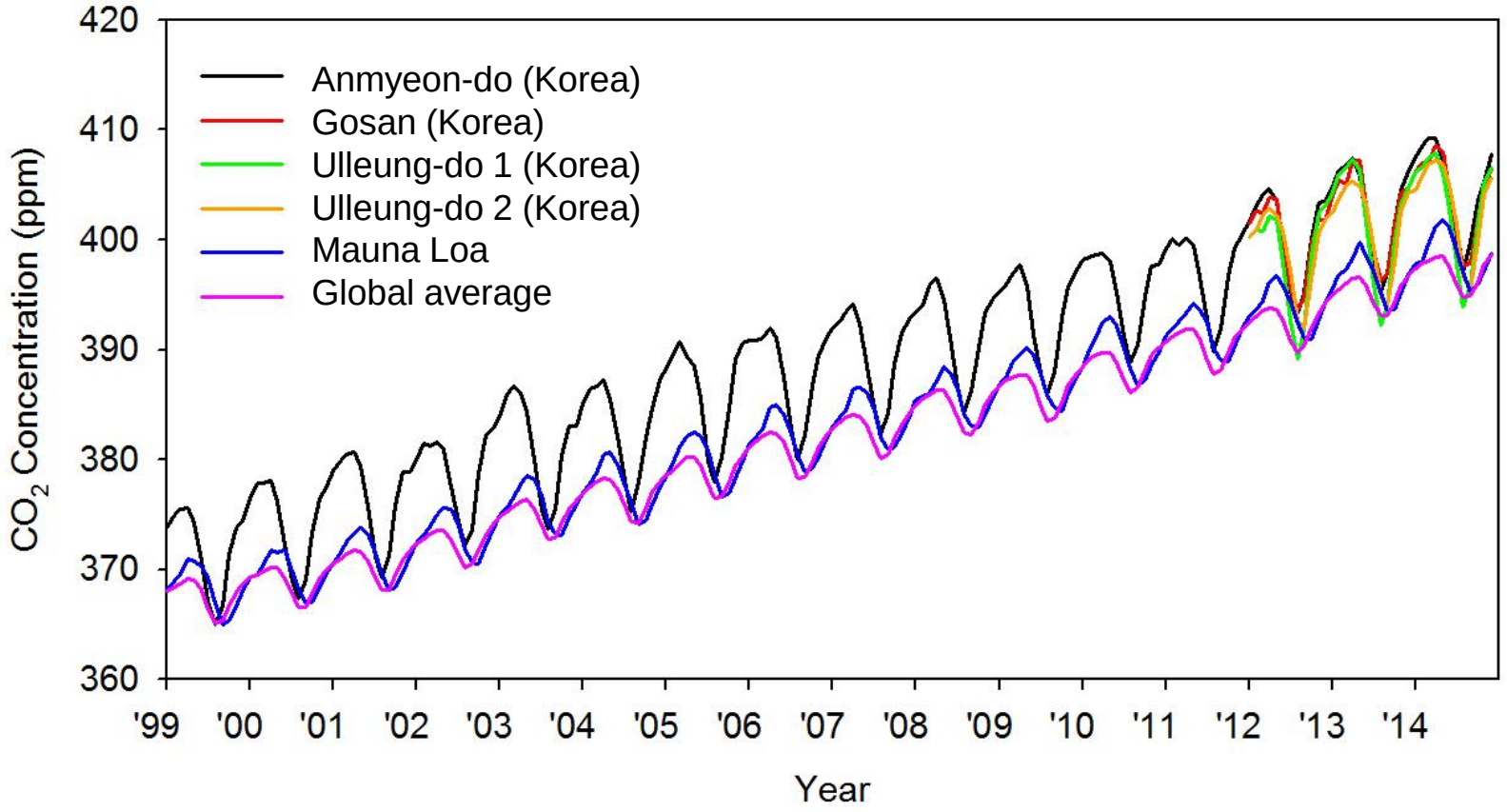


※ 측정소: 안면도 기후변화감시소
※ 월평균과 연평균값은 1년후 발표됩니다.

UV index



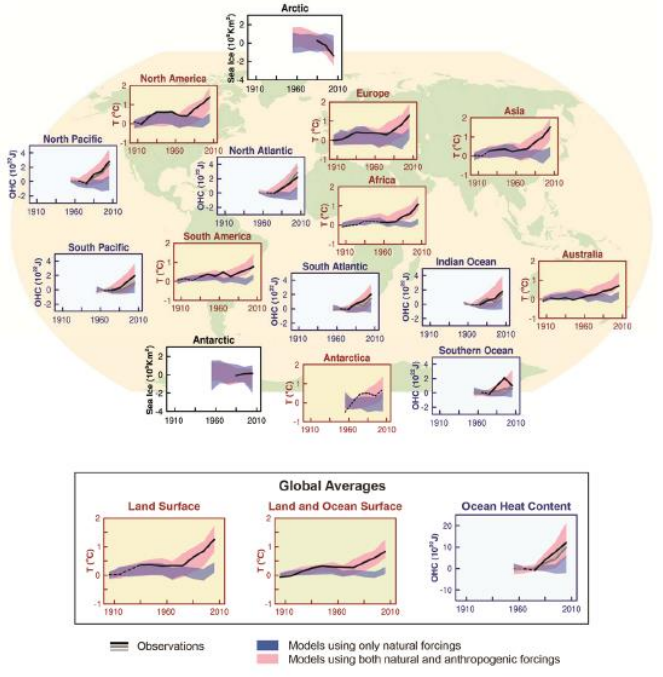
Summary (1/2) : Current



We make this kinds of plots on other components in fields of GAW, and improve/develope techniques for the GAW activities

Summary (2/2) : Future Plan

- ❖ Int'l cooperation
  - Share the data and techniques
- ❖ Estimation of emissions from measurement data
  - using top-down approach
- ❖ Retrieval of the vertical information
  - using ground-based/satellite-borne remote sensing techniques



- ❖ Climate system
  - Atmosphere: Temp., Precip.
  - Ocean: Sea level, Surf. temp., Acidity
  - Cryosphere: Glaciers, Snow cover
  - Carbon and Other Biogeochemical Cycles
  - Ecosystem Change

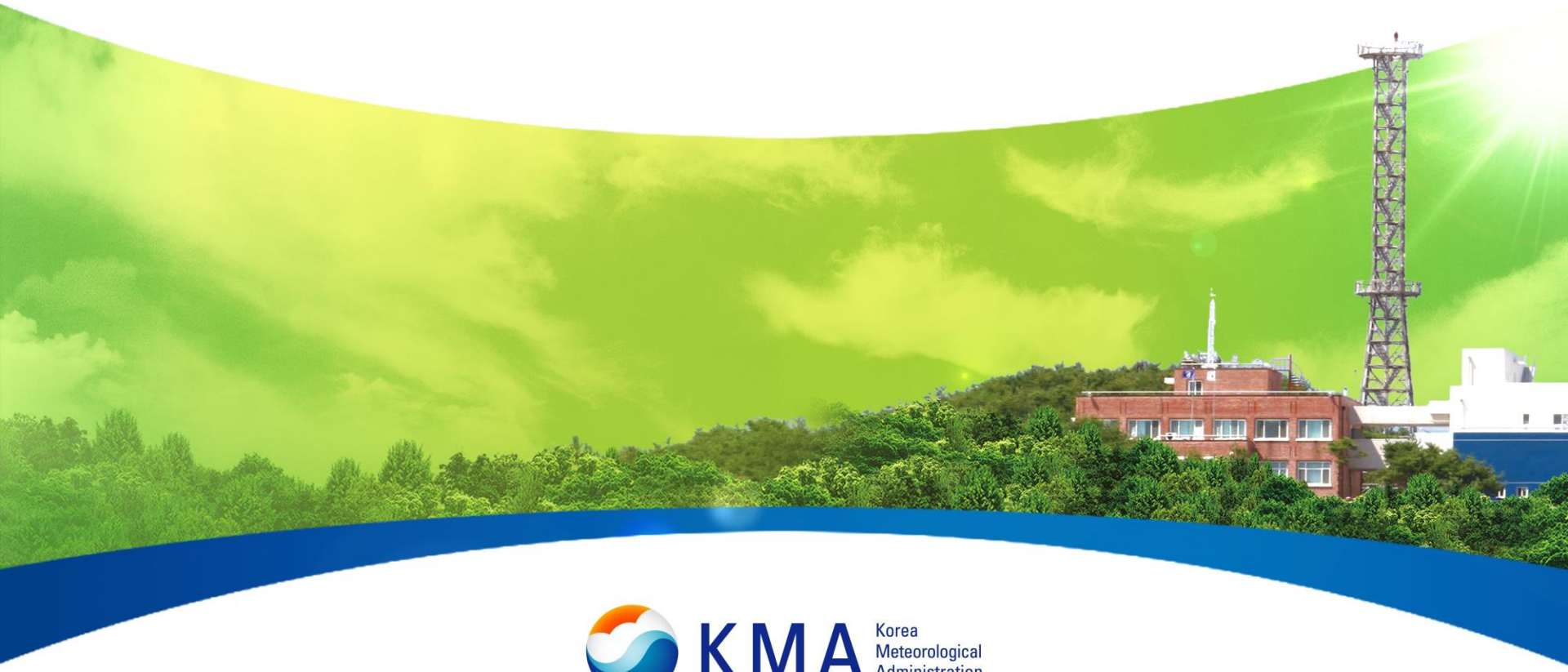
Extra

History of GAW in Korea

1987. 1.	Establishment of a weather station at Mt. Soback (Purpose of air pollution measurements)
1996. 9.	Movement from Mt. Soback to Anmyeondo Beginning of background atmosphere watch at Anmyeondo
1998. 4.	Continuous measurement of greenhouse gases and radiation (CO_2 , CH_4, N_2O, CFC-11,12, designated a GAW regional station)
2003. 12.	Sampling from 40 m tower (AGL) (~86 m ASL)
2007. 1.	Beginning of continuous measurement of CFC-113 and SF_6 Aerosol sampling from the integrated inlet system
2009. 1.	Operation of the Jeju Gosan (JGS) station (Designated a GAW regional station in 2013)
2012. 10.	Establishment of WMO/GAW World Calibration Centre for SF_6
2014. 5.	Operation of the station at Ulleungdo

Climate Change Monitoring Division

Measurement Stations of KGAWC



KMA Korea Meteorological Administration

Anmyeondo (AMY) Station

Greenhouse Gases
CO_2, CH_4, N_2O,
$CFC_{11, 12, 113}$, SF_6

Aerosols
Physical, chemical,
optical properties

Reactive Gases
SO_2, CO, NOx, O_3

Ozone & UV
UV-A, UV-B
Stratospheric Ozone

Precipitation Chemistry
Acidity, Conductivity
F^-, Cl^-, NO_3^-, SO_4^{2-},
Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}

Atmospheric Radiation
Direct/diffuse sunlight
Solar/terrestrial radiation
Net radiation

Anmyeondo (AMY) Station

Tower (40m) inlets for GHGs

Lat.: 36.538 86° (36°32’19.9”)
Lon.: 126.329 95° (126°19’47.8”)
ASL: 85.119 m

AWS, Inlets for aerosols Aerosol LIDAR

Lat.: 36.538 79° (36°32’19.7”)
Lon.: 126.330 22° (126°19’48.8”)
ASL: 57.697 m

Brewer, Sunphotometer, Precision Filter Radiometer

Lat.: 36.538 65° (36°32’19.1”)
Lon.: 126.330 05° (126°19’48.2”)
ASL: 56.496 m

FTIR (KMA/NIMS, KRISS)

Lat.: 36.538 79° (36°32’17.7”)
Lon.: 126.330 22° (126°19’48.8”)
ASL: 57.697 m

FTS (KMA/NIMS)

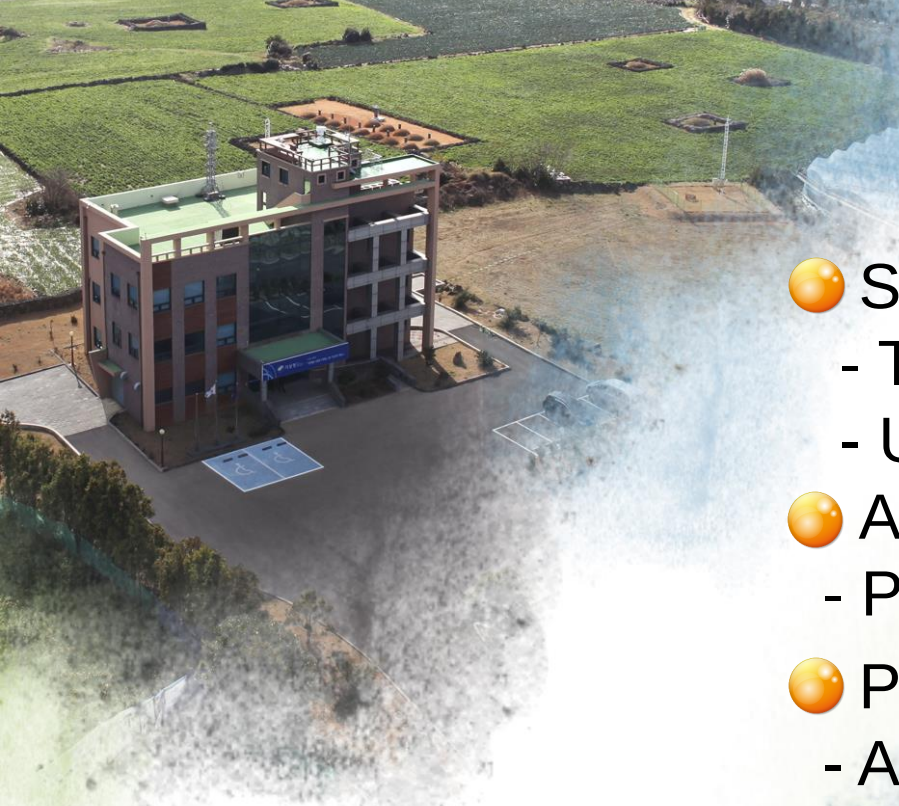
Lat.: 36.538 22° (36°32’17.6”)
Lon.: 126.331 02° (126°19’51.7”)
ASL: 23.810 m

Atmospheric Radiation

Lat.: 36.538 46° (36°32’18.5”)
Lon.: 126.329 95° (126°19’47.8”)
ASL: 47.026 m

Jeju Gosan (JGS) Station

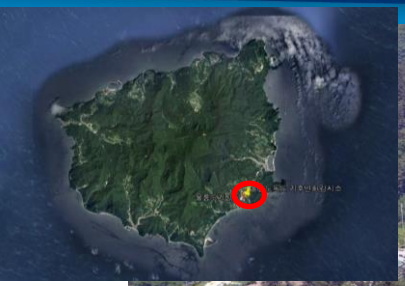
Lat./Lon. : 33°18'N / 126 °12'E



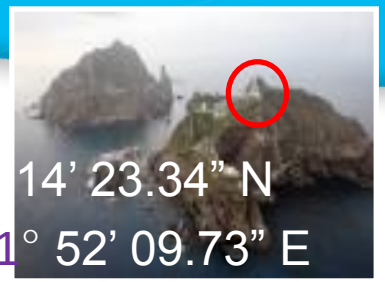
- Stratospheric O_3 /UV-A, UV-B,
  - Total O_3 Column
  - UV-A, UV-B,
- Atmospheric radiation
  - PFR, Solar/ Terrestrial radiation
- Precipitation chemistry
  - Acidity, Conductivity, Ions

- Greenhouse gases
  - CO_2, CH_4, N_2O, SF_6
- Reactive gases
  - CO, SO_2, NOx, O_3
- Aerosols
  - PM_{10}, APS (0.5-20 ㎛), CPC (0.01-3 ㎛), $PM_{1,2.5,10}$
  - AOD (from PFR)

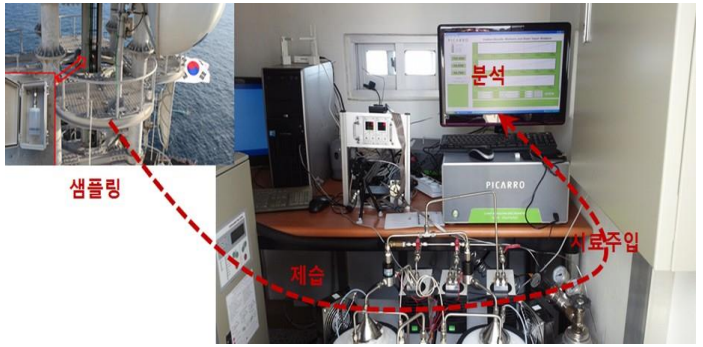
Ulleungdo (ULL) Station



~80 km



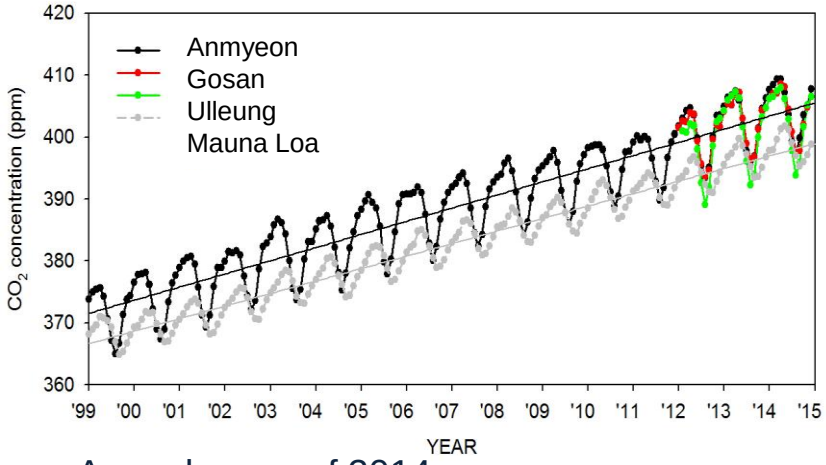
- Greenhouse gases : CO_2, CH_4, N_2O, SF_6
- Reactive gases : CO
- Aerosols : $PM_{1,\ 2.5,10}$, AOD, APS (0.5-20 ㎛)
- Radiation
  - UV-A, UV-B, PFR
  - Solar/ Terrestrial radiation
- Precipitation chemistry
  - Acidity, Conductivity, Ions



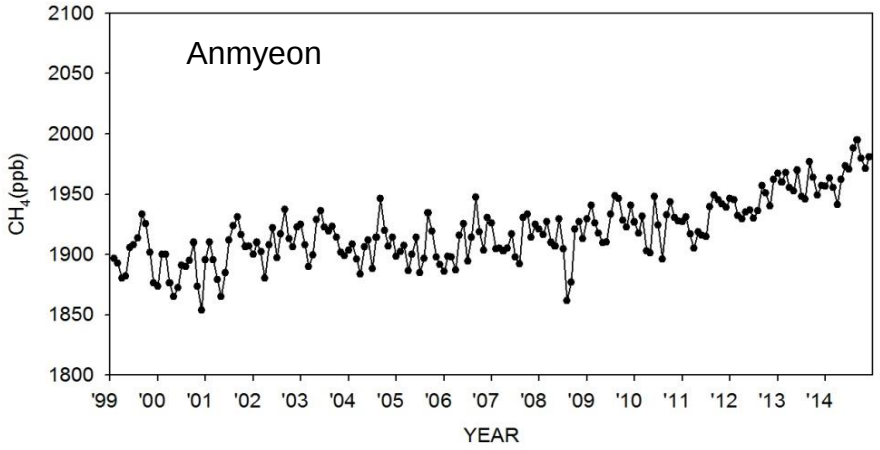
- Greenhouse gases
  - CO_2, CH_4

(Remotely controlled)

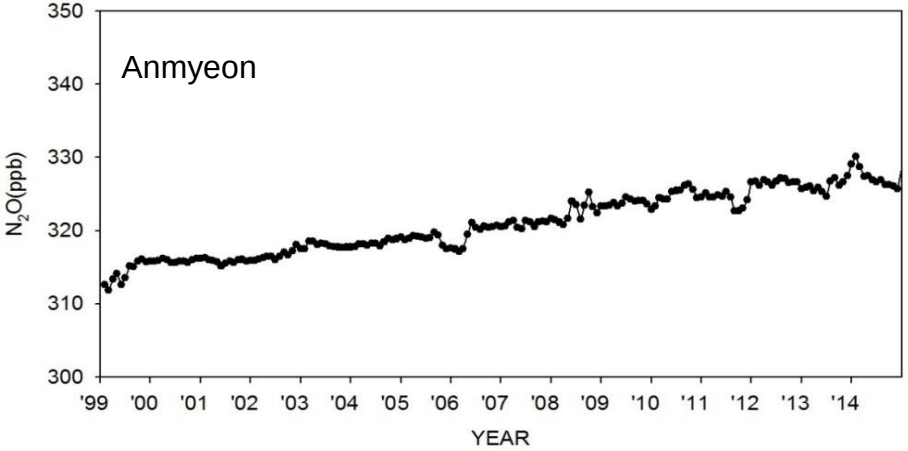
E.g. of GHG Measurements



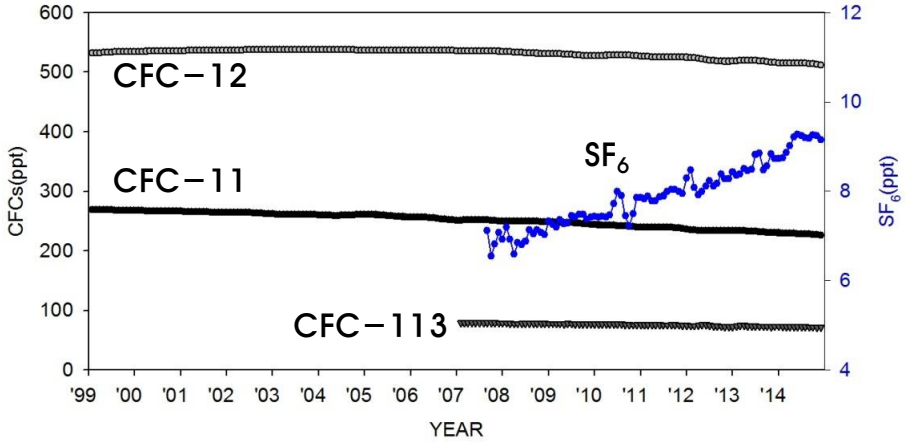
Annual mean of 2014:
- 404.8 ppm in Anmyeon, 404.2 ppm in Gosan
- 398.6 ppm in Mauna Loa



1970 ppb in 2014



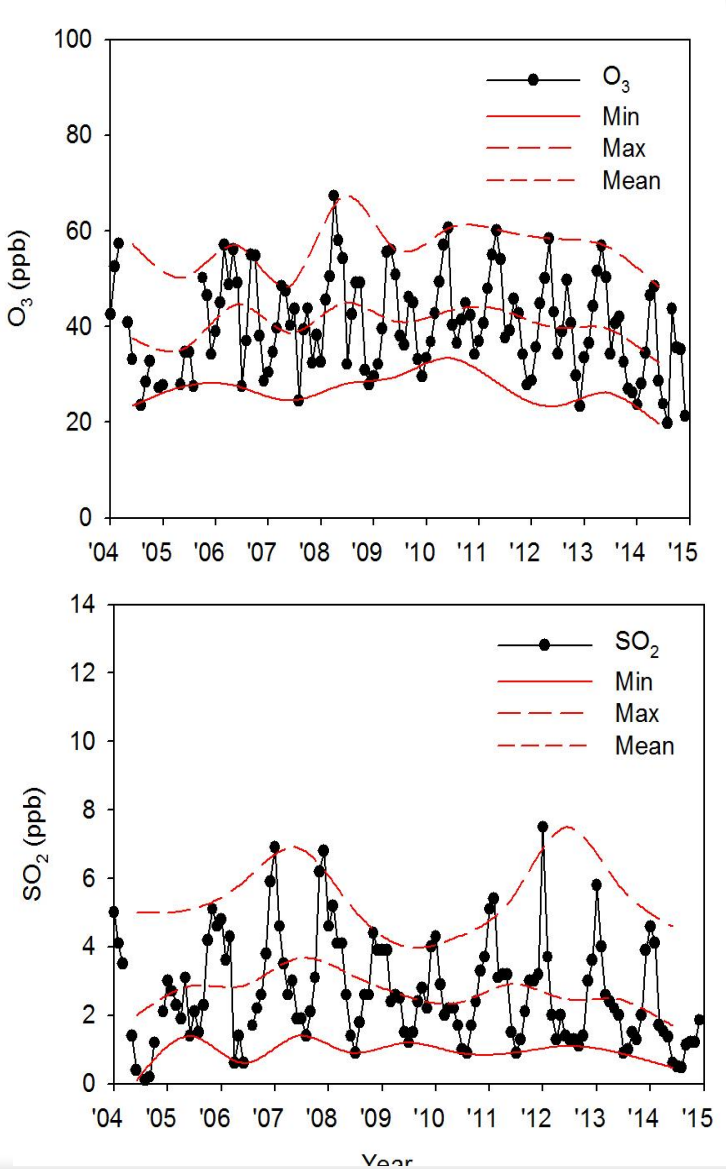
327.2 ppb in 2014

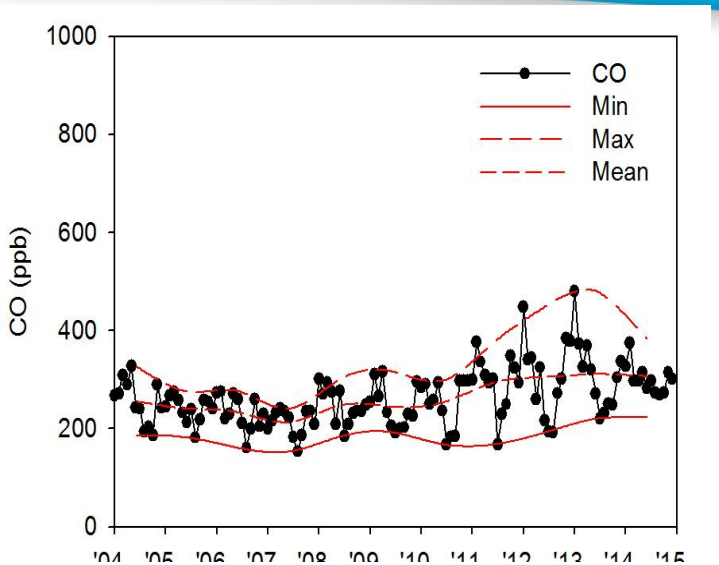


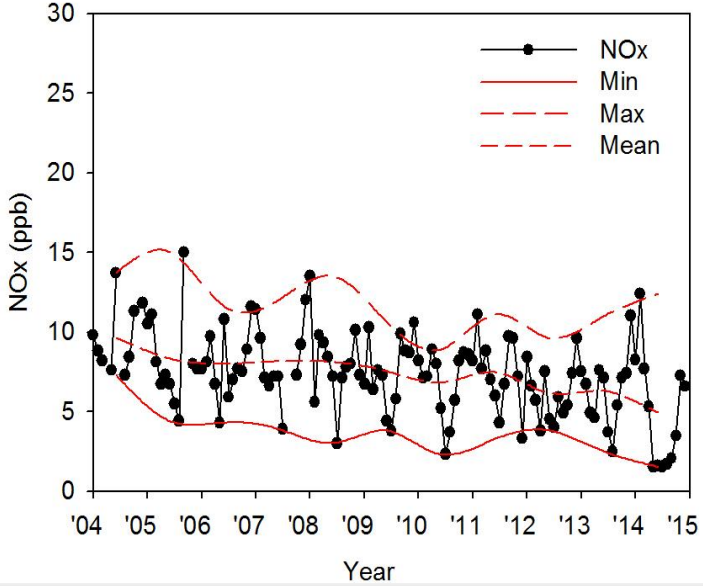
228.3, 514.0, 72.2, 9.0 ppt for CFCs & SF_6 in 2014

* Global/ML data was obtained from WDCGG

E.g. of Reactive Gas Measurements





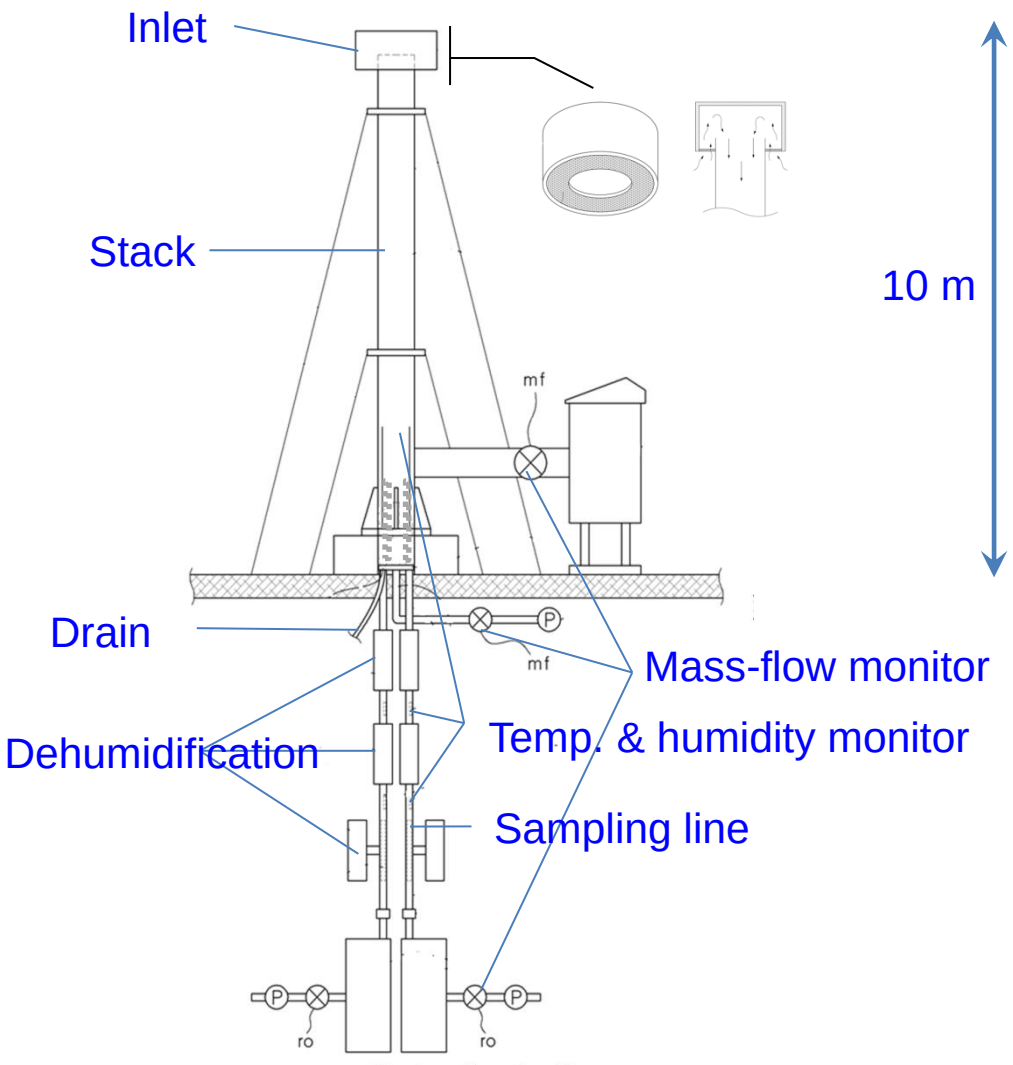


Aerosols – Inlet System

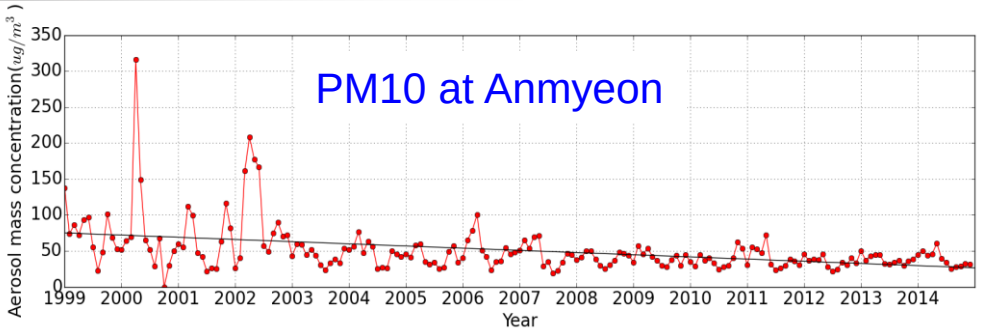
Nephelometer
Aethelometer

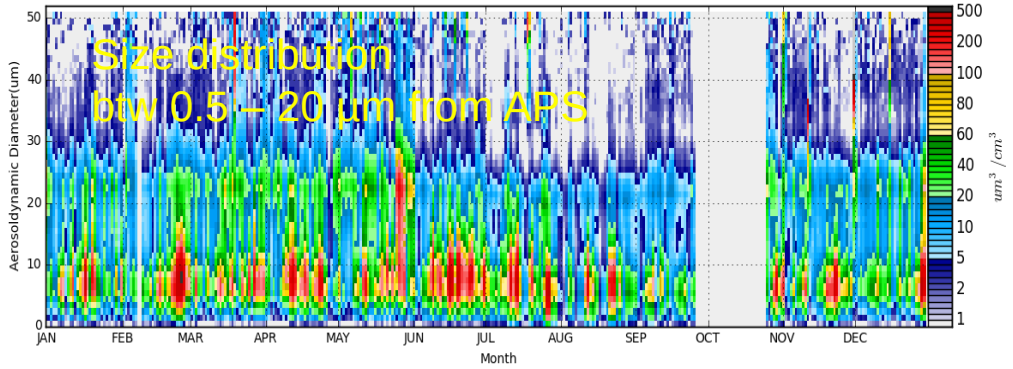
APS
SMPS
PMx

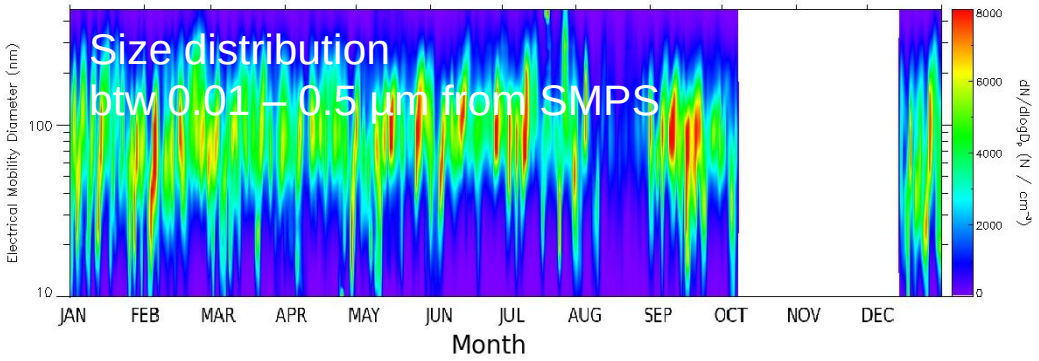
β-ray PM10

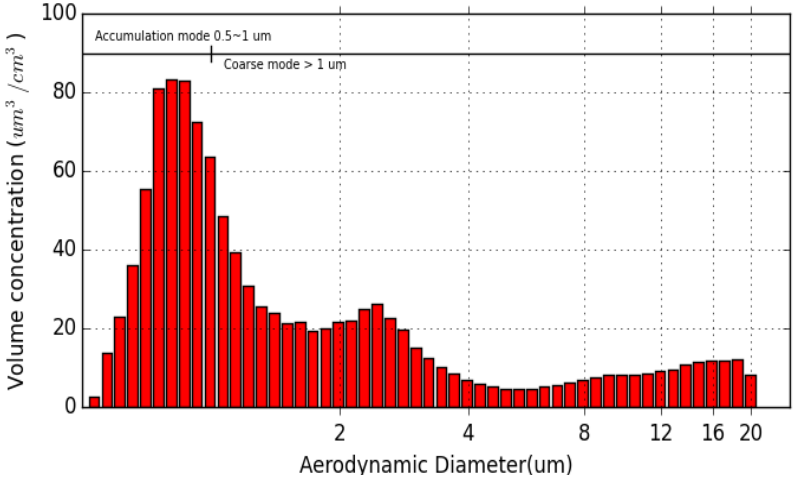


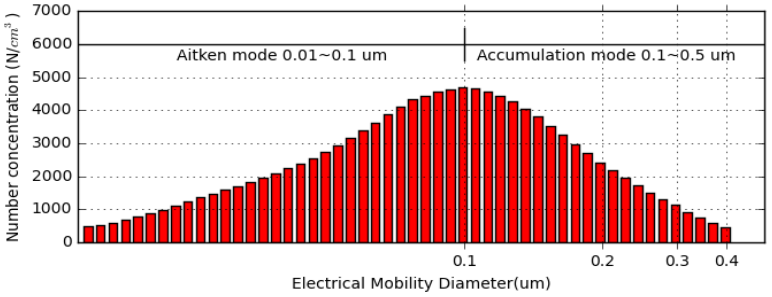
E.g. of Physical Properties



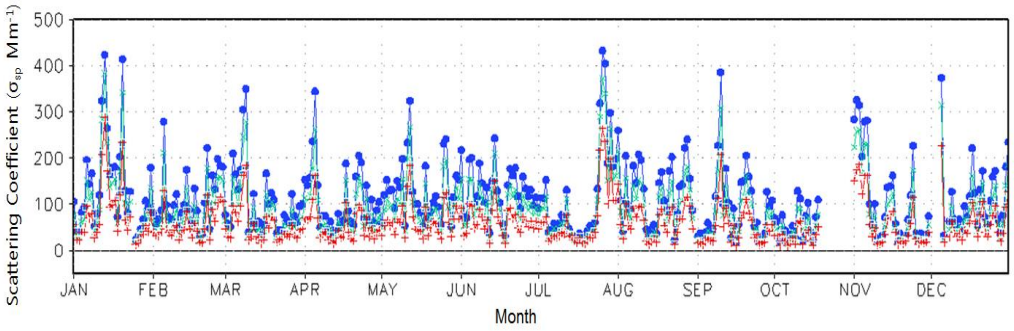




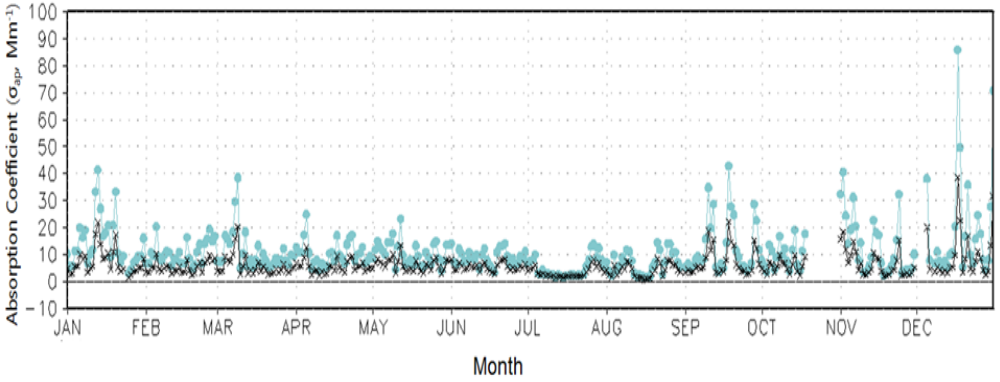




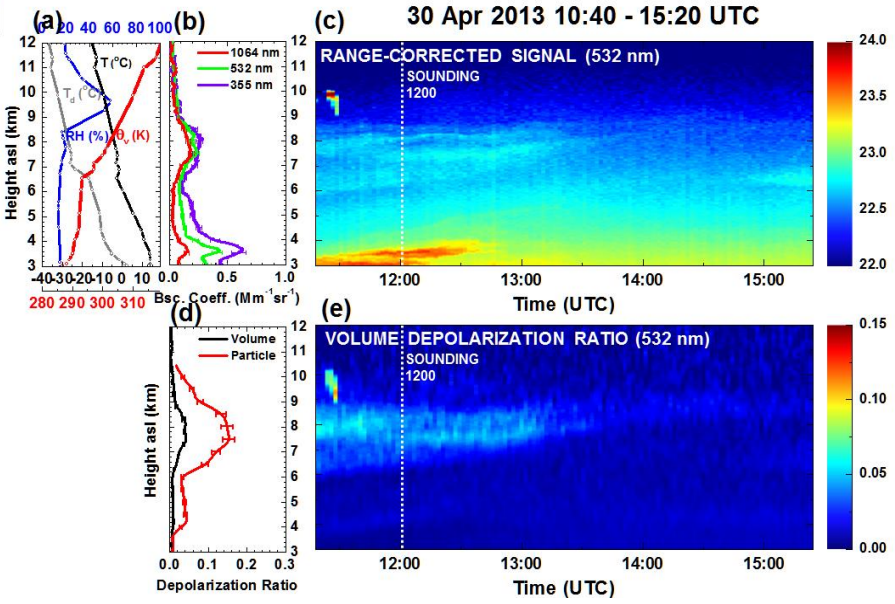
E.g. of Optical Properties



Scattering coefficients
at 450 nm (blue), 550 nm (Green), 700 nm (Red)

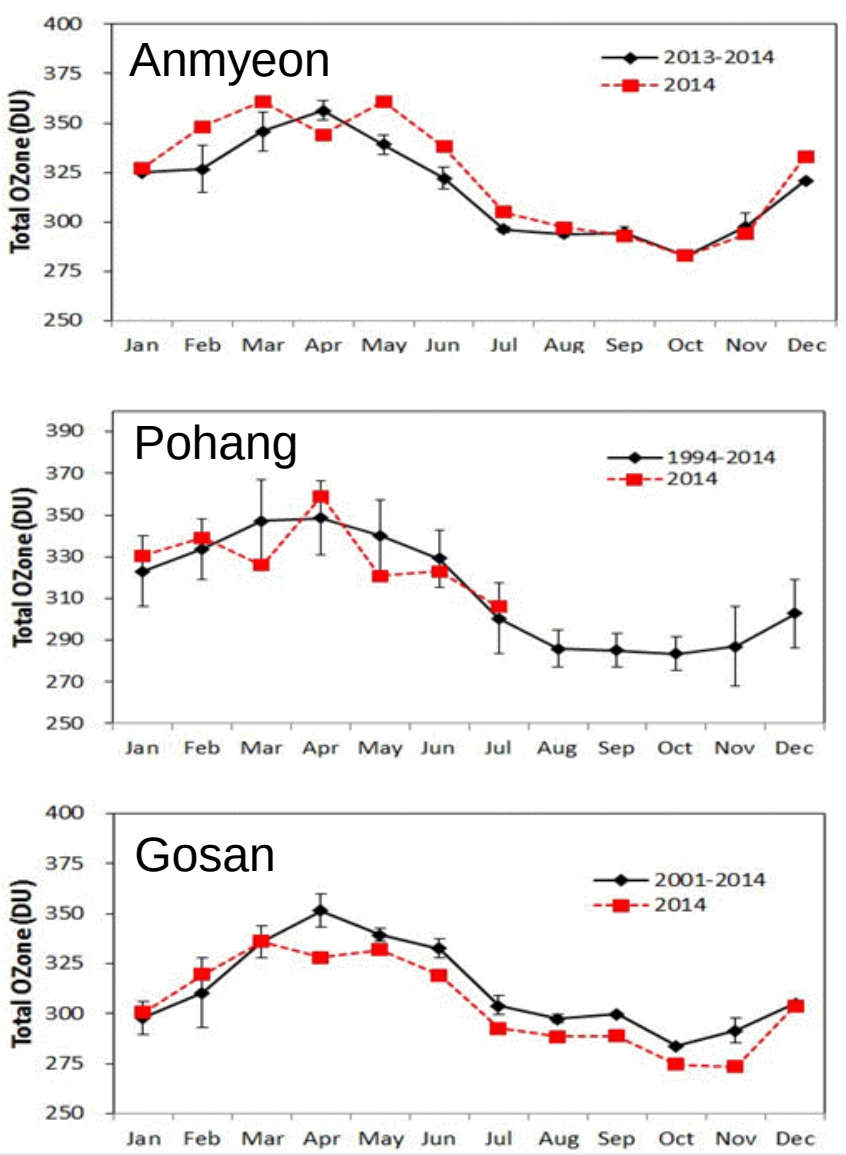


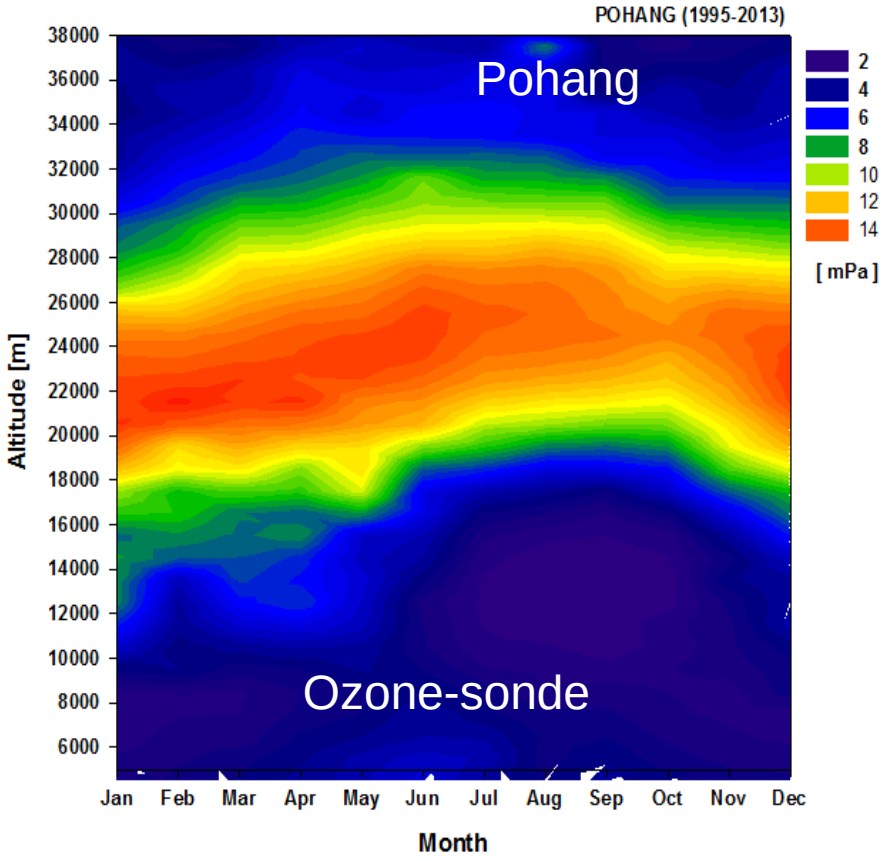
Absorption coefficients
at 520 nm (Blue-green), 880 nm (Black)



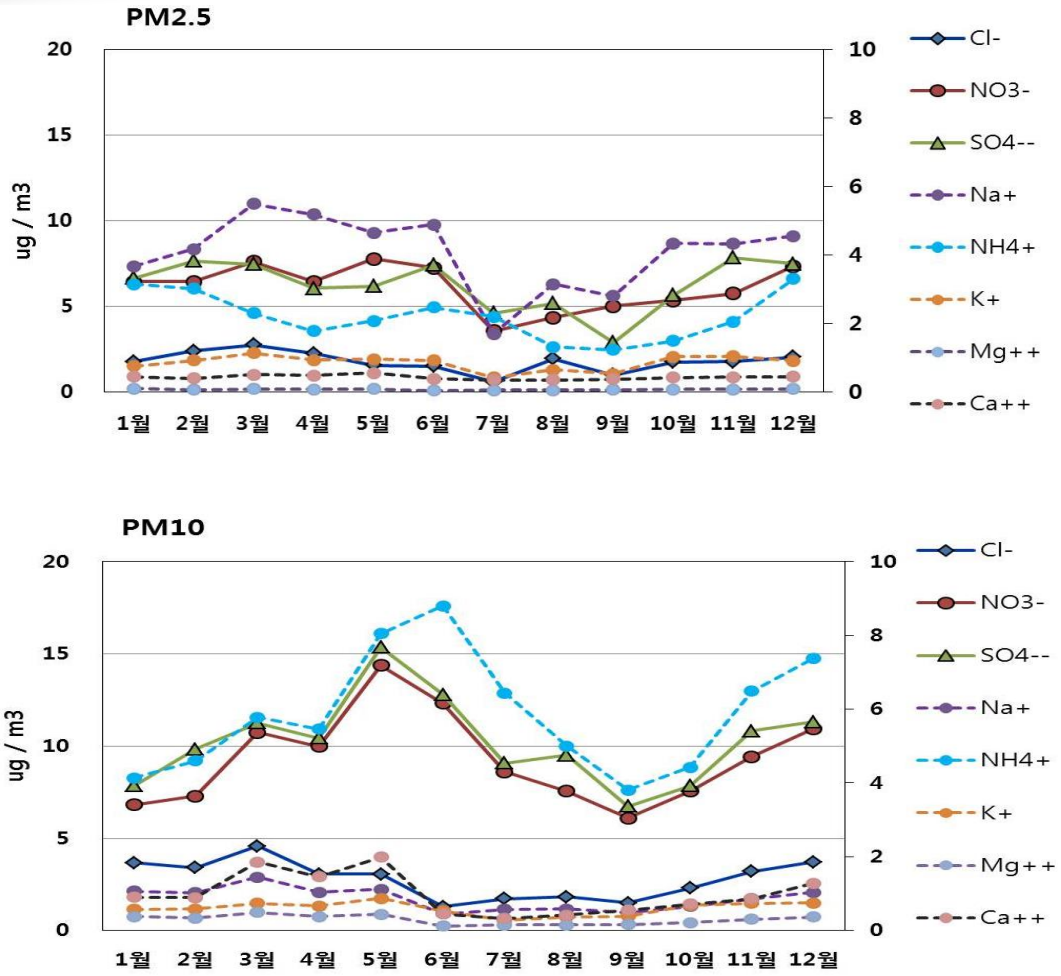
Backscattering coefficients &
depolarization ratio
from LIDAR

E.g. of Strat. Ozone Measurements

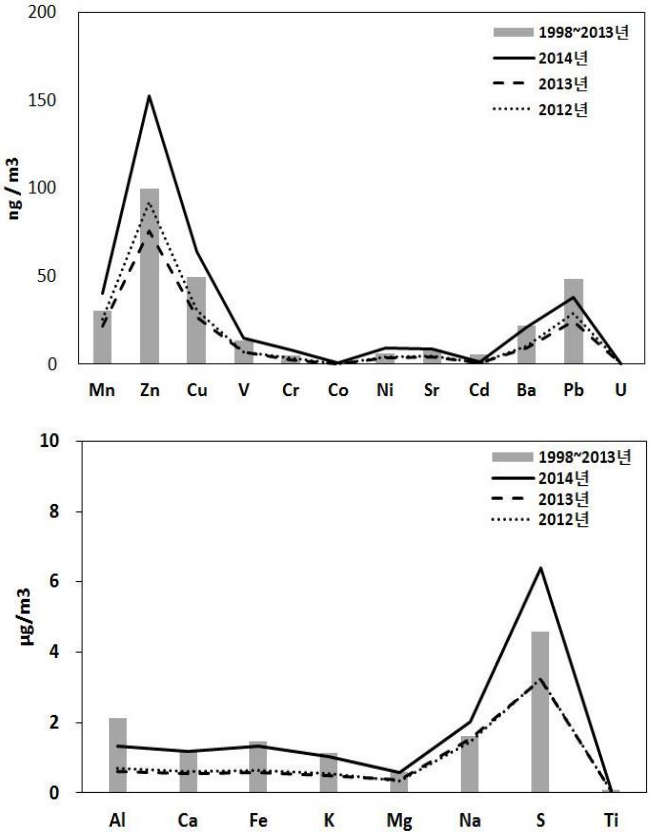




E.g. of Chemical Properties



Seasonal variation in ion components and metals in PM2.5 and PM10 for 1999 - 2014



E.g. of Precipitation Chemistry Measurements