SKYFORA

Next-generation weather intelligence

Novel uses of GNSS for meteorology

10/23/2022

Skyfora in a nutshell

The company is built on the insight that machine learning and new measurement techniques revolutionize weather forecasting.

Key personnel has decades of experience in weather instrumentation, GPS/GNSS engineering, machine learning and weather forecasting.

Products:

- AI Weather Forecasts for renewable energy, insurance etc
- World's lightest weather sonde
- **GNSS meteorology data**

Staff: 13
Turnover: 255 k€
Funded by: EIC accelerator, European Space Agency, Business Finland, Voima Ventures, Icebreaker VC etc

GNSS and meteorology (until now)

- Radio signals get delayed and bent in the atmosphere
- For GNSS frequencies, zenith dry delay ~2.3 m, wet delay ~0.1-0.5 m
- Since 1990s: ZTD and RO **assimilated** in Numerical weather prediction

Zenith Tropospheric Delay (ZTD)
is a known technology to calculate meteorological parameters (water vapor, pressure and temperature) used as input in numerical weather predictions to improve weather forecasting

Radio Occultation (RO)
is traditionally done with Low Elevation Orbiting (LEO) satellites, and with aircrafts (ARO). The obtained data is used today in meteorology as input in numerical weather predictions.

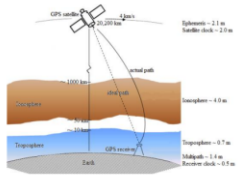


Image credit: Anthony Joseph Kiroe

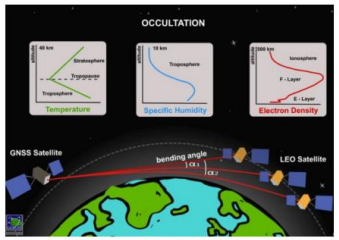
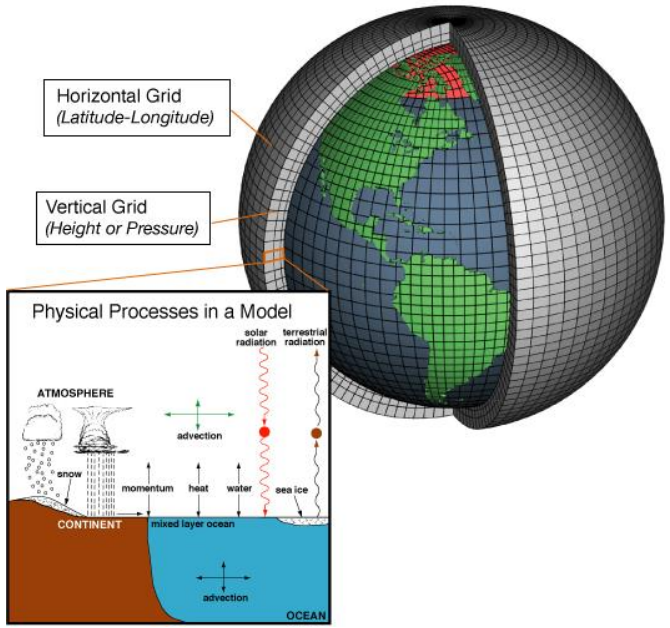


Image credit: https://ggos.org/item/gnss-radio-occultation/



Climate Change makes weather more extreme and less predictable


Wildfires


Heatwaves


Water scarcity


Intensifying Storms


Droughts


Rising Sea Levels


Melting Polar Ice


Floods


New rainfall patterns

The World Bank:
*"Weather-sensitive sectors could benefit over **€160 billion annually** from improved weather intelligence"*

2022 damages:

Hurricane Ian	> $100bn
European drought	> $20bn
Flooding in China	> $12bn
Drought in China	> $8bn
Flooding in Australia	> $7bn

Between 1980 and 2021, weather- and climate-related extremes caused losses estimated at EUR **560 billion** in the EU Member States*

Pakistan floods **displaced 7m** people and caused more than **$30 billion** in damages. Only $5.6 billion covered by insurance. **1739 killed**.

Only 0.004% of atmosphere is measured

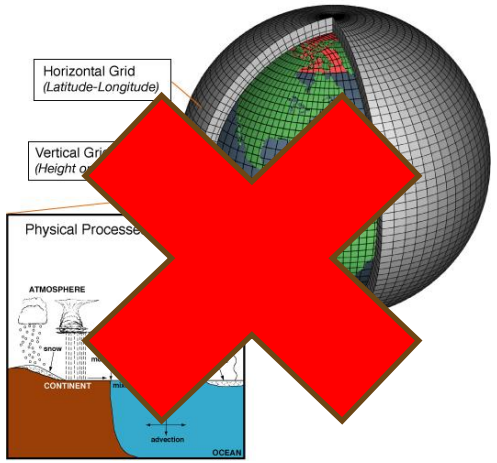
Traditional physical simulations for weather forecasting are insufficient

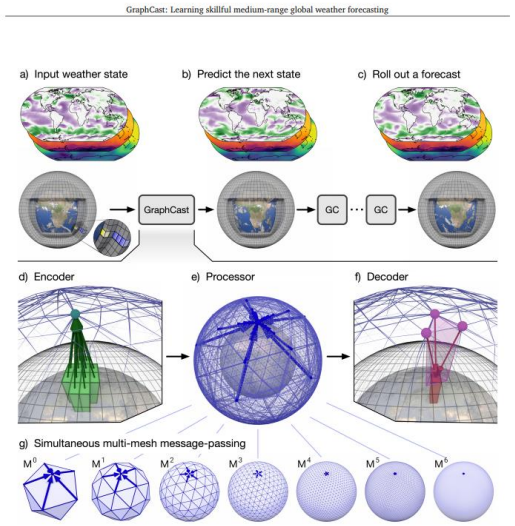
New technologies allow for new approaches

The need is imminent – Industries and governments need to adapt

GNSS and meteorology in the AI era

- Recent breakthrough: graph neural network based weather forecasting is at a par with numerical weather predictions
- AI algorithms are capable of digesting much larger volumes of data than numerical methods





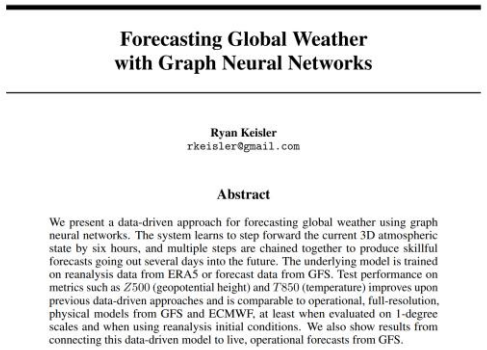


Figure credits: ECMWF, Ryan Keisler, DeepMind

GNSS (AND SATELLITE) DATA VOLUME

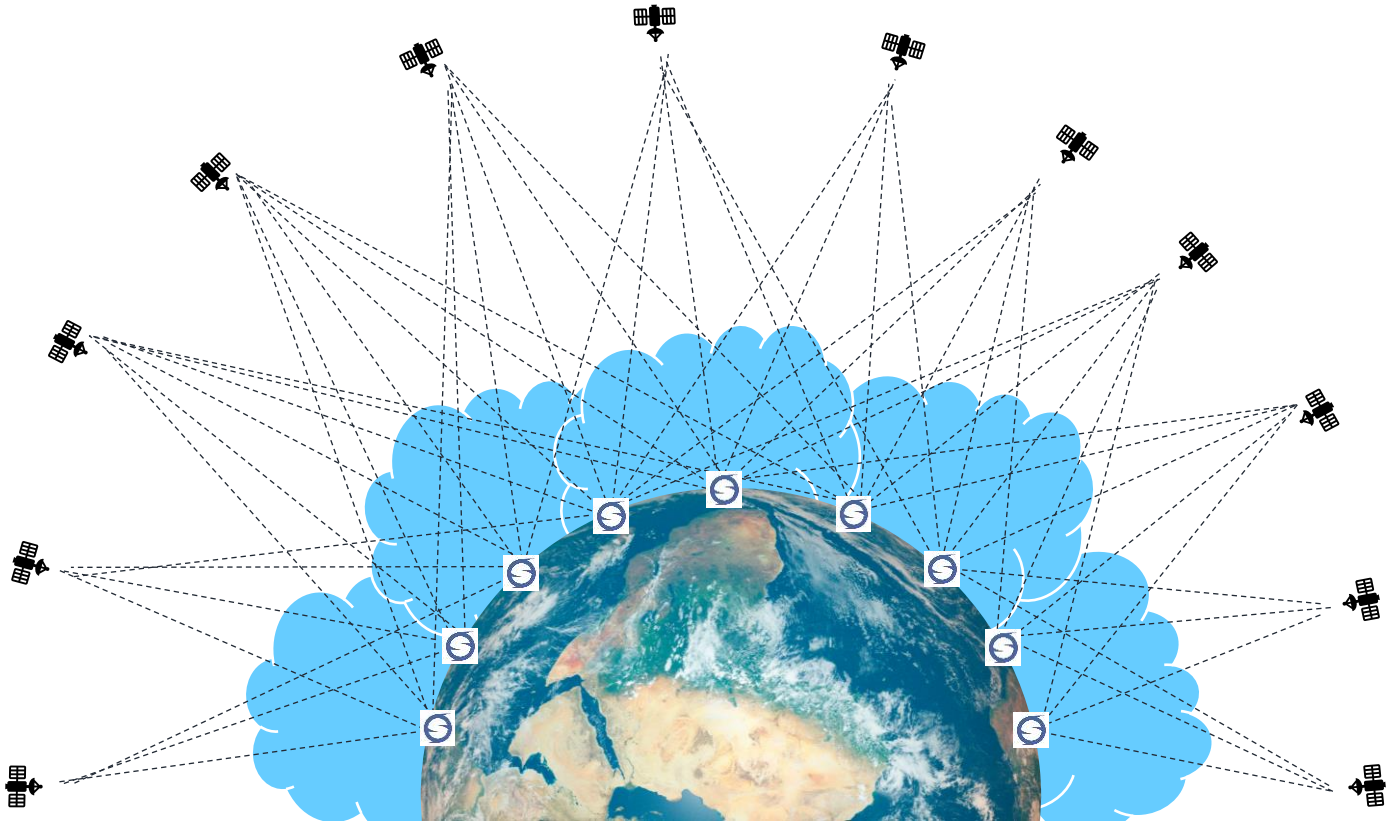
Instrument type	Number	Unique data points per 10 min
Weather stations	10000	10000 * 1 = 10000
Upper-air stations	1000	1000 * 4 * 300 / (24*6) = 8000
Ships	7000	7000 * 1 = 7000
Buoys	1000	1000 * 1 = 1000
Weather radars	500	500 * 1000 = 500 000
Aircraft	3000	3000 * 3 = 9000
Meteorological satellites	30	30 * 10 ch * 100 000 = **30 million**
Research satellites	200	10s of millions
Dual-band GNSS receivers	3 million?	3 million * 40 sat/rec / 3 = **30 million**

The “Tomographic Era” of Weather

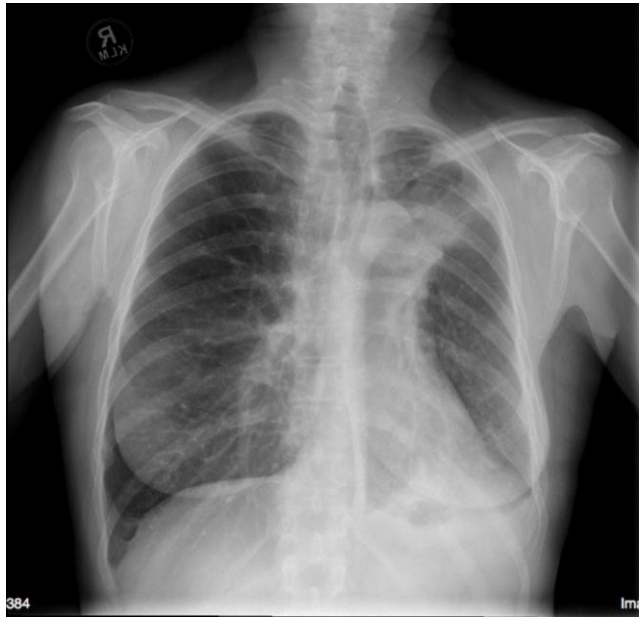
By measuring GNSS signal delays in all directions:

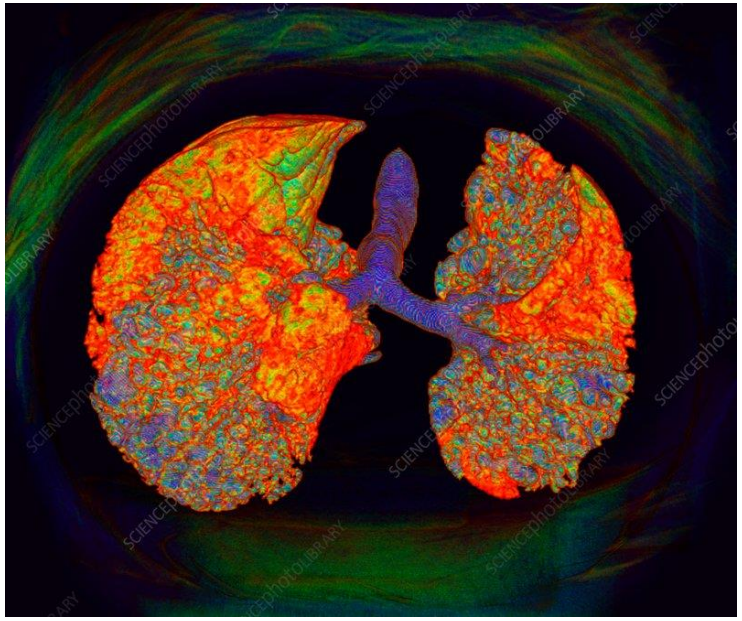
- Much larger volume of data than before from **GNSS slant delays from large number of receivers**
- Humidity, temperature, pressure and wind is imaged clearly in high resolution in 3D
- Relevant information also for space weather
- Instrument and calibration independent solution also good for climate change monitoring
- Made possible by the abundance of dual-band GNSS receivers

~ 40 GNSS satellites visible globally
- GPS, Galileo, Beidou
- Sending on 2 frequencies



Analogy
Medicine



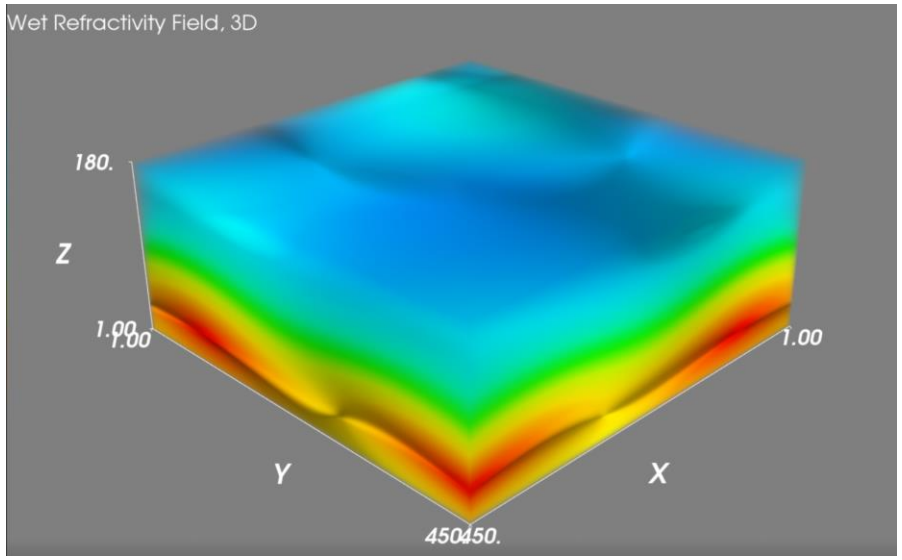


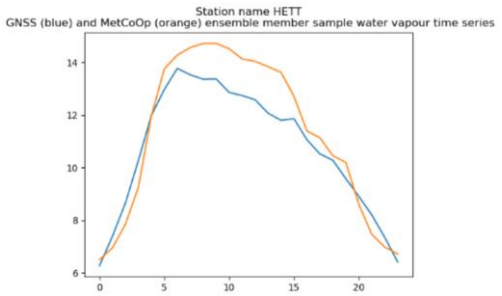
1890s 2D X-ray images

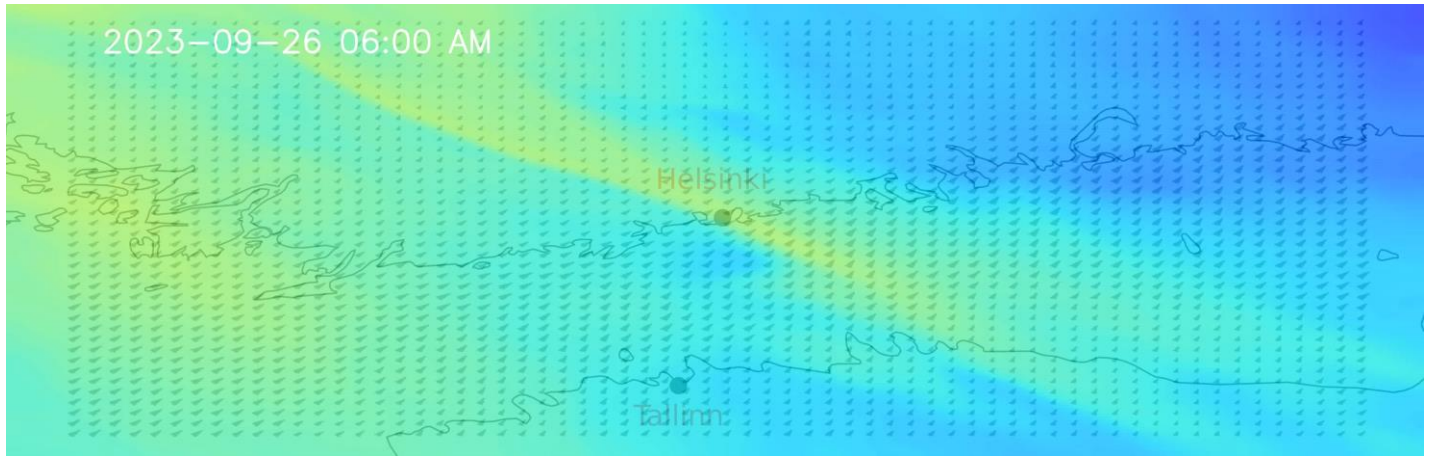
1971- 3D tomography images

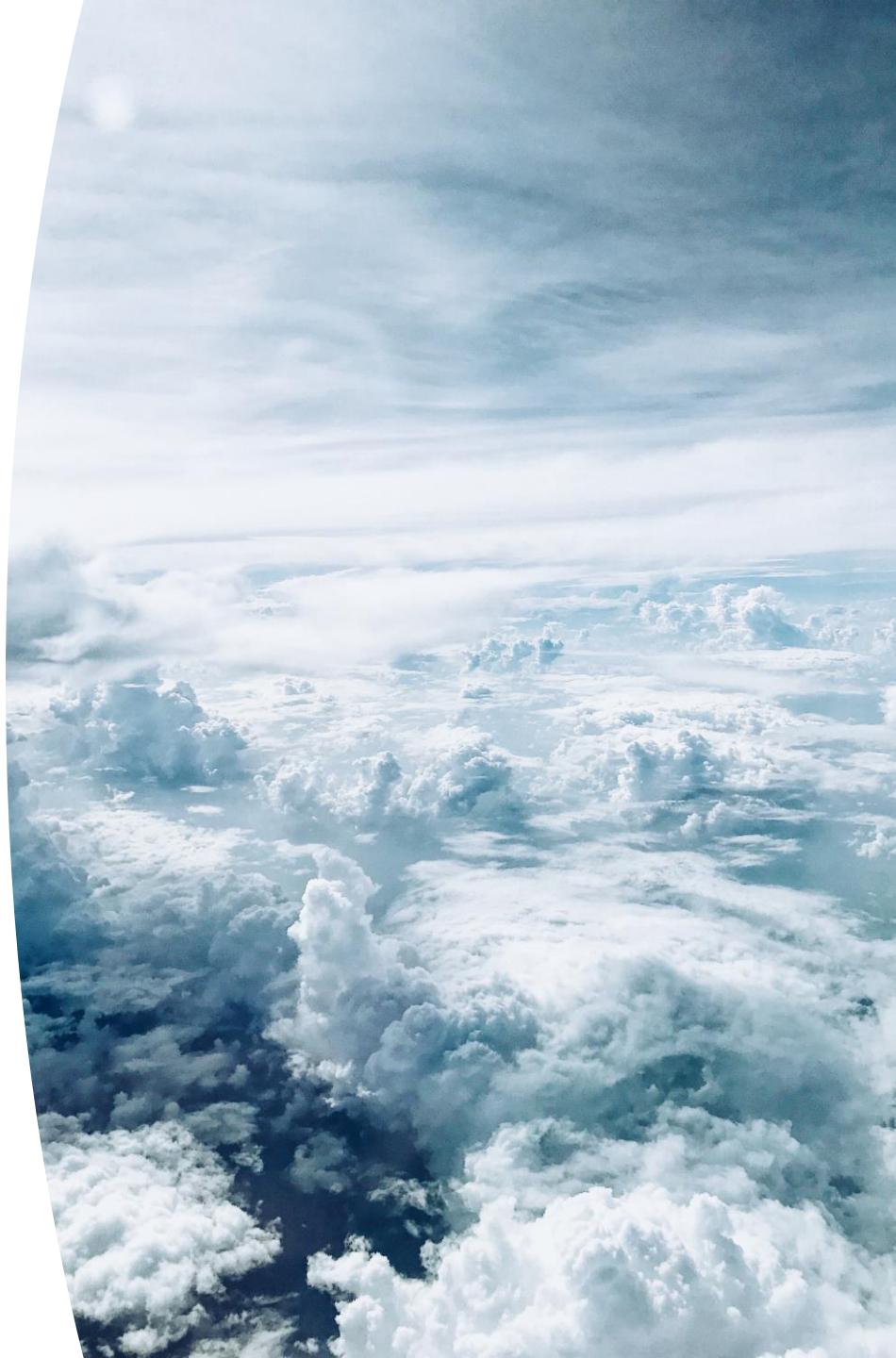
Many types of diseases or tumors can only be seen in tomography images, or they can be seen much earlier for impactful treatment

Wet refractivity in great detail





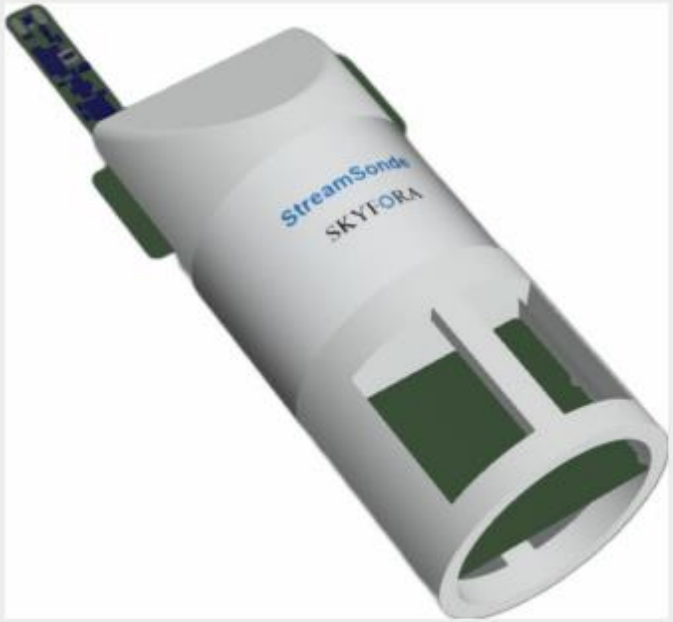




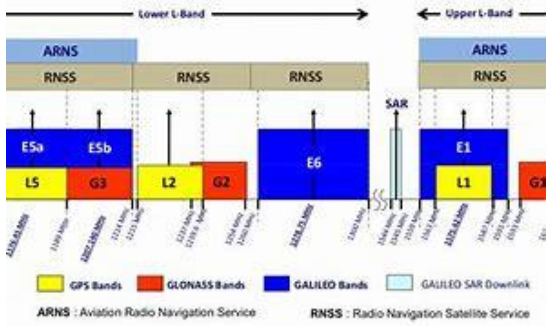
Underlying technology:
Proprietary Receivers and Weather Sensors

Skyfora's GNSS receiver is a low power custom built Dual-band receiver in a 10x10mm form factor

- StreamSondes utilizing dual band GNSS is already in use by NOAA Hurricane Hunters
- Dual band receiver capable of using
  - GPS L1CA & L5
  - Galileo E1B & E5a
  - Beidou B1I, B1C & B2A
  - QZSS L1CA, L1S & L5
  - Navic
- NMEA & RTCM protocols (MSM7 messages)
- GNSS antenna is omni-directional as the orientation of the StreamSonde can not be controlled



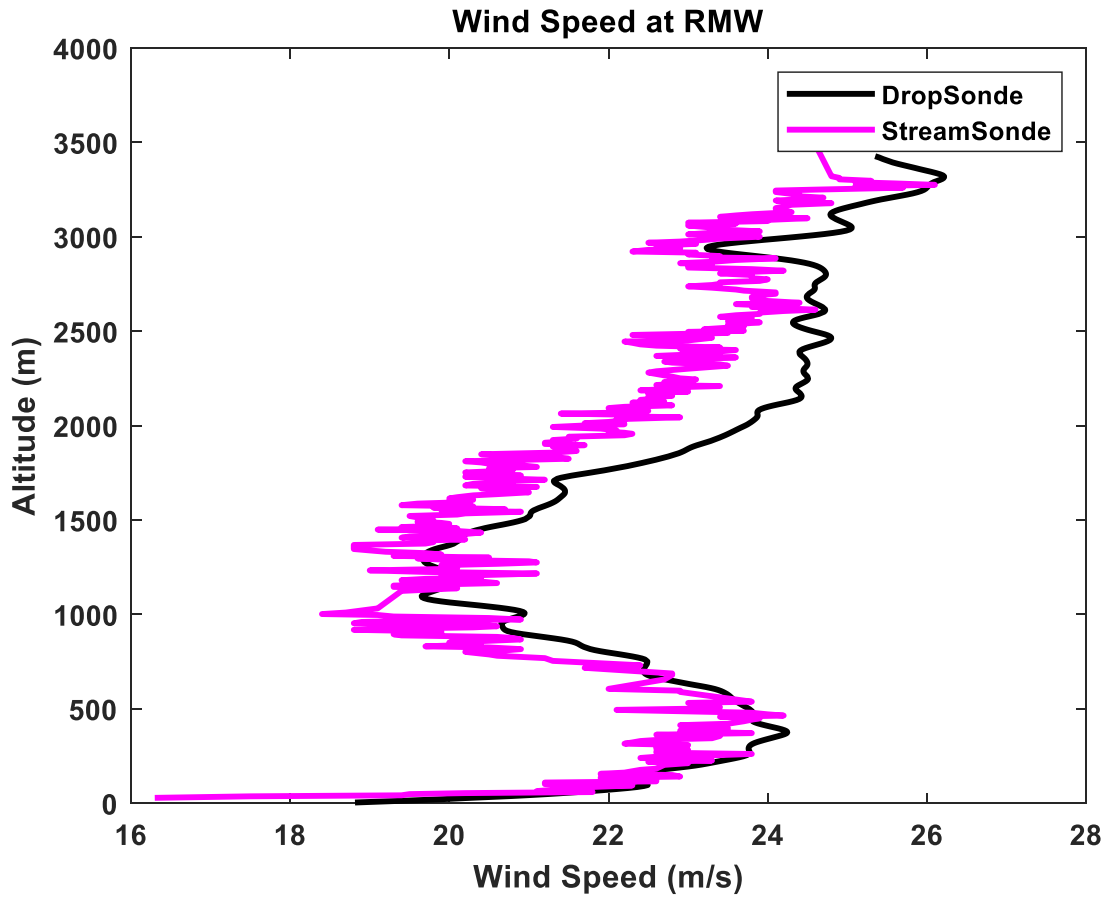
Skyfora
Evolution of wind measurements



	Omega	Loran-C		GPS (single band)		GNSS (dual band) (Skyfora)
Coverage	Global	Regional		Global		Global
Availability in sondes	→1997	Not utilized today		1996 →		2022 →
Accuracy (vel.)	10m/s	5m/s	**10x** Improvement	0.5m/s	**2.5x** Improvement	0.2m/s
Accuracy (pos.)	~1km	~100m		2.5m		1m
Number of visible satellites	N/A	N/A		12		40
Number of usable signals	N/A	N/A		12		80
Satellite signals	N/A	N/A		GPS L1C (Galileo E1)		GPS L1C & L5 Galileo E1 & E5a Beidou B1I, B1C & B2a QZSS L1 & L5

StreamSonde

StreamSonde DS in Hurricane Nigel

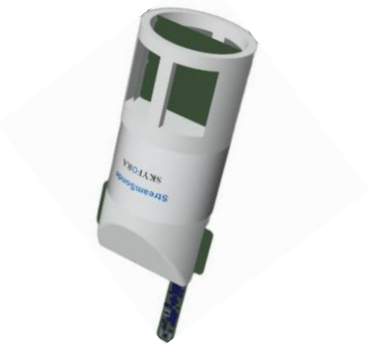


NHC (National Hurricane Center) analysis and comparison

- Skyfora D-file vs.
- AVAPS/ASPEN D-file

Higher level of wind details with StreamSonde

StreamSonde:
Un-filtered dual band GNSS winds



DropSonde:
Filtered single band GPS winds

Ongoing and planned projects

- EIC accelerator GNSS meteorology project 2023-2025
  - R&D on GNSS data, hardware, tomography
  - Business model development and piloting
- ESA Navisp planned in collaboration with University of Vaasa:
  - 20Hz data from LEO-PNT demonstrator satellite
  - Tallysman TW3972E embedded triple band GNSS patch antenna with L-band designed for triple frequency precision positioning
  - PPP solution to be used
- Collaborations with Finnish Geospatial Research Institute, Aalto University and other academic institutions
- Weather sonde with precise positioning
- Open to collaboration, come and discuss!

Thank you!

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