A ‘Boscastle-type’ quasi-stationary convective system over the UK Southwest Peninsula

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1. Introduction

Quasi-stationary convective systems (QSCSs) occur when convective cells repeatedly initiate and move over the same area for an extended period of time. The combination of high rain rates and a long event duration results in large rainfall accumulations and the potential for flash flooding. Here, we present a case study of a QSCS which occurred in the UK in summer 2010 and showed remarkable similarity to the flash flood-producing Boscastle storm of 16 August 2004.

2. Case Study: 21 July 2010

- Line of convective cells which developed along the west coast of the Southwest Peninsula, remaining quasi-stationary for several hours before propagating inland and dissipating (Fig. 1)
- Maximum accumulations of around 50 mm in 3 hours
- No flooding was reported and the effect on river levels was “unremarkable” (Maggie Summerfield, Environment Agency)

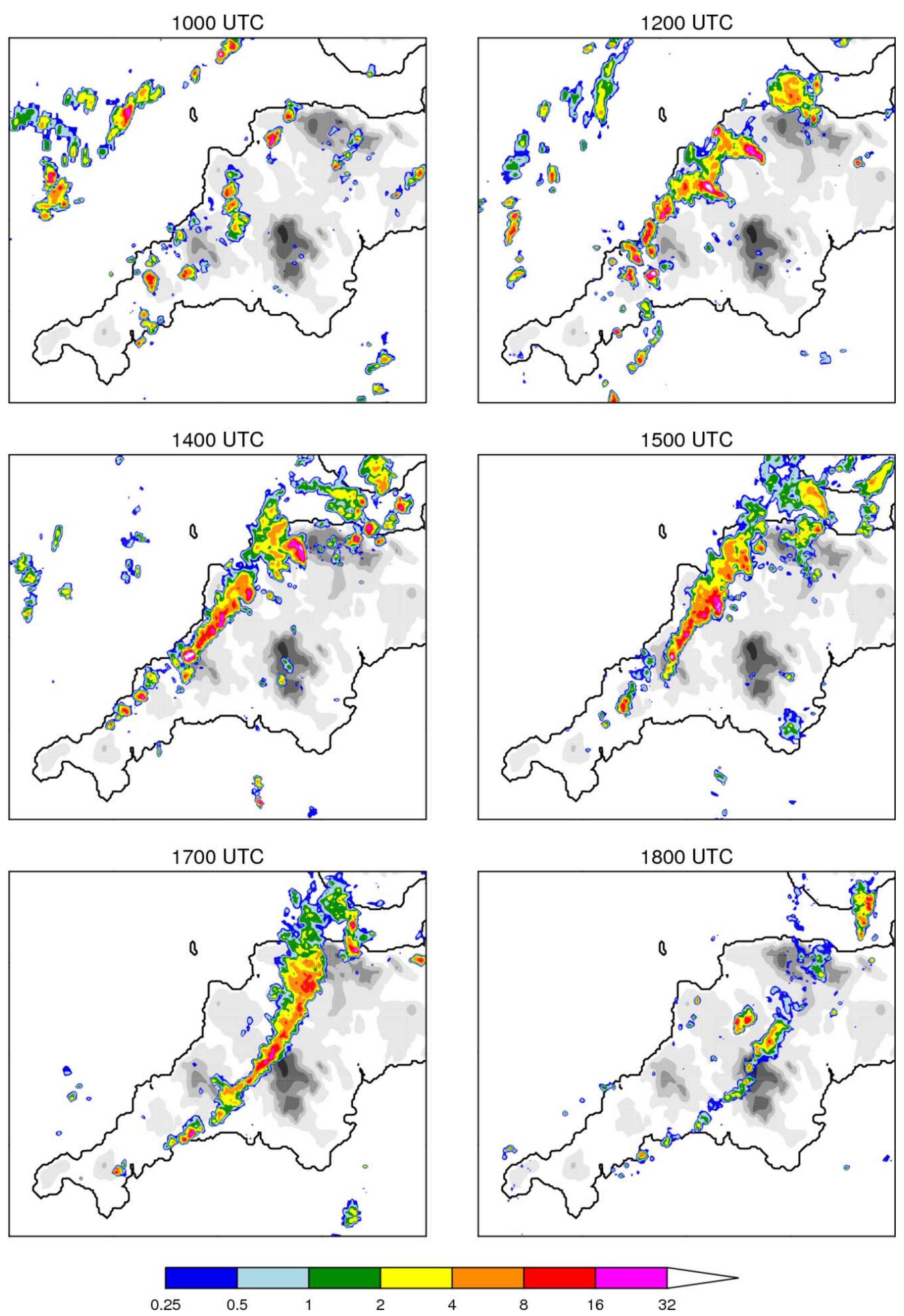

Figure 1. Radar-derived surface rain rates (mm hr^{-1}, colour shading) at 1-km grid spacing for various times on 21 July 2010. Orography height is shown in grey-scale with a contour interval of 100 m.

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3. Comparison to Boscastle Storm

- The Boscastle storm was a QSCS which formed in the same location on 16 August 2004 and produced devastating flash flooding in the coastal village of Boscastle, Cornwall [1]
- Higher rain rates (associated with a warmer, moister profile and deeper convective clouds) and a longer system duration (due to slower evolution of the large-scale flow) resulted in much higher rainfall accumulations in the Boscaslte case (Fig. 2)
- The heaviest rainfall was also distributed across fewer river catchments (not shown)

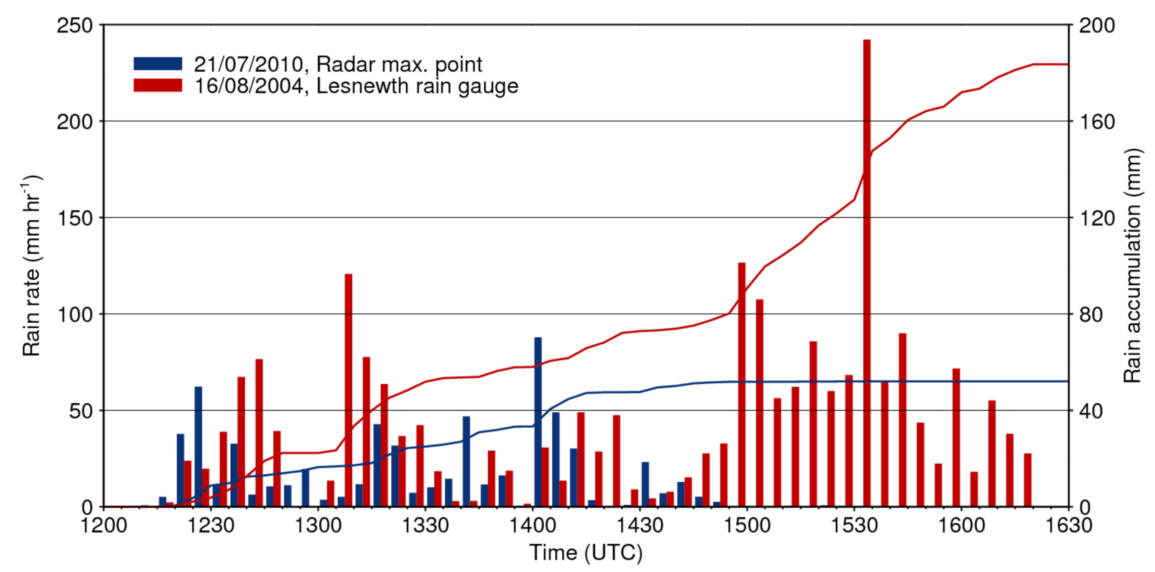

Figure 2. Time series of rain rate (bars) and rain accumulation (lines) for the point of maximum radar-derived rain accumulation on 21 July 2010 (blue) and for the tipping bucket rain gauge at Lesnewth, Cornwall on 16 August 2004 (red). A heuristic correction has been applied to the Lesnewth data to account for under-reading during periods of intense rainfall [1].

4. Numerical Simulation

- Simulation performed using the Met Office Unified Model (UM) with 1.5-km grid spacing and 70 vertical levels (UKV configuration)
- Initial and lateral boundary condition data taken from the operational NWP suite
- Model captures repeated development of convective cells along coastline and inland propagation after 1400 UTC
- Observed rainfall accumulation pattern is reproduced quite well but maximum is too low and around 100 km too far northeast (Fig. 3)

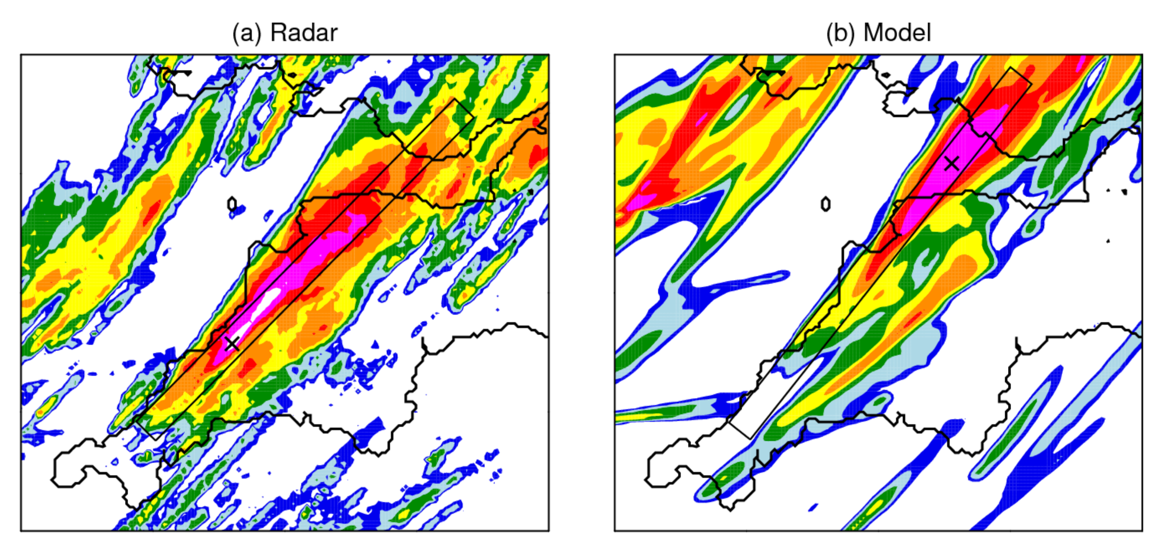

Figure 3. Accumulated rainfall (mm; see Figure 1 for scale) for 0900–1800 UTC on 21 July 2010 from (a) the radar and (b) the model simulation. The boxes show the areas used to produce the Hovmöller diagrams in Figure 4. These both originate at the same point, are 200 km long and 10 km wide, and are orientated such that they pass through the points of maximum accumulation (indicated by the crosses).

- Several issues with simulated system evolution (Fig. 4):
  - Onset of precipitation is delayed by around 90 minutes and occurs slightly too far northeast
  - Initiation of new cells occurs less frequently so they remain isolated rather than forming a continuous line
  - Cells are too large and intense, and evolve too slowly

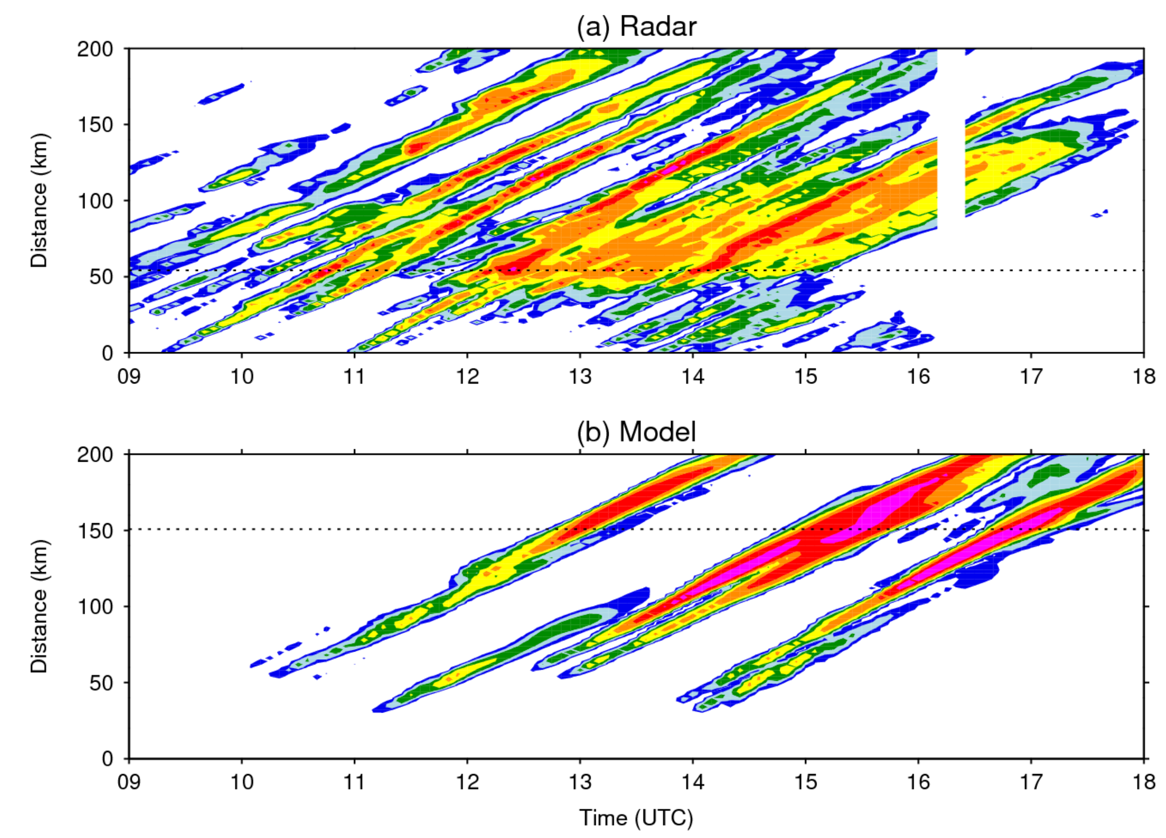

Figure 4. Hovmöller diagrams showing surface rain rate (mm hr^{-1}; see Figure 1 for scale) for 0900–1800 UTC on 21 July 2010 from (a) the radar and (b) the model simulation. Values were computed along the boxes shown in Figure 3 and averaged over the short axes. Dotted lines show the locations of the maximum rainfall accumulation.

- Divergence field (Fig. 5) shows that, like the Boscastle storm [2], this QSCS was forced by a quasi-stationary convergence line
- Inland propagation of the system after 1400 UTC was due to veering low-level flow ahead of an approaching trough to the west

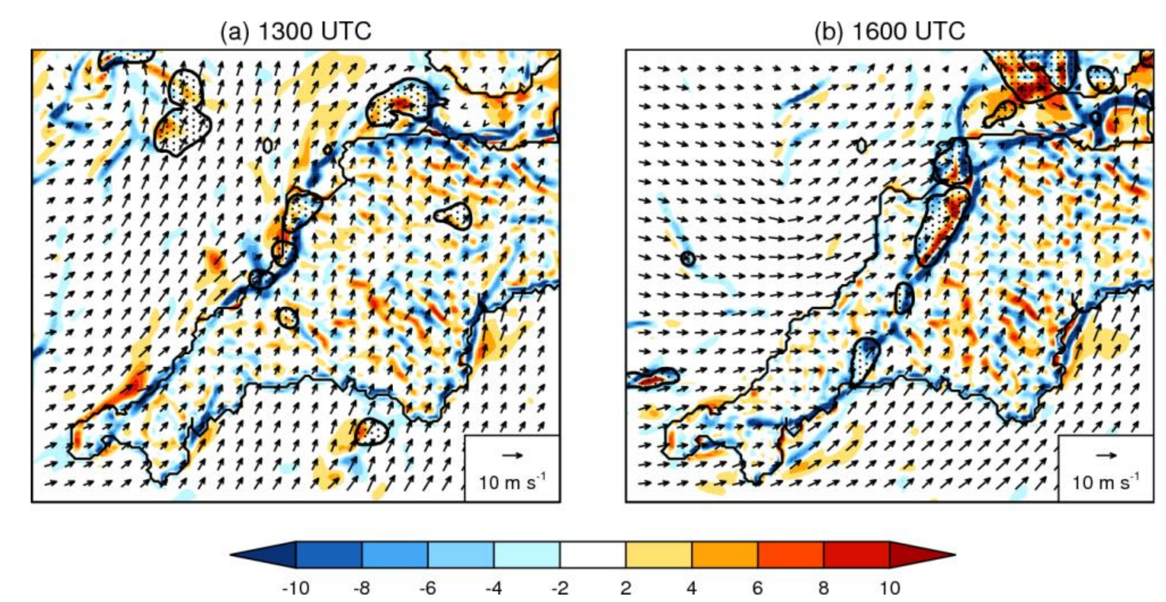

Figure 5. Divergence (10^{-4} s^{-1}) and wind vectors at 10 m, and surface rain rate > 0.25 mm hr^{-1} (black contours, stippled) in the model simulation at (a) 1300 and (b) 1600 UTC.

5. Convergence Line Formation

- Several sensitivity tests carried out to investigate the mechanisms controlling the convergence line

Name	Factor under investigation	Methodology
WEAKSUN	Differential surface heating	Solar constant reduced to 400 Wm^{-2}
SAMEROUGH	Differential surface roughness	Roughness length for momentum set to 4 x 10^{-5} m over land and sea
NOOROG	Orography	Land height over southwest peninsula set to zero
NOOUTFLOW	Convective outflow	Latent cooling in microphysics scheme switched off

- A positive land–sea temperature contrast was found to be a necessary condition for the development of the convergence line
- Other factors had only a minor influence on the convergence line

6. Sensitivity to Horizontal Resolution

- An additional simulation with 500-m grid spacing was performed
- Initial conditions and ancillary data were not changed
- The convergence line is better resolved, resulting in a greatly improved representation of the repeated initiation of convective cells and thus the accumulation pattern (Figs. 6 and 7)
- Rate of convective development is also improved, but rain rates are still too high, giving excessive accumulations

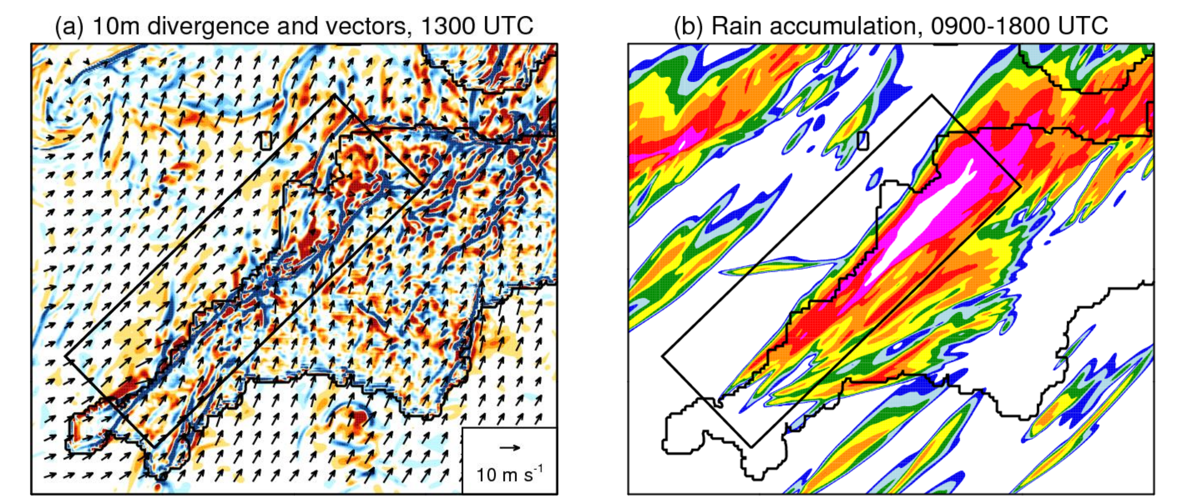

Figure 6. Output from the 500-m simulation: (a) 10-m divergence (10^{-4} s^{-1}; see Figure 5 for scale) and wind vectors at 1300 UTC; (b) accumulated rainfall (mm; see Figure 1 for scale) for 0900–1800 UTC.

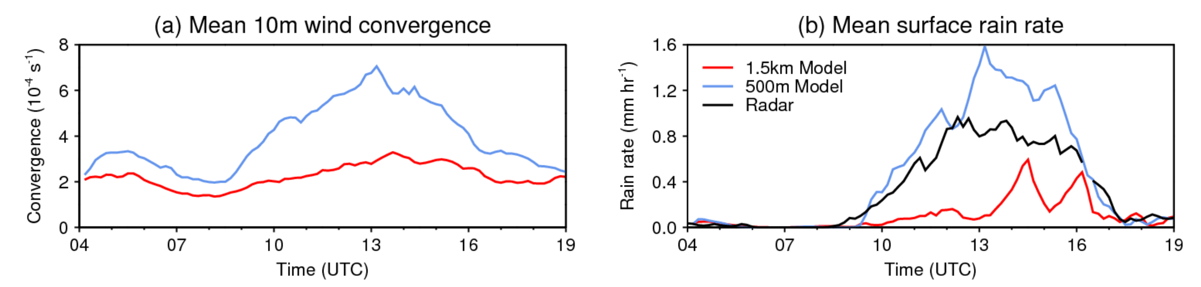

Figure 7. Time series, computed over the box shown in Figure 6, of (a) mean 10-m convergence and (b) mean surface rain rate from the 1.5-km (red) and 500-m (blue) grid-length simulations. The black line in (b) shows radar-derived values.

7. Conclusions

- **The 21 July 2010 QSCS was very similar to the Boscastle storm; however, differences in the rainfall intensity, system duration, and exact storm location resulted in very different impacts**
- **In both events, convective cells were repeatedly initiated along a quasi-stationary convergence line, which resulted from a balance between the ambient wind and a thermally driven onshore flow (sea breeze)**
- **The land–sea roughness contrast, orography, and convective outflow did not significantly influence the development of the convergence line in the 2010 case**
- **The highest resolutions currently used in operational NWP models may still be insufficient when forecasting convection initiated by narrow convergence lines**

References

1. Burt S. 2005. Cloudburst upon Hendraburnick Down: The Boscastle storm of 16 August 2004. *Weather* **60**: 219–227.
2. Golding B, Clark P, and May B. 2005. The Boscastle Flood: Meteorological analysis of the conditions leading to flooding on 16 August 2004. *Weather*, **60**, 230–235.

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