GRUAN Report 5

Cloud observations

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GRUAN

GCOS Reference Upper-Air Network

GRUAN Report 5

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Table of contents

1. Introduction

- Originally, there were two very different motivations:
  - i) For **satellite** data calibration and validation purposes, **cloud amount information with radiosonde GDP profiles** is very useful, to identify clear-sky conditions → the reporting recommendations of already available cloud observations at GRUAN sites
  - ii) For improvement of the **uncertainty evaluation of radiosonde T and RH GDPs**, obtaining information on solar radiation which is a function not only of solar elevation angle and temperature sensor orientation but also of **cloud properties** above, below, and around the radiosonde

- Discussions went beyond the above two toward:
  - Ideal instrumentations toward vertically resolved cloud-related GDPs
  - **GCOS Essential Climate Variable (ECVs) for clouds** include:
    - Cloud Amount, Cloud Top Pressure, Cloud Top Temperature, Cloud Optical Depth, Cloud Water Path (liquid/ice), and Cloud Effective Particle Radius (liquid and ice)

- Thus, GRUAN RP No.5 summarizes:
  - i) recommendations for cloud obs. reporting
  - ii) recommendations for further discussions toward cloud-related GDPs (incl. improvement of radiosonde T/RH GDPs)

2. Current status of various cloud observations at GRUAN sites

- **Appendix A** provides the results from GRUAN site survey on cloud observations . . . Of the total of 13 sites:
  - 8 sites that currently do manual (visual) cloud observations, and among them, 6 sites have already been reporting as WMO code, etc.
  - Some sites indicated the availability of automated instrumentation
  - 3 sites do not have any kind of routine cloud observations program
- For data providers (sites):
  - Use either "WeatherCondition.SynopClouds" or "WeatherCondition.CloudsText" or "WeatherCondition.Comment"
- For GDP data users:
  - Cloud info can be found in either "g.SurfaceObs.SynopClouds" or "g.SurfaceObs.CloudsText" or "g.SurfaceObs.Comment"

- **Recommendations:** All the future versions of the GDPs (for all radiosonde instruments) shall include cloud information that has already existed in the GMDB.

3. Manual/visual cloud observation information

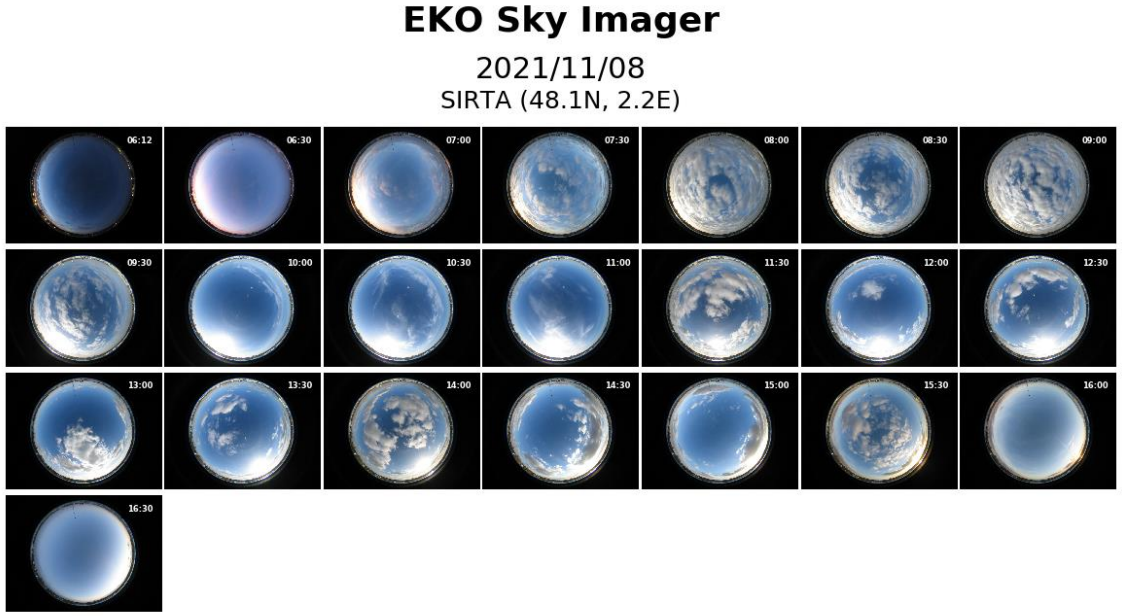
- Manual (i.e. visual) cloud observations include **the cloud cover in octas**, **cloud-base height**, and **cloud type**
- These observations have historically been conducted at sites operated by national meteorological services for many years and are still being made at many sites all over the world (incl. some GRUAN sites)
- **Appendix B** provides a very quick guide to the “WMO Manual on Codes” (WMO, 2017) for cloud information manually obtained

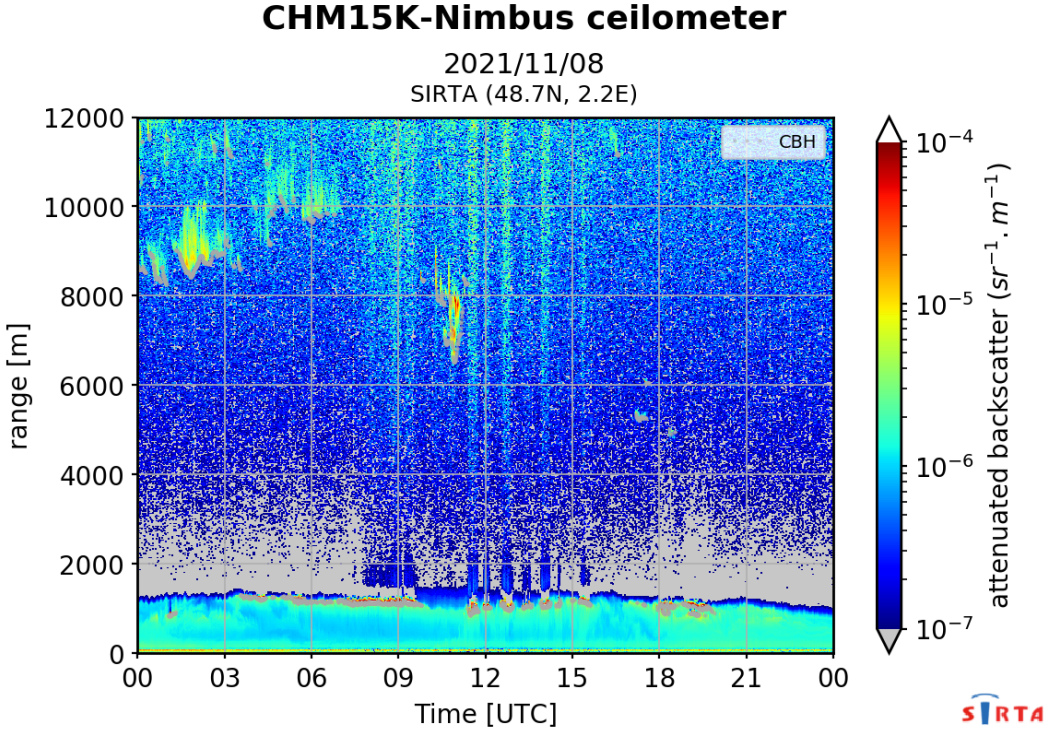
- The manual cloud observations are inherently subjective, and thus have issues
- Also, manual cloud reporting according to WMO coding requires a certain meteorological background and training that personnel at research associated sites often do not have
- But, manual cloud observations play an important role as indicated by many peer-reviewed studies, and thus are very useful

- **Recommendations:**
  - Cloud amount information manually obtained at radiosonde launch time at GRUAN sites shall be reported
  - Reporting format should preferably be consistent with octas (see Appendix B)
  - If manual observations are not available at the site but are available from “nearby” sites, they can be considered

4. Automated ground-based cloud observations

- WMO (WMO, 2017) also presents a **laser ceilometer**, **pyrometer**, and **sky camera** as three examples of the “instrumental measurements of cloud amount”.





Sky-imager pictures (above) and ceilometer measurements (right) on November 8, 2021 taken at SIRTA site (48.1N, 2.2E) (or GRUAN Trappes Palaiseau site)

4. Automated ground-based cloud observations

- **Recommendations:**
- For those sites that have ceilometer, sky imager and/or other combination of remote sensing instruments that are capable of providing cloud cover measurements,
  - (i) GRUAN LC and the sites should consider to archive and disseminate those data as ancillary measurements only (i.e. not a GDP with uncertainty evaluation) for the radiosonde GDPs
  - (ii) GRUAN should consider studying and producing a guide to the reporting, interpretation and value of such multi-instrument cloud information
  - (iii) the Task Team on Ground-based Remote Sensing Measurements shall lead this activity and keep in mind future cloud GDP development

5. In-situ cloud instruments flown together with radiosondes

- There are several balloon-borne particle instruments, measuring backscatter from particles (i.e. size and density information), size distribution, phase of cloud particles (droplet or ice), and cloud particle images (i.e. shape of ice crystals)
- Also, there are many ways to infer the presence of clouds indirectly using radiosonde data
- → Possible instrumentations toward vertically resolved cloud-related GDPs, keeping in mind GCOS Essential Climate Variable (ECVs) for clouds ?

- Another motivation is **to reduce uncertainty of radiosonde T and RH GDPs**
  - This is because solar radiation correction is the largest factor for radiosonde temperature uncertainty during daytime flights, and the solar radiation field is strongly affected by cloud distribution below, above, and around the flying radiosonde
  - Thus, taking actual or real time cloud information into account for future versions of radiosonde GDPs could be one avenue to improve the GDPs
  - Also, direct radiation measurements may be more straightforward (e.g. Becker et al., 2020; Kochin et al., 2021)

- **Recommendations:**
  - The GRUAN community shall monitor and report proactively on new instruments to measure cloud extent and classify cloud types and to assess their quality in comparison with existing and established methods/instruments
  - This could be carried out through an active encouragement and call to instrument manufacturers and/or multi-instrument cloud reporting algorithm developers

6. A road to cloud-related GRUAN Data Products (. . . some thoughts)

- The development of cloud-related GDPs, with quantified and traceable uncertainties, can be the results of a joint effort within the GRUAN community
- The most mature measurement techniques and those of most common usage at the GRUAN sites should be considered as a priority and cost-effective option for generating cloud-related GDPs

- The two main goals of GRUAN to act as a reference network for cloud observations would be as follows:
  - (1) Provide ancillary information for the radiosonde GDPs. This is challenging, not easy. . . A possible approach is the integration of ceilometers with total sky imagers or geostationary satellite images to at minimum identify the sky condition and in support of evaluation of the radiosonde GDPs
  - (2) Enhance the level of characterization of the atmospheric column investigated at the GRUAN sites. . . Ceilometers may be the primary option to consider because they are frequently available at GRUAN sites and can provide the cloud height at all tropospheric levels, and derived boundary layer height

7. Summary of the recommendations

- (Sect. 2) All the future versions of the GDPs (for all radiosonde instruments) shall include cloud information that has already existed in the GMDB

- (Sect. 3) Cloud amount information manually obtained at radiosonde launch time at GRUAN sites shall be reported. Reporting format should preferably be consistent with octas (see WMO (2017)) if possible (see also Appendix B). If manual observations are not available at the site but are available from “nearby” sites, they can be considered. However, validity of the “proximity” of useful observation sites needs to be discussed in the GRUAN community on a case-by-case basis.

7. Summary of the recommendations

- (Sect. 4) For those sites that have ceilometer, sky imager and/or other combination of remote sensing instruments that are capable of providing cloud cover measurements,
  - (i) GRUAN LC and the sites should consider to archive and disseminate those data as ancillary measurements only (i.e. not a GDP with uncertainty evaluation) for the radiosonde GDPs
  - (ii) GRUAN should consider studying and producing a guide to the reporting, interpretation and value of such multi-instrument cloud information
  - (iii) the Task Team Ground-based shall lead this activity and keep in mind future cloud GDP development

- (Sect. 5) The GRUAN community shall monitor and report proactively on new instruments to measure cloud extent and classify cloud types and to assess their quality in comparison with existing and established methods/instruments. This could be carried out through an active encouragement and call to instrument manufacturers and/or multi-instrument cloud reporting algorithm developers.

- (Sect. 6) A road to cloud-related GDPs was also presented for future reference