National Centre for Atmospheric Science
School of Earth and Environment &
School of Mathematics

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Predicting the weather and climate of Africa:
a global challenge

Headingley Café Scientifique, Monday 9th January 2023
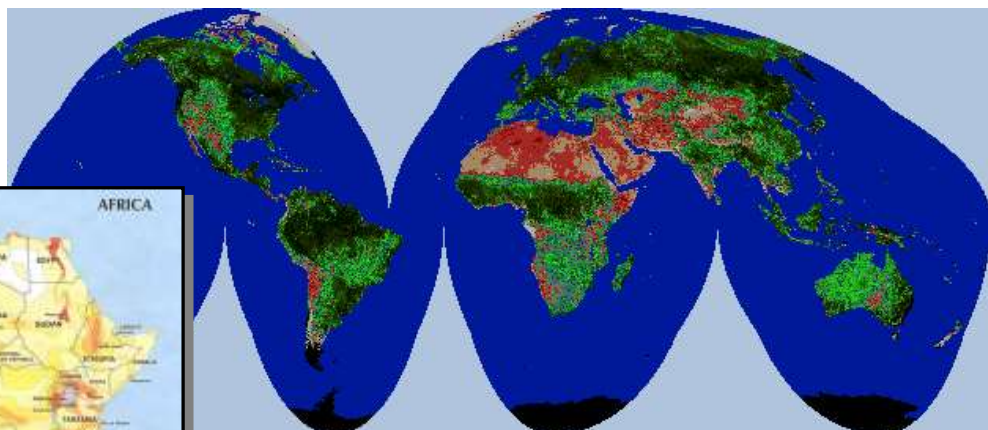Doug Parker [and the work of many others].

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Geography

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Population density

AFRICA

Normalised Digital Vegetation Index (NDVI) 20-30
August 2000 (NASA-DAAC)

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Africa's weather and climate challenges.

East African drought, 2020-2022, Ouagadougou floods 2009 (NBC News), Durban floods/landslides 2022 (BBC). Ongoing ~15% impact on GDP.

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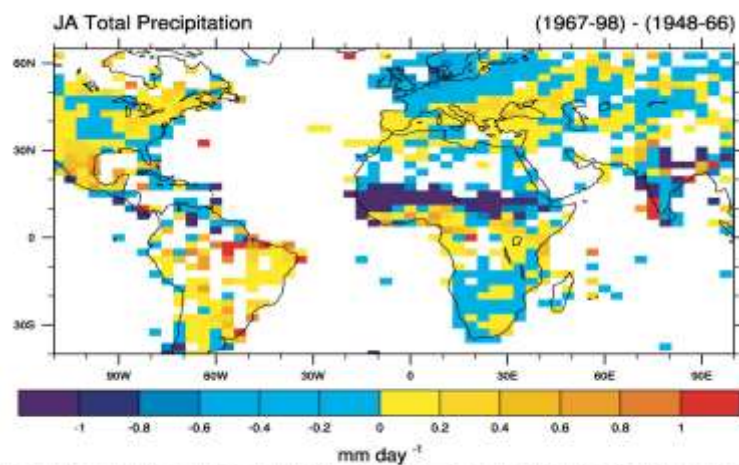## 70s-90s : The largest regional precip deficit on Earth was in the Sahel

Fig. 3: The change in high summer (July-August) total precipitation (mm day⁻¹), 1967-1998 minus 1948-1966, estimated from land surface records ('g55old0098.dat' constructed and supplied by Dr. Mike Hulme at the Climatic Research Unit, Univ. of East Anglia, Norwich, UK).
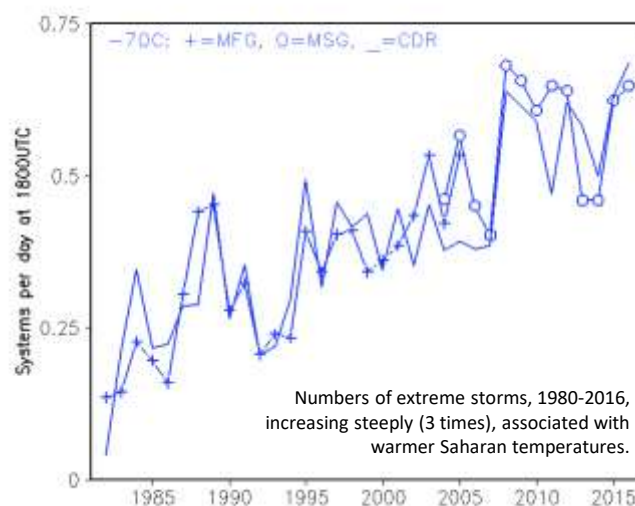
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Sahel precipitation record

Sahel precipitation anomalies 1901-2017
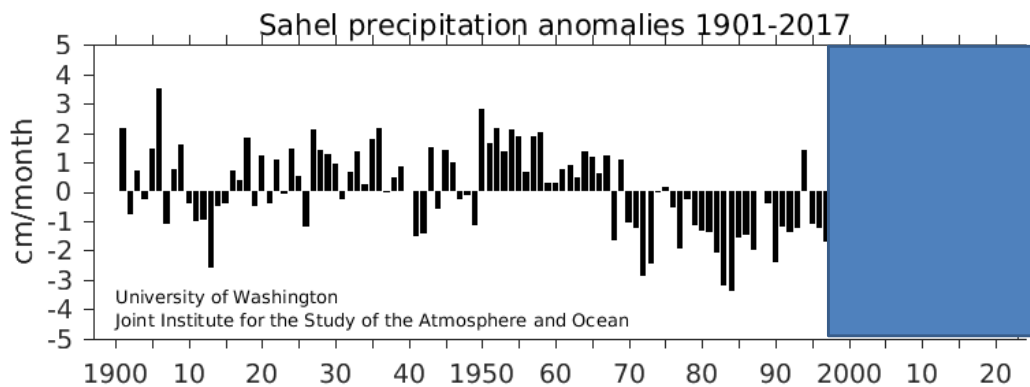
June through October averages over 20-10°N, 20°W-10°E. 1900-2017 climatology
Deutscher Wetterdienst Global Precipitation Climatology Centre data

University of Washington
Joint Institute for the Study of the Atmosphere and Ocean

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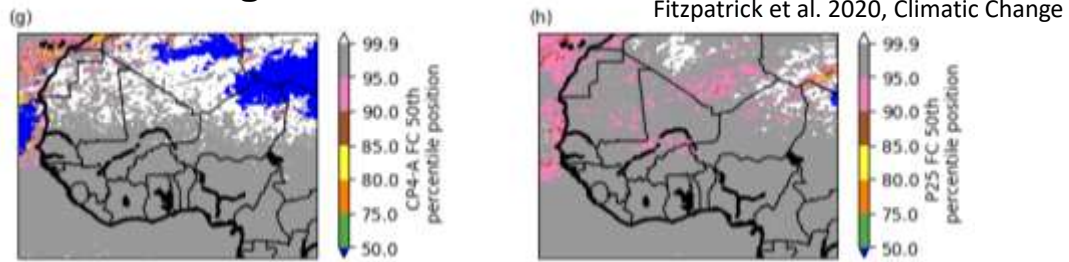NATURAL ENVIRONMENT RESEARCH COUNCIL

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A new climate

Although Sahel rainfall has "recovered", it has a different pattern to previous decades, with extreme storms, and more gaps between them.

Numbers of extreme storms, 1980-2016, increasing steeply (3 times), associated with warmer Saharan temperatures.

Taylor et al, Nature 2017

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Rainfall when raining.

Fitzpatrick et al. 2020, Climatic Change

(g) (h) The percentile of current climate days which have a daily "rainy day" rainfall rate less than the median value in the future climate – grey values denote regions where >95% of CC days have daily rain rate lower than the typical future median value.

What do we need to do?
- Mitigation (global / local)
- Adaptation …

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Weather forecasts save lives.

In a changing climate, African weather events *are already more intense than in recent decades,* and expected to get worse.

Climate is changing now: this is not a rehearsal for the future: solutions are needed now.

**The "HIGHWAY" project (WMO / WISER, 2017-2020) is saving hundreds of lives every year on Lake Victoria [using SWIFT data products].**

Watkiss, P., Powell, R. and Hunt, A. (2020). Socio-Economic Benefits of the HIGHWAY project. Policy brief. Published July 2020.

30%
Estimated reduction in weather-related deaths on Lake Victoria due to HIGHWAY activities

About 300 lives saved per annum.

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Do not assume that African forecast products are as good as those we enjoy in the Global North,

"… even post-processed forecasts are hardly better than climatology."

Vogel et al. 2020. Skill of Global Raw and Postprocessed Ensemble Predictions of Rainfall in the Tropics

Continuous Ranked Probability Skill Score (CRPSS) for 1-day ECMWF (a) raw and (b) postprocessed forecasts for accumulated precipitation amount relative to Extended Probabilistic Climatology during 2009–2017.

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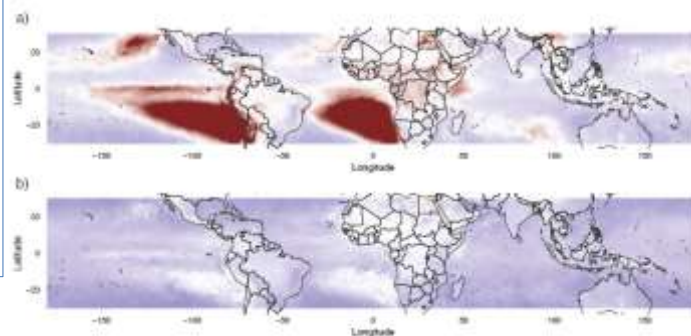
Only 44% of Africans have any access to early warnings.
- Cullmann *et al.* (2020) 2020 State of climate services …, WMO-No. 1252. ISBN 978-92-63-11252-2

Why is African (tropical) rainfall more difficult to predict [than midlatitude rainfall]?

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- Planetary rotation is weaker in the tropics.
- Convection is stronger [in fact Africa-like UK summer convection is also hard to predict]

- And … on longer timescales, it's actually easier to predict tropical rainfall than extratropical rainfall.
  - For the average rainfall over longer timescales (weeks to months), tropical rainfall may be easier to predict than midlatitude, due to control by the (slowly varying) sea surface temperatures.

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Faced with inaccurate NWP (computer) rainfall prediction, what do we do?

Subseasonal-to-seasonal (S2S) forecasts are rapidly developing useful skill for circulation and mean rainfall.
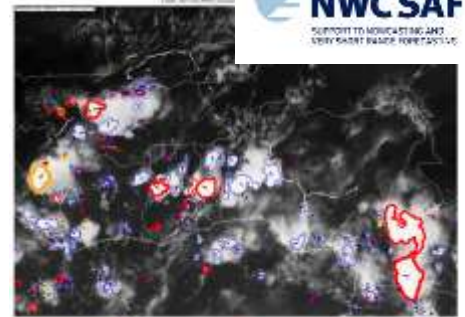
Convection-permitting forecast models offer the chance to radically improve 1-day rainfall forecasts.

Satellite Nowcasting solutions (0-6h) can be developed for Africa now.

Statistical methods cut across timescales.

Human intervention in the forecast process. Needs skills!

Forecast evaluation is critical

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SCIENCE FOR WEATHER INFORMATION AND FORECASTING TECHNIQUES

Subseasonal-to-Seasonal S2S

> We find that there is useful prediction skill for East African rainfall at up to 4-week timescale, if the predictions of tropical modes are linked to statistical analysis of rainfall modulation by those modes.
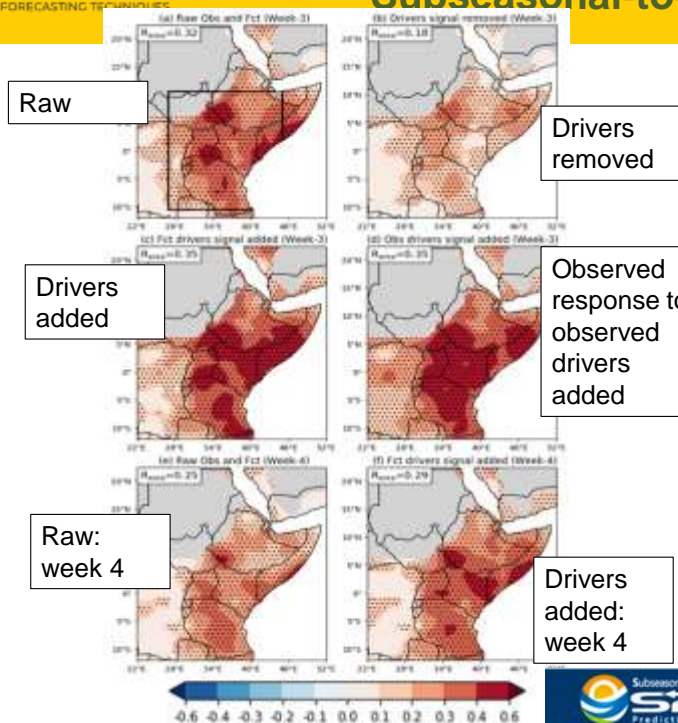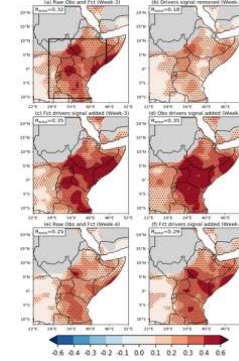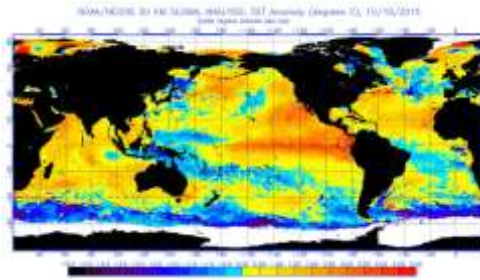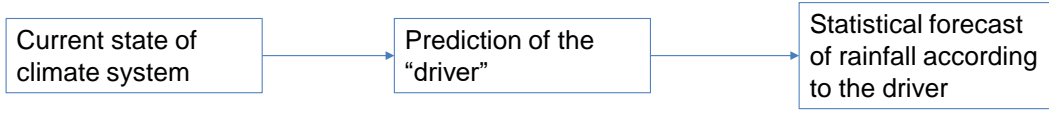

Figure 1: Pearson's correlation coefficients computed between ECMWF hindcast ensemble mean and GPCP accumulated precipitation anomalies for Week-3 (forecast days 19-25) and Week-4 (forecast days 26-32) using initializations within October-November-December from 1997 to 2014. Correlations for Week-3 were obtained with (a) raw observations and hindcasts, (b) drivers' signal removed from hindcasts and observations using appropriate linear regression patterns, (c) hindcasts adjusted by adding observed linear response to forecast drivers' signal in place of forecast response in hindcasts and (d) hindcasts adjusted by adding observed response to observed drivers in place of forecast response to forecasted drivers, indicating the potential skill with a perfect forecast of both the drivers and the local response. (e) and (f) show the same as (a) and (c) but for Week-4: the skill for week 4 shows a decrease from week 3 (e) but correcting the response to the forecast drivers improves the skill (f). Drivers' activity was represented by the Niño 3.4, DMI, and RMM indices. Square in (a) denotes the region used to calculate the regional average of the correlation shown on the top left of each panel. Stipples indicate correlations statistically significant at the 95% level (two-sided Student's t test). Grey shading denotes a dry mask applied over regions where the observed weekly precipitation climatology is less than 1 mm for more than 50% of initializations within a season. See de Andrade et al (2020) for details.

Figure 1: de Andrade, F. M. and Coauthors, 2020: Sub-seasonal precipitation prediction for Africa: forecast evaluation and sources of predictability. *Wea. Forecasting*, 36, 265-284,. https://doi.org/10.1175/WAF-D-20-

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Current state of climate system	→	Prediction of the "driver"	→	Statistical forecast of rainfall according to the driver

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S2S testbed case studies:

Introducing meningitis forecasting
ACMAD working with WHO to supply bespoke, multi-variable sub-seasonal forecast products for meningitis vigilance across 26 countries in the meningitis belt (~300 million people)
- Added forecasts to existing vigilance extended window for preparedness action by 2 weeks
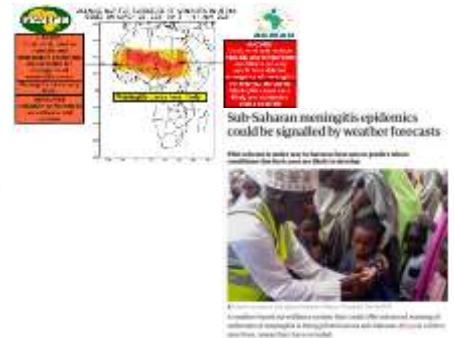
**Improving energy generation planning in Kenya**
KMD working with KenGEN (user involved since testbed kick-off) to produce bespoke forecasts for hydropower generation planning
- Forecasts help manage dam levels – maximise levels without downstream flooding
- Impact: uninterrupted power for Kenya, eliminated use of emergency diesel generators.

- When forecasts are uncertain, we need Nowcasting.
- Prior to SWIFT, Nowcasting was not formally being conducted in these countries. We have made NWC SAF products available. Operational agencies are starting to use them. Universities using them for teaching.
- Evaluation shows impressive skill for rainfall.
- We are innovating on new nowcasting methods, out to 4+ hours, including AI.
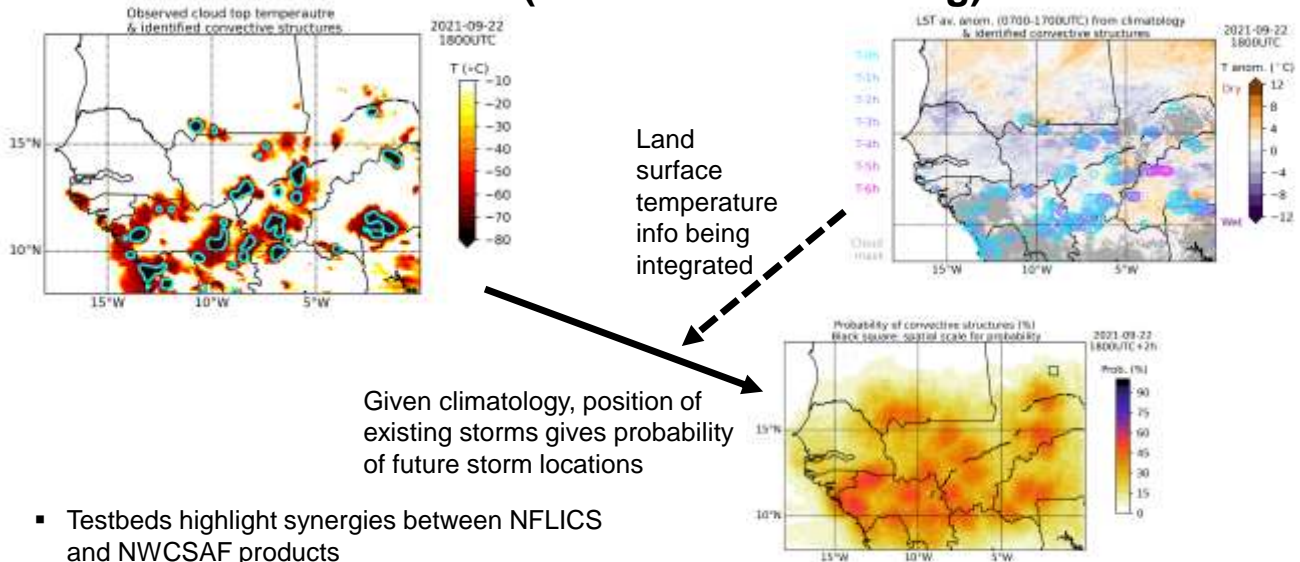
Obs

Nowcasts

Convective rainfall rate (mm/hr)
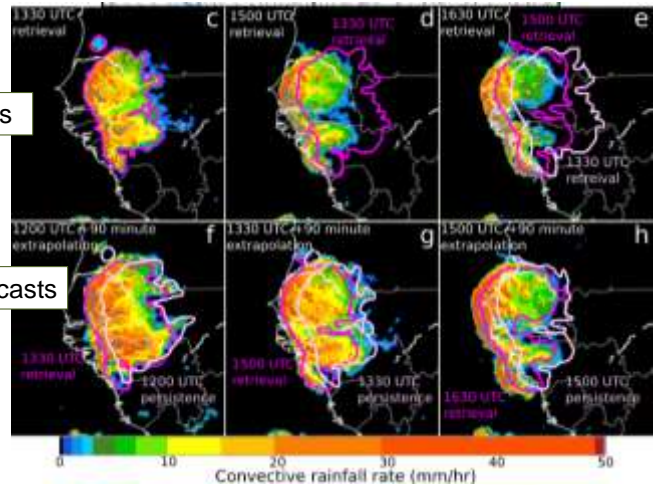
GMet NWCSAF installation, February 2021: Dr. Jeffrey N. A. Aryee (KNUST), Mr. Kwesi Twentwewa Quagraine (KNUST), Mr. Alfred Obodai (GMet), and Mr. Nutifafa Agbenor-Efunam Yao (KNUST).

- The hardware has successfully been installed at Kwame Nkrumah University of Science and Technology (KNUST), Kumasi.
- KNUST staff have then installed the software at GMet:
an African solution.

EUMETSAT
NWC SAF
SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING

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NFLICS (Statistical Nowcasting)

(CEH, Chris Taylor)

Land surface temperature info being integrated

Given climatology, position of existing storms gives probability of future storm locations

- Testbeds highlight synergies between NFLICS and NWCSAF products

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Are we decolonising weather prediction?

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FASTA extension project

- We have created an application programming interface (API) and app for users to see nearby storms:
  - Released in Kenya, March 2022, on the Google Play Store.
- Will license use of the API via a subscription
  - Making progress with groups in Kenya, e.g. civil aviation.
- Working with NMSs (KMD first) whilst trying to make the product commercially viable.
  - FREE service to general public in Kenya.
  - Working principles constitution to guide our ethics.
- https://africanswift.org/fasta/

Mockup of the free application indicating the position of intense rainfall. Credit: Alex Roberts

We are actively seeking new funded collaborations in this area.

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- Best-in-the-world accuracy for average conditions (e.g. unusually wet or dry), on weekly to seasonal timescales.
- World-beating accuracy for nowcasting, due to size and longevity of weather systems.
- Communications revolution … access to warnings for the other 56% of African people.
- A transformation in observational data through informal networks.
- A forecast industry employing Africans in the public and private sectors.
- Much better coordination between prediction, finance and decision-making.

What's needed? Many more African specialists (Physics, Maths, Data Science etc) and sustainable operational funding.

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- This is the sound of Africa's changing climate …

https://futureclimateafrica.org/news/this-is-the-sound-of-west-africas-changing-climate/

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