Intelligent All-sky Cameras for Dense Mesoscale Observations

Dr. Ben Pickering, Founder, Wx Labs Ltd

16th April 2026

How did I get here?

– 2012

First website; categorised cloud images

Meteorology obsession begins; 1st WxStation: IROX (UKWeatherShop)

2012 – 2016

UoR MMet, UoOklahoma Exchange Year

Dissertation on wxUAS Sensor Verification

Developed RU Weather Green Screen Forecasts

2016 – 2020

VOLATILITY Storm Chasing w/ dual 360° cameras

PhD on Precipitation Type Measurement Verification

Radar calibration with UAS, CAD & 3D printing

ECMWF Data Assimilation Training Course

Netatmo Study led by J. Coney

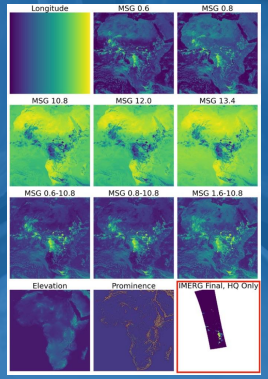
2021 – 2025

Co-founded a wxUAS Startup

Led wxUAS on WesCon–WOEST

Led first patent, pending

KNMI Cabauw Sensor Validation Campaign(s)



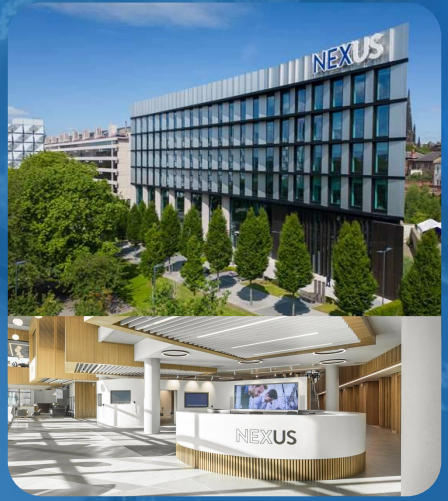
SWIFT Postdoc: RF Machine Learning on MSG

Founded & donated a T-shirt business

Hello Wx Labs

Mission

Accelerate the skill of weather prediction through novel observing technologies



Wx Labs

Five Principles

1) Open-source Guarantee:
if company can no longer serve customers—publish all IP.

2) Observations are the operational bedrock of meteorology and climate science.

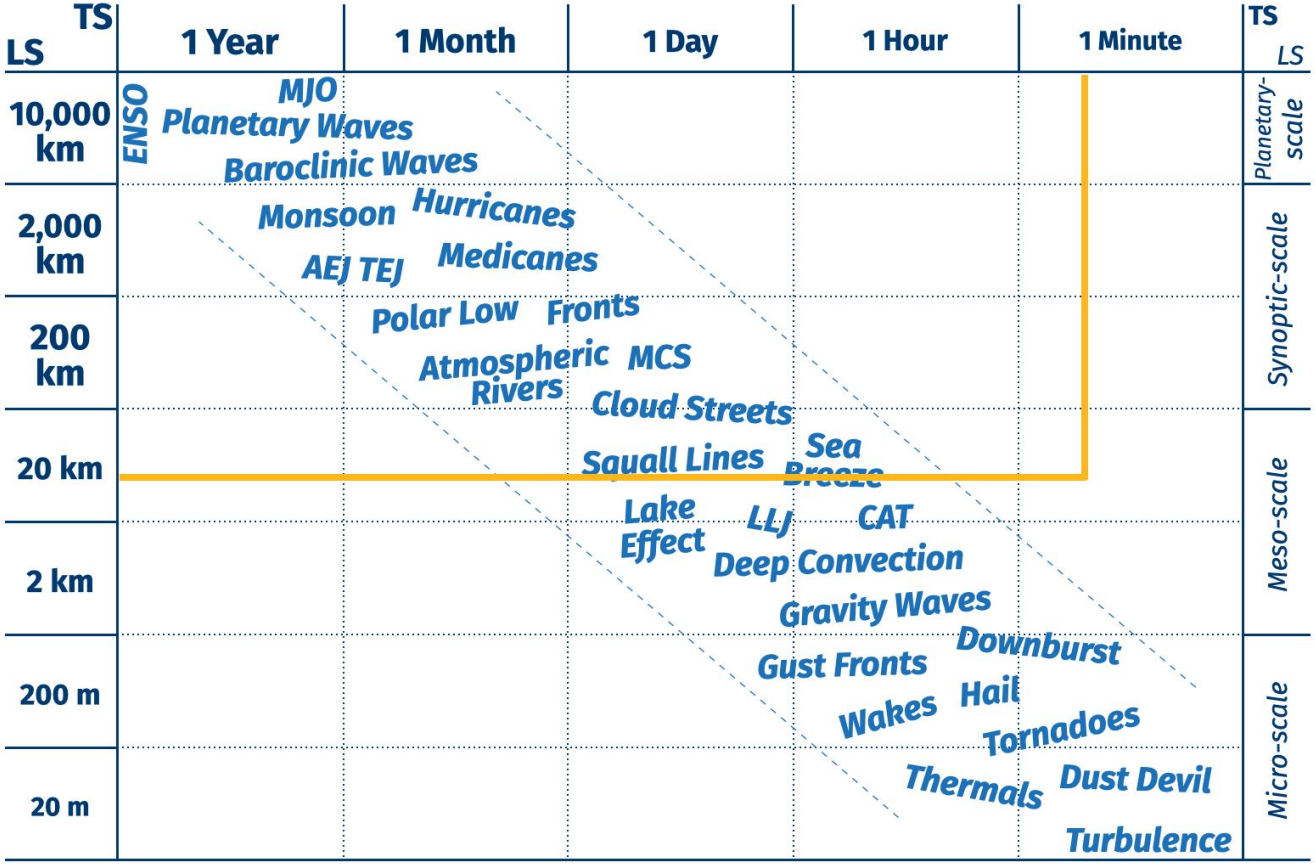
3) Vertical integration—a unified, passionate team with a highly focussed mission.

4) Holistic approach; build systems not things.

5) High operational efficiency for low overheads, thus lower product costs, and a greater global reach.

5th ECMWF-ESA ML ben.pickering@wxlabs.co.uk linkedin.com/in/wxUAS

The Observing ~~Gap~~ Opportunity



Station spacing average for Oklahoma Mesonet, UK Met Office SYNOP, and SwissMetNet

Adapted from Orlanski 1975. BAMS, http://www.jstor.org/stable/26216020

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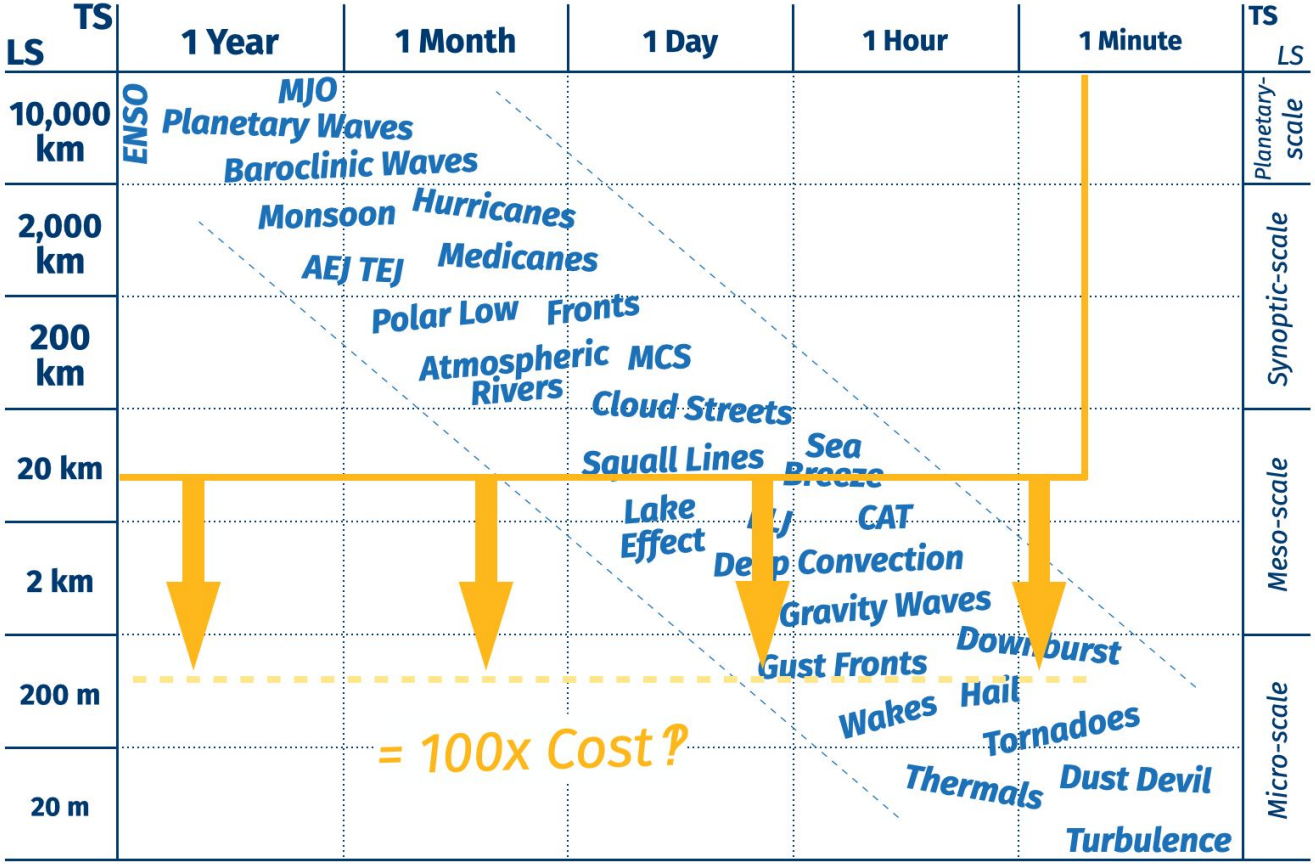

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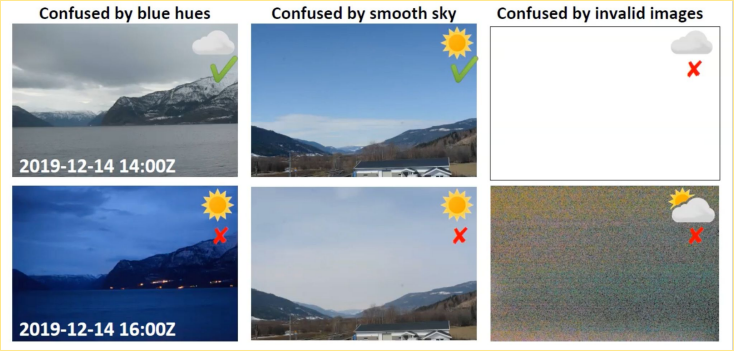
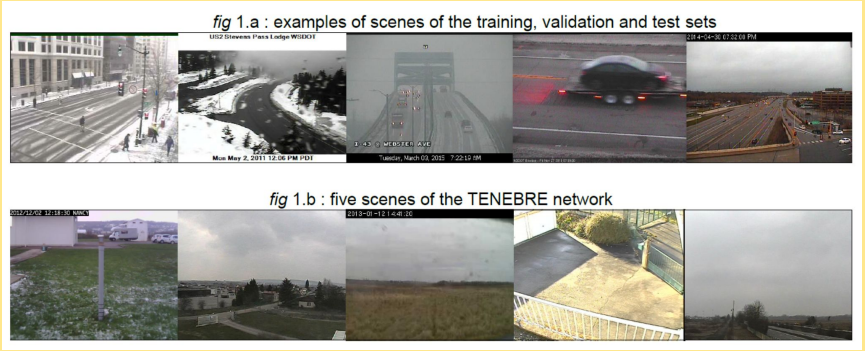
What about Webcams?



Nipen et al., 2020, AMS 100th Conference

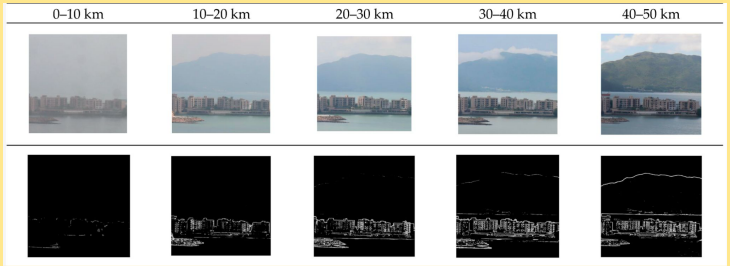


Lepetit et al., 2020. 10th Conf. on Cli. Informatics [hal-02926386v1]

Challenges -> Solutions

1. Image FOV/res differences -> **Standardise**
2. Fraction of sky observed -> **All-sky Camera**
3. Lack of weather context -> **Co-locate Wx Sensors**
4. Class imbalance/long-tail -> **Deploy at Scale**

An Opportunity Exists for Improvement



Lo et al., 2025, MIDI

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Introducing WxVision

360x180º All-sky 7.3 MP Camera

Back-illuminated CMOS

7.3 MP effective sky resolution

0.06º pixel angular resolution (sun/moon 9 px ∅)

~10 W dome heater for condensation

Lightning Detection

40 km range in 14 increments

Unibody Stevenson Screen

White exterior, black interior (opposing spiral)

Simplified manufacture, strong, locally printable

Single cable for Power & Data

Power over Ethernet (PoE+ IEEE 802.3at)

Used widely in CCTV, routers, ecosystem of accessories

Local-hosted web app, cloud server optional

OTA software updates

Pressure

Absolute accuracy 0.5 hPa [1]

Relative accuracy 0.03 hPa [1]

Aspirated Temperature and RH

Absolute accuracy up to ± 0.1 ºC and up to ± 1% [1]

Aspiration vastly improves accuracy + response time (<10s)

[1] Typical accuracy claimed by manufacturer under lab conditions. Real world will be greater and site-dependent. Real-world intercomparison ongoing, contact for collaboration.

2D sonic anemometer compatible with WxStation base is in early development. Acoustic + visual precipitation estimation is in concept phase. Contact for collaboration.

Webcam vs. All-sky Camera

Demo: Equirectangular PANO

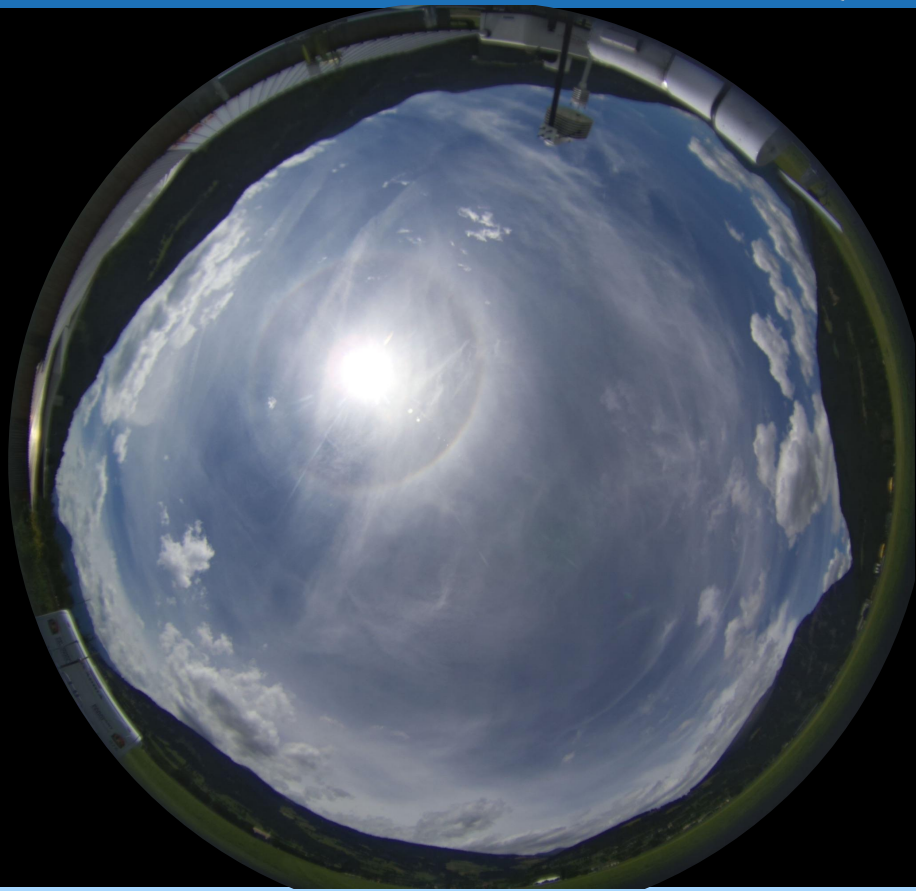
Produced on-device

Many potential applications

360° Demo

All-sky Imagery: Potential Applications

- Persistent contrail detection and attribution



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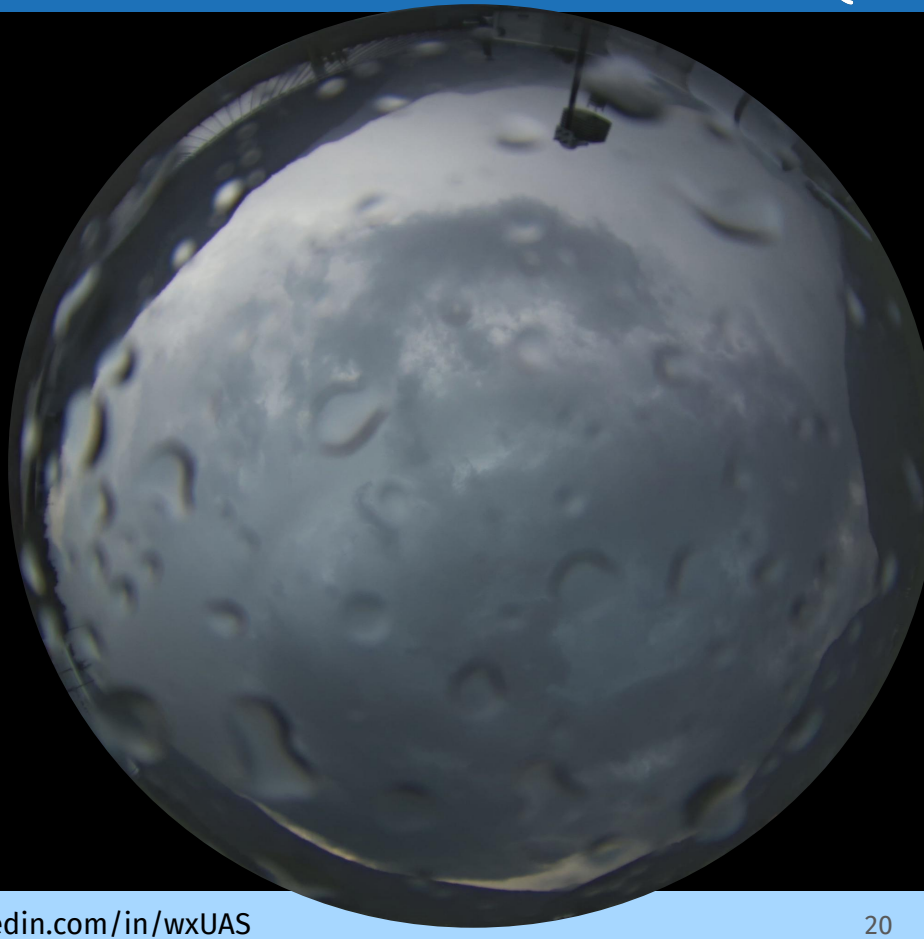

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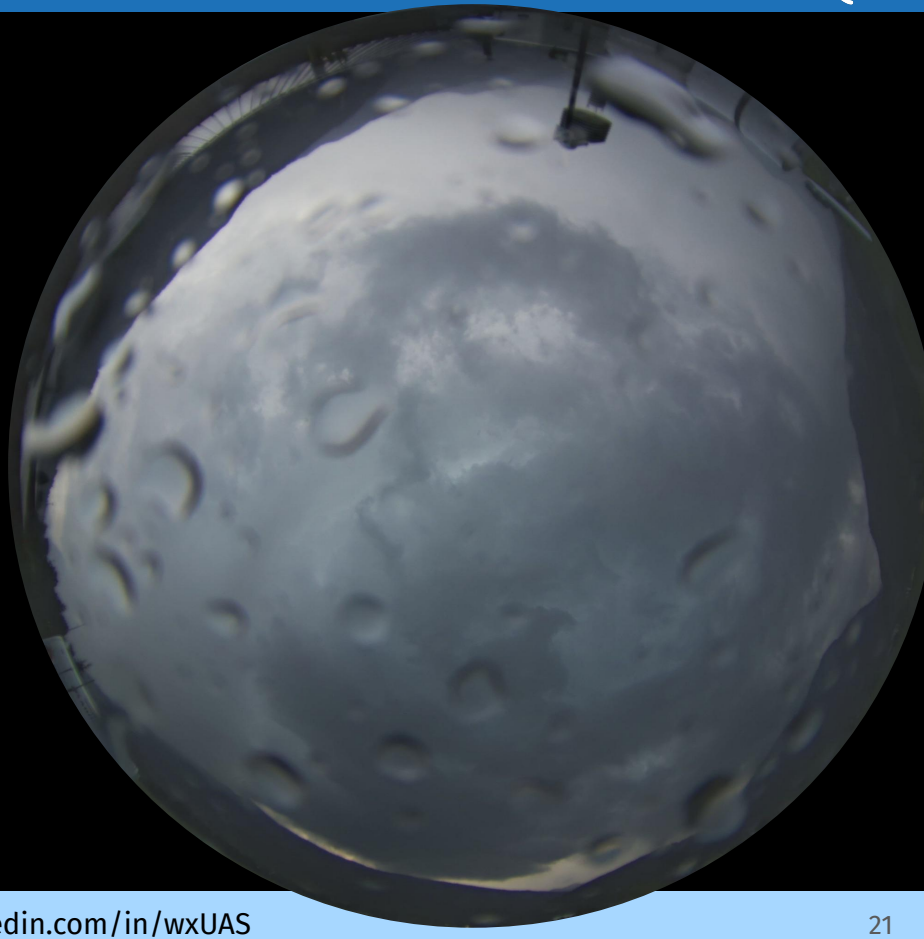

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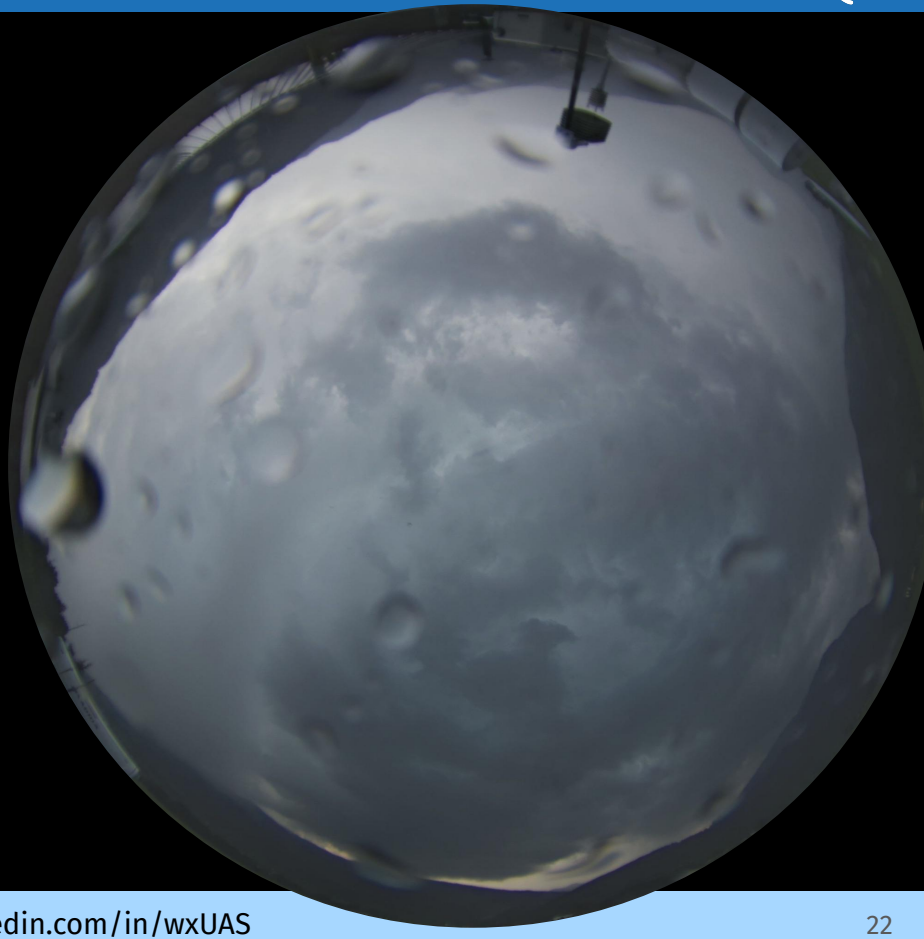

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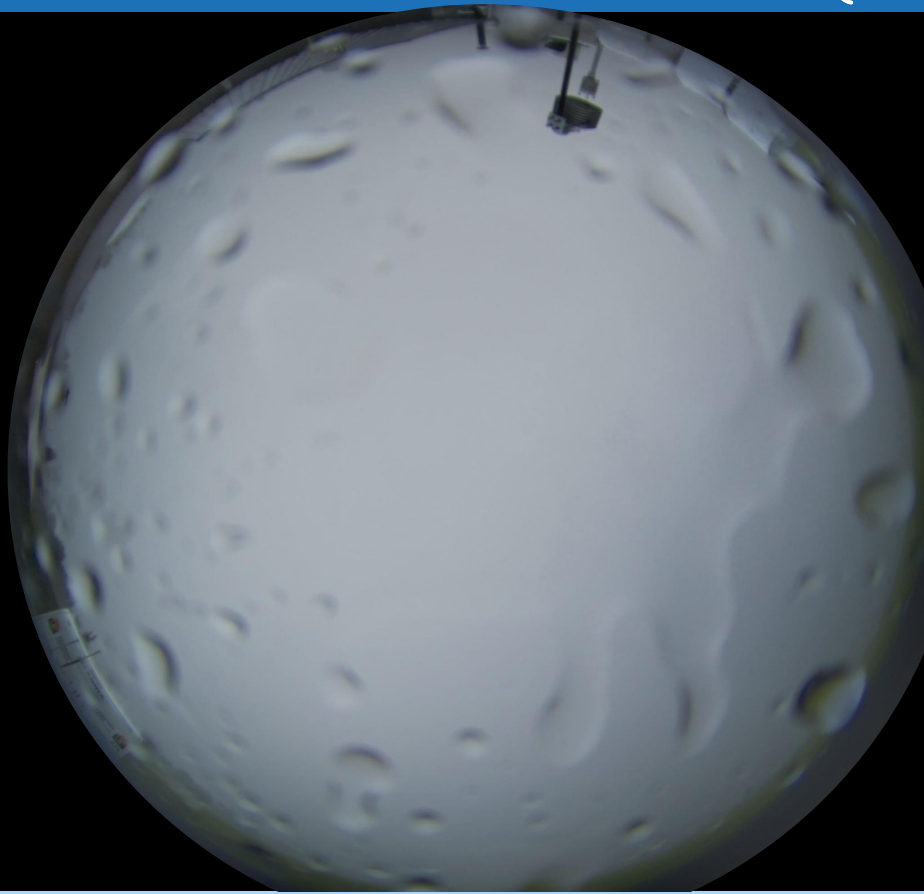
- Approximate visibility *
- Precipitation type (w/ temperature & acoustic)



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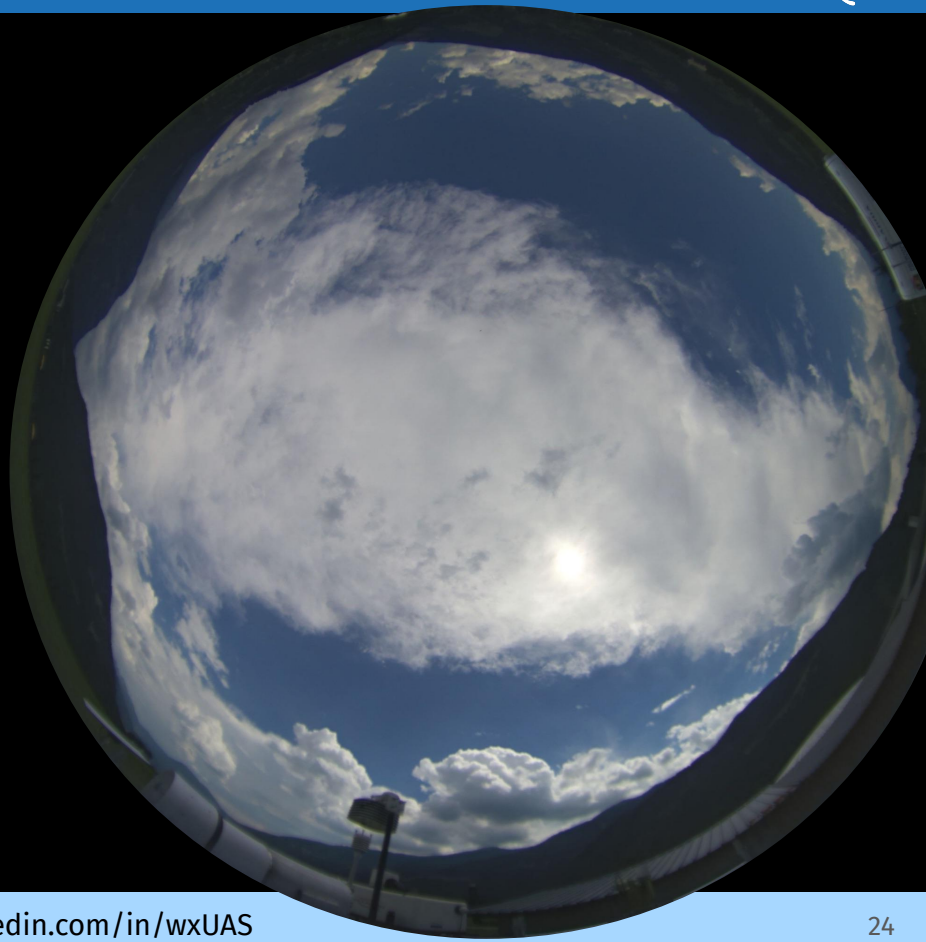

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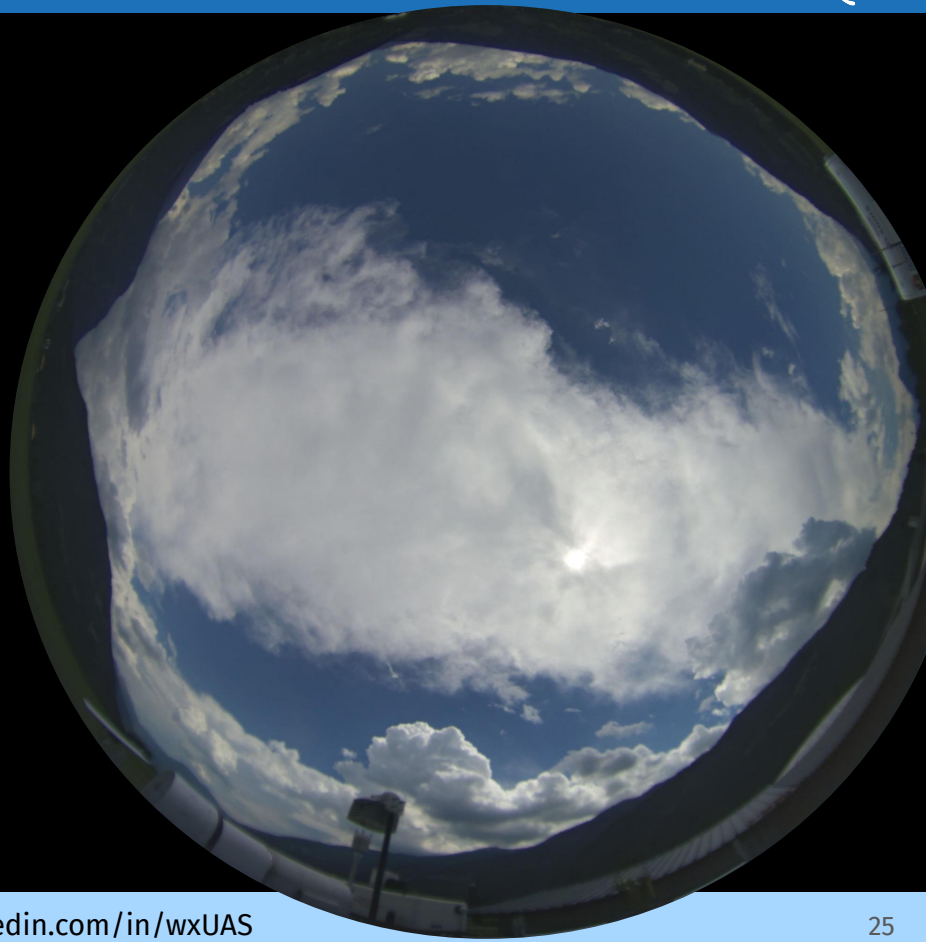

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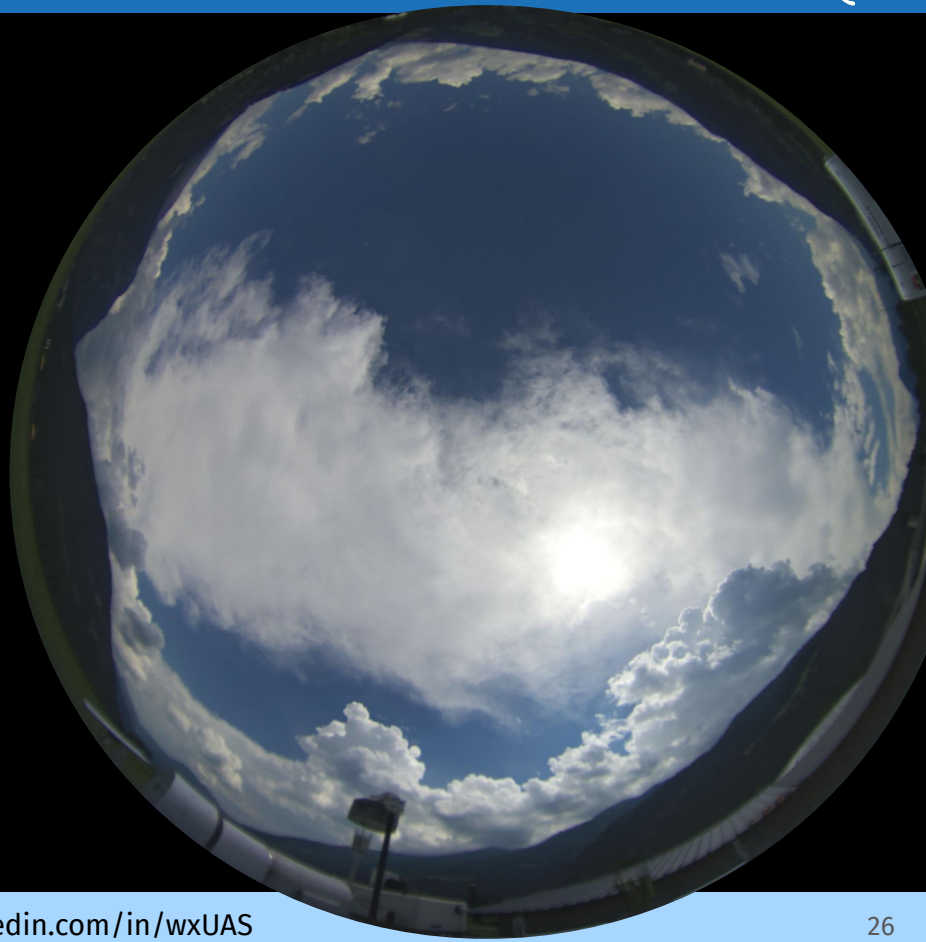

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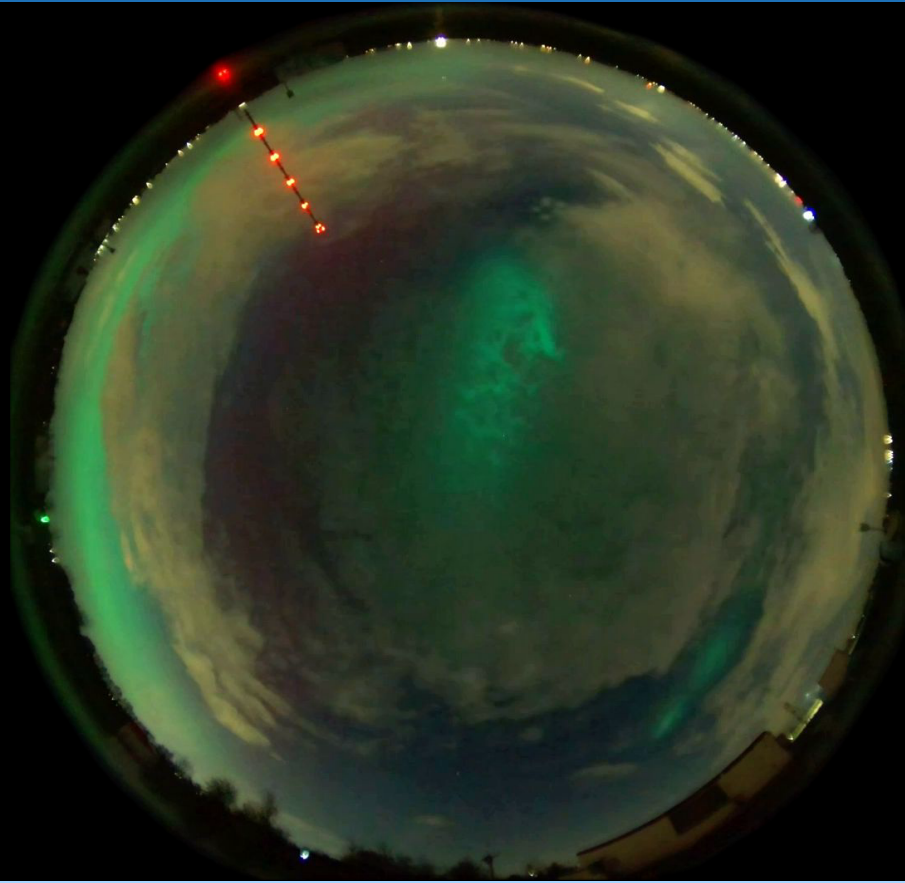

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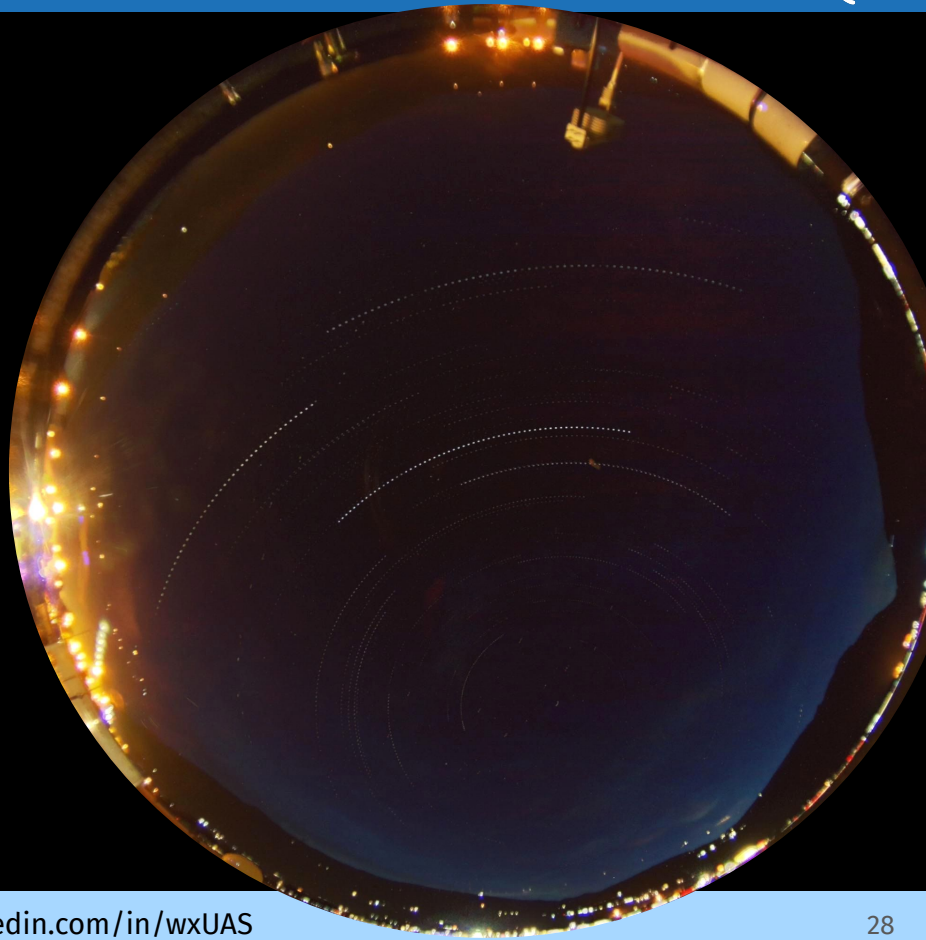

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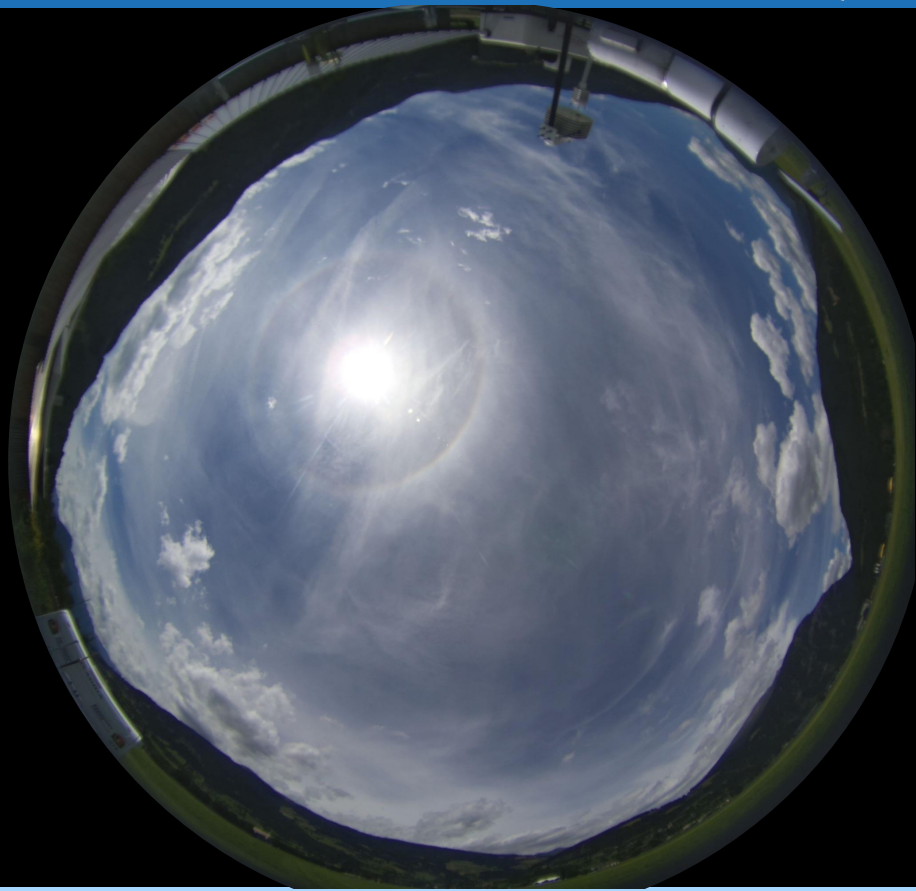
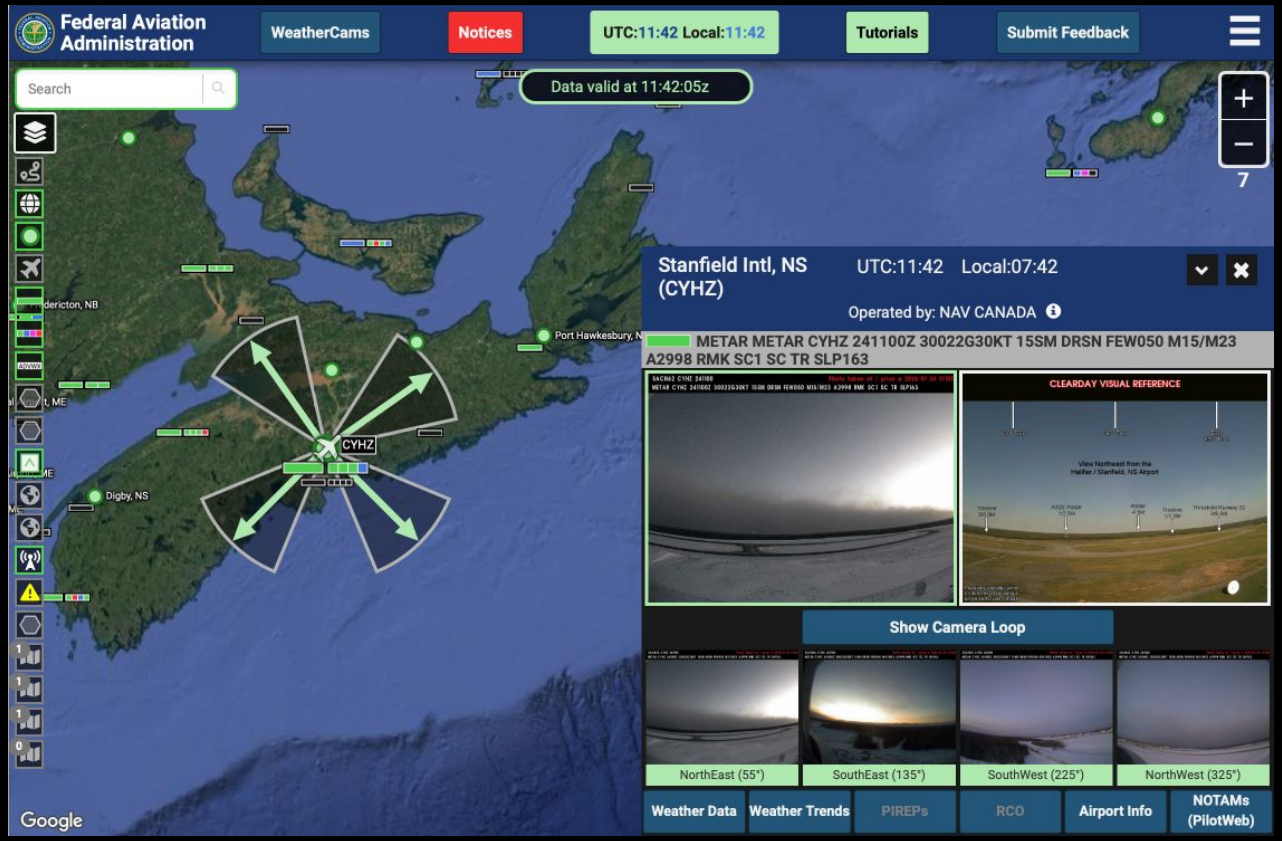
- Solar nowcasting for energy trading
- Education & scientific communication
- Direct assimilation into NWP / AIWP (moonshot)
- Approximate aerosol optical depth *
- Wildfire smoke detection / triangulation
- Volumetric cloud reconstruction
- Light pollution mapping
- Mesocyclone rotation detection
- Sunshine duration
- … and future ideas via OTA software updates



Network Situational Awareness



Networks of all-sky cameras unlock extra capability.

Equivalent of the FAA WeatherCams map tool.

Improve situational awareness for NFOs, SPC, aviation, solar forecasting etc.

Feasible to triangulate hazards such as first smoke plume from wildfires, with >5-min update.

Label landmarks, visual aids (as here) for estimates of visibility.

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TEAMx Deployment, June–September 2025

To improve our understanding of transport and exchange processes, both surface–atmosphere and within the atmosphere, over mountainous terrain.

Many thanks to Phil Rosenberg and James Groves at NCAS for enabling this opportunity!

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

TEAMx

Will be available on CEDA soon!

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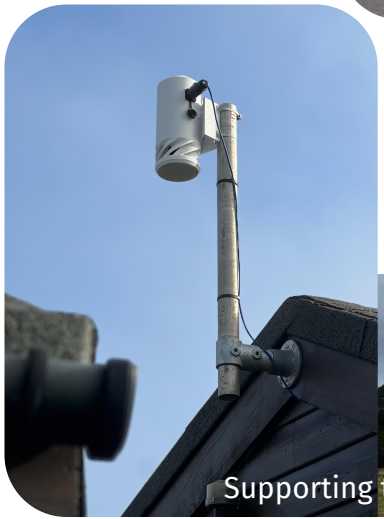
Ongoing Deployments

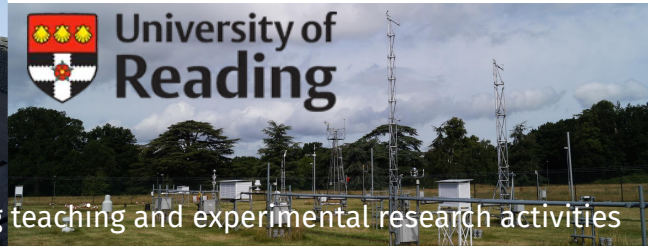
GAMB²LE
Greenland Automated Mass Balance and Boundary Layer Experiment

Preparations for a Greenland ice sheet off-grid observatory



DOOC
Drone Observation Of Clouds

Nowcasting cloud motion for wxUAS interception



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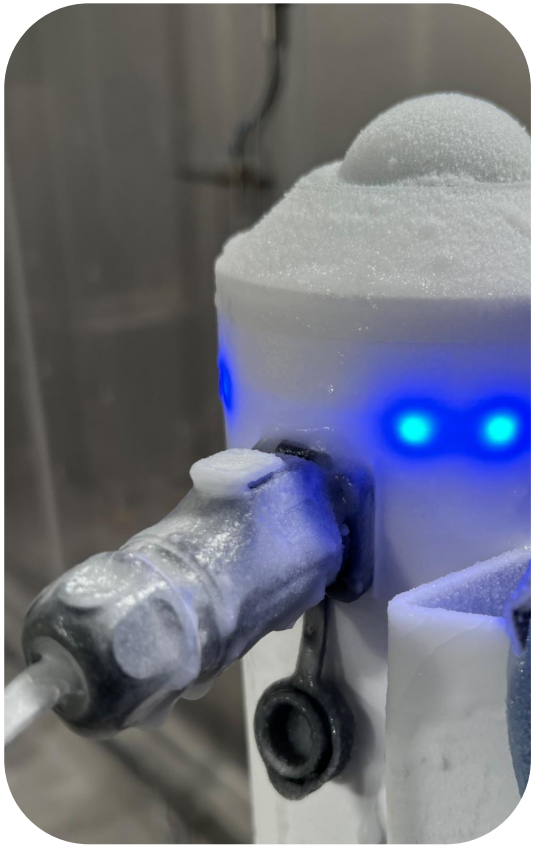
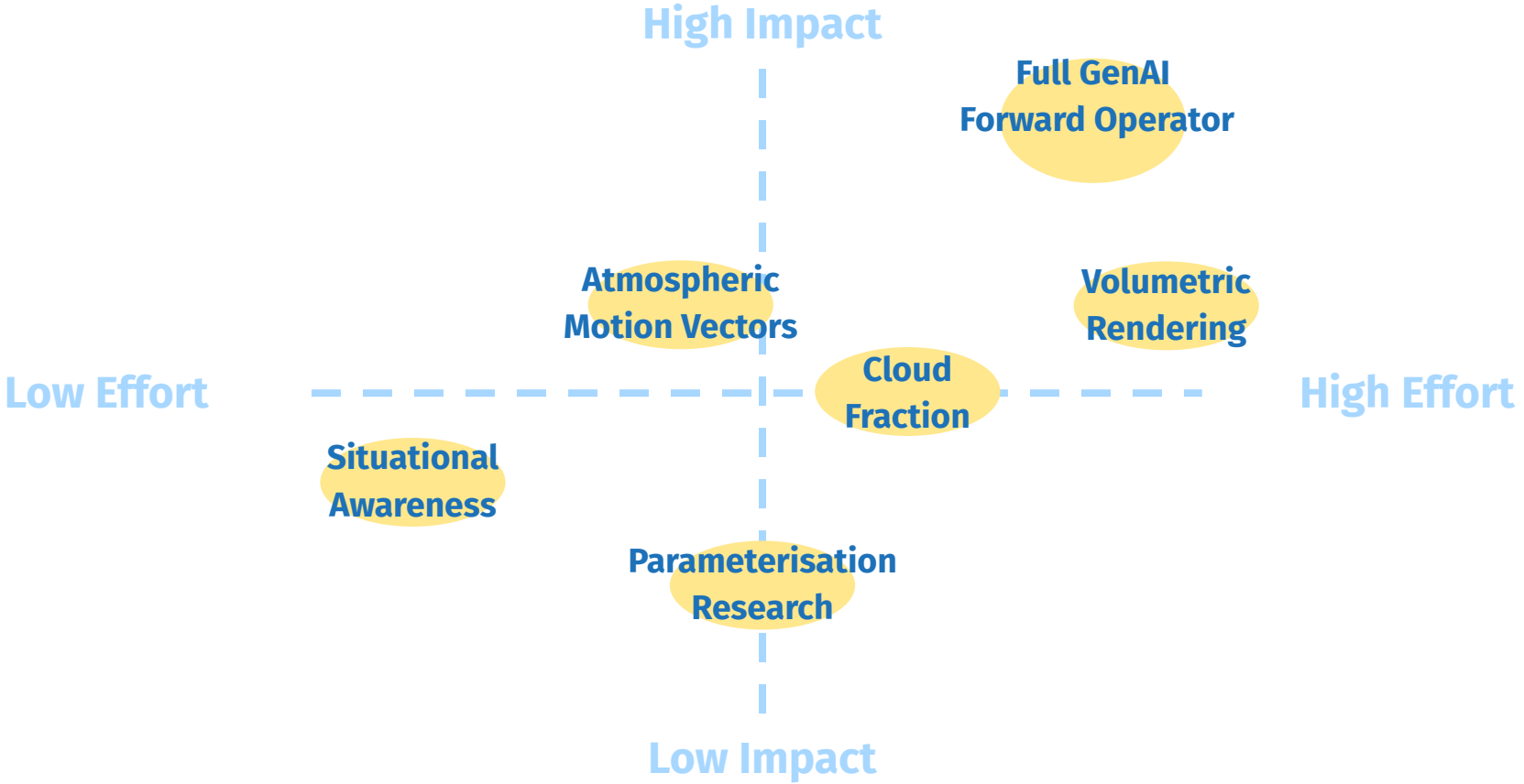
Environmental Testing at –50 °C



Pathways to Impact (FSOI)



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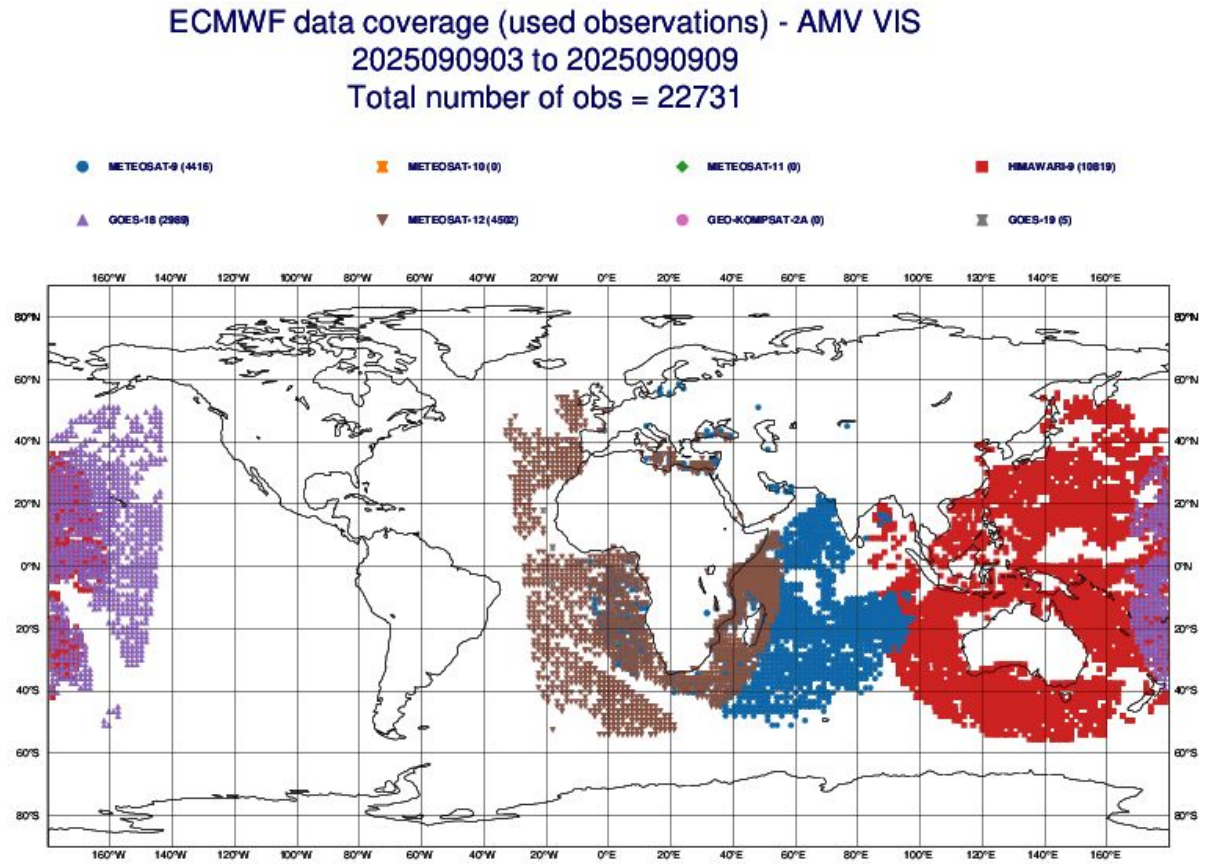
Low-hanging FSOI Fruit: Atmospheric Motion Vectors



AMV (focus on VIS)

1. 10–15 min time intervals (50–90 min at poles).
2. Predominantly cloud tops/highest cloud layer.
3. O–B errors 3–5 m/s (larger for IR/WV), increasing with latitude.
4. Predominantly low latitude (IR+WV better).
5. Predominantly daytime.
6. Predominantly oceanic (ObErr too high inland).
7. 98% discarded (diminishing return).
8. All AWV ≈ 7–11% FSOI

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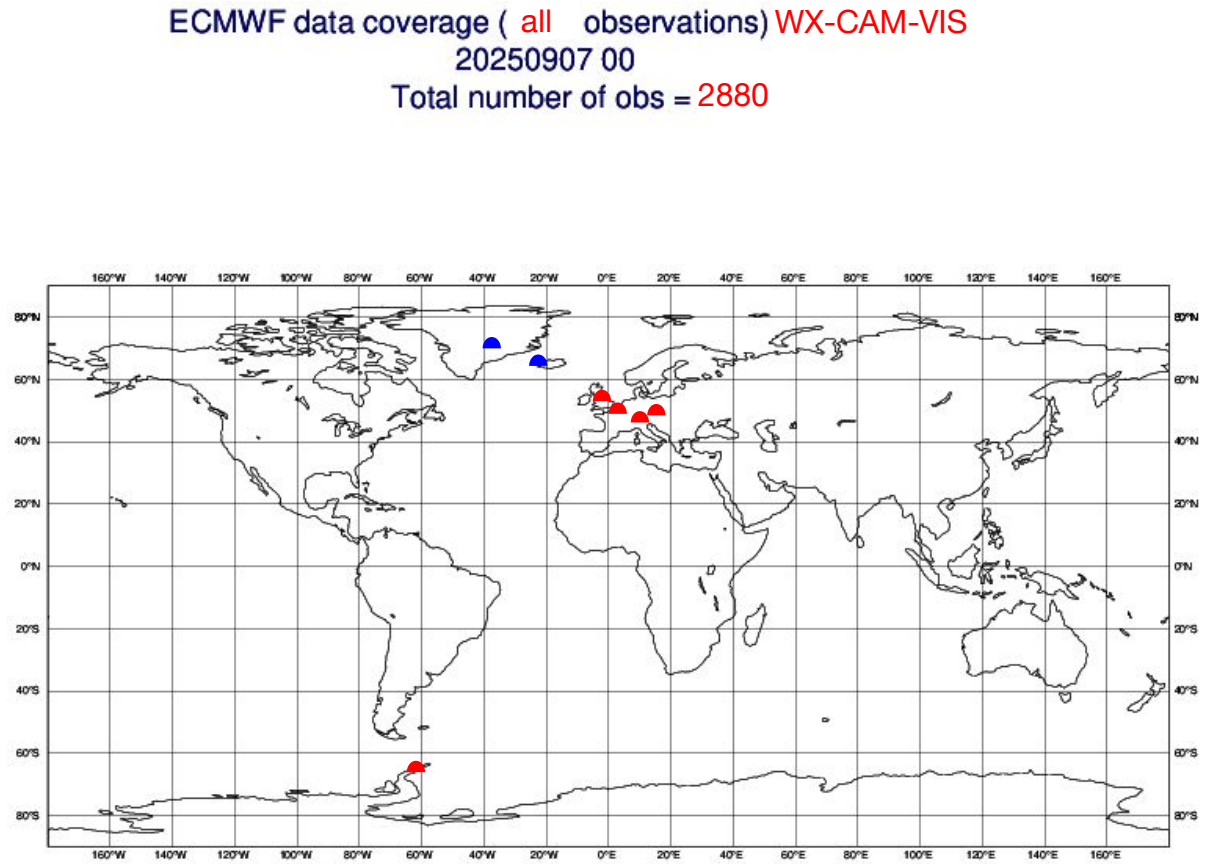

WX CAM VIS

1. **15 sec** to **5 min** time intervals.
2. Predominantly cloud **bases/lowest** cloud layer.
3. O–B errors TBD (likely << 3 m/s). Height estimation with 2+ cameras.
4. Works in **high latitudes**.
5. Works at night (in some conditions, % TBD).
6. Predominantly inland (ship/buoy possible).
7. NWP benefit should scale well with network = **less discarded**.
8. FSOI % TBD.

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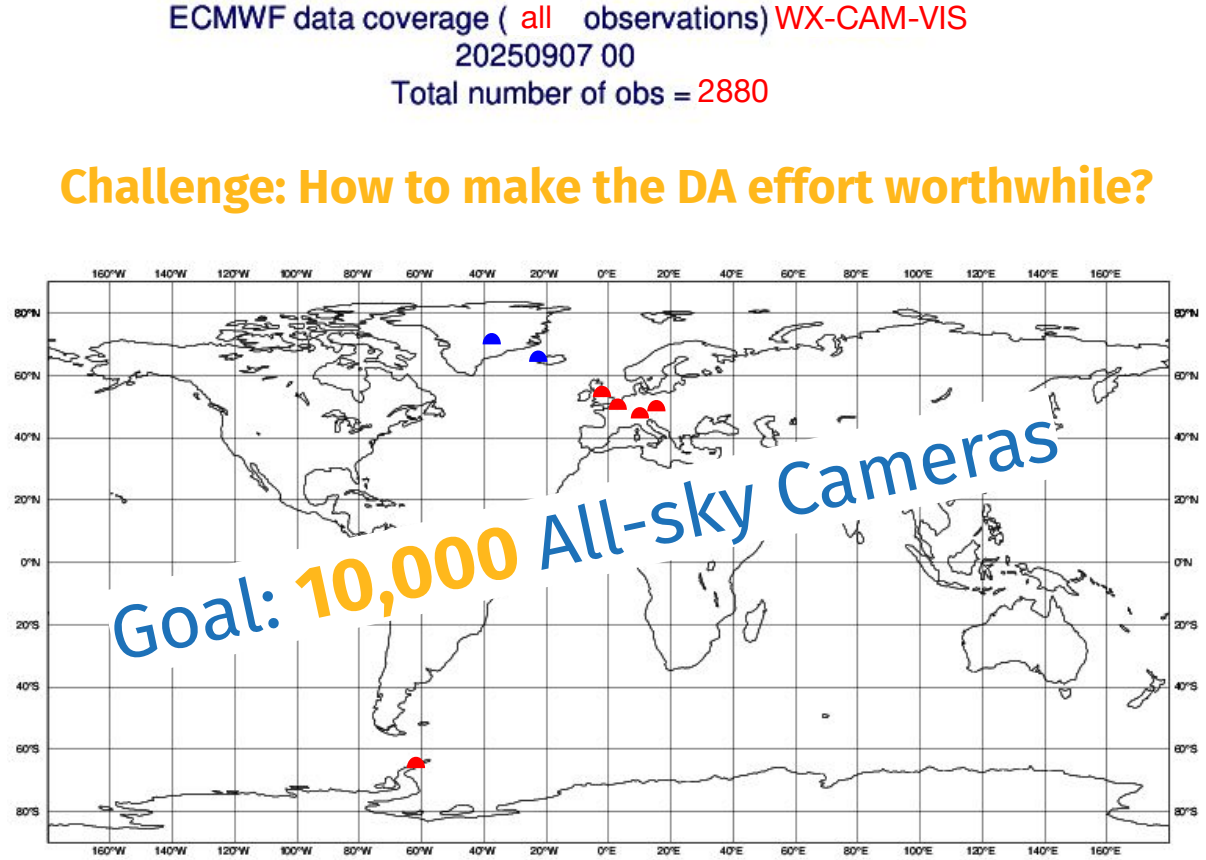

Challenge: How to make the DA effort worthwhile?

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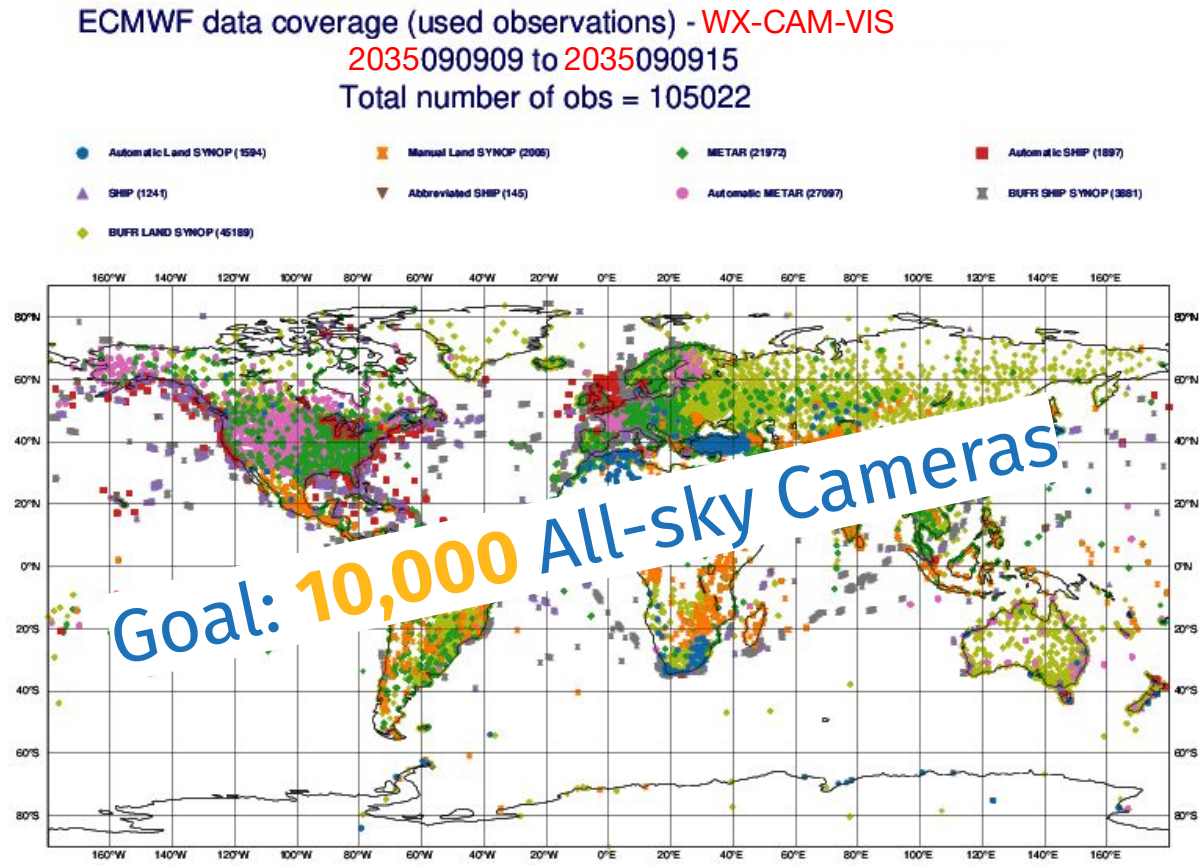

The Plan:

Pilot Trials for Academics, NMHSs.
Expert Feedback to Iterate, Optimise

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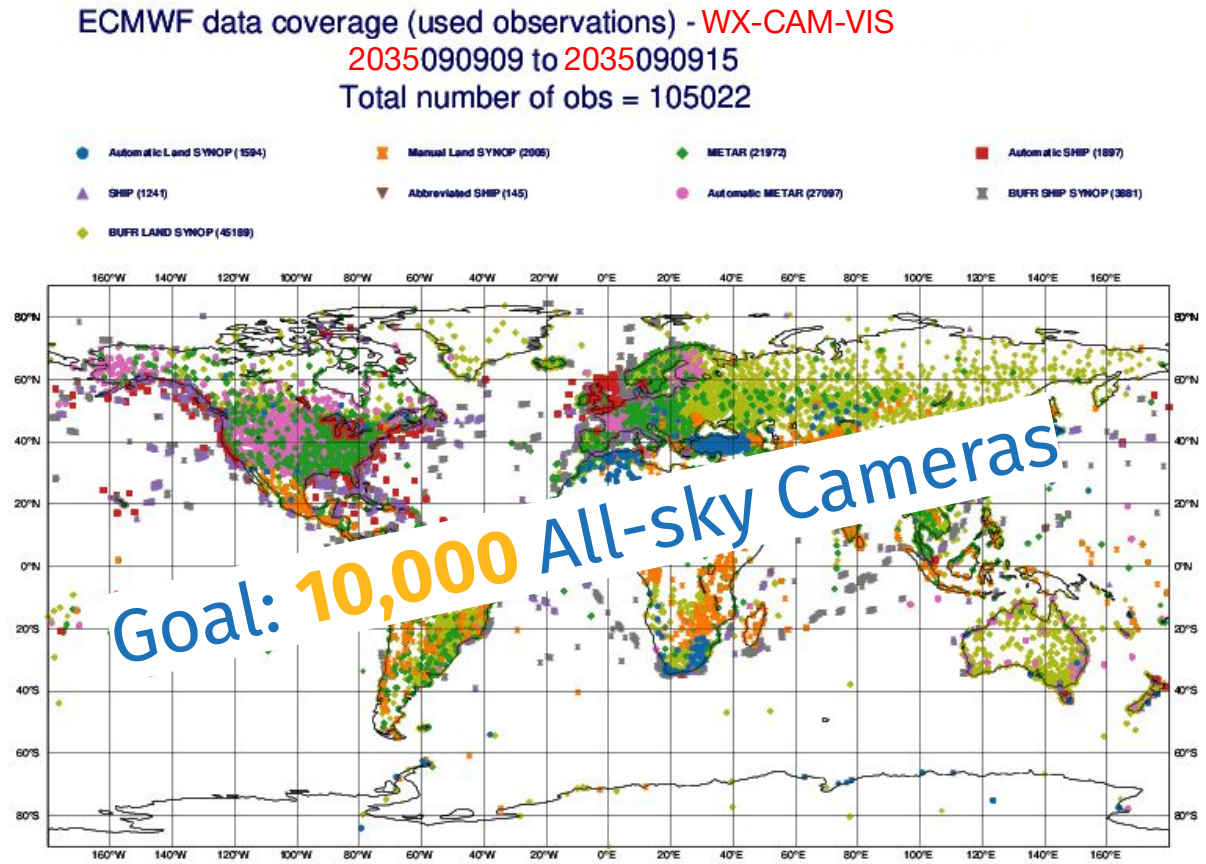

The Plan:

- **Pilot Trials for Academics, NMHSs. Expert Feedback to Iterate, Optimise**
- Larger Network Deployments for NMHSs
- High-end Personal Weather Station (Crowdsourcing)
- Scale up Localised Manufacture; Reduce Total Cost of Ownership
- Data Assimilation Trials (OSE, FSOI)

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Concluding questions for discussion

If this kind of observing network exists at scale in 2035, what do you wish we had started recording in 2026?

What would make an all-sky station output scientifically legible to your ML or DA pipeline, rather than just visually interesting?

What benchmark or pilot problem should devices like this target first to be worth the community's attention?

Thank You!

Follow updates on **LinkedIn**:

or email me directly: **ben.pickering@wxlabs.co.uk**