Pilot phase of the Adriatic meteotsunami research and warning network

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Outline

- Motivation for developing a meteotsunami research and warning network
- The Adriatic meteotsunami research and warning network
- Network application to a real situation

Motivation…

- Strong meteotsunamis occur at the Adriatic once every few years
- Develop a meteotsunami research network
  - Better understanding of a meteotsunami generation and propagation mechanism
  - How much in advance can we predict a meteotsunami?
- Develop a meteotsunami warning network
  - Issue warning in time to:
    - Get off the beach
    - Re-park cars
    - Move boats out of the harbours

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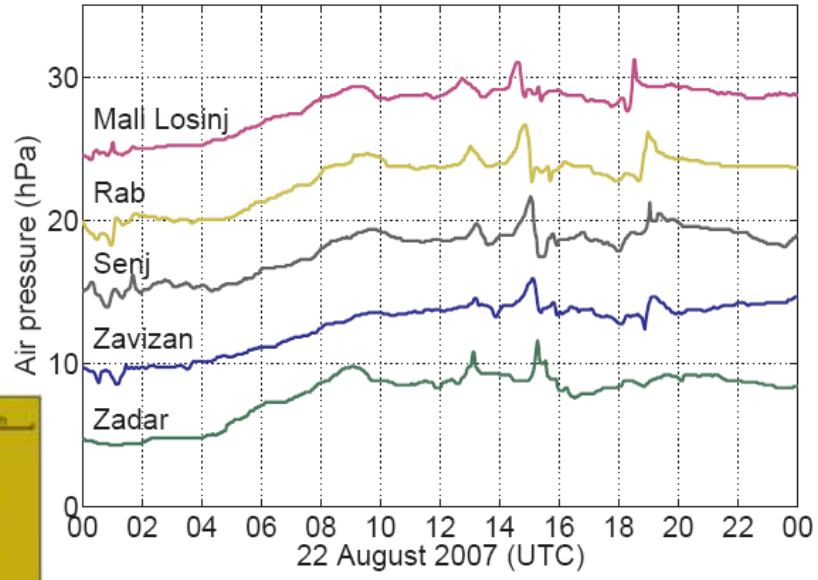
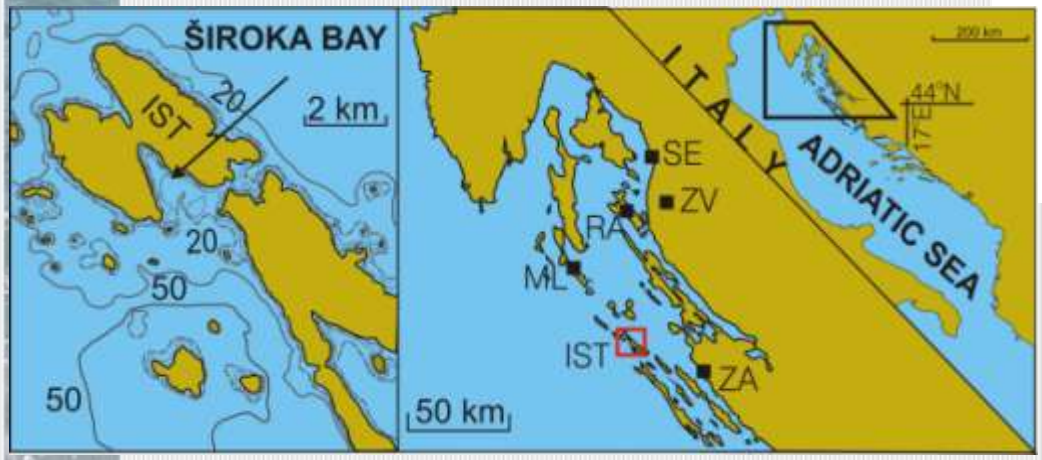
Generation mechanism…

- Remarkable air pressure disturbance ~ 4 mbar/15 min.

Široka Bay meteotsunami, 22 August 2007, ~ 4 m high waves





(*Šepić et al., 2009*)

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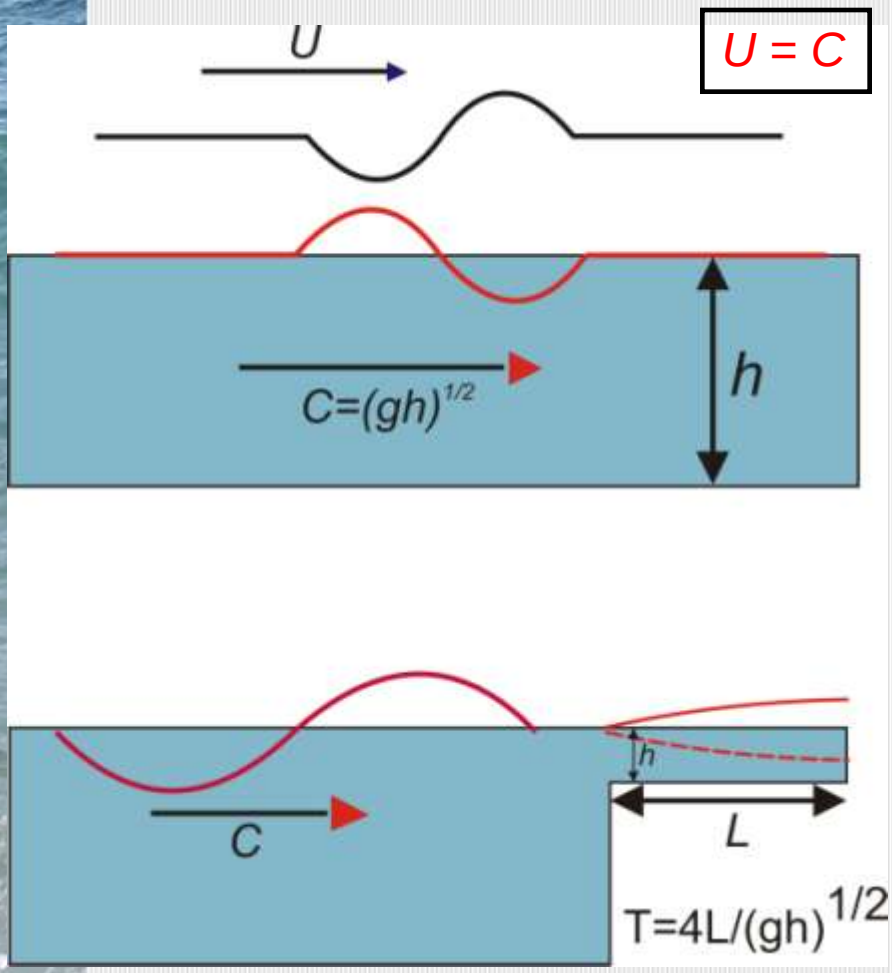
Generation mechanism



- Air pressure disturbance generates and enhances barotropic ocean waves via Proudman resonance
- Open sea waves generate seiches in harbors and bays via harbor resonance (open sea waves should have high energies at seiche periods!)

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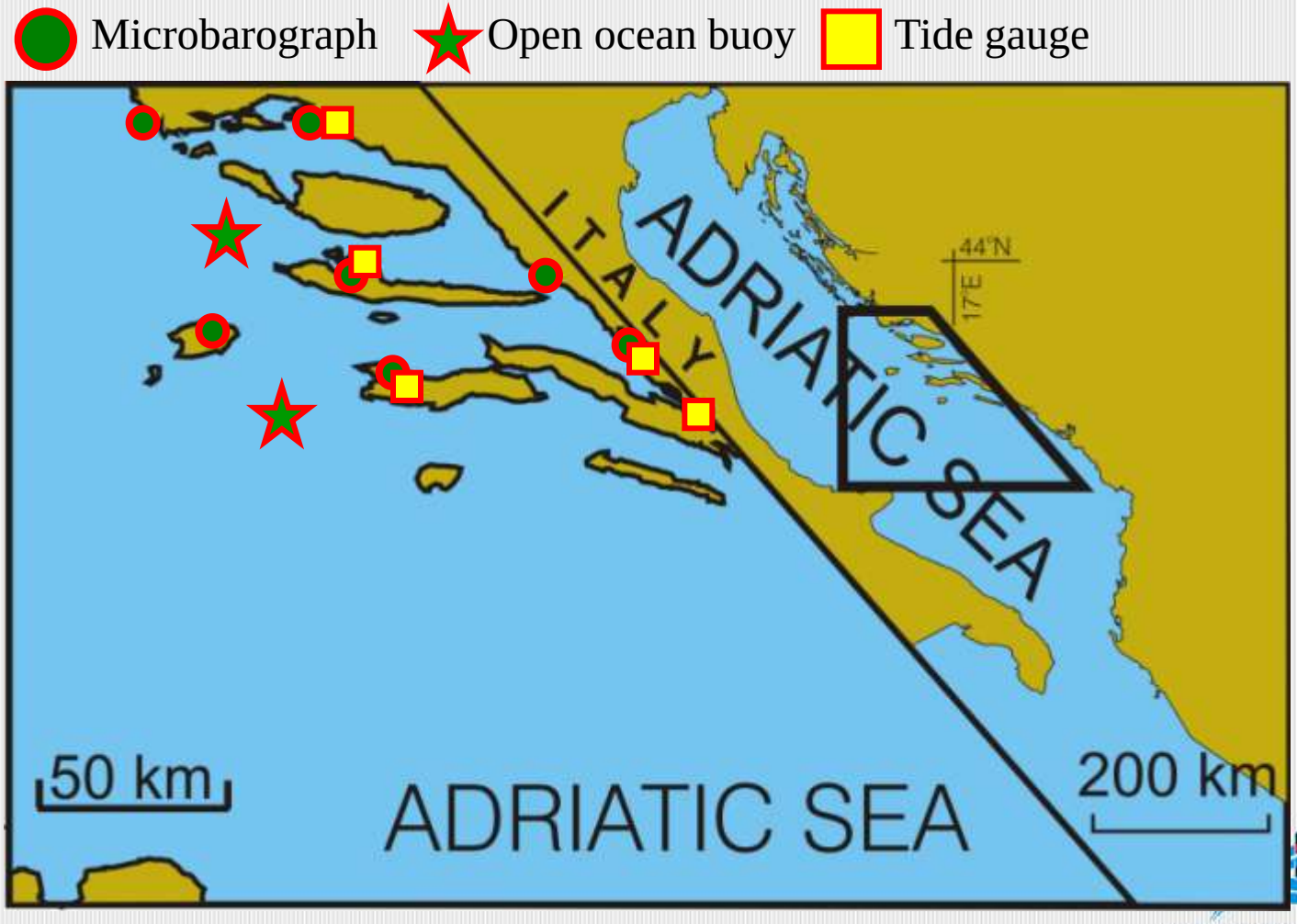
Research network…



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Warning network…

- Possibilities for warning systems:
  - Monitoring synoptic conditions (*Šepić and Vilibić, 2012*)
    - *An indication that an event might happen, but no indication on strength of the event.*
  - Mesoscale atmospheric modeling (*Belušić et al., 2007*)
    - *Very difficult to reliably model air pressure disturbances in real-time.*
  - Tracking convective clouds (*Belušić and Strelec Mahović, 2009*)
    - *Sucesfull for some events, but not all meteotsunamis are related to convective clouds, and not all convective clouds are related to meteotsunamis -> might not allow enough time for reaction.*
  - Tracking air pressure disturbances *(Šepić and Vilibić, 2011)*
    - *Cheap and reliable solution -> might not allow enough time for reaction*
  - Sea level measurements (*Marcos et al., 2009*)
    - *Sea level oscillations often strong enough to be considered a tsunami only at one location, hard to precisely determine their onset time.*

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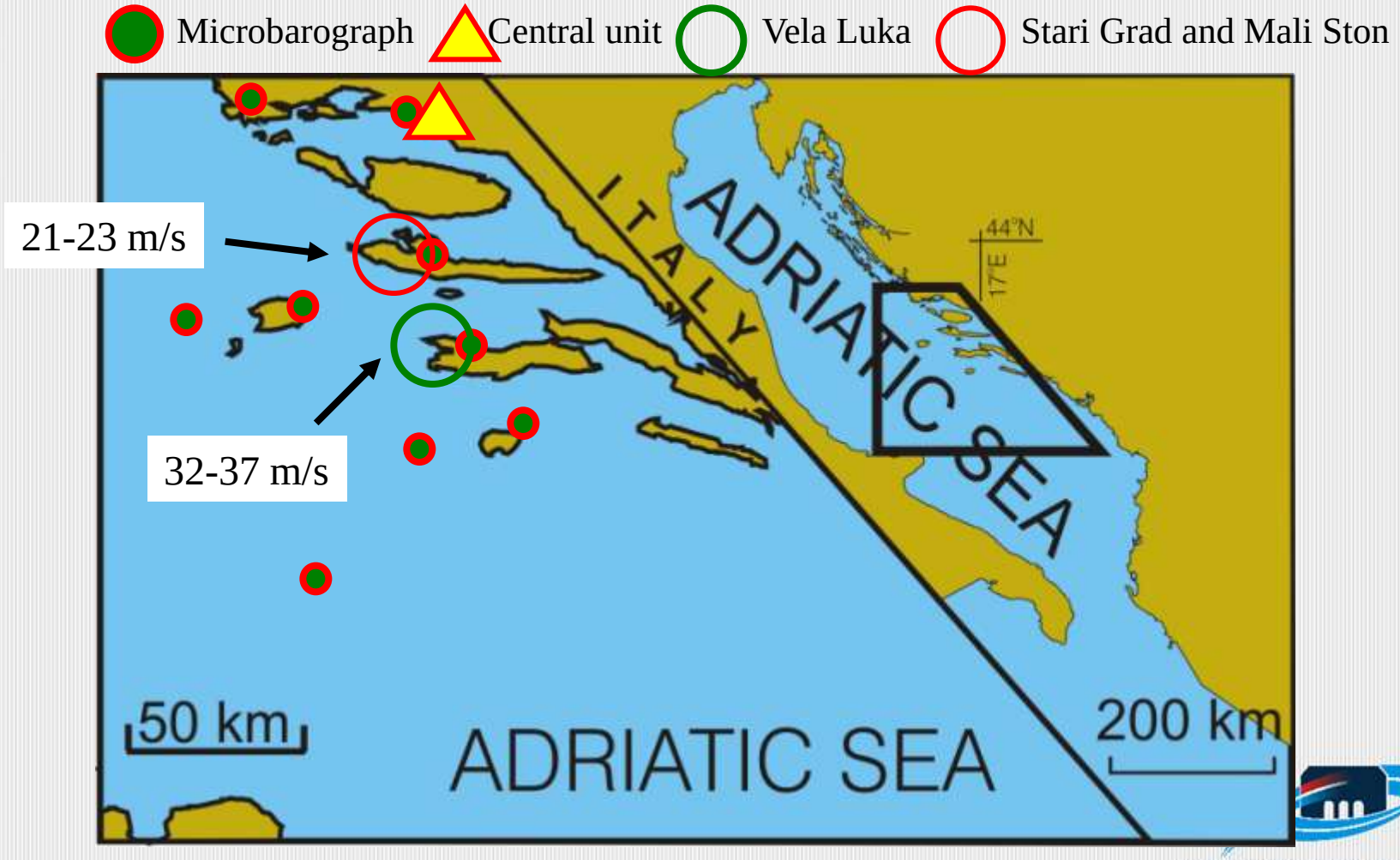
Warning network…



Warning network… Vela Luka meteotsunami decision matrix (*based on theory and modeling by Orlić et al., 2010*)

Rate of air pressure change (hPa/5 min)	Velocity (m/s)	Direction ( )	Meteotsunami danger
> 2.0	[32-37]	[200-250]	Large
> 2.0	[32-37]	[180-200] or [250-270]	Moderate
> 2.0	[23-32] or [37-40]	[200-250]	Moderate
[1.0 – 2.0]	[32-37]	[200-250]	Moderate
> 2.0	[23-32] or [37-40]	[180-200] or [250-270]	Low
[1.0 – 2.0]	[32-37]	[180-200] or [250-270]	Low
[1.0 – 2.0]	[23-32] or [37-40]	[200-250]	Low
[1.0 – 2.0]	[23-32] or [37-40]	[180-230] or [250-270]	Very low

Warning network… Stari Grad meteotsunami decision matrix (*based on theory and modeling by Vilibić et al., 2004*)

Rate of air pressure change (hPa/5 min)	Velocity (m/s)	Direction ( )	Meteotsunami danger
> 2.0	[21-23]	[270-290]	Large
> 2.0	[21-23]	[235-270] or [290-325]	Moderate
> 2.0	[17-21] or [23-27]	[270-290]	Moderate
[1.0 – 2.0]	[21-23]	[270-290]	Moderate
> 2.0	[17-21] or [23-27]	[235-270] or [290-325]	Low
[1.0 – 2.0]	[21-23]	[235-270] or [290-325]	Low
[1.0 – 2.0]	[17-21] or [23-27]	[270-290]	Low
[1.0 – 2.0]	[17-21] or [23-27]	[235-270] or [290-325]	Very low

Existing network locations

- Triangular shape
- Areas with high meteotsunami risk

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Measurement stations

- Vaisalaa air pressure sensor (accuracy of 0.01 hPa)
- Sampling every 1 second
- Embeded linux computer (Axis)
- Specialy developed software
- Multi process architecture
- Watch dog process

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Real-time system specifications

- Full automatic data processing
  - FTP synchronisation (data transfer)
  - Database inserting
  - Database processing
- Automatic recovery from communication gaps
- Database storage
- Database driven dynamic web pages
- Flash graph (plan to switch to javascript graphs)

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Real time data transfer, processing and visualisation

Sensor

Embeded computer

GPRS, EDGE, UMTS router

Station case

Interne
t

Data center

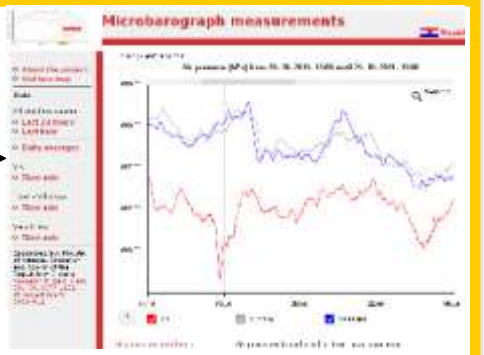
Automatic FTP synchronization and data inserting

MEDAS

ORACLE database

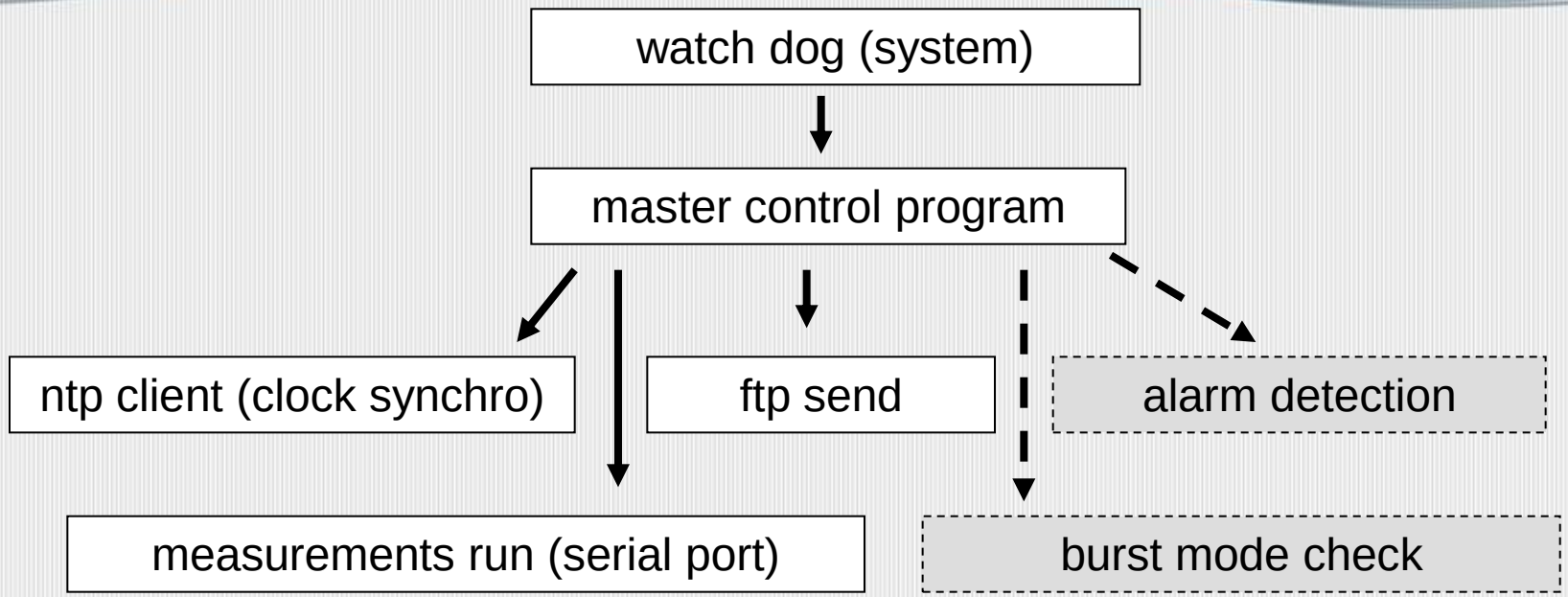
Application server

ORACLE App. Serv.



Web page with real-time data

Programs shema



- 4 active processes
- restart in case of nonresponding state

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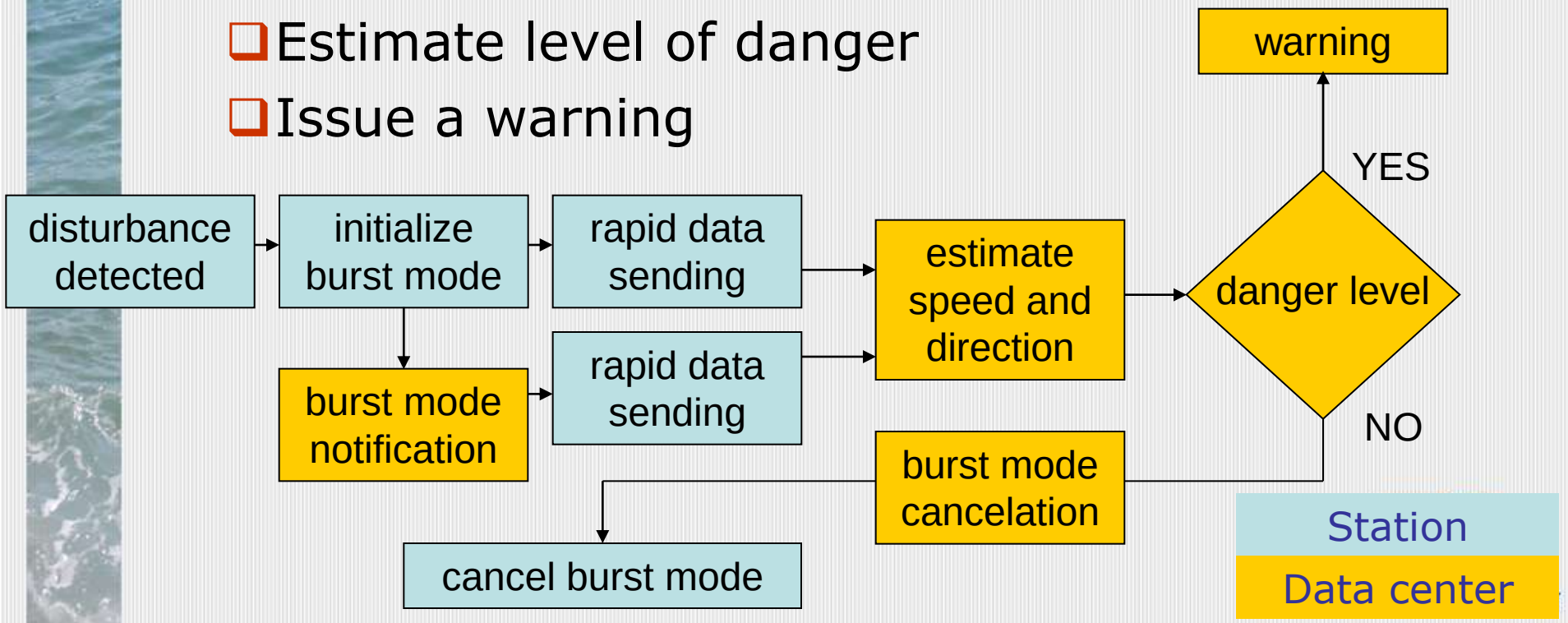
Warning network…

- Use microbarographs data to:
  - Detect a pronounced air pressure disturbance (> 1.0 mbars/5 min)
  - Estimate speed and direction of propagation of the air pressure disturbance
  - Estimate level of danger
  - Issue a warning



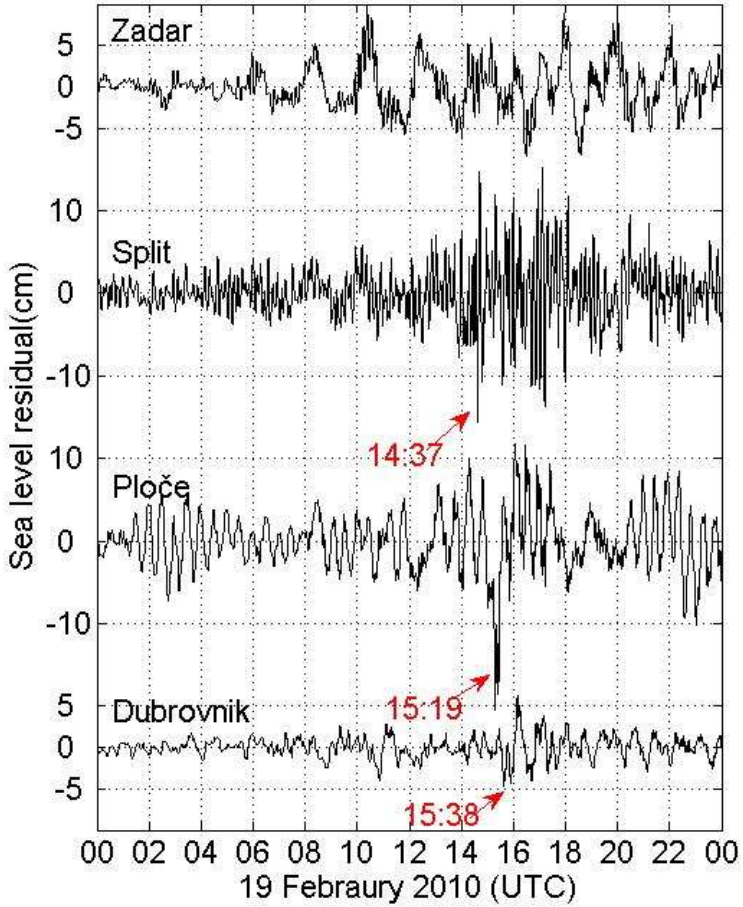
Using the network: Stari Grad meteotsunami 19 February 2009

Weak meteotsunami reported at Stari Grad:

- **maximum wave height 60 cm**
- strong currents pulled one car and several large garbage containers into the sea

Stari Grad, 19 February 2009

Coastal tide gauges



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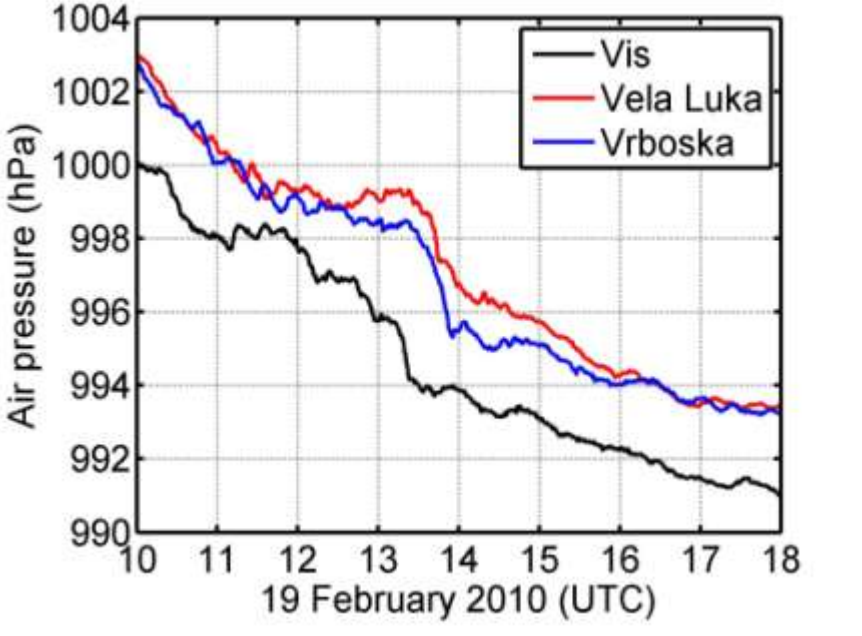

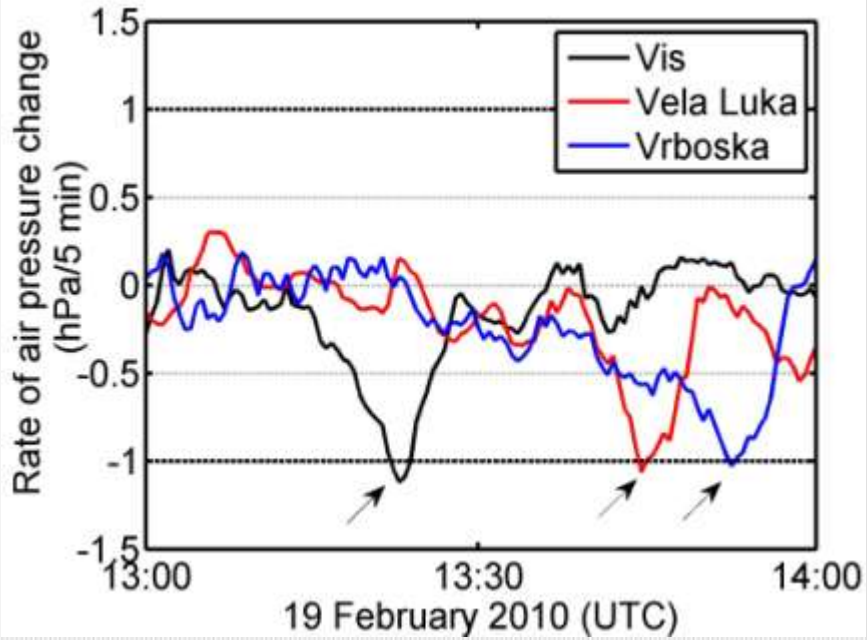

Threshold pressure tendency: 1.0 hPa/5 min

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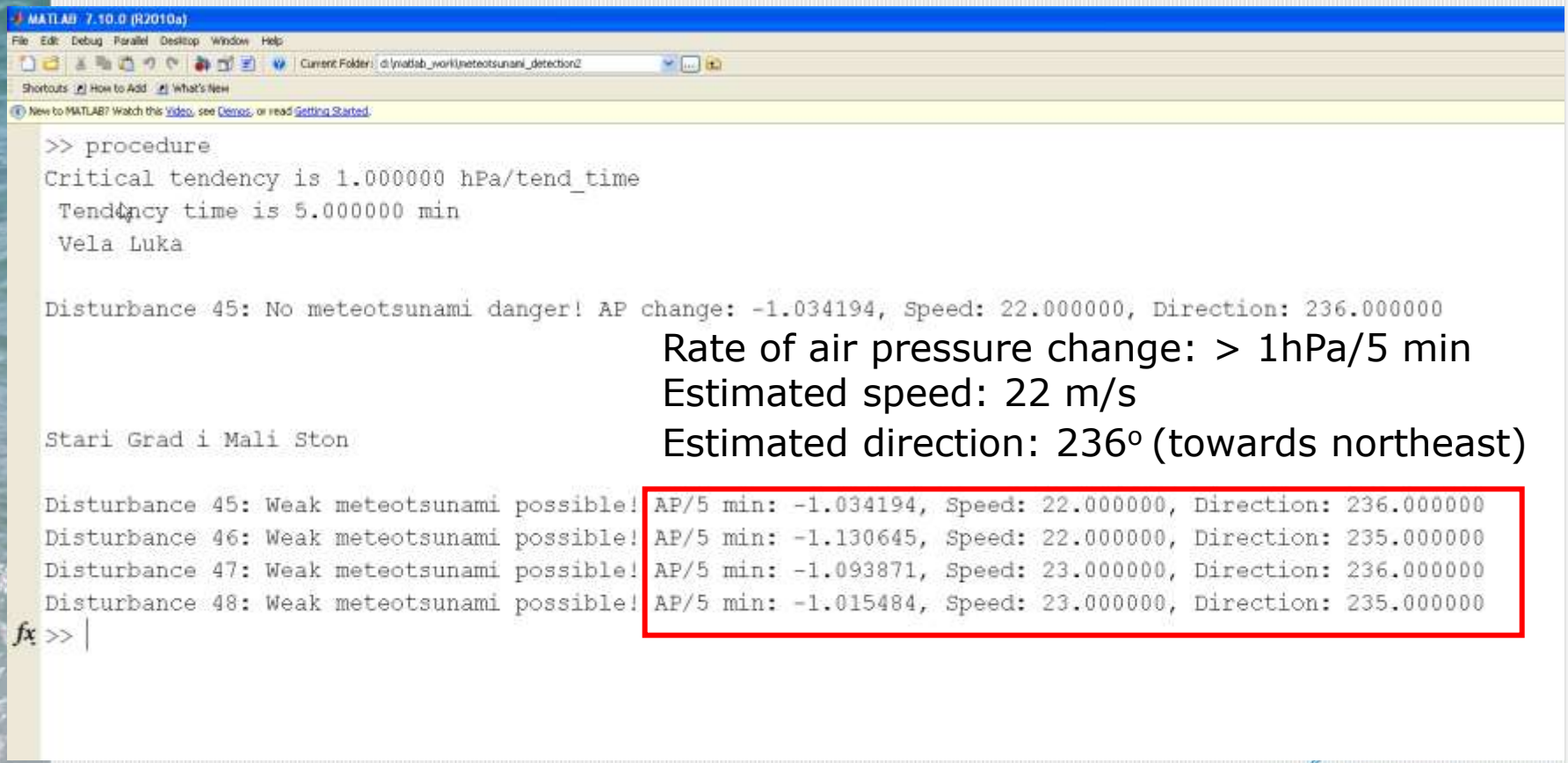
Using the network: Stari Grad meteotsunami 19 February 2009

Warning algorithm – MATLAB code developed to analyze data and estimate danger



Conclusions

- Upsides:
  - Cheap and reliable warning system
- Downsides
  - Might not allow enough time for warning:
    - for possibly most destructive air pressure disturbances:
      - Warning 10 – 20 before a meteotsunami hits Vela Luka.
      - Warning 20 – 25 min before a meteotsunami hits Stari Grad.


Thank you for your attention!
Questions?

Literature

- Belušić, D., and N. Strelec Mahović, 2009. Detecting and following atmospheric disturbances with a potential to generate meteotsunamis in the Adriatic, Physics and Chemistry of the Earth, 34, 918-927.
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