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Latest LAPS developments Assimilating remote sensing data and its impact on LAPS predictability

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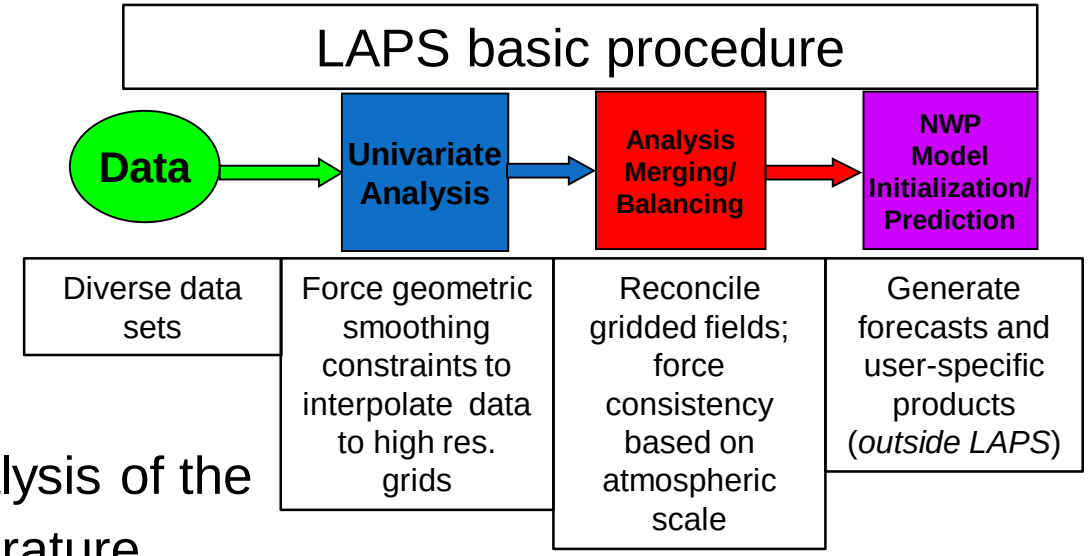
Introduction and aim

- ✓ NOAA's Local Analysis and Prediction System (LAPS) is an advanced mesoscale meteorological data assimilation tool designed to exploit all available data sources (local and global) and produce analyzed and guessed grids (*Albers*, 1995)
- ✓ LAPS incorporates a number of surface and upper air observations to produce high spatial and temporal resolution analysis fields
- ✓ A description of the LAPS main characteristics, as an alternative data assimilation and nowcasting system in Europe, will be provided here, including methods and techniques developed in ISAC-CNR, Italy and HUA, Greece
- ✓ The sensitivity of LAPS on the ingestion of ground radar precipitation is assessed in a high impact storm occurred in the sub-urban area of Mandra, western Attica, Greece

LAPS basic components

- Data Acquisition and Quality Control



- Univariate Analysis of the
  - Temperature
  - Winds
  - Water Vapor
  - Clouds
    - Microphysical variables
    - Vertical motions

LAPS analysis processes

- LAPS uses objective analysis: multi-scale successive correction methods (New analysis-system is also available: Variational-LAPS-STMAS).

LAPS processes are made in sequences:

- **Surface analysis:** Temp., winds, rel. humidity, station pressure etc.
- **Upper air analysis:**
  - **3-D Wind:** Upper air winds (interaction with sfc winds) etc.
  - **3-D Temperature:** Temperature and height (interaction with sfc temp)
  - **Cloud coverage (2D/3D):** Include check for low inversion-clouds
  - **Water vapor (humidity):** Specific and relative humidity (interaction with cloud) etc.
- **Derived products:** Cloud liq. water and ice, hydrometeors etc
  - **Accumulation:** Liquid (rain) and snow accumulation
  - **Soil moisture:** Soil moisture, evaporation etc.
  - **Balance:** Winds, temp and height being balanced for NWP ingestion
  - **LAPSPREP:** Format conversion, preparation for ingest to fc. model

LAPS basic components

- LAPS estimates functions that are best fitting of weather through backgrounds and observations. The following data assimilation techniques are applied:
  - 3DVar (*global fitting scheme*),
  - Barnes (*point wise fitting*)

- It is based on the 3D cost function minimization

$$\min \frac{1}{2}\left(x-x^{b}\right)^{T} B^{-1}\left(x-x^{b}\right)+\frac{1}{2}\left(H(x)-y\right)^{T} O^{-1}\left(H(x)-y\right)+\text{constraints}$$

  - B is the model error covariance matrix; O is the observational error matrix (diagonal);
  - x is the control variable; x^b is the background field;
  - H is the observation operator (nonlinear); y is the observation

The European LAPS (ELAPS) community

ELAPS community aims at:

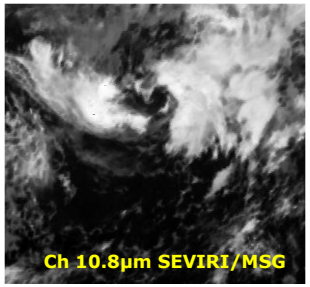
- The establishment of a high-quality, trans-national collaboration in data assimilation, nowcasting, atmospheric dynamics and predictability;
- The implementation of an integrated approach in order to improve the forecast skill of the limited area atmospheric models, based on the use of LAPS analyses as initial conditions;
- The common development of tools and modules of the system;
- Improvement of various LAPS modules (cloud analysis, surface analysis, etc)

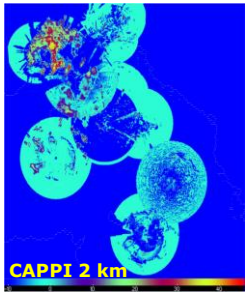
ELAPS members

- **ISAC-CNR and LaMMA, Italy**
- **FMI, Finland**
- **METEOCAT, Spain**
- **RHS and U. of Belgrade, Serbia**
- **HUA and HCMR, Greece**

Analysis of meteorological data for the atmospheric models at high resolution

Alessandro Tiesi, Mario Marcello Miglietta





The Local Analysis and Prediction System (LAPS, https://laps.noaa.gov/) is a numerical tool designed at the National Oceanic and Atmospheric Administration (NOAA, USA) for the generation of mesoscale analyses. LAPS analyses, based on the Barnes recursive approach, can be used as initial conditions for limited-area meteorological models as well as a tool to construct consistent 3-D atmospheric fields suitable for nowcasting applications. LAPS allows the exploitation of meteorological data coming from any sort of conventional and nonconventional sources, including remotely sensed data.

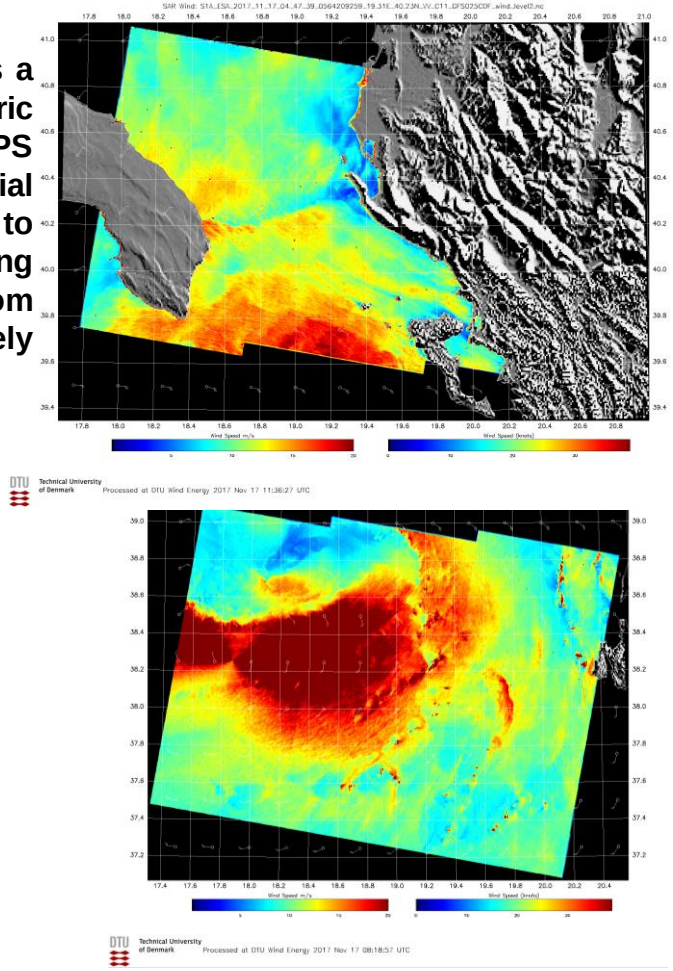
The system is implemented to initialize the meteorological models used at CNR-ISAC:
BOLAM e **MOLOCH** (http://www.isac.cnr.it);
WRF-ARW (https://www.mmm.ucar.edu);

Data involved: METAR (surf. st.), Radiosoundings, Radar Reflectivity (CAPPI 3 levs), SEVIRI/MSG, SAR/Sentinel-1;

Recent projects involving model initialization:
2015-2016: Flagship project RITMARE (MIUR);
2016-2017: Pilot project RAMSES (Railways Meteo Security System) RFI S.p.A., Phase 1 test;
2017-2018: CEASELESS (Horizon 2020, European Copernicus);
2019: Pilot project RAMSES (Railways Meteo Security System) RFI S.p.A., Phase 2 operative.

Collaborations: CNR-ISMAR, CNR-IRPI, ARPA Liguria, ARPA Friuli Venezia Giulia, SMC (Servei Meteorològic de Catalunya, Barcellona; Spain), National Oceanic and Atmospheric Administration (NOAA; Boulder, USA)

Latest data analysis implemented:
Sentinel 1 sea surface wind
(medicane 17-11-2017 04:48 UTC)



LAPS advection scheme

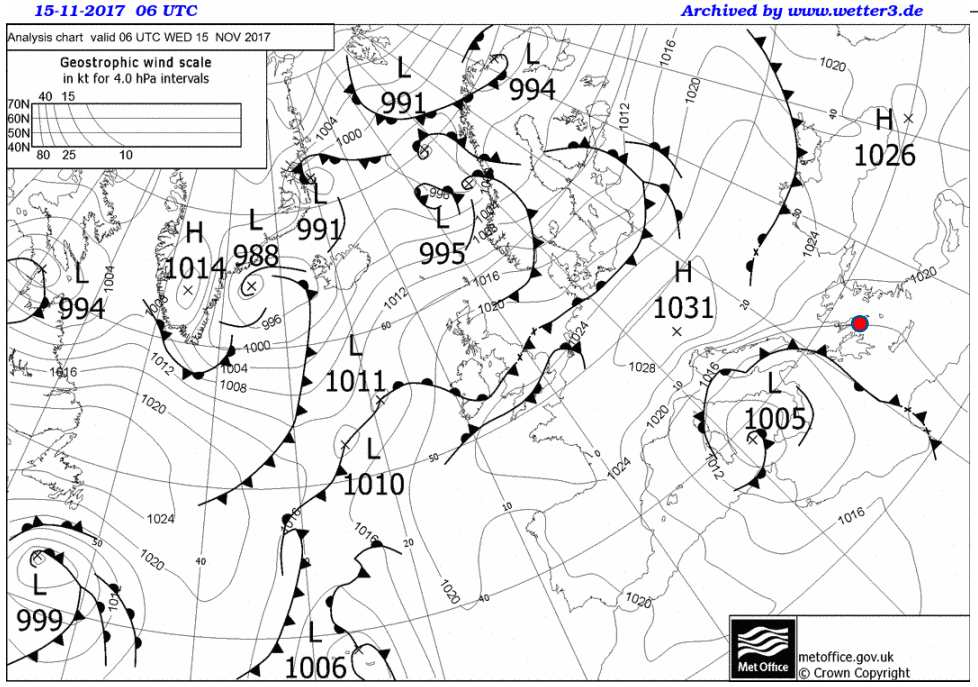
- Simple first order advection scheme in 2 dimensions (x,y)
- Solving the advection equation for various meteorological parameters (Temperature, Precipitation, Humidity)
- $\frac{\partial u}{\partial t} + CU\frac{\partial u}{\partial x} = 0$ and $\frac{\partial v}{\partial t} + CV\frac{\partial v}{\partial y} = 0$ (1)
- C is the Courant number defined as $CU = u\frac{\Delta t}{\Delta x}$ and $CV = v\frac{\Delta t}{\Delta y}$
- Equations (1) can be written as $\frac{{u_i}^{t+1} - u^t}{\Delta t} + \frac{{u_{i+1}}^{t+1} - u^t}{\Delta x} = 0$ (2)
- First the Courant number is calculated in order to see if the time-step selected assures the stability of the formulation
- By solving equation (2) we can find the value of the parameter at time t+1 using information at time t

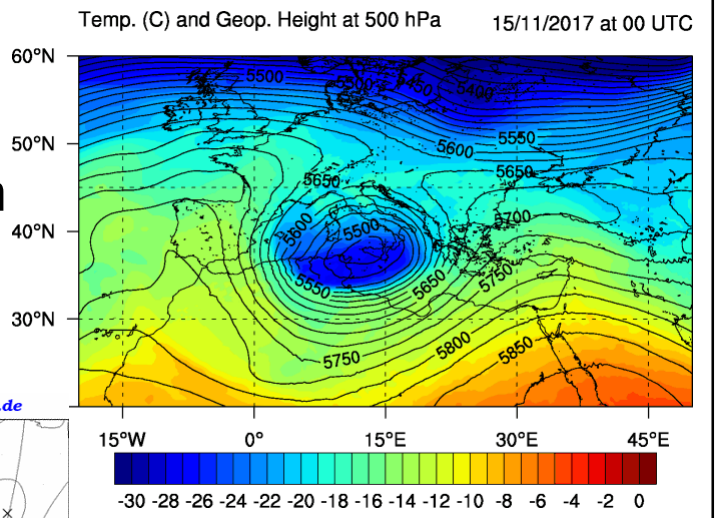
Extreme Flash Flood Event in West Attica (Mandra) in November 15, 2017

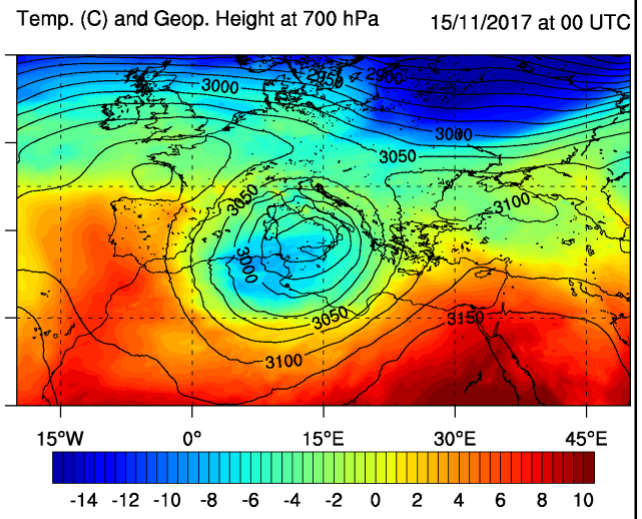
- A three-days (14 – 16 November) wave of adverse weather with extreme precipitation in the west sub-urban area of Athens resulted in tremendous flooding with landslides and 24 fatalities

Synoptic conditions at Nov 15, 2017

- The event was related to an upper air trough existence originating from NE Europe to central Mediterranean leading to the generation of a barometric low centered over Italy

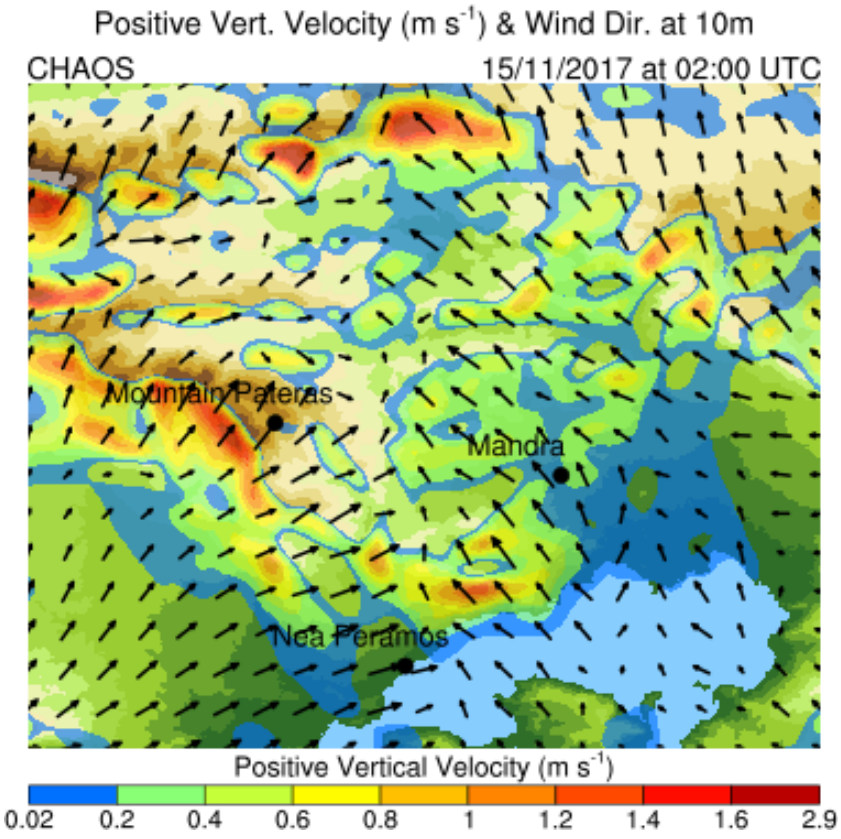






Mesoscale conditions at Nov 15, 2017

- The dominant mechanism that triggered the torrential rain is the orographic convergence of humid SE airflow over SE slopes of Pateras mountain
- The local convergence is collocated with the dry downdrafts over the eastern slopes of Pateras mountain which are attributed to the middle- and upper-level air circulation



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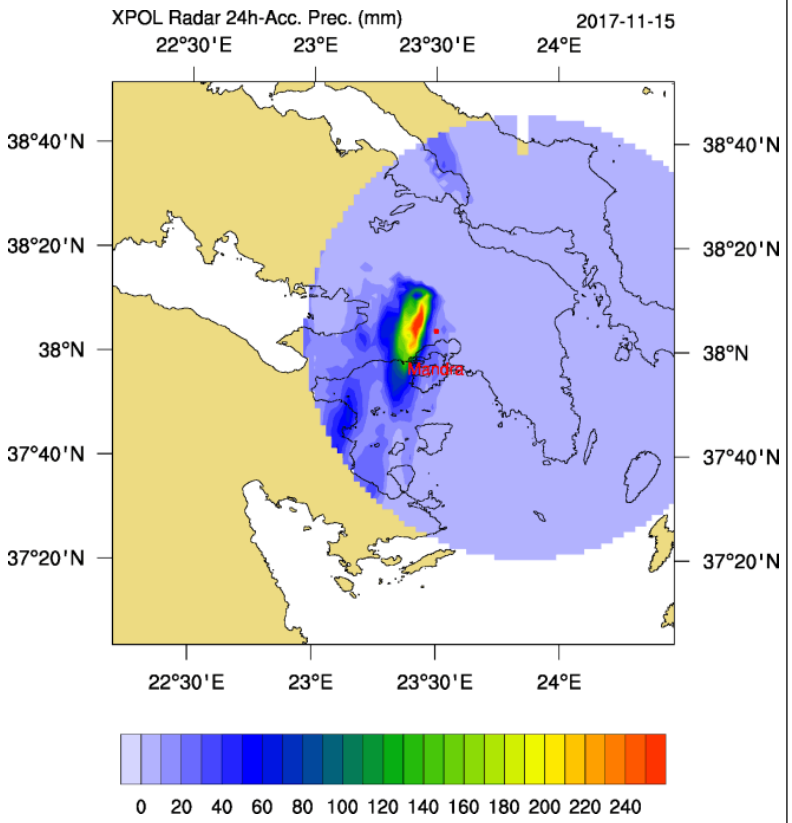
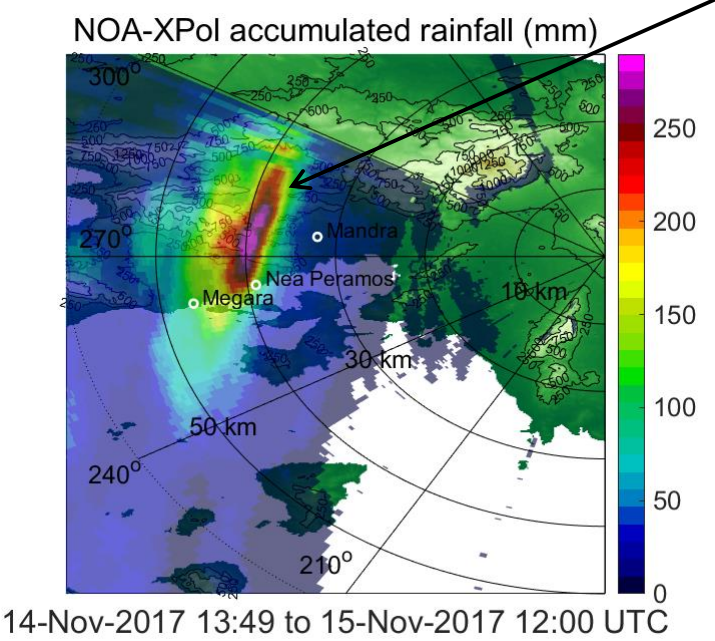
XPOL radar characteristics

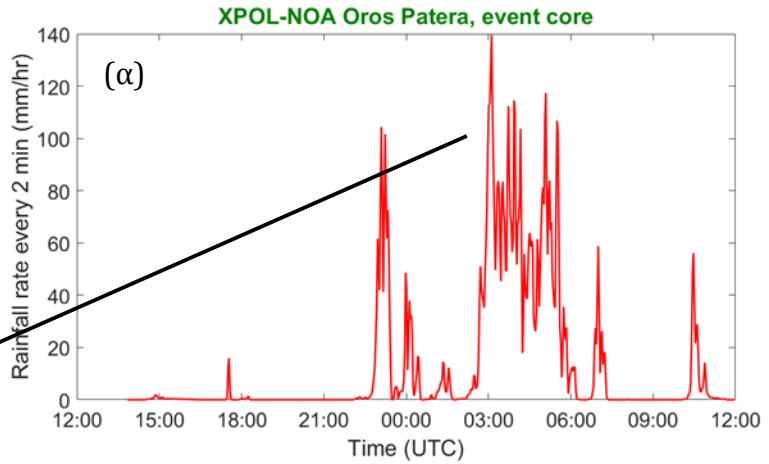
- Remote sensed precipitation obtained from the National Observatory of Athens X-band dual-polarization ground radar located on Penteli Mt. (~35 km east of Mandra)
- XPOL operates in plan position indicator (PPI) mode taking measurements in a sector scan of 180˚, at 0.5˚, 1.5˚ and 2.5˚ elevation sweeps with a range resolution of 120 m for the total range of 65 km
- During the peak of the storm, at 00:00-06:00 UTC, there were instances that the XPOL observed basin-average precipitation rates exceeded 55 mm/h

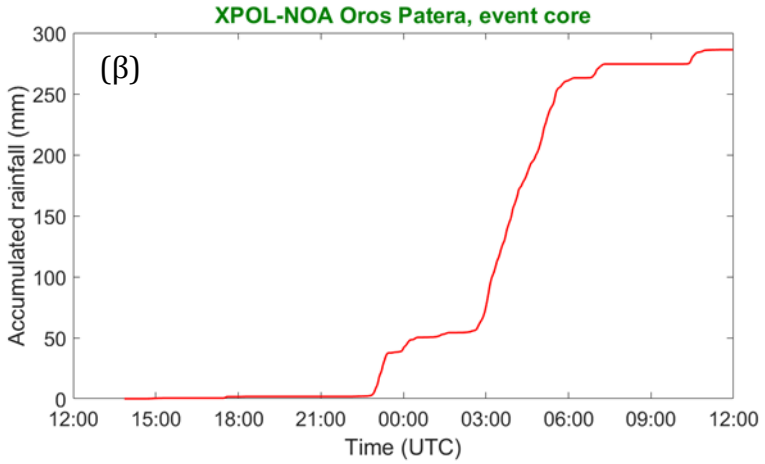


XPOL radar precipitation

- XPOL recorded more than 200 mm accumulated precipitation in the core of the storm
- During 03:00-06:00 UTC observed the highest rainfall rates (120–140 mm/hr) around Patera Mt.







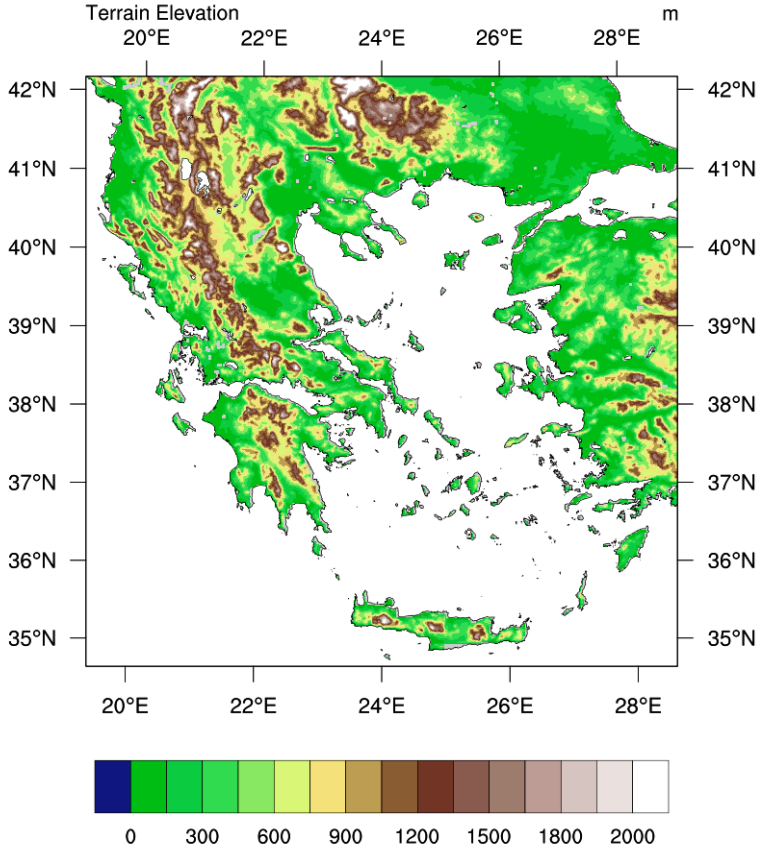
LAPS Setup

Horizontal Resolution	Vertical Domain	Background Data	Topography
2Km X 2Km	21 Levels up to 10 hPa	GFS 0.5 X 0.5 degrees	30 X 30 sec USGS

Ingested data (MADIS)

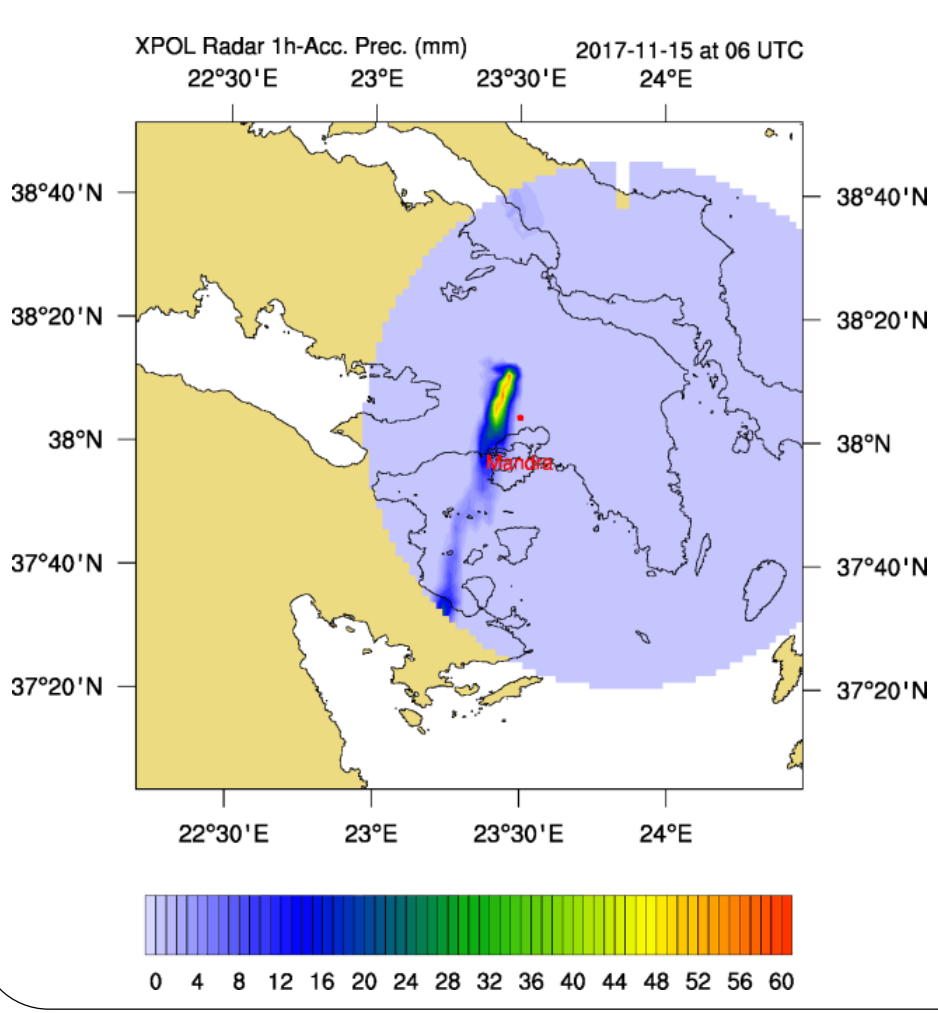
- ✓ Metar
- ✓ Synop
- ✓ Raob
- ✓ Buoys
- ✓ Mesonet
- ✓ ACARS

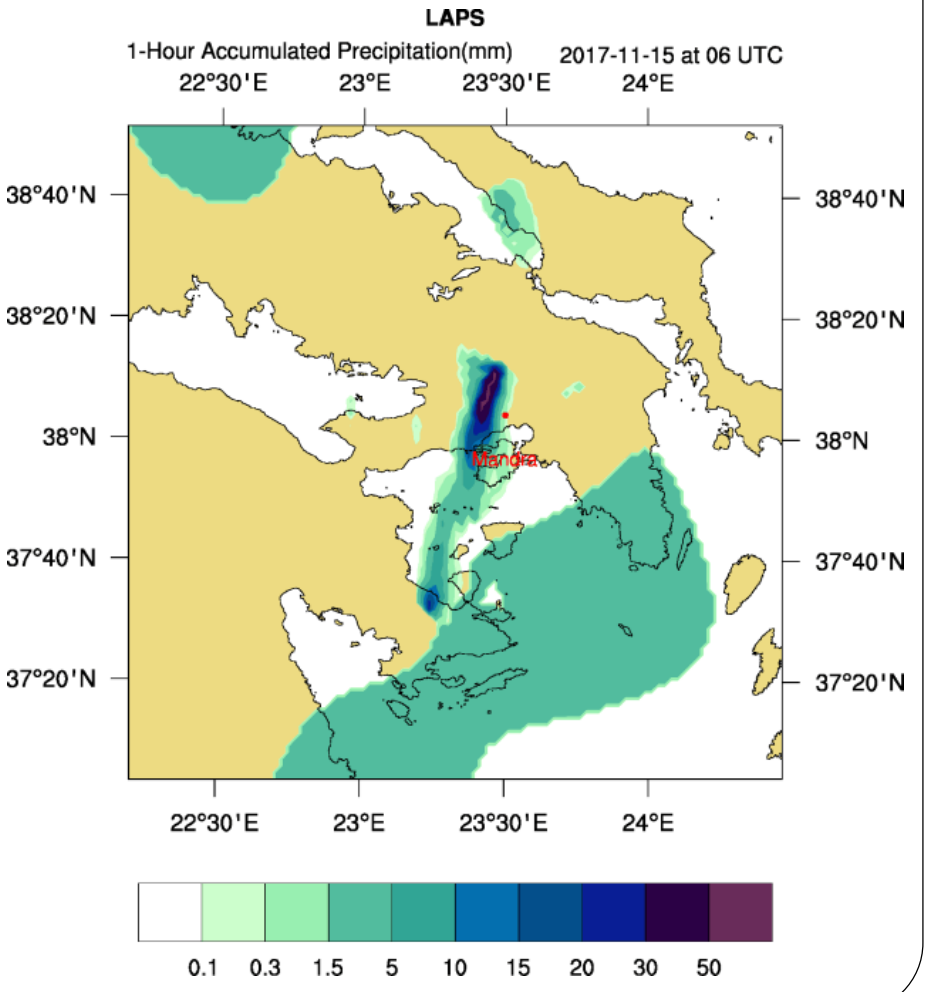
+ **XPOL Radar precipitation**



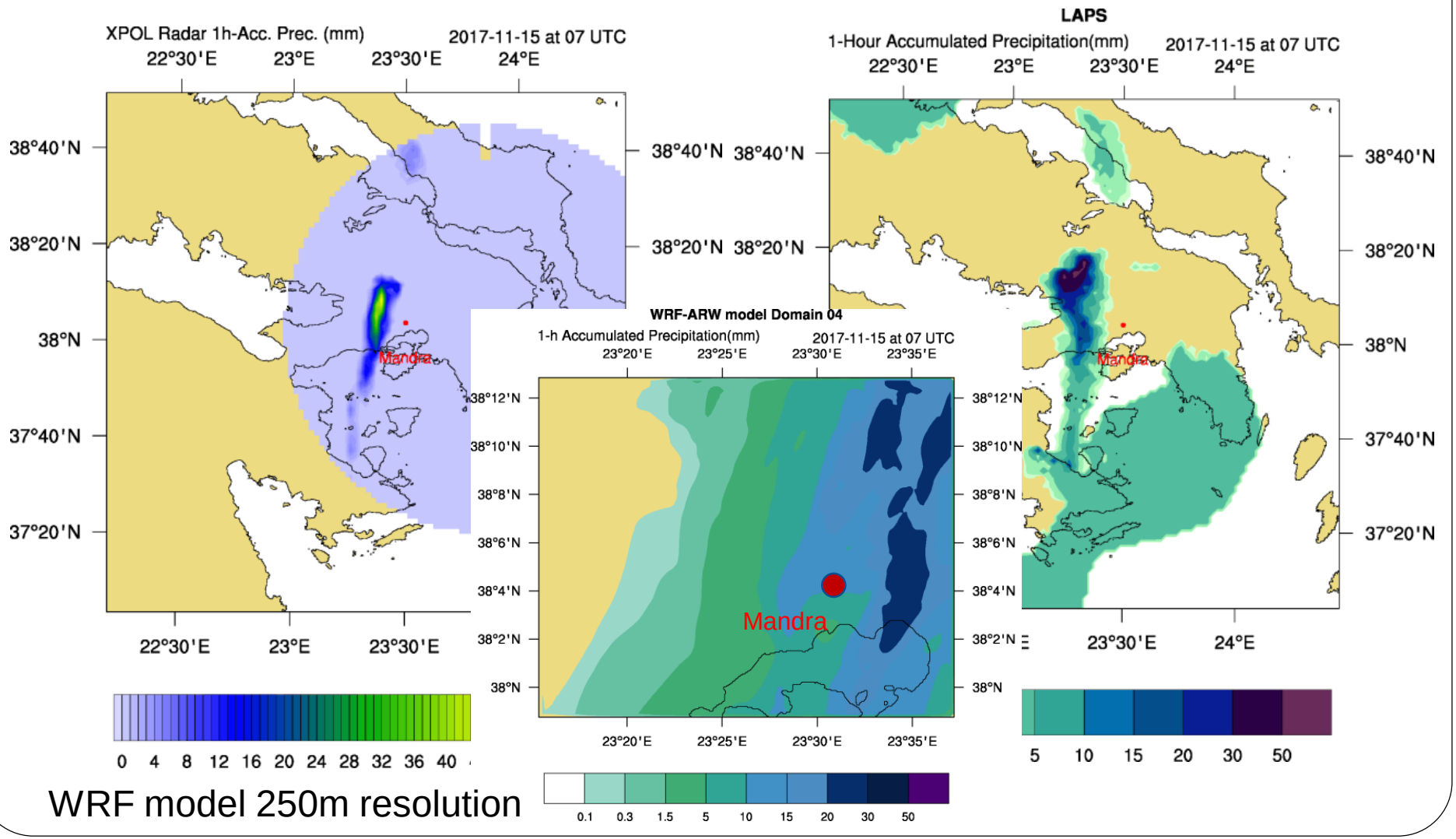
LAPS analysis Nov 15, 06:00UTC

- LAPS precipitation (XPOL+background)



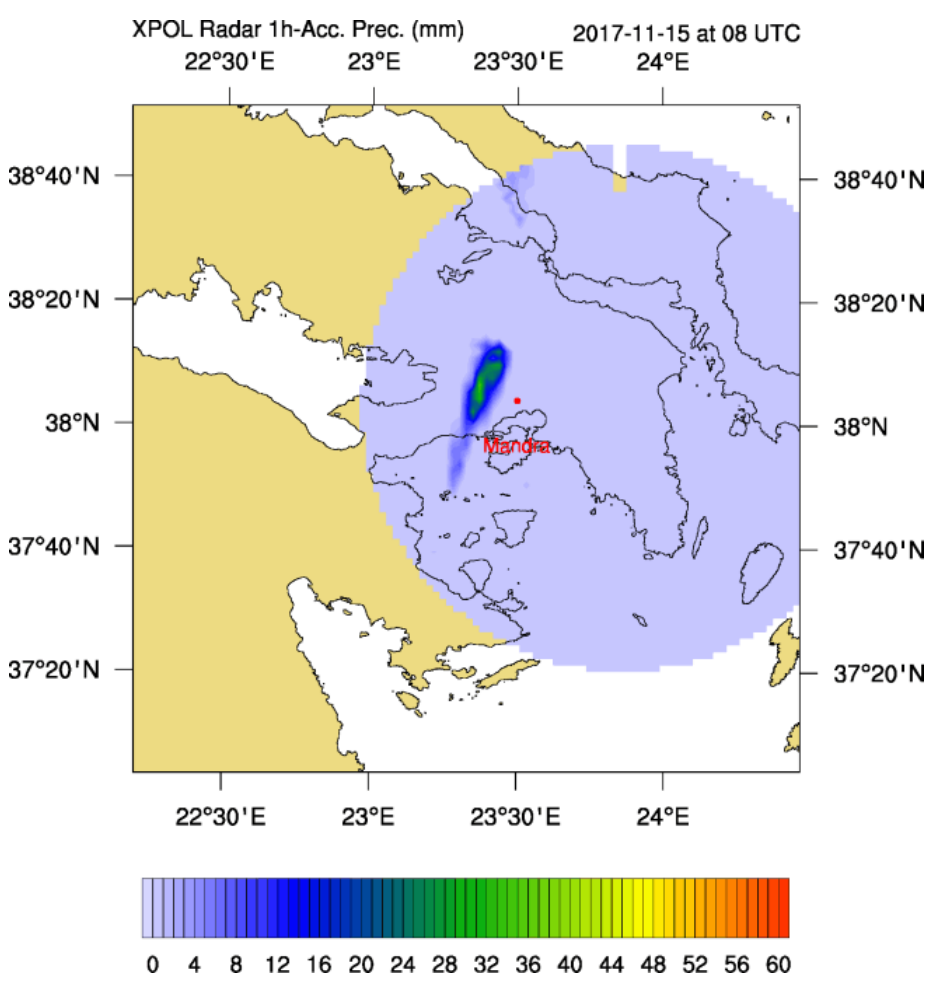


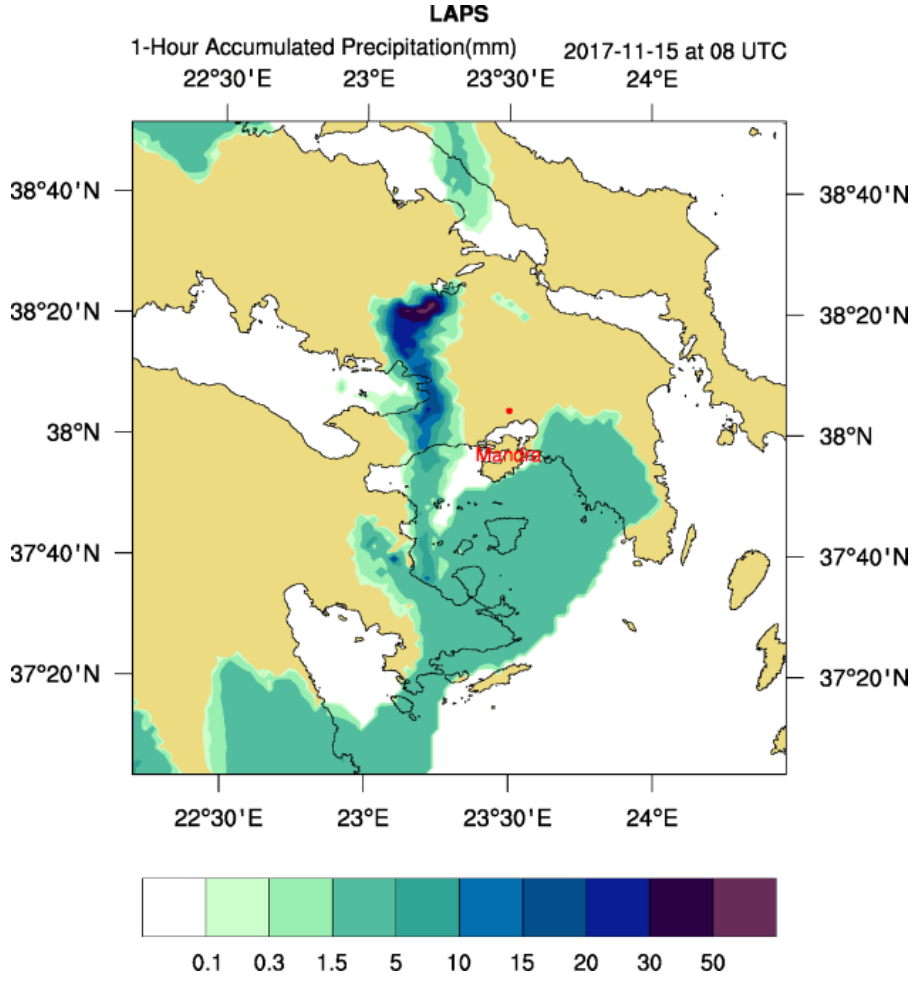
LAPS nowcast (+1hr), Nov 15 at 07:00UTC



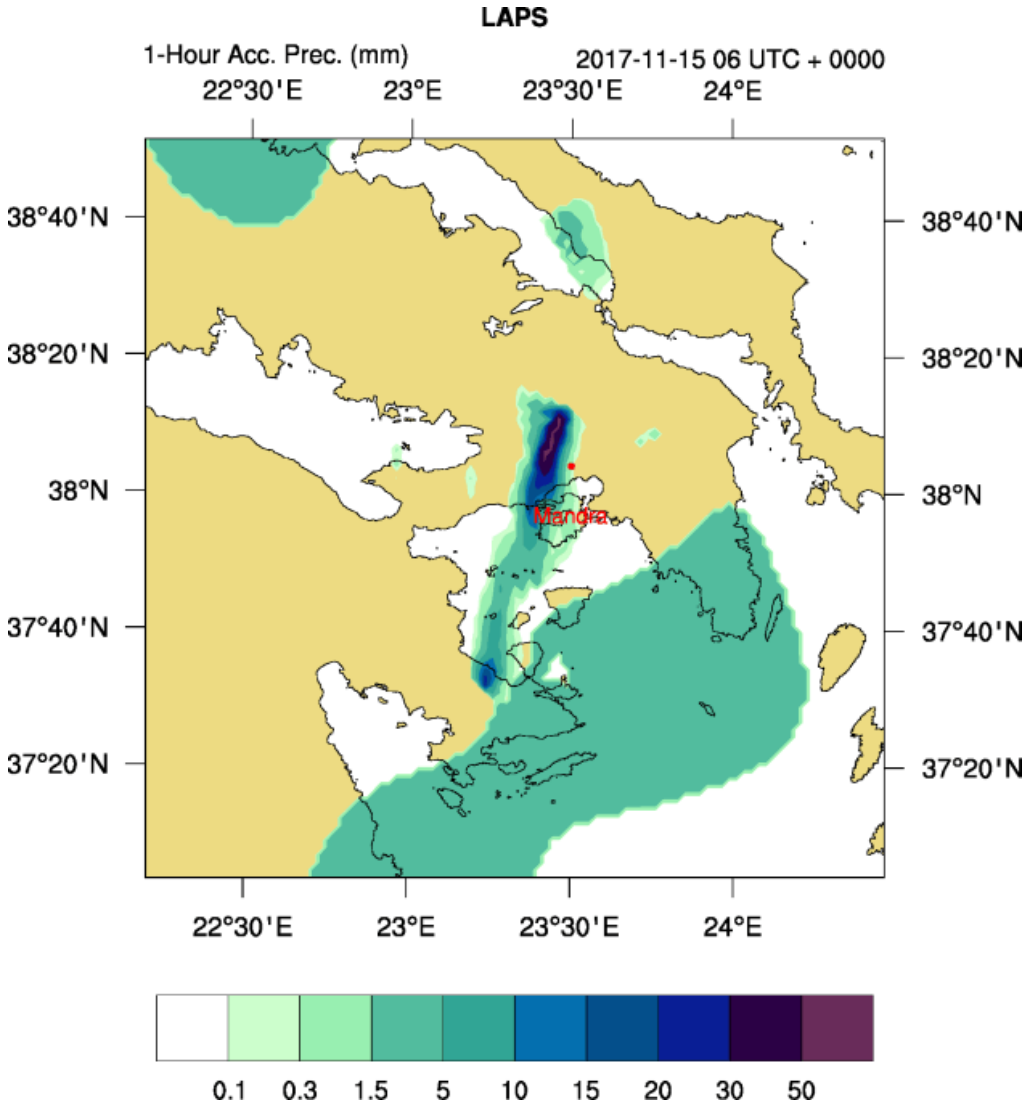
WRF model 250m resolution

LAPS nowcast (+2hr), Nov 15 at 08:00UTC



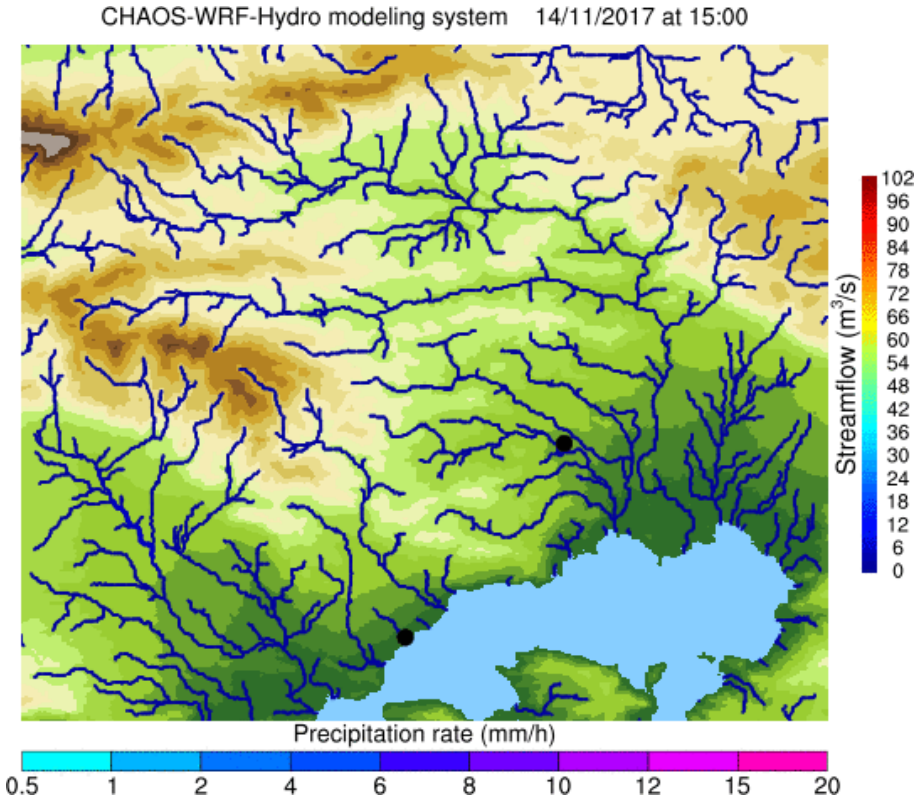


LAPS Advection – Background Rain



In progress…

- ✓ Coupling LAPS analysis and nowcasts with a hydrological model



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