Short-term forecasting of severe flood events in Cyprus

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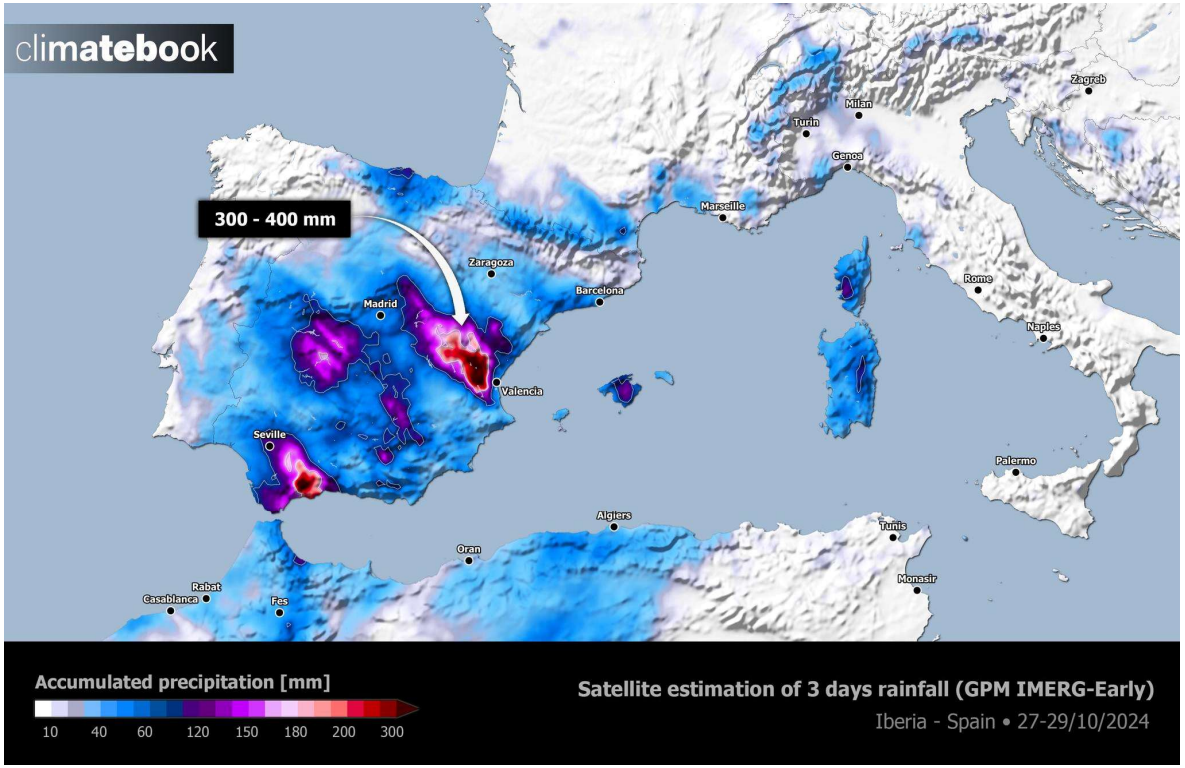
Εκπαιδευτική Ημερίδα, CNP Ασφαλιστική, «Φυσικές Καταστροφές & Ασφάλεια Κτιριακών Εγκαταστάσεων», Πέμπτη, 5 Δεκεμβρίου 2024

Extreme precipitation weather disasters

- **Valencia storm on Oct 2024** >200 people lost their lives



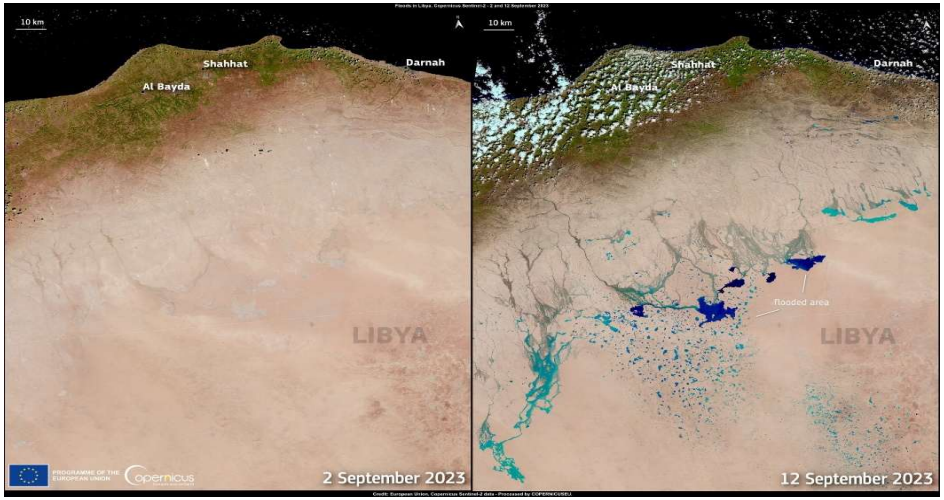
A view of the flooded area after a deluge brought up to 200 liters of rain per square meter (50 gallons per square yard) in hours in La Torre neighborhood of Valencia, Spain on October 30, 2024. PHOTO: ALEX JUAREZ/ANADOLU VIA GETTY

Climate change - Extreme events at Mediterranean region

- **Medicane Daniel** >11,000 in Libya & 17 deaths in Greece
  Sept 2023

Greece

Libya



In early September 2023, a set of extreme rainstorms led to devastating flooding in parts of Greece, Bulgaria and Turkey.

These events related to development of a surface cyclone nearby on the night of 4 September, assigned the name 'Daniel' as part of a EUMETNET cyclone naming initiative.

Cost Action 2020-2024

Cost Action 2023-2027

REFERENCES:
(ECMWF) https://www.ecmwf.int/en/newsletter/179/earth-system-science/medicane-daniel-extraordinary-cyclone-devastating-impacts
(MEDcyclones Cost Action) https://medcyclones.eu/medicanes-qa/

Climate change - Extreme events at Mediterranean region

- **Medicane Daniel**

Sep 2023

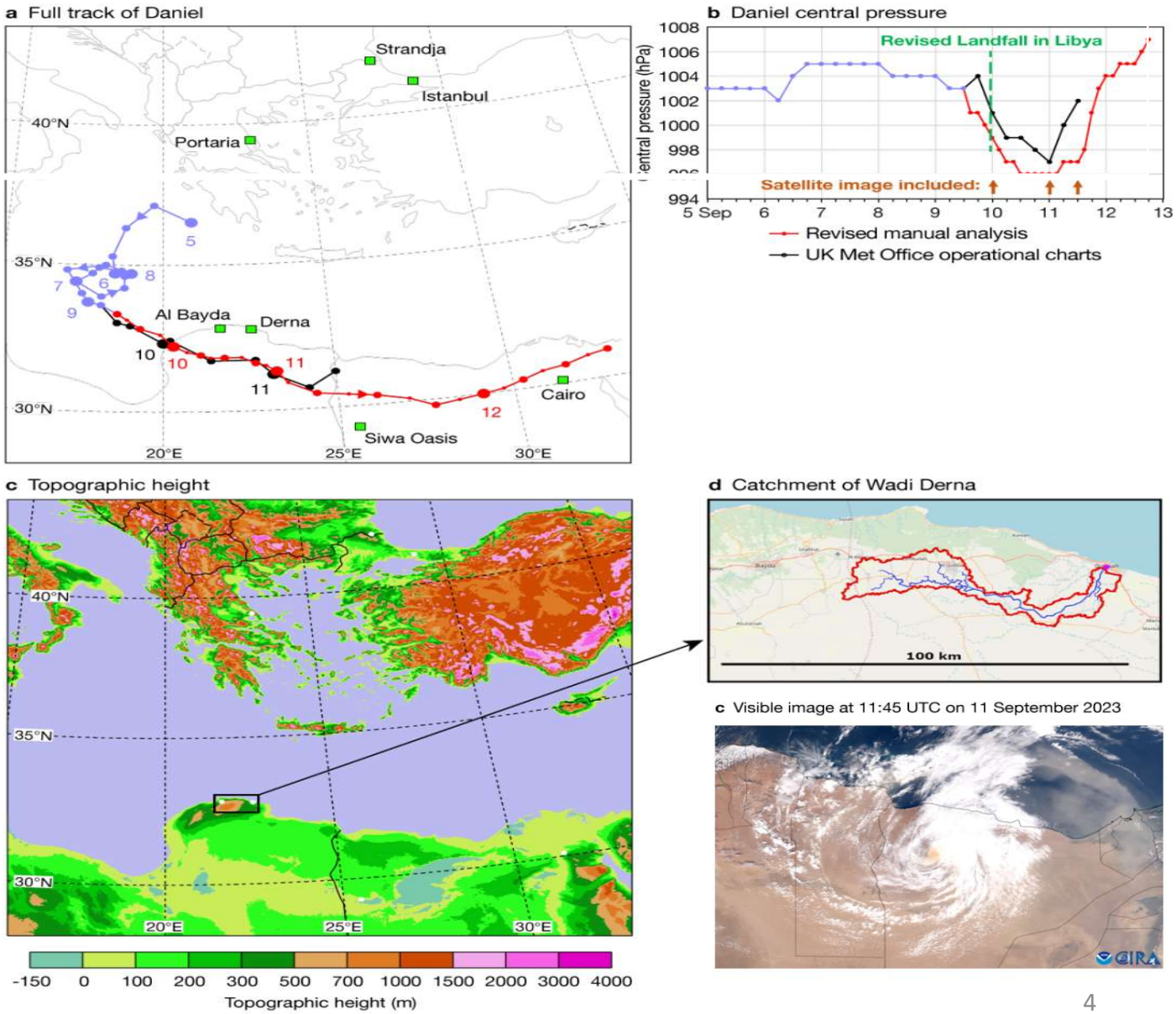
From 5 Sept, Daniel meandered slowly across the Mediterranean before adopting **an east-south-eastward trajectory** near northern Libya late on 8 September, whereupon it became a medicane.

Landfall was near Benghazi around 23 UTC on 9 September.

Remarkably, the medicane deepened further over land.

The resulting intense rainfall over the Akhḍar (Green) mountains of northern Libya on the night of 10–11 September drained into the small Wadi Derna catchment and went on to cause catastrophic flooding in the city of Derna.

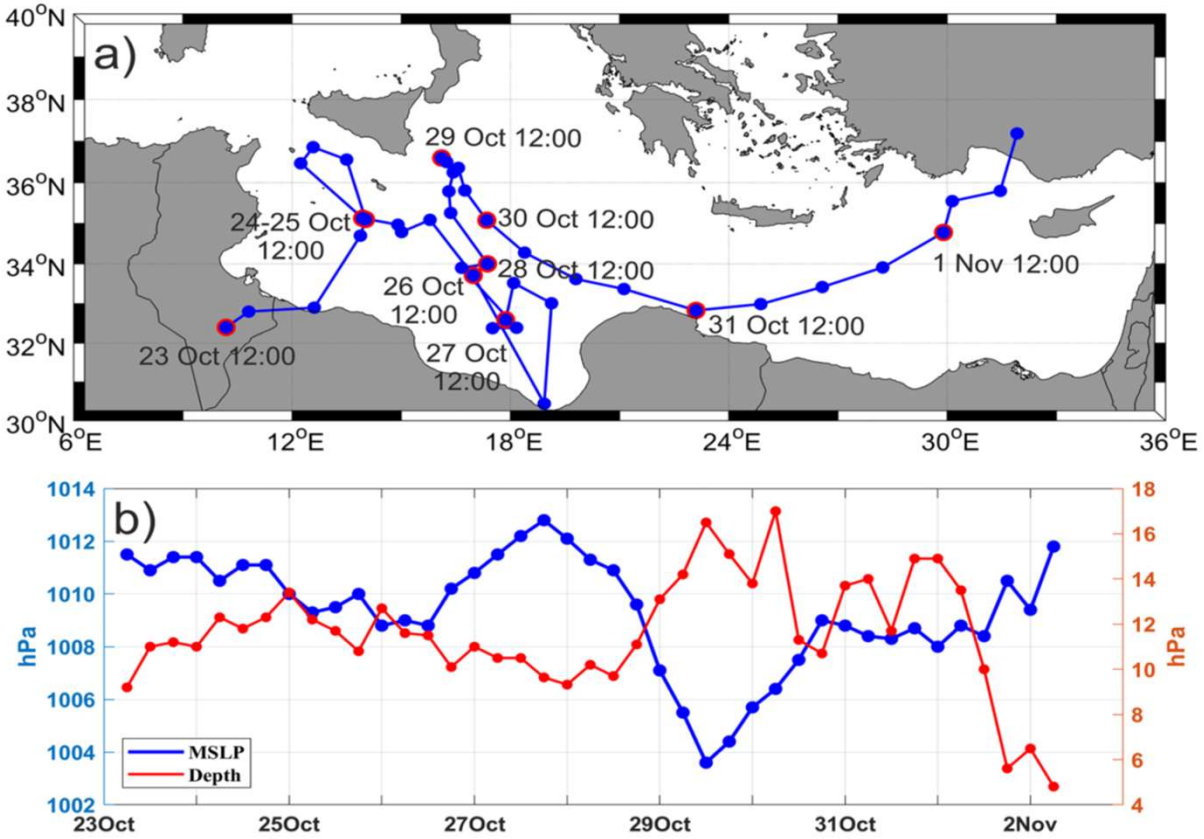
Two dams burst, and there were 5,000–15,000 fatalities as buildings were swept away. This was likely the deadliest rainfall-related flooding disaster since ECMWF started producing operational forecasts in the late 1970s



Climate change - Extreme events at Mediterranean region

- **Medicane Apollo** (7 people lost their lives)

Oct 2021



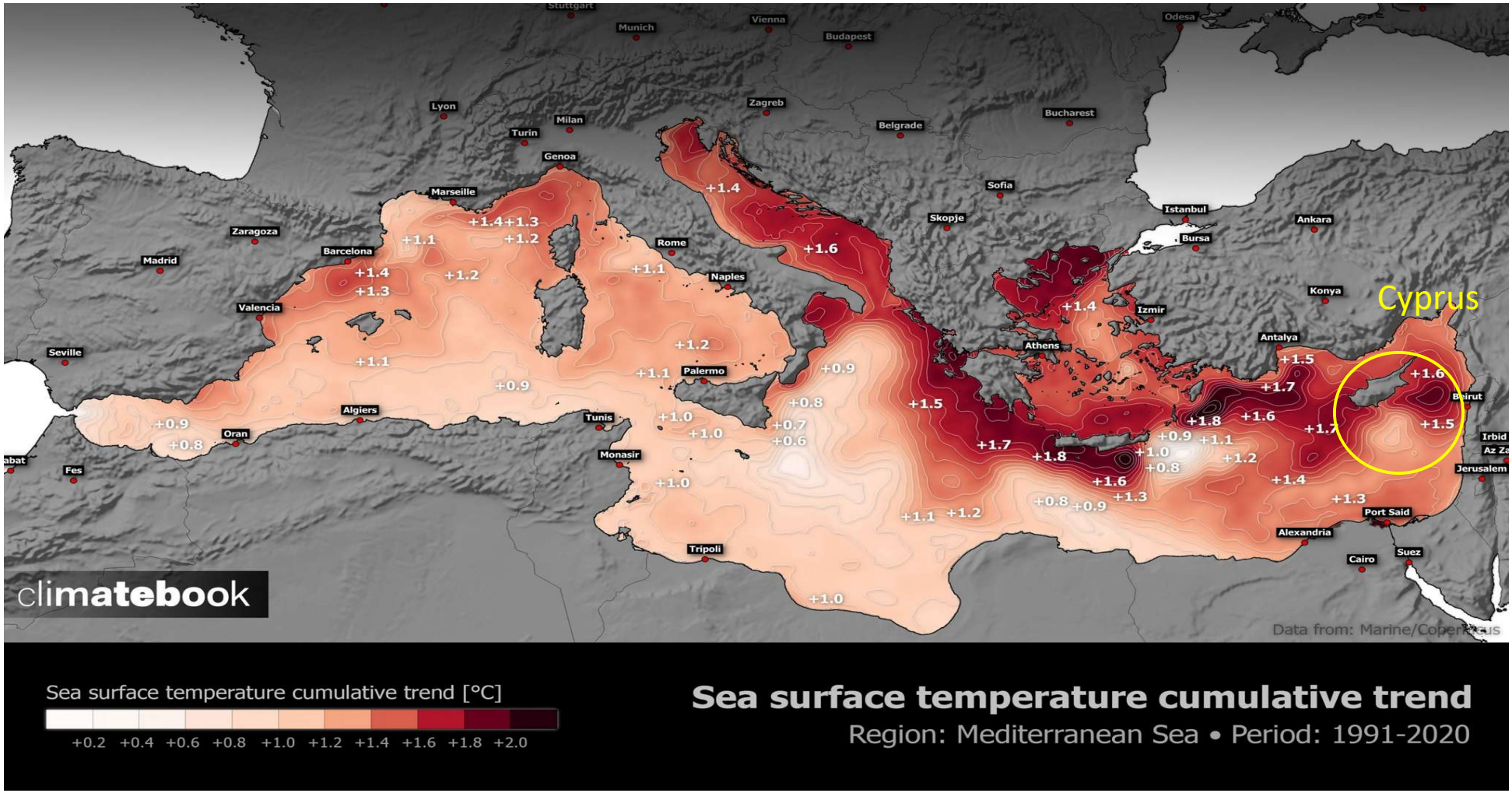
Reference: *Menna M, Martellucci R, Reale M, Cossarini G, Salon S, Notarstefano G, Mauri E, Poulain PM, Gallo A, Solidoro C. A case study of impacts of an extreme weather system on the Mediterranean Sea circulation features: Medicane Apollo (2021). Sci Rep. 2023 Mar 8;13(1):3870. doi: 10.1038/s41598-023-29942-w. Erratum in: Sci Rep. 2024 Jun 14;14(1):13773. doi: 10.1038/s41598-024-64630-3. PMID: 36890142; PMCID: PMC9995500.*

a) 6 h Medicane Apollo track between 23 October 2021 12:00 UTC to 2 November 2021 06:00 UTC (blue dots); Medicane daily positions at 12:00 UTC are circled in red

b) Time series of MSLP and cyclonic depth (i.e. a metric for the cyclone intensity) derived from ERA5

Climate change - Extreme events at Mediterranean region

- **Mediterranean Sea Surface Temperature rise**



Source: climatebook.gr

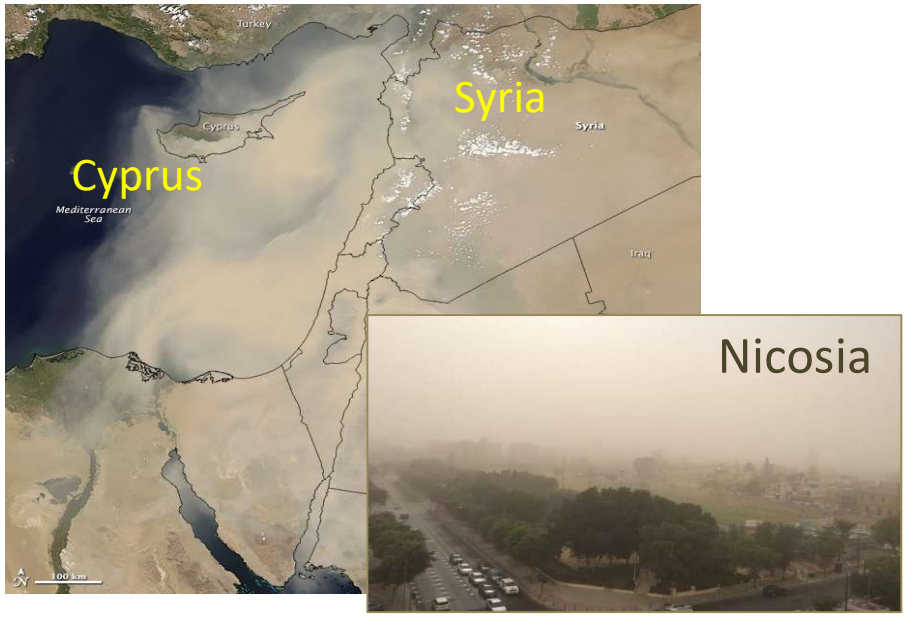
The Mediterranean Sea is warming rapidly – Eastern Mediterranean Hotspot

Severe LOCAL weather events in Cyprus

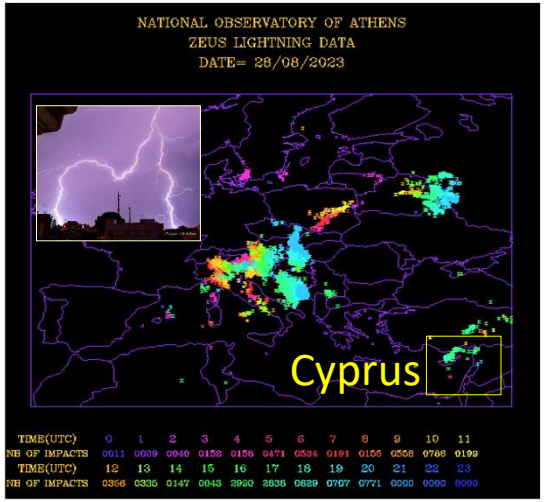
- **Dec 2018** **4 deaths** from flood
- Jan 2023 Rare floods in Ayia Napa
- Aug 2023 Extreme lighting activity & rainfall – Unusual storm trajectory not predicted by NWP models
- Sept 2015 **> 90** people in hospital (Breathing difficulty) from dust storm in EM
- 1966 -now **6 deaths** from Tornadoes
  126 cases of tornadoes

Flood, January 2023, Ayia Napa, Cyprus

Dust storm, September 2015, Cyprus



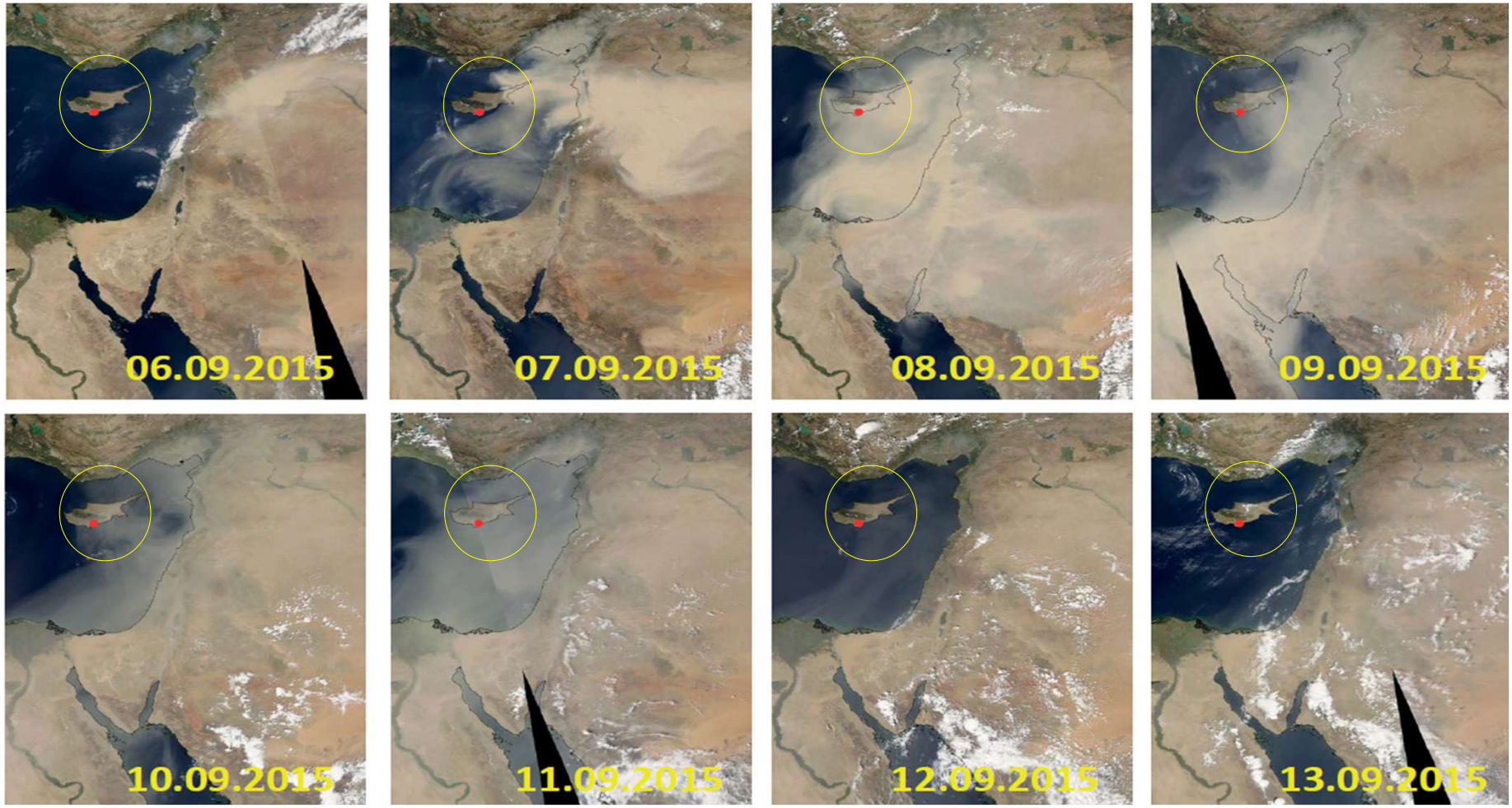
Lightning over Nicosia, August 2023



Tornadoes in Cyprus

Severe LOCAL weather events in Cyprus

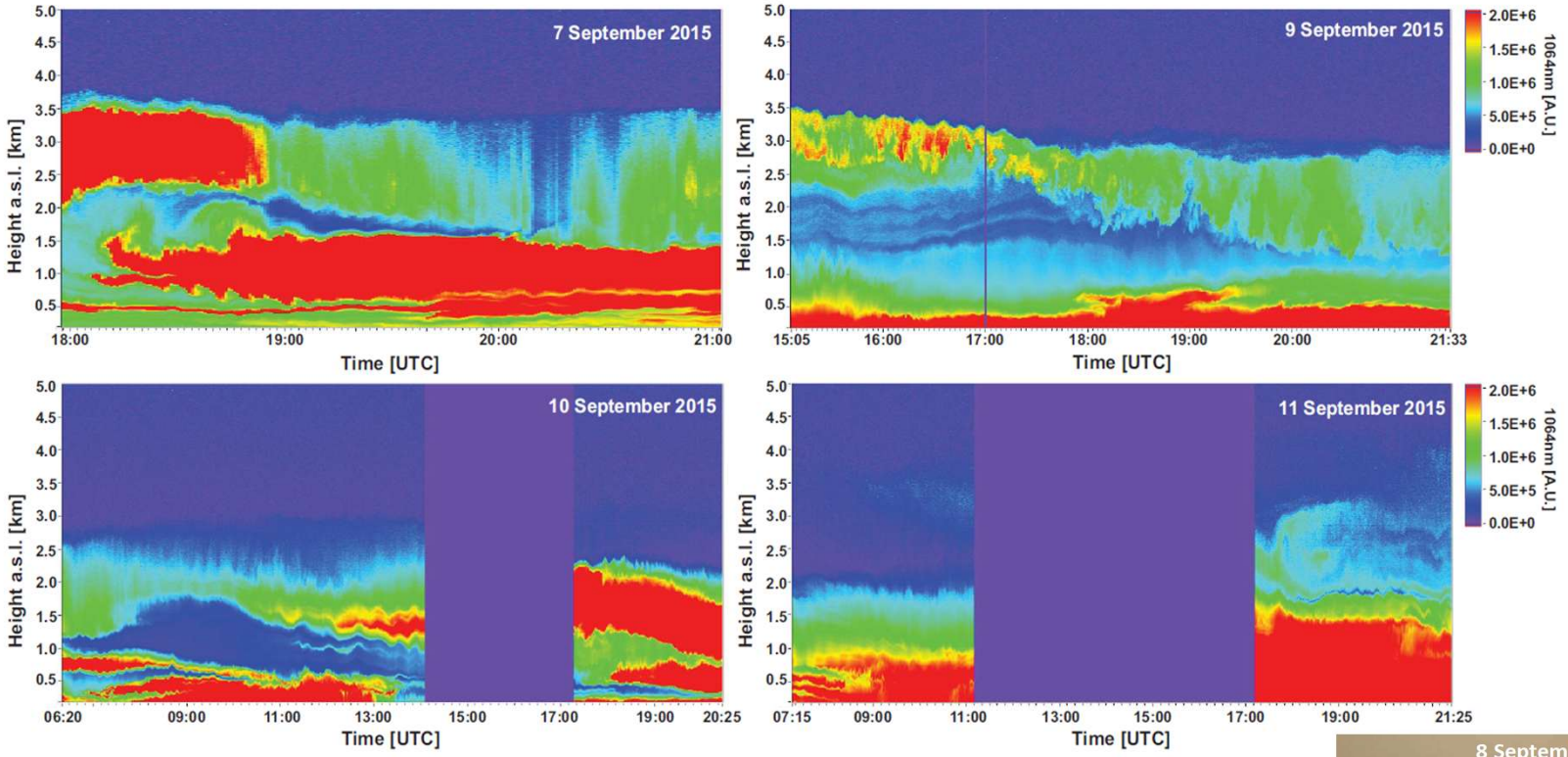
- **Severe Dust storm, September 2015, Cyprus**



(As seen from: aqua-MODIS, 10:30–11:30UTC overpasses, 13:30–14:30 EEST)

Severe LOCAL weather events in Cyprus

Dust storm, September 2015, Cyprus



REFFERENCE:
Mamouri et al. 2016. Extreme dust storm over the eastern Mediterranean in September 2015: satellite, lidar, and surface observations in the Cyprus region. Atmos. Chem. Phys., 16, 13711–13724, 2016
www.atmos-chem-phys.net/16/13711/2016/
doi:10.5194/acp-16-13711-2016

Desert dust layers observed with lidar over the EARLINET station of Limassol, Cyprus, on 7, 9, 10, and 11 September 2015.

Range-corrected 1064 nm backscatter signals (in arbitrary units, A.U.) are shown. On 7–10 September, a double layer structure dominated with dust layers below about 1–1.7 km height and another layer reaching to 2.5–3.7 km height. Local time (EEST) is time in UTC plus 3 h

Need for nowcasting weather

Nowcasting weather = to forecast near future (0-6 hours) local phenomena, e.g. flash floods in a city, using near real-time observations

Nowcasting enhances forecasting skill, for abrupt and local storms so that people can take actions to save life and property

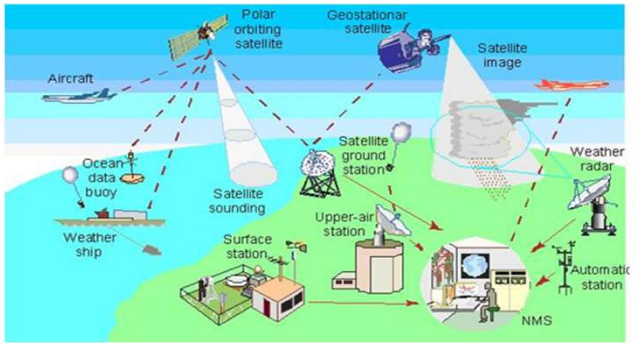
Medicane **'Ianos'**
tropical–like cyclone in Mediterranean Sea
17 September 2020
3 people dead in Greece

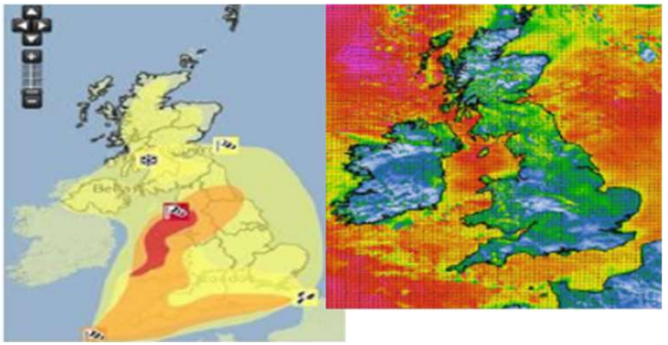
Applications of nowcasting weather

Need for more data for nowcasting weather – Why now?

- To provide nowcasting weather for local, extreme phenomena, we need to **rapidly import** Meteorological Data into **Numerical Weather Prediction (NWP) models**

- We need to **UPGRADE** the "traditional" meteorological observing system which is not built for so high temporal and spatial resolution data needed to run NWPs





Data → **NWP Models** → **Local Forecasts**

- WE NEED DATA with:

✓ higher density
✓ higher temporal resolution

- WE NEED:

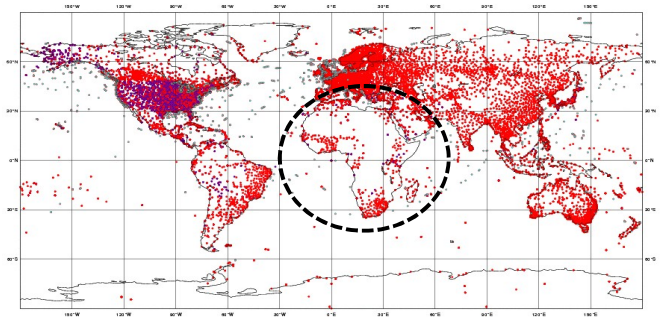
✓ **more** data
✓ to **combine** data from **different sources** (radar, satellite, profilers, opportunistic sensors etc.)

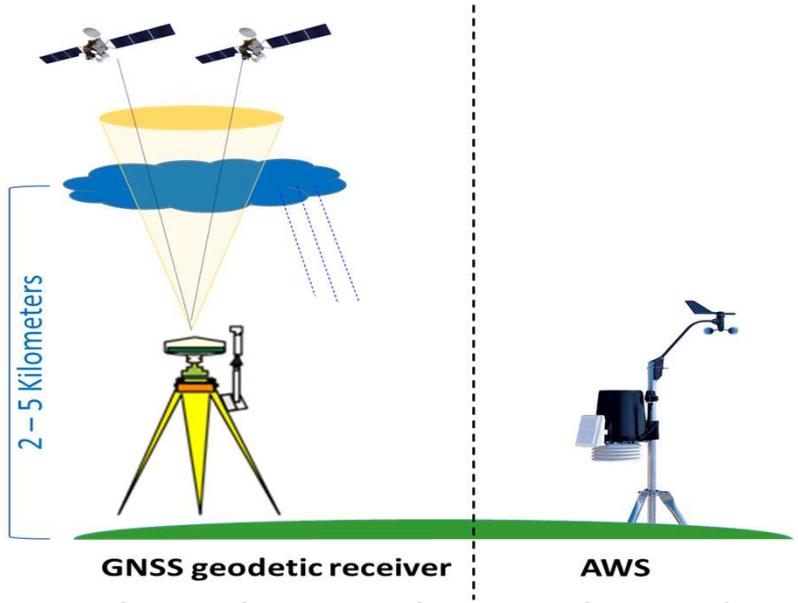
GNSS tropospheric products for weather monitoring

Water Vapour Measurement & Importance

- To improve nowcasting of local heavy rainfall and flash storm events we need **Precipitable Water Vapour** (PWV) data
- PWV indicates how much liquid water is available for potential rainfall above us
- In Cyprus and globally IWV data are sparse and inhomogeneous
- Currently **17 National Meteorological Services in Europe** (UK, France etc), Japan MS, do **assimilate** PWV into their NWP model operationally

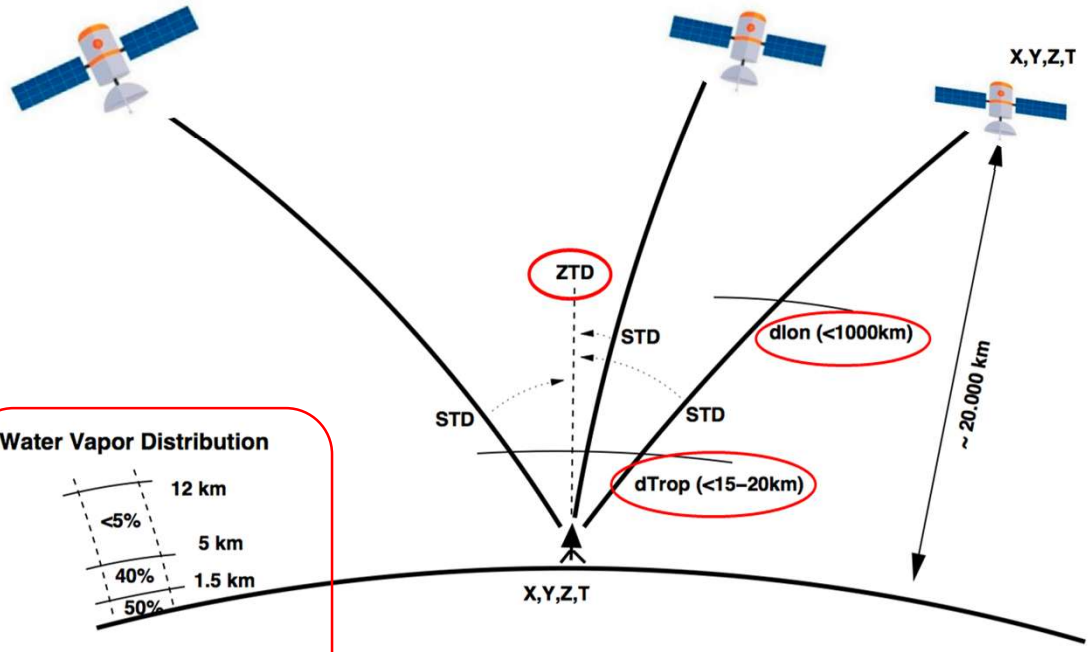
Automatic Weather Stations (AWS) **do not provide PWV**





One technique to estimate PWV is by exploiting the propagation delay of the **GNSS satellites signals**

How PWV is estimated from GNSS?



Precipitable Water Vapor - PWV

is the amount of water potentially available in the atmosphere for precipitation, vertically integrated and it is a valuable predictor for weather forecasting

- Radio signals transmitted on two L-band frequencies from GNSS satellites are delayed by the neutral part of atmosphere (whose lowest portion is troposphere) before being received on earth surface by GNSS antennas.
- This **zenith tropospheric delay (ZTD)** consists of the hydrostatic (dry) component which is caused by dry air gases in the atmosphere and accounts for the greatest part of delay and of the wet component which is caused by the water vapor of the atmosphere:

$$ZTD = ZHD + ZWD$$

$$\mathrm{ZHD} = (0.0022768 \pm 0.0000005)\frac{\mathrm{P_{GNSS}}}{\mathrm{f(\varphi(h)}}$$

Surface Pressure

with f (φ, h) = 1 − 0.0026 cos 2φ − 0.00028 h, where φ is the latitude and h is the height (km)

$$PWV = \frac{ZWD}{Q}$$

$$Q = 10^{-6}\rho\frac{R_0}{M_W}(k'_2 + \frac{k_3}{T_m})$$

Surface Temperature

*the **Q factor** depends on surface temperature:*

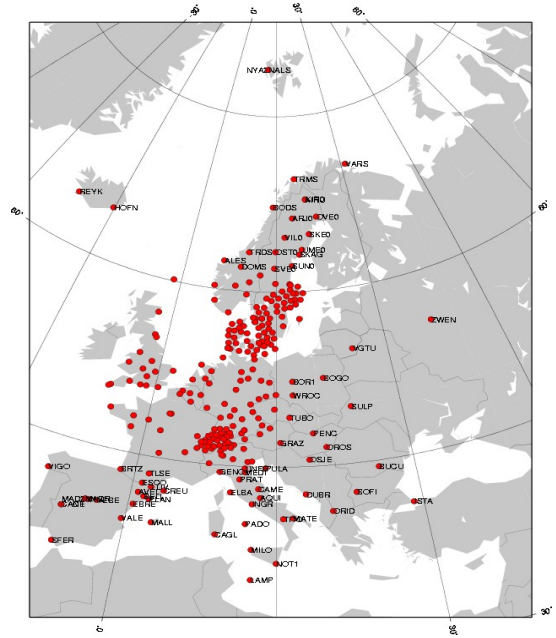
where ρ is the density of liquid water, R_0 is the universal gas constant, M_W is the molar mass of water vapor and T_m is the weighted mean temperature of the atmosphere in [K]. The physical constants k'_2=17 Kmb^{-1} and $k_3 = 3.776 \cdot 10^5$ Kmb^{-1}.

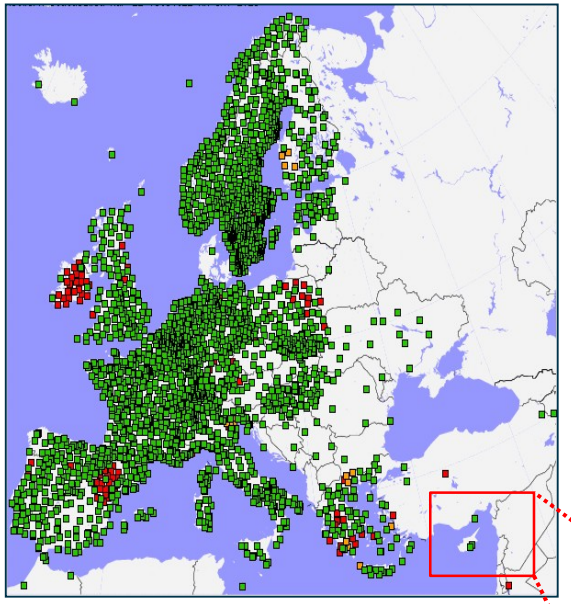
COST ACTION 2013 -2017 (GNSS4SWEC)

ES1206 - Advanced GNSS tropospheric products for monitoring severe weather events & climate

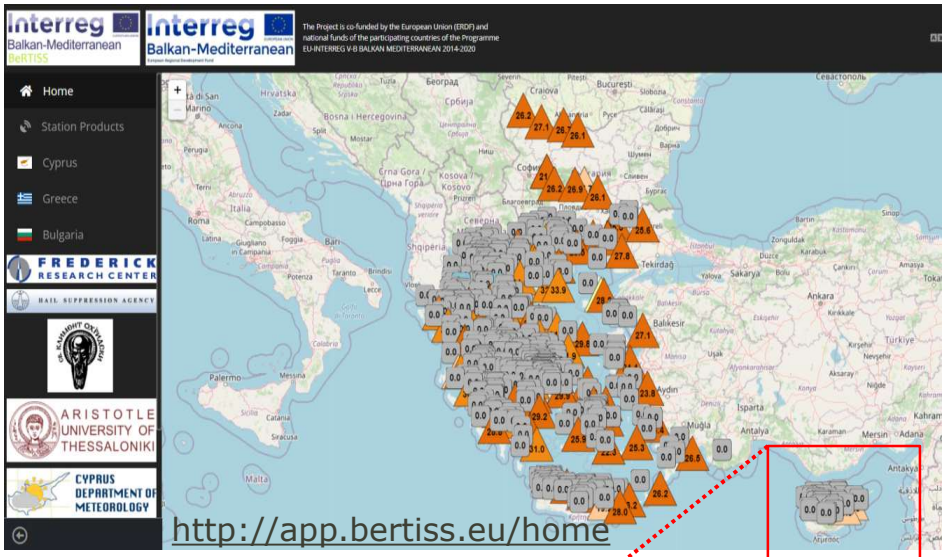
E-GVAP 2003 → **E-GVAP 2023** →

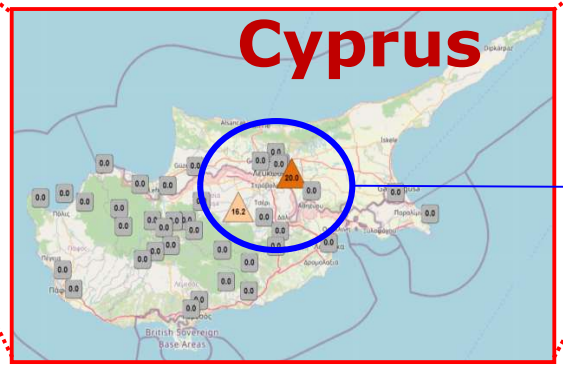
BeRTISS project 2017 (Interreg)
(FRC, DoM, NOA project partners)





Balkan-Mediterranean Real Time Severe Weather Service





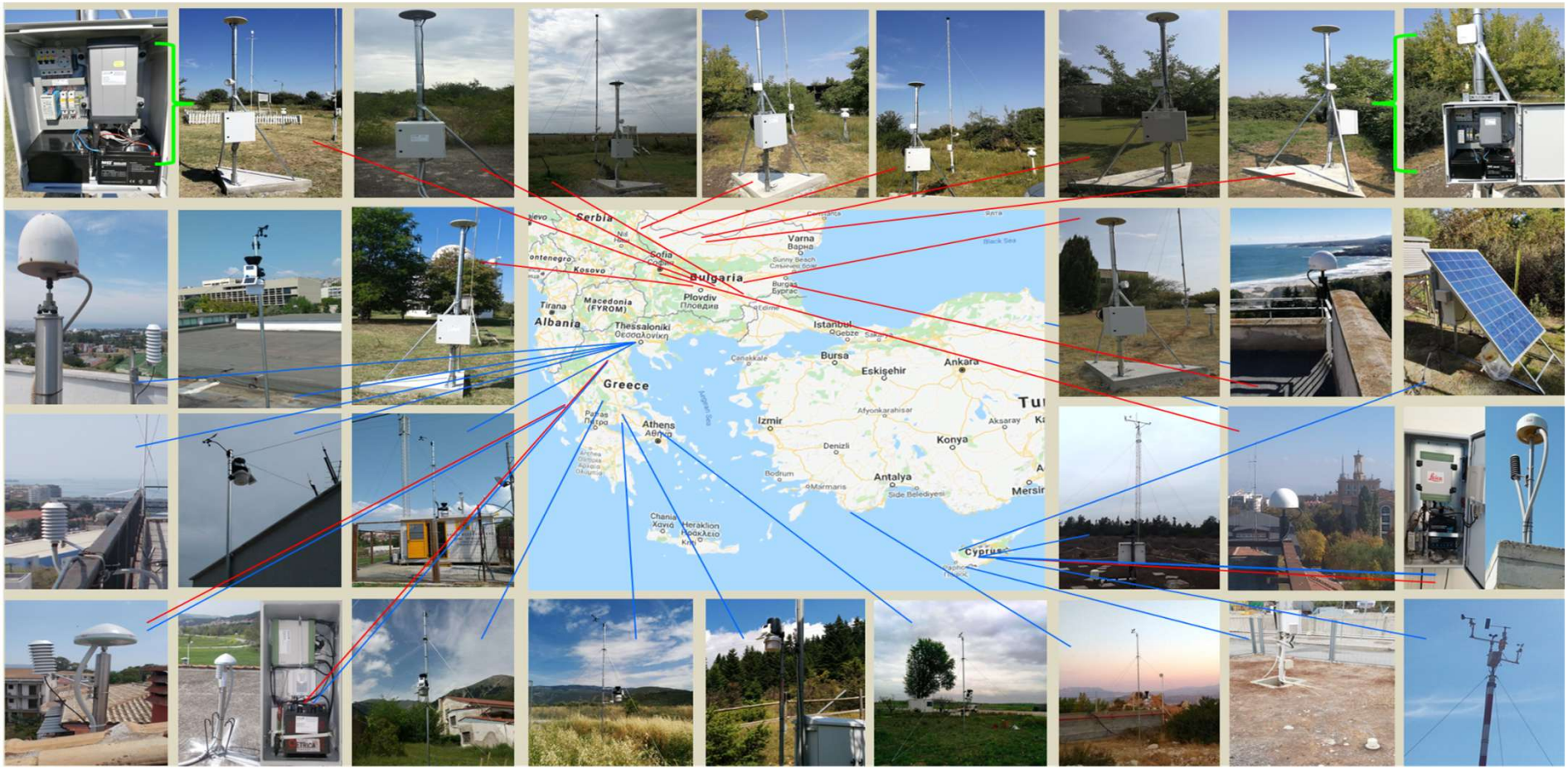
EUMETNET Programme E-GVAP:

The GNSS **water vapour programme** was set up, in April 2005, to provide its **EUMETNET** (European National Meteorological Services) GNSS delay and water vapour estimates for **operational meteorology in near real-time**
http://egvap.dmi.dk

Only 2 GNSS geodetic stations estimate PWV in Cyprus in BeRTISS

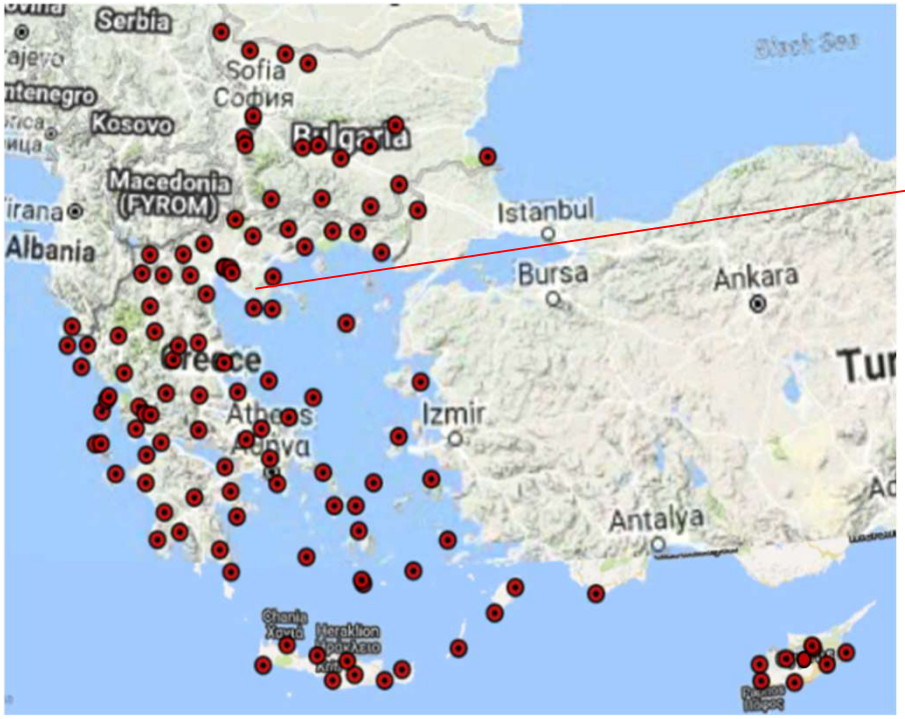
BalkanMed real time severe weather service – BeRTISS 2017

Interreg Balkan - Mediterranean project coordinated by Frederick University (CyIRG)



- **15 new GNSS stations** were installed in Bulgaria (12), **Cyprus (1)** and Greece (2) (red lines)
- **25 new Meteorological stations** were installed in Bulgaria (3), **Cyprus (8)** and Greece (14) (blue lines)

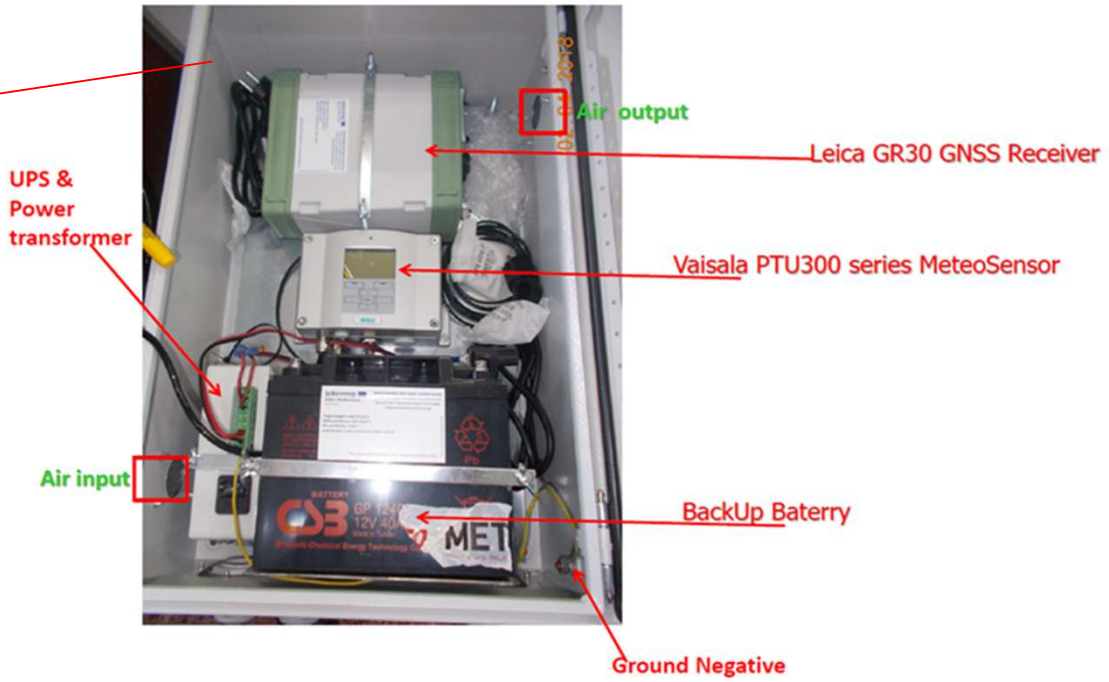
BalkanMed real time severe weather service
BeRTISS



Permanent GNSS stations located in Greece, Bulgaria and Cyprus used at BeRTISS
http://app.bertiss.eu/home

PWV, ZTD and gradients every 10 min
Starting from 2020 up to now

GNSS and Meteo-stations Config. & Installation



High-grade GNSS receiver Cost: 13.000 euros

CLOUDWATER Ltd - 2021

*R&D SME company focusing on **low-cost GNSS** (Global Navigation Satellite System) **receiver** development established in **2021** at Nicosia, Cyprus, after receiving funding from Republic of Cyprus through IDEK in the frames of **PRE-SEED** RESTART 2016-2020 Programme*

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Director

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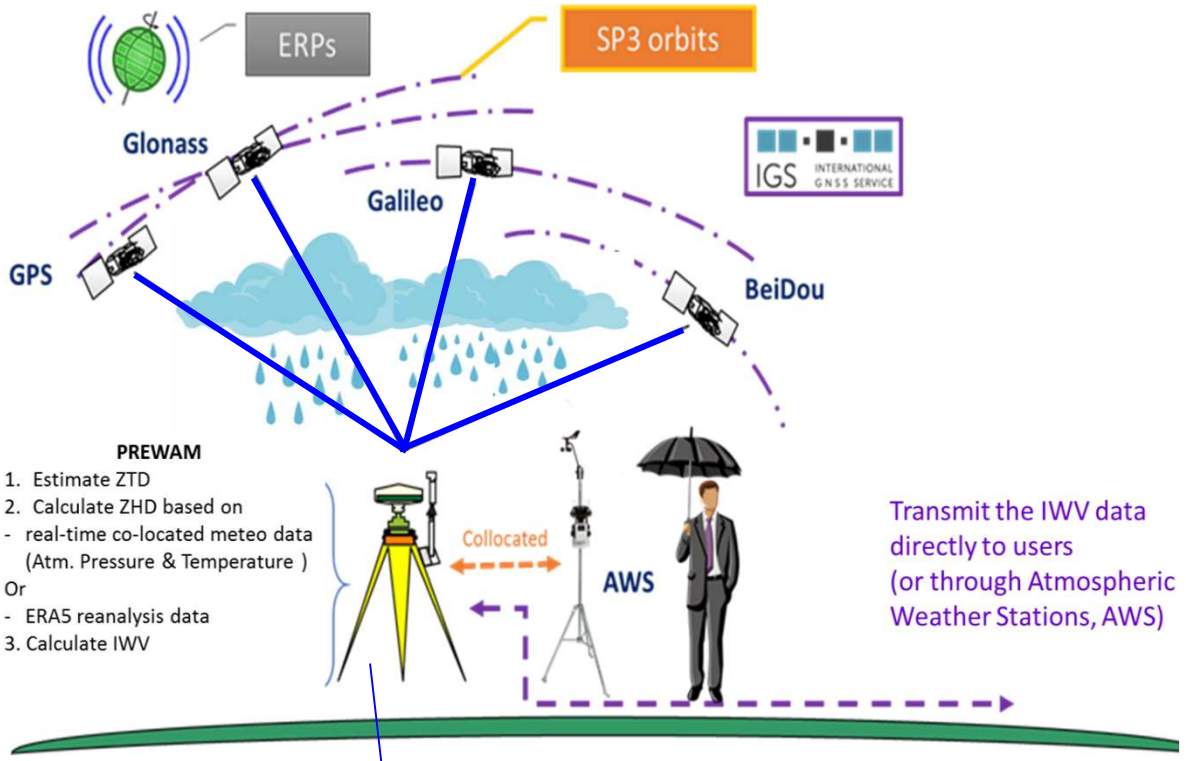
c.oikonomou23@gmail.com

PREWAM
PREcipitable WAter vapour Monitor

CLOUDWATER Ltd: Low-cost GNSS receiver for water vapor monitoring



ground GNSS station

PWV with 15 min resolution

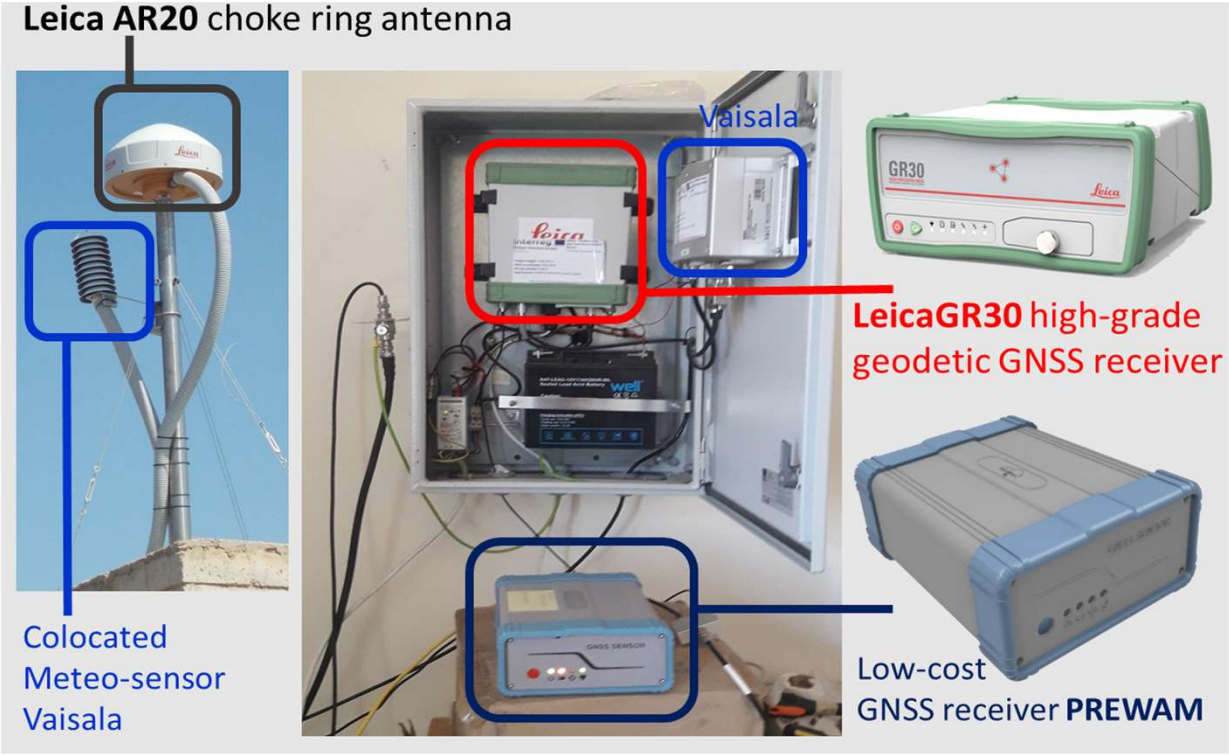
PREcipitable WAter vapour Monitor

'PREWAM'
Developed by Cloudwater ltd

CloudWater

- ✓ **Low-cost GNSS receiver for** near-real time estimation of PWV with high-resolution (15min)
- ✓ **Cost around 2.000 euros**
- ✓ Takes fully advantage of all GNSS satellite systems: GPS, GALILEO, GLONASS and BeiDou
- ✓ Constructed by **3D Printing** technology
- ✓ Can be embedded to AWS stations (Cambell, Vaisala, Davis, etc)

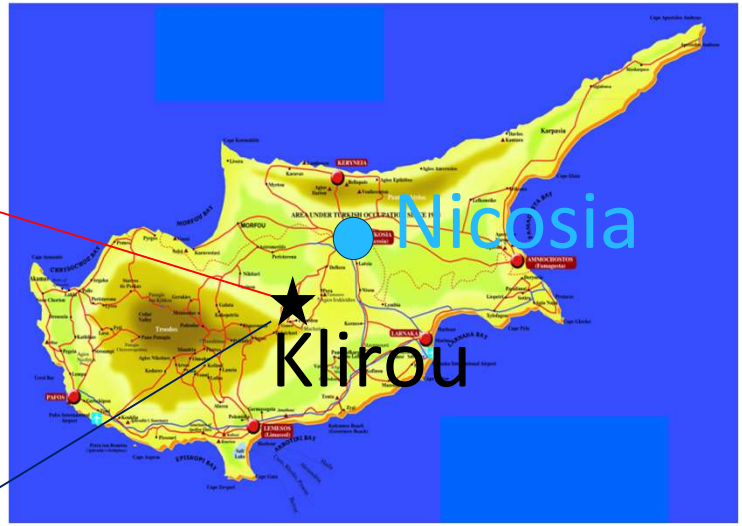
Comparison BeRTISS (Geodetic Leica receiver) **– CLOUDWATER** (Low-cost PREWAM receiver)



Klirou station

KLIR (BeRTISS)

KLIC (CLOUDWATER partner)



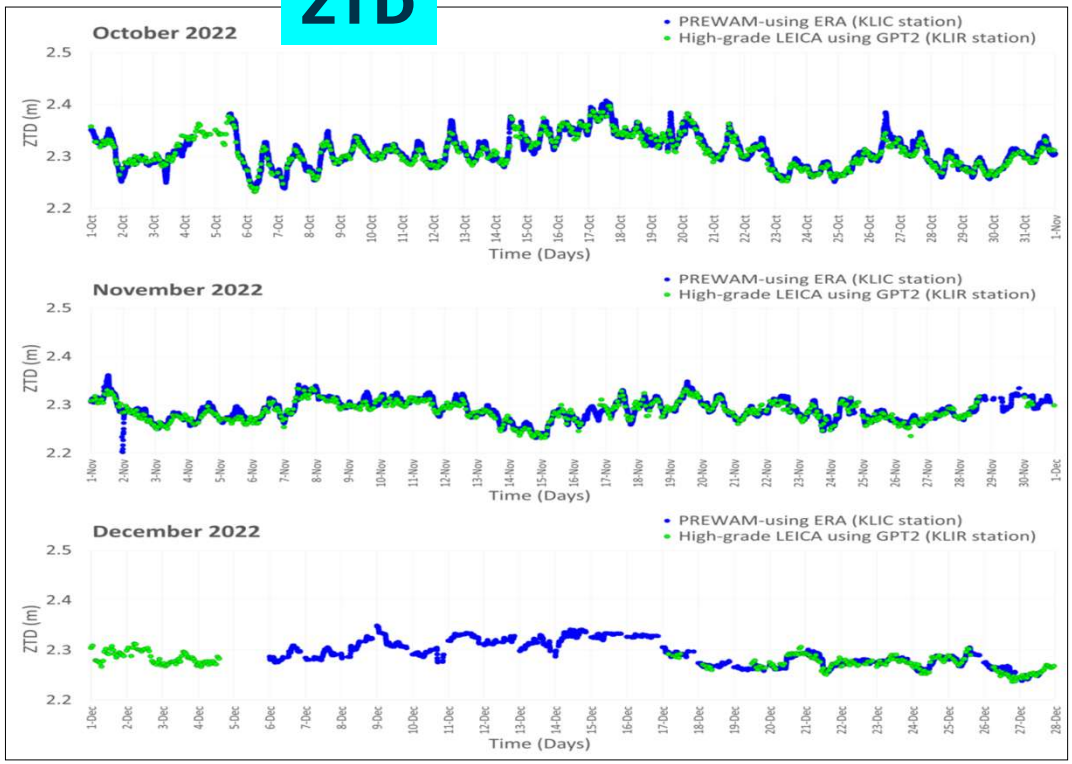
High-grade geodetic receiver **LeicaGR30** and low-cost **PREWAM** receiver used for **PWV estimation**
Period of study: October 2022 – December 2022

Comparison BeRTISS (Geodetic Leica receiver, Bernese) **– CLOUDWATER** (Low-cost PREWAM rec. RTKLIB)

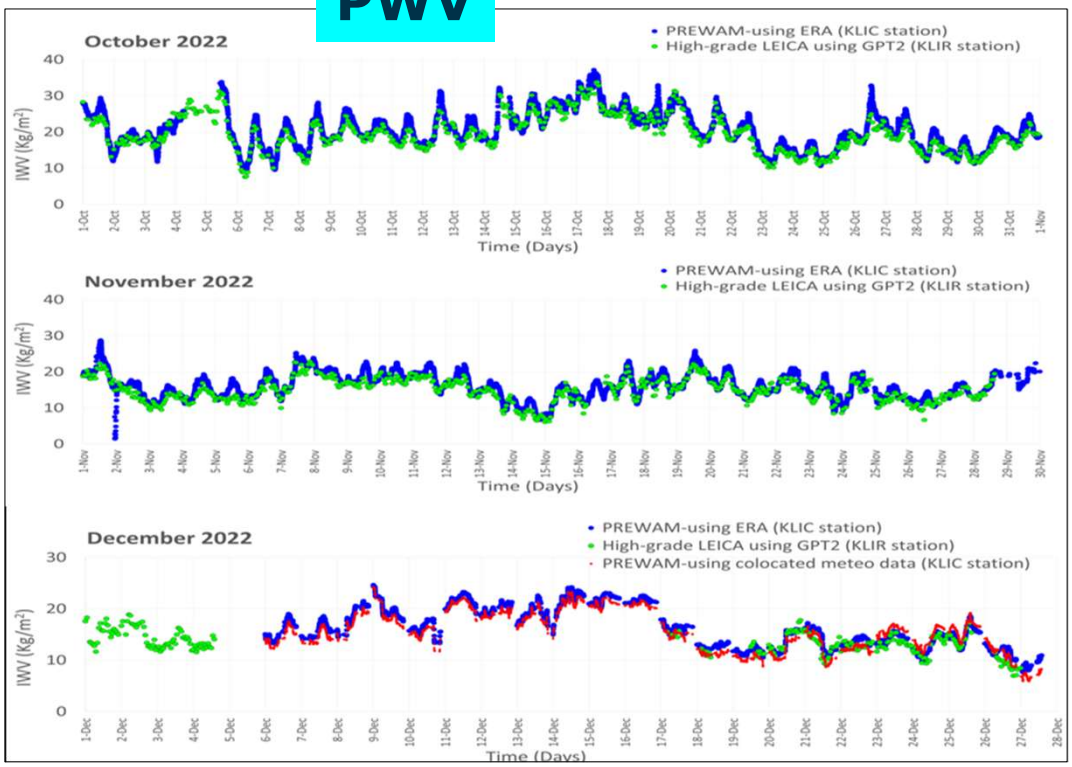
- **Leica GR30 geodetic receiver KLIR**
- **PREWAM low-cost receiver KLIC**

- Leica GR30 geodetic receiver – KLIR
Using empirical blind model GPT2w
- PREWAM low-cost receiver – KLIC
Using ERA5 empirical model for P,T estimation

ZTD **Correlation Coefficient R = 0.96**



R = 0.95 **PWV**



FIRST POTENTIAL CLIENTS INTERNATIONAL

12 Letters of Interest

Cloudwater plan: Low-cost GNSS network densification

Technical characteristics

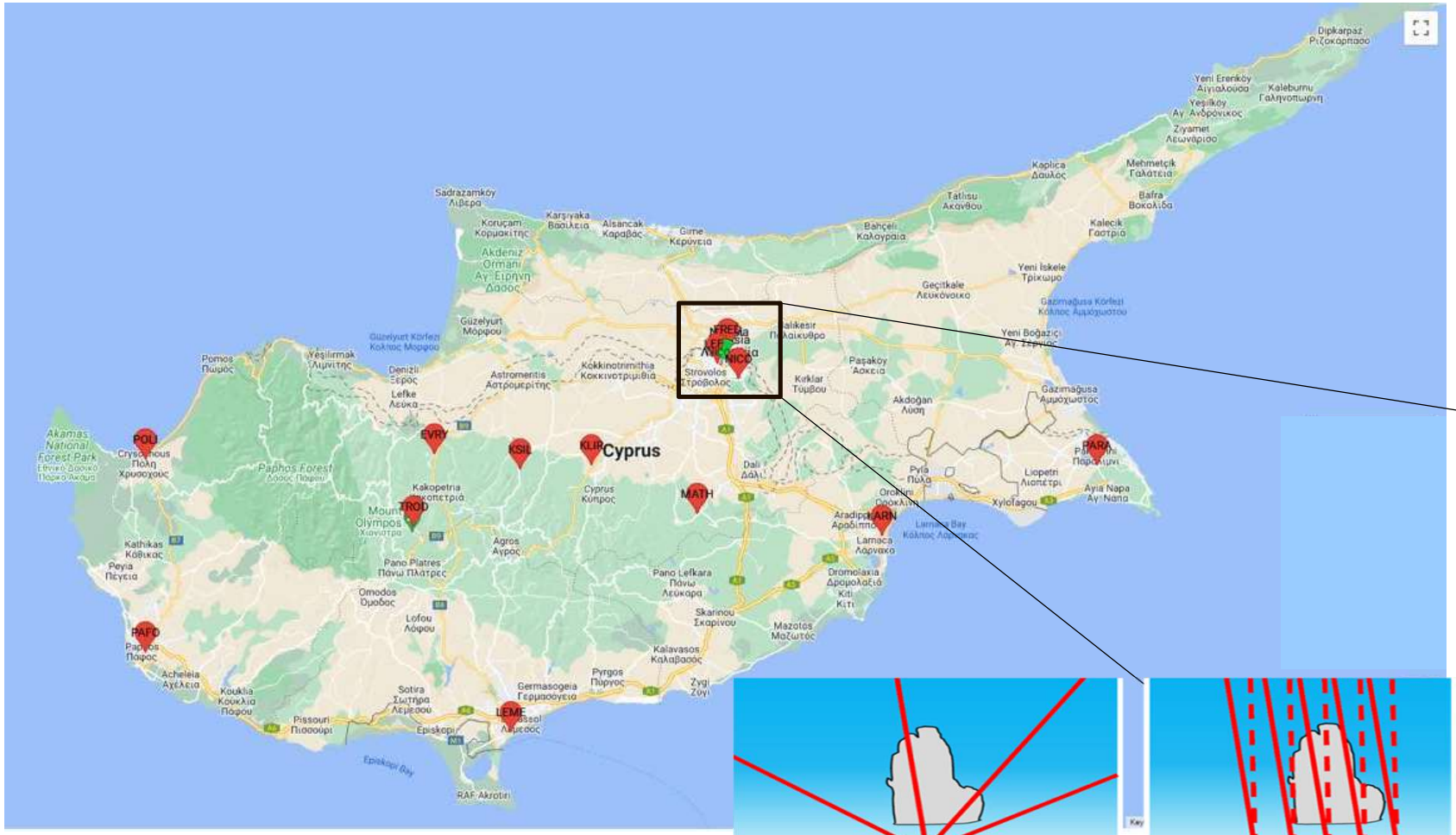
of low-cost GNSS receivers

No	Station Name	Location	Geogr. Lat (°)	Geogr. Lon (°)	Altitude (m)	Constellation	Company	Board	Antenna	Data access
1	MATH	Mathiati	34.9450707	33.34077918	457.435	GPS, Galileo, GLONASS, BeiDou	Cloudwater low-cost	u-blox ZED-F9P	CNTAT340	online near real-time ZTD etc every 15min
2	KLIR	Klirou	35.0251689	33.15731136	509.826	GPS, Galileo, GLONASS, BeiDou	LEICA GR30	Novatel	LEIAR20 LEIM	online near real-time ZTD etc every 15min
3	KSIL	Xyliatos	35.0386686	33.05772944	562.61	GPS, Galileo, GLONASS, BeiDou	Cloudwater low-cost	u-blox ZED-F9P	CNTAT340	online near real-time ZTD etc every 15min
4	TROD	Troodos mountain close to peak	34.9430876	32.86541034	1860.999	GPS, Galileo, GLONASS, BeiDou	Cloudwater low-cost	SinoGNSS K803 (Chinese)	CNTAT340	online near real-time ZTD etc every 15min
5	FRED	Nicosia, Frederick University	35.1810424	33.37923394	178.542	GPS, Galileo, GLONASS, BeiDou	Septentrio PolaRx5S	Septentrio	SEPCHOKE_B3E6 NONE	online near real-time ZTD etc every 15min
6	NICO	Nicosia, Athalassas meteo station	35.1409843	33.3964404	190.169	GPS, Galileo, GLONASS, BeiDou	LEICA GR50	Novatel	LEIAR25.R4 LEIT	online near real-time ZTD etc every 15min
7	POLI	Polis Chrisohous	35.0330405	32.42751978	68.639	GPS, Galileo, GLONASS, BeiDou	LEICA GR30	Novatel	LEIAR20 LEIM	online near real-time ZTD etc every 15min
8	PAFO	Paphos	34.7741019	32.42801017	109.902	GPS, Galileo, GLONASS, BeiDou	LEICA GR30	Novatel	LEIAR20 LEIM	online near real-time ZTD etc every 15min
9	LEME	Limassol	34.6675749	33.02513635	50.195	GPS, Galileo, GLONASS, BeiDou	LEICA GR30	Novatel	LEIAR20 LEIM	online near real-time ZTD etc every 15min
10	LEFK	Nicosia	35.1610657	33.36290149	192.677	GPS, Galileo, GLONASS, BeiDou	LEICA GR30	Novatel	LEIAR20 LEIM	online near real-time ZTD etc every 15min
11	LARN	Larnaca	35.9307157	33.63200523	47.049	GPS, Galileo, GLONASS, BeiDou	LEICA GR30	Novatel	LEIAR20 LEIM	online near real-time ZTD etc every 15min
12	PARA	Paralimni	35.0255799	33.98350984	110.058	GPS, Galileo, GLONASS, BeiDou	LEICA GR30	Novatel	LEIAR20 LEIM	online near real-time ZTD etc every 15min
13	EVRY	Evrihou	35.038535	32.89995064	473.64	GPS, Galileo, GLONASS, BeiDou	LEICA GR30	Novatel	LEIAR20 LEIM	online near real-time ZTD etc every 15min

Cloudwater low-cost GNSS PREWAM network

Colocated at Cyprus Institute CAO stations (Cyprus Atmospheric Observatory)

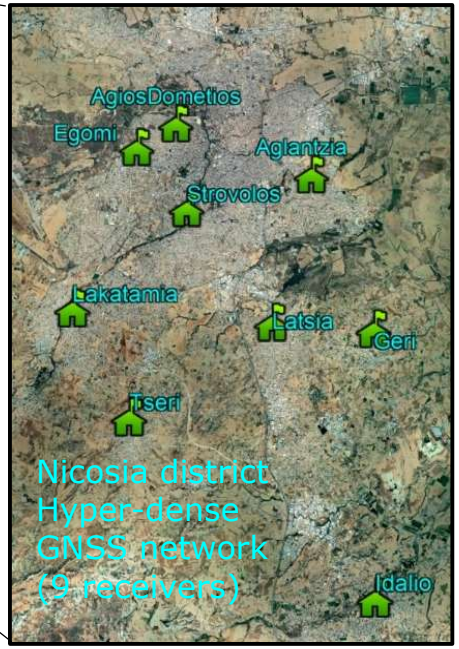
Cloudwater plan: PREWAM GNSS network densification



NEW Equipment

9 low-cost PREWAM GNSS receivers

(Nicosia district Hyper-dense GNSS network, in the frames of CYGMEN project)

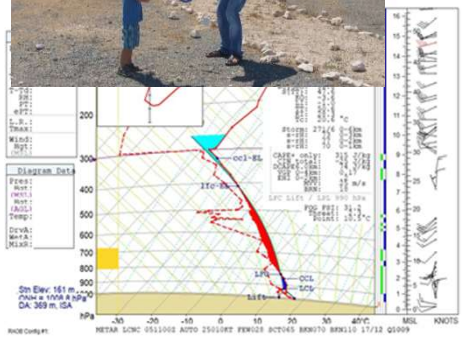


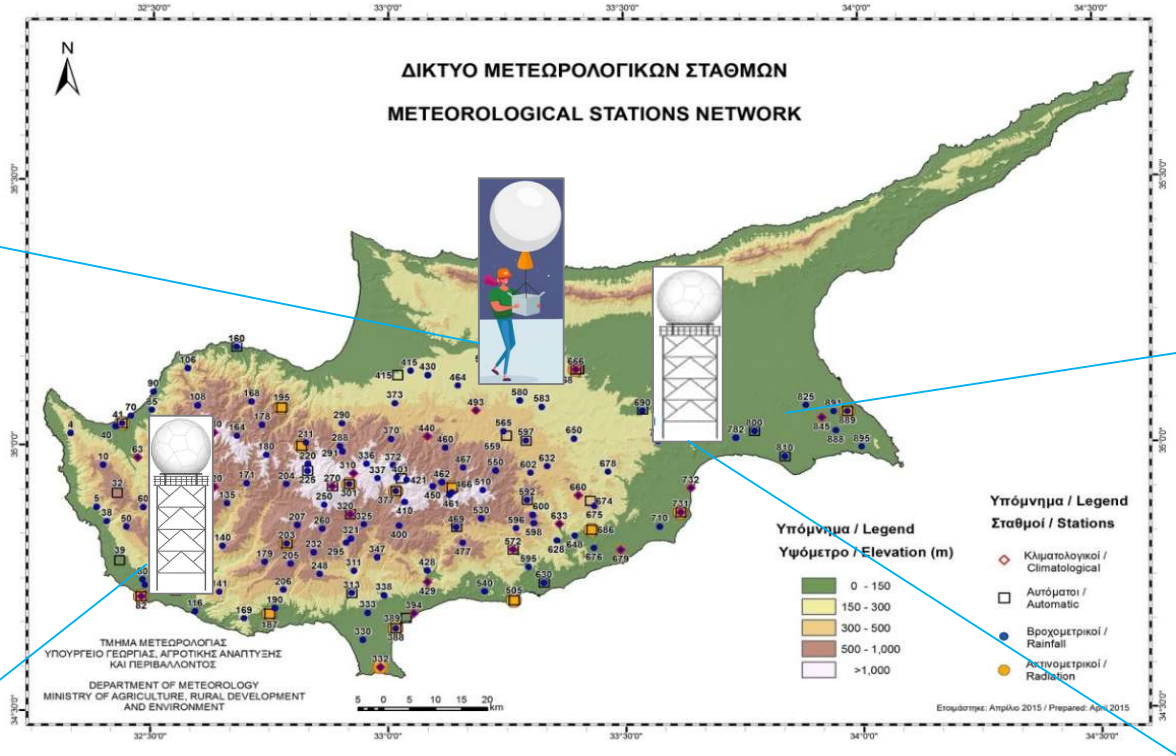
Precipitable Water Vapor PWV

- ✓ Deliver high, spatial & temporal, resolution of PWV, Slant & Zenith Tropospheric Delay (STD &ZTD)
- ✓ PWV data Assimilation into NWP model
- ✓ Research on PWV climatology (long-term)

Existing Meteorological infrastructure – Dep. Of Meteorology

Radiosonde Nicosia





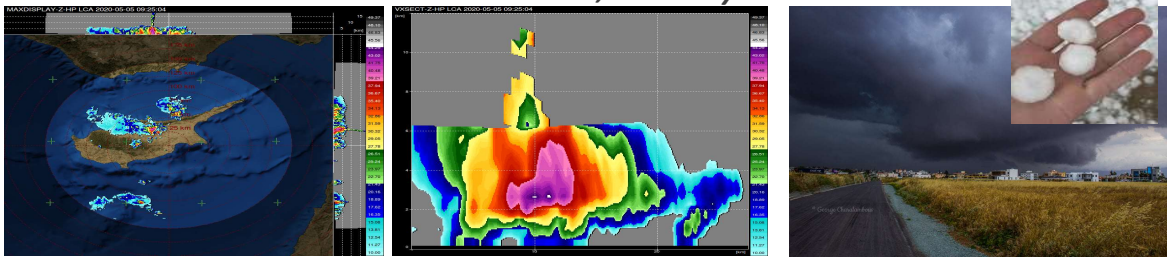
>100 Conventional and Automatic (AWS) Weather Stations (10 MINUTE AVERAGE VALUES)

https://www.dom.org.cy/AWS/ALL_STATIONS_MAP.html

Paphos Radar

2 X-Band, Doppler, dual-polarization Weather RADAR

Hail storm, 5 May 2020

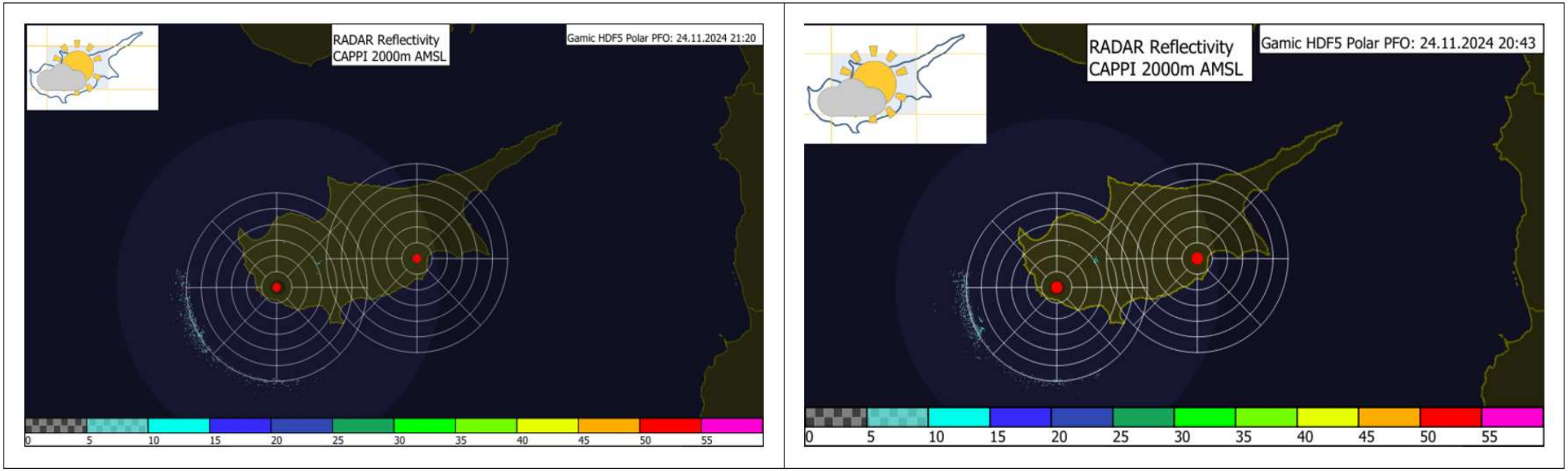


Larnaca Radar

Existing Meteorological infrastructure – Dep. Of Meteorology

LATEST RADAR IMAGES (Time is shown in UTC)

2 X-Band, Doppler, dual-polarization Weather RADARS



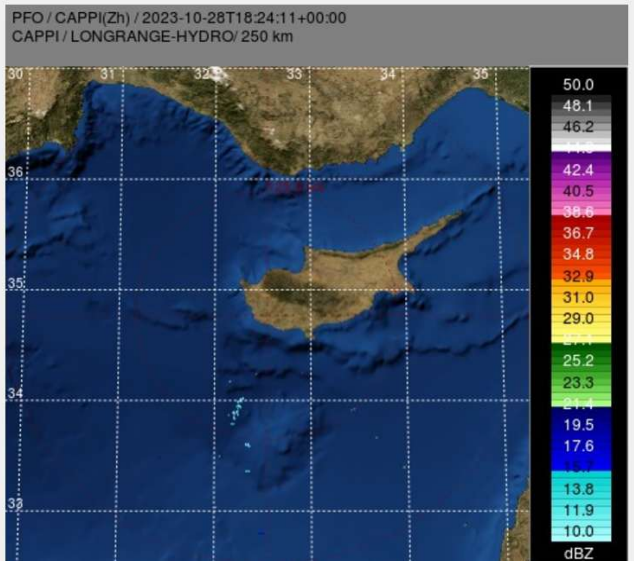
- Each system features an X-Band, Doppler, dual-polarization RADAR, allowing for accurate estimation of both rainfall as well as hydrometeor classification (hail, snow etc).
- Both RADAR systems perform simultaneous horizontal and vertical scans ("volume scanning")
- Images from the two RADAR systems are available in near real time on the Departmental website (below)
- Release Date: 2019

SOURCE:

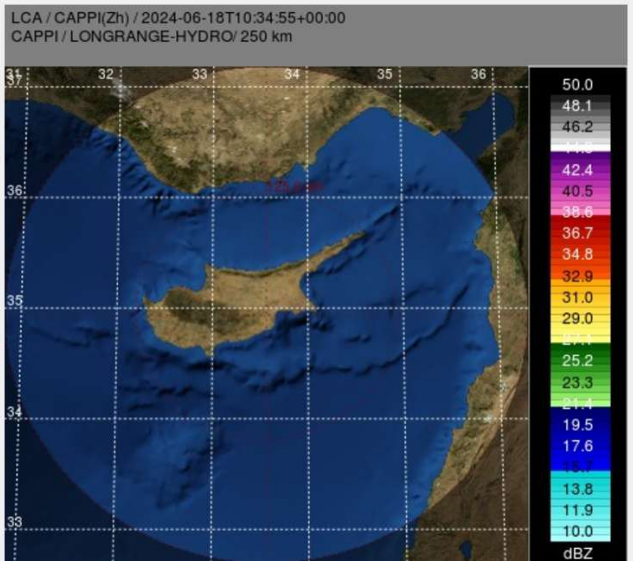
https://www.moa.gov.cy/moa/dm/dm.nsf/radar_en/radar_en?OpenDocument

Existing Meteorological infrastructure – Dep. Of Meteorology

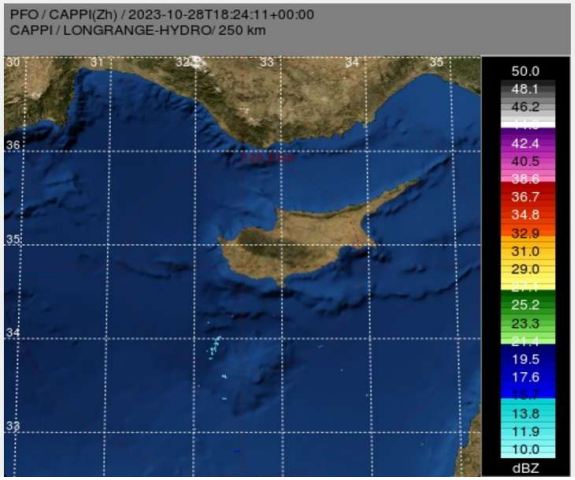
PAPHOS RADAR (CAPPI IMAGE)
LONGRANGE REFLECTIVITY



LARNACA RADAR (CAPPI IMAGE)
LONGRANGE REFLECTIVITY



RADAR COMPOSITE IMAGE (CAPPI MOSAIC RAW IMAGE DATA)
LONGRANGE REFLECTIVITY



The products provided include:

1) Reflectivity (dbZ) in CAPPI Mosaic, PPI & MAX DISPLAY

2) Doppler Velocity (m/s) in PPI & MAX DISPLAY

The radar images are normally refreshed approximately **every 10 minutes** and are provided either as GIF or jpeg images. The **CAPPI Mosaic scan layer height is 2km**, with appropriate (interpolated) filling of the gaps that are generated between different antenna elevation angles (several are used to generate a CAPPI image). The MAX display layer cut-off is at 18km. The range is as indicated on the pictures (200 km in some cases).

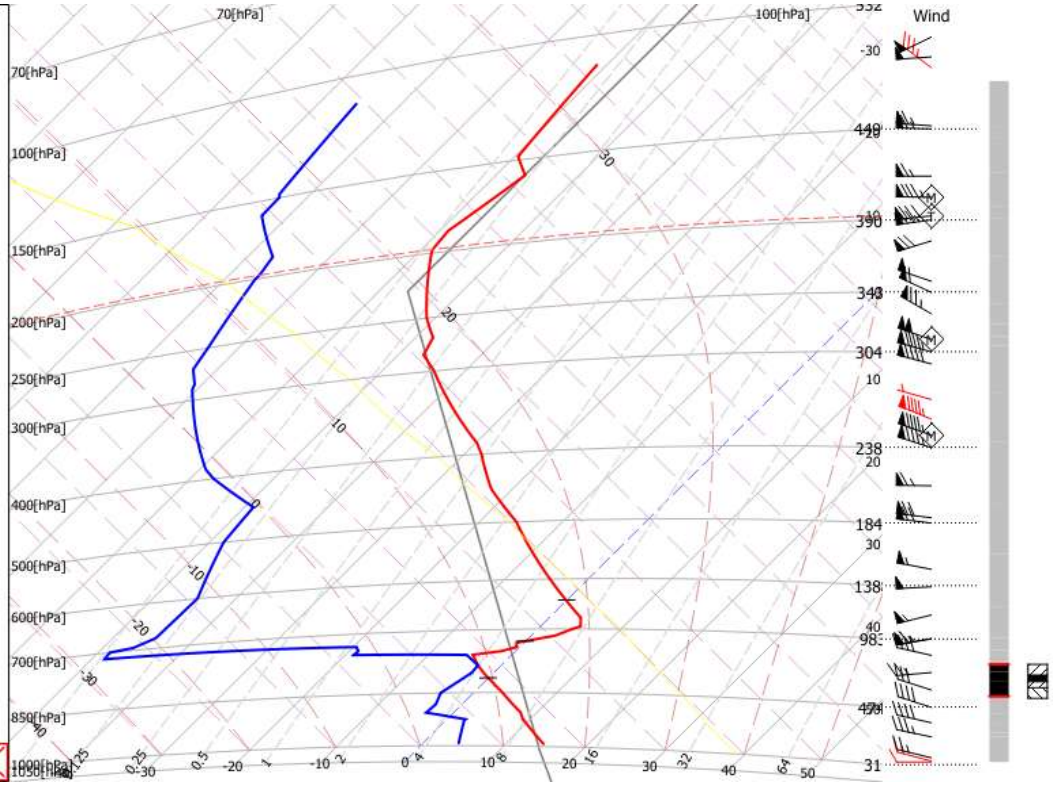
SOURCE:

https://www.moa.gov.cy/moa/dm/dm.nsf/radar_en/radar_en?OpenDocument
https://www.dom.org.cy/RADAR_DATA/
https://www.data.gov.cy/index.php/en/dataset/1067

Existing Meteorological infrastructure – Dep. Of Meteorology

Radiosonde station at Nicosia

Sounding Indices	
TEMP 17607 at 24.11.2024 05:06	
Position	35°09'N 33°24'E
Elevation	525ft
Name	ATHALASSA
KINX	-37.8
CTOT	11.6
VTOT	19.0
TTOT	30.6
LCLT	1.5°C
LCLP	5010ft
GLCLT	2.1°C
GLCLP	4740ft
LFCP	6055ft
EQLP	7860ft
SHOW	13.9
LIFT	11.4
MLI	7.0
KOINX	9.7
SINX	-24.2
JEFF	-6.0
THOM	-49.2
MAXT	16.0°C
CAPE	14 J/kg
MLCAPE	12 J/kg
CIN	39 J/kg
MLCIN	33 J/kg
BRN	0.3
DMAPE	0 J/kg
WBZ	4980ft
BOYDEN	85.8
PWAT	10.6 kg/m²
SWEAT	143
Zero Degree (A)	5920ft
Zero Degree (B)	8850ft



- The station became operational in **1981** with the aim to provide upper air measurements, also known as soundings or radio-soundings.
- These devices are equipped with meteorological sensors for measuring atmospheric temperature, humidity, pressure as well as a GPS sensor.
- The end result of the sounding is the determination of a thermodynamic profile of the atmosphere, which includes all of the above parameters as a function of height (and time of ascent), from the surface all the way to the stratosphere.
- Soundings at Athalassa (Nicosia) take place twice per day, **at 06 and 12 UTC.**

SOURCE:
https://www.dom.org.cy/index.html

The Problem in Cyprus weather prediction system

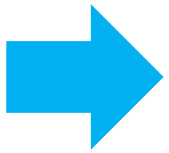
Observational Component

No lightning observations
(only 1 sensor of ZEUS network –no accurate data due to no extrapolation)

No dense wind profiles observations
(only 2 balloon soundings per day in Nicosia)

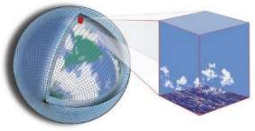
No dense (in 3D) humidity/water vapor observations
(only 1 Radiosonde & 2 Weather Radars with no profile info)

No space-based, only ground-based observations
(No dense GNSS water vapor data, no access to EUMETSAT satellite products)

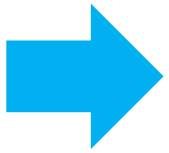


- Insufficient observational capacity to monitor the **structure, motion and intensity of local convective systems** over Cyprus

Modelling Component



No observational Data Assimilation into NWP model



- Decreased forecasting **accuracy** of **local-scale** extreme events
- Possible False **warnings**

CYGMEN
CYPRUS GNSS METEOROLOGY ENHANCEMENT - 2023

STRATEGIC INFRASTRUCTURES - National project, *Duration: 3 years, started 31st December 2023*

Christina Oikonomou, PhD
Project Coordinator
Frederick Research Center -FRC

CYPRUS RESEARCH & INNOVATION FOUNDATION

Funding: 1.500.000 euro

PROJECT PARTNERS

FREDERICK RESEARCH CENTER

CloudWater

DEPARTMENT OF METEOROLOGY

ΕΘΝΙΚΟΝ ΑΣΤΕΡΟΣΚΟΠΕΙΟΝ ΑΘΗΝΩΝ
NATIONAL OBSERVATORY ATHENS

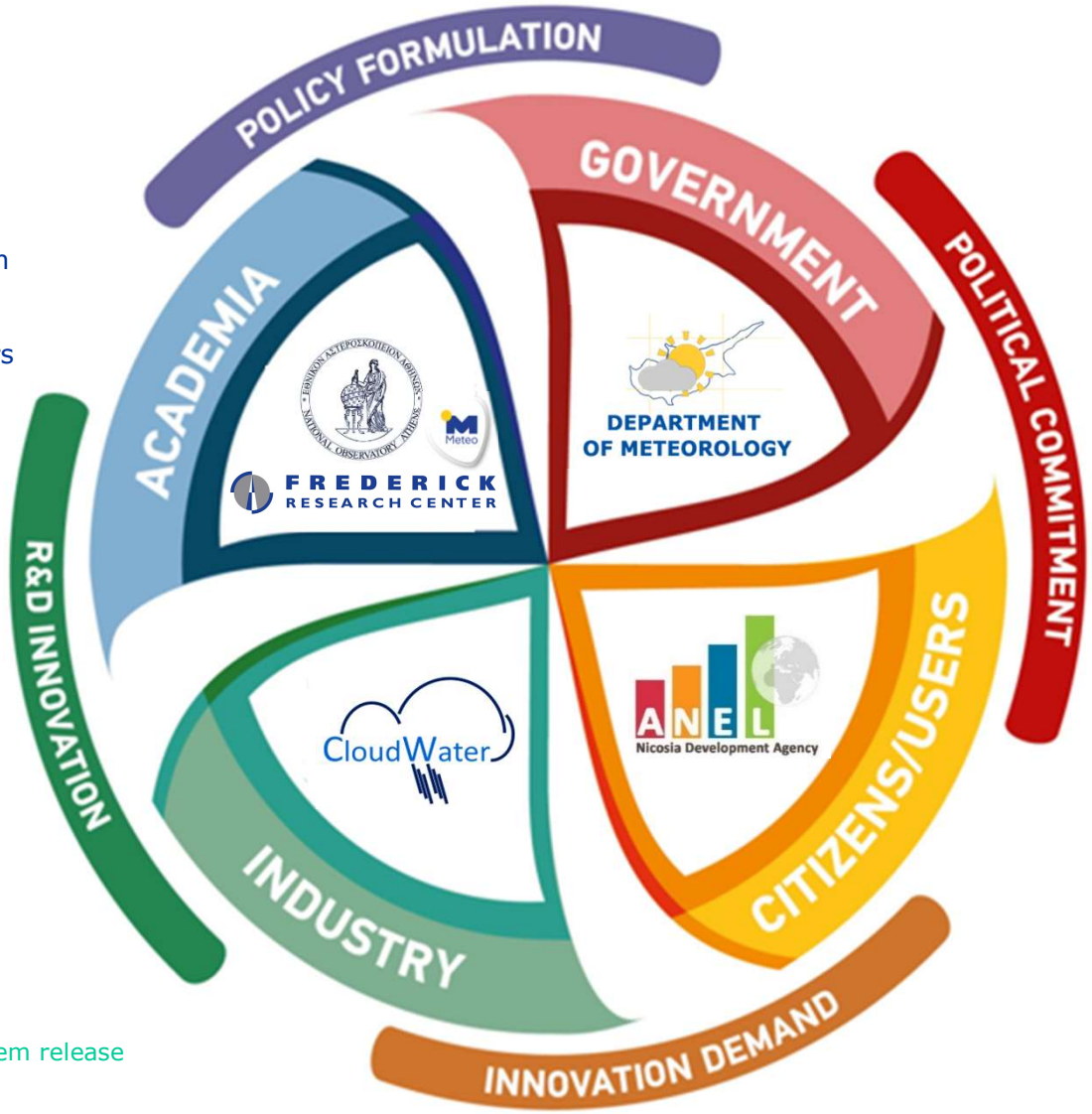
ANEL
Nicosia Development Agency

Consortium-Quadruple Helix

Frederick Research Center
- Project management
- Project Visibility/Dissemination
- Development new Infrastructure
- Sustainability Plan for Infrastructure
- Meteorological Service development
- Meteo data processing & Algorithms development
- Data Assimilation into weather prediction model
- Data management Plan & IPR handling
- Open Access Policy for service/data users
- All new products validation

National Observatory of Athens
- Installation of meteorological infrastructure (Lighting Detector network)
- Meteorological products validation
- Support in Data Assimilation to weather prediction model

Cloudwater Ltd
- Installation of GNSS receivers network
- Support Maintenance of GNSS network
- Service (Web-portal) development & System release
- GNSS tropospheric data processing
- GNSS products validation



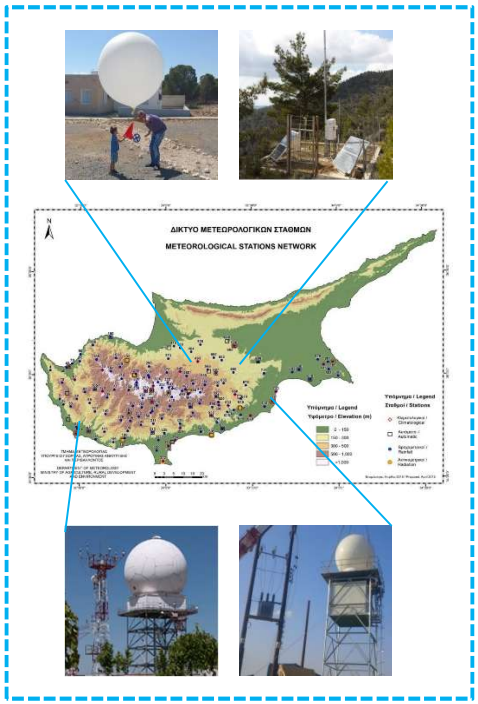
Department f Meteorology
- Installation of Meteo infrastructure (Radar wind Profiler, Radiometer)
- New meteorological Service products validation
- Processing of raw meteorological Observations
- Operational forecasts
- Support in Data Assimilation to weather prediction model
- Maintenance of new infrastructure
- Contribute to development of weather disasters risk management/mitigation policies

Nicosia Development Agency
- Nicosia hyper-dense GNSS network installation
- Support to operation and maintenance of GNSS network
- Support Project visibility in local level
- Networking with local stakeholders when a process for policy making for weather disasters mitigation is ongoing

Proposed Solution -current activity of CYGMEN strategic infrastructure project

CyMETEO infrastructure & service

Existing Meteo system



- 2 Weather RADAR (Humidity)
- 1 Radiosonde (Humidity)
- 500 Meteo stations

5 Lighting detectors network

Radar wind profiler **RWP**

Microwave Radiometer **MWR** Water Vapor profiles

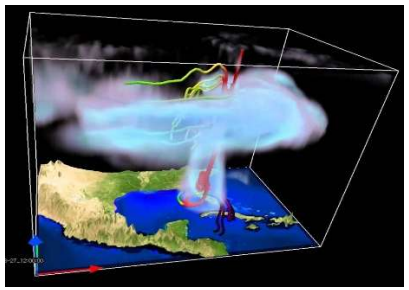
GNSS network Densification Integrated Water vapor

Observational Component

Observational Data Assimilation (DA) In NWP model (first time in Cyprus)

Modelling Component

CyMETEO Web-portal



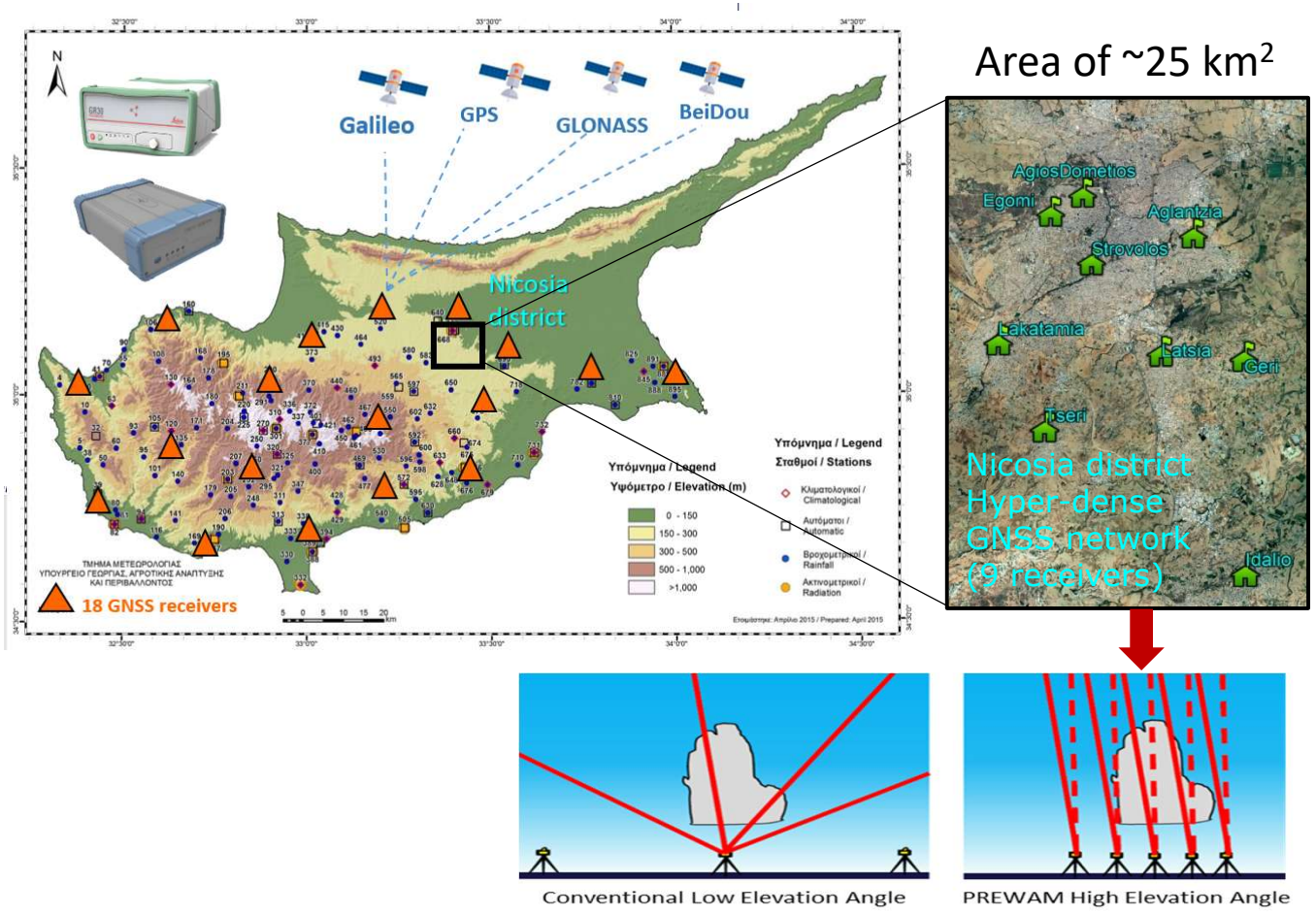
'WRF' NWP model used by Cyprus Dep of Meteorology

New supercomputer for DA

CyMETEO infrastructure – GNSS network densification

Precipitable Water Vapor PWV

- ✓ Deliver high, spatial & temporal, resolution of PWV, Slant & Zenith Tropospheric Delay (STD &ZTD)
- ✓ PWV data Assimilation into NWP model
- ✓ Research on PWV climatology (long-term)



NEW GNSS receivers Equipment

9 low-cost PREWAM GNSS receivers
(Nicosia district Hyper-dense GNSS network)

3 geodetic Leica GR30 GNSS receivers
(with AR20 Choke Ring antennas)

✚

Existing Equipment

7 CYPOS system of the Dep. of Lands and Surveys (DLS) GNSS stations

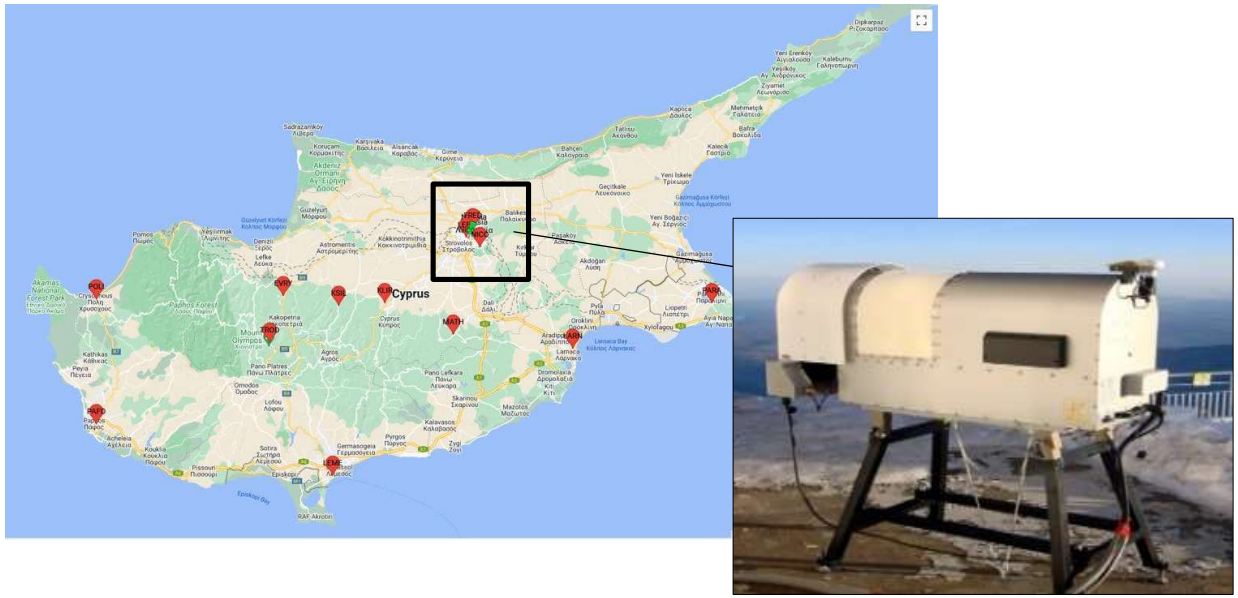
4 high-grade LEICA receivers of Coordinator Project partner (FRC)

4 low-cost PREWAM GNSS receivers of Cloudwater Ltd partner

CyMETEO infrastructure – **Microwave Radiometer MWR** at Nicosia capital

MWR for
Humidity and Temperature profiles,
Precipitable Water vapor

- ✓ Deliver high time & vertical resolution temperature, water vapour and relative humidity profiles over Nicosia capital city
- ✓ Installed at the Athalassa met. station of Dep. Of Meteorology –Nicosia capital
- ✓ Used by forecasters –operational forecasts
- ✓ Used as reference station for validation of GNSS-derived water vapor
- ✓ Will be assimilated into NWP model



Equipment	**MWR**
Indicative Model	RPG MWR radiometer
Measure-ments	Humidity and Temperature vertical profiles, Precipitable Water Vapor
Temperature profile Vertical resolution	BL-Mode: 30 m (range 0 -1200 m) Z-Mode: 200 m (range 1200 -5000 m) 400 m (range 5000 -10000 m)
Humidity profile Vertical resolution	200 m (range 0-2000 m) 400 m (range 2000-5000 m) 800 m (range 5000-10000 m)
Data Format	NetCDF
Dimensions	63 × 36 × 90 cm^3
Cost	**€200,000** (includes transport, installation)

CyMETEO infrastructure – **Microwave Radiometer MWR** at Nicosia capital

Radiosonde

Hyper-dense
GNSS network

MWR

Nicosia capital

RWP

Larnaca Airport

Paphos airport

Weather Radar Paphos

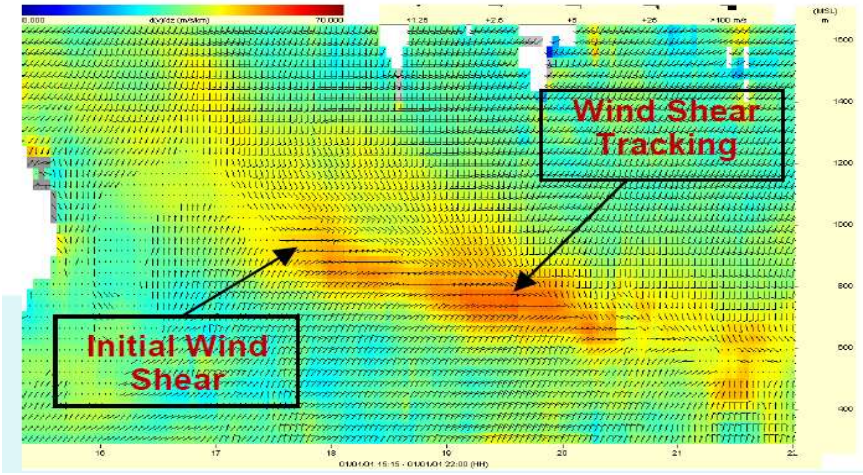
Weather Radar Larnaca

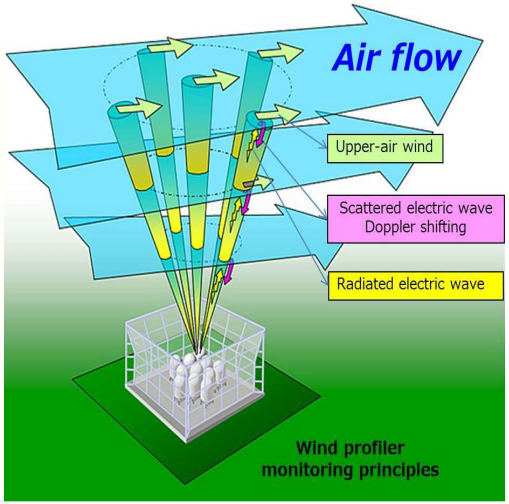
13 GNSS network stations

CyMETEO infrastructure – **Radar Wind Profiler RWP** in Larnaca Airport

Vertical profiles of wind speed to be used for:

- ✓ Operational forecasting of turbulence/wind at Larnaca airport
- ✓ Assimilation into NWP model
- ✓ Research activities on Atmospheric Boundary Layer & extreme dust episodes in Cyprus



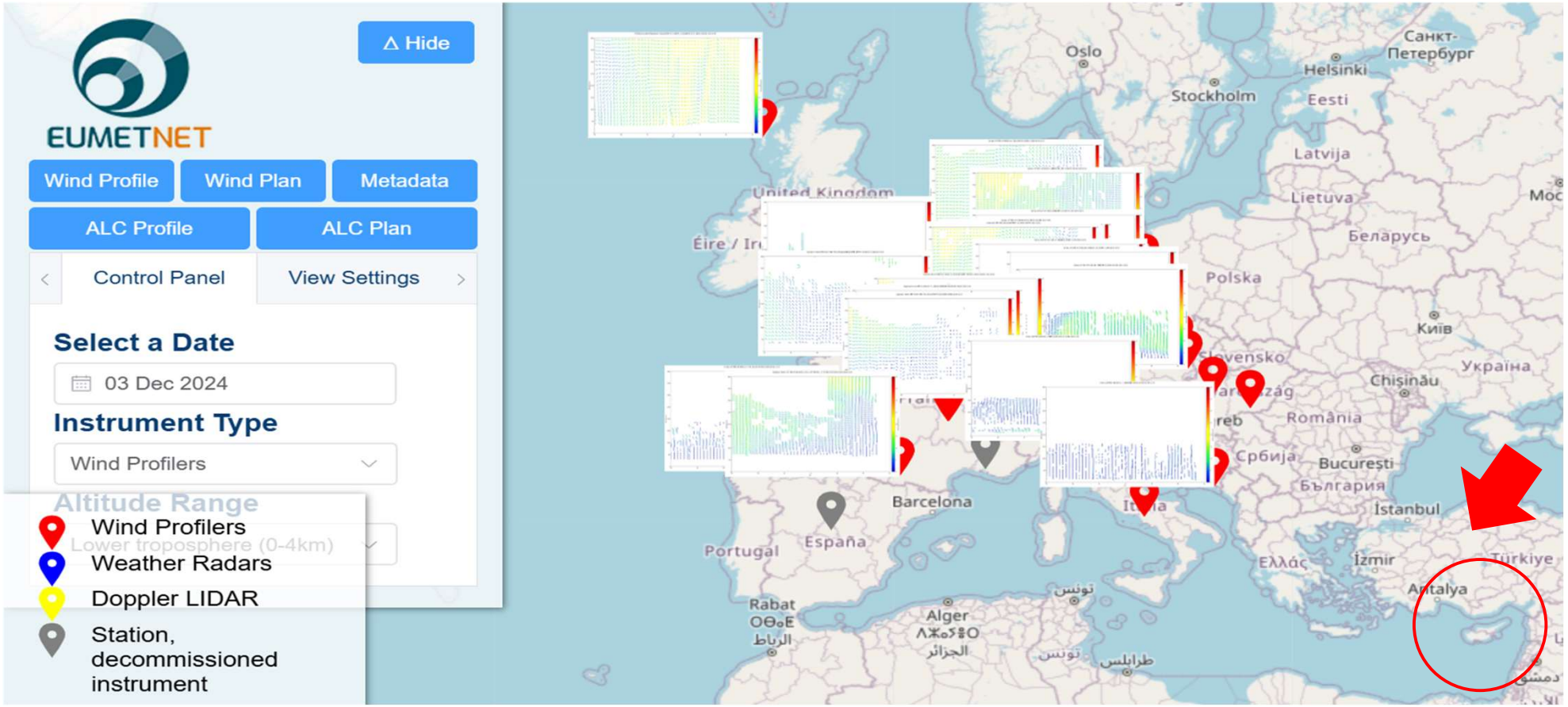


Equipment	RWP
Indicative Model	SCINTEC
Measure-ments	profiles of (U, V, W) wind speed components, turbulence)
Vertical Height	from 75m to 5000m
Operational Time resolution	1 min to 1 hour (user-defined settings)
Data Format	NetCDF or BUFR
Degreane Software	Inhouse software provides data in NetCDF, BUFR format easy to be assimilated into NWP model
Cost	**€450,000** (Includes transport, installation, commissioning, training)

EUMETNET– Radar Wind Profiler European network

E-PROFILE is part of the EUMETNET Composite Observing System, EUCOS, managing the European networks of radar wind profilers (RWP) and automatic lidars and ceilometers (ALC) for the monitoring of vertical profiles of wind and aerosols including volcanic ash.

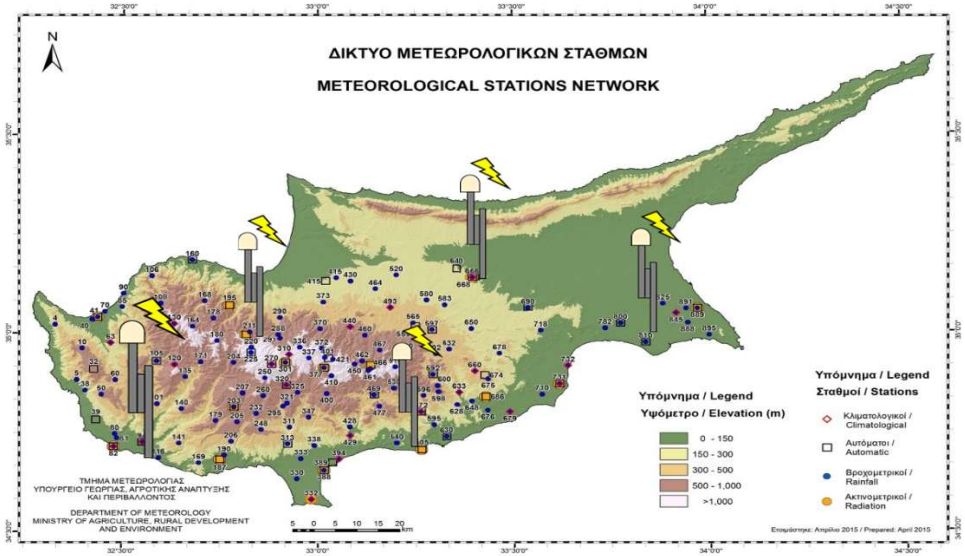
https://e-profile.eu/

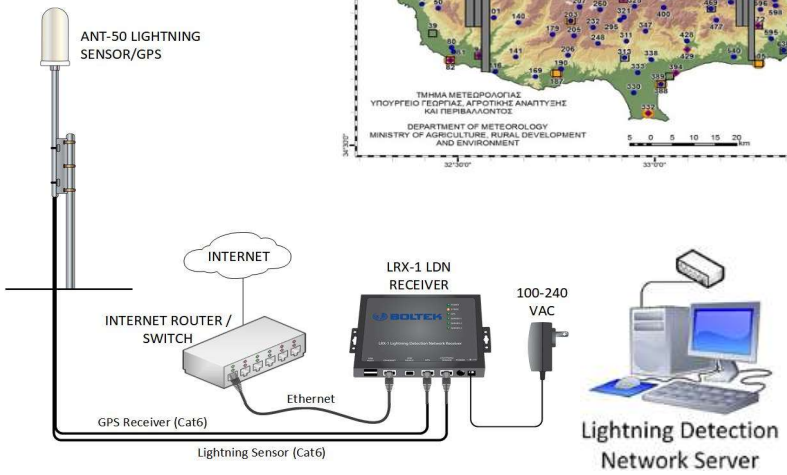


CyMETEO infrastructure – Lightning detection network

Lightning activity

- ✓ Deliver strike data to up to three separate servers within milliseconds of a strike occurrence
- ✓ Assimilation of lighting data into NWP model
- ✓ Lighting climatology for the wider Cyprus area at high spatial and temporal resolution (long-term)





Equipment	**5 LIGHTNING DETECTOR NETWORK**
Indicative Model	**Boltek LRX-1**

- LRX-1 Lightning Detection Network Reciever
- ANT-50 Lightning Sensor / GPS
- Pole Mount Bracket / Mast for ANT-50
- 100-240VAC Power Supply
- 100Ft (30m) CAT5 Cable for ANT-50 Lightning Sensor
- 100Ft (30m) CAT5 Cable for ANT-50 GPS
- 6Ft (1.8m) CAT5 Cable for Network 8 3,790.00 30,320.00
- Lightning Detection Network Server Software for Microsoft Windows

Measure-ments	Number of Strikes
Cost	**€25,000** (Includes transport, installation)

CyMETEO infrastructure

Radiosonde

MWR

RWP

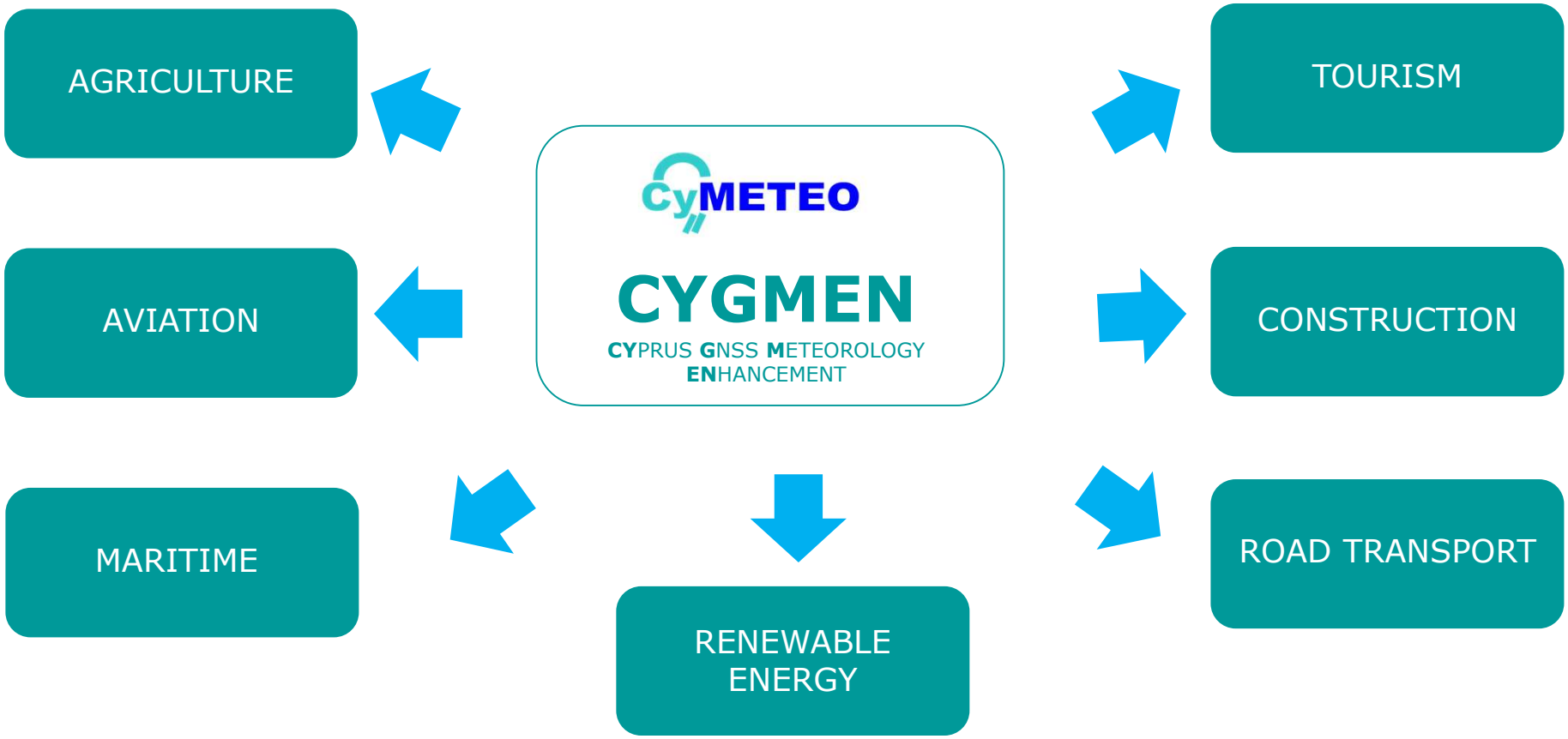
Weather Radar Paphos

Weather Radar Larnaca

Relation and Impact on the Smart Specialisation Strategy (S_3Cy) sectors

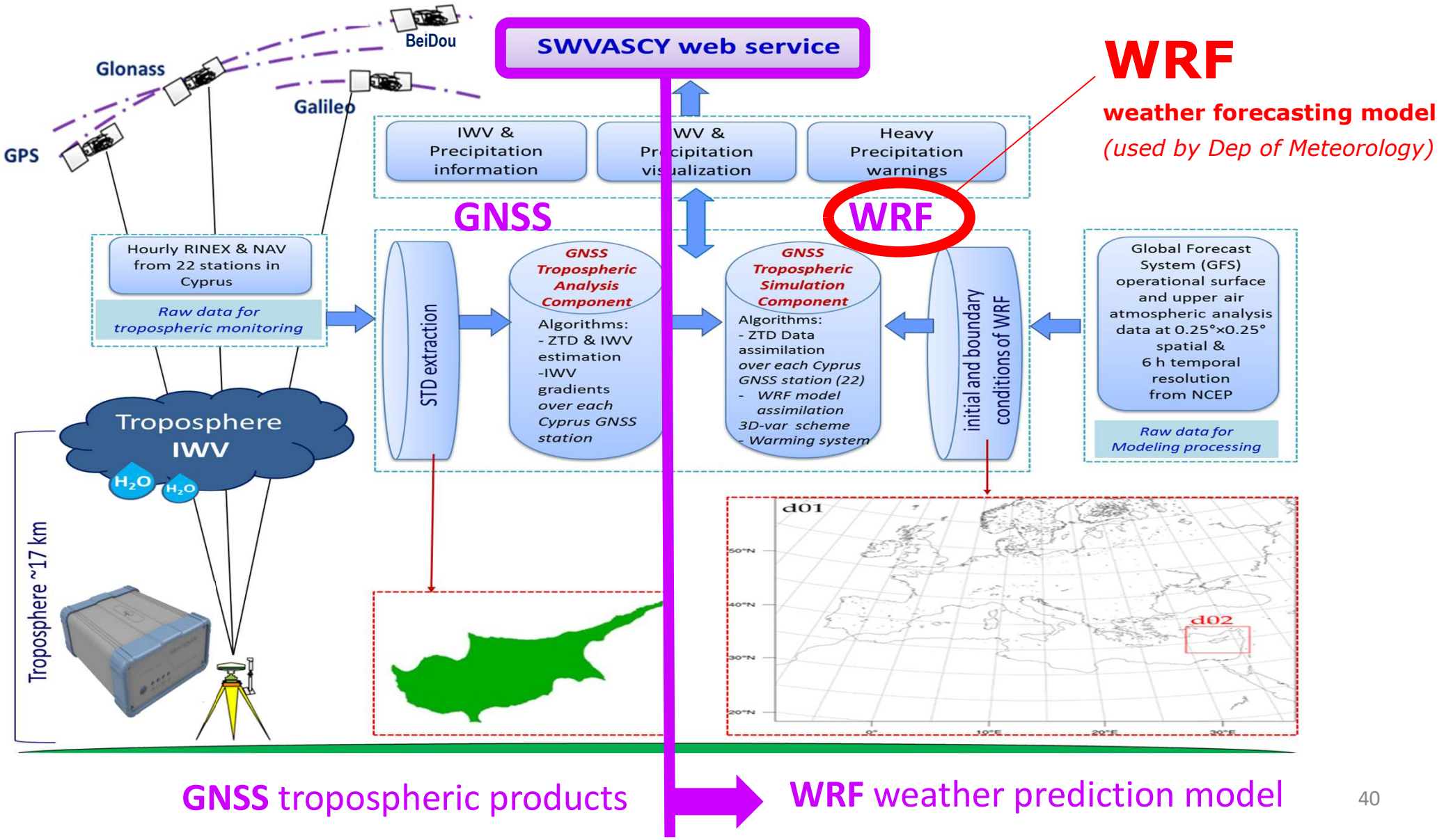
This field of research is fully in line with the relevant subtopics targeted by the Cyprus S_3Cy focusing in particular to Sustainable growth through Adjustment to Climate Change-prevention and management of risk addressed on an operational level. Digital technologies and Earth Observation for monitoring and decision making.

According to the updated S3Cy of Cyprus addressing environmental challenges such as extreme weather events is a crucial enabler for the strategy's success in sectors linked or exposed to weather such as agriculture, tourism, construction, transport and energy (including renewable energy systems), transport (including maritime, aviation).



ESA PECS project: **S**atellite **W**ater **VA**pour **S**ervice **CY**prus - **SWVASCY**

Coordinator: Cloudwater Ltd, Partner: Frederick University



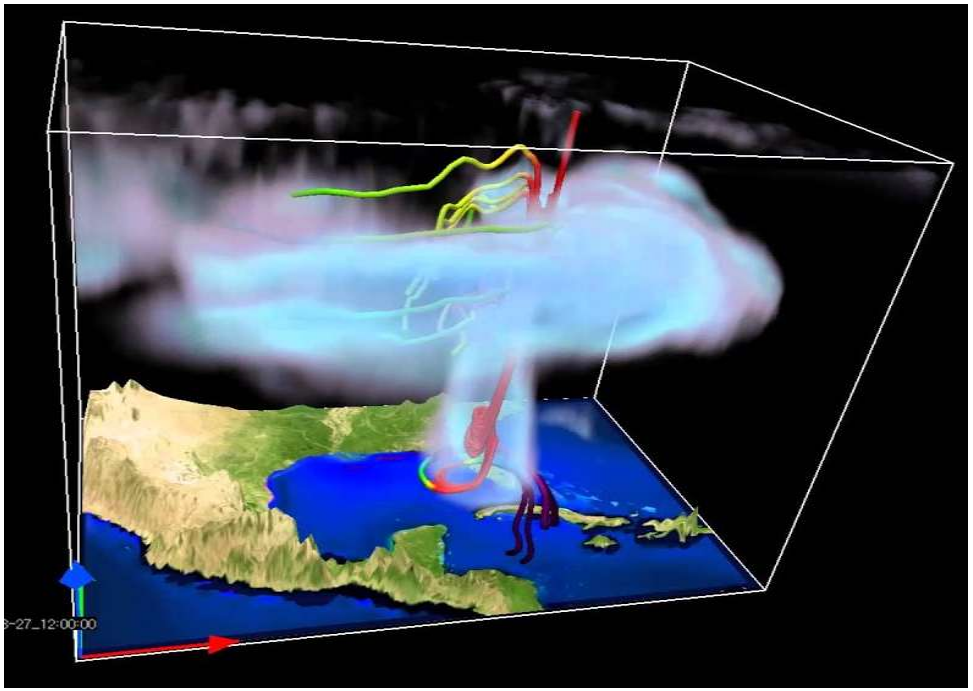
WRF weather forecasting model

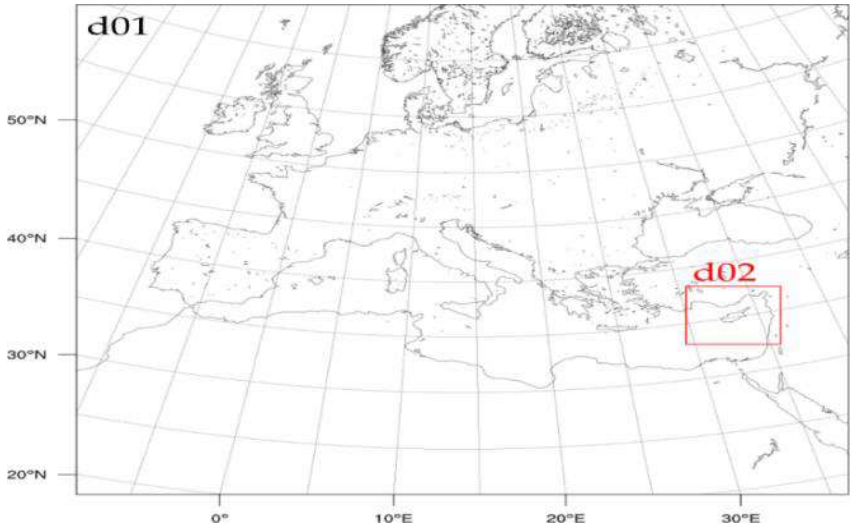
Configuration and experimental design set up

- Two-way nested modeling domains: d01) 10x10 km, d02) 2x2 km (Cyprus)
- Two simulations for each day of the examined events:

a) Control (CTL) experiment,
b) GNSS observations assimilation (ZTD) experiment using 3D-var under cycling mode

Used operationally also by Cyprus Department of Meteorology but without the capability of Data Assimilation into model



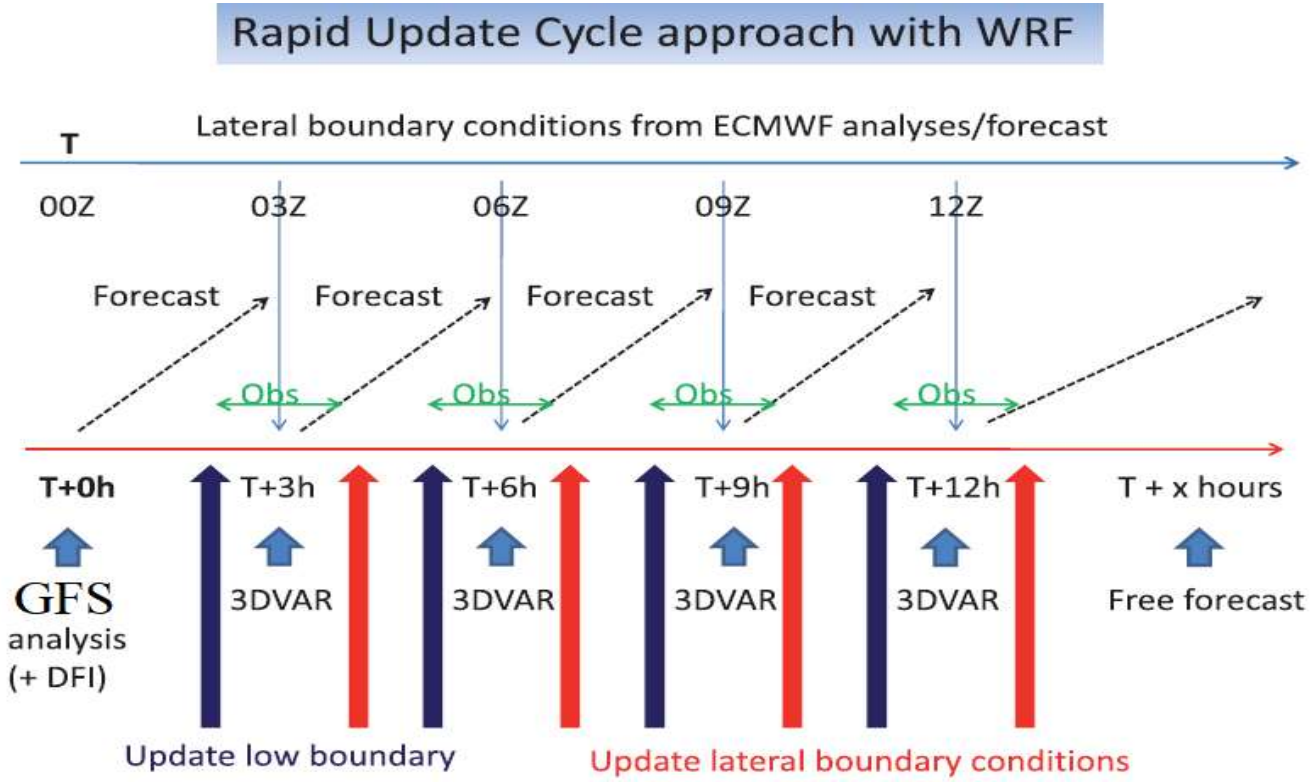


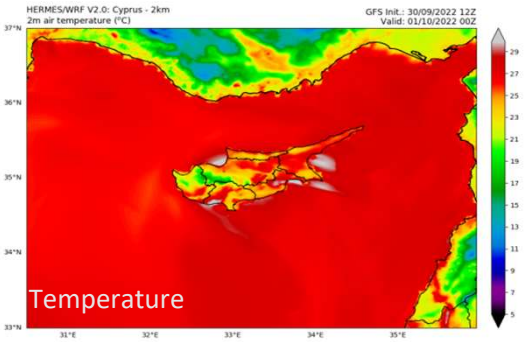
Hurricane Katrina (2005) simulation using WRF model 2D flow of Water Vapor

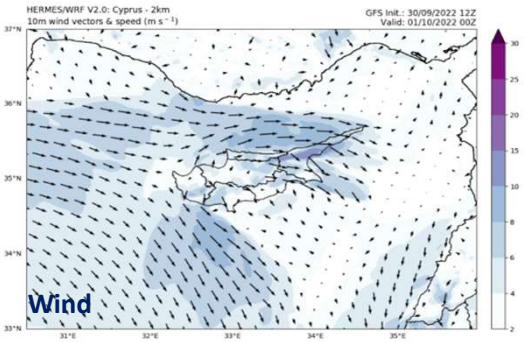
WRF weather forecasting model

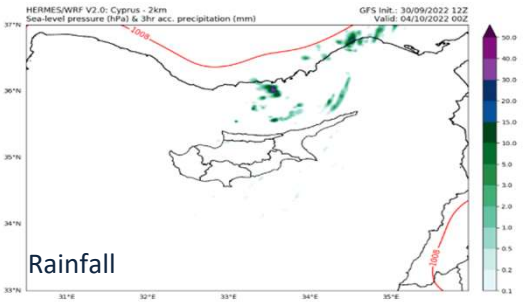
Forecasting – WATER VAPOR GNSS Data assimilation strategy

- WRF background error covariances (regional "gen_be"; operationally updated on a monthly basis)
- **Two updates per day** (0000 UTC and 1200 UTC forecasting cycles)





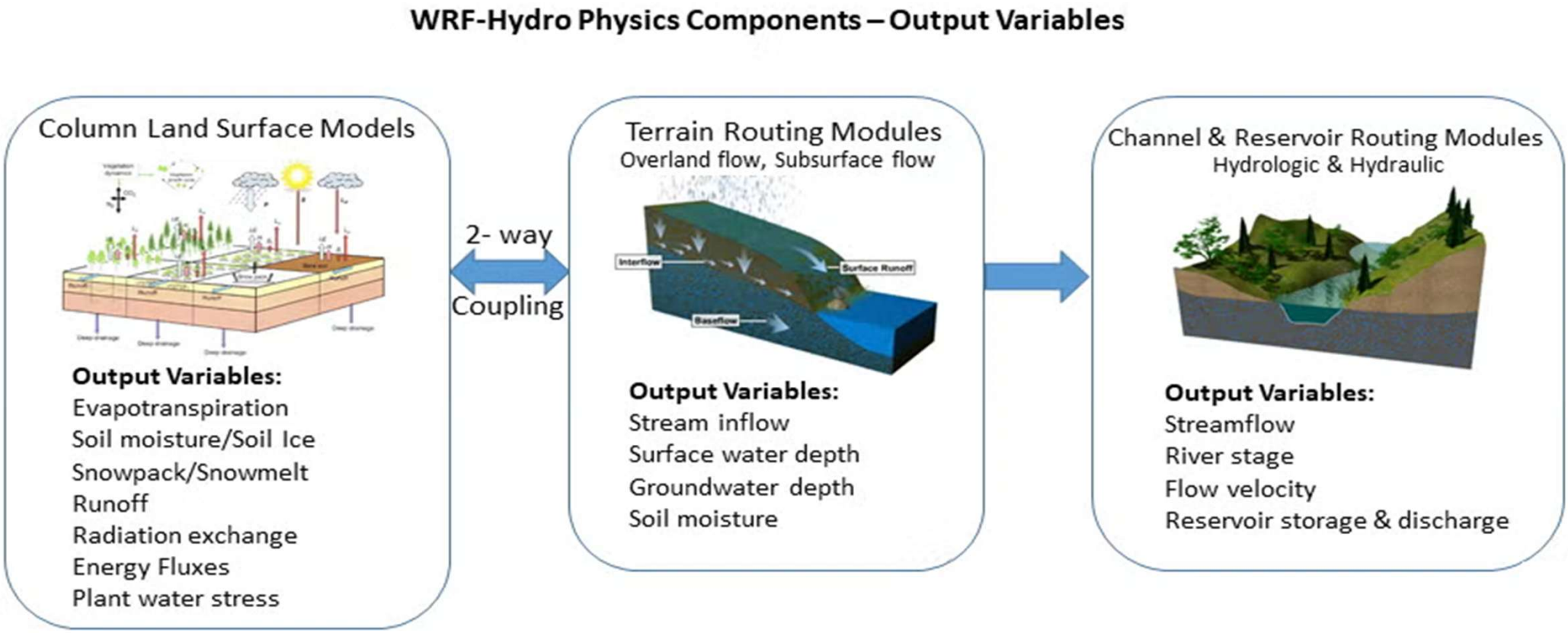




WRF model + Hydro component

Open-source software tool developed and used by USA national meteorological service

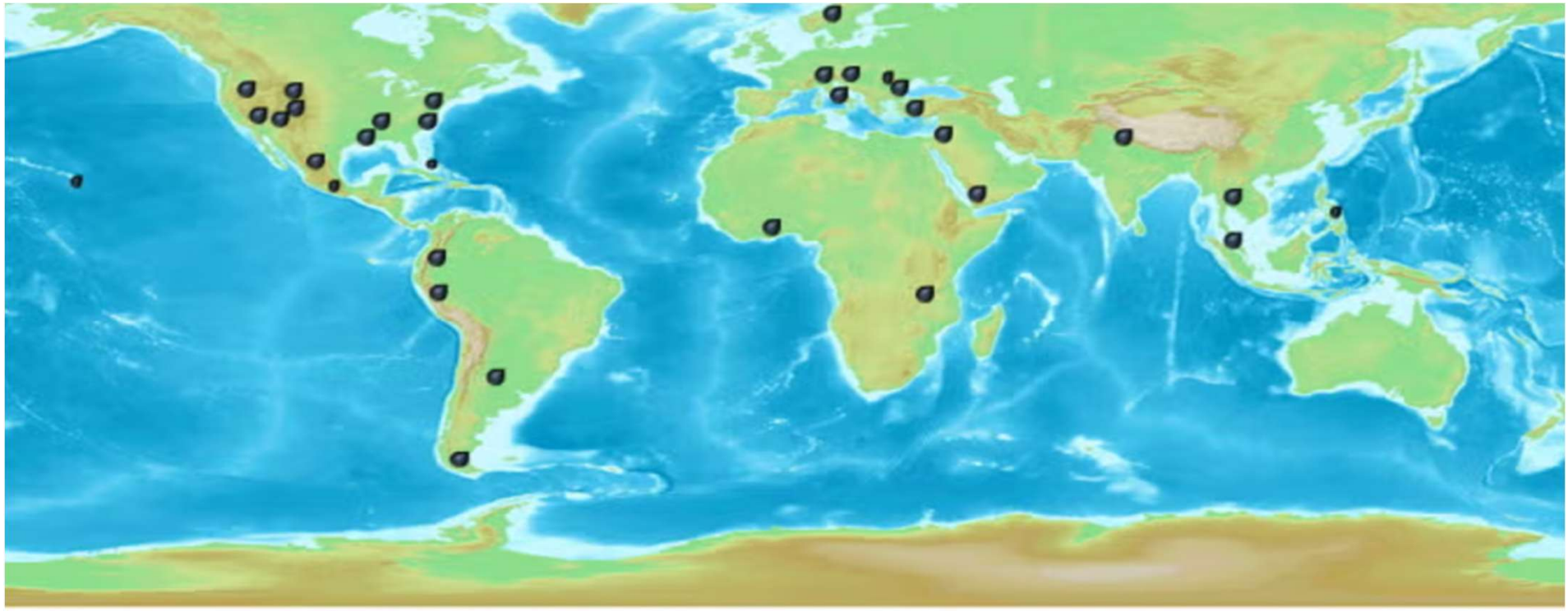
https://ral.ucar.edu/projects/wrf_hydro#applications4



Conceptual diagram of WRF-Hydro components

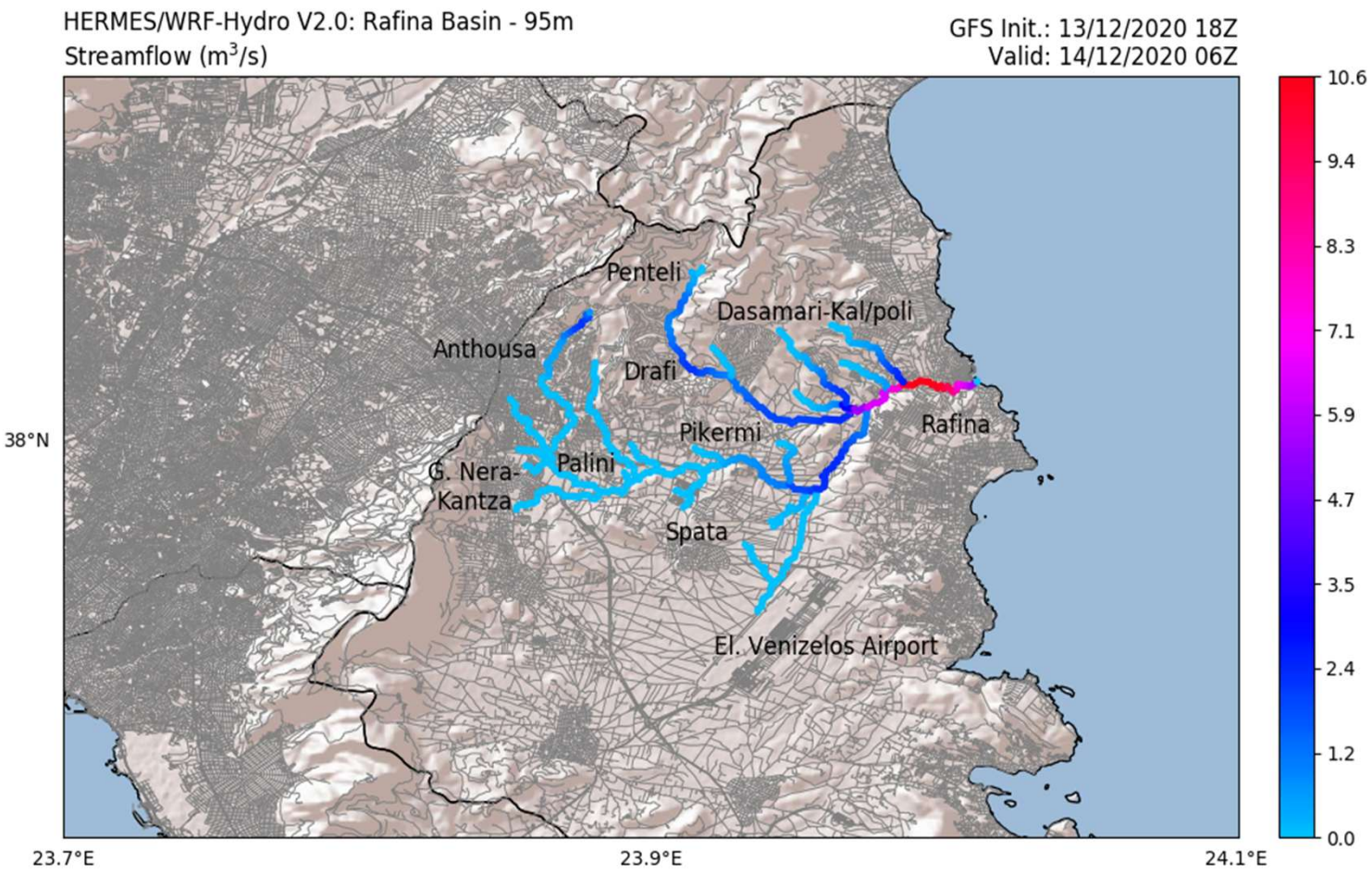
WRF - Hydro Modeling System

Applications around the world



- Operational Streamflow Forecasting
- Streamflow Prediction Research
- Diagnosing Climate Change Impacts on Water Resources
- Diagnosing Land-Atmosphere Coupling Behavior in Mountain Front Regions
- Diagnosing Impacts of Disturbed Landscapes on Coupled Hydrometeorological Predictions
- Coupling WRF-Hydro with Coastal Process Models

WRF - Hydro



Simulated discharge across the Rafina stream, Attica Greece

- **WRF** operates once **daily (1200 UTC cycle)** to simulate the meteorological conditions for the next 3 days over Cyprus and Greece at a horizontal grid resolution of **2 km**
- **WRF-Hydro** is initialized, when a significant precipitation episode is being forecasted over **Archngelos-Kamitsis (Larnaca, Cyprus)**, **Sarantapotamos** and **Rafina (Attica, Greece)** basins.
- The coupled WRF-Hydro model provides **1.5-day forecasts at ~667m (meteorological component)** and **~95 m (hydrological component)** spatial resolutions over the **targeted catchments**

WRF model + Hydro component

According the preliminary warning thresholds, which were defined according to the hydrometeorological and socio-economic impact analysis that conducted in the framework of CyFFORS in the area [1], this exceedance corresponded to possible minimal impacts (Table 1). For this, a flood alert associated with this expected level of impact was issued, as shown in Figure 2. This warning corresponds well to the localized flooding reported in the area by the local media (https://www.irafina.gr/rafina-afti-ine-i-katastasi-stis-gefires-tis-arionos-ke-tou-varda-pou-plimmirisan-apo-tin-kakokeria-foto/).

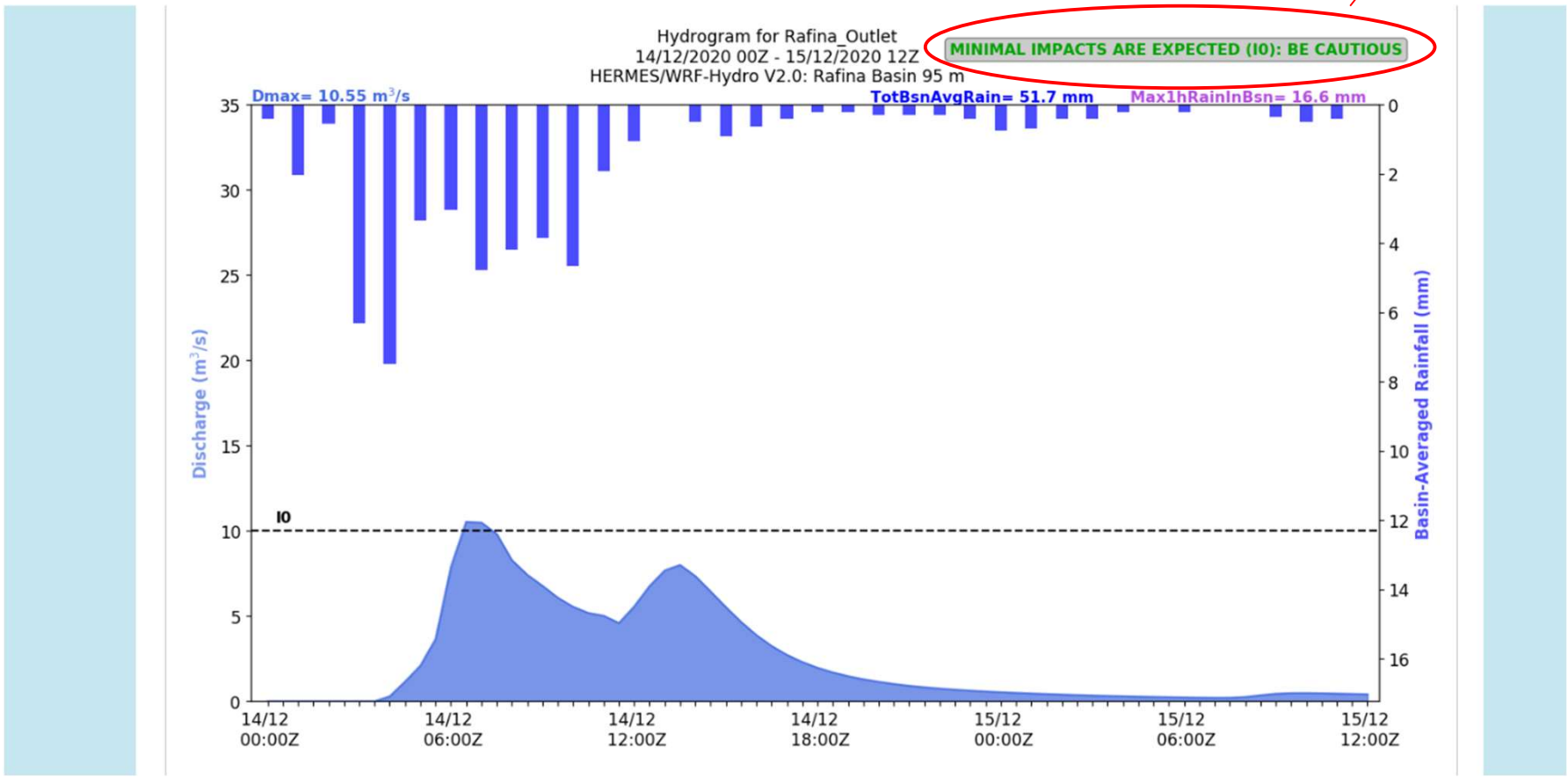
Table 1. Socioeconomic impact intensity classification.

	I0: Minimal	I1: Minor	I2: Significant	I3: Severe
Human life	Not expected	Risk for vulnerable groups of people and/or involved in endangered situations	Danger to life due to physical hazards associated with flooding water	Danger to life due to physical, chemical and utility hazards associated with flooding water
Damage to properties and public structures	Not expected	Light damage to individual properties	Important damage to many properties and/or public structures	Extensive damage to multiple properties and/or public structures
Transportation	Little or no disruption to river crossings and/or roads close to the river/stream	Small-scale disruption (local and short term)	Large-scale disruption (broad and long term) and/or important damage to the transport network	Extensive disruption (broad and long term) and/or extensive damage to the transport network
Utilities	Not expected	Small-scale disruption (local and short term)	Large-scale disruption (broad and long term)	Extensive disruption (broad and long term) and/or loss of utilities

Warning message

WRF model + Hydro component

Warning message



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(including Cyprus Dep of Meteorology)

EMMA (European Multi service Meteorological Awareness) and the

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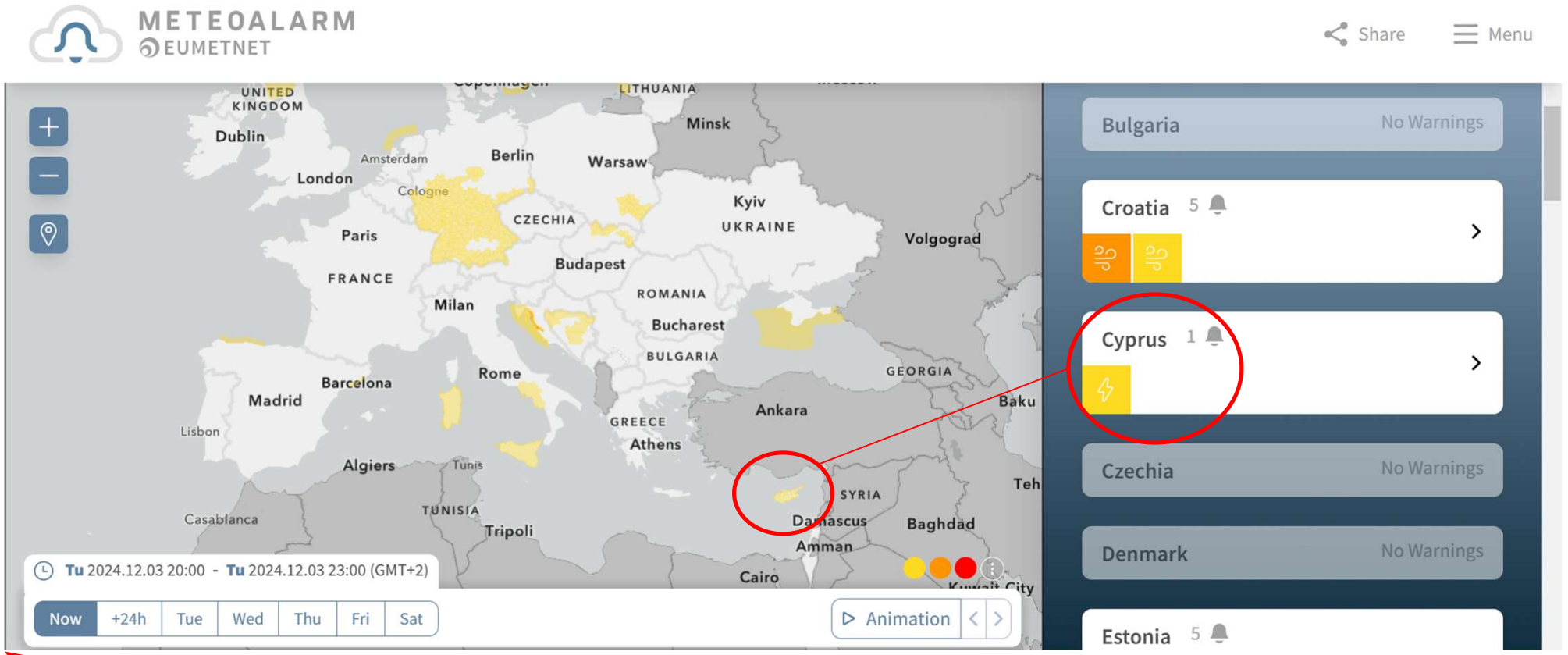
https://meteoalarm.org/en/live/



Extreme weather forecast

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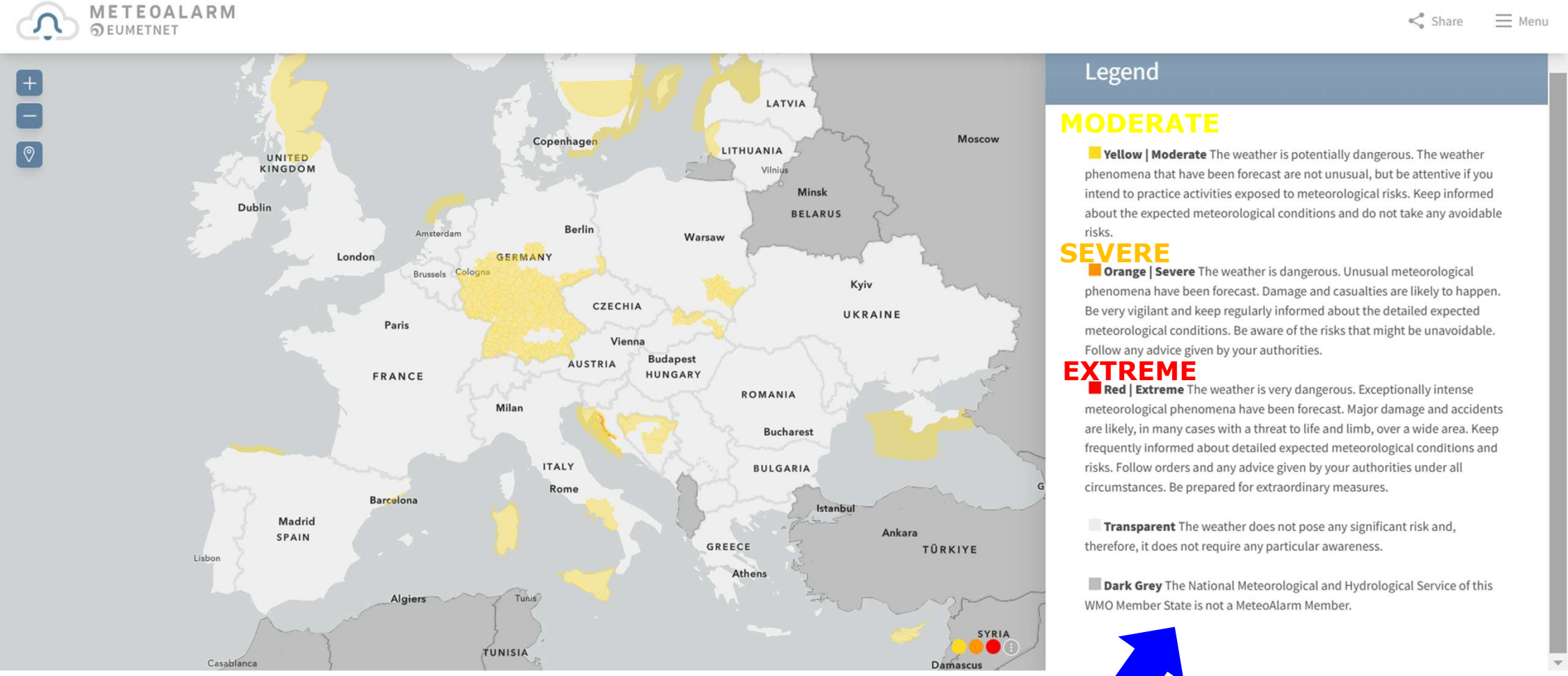

COLOR-SCALED Extreme weather awareness level

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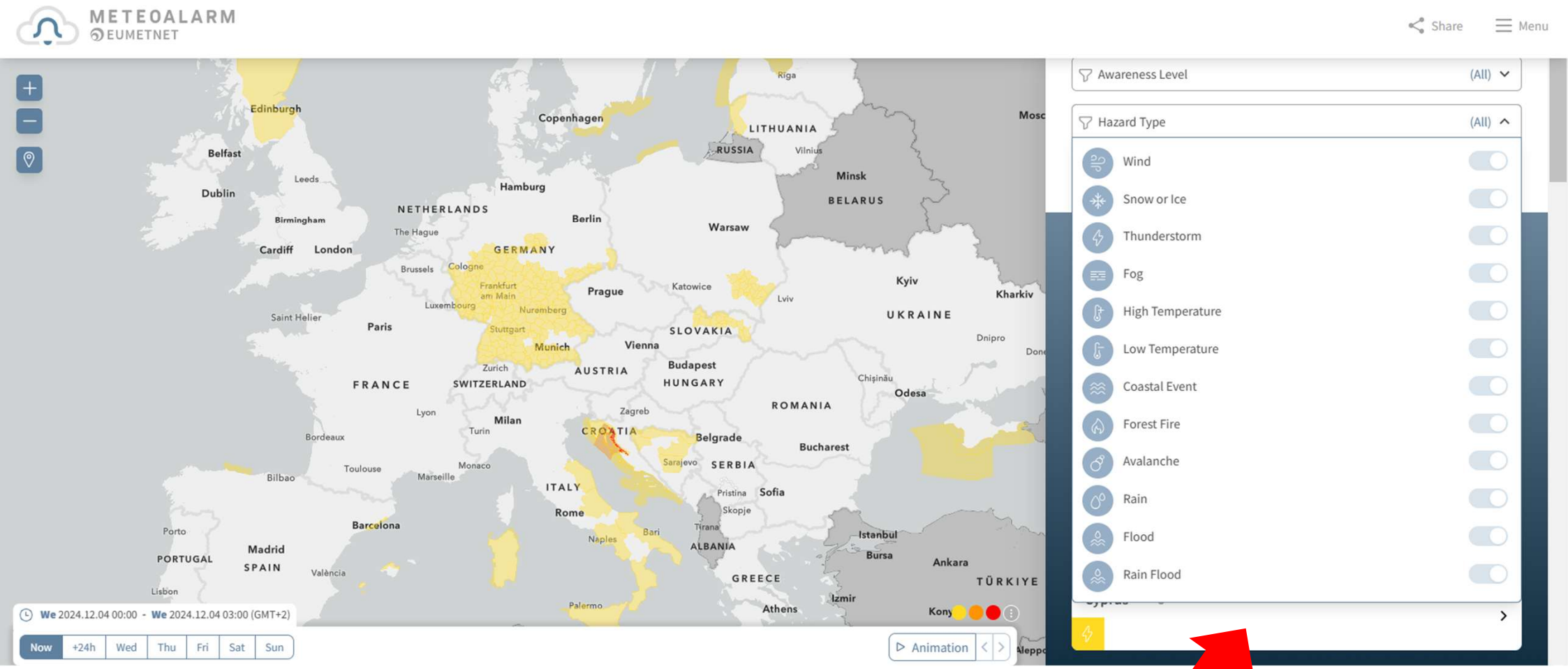

HAZARD TYPE

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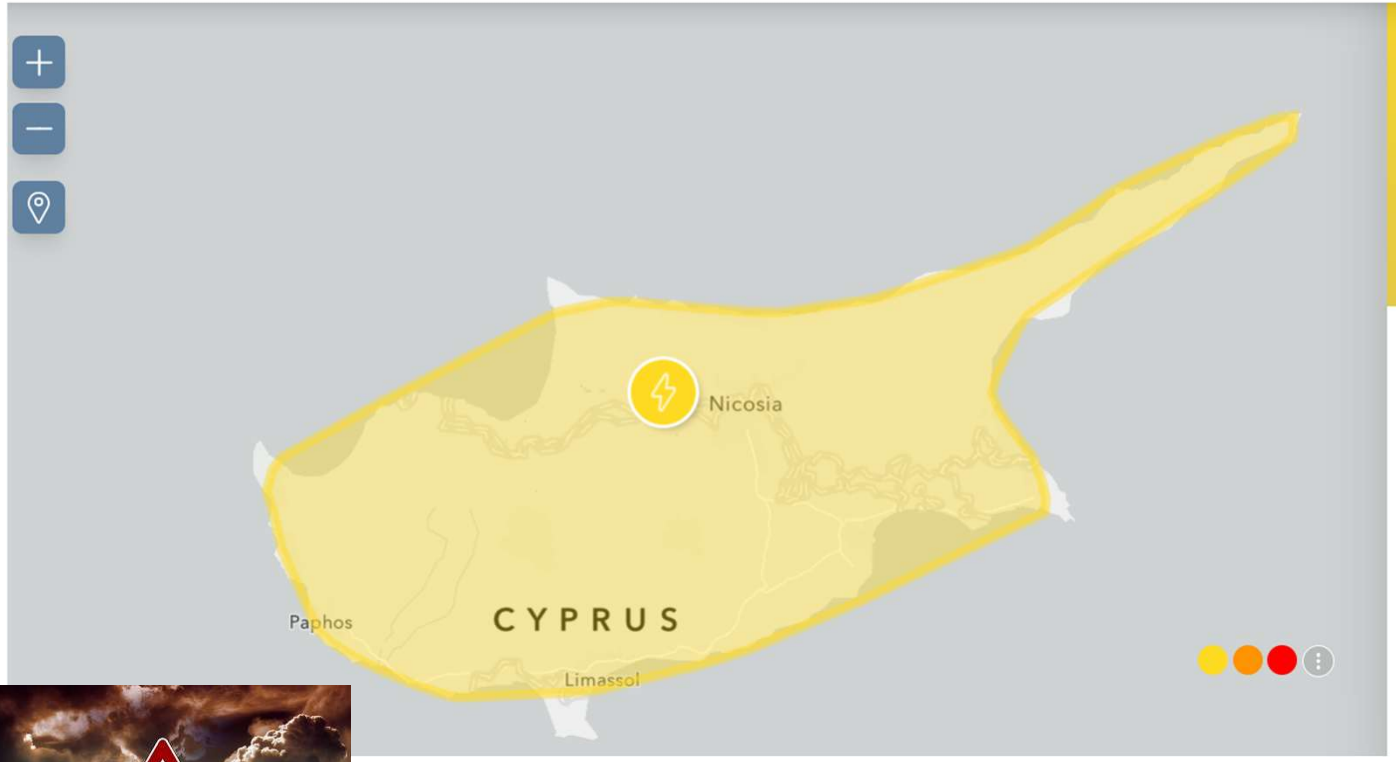


Thunderstorm
Cyprus

Start & End
03.12.2024 / 18:00 (GMT+2)
04.12.2024 / 08:59 (GMT+2)

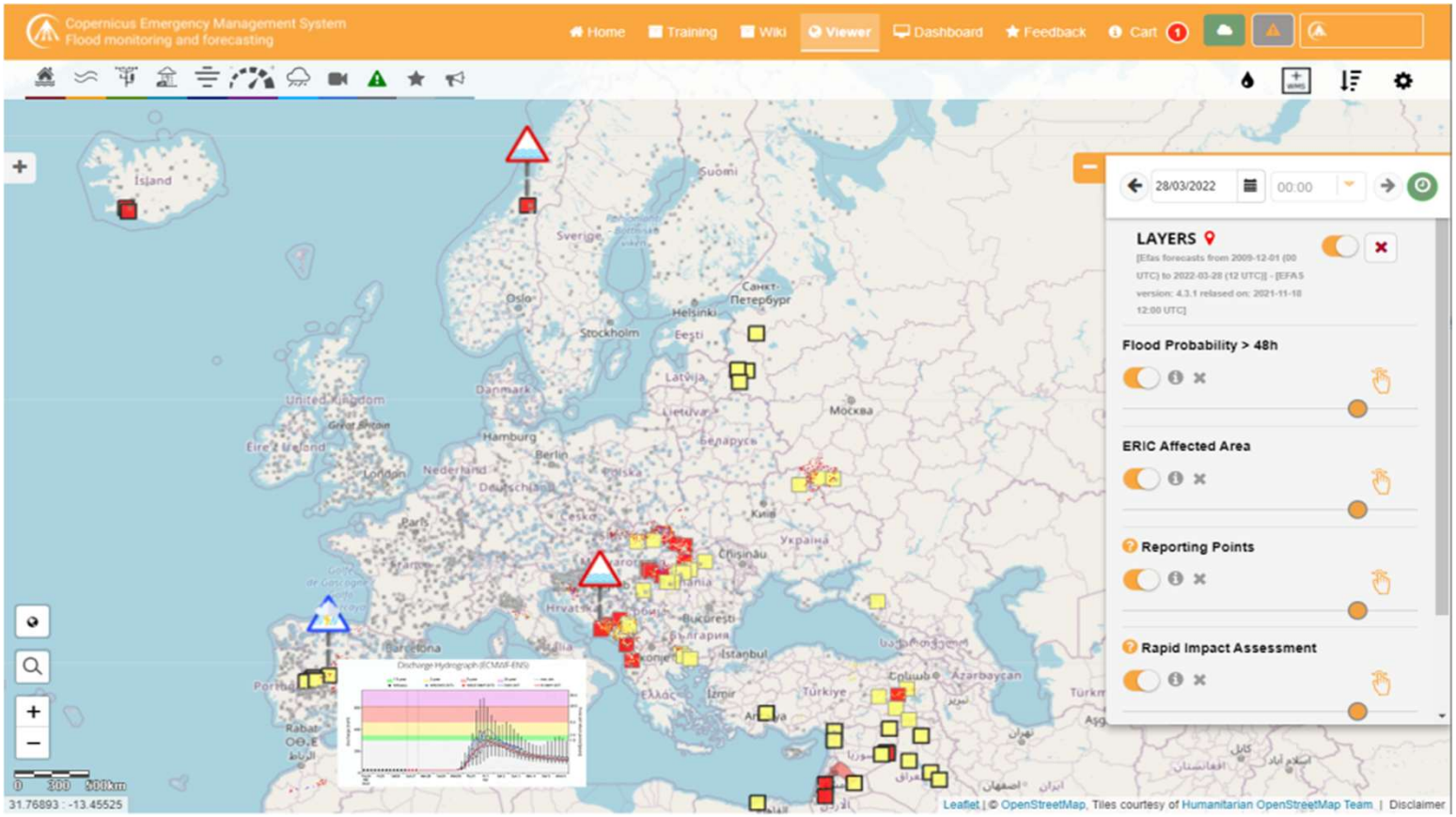
ISOLATED SEVERE THUNDERSTORMS ARE EXPECTED TO AFFECT THE AREA. PRECIPITATION RATE WILL RANGE BETWEEN 35 AND 55 MILLIMETERS PER HOUR. IN STORM AREAS HAIL IS LIKELY AND STRONG WINDS GUSTS ARE ALSO POSSIBLE.

Warning message

EFAS - European Flood Awareness System

- ✓ The European Flood Awareness System (EFAS) is the first operational pan-European flood forecasting and monitoring system
- ✓ EFAS provides constantly updated early flood forecasting information to support national and regional flood risk management authorities in arranging preparatory measures before an event strikes. It also estimates and maps the potential socio-economic impact of those events.

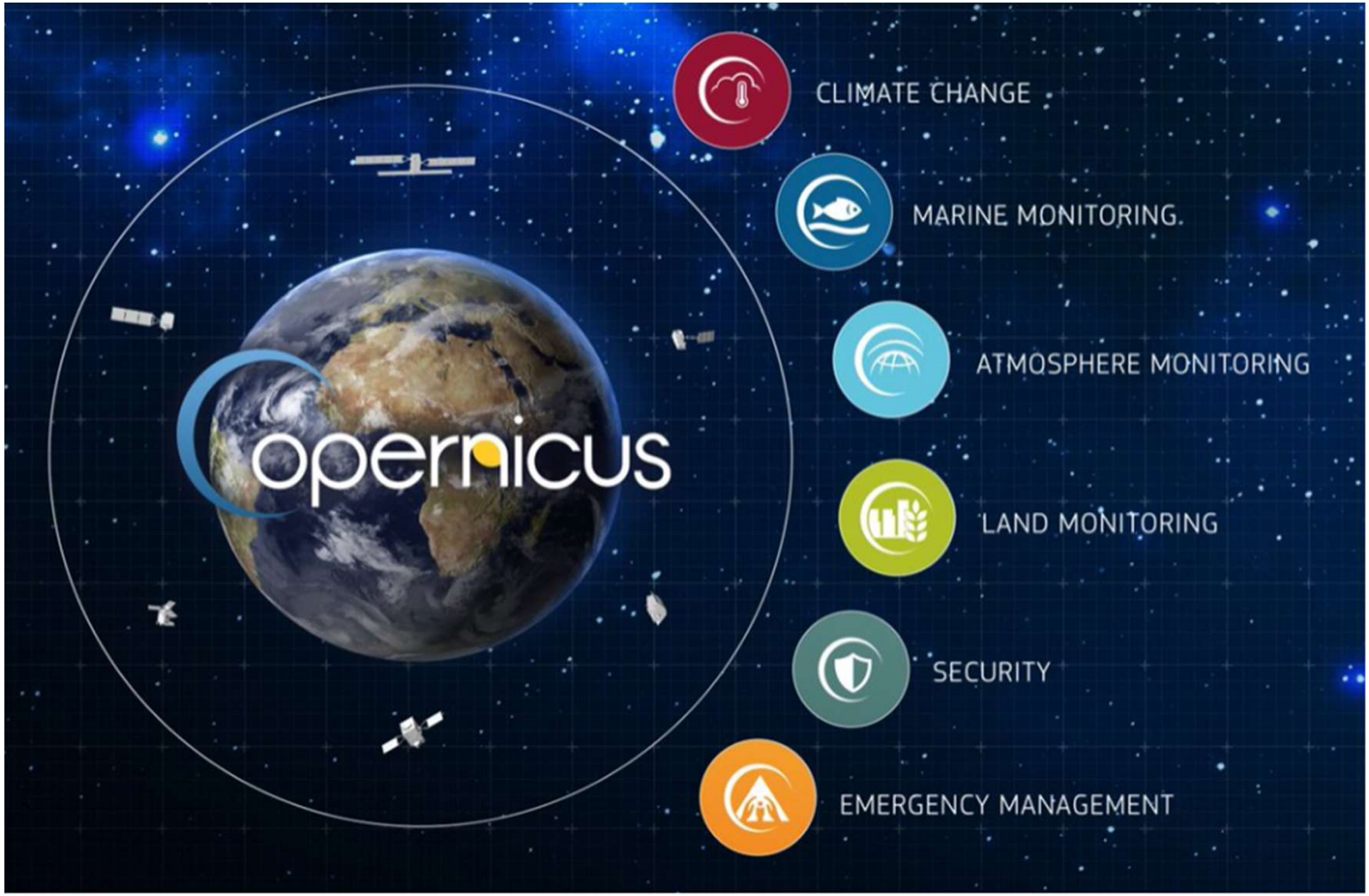
https://www.copernicus.eu/en/european-flood-awareness-system



Copernicus Emergency Management Service

CEMS

Copernicus Emergency Management Service *CEMS*



COPERNICUS
The Earth Observation component of the EU's space programme

opernicus
Europe's eyes on Earth

PROGRAMME OF THE EUROPEAN UNION

EUMETSAT
provides satellite data, products and support **services to the Copernicus** information services and user communities, with a focus on the oceans, the atmosphere and more generally the climate.

CyMETEO infrastructure & service

Thank You !!

CyMETEO

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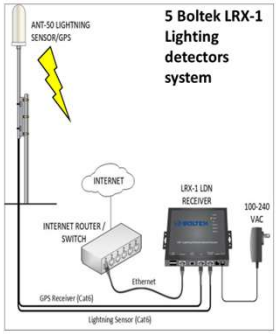

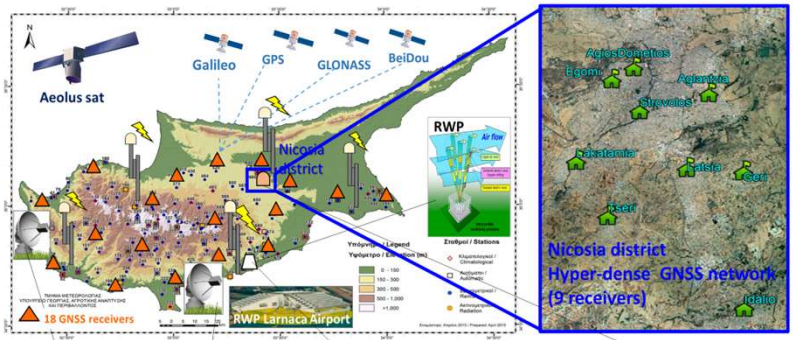

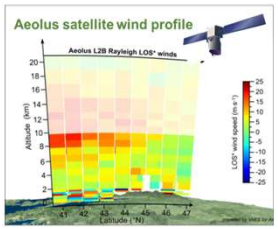

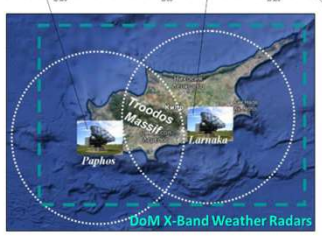

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