Quasi-stationary convective storms in the UK: A case study

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1. Introduction

Quasi-stationary convective storms (QSCSs) occur when convective cells are repeated triggered in roughly the same location for an extended period of time, and subsequently move with a consistent track over a confined area. The combination of high rain rates and a long precipitation duration gives large accumulations and the potential for flash flooding [1]. Here, we present a case study of a QSCS in the UK from summer 2010.

2. Case Study – 21/07/2010

- Persistent, narrow line of storms along north coast of Southwest Peninsula.
- Line was quasi-stationary between 12 and 15 UTC, and propagated inland thereafter.
- Maximum accumulations exceeding 50 mm; most of this fell from 12–15 UTC.

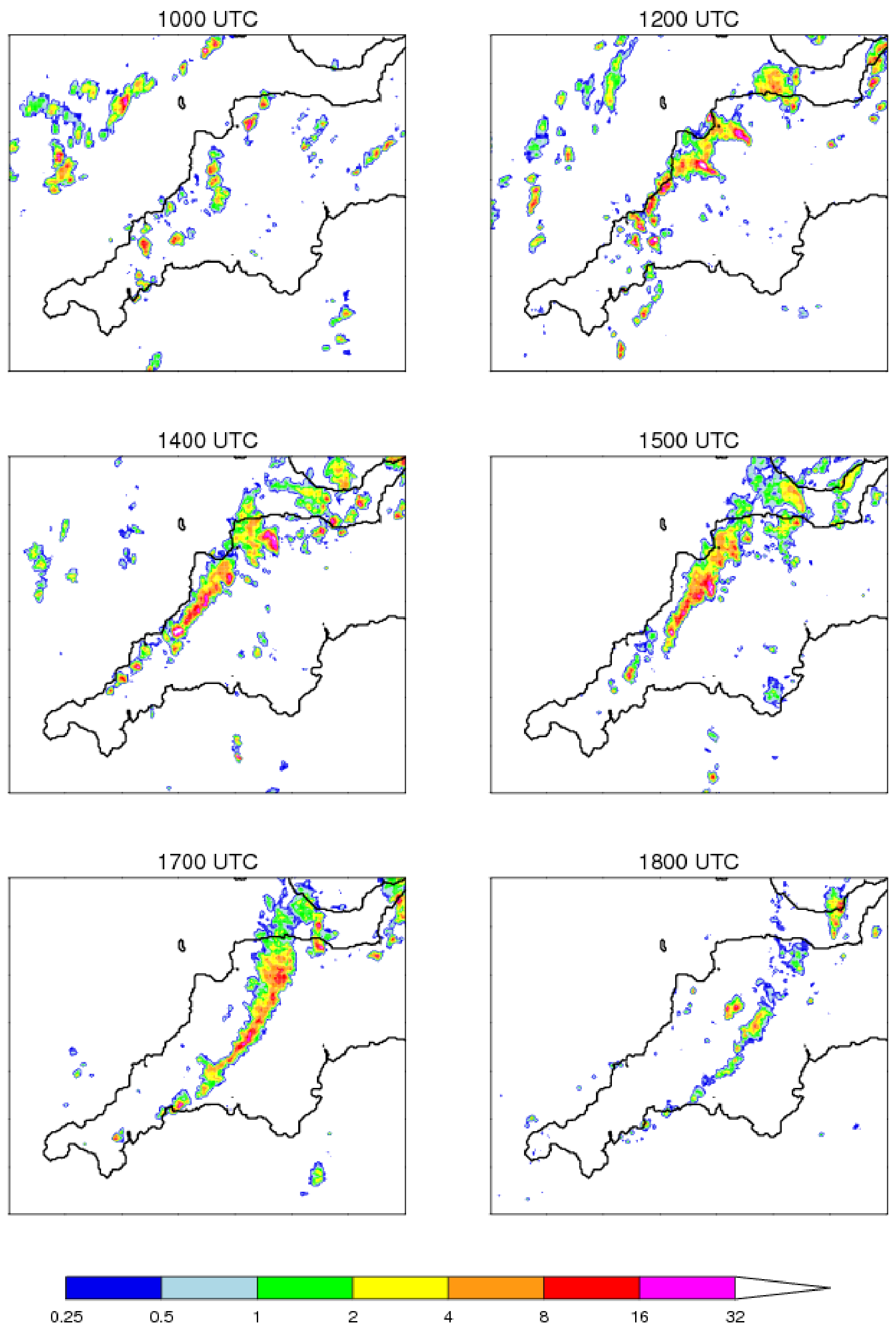

Figure 1. Radar-derived surface rainfall rates (mm hr^{-1}) over the Southwest Peninsula from the Met Office's Nimrod system, for various times on 21/07/2010.

3. Comparison to Boscastle storm

Similarities:

- QSCS over north coast of Southwest Peninsula;
- Highest accumulations along slopes of Bodmin Moor;
- Moist southwesterly flow over a deep layer.

Differences:

- Significantly higher rain rates and accumulations in Boscastle case, leading to severe flash flooding;
- Greater instability and column moisture in Boscastle case (Fig. 2);
- Slower synoptic evolution in Boscastle case;
- Boscastle storm developed later but remained stationary for longer.

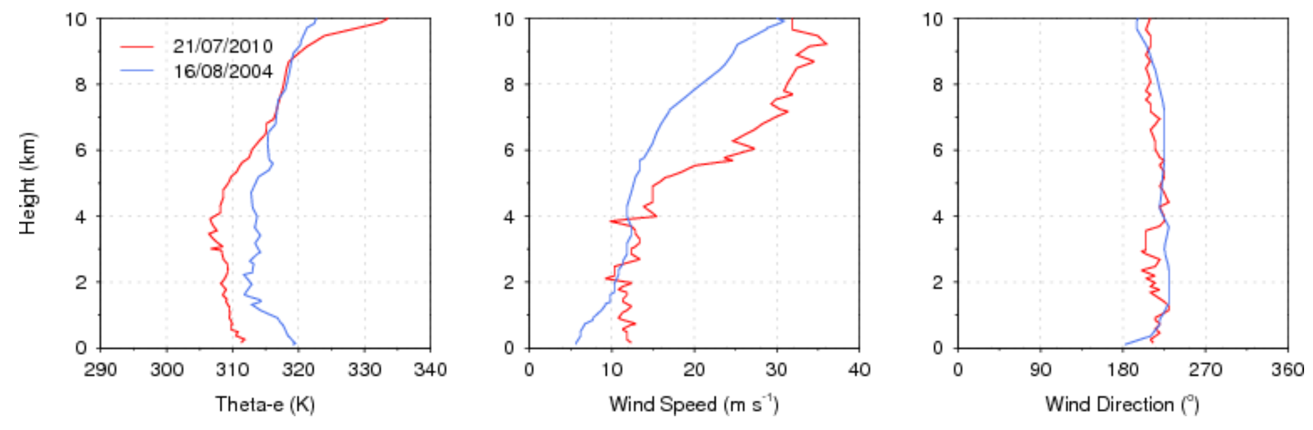

Figure 2. Vertical profiles of equivalent potential temperature (left), wind speed (middle), and wind direction (right) derived from 12 UTC Camborne soundings on 21/07/2010 (red) and 16/08/2004 (blue).

4. Simulation Methodology

- Event simulated using Met Office Unified Model (UM) with 1.5-km grid-length and 70 vertical levels (UKV model).
- Simulation initialised from 04 UTC analysis from operational UKV model; lateral boundary condition (LBC) data from operational NAE model.
- Smaller domain covering Southwest Peninsula, with same resolution, nested within UKV model for computational efficiency in sensitivity tests.

5. Control Simulation

- Model reproduces observed precipitation accumulation pattern fairly well (Fig. 3, top panels)
- Captures storm development along coastline and inland propagation after 15 UTC
- Several issues with simulated storm evolution (Fig. 3):
    - Initiation is ~ 1.5 hours too late and ~ 30 km too far north along coastline
    - Cells are isolated rather than forming a continuous line
    - Precipitation intensity is too great during afternoon

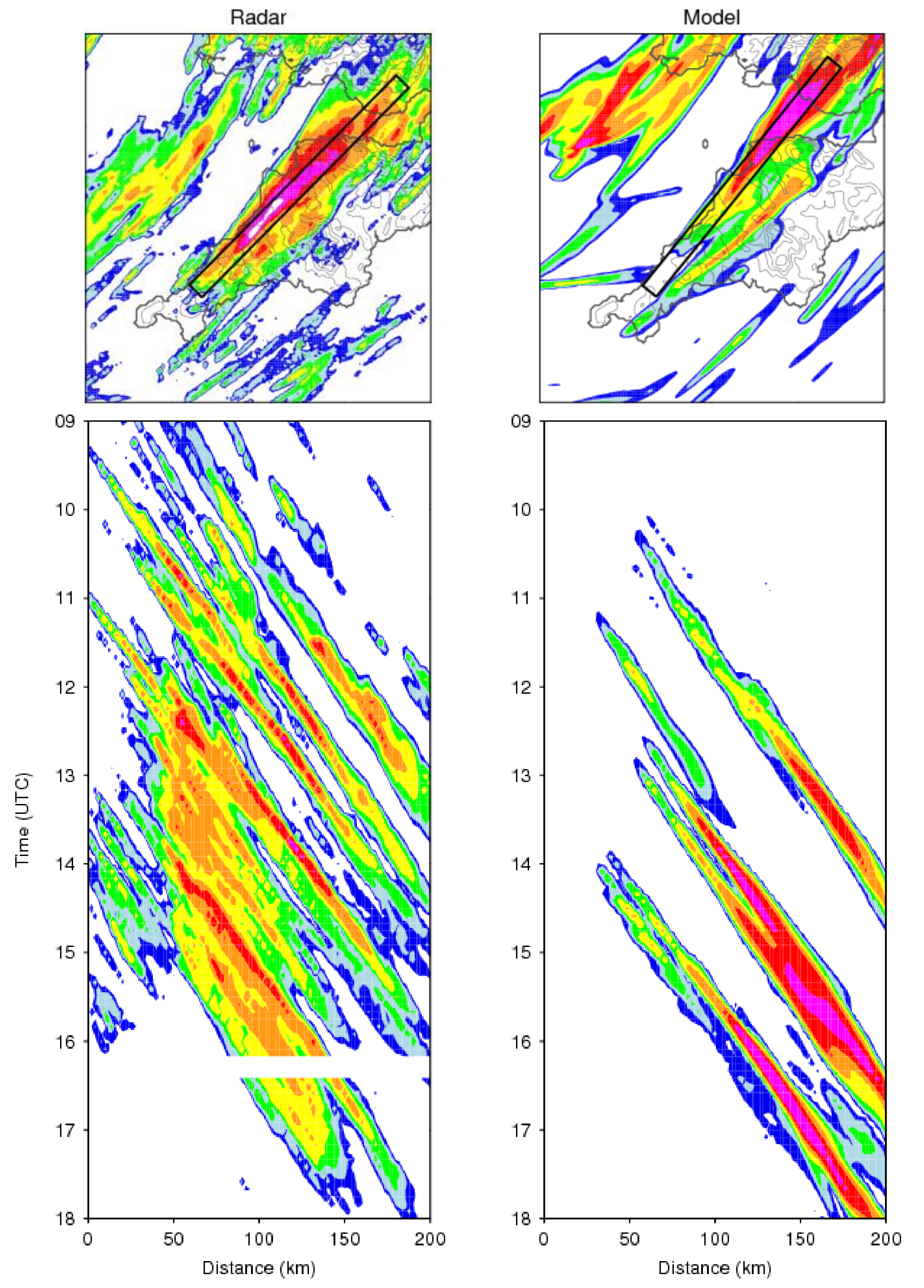

Figure 3. Top panels: Accumulated rainfall (mm) from radar (left) and model (right) for 09–18 UTC. Boxes show the regions for which Hovmoller diagrams were created – points were taken along the long axis of each box and averaged over the short axis. Bottom panels: Hovmoller diagrams of rain rate (mm hr^{-1}) from radar (left) and model (right) for the boxes in the corresponding top panels. Colour scale is same as in Figure 1.

- Divergence field (Fig. 4) shows that, like the Boscastle storm [2], this QSCS was forced by a persistent narrow convergence line.
- Inland propagation of storms after 15 UTC is due to veering wind ahead of approaching trough to the west.

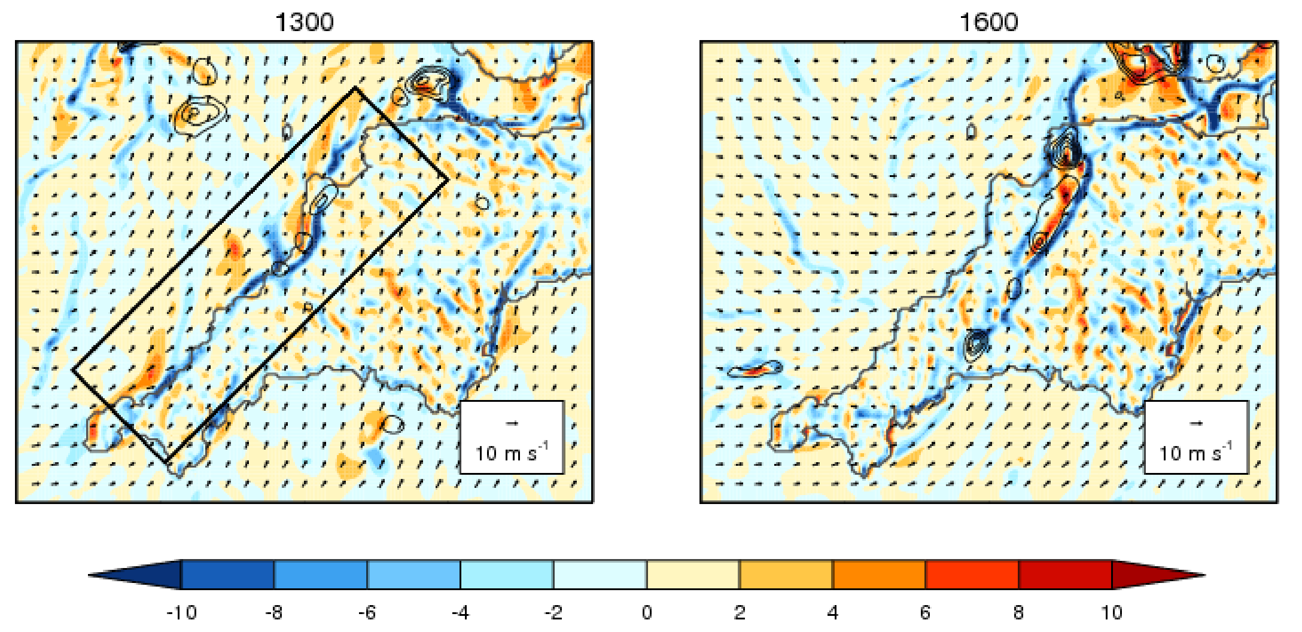

Figure 4. Horizontal wind divergence at 10 m (colours, 10^{-4} s^{-1}), rain rate (black contours; 1, 5, 10, 20 and 40 mm hr^{-1}), and wind vectors at 10 m for 13 UTC (left) and 16 UTC (right). Black box in left panel shows area used in Fig. 5.

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6. Sensitivity Tests

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

Name	Factor under investigation	Methodology
OROG	Orography	Land height over southwest peninsula set to zero
DZ0	Differential surface roughness	Roughness length for momentum over land fixed to sea value
DT	Differential surface heating	Solar constant reduced to 400 W m^{-2}
CP	Cold pools	Temperature changes associated with evaporation of rain and melting of snow removed

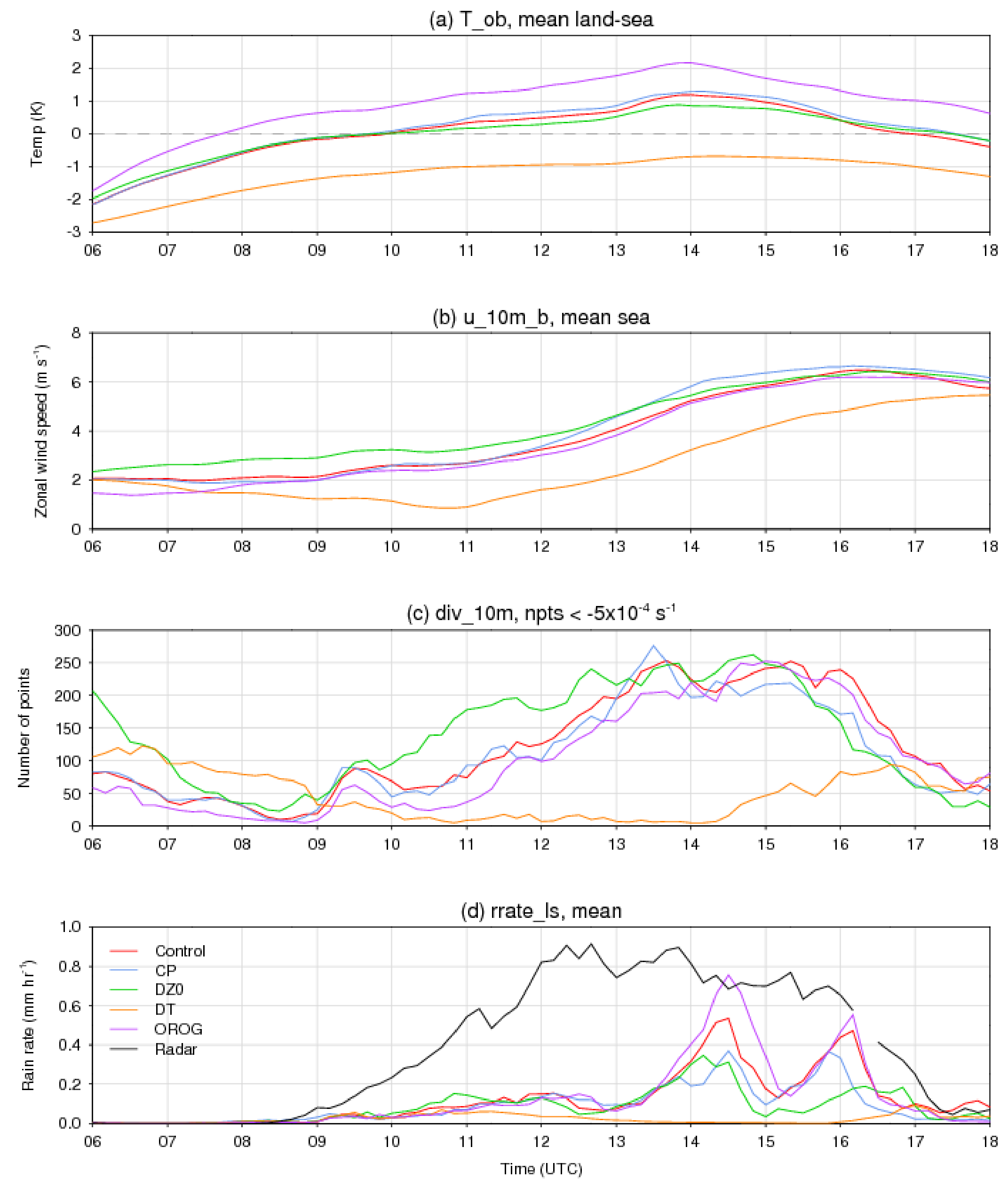

Figure 5. Time series of four variables computed over box shown in Fig. 4 for control run and each of the sensitivity tests listed in the table above. Variables are: (a) mean land-sea temperature difference at 1.5 m, (b) mean zonal wind speed at 10 m over sea-points, (c) number of grid-points with 10-m convergence greater than 5×10^{-4} s^{-1}, and (d) mean rain rate. Black line in (d) shows values from radar.

- Differential heating of land and sea surface is the primary control on the convergence line - frictional backing of wind over land, orography, and storm cold pools all have only a minor influence.

7. Conclusions and Future Work

- **Convergence line which forced QSCS appears to be due to a balance between the shore-parallel low-level flow and a thermal circulation associated with differential surface heating (c.f. Boscastle case [2]).**
- **Convergence was only weakly sensitive to frictional effects over land, orographic features, and latent cooling associated with microphysical phase changes.**
- **Delayed storm initiation may be a resolution issue – a run with 500-m grid-spacing is being carried out to investigate this possibility.**
- **A climatology of QSCSs in the UK is being developed to identify favourable regions for QSCS development.**
- **Idealised simulations will be used to investigate further the development of stationary convergence lines alone coasts.**

References

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2. Golding, B., P. Clark, and B. May, 2005: The Boscastle Flood: Meteorological analysis of the conditions leading to flooding on 16 August 2004. *Weather*, **60**, 230–235.

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