Office of Climate Change

Queensland Climate Change Centre of Excellence

Research Report

Department of Environment and Resource Management

Rainfall in Queensland

Part 2: Is the inter-annual variability in Queensland rainfall due to variability in rainfall frequency, intensity or both?

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Walker Institute

National Centre for Atmospheric Science
Natural Environment Research Council

Toward Q2 Tomorrow's Queensland

Queensland Government

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1 Executive Summary

This report investigates the effect of changes in the number of rainy days, the amount of rain that falls on rainy days or a combination of the two on the inter-annual variations in Queensland rainfall. The objective is to determine the association between climate drivers and the occurrence of rainfall in Queensland. Analysis of this relationship will enable focusing on the impact of those drivers that influence the key portions of the rainfall distribution in Queensland by using this information and knowledge to predict how these drivers will influence the occurrence of rainfall in a changing climate. Understanding the frequency and magnitude of these phenomena can significantly improve societal resilience.

Knowledge of the relationship between climate drivers and occurrence of rainfall allows for a better understanding of global climate model outputs. The future analysis of key climate drivers for Queensland rainfall variability depends on which of these drivers affect the key portions of the rainfall distribution that are variable on inter-annual temporal scales. Because of limited horizontal resolution global climate models are not able to capture observed distribution of rainfall intensity particularly for intense rainfall. However, if the models are able to capture the observed frequency of rainfall in Queensland, then this information could be used to assess the inter-annual variability of rainfall amounts in these models. Focusing attention on changes in the frequency and intensity of Queensland rainfall in association with global and regional climate phenomena will help understand how these drivers will influence rainfall occurrence in future.

The gridded SILO rainfall dataset was analysed for 1900-2008. Analysis was performed on the November-April half-year, as this period accounts for at least 80% of the annual rainfall in Queensland. Several thresholds of rainfall were used to define a "rainy day": 5 mm/day, 10 mm/day, 25 mm/day and 50 mm/day.

2 Introduction

This preliminary report analyses observed Queensland rainfall to determine whether the dominant control on inter-annual rainfall variability is variability in the frequency of rainfall, the intensity of rainfall, or the combination of variability in frequency and intensity.

To accomplish this objective, a series of thresholds for daily rainfall are applied to a dataset of interpolated station observations collected from across Queensland. The mean and inter-annual standard deviation of the frequency and intensity of “wet days” above each of the rainfall thresholds is computed to determine, for each region of Queensland, which portions of the distribution of daily rain amounts are the most variable on inter-annual temporal scales. The mean contribution to the annual-total rainfall from wet days above each threshold allows for analysis of the relative importance of rain events of different intensities. When the contributions are combined with information on the mean and variability in the frequency and intensity of wet days above each threshold, the vulnerability of Queensland’s annual rainfall to changes in the distribution of daily rainfall can be inferred.

Further, this report introduces a method for partitioning the seasonal or annual rainfall anomaly into contributions from:

(a) changes in only the frequency of rainfall

(b) changes in only the intensity of rainfall, and

(c) the combined influence of the changes in frequency and intensity of rainfall.

When the same wet-day thresholds of daily rainfall are applied to this technique, it is possible to determine to what extent the seasonal or annual rainfall anomaly is influenced by changes in the frequency and intensity of daily rainfall amounts above a given threshold. In this report, this partitioning technique is applied to November–April rainfall, during which Queensland receives approximately 80 per cent of its annual rainfall. The partitioning is performed for November–April half-year in the upper and lower terciles of total rainfall separately, so as to determine whether the contributions from rainfall frequency and intensity are consistent for wet and dry years.

This report answers two questions. First, is Queensland’s annual rainfall sensitive to variability in either the frequency or intensity of daily rainfall above a certain threshold? In other words, are there particular portions of the rainfall distribution that are highly variable on inter-annual temporal scales, either in their frequency or intensity, but which, in the mean, make a significant contribution to Queensland’s annual rainfall?

Secondly, is the inter-annual variability in November–April Queensland rainfall primarily due to changes in the frequency or intensity of rainfall, or a combination of those changes? The answers to these questions will inform future analysis of the key climate drivers of Queensland rainfall variability, by focusing attention on the most important features of the distribution of daily rainfall for inter-annual rainfall variability.

3 Methods

3.1 Data

This report uses rainfall analyses from the SILO dataset. SILO consists of rain-gauge observations that have been kriged onto a 0.05° x 0.05° regular longitude–latitude grid. For ease of plotting and analysis, the SILO data were first interpolated onto a 0.25° × 0.25° grid using an area-weighted method. Although SILO covers the period 1881–2008, only 1900–2008 have been used here due to concerns about the number of observations in the dataset prior to the twentieth century.

It is important to note that the kriged SILO grid extends across the Australian coastline, such that the figures in this report show data over the ocean immediately surrounding Australia. As no oceanic observations were included in SILO, these points are entirely an extrapolation from coastal values; they should be ignored. Future versions of this report will include a high-resolution land–sea mask.

3.2 Separating "wet seasons" from "dry seasons"

As described in Section 1, the technique of partitioning seasonal rainfall anomalies into the contributions from the changes in the frequency and intensity of rainfall is applied to the November–April total rainfall anomalies separately for wet and dry years. The SILO analyses show that, in the mean, Queensland—here defined crudely as all land points within a box extending over 10–28°S and 140–153°E—receives 80 per cent of its annual rainfall during this half-year. Sections 2.3 and 2.4 describe the technique itself. This section describes how the SILO dataset is separated into wet and dry years.

At each 0.25° grid cell, the timeseries of total November–April SILO rainfall for all years in 1900–2008 was separated into terciles. November–April half-year within the upper tercile of total rainfall are hereafter referred to as "wet seasons"; November–April half-year within the lower tercile are referred to as "dry seasons". These terms are distinct from the normal definition of a "wet season" as the portion of the year in which a region receives the majority of its annual rainfall. In this report, "season" always refers to the November– April half-year. It is also important to note that because the terciles are defined at each grid cell separately, the seasons contained within each tercile are not consistent from one grid cell to the next.

There is considerable variation between dry (Fig. 1a) and wet seasons (Fig. 1c) across Queensland, emphasising the higher inter-annual variability in rainfall in the state. In the mean, wet seasons have at least 50 per cent more rainfall than dry seasons at all grid cells in Queensland, with the coastal strip and the interior experiencing the greatest variation between wet and dry (Fig. 1d). The higher variability in the interior is not surprising, given the relatively low frequency of rainfall there, as will be discussed in Section 3.1.

3.3 Partitioning of rainfall anomalies

This report examines whether wet (dry) seasons in Queensland are primarily due to more (less) frequent rain events, more (less) intense rain events, or the simultaneous change of frequency and intensity (i.e. the interference of the changes in frequency and intensity). To accomplish this, at each grid cell we consider the anomalous rainfall during any particular anomalously wet or dry November-April half-year, R'

$$R' = R - R \qquad (1)$$

Where R is rainfall during the season and R is the climatological seasonal rainfall. This anomalous rainfall can be partitioned into those portions that can be explained (a) by change in only the frequency of rain events (R'_{freq}), (b) by change in only the intensity of rain events (R'_{intns}) and (c) by the interference of these changes in frequency and intensity (R'_{resid}). Given a climatological frequency (F) and intensity (I) of rainfall at that grid cell, defined using all years in the study period, these three terms contributing to R' can be defined as

$$R'_{freq} = (F - F)\,\bar{I} \qquad (2)$$

$$R'_{intns} = (I - \bar{I})\,F \qquad (3)$$

$$R'_{resid} = (I - \bar{I})\,(F - F) \qquad (4)$$

where F and I are frequency and intensity of rainfall, respectively, in the particular wet or dry season under consideration. In a wet season, then, R'_{freq} gives the expected rainfall anomaly from only the change in rainfall frequency, maintaining the climatological intensity; R'_{intns} gives the expected rainfall anomaly from only the change in rainfall intensity, maintaining the climatological frequency; R'_{resid} is the residual, or interference, term due to the fact that the changes in the frequency and intensity occur simultaneously (i.e., in the same season). If all rain events are considered then

$$R'_{freq} + R'_{intns} + R'_{resid} = (F - F)\,\bar{I} + (I - \bar{I})\,F + (I - \bar{I})\,(F - F) \qquad (5)$$

$$= F\bar{I} - FI + FI - FI + FI - FI - F\bar{I} + FI \qquad (6)$$

$$= FI - FI \qquad (7)$$

$$R'_{freq} + R'_{intns} + R'_{resid} = R' \qquad (8)$$

If a non-zero threshold for daily rainfall is used to detect "wet days", then eqn 8 must be modified; see Section 2.4.

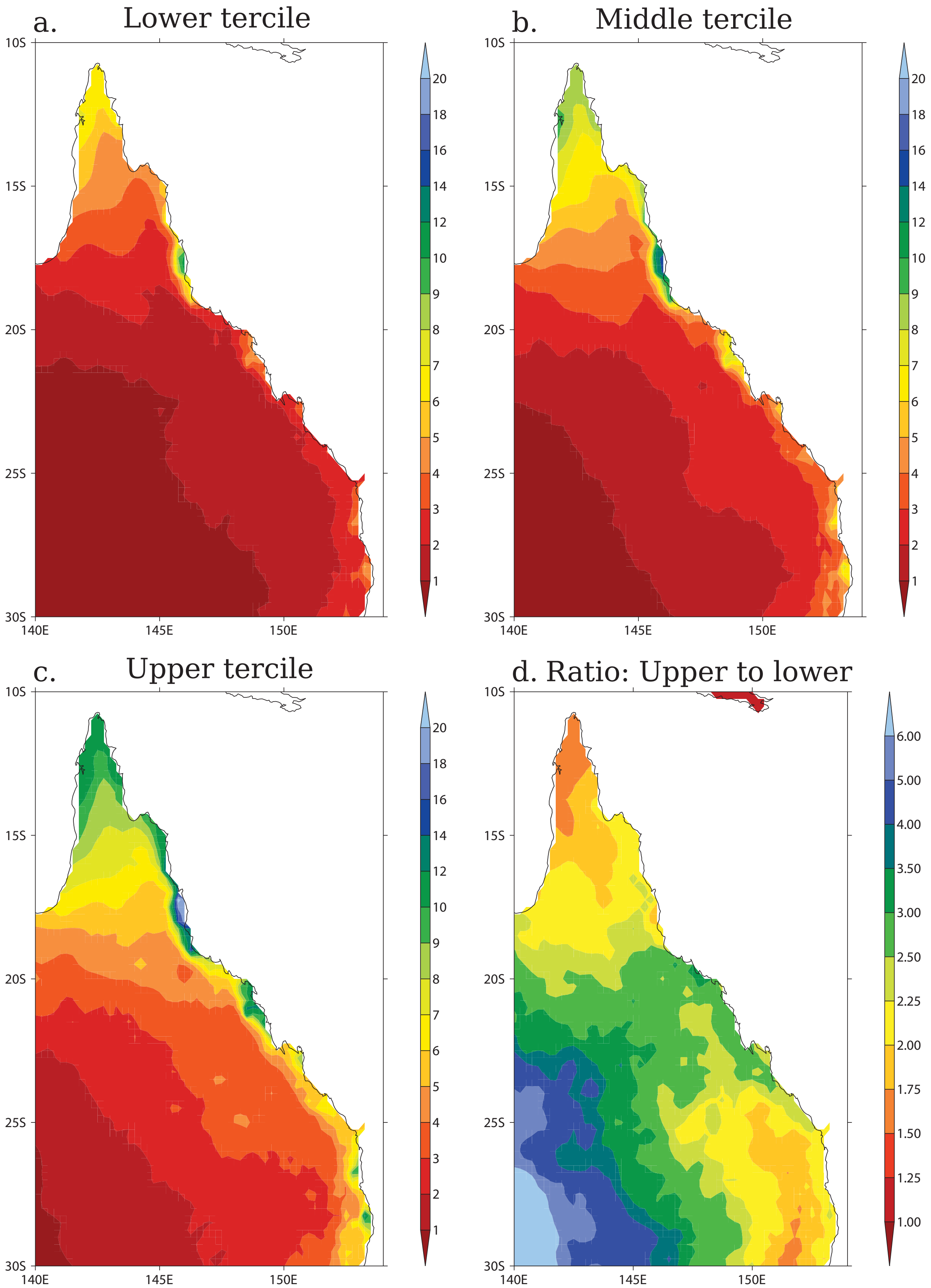

Figure 1: (a–c) Mean rainfall (mm day^{-1}) during November–April half-year in (a) the lower tercile ("dry seasons"), (b) the middle tercile ("normal seasons") and (c) the upper tercile ("wet seasons"); (d) the ratio of mean rainfall in wet seasons to mean rainfall in dry seasons. The terciles are defined at each 0.25° grid cell separately, based on the 1900–2008 SILO analyses.

This analysis is applied to all wet and dry seasons. Sums of R', R'_{freq}, R'_{intns} and R'_{resid} are computed across all wet seasons and across all dry seasons. This allows one to define the fractional contribution to the total rainfall anomaly across all wet or dry seasons from only changes in frequency (C_{freq}), only changes in intensity (C_{intns}) and only the interference of changes in frequency and intensity (C_{resid}) as

$$C_{freq} = \frac{\sum R'_{freq}}{\sum R'} \quad (9)$$

$$C_{intns} = \frac{\sum R'_{intns}}{\sum R'} \quad (10)$$

$$C_{resid} = \frac{\sum R'_{resid}}{\sum R'} \quad (11)$$

From eqn. 8, it is clear that the sum of C_{freq}, superscripts of ^{dry} and ^{wet} will hereafter be used to refer to the fractional contributions in dry and wet seasons, respectively (e.g. C^{wet}_{freq} is the fractional contribution to the total rainfall anomaly across all wet seasons from only the change in rainfall frequency).

3.4 Partioning when using rainfall thresholds

Setting a non-zero threshold daily rainfall amount for considering a day to be "wet" is useful when analysing which portions of the rainfall distribution change most between wet and dry seasons. The partitioning of a seasonal rainfall anomaly into contributions from changes in frequency, intensity and their interference applies equally well to zero and non-zero thresholds for wet days. For non-zero thresholds, however, the sum of C_{freq},

C_{intns} and C_{resid} is no longer equal to unity. Rather, the sum is equal to the fractional contribution to the total rain anomaly from events over the threshold defined. It is important to note that this quantity may be greater than unity. For example, in a dry season, the rainfall from intense events may decrease by more than the seasonal anomaly if the rainfall from light events actually increases. In this case, the sum of C^{dry}_{freq}, C^{dry}_{intns} and C^{dry}_{resid} for a large threshold (e.g., 25 millimetres per day) would be greater than unity.

4 Results

4.1 Mean and variability of rainfall frequency

Before undertaking a detailed analysis of wet and dry seasons using the method in Section2.3, this report first examines the climatology and inter-annual variability of the frequency and intensity of rainfall in eastern Australia. Here, all months in the SILO 1900–2008 record are used. Four daily rainfall thresholds for wet days are considered: 5 millimetres per day, 10 millimetres per day, 25 millimetres per day and 50 millimetres per day. A threshold of 100 millimetres per day was also applied, but there were only 19 grid cells—all in coastal north-eastern Queensland—with a mean frequency of more than one wet day per year. While it may be beneficial to examine such extreme events in future, perhaps in the context of tropical cyclones or east-coast lows, this report does not consider the 100 millimetres per day threshold.

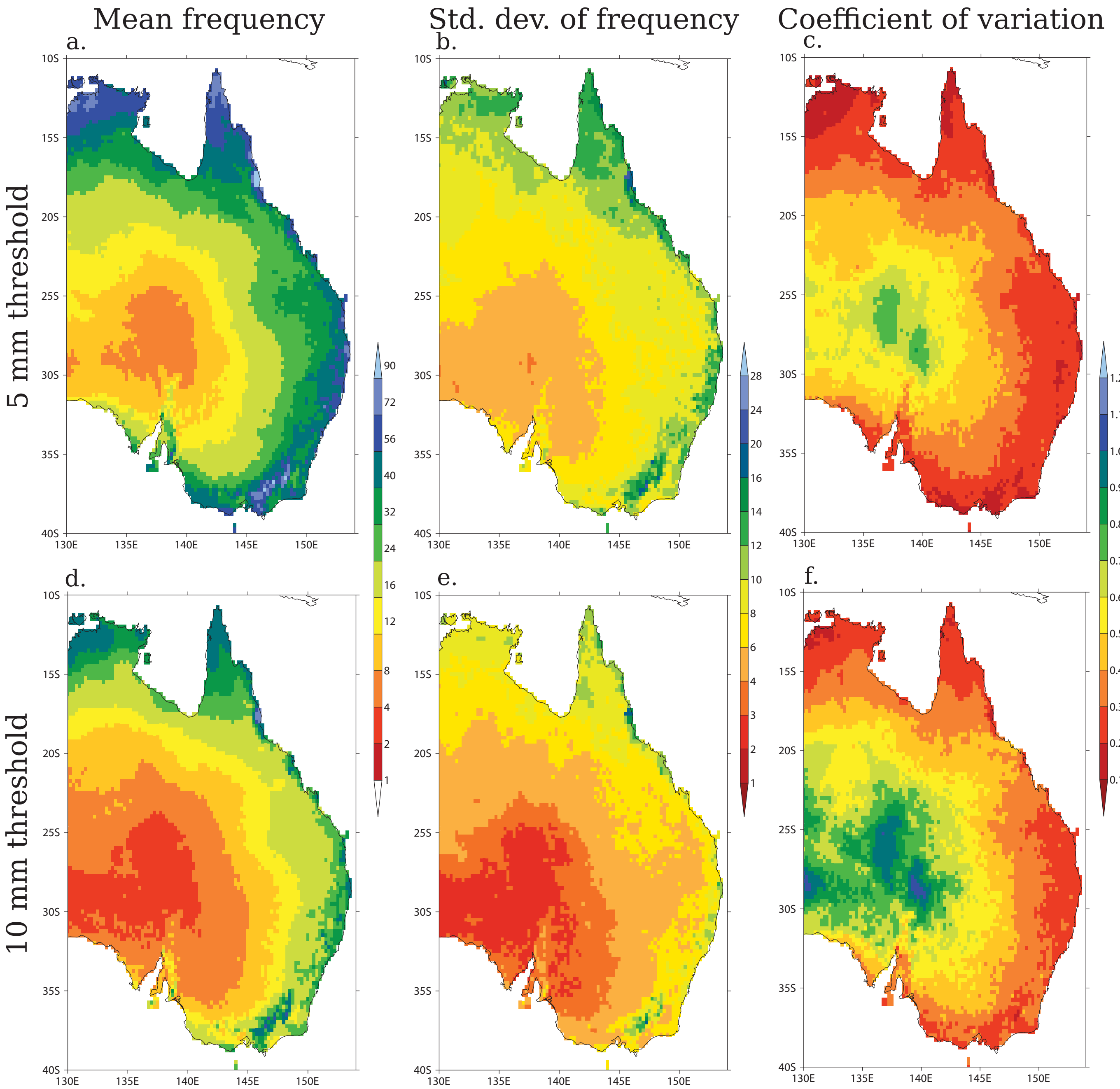

Figure 2: For rainfall thresholds of (top) 5 mm day^{-1} and (bottom) 10 mm day^{-1}, (left) the mean number of days year^{-1} with rainfall above that threshold, (middle) the standard deviation in days year^{-1} above that threshold and (right) the coefficient of variability (the standard deviation divided by the mean) for the number of days year^{-1} above that threshold.

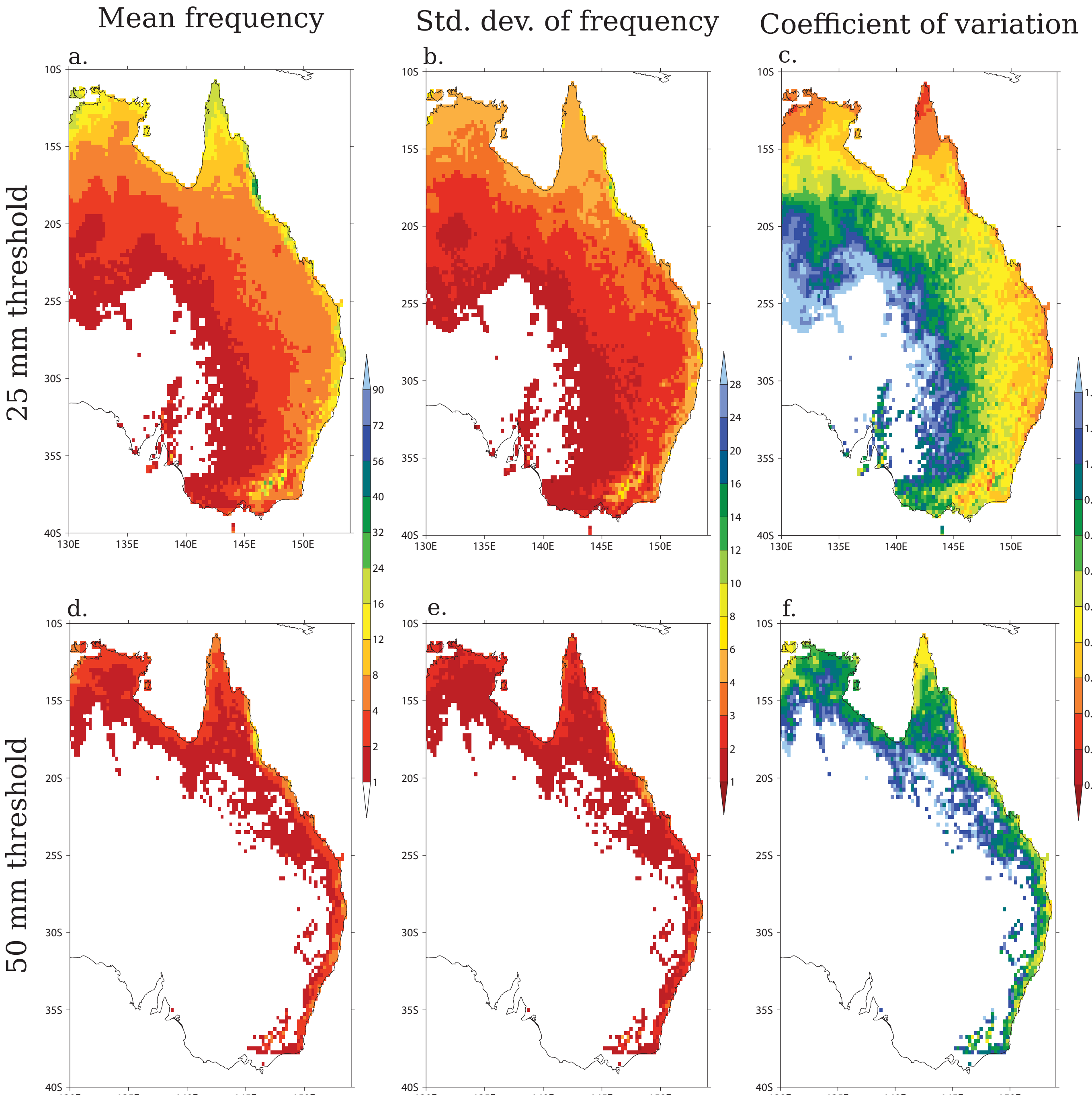

Figure 3: As in Fig. 2, but for rainfall thresholds of (top) 25 mm day^{-1} and (bottom) 50 mm day^{-1}. White grid cells have less than one event year^{-1} above the rainfall threshold; the inter-annual variability and coefficient of variability are not computed for these grid cells.

In the climatological mean, most of Queensland experiences more than 24 days per year with daily rainfall at or above 5 millimetres per day (Fig. 2a). Coastal and northern regions of Queensland have the highest frequency of rainfall greater than 5 millimetres per day, with values greater than 40 days per year. While in south-eastern Queensland these days are spread relatively evenly throughout the November–April wet season, in the north most events occur in December–February and are associated with the summer monsoon.

There is relatively low inter-annual variability in the frequency of rainfall above 5 millimetres per day (Fig. 2b), with the wettest regions of the state having a standard deviation less than 20 per cent of their means (Fig. 3c). Similar results are found for a threshold of 10 millimetres per day, with a reduction in frequency across the state

(Fig. 2d), but still a modest inter-annual variability (Fig. 2e) and a coefficient of variability of 30 per cent or less in the wettest regions (Fig. 2f).

All grid cells in Queensland receive, in the mean, at least one day per year with rainfall over 25 millimetres per day (Fig. 3a). There is substantial inter-annual variability in the frequency of that rainfall (Fig. 3b), however, particularly in the interior of the state where the standard deviation approaches or exceeds the mean (Fig. 3c). Across the northern peninsula and along the coastline, the coefficient of variability is 0.30–0.50, or roughly twice that for the 5 millimetres per day threshold. The frequency of intense rainfall is therefore far more prone to inter-annual fluctuation than the frequency of lighter rainfall. This high inter-annual variability of heavy rainfall, particularly along the coast, will become critical when the contribution of heavy rainfall to the annual total rainfall is considered in §3.3. Using a threshold of 50 millimetres per day yields similar results to the 25 millimetres per day threshold, although these events are far fewer in number, with only coastal grid points exceeding 4 days per year in the mean (Fig. 3d). The inter-annual standard deviation (Fig. 3e) is more than half the mean throughout the state (Fig. 3f).

4.2 Mean and variability of rainfall intensity

The mean, inter-annual standard deviation and coefficient of variability of daily rainfall intensity are computed for each of the four rainfall thresholds used in Section 3.1. The mean intensity is calculated from all days in the 1900–2008 that are above the given threshold; the inter-annual standard deviation is computed from the mean intensities in each year; the coefficient of variability is as described in Section 3.1.

Even when using a relatively low, 5 millimetres per day threshold for detecting wet days, the mean daily rainfall exceeds 15 millimetres per day across most of Queensland (Fig. 4a). The inter-annual variability in that intensity is very low (Fig. 4b); in the vast majority of the state, the coefficient of variability is less than 0.30 (Fig. 4c). The coefficient of variability for intensity is considerably lower than that for frequency (Fig. 2c), which provides a first indication that the inter-annual variability in total seasonal rainfall may be controlled more by the variability in rainfall frequency than rainfall intensity. When the threshold for wet days is increased to 10 millimetres per day , there is a corresponding increase in the mean intensity on those wet days (Fig. 2d) but the inter-annual variability in intensity remains low (Fig. 2e), particularly compared to the mean intensity (Fig. 2f).

On days with rainfall greater than 25 millimetres, the mean intensity of rainfall in coastal Queensland is larger than 40 millimetres per day (Fig. 5a). The inter-annual standard deviation in that intensity is still small, however, (Fig.5b) as only a few locations have a coefficient of variation greater than 0.30 (Fig. 5c). The results for a wet-day threshold of 50 millimetres per day (Figs. 5d–f) are consistent with those for a threshold of 25 millimetres per day.

4.3 Contributions to the annual total

This section considers the contributions to the annual total rainfall made by days with rainfall greater than each of the four thresholds—5 millimetres, 10 millimetres, 25 millimetres and 50 millimetres—used in Sections 3.1 and 3.2. For each wet-day threshold, these contributions are calculated separately for each year in the 1900–2008 SILO dataset; the mean contributions across all years are considered here.

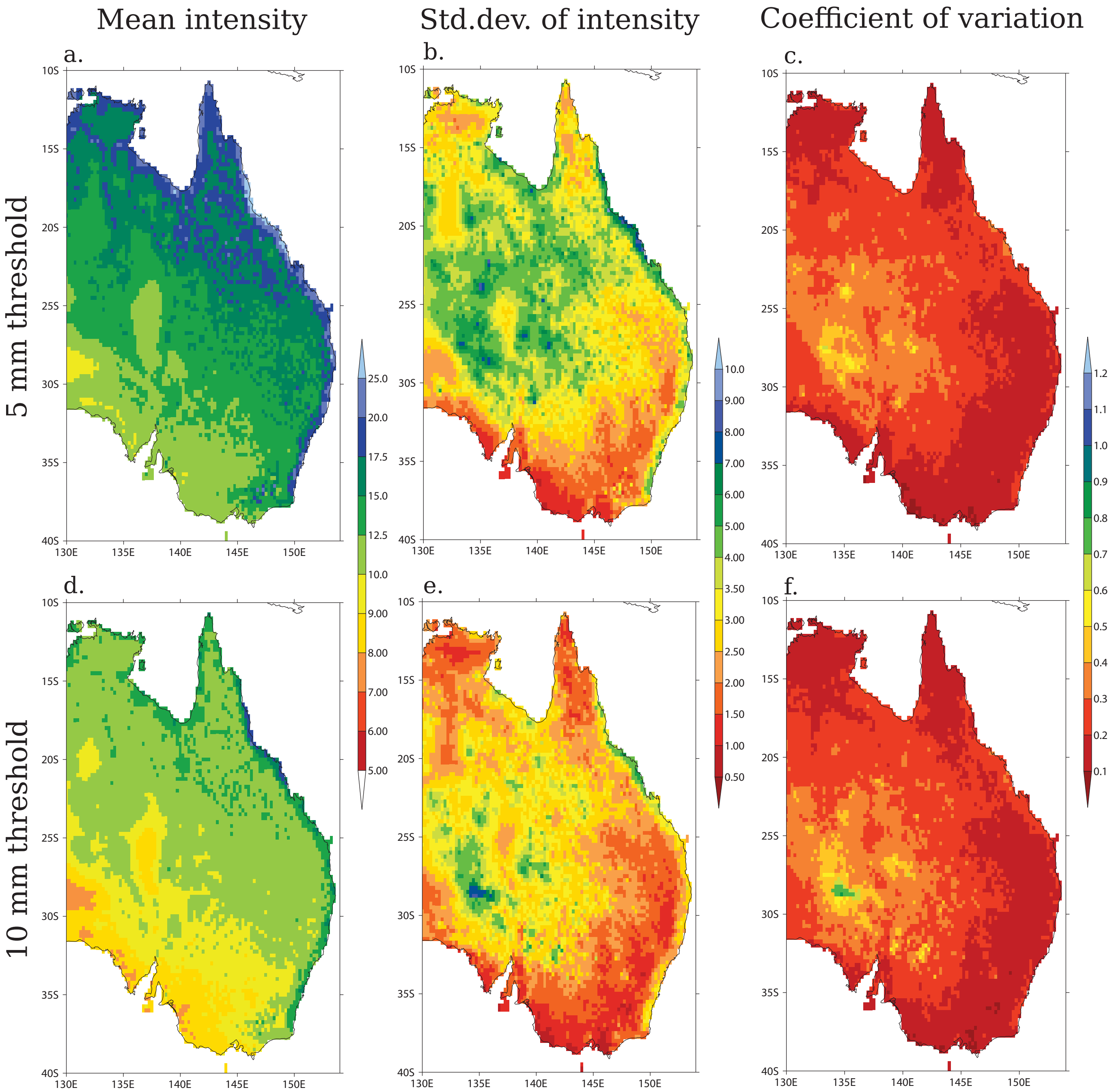

Figure 4: For rainfall thresholds of (top) 5 mm day^{-1} and (bottom) 10 mm day^{-1}, (left) the mean intensity of rainfall (mm day^{-1}) on days with rainfall above that threshold, (middle) the inter-annual standard deviation in the intensity of rainfall (mm day^{-1}) on days with rainfall above that threshold and (right) the coefficient of variability (the standard deviation divided by the mean) for the intensity of rainfall on days with rainfall above that threshold.

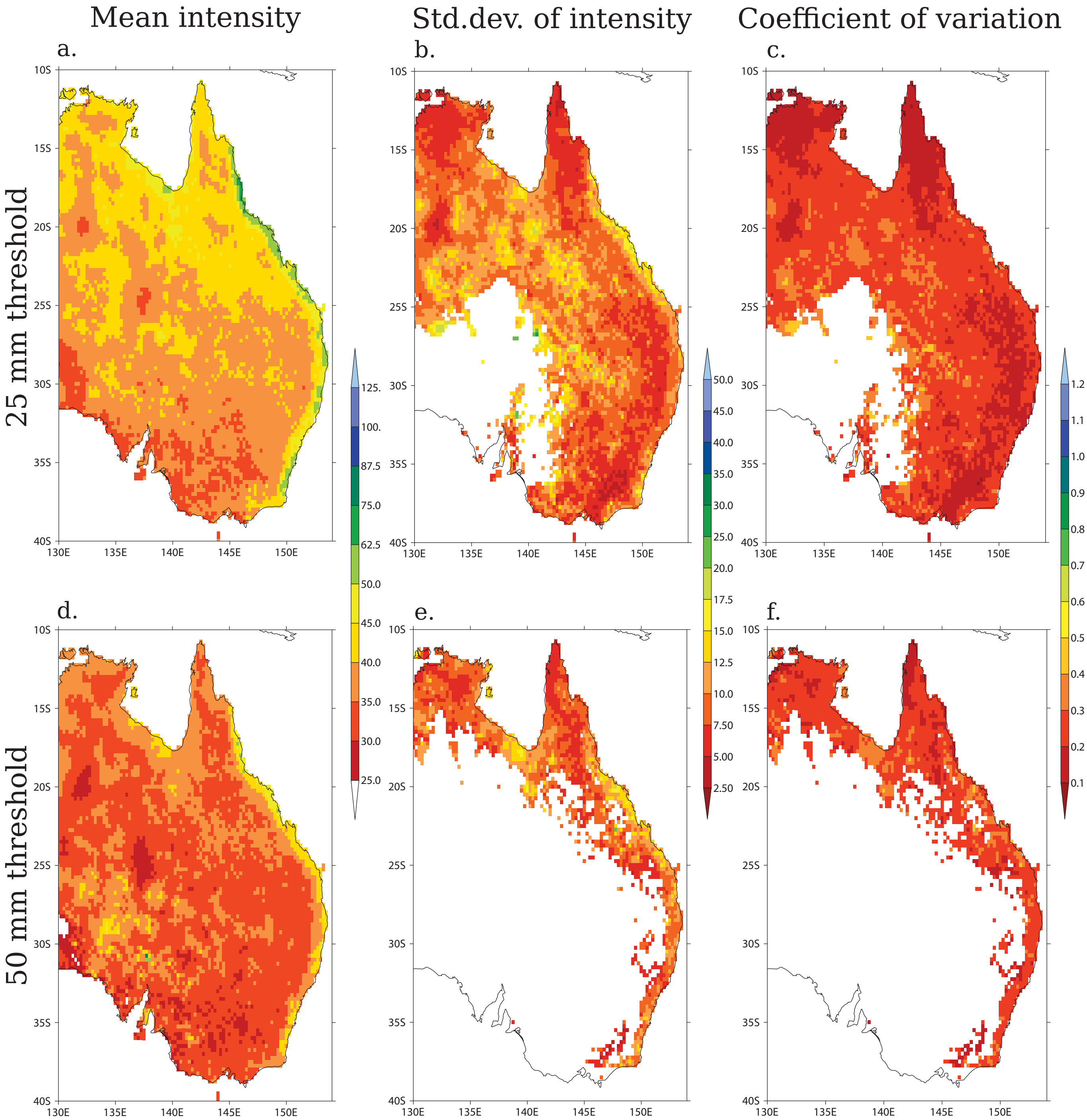

Figure 5: As in Fig. 4, but for rainfall thresholds of (top) 25 mm day^{-1} and (bottom) 50 mm day^{-1}. White grid cells have fewer than one day year^{-1} above the rainfall threshold in the mean; the standard deviation and coefficient of variability are not computed for these grid cells.

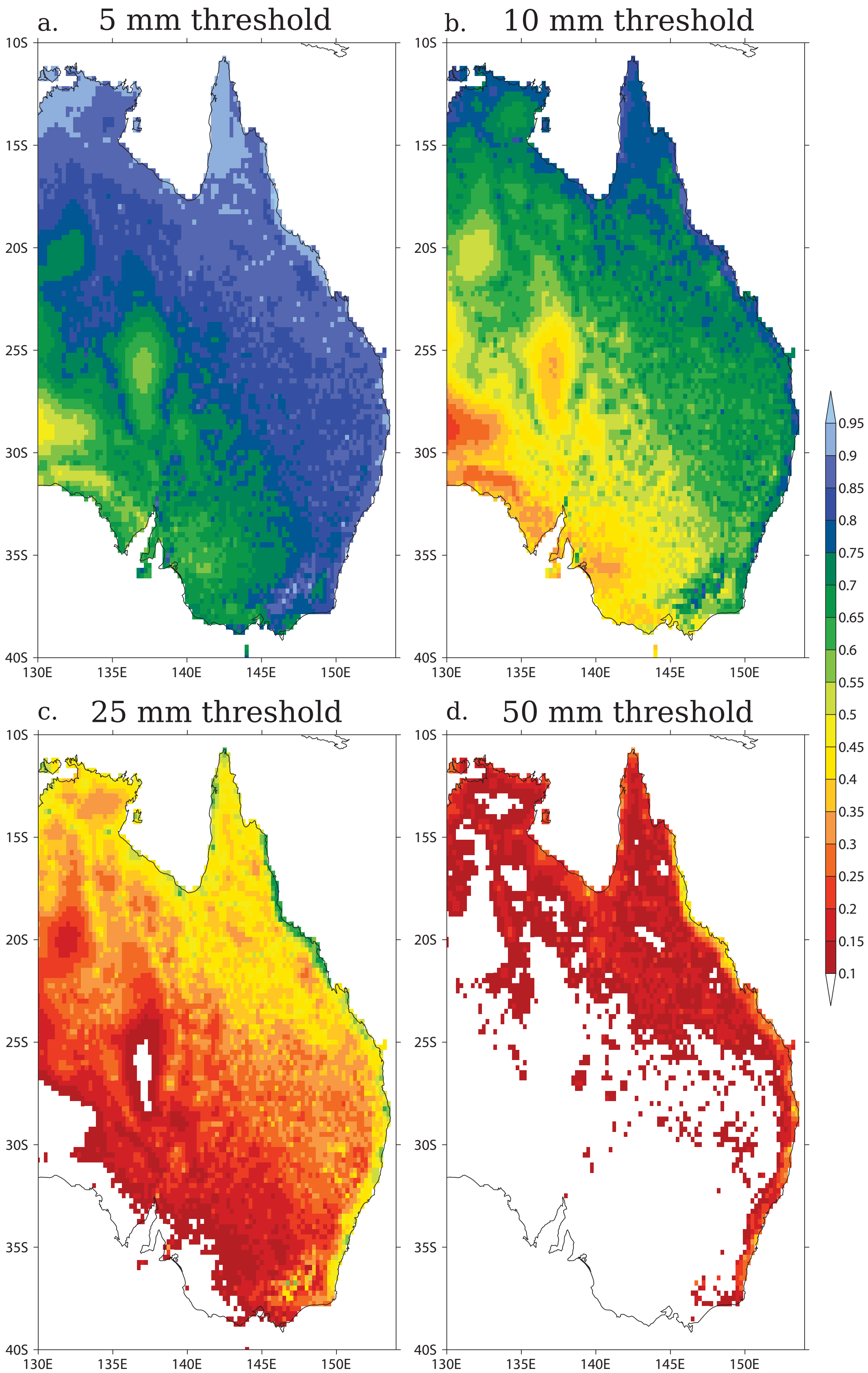

Figure 6: The mean fractional contribution to the annual total rainfall from days with rainfall greater than (a) 5 mm, (b) 10 mm, (c) 25 mm and (d) 50 mm. White grid cells have fewer than one day year^{-1} above the threshold in the mean; the contribution to the annual total is not computed for these grid cells.

Days with rainfall totals greater than 5 millimetres are responsible for nearly all of the annual total in Queensland (Fig. 6a). This contribution is highest along the coast and in the northern peninsula, where it exceeds 90 per cent; across the remainder of the state the contribution is generally at or above 80 per cent.

Days exceeding the threshold of 10 millimetres per day comprise more than 60 per cent of the annual rainfall throughout Queensland, increasing to nearly 80 per cent along the coast (Fig. 6b).

Even when a threshold of 25 millimetres per day is used, the fractional contribution remains above 40 per cent in most of Queensland (Fig. 6c).

Days with rain in excess of 50 millimetres per day make a substantial contribution to the annual total only in north-eastern coastal Queensland, but it is remarkable that the mean contribution there is more than 30 per cent (Fig. 6d).

These results indicate that intense rain events (i.e. those days with rainfall greater than 25 millimetres) form an essential contribution to the annual total rainfall across Queensland. Yet these events are also highly variable on inter-annual temporal scales, particularly in their frequency (Figs. 3b,e) if not in their intensity (Figs. 5b, e). This suggests that Queensland's annual rainfall is highly vulnerable to shifts in the frequency of the most intense rain events.

4.4 Partitioning of rainfall anomalies

In this section, seasonal (November–April) rainfall anomalies in seasons in the upper and lower terciles of total rainfall are partitioned into the contributions from changes in rainfall frequency, rainfall intensity and the interference of frequency and intensity. Note that while the previous sections considered the entire year, this section analyses only the November–April half-year. The same rainfall thresholds are employed here as were used in Sections 3.1 and 3.2. The partitioning technique was described in Sections 2.3 and 2.4.

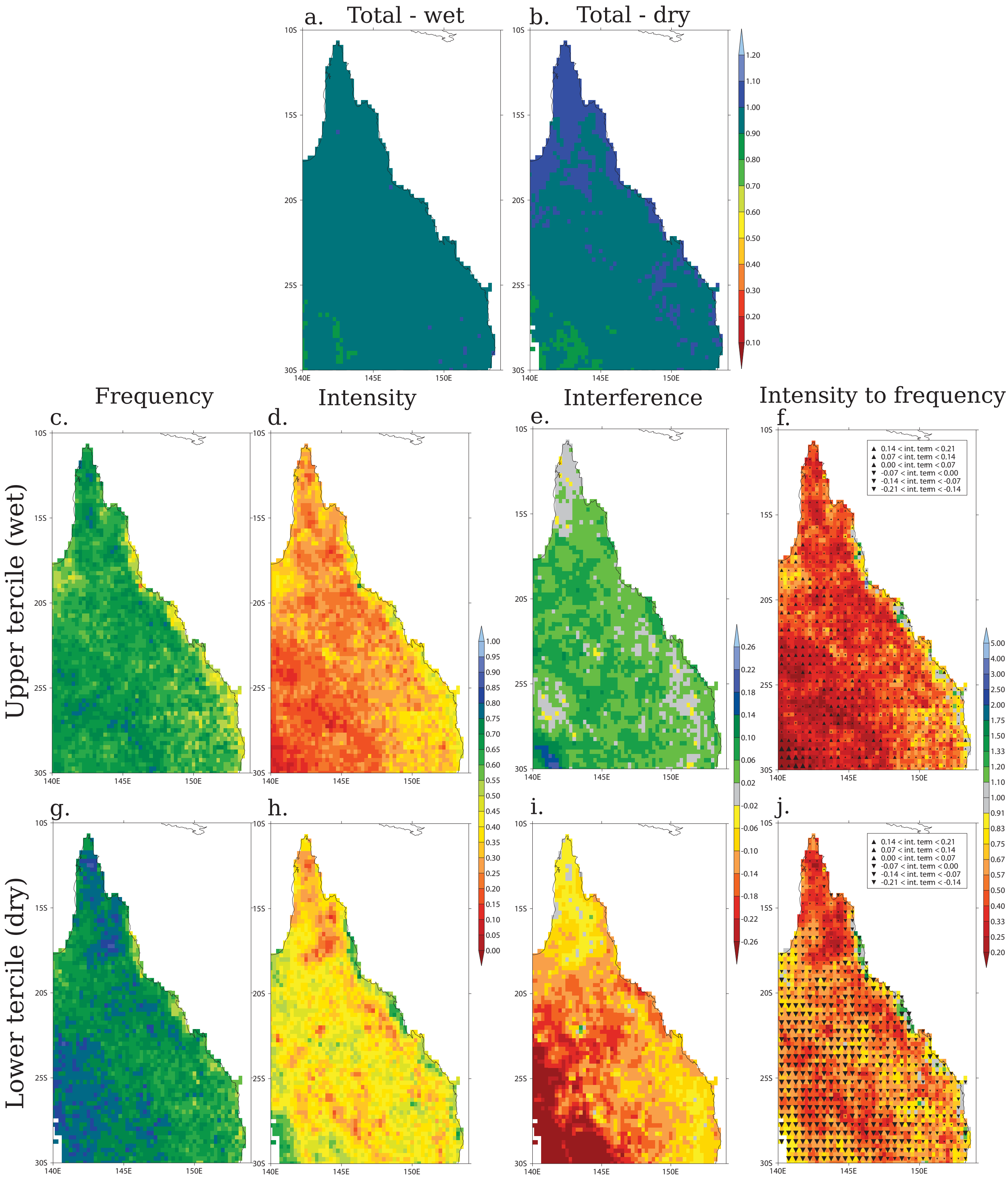

Figure 7: Using a wet-day threshold of 5 mm day^{-1}, (top) the total fractional contribution to the rainfall anomalies in (left) wet seasons and (right) dry seasons from changes in wet days; the contribution to rainfall anomalies in (middle) wet seasons and (bottom) dry seasons from (left column) the change in only the frequency of wet days, (second) the change in only the intensity of wet days, (third) the change due only to the interference of changes in frequency and intensity of wet days, (right) the change due only to intensity divided by the change in only frequency.

Variations in the frequency and intensity of wet days with rainfall greater than 5 millimetres per day account for nearly all of the seasonal rainfall anomaly in both wet (Fig. 7a) and dry (Fig. 7b) seasons. (As described previously, "wet (dry) seasons" are seasons in the upper (lower) tercile of total seasonal rainfall, where the terciles are computed for each grid cell separately.)

The total fractional contribution made to the anomalous rainfall in wet and dry seasons from wet days exceeding 5 millimetres of rainfall is nearly unity at all grid cells in Queensland. Combined with Fig. 6a, this result suggests that 5 millimetres per day is a suitable minimum threshold for wet days when analysing rainfall in Queensland, as it clear that days with rainfall less than 5 millimetres contribute very little to the seasonal rainfall anomaly in either wet or dry seasons.

The seasonal rainfall anomalies are partitioned into the fractional contributions from the changes in frequency alone (C_{freq}), intensity alone (C_{intns}) and their interference (C_{resid}) for wet seasons (Fig. 7c–e) and dry seasons (Fig. 7g–i). In addition, the ratio of the contributions of intensity and frequency are computed for wet (Fig. 7f) and dry seasons (Fig. 7j) to aid in determining which contribution dominates the seasonal rainfall anomaly. Contributions with the same (opposite) sign as the seasonal anomaly are shown as positive (negative) values. Thus C^{dry} is negative (Fig. 7i), as the interference of less rain and fewer wet days generates a positive (i.e. "wet") contribution to the seasonal anomaly in dry seasons (eqn. 4). By contrast, C^{wet}_{resid} is positive (Fig. 7e) because the interference of more rain and more wet days acts with the same sign as the seasonal anomaly in wet seasons.

It is immediately apparent that C_{freq} dominates C_{intns} for both wet and dry seasons in all regions of Queensland except for the grid cells closest to the eastern coast. The change in the frequency of wet days with rainfall greater than 5 millimetres can explain at least 60 per cent of the seasonal rainfall anomaly across much of Queensland; changes in intensity generally explain less than 40 per cent of the seasonal rainfall anomaly. C_{resid} has a greater magnitude in dry seasons (Fig. 7i) than in wet seasons (Fig. 7e), particularly in the interior of the state. This implies that considering changes in rainfall frequency or intensity independently is a poor assumption in the interior, as the interaction of frequency and intensity exerts a substantial influence on the seasonal total rainfall.

Towards the coast, where rainfall is more frequent (Fig. 2a) and variability on inter-annual temporal scales is small relative to the mean (Fig. 2c), C_{resid} is much smaller in magnitude, especially in wet seasons. In coastal regions, then, it is reasonable to assume that the contributions of frequency and intensity can be considered independently.

In wet and dry seasons, almost all of Queensland is affected more by changes in the number of days with rainfall greater than 5 millimetres than by the intensity of rainfall on those days (Figs. 7f and 7j).

Anomalous rainfall on days with at least 10 millimetres of rain account for at least 70 per cent of the seasonal rainfall anomaly in wet (Fig. 8a) and dry (Fig. 8b) seasons, increasing to more than 90 per cent towards the coast and across northern Queensland. As for the 5 millimetres threshold, the C_{freq} trumps C_{intns} of rainfall for wet (Figs. 8c, d) and dry (Figs. 8g, h) seasons. C_{resid} remains high in the interior of the state in dry seasons, suggesting that the combined effect of the changes in frequency and intensity is critical there. When rains fail in the interior, it is because they are simultaneously less frequent and less intense, although changes in frequency still play a marginally greater role than changes in intensity. In most of the rest of Queensland, the changes in the frequency of wet days make contributions to the seasonal rainfall anomaly that are 3–5 times as large as changes in intensity, for wet (Fig. 8f) and dry (Fig. 8j) seasons.

When the wet-day threshold is increased to 25 millimetres, the anomalous rainfall on those wet days is 50 per cent or more of the total seasonal anomaly across much of Queensland in wet (Fig. 9a) and dry (Fig. 9b) seasons. This agrees well with Fig. 6c), which showed that wet days with rainfall exceeding 25 millimetres accounted for 40 per cent or more of the annual total rainfall in the majority of the state. Immediately along the coast, changes in wet days over 25 millimetres account for 70 per cent or more of the seasonal rainfall anomaly. Once again, the rainfall anomaly due to the change in frequency of these wet days is much larger than the rainfall anomaly due to the change in intensity for wet (Fig. 9c, d) and dry (Fig. 9g, h) seasons. In wet seasons, the contribution from the change in frequency is more than five times larger than the contribution from intensity at all but a few coastal grid cells (Fig. 9f).

Similar results are obtained when using a wet-day threshold of 50 millimetres, although with such a high threshold the contribution to the total seasonal anomaly falls to less than 50 per cent across much of the state (Figs. 10a, b). Still, in the densely populated coastal regions, changes in the frequency and intensity of wet days with rainfall exceeding 50 millimetres contribute anywhere from 40 per cent to 80 per cent of the seasonal anomaly. Once again, the rainfall anomalies due to changes in the frequency of wet days are far greater than the rainfall anomalies due to the change in the intensity of wet days, by a factor of five or more across the state for wet seasons (Fig. 10f) and by a factor of two or more for dry seasons (Fig. 10j).

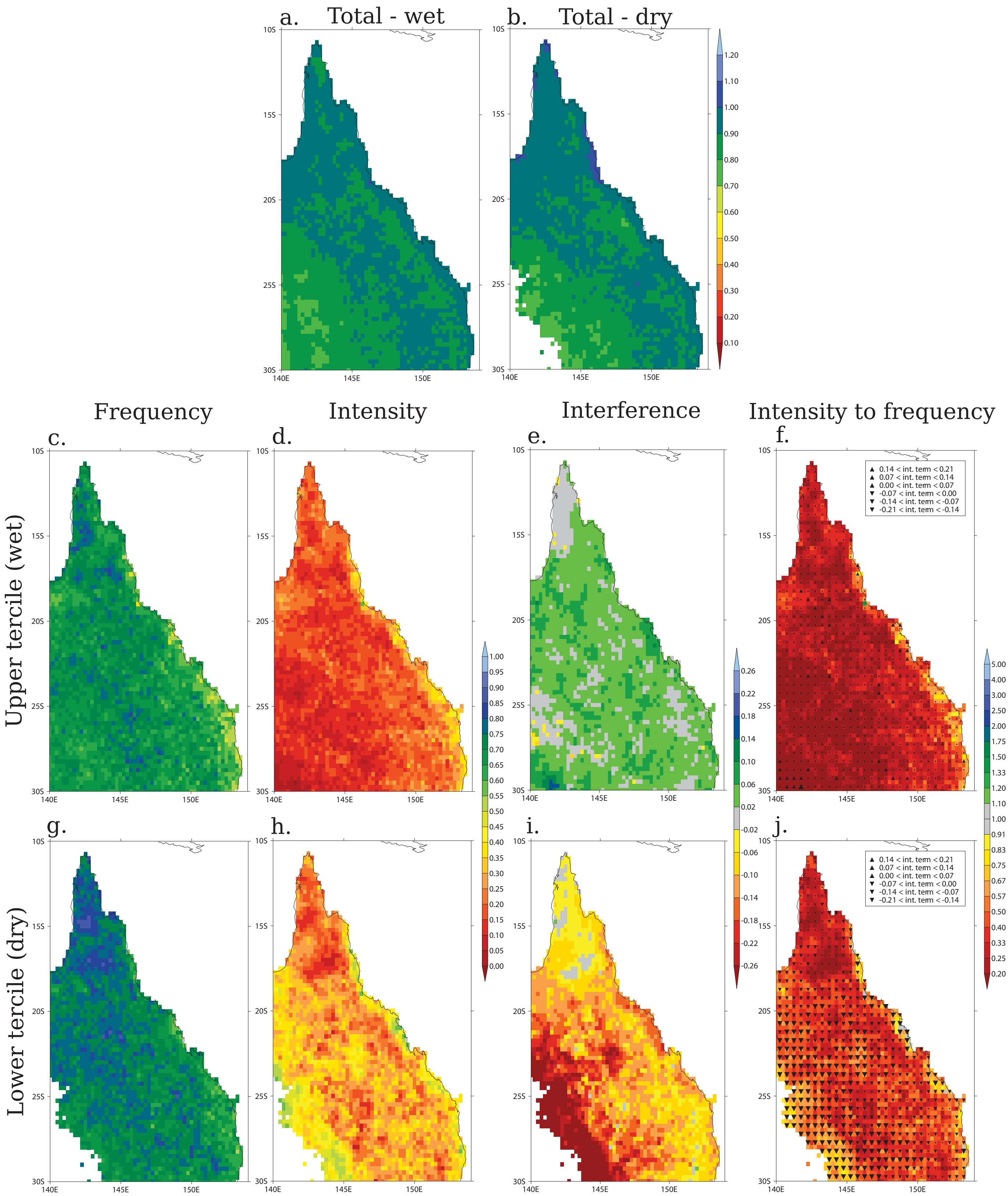

Figure 8: As in Fig. 7, but using a wet-day threshold of 10 millimetres per day. Grid cells shaded in white have fewer than one wet day per year for years in the given tercile; fractional contributions are not computed for these grid cells.

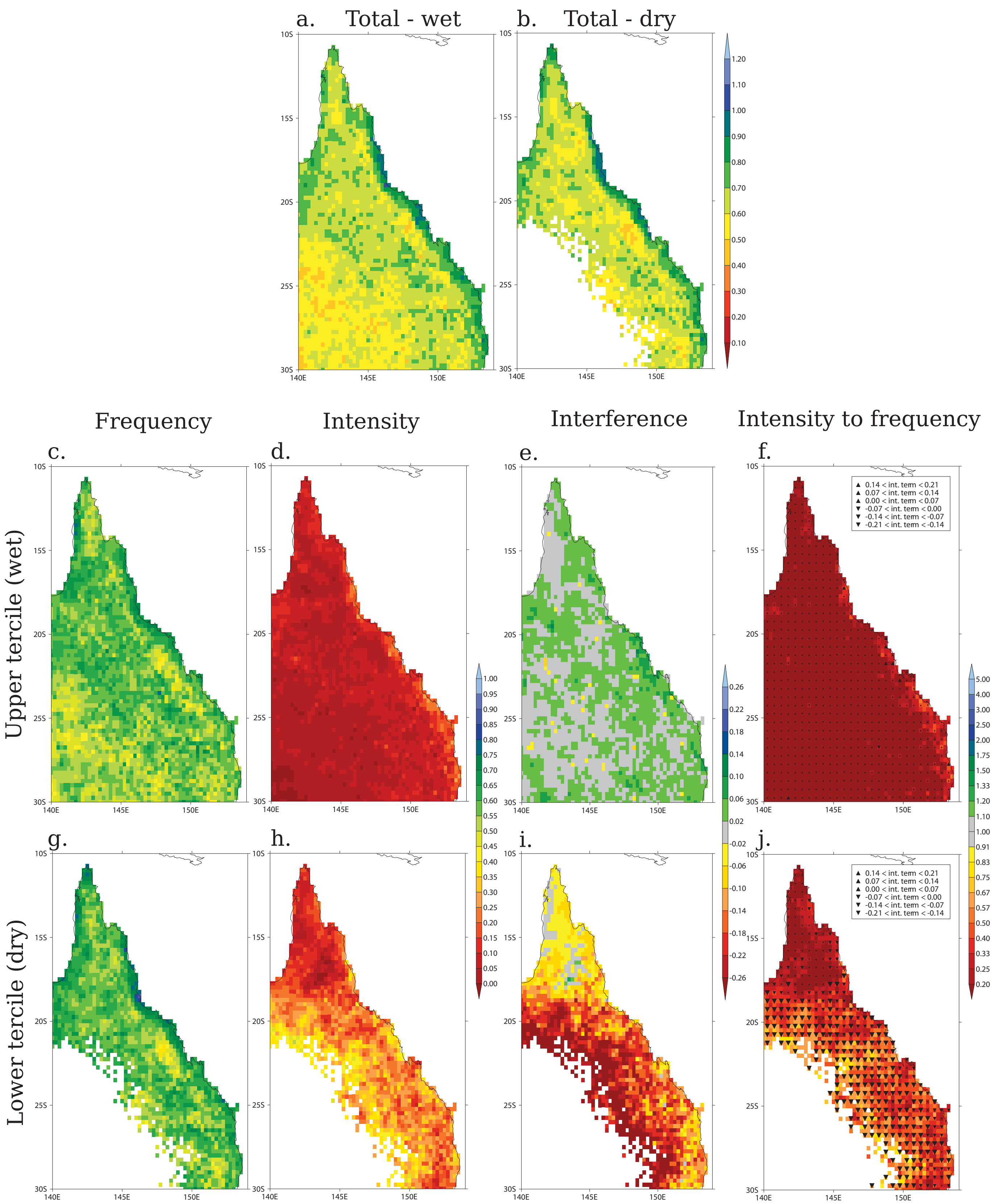

Figure 9: As in Fig. 7, but using a wet-day threshold of 25 mm day^{-1}. Grid cells shaded in white have fewer than one wet day year^{-1} for years in the given tercile; fractional contributions are not computed for these grid cells.

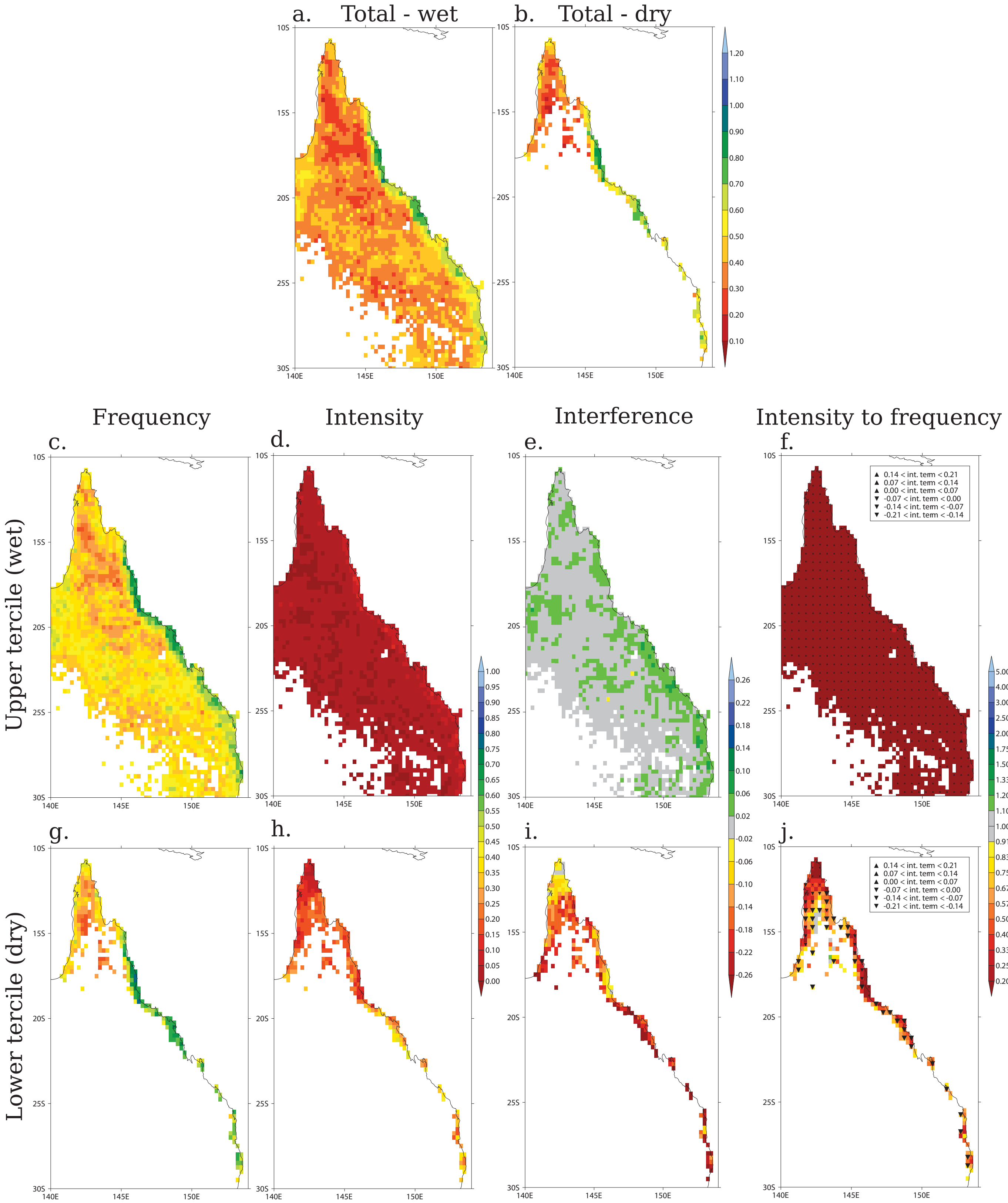

Figure 10: As in Fig. 7, but using a wet-day threshold of 50 mm day^{-1}. Grid cells shaded in white have fewer than one wet day year^{-1} for years in the given tercile; fractional contributions are not computed for these grid cells.

5 Summary and conclusions

Using four wet-day thresholds—5 millimetres per day, 10 millimetres per day, 25 millimetres per day and 50 millimetres per day —this report has examined the mean and inter-annual variability of the frequency and intensity of rainfall in Queensland.

The same thresholds were used to partition the seasonal (November–April) rainfall anomalies during “wet” (i.e. upper tercile of seasonal total rainfall) and “dry” (i.e. lower tercile of seasonal total rainfall) into contributions from changes in only the frequency of wet days, only the intensity of wet days and only the interference of frequency and intensity of wet days.

Queensland receives approximately 80 per cent of its annual rainfall during the November–April half-year (Section 1). All analysis in this report used the SILO daily rainfall dataset, which, as employed here, covered the period 1900–2008 with a horizontal resolution of 0.25°. Seasonal (November–April) and annual total rainfall in Queensland is highly dependent upon the frequency of wet days exceeding 25 millimetres of rainfall. This dependence extends across the state, but is highest in the heavily populated coastal regions, where 40–60 per cent of the annual total rainfall falls on days with accumulations of more than 25 millimetres (Fig. 6c). Such wet days occur rarely, with fewer than 16 days per year in the mean along the southern half of the coast and fewer than 24 days per year along much of the northern half (Fig. 3a).

The frequency of wet days with rainfall totals above 25 millimetres also varies considerably on inter-annual temporal scales, with a standard deviation of at least 30 per cent of the mean along much of the coastline and 50 per cent or higher in the interior regions of Queensland (Fig. 3c). By contrast, the inter-annual variability in frequency at lower wet-day thresholds (i.e., 5 millimetres per day and 10 millimetres per day) is considerably smaller as a percentage of the mean frequency (Figs. 2c, f). Similarly, these rare rain events contribute a substantial fraction of the seasonal rainfall anomaly in wet and dry years across Queensland (Figs. 9a, b).

As for the other wet-day thresholds considered in this report, the frequency of wet days above 25 millimetres is far more important than the intensity of rainfall on those wet days (Fig. 9f, j). Queensland is therefore in the rather unenviable position of relying on intense rain events that are not only infrequent in the mean, but which also have substantial inter-annual variability in that frequency.

To respond to the questions posed in Section 1, the rainfall anomalies in wet (dry) years in Queensland are largely due to changes in the frequency of wet days, not their intensity. Furthermore, intense rain events with a daily accumulation of more than 25 millimetres are responsible for at least half of the November–April rainfall anomaly in years within the upper or lower terciles for seasonal rainfall. Along the coast, days exceeding 25 millimetres can contribute more than 70 per cent of the seasonal anomaly, which is remarkable given that, in the mean, these events account for only 15–20 per cent of all wet days (i.e., days with more than 1 millimetres of rainfall) along the coast (not shown). For days above 25 millimetres, again the frequency of wet days matters far more than the amount of rainfall on those days.

These conclusions hold equally well for wet years and dry years, although in dry years the changes in rainfall intensity hold slightly more importance than they do in wet years. In dry years, the interference of the changes in frequency and intensity (i.e. the fact that it rains less on fewer days) make a substantial contribution to the seasonal anomaly, particularly in the interior of the state, which challenges the assumption that the contributions from frequency and intensity can be considered independently. In wet years, by contrast, the interference term (i.e. the fact that it rains more heavily on more days) rarely makes a contribution of more than a few percent to the seasonal anomaly.

From this analysis, it is clear that future work on identifying climate drivers responsible for variability in Queensland rainfall should focus on the impact of such drivers on the frequency of intense rainfall. This does not mean that the work should ignore the impacts of climate drivers on rainfall intensity or on other portions of the rainfall distribution, but that the effects on the frequency of days exceeding 25 millimetres per day should be of paramount importance. Variability in the frequency of these wet days could arise, for example, due to variability in the number of tropical cyclones or east-coast lows, which may in turn be due to climatic drivers such as the El Niño Southern Oscillation.

The conclusion that the frequency of rainfall makes a greater contribution to the seasonal total and the inter-annual variability of Queensland rainfall will be important when examining Queensland rainfall in climate models and in reanalysis data. Because of their limited horizontal resolution, climate models are often not able to capture the observed distribution of rainfall intensity, particularly for intense rainfall. The same holds for reanalysis datasets, since they are also produced by general circulation models, again with limited horizontal resolution. If these models are able to capture the observed frequency of rainfall in Queensland, however, then this information could be used to assess the inter-annual variability of rainfall amounts in these models, based on the conclusion from this report that variations in rainfall frequency provide the dominant control on variations in total annual rainfall.