DROP

A Probabilistic Drought Monitoring Tool

Adapted from “A Global Probabilistic Dataset for Monitoring Meteorological Droughts,” by **Marco Turco** (University of Murcia, Spain), **Sonia Jerez**, **Markus G. Donat**, **Andrea Toreti**, **Sergio M. Vicente-Serrano**, and **Francisco J. Doblas-Reyes**. Published online in *BAMS*, October 2020. For the full, citable article, see [DOI:10.1175/BAMS-D-19-0192](https://doi.org/10.1175/BAMS-D-19-0192).

The powerful impacts of droughts necessitate a move from post-crisis to preimpact drought risk management, and point to the need for innovative solutions providing the full range of drought-monitoring information. The quality of real-time data and the lack of quantified inherent uncertainty, however, are constraints in global drought monitoring. The uncertainty originates mainly from data-quality issues, periods of data unavailability, and/or poor spatial coverage of observations. Moreover, gridded datasets are the main source for drought monitoring, yet have a number of potential inaccuracies and errors, which generally increase as the network density decreases. Satellite observations provide more homogeneous and consistent spatial coverage, though uncertainties must be dealt with here as well, as precipitation cannot be directly measured by satellites.

To try to alleviate these problems, a number of datasets combine rain gauge analyses with satellite estimates. Reanalyses combine data into physically consistent estimates of climate variables with temporal continuity and spatial homogeneity. However, uncertainties in the assimilated observations and the model limitations influence the quality of the estimates generated by the reanalyses.

A careful assessment of meteorological datasets providing data in near-real time could help to characterize the uncertainties relevant to meteorological drought, a crucial step in translating data into actionable information. As part of such an assessment, we describe here the development of Drought Probabilistic (DROP), a new probabilistic monitoring tool offering near real-time estimates of drought and associated uncertainties based on an ensemble of observation-based datasets.

Data and methods

There are three main steps in producing the DROP dataset. First, we found 10 precipitation datasets that are publicly available in near-real time and cover at least the last three decades. Three are based exclusively on interpolated station observations,

four are based exclusively on reanalysis data, and three combine gauge and satellite data.

Next, we calculate the standard precipitation index (SPI) for each dataset, creating an ensemble of 10 SPI estimates. SPI transforms the accumulated precipitation values over a specific time scale (here over 1, 3, 6, and 12 months) into a standard Gaussian distribution with mean 0 and standard deviation 1. Positive values indicate surplus of rainfall, whereas negative values identify dry conditions relative to the long-term climatology.

The ensemble mean of the different SPI estimates is rescaled to retain the unit standard deviation, and the ensemble spread (i.e., the standard deviation) provides an uncertainty estimate. DROP also provides a simple color-coded drought warning based on a combination of uncertainty and severity. In addition, DROP provides the confidence level of having (at least) moderate drought, thus giving a more detailed illustration of the drought uncertainty.

We evaluate the quality of the DROP dataset against the independent data of the European Space Agency (ESA) soil moisture dataset, the

Validation of DROP data. Correlation of annual SPI 12-month values based on DROP against independent datasets. Points in (a)–(c) and colored circles in (d) indicate significant correlations (p values < 0.05).

Gravity Recovery and Climate Experiment (GRACE), and the Global Streamflow and Metadata Archive (GSIM), a global collection of streamflow time series.

We also consider the Multi-Source Weighted-Ensemble Precipitation (MSWEP) precipitation dataset for the evaluation, but not as a DROP ensemble member (it is not available in near-real time). Currently, MSWEP is the only global precipitation dataset at high spatial resolution (0.1° resolution) obtained by merging rain

Case example: Extreme drought in Africa in 1984, particularly in eastern, western, and southern Africa, resulted in one of the worst humanitarian disasters of the twentieth century. Observed 12-month SPI representing rainfall during January–December 1984 in Africa (a–d) as labeled, (e) as defined according to the table of drought risk (previous page), and with (f) the confidence level for moderate drought occurrence (i.e., $SPI < -0.8$). The time series derived for the pixel indicated by an arrow in (c) is shown in the next figure. The DROP ensemble spread (d) clearly points to large uncertainty in most regions, thus indicating that normal and drought conditions could be equally likely and highlighting the challenge of monitoring and alert systems. The map allows users to focus on the areas where there is higher confidence in the severity of the drought conditions.

gauge, satellite, and reanalysis estimates. To compare the various gridded datasets, precipitation values are remapped from their original resolution to the coarsest grid of the available datasets, defined by the Global Precipitation Climatology Project (GPCP, $2.5^\circ \times 2.5^\circ$).

Results and discussion

There is strong agreement between the DROP and MSWEP precipitation datasets for most of the grid cells. Furthermore, DROP shows extensive regions having statistically significant correlations with ESA soil moisture, with the highest values in the United States and portions of Europe, Asia, Africa, South America, and Australia. Over most land areas, DROP is positively and statistically significant correlated with the variations in GRACE total water storage. Furthermore, around 90% of the streamflow data show positive and statistically significant correlations with DROP.

In the best-performing individual members of the DROP ensemble, more than half of the grid cells have correlation values with MSWEP above 0.8. However, DROP systematically outperforms the individual products, especially reducing the spread in the verification metrics by improving, in particular, the agreement in regions with the lowest skill. The high quality of DROP is also confirmed by the generally low mean absolute error (MAE) across all datasets. Moreover, DROP reduces the MAE of the individual members.

Clearly, DROP is capable of monitoring drought conditions in different systems. The performance of DROP is very similar to MSWEP, but regular updates allow DROP to be used as a monitoring product.

The inherent large uncertainties in monitoring drought make uncertainty estimates valuable. In at least some cases, DROP overestimates low confidence levels and underestimates high confidence levels. DROP is still very useful for decision-making and has skill in terms of identifying drought occurrence probabilistically.

The skill estimates based on past performance of the system may guide end users as to the expected performance of the system in monitoring drought events, as illustrated by a case study of extreme drought in Africa in

★ Drought case study for Africa: While MSWEP estimates moderate drought conditions for the entire period considered here, DROP does only for some months. This time series evolution is of the observed 12-month SPI considering the individual ensemble members (in gray), the DROP ensemble mean (in green), and the MSWEP data (in orange). Location: longitude = 26.25°, latitude = 13.75°, as shown in the previous figure.

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¹ www.um.es/gmar/projects/predfire.html; all codes used in the production of DROP are also freely available via the DROP archive.

1984. The spatial pattern of the drought severity depicted by the DROP ensemble mean resembled the pattern of MSWEP. A generally consistent pattern emerges, further supporting the robustness of DROP. However, among the individual ensemble members, the spread is very large, with some datasets indicating extreme droughts and others indicating wet conditions. Finally, a high level of uncertainty was associated with the estimated end of this drought event. MSWEP is also affected by uncertainties, especially in areas with limited observations. This further emphasizes the importance of ensembles in monitoring datasets for drought-alert systems.

Conclusions

DROP uses an ensemble approach to near real-time drought monitoring, where the members are available observations-based products.

DROP is publicly available online,¹ and could become an important tool to inform end users across a range of socioeconomic sectors (e.g., energy and water management, insurance, agriculture, fire risk).

In the future, we may see development of more refined specific monitoring systems at regional scales where high-resolution data are available. The recently developed ERA5 reanalysis offers an ensemble that could be beneficial in estimating uncertainty of different climate variables relevant for drought monitoring (while for DROP we use the ensemble mean of only one variable, the precipitation).

We believe that the high-quality and probabilistic information provided by DROP helps meet the need for predrought risk management. The ensemble tool may help to develop priorities in alleviating drought impacts, especially in countries where meteorological monitoring is still challenging. ☼

300 miles

>> How a silver lining forms

>> It starts at sea.
>> Tropical waters heat up.
>> Warm air soars skyward.
>> Cold air rushes to the void.
>> Cold air warms up.
>> Cycle repeats.
>> Faster and faster—a 50,000 foot engine of air.
>> At seventy four miles per hour it earns a name.
>> Harvey, Irma, Katrina.
>> Then landfall.
>> Roads rendered useless.
>> Buildings destroyed.
>> Families stranded.
>> But for a brief moment,
>> A silver lining appears.
>> People see neighbors instead of strangers.
>> And labels that divide are forgotten.

>> But when rains ease,
>> when clouds part,
>> silver linings need not fade.

>> Let's embrace our shared humanity.
>> Let's connect with one another.
>> Let's find our love for each other.
>> Every single day.

>> Come together at lovehasnolabels.com

love
has
no
labels

ad
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