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Optical Lightning Detector optimized for Jovian lightning flashes

Scientific importance and observational strategy

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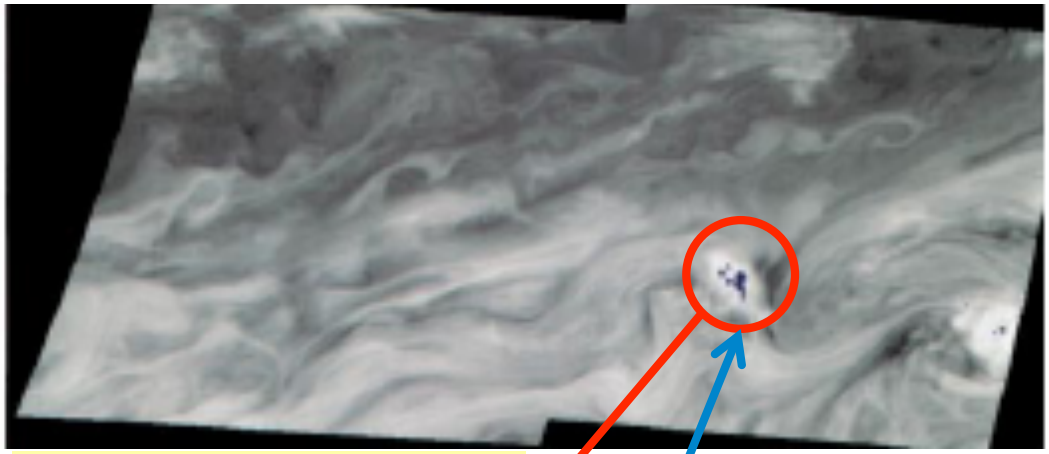
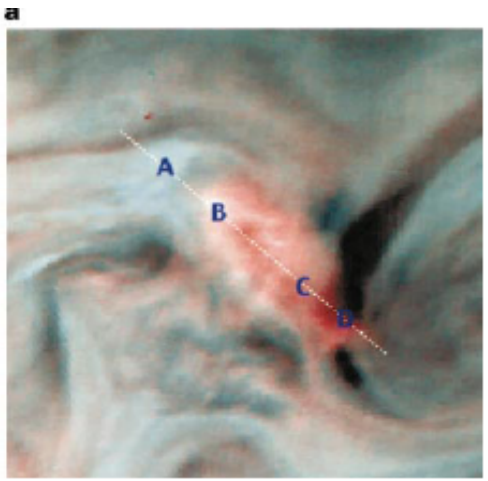
Strong convective clouds = thunderclouds exist in Jupiter

Only planet in which optical lightning flash is detected.

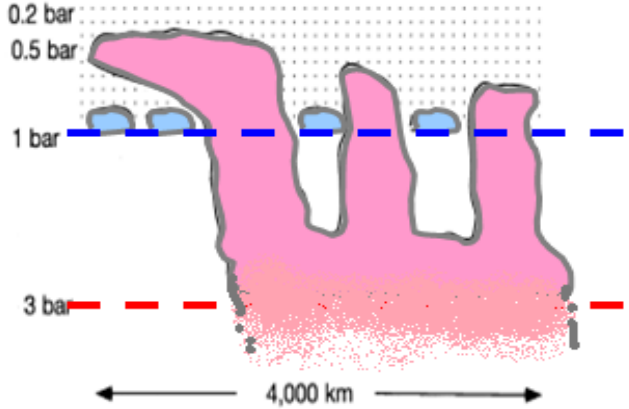


Number of observed storms is rather small.



Correspondence with lightning flashes (blue dots)

Depth of flashes remains unknown.



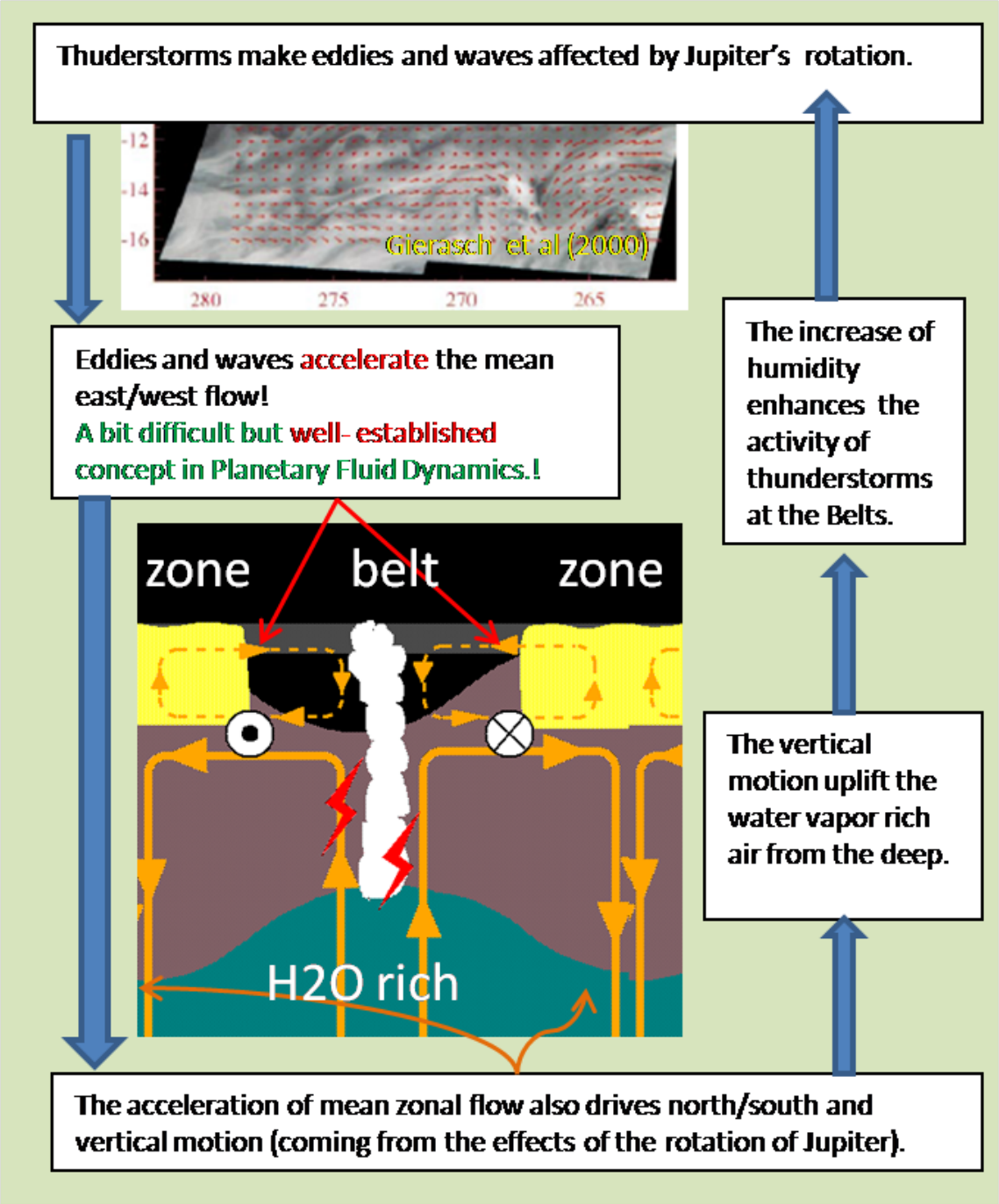
Cloudbase remains unconstrained

Observation from Galileo Orbiter (e.g., Gierasch et al, 2000)

Convective clouds is the key to solve the mechanism for “belt-zone” structure

Discovery of lightning flash **<u>in belt</u>** impacted studies on atmospheric structure.

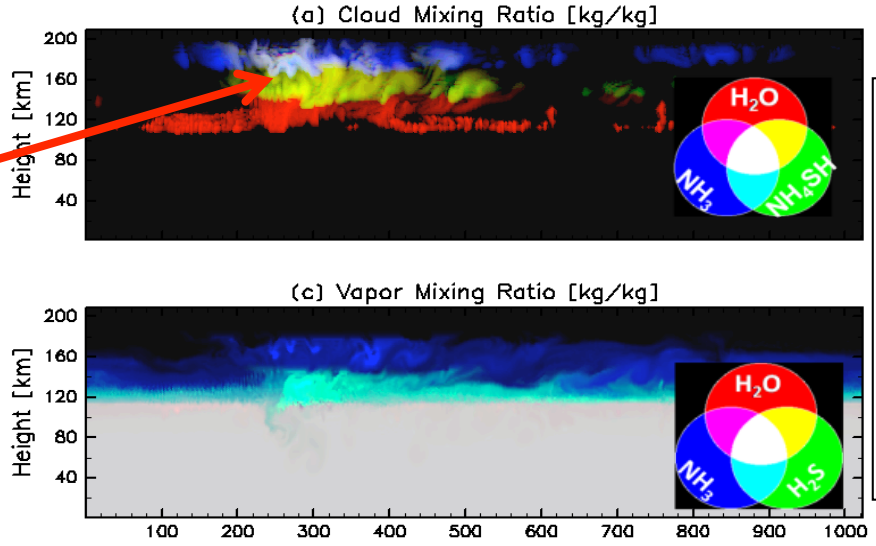
The interaction between the east/west jets and thunderstorms is essential to the belt/zone structure?
e.g. Ingersoll et al (2000), Lian and Showman (2008)



Moist convection as a probe to examine deep atmosphere composition

The latest numerical modelings (e.g., Sugiyama et al., 2008) predict fully new pictures … very much different from the classical ones:

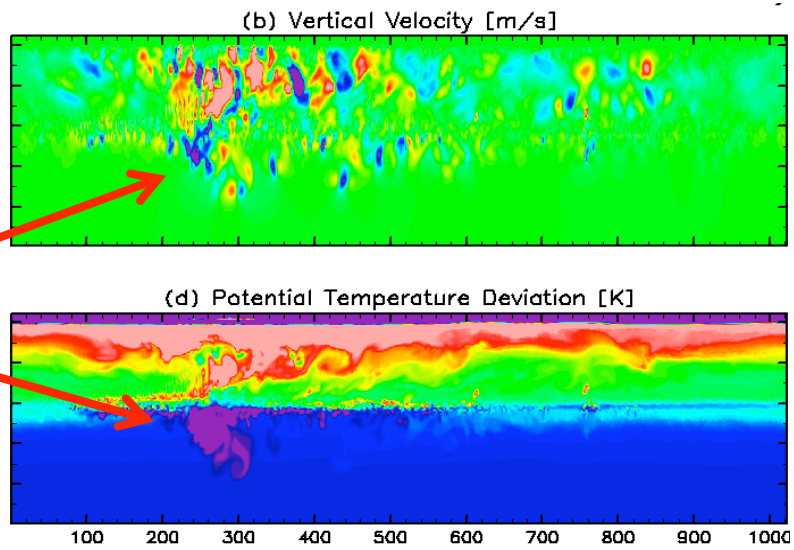
Updraft carries water cloud, produced at ~5bar, to tropopause (1bar).



All three kinds of clouds, and all three kinds of condensates are included with thermodynamics and cloud microphysics.

km

Cool "downburst" driven by the evaporation of rain water



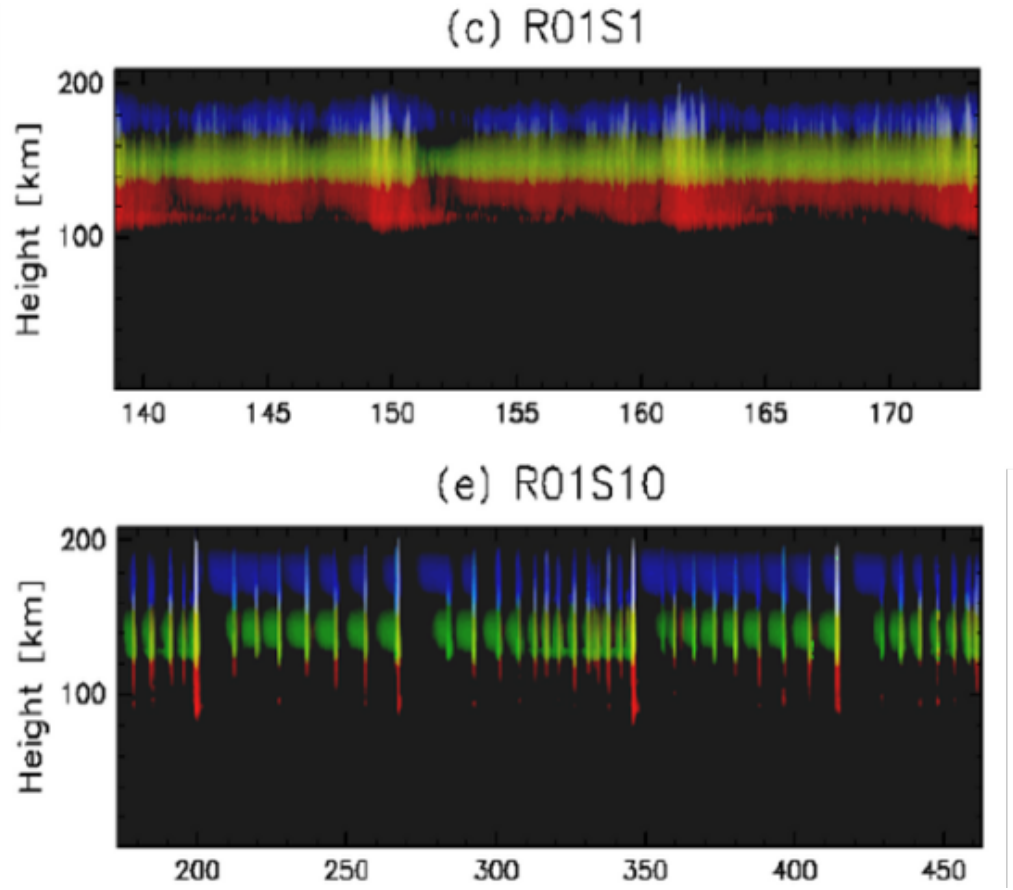
Vigorous dynamical processes both in cloud and below cloud base are simulated.

km

Predicted time evolution of cloud amount

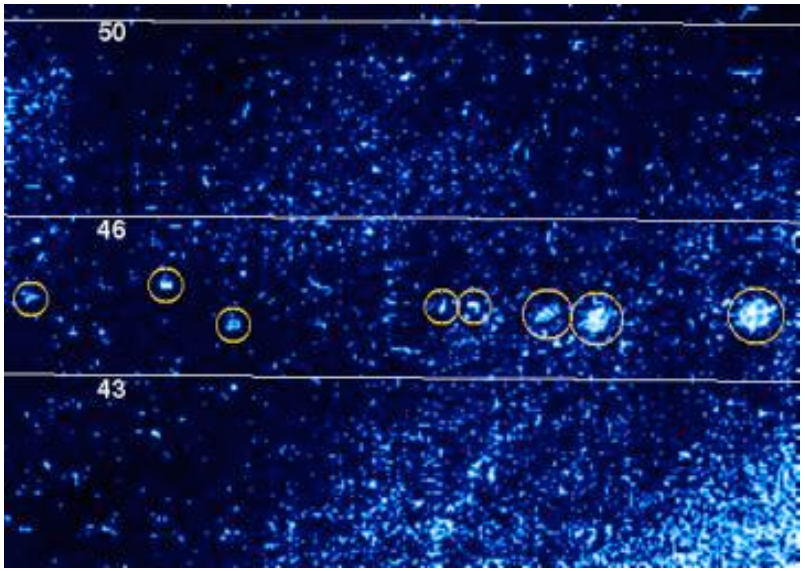
- Cloud activity exhibits distinct active/break cycle.

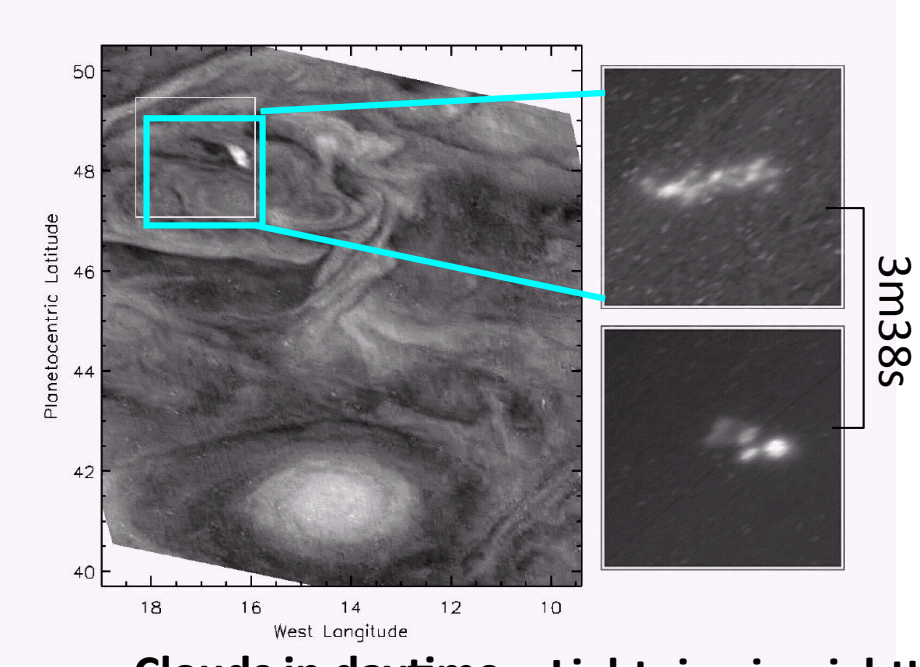
-The time interval between active periods is roughly proportional to the abundance of condensible gasses in deep atmosphere!



Thundercloud could be a new “probe” of deep atmospheric composition.

Lightning observation is new and promising direction





Clouds in daytime **Lightning in nighttime**

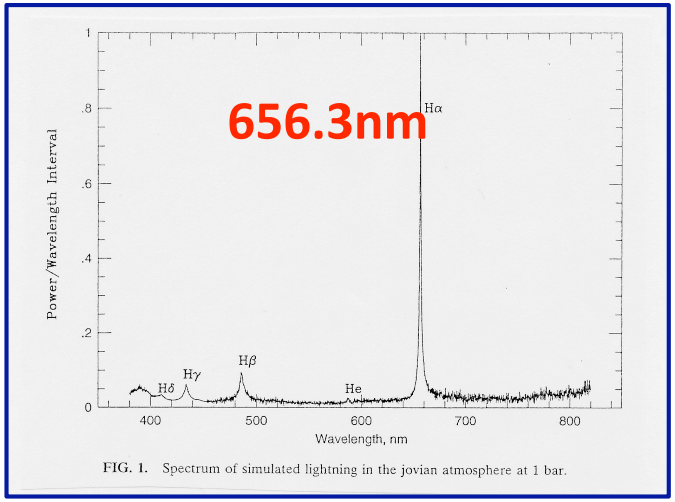
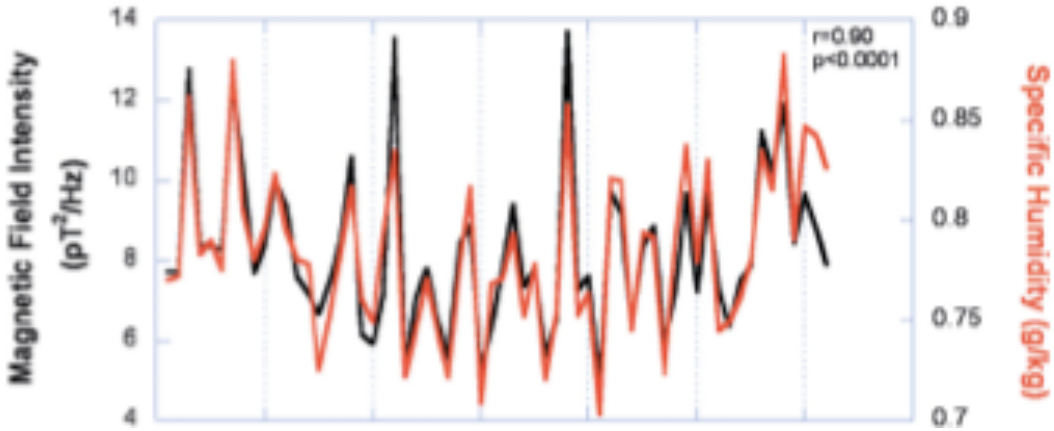


FIG. 1. Spectrum of simulated lightning in the jovian atmosphere at 1 bar.

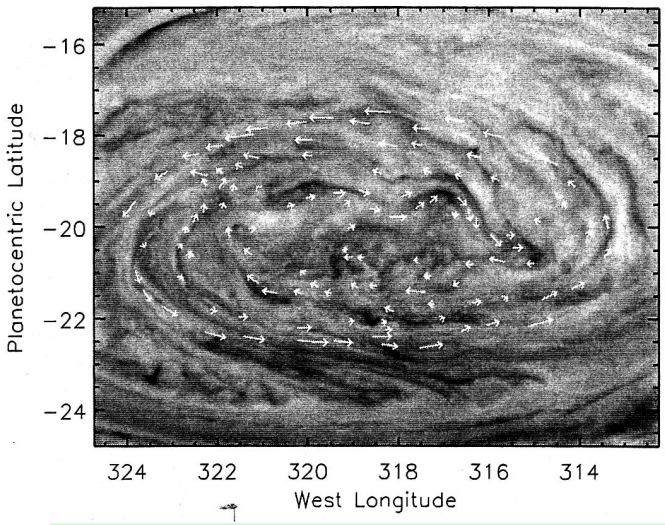
Expected spectrum of Jovian lightning



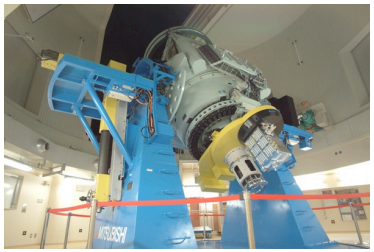
Lightning is an excellent proxy of atmospheric circulation **in the Earth**

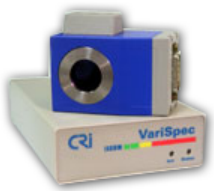
JGO is the ideal vehicle

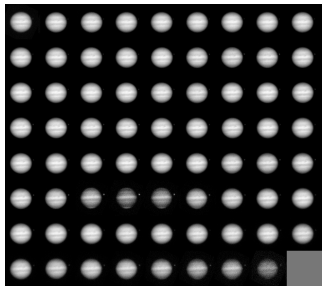
Simultaneous measurements of atmosphere such as spectral imaging, which determine the horizontal motion of clouds and the altitude of cloud top, are essential to investigate the role of thunderstorm.



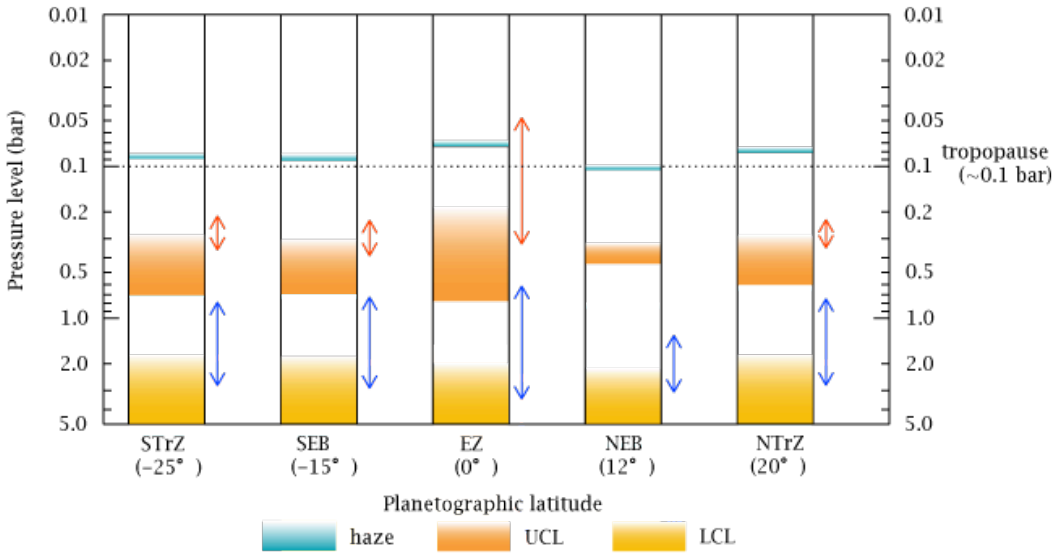
Cloud tracking provides information of wind speed and nature of eddies.







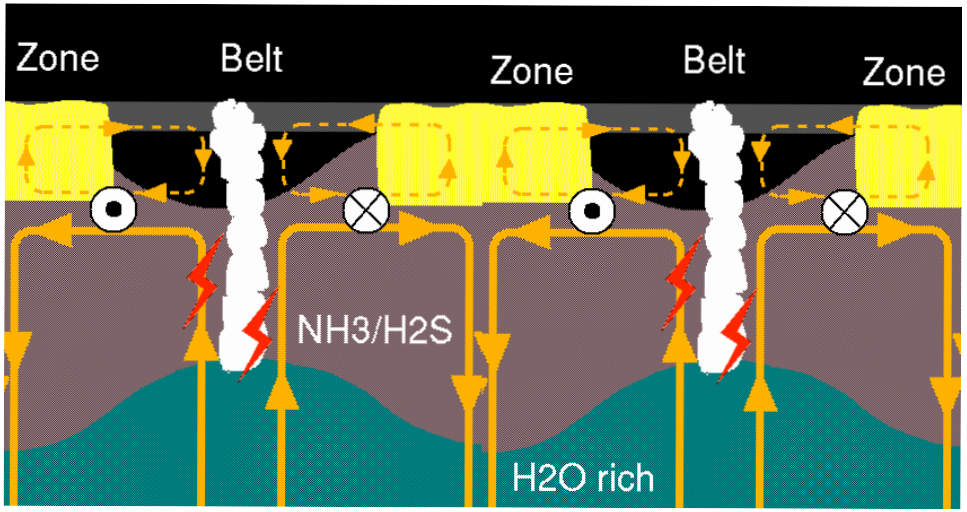
Recent spectral imaging on the ground suggests no significant alt. difference of cloud top between NEB/SEB and NTrZ/STrZ

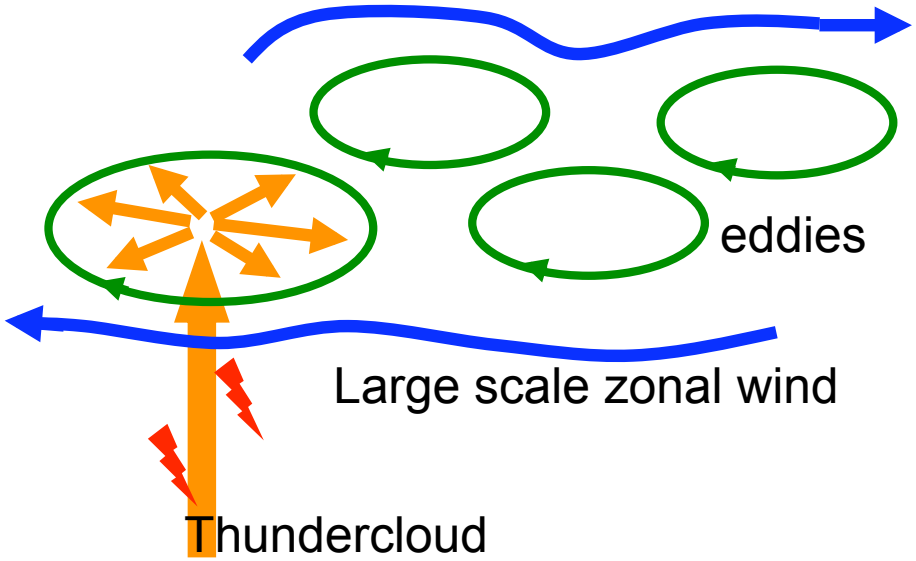


Strategy of thunderstorm study in Jupiter

to validate a possible scenario of momentum transfer by thundercloud, which make large scale structures

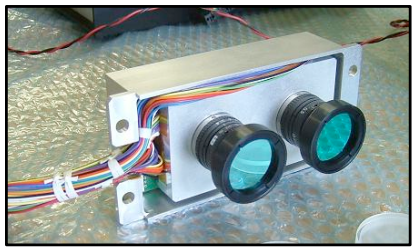
upward wind in thundercloud ➡ small eddies ➡ belt/zone and ovals

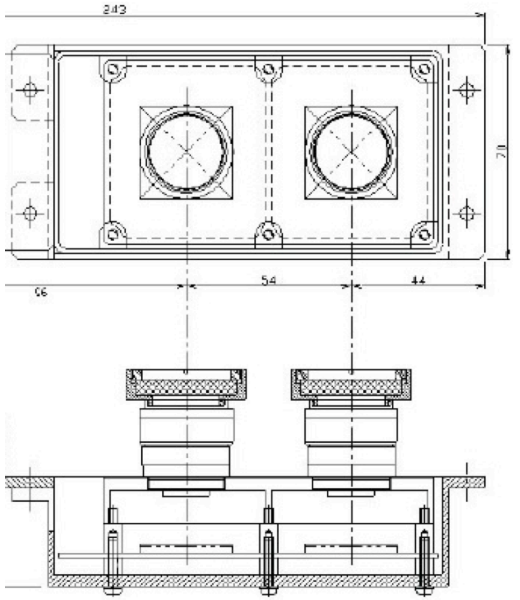




- **Wind velocity** in belt/zone, ovals and eddies… by cloud tracking
- **Cloud top altitudes** of belt/zone and thundercloud … by spectral imaging
- **Lightning activity with depth info.** … by lightning flash detector

Suggested instrumentation for lightning flash detection





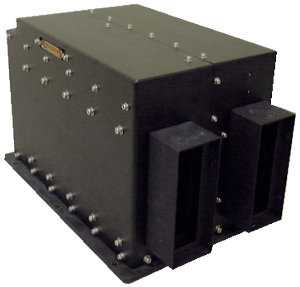
Sensor: CMOS (e.g., STAR250.. up to 10s of MRad)
Filter: H Balmer Alpha line (656.3nm) narrow/wide
Triggering: transient flash detected by FPGA logic
should be optimize for Jovian lightning
Sampling rate:
normal mode: 29ms for full frame (512x512 pixels)
high-speed mode: up to ~0.1ms
for 30x30 pixels by focusing thunderstorm area.
Weight: ~1kg
Size: 16x7x5.5 cm (sensor) and 16x12x4 cm (circuit case)
Power consumption: ~4W
Data: only intensity and pixel location with time …reduced significantly

Those specs. can be modified according to spacecraft resources,
or even can be combined with other imagers.

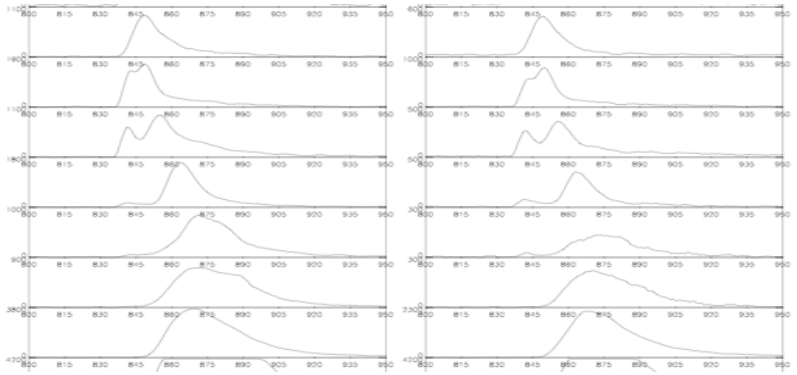
Heritages

plenty of experiences not only in **optical design and handling of sensors**, but also in developing **lightning- triggering logic** both for photometric and imaging measures using FPGA and/or CPU.

Array Photometer / ISUAL onboard
FORMOSAT-2 by Taiwan (2004-)

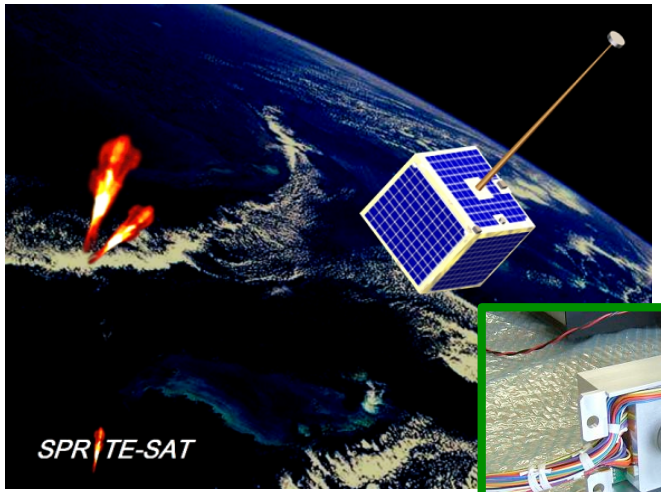


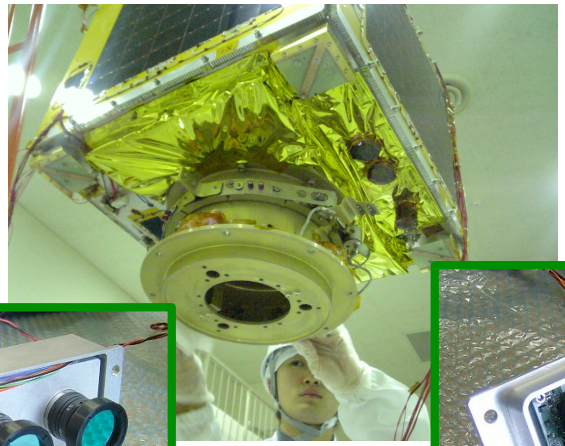
Motion of sprites with high speed sampling

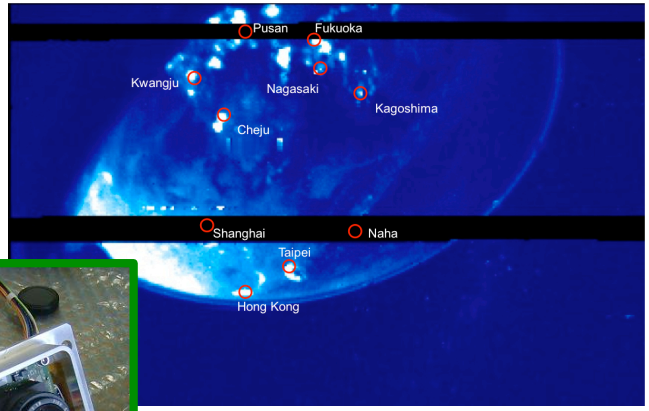


CMOS/CCD cameras onboard
RISING-1 and -2 satellite (2009-)

50-kg University satellite
developed in Tohoku University

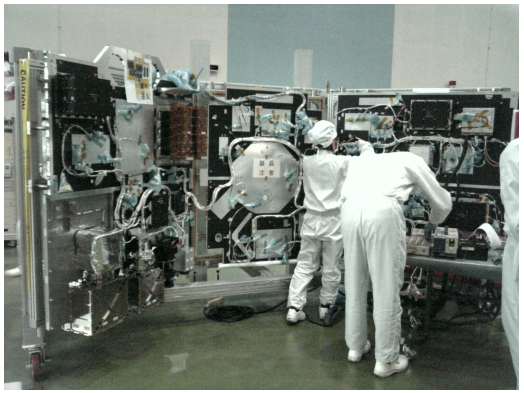


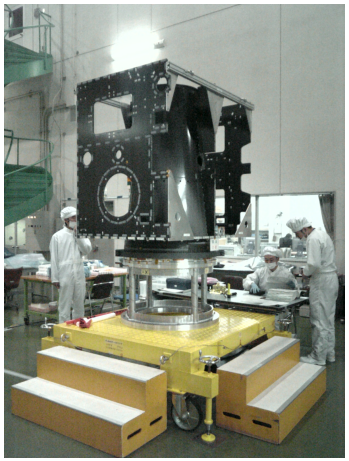


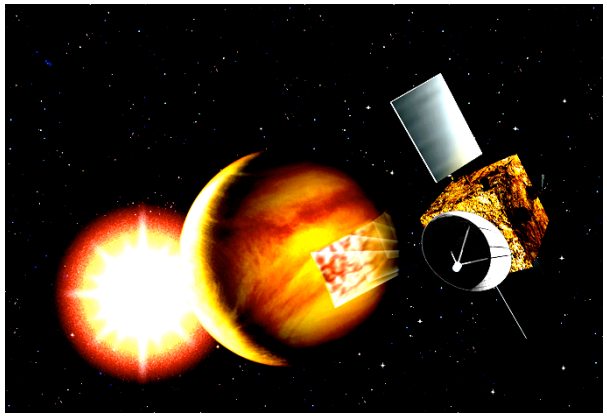


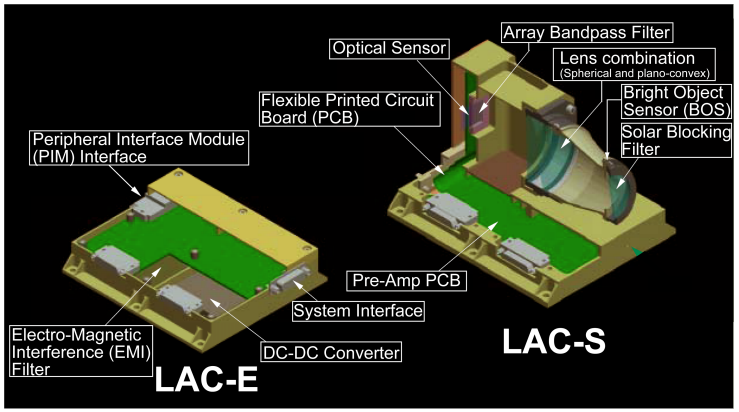
Lightning and Airglow Camera onboard **Planet-C**: Venus Climate Orbiter (2010)

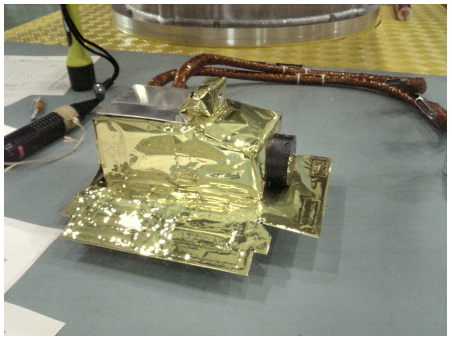
using newly developed APD matrix sensor



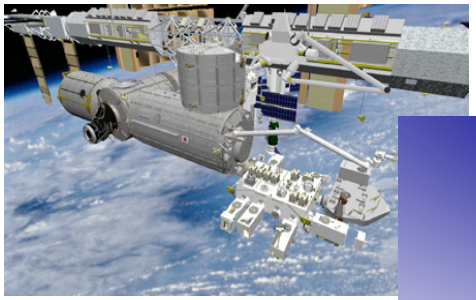


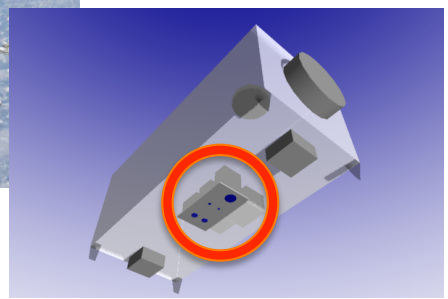




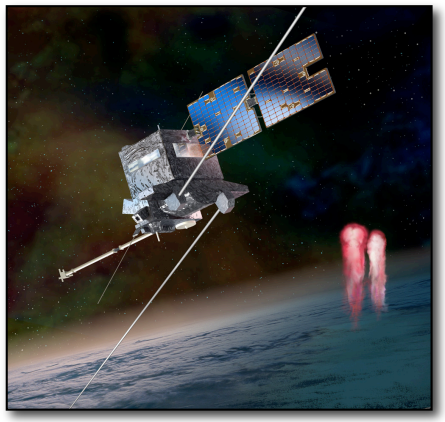


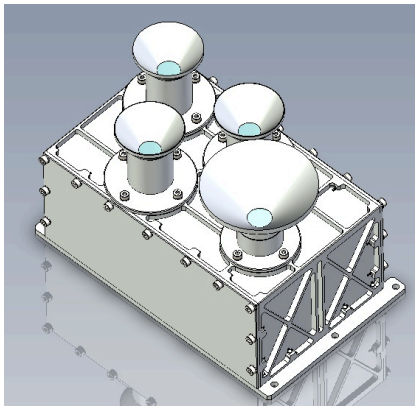
CMOS cameras and Photometers of **GLIMS** onboard **JEM/ISS** (2012)





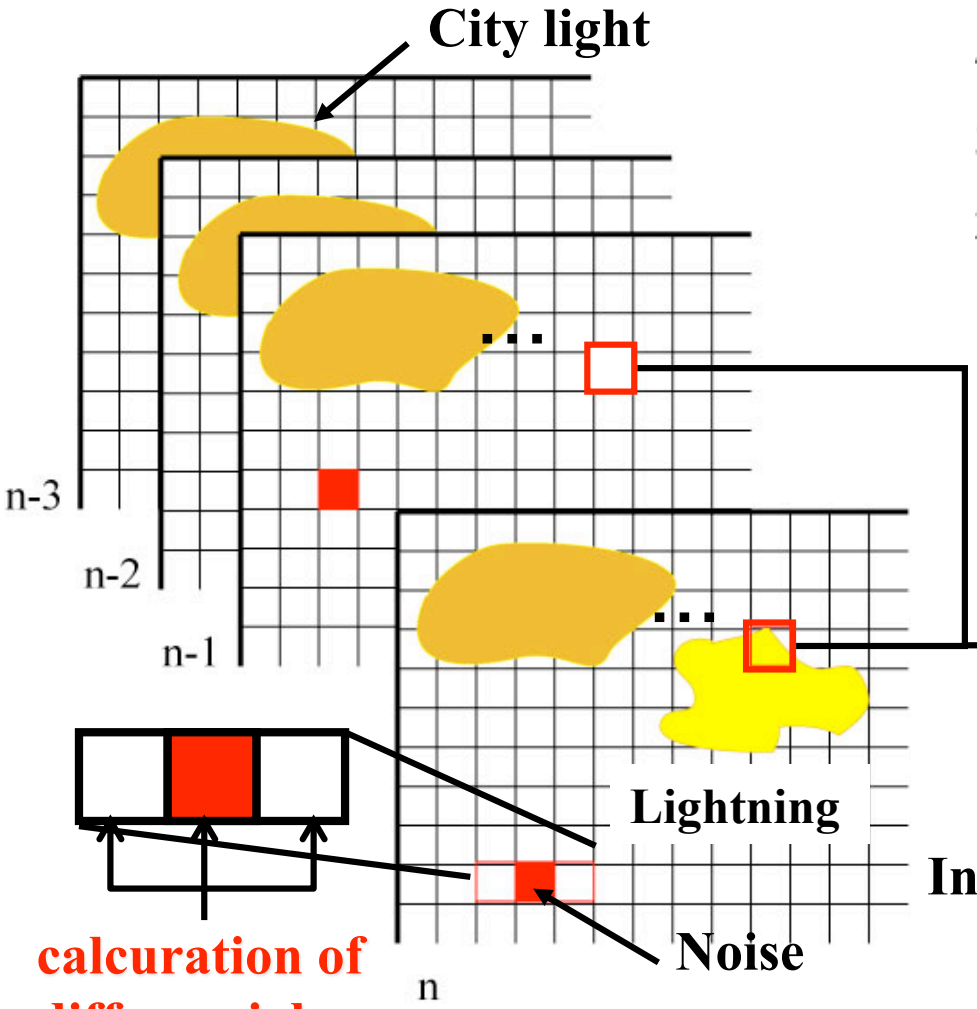
Photometers onboard **TARANIS** by CNES (2013)





Imager onboard RISING satellite (LSI-1, -2, WFC)

29 frames/sec for LSI
30 or 60 frames/sec for WFC



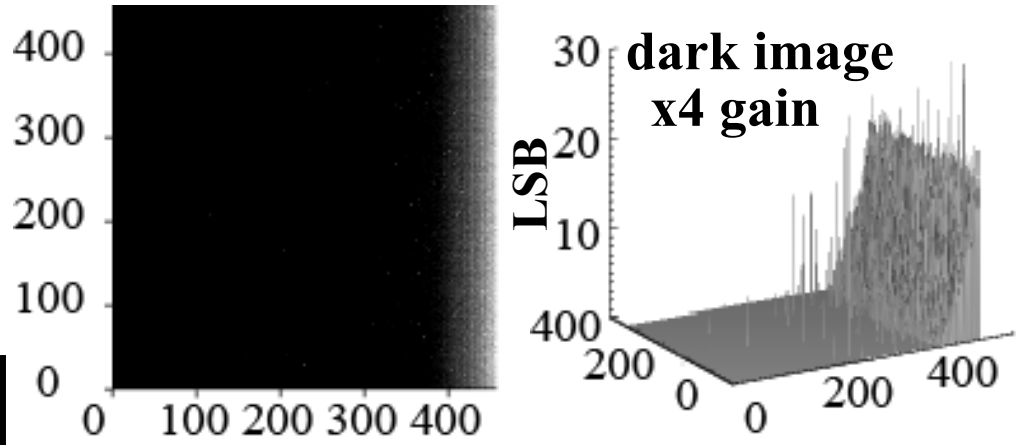


Fig.: sample dark image of CMOS camera

Differential of same pixel (C_n-C_{n-1})

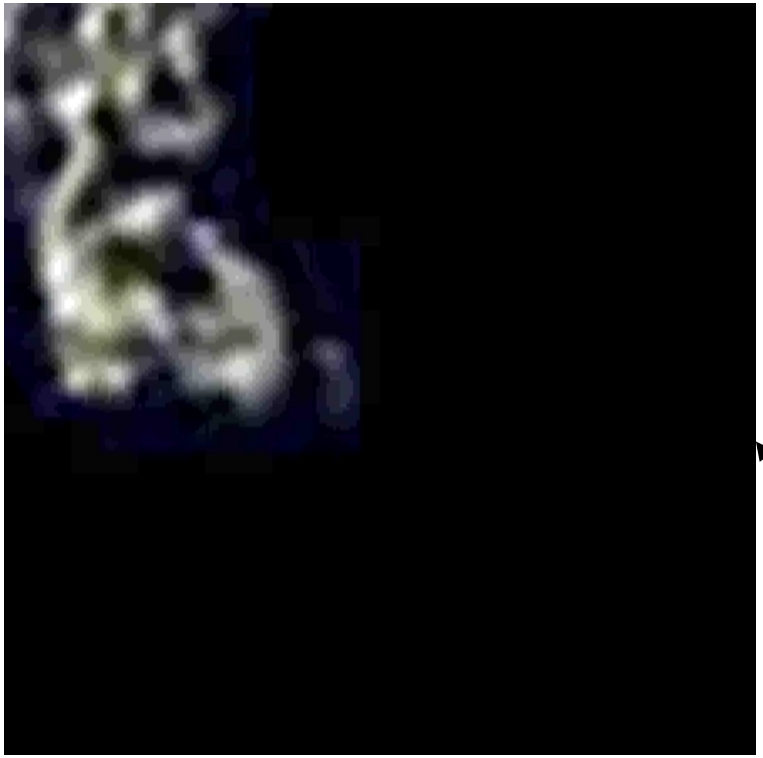
$>$ threshold ? $(C_n-C_{n-1} > T_P)$

Integration of (C_n-C_{n-1}) $(F_n=F_n+(C_n-C_{n-1}))$

$>$ threshold ? $(F_n-F_{n-1} > T_F)$

Transient Emission (Lightning, TLEs)

Validation of the FPGA trigger logic



Lightning simulator

GPS time counting system

1PPS (Pulse Per Second)

Time data

Clock counting in FPGA

PC

Imaging of display

CMOS(LSI)

dT = 100 μsec

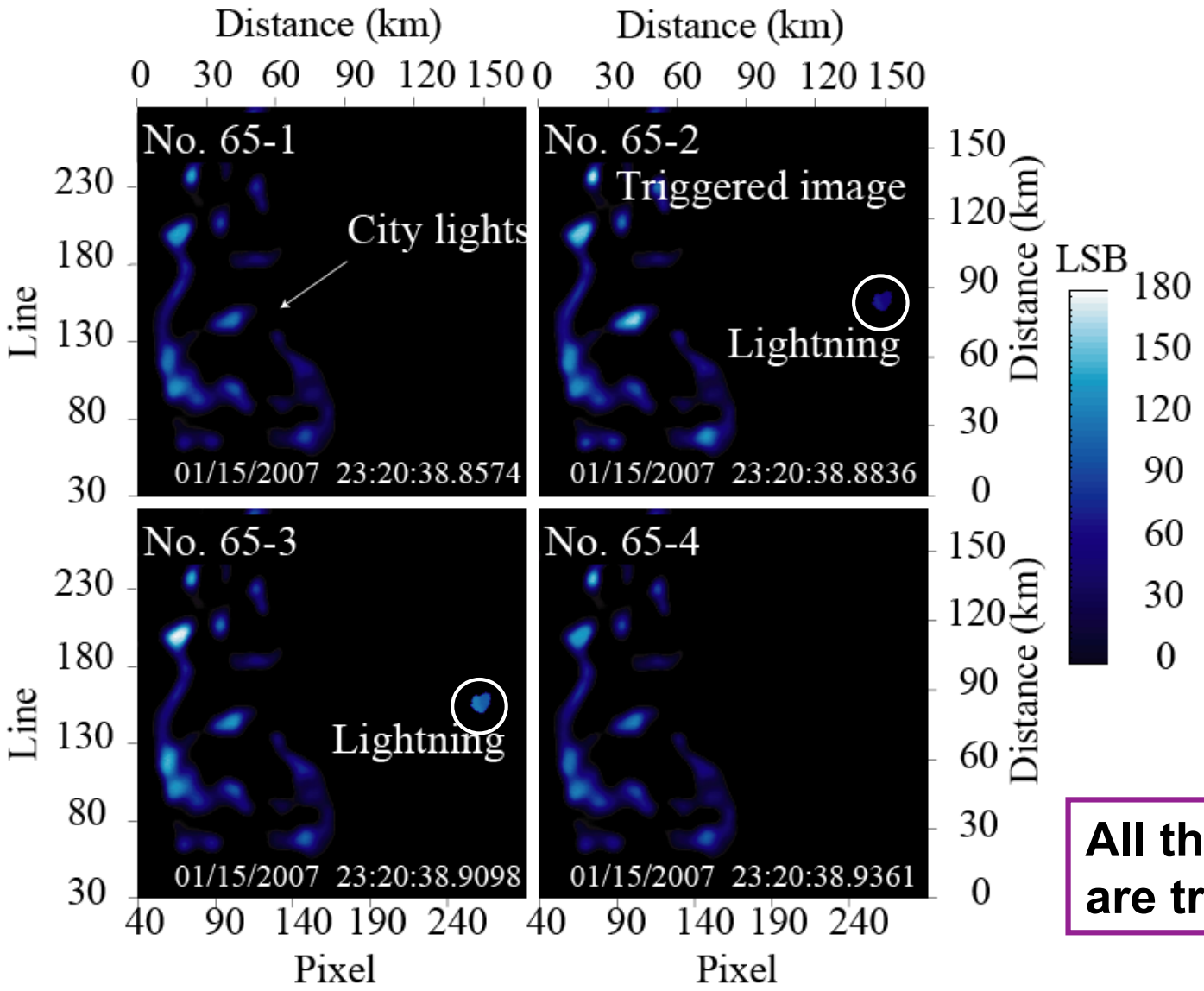
Time data

Camera parameters

Image header = 16 Byte

Image data

Simulated lightning flash with city light contamination



All the lightning events are triggered properly

Summary

Quantitative understanding of thunderstorm activity with cloud monitoring would be a key to solving mechanisms of zone/belt and big oval structures. It is also dedicated to probing of the water vapor in deep atmosphere.

Counting lightning flashes is the only way to estimate thunderstorm activity quantitatively.

Triggering logic is already established and will be tested in the earth orbit soon and expected to be improved.

Compact, light and simple detector can be modified according to the spacecraft resources.

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