Risk and Impact of a Data Gap in the Earth Radiation Budget Satellite Climate Data Record

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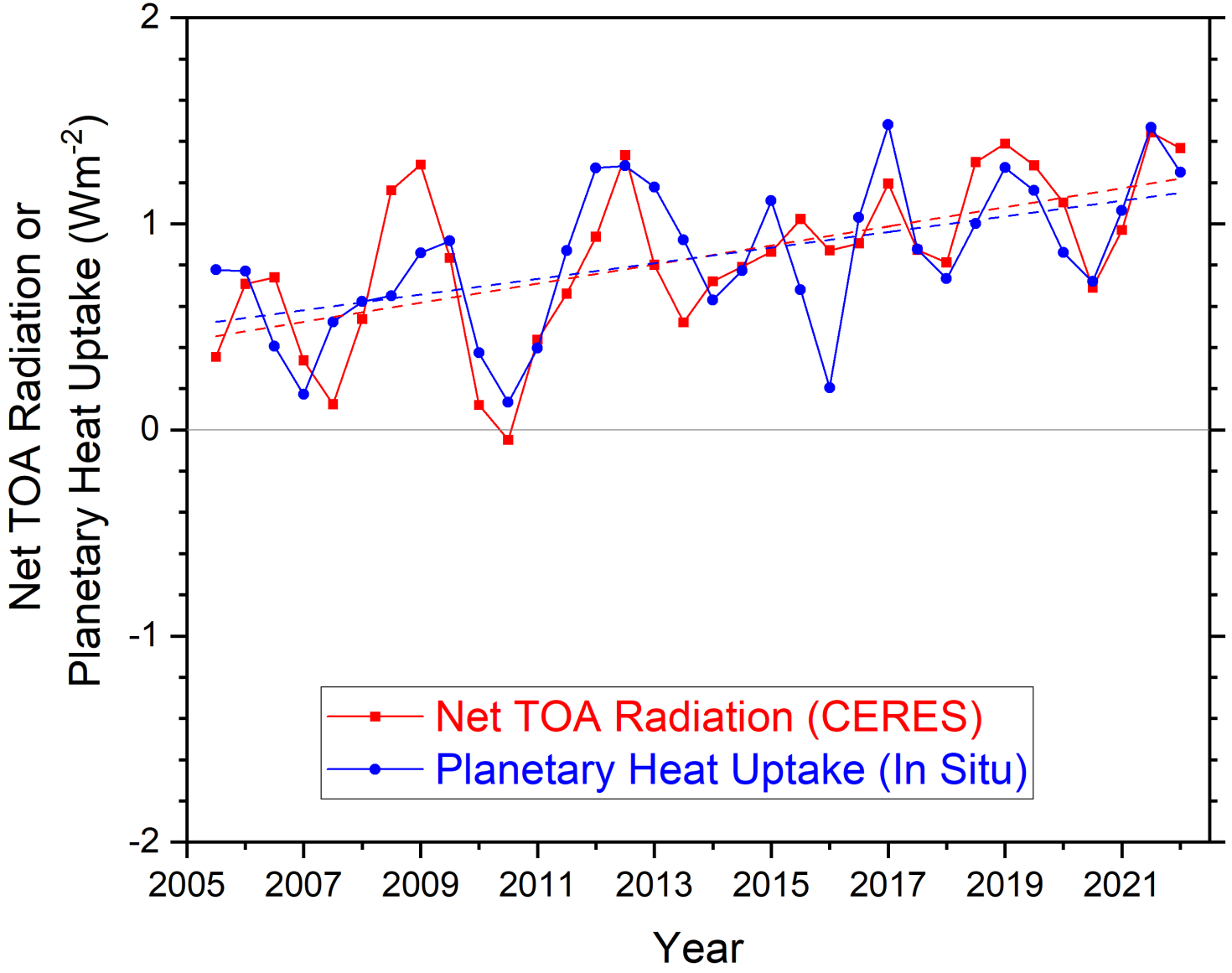
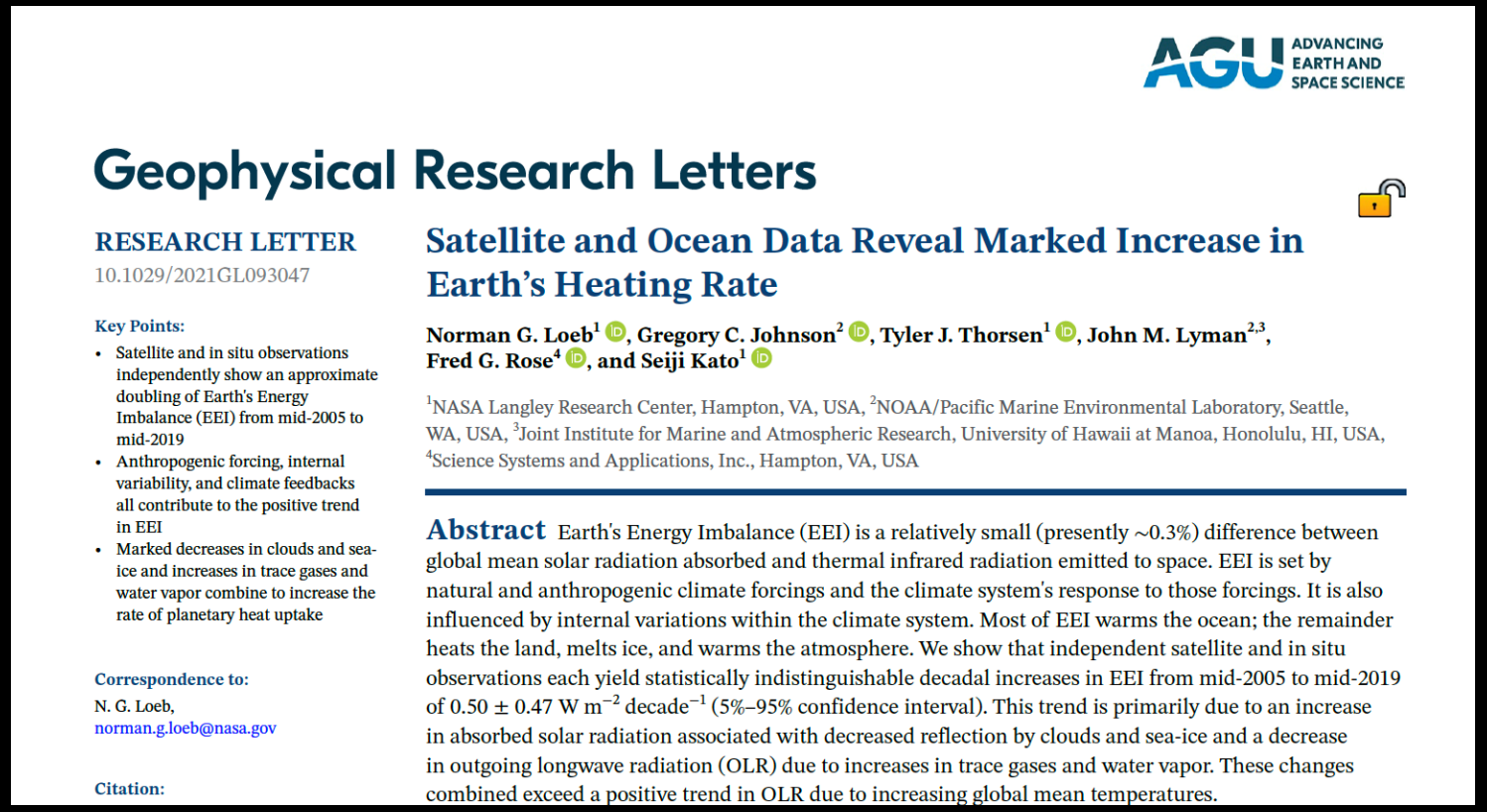
Annual Mean Net TOA Radiation & In-Situ Planetary Heat Uptake (07/2005-06/2022)



	Trend (Wm^{-2} dec^{-1})
CERES EBAF Ed4.2	0.46 ± 0.33
In-Situ	0.38 ± 0.31
Difference	0.084 ± 0.24
R^2	0.54

(Schmidt et al., 2023)

Media Interest



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Geophysical Research Letters

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Key Points:

- Satellite and in situ observations independently show an approximate doubling of Earth's Energy Imbalance (EEI) from mid-2005 to mid-2019
- Anthropogenic forcing, internal variability, and climate feedbacks all contribute to the positive trend in EEI
- Marked decreases in clouds and sea-ice and increases in trace gases and water vapor combine to increase the rate of planetary heat uptake

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Citation:

Satellite and Ocean Data Reveal Marked Increase in Earth's Heating Rate

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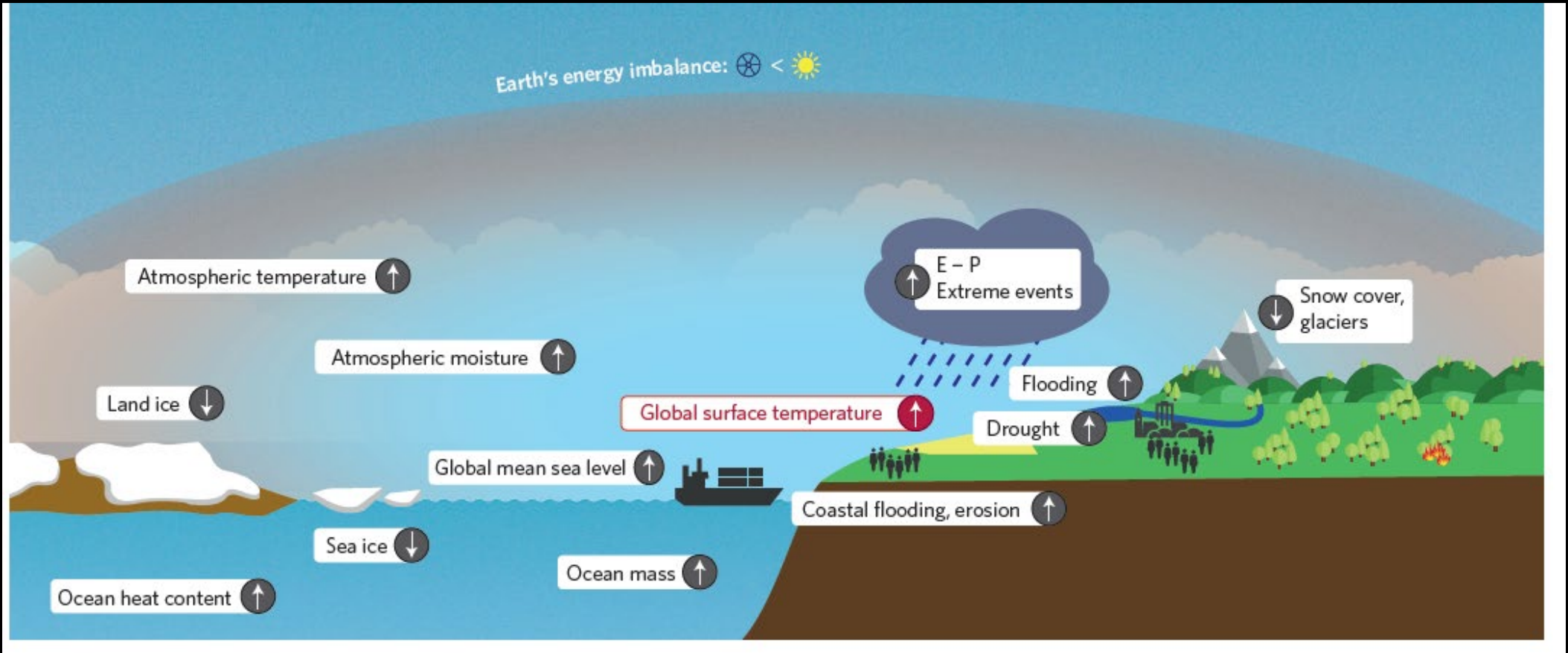
Abstract Earth's Energy Imbalance (EEI) is a relatively small (presently ~0.3%) difference between global mean solar radiation absorbed and thermal infrared radiation emitted to space. EEI is set by natural and anthropogenic climate forcings and the climate system's response to those forcings. It is also influenced by internal variations within the climate system. Most of EEI warms the ocean; the remainder heats the land, melts ice, and warms the atmosphere. We show that independent satellite and in situ observations each yield statistically indistinguishable decadal increases in EEI from mid-2005 to mid-2019 of 0.50 ± 0.47 W m^{-2} $decade^{-1}$ (5%–95% confidence interval). This trend is primarily due to an increase in absorbed solar radiation associated with decreased reflection by clouds and sea-ice and a decrease in outgoing longwave radiation (OLR) due to increases in trace gases and water vapor. These changes combined exceed a positive trend in OLR due to increasing global mean temperatures.

CNN
Washington Post
E&E
Scientific American
Harper's Magazine
The Guardian
The Independent
BBC Science in Action
Gizmodo/Earther
Yahoo! News
Fox News
Seattle Times
The Week
The Hill
MSN
Sydney Morning Herald
World Economic Forum

Daily Mail
Business Insider
Weather Channel
Tech Times
India Times
SF Gate
IFL Science
NY Post
UNILAD
The Verge
AllTop Viral

“Symptoms” of a Positive Earth Energy Imbalance



A positive EEI leads to:

- A rise in Earth’s surface temperature and atmospheric moisture
- Shifts in atmospheric circulation patterns, leading to more extreme weather (⇒ flooding, drought)
- Increase in ocean heat content and decrease in snow and ice over land (⇒ sea-level rise)

von Schuckmann et a. (2016)

Science Addressed by CERES Observations

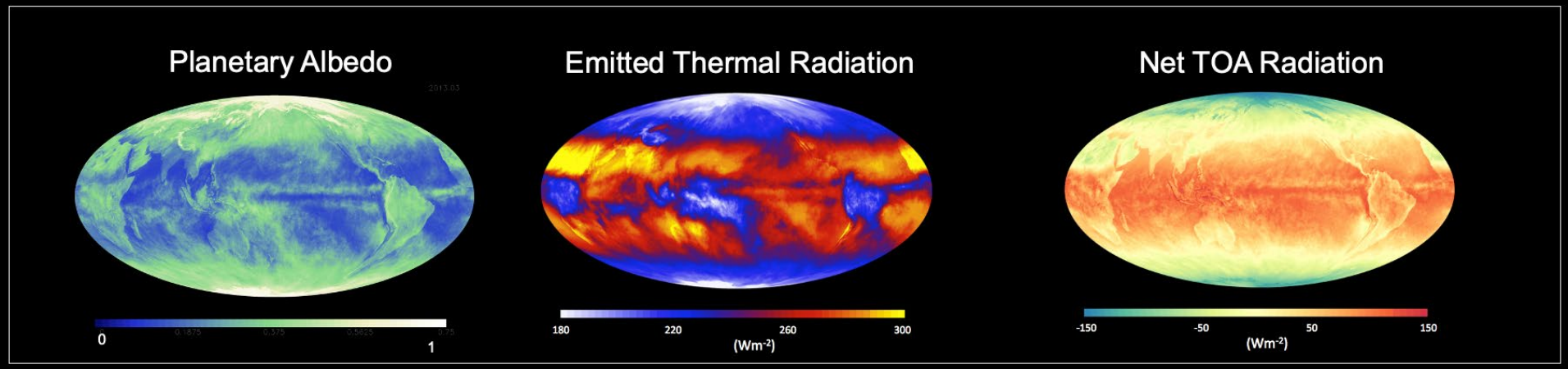
CERES observations provide critical data for:

1) Quantifying how the heat uptake of the planet changes on monthly to decadal timescales.

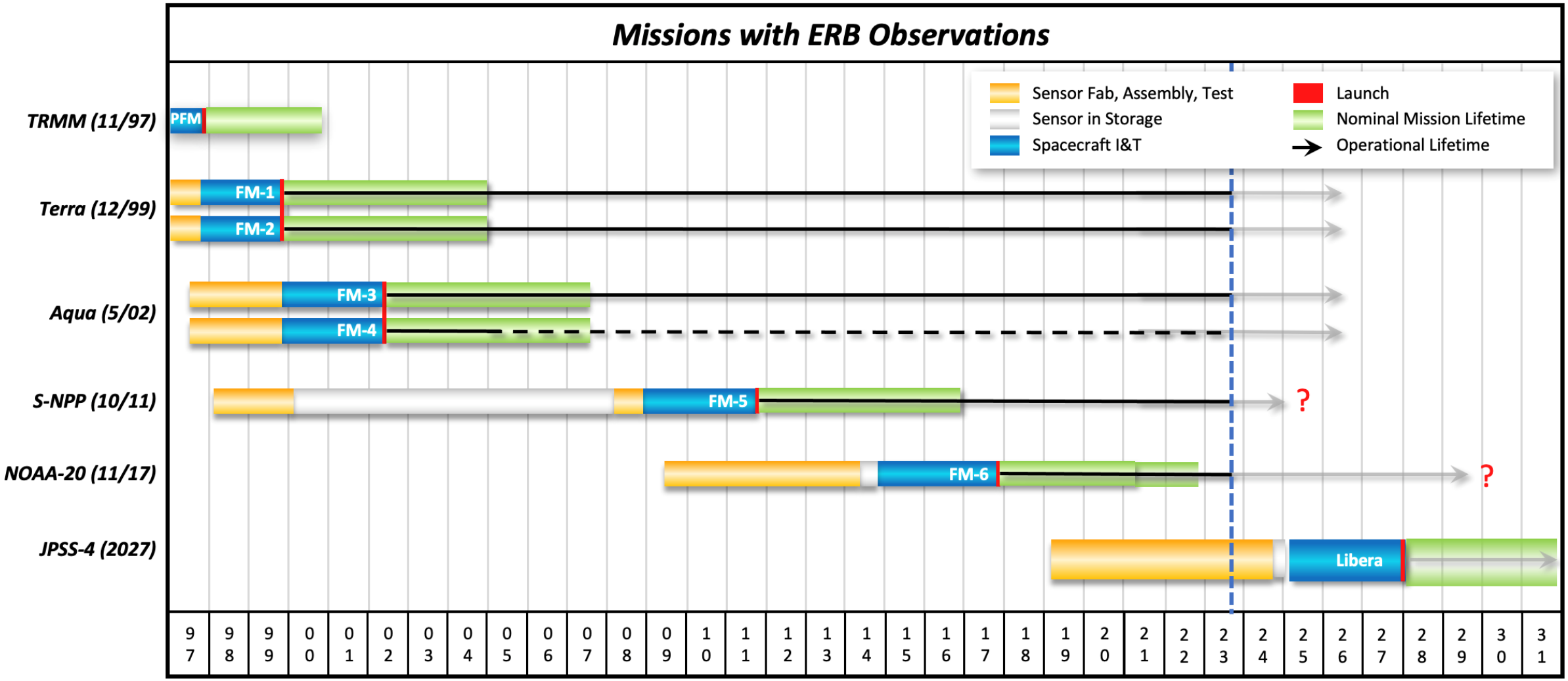
2) Constraining climate model projections of future warming by narrowing uncertainty in cloud feedback.

3) Quantifying Aerosol Radiative Forcing.

CERES is the only dedicated global satellite observing system of Earth's Energy Budget in the world



Flight Schedules



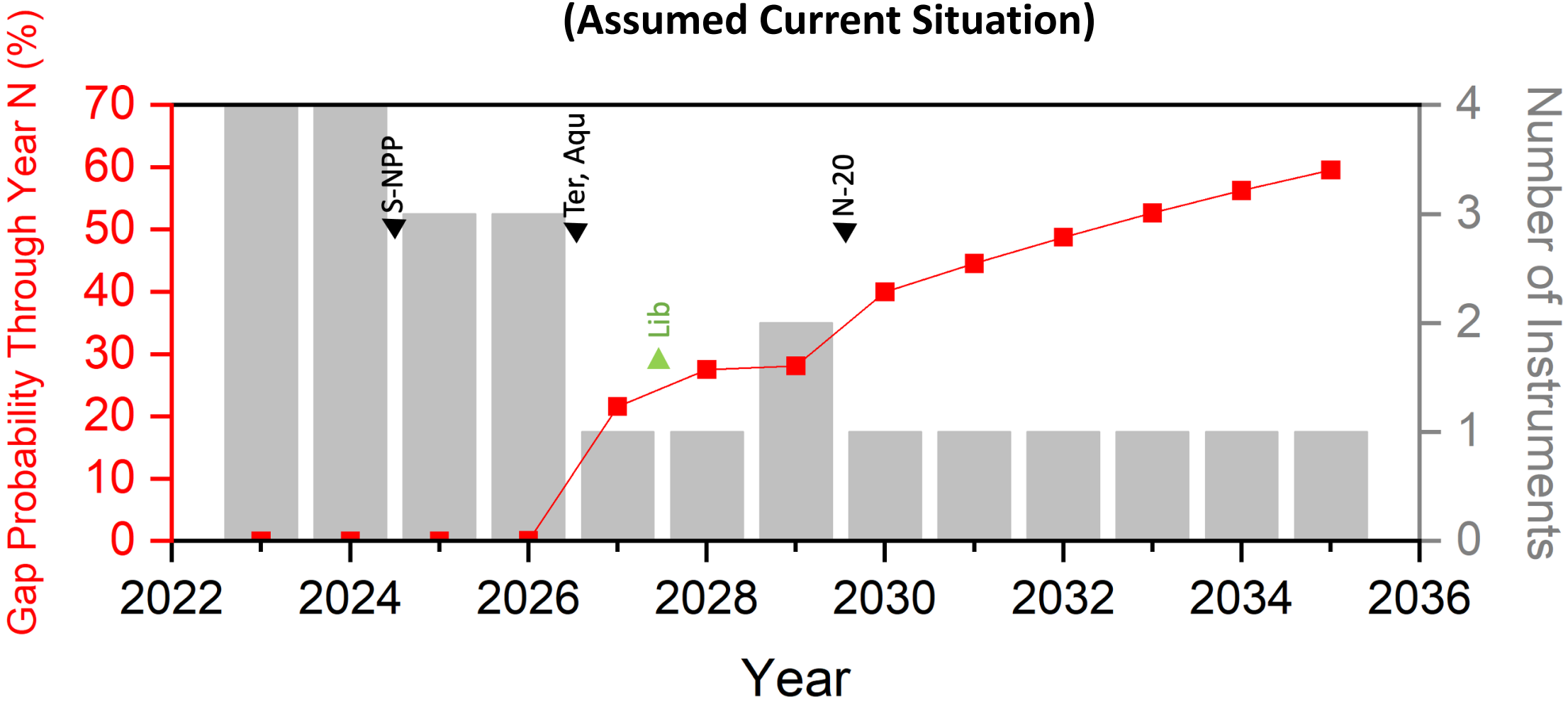
- Currently, 6 CERES instruments fly on 4 satellites: Terra (L1999), Aqua (L2002), SNPP(L2011), NOAA-20 (L2017)
- Libera scheduled for launch in 2027 on JPSS-4

Gap Risk Analysis

- Goal is to estimate of the probability that a data gap will occur in the Earth Radiation Budget climate data record given the ERB instrument flight schedule and historical spacecraft and instrument survival rates
- Period considered: present to 2035
- We assume that a mission terminates if either the ERB instrument, imager it flies with, or spacecraft fails.
- A further assumption is that an ERB instrument can bridge a data gap and maintain radiometric continuity of the ERB CDR even if its orbit drifts in mean local time (MLT) past its nominal mission requirement.

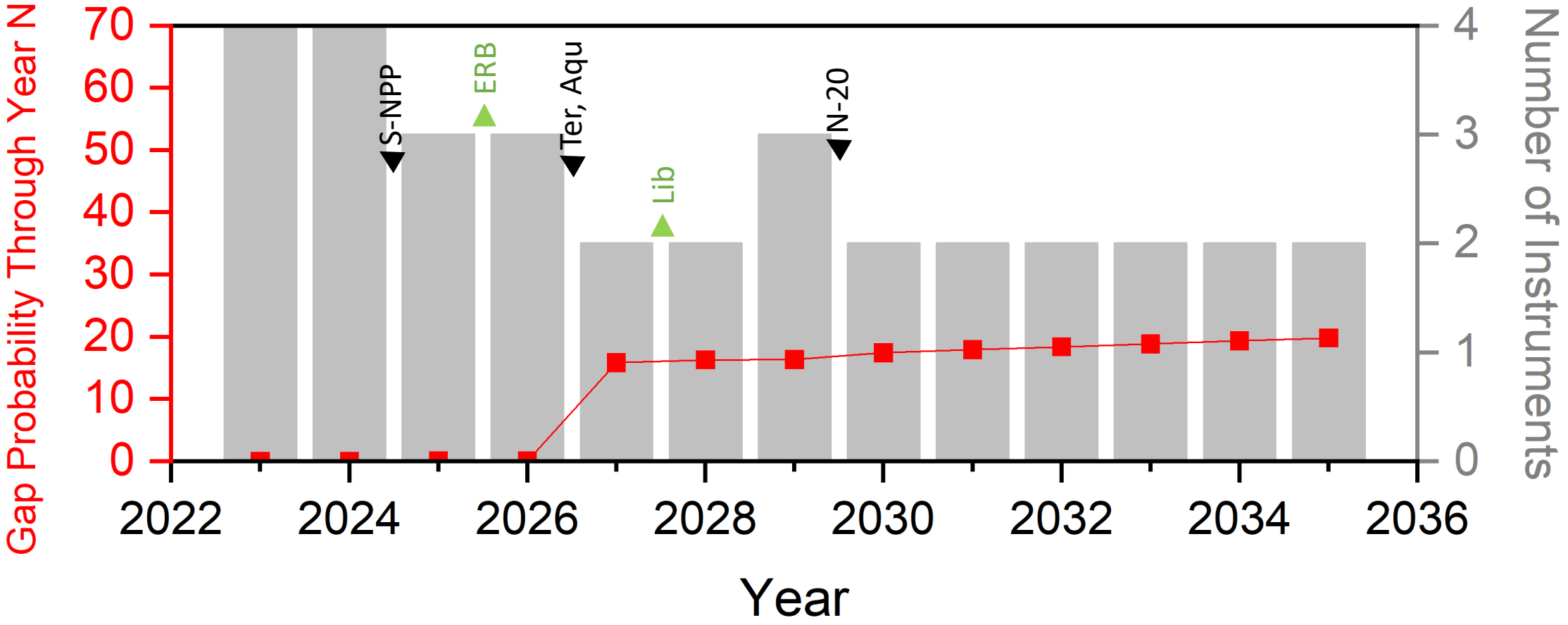
Probability of a Data Gap Through Jan 1 of Year N

(Assumed Current Situation)



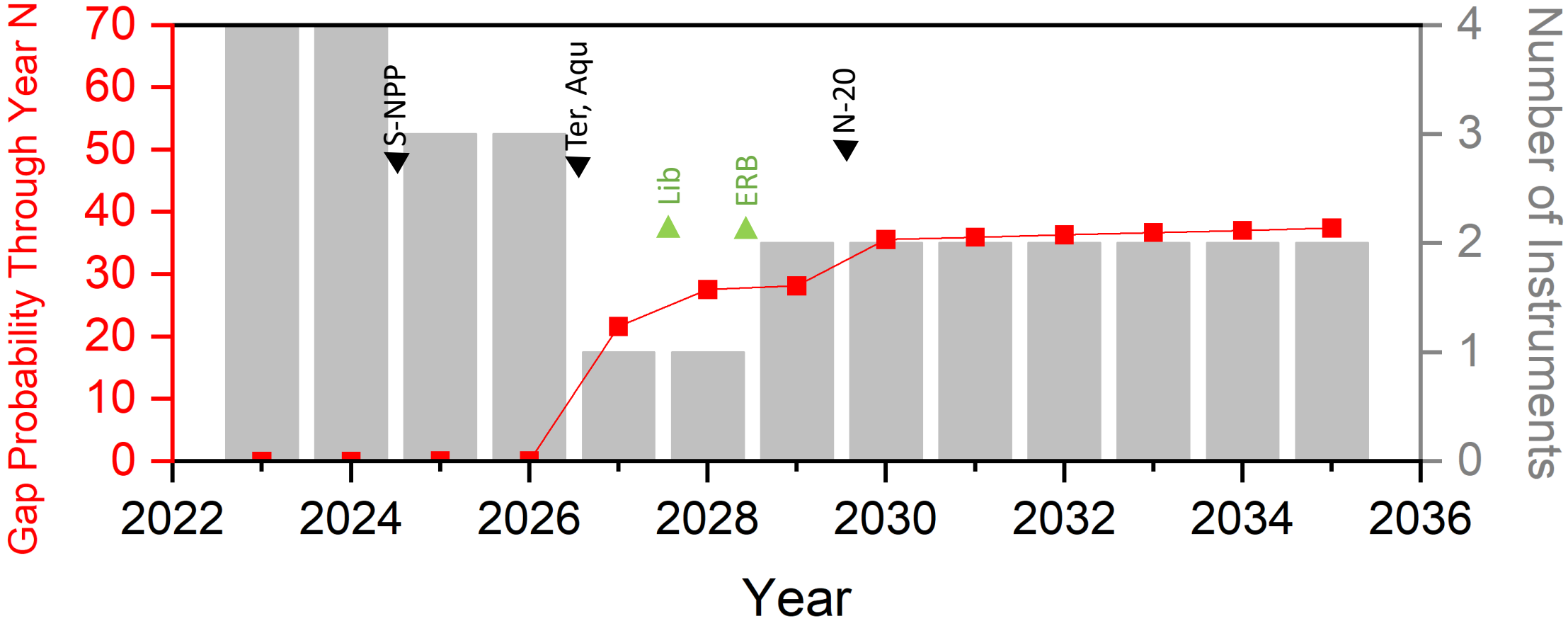
- **Probability of a data gap reaches 28% by 2028 and increases to 60% by 2035.**

Probability of a Data Gap Through Jan 1 of Year N
(Impact of a New Launch in 2025)



- **Probability of a data gap remains < 20% through 2035.**

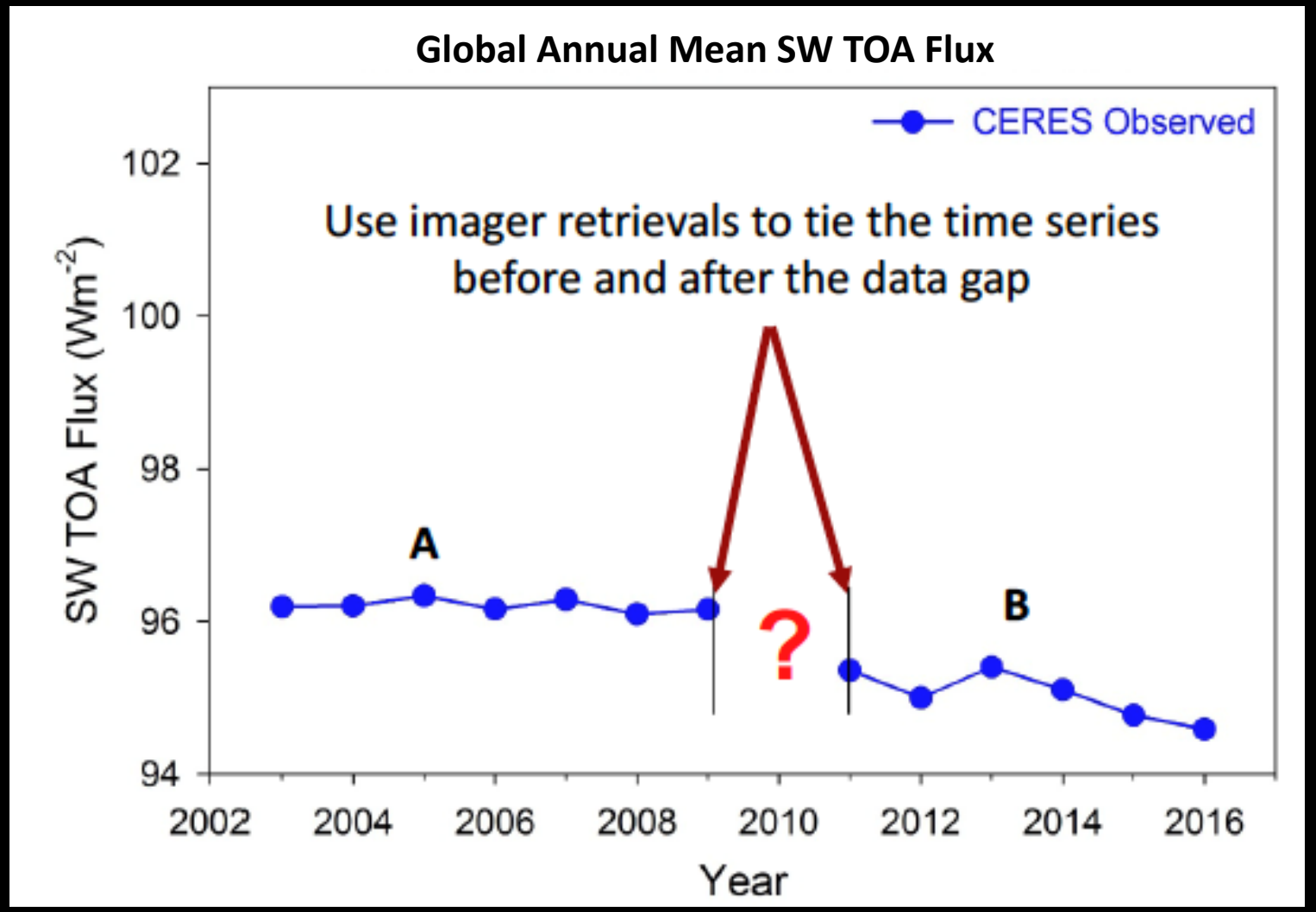
Probability of a Data Gap Through Jan 1 of Year N
(Impact of a New Launch in 2028)



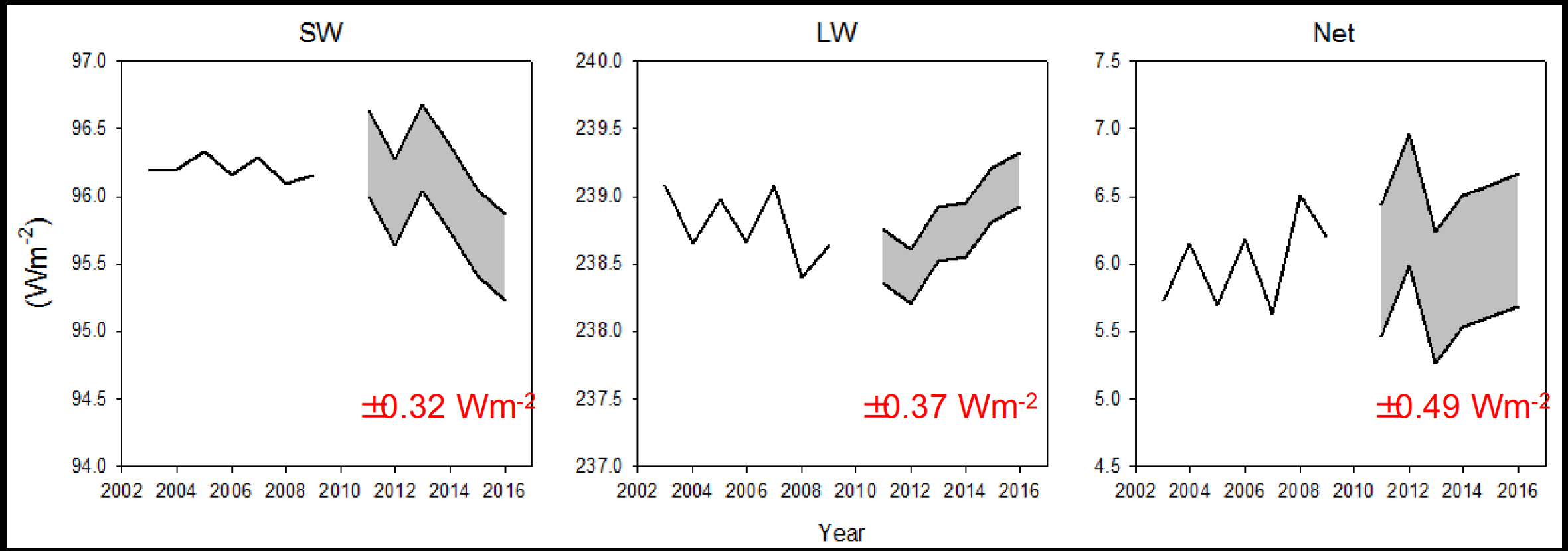
- **Flying an ERB instrument after Libera flattens gap probability following loss of NOAA-20.**

Bridging a Data Gap in the ERB CDR

Goal: Examine the feasibility of using less-accurate imager retrievals to compute radiative fluxes and tie the time series before and after a data gap together.



Bridging a Data Gap in the ERB CDR

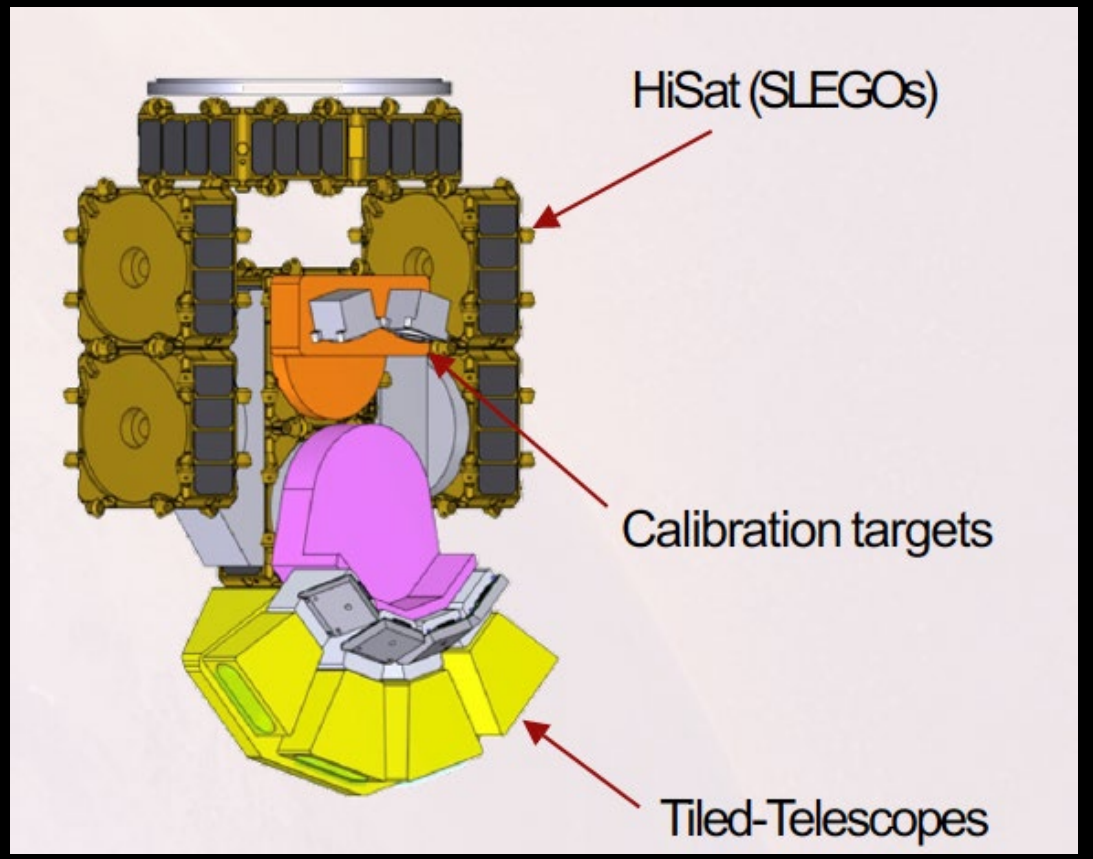


- Assumes imager remains healthy and perfectly stable across the data gap. The longer the gap, the greater the risk.
- The resulting uncertainty is too large to enable decade-to-decade changes in EEI to be resolved.
- Time to detect a real trend above uncertainty would increase substantially.
- A gap would require considerable extra post-processing effort, thereby delaying release of the ERB data products.

Next Generation Earth Radiation Budget Observations

DEMETER (DEMonstrating the Emerging Technology for measuring the Earth's Radiation)

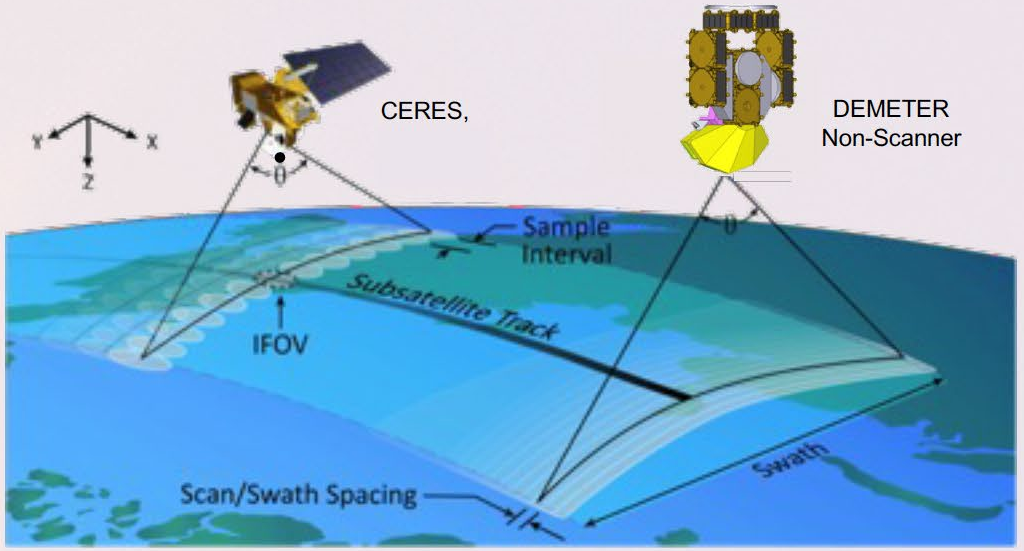
- Free-flying sensorcraft (small satellite)
- Can host both ERB sensor and imager
- Reduces mass, power and cost by an order-of-magnitude over current state-of-the-art approach (e.g., CERES/Libera on JPSS)
- Can be ready by late 2025 if given the opportunity



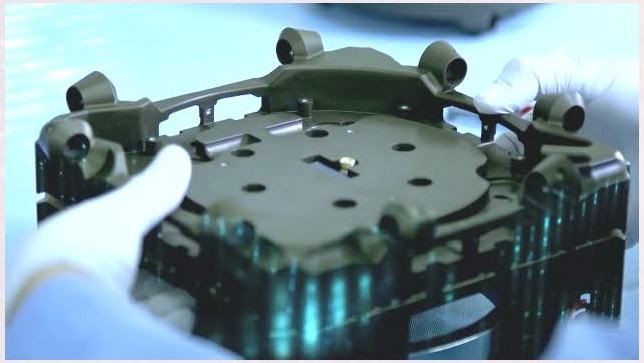
	DEMETER	CERES
Payload Mass (kg)	~20	50
S/C Mass (kg)	150	~2,500

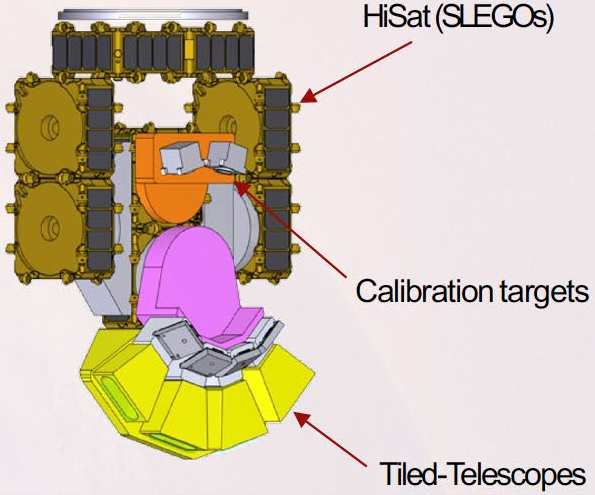
Sensorcraft Concept of Operations

- **Non-scanning, Pushbroom, wide field of view** radiometer to measure limb-to-limb TOA radiances, while integrated with a NovaWurks Hyper Integrated Satlet (HISat) sensorcraft.
- Detector array oriented perpendicular to the satellite ground track to simultaneously collect a single limb-to-limb swath.
- Successive readouts of the array represent consecutive swaths providing the necessary spatial coverage of the TOA radiation fields for nominal observations.



DEMETER enlarged for comparison





Spectral coverage includes **broadband** (CERES-like) plus **spectrally resolved** (VIIRS-like)

Conclusions

- Global warming is a consequence of a positive Earth energy imbalance (EEI)
  - CERES has observed a doubling in EEI since 2000
  - It is imperative that we continue to monitor EEI from satellite
- A data gap would significantly increase uncertainties in observed trends in EEI and cloud and aerosol radiative effects
  - If S-NPP does not overlap with Libera, and no other ERB instrument is launched, there is a **28%** probability of a data gap by 2028
  - Gap probability increases to **60%** by 2035
- The technology exists to significantly reduce the risk of a data gap at a lower cost
  - An ERB instrument launch in 2025 ensures the gap probability remains < 20% through 2035
  - DEMETER can be ready by late 2025
  - Overlap with existing instruments is critical