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Unveiling Infrasound Signatures of Mediterranean Hurricanes

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INTRODUCTION

Mesoscale cyclones are a source of coherent noise at infrasound stations.

We investigate Mediterranean hurricanes previously documented.

We use complementary observation datasets and modelling to help the source identification.

METHODS/DATA

Data/Tools we use :

- IS48 (Tunisia) IMS data processed using PMCC
- Satellite observations
- Lightning detection network
- Meteorological reanalysis products
- A model for ocean ambient acoustic noise

START

RESULTS

Three out of 6 investigated cyclones lead to infrasound detections.

Cloud-to-ground lightning in deep convection area is the main source at 1-8 Hz.

Cyclonic wind-induced waves' detections, at 0.1-0.6 Hz, are reproduced through modelling.

CONCLUSION

Infrasound signatures of Medicanes demonstrated for the first time.

Use of multi-technology approach to explain infrasound detections

Limitations due to single-station consideration, and multi-source issues

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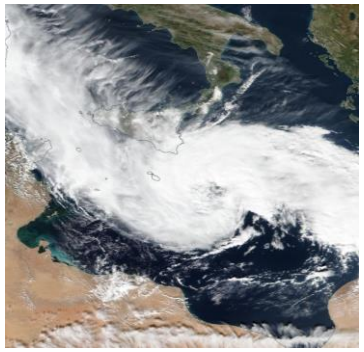
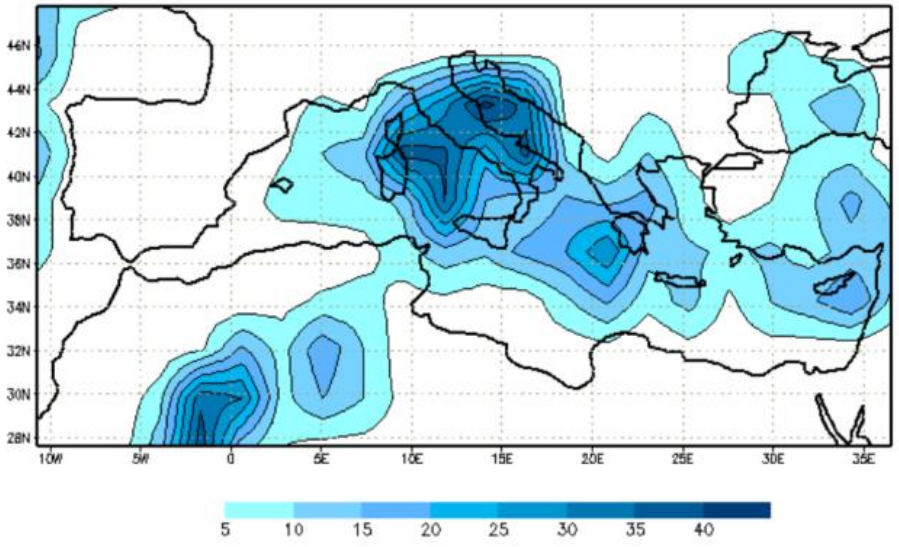
Introduction : cyclones and medicanes in the mediterranean sea



Mediterranean hurricane *or* **Medicane** = a tropical-like cyclone with a distinct central eye along with spiral clouds

(Apollo, 2021, NASA/Worldview)

Cyclogenesis in general is favored in the Mediterranean by land-sea surface temperature contrasts and orography



Number of intense cyclones/year (not only medicanes) (1957-2002) in the ERA-40 database: the average is ~30 intense cyclones / year (Flaounas et al. 2022)

Distribution of Medicane impacts 1969-2014 (Nastos et al. 2018)

Formation : one or two medicanes a year (Sep-Jan)

- Presence of an higher altitude cold low pressure system
- Sea surface temperature ~15-23°C

Strong impact on the coasts :

- Strong winds and intense precipitations (100s mm in <24h)
- Important damages (floods, landslides, …) and casualties

As other severe weather events, cyclones may cause coherent acoustic noise at IMS stations (here at IS48).

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Objectives : document infrasound signatures of mediterranean hurricanes

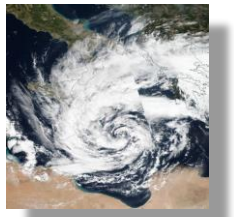
Severe weather events have infrasound signatures :

- Polar lows (polar mesocyclones), tornadoes, lightning, have beend evidenced as infrasound sources.

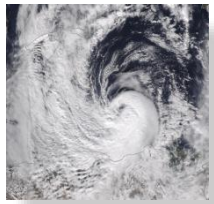
e.g. Resp. Claud et al. 2017 ; Bedard et al. 2005 ; Farges et al. 2021

- Phase transition/hail processes in rotating systems correlate with IS emissions *e.g. Elbing et al. 2019*
- Storm-induced waves interacting with the ambient swell produce infrasond *e.g. Hetzer et al. 2008*

Are Mediterranean Hurricanes responsible for coherent detections at IMS station IS48, and why ?

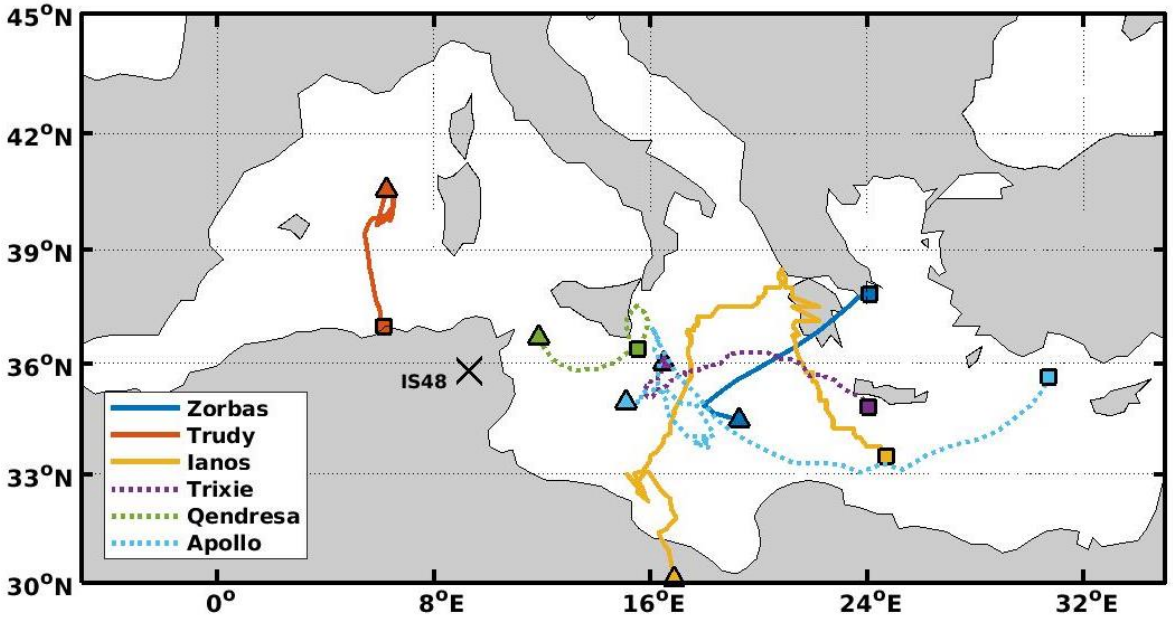


Zorbas Credit: NASA/Worldview

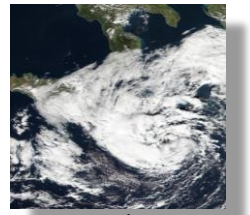


Trudy Credit: NOAA/JPSS

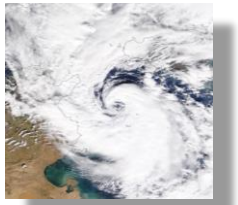
Ianos Credit: ESA/Sentinel



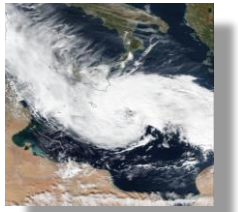
Trajectories of the six medicanes investigated



Trixie Credit: NASA/Worldview



Qendresa Credit: NASA/Worldview



Apollo Credit: NASA/Worldview

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Method and datasets used

METHOD :

1. Process infrasound data during Medicane periods
2. Investigate detections in the direction of the cyclone's trajectory
3. Look for patterns (changing azimuth, amplitudes w.r.t. medicane evolution)
4. Check guiding conditions in the middle atmosphere and wind noise at the station
5. Parallell with lightning and deep convection observation, look for competing sources
6. Model microbarom detections and compare with observations

DATA :

- Infrasound IMS station IS48 in Kesra, Tunisia *:* 7-element array

  Friha et al. 2017; Mejri et al. 2017

  Array Processing uses PMCC with 1/3 octave band progression (0.05-8 Hz)

  Cansi, 1995

- Meteorological data : ECMWF reanalysis ERA5

  Hersbach et al., 2020

- Worldwide Lightning Location network (WWLLN) :
  70 sensors, 10 km location accuracy

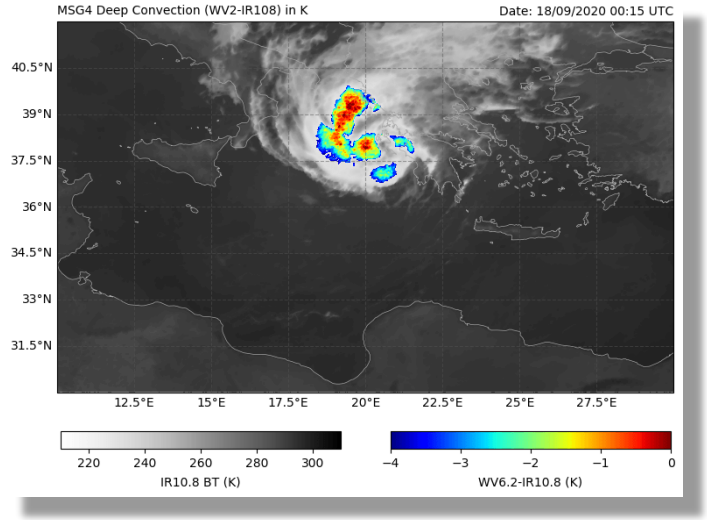
  Dowden et al., 2002

- Deep moist convection from satellite observations

  Dafis et al., 2020

- Acoustic source model for microbaroms : AtmospheRIC infRasound by Ocean Waves model

  De Carlo et al., 2022; based on De Carlo et al. 2020, 2021



ΔBT (WV6.2 − IR10.8) > 0 (SEVRIRI/mSG satelllite) attributed to intense convection that penetrates the tropopause and to overshooting tops

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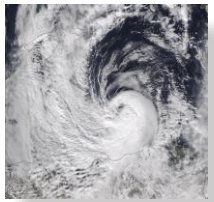
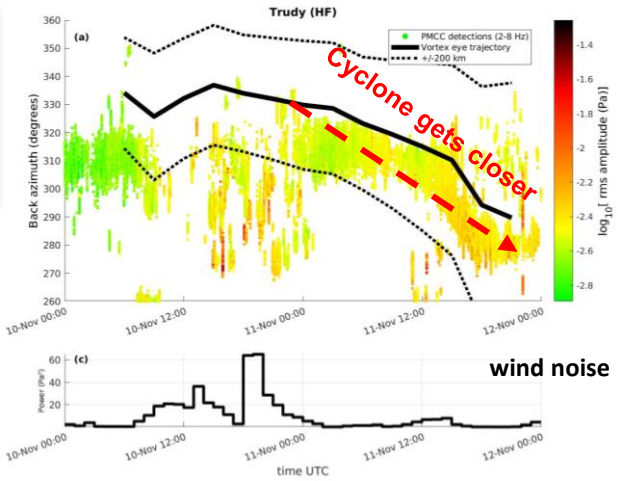
Results : swell and thunder of medicanes



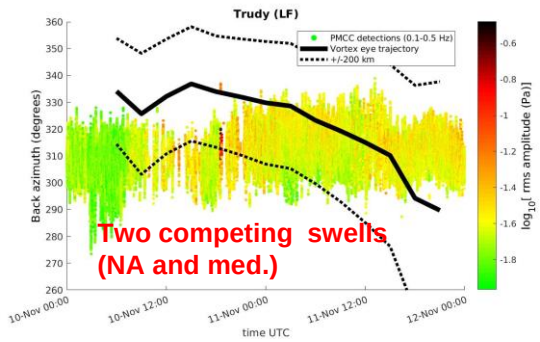
Trudy (Nov. 19)

Infrasound: 2-8 Hz



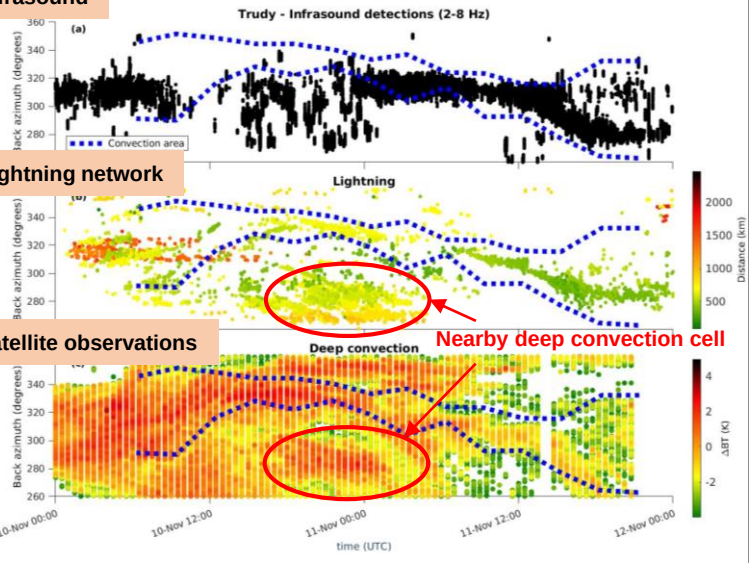
Wind noise and another competing source lead to noisy detections after 10 November 12:00

0.1-0.6 Hz



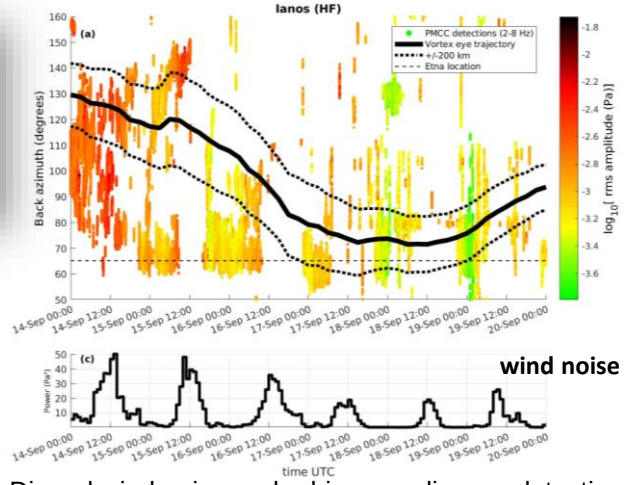
Medicane Trudy is detected (for thunder, not swell). Multitechnology approach allows to confirm sources.

Infrasound



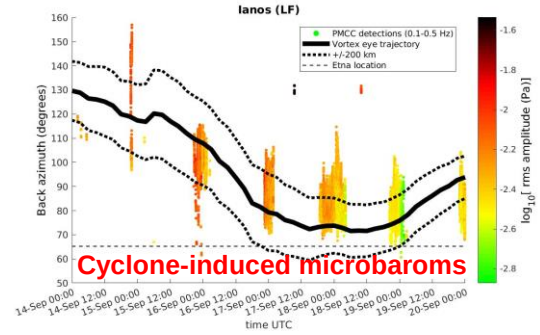
Ianos (Sep. 20)

Infrasound: 2-8 Hz



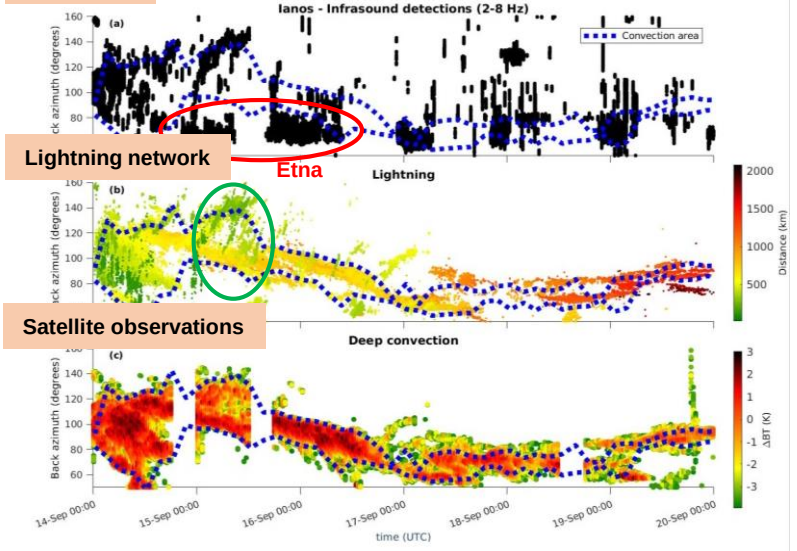
Diurnal wind noise cycle drives medicanes detections
And Etna is causing detections before 16 Sep. 12:00

0.1-0.6 Hz



Medicane Ianos is detected (thunder and swell) Multitechnology approach allows to confirm sources.

Infrasound



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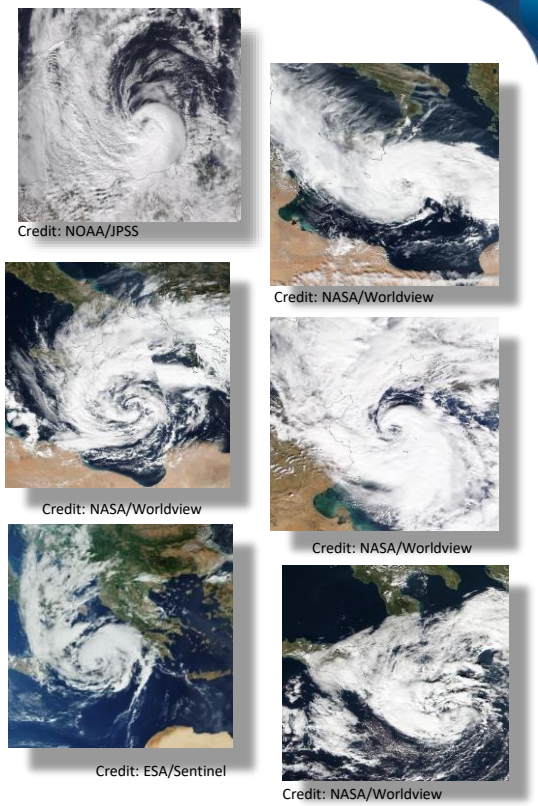
Conclusion : first documented infrasound detections of medicanes

- **Demonstration of the infrasound detections coming from medicanes** documented in the recent literature (Zorbas, Sep. 2018; Trudy, Nov. 2019; Ianos, Sep. 2020).
- Stratospheric winds and wind noise at the station explain **the presence or lack of detections** well (lack of detections for Qendresa, Trixie, Apollo).
- PMCC back-azimuths correspond to documented trajectories of the medicanes. **Amplitudes are consistent with the evolution of the cyclones' distance** to IS48.
- In favorable conditions (little wind noise, no perturbing source like the Etna volcano), **80% to 100% of the >2 Hz detections can be explained by lightning.**
- 0.1-0.5 Hz detections explained by the **medicane-induced swell**, using a microbarom source model
- **Room for additional IS sources related to deep convection/dynamical processes/intra-cloud lightning** (missed by WWLLN) to explain all infrasound detections.
- **Multi-source cases highlighted** during Trudy and Ianos (competing convective cells and swell)



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Results are published in :

Listowski et al.
Remote Monitoring of Mediterranean Hurricanes using Infrasound. Remote Sens. 2022, 14, 6162.
https://doi.org/10.3390/rs14236162

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