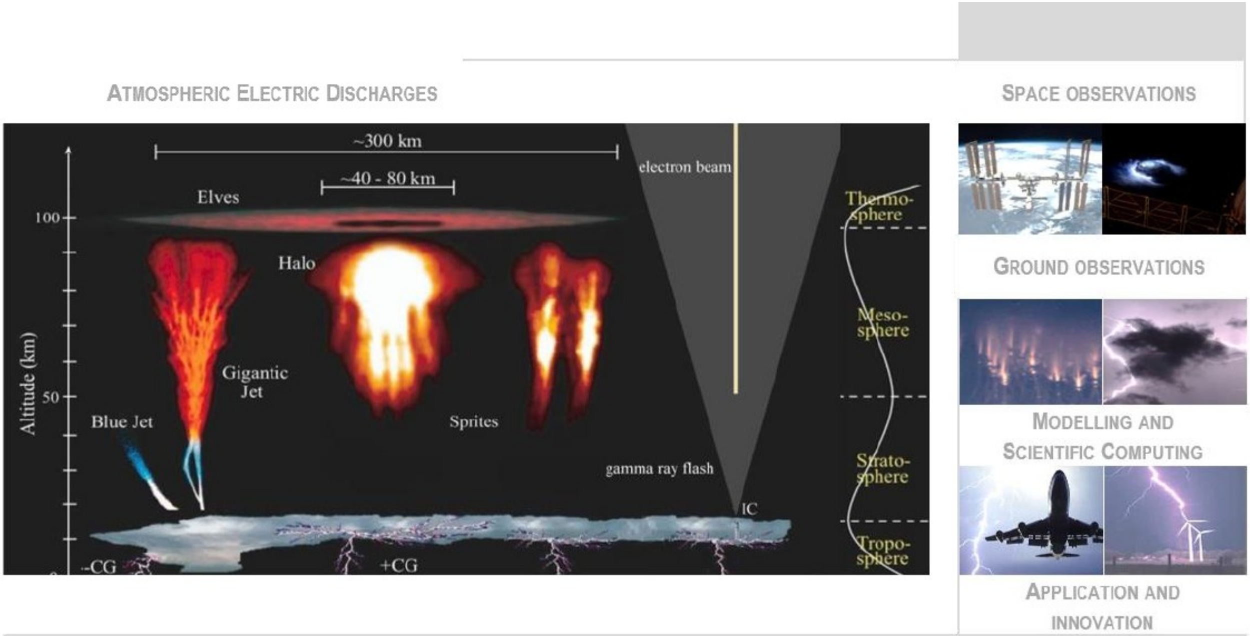
SAINT Winter (Spring) School 3



~~March, 23rd, - April, 3rd, 2020~~

POSTPONED UNTIL FURTHER NOTICE

Programme

Week 1: IPR Work Session IV (first room: primary meeting room; second room: additional meeting room)

	Monday 23/3 (101/S01 and S06)	Tuesday 24/3 (356/066 and 057)	Wednesday 25/3 (101/S01 and S07,9-11 h / S06,11-16 h)	Thursday 26/3 (356/066 and 057)	Friday 27/3 (101/S01 and S06)
08:45-09:00	Intro w. CK	Intro w. CK	Intro w. CK	Future Projects (TN)	Intro w. CK
09:00-09:20	WP2: Torsten Neubert	Michele Urbani	Marcelo Arcanjo	Torsten Neubert ASIM perspectives	
09:20-09:40	Matthias Heumesser	Ny Kieu	Shahriar Mirpour	Jean-Louis PINCON TARANIS persp	
09:40-10:00	Krystallia Dimitriadou	WP4: Ute Ebert	Sergio Soler		
10:00-10:20	Carolina Maiorana	Hani Francisco	Anthony Schmalzried	Heidi Huntrieser Thunderstorm Chemistry	
10:20-10:40	Break	Break	Break	Break	Break
10:40-11:00	Simon Ghilain	Andy Martinez	Alejandro Malagón-Romero	Javier Perez-Invernón Thunderstorm Chemistry	
11:00-11:20	WP3: Martin Füllekrug	Mojtaba Niknezhad	Dongshuai Li	Ramiro Serra Discharges	
11:20-11:40	Zaida Gomez	WP5: Sander Nijdam	Christoph Köhn	Eigil Kaas Atmospheric transmission	
11:40-12:00	Adam Peverell	Andrea Pizzuti			
12:00-13:00	Lunch	Lunch	Lunch	Lunch	Lunch
13:00-15:00	Workshop session	Workshop session	Workshop session	European Commission proposal discussion	Workshop session
15:00-15:20	Break	Break	Break	Break	Break
15:20-17:00	Workshop session	Workshop session	Workshop session	European Commission proposal discussion	Workshop session
17:00-18:00		ESR meeting	Supervisory Board meeting/ Final reporting	Dinner	

Week 2: SC7: Satellite management TS4: Project Management

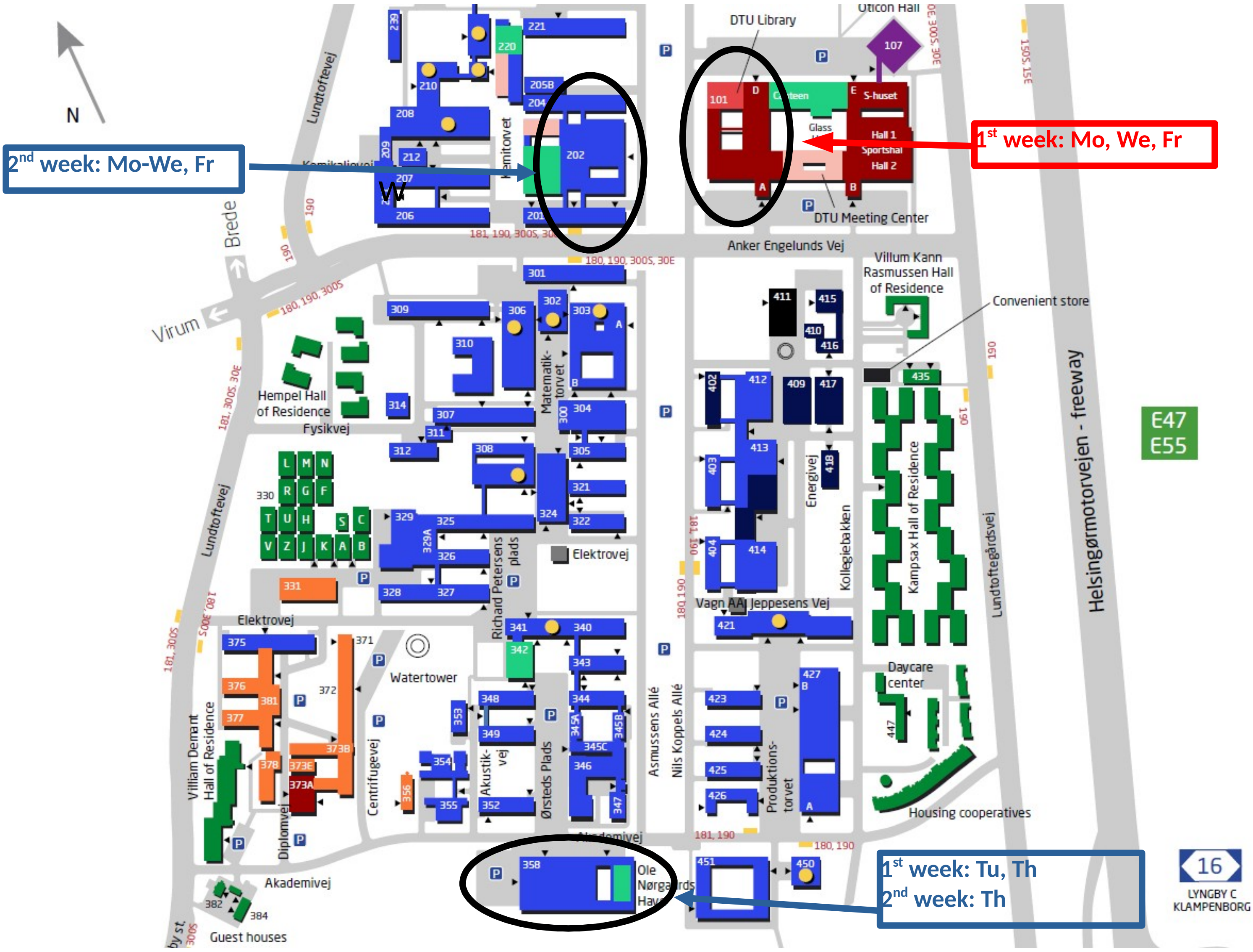
	Monday 30/3 (202/R1005) Proposal writing	Tuesday 31/3 (202/R1005) Project management	Wednesday 1/4 (202/R1005) Satellite operations	Thursday 2/4 (356/066) Satellite operations	Friday 3/4 (202/R1005)
Morning 1	Innovayt A/S Louis Lima	Thales Rémi Joyeux	TARANIS Jean-Louis Pinçon	B.USOC Alice Michel Carla Jacobs	
Coffee					
Morning 2					
Lunch					
Afternoon 1				ASDC	
Coffee					
Afternoon 2					

Participants

Partner	Name	Position	Arrival	Departure	Courses 2nd week
DTU	Torsten Neubert	Senior	23.3.2020	27.3.2020	
	Christoph Köhn	Senior	23.3.2020	30.3.2020	(x)
	Olivier Chanrion	Senior	23.3.2020	27.3.2020	
	Matthias Heumesser	SAINT ESR 01	23.3.2020	3.4.2020	x
	Krystallia Dimitriadou	SAINT ESR 02	23.3.2020	3.4.2020	x
	Mojtaba Niknezhad	SAINT ESR 11	23.3.2020	3.4.2020	x
CSIC	F. J. Gordillo-Vàzquez	Senior	23.3.2020	26./27.3.2020	
	Alejandro Luque	Senior	23.3.2020	27.3.2020	
	Dongshuai Li	PostDoc	23.3.2020	27.3.2020	
	Alejandro Malagón	PostDoc	23.3.2020	27.3.2020	
	Kieu Ny	SAINT ESR 08	23.3.2020	3.4.2020	x
	Sergio Soler	PhD	23.3.2020	27.3.2020	
	Anthony Schmalzried	PhD	23.3.2020	3.4.2020	x
CWI	Ute Ebert	Senior	23.3.2020	27.3.2020	
	Hani Francisco	SAINT ESR 09	23.3.2020	3.4.2020	x
	Andy Martinez	SAINT ESR 10	23.3.2020	3.4.2020	x
UBAT	Martin Füllekrug	Senior	23.3.2020	27.3.2020	
	Keri Nicoll	Senior	23.3.2020	26.3.2020	
	Adam Peverell	SAINT ESR 04	23.3.2020	3.4.2020	x
	Simon Ghilain	SAINT ESR 06	23.3.2020	3.4.2020	x
DENA	Marcelo Arcanjo	SAINT ESR 14	23.3.2020	3.4.2020	x
	Victor Lorenzo	Senior	23.3.2020	26.3.2020	
TU/e	Sander Nijdam	Senior	22.3.2020	27.3.2020	
	Ramiro Serra	Senior	25.3.2020	27.3.2020	
	Shahriar Mirpour	SAINT ESR 15	23.3.2020	3.4.2020	x
BIRAL	Andrea Pizzuti	SAINT ESR 13	23,3,2020	3.4.2020	x
UPC	Michele Urbani	ESR	23.3.2020	3.4.2020	x
	Joan Montanyà	Senior	23.3.2020	25.3.2020	
	Oscar van der Velde	Senior	23.3.2020	27./28.3.2020	
UPST	Serge Soula	Senior	23.3.2020	27.3.2020	
	Zaida Gomes	SAINT ESR 05	23.3.2020	3.4.2020	x
UiB	Carolina Maiorana	SAINT ESR 03	23.3.2020	3.4.2020	x
DLR	Francisco Javier Perez-Invernon	PostDoc	26.3.2020	26.3.2020	
	Heidi Huntrieser	Senior	26.3.2020	26.3.2020	
B.USOC	Alice Michel	Senior	2.4.2020	2.4.2020	x

	Carla Jacobs	Senior	2.4.2020	2.4.2020	x
Taranis	Jean-Louis Pinçon	Senior	26.3.2020	26.3.2020	
			1.4.2020	1.4.2020	
Innovayt A/S	Louis Lima	Senior	30.3.2020	30.3.2020	x
Thales	Rémi Joyeux	Senior	31.3.2020	31.3.2020	x

Venue: Technical University of Denmark, Lyngby Campus



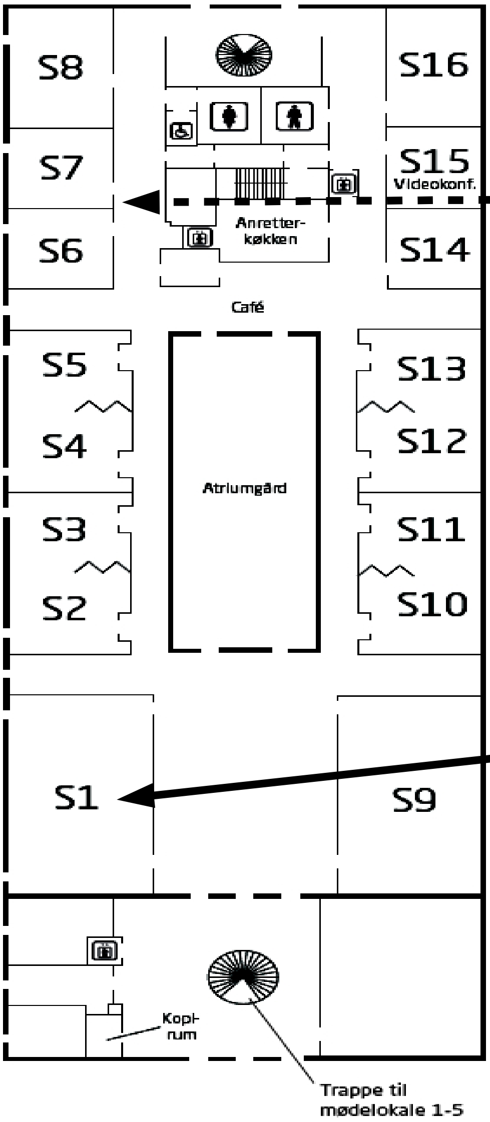
From Copenhagen Central Station (”København H”) take S-train (”S-tog”) A to Lyngby St.

From Lyngby St. busses 300 S and 180 and from Lyngby Storcenter busses 300 S and 30 E ride to ”DTU” (Anker Engelunds Vej), close to building 101 and 202.

From Lyngby St. and Lyngby Storcenter bus 300 S rides to ”Lyngby Swømmehal”, close to building 358.

You can find your way under www.rejseplanen.dk

Overview meeting rooms in 101

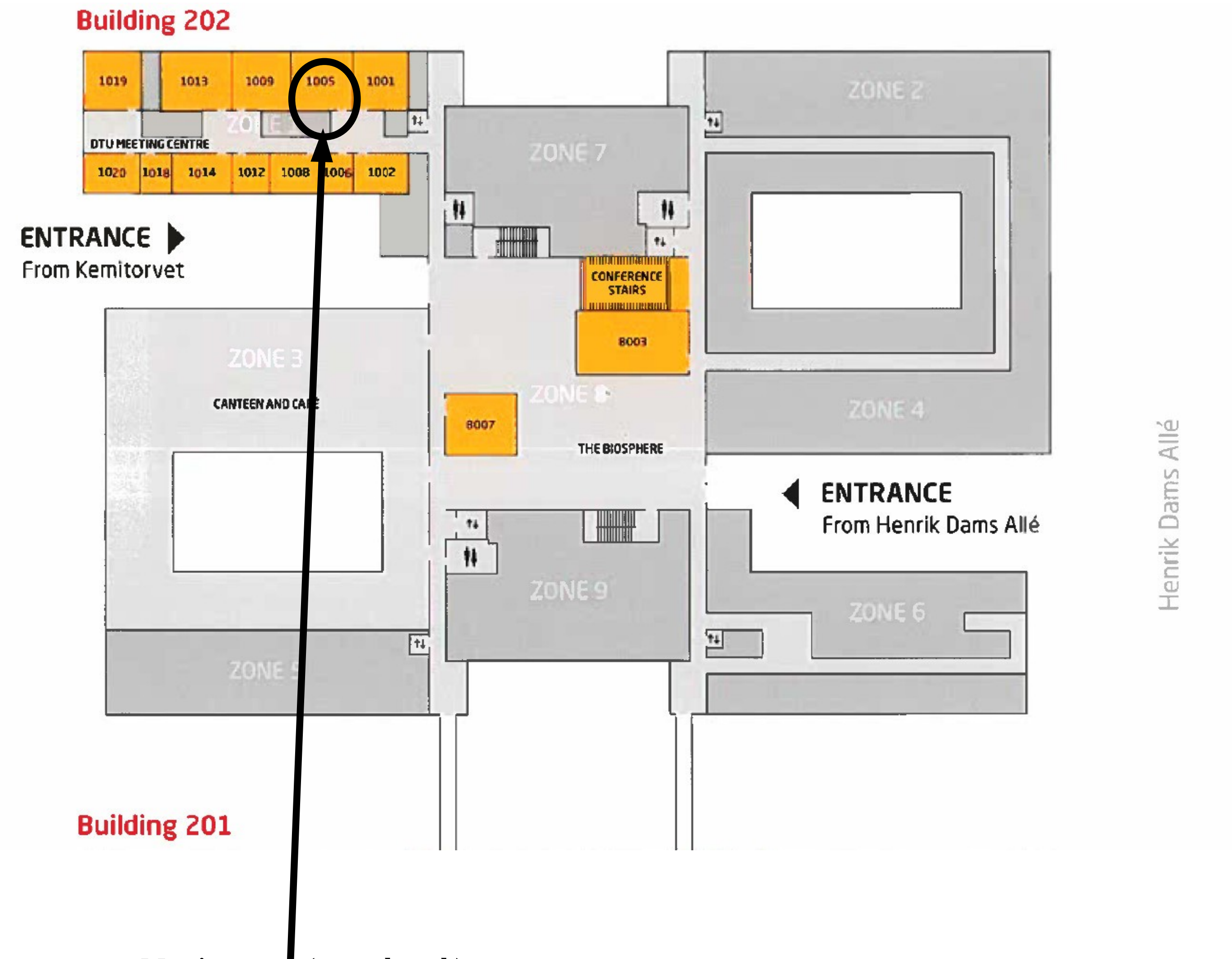


Secondary meeting rooms

Primary meeting room

Entrance 101A =>

Overview meeting rooms in 202



Meeting room (second week)

Monday, March, 23rd

Characterizing the lighting stroke associated with TGFs and its implications on production mechanisms

M. Heumesser[1], O. Chanrion[1], T. Neubert[1], K. Dimitriadou[1], C. Köhn[1], A. Mezentsev[2], F. J. Gordillo-Vazquez[3], A. Luque[3], F. J. Pérez-Invernón[3], H. Christian[4], N. Østgaard[2], M. Marisaldi[2] and V. Reglero[5]

1) National Space Institute, Technical University of Denmark (DTU Space), Denmark
2) Birkeland Centre for Space Science, University of Bergen, Norway
3) Instituto de Astrofísica de Andalucía (IAA - CSIC), Granada, Spain
4) Earth System Science Center, University of Alabama in Huntsville, Alabama, USA
5) Image Processing Laboratory, University of Valencia, Spain

Simultaneous measurements of high energy photons from Terrestrial Gamma-Ray Flashes (TGFs) and optical radiation from associated lightning activity by the Atmosphere-Space Interactions Montior (ASIM) have resolved the chronology of the events and shown that TGFs occur before the main optical pulse from a stroke. In this presentation, we will quantify the optical activity before as well as the characteristics of the stroke associated with a TGF.

In the majority of cases of this study, TGFs occur after 1-3 small optical pulses. Those pulses get faster, shorter and more intense the closer they are to the main pulse. Durations are mainly between 1 and 6 ms, while their intensity varies from 5 to 30% of the peak. This activity is interpreted as the accelerating, stepped leader that gets more luminous the closer it is to the opposite charge region.

The TGF itself occurs at the onset of the optical pulse and ends before the optical intensity reaches its maximum, showing that the necessary field to generate a TGF is discharged by the stroke and the remaining field is not high enough any more to produce further gamma rays by bremstrahlung from electrons.

Short rise times of the main optical pulse between 0.2 and 0.4 ms are consistent with previous measurements of lightning strokes, while the FWHM is unusually long with 0.9 – 1.7 ms for the 337 nm band and 0.7 – 1.2 ms for the 777.4 nm band. Combined with secondary pulses on the tail of the main optical pulse in 777.4 nm in about half the analyzed cases, this shows continued activity in the upper region of the cloud immediately following the stroke, indicating a large amount of deposited charge which triggers streamer and leader activity to redistribute the charge in the upper region. The long duration of the 337 nm pulse is typical for strokes associated with TGFs, pointing at streamer activity in nearly all cases, while the secondary pulses in the 777.4 nm show the formation of consecutive leaders in about half the cases.

Based on these measurements, we conclude that TGFs occur during the leader progression of a vertical intra-cloud lightning, just before the luminous stroke, followed by a redistribution of charge in the upper cloud region.

Analysis of Blue Lightning in Thunderclouds

K. Dimitriadou[1], O. Chanrion[1], T. Neubert[1], M. Heumesser[1], A. Protat[2], V. Louf[3], H. Christian[4], R. Blakeslee[5], C. Köhn[1], N. Østgaard[6] and V. Reglero[7]

1. National Space Institute, Technical University of Denmark (DTU Space), Kgs. Lyngby, Denmark

2. Australian Bureau of Meteorology, Science and Innovation Group, Radar Science and Nowcasting Team, Melbourne, Australia

3. Monash University, School of Earth, Environment and Atmosphere, Melbourne, Australia

4. NASA Marshall Space Flight Center, Huntsville, Alabama, USA

5. Earth System Science Center, University of Alabama in Huntsville, Alabama, USA

6. University of Bergen, Birkeland Centre for Space Science, Bergen, Norway

7. University of Valencia, Image Processing Laboratory, Valencia, Spain

The Modular Multispectral Imaging Array (MMIA) of the Atmosphere-Space Interactions Monitor (ASIM) contains 3 photometers and 2 cameras, that monitors electrical discharges in and above thunderstorms. The 3 photometers sample in the bands: 337/4 nm, the VUV band 180-230 nm and 777.4/5 nm at 100 kHz; and the 2 cameras record in the bands 337/5 nm and 777.4/3 nm, with a temporal resolution of 12 frames per second. The 337 nm corresponds to the strongest line of $N_2$2P, the VUV band include part of the N_2 LBH and the 777.4 nm band corresponds to the OI line which is the strongest emission line of lightning leader channel.

Hereby we present new results regarding the evolution of a multi-cell thunderstorm that was formed over Australia and was captured by ASIM and NASA's Lightning Imaging Sensor on the ISS. The storm was exceptional regarding its electrical activity and meteorological characteristics. Weather satellite images and radar data indicated an intense and long lasting thunderstorm complex, with cloud turrets (overshooting tops) penetrating the lower stratosphere and maintaining a vigorous convective activity beneath. MMIA detected lightning and TLEs simultaneously in different phases of the storm cells. With the synergy of the VAISALA's lightning network GLD 360, the calculated flash rates revealed that the northern cells were in the dissipation stage and the southern cells were in the intensification phase of the storm. Through a plethora of different type of discharges, hereby we focus on the cases that are predominant blue and we propose that they emanate from the overshooting tops into the lower stratosphere. This work signifies a first step to explore in detail the thunderstorm conditions leading to blue lightning.

What is the connection between lightning discharge and Terrestrial Gamma-ray Flashes?

Carolina Maiorana, Martino Marisaldi, Nikolai Østgaard, Martin Fullekrug, Torsten Neubert

Thunderclouds and lightning can accelerate electrons up to relativistic speeds and produce bursts of X- and gamma-rays. Those bursts of gamma-rays are known as Terrestrial Gamma-ray Flashes; after being produced inside the thundercloud they typically travel upwards and are detected by space-born instruments such as ASIM. The exact mechanism of production is still not known: in particular, we need better understanding of the relationship between the characteristics of the parent lightning and the occurrence of TGFs. One way of exploring this relationship is by correlating TGFs with all available data from lightning detection networks, including the recording of radio sferics, and the characteristics of the parent storm. We did this for a sample of nine TGFs detected by ASIM at high latitudes (above 35 degrees). Those events are interesting mainly because TGFs were not expected to occur or at least to be detectable at high latitudes, due to the lower altitude of the tropopause and lower lightning flash ratio. Moreover, storms in temperate regions are different from the deep convection occurring at the tropics, and hence the study of these events can reveal specific characteristics or conditions that are associated with production of TGFs. This project is the topic of my second paper and the focus of my secondment at the University of Bath, since the radio sferics associated with those events were analysed in collaboration with the SAINT members employed there.

My third paper will analyse the case study of a multi-pulse TGF detected in association with radio recordings from both LINET network and Duke University. It's the first time the sferic of the parent lightning is recorded for a multi-pulse event and we expect to gain hints on what makes the gamma-ray production process repeat itself, generating several pulses of radiation.

Both these papers fit into the goal of characterizing the electrical discharges associated with TGF production (deliverable number 2.1).

My first project and paper was compiling the third catalogue of TGFs for the AGILE mission, after revising and improving the algorithm for the offline search. The paper is currently under review in JGR: Atmospheres and the online catalogue is available at http://www.ssdc.asi.it/mcal3tgfcat/ .

The second secondment of my project is planned for April 2020 at DTU. I will work with ESRs 1 on the analysis of the optical signals from the MMIA instrument and the data from LIS; we will use those data in our third paper.

Optical discrimination of sprite and lightning by use of green light from ~495-505 nm

Simon Ghilain[1], Martin Fullekrug[1]

1. University of Bath, Department of Electronic and Electrical Engineering, *UK*

Sprites are transient illuminations of the middle atmosphere above thunderclouds which often occur after intense lightning discharges. Here we report optical recordings of sprites and lightning taken with a video camera and photometers in northern Colombia during October 2019.

Optical observations of sprites are often superimposed on the scattered light produced by the parent lightning discharge. This superposition of two optical sources can result in a misinterpretation of the photometer recordings, for example the determination of the rise time of an optical waveform.

Here we propose to use the green light emissions from ~495-505 nm to discriminate between sprite and lightning. This experimental discrimination has become possible because recent modeling studies suggest that lightning emits green light whilst sprite do not emit green light (*Gordillo Vazquez et al., 2011; Xue et al., 2015*).

The optical signals are detected by a white light video camera and a photometer which is fitted with a ~495-505 nm band pass filter to detect green light. The observed lightning discharges are characterized by significant green emissions in the ~495-505 nm wavelength band. These green emissions are part of the diffuse glow detected by the video camera which is caused by the scattered light from the lightning discharge. This light is scattered during its propagation through the atmosphere which is most likely caused by aerosols, for example related to the ambient humidity and dust. The majority of sprite observations are contaminated by such a diffuse glow with significant ~495-505 nm emissions. The observation of one particular sprite does not exhibit any significant ~495-505 nm emissions and it is therefore attributed to a 'pure sprite'. The rise time of these optical emissions and the characteristics of other wavelengths recorded by several photometers will be reported for this particularly pure sprite event.

The knowledge gained from these ground-based observations may assist the interpretation of measurements with photometers onboard the ASIM payload on the International Space Station and the forthcoming TARANIS satellite.

Gordillo-Vazquez, F.J., Luque, A. and Simek, M.(2011). Spectrum of sprite halos. *Journal of Geophysical research*, **116**, A09319. doi: 10.1029/2011JA016652.

Xue, S., Yuan, P., Cen, J., Li, Y. and Wang, X.(2015). Spectral observations of a natural bipolar cloud-to-ground lightning. *Geophysical Research Letters*, **120**, 1972–1979. doi:10.1002/2014JD022598

Atmospheric Electrical Discharge Analysis from Ground and Space Observations

Zaida Gomez Kuri

1. Universite de Toulouse III - Paul Sabatier

Although Transient Luminous Events (TLEs) were first discovered thirty years ago the, mechanisms governing their formation and development are still not fully understood. Furthermore, the role that the ionosphere plays in their development has been established theoretically, however there is little research involving real time observations. In this work, ground and space observations of TLEs are used to investigate certain parameters responsible for their production including their relation to lightning activity. The main parameters involved are TLE producing strokes including their peak currents and current moment changes (CMCs), cloud top temperature (CTT), optical intensities, and thundercloud characteristics. Also, the electrical relationship between the ionosphere and stratosphere is investigated by studying how the electron density is modified throughout TLE producing storms using the Total Electron Content (TEC). All of this is achieved through a ground network of low light cameras, the ASIM MMIA instrument, ground and space based lightning detection systems, and other satellite systems for the CTT and TEC. These results will be used for the validation of the space based lightning detection algorithm for the Lightning Imager (LI) onboard Meteosat Third Generation (MTG) which will be launched in 2021.

Lightning and Sprite Current Sensing with Small Low Frequency Arrays

Adam Peverell[1], Martin Fullekrug[1]
1. Bath University, Bath, UK.

This aim of this project is to develop novel techniques to determine the currents of lightning and sprites with small low frequency radio receiver arrays. The radio sensor arrays, deployed on scales of a few hundred metres to a km, provide measurements of radio signals associated with distant atmospheric discharge processes, which should further knowledge of the characteristics of exceptional lightning flashes, and the transient luminous events associated with them. Hardware to capture the radio signals, software to process the data, and techniques to analyse the results were developed, tested and validated against signals from VLF transmitters, and deployed in various locations to measure lightning and sprite waveforms in order to calculate directions of incoming radiation, in order to draw conclusions about the causative events.

Tuesday, March, 24th

High-energy radiation from natural lightning observed in coincidence with a VHF Lightning Interferometer

Michele Urbani[1], Joan Montanyà[1], Oscar van der Velde[1], Jesús Alberto López[1]

1. Universitat Politècnica de Catalunya, Terrassa, Barcelona, Spain

In this work we present the first simultaneous detections of X-rays produced by natural lightning in coincidence with a VHF lightning interferometer.
It is well known that lightning strikes can produce high energy radiation, but the mechanisms and conditions under which these emissions occur are not yet fully understood.
Currently, there is great interest in the scientific community for the "Terrestrial Gamma-ray Flashes" (TGFs), intense bursts of gamma radiation that can be produced during thunderstorm. Nowadays several satellites for astrophysics like AGILE and FERMI are able to detect and map TGFs and dedicated instruments like the ASIM detector on the ISS are studying this phenomenon from space.
In the atmosphere, the high-energy radiation undergoes a strong absorption exponentially proportional to the air density which makes it more difficult to detect TGFs on the ground. Nonetheless, ground measurements were conducted and observed that even in cloud-to-ground lightning high-energy radiation were produced. In particular, the works of Moore et al. [2001] and Dwyer et al. [2005] highlight two lightning processes in which the X-ray emission could be produced: downward negative stepped leader and dart leader.
Currently, it is not clear if the emissions revealed on the ground and the TGFs observed in space are essentially the same phenomenon or how these phenomena are related.
Recently an observation campaign was conducted in Colombia with two VHF Lightning Interferometers and two X-rays detectors. This interferometry system was installed in the coverage area of a Lightning Mapping Array (LMA) and LINET to take advantage of the complementary information that these lightning location networks could provide.
At the moment, about fifteen lightning events with X-ray emissions were observed, including five X-ray bursts from downward negative leaders and two emission from dart leader.
Further studies and analysis of the collected data are still ongoing.

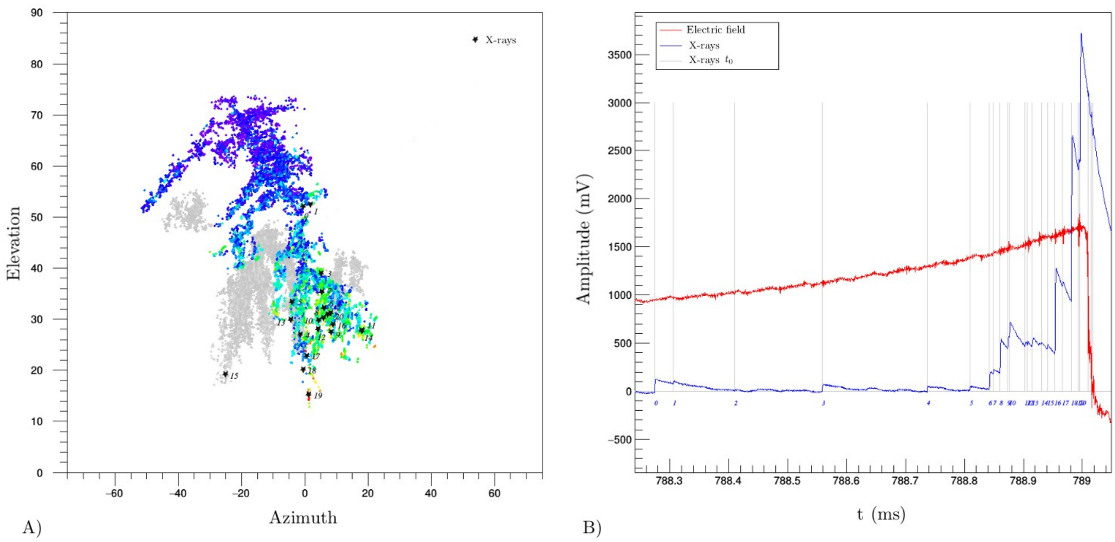


Figure 1: A) The VHF Lightning map of the downward leader event 20191111-063907 recorded by the UPC Interferometer (INTF-2) in Barancabermeja (Colombia). The image is colored by VHF power and the numbered black stars are the most likely location of the X-ray origin. B) Electric field and X-rays measurements during the approach of the downward leader.

Ultrahigh speed spectroscopy of lightning-like discharges with GALIUS

N. Kieu[1], F.J. Gordillo-Vázquez[1], M. Passas[1], J. Sánchez[1],

[1] *Solar System Department, IAA - CSIC, Glorieta de la Astronomía s/n Granada, Spain*

After construction, GALIUS - GrAnada LIghtning Ultrafast Spectrograph – had been tested with small electrostatic discharges (Wimshurst machine , 2 – 10 cm, 60 - 300 kV) at IAA-CSIC (Granada). Spark spectra were recorded from the near UV to the near IR with recording speeds varying from 672 kfps to 2.1 Mfps using different VHPs (Volume Holographic Phase) gratings for each spectral range. In the second period, GALIUS was moved to Barcelona - Spain to work with high voltage (HV) (600 - 900 kV) laboratory where lightning-like electric discharges (0.7 – 1 m long) were generated in the switching and lightning impulse mode. In switching impulse (SI) mode, the voltage slowly rises up to its peak in about 70 µs - 80 µs while during the lightning impulse (LI) mode the voltage rises suddenly (in ~ 1 µs) to its peak and remains there for a few microseconds.

GALIUS spectra recorded at 2.1 Mfps show the dynamics of three emission lines: H alpha (656 nm) and two ion nitrogen (648 nm and 661 nm) lines. We have determined the time variation of the gas (electron) temperature and electron density from different discharges in comparison to those estimated from real lightning by Uman [1] - [3] and Orville [4]. GALIUS spectra recorded at 1.2 M fps show the emission of two neutral oxygen (777 nm and 794 nm) in longer dynamic time while at 672 000 fps these spectra indicated the changing emission of some ion and neutral lines in the near UV (380 – 440 nm) and visible range (450 nm – 800 nm) in the same spark.

[1] M. Uman et al., J. Atm. Sci., 21, 306-310, 1964

[2] M. Uman, J. Atm. Sol. Terr. Phys., 26, 123 - 128, 1964

[3] M. Uman, IEEE Spectrum, 102 - 110, August 1966

[4] R. E. Orville, J. Atm. Sci., 25, 839 - 850, 1968

SIMULATION OF POSITIVE STREAMERS IN AIR: EFFECT OF ATTACHMENT AND LINE APPROXIMATION

Hani Francisco[1], Behnaz Bagheri[2], Jannis Teunissen[1], Ute Ebert[1,2]

1. Centrum Wiskunde & Informatica, Amsterdam, The Netherlands
2. Eindhoven University of Technology, The Netherlands

Lightning and other electric discharges are preceded by ionized channels called streamers. These propagating filaments are characterized by a curved charge layer at their tip and an enhanced electric field region ahead of it. In this study, we analyze streamers and the requirements for their sustained propagation. We look at the conductance and the current within streamers and investigate their effect on streamer dynamics. Streamers with different electron density profiles are considered, and these are realized through simulations in air using increased electron attachment rates. In the set-up, the effective ionization rate is modified to have a greater negative value in regions where the electric field is below electric breakdown value. A fluid model is used in the streamer simulations with the afivo-streamer code [Teunissen and Ebert, J. Phys. D 2017], which utilizes a drift-diffusion-reaction model coupled with Poisson's equation with a local field approximation. Streamers were found to continue to propagate even though the electric current is limited to only a small region behind the streamer head rather than extending through the whole streamer channel.

Understanding Discharge Inception in air using high-voltage experiments and particle-in-cell simulations

A. Martinez[1], S. Mirpour[2], J. Teunissen[1], S. Nijdam[2], and U. Ebert[1,2]

1. Centrum Wiskunde & Informatica (CWI), 1098XG Amsterdam, The Netherlands
2. Department of Applied Physics, Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands

Understanding discharge inception is important for fields like lightning research, lightning protection, and high-voltage technology. In this study, the inception times and probabilities of discharges are measured in a vessel filled with dry air between 100 and 1000 mbar. A pin-to-plate electrode geometry is considered, in which tens of kV are applied over a cm-scale gap. The inception time is defined as the moment a photomultiplier tube measures a signal above the background noise. The inception probabilities and spread of inception times are compared to Monte-Carlo particle simulations with different initial charge densities (e-, and O2-) to find conditions that reproduce the statistics from the experiments.

Preliminary results show several distinct inception timescales: from tens of ns to hundreds of µs. Results also show a long lived source of electrons (> 5 s at 500 mbar) is present in the gap. This source seems to be difficult to remove and will influence subsequent discharges if the repetition frequency is too high. Further analysis on the different electron sources within the gap are performed by comparing experiment and simulation.

Electric Discharges in Unsteady Air Flow

Mojtaba Niknezhad[1], Olivier Chanrion[1], Christoph Köhn[1], Joachim Holbøll[2] and Torsten Neubert[1]

2. National Space Institute, Technical University of Denmark, Kongens Lyngby, Denmark
3. Technical University of Denmark (DTU Elektro), Kongens Lyngby, Denmark

We have developed a 3D fluid model to simulate streamer discharges in unsteady air flow. The model couples the drift-diffusion equations for the charged particles, the Navier-Stokes equations for the air and the Poisson equation for the electric field. It allows to study electrical discharges at different timescales defined by light and heavy particles and to investigate the effects of unsteady airflow. The model treats the time integration in an implicit manner to allow longer time steps, which makes the simulation of long duration discharges feasible. Moreover, the model uses an unstructured mesh with adaptive refinement allowing the incorporation of solid bodies with complex geometries. The accuracy of the model has been verified by comparing its results with a test case from the literature comparing simulation in steady air from five different streamer codes. Our results were consistent and among the most accurate. I will present the latest result from the model showing that the impact of a low speed air flow on the streamer comes essentially from the ions being blown away by the wind.

Using quasi-electrostatic thunderstorm detectors to investigate Earth's atmospheric electricity

Andrea Pizzuti[1,2], Alec Bennett[1,2] and Martin Fullekrug[1]

4. Department of Electronic and Electrical Engineering, University of Bath, Bath, UK
5. Bristol Industrial and Research Associates Limited (Biral), Portishead, UK

The present project uses data from a unique single-site lightning detector recently developed by Biral (the BTD-300) to warn of local thunderstorm activity at airports and other facilities. The technique employs a novel method of discriminating between lightning and non-lightning sources of quasi-electrostatic field change in the range 1-45 Hz by comparison of the signal strength measured simultaneously on three co-located electrodes, exposed to the atmospheric electric field. Detection of anomalously strong transient signals from powerful lightning discharges several hundred kilometers away, often positive CG strokes exceeding peak currents of 150 kA, is of particular interest to this project, since their amplitudes are not consistent with a sole electrostatic dipole approximation and pose a potential issue to the sensor in terms of false warnings. The main aim of this research is then to unveil the physical mechanism leading to such strong transients and to mitigate their impact on the flash detection algorithm as well as implementing technical upgrades. On the other hand, an extensive electromagnetic characterization of these sources and comparison against optical observations established a link to CG strokes producing upper-atmosphere transient luminous events (TLEs). Data collected using multiple sensors simultaneously in UK and southern France suggest that the method can be profitably used to report large +CG strokes, occasionally rejected by the processing algorithms of VLF/LF lightning detection systems. In addition, the observed seasonal distribution of BTD transients led us to investigate the properties of small-scale low-flash rate winter thunderstorm at high latitude in northern Europe. We found that isolated flashes, not preceded or followed by any IC/CG activity in the same thundercell, are capable of triggering sprites. The characteristics of the thunderstorm, as the cloud top temperature (CTT), the size and the meteorological context, are considered in order to better understand the conditions leading to the observed events. Further research applications are also evaluated, including the long-term seasonal variability of the Schumann resonances background, providing relevant data for climatology, and the monitoring of ash clouds electrification and volcanic lightning.

Wednesday, March, 25th

Corona and Leader Properties Investigation for use in Lightning Protection

Marcelo Arcanjo[1,2], Joan Montanyà[1], Victor Lorenzo[2],
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Lightning represents a highly severe hazard for buildings, electrical installations, equipment, animals, goods and people. Numerous investigations have been conducted since Benjamin Franklin's first experiment proposals back in the 17th century to study and better understand the nature of, and physics behind, lightning phenomena.

This project aims to contribute to the understanding of various mechanisms involved in the inception of lightning streamers/leaders from a lightning rod. The knowledge obtained from this research will be applied for developing a prototype of a novel lightning rod.

Previously, we showed results of several experiments conducted using a plane-to-point setup with a DC High voltage Power supply, performing measurements of the corona current recorded with different sensors, correlated with E-field variation and optical detections. We installed three prototypes in different locations, in sites that exhibit different orography and surrounding structures. Similar pulses to those observed at the laboratory have been recorded with the sensors during nearby storms and under high background electric field conditions.

Currently, analyzing the outcomes of several months of campaign, we discuss the correlation between the frequency of the pulses and background electric field of signals measured outdoor under stormy conditions. We also show preliminary data obtained with the corona sensor prototype with high voltage sparks obtained with a Marx generator. We intend to present results of a three-month secondment performed at TU/e, in which the streamer inception was investigated for very sharp (in the micrometer range) tips.

Further steps on this investigation involve the experiments with the prototype using a Marx generator, investigating the streamer-to-leader transition and the development of the sensor for detecting the occurrence of the leader stage and lightning impacts, to be incorporated into the final prototype.

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Pulsed laser discharges for use in streamer initiation

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While lightning has been thoroughly researched throughout the years, several fundamental questions still remain. One that this project aims to address is the initiation of lightning and investigate the contributing factors of such phenomena. The focus here is on the streamer discharges that precede the lightning. These discharges will be reproduced in a lab setup under controlled conditions. Up until now streamers have usually been induced by two electrodes. However, the geometry of the electrodes can potentially influence the streamer propagation. In order to better emulate the electrodeless discharges occurring in nature and in simulations, a strong pulsed Nd:Yag laser is used to create the seed from which the streamers propagate. This is done by first focusing the laser to a point inside a vessel filled with dry air, creating a short-lived plasma, after which an electrical field is applied to the plasma. This should cause the charges to separate and create streamers. An initial analysis was made by causing discharges with the laser at varying pressures and laser energies. Images were taken using an intensified CCD camera. Hopefully, this study will lead to a better understanding of streamers and lightning and possibly improved simulations.

Application of neural networks for regional lightning forecast

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Lightning databases store hundreds of terabytes of information. In this work we show how from filtered data of the Earth Networks Total Lightning Network (ENTLN) database combined with some atmospherical variables from reanalysis data retrieved by the recent ERA5 ensemble, we can make seasonal and yearly forecasts for lightning distributions using a deep learning technique called neural networks.

Super-particle Curtailment and Improved Spectral Resolution Method

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In Monte-Carlo simulations of electron swarms in regions above conventional breakdown, the growth of the population can lead to an undesirably high proliferation of electrons. To avoid this one usually samples a reduced number of particles, called super-particles, each of them standing for an ensemble of physical particles according to an statistical weight. Deciding which particles to keep in a simulation depends on the objective of the user: the phenomena to be observed, the quantities to be measured, etc. A simple case occurs when we are interested in electron thermal runaway: a mechanism enabling very few electrons to accelerate in the electric field from their initial thermal conditions until they reach energies where they start radiating X-rays through bremsstrahlung. One way to boost the chances to observe this phenomenon with few super-particles is to control the number of electrons in each energy bin through a pre-imposed energy distribution of super-particles. We show how this is done in a simple simulation setup with a homogeneous electric field and then we apply it to a streamer front model.

Leader discharge stepping in dry and humid air

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Long spark discharges of about one meter and natural lightning show a polarity asymmetry. While positive discharges propagate continuously, negative discharges propagate in a stepped manner. This stepped propagation is mediated by the so-called space stem, an isolated region in the streamer corona of depleted electron density and enhanced electric field. Kostinskiy et al. 2018 [1] reported the stepping of positive leaders under high humidity conditions and Malagón-Romero et al. 2019 [2] showed that positive leader steps, if they exist, would be shorter and thus harder to observe in experiments.

In this work we present the results of our simulations for the evolution of a space stem precursor [2] under dry and humid air conditions. These results show that the presence of water molecules enhances the electric field and the heating rate of the space stem, reaching 2000 K considerably faster than in dry air. This could make feasible the stepping of positive leader discharges under high humidity conditions as observed by Kostinskiy et al. 2018 [1].

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The ASIM observation of blue starters associated with negative NBEs

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On 7 August 2019 in South China, a series of negative NBEs were observed inside an active thunderstorm by the Jianghuai Area Sferic Array (JASA) lightning location network. Optical emissions were simultaneously recorded by the Modular Multispectral Imaging Array (MMIA) of the Atmosphere-Space Interactions Monitor (ASIM). Here we show that all detected negative NBEs pulses are associated with pure blue events, only detected in the 337nm photometer and 337 nm ltered camera of MMIA, with no signal in the 180 - 230 nm photometer nor in the 777 nm photometer and ltered camera. The rise times of the blue events in the 337 nm photometer are between 20 to 90 s with peak brightness varying from 20 to 140 W=m2. The modeling results of our cloud optical radiation model agree reasonably with the image recorded by the 337 nm ltered camera of MMIA, suggesting that the blue events occurred above the top of the thunderstorm as in the phenomenon called \blue starter" introduced by [1]. This supports a connection between blue discharges above the thunderstorms and negative NBEs [2] and oers a convenient approach to analyze negative NBEs from space.

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The emission of energetic electrons from the complex streamer corona adjacent to leader stepping

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We here model the production of energetic electrons serving as a source of X-rays and γ-rays, associated to electric discharges in preionized and perturbed air. During its stepping, the leader tip is accompanied by a corona consisting of multitudinous streamers perturbing the air in its vicinity and leaving residual charge behind. We explore the relative importance of air perturbations and preionization on the production of energetic run-away electrons by 2.5D cylindrical Monte Carlo particle simulations of streamers in ambient fields of 16 kV cm^{-1} and 50 kV cm^{-1} at ground. We explore preionization levels between 10^{10} m^{-3} and 10^{13} m^{-3}, and air perturbation levels between 0% and 50% of ambient air. We determine the velocities of positive and negative streamer fronts as well as the temporal evolution of the electron density and the electric field. We calculate the temporal evolution of the energy distribution of electrons. Conclusively, we obtain the fluence of run-away electrons and determine which conditions favour the production of high-energy electrons and photons.

Thursday, March, 26th

TARANIS: status, commissioning, and perspectives

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TARANIS is a CNES satellite for the study of TLEs and TGFs to be launched on Friday 19th June 2020 by a Vega rocket from the Kourou Space Center (French Guyana). TARANIS will provide combined Nadir observations of TLEs and TGFs, high resolution measurements of energetic electron beams, and high resolution wave field measurements. The TARANIS data will be distributed to the atmospheric and space electricity community through the TARANIS Scientific Mission Center (CMST). After a brief overview of the TARANIS scientific payload, the status of the mission, the logic of the commissioning planned to extend up to 6 months after the launch, and the strategy adopted for future collaborations will be presented.

TARANIS Spacecraft at CNES Technical Center in Toulouse (France)

Quantification of Thunderstorms Role in Atmospheric Dynamics and Chemistry: Some Thoughts on Thunderstorm Research with Upcoming Lightning Instruments in Space

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Since the launch of the Sentinel-5P ESA mission in autumn 2017, a multichannel instrument named TROPOMI provides daily images of highly resolved vertical column densities of a number of important trace species (as O_3, NO_2, SO_2, HCHO, CO, CH_4 and aerosols) with a pixel size of ~7 km x 3 km, which has revolutionize the view on Earth, allowing us to even sort out single pollution sources as cities and power plants. In addition, first attempts have recently been undertaken over the U.S. to combine TROPOMI-NO_2 measurements with the GOES-R Geostationary Lightning Mapper (GLM) to estimate the contribution of lightning-produced NO_x.
In near future, 2023, EUMETSAT/ESA will launch Meteosat Third Generation (MTG) consisting of a geostationary imaging satellite (MTG-I), with a lightning mapper, and a sounding satellite (MTG-S). The latter includes an interferometer, the Infrared Sounder (IRS), and the Copernicus Sentinel-4 instrument, a high resolution Ultraviolet Visible Near-infrared (UVN) spectrometer, which can measure a number of different trace species (NO_2, O_3, CO, H_2O, SO_2, HCHO and aerosols) with a high spatial resolution of ~4 km x 4 km and 8 km x 8 km, respectively. Vertical resolved measurements will also be available for the latter four trace species. MTG-S will monitor whole Europe and northern Africa with a high temporal resolution of 1 hour. The high temporal and spatial resolution of MTG will for the first time enable a combined monitoring of the evolution of trace species and lightning in vicinity of fast developing thunderstorms. In combination with measurements of the corona activity (blue discharges) in the upper cloud levels from ASIM on the ISS, hopefully a wealth of details on the transport, production and transformation of a variety of trace species in the upper troposphere – lower stratosphere region will be available. For example, the production of trace species from corona activity can be contrasted to the well-known NO_2-production by lightning. The convective transport of tracers as CO, H_2O and O_3 can be investigated, and the scavenging and washout of HCHO. Furthermore, the production of new particles by precursors as SO_2 in vicinity of thunderstorms can be studied. The transformation of trace species within dissipating deep convection can be monitored over hours and days to estimate e.g. the production of ozone by lightning-produced NO_x. Presently it is however unknown if the resolution of MTG will be high enough to observe all these features of our interest, though the set-up is promising especially for studies on extended, long-lived deep convective systems as Mesoscale Convective Systems (MCSs).

Chemistry and transport models simulations of electrical discharges

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It is well established that lightning is a source of chemical perturbations in the Earth’s atmosphere. Of particular interest is the production of nitrogen radicals (NOx), and its subsequent impact on the atmospheric chemistry including effects on hydrogen species and ozone. Although several model and measurement studies on lightning NOx (LNOx) have been presented in recent years, there are still considerable uncertainties regarding LNOx production rates. Even less well investigated are the effects of discharges in the lower stratosphere such as blue jets, blue starters, and coronas near the top of thunderstorm clouds. However, any release of reactive species in the stratosphere is of interest as it potentially affects the ozone layer. The proposed TOR instrument would provide very valuable data on the electrical activity in thunderstorm clouds, and help to improve estimates on NOx production and other initial discharge effects. These data could be used as input for chemistry and transport models (CTMs) in order to simulate chemical effects from local to global scales. We will present different CTM approaches focusing on Lagrangian dispersion models intended to simulate the reactive mixing of a cloud of reactive species with the ambient atmospheric gas. Such models can bridge the gap between the local scales of electrical discharges and the grid scales of global CTMs or climate chemistry models.

Friday, March, 27th