Interactive 3D visual analysis in weather forecasting

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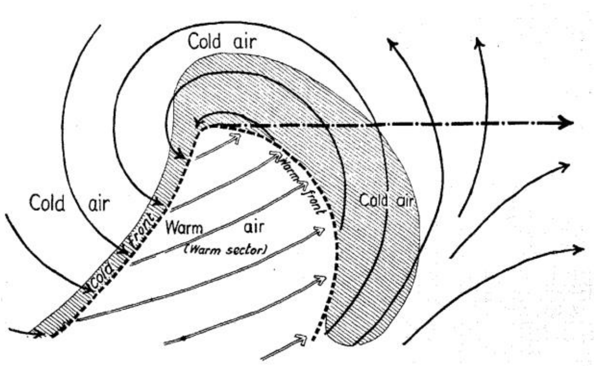
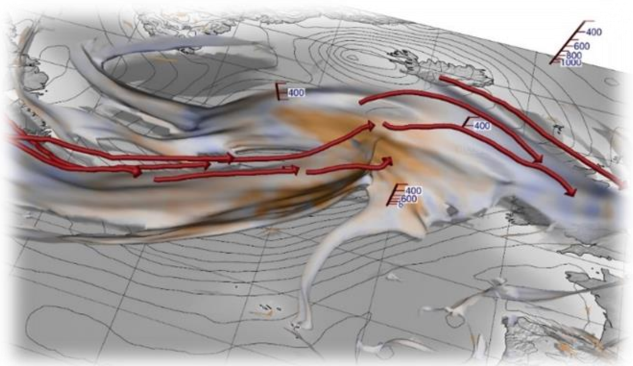
Bjerknes and Solberg (Geof. Publ. 1922)



Kern et al. (TVCG 2019)



These slides won't replace a real presentation but are aimed at providing an overview of our topic and to point to further resources. Some comments are provided in these blue boxes.

About 100 years have passed between these two visualizations. Compare the conceptual drawing of a cyclone by Bjerknes and Solberg to our 3D interactive display of a frontal structure (here: Cyclone Vladiana, 2016) generated from NWP data.

Here we present parts of our work in 3D interactive visual analysis with methods potentially useful for weather forecasting.

Met.3D

WAVES TO WEATHER

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WAVES TO WEATHER

"Visual displays provide the highest bandwidth channel from the computer to the human" [.. and hence ..] "one of the greatest benefits of data visualization is the sheer quantity of information that can be rapidly interpreted if it is represented well."

Ware (2013), "Information Visualization"

Visualization research covered topics relevant for meteorology

State of the art: application domain vs. vis research

3268 IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS, VOL. 24, NO. 12, DECEMBER 2018

Visualization in Meteorology—A Survey of Techniques and Tools for Data Analysis Tasks

Marc Rautenhaus, Michael Böttinger, Stephan Siemen, Robert Hoffman, Robert M. Kirby, Mahsa Mirzargar, Niklas Röber, and Rüdiger Westermann

Abstract—This article surveys the history and current state of the art of visualization in meteorology, focusing on visualization techniques and tools used for meteorological data analysis. We examine characteristics of meteorological data and analysis tasks, describe the development of computer graphics methods for visualization in meteorology from the 1960s to today, and visit the state of

Rautenhaus, Böttinger et al. (2018)

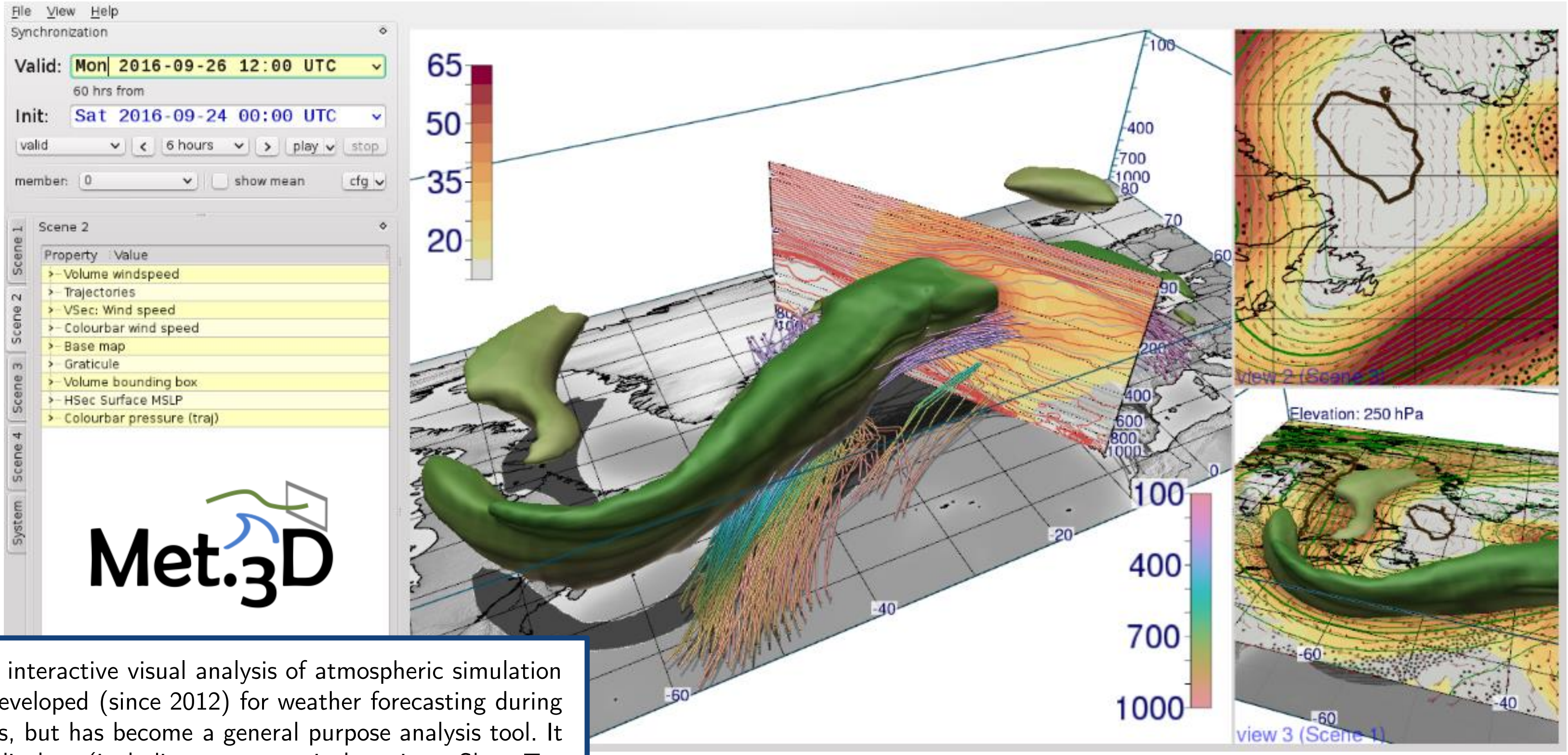
https://ieeexplore.ieee.org/document/8126857/

Visualization research has in recent years covered many aspects that are directly or potentially of interest to meteorology. We have surveyed the current state of the art in this 2018 article in the IEEE Transactions of Computer Graphics and Visualization.

Met.3D: Ease transition by building a bridge from 2D to 3D

Do **not replace proven 2D techniques** but put them into a **3D context** and use 3D elements to add value.

Intuitive interaction and spatial perception are key elements.

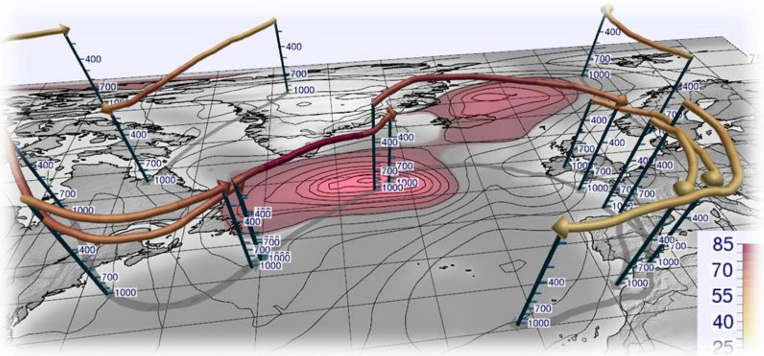


Met.3D is our framework for interactive visual analysis of atmospheric simulation data. It has originally been developed (since 2012) for weather forecasting during aircraft-based field campaigns, but has become a general purpose analysis tool. It combines "traditional" 2D displays (including maps, vertical sections, Skew-T diagrams) with 3D elements and provides support for ensemble forecasts. Currently, we receive funding within the German Collaborative Research Centre "Waves to Weather" for Met.3D research and development.

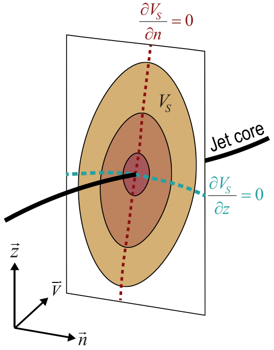
met3d.wavestoweather.de

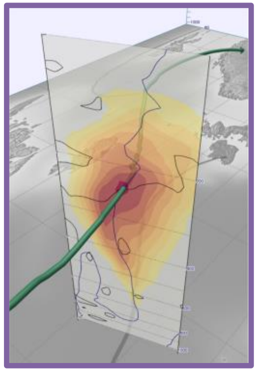
Detection and visual analysis of jet-stream core lines

Goal: extract visual abstraction for jet stream from NWP data that can be combined with other visualization elements and be used to characterize uncertainty.

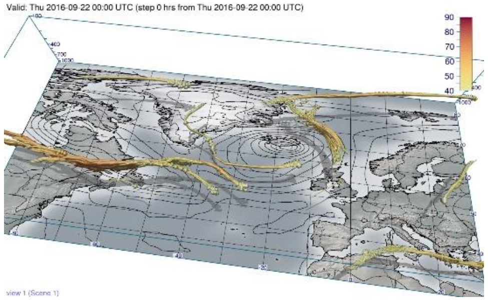


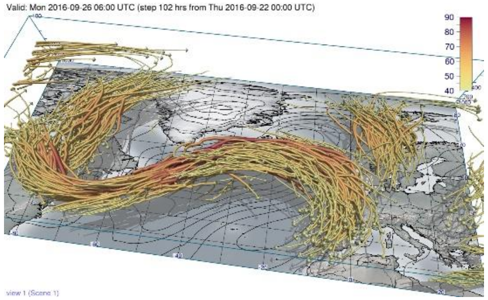
Kern, Hewson, Sadlo, Westermann, Rautenhaus (2018)





https://ieeexplore.ieee.org/document/8017585/



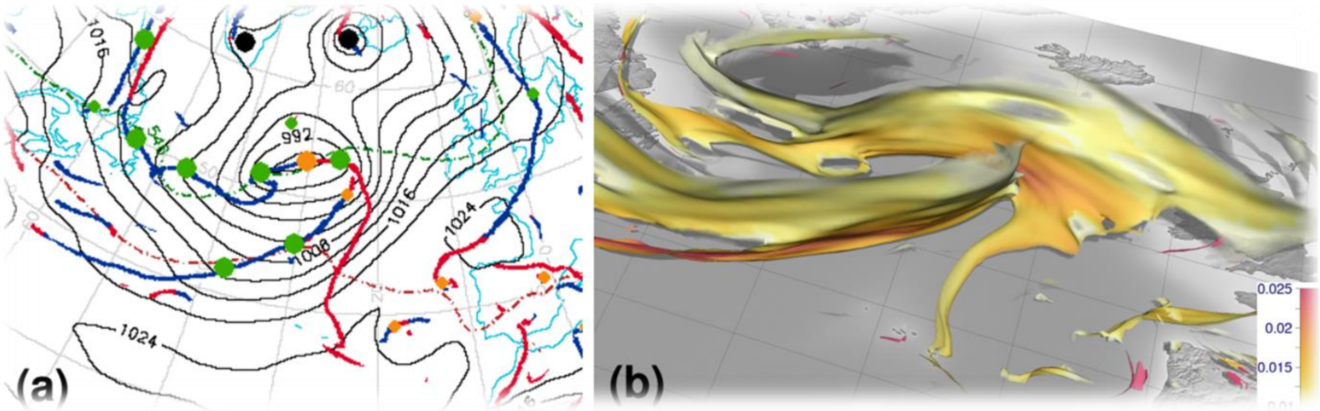


Within Waves to Weather, we have (and are continuing) developed a number of visual analysis techniques for atmospheric simulation data. One example is this detection and visualization technique for jet-stream core lines. Detection is based on the derivatives of the wind field to find the maximum lines (figures above). The core lines can be plotted as spaghetti plots to illustrate ensemble uncertainty (left images show an ECMWF ensemble forecast at analysis time and at 102 h lead time.

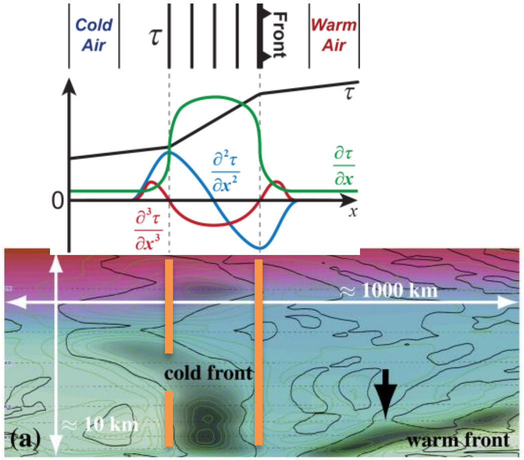
Detection and visual analysis of frontal surfaces

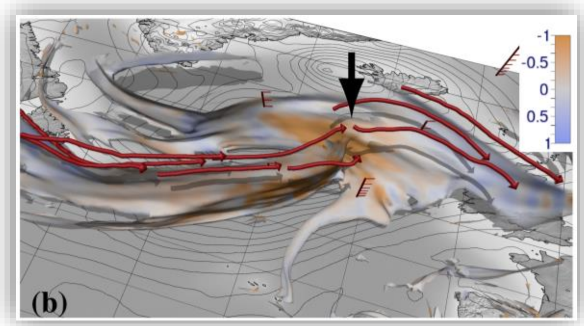
Similar approach for 3D frontal surfaces, building on 2D detection by Hewson (1998).

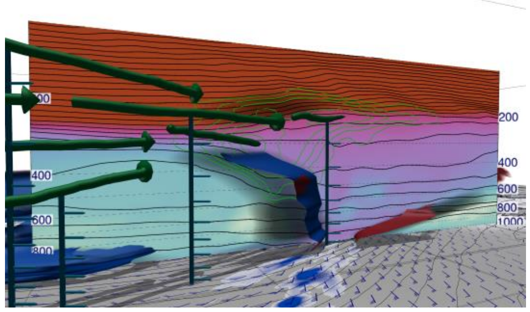
https://ieeexplore.ieee.org/document/8440076/



Kern, Hewson, Schäfler, Westermann, Rautenhaus (2019)



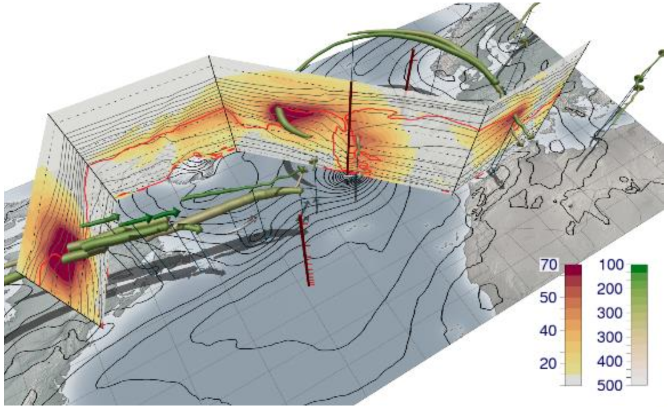


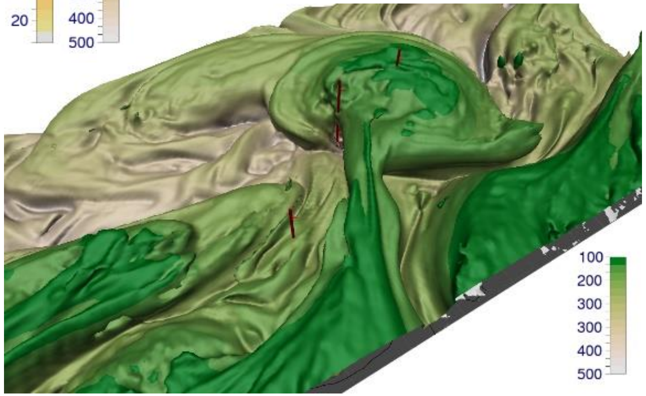


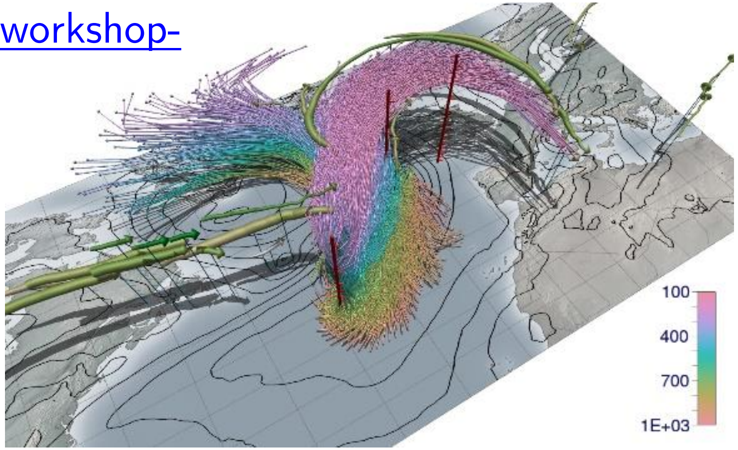
Another example is a detection method for 3D frontal surfaces, based on the 2D detection method by Tim Hewson (upper left image). The method analyses gradient zones in the wet-bulb potential temperature field (blue to warm shading in the vertical sections). Frontal features can be combined with the jet-stream core lines.

Example: Extra-tropical transition of Hurricane Lorenzo

Example visualizations showing aspects of Hurricane Lorenzo (2019). For further details see https://www.ecmwf.int/en/newsletter/162/news/cyclone-workshop-showcases-3d-visualisation.



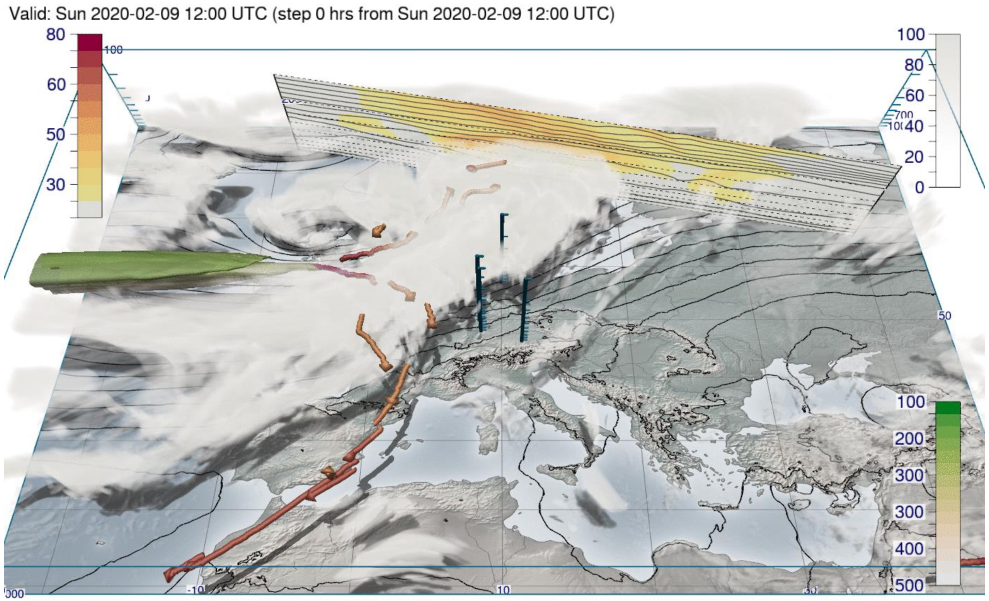




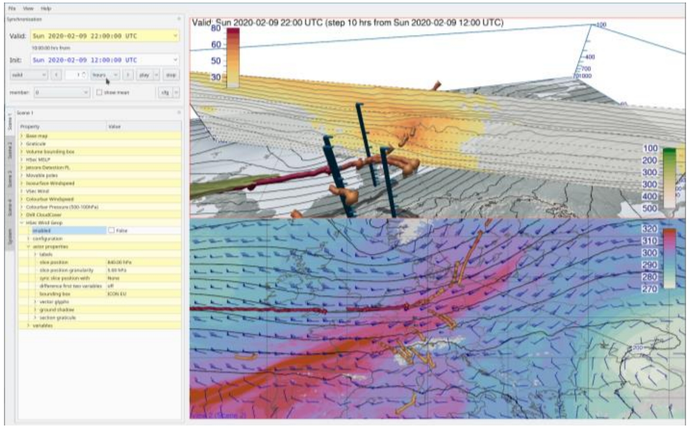
These images show examples of Met.3D being used to analyse an ECMWF forecast of Hurricane Lorenzo (early October 2019). We are analysing (left) the jet stream using the core lines and vertical sections showing wind speed, (middle) the structure of the dynamic tropopause using the 2-PVU potential vorticity isosurface, and (right) the warm conveyor belt using trajectories filtered according to an ascent of more than 500 hPa in 48 h. Some more details can be found at the link provided above.

Example: Winter storm "Ciara"/"Sabine"

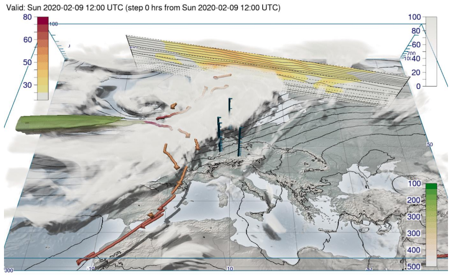
Winter storm "Sabine" ("Ciara") hit Germany on 9/10 February 2020. It featured an extremely strong jet stream – the green isosurface encloses wind speeds > 90m/s!

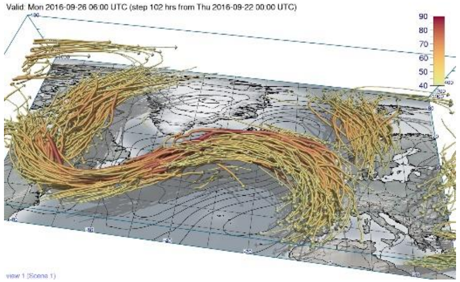


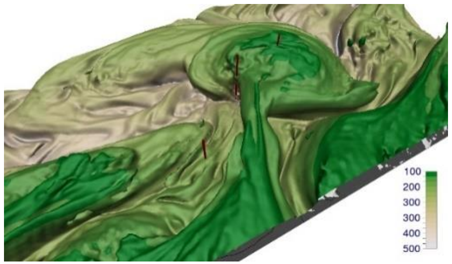
During the "real" EGU, I would have shown you some live demo of the system. These are screenshots of an analysis of the ICON-EU forecast provided openly by DWD at opendata.dwd.de. The left image shows jet stream core lines, along with an isosurface of wind speed and a volume rendering (white) of cloud cover. The vertical section shows wind speed in m/s. In the bottom image, Met.3D is used with a split screen also showing a map of equivalent potential temperature.



What's next? Website with near-real-time products soon!







We are in the process of setting up a website with near-real-time products (from open NWP data) similar to the visualizations of Lorenzo and Sabine shown in this presentation. It was supposed to be online by now, but due to Corona we'll need a bit more time. We'll announce the launch on the Met.3D website at met3d.wavestoweather.de. Or just send an email and we'll let you know.

Of course, the website will not have the level of interactivity that Met.3D provides on the desktop. However, we'll provide configuration files so that if a situation is of interest you can download the NWP data and explore locally on your system.

Thanks for your interest – please contact us with any questions, suggestions, feedback!

met3d.wavestoweather.de

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