User expectations from a medium-range and seasonal forecasting system

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1. The ECMWF medium-range forecasting system

ECMWF (the Centre) produces operational medium-range forecasts out to 10 days every day. The forecasting system comprises the 4-dimensional variational data assimilation system (4D-Var); the global high resolution forecast model (T511 spectral, reduced Gaussian grid at 40 km resolution) and the ensemble forecasting system (T255 spectral, reduced Gaussian grid at 80 km resolution) based on 50 forecast runs starting from perturbed initial conditions. Details of the forecasting system can be found in the annex.

2. The underlying numerical products

The list of products available from the operational forecasting system can be found on the web under http://www.ecmwf.int/products. The web pages also give several examples of real-time forecast products in graphical form. In summary, these products fall into the following three categories:

- Atmospheric global forecasts
  - Forecasts to ten days from 12 UTC at 40 km resolution (T511)
  - Ensemble of 51 forecasts to ten days from 12 UTC at 80 km resolution (T255)
  - Four forecasts to three days at 40 km resolution (Optional Project in support of LAM activities in participating Member States)
- Ocean wave forecasts
  - Global forecasts to ten days from 12 UTC at 40 km resolution
  - European waters forecasts to five days from 12 UTC at 0.25 deg resolution
  - Ensemble of 51 forecasts to ten days from 12 UTC at 80 km resolution (T255)
- Seasonal forecasts: atmosphere-ocean coupled model
  - Global forecasts to six months based on 40-member ensemble.

To bridge the gap between the medium-range and the seasonal forecast ranges, the Centre recently started experimental monthly forecasting based on a coupled ocean-atmosphere forecasting system using the ensemble technique with 50 members.

3. User requirements, expectations and forecasting system performance

Through regular contacts with the users in the Member States and Co-operating States the Centre keeps under review the use of its products, establishes the user requirements for medium-range forecast products and continuously updates these requirements.

Most weather services in the Member States and Co-operating States nowadays feel comfortable with their practice of issuing medium-range forecast out to 5-7 days to the general public. Beyond three days these forecasts are mainly addressing the evolution of the weather pattern in broader terms. For this the forecasters expect the numerical guidance to capture major changes (or continuation) in the synoptic flow pattern, i.e. change from zonal to blocked flow or vice versa, cold air outbreaks, or periods of hot and cold, wet and windy weather. The latter implies that the forecasting system has a sufficiently high resolution and incorporates a good physical parametrization to provide high quality weather element forecast guidance at the regional and the local level.

ECMWF operates a comprehensive verification system to monitor the performance of the forecasting system both in the free atmosphere and for the weather parameters. Fig. 1 shows the evolution of the forecast skill from the ECMWF deterministic model for the northern and the southern hemispheres as measured by the anomaly correlation of the geopotential height at 500 hPa. Over the last ten years there has been an overall gain in skill of one day or more at all forecast ranges (*Simmons and Hollingsworth*, 2002). It is also interesting to see that mainly due to the availability and efficient use of the satellite data, the skill in the southern hemisphere is almost comparable to that in the northern hemisphere. Such good quality forecasts will enable the forecasters to predict with high confidence the major flow and temperature pattern out to day five from the deterministic guidance. In recent winters, only some 5% of the forecast had to be classified as misleading. Figs. 2 and 3a and b give examples of successful forecasts of blocking and cold-air outbreaks over Europe.

Especially in the earlier ranges of medium-range forecasting the users expect the system to predict the regional and local "weather" directly. Developments in model resolution, better model physics and a much improved formulation at boundary layer processes have resulted in the successful provision of model forecast guidance of near surface temperature and wind, including gustiness, cloud, amount and type of precipitation, with a reasonable level of skill to five days, even longer e.g. for precipitation when information of accumulated values in time and averaged over an area is required.

However, regardless of the advances in numerical weather prediction in recent years, the deterministic approach to forecasting has its limitations, which depending on the application and the predictability of the atmosphere, may become apparent at an earlier or later stage in the forecasting process. In particular point weather forecasts will be affected by this uncertainty.

To take into account the stochastic nature of the medium-range forecast problem, the Centre runs every day 50 ensemble forecasts starting from perturbed initial conditions at lower model resolution. In addition, to simulate model errors, the concept of stochastic physics was introduced with a stochastic perturbation of the physical tendencies. Recently, perturbations in tropical regions were added with a particular focus on tropical cyclone forecasting, but with potential benefit also for extra-tropical developments. Ensemble forecasts provide the tools to capture the statistics of weather developments and to predict the event probabilities.

To make direct use of the forecast probabilities, the EPS needs to be an unbiased forecasting system. Otherwise it will be necessary to apply statistical adaptation and post-processing schemes tailored to the needs of the users.

Fig. 4 shows a 10-day forecast at a grid point location displayed in a probabilistic meteogram. The time evolution of weather parameters is shown in one diagram for the deterministic model results and the EPS members. The EPS spread is indicated by the range of forecast values, the extreme values and the most likely solutions are depicted.

4. Severe weather forecasting

Severe weather events post a threat for life and property. Such events may be highly localised such as extreme wind gusts and heavy precipitation related to thunderstorms. However, also large scale weather events, such as droughts, hot or cold spells or large scale continuous precipitation during snow melt in spring may lead to circumstances which would justify a warning preferably in the medium-range to give early notice to the civil protection authorities to help them prepare for the event.

The combined use of guidance from the EPS and the high-resolution deterministic forecasting system is particularly beneficial for severe weather prediction. The EPS provides information on the probability of the event occurring and allows an objective risk assessment with respect to user applications, while the deterministic system, because of its high resolution, helps to further assess the intensity and severity of the event, such as gale force winds, high precipitation rates or the intensity of a tropical storm. An example is given in Fig. 6, showing the gales predicted in the English Channel and over the adjacent land areas for 7/8 October 2001. The deterministic model captured the strong winds several days in advance, while the probabilities of strong winds tend to increase with shorter forecast times and thus help to strengthen the confidence in the forecast guidance.

5. Seasonal forecasts

Seasonal forecasts have been produced routinely at ECMWF for some years. They are based on a coupled ocean-atmosphere model with a resolution of some 200 km grid space. Once every month, 40 ensemble members are run starting from perturbed ocean-atmosphere conditions. Monthly mean products of temperature and precipitation for the globe out to six months are provided to the Member States, Co-operating States and also to the NHMSs of the WMO from a password protected web page.

The seasonal forecasts exhibit clear signs of skill in tropical regions, e.g. successful forecasts of tropical cyclone activity in the Pacific, while in mid-latitudes, in particular in years of a weak ENSO activity, it is difficult to find regions where the forecast signal is significant. Nevertheless, there is a substantial interest in seasonal forecast products amongst Member States and Co-operating States, in particular amongst the users with specific commercial applications.

6. Access to the Centre's products

The operational distribution of the Centre's products is accomplished through the dissemination system, sending digital products via the dedicated communication links. However, in recent months the Centre has revised its web pages and now provides a comprehensive service and access to forecast products on the web. The products are complemented by a wide range of documentation and also verification results. The public web pages are accessible from http://www.ecmwf.int which also contain a subset of public real-time forecast products and the seasonal forecasts for the tropics. Member States and Co-operating States have access to a wider range of services.

Reference:

A.J. Simmons and A. Hollingsworth, 2002: Some aspects of the improvement in skill of numerical weather prediction, *Q.J.R. Meteorol. Soc.*, **128**, 647-677.

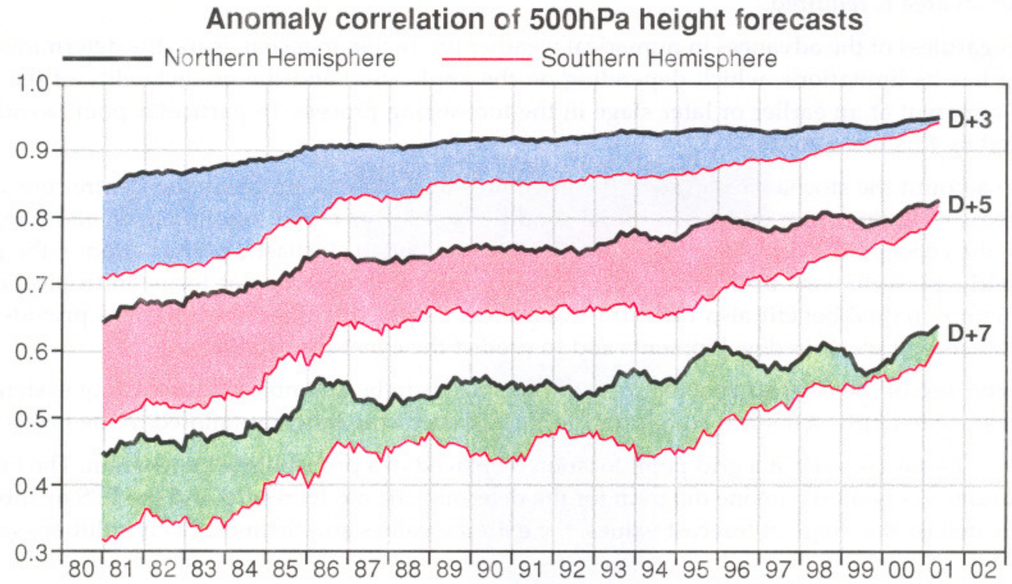

Fig 1: Anomaly correlation coefficients of 3-, 5- and 7-day ECMWF 500 hPa height forecasts for the extratropical northern and southern hemispheres, plotted in the form of annual running means of archived monthly-mean scores for the period from January 1980 to August 2001. Values plotted for a particular month are averages over that month and the 11 preceding months. The shading shows the differences in scores between the two hemispheres at the forecast ranges indicated (*Simmons and Hollingsworth*, 2002).

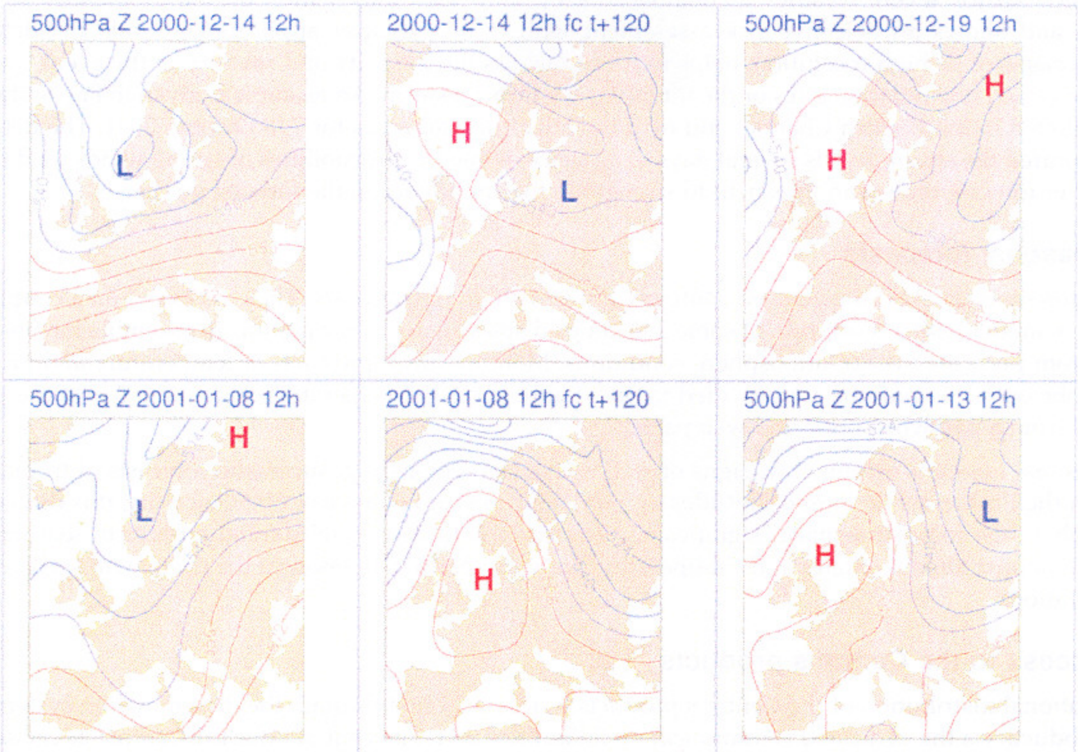

Fig 2: Onset of blocking in two 5-day forecasts of height at 500 hPa starting from the analyses of 14 December 2000 (top) and 8 January 2001 (bottom). The verifying analyses are shown in the panels on the right.

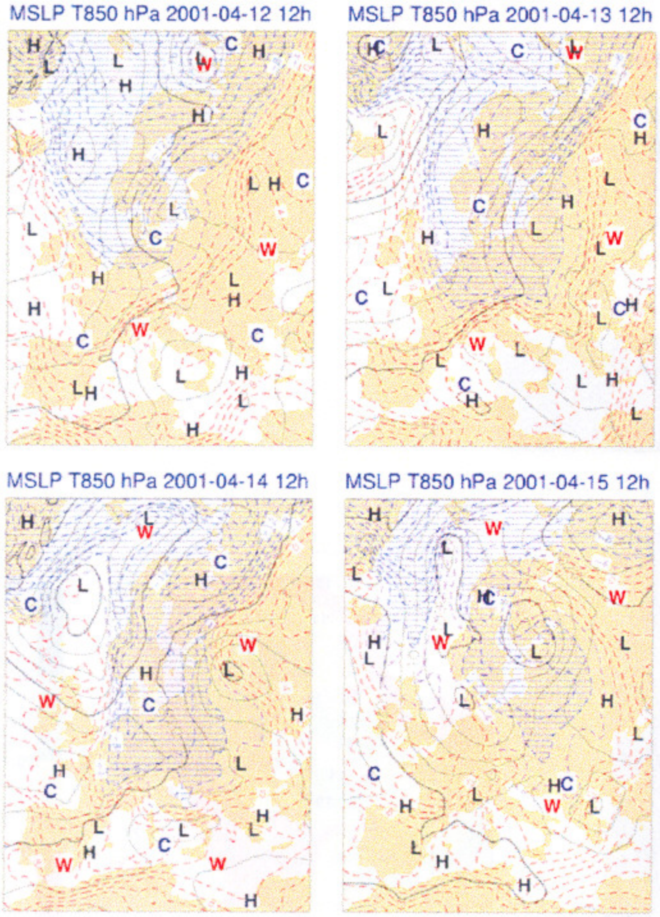

Fig 3a: Cold outbreak into Europe. Shown are the analyses of mean sea level pressure and temperature at 850hPa for 12-15 April 2001

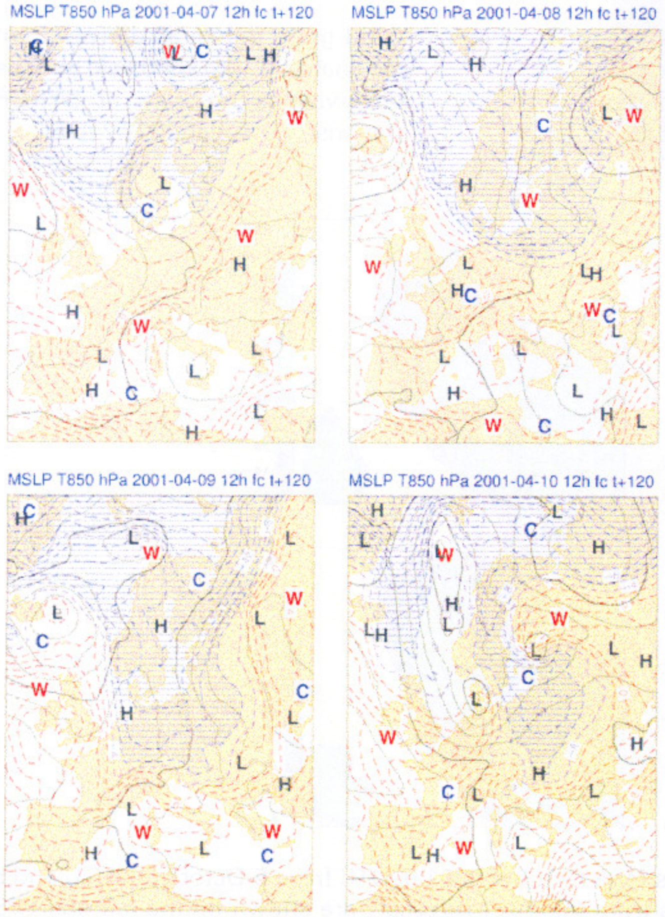

Fig 3b: Same as figure 3 a but for the four consecutive 5-day forecasts verifying on the same days 12-15 April 2001

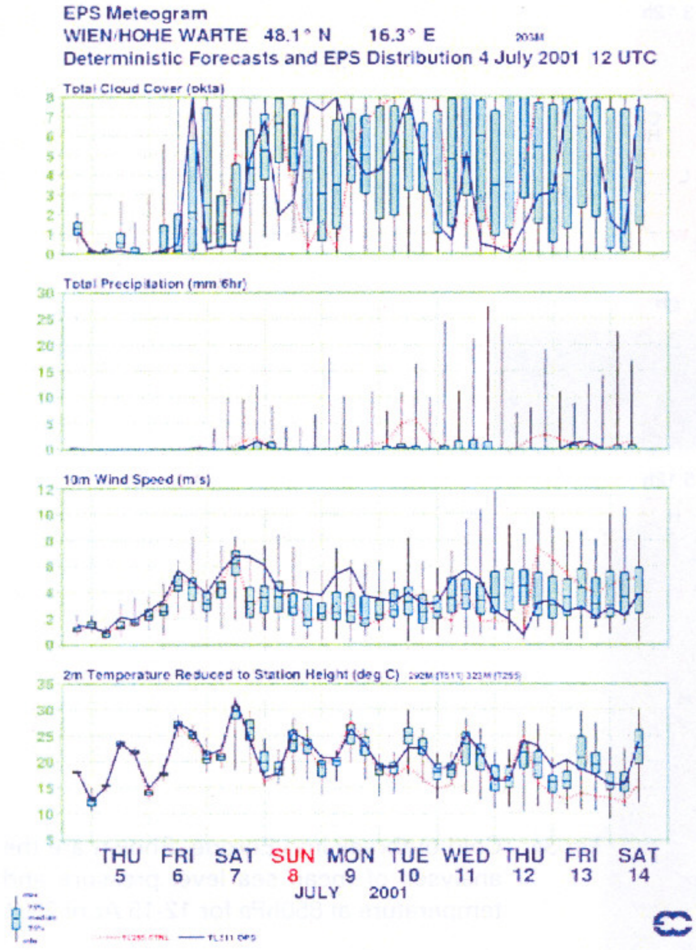

Fig 4: Meteogram for Wien/Hohe Warte, showing the evolution of the weather parameters clouds, precipitation, wind speed and temperature (top to bottom) from the T511 deterministic forecast and the EPS.

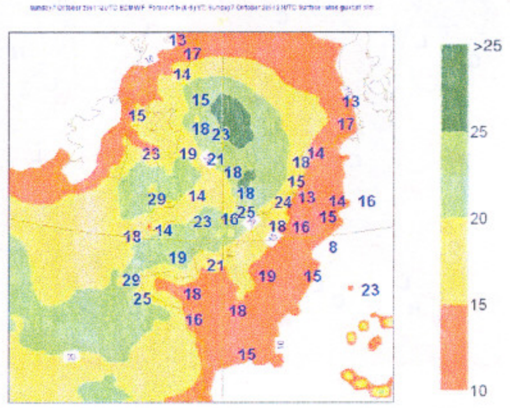

Fig 5: Wind gusts in m/s as derived from the analysed 10m wind field and the observations reported at SYNOP stations, 7 October 2001 21UTC

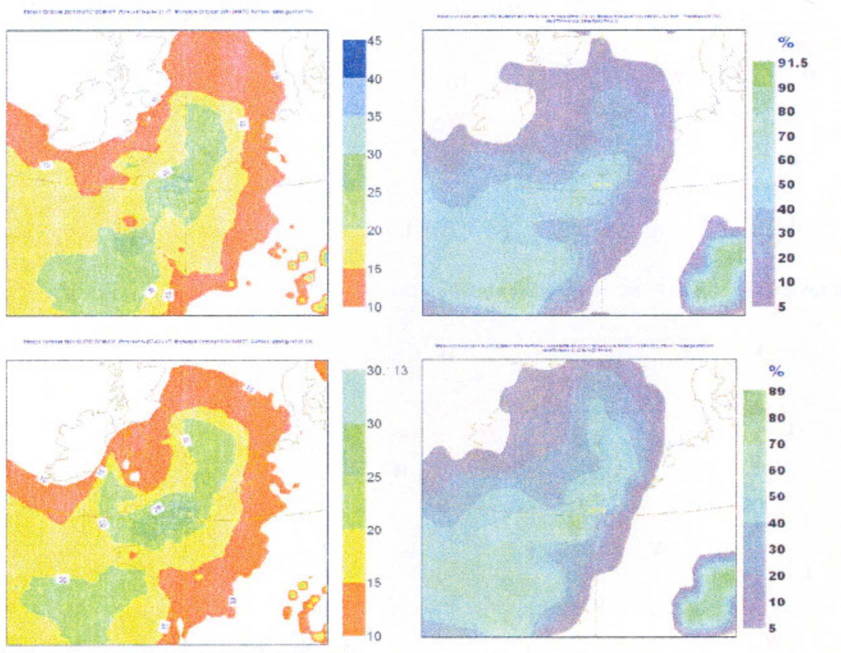

Fig 6: 69-72 and 57-60 hour forecasts of wind gusts for 8 October 2001 00UTC from 5 October 00UTC and 5 October 12UTC respectively. The wind gusts from the T511 forecasts are shown on the left, the EPS probabilities on the right.

Annex

ECMWF Operational Forecasting System 2001

ECMWF produces routine global analyses for the four main synoptic hours 00, 06, 12 and 18 UTC and global 10-day forecasts based on 12 UTC data.

(i) Atmospheric model and data assimilation Model

Model formulation

Numerical T_L511L60 (triangular truncation, resolving up to 511 waves on a great circle around the globe, linear reduced Gaussian grid. 60 levels between the earth's surface and 65 km), semi-Lagrangian, two-time-level semi-implicit formulation.

Grid for computation of physical processes is the Gaussian grid, on which single-level parameters are available. The grid spacing is 40 km.

Variables at each grid point (recalculated at each time-step): wind, temperature, humidity, cloud water and ice content, cloud fraction (also pressure at surface grid points).

Included in model

Orography (terrain height and sub-grid-scale characteristics). Four surface & subsurface levels (allowing for vegetation cover, gravitational drainage, capillarity exchange, surface and subsurface run-off). Stratiform and convective precipitation, carbon dioxide (345 ppmw fixed). Aerosol, ozone, solar angle, diffusion, ground & sea roughness, ground and sea-surface temperature, ground humidity, snowfall, snow cover & snow melt, radiation (incoming short-wave and outgoing long-wave), friction (at surface and in free atmosphere), sub-grid-scale orographic drag – gravity waves and blocking effects, evaporation, sensible & latent heat flux.

Data assimilation

Global wind, temperature, humidity, ozone, and surface pressure; four dimensional variational assimilation system at 12-hourly intervals.

Surface parameters: sea surface temperature from NCEP, sea-ice from SSM/I satellite data, soil water content, snow depth, ocean surface waves.

In-situ conventional data (SYNOP, TEMP, PILOT over land and sea, DRIBU, aircraft reports.

Satellite data.

(ii) Ocean wave models

Coupled Ocean Wave Model (WAM Cycle 4)

Domain: global

Numerical irregular lat/lon grid, 55 km horizontal resolution; spectrum with 30 frequencies and 24 directions.

Coupling: one-hourly wind forcing of waves, two-way interaction of winds and waves, sea state dependent drag coefficient.

Limited area model (WAM Cycle 4)

Domain: North Atlantic, North Sea, Baltic, Mediterranean and Black Sea.

Numerical irregular lat/lon grid, 28 km spacing; scheme: spectrum 30 frequencies and 24 directions.

Forcing: six-hourly wind forcing of waves.

(iii) ECMWF Ensemble Prediction System

ECMWF produces a 51-member ensemble of 10-day forecasts every day, comprising one control integration and 50 perturbed integrations.

Control integration

The control integration is run at T_L255L40 resolution using the operational model cycle from the operational T_L511 analysis truncated at T_L255.

Perturbed integrations

The 50 perturbed integrations are run with the same model cycle and resolution as the control integration but with the inclusion of a stochastic physics parametrization. Each member of the 50 perturbed integrations is run with a randomly drawn realisation of the stochastic physics scheme.

Perturbed initial conditions

Each member of the 50 perturbed integrations is run from the perturbed initial conditions. These perturbations are constructed from fast-growing instabilities of the circulation, calculated from the dominant singular vectors of the forward tangent propagator of the linearised dynamics.