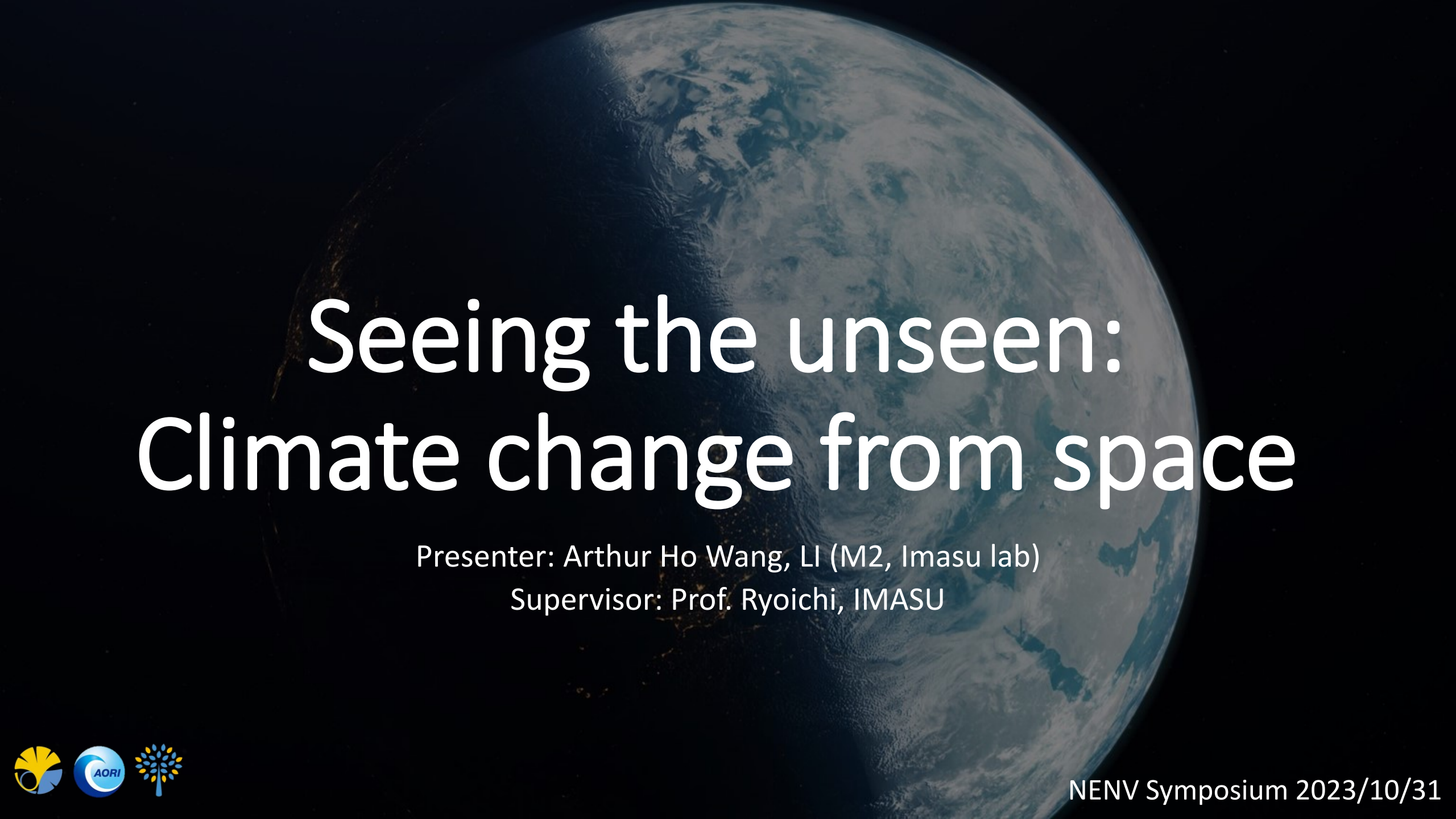
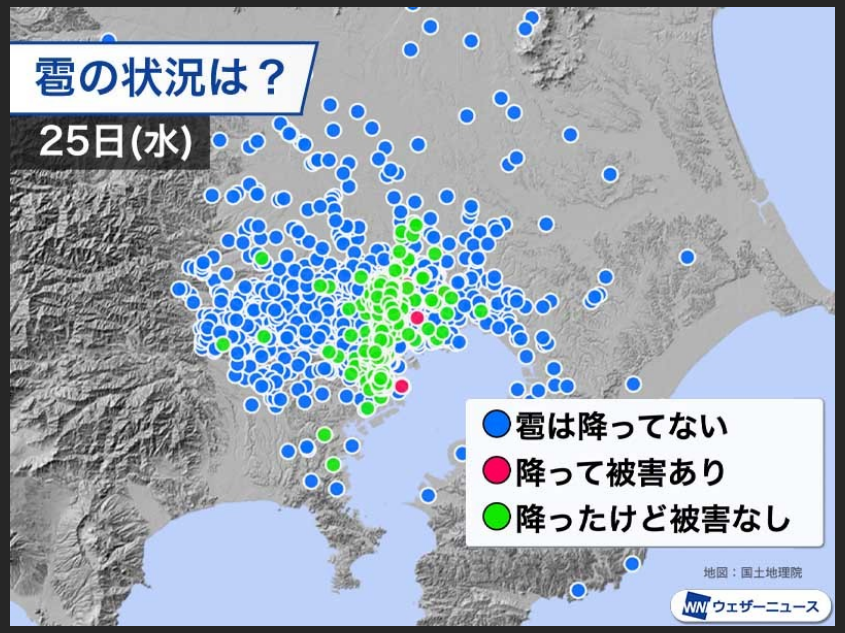


Seeing the unseen: Climate change from space

Presenter: Arthur Ho Wang, LI (M2, Imasu lab)
Supervisor: Prof. Ryoichi, IMASU

NENV Symposium 2023/10/31


東京都文京区
10月25日(水)21時半頃


雹の状況は？
25日(水)
雹は降ってない
降って被害あり
降ったけど被害なし
地図：国土地理院
ウェザーニュース


A GLIMPSE OF THE FUTURE:
OOO! OOO!
IT'S SNOWING.
GLOBAL WARMING
ISN'T REAL.
©WWW.MATTBORS.com
1-3-10
BORS
COLLAPSE
JARED DIAMOND
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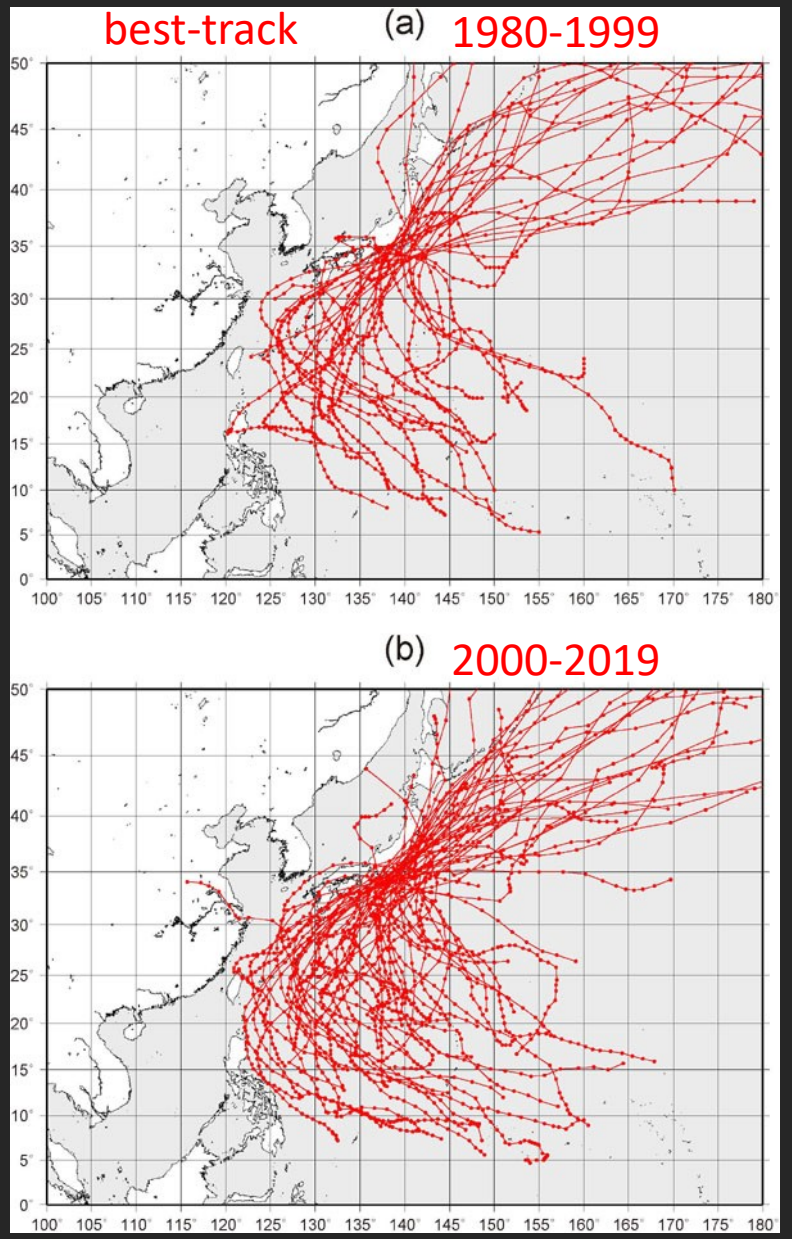
Climate change basics

- **Weather**
  - The transient state of the atmosphere over short period
- **Climate**
  - The statistical description of relevant properties of the atmosphere over long period (30-year average by IPCC)
  - Temperature, humidity, precipitation, cloud, pressure, wind
- **Extreme events**
  - Magnitude, frequency

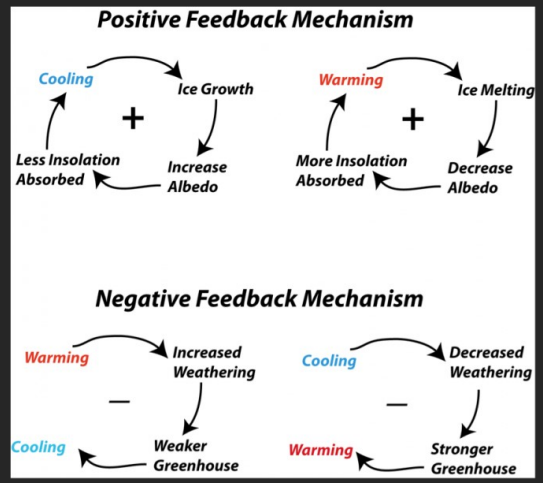
Data: JMA best-track



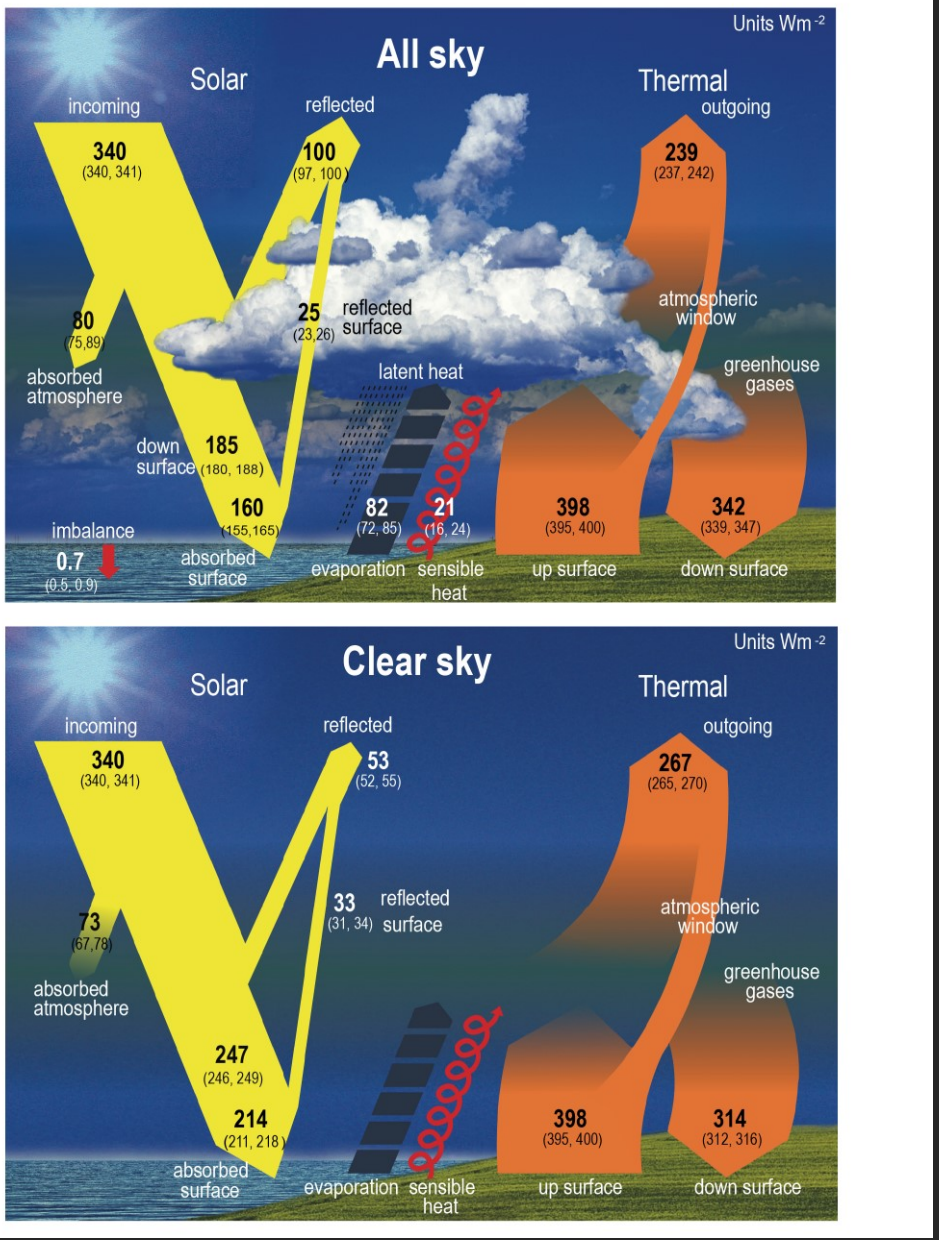
(Yamaguchi & Maeda, 2020)

Climate change basics

- **Energy balance**
  - Energy from the sun, escape to space
- **Climate is a highly complex system**
  - Atmosphere, hydrosphere, cryosphere, lithosphere, biosphere
- **Feedback mechanism**
  - The interactions



(Source: NASA)



(Source: IPCC AR6)

Energy balance in simple math…

- Energy is balanced by I/O:

$$Input = output$$

- Input is solely from the sun, which is constant, and reflected (α_p):

$$Input = \frac{S_0}{4}(1 - \alpha_p)$$

- Earth absorbs energy becoming “warm”, thus emits IR (Stefan-Boltzman’s law):

$$Output = \sigma T^4$$

- Then, we balance the I/O:

$$\frac{S_0}{4}(1 - \alpha_p) = \sigma T^4$$

Energy balance in simple math…

- Given S_0=1367 W m^{-2}, α_p=0.3, we rearrange the equation:

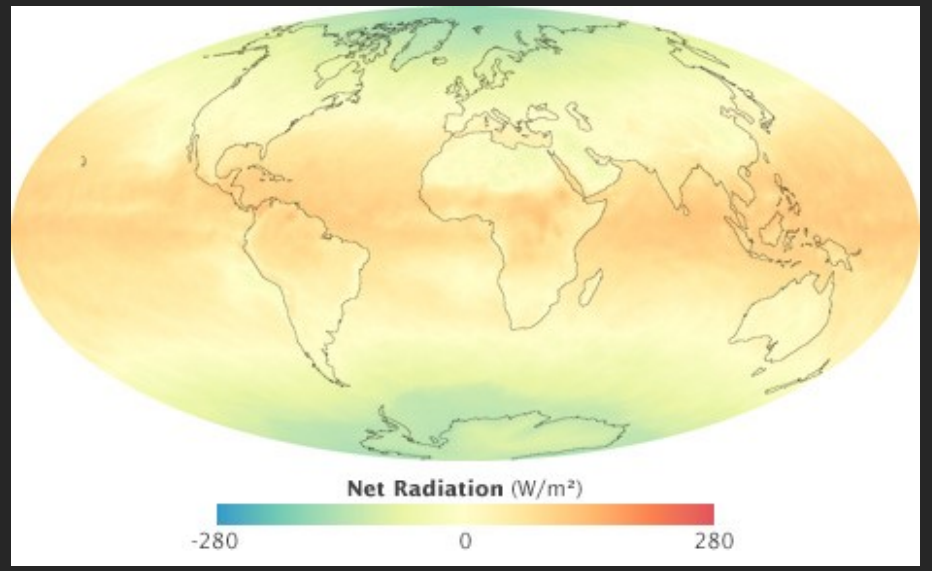
$$T = \left[\frac{S_0(1-\alpha_p)}{4\sigma}\right]^{\frac{1}{4}}$$

$$T \approx 255\ K$$

- But in reality, global mean surface T is 15 C (288 K)!

	r 10^9 m	S_0 W m^{-2}	α_p	T_e K	T_m K	T_s K	τ Earth days
Venus	108	2632	0.77	227	230	760	243
Earth	150	1367	0.30	255	250	288	1.00
Mars	228	589	0.24	211	220	230	1.03
Jupiter	780	51	0.51	103	130	134	0.41

John and Plumb (2007)

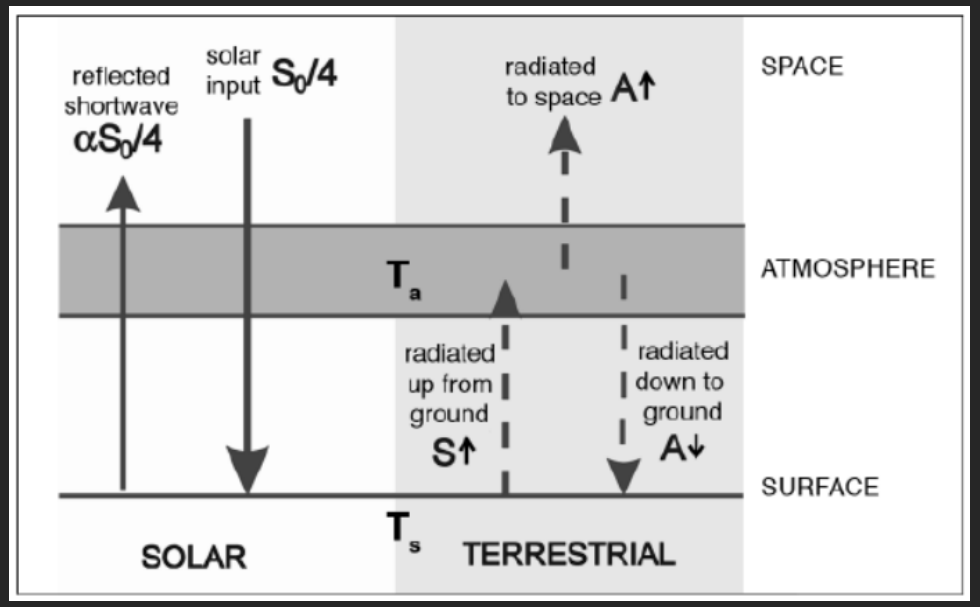


(Source: NASA)

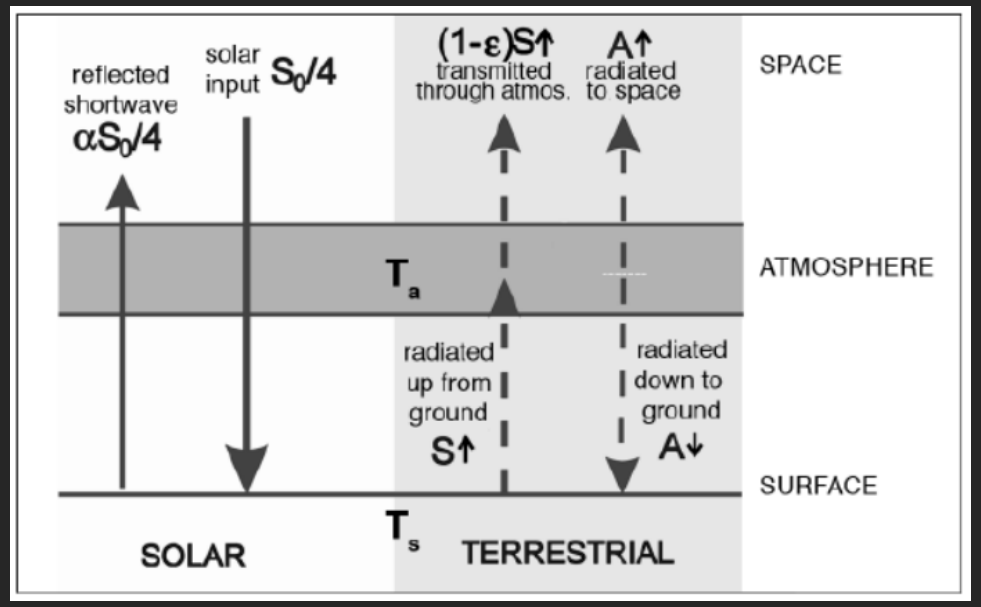
The actors of climate change: GHGs

- The atmosphere: a thin film of fluid on the Earth
  - A mixture of permanent gases (O_2 and N_2) and minor compositions (CO_2 etc)
  - Greenhouse effect

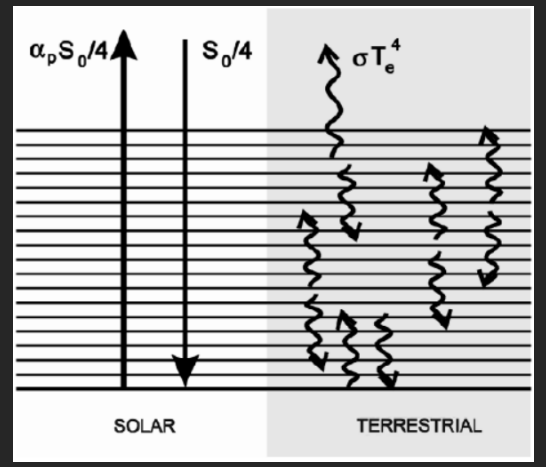
Simplest GH



"Leaky" GH



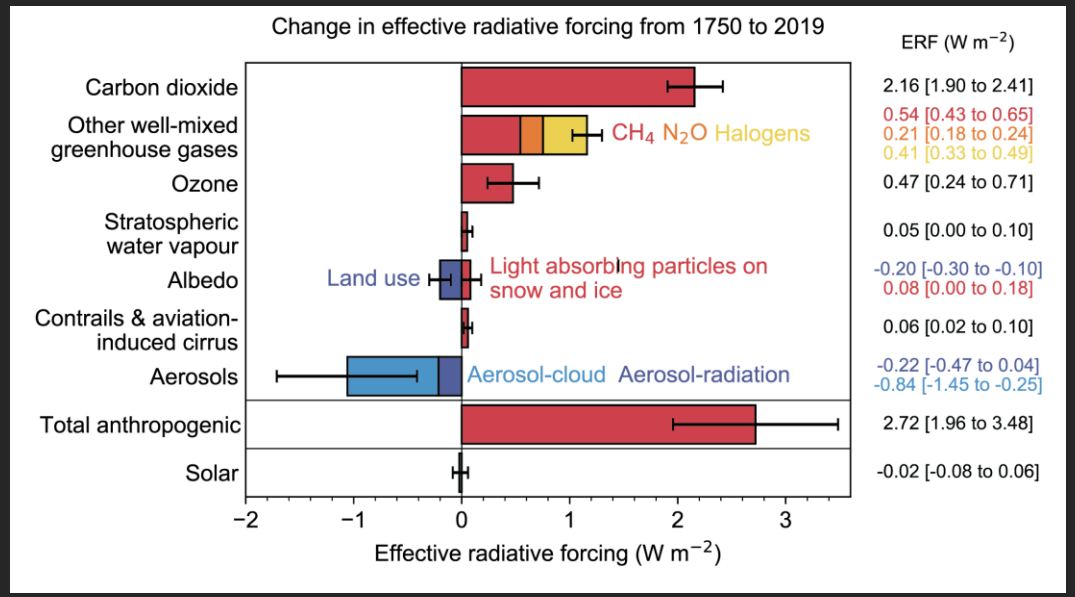
"Actual" GH



John and Plumb (2007)

Why SLCFs Matter

- Short-lived climate forcers: Black carbon, O_3, CH_4, Helogens
  - Short-lived and higher global warming potential (GWP)
  - CO_2 formation
- Well…because they are short-lived
  - Mitigation of climate change -> quick response



(Source: IPCC AR6)

Fun fact: CO_2 is stable, and it is the final product of reactions.
Easy to form, hard to deform.

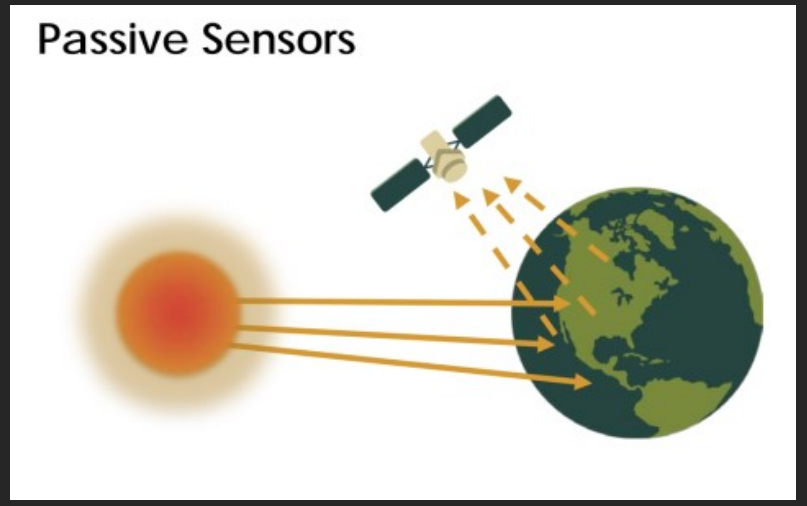
$$CH_4 + OH \rightarrow CH_3 + H_2O$$
$$CH_3 + O_2 + M \rightarrow CH_3O_2 + M$$
$$CH_3O_2 + HO_2 \rightarrow CH_3OOH + O_2$$
$$CH_3OOH + OH \rightarrow CH_2O + OH + H_2O$$

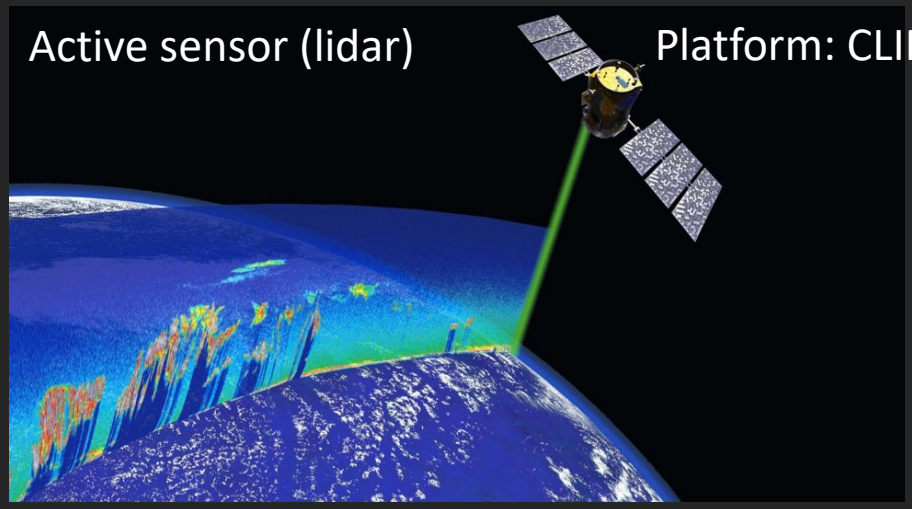
$$CH_2O + OH \rightarrow CHO + H_2O$$
$$CH_2O + hv \rightarrow CHO + HO_2$$
$$CH_2O + hv \rightarrow CO + H_2$$
$$CHO + O_2 \rightarrow CO + HO_2$$

Net CO-mechanism: $CO + 2O_2 \rightarrow CO_2 + O_3$

Overview of satellite observation

- We call satellite “platform”
  - Altitude, orbit
- Sensors: active & passive
- Japanese satellites: many
  - Specialised for GHGs:
  - GOSAT (2009-), GOSAT-2 (2018-)
  - GOSAT-GW (2024?)

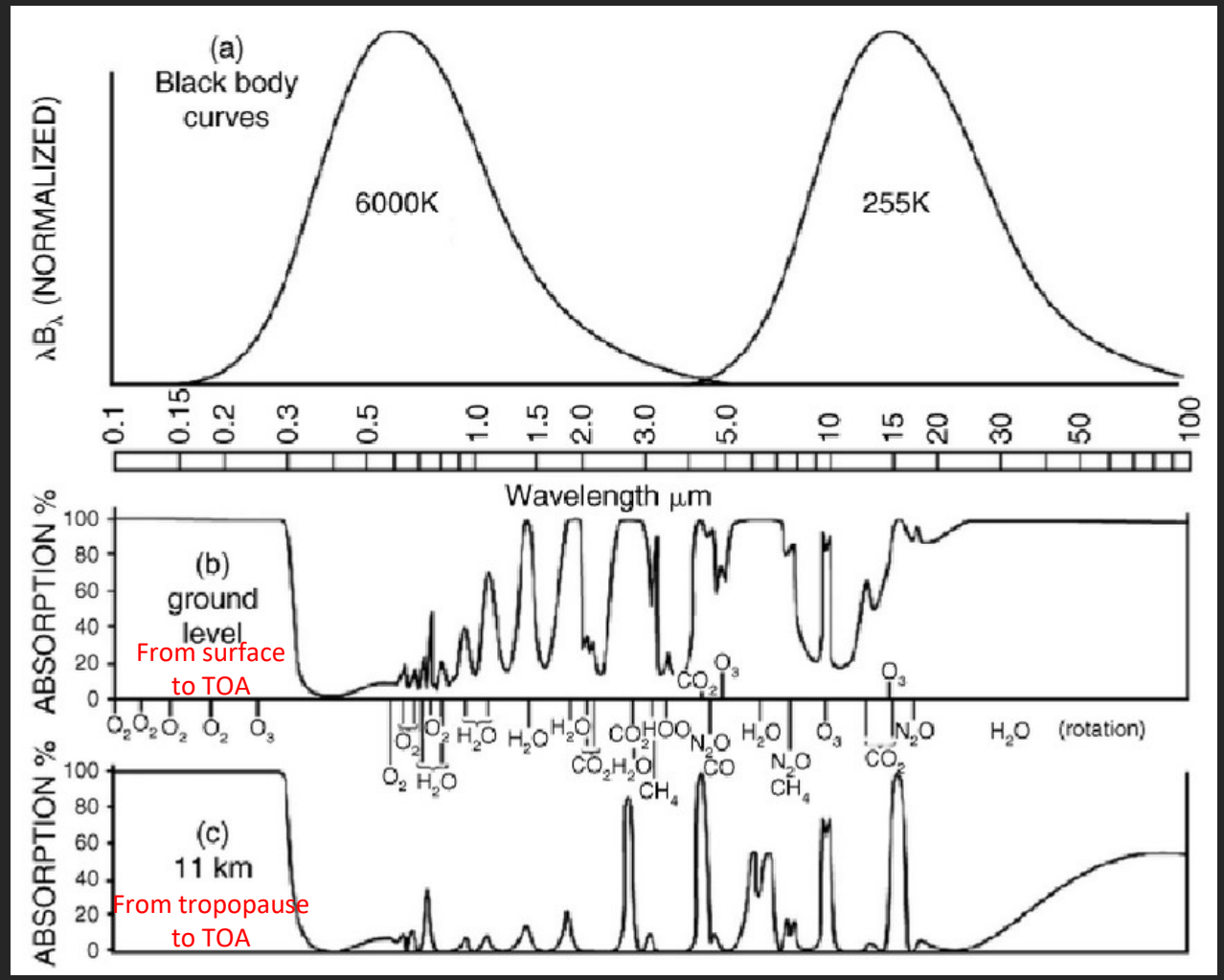




(Source: NASA)

Satellite Data Collection

- NOT direct observations
  - Proxy of variables (e.g., reflectance)
  - Unseen by naked-eye
- Electromagnetic spectrum
  - Absorption by molecules
- Inversion
  - From proxy to oxy



John and Plumb (2007)

SLCF Monitoring by Satellites

- Inverse analysis (aka the retrieval)

$$y = F(x) + \varepsilon$$

- y is the observation (“effect”), x is state vector (“cause”)
- F is forward model, aka the model that describes the physical system.
- We want x, but y is what we get!
- So, we use Bayes’ theorem to find the “most likely” result:

$$P(x|y) = \frac{P(y|x)P(x)}{P(y)}$$

- The prior statistics, P(x), help us obtain better result.

SLCF Monitoring by Satellites

- Conceptual diagram of inverse analysis

Observations

Who made
this footprint?

+

A priori
knowledge

1. Most dragons have wings
2. Green dragons have three fingers

=

Descriptions in Maahn et al. (2020)

SLCF Monitoring by Satellites

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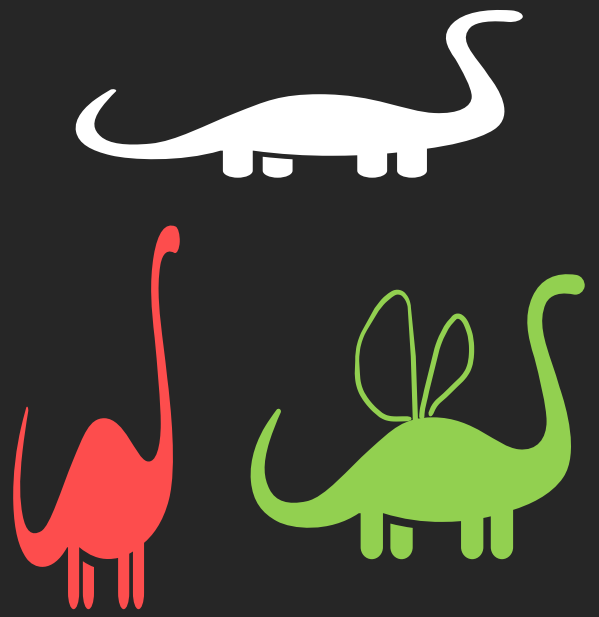
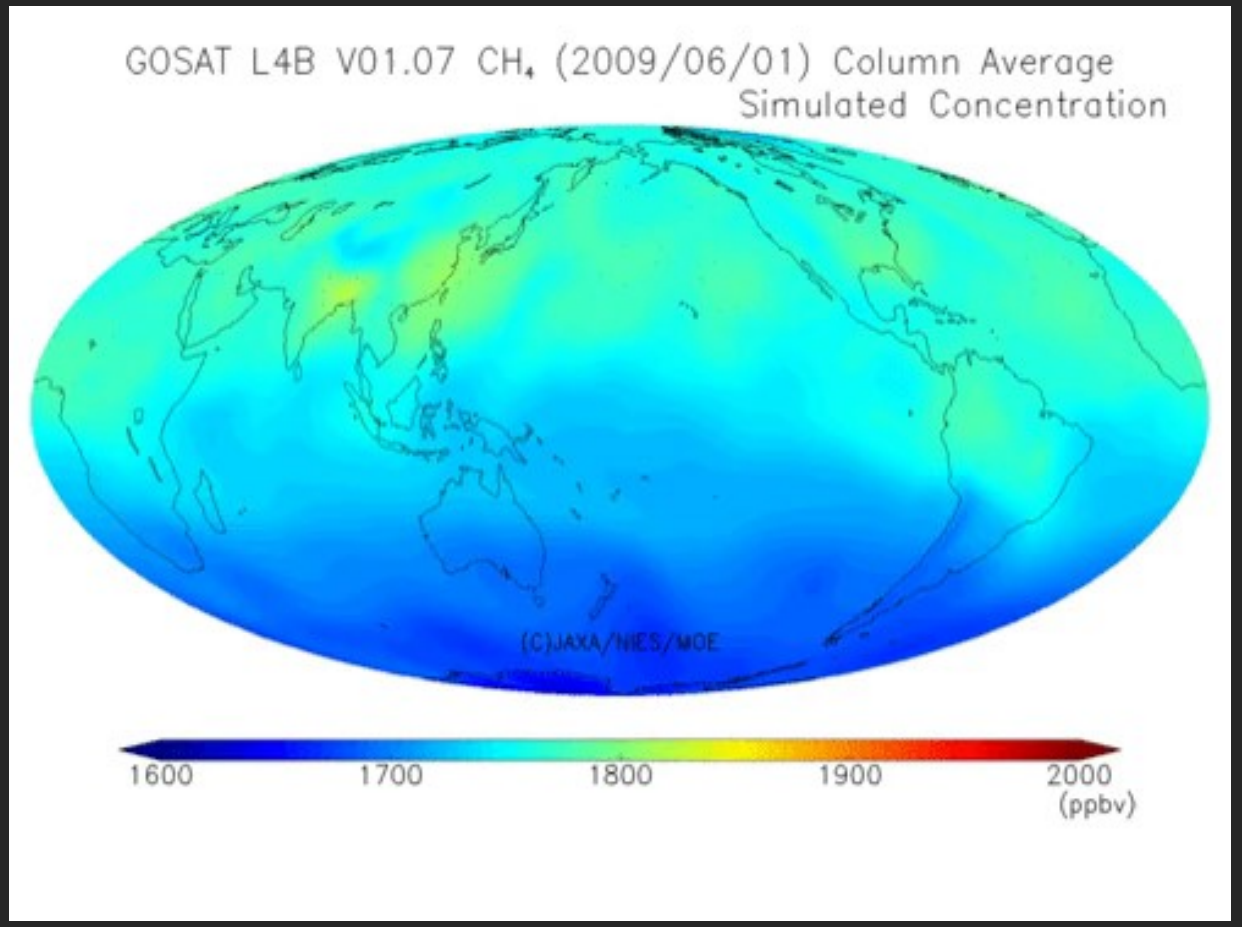


Descriptions in Maahn et al. (2020)

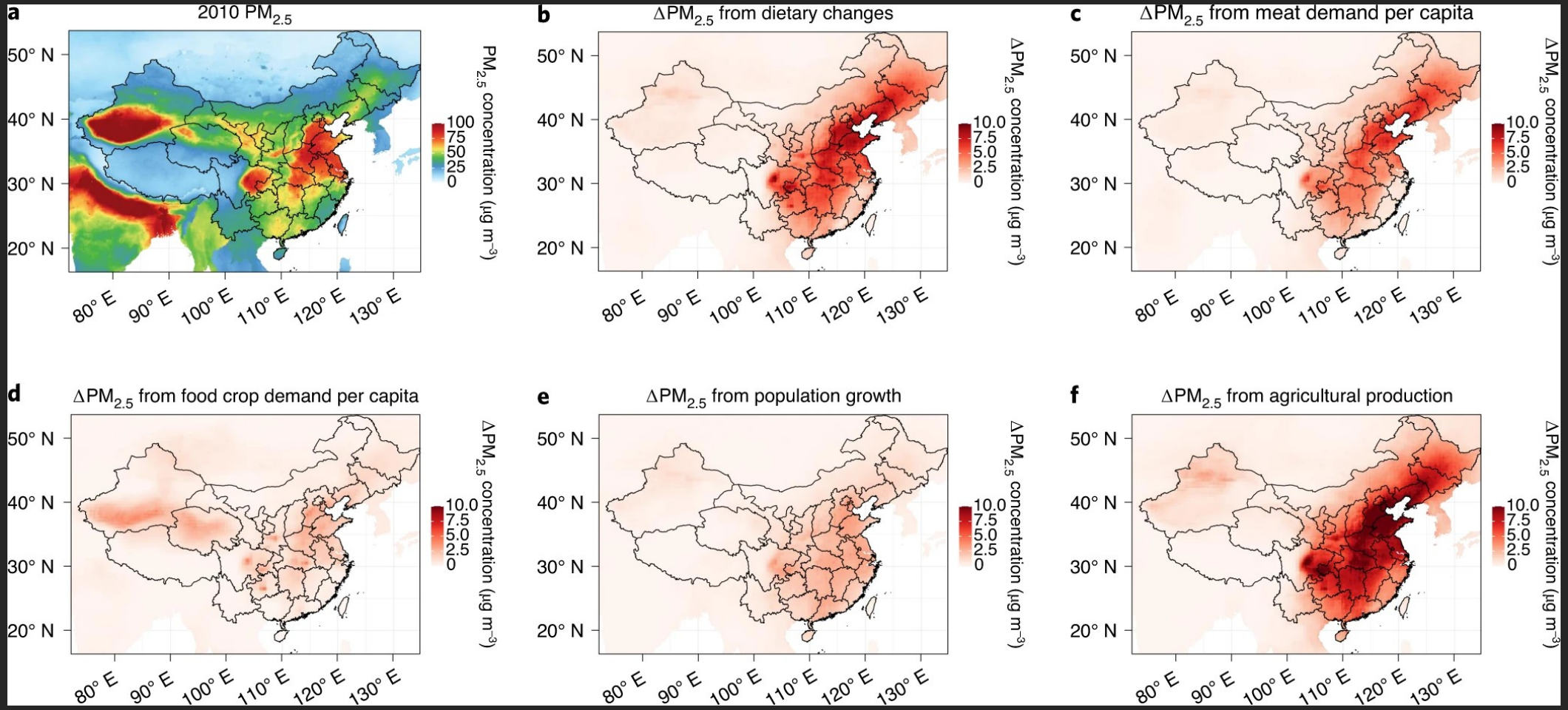
Case Study: Methane



(Source: JAXA)

Climate change: What can we do?

- One simple way: choose what you eat!



(Liu et al., 2020. *Nature Food*)

Conclusion

- The concepts of weather and climate, basic climate system
- Greenhouse gases and short-lived climate forcers
- Satellite observations with best estimation
- Action: start from diet ‼️

Thank you

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