Can CAPE be used as a postprocessing tool for systematic errors in shortwave radiation forecasts?

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1 Introduction

Convective available potential energy (CAPE) can be used to represent the stability of the atmosphere. CAPE measures the potential buoyancy of a theoretical rising air parcel and therefore is an indication of tropospheric instability at a given time [Holley et al., 2014]. Large amounts of CAPE indicate that an air parcel would be much warmer than its surrounding environment and therefore, very buoyant. It is defined by equation 1.

$$CAPE = R_d \int_{EL}^{LFC} (T_v' - T_v) dlnp \tag{1}$$

where LFC is the Lifting Condensation Level, EL is the Equilibrium Level, T_v is the virtual temperature and p is the pressure.

This report is a result of research into the use of CAPE as a representation of convective instability in the atmosphere and convective clouds. These clouds would result in differing values of shortwave radiation (SW) and could produce a possible systematic error in reanalysis data. Through post-processing this systematic error could be reduced to create a better representation of SW in reanalysis over Ireland.

2 Data

The surface value of *Convective Available Potential Energy* from ERA-Interim. ECMWF describe the parameter as "For computational efficiency CAPE is computed as the vertical integral of excess of equivalent potential temperature of an undilute updraught compared to the saturated equivalent potential temperature of the environment. The results tends to be about 20% higher than the CAPE based on virtual temperature." It has units of J kg^{-1}. CAPE is available as forecasted parameter in 3 hourly time steps initialized at 00Z and 12Z. In ERA-Interim there is an error in how CAPE is calculated at step 3 (+03 hours forecast). Therefore, the value of CAPE at 03UTC and 15UTC will always be erroneously zero. The error does not affect other steps.

No equivalent parameter could be found at the time in MERRA2 reanalysis data. The closest was *vertical velocity*. However, this was only available on each model level and not as a single value for all levels. Therefore, it was decided not to be a suitable parameter to use in this analysis.

3 CAPE Climatology

Holley et al. [2014] studied the climatology of CAPE in Great Britain using a dynamically downscaled WRF simulation. They found that there are three main CAPE seasons: 'land dominated CAPE' between April and September, 'Sea dominated CAPE' between September and January and 'low CAPE' from January to April. In summer, higher CAPE occurs more frequently over land than over adjacent seas, a result of the warmer land surface temperatures (LSTs) compared to the warmer sea surface temperatures (SSTs). The majority of 'land CAPE' is generated as a result of cooling aloft by polar air masses, coupled with warm LSTs (figure 1(b)). In, Britain CAPE is at its lowest during winter. High CAPE is most frequent over open waters during winter months because of the warmer SSTs relative to LSTs. Autumn is the main transitional period from 'land CAPE' to 'sea CAPE' as LSTs continue to decrease whereas SSTs retain warmth for some time, combined with increasingly cold air aloft. Spring has the lowest CAPE values as LSTs begin to recover, although slowly, whereas SSTs remain relatively cool coupled with cold air aloft and hence a limit to the occurrence of extreme vertical temperature gradients.

Holley et al. [2014] also found a reduction in CAPE in urban areas which is possibly due to reduced water vapour in the model over urban areas leading to less CAPE and more convective inhibition (CIN).

4 Data Analysis

Data analysis was performed on the CAPE from ERA-Interim. Similar results to that mentioned in section 3 were found for Ireland. See figure 2 in which Belmullet is taken to represent a coastal location and Birr to represent an inland location. The 'land dominated CAPE' is evident in figure 2b with a peak in CAPE during the summer, the 'sea dominated CAPE' is also evident during winter in figure 2a.

4.1 Correlations

Further analysis was performed using correlations of daily mean CAPE against SW error (observed SW subtracted from ERA-Interim SW). Correlations were also separated into positive and negative SW errors as in figure 3. Each station has a different pattern associated with it (not shown) and no clear conclusions were found.

5 Large SW error events

The daily CAPE during the largest 10 positive and negative SW error events for each station were examined. No conclusions were found due to the low resolution.

6 Future Work

CAPE is highly variable both spatially and temporally. There is potential to return to this research with a higher resolution model. CAPE in a high resolution model could provide indications of instability and therefore evidence of convective cloud in the region. Holley et al. [2014] describe how "the ability of the model to simulate accurately CAPE depends heavily on the vertical grid spacing in the critical layers".

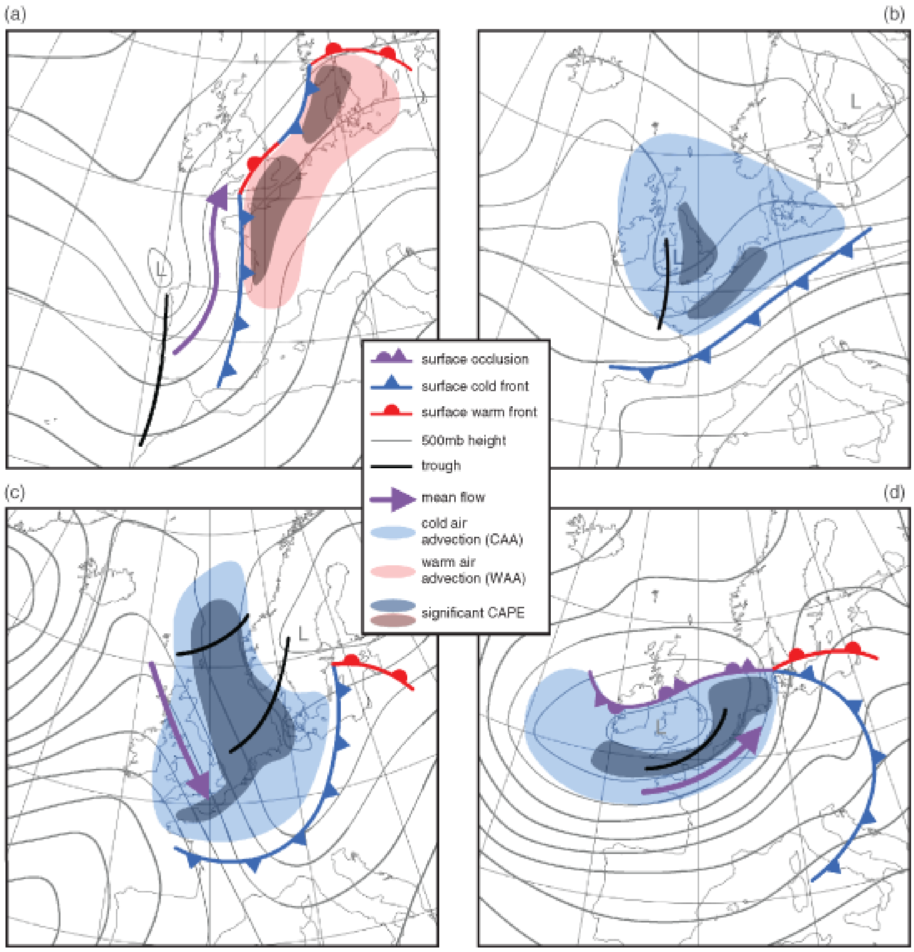
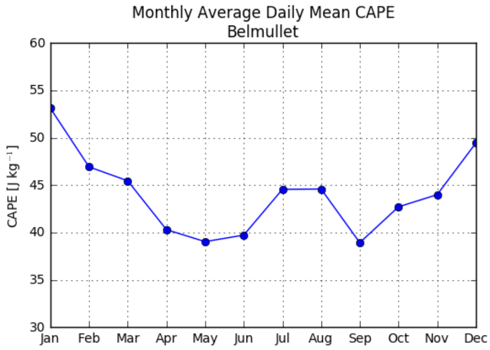


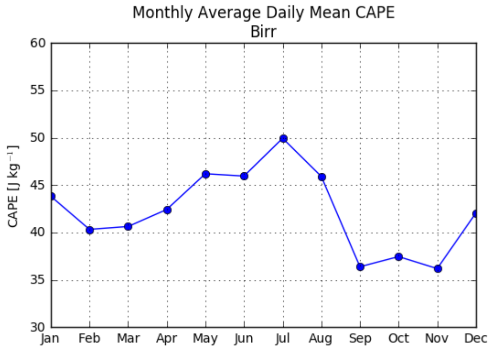
Figure 1: Schematics of typical CAPE-generating synoptic setups across Britain. (a) Represents a Spanish plume (adapted from ESTOFEX, 2010), (b) a general slack setup with cooling aloft during the summer, (c) a cold, showery northerly flow and (d) a cool, showery west or southwesterly flow. Reproduced from Holley et al. [2014].

Bibliography

DM Holley, SR Dorling, CJ Steele, and N Earl. A climatology of convective available potential energy in Great Britain. *International Journal of Climatology*, 34(14):3811–3824, 2014.

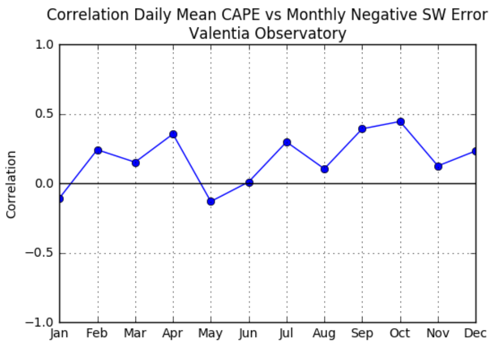


(a) Coastal

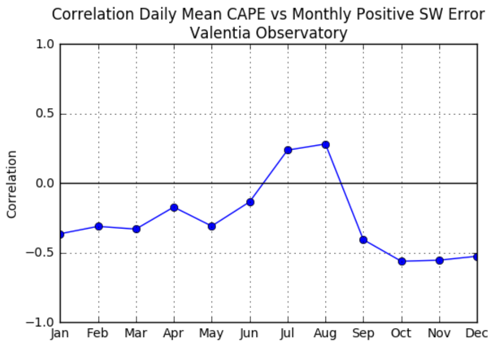


(b) Inland

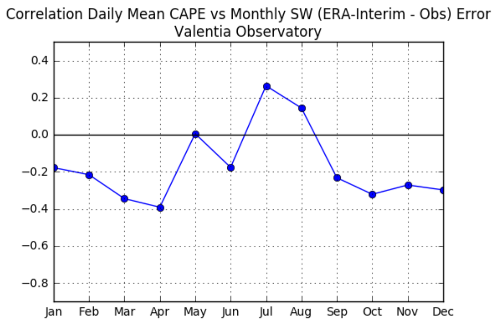
Figure 2: Annual cycle of daily mean CAPE at (a) Belmullet representing a coastal location and (b) Birr representing an inland location.



(a) Coastal



(b) Inland



(c) Inland

Figure 3: Annual cycle of the correlation of daily mean CAPE with SW errors for (a) negative SW errors, (b) positive SW errors and (c) all SW errors at Valentia.