ELECTRICAL DISCHARGE FROM A THUNDERCLOUD TOP TO THE LOWER IONOSPHERE

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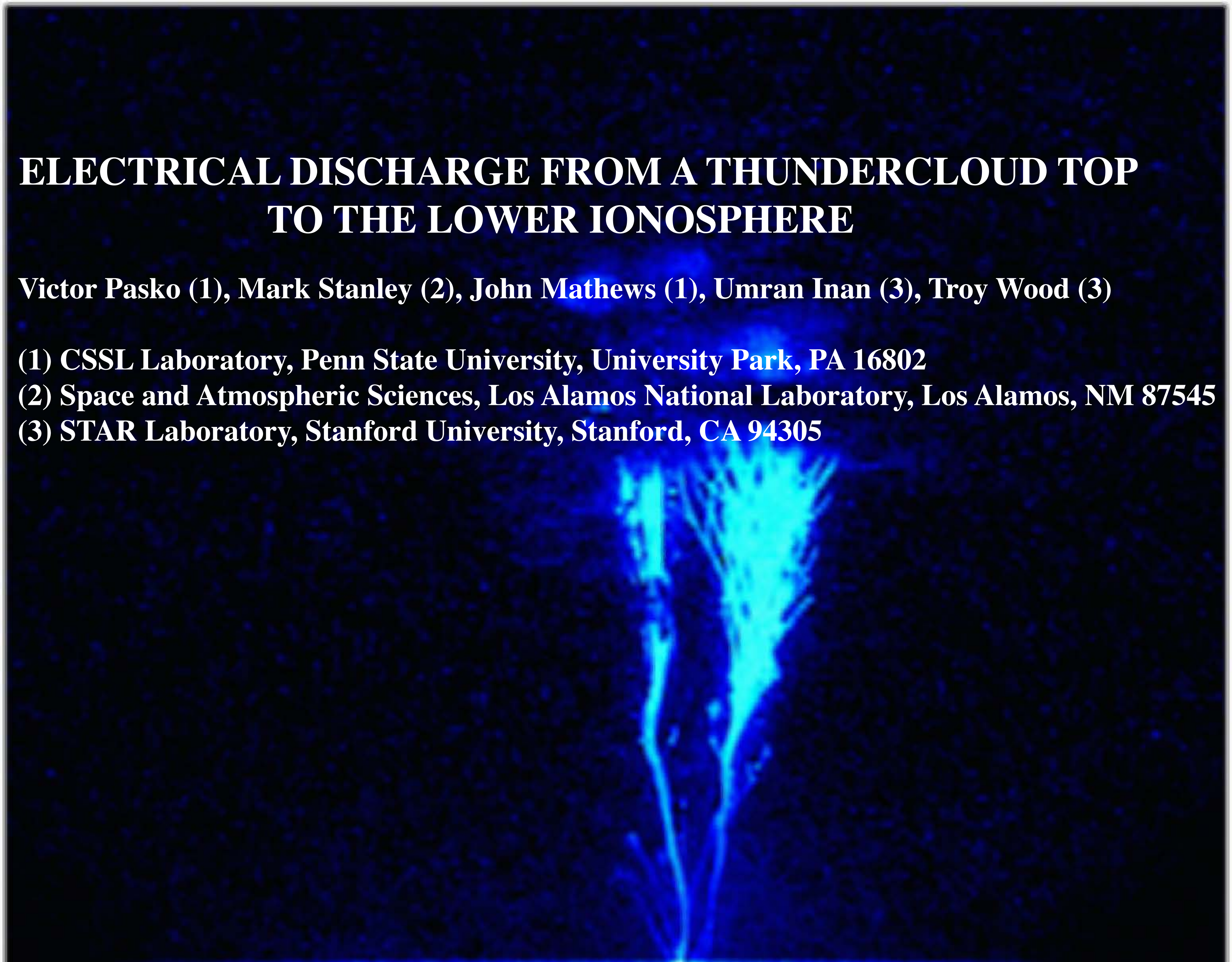

Acknowledgments

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- We thank W. Lyons and W. Boek for providing video materials for this presentation

Plan of presentation:

1. Introduction

2. Summary of experimentally observed features of sprites

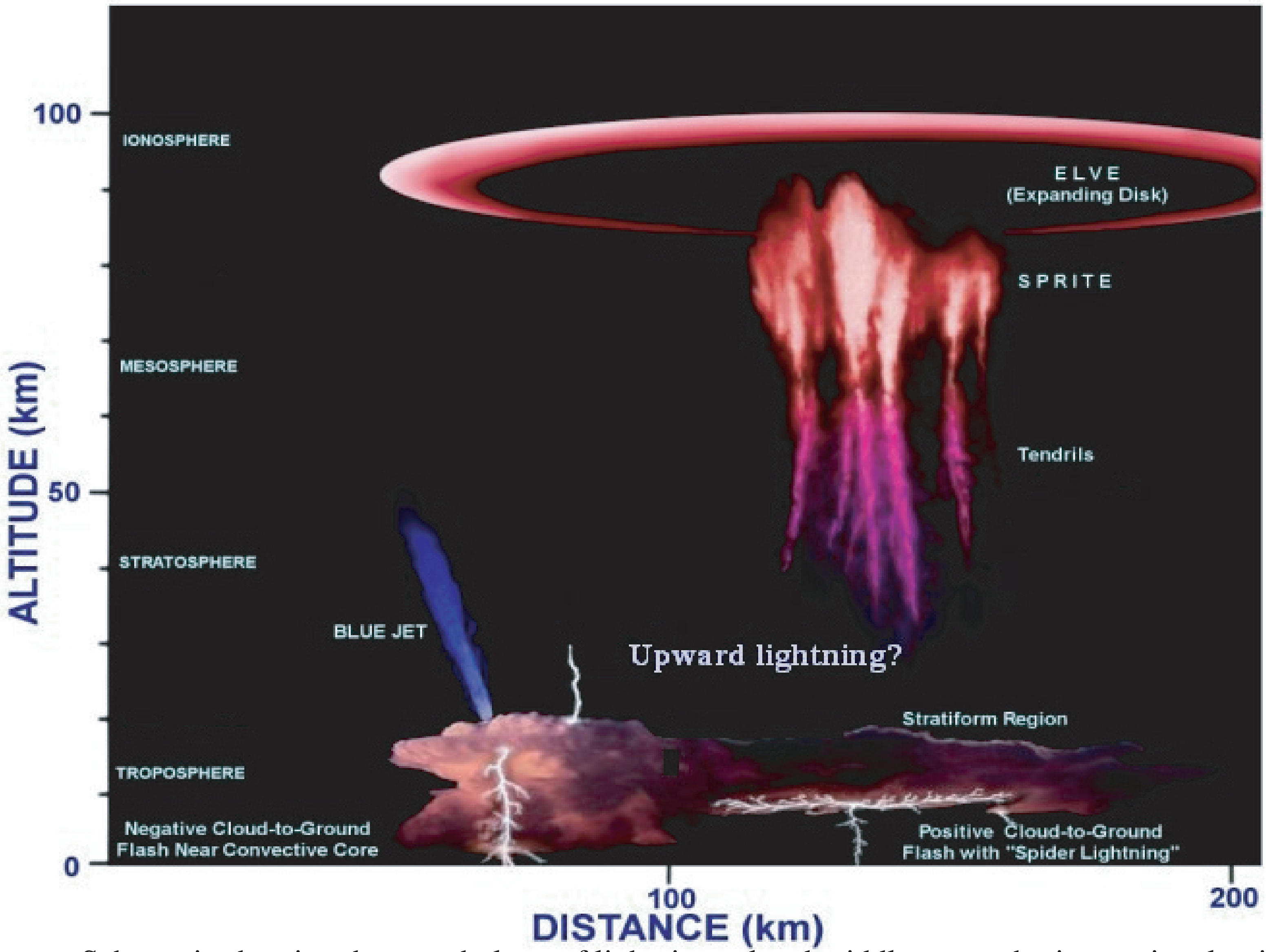
3. Summary of experimentally observed features of blue jets

4. Electrical discharge from a thundercloud top to the lower ionosphere

5. Comparison of recent observations of blue jets

6. Conclusions

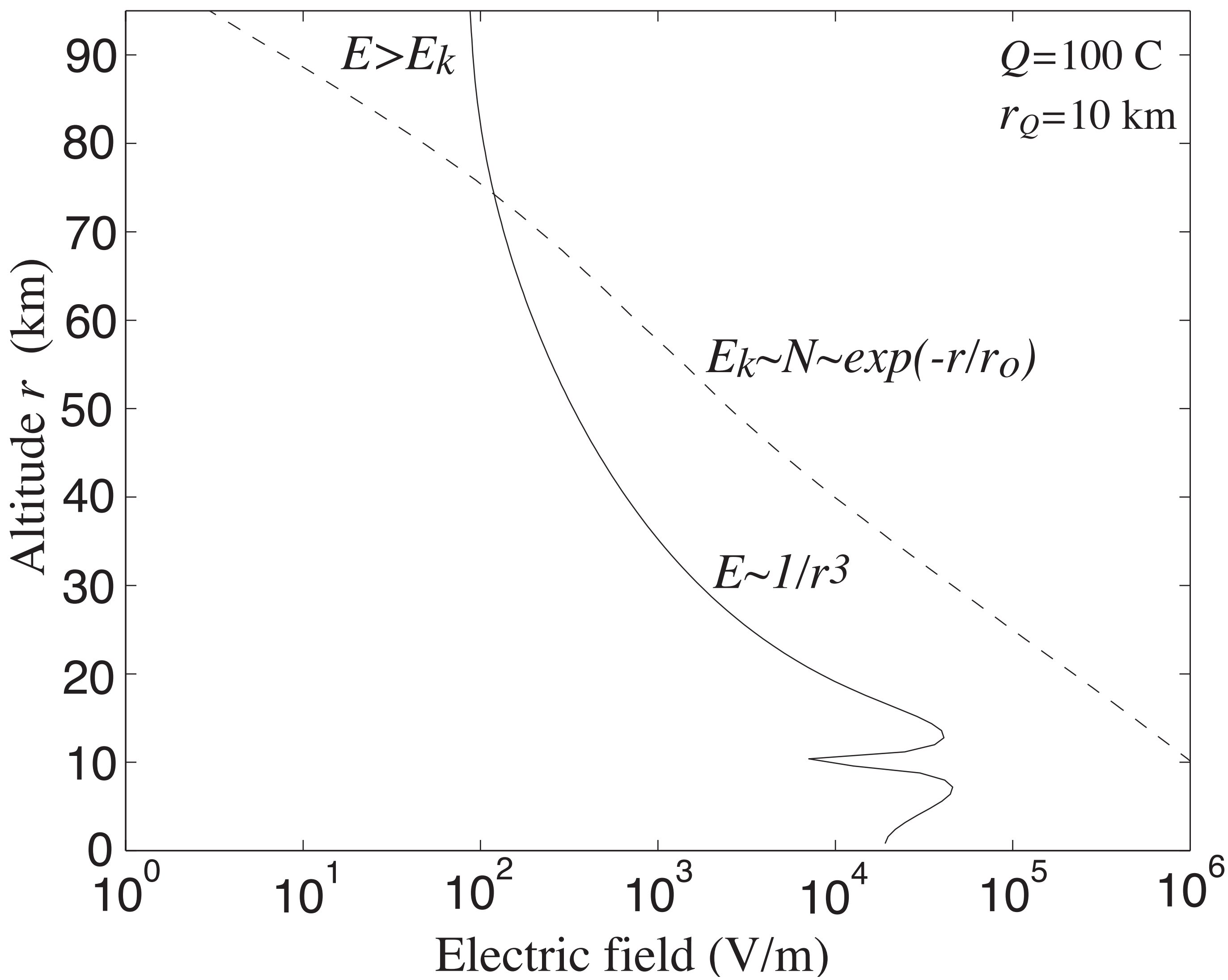
Lightning-related middle atmospheric transient luminous events



Schematic showing the morphology of lightning-related middle atmospheric transient luminous events including red sprites, blue jets and elves. Also indicated is an additional type of discharge from cumulonimbus tops that may be a true “cloud-to-stratosphere” lightning or simply another manifestation of the blue jet phenomenon. Adapted from Lyons et al. (2000)

"While the electric force due to the thundercloud falls off rapidly as r increase, the electric force required to cause sparking (which for a given composition of the air is proportional to its density) falls off still more rapidly. Thus, if the electric moment of a cloud is not too small, there will be a height above which the electric force due to the cloud exceeds the sparking limit."

C.T.R. Wilson, Camb. Phil. Soc., Nov. 24 (1924)



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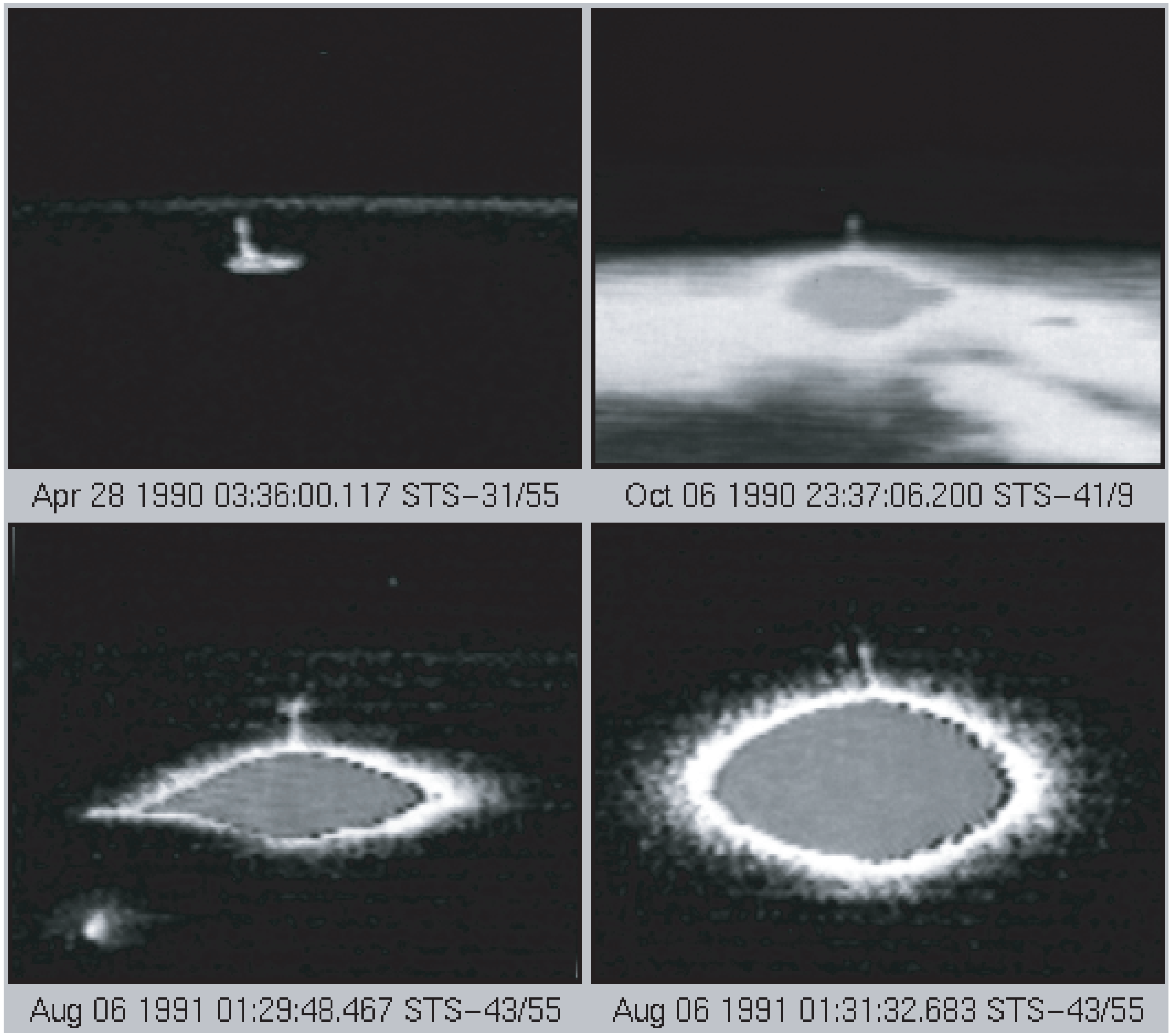
The first TV image of an optical flash above thundersorms [Franz et al., 1990]

The first recorded image of unusual optical flashes occupying large volumes of space above thunderstorms was obtained serendipitously on July 5, 1989 during a test of a low-light-level TV camera at the O'Brien Observatory of the University of Minnesota near Minneapolis.

Observations of optical flashes above thunderstorms from the space shuttle [Boeck et al., 1995]

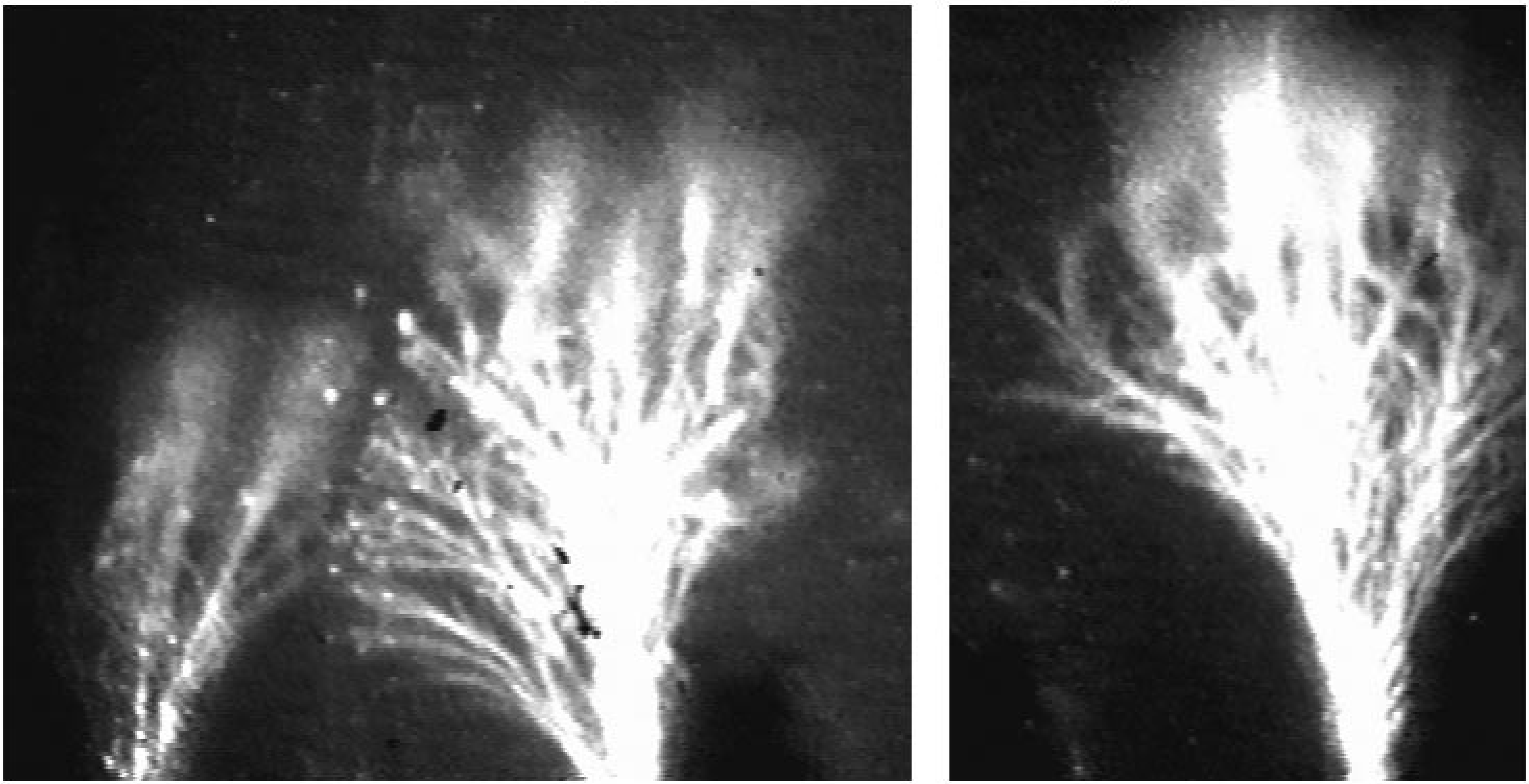


An optical flash observed at 0607 UTC on July 7, 1993 from the ground by Lyons [1994]

The distant storm cloud top heights are estimated to be between 10 and 15 km altitude. If so, the uppermost extent of the structures would be from 50 to 65 km altitudes [Lyons, 1994].

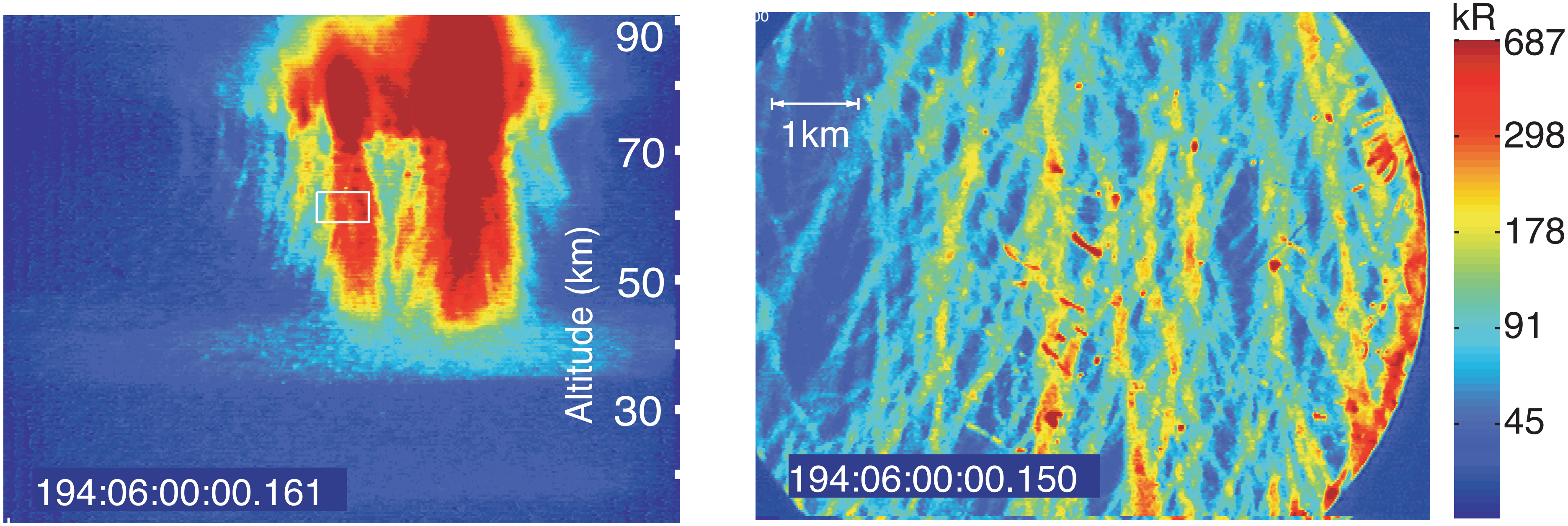
A sprite event (one of the largest) recorded on color video on 4 July 1994 at 0400:20 UT [Sentman et al., 1995]

Images of Fine Spatial Structure and Upward-branching in Sprites (observed from Langmuir Laboratory on July 25, 1996)

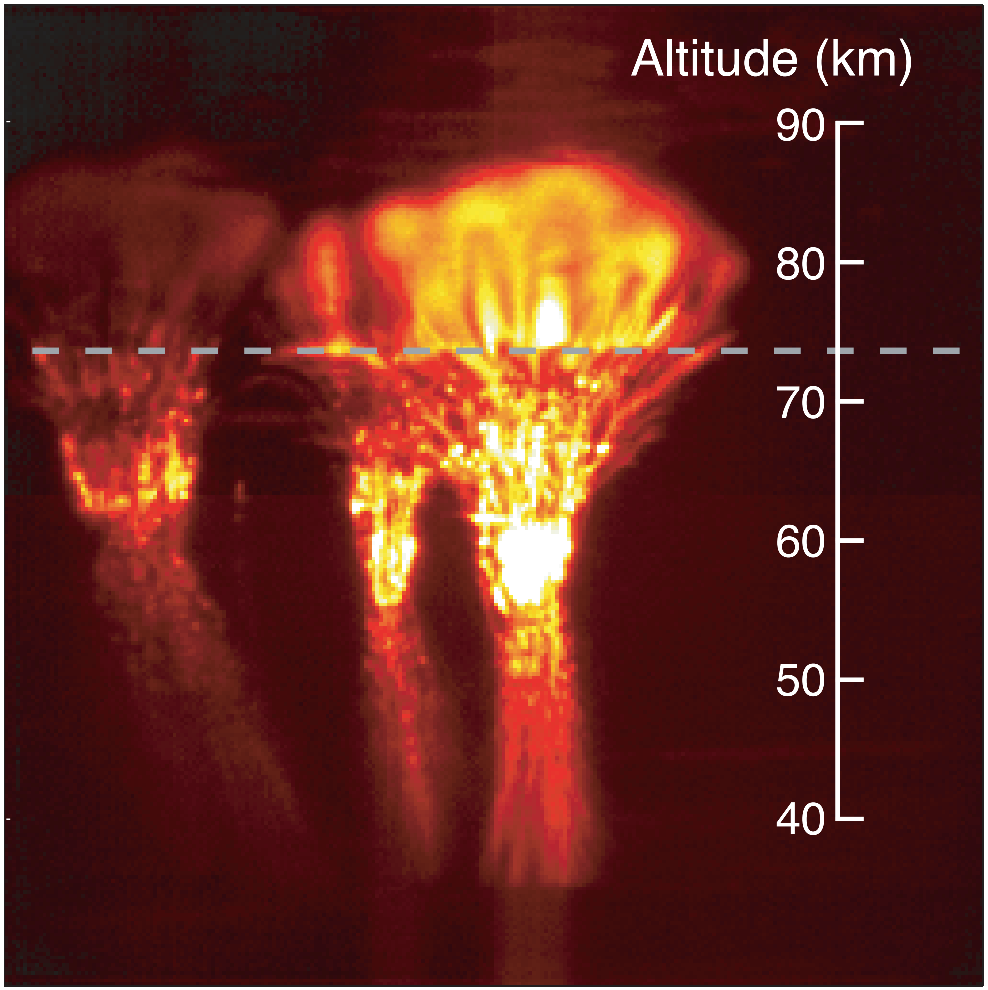


[Stanley et al., Fall AGU 1996]

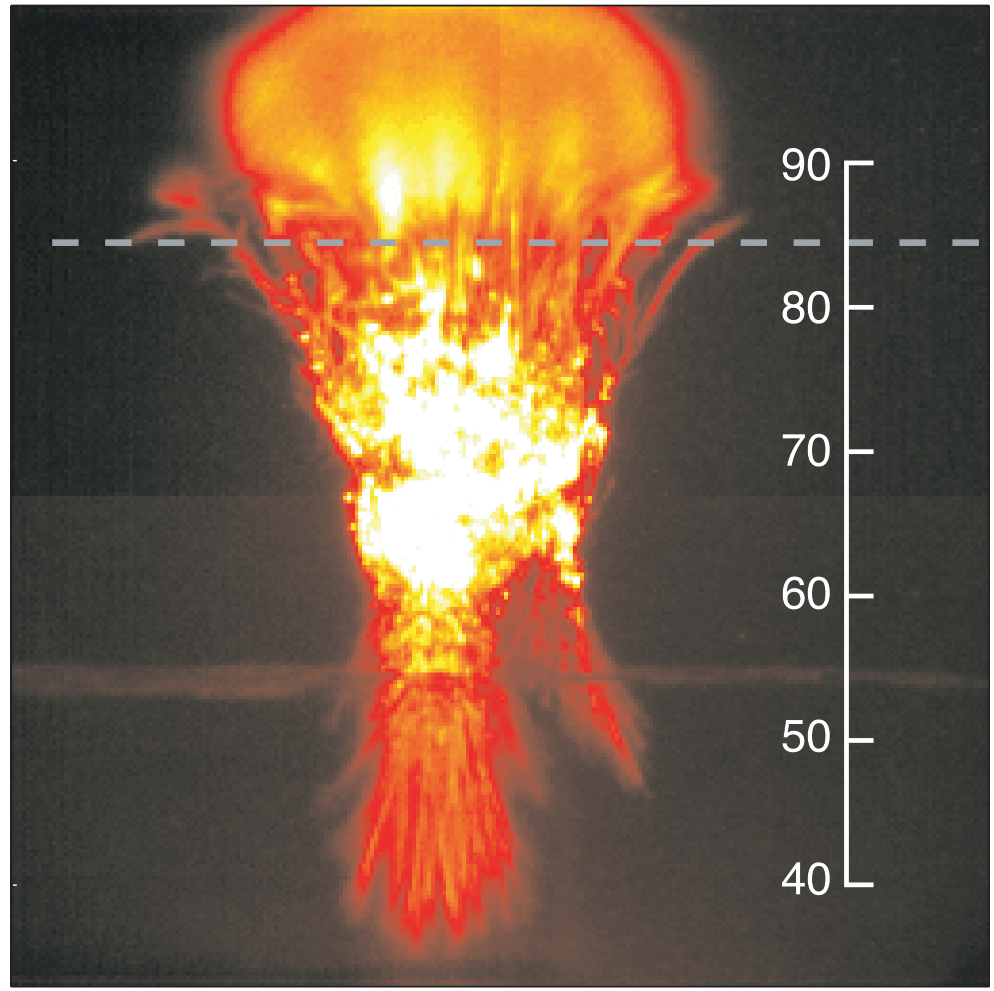
Telescopic imaging of sprites. Wide (left panel) and narrow (right panel) field of view images of a bright sprite event [Gerken et al., 2000].



The images illustrating the altitude transition between diffuse and streamer regions in sprites observed on August 18, 1999 by Stenbaek-Nielsen et al. [2000]



04:36:09.230 UT



05:24:22.804 UT

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One of several upwards discharges (out of about 15) photographed during time exposures above a nocturnal thunderstorm during March, 1968, near Mt. Isa, Queensland, Australia. The discharges were perceived by the naked eye to be long lasting, propagating upward and slowly dissipating over a one to two second interval. Though taken on very slow (ISO 50) film, the original transparencies reveal a flaring blue flame (difficult to see in this reproduction) coming off the upper tip of the white channel, extending again about as high. Image courtesy of Tudor Williams.

Upward discharge captured on film by Australian photographer Peter Jarver. The image was obtained during a time exposure of a lightning illuminated thunderstorm near Darwin during the 1980s. Though difficult to see in reproduction, the original transparency shows an upward flaring blue flame at the tip of the white channel which extends at least as far again upwards. Photograph kindly made available by Earle Williams.

1989

FIRST JET

SPACE SHUTTLE VIDEO

IMAGE INVERTED

A blue jet event [Wescott et al., 1995]

One of the 17 upward propagating discharges arising out of the convective dome of a High Plains supercell storm during a 20 minute period (0612-0633 UTC) on 22 July 2000. The bright spot above the anvil in the middle is a star. Image is provided through the courtesy of Walt Lyons.

A remarkable color photograph of a blue jet taken from Reunion Island in the Indian Ocean (March 1997), which shows details of streamers never before seen [Wescott et al., 2001].

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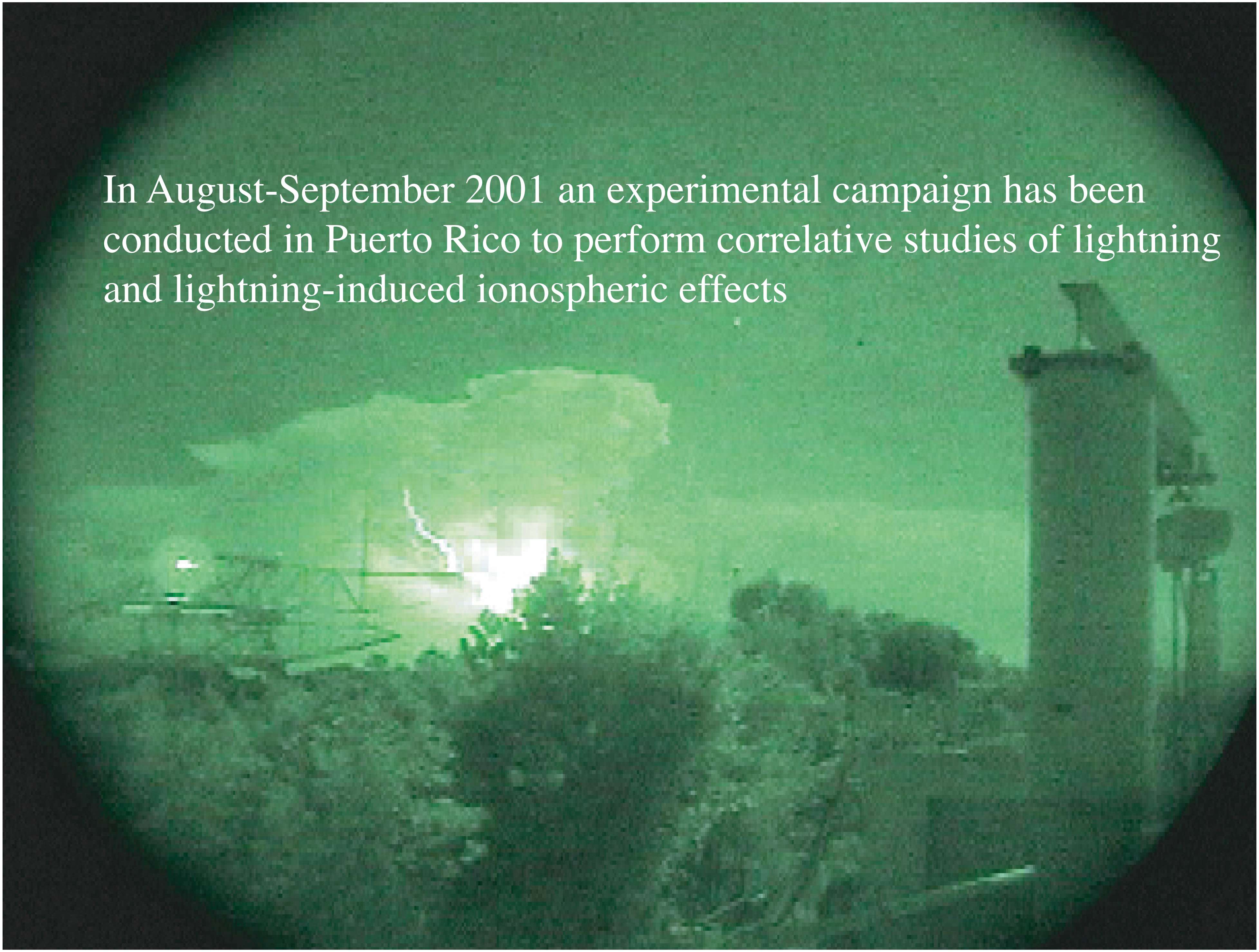

In August-September 2001 an experimental campaign has been conducted in Puerto Rico to perform correlative studies of lightning and lightning-induced ionospheric effects

Participants

- Victor Pasko and John Mathews, CSSL Laboratory, The Pennsylvania State University, University Park, PA

- Mark Stanley, Department of Physics, New Mexico Tech, Socorro, NM

- Umran Inan and Troy Wood, STAR Laboratory, Stanford University, Stanford, CA

- Sixto Gonzalez, Qihou Zhou, Mike Sulzer, Craig Tepley, Arecibo Observatory, Arecibo, PR

Scientific goals

- Studies of ionospheric effects of thunderstorms
- Studies of VHF-quiet positive leaders
- Studies of large scale optical phenomena above ocean thunderstorms in tropics

Instrumentation

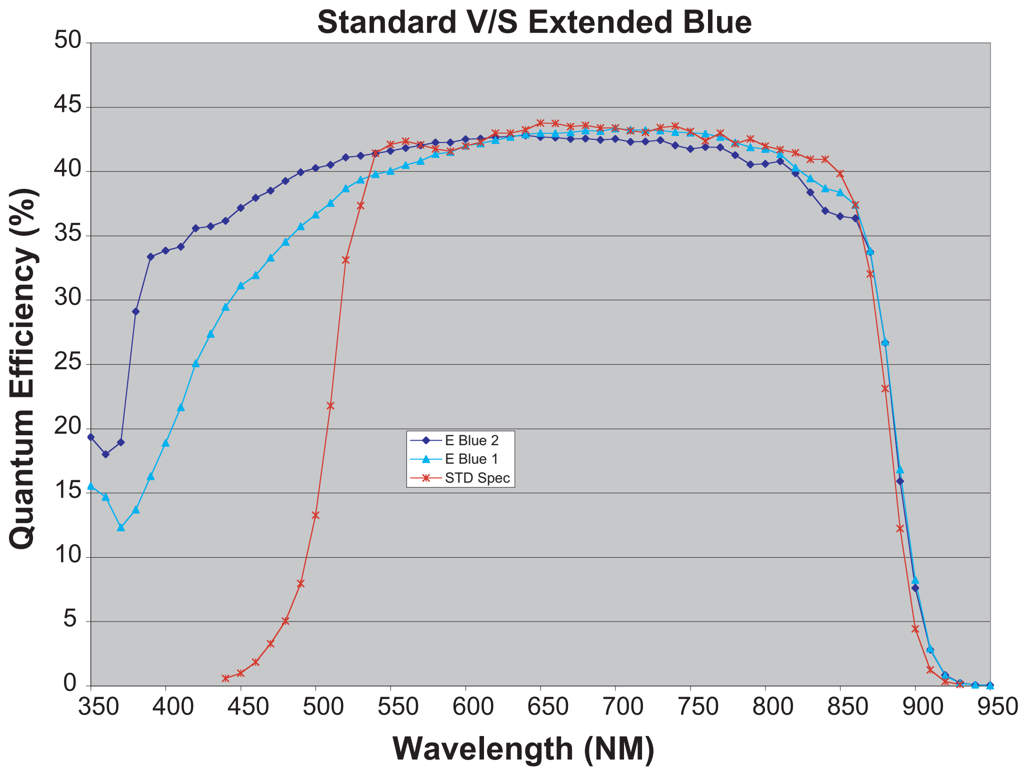
- Arecibo Observatory 430 MHz UHF radar
- VHF radio interferometer and broadband electric field plate antenna of New Mexico Tech
- Broadband and narrowband VLF receivers of Stanford University
- A low light video camera
- GOES 8 weather imagery was continuously acquired and archived

Low-light video system

- SONY DCR TRV 730 CCD video camera equipped with a blue extended ITT Night Vision GEN III NQ 6010 intensifier with a 40^{o} circular field of view was deployed at the Lidar Laboratory of Arecibo Observatory, Puerto Rico (18.347^{o} N, 66.754^{o} W, elevation 305 m above the sea level).

Blue extended GEN III NQ 6010

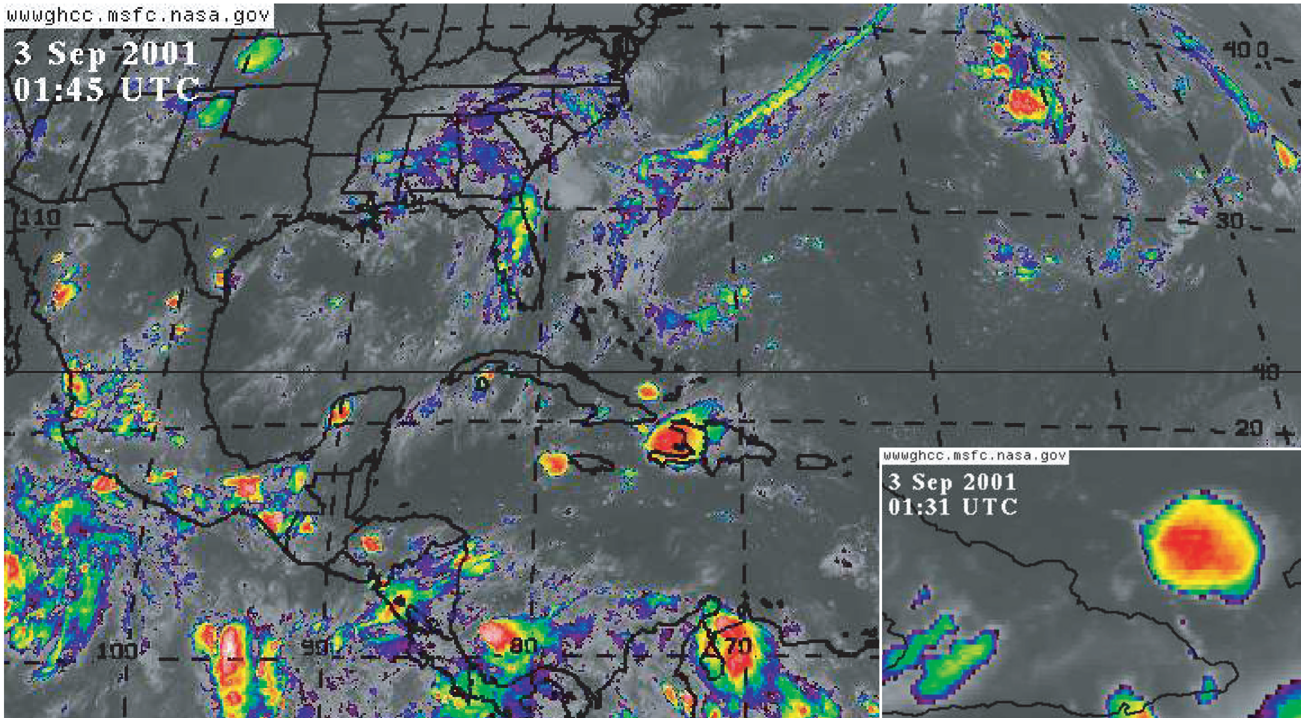
- The operational wavelength region of the intensifier was 390-870 nm at 77% sensitivity and 350-890 nm at 44% sensitivity.

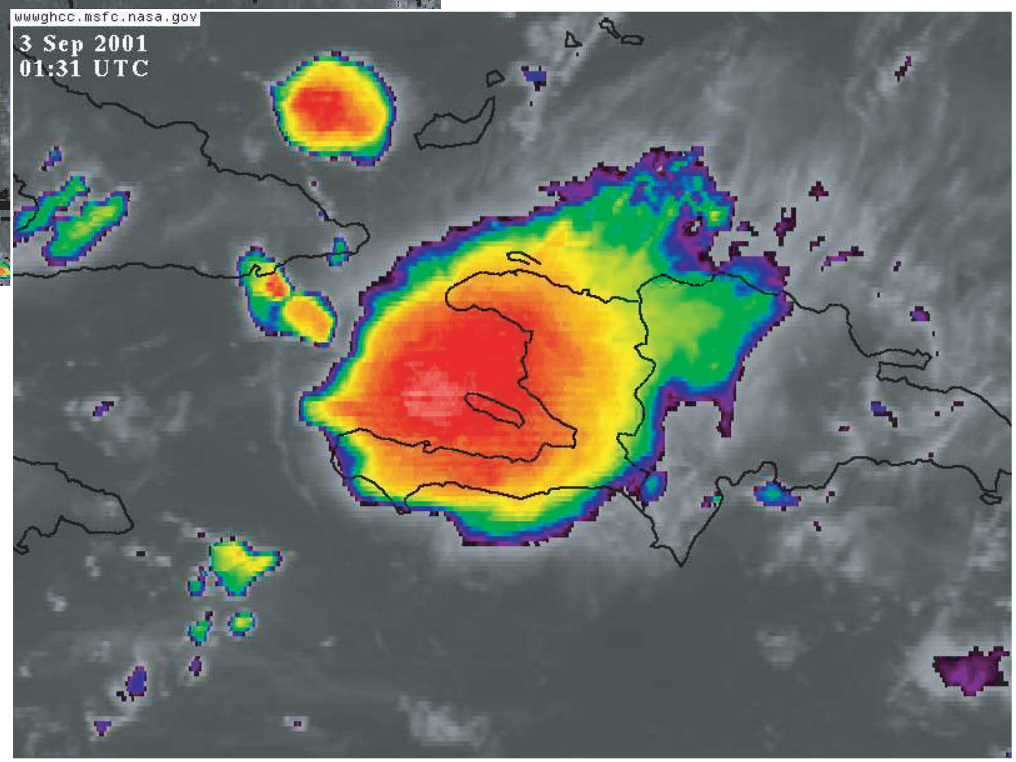


Courtesy of M. Robinson, ITT Night Vision Industries

GOES 8 images

- GOES 8 satellite infrared images acquired on September 3, 2001





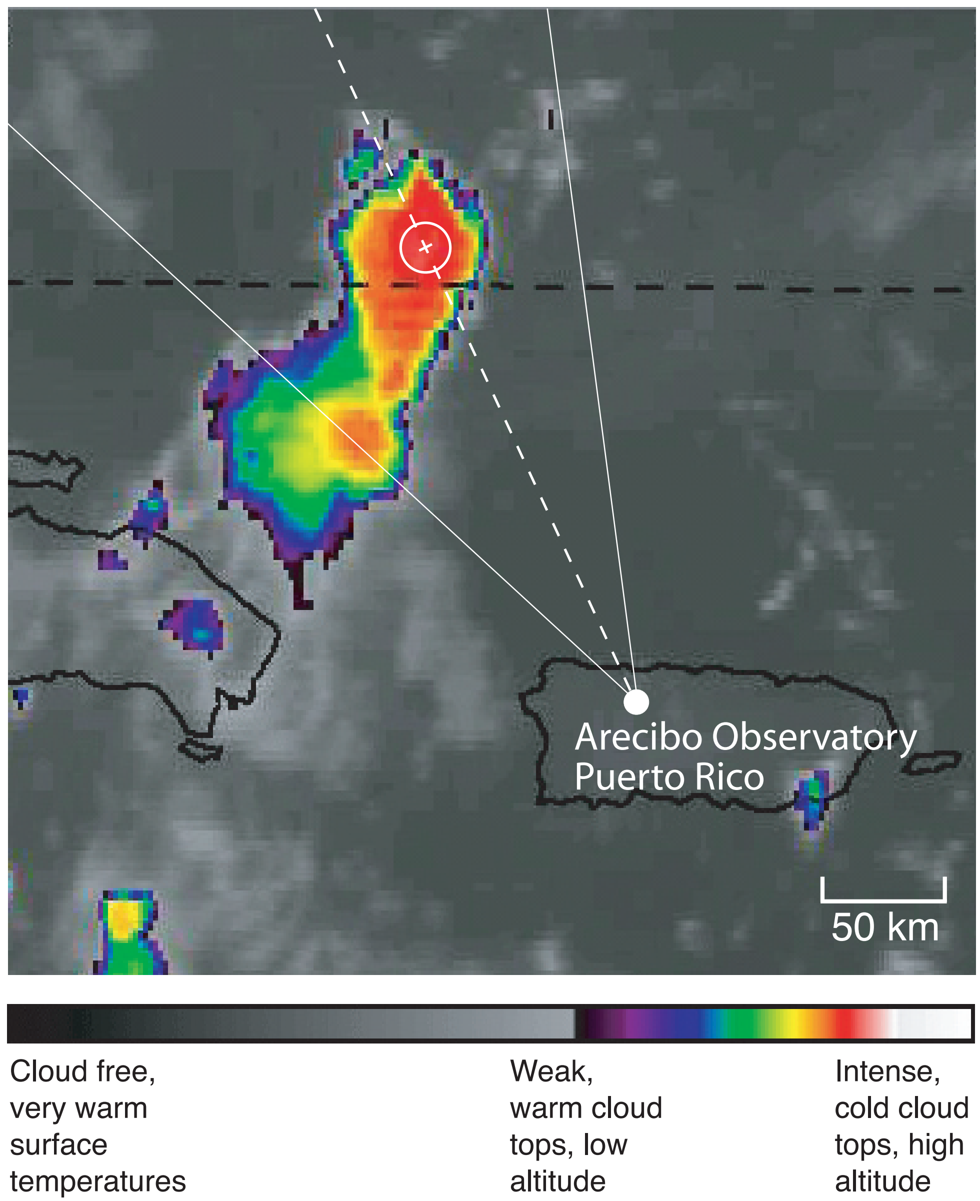

Sprite event observed at 01:10:44.582 UT
on September 3, 2001


Sprite event observed at 02:38:44.722 UT
on September 3, 2001


Sprite event observed at 02:44:14.786UT
on September 3, 2001

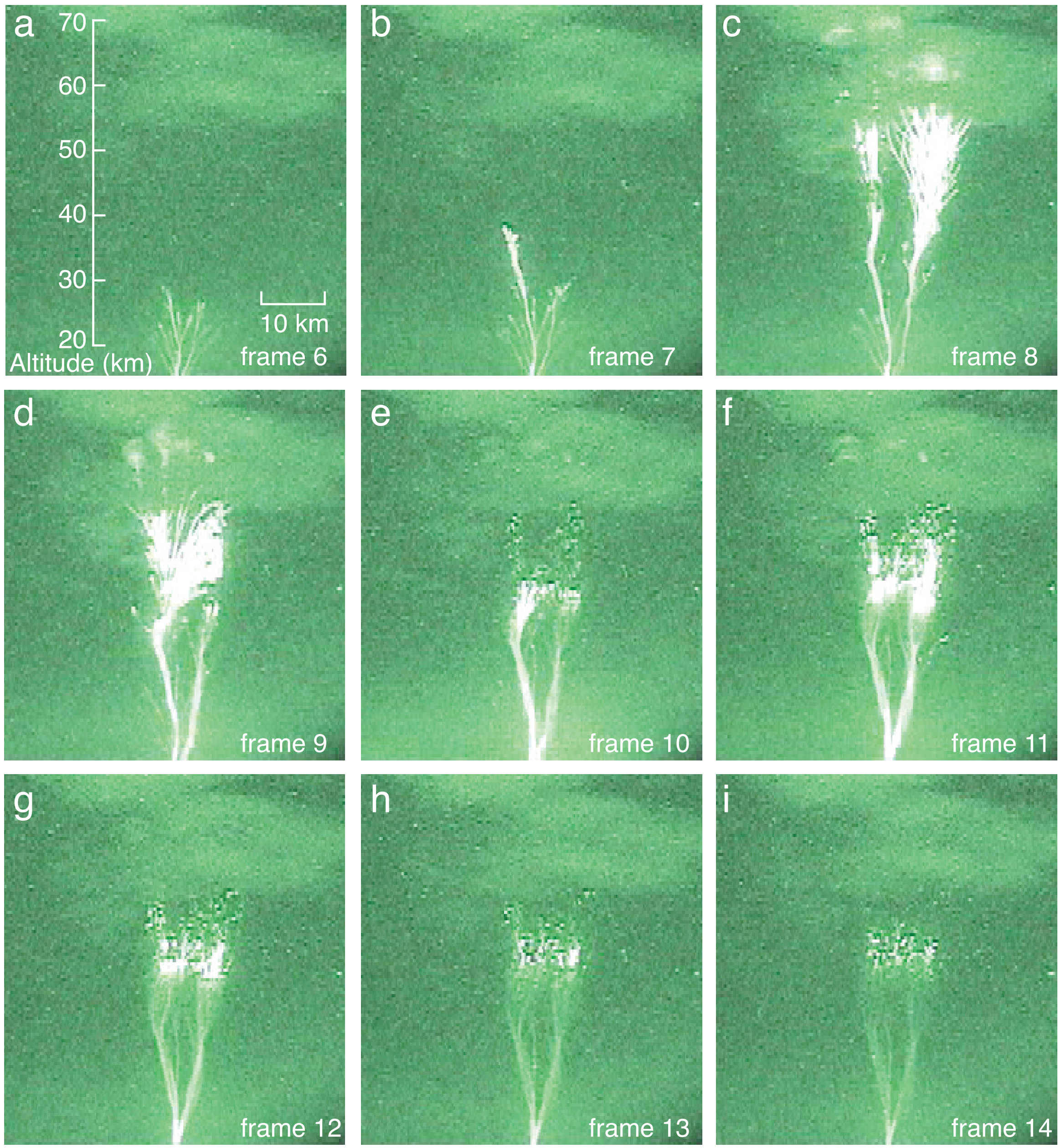
GOES 8 image

- GOES 8 satellite infrared image acquired at 03:15 UT (23:15 Atlantic Standard Time) on September 15, 2001:



Observed phenomena

- The event was observed starting at 03:25:0.782 UT on September 15, 2001 and lasted a total of 24 video frames

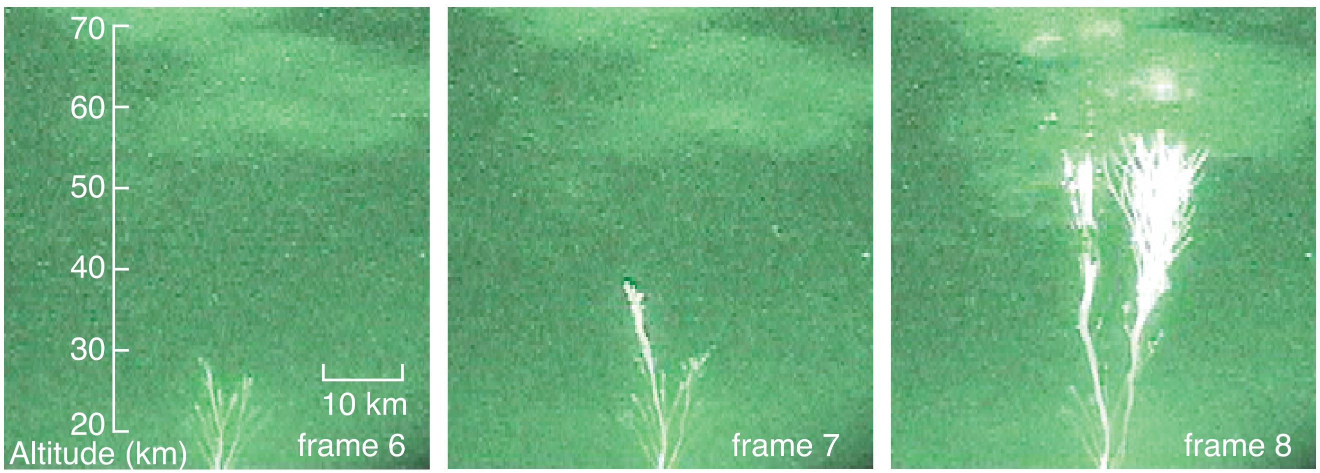


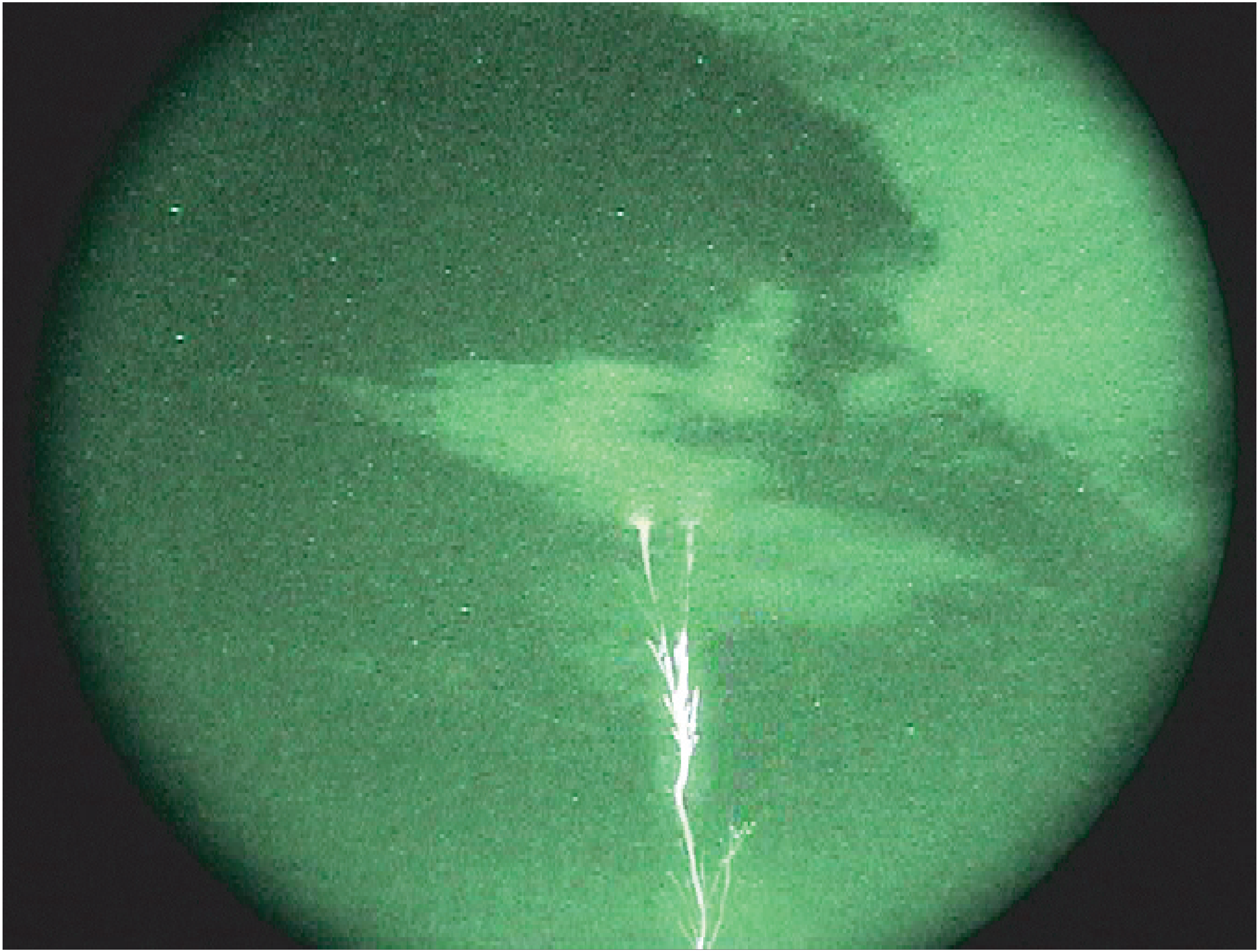
Characteristics of the phenomena

- The apparent speed of upward propagation of the observed phenomena remained remarkably stable at the level 50 km/s during the first five frames, increased to 160 km/s between frames 5 and 6, to 270 km/s between frames 6 and 7, and >~2000 km/s between frames 7 and 8.

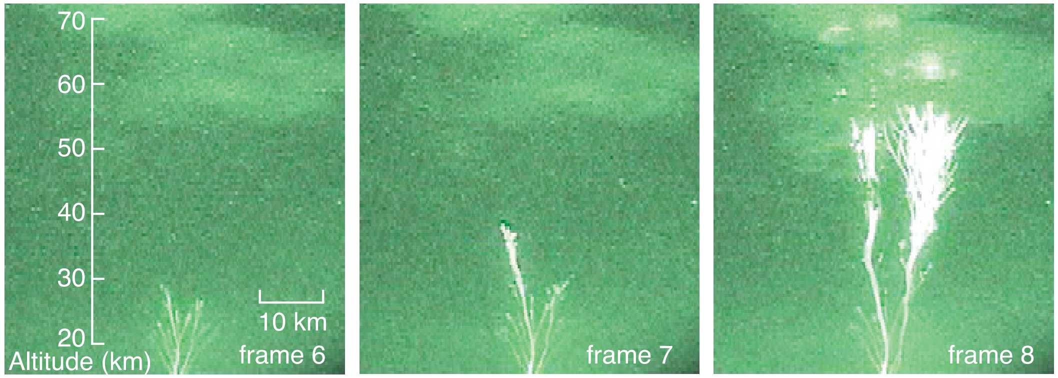
- The upward branches of the reported phenomena exhibit a diffuse termination at an altitude of approximately 70 km in frame 8.

- The apparent diameter of the breakdown filaments in the recorded images is estimated to be 1.26 km (+-0.26 km), similar to estimated diameters of stars recorded in the same images.





Summary of results



- We report the first video recording of a direct electrical discharge between a thundercloud and the lower ledge of the Earth's ionosphere

- The video was obtained during nighttime observations on September 15, 2001 using a blue-sensitive, low-light video system operated at Arecibo Observatory, Puerto Rico

- The lower part of the observed phenomena exhibits several of the known features of blue jets, while its structure and behavior in the upper part closely resembles features often observed in sprites

- Reported results represent the first video observation of blue jet phenomena from the ground and provide the most detailed evidence presented to date of theoretically predicted internal streamer structure of blue jets

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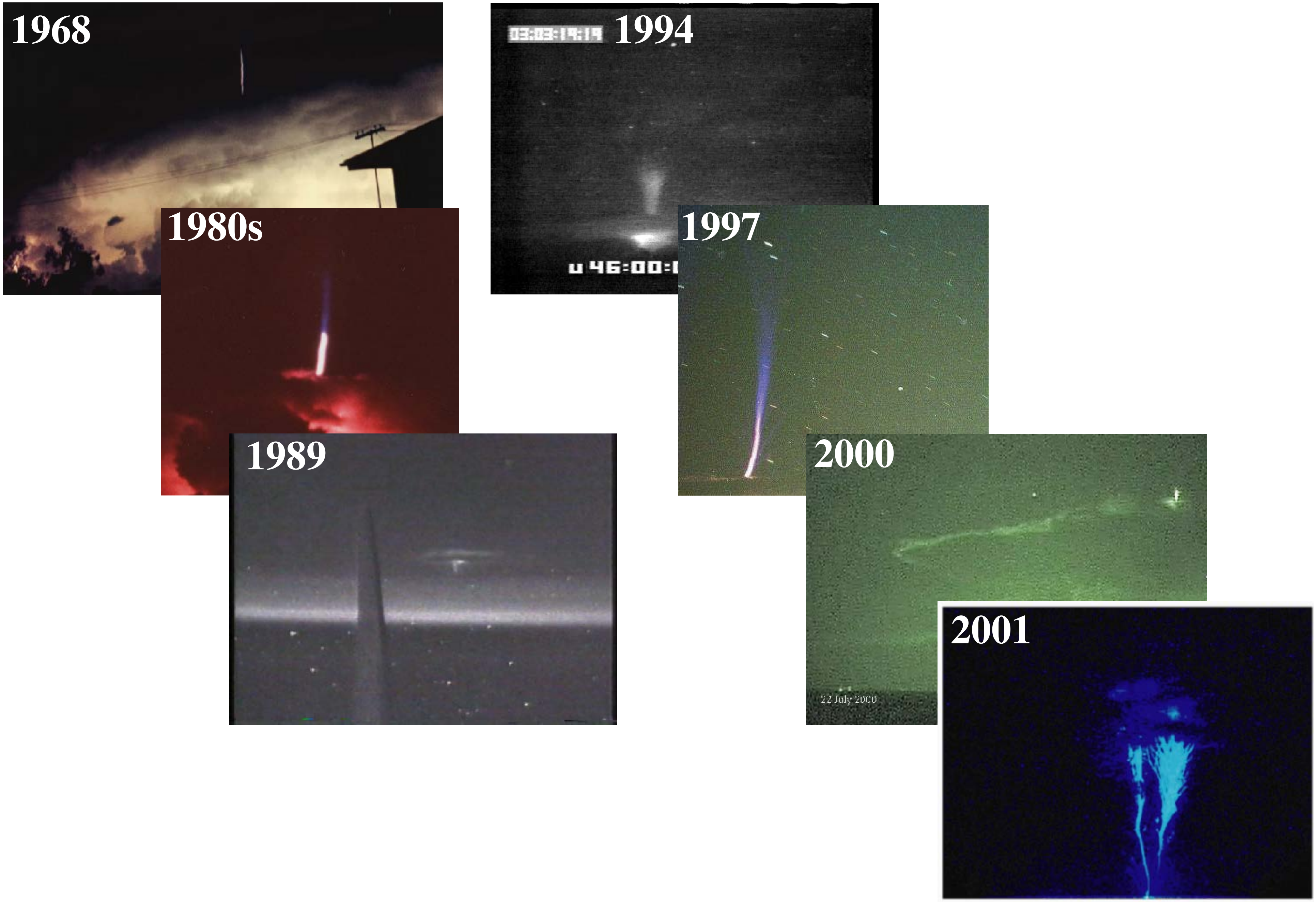
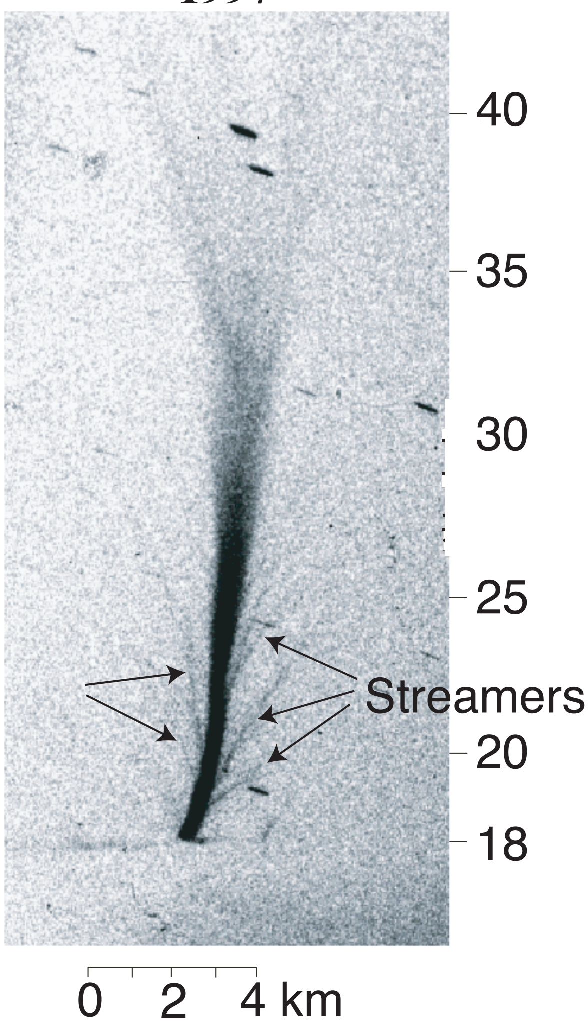
Summary of blue jet observations



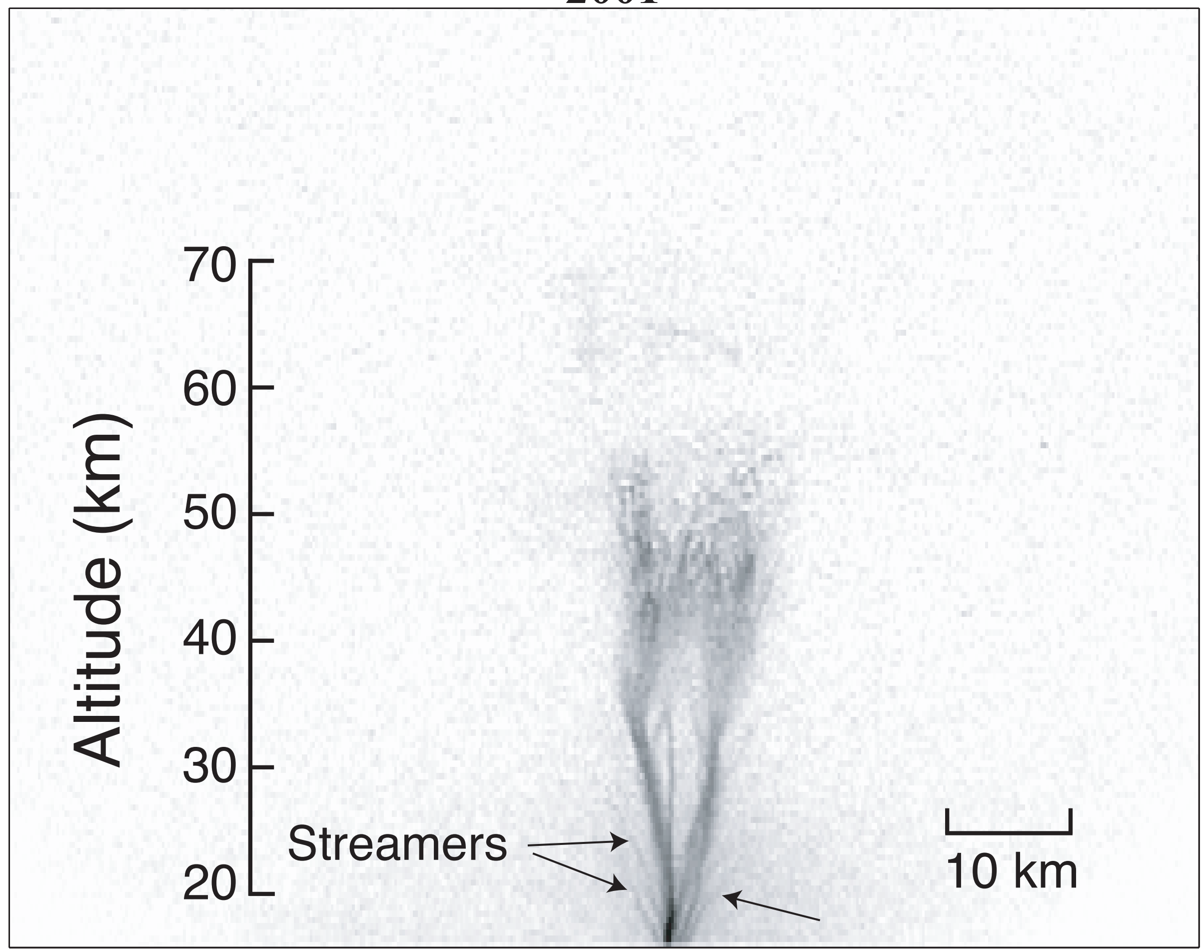
Comparison of recent observations of blue jets

1997



A black and white image of a 2-min time exposure of a blue jet. The image is provided through the courtesy of Gene Wescott, University of Alaska [Wescott et al., 2001].

2001



Processed image obtained by averaging the sequence of video fields from [Pasko et al., 2002].

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Supplementary information is available at http://pasko.ee.psu.edu/Nature/