地球科学と大気科学の100年史から見た現代的課題

中島映至
JAXA Earth Observation Research Center, Chief Scientist
前IAMAS事務局長
IUGG, IAMAS, AMS Centennial Celebrations

- IUGG100, IAMAS100 articles
  - Hist. Geo Space Sci., 10, 2019
  - IAMAS: a century of international cooperation in atmospheric sciences by M.C. MacCracken and H. Volkert
- AMS100 celebration
  - https://journals.ametsoc.org/doi/10.1175/AMSMONOGRAPHS-D-18-0020.1
  - 100 Years of Progress in Forecasting and NWP Applications by S.G. Benjamin, J.M. Brown, G. Brunet, P. Lynch, K. Saito, T.W. Schlatter
Development of Meteorology and Atmospheric Sciences

Boyle's law 1662
  Industrial revolution mid 17C
Hadley circulation 1735

Barometer, Torricelli 1643
   Mercury thermometer, Fahrenheit 1714

Fourier, radiation effect 1824
Arrhenius, global warming 1896

IMO 1879
IUGG 1919
  6 sections w Meteorology

Frontal activity, Bjerknes 1917

Int. Assoc. Meteorol. 1933
  Failure of Richardson’s experiment ~1920
  6 hour forecast for 2 month hand calculation
  he wrote “64,000 calculators work”

8th meeting of the International Commission for the Scientific Investigation of the Upper Air, on 25 July 1921, Bergen, Norway (Volkert, ASS’17)
Development of Meteorology and Atmospheric Sciences

Boyle's law 1662
Industrial revolution mid 17C
Hadley circulation 1735
IMO 1879
IUGG 1919

Barometer, Torricelli 1643
Mercury thermometer, Fahrenheit 1714

Fourier, radiation effect 1824
Arrhenius, global warming 1896

Int. Assoc. Meteorol. 1933
Richardson’s experiment ~1920

IGO 1957-58
CO2 monitoring at Mauna Loa 1958
TIROS-1 meteorol. satellite, 1960

Global warming GCM,
Manabe, Wetherald 1975

Ozone hole, Farman et al 1985
Crutzen, Molina, Rowland,
Nobel Prize in Chemistry 1995

Earth Simulator 2002, 36TF
Hurricane Katrina 2005
Extreme weather increase

IPCC 1988
IAMAS 1991
ISC 2018

IPCC-AR5 2013

Radiation, Ozone commissions 1948
WMO 1950
IAMAP 1957
WCRP 1980

Kei Yoshimura@UT
Development of Meteorology and Atmospheric Sciences

- **Boyle's law 1662**
- **Hadley circulation 1735**
- **Fourier, radiation effect 1824**
- **Bjerknes 1917**
- **Arrhenius, global warming 1896**
- **IMO 1879**
- **Int. Assoc. Meteorol. 1933**
- **IAMAP 1957**
- **WMO 1950**
- **IGY 1957-58**
- **CO2 monitoring at Mauna Loa 1958**
- **TIROS-1 meteorol. satellite, 1960**
- **IUGG 1919**
- **IPCC 1988**
- **IPCC-AR5 2013**
- **WCRP 1980**
- **ISC 2018**

**Community formation**
- International frameworks and services

**International Geophysical Year (IGY)**
- Golden era of earth observation

**Climate simulations and awareness to global warming**
- New sciences and applications

**Data nexus and Earth Science/AI modeling**

**Society affected by weather and climate**

Establishment of Meteorology as a natural science

**Industrial revolution mid 17C**
- **Earth Simulator 2002, 36TF**
- **Hurricane Katrina 2005**
- **Extreme weather increase**

**Richardson's experiment ~1920**

- **Community formation**
- **International frameworks and services**

- **CO2 monitoring at Mauna Loa 1958**

- **TIROS-1 meteorol. satellite, 1960**

- **International Geophysical Year (IGY)**

- **Climate simulations and awareness to global warming**

- **New sciences and applications**

- **Data nexus and Earth Science/AI modeling**

**Society affected by weather and climate**

Establishment of Meteorology as a natural science

**International frameworks and services**

- **CO2 monitoring at Mauna Loa 1958**

- **TIROS-1 meteorol. satellite, 1960**

- **International Geophysical Year (IGY)**

- **Climate simulations and awareness to global warming**

- **New sciences and applications**

- **Data nexus and Earth Science/AI modeling**

**Society affected by weather and climate**

Establishment of Meteorology as a natural science

**International frameworks and services**

- **CO2 monitoring at Mauna Loa 1958**

- **TIROS-1 meteorol. satellite, 1960**

- **International Geophysical Year (IGY)**

- **Climate simulations and awareness to global warming**

- **New sciences and applications**

- **Data nexus and Earth Science/AI modeling**
Air quality change and climate forcing

GOME (’95—’11), SCIAMACHY (’02-’12), OMI (’04-), GOME-2 (’06-) etc
TEMPO-Sentinel4-GEMS Geo system

High resolution modeling

Short-lived pollutants measurements from space (SO2, NO2, HCHO, NH3 etc)

Long term surface monitoring

GHGs monitoring from space (CO2, CH4 etc)

GOSAT (’09-)
OCO2 (’14-)
TanSat (’16-) etc

TEMPO-Sentinel4-GEMS Geo system

CO2 column mean (ppm)

400 ppm

Air pollution

Physics and chemistry process
Health impacts etc

Climate forcing

GHGs SLCPs emission

Global warming

Radiative forcing: Greenhouse effect, Parasol effect etc

Natural and human activities
Atmospheric feedbacks and impacts

Vertical profiling of the atmosphere

- CALIPSO ('06-)
- CLOUDSAT/ ('06-)
- EarthCARE
- TRMM/PR ('97-'15)
- GPM/DPR ('14-)
- TERRA/MODIS ('99-), SUOMI ('11-),
  GCOM-C ('17-) etc

Aerosol and cloud interaction

- AQUA/AMSR-E ('02-'15)
- GCOM-W/AMSR2 ('11-)

3D structure of precipitation

- Precipitation map (GSMaP)

Climate sensitivity

Dynamics Feedbacks

Severe weather

Disaster reduction

Precipitation Water cycle

Impacts

Human society and ecosystem

Iren Petrova@GATAG
Improved understanding in climate change mechanisms

Recent topics:
- Black carbon reduction decrease surface temperature???
- Air pollution decrease low level cloud???

Projected changes in tropical cyclone statistics

IPCC-AR5 to future AR6
Proposals of mitigation scenario

- Large CO2 reduction needed
- Total effect of other material reductions positive, but large variability of 0.5C
- -0.5C very important
- Short Lived Climate Pollutants (SLCP), UNEP/CCAC, BC not effective
- Need an optimum SLCP reduction scenario (suitable SO2, BC, NOx, CH4 combination)
A new science: First data assimilation of satellite radar precipitation data (GPM/DPR) for NWP

- One hour precipitation more than 50mm/hr increased 1.4 times in the last decade in Japan, (2008-2017)/(1976-1985) (JMA Climate change monitoring report)

Kinu river flood in Sept. 2015

(a) MSM (Without DPR)  
(b) MSM (With DPR)  
(c) Ground Radar Obs.
Mission recommendations by Remote sensing TF (25 societies)

- Effects to Human Society & Ecosystem
- Change in Water Cycle
- Greenhouse Effect
- Heating/Cooling
- Change in Clouds & Precip
- Short-Lived Climate Pollutants
- Long-Lived Greenhouse Gases
- Forest biomass estimation
- Understanding global scale climate change & water cycle mechanisms
- Understanding cloud & precipitation processes
- Monitoring global environmental changes
- SLCP reduction
- Missions for monitoring greenhouse gases (GOSAT Series etc)
- Land monitoring (ALOS series etc)
- Forcing
- Feedbacks, Sensitivity

T. Nakajima
Radio-Cs transportation from Fukushima accident

(a) 3/15/6h
(b) 3/15/12h

Atmospheric concentration ($^{137}$Cs, Bq m$^{-3}$)

Beta-ray type SPM monitoring sites

Tsuruta+ (Sci. Rep’14)
Nakajima+ (PEPS’17): most downloaded paper, most cited paper in 2019
Future prospects

• Climate change projection still has large uncertainties: Forcing by GHGs and SLCP (Short-Lived Climate Pollutants), Climate sensitivities (convection, cloud feedbacks)

• New sciences and applications w other fields (ocean, hydrology, cryosphere, ecosphere etc.)

• More societal applications: Disaster reduction, food, SDGs etc.

• High resolution modeling, Human dimension; Combination of first principle models and AI technology

• Sustainable observation system, esp. satellite systems

• 2021: IAMAS-IAPSO-IACS, Busan, Korea