Satellite Observations for the Science and Impact of Global Warming

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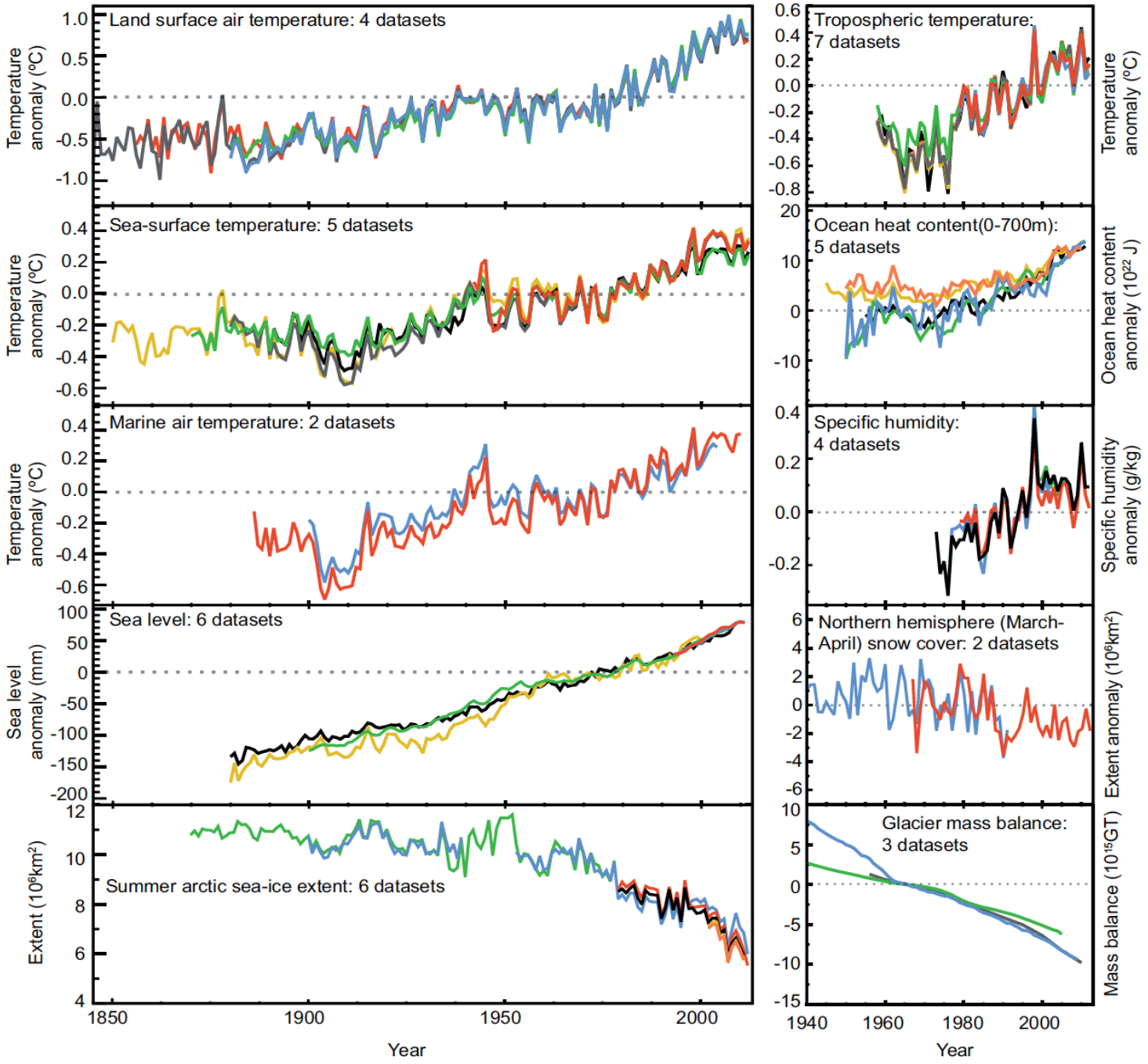
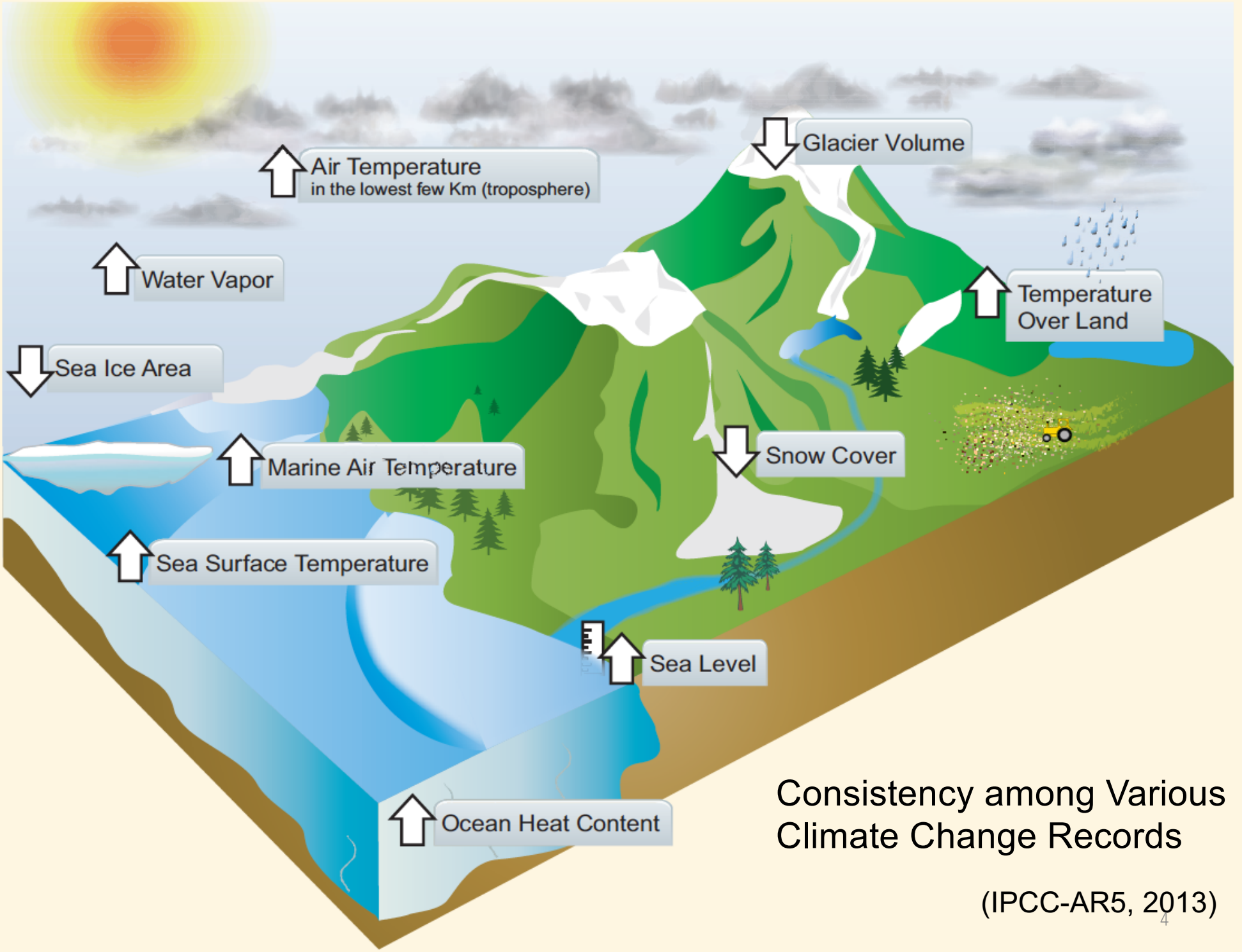
Outline

- Global warming issue is climate change issue related to human society.
- We can explain a large amount of climate change data consistently as caused by human activity.
- Satellite observations cover the essential climate variables (ECVs) in time and space.
- Topic 1: Climate feedbacks
  - Cloud (GCOM-C, GCOM-W, GPM, EarthCARE)
  - Water vapor (GCOM-W, GOSAT)
  - Ice and Snow (GCOM-W, GCOM-C)
  - Carbon (GOSAT, GCOM-C)
- Topic 2: Natural disasters
  - Wildfire, Drought, Heatwave (GCOM-C, GCOM-W, GOSAT, ALOS)
  - Flood (GPM, GCOM-W, ALOS)
- Summary

Global Warming - Consistency among Climate Change Records

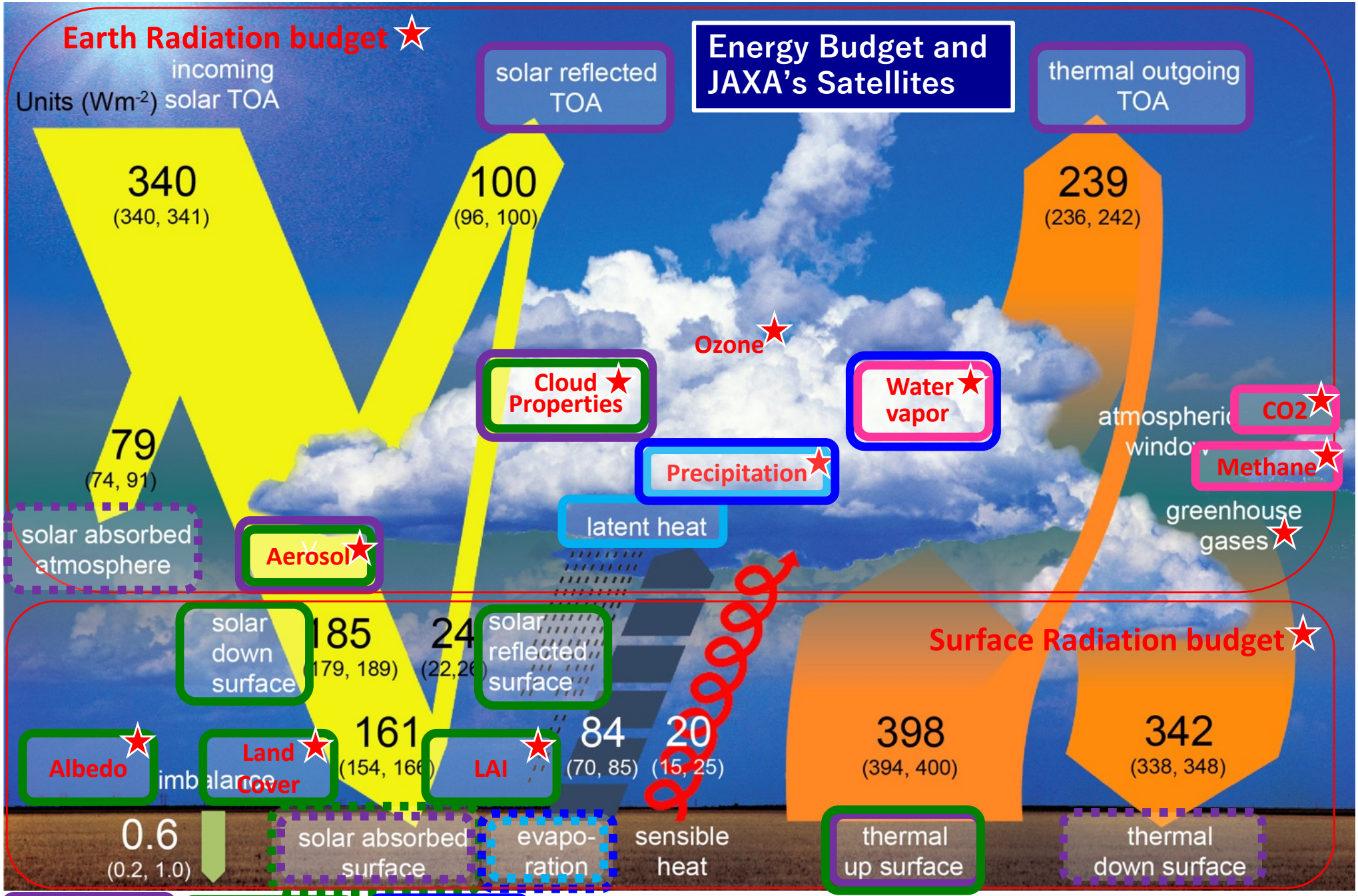
(IPCC-AR5, 2013)





Consistency among Various Climate Change Records

(IPCC-AR5, 2013)

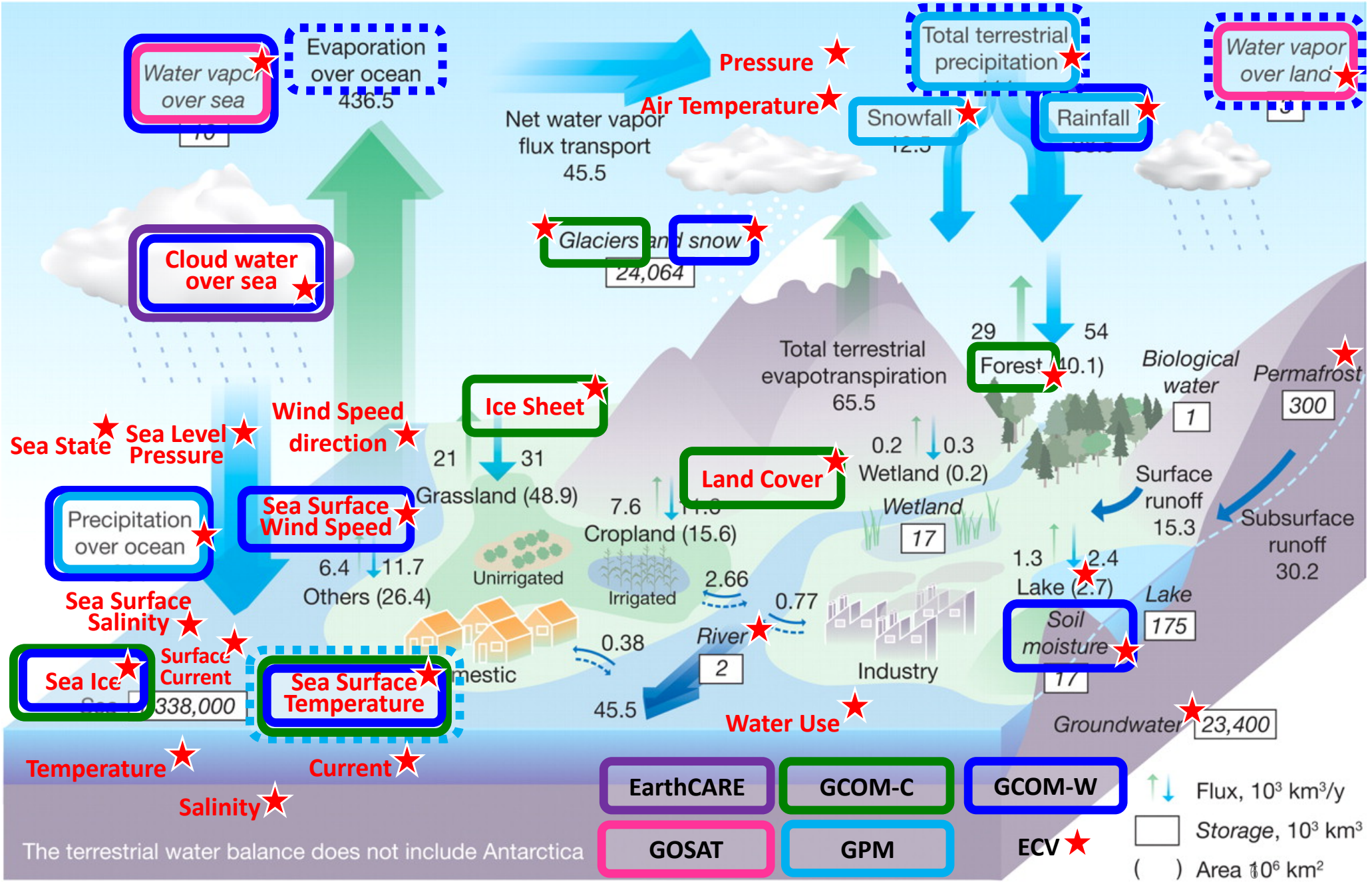


IPCC-AR5; Wild *et al*. (Clim. Dyn. '15)

***Variables enclosed by broken line are indirectly obtained with models**

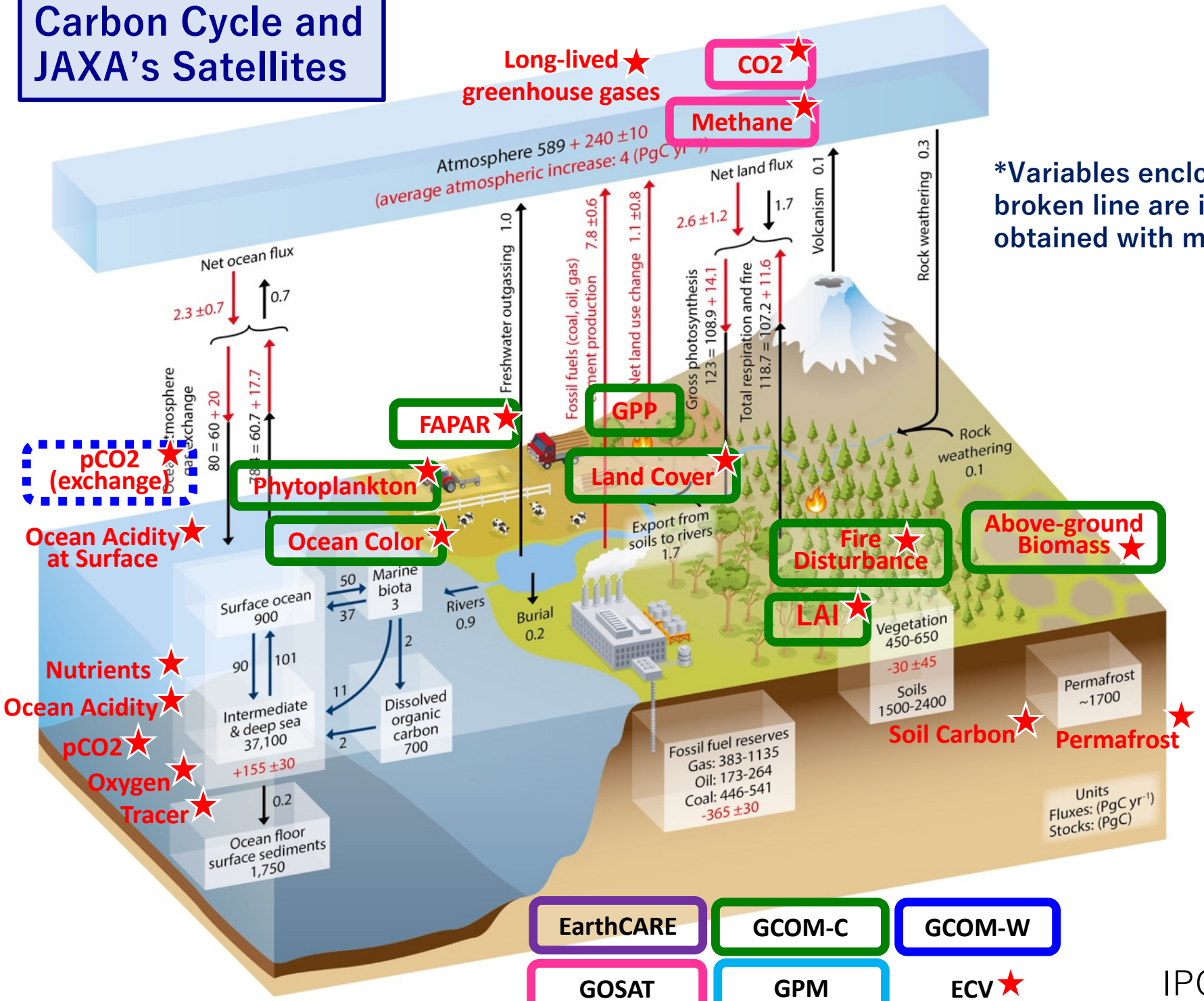
Water cycle and JAXA's Satellites

*Variables enclosed by broken line are observable under some conditions



Oki and Kanae (Science, 2006)

Carbon Cycle and JAXA's Satellites



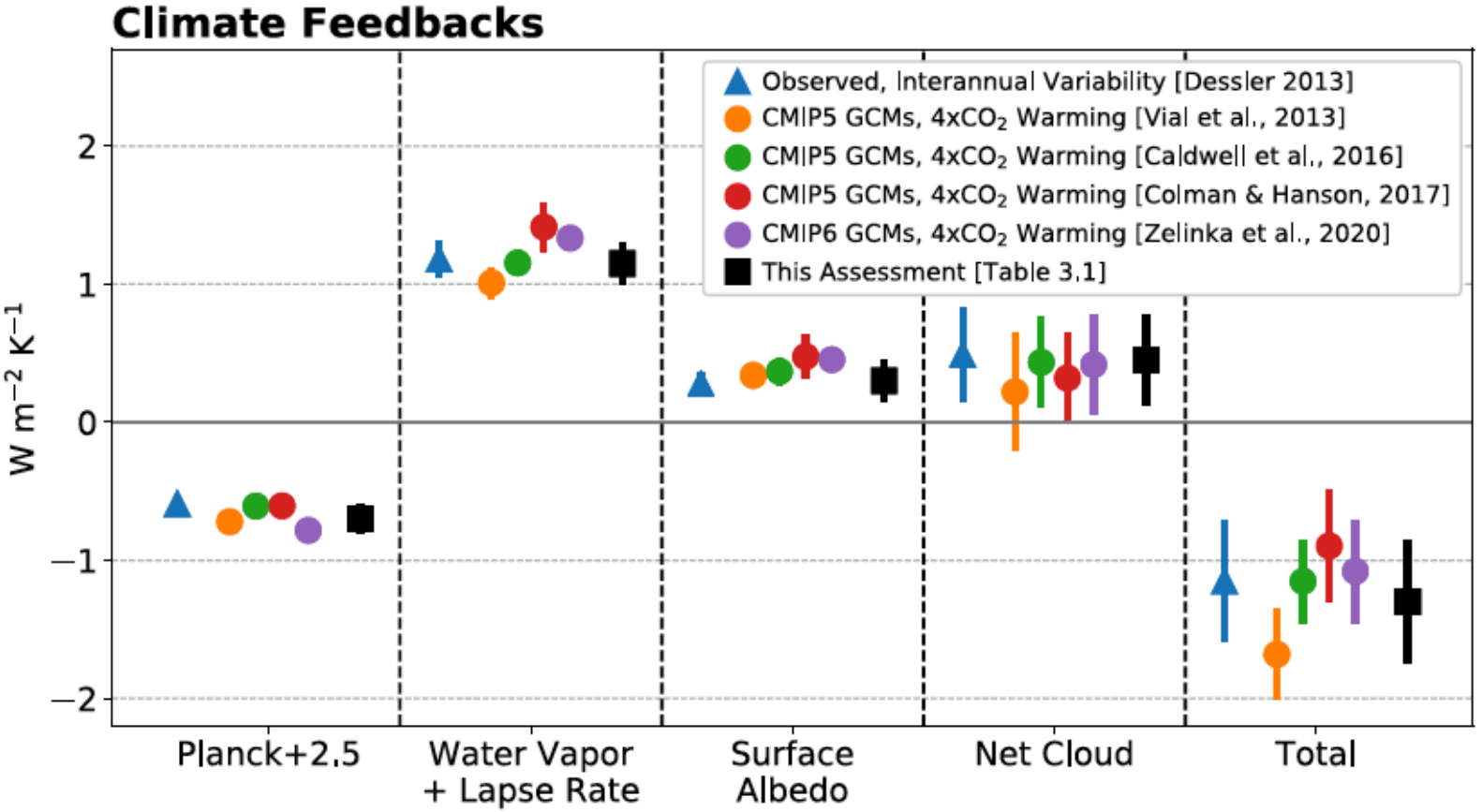
*Variables enclosed by broken line are indirectly obtained with models

Topic 1: Climate Feedbacks

- Planck Feedback
- Water Vapor and Lapse Rate Feedbacks
  - Vertical profiles of water vapor and temperature
- Cloud Feedbacks
  - Cloud top height
  - Cloud cover
  - Cloud optical thickness
- Surface Albedo Feedback – Ice and Snow

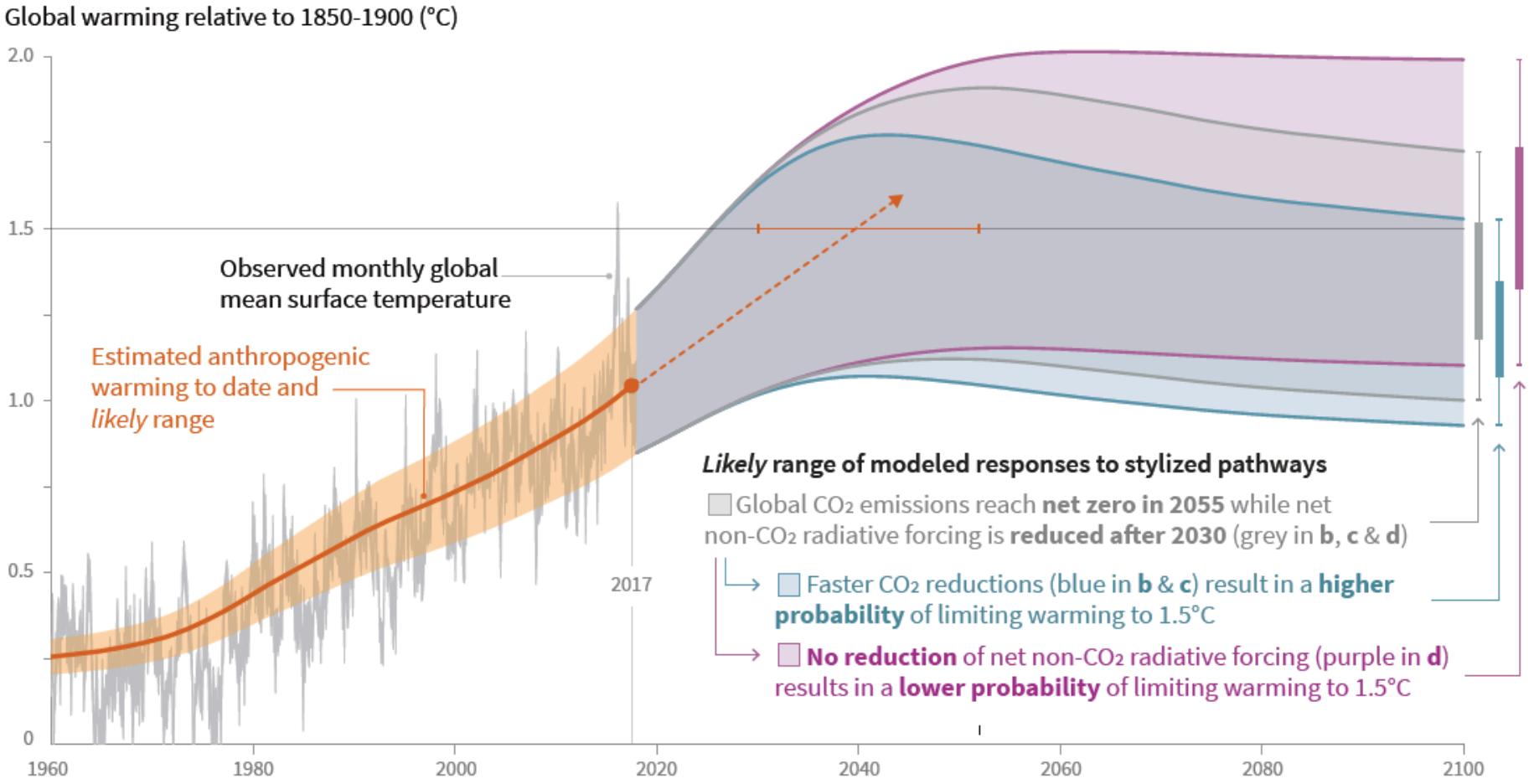
Summary of Climate Feedbacks

Uncertainties of cloud feedback are crucial for the future climate prediction.



(Sherwood et al. 2020)

Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways.



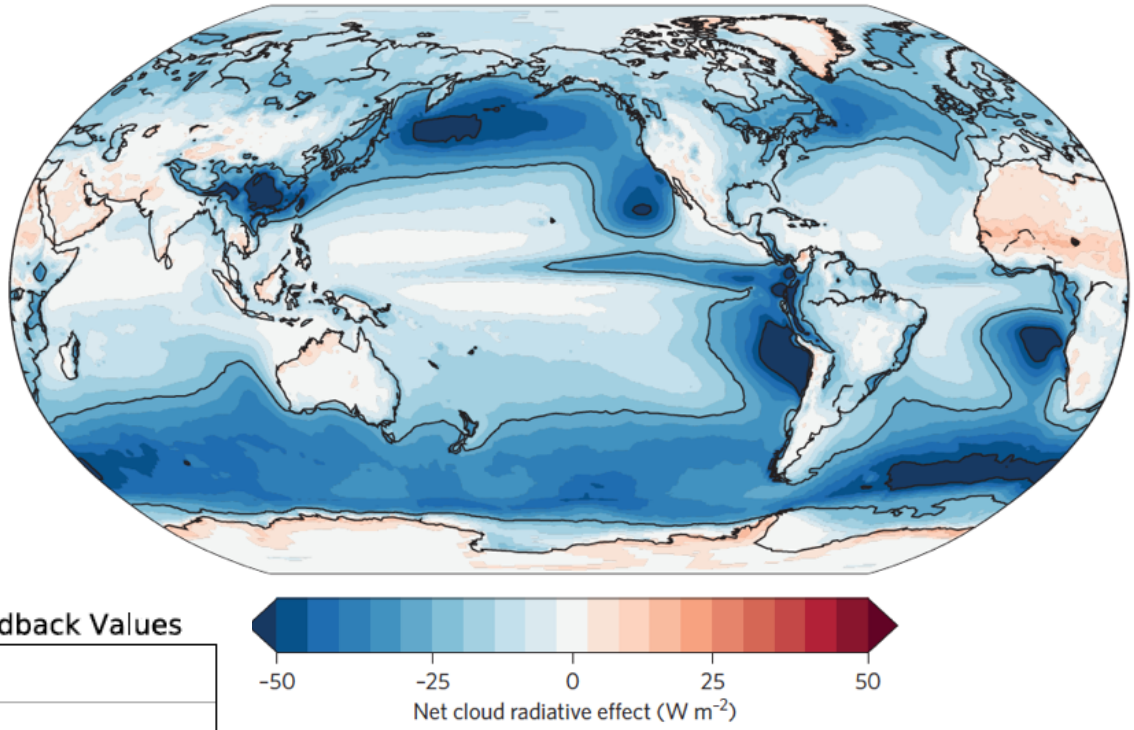
Large uncertainty of future climate prediction is due to uncertainty in feedback mechanism of climate system, particularly of cloud.

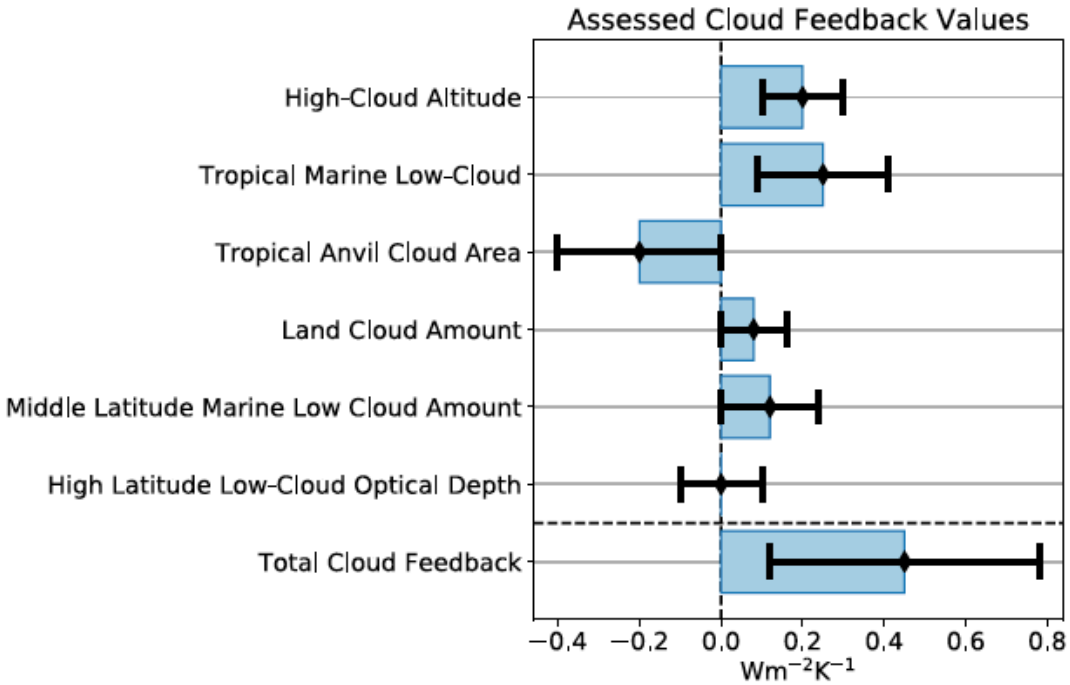
(IPCC SR GW1.5, 2018)

Cloud Radiative Effect and Cloud Feedback

Geographical distribution of the annual averaged net cloud radiative effect at the top of the atmosphere for 2001-2016 (Zelinka et al. 2017)

SW : -46 Wm^{-2}
LW : +28 Wm^{-2}
NET: -18 Wm^{-2}



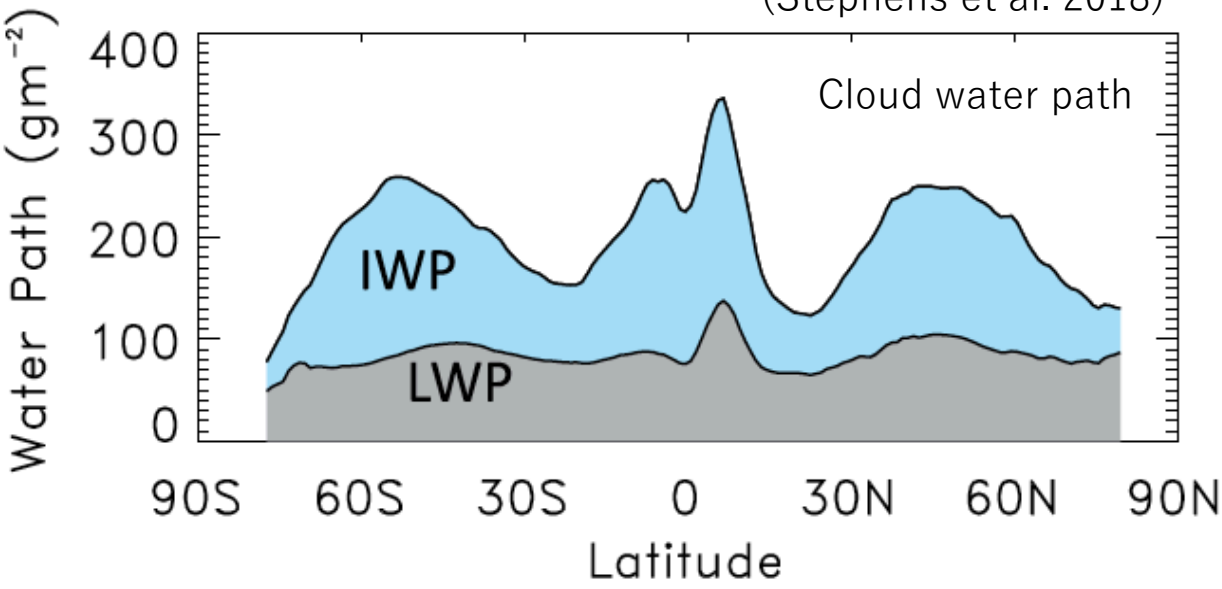


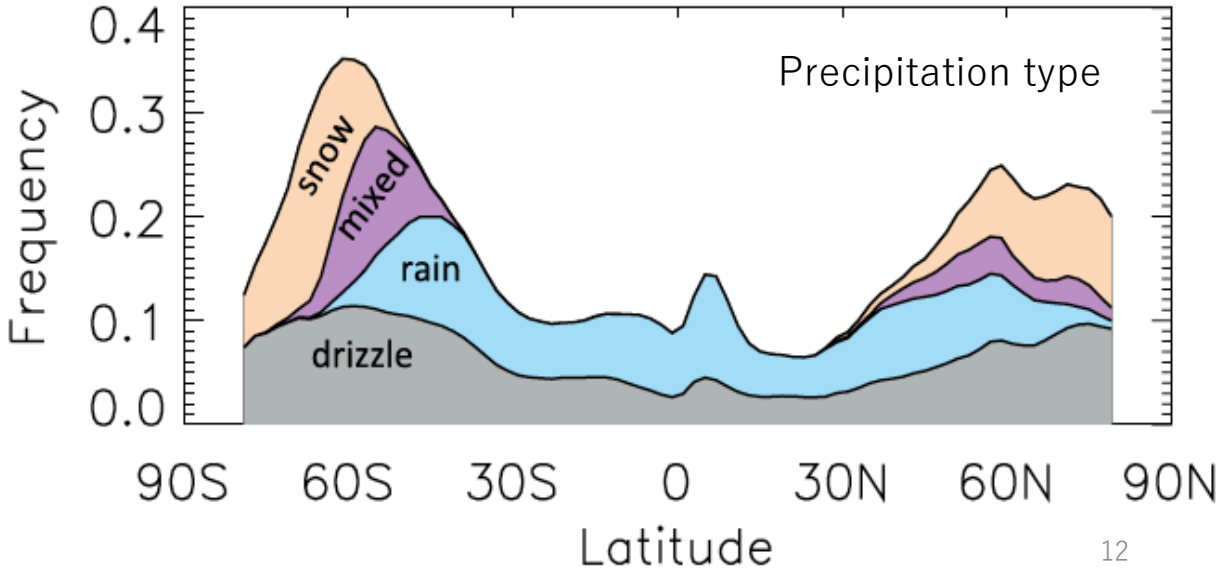
Individual cloud feedbacks and total cloud feedback (Sherwood et al. 2020)

Cloud Ice/Water Path and Type of Precipitation Observed by CloudSat and CALIPSO

- Ice and liquid water paths are comparable but the mixture of them is still uncertain.
- Distribution and the radiative effects of multilayer cloud are not well studied.
- Cloud particle type strongly affects precipitation and radiative properties, especially of SW component.
- Precipitation type is complicated in mid-latitude and uncertain.
- Changes in ice/liquid water content in the atmosphere are critical to understanding climate feedback mechanism.

(Stephens et al. 2018)

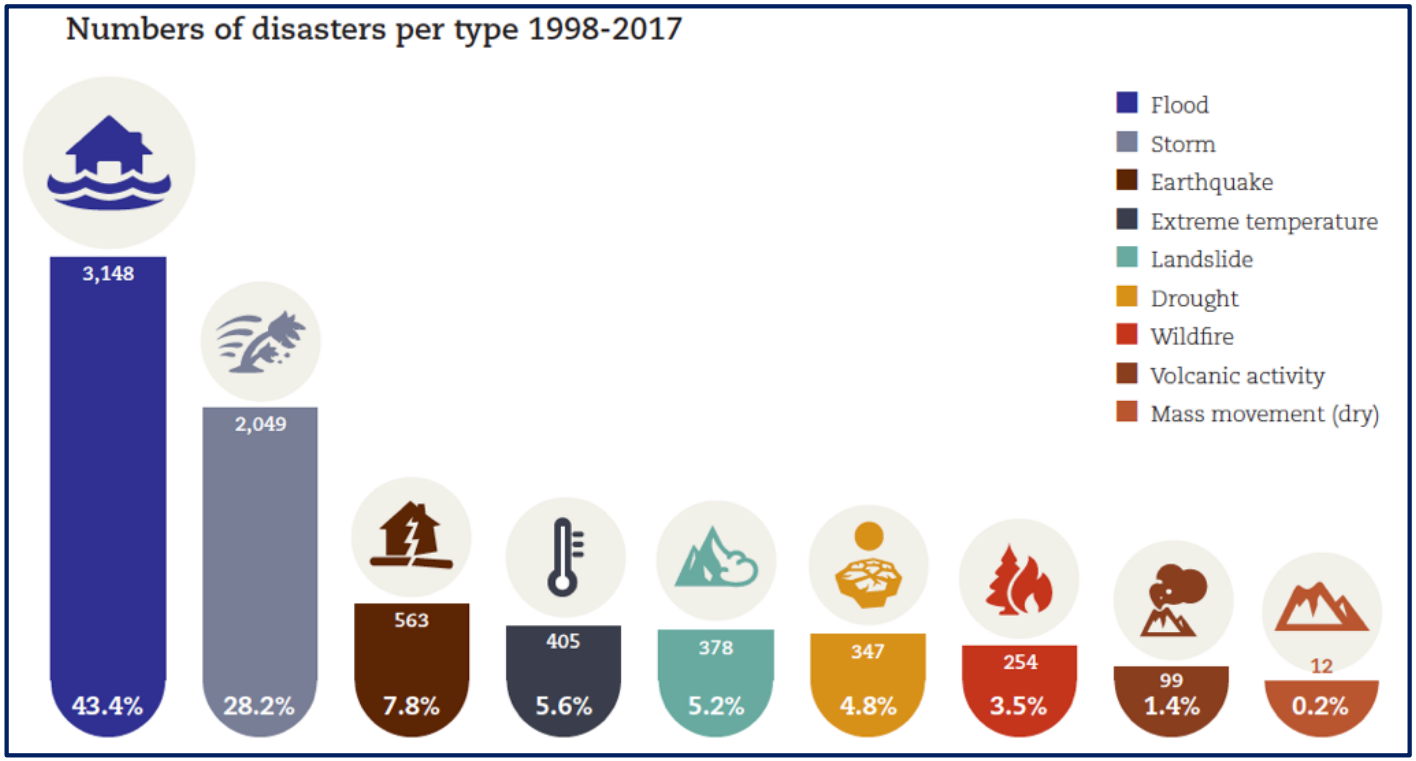




Topic 2: Natural Disaster

For the period 1998-2017 (20 years)

- 7255 natural disaster events were recorded.
- 91% of all disasters were caused by floods, storms, droughts, heatwaves and other extreme weather events.
- Natural disasters killed 1.3 million people and left 4.4 billion injured, homeless, displaced or need of emergency assistance.
  - 45%: Flood, 33%: Drought, 16%: Storm, 2%: Extreme temperature
- Direct economic losses valued at US$ 2,908 billion, of which climate-related disasters caused 77% of the total.

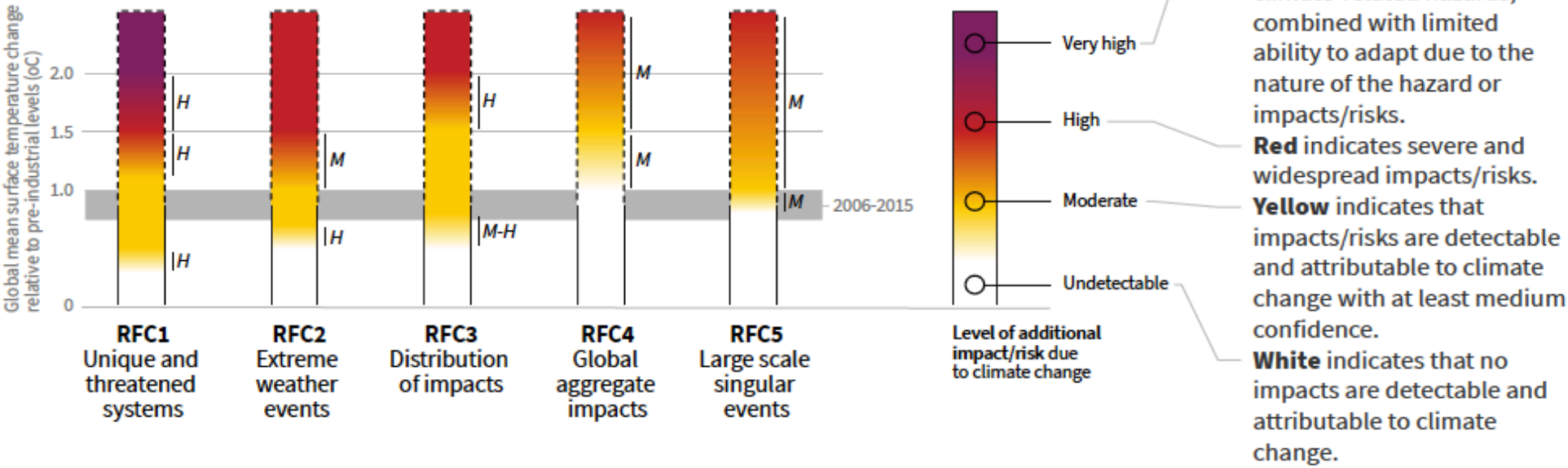


(UNDRR, 2018)

Impacts and Risks of Global Warming

Five Reasons For Concern (RFCs) illustrate the impacts and risks of different levels of global warming for people, economies and ecosystems across sectors and regions.

Impacts and risks associated with the Reasons for Concern (RFCs)

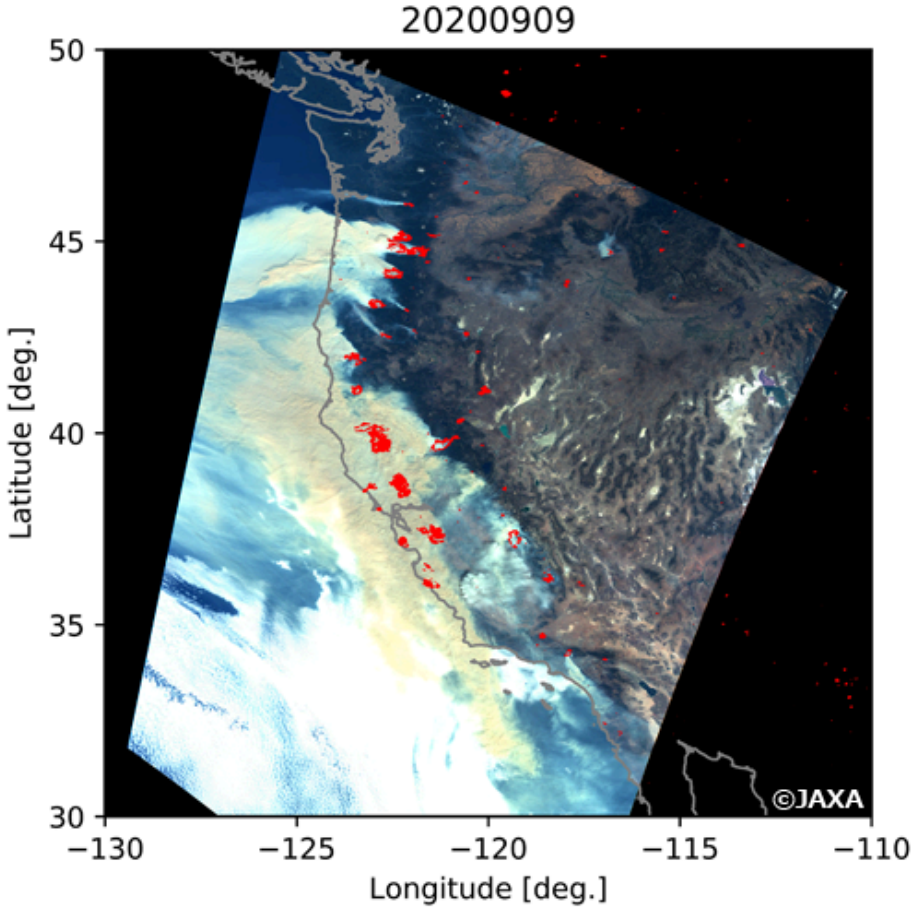


- Wildfire (RFC1, RFC2)
- Flood (RFC2, RFC3)
- JAXA's satellites: GCOM-C, GOSAT, GPM, ALOS

(IPCC SR1.5, 2018)

Wildfire of California

California in USA has experienced many wildfires due to dry condition in summer. California's wildfires occurred on August 16, 2020 recorded the worst scale damage as of late in September 2020. This kind of wildfires damage our health and economic activity or land ecosystem. Furthermore, it is known to have a big impact on air quality related with the emission of greenhouse gases, aerosols, and so on.



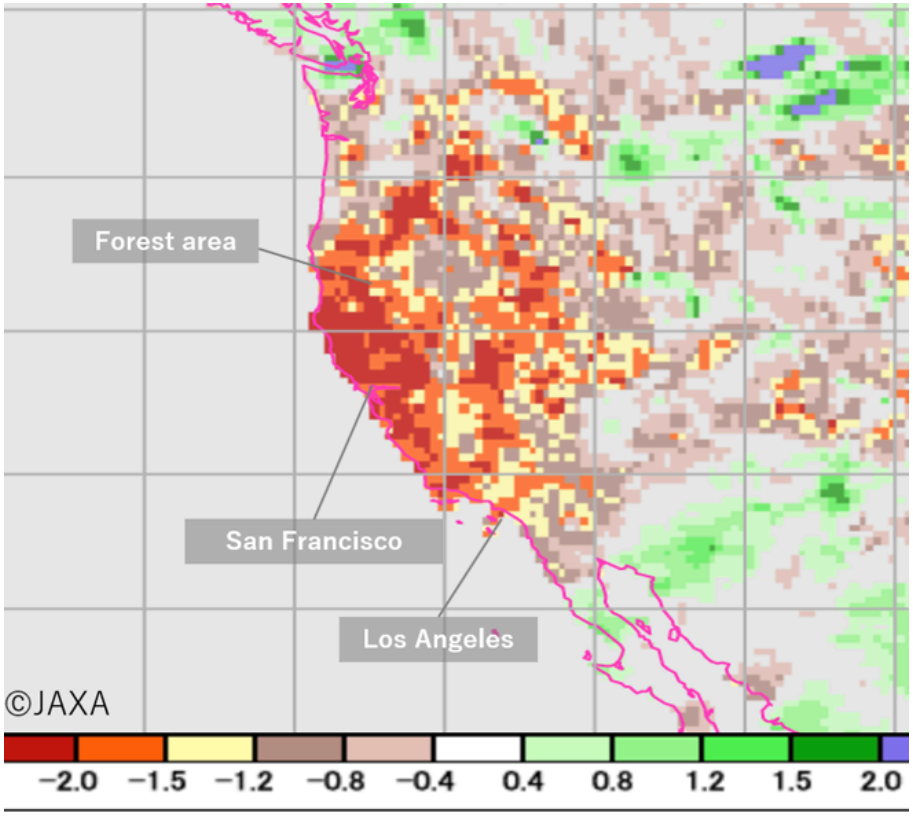
The condition of California wildfires on September 9, 2020 combining RGB image of GCOM-C visible band.

The overlayed plotted red points show the hotspots (the point which seems to be burning at the moment) extracted by thermal infrared band of GCOM-C during August 1 to September 9.

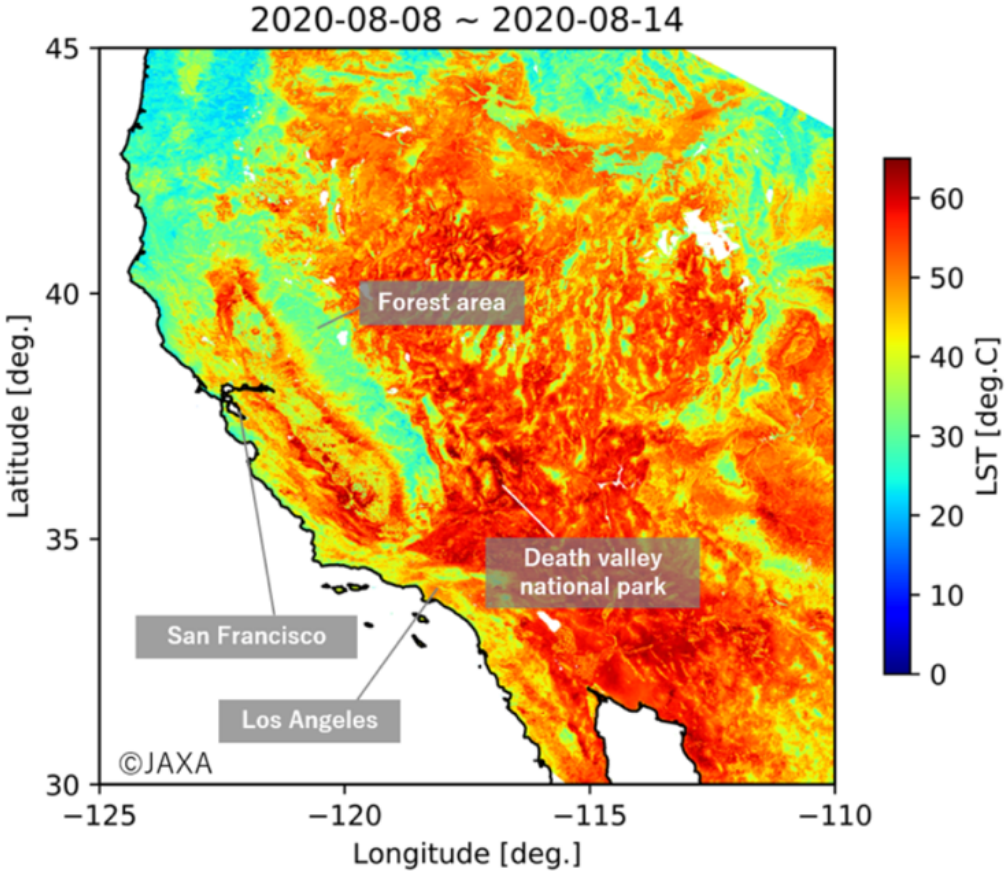
Originating the hot spots, the yellow colored smoke is transported to the Pacific side.

Wildfire of California – Background

“Drought” and “Heatwave”

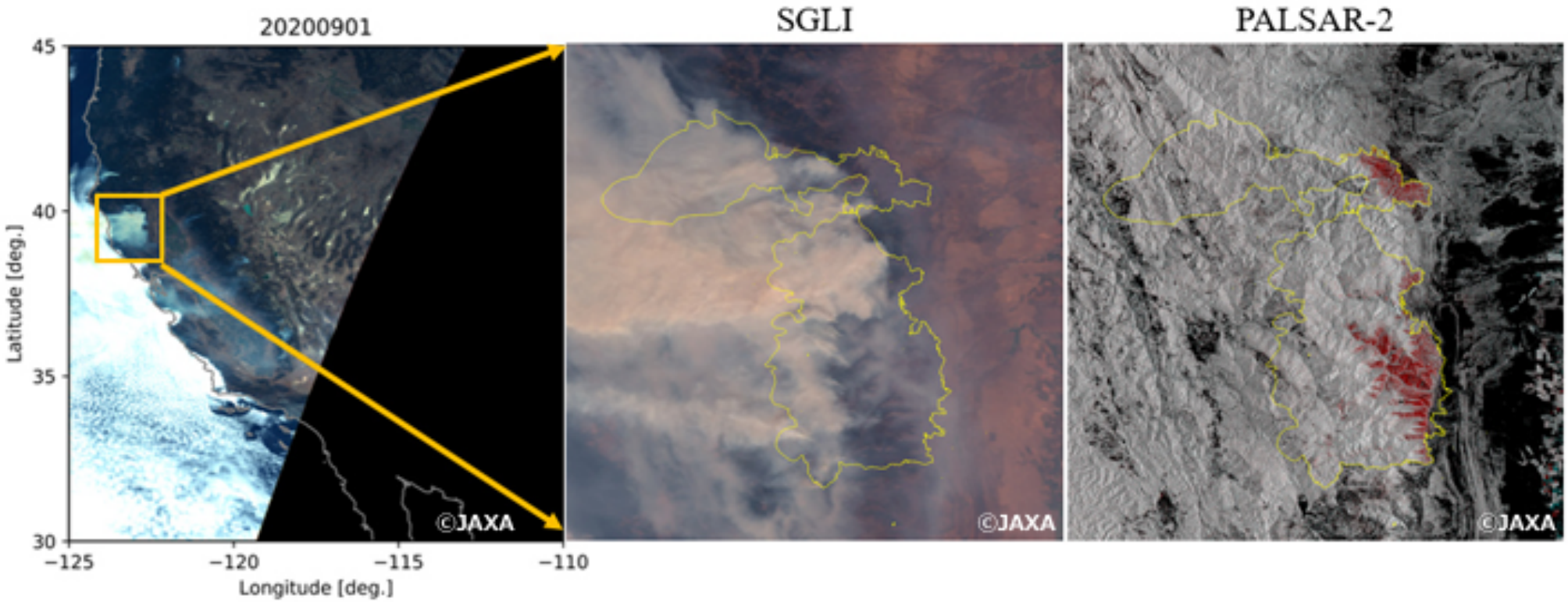


The Standardized Precipitation Index (SPI) in a month. SPI of California calculated by GSMaP precipitation amount in February 2020. SPI in most part of California indicates less than -1.5. It shows that California faced significant drought condition compared with normal year.



Land Surface Temperature (LST) estimated from GCOM-C infrared band (wavelength 10.8 μ m, 12.0 μ m) during August 8-14, 2020. Red parts show higher temperature. Especially, the land surface temperatures of bare land, fields around forests and shrubby areas exceeded 60° C.

Wildfire of California – Land Change



Comparison between visible image and PALSAR-2 image of the fire area on September 1, 2020.

Left : Visible image of west coast of North America obtained by GCOM-C.
Middle : Extended figure of the fire area by GCOM-C. The yellow line shows the fire spread area released by the National Interagency Fire Center up to September 10.
Right : Extended figure of the fire area obtained by ALOS-2. RGB composite image of two terms - July 7 and September 1, 2020. The red color shows fired area according to a decrease in backscattering coefficient. The yellow line is the same as described in middle image.

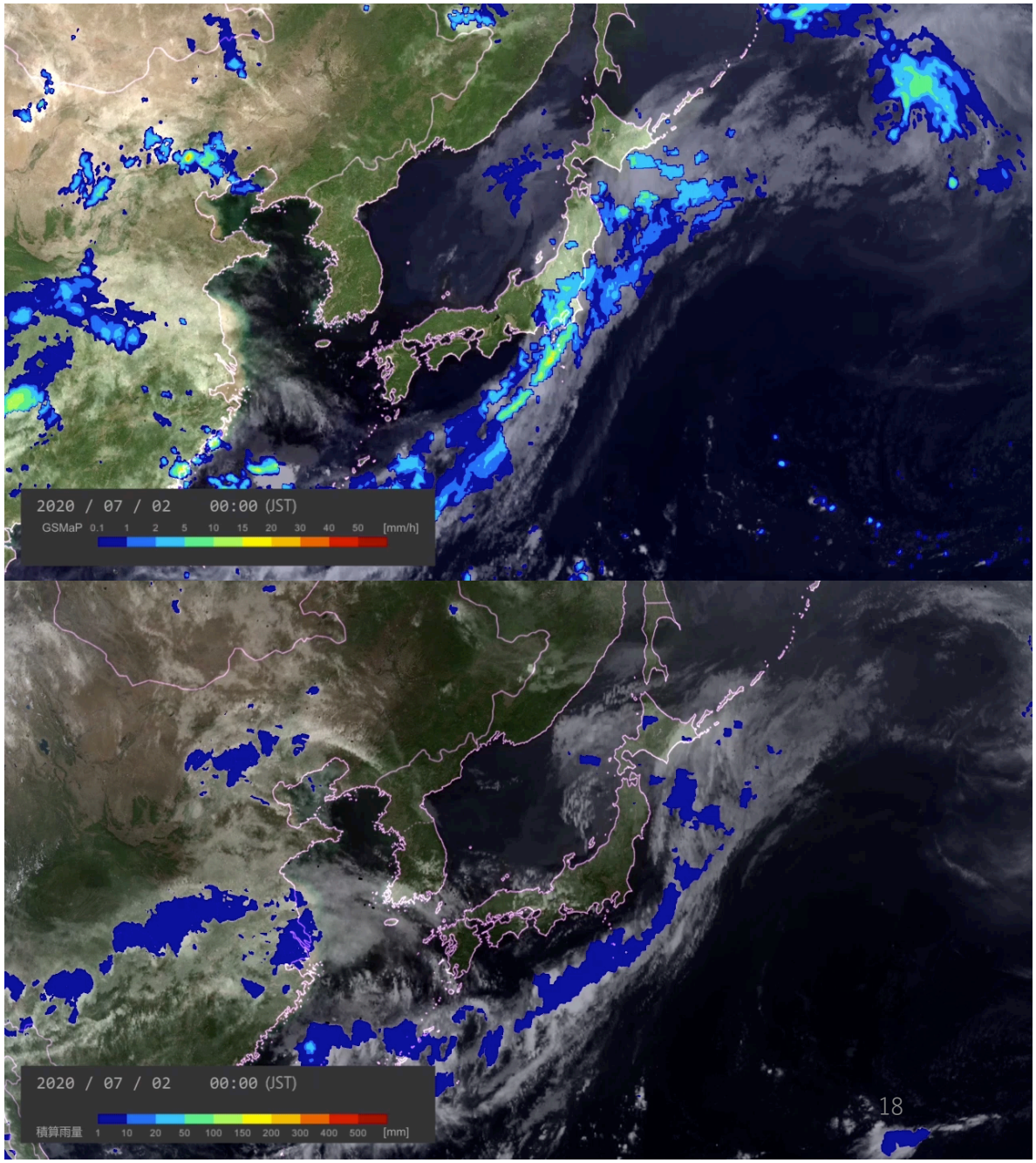
Visible image cannot show the condition under the smoke, but PALSAR-2 image can describe the damage condition of ground surface clearly.

Heavy Rain and Flood in Japan, July 2020

In Japan, more than 100/year people as an average have been killed by disasters caused by extreme weather condition.

Heavy rain was observed in the western part of Japan for the period of July 2020.

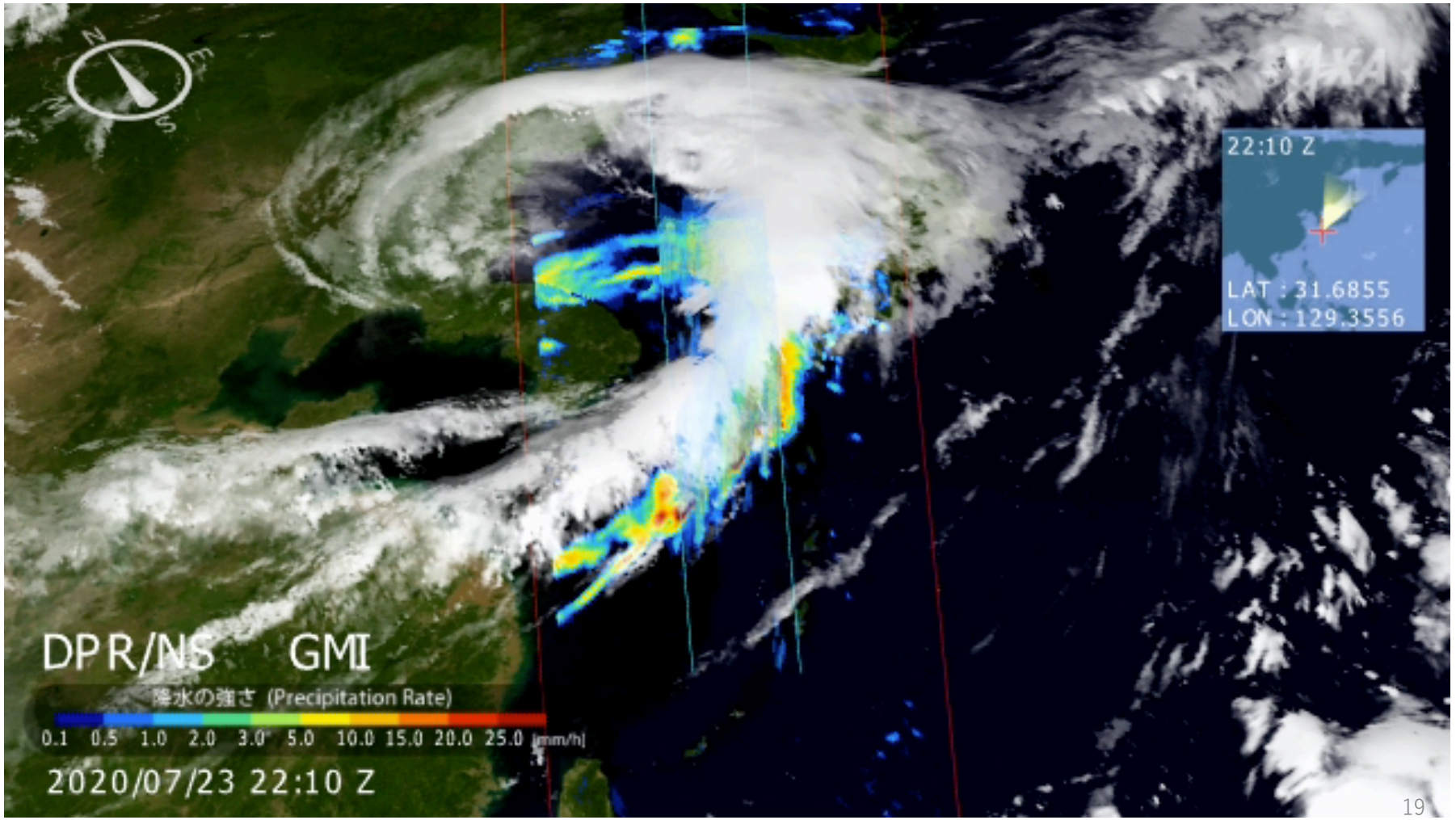
GSMaP captured the growth of heavy rain and accumulated precipitation for this period of 2-7 July 2020.



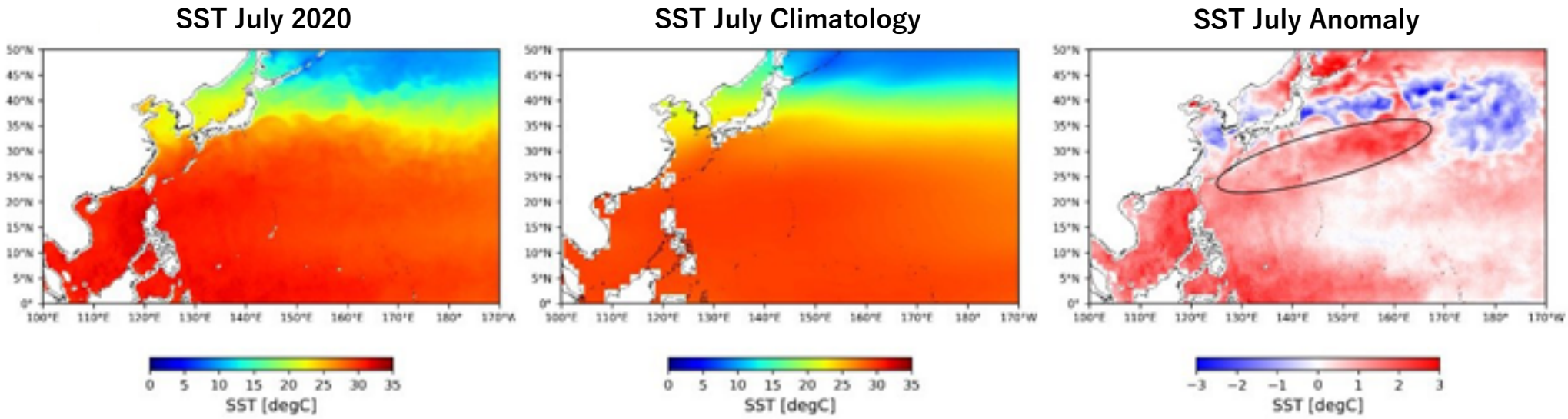
Heavy Rain in Kumamoto, Japan Observed by GPM DPR/GMI

In addition to horizontal distribution of precipitation by GSMaP, DPR and GMI on board GPM could observe the 3-D structure of the heavy rain over Kumamoto, Japan in July 2020.

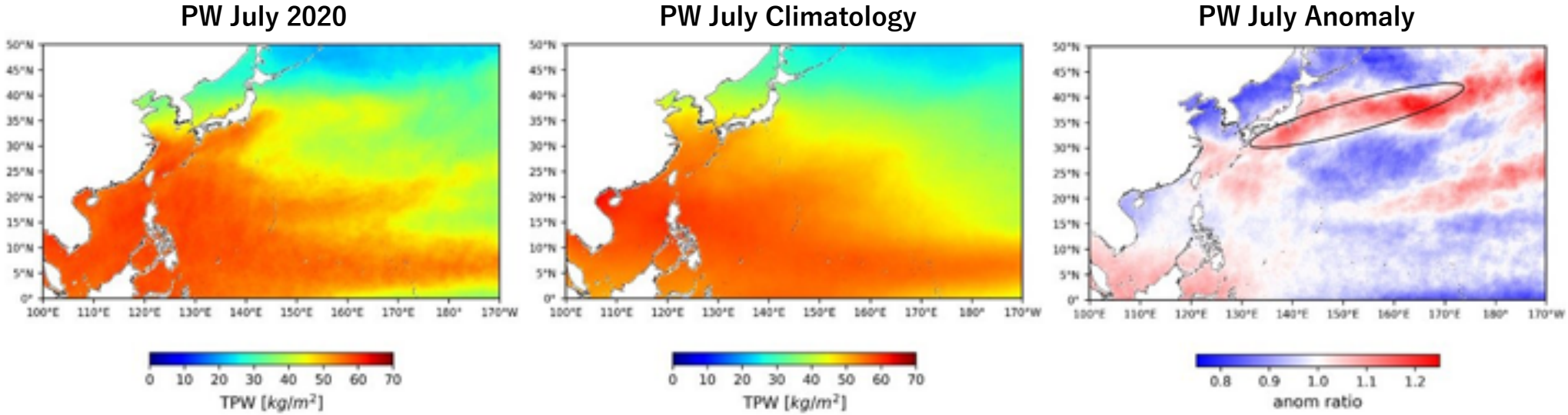
Large latent heat release : 1 mm/h = 694 Wm^{-2}



Monthly Average SST and PW of July in 2020 and Climatology



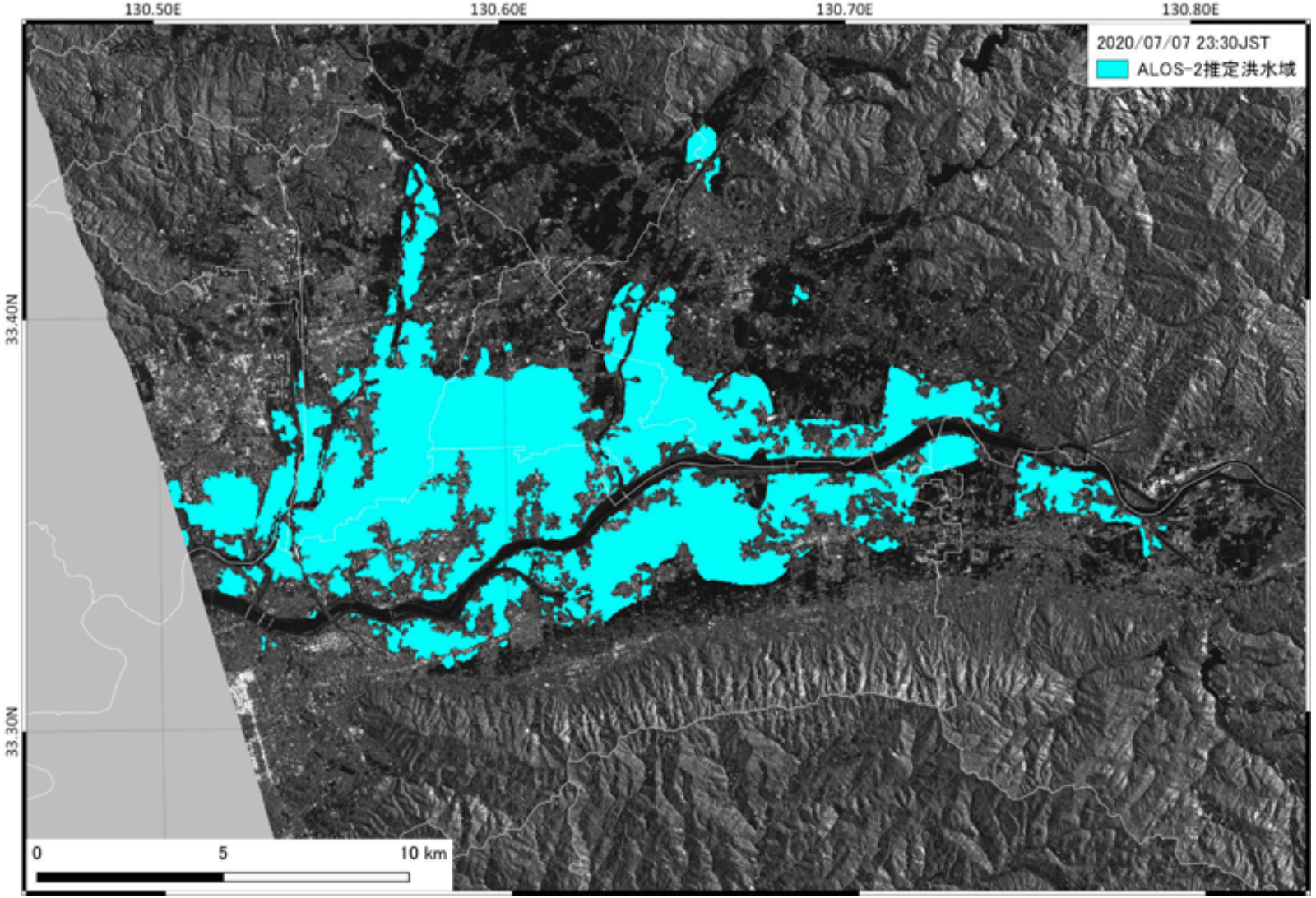
SST of July in 2020 observed by GCOM-W (left), SST of July averaged for 1990-2019 (middle), and anomaly of 2020 from the climatology



Precipitable water (PW) of July in 2020 observed by GCOM-W (left), PW of July averaged for 1990-2019 (middle), and anomaly of 2020 from the climatology

Flooded Area Observed by PALSAR-2 on ALOS-2
23:30JST, 7 July 2020

Synthetic Aperture Radar can capture the flooded area with high spatial resolution even under the cloudy sky condition.



SAR observation and “Today’s Earth-Japan” in collaboration with University of Tokyo

Summary

- Climate change caused by the global warming
  - ➢Energy budget
  - ➢Water cycle
  - ➢Global warming agents; anthropogenic and natural
- Consistency among essential climate variables (ECVs)
- Advantage of multiple satellite observations to obtain ECVs and impact of climate change
- Contribution of satellite observation to natural disaster risk reduction and restoration from damage
- Synergy effect on the understanding of climate system with numerical model and ground/marine/airborne observations

JAXA expects PIs to develop and progress new science of the Earth as well as contributions to making better society in the future, by using the Earth observing satellite data.