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Supplement of

Refining the Lagrangian approach for moisture source identification through sensitivity testing of assumptions using BTrIMS1.1

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Section S1 Figures for synoptic features of the three events

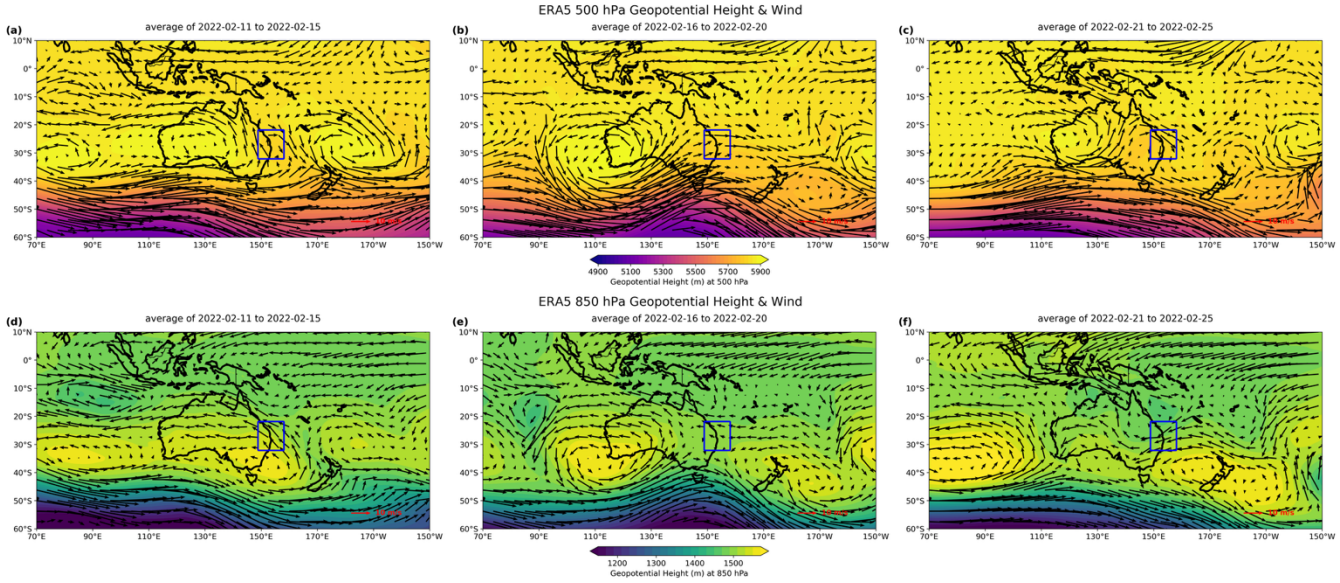


Figure S 1 Average 500 hpa geopotential height (m) and wind field (a,b,c); and average 850 hpa geopotential height(m) and wind field (d,e,f) for 14 to 10 days(a,d), 9 to 5 days (b,e) and 4 to 0 days (c,f) before 25th Feb 2022.

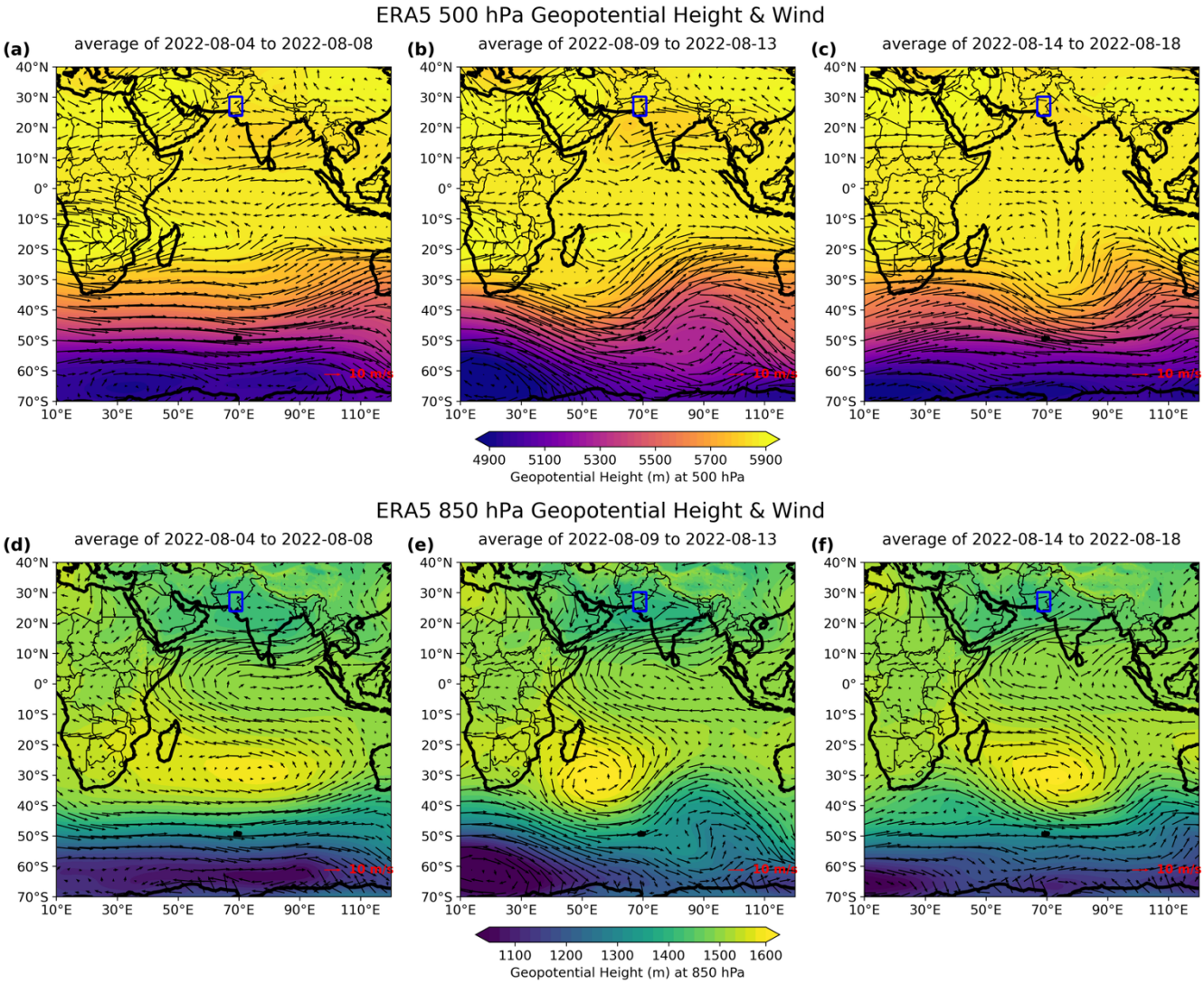


Figure S 2 The same as Fig. S1, but for the Pakistan event.

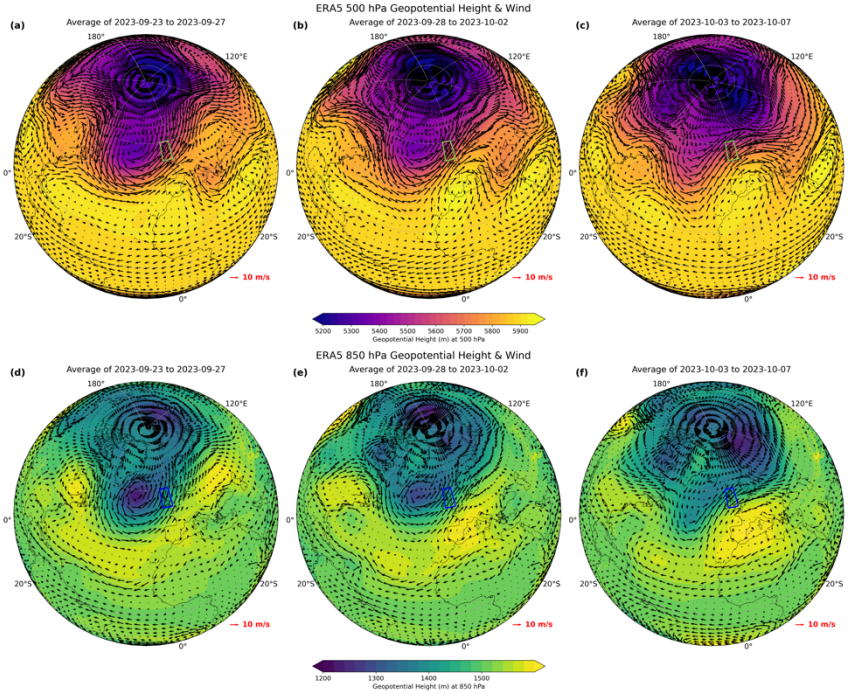


Figure S 3 The same as Fig. S1, but for the Scotland event.

Section S2 Moisture source result using standard Watersip method

To enable comparison of this study to other methods, here we show the results of using standard WaterSip method.

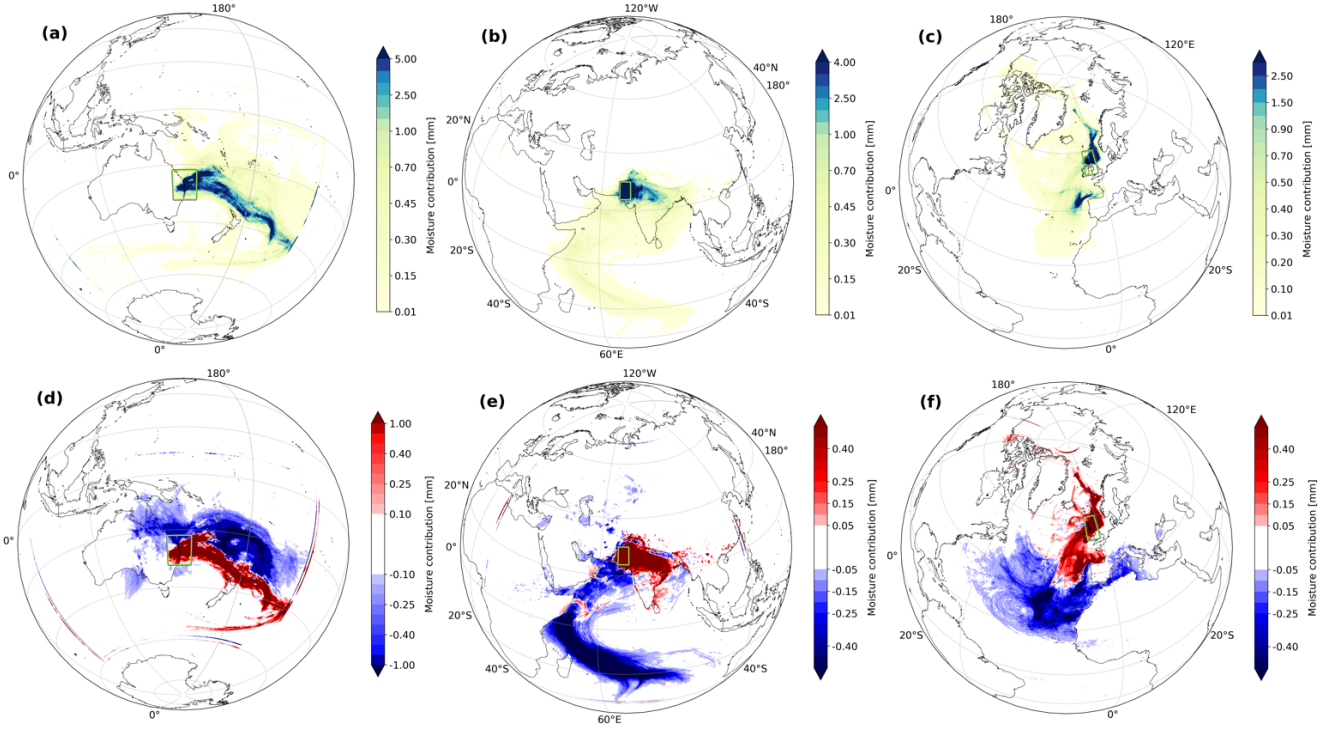
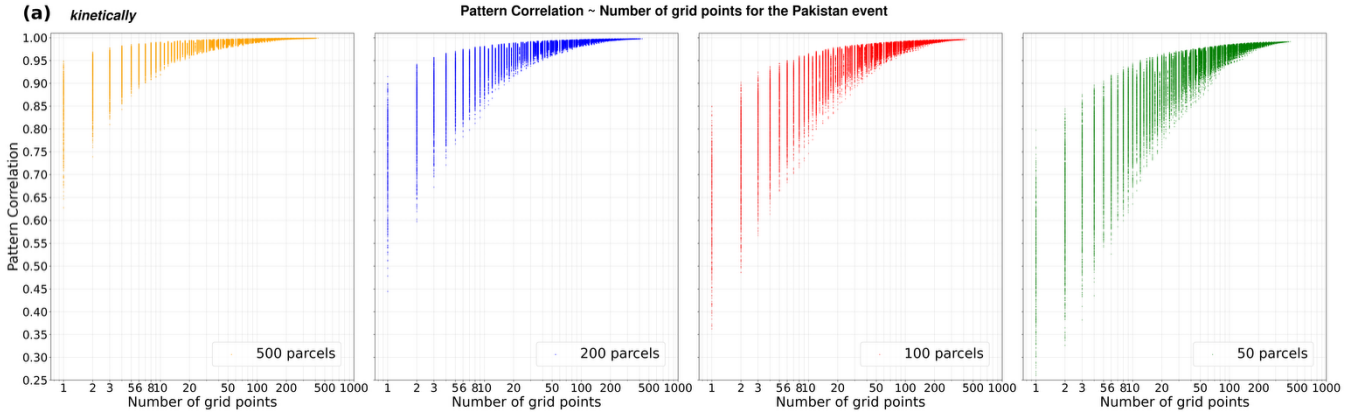
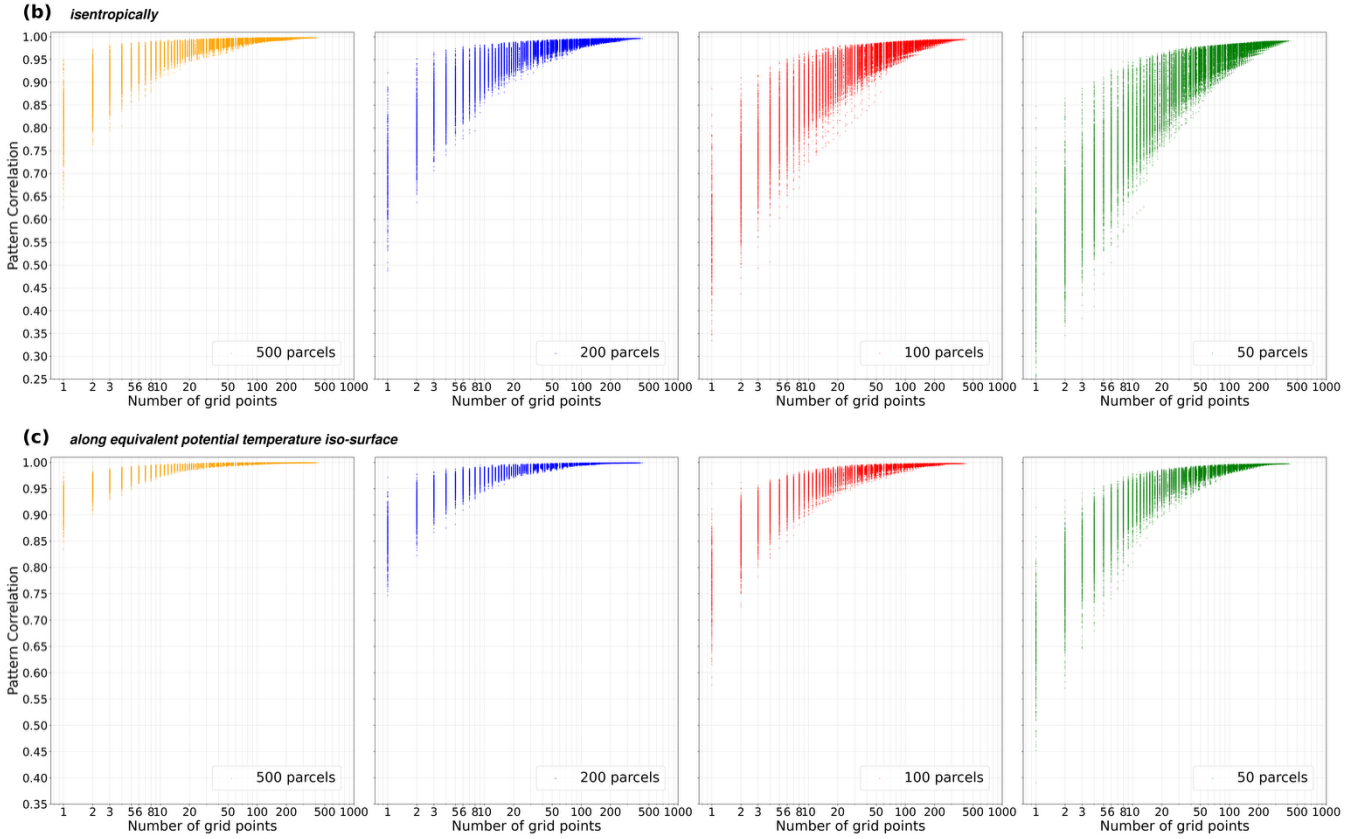


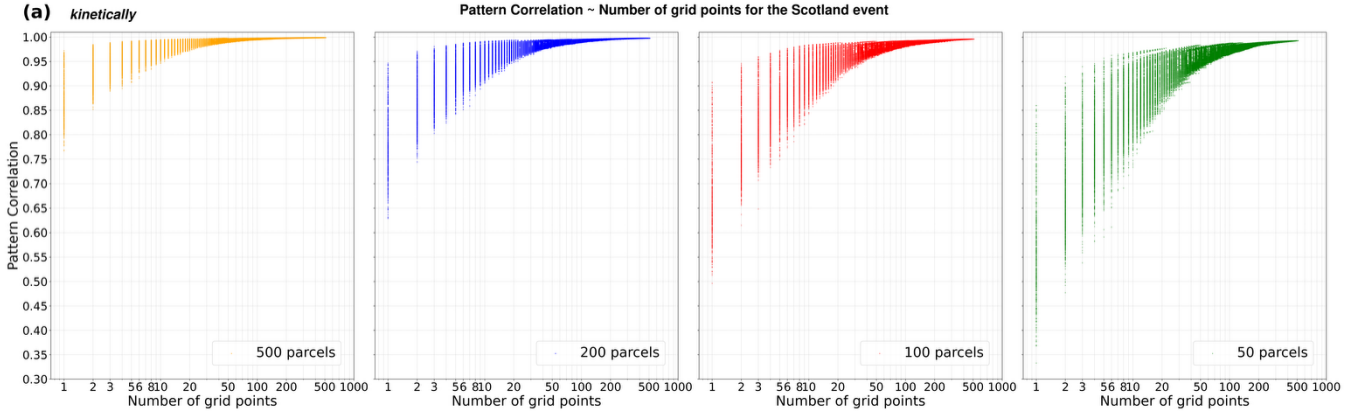
Figure S 4 The results of standard WaterSip method for Australia (a), Pakistan(b) and Scotland(c) events; and the difference between it and Option1 (standard WaterSip – Option1) in panels (d–f).

Section S3 Other figures





15 **Figure S 5 The same as Fig. 1 but for the Pakistan event.**



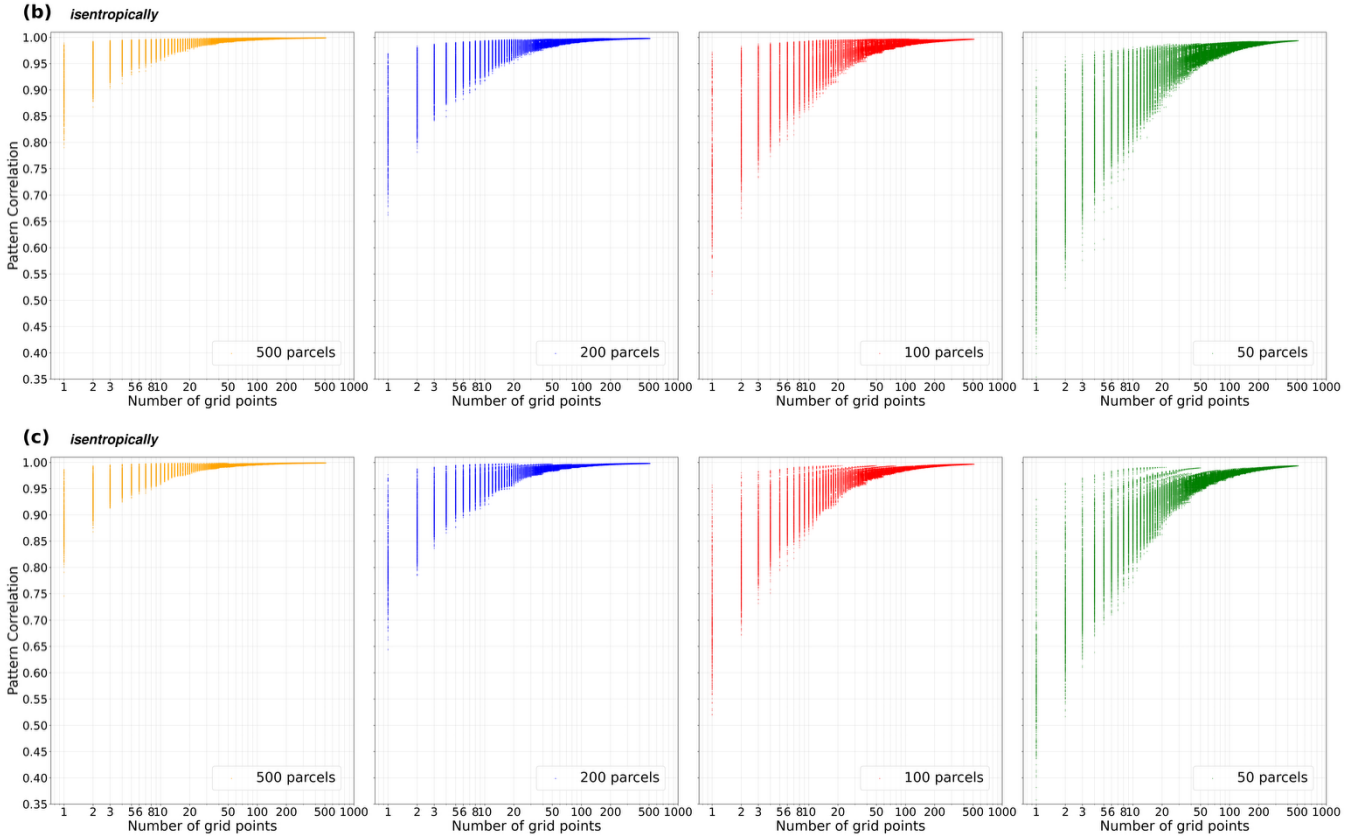


Figure S 6 The same with Fig. 1 but for the Scotland event

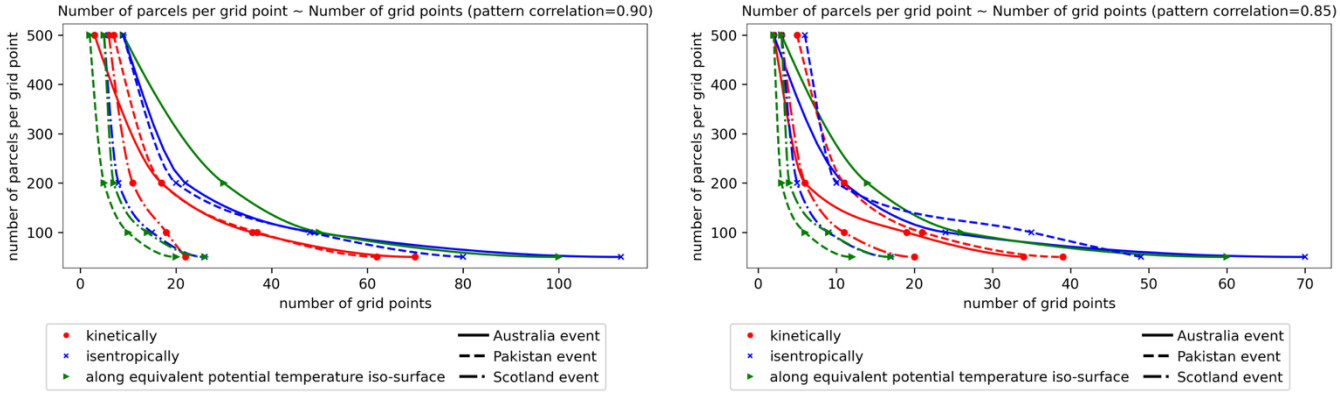
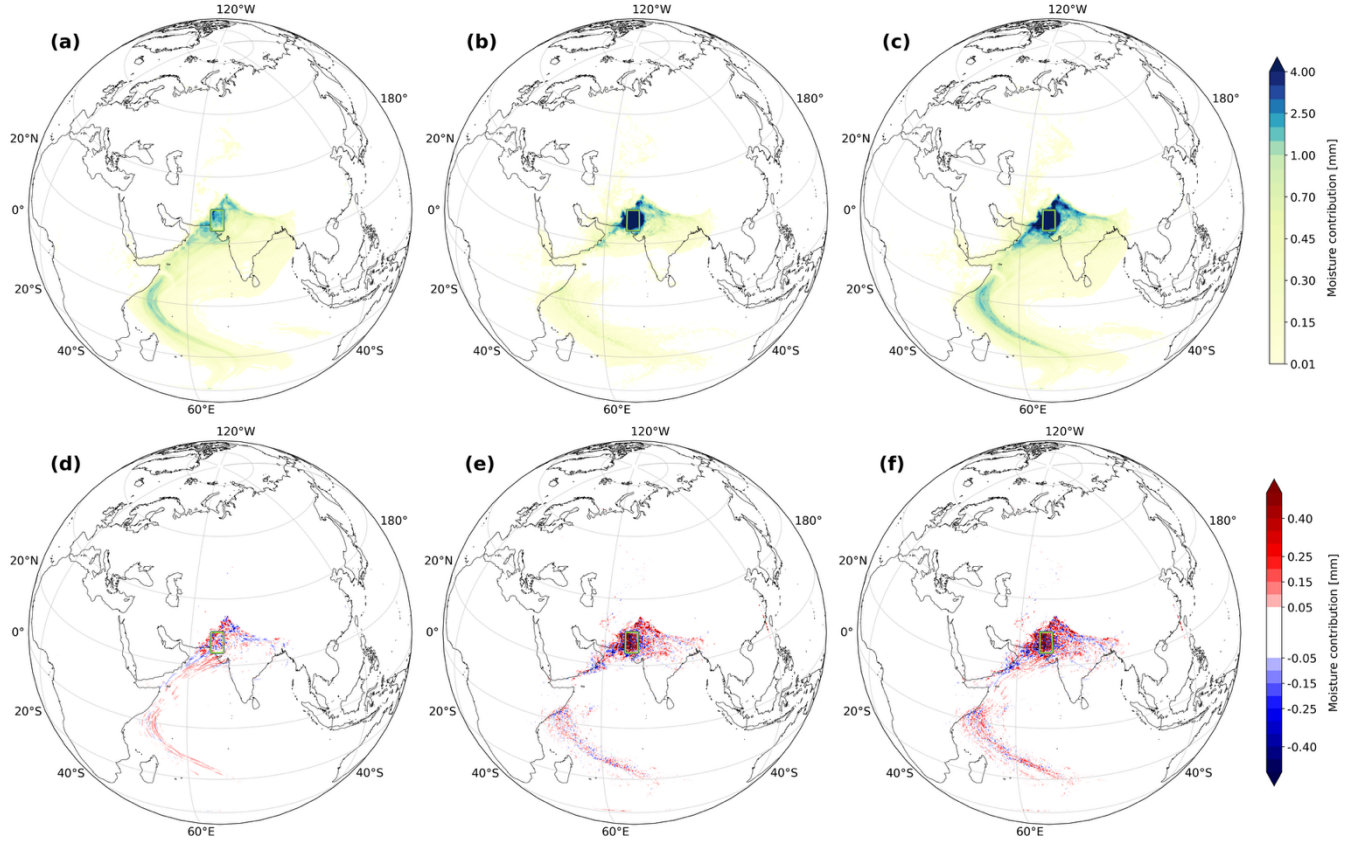


Figure S 7 The same as Fig. 2 but for pattern correlation 0.90 (left) and 0.85 (right).



20 **Figure S 8 The same as Fig. 6 but for the Pakistan event.**

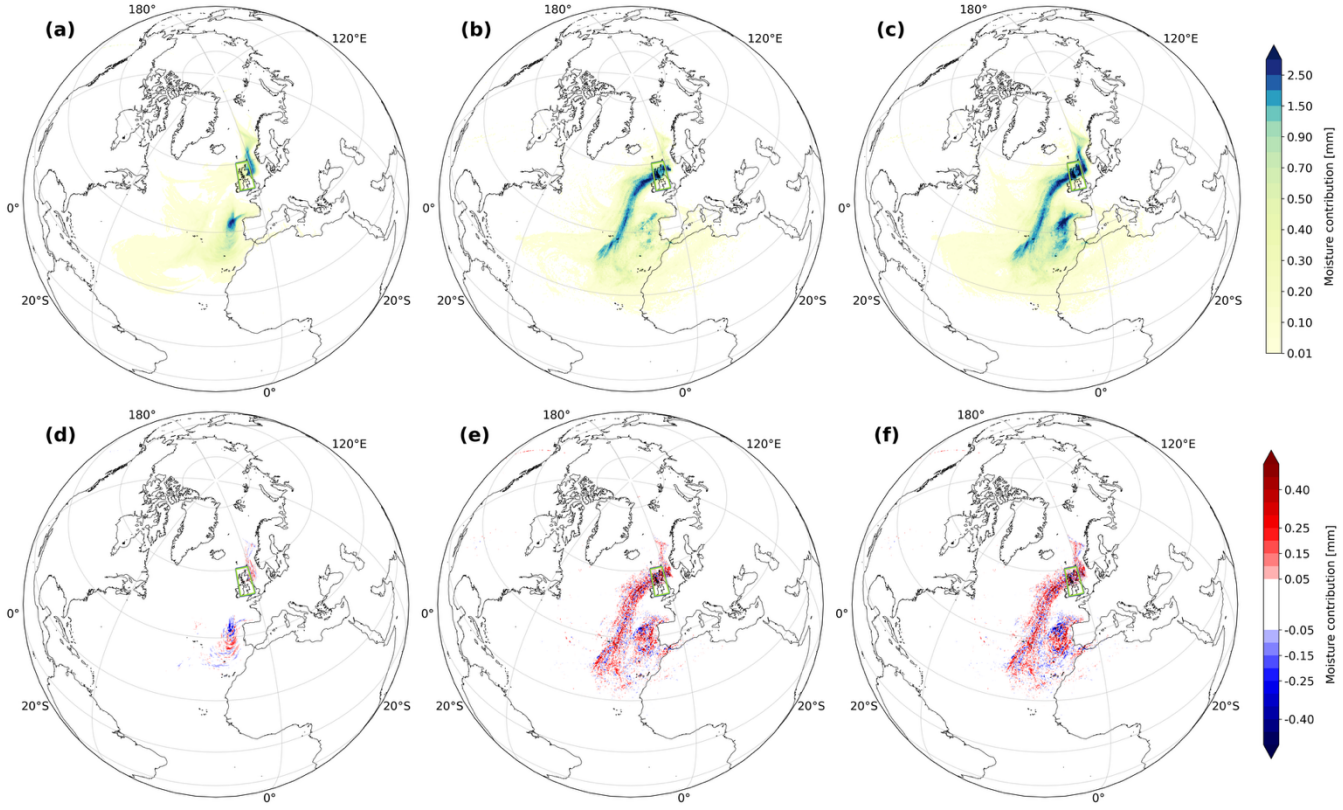
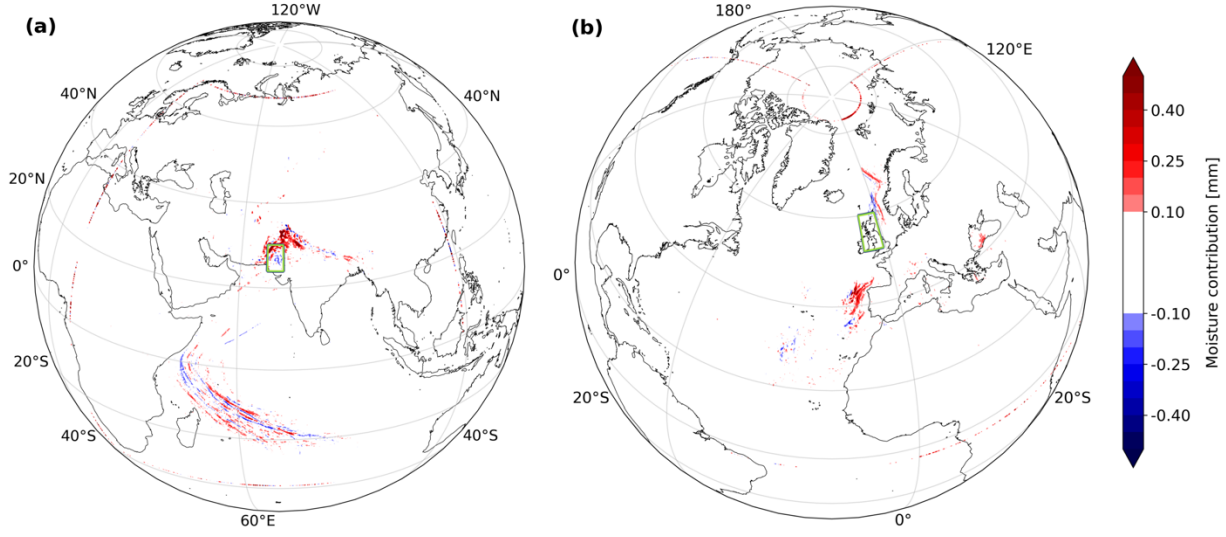


Figure S 9 The same with Fig. 6 but for the Scotland event.



25 **Figure S 10 The same as Fig. 7 but for the Pakistan (a) and Scotland (b) events**

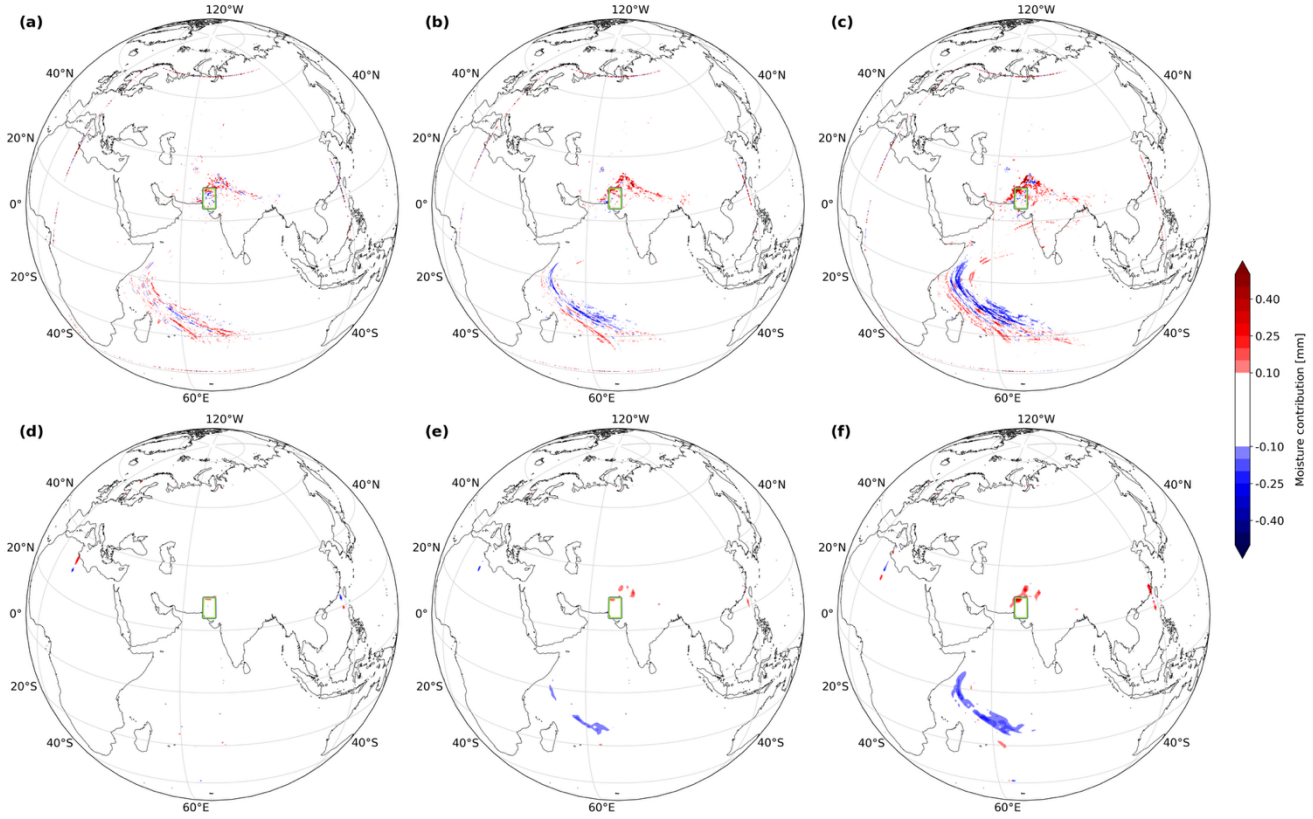


Figure S 11 The same as Fig. 8 but for the Pakistan event.

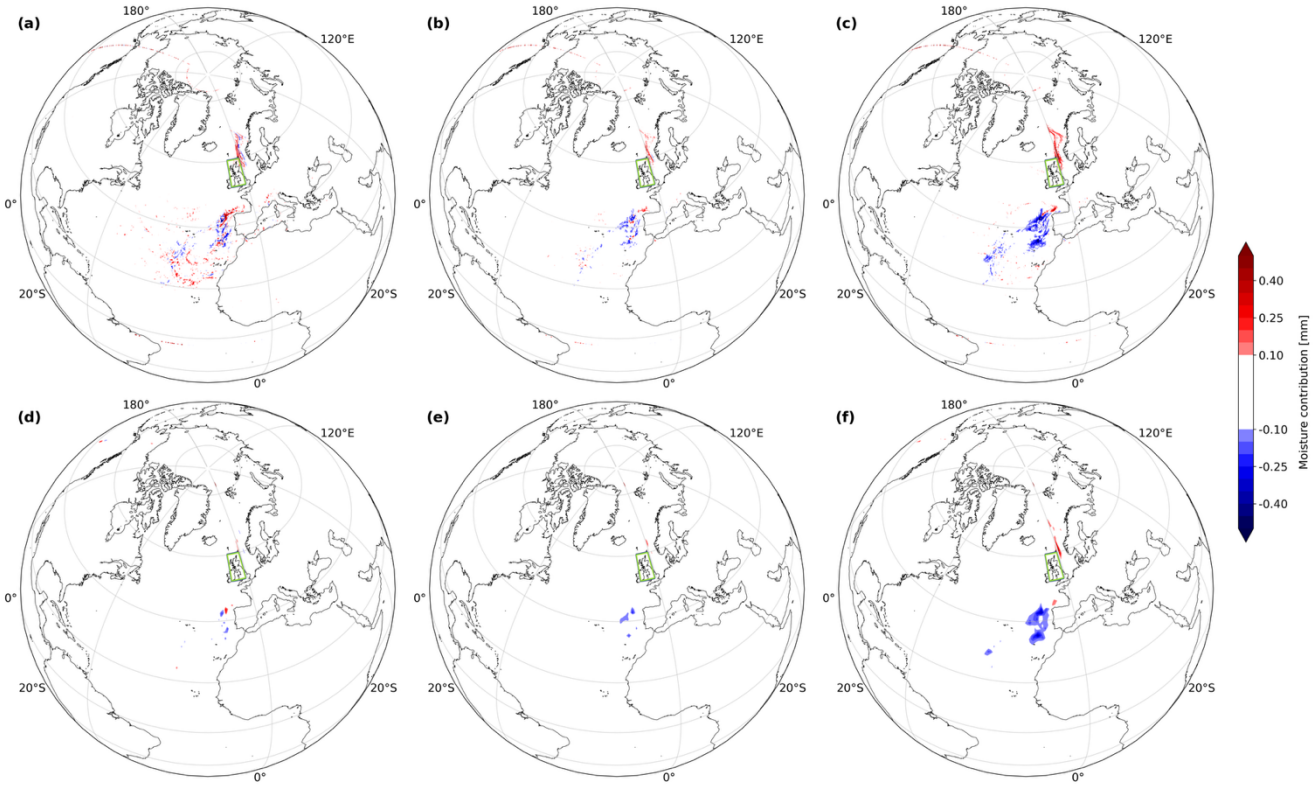


Figure S 12 The same with Fig. 8 but for the Scotland event

Section S4 Equations

The equation to calculate equivalent potential temperature used in this study:

$$es = 611 \exp\left(\frac{17.2964 \times (T - 273.16)}{T - 35.86}\right)$$

$$mix_s = \frac{R_d}{R_v} \times \frac{es}{P - es}$$

$$\theta_e = T \times \frac{P_0}{P}^{\frac{Rd}{Cp+C_l \times mixtot}} \times mix_s^{\left(-mix \times \frac{R_v}{C_p+C_l \times mix_{tot}}\right)} \times \exp\left(L_v \times mix/(C_p + C_l \times mix_{tot}) \times T\right) \quad \text{(S1)}$$

es: saturation vapor pressure，Pa;

T: air temperature, K;

mix_s: saturated mixing ratio, kg/kg;

P: air pressure, Pa;

P_0: reference surface pressure, 1000hPa;

C_p: heat capacity of air at constant pressure, 1004.67 (J/kgK);

C_l: heat capacity of liquid water at ~-20C, 4400 (J/kgK);

mix: specific humidity of water vapor, kg/kg;

mix_{tot}: specific humidity of total water, kg/kg;

L_v: latent heat of vaporization of water, 2.25E6 (Jkg-1);

R_d: ideal gas constant for dry air, 287.053 (J/kgK);

R_v: gas constant of water vapor, 461.5 (J/kgK).