FOSSCOMM 2017, 4-5 Nov. @ Athens, Greece

Galene

Online prediction of sea state and risk assessment for small boats as a lightweight web SaaS

P.Petrou, J.Kontoulis, H.Georgiou @ Data Sci Lab (UniPi)

Outline

1. Problem definition
2. Theory & Models
3. System Overview
4. *GALENE* in action
5. Planning & Release

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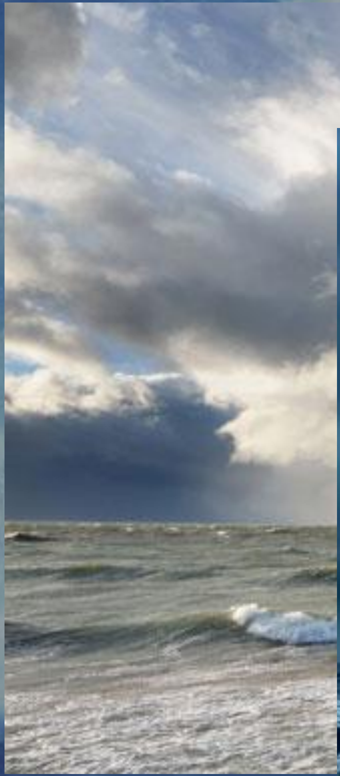
The Challenge

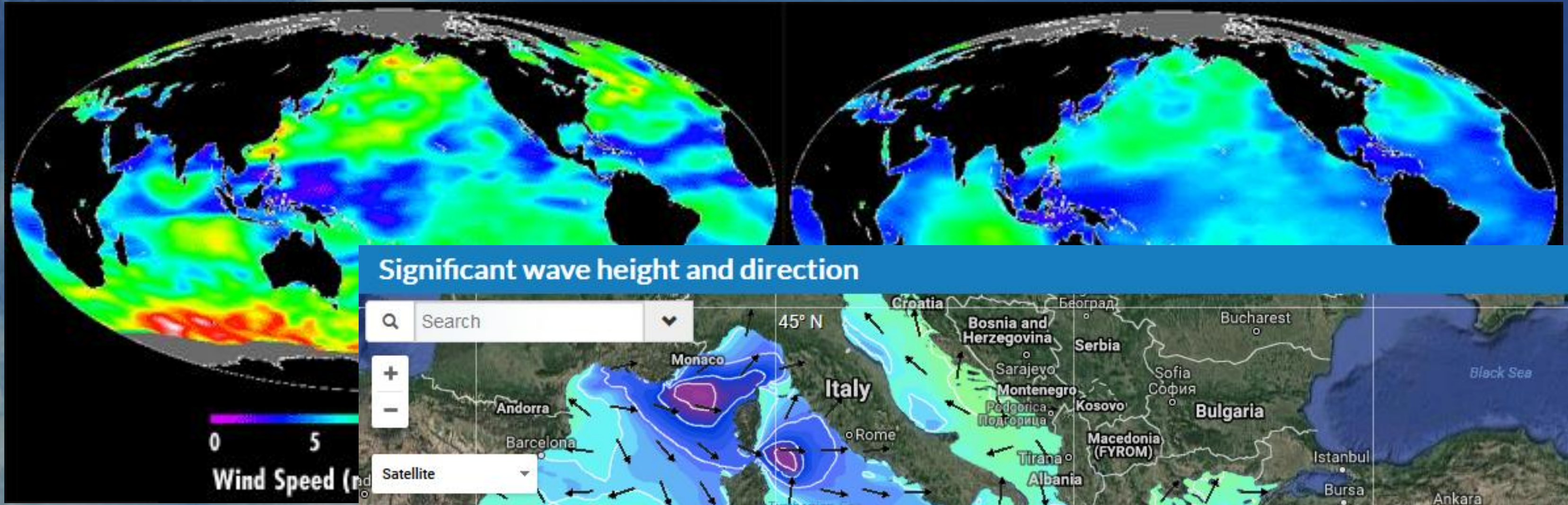


A calm afternoon…

An hour later…

6-7B, Mediterranean Sea

8-9B, Atlantic Ocean


0
5
Wind Speed

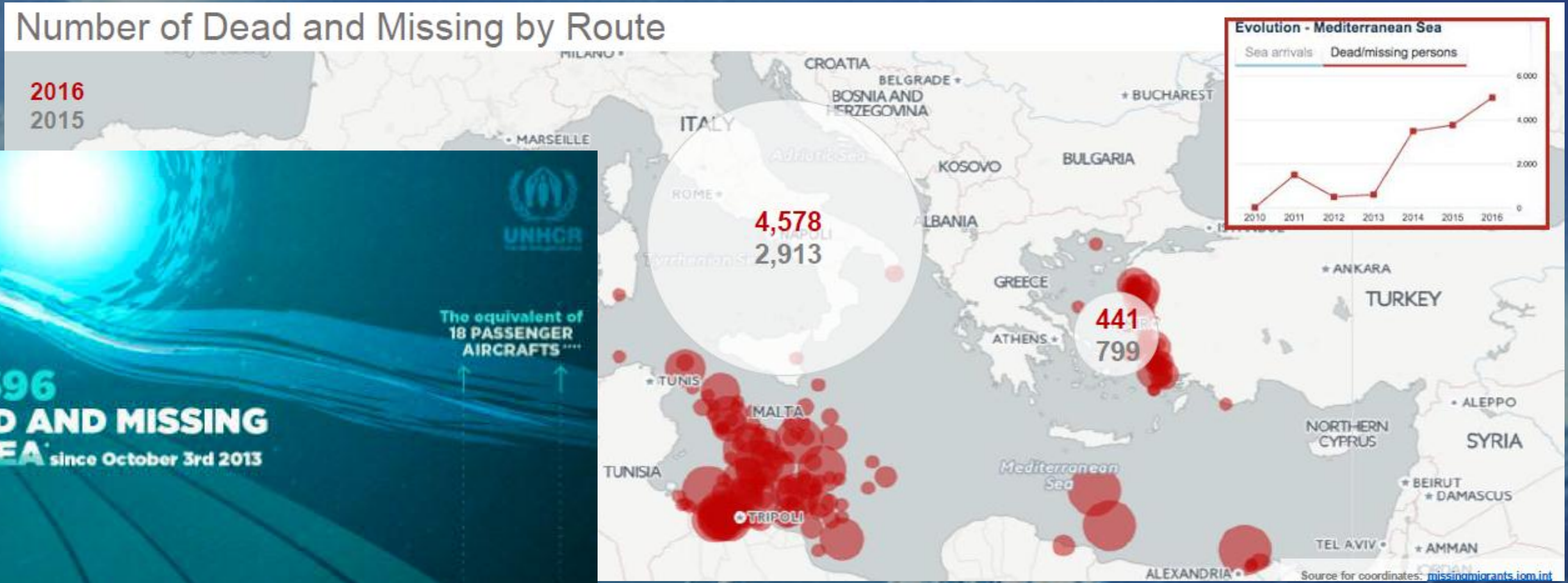

Significant wave height and direction
Search
Satellite
Coastline
Opacity: 100%
-
+
45° N
40° N
35° N
0° W
10° E
30° N
20° E
30° E
Croatia
Bosnia and Herzegovina
Sarajevo
Serbia
Montenegro
Kosovo
Macedonia (FYROM)
Tirana
Albania
Bucharest
Sofia
София
Bulgaria
Black Sea
Istanbul
Bursa
Ankara
Turkey
Izmir
Antalya
Adana
Greece
Athens
Αθήνα
Cyprus
Lebanon
Beirut
Jerusalem
Jordan
Israel
Alexandria
Cairo
Monaco
Italy
Rome
Andorra
Barcelona
Algiers
Tunis
Tunisia
Malta
Tripoli
degree
m
DOUGLAS
6
5
4
3
2
6>
5
4
3
2.5
2
1.6
1.25
0.8
0.5
Google
Map data ©2017 GeoBasis-DE/BKG (©2009), Google

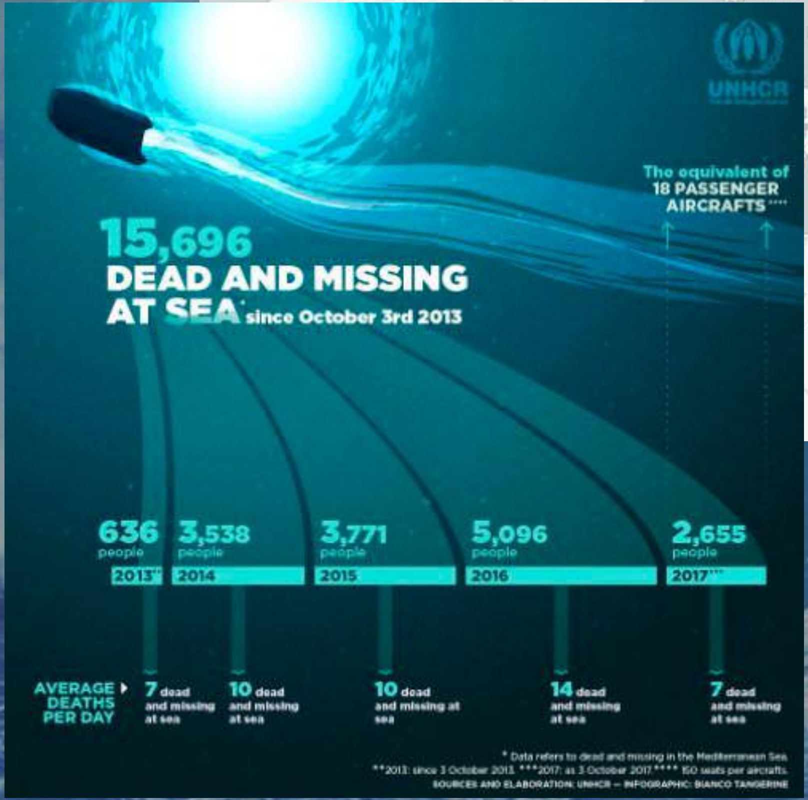
SIEV 221 (“Suspected Irregular Entry Vessel”)
15 December 2010, Christmas Island, Australia
50 dead of 89 Iranian and Iraqi asylum seekers

Skala Sykamneas, Lesvos, Greece (locals: 140)
(2015): 540,000-550,000 people landed there
1:5 rescued from the sea, 1:214 dead/missing


AFP


Anadolu





Turkey-Greece crossings: 5-10 n.m. / ≈ 1.5m waves (max)

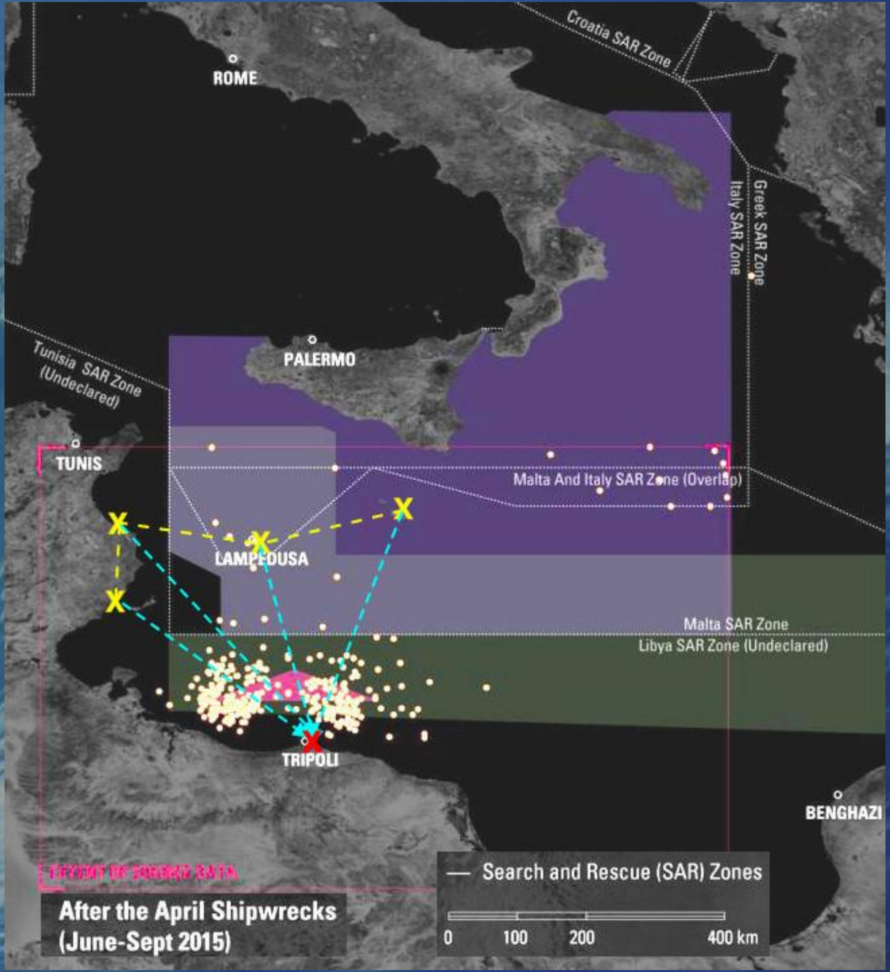
Libya-Italy crossings: 200-300 n.m. / ≈ 4.5m waves (max)

⇒ *Even with the same weather intensity, risk factor for small/medium boats becomes at least **x5 times** deadlier due to much larger open distance (fetch) and sea depth.*

Libya-Italy crossing, present day (Photo: `Aquarius' crew)

24-hour SAR patrols, NGO ships outside Libyan waters

⇒Most shipwrecks go unnoticed, difficult to guess and access possible locations due to vast area, ***inaccurate weather/boats data*** *and aggressive Libyan gunboats.*



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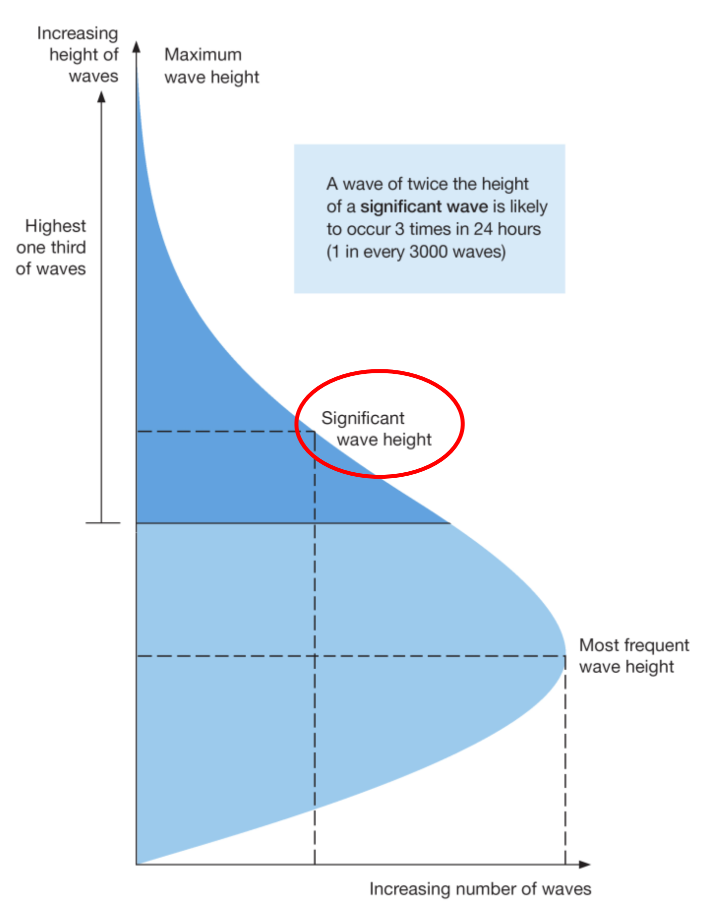
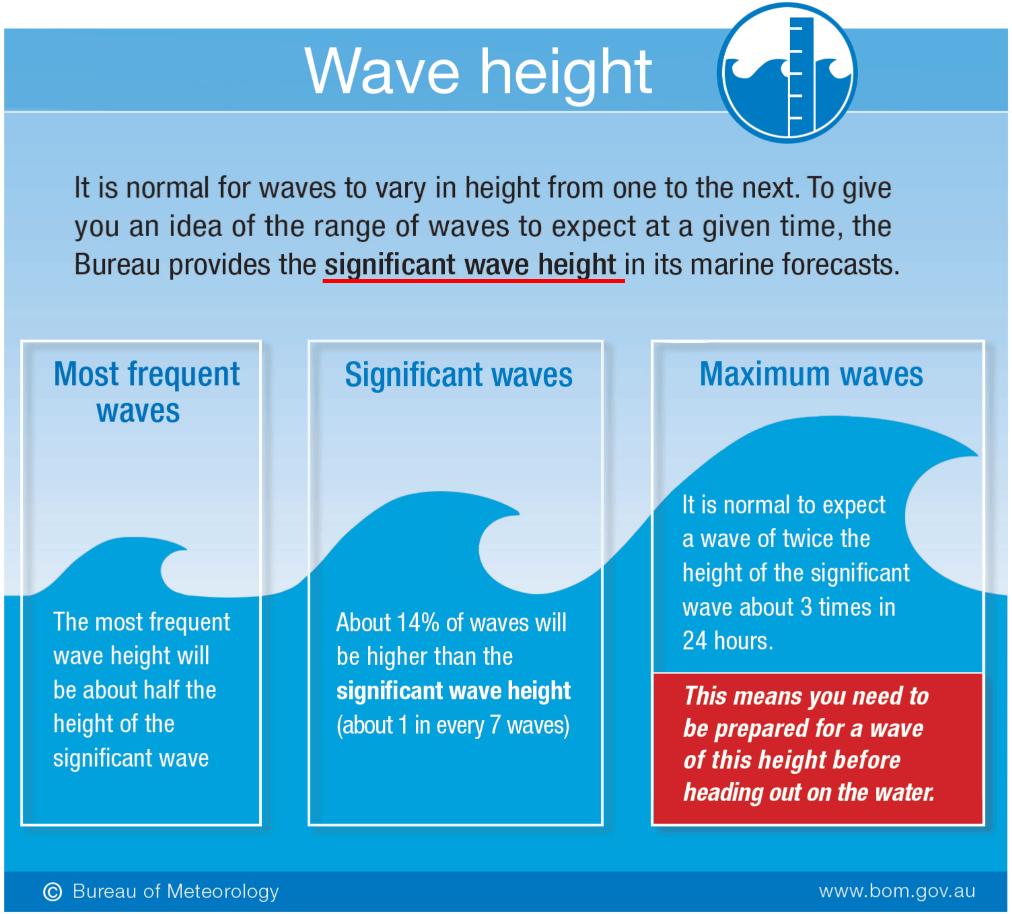
Inner Workings

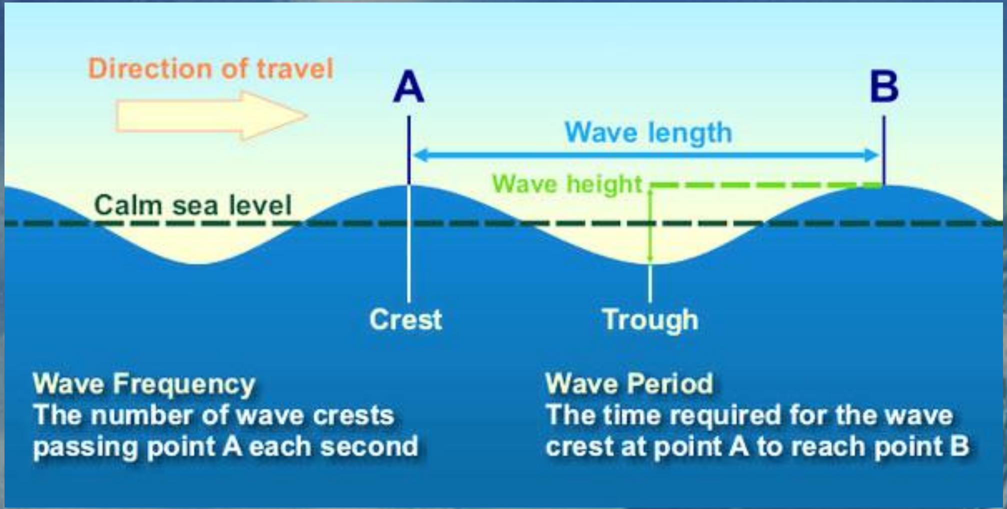
↙ INPUT ↙ OUTPUT

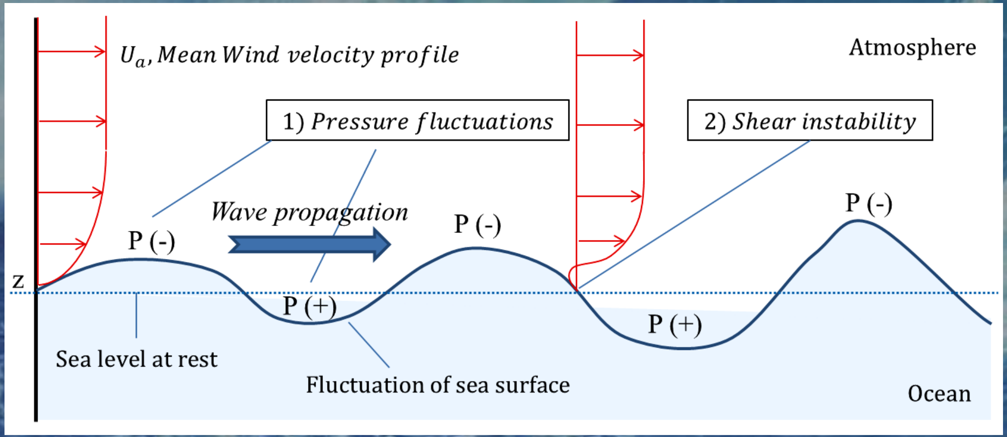
Beaufort number	Wind speed kt	km/h	mph	m/s	Mean wind speed (kt / km/h / mph)	Description	Wave height m	ft	Sea conditions	Land conditions
0	0	0	0	0-0.2	0 / 0 / 0	Calm	0	0	Flat.	Calm. Smoke rises vertically.
1	1-3	1-6	1-3	0.3-1.5	02 / 04 / 2	Light air	0.1	0.33	Ripples without crests.	Wind motion visible in smoke.
2	4-6	7-11	4-7	1.6-3.3	05 / 09 / 6	Light breeze	0.2	0.66	Small wavelets. Crests of glassy appearance, not breaking	Wind felt on exposed skin. Leaves rustle.
3	7-10	12-19	8-12	3.4-5.4	9 / 17 / 11	Gentle breeze	0.6	2	Large wavelets. Crests begin to break; scattered whitecaps	Leaves and smaller twigs in constant motion.
4	11-16	20-29	13-18	5.5-7.9	13 / 24 / 15	Moderate breeze	1	3.3	Small waves.	Dust and loose paper raised. Small branches begin to move.
5	17-21	30-39	19-24	8.0-10.7	19 / 35 / 22	Fresh breeze	2	6.6	Moderate (1.2 m) longer waves. Some foam and spray.	Smaller trees sway.
6	22-27	40-50	25-31	10.8-13.8	24 / 44 / 27	Strong breeze	3	9.9	Large waves with foam crests and some spray.	Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult.
7	28-33	51-62	32-38	13.9-17.1	30 / 56 / 35	Near gale	4	13.1	Sea heaps up and foam begins to streak.	Whole trees in motion. Effort to walk against the wind.
8	34-40	63-75	39-46	17.2-20.7	37 / 68 / 42	Gale	5.5	18	Moderately high waves with breaking crests forming spindrift. Streaks of foam.	Twigs broken from trees. Cars veer on road.
9	41-47	76-87	47-54	20.8-24.4	44 / 81 / 50	Strong gale	7	23	High waves (2.75 m) with dense foam. Wave crests start to roll over. Considerable spray.	Light structure damage.
10	48-55	88-102	55-63	24.5-28.4	52 / 96 / 60	Storm	9	29.5	Very high waves. The sea surface is white and there is considerable tumbling. Visibility is reduced.	Trees uprooted. Considerable structural damage.
11	56-63	103-117	64-72	28.5-32.6	60 / 111 / 69	Violent storm	11.5	37.7	Exceptionally high waves.	Widespread structural damage.
12	>63	>117	>72	>32.7	N/A	Hurricane	14+	46+	Huge waves. Air filled with foam and spray. Sea completely white with driving spray. Visibility very greatly reduced.	Massive and widespread damage to structures.

Aegean Sea (avg.wind: <12 m/s)


Increasing height of waves
Maximum wave height
A wave of twice the height of a **significant wave** is likely to occur 3 times in 24 hours (1 in every 3000 waves)
Highest one third of waves
Significant wave height
Most frequent wave height
Increasing number of waves


Wave height
It is normal for waves to vary in height from one to the next. To give you an idea of the range of waves to expect at a given time, the Bureau provides the significant wave height in its marine forecasts.
Most frequent waves
The most frequent wave height will be about half the height of the significant wave
Significant waves
About 14% of waves will be higher than the **significant wave height** (about 1 in every 7 waves)
Maximum waves
It is normal to expect a wave of twice the height of the significant wave about 3 times in 24 hours.
This means you need to be prepared for a wave of this height before heading out on the water.
© Bureau of Meteorology
www.bom.gov.au





Basic principles: **Wave theory**

Main wind wave parameters:

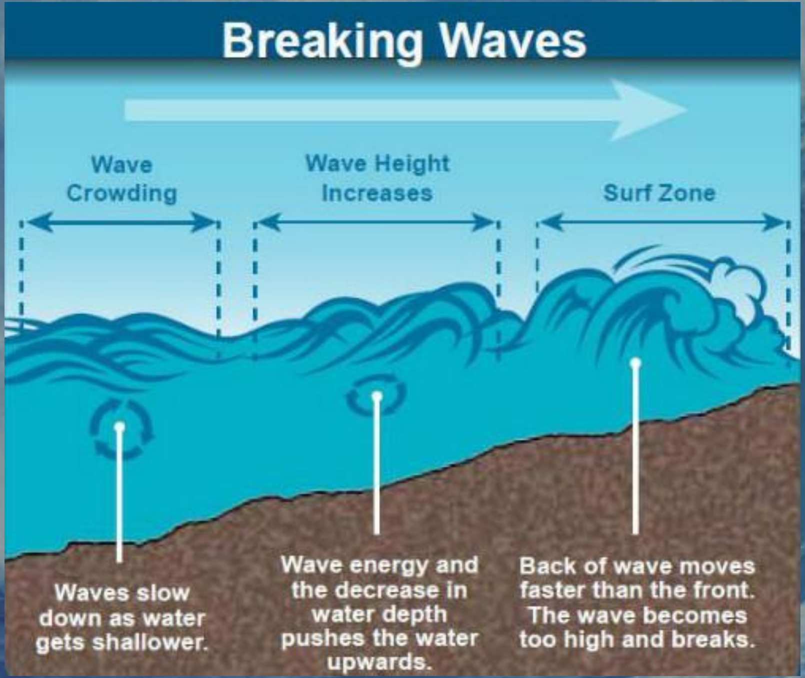
→ Amplitude (height)
→ Length
→ Period
→ Frequency (speed)
→ Direction of propagation

In reality: **Fluid dynamics**

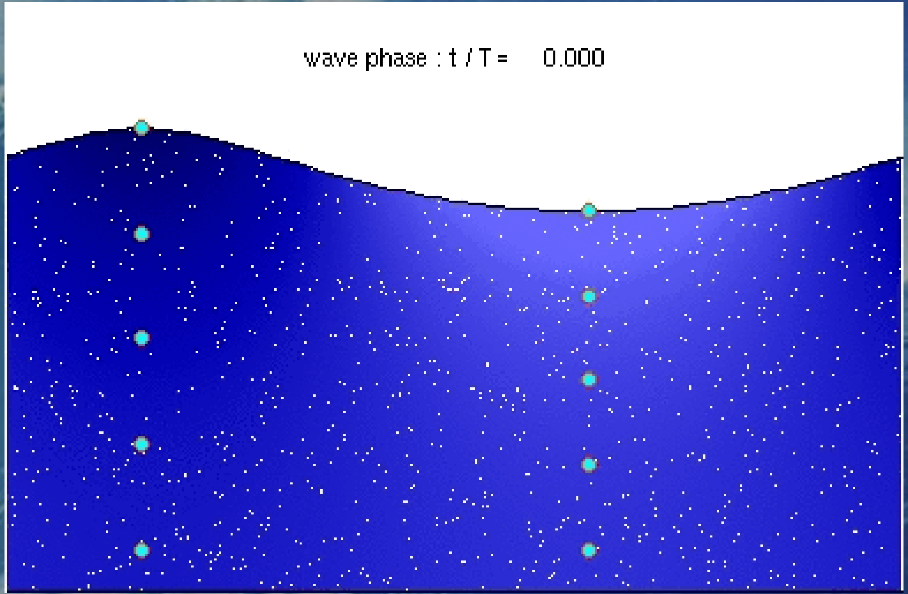
Wind wave generation factors:

→ Wind speed (near surface)
→ Fetch (open distance)
→ Sea depth (deep/shallow)
→ Duration of acceleration
→ Non-linearities (e.g. shearing)

Fluid dynamics: shallow waters



Fluid dynamics: internal trajectories



https://commons.wikimedia.org/w/index.php?curid=3374567
By Kraaiennest - Own work, GFDL (2017)

$$c = \sqrt{\frac{g\lambda}{2\pi}\tanh\left(\frac{2\pi d}{\lambda}\right)}$$

$$c_{\text{deep}} = \sqrt{\frac{g\lambda}{2\pi}} \approx 1.25\sqrt{\lambda}$$

$$E = \frac{1}{8}\rho g H^2 = \frac{1}{2}\rho g a^2$$

$$S(\omega) = 155\frac{H_{1/3}^2}{T_1^4\omega^5}\exp\left(\frac{-944}{T_1^4\omega^4}\right)(3.3)^Y$$

$$S^+(\omega) = \frac{1}{4}\frac{\left(\frac{4\lambda+1}{4}\omega_m^4\right)^\lambda}{\Gamma(\lambda)}\frac{\zeta^2}{\omega^{4\lambda+1}} exp\left\{-\left(\frac{4\lambda+1}{4}\right)\left(\frac{\omega_m}{\omega}\right)^4\right\}$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + fu = -g\frac{\partial h}{\partial y} - bv + \nu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right)$$

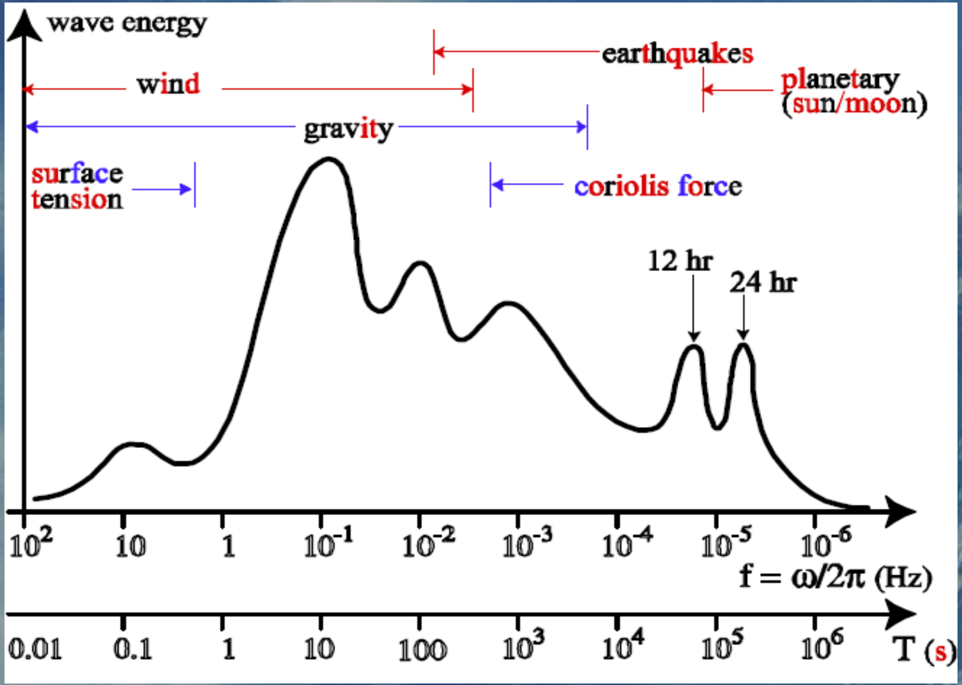
$$Y = \exp\left[-\left(\frac{0.191\omega T_1 - 1}{2^{1/2}\sigma}\right)^2\right]$$

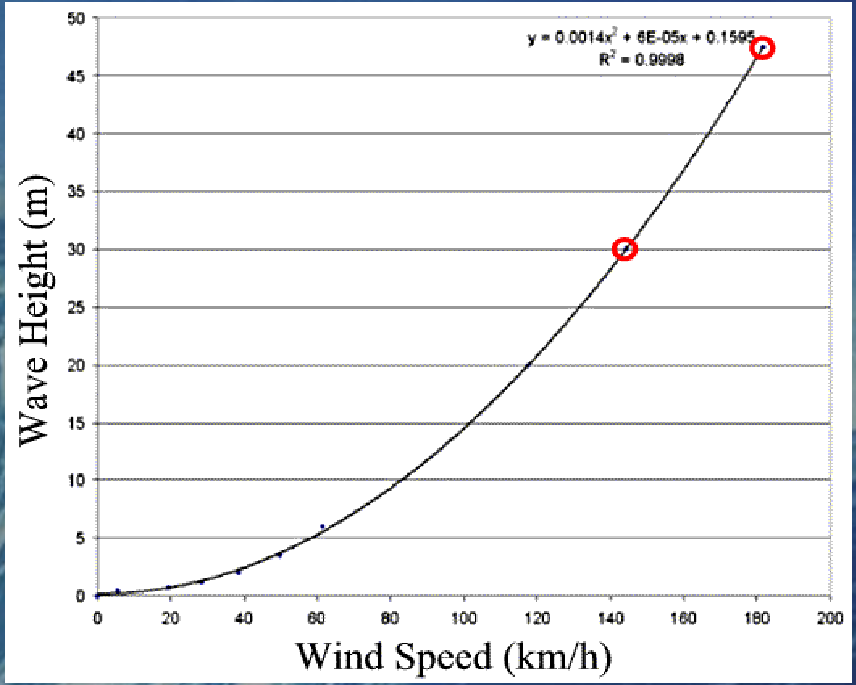
$$\zeta = \sum_{j=1}^{N}\sqrt{2S(\omega_j)\Delta\omega_j}\,\sin(\omega_j t - k_j x\cos\Theta_j - k_j y\sin\Theta_j + \epsilon_j)$$

$$N_{h_o} = \sum_i \frac{T}{\overline{T}} P_i\, e^{-\left(\frac{2h_o^2}{\zeta_i^2}\right)}$$

$$\frac{S(\omega)}{H_{1/3}^2 T_1} = \frac{0.11}{2\pi}\left(\frac{\omega T_1}{2\pi}\right)^{-5}\exp\left[-0.44\left(\frac{\omega T_1}{2\pi}\right)^{-4}\right]$$

$$\overline{\eta^{1/N}} \approx \frac{2N\sqrt{1-\varepsilon^2}}{1+\sqrt{1-\varepsilon^2}}\int_{\eta^{1/N}}^{\infty}\eta_o^2 e^{-\eta_o^2/2}d\eta_o$$





The Degree (D) value is almost linearly dependent to the square root of the average wave Height (H) above, i.e., $D \simeq \beta + \lambda\sqrt{H}$. Using linear regression on the table above, the coefficients can be calculated for the low Height values ($\lambda_L = 2.3236, \beta_L = 1.2551$) and for the high Height values ($\lambda_H = 2.0872, \beta_H = 0.6091$). Then the Degree can be approximated as the average between the low and high estimations, i.e.:

$$D \simeq \left[\frac{1}{2}\left(\lambda_L\sqrt{H_L} + \lambda_H\sqrt{H_H}\right) + \frac{1}{2}\left(\beta_L + \beta_H\right)\right]$$

(added in Wikipedia lemma: "Douglas Scale" for sea state)

where [.] is the optional rounding to the closest integer value. Without the rounding to integer, the root mean square error of this approximation is: $RMSE \leq 0.18$.

Small & medium boats: Hazardous conditions

- Difficult to formulate, depends on exact boat design
- Steering (orientation) vs. waves is a major factor
- Includes capsizing, gradual sinking, people overboard

⇒ *"...a closed, perfectly balanced vessel" (i.e., a submarine)*

General safety rules:

- ✓ $H_{wave} < 30\% * L_{boat}$
- ✓ $L_{wave} > 7 * H_{wave}$

...but not always necessary ⇒

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Devising the Solution

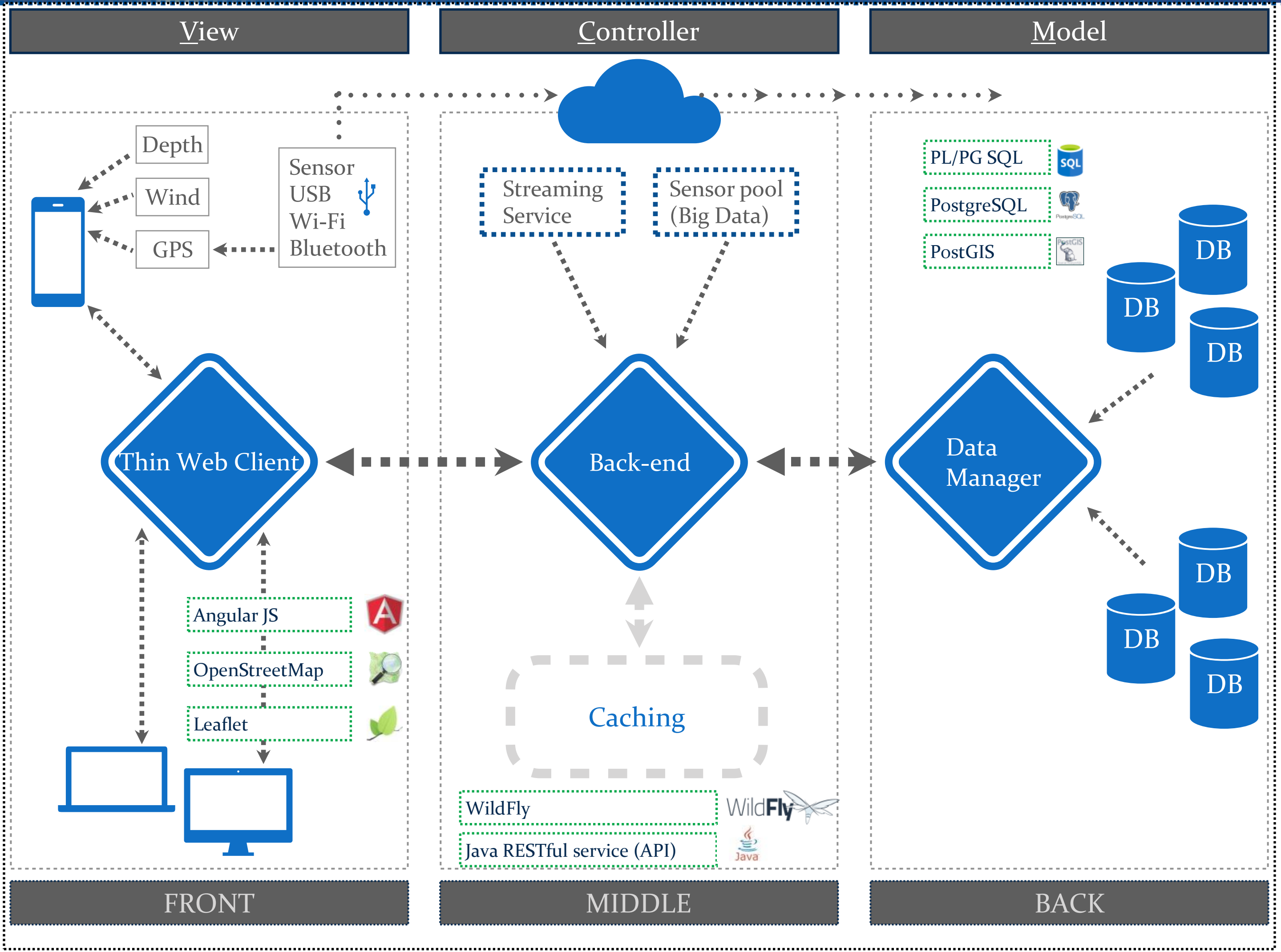
Estimating sea condition & wind waves in real-time:

- Input: Avg.Wind (U10 & Dir.), Fetch, Depth, Duration
- Output: Wave Height (avg, signf, R-distrib), sea condition (DS)
- Spot estimation can be offline, full-map mode is networked
- Small/medium-sized vessels (<20m) is the main focus group
- The first truly front-line tool for SSAR field teams in “hot” areas

Assumptions & Constraints:

- Local area: flat/orthogonal geometry (for distances & winds)
- Full spectral models too complex, statistical are still valid
- No heavy processing (weather sim.), **100% open platform**

* *Disclaimer: “The sea is dangerous. Sail safe. No shortcuts.”*


View
Controller
Model
Depth
Wind
GPS
Sensor
USB
Wi-Fi
Bluetooth
Streaming Service
Sensor pool (Big Data)
PL/PG SQL
PostgreSQL
PostGIS
DB
DB
DB
DB
DB
DB
Thin Web Client
Back-end
Data Manager
Angular JS
OpenStreetMap
Leaflet
Caching
WildFly
Java RESTful service (API)
FRONT
MIDDLE
BACK

- **PostgreSQL:** Open source object-relational database system.
- **PostGIS**: Spatial database extender for PostgreSQL object-relational database.
- **PL/PG SQL:** Loadable procedural language for the PostgreSQL database system.
- **Java RESTful service (API):** Java programming language API spec that provides support in creating web services according to the Representational State Transfer (REST) architectural pattern (Wikipedia).
- **Angular JS:** Framework for building client applications.
- **JavaScript:** High-level, dynamic, weakly typed, prototype-based, multi-paradigm, and interpreted programming language.
- **HTML5:** Markup language used for structuring and presenting content on the World Wide Web (Wikipedia).
- **OpenStreetMap:** Free wiki world map.
- **Leaflet:** Open-source JavaScript library for mobile-friendly interactive maps.
- **WildFly:** Application server.


OUTEST
AIR FLOW ANEMOMETER
43°
60%
63
80%
260
T-STORM
92
DAVIS
Vantage VUE
MS6252A
DIGITAL ANEMOMETER
8.8.8.8
HYELEC
FUNC
HOLD
UNIT

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The Workbench

Settings

Wind direction (degrees) *

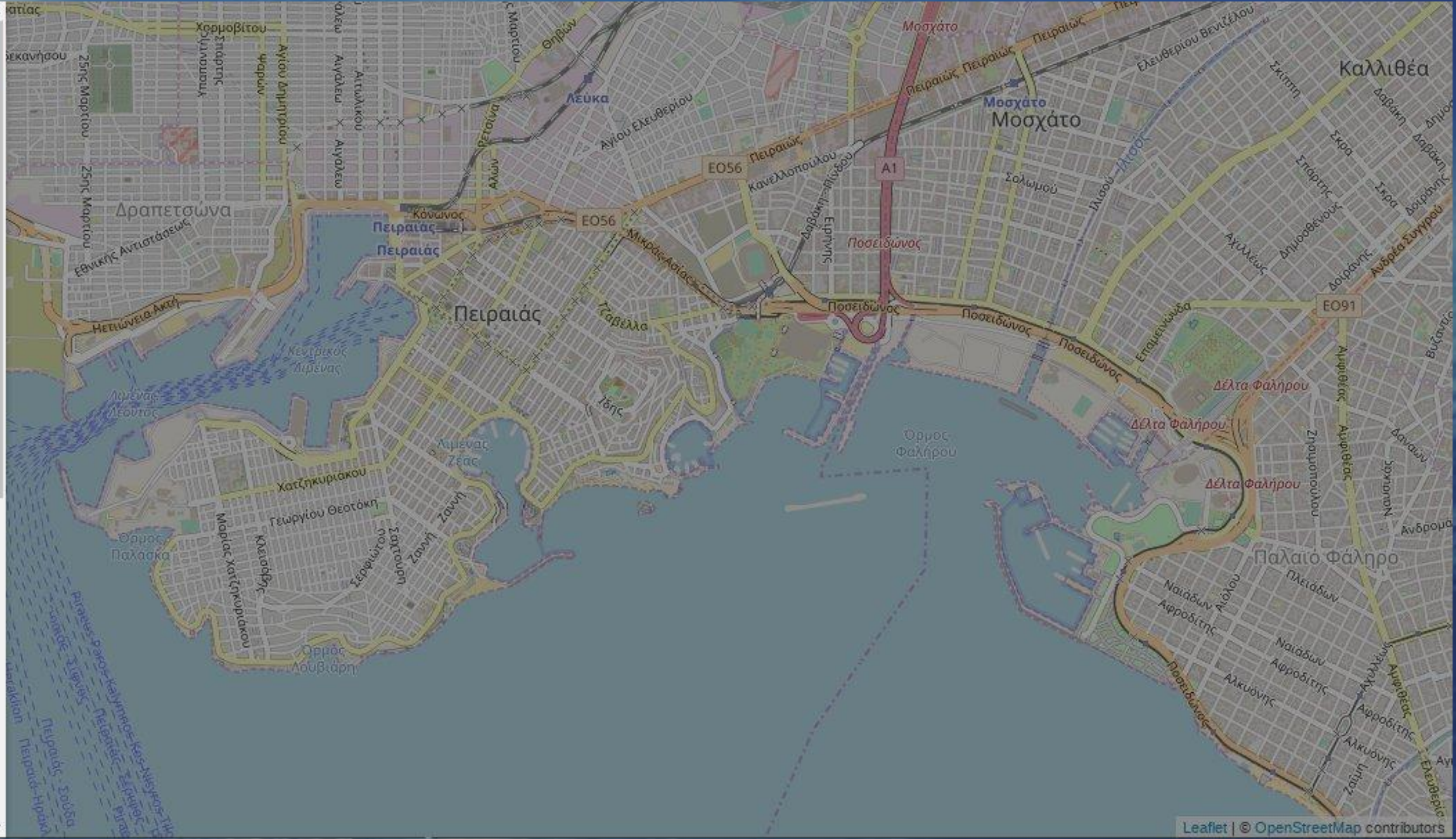
Wind Speed (km/h) *

User longitude *

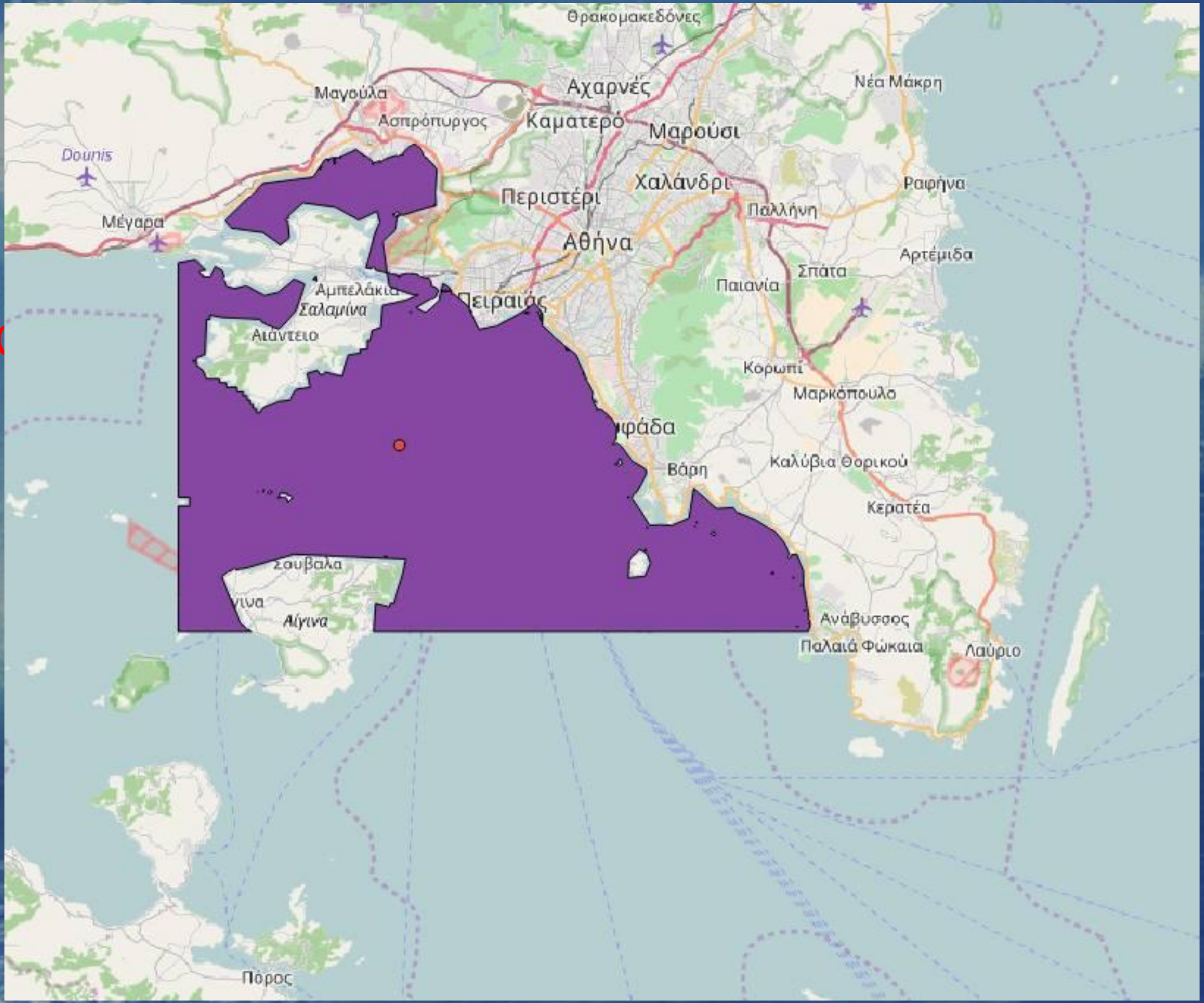
User latitude *

Wind duration (hours) *

Time offset (hours) *

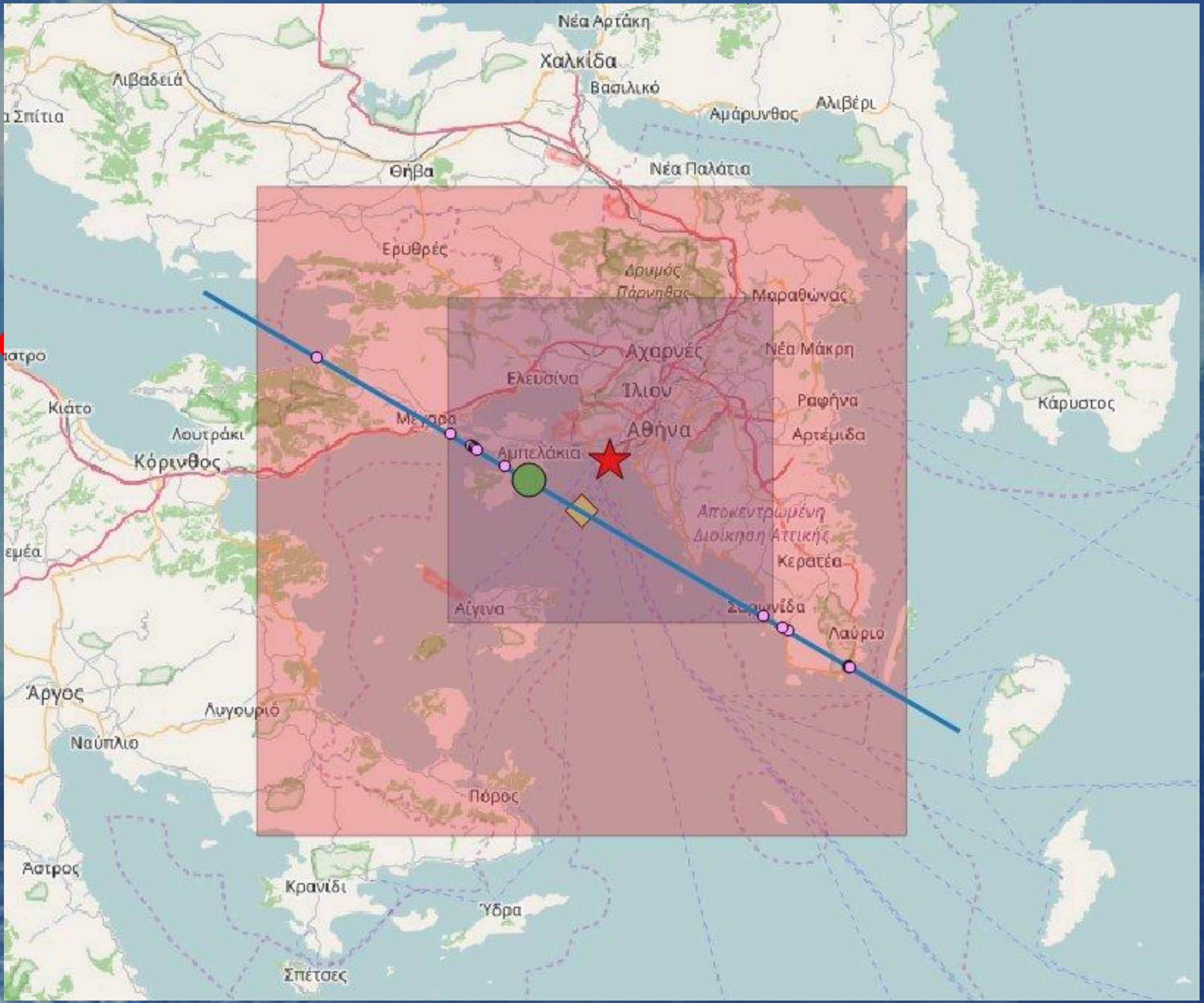


GUI SC

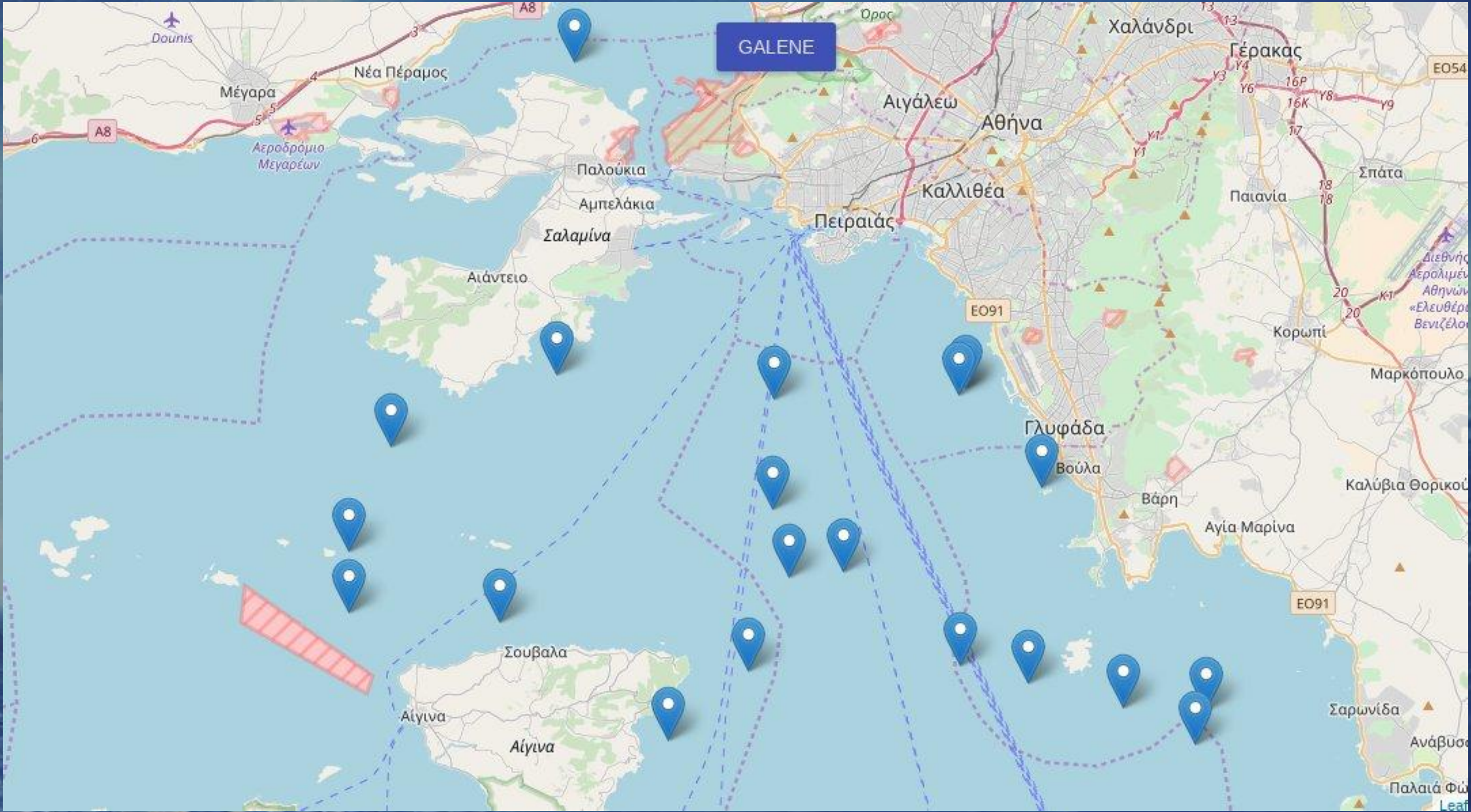


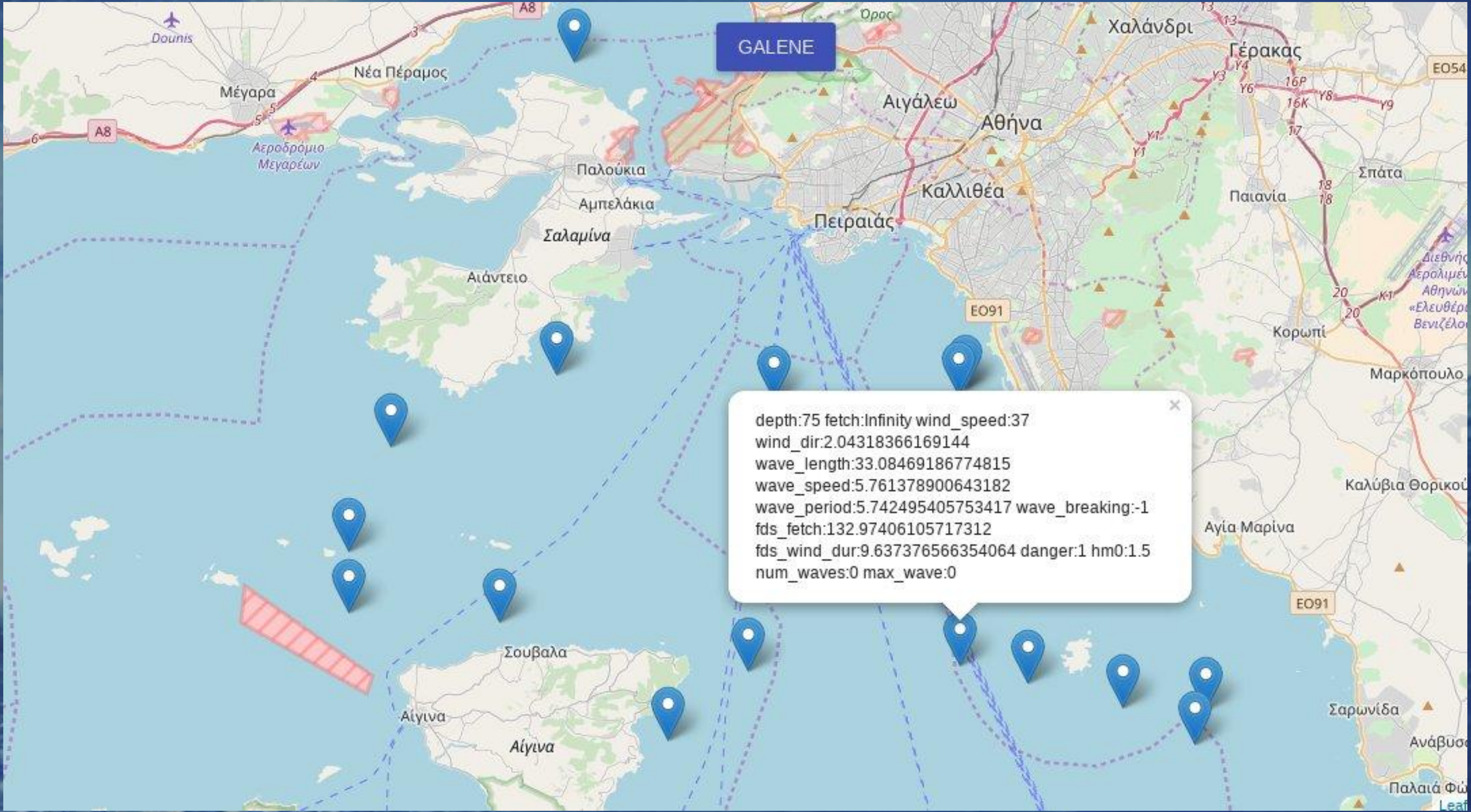
Θρακομακεδόνες
Αχαρνές
Μαγούλα
Νέα Μάκρη
Ασπρόπυργος
Καματερό
Μαρούσι
Dounis
Χαλάνδρι
Ραφήνα
Περιστέρι
Παλλήνη
Μέγαρα
Αθήνα
Αρτέμιδα
Σπάτα
Αμπελάκια
Παιανία
Πειραιάς
Σαλαμίνα
Αιάντειο
Κορωπί
Μαρκόπουλο
Βάρη
Καλύβια Θορικού
Κερατέα
Σουβαλα
Αίγινα
Ανάβυσσος
Παλαιά Φώκαια
Λαύριο
Πόρος

GUI S



Νέα Αρτάκη
Χαλκίδα
Βασιλικό
Λιβαδειά
Σπίτια
Αμάρυνθος
Αλιβέρι
Θήβα
Νέα Παλάτια
Ερυθρές
Μαραθώνας
Αχαρνές
Νέα Μάκρη
Ελευσίνα
Ίλιον
Ραφήνα
Κιάτο
Αθήνα
Αρτέμιδα
Λουτράκι
Αμπελάκια
Κόρινθος
Κάρυστος
Αποκεντρωμένη Διοίκηση Αττικής
Κερατέα
Αίγινα
Λαύριο
Άργος
Λυγουριό
Ναύπλιο
Πόρος
Άστρος
Κρανίδι
Ύδρα
Σπέτσες


GALENE
Dounis
Μέγαρα
Νέα Πέραμος
A8
Αεροδρόμιο Μεγαρέων
Παλούκια
Αμπελάκια
Σαλαμίνα
Αιάντειο
Αιγάλεω
Αθήνα
Καλλιθέα
Πειραιάς
Χαλάνδρι
Γέρακας
Σπάτα
Παιανία
Κορωπί
Μαρκόπουλο
EO91
Γλυφάδα
Βούλα
Βάρη
Αγία Μαρίνα
Καλύβια Θορικού
Σουβαλα
Αίγινα
Αίγινα
Σαρωνίδα


GALENE
depth:75 fetch:Infinity wind_speed:37
wind_dir:2.04318366169144
wave_length:33.08469186774815
wave_speed:5.761378900643182
wave_period:5.742495405753417 wave_breaking:-1
fds_fetch:132.97406105717312
fds_wind_dur:9.637376566354064 danger:1 hm0:1.5
num_waves:0 max_wave:0
Μέγαρα
Νέα Πέραμος
Αεροδρόμιο Μεγαρέων
Παλούκια
Αμπελάκια
Σαλαμίνα
Αιάντειο
Αιγάλεω
Αθήνα
Καλλιθέα
Πειραιάς
Χαλάνδρι
Γέρακας
Σπάτα
Παιανία
Κορωπί
Μαρκόπουλο
Αγία Μαρίνα
Σουβαλα
Αίγινα
Σαρωνίδα
EO91

```
$http.get(rest)
.then(function (response) {
    $scope.data=response.data;

    for (var i = 0; i < $scope.data.length; i++) {
        points.push({
            lat: $scope.data[i].y,
            lng: $scope.data[i].x,
            message: "depth:" + $scope.data[i].depth + "\n" +
            "fetc
            "wind
            "wind
            "wave
            "wave
            "wave
            "wave
            "fds_
            "fds_
            "dang
            "hm0:
            "num_
            "max_
        })
    }
```

```
BEGIN
        box := st_expand(st_transform(st_setsrid(st_makepoint(lon,lat),4326), 3857),30000) ; --user box

        FOR new_point in select (ST_DumpPoints(ST_GeneratePoints(st_union(st_intersection(st_transform(box, 4326),geom)), 20))).geo
                from greek_bathmetry
                where st_transform(box, 4326) && geom
                and st_intersects(st_transform(box, 4326), geom) LOOP

                select depth
                from greek_bathmetry
                where new_point && geom AND
                st_intersects(new_point, geom) INTO new_point_depth;

                ref_point_box := st_expand(st_transform(new_point,3857), 60000);
                rotate_line := ST_Rotate(ST_BoundingDiagonal(st_transform(ref_point_box,4326)), wind_dir, ST_Centroid(st_transform(

                select foo.new_geom as geom, st_distance(foo.new_geom, st_transform(new_point,2100)) as distance
                from (
                        select (ST_DumpPoints(st_intersection(
                                                                st_transform(rotate_line,2100),
                                                                geom
                                                ) ) ).geom as new_geom
                        from aktogrammh
                        where st_transform(rotate_line,2100) && geom
                ) as foo
```

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Next Steps

Platform Enhancements:

- Integrate GUI with geo-location for spot selection via local map
- Extensive code testing, Agile increments, alpha/beta/RC versioning
- Open the platform to the community when it becomes more mature
- Exploit any useful open data feed as inputs (e.g. weather telemetry)

Future Work:

- Produce heat-maps for boat risk based on more precise specs
- Improve model accuracy, include wind variability (statistics)
- Extend to non-flat geometry for larger geo-location window
- Back-end caching of results, smaller networking footprint
- Implement Android & iOS client apps (exploit native APIs)

GALENE team:

Petros Petrou (PhD cand.)
John Kontoulis (PhD cand.)
Harris Georgiou (post-doc)

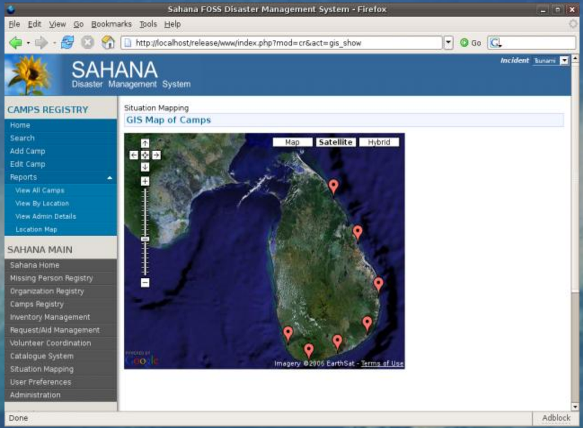
Data Science Lab @ Univ. of Piraeus:

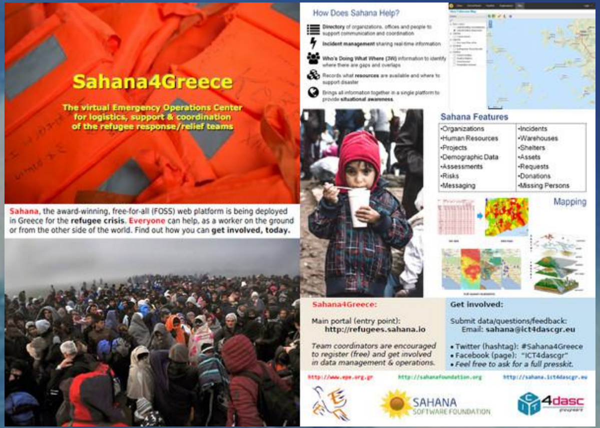
"...Our goal is to address the challenging problems related to the wealth data, by advancing research and producing solutions to real world problems related to efficient and scalable management of Big Data (gathering and cleansing data, storing and indexing data, analyzing, and mining data)..."

Related Works:

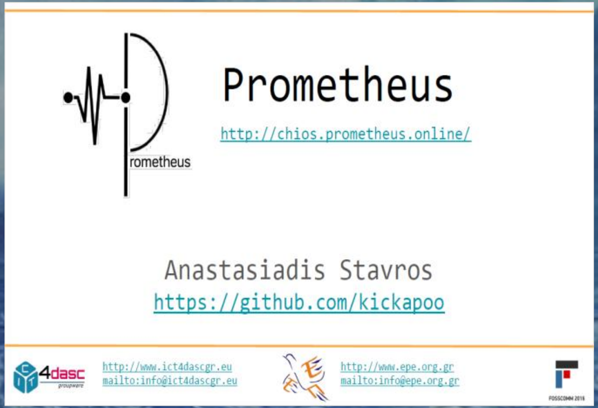
Sahana4Greece (Lesvos)
(⇒ *FOSSCOMM 2015*)

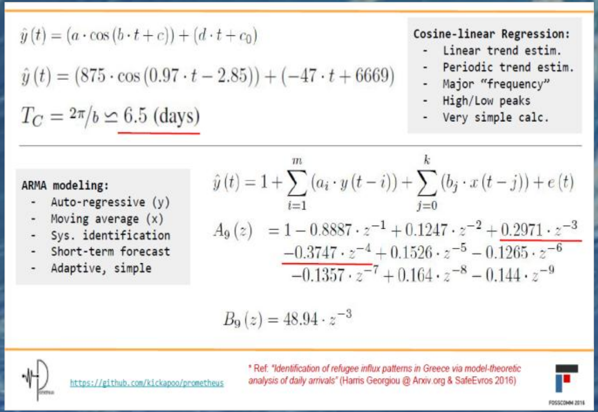
Prometheus (Chios)
(⇒ *FOSSCOMM 2016*)

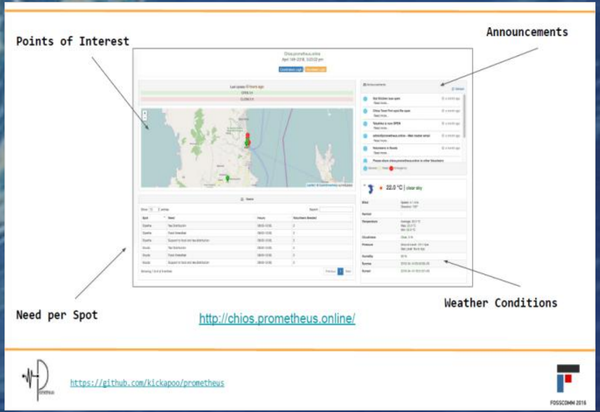




http://sahana.ict4dascgr.eu/







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