Application and verification of ECMWF products 2018

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1. Summary of major highlights

It is expected that a more detailed description of any items included here will appear in section(s) below.

- ECMWF deterministic runs are used to issue most of the operational forecasts at IMS
- Systematic issues experienced with ECMWF forecasts: 1) Strong precipitation on coast line with insufficient penetration inland; 2) Marine inversion, visibility and stratus are too low over coastline.
- Seasonal forecast for the JJA 2017 is skilful but is meaningless due to climate change in the reference period. DJF 2017-2018 precipitation forecast has no skill. New SEAS5 has a lower precipitation skill compared to old Sys4 based on years 1981-2016.
- Performance of HRES-SAW current vs. previous version: Improved bias with Ashdod buoy as forecast wave height increases in the current version. No improvement with Haifa buoy, despite that current model uses a higher resolution wind field over Haifa bay.
- Comparing SWH from ECMWF WAM ENS, ECMWF HRES-SAW, and buoys: Too little spread in the ENS members. While HRES-SAW has practically no monthly bias with the buoy, the ENS mean is overestimating by ~10%. During high wave events the ensemble mean (EM) performance improves while the HR performance deteriorates compare to their mean performance for the whole month.
- New and modified ECMWF products requests are described in sec. 2.2.2. The list includes potential useful products for IMS, suggestions for ecCharts- interface modifications and new parameters, and request for new web tools/interfaces.
- INCA (Integrated Nowcasting through Comprehensive Analysis) system, based on IFS forecasts and automatic station, improves IFS forecasts. Bias removal manages to improve significantly 2m-Temperature forecasts for stations points.
- IMS uses ECMWF fields as boundary conditions for COSMO forecasts
- A Python code for plotting upper air sounding on Tephigram (as opposed to skew-T) was generated and delivered to ECMWF (3/2018)

Most of the above highlights are described below and were presented at the UEF2018 meeting.

2. Use and application of products

Include medium-range deterministic (HRES) and ensemble (ENS) forecasts, monthly forecast, seasonal forecast.

2.1 Post-processing of ECMWF model output

Describe the different ways in which you post-process ECMWF forecasts, in the following categories:

2.1.1 Statistical adaptation

See previous report for more information.

2.1.2 Physical adaptation

Include limited-area models, hydrological models, dispersion models etc. that use ECMWF model data (HRES and/or ENS) as input (e.g. for initial conditions / boundary conditions / etc.)

a. ECMWF deterministic model output is ingested to INCA (Integrated Nowcasting through Comprehensive Analysis) high resolution (1-km) nowcasting system (Haiden et. al. 2011) together with data from 81 meteorological stations. INCA (from ZAMG) together with automatic station data yield a corrected analysis and nowcasting up to 6 hours.

b. The short-range forecasting non-hydrostatic model COSMO (www.cosmo-model.org) is running operationally with two domains: 1) 7-km resolution driven by ECMWF global model IFS, 2) 2.8-km resolution. The ECMWF fields are used as frame boundary conditions inserted every 3-hours.

2.1.3 Derived fields

Include post-processing of ENS output e.g. clustering, probabilities

See previous report.

2.2 ECMWF products

2.2.1 Use of Products

Describe how ECMWF products are used in operational duties, in particular for severe weather situations. For example:

- Does the EFI help to identify areas of potential hazard?
- Do the cyclone tracks help the forecast areas at risk of severe storms?
- Does the new precipitation type make your decision-making more efficient?

The main use of ECMWF products is to provide guidance for the medium forecast range. The various output fields are made available to the forecaster. The EPS threshold probabilities, meteograms and EFI are used increasingly by the operational meteorologists to assess the likelihood of alternative forecast developments.

2.2.2 Product requests

Include here any particular requests you may have for new or modified ECMWF products

EcCharts: Interface Modifications

- ecCharts/forecaster- Having a layer of cities to avoid typing each time the city name
- ecCharts/forecaster- Contour labels are too small. Can we defined font size?
- ecCharts/forecaster- Option to save (replace) a product in addition to "save as" (relevant also for dashboard)
- ecCharts/dashboard - Option to control all charts simultaneously
- EcCharts: Useful parameters/products for IMS

- Early warnings (EFI or risk matrix) for fog conditions, potential wild fires, heat stress (T & RH)
- Probability of cloud base below some given heights
- CAMS's Aerosols forecasts as input to improve operational model visibility forecast (visibility is reduced not only when humidity exists but also due to aerosols)
- TFP (Thermal Front Parameter) --fronts analysis
- PVA (Potential Vorticity Advection) and CVA (Cyclonic Vorticity Advection) at 500- and 300hPa
- PVU (Potential Vorticity Unit) height (1.5PVU or 2PVU) --tropopause analysis
- PV (Potential Vorticity) and Wind at different potential temperatures levels (300/330K); currently only at 315K
- Wet-bulb potential temperature at 1000hPa, 950hPa, and 925hPa; currently only at 850hPa
- Vertical velocity at 850hPa ,800hPa, 600hPa, and 500hPa; currently at 700hPa only
- θ_e (equivalent potential temperature) at 850hPa, 700hPa, and 500hPa

New web tools/interfaces

- A tool for forward/ backward air parcel trajectory (e.g., NOAA HySplit tool)
- A tool for creating vertical cross sections of atmospheric parameters (e.g., temperature, wind speed and flags, relative humidity, potential temperatures, equivalent potential temperature)

3. Verification of products

Include medium-range HRES and ENS, monthly, seasonal forecasts. ECMWF does extensive verification of its products in the free atmosphere. However, verification of surface parameters is in general limited to using synoptic observations. More detailed verification of weather parameters by national Services is particularly valuable.

At this point in time (2018) ECMWF would particularly welcome:

- Evaluation of systematic errors in near-surface parameters
- Evaluations related to visibility, humidity and clouds
- Conditional verification results (e.g. 2m temperature bias stratified by cloud cover)
- Comparisons between ECMWF ENS and external LAM-EPS systems (for probabilistic forecasts)

3.1 Objective verification

Describe verification activities and show related scores.

3.1.1 Direct ECMWF model output (both HRES and EPS)

Focus on local weather parameters verified for locations that are of interest to your service

a. Introduction

Israel has a warm Mediterranean climate with long, warm, rainless summers and relatively short, mild, rainy winters. Israel also has a warm and cold semi-arid climates, and a warm desert climate. The characteristics of the Israeli Climate are caused by Israel's location between the subtropical arid areas of the Sahara and the Arabian deserts, and the subtropical humid areas of the Levant and Eastern Mediterranean. The climate conditions are highly diverse within the state and depend locally on altitude, latitude, and the proximity to the Mediterranean Sea.

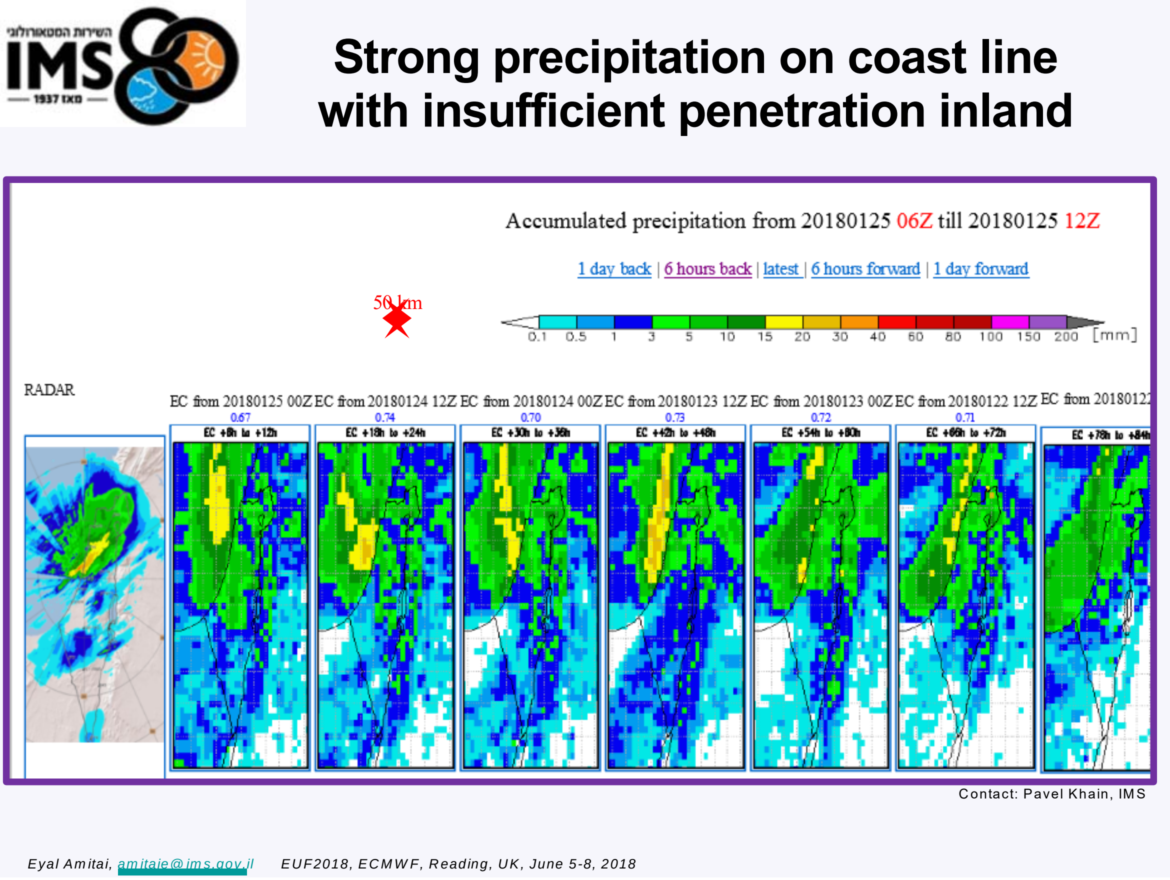
Issues of concern are (ECMWF systematic forecast errors):

a. Strong precipitation on coast line with insufficient penetration inland (Fig. 1);

b. Marine inversion, visibility and stratus are too low over coastline (Fig. 2);

c. Seasonal rainfall forecast: New SEAS5 has lower skill compared to old Sys4 based on years 1981-2016. Forecast does not pick up extreme years, which contribute much to our water budget (Fig. 4).

The above were presented at the UEF2018 meeting. Key power point slides are posted here again (Figs. 1, 2, and 4). In addition, the seasonal forecast verification section includes results from past year temperature and precipitation forecasts. Also included is an extended section on wave model verification.



Strong precipitation on coast line with insufficient penetration inland

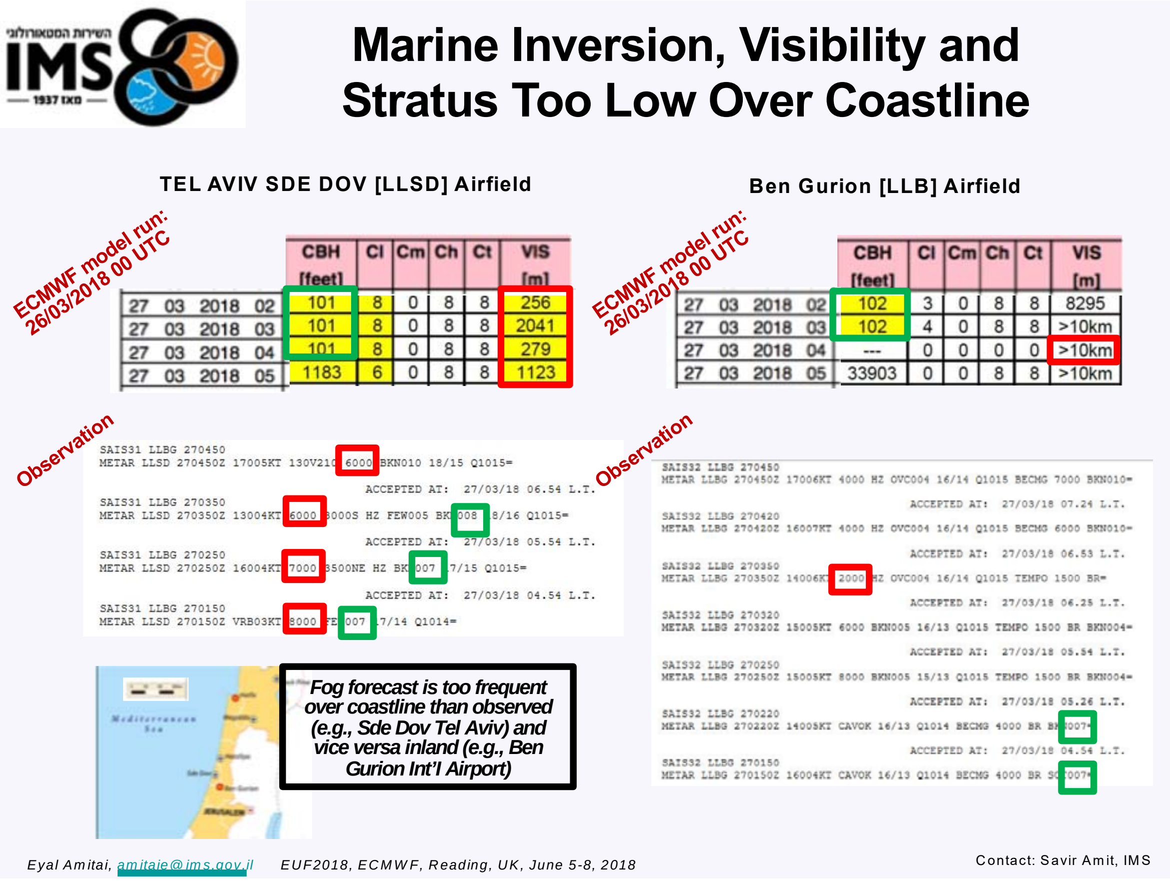
Accumulated precipitation from 20180125 06Z till 20180125 12Z

1 day back | 6 hours back | latest | 6 hours forward | 1 day forward

Contact: Pavel Khain, IMS

Eyal Amitai, amitaie@ims.gov.il EUF2018, ECMWF, Reading, UK, June 5-8, 2018

Fig. 1 Strong precipitation on coast line with insufficient penetration inland (slide presented at the UEF2018 meeting)



Marine Inversion, Visibility and Stratus Too Low Over Coastline

TEL AVIV SDE DOV [LLSD] Airfield

ECMWF model run: 26/03/2018 00 UTC

				CBH [feet]	Cl	Cm	Ch	Ct	VIS [m]
27	03	2018	02	101	8	0	8	8	256
27	03	2018	03	101	8	0	8	8	2041
27	03	2018	04	101	8	0	8	8	279
27	03	2018	05	1183	6	0	8	8	1123

Observation

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SAIS31 LLBG 270450
METAR LLSD 270450Z 17005KT 130V210 6000 BKN010 18/15 Q1015=

                              ACCEPTED AT:  27/03/18 06.54 L.T.
SAIS31 LLBG 270350
METAR LLSD 270350Z 13004KT 6000 3000S HZ FEW005 BK 008 8/16 Q1015=

                              ACCEPTED AT:  27/03/18 05.54 L.T.
SAIS31 LLBG 270250
METAR LLSD 270250Z 16004KT 7000 3500NE HZ BK 007 7/15 Q1015=

                              ACCEPTED AT:  27/03/18 04.54 L.T.
SAIS31 LLBG 270150
METAR LLSD 270150Z VRB03KT 8000 FE 007 7/14 Q1014=
```

Fog forecast is too frequent over coastline than observed (e.g., Sde Dov Tel Aviv) and vice versa inland (e.g., Ben Gurion Int'l Airport)

Ben Gurion [LLB] Airfield

ECMWF model run: 26/03/2018 00 UTC

				CBH [feet]	Cl	Cm	Ch	Ct	VIS [m]
27	03	2018	02	102	3	0	8	8	8295
27	03	2018	03	102	4	0	8	8	>10km
27	03	2018	04	---	0	0	0	0	>10km
27	03	2018	05	33903	0	0	8	8	>10km

Observation

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SAIS32 LLBG 270450
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SAIS32 LLBG 270420
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                              ACCEPTED AT:  27/03/18 06.53 L.T.
SAIS32 LLBG 270350
METAR LLBG 270350Z 14006K 2000 HZ OVC004 16/14 Q1015 TEMPO 1500 BR=

                              ACCEPTED AT:  27/03/18 06.25 L.T.
SAIS32 LLBG 270320
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                              ACCEPTED AT:  27/03/18 05.54 L.T.
SAIS32 LLBG 270250
METAR LLBG 270250Z 15005KT 8000 BKN005 15/13 Q1015 TEMPO 1500 BR BKN004=

                              ACCEPTED AT:  27/03/18 05.26 L.T.
SAIS32 LLBG 270220
METAR LLBG 270220Z 14005KT CAVOK 16/13 Q1014 BECMG 4000 BR BK 007=

                              ACCEPTED AT:  27/03/18 04.54 L.T.
SAIS32 LLBG 270150
METAR LLBG 270150Z 16004KT CAVOK 16/13 Q1014 BECMG 4000 BR S 007=
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Eyal Amitai, amitaie@ims.gov.il EUF2018, ECMWF, Reading, UK, June 5-8, 2018

Contact: Savir Amit, IMS

Fig. 2 Marine inversion, visibility and stratus are too low over coastline (slide presented at the UEF2018 meeting)

b. Seasonal forecast

1. Analysis of the JJA 2017 temperature

The Sys4 JJA averaged temperature forecast over Israel (10 grid point) assigned 73% chance for the “above normal” tercile, 25% for the “normal” tercile, and 2% for the “below normal” tercile, and was located in the 94th percentile of the 1981-2010 distribution. The observed JJA 2017 average temperature over 5 representing stations is Israel was warmer by 1.5°C relative to the 1981/82-2010/11 period, which is located in the 99% percentile of 1981/82-2010/11 distribution (Fig. 3).

Conclusion: Due to climate change, a forecast relative to the 1981-2010 reference period is useless (Fig. 3).

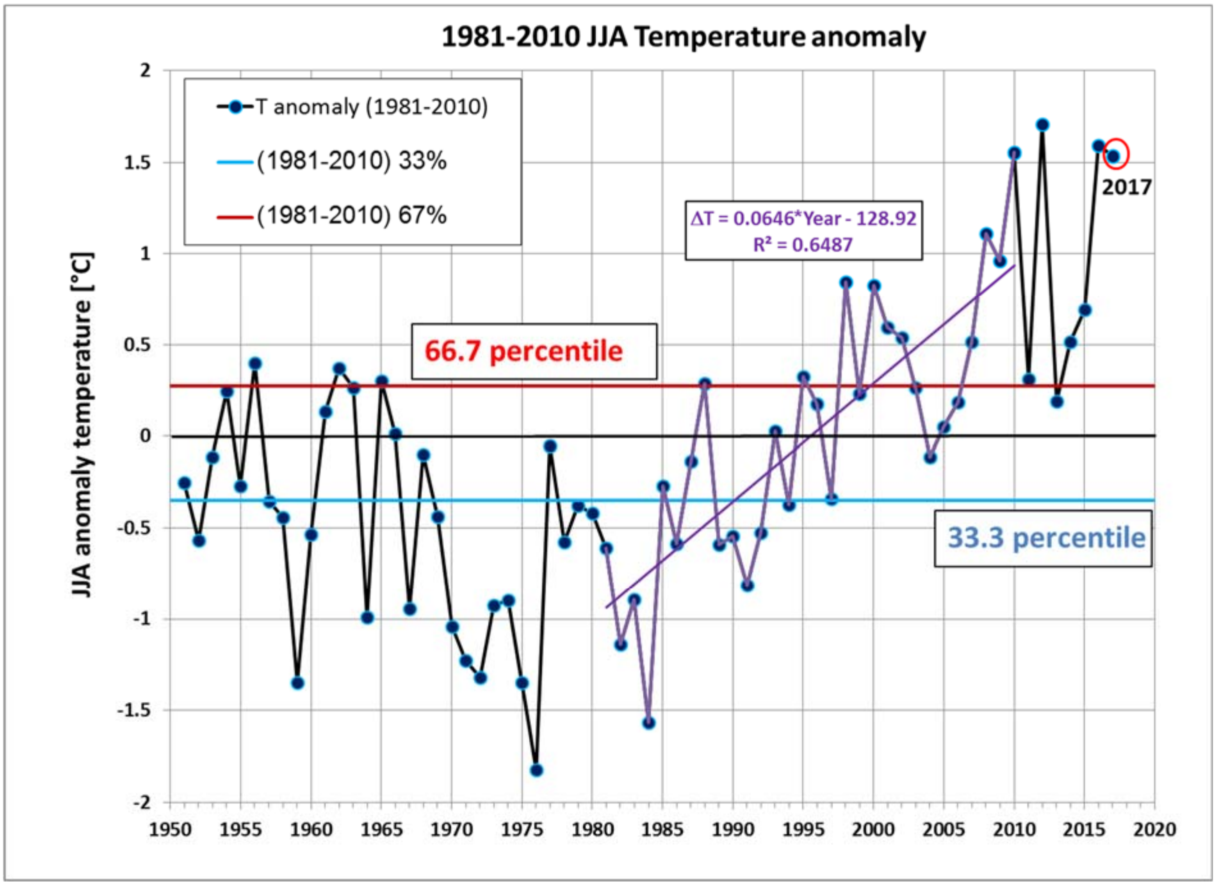


Fig. 3 JJA average temperature anomalies for Israel since 1951. The horizontal lines represent the upper and lower tercile thresholds for the 1981-2010 reference periods.

2. Analysis of DJF 2017/18 precipitation

The SEAS5 (Sys5) DJF 2017/18 averaged precipitation forecast over Israel (5 grid points in Northern Israel) assigned 25% chance for the “above normal” tercile, 35% for the “normal” tercile, and 40% for the “below normal” tercile, and was located in the 94th percentile of 1981-2010 distribution.

The average DJF 2017/18 precipitation observed for Israel was 356.2 mm. This value is 7.3% above the 1981/82-2010/11 average, 20.2% above the median, and resides in the 74.8% percentile from the precipitation distribution. Hence, DJF 2017/18 resides in the “above normal” tercile of 1981/82-2010/11, yielding a negative Rank Probability Skill Score (RPSS = -0.3), (Table 1).

Table 1: Verification summary of the seasonal forecast for Israel.

	Seasonal temperature			**Seasonal precipitation**		
	Observed	ECMWF forecast	RPSS	Observed	ECMWF forecast	RPSS
DJF 2017/18 (SEAS5)	above normal	50% above normal 30% ~normal 20% below normal	0.48	above normal	25% above normal 35% ~normal 40% below normal	-0.30
JJA 2017 (SYS4)	above normal	78% above normal 25% ~normal 2% below normal	0.87	Dry season		

3. Analysis of 1981-2016 SYS4 and SEAS5 precipitation

Verifying the SEAS5 hindcast ability to produce year-by-year variability (Fig. 4) did not indicate optimistic results. Furthermore, the hit score of SEAS5 (39%) was lower than SYS4 (57%) and close to a random probability (33.3%).

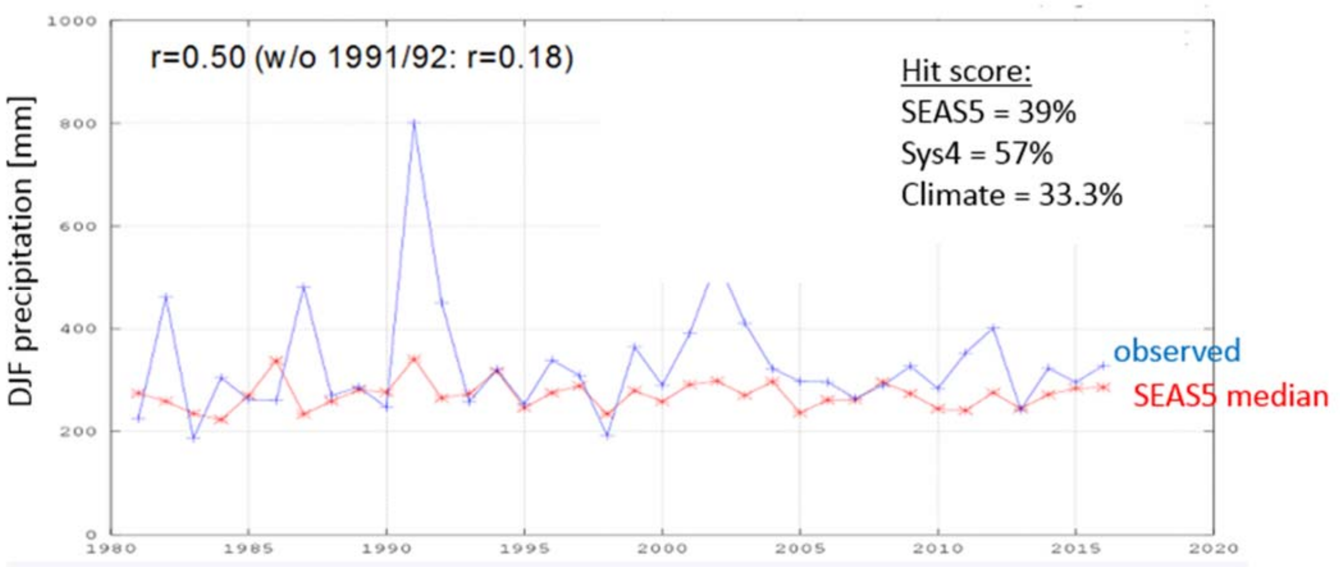


Fig. 4 Precipitation time series of SEAS5 hindcast and observations for Northern and Central Israel (slide presented at the UEF2018 meeting).

c. Wave model

Several wave model validation studies were conducted since last report. The main activities of interest are:

1. Comparing HRES-SAW expver=1 and expver=69 with buoy data

The ECMWF High RESolution Stand Alone Wave model (HRES-SAW) expver=1 and expver=69 of Dec 2015 through Feb 2016 have been evaluated based on comparisons with buoy data. The expver=69 was a test version based on high resolution winds, which replaced the operational version expver=1 in spring 2016. Both versions were running at the ECMWF during December 2015 through February 2016. Figure 5 shows the mean difference in Significant Wave Height (SWH) between the old and the new wind forcing for the stand-alone wave model for the Eastern Mediterranean (figure provided by Jean Bidlot of the ECMWF). The new model has generally slightly higher waves.

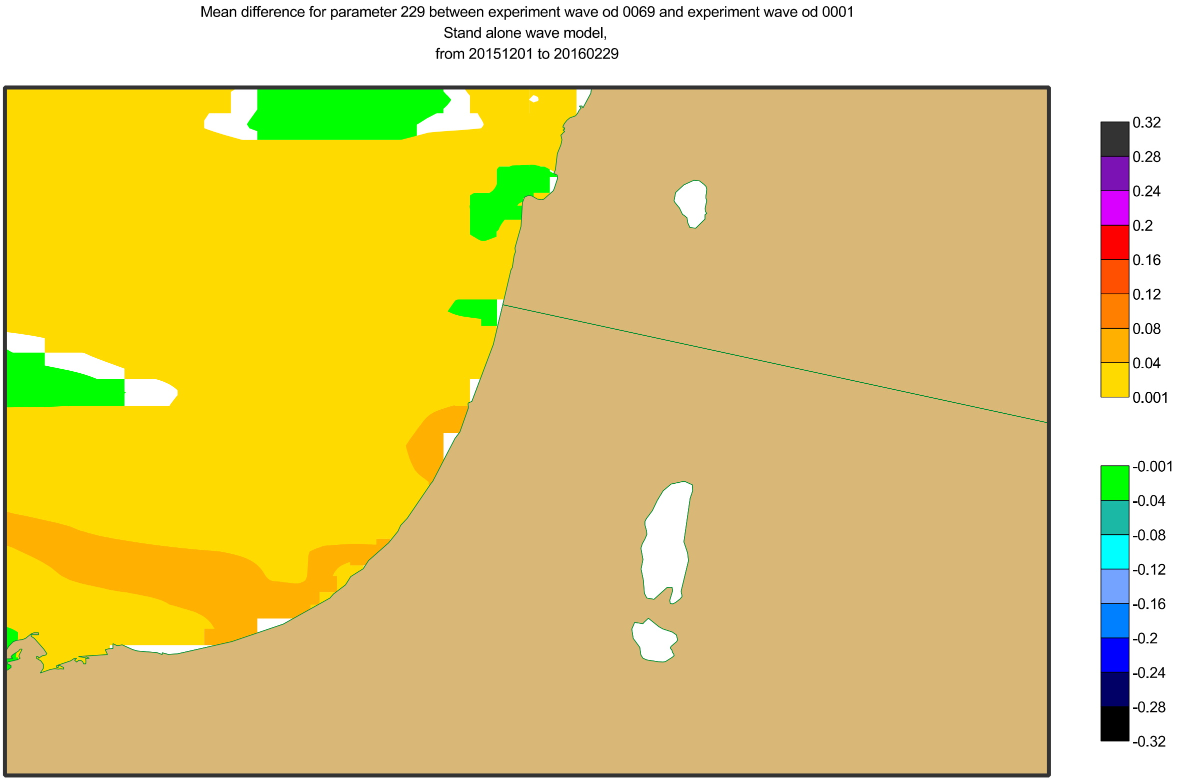


Fig. 5 SWH mean difference during Dec 2015 through Feb 2016 between the old and the new wind forcing for the HRES-SAW model for the Israeli coast (figure provided by Jean Bidlot of the ECMWF).

The IMS has compared the results with SWH data taken from two buoys located off the Israeli coast for the same period (Dec 2015 through Feb 2016). The buoys are located in Haifa (32.844°N, 34.938°E) and in Ashdod (31.875°N, 34.649°E). The comparisons (Fig. 6) are based on a linear average of two grid points for Haifa (domain=M, grid=0.1/0.1, area=32.9/34.9/32.9/35.0), and a single point for Ashdod (domain=M, grid=0.1/0.1, area=31.9/34.6/31.9/34.6). The original values at both locations are interpolated but for

Haifa, it is a simple bilinear interpolation because both points are within the native grid where values are non-missing; for Ashdod, the interpolation degenerates to the closest grid point because the other point on the native grid is missing (land).

In agreement with Fig. 5, as we switch from v1 to v69, the average height in Haifa decreases by about 1cm while in Ashdod it increases by about 5cm (the exact values are displayed on each panel).

Comparisons with buoys: In Haifa no improvement is found upon running v69. Actually, the underestimation increases by about 1% as we switched to the high-resolution winds around the bay. In Ashdod, however, there is an improvement. The overall bias (underestimation) has been reduced from 0.94 to 0.99. Correlation, *R*, remain the same in both locations (2 decimal places rounding).

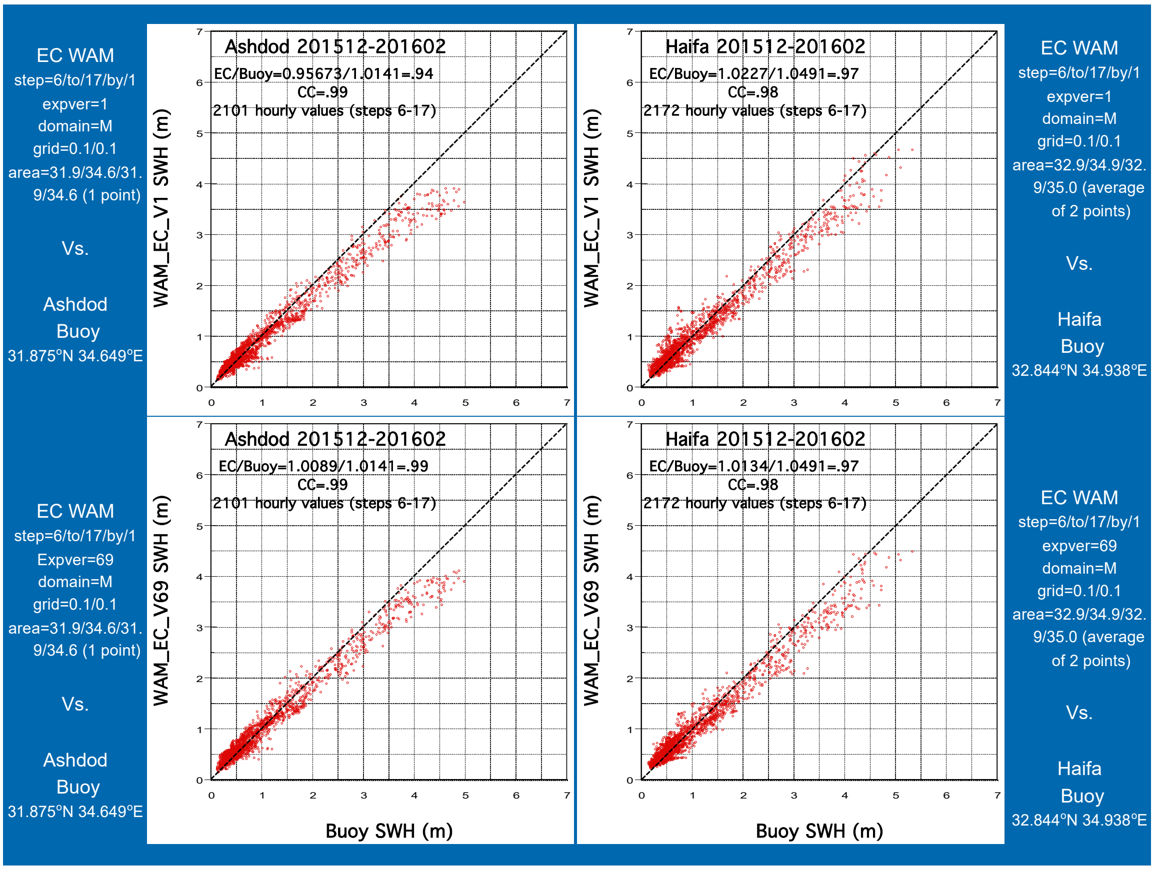
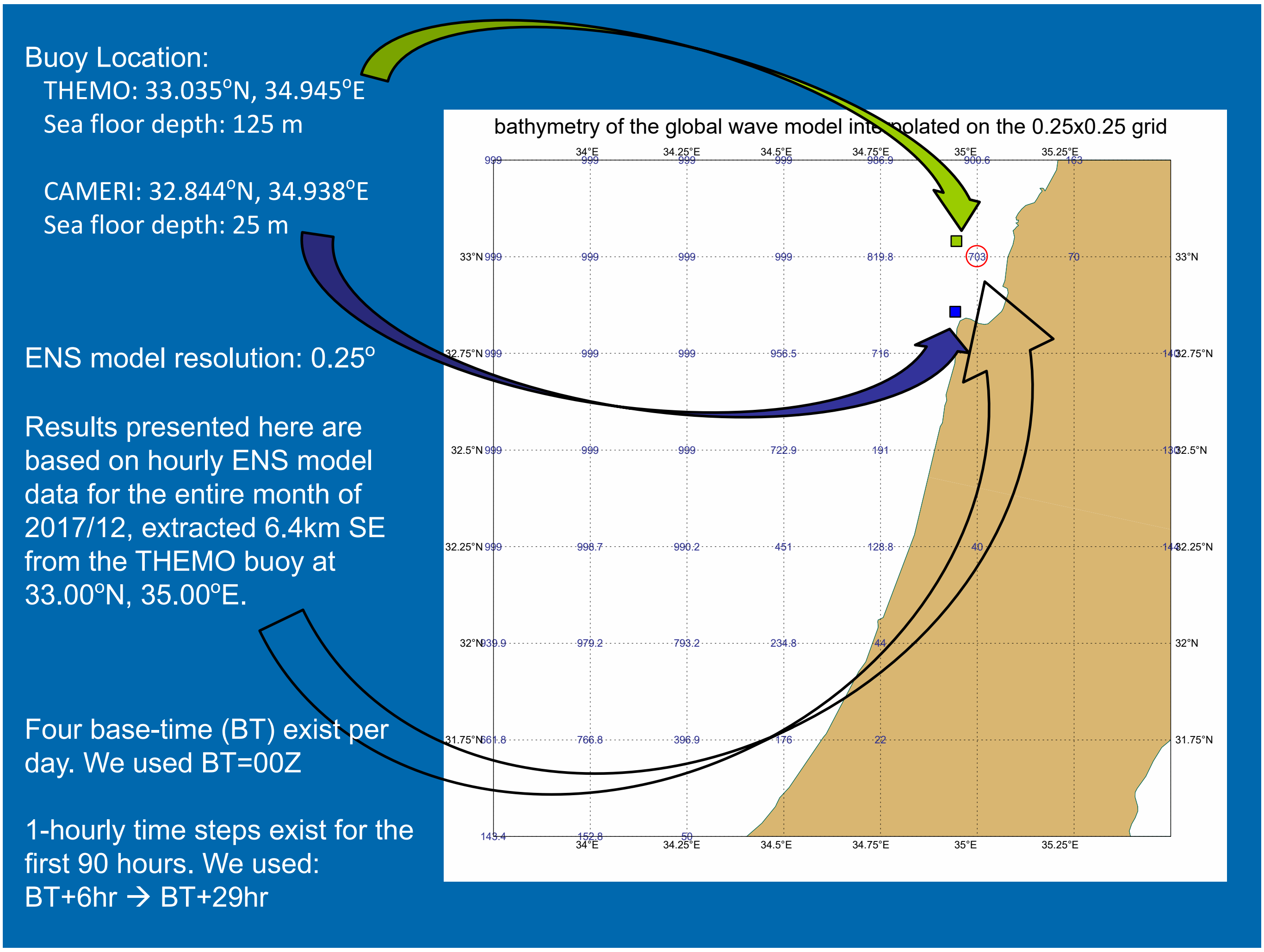


Fig. 6 The ECMWF HRES-SAW Dec 2015 through Feb 2016 expver=1 and expver=69 SWH forecasts over Ashdod (left) and Haifa (right) buoys vs. the buoy hourly-interpolated heights. Model data are based on base+6-hr till base+17-hr, and therefore, represent the most continuous short term forecast available.

2. Comparing SWH from ECMWF WAM ENS and ECMWF HRES-SAW with buoys

For the first time, we started analyzing ECMWF ENS SWH data. From the 50 ENS members several parameters were calculated, such as ensemble-mean (EM), StD, and P(SWH>2m). Utilizing buoy data, the ENS members were also ranked for checking the equal likelihood of each member using a Rank Histogram (aka Talagrand diagram). First results of this ongoing effort are presented here. The ENS data include so far one-month worth of data (Dec 2017) taken from a grid point near the buoys. Hourly model forecasts from steps 6 to 29 are currently used (as opposed to results presented in section 1 in which the model data are based on steps 6 to 17). Data from two buoys are used: 1) CAMERI Haifa buoy, which has been used for many years, described in previous reports and in section (1) above, and; 2) THEMO B125, a new 2.25m diameter surface buoy of University of Haifa located at 12 km off the northern Israeli coast at 125 m water depth (Fig. 7). While the CAMERI SWH are obtained every 30-minutes based on a 30-minutes sample, the THEMO SWH values are calculated from a 10-minutes sample, then, no sampling is performed for about 20 minutes until the next sampling. Data are interpolated into hourly resolution to match model output times. The THEMO effort (http://themo.haifa.ac.il/buoys) is expected to include a second buoy scheduled for deployment end of August 2018 at deep water (1500 meter) about 55 km off the northern Israeli coast after the continental shelf. Precise location TBD. The THEMO moorings have real-time RF communication capabilities. QARTOD quality control is used.



Buoy Location:
THEMO: 33.035°N, 34.945°E
Sea floor depth: 125 m

CAMERI: 32.844°N, 34.938°E
Sea floor depth: 25 m

ENS model resolution: 0.25°

Results presented here are based on hourly ENS model data for the entire month of 2017/12, extracted 6.4km SE from the THEMO buoy at 33.00°N, 35.00°E.

Four base-time (BT) exist per day. We used BT=00Z

1-hourly time steps exist for the first 90 hours. We used: BT+6hr → BT+29hr

Fig. 7 Location of the buoys and the ECMWF WAM ENS grid point selected for comparisons.

Time series of SWH from the ECMWF forecasts and from the buoys are presented in Figs. 8-9. In general, the new THEMO buoy underestimates the wave heights by 30-40%. Unreliable ensemble or unreliable buoy?

Similar underestimation is obtained upon comparing the THEMO and the CAMERI buoy obs: THEMO is found to underestimate the SWH by about 1m during high waves of 3-4m.

Using both buoys as validation for the ENS we generate *Talagrand Diagrams* (Fig. 10), *"Spread-Error" scatterplot* comparing the standard deviation of the ensemble members with the error of the ensemble-mean (EM), and calculate the monthly mean EM error relative to each buoy and the monthly mean StD (Fig. 11). Both figures suggest--based on the *CAMERI buoy obs (which we considered reliable)--that there is* ***too little spread in the ENS members***.

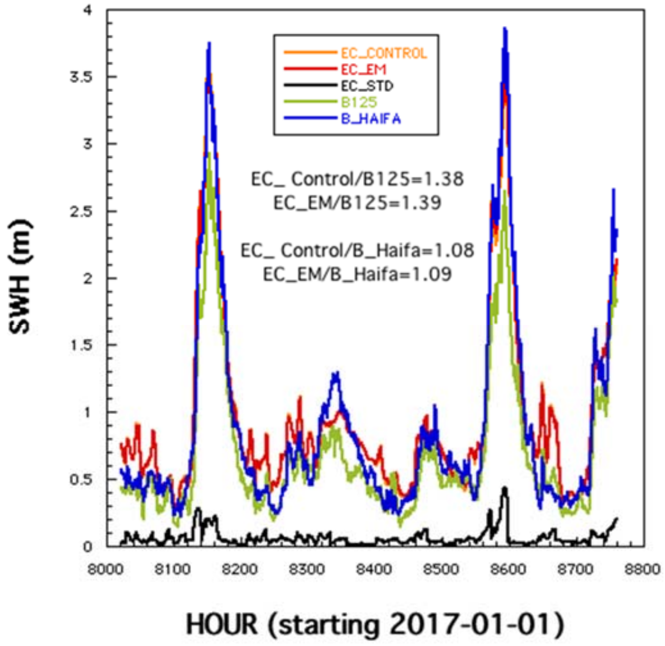


Fig. 8 SWH during Dec 2017 obtained from ECMWF ENS products (Control, Ens Mean, Ens Std), from CAMERI Haifa buoy (B_Haifa) and from Haifa University THEMO buoy (B125).

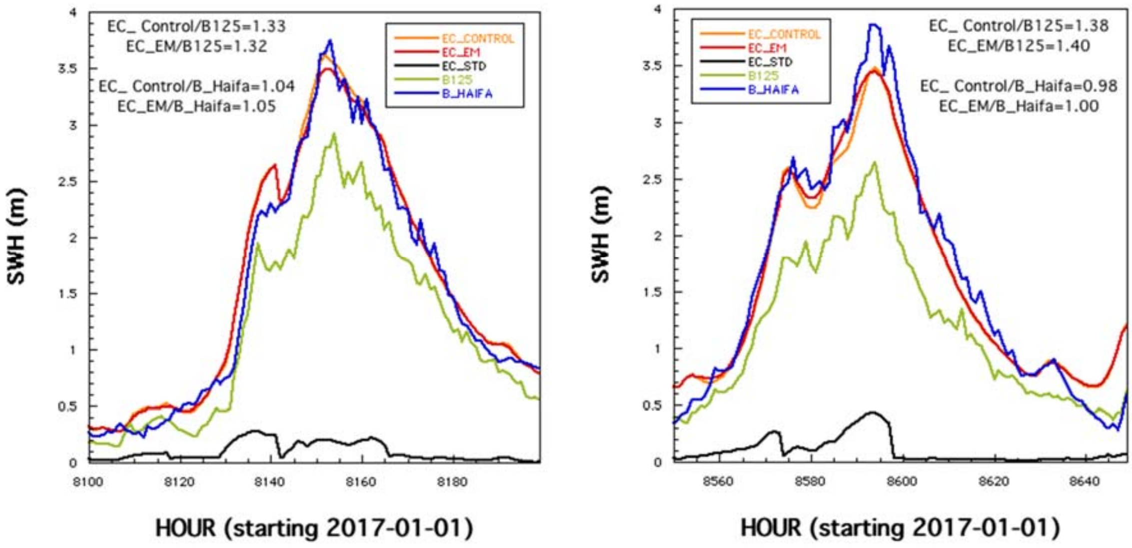


Fig. 9 Zooming into Fig. 8 on hours 8100-8200 (left) & 8500-8600 (right).

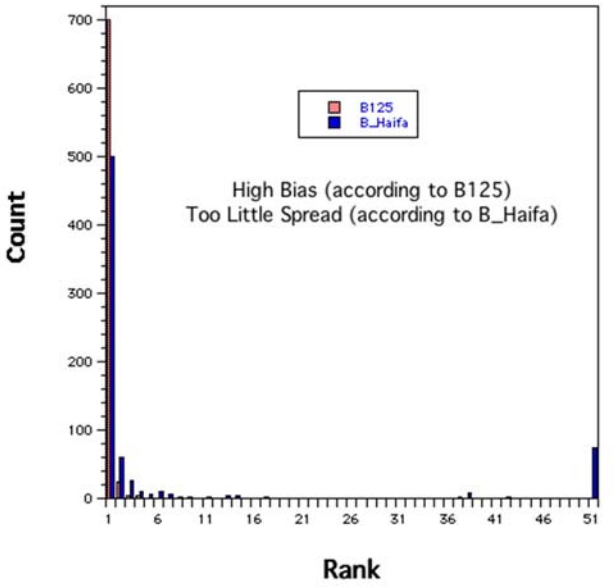


Fig. 10 Talagrand Diagram: How well does the ensemble spread of the forecast represent the true variability (uncertainty) of the observations? Where do the verifying obs falls w.r.t. the ensemble forecast data, which is arranged in increasing order? According to the 738 hourly values calculated from the CAMERI buoy obs (which are considered reliable) there is too little spread in the ENS members.

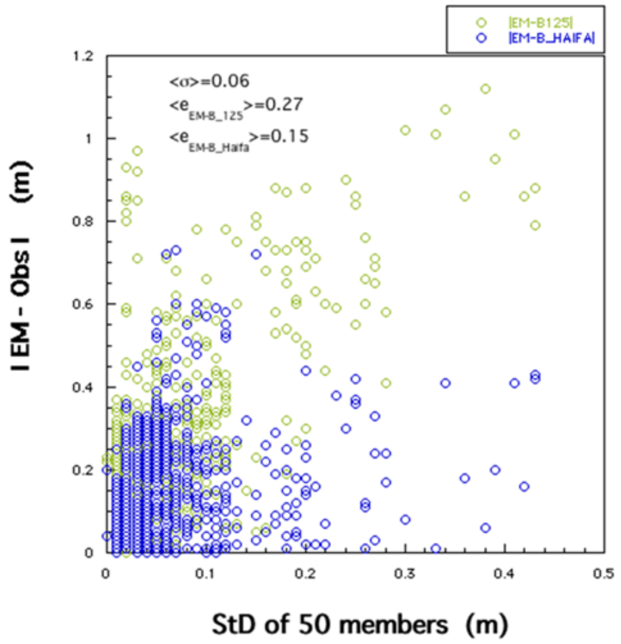


Fig. 11 "Spread-Error" Assessment: The relations between the hourly ensemble-mean (EM) error and the ensemble standard deviation. The monthly mean standard deviation <σ> is smaller than the mean error $<e_{EM-B}>$ suggesting too little spread in the ensemble.

In addition, *Reliability Diagram* has been generated to see how well the predicted probabilities of SWH>2m correspond to their observed frequencies (Fig. 12). Due to a small sample size, the forecast probabilities are classified only into three bins. This is an ongoing effort; extending the sample beyond 2017/12 is expected. *Brier Scores (BS)* are calculated to estimate the magnitude of the probability forecast errors.

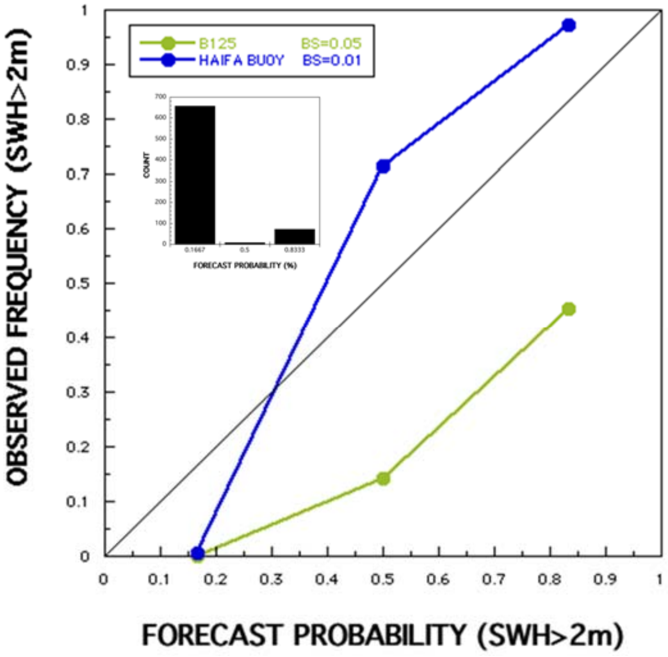
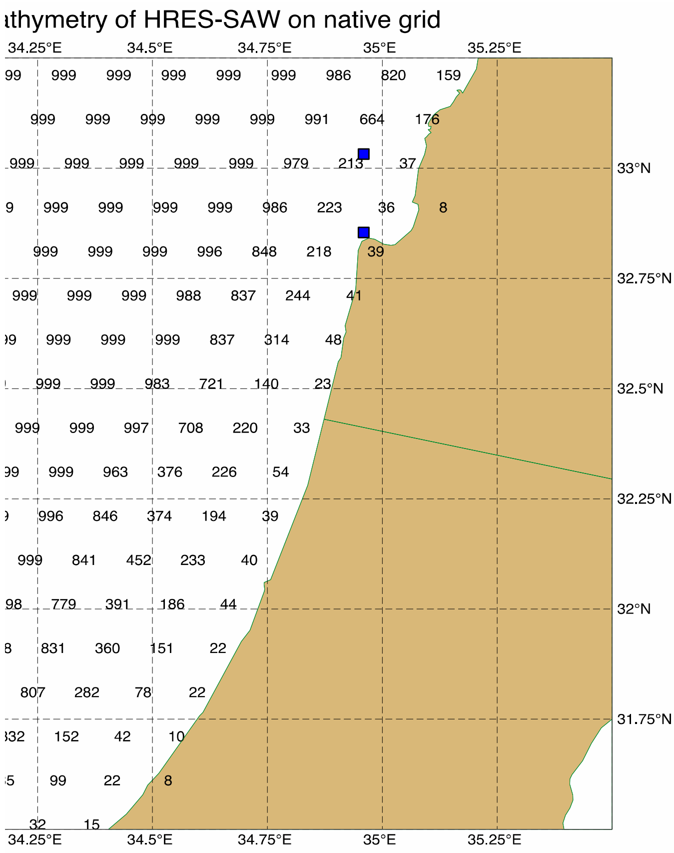
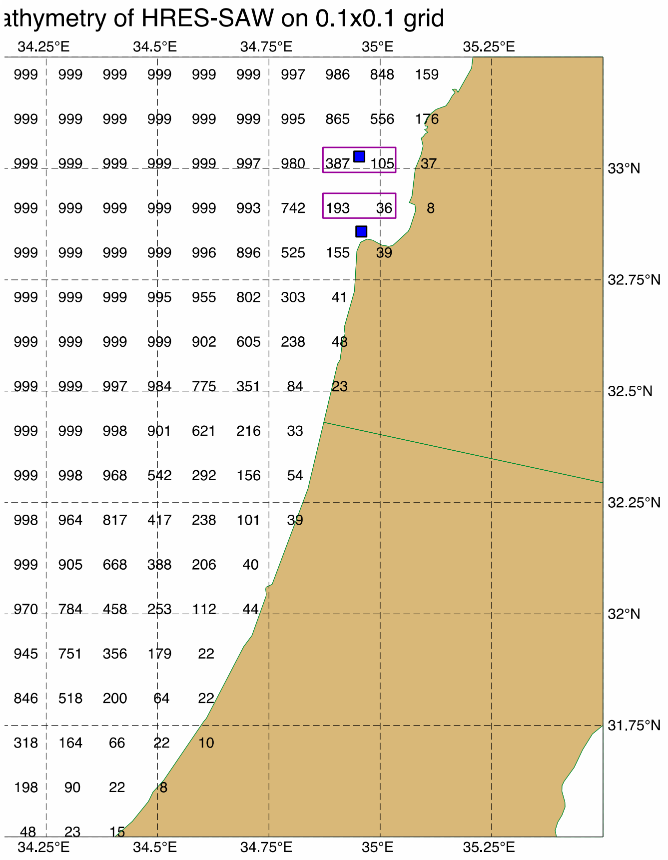


Fig. 12 Reliability Diagram and BS scores for forecasting SWH>2m upon classification of the forecast probabilities into three bins. Extending the sample beyond 2017/12 is expected in this ongoing effort.

In an effort to study the superiority of the EM to a single HR deterministic forecast, we added the ECMWF HRES-SAW deterministic model forecasts to the analysis. The initial results include only 24 hours lead-time values (i.e., steps 6 to 29 for all model with base time at 00Z) but extending the evaluation effort to longer lead times is planned. Fig. 13 presents the HRES-SAW deterministic model grid, buoy locations, and model grid points used for the comparisons. Time series (Figs. 14-15) and scatterplots (Fig. 16) of the SWH show that for the monthly mean the HR has practically no bias with the CAMERI buoy while the EM is overestimating by roughly 10%. During high wave events (Fig. 15) the EM performance improves while the HR performance deteriorates compare to their mean performance for the whole month (Fig. 14). This can also be seen from the scatterpolt in Fig. 16 lower-right panel.





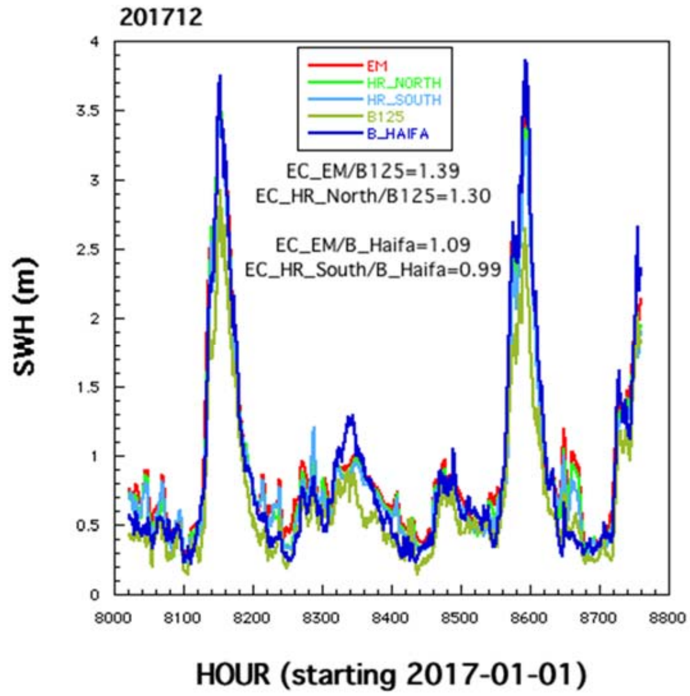


Fig. 14 SWH during Dec 2017 obtained from ECMWF ENS (EM), from the HRES-SAW (HR_NORTH, HR_SOUTH), and from the buoys [Haifa University THEMO buoy (B125) and CAMERI Haifa buoy (B_Haifa)].

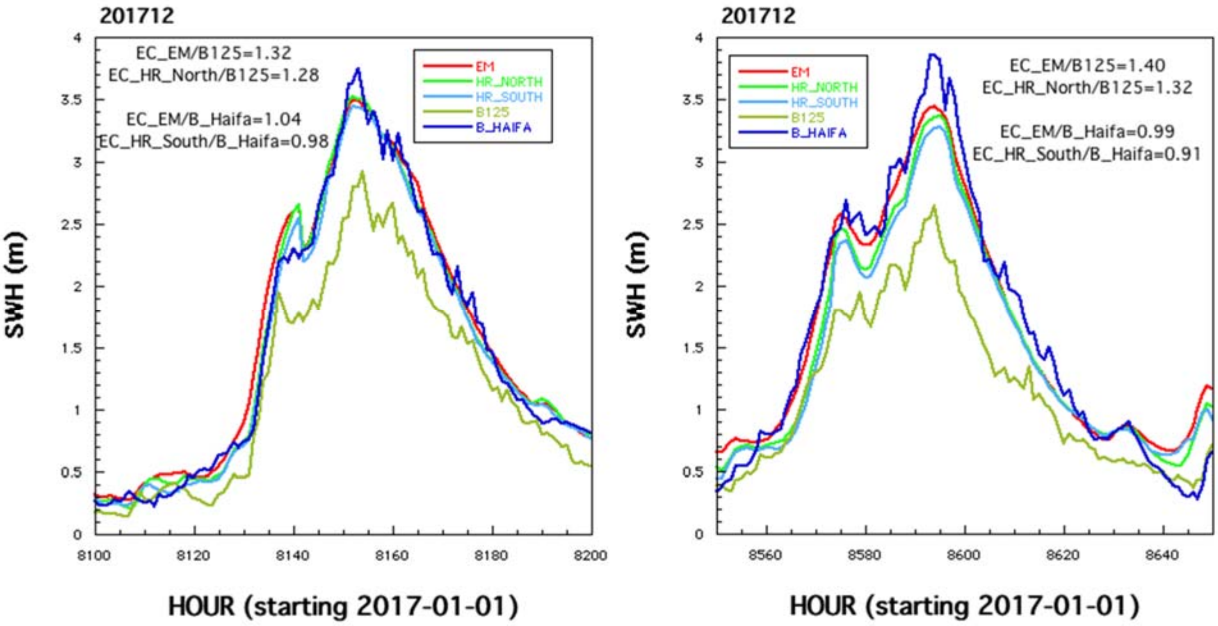


Fig. 15 Zooming into Fig. 14 on hours 8100-8200 (left) & 8500-8600 (right).

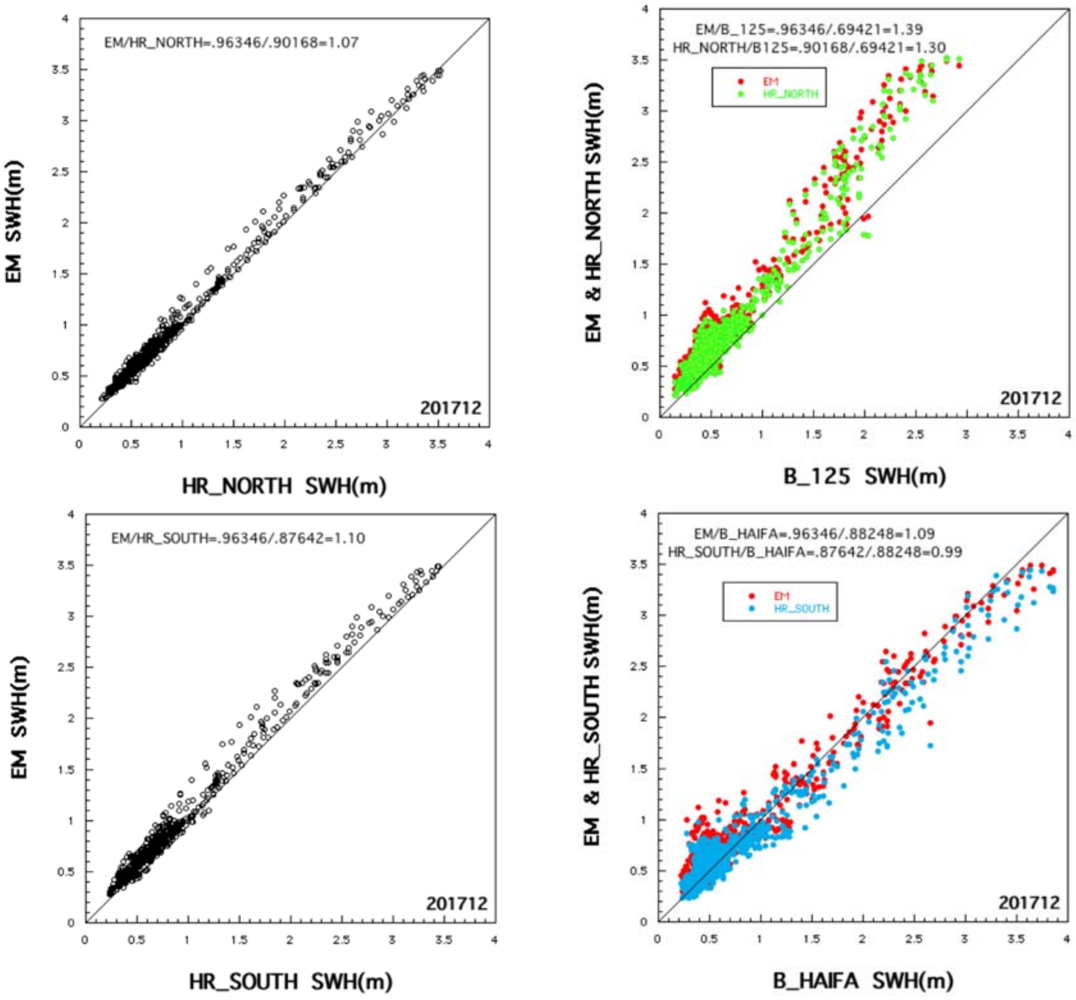


Fig. 16 SWH from the ECMWF ENS (EM) compare to SWH from the HRES-SAW at the north (upper left panel) and south (lower left panel) grids. SWH from the ECMWF ENS (EM) and from the HRES-SAW north grid compare to the B125 buoy (upper right panel). SWH from the ECMWF ENS (EM) and from the HRES-SAW south grid compare to the B_Haifa buoy (lower right panel).

3. Other wave model activity of interest--

A SWAN model, for the Red Sea was developed. Model output based on ECMWF winds and based on COSMO regional H-Res (3 km) winds were compared (results are not shown here).

3.1.2 ECMWF model output compared to other NWP models

Compare the performance of ECMWF models with other NWP models used by your service

See previous report.

3.1.3 Post-processed products

e.g. Kalman-filtered products, calibrated ENS probabilities, etc.

ECMWF and INCA forecasts were verified before and after bias corrections. For ECMWF the average bias of the last 8 days, excluding the day with the highest bias, was removed. For the INCA system an internal bias correction module based on the last 20 days was used. The verification was performed for the year 2017 for 15 metrological stations representing the climate of Israel, for lead time of 30, 36, 42 and 48 hours. The average ECMWF temperature RMSE for 2017 was 0.7°C, the INCA system manages to reduce the average error to 0.57°C. The INCA bias correction module reduced the RMSE to 0.44°C and the simple 8 day bias removal reduced the RMSE to 0.43°C (Fig. 17).

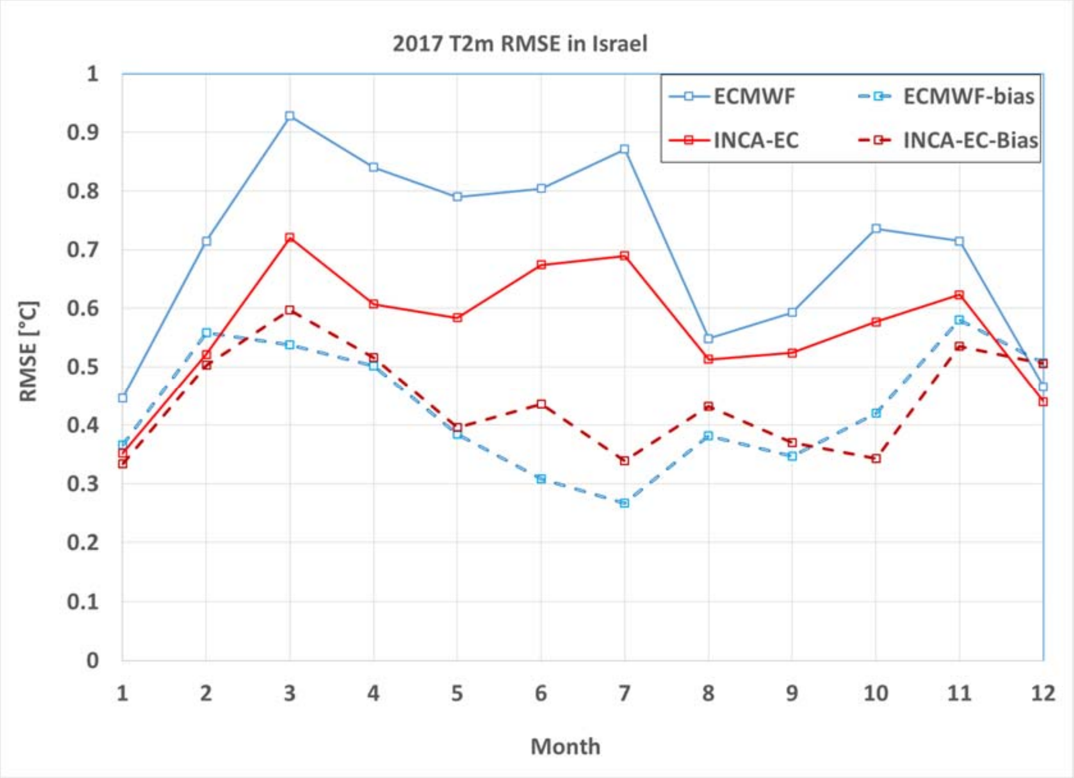


Fig. 17 2017 temperature forecast RMSE for ECMWF, INCA-EC (solid lines) and after removing biases (dashed lines) for 30-48 hours lead time. The RMSE is averaged for 15 representative stations in Israel and is based on 00Z and 12Z runs. Every point is an average of 30 days (60 run).

3.1.4 End products delivered to users

3.2 Subjective verification

3.2.1 Subjective scores (including evaluation of confidence indices when available)

3.2.2 Case studies

Severe weather events/non-events are of particular interest. Include an evaluation of the behaviour of the model(s). Reference to major forecast errors, even if they are not in a “severe weather” category, are also very welcome

An example of a model bust was presented at the UEF2018 meeting. Forecast for April 26, 2018 in south Israel in the region in which flash floods killed 10 teens (Nahal Tsafit, 31.00N, 35.24E) show no rainfall for the watershed, and zero probabilities for Rainfall>5mm during the 6 hours centered on the event time. Radar estimates 30-40 mm.

4. Feedback on ECMWF "forecast user" initiatives

We invite comments on how useful you find the information provided on ECMWF's "Forecast User Portal", see: (https://software.ecmwf.int/wiki/display/FCST/Forecast+User+Home), and on any changes you would like to see. A new web-based "Forecast User Guide" will be added soon (due May 2018) and we would particularly welcome initial comments on that.

5. References to relevant publications

(Copies of relevant internal papers may be attached)

Haiden, T., A. Kann, C. Wittmann, G. Pistotnik, B. Bica, C. Gruber, 2011: The Integrated Nowcasting through Comprehensive Analysis (INCA) System and Its Validation over the Eastern Alpine Region. Wea. Forecasting, 26, 166–183.