2022年度MU/EAR-Campaign申請書

申請日：2021/12/22

受付番号：2022-RISH-MU/EAR-Campaign-00001

【申請者（研究代表者）】

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【申請内容】：

◆新規・継続　：新規

◆研究種別　：MU/EAR-Campaign

◆研究題目（日本語）　：層状性降水域における固体降水粒子の観測

◆研究題目（英語）　：Observation of precipitating ice particles in regions of stratiform precipitation

◆研究目的(継続の場合は理由も記入のこと)(300～500字程度)：

「2018年7月西日本豪雨」をはじめ、近年日本域で多発している広域豪雨では、層状性降水が総雨量の大部分をもたらしている。層状性降水過程は弱い上昇流の下での固体降水粒子の成長というミクロな雲微物理過程が本質的な役割を果たしており、観測が困難である。一方、文字通り水平一様な層構造をなしており、鉛直一次元ながらも高時間分解能で大気の鉛直流を直接観測できるMUレーダの特性を最大限に活かせる対象である。また、日本は層状性降水を付随する様々な降水システム(メソ対流系、温帯低気圧、台風など)が発生し、夏季に特徴的な層状性降水が観測される東アジア域に位置するという地理的優位性を有している。本研究はこれらの点に着目し、MUレーダによる大気鉛直流、名古屋大学Ka帯偏波レーダによる固体降水粒子落下速度の鉛直1次元連続観測などによって層状性降水のミクロな雲微物理過程を明らかにする。

◆現在までの成果と期待される成果(200～400字程度)：

現在まで全球降水観測計画(GPM)主衛星搭載の二周波降水レーダ(DPR)で得られた二周波反射強度比を用いた固体水粒子の判別を行ってきた(Akiyama, et al. 2019)。これは、固体降水粒子の形状に関するシグナルに基づいているが、固体降水粒子からのレーダ反射強度が小さく、さらに固体降水粒子のレーダ散乱特性に関して仮定が必要なため、間接的で不確実性が大きい。固体降水粒子の落下速度は雪片(～0.1⊠0.7 m s^-1)と霰(～1⊠3 m s^-1)で大きく異なるため、固体降水粒子の形状に基づくレーダ観測よりも直接的な観測になると期待される。

◆研究計画(300～500字程度)：

鉛直に向けたKa帯偏波レーダで得られるドップラー速度Vは、固体降水粒子の落下速度Vtと大気の鉛直速度Vaとの和である(V = Vt +Va)。このため、MUレーダから得られる大気の鉛直速度Vaを差し引いて、固体降水粒子の落下速度を求める(Vt = V - Va)。また、地上設置のKa帯レーダから送信された電波は、固体降水層に到達する前に降雨層ならびに融解層の水によって減衰されてしまうので、観測された反射強度Zmから減衰補正した反射強度Zeを求める必要がある。降雨層における減衰補正は、ディスドロメータを設置して取得した地上の雨滴粒径分布データならびにMUレーダからの雨滴粒径分布データを用いて実施する。融解層における減衰補正は、融解層モデルを適用する。

以上のようにして得られた固体降水粒子の落下速度Vtと減衰補正した反射強度Zeから、固体降水粒子を雪片と霰に分類する。さらに水平一様性の仮定の下、質量フラックスの地表に向かっての変化を融解層上端からの関数として求めて、雪片が増加(凝集成長)している高度と霰の増加(雲粒捕捉成長)している高度を求める。

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研究組織

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研究分野: ☑ A.信楽対流圏・成層圏　☐ B.信楽中間圏・電離圏　☐ C.赤道対流圏・成層圏　☐ D.赤道中間圏・電離圏　☐ E. その他

MUレーダー装置

観測モード:　☐ 対流圏・成層圏標準　☐ 中間圏標準　☐ 電離圏標準

☐ 電離圏E領域FAI　☐ 電離圏F領域FAI　☐ 干渉計　☐ 流星　☑ その他

希望時期:　2022.7-2023.5 月頃

標準観測以外の使用時間:　700 時間

赤道大気レーダー装置

観測モード:　☐ 対流圏・成層圏標準　☐ 電離圏E・F領域FAI標準　☐ 干渉計(FDI)　☐ RASS　☐ その他

希望時期:　月頃

標準観測以外の使用時間:　時間

他の利用設備（下記以外の設備についても、希望があれば記入のこと）

☐ 信楽アイオノゾンデ　☑ 地上気象観測器　☑ 雨量計　☑ 境界層レーダー　☐ 流星レーダー　☑ その他

備考（使用時間の根拠、「その他」の場合の具体的な観測モード・利用設備など）

近年日本域で毎年のように発生している広域豪雨は長時間継続する層状性降水によってもたらされており、「2018年7月西日本豪雨」では約11日間である。さらに温帯低気圧や台風など様々な降水システムに付随する層状性降水を観測するため700時間の使用が必要である。層状性降水をもたらす対流圏中上層の弱い上昇流(～1-10 cm s^{-1})を高精度で捉えるため、鉛直ビームの数を増やした鉛直流モードでの観測実施が必要である。なお、名古屋大学Ka帯偏波レーダをMUレーダ観測所に移設し、MUレーダとの鉛直方向ドップラー同時観測を予定している。ただし、名古屋大学Ka帯偏波レーダの修理が必要となって予定を変更する可能性がある。

ラジオゾンデ利用者持込個数:　個

来所計画（氏名、来所回数、日数など。旅費を希望する場合はその旨記入のこと）

2022年7月：Kaレーダ設置作業 ２～３日間（雨天を除く）　篠田太郎・重尚一他
2022年9月：観測状況確認 日帰り　篠田太郎・重尚一他
2022年11月：観測状況確認 日帰り　篠田太郎・重尚一他
2023年1月：観測状況確認 日帰り　篠田太郎・重尚一他
2023年3月：観測状況確認 日帰り　篠田太郎・重尚一他
2022年5月：Kaレーダ撤収作業 ２～３日間（雨天を除く）　篠田太郎・重尚一他

研究費（本申請課題に関する研究費（申請中を含む）の名称・課題名、P.I.等を記入のこと）

基盤研究(A)（一般）・レーダリモートセンシングを駆使した層状性降水過程の解明・研究代表者：重 尚一・2022年度−2024年度（申請中）

2022年度MU/EAR-Campaign申請書

申請日：2022/01/18
受付番号：2022-RISH-MU/EAR-Campaign-00002

【申請者（研究代表者）】

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【申請内容】：

◆新規・継続　：継続
◆研究種別　：MU/EAR-Campaign
◆研究題目（日本語）　：信楽UAV・レーダー・ライダー実験（ShURLEX）2022
◆研究題目（英語）　：Shigaraki UAV Radar Lidar Experiment (ShURLEX) 2022

◆研究目的(継続の場合は理由も記入のこと)（300～500字程度）：

During the ShUREX 2015, 2016 and 2017 campaigns, specially equipped University of Colorado DataHawk UAVs were flown near and over the MU radar to collect data in the atmospheric column up to about 4 km altitude. An IMET radiosonde was also mounted on the UAV, along with high frequency response (800 Hz) cold wire and pitot tube sensors, enabling collection of data that was then used to extract information on turbulence in the atmospheric column in the vicinity of the radar. The autonomous UAV was commanded to sample interesting atmospheric structures detected by the radar in near-real time. The resulting dataset has been used to extract the TKE dissipation rate and CT2 profiles and compare them with radar returns to better understand atmospheric processes and radar observations.
While earlier ShUREX campaigns were highly successful (see cited publications, especially the one on Atmospheric Structures in PEPS), more work still remains. We took the time between 2017 campaign and now to finalize analysis techniques and thoroughly analyze the data collected during the three campaigns. Twelve papers have been published in reputable journals. Still there is more work to be done. During the interim, DataHawk UAV has been deployed in numerous campaigns in US (ISAARA, IDEAL etc.) and therefore the launching, tracking and real-time displays have been improved to such an extent that the launches are more consistent, and no constant antenna adjustment is needed. As such, we are now able to concentrate more on science aspects, instead of engineering. We also have perfected a technique to extract winds from UAV data, a task that was quite hard. We can also fly more than one UAV at a time.
We were unable to sample thoroughly the intermittent Kelvin-Helmholtz instability (KHI) event. Nor were we able to map the evolution of a Mid-level Cloud-base Convection (MCT) event. We did not properly sample the convective boundary layer (CBL), and especially its decaying stage. We did not launch enough radiosondes to supplement UAV data. In ShURLEX 2022, we intend to remedy these shortcomings. We were supposed to do so during ShUREX 2020, but Covid19 lockdowns in April and May 2020, travel restrictions from US and mandated 14 day quarantine did not allow us to conduct the campaign. Prof. Kantha had to resign his Visiting Professorship a month earlier and return to US in June 2020. Covid also made us cancel ShUREX 2021. We are hoping that covid19-related issues will have been resolved by May 2022 so we can carry out ShURLEX 2022 in May - June 2022.
We expect to collect a rich collocated radar/UAV dataset from which we can explore dynamical processes involved in evolution and decay of CBL and MCT. To explore these structures and to catch the highly transient MCT events, we need again a 3 to 4-week campaign, with the earlier part focusing on MCT, and the later part on CBL. We also need to launch sondes at hourly

intervals during the two IOPs, one on CBL and another on MCT. If “Kakenhi-granted”, we propose to use a Doppler lidar to complement LQ7 and MU radars in the measurement of turbulence, as well as a met suite to measure fluxes at the ground level.
Because of the recent discoveries we have made in extracting turbulence from radar spectral width, which appears to be quite significant, we need even more data to validate these findings and so ShuRLEX 2022 has become even more important.

◆現在までの成果と期待される成果(200～400字程度)：

7. Expected outcome (if continued project, also describe the results already obtained)
Earlier ShUREX campaigns yielded some data on the atmospheric structures we were able to probe and resulted in many publications, and presentations at the MST15/EISCAT18 meeting at NIPR, Tokyo. The datasets have highlighted the need for more comprehensive data on these structures, especially MCT and CBL. The proposed campaign will help probe these atmospheric structures more completely and better understand the evolution of these structures.
In 2021, Dr. Luce and Prof. Kantha made significant advances in extracting TKE dissipation rate from better processing of radar signals using the mean shear instead of buoyancy frequency. If proven correct, this is likely a breakthrough in this field. We hope to collect enough data during ShURLEX 2022 to validate this idea (please see Dr. Luce's pptx on “Analysis of KH layer events 2011-2021).

◆研究計画(300～500字程度)：

The plan is to conduct a roughly three-week campaign from late May to June 2022, with UAVs bungee-launched using a launch ramp from the adjacent open field utilized in previous campaigns. The UAVs will be flown upwind and over the MU radar. We will focus on CBL and MCT sampling. Analysis of earlier ShUREX data has taught us a lot about these processes and we now know exactly what we need to do to obtain comprehensive data on these atmospheric structures.
As mentioned in the published papers, there are still many unresolved science issues related to these structures and we hope to resolve them through the ShURLEX 2022 campaign. We hope to sample the evolution of the CBL from dawn to dusk when forecasts indicate a clear sunny day, using concurrent UAV and sonde flights every hour. We will use small balloons to make sure they burst just above 12 km height so we can launch more frequently, using both Meisei and Vaisala sondes. We will also make better use of LQ7 radar and lidars at the observatory. The main reason is that these can add significant scientific information on CBLs. As for MCT, if it occurs during daylight and within reachable altitude, we will fly UAVs to sample it. However, if MCT is too high or occurs at night, we will use sondes to sample it at hopefully hourly intervals. When neither MCT nor CBL exploration is feasible, we will focus on Sheet and Layer structures. Overall, the goal is to thoroughly sample these features so that their dynamics can be better understood, and adequate data collected to numerically model them with good fidelity.
An exciting development has taken place. Prof. Lawrence has been able to deploy his high-resolution sensor suite on a balloon and test the feasibility of obtaining turbulence data. The idea is to loft a Hot Wire anemometer and Cold Wire thermometer instrument with the balloon, venting the balloon lifting gas at a pre-determined altitude to descend at about 2 m/s so that turbulence data can be obtained without contamination from the balloon wake. This system has been flown more than 85 times in the US, taking turbulence measurements from 30km down to 18km. We indent to deploy this system up to 4 times during ShURLEX 2022.
While MU radar (if CBL top is higher than ~ 1.3 km), LQ7 radar, UAVs and sondes will be used to sample CBL, it would be helpful if Dr. Yabuki can get the new UV lidar working in time so we can also make continuous measurements of humidity and temperature. Measurements of fluxes near the ground would also be desirable.
Dr. Luce, in collaboration with RISH scientists, will be responsible for the MU, LQ7 radar and Doppler Lidar components. If he is available, Dr. Yabuki will be in charge of lidar component. Professors Kantha and Lawrence will be responsible for the UAV, sonde, and high-altitude balloon components and will be assisted by one of their students (post-docs). We need someone to help with intense sonde launches during IOPs. All the PIs will participate in data analysis/synthesis and technical publications.

◆継続の場合は発表論文等：

1. Luce, H., L. Kantha, H. Hashiguchi, A. Doddi, D. Lawrence and M. Yabuki, 2020. On the relationship between TKE dissipation rate and the temperature structure function parameter in the convective boundary layer. J. Atmos. Sci., 77, 2311-2326. DOI: 10.1175/JAS-D-19-0274.1

2. Luce, H., D. Lawrence, H. Hashiguchi and L. Kantha, 2019. Estimation of turbulence parameters in the lower troposphere from ShUREX (2016-2017) UAV data. Atmosphere, 10, 384. doi:10.3390/atmos10070384
3. Kantha, L., H. Luce, H. Hashiguchi and A. Doddi, 2019. Atmospheric structures in the troposphere as revealed by high resolution backscatter images from MU radar operating in range-imaging mode. Prog. Earth Planet. Sci. 6:32, https://doi.org/10.1186/s40645-019-0274-1
4. Kantha, L., H. Luce and H. Hashiguchi, 2019. Mid-level cloud-base turbulence: radar observations and models. J. Geophys. Res. Atmos. 124. https://doi.org/10.1029/2018JD029479.
5. Luce, H., L. Kantha, H. Hashiguchi, D. Lawrence and A. Doddi, 2018. Turbulence kinetic energy dissipation rates estimated from concurrent UAV and MU radar measurements. Earth Planets Space, 70-207 (MST Radar Special Issue). DOI:10.1186/s40623-018-0979-1
6. Kantha, L., H. Luce and H. Hashiguchi, 2018. On a numerical model for extracting TKE dissipation rate from VHF radar spectral width. Earth Planets Space, 70-205 (MST Radar Special Issue). DOI:10.1186/s40623-018-0957-7
7. Kantha, L. and H. Luce, 2018. Mixing coefficient in stably stratified fluids. J. Phys. Oceanogr., 48, 2649-2665. DOI: 10.1175/JPO-D-18-0139.1
8. Luce, H., L. Kantha, M. Yabuki, and H. Hashiguchi, 2018. Atmospheric Kelvin-Helmholtz billows captured by the MU radar, lidars and a fish-eye camera, Earth Planets Space, 70:162. https://doi.org/10.1186/s40623-018-0935-0
9. Luce, H., L. Kantha, H. Hashiguchi, D. Lawrence, T. Mixa, M. Yabuki, and T. Tsuda, 2018. Vertical structure of the lower atmosphere derived from MU radar, unmanned aerial vehicle and balloon measurements during ShUREX 2015, Prog. Earth Planet. Sci., 5:29, DOI 10.1186/s40645-018-0187-4
10. Luce, H., H. Hashiguchi, L. Kantha, D. Lawrence, T. Tsuda, T. Mixa and M. Yabuki, 2018. On the performance of the range imaging technique estimated using unmanned aerial vehicles during the ShUREX 2015 campaign. IEEE Trans. Geosci. Remote Sensing, 56, 2033-2042, DOI 10.1109/TGRS.2017.2772351.
11. Kantha, L., D. Lawrence, H. Luce, H. Hashiguchi, T. Tsuda, R. Wilson, T. Mixa and M. Yabuki, 2017. Shigaraki UAV-Radar Experiment (ShUREX): Overview of the campaign with some preliminary results. Prog. Earth Planet. Sci., 4:19, DOI 10.1186/s40645-017-0133-x Correction: https://doi.org/10.1186/s40645-018-0210-9
12. Luce, H., L. Kantha, H. Hashiguchi, D. Lawrence, M. Yabuki, T. Tsuda and T. Mixa, 2017. Comparisons between high-resolution profiles of squared refractive index gradient M2 measured by the Middle and Upper Atmosphere Radar and unmanned aerial vehicles (UAVs) during the Shigaraki UAV-Radar Experiment 2015 campaign. Ann. Geophys., 35, 423-441.

研究代表者			
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所内担当教員			
Luce　Hubert			

Research Organization

Name	Affiliation, Position	E-mail Address	Male/Female	Age
(Principal Investigator)				
Lakshmi Kantha	University of Colorado, Emeritus Professor			
(Cooperative Researcher(s))				
Hiroyuki Hashiguchi	Kyoto University, RISH, Professor			
Dale Lawrence	University of Colorado, Professor			
Masanori Yabuki	Kyoto University, RISH, Dr			
Abhiram Doddi	GATS, Boulder, Dr			
Hubert Luce	Kyoto University, RISH, Professor			

Category: ☑ A. MUR Troposphere/Stratosphere ☑ B. MUR Mesosphere/Ionosphere
☐ C. EAR Troposphere/Stratosphere ☐ D. EAR Mesosphere/Ionosphere ☐ E. Others

MU Radar (MUR) usage

Observation Mode: ☑ Tr./St. Standard ☐ Me. Standard ☐ Iono. Standard
☐ E-Region FAI ☐ F-Region FAI ☑ Interferometry ☐ Meteor ☐ Others

Expected Period (Month): June

Usage time other than standard mode: ~230 hours

Equatorial Atmosphere Radar (EAR) usage

Observation Mode: ☐ Tr./St. Standard ☐ E/F-Region FAI Standard
☐ Interferometry(FDI) ☐ RASS ☐ Others

Expected Period (Month):

Usage time other than standard mode: hours

Other facilities ☐ Ionosonde ☑ Surface weather instrument ☐ Raingauge ☑ Boundary layer radar
☐ Meteor radar ☐ Others

Remarks (Details of what is described above)

In Range imaging mode: 5 equally spaced frequencies from 46.0 MHz to 47.0 MHz. 3 beams (0,0), (0,10), (90, 10), 1 channel, 16-bit optimal code (subpulse duration 1 us), NCOH=16 or 32, NFFT=128, NGATE=128. The usage time is approximative. It is based on the use of the MU radar during day time (~10 hours) for about 3 weeks and about 20 hours during night time for radar-balloon observations

Number of Radiosondes: 40

Planned schedule of visit to the site

ShURLEX2022 campaign will be conducted in late May-June 2022 if possible. This will provide the required time to set up UAV operations for the site, acquire about 3 weeks of data (accounting for inclement weather) on evolution of the atmospheric structures of interest. There is no need to use the MU radar on rainy and very windy days during which UAVs cannot be flown

Financial support (Fill in type, title, and P.I. of research budget related to this proposal)

As before, we paln to bring 5 UAVs and we need funds to transport them to and from Japan. We also need about 40 radiosondes if possible. Internationl travel expense for Prof. Kantha will be self-supported (since he is now retired) if no ther source of funding can be identified. International travel expenses for Prof. Lawrence and Dr Doddi will be borne by Prof. Lawrence. However, internal travel and subsistence expenses for all participants are requested from RISH funding.

2022年度MU/EAR-Campaign申請書

申請日：2022/01/18

受付番号：2022-RISH-MU/EAR-Campaign-00003

【申請者（研究代表者）】

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【申請内容】：

◆新規・継続　：新規

◆研究種別　：MU/EAR-Campaign

◆研究題目（日本語）　：ドップラーライダー、MUレーダー、LQ7ウィンドプロファイラーによる大気パラメーターの計測

◆研究題目（英語）　：Measurements of atmospheric parameters from a Doppler Lidar, MU radar and LQ7 wind profiler

◆研究目的(継続の場合は理由も記入のこと)（300～500字程度）：

This project aims at operating a Doppler lidar (a scanning WindCube 200S lidar from Leosphere/Vaisala company) at Shigaraki MU observatory for wind and turbulence parameter measurements, mainly in the convective boundary layer (CBL) (and above, if it is possible). Due to its flexibility, we can potentially apply several methods to estimate turbulence kinetic energy dissipation rates ε. Comparisons with ε estimates derived from MU radar and LQ7 wind profiler will be made. These estimates will be obtained from simple models developed from previous comparisons with UAV data during the ShUREX2016-2017 campaigns. The main scientific objective will be to test the consistency of the different estimates of the three instruments. Radiosondes will be launched to get information about the background atmosphere conditions during CBL events and to evaluate the applicability of the Thorpe method use to estimate ε in stratified conditions.
1) This project is conditional on obtaining Kakenhi funding for the lidar lease.
2) This project is part of the ShURLEX campaign proposed by Prof. Kantha and should be scheduled accordingly. However, if the ShURLEX campaign cannot be conducted due to sanitary conditions, and if the Doppler lidar is granted by Kakenhi fundings, this project is proposed by default, as an alternative to the ShURLEX campaign in 2022.

◆現在までの成果と期待される成果(200～400字程度)：

We expect original results from simultaneous and colocated measurements of TKE dissipation rates ε from the radars, lidar and radiosondes in convective boundary layers. Cross-comparisons will allow us to evaluate the performance of the instruments, models and methods to estimate ε. Depending on the results obtained with the lidar, new perspectives on the validity of the radar, lidar and radiosonde models will be obtained. This project would be strongly enhanced by direct estimates of ε from UAV data, used as a reference and expected to be obtained during the ShURLEX2022 campaign. The use of a scanning Doppler lidar will also allow us to compare vertical wind measurements with radar techniques and to study the horizontal inhomogeneity of the wind field in the CBL.

◆研究計画(300～500字程度)：

The plan is to conduct simultaneous observations with the three instruments. It is proposed to operate the MU radar at a high time resolution (12-24 s) and in range imaging mode during CBL formation during the day (say, 06:00 to 16:00 LT) for about 10 selected days during the time slot reserved for ShURLEX. The MU radar parameters are those usually applied for range imaging. The LQ7 wind profiler will be operated in routine mode, no change is required. The focus will be on Doppler lidar operations to adjust observational parameters and collect data to estimate the desired atmospheric parameters.

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Category: ☑ A. MUR Troposphere/Stratosphere ☐ B. MUR Mesosphere/Ionosphere
☐ C. EAR Troposphere/Stratosphere ☐ D. EAR Mesosphere/Ionosphere ☐ E. Others

MU Radar (MUR) usage

Observation Mode: ☑ Tr./St. Standard ☐ Me. Standard ☐ Iono. Standard
☐ E-Region FAI ☐ F-Region FAI ☑ Interferometry ☐ Meteor ☐ Others

Expected Period (Month): June

Usage time other than standard mode: ~100 hours

Equatorial Atmosphere Radar (EAR) usage

Observation Mode: ☐ Tr./St. Standard ☐ E/F-Region FAI Standard
☐ Interferometry(FDI) ☐ RASS ☐ Others

Expected Period (Month):

Usage time other than standard mode: hours

Other facilities ☐ Ionosonde ☑ Surface weather instrument ☐ Raingauge ☑ Boundary layer radar
☐ Meteor radar ☐ Others

Remarks (Details of what is described above)

In Range imaging mode: 5 equally spaced frequencies from 46.0 MHz to 47.0 MHz. 3 beams (0,0), (0,10), (90, 10), 1 channel, 16-bit optimal code (subpulse duration 1 us), NCOH=16 or 32, NFFT=128, NGATE=128. The usage time is approximative. It is based on the use of the MU radar during day time (~10 hours) for about 10 days.

Number of Radiosondes: 20

Planned schedule of visit to the site

The observations will be made during the ShURLEX 2022 campaign if conducted (~June 2022), or during the time slot of the campaign if not conducted due to sanitary conditions. An additional constraint is the delivery time of the lidar from EKO company. If delayed, any available time during the summer period will be convenient (period expected to be conducive to the deepest CBL events).

Financial support (Fill in type, title, and P.I. of research budget related to this proposal)

The project is expected to be funded by Kikenhi Kiban B submitted in September 2021. Additional radiosondes (20) are already available from INSU funding (CNRS, France, 2020). These sondes are expected to be used during ShURLEX2022.