

National Aeronautics and
Space Administration



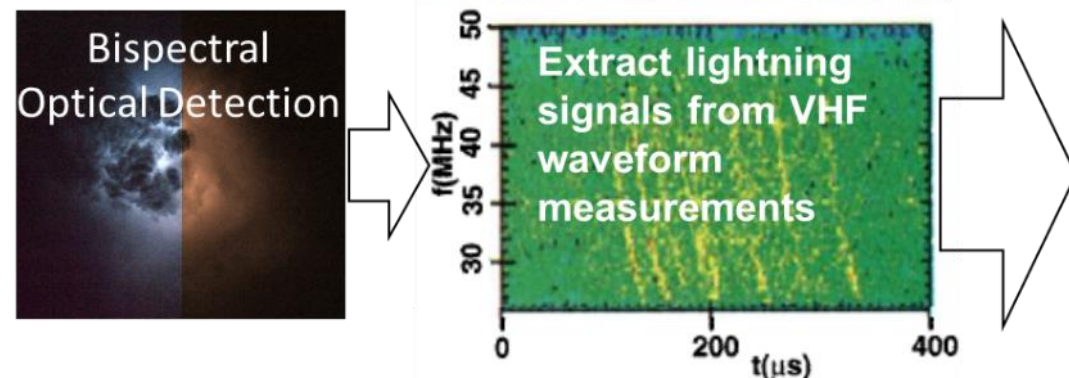
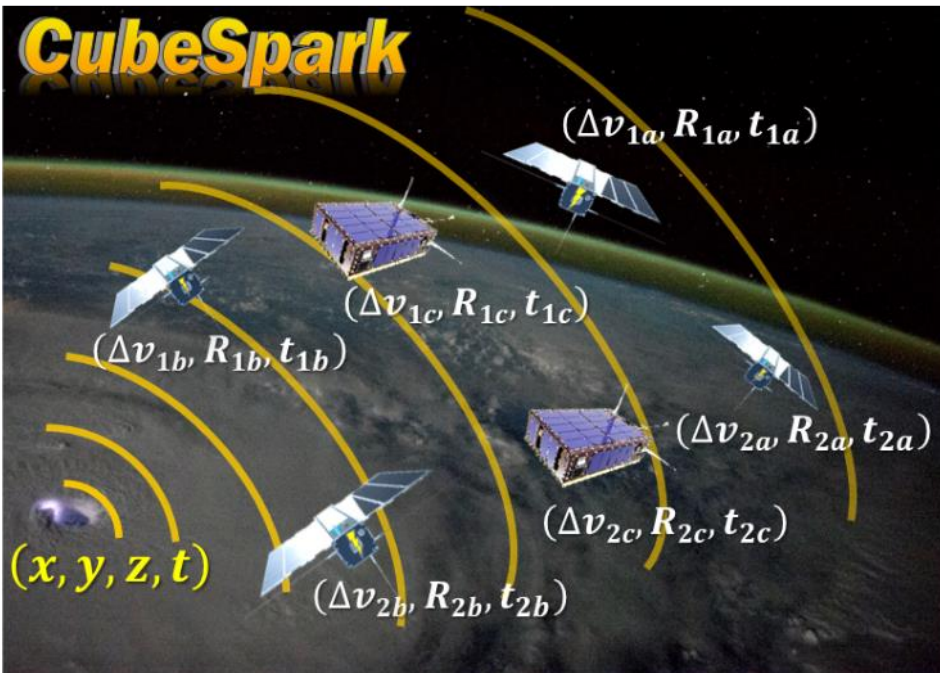
An update on the CubeSpark 3D Lightning Mapping Concept

Patrick Gatlin, Timothy Lang, Mason Quick, Jackson Remington, Bill Koshak, Chris Schultz, Dan Cecil, NASA Marshall Space Flight Center

Phillip Bitzer, Sarah Stough, Univ. of Alabama in Huntsville

Sonja Behnke, Harald Edens, Los Alamos National Laboratory

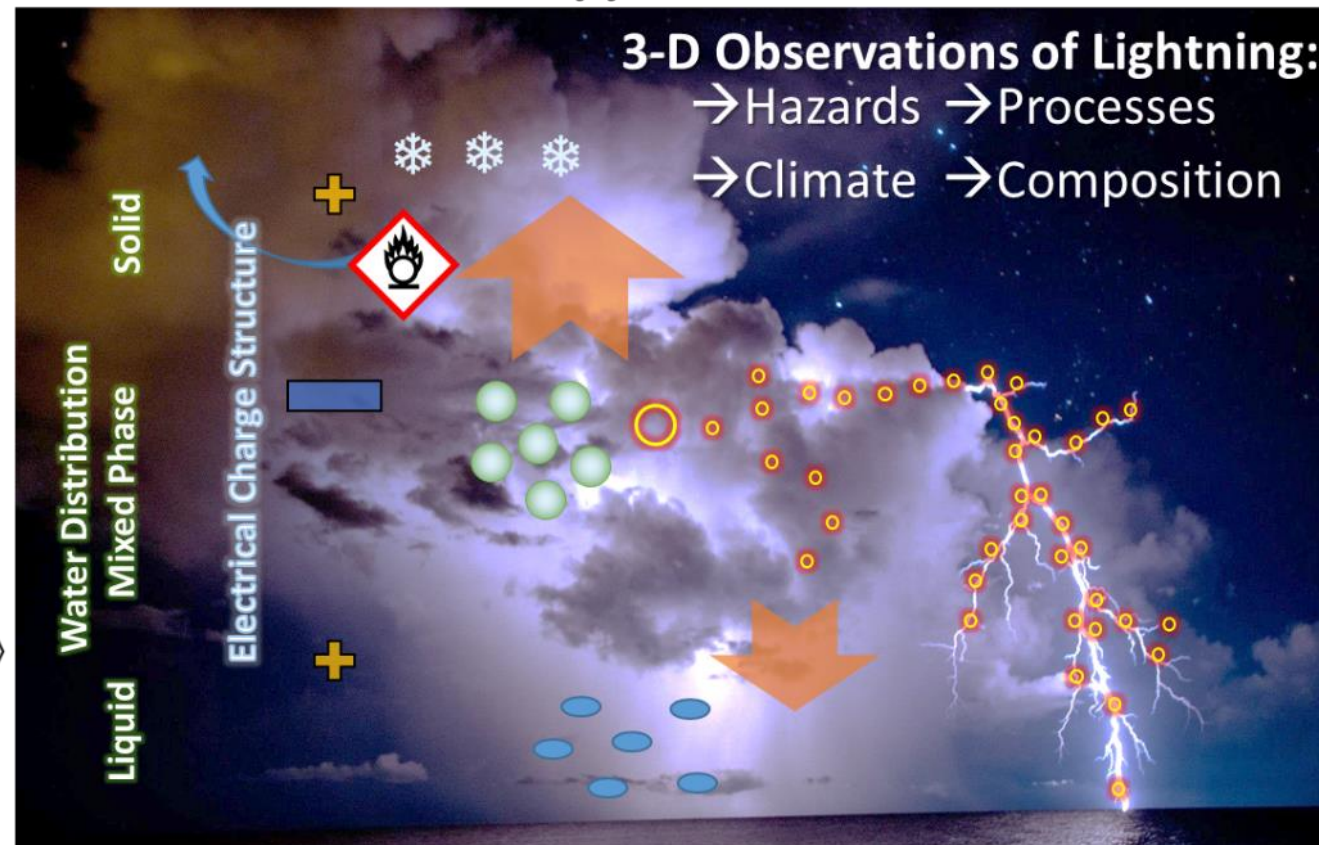
GLM Science Meeting 2022



Measurement Concept



Enabled Science and Applications

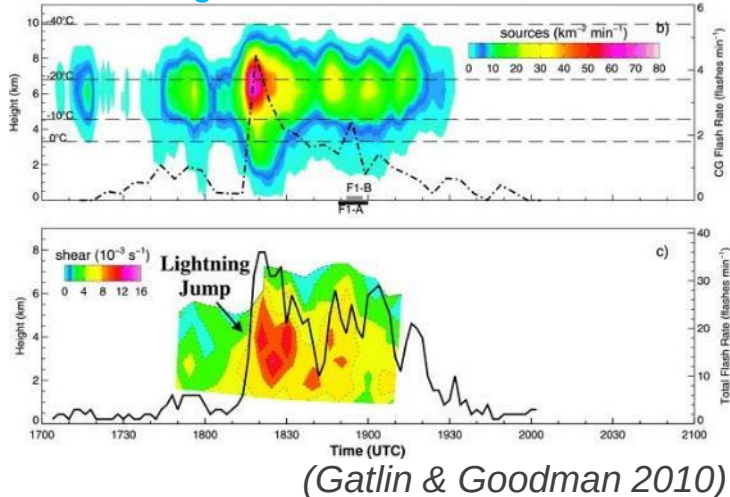


Primary Measurement Objectives:

1. Locate the horizontal **and vertical** origin of lightning events with an uncertainty ≤ 2 -km (1-km goal)
2. Improve detection of **small, optically dim pulses** that can evade current imagers and frequent intense or anomalous storms

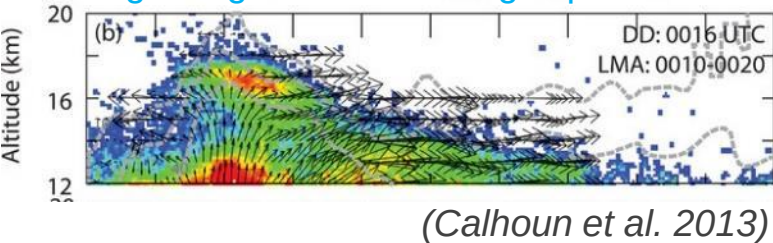
Vertical information provides key insights about thundercloud effects on its surrounding environment

Vertical growth as storm intensifies



(Gatlin & Goodman 2010)

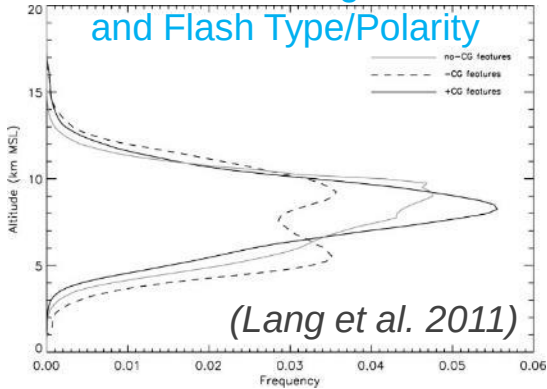
Lightning in Overshooting Tops



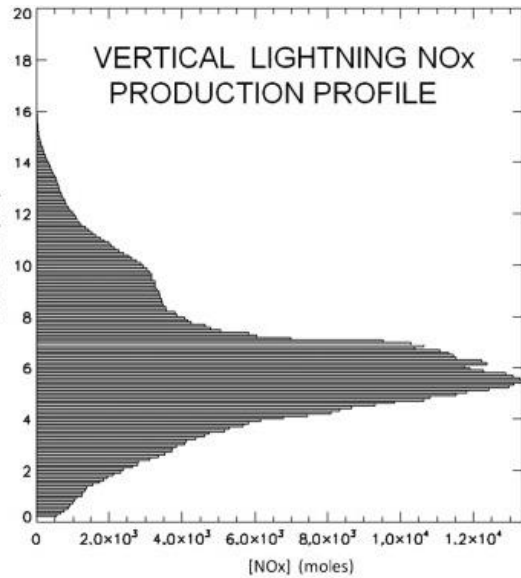
(Calhoun et al. 2013)

3D LMA observations are extremely insightful but limited to regional networks

Anomalous Charge Storms and Flash Type/Polarity



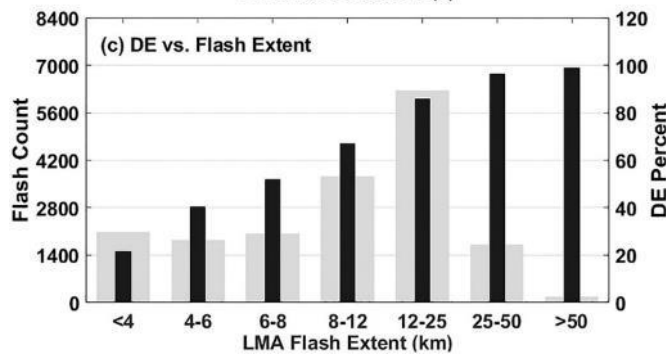
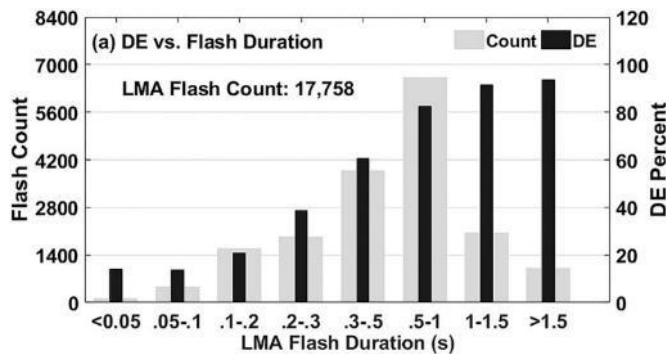
(Lang et al. 2011)



(Koshak et al. 2014)

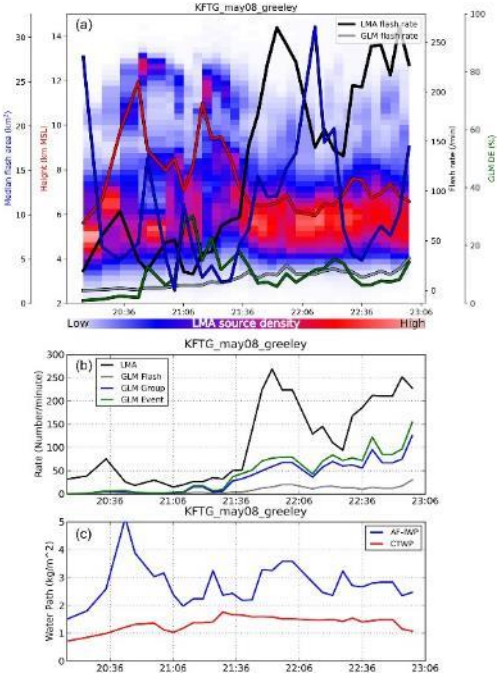
Detecting small and low-altitude flashes are important for diagnosing storm intensification and severe weather

GLM vs KSCLMA Detection



(Zhang & Cummins 2020)

GLM vs COLMA

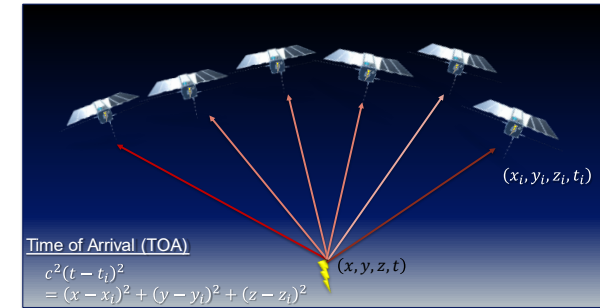
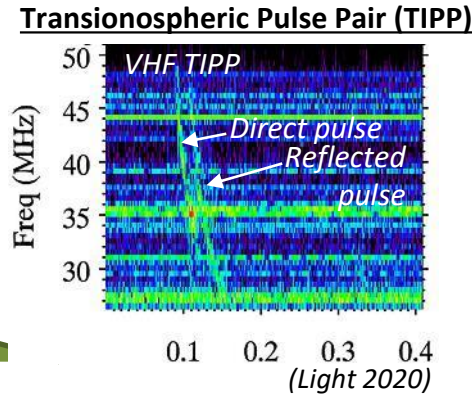
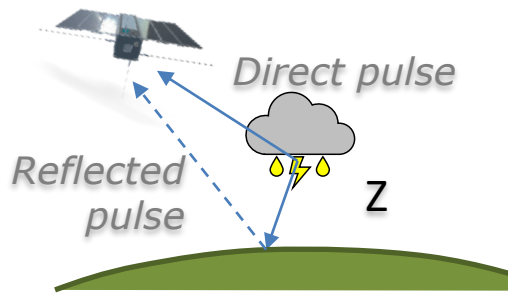


(Rutledge et al. 2020)

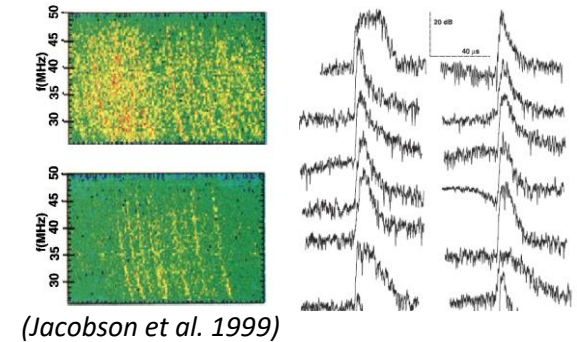
Small, dim flashes are difficult detect with coarse resolution imagers

→ Need to better resolve unknown characteristics of these lightning flashes

Single vs Multi-satellite Approaches for 3-D retrieval



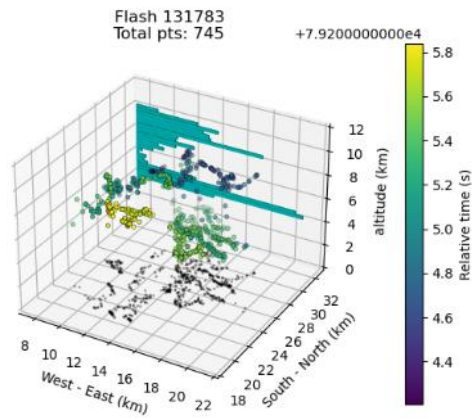
Time-of-arrival of impulsive VHF events



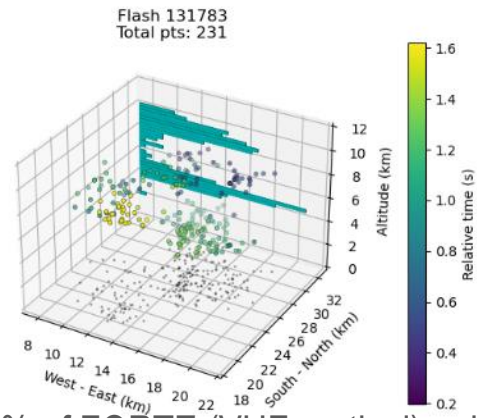
- RF gives altitude; Optical gives latitude and longitude
- 3D requires detection of reflected pulses coincident with optical
 - ~37% of FORTE VHF+optical dataset are TIPPs (Jacobson & Light 2002)
- 3D location accuracy in single-satellite retrieval:
 - Horizontal RMS error ~ resolution of optical (≤ 2 -km)
 - Vertical RMS error ~ 300 m (assumed $\sigma_{\text{timing}} = 0.5 \mu\text{s}$)
- Doesn't rely on reflected pulse for 3D
- Optical increases observation time
 - Train of satellites to observe evolution of storm for several minutes
 - Parallax-based pulse altitude
 - Constrain TOA solution (requires fewer VHF detections for 3D retrieval)
- 3D location from solely VHF time-of-arrival (TOA)
 - Horizontal RMS error ~ 500 m
 - Vertical RMS error ~ 1-2 km

Simulations: Single vs Multi-satellite

LMA Source Flash



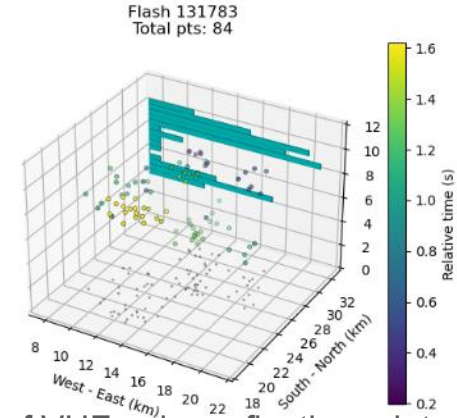
Single-sat solution 32 % TPP



32% of FORTE (VHF+optical) pulse

reflections detected (Light & Jacobson 2002)

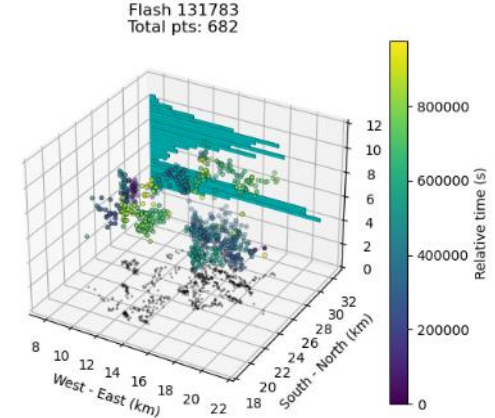
Single-sat solution 12 % TPP



12% of VHF pulse reflections detected

(Peterson 2022)

Multi-sat solution



- Single-sat captures general charge regions
- Multi-sat gives more detail of 3D flash structure
 - LNOx needs robust estimate of flash length (Koshak et al. 2014)
 - Flash extent closely tied to kinematics (e.g., Bruning & MacGorman 2013)
- Examining bulk flash statistics of simulations initialized from a larger LMA dataset (RELAMPAGO, NALMA, WTLMA)

Simulations: Jackson Remington (MSFC NPP)

CubeSat Lightning Imaging and Detection Experiment (CLIDE)

- Purpose: To detect small and optically dim lightning flashes that frequent intense thunderstorms
- Specifications:
 - Center wavelengths: 777.4 ± 0.5 nm; 337 ± 1 nm
 - Spectral bandwidth: ≤ 1 nm FWHM
 - 60 x 60 deg FOV (≥ 90 -sec storm observation time)
 - ≤ 2 -km spatial resolution
 - < 1 -ms temporal resolution
 - Event detection threshold: $\leq 2 \mu J m^{-2} sr^{-1}$
- Being designed for use on small satellite missions like CubeSpark
 - Includes a more compact optics design to reduce size, weight, and cost of telescope
 - Uses faster and higher resolution CMOS detectors with new AI-based storm detection and dynamic sampling strategy

Collecting community input for a White Paper on the CubeSpark concept

Objectives:

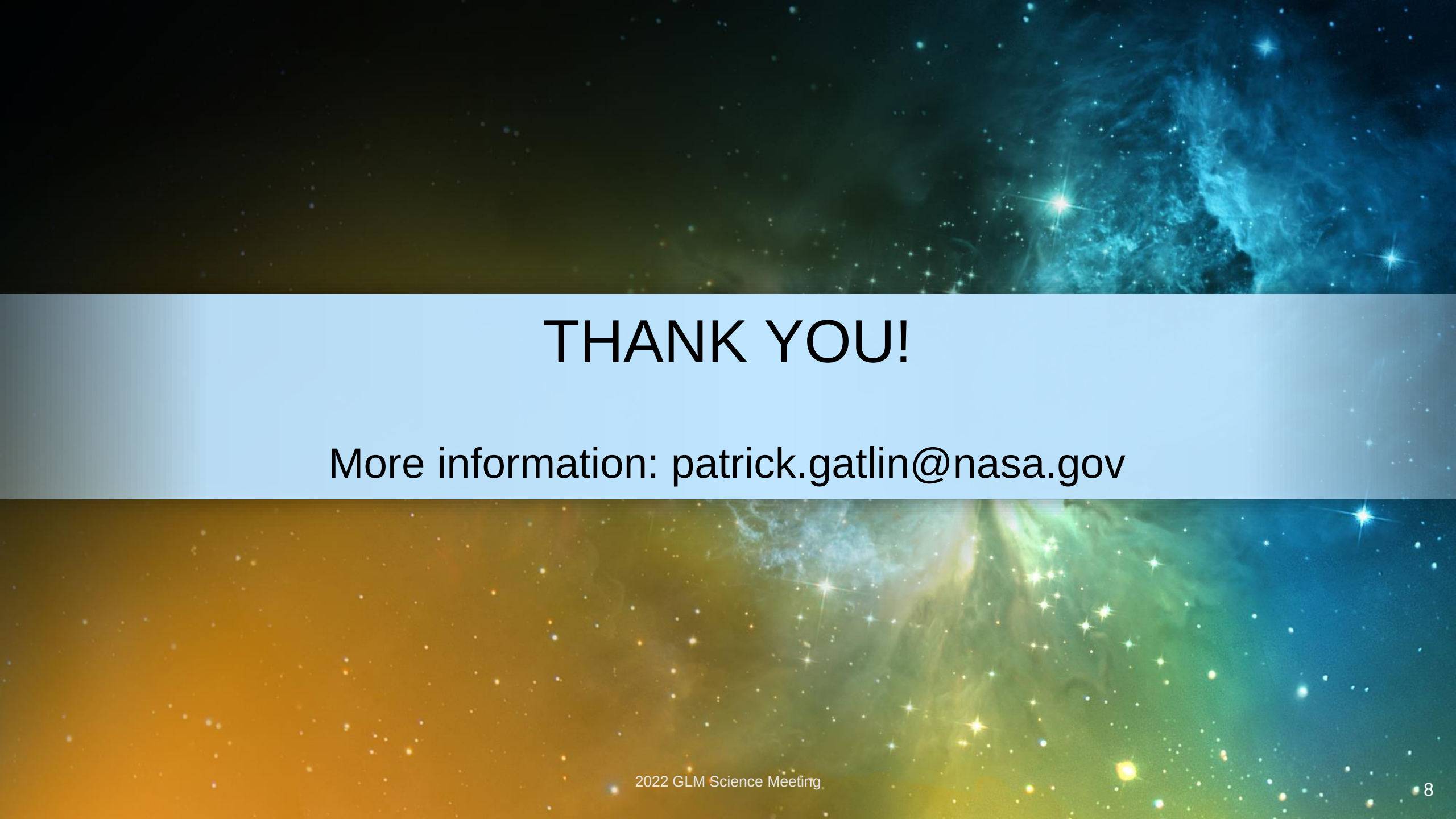
1. Capture scientific justification and benefits
2. Demonstrate community support
3. Recommendations to stakeholders at NASA, NOAA, DoD, others

Target completion date: January 2023

How can you contribute?

→ 10-min questionnaire: <https://tinyurl.com/CubeSpark>

→ Send this link to colleagues



THANK YOU!

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