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# The origin of Asian monsoons: a modelling perspective

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**Supplementary Materials**

**Figure 1: Wettest month of the year for the control simulation (a) and the GPCP observations. Regions receiving less than 1mm/day are kept blank.**

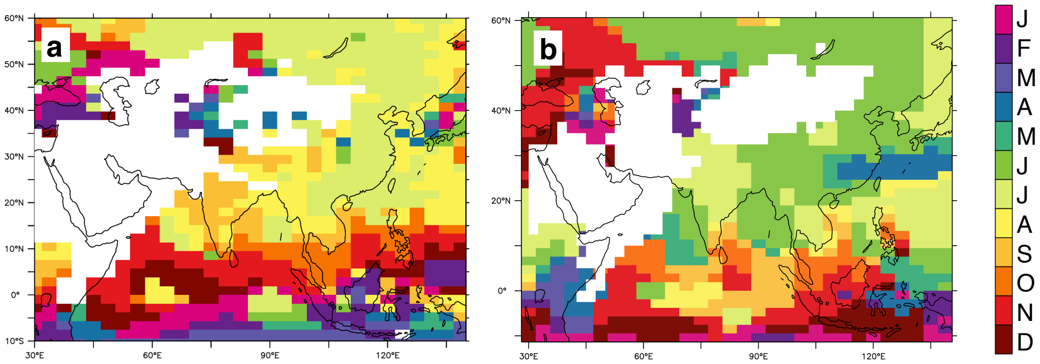



**Figure 2: a) paleotopography and paleobathymetry and b) idealized vegetation map prescribed. For b), color coding is: Boreal Needleleaf Summergreen (red), Boreal Broadleaf Summergreen (cyan), Temperate Broadleaf Evergreen + Temperate Broadleaf Summergreen (light green), Bare soil (yellow), C3 grasses (orange) and Tropical Broadleaved Evergreen + Tropical Broadleaved Raingreen (dark green).**

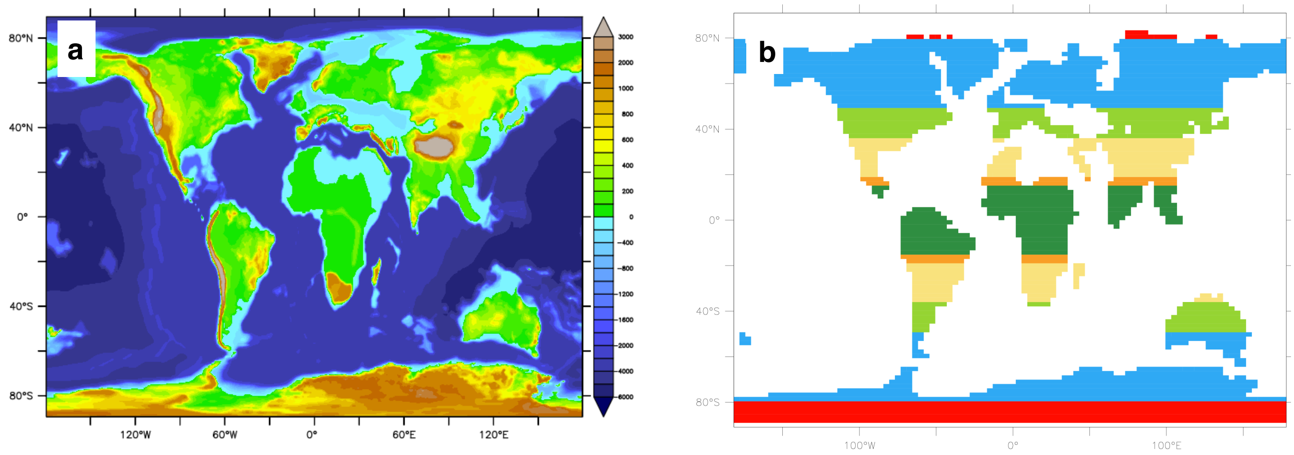


**Figure 3: Oceanic heat content stability plots for the 3000 years reference simulations EOC_4X (a). Plotted depth are 5 m (black), 500 m (purple), 1800 m (red) and 4750 m (blue). The simulation shows a drift inferior to 0.1°C per century over the last 500 years for the deep ocean (4750 m).**

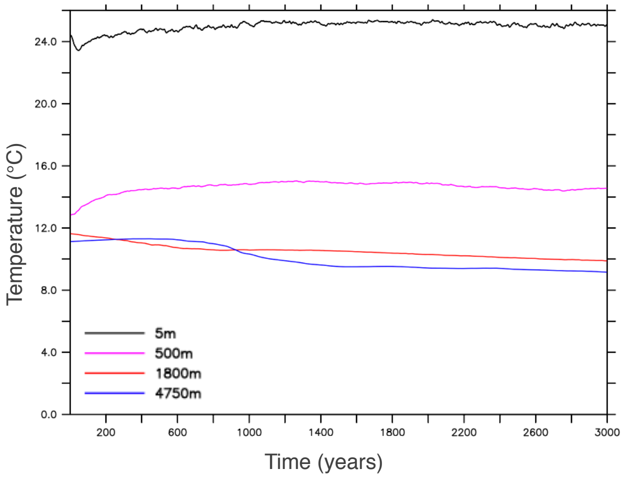



**Figure 4: Regression between SST given by the proxies and the one obtained from the model.**
**In purple: Late-middle Eocene proxy-model regression yields a $r^2$=0.72, in orange: late Eocene proxy-model regression a yields $r^2$=0.54. The detailed proxy compilation is given in Tables 1 to 4.**

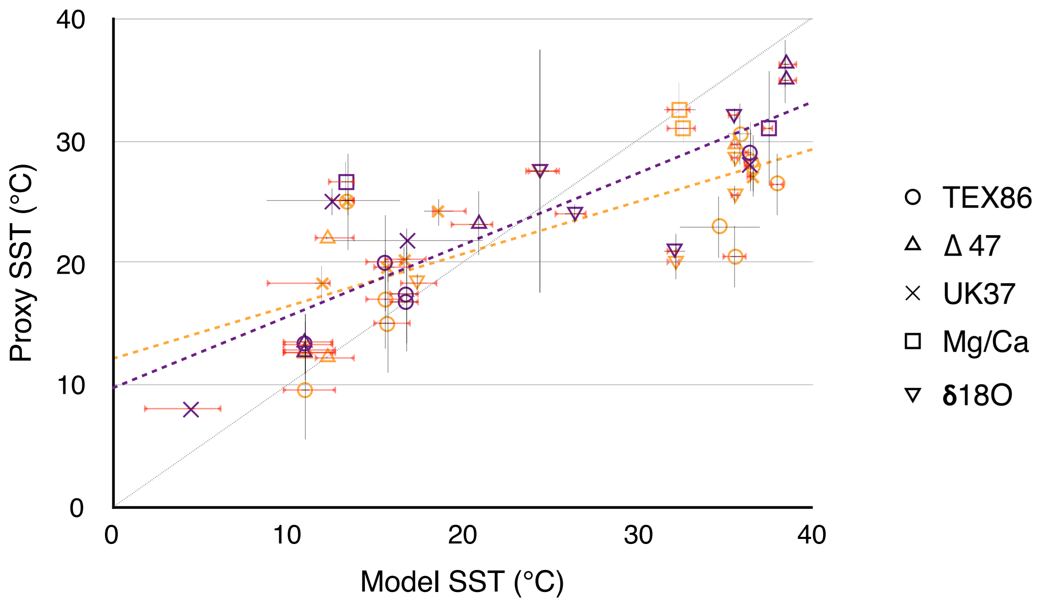
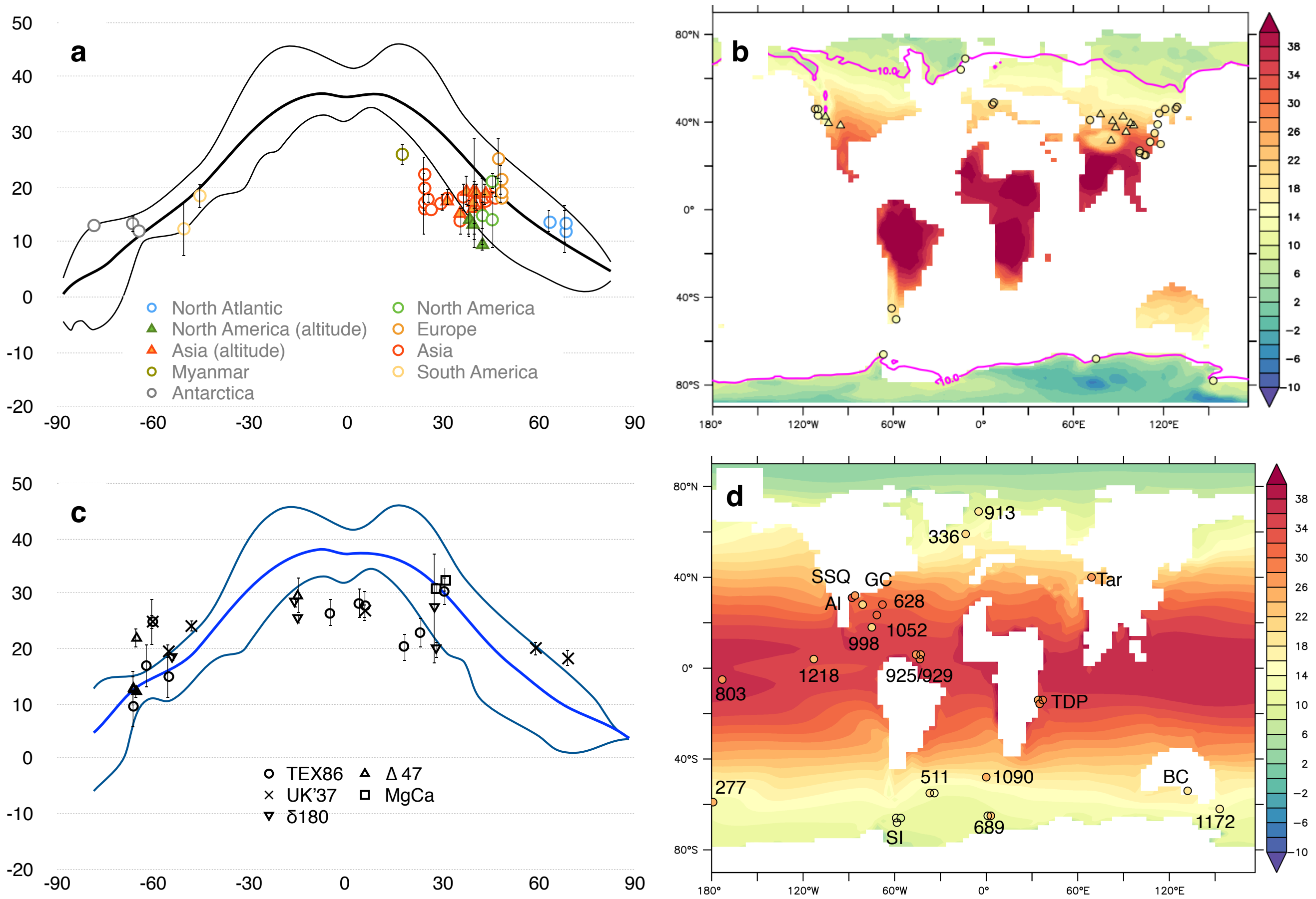


**Figure 5: Late Eocene data-model comparison for MAT (a,b), ans SST (c,d). In (a, c), thick line represent the mean temperature from EOC_4X, thin lines are min and max latitudinal temperature from EOC_4X. High altitude proxies (>1000 m) are represented by triangles, others by circles. In b pink thick line represents the 10°C isotherm. Detailed compilation is provided in Table 1 and 2.**



**SST and terrestrial temperature compilation description**

The proxy compilations used in this study were taken from an existing compilation by Baatsen et al. (2018). It was further completed with results from the available literature (Hunt et al.2001, Utescher et al. 2015, Kohn et al. 2015, Francis et al. 2007, Greenwood et al. 2010, Licht et al. 2014, Spicer et al. 2017, Hoorn et al. 2012), for the continental compilation. Since a steady declining trend in temperatures is observed through the Middle to Late Eocene (Zachos et al. 2001), samples are divided into two broad categories: «late-middle Eocene» and «late Eocene» (hereafter LME and LE, respectively), corresponding to periods of 42 to 38 Ma and 38 to 34 Ma, respectively. As no sharp variation in temperature and $pCO_2$ is expected between LME and LE, some samples, dated around 38 Ma, are present in both groups. Considering the scarcity of SST estimates at high northern latitudes, we exceptionally included the 44.5 Ma ACEX drilling SST proxy in the LME group, as no value is available for our period of interest, due to a hiatus in the core spanning from 44.5 to 18.3 Ma (Weller and Stein, 2008). We consider reasonable to include this value in our compilation, keeping in mind that it could present a slight overestimation of the SST at this location.

Note that several $TEX_{86}$ calibration methods exist for SST reconstructions. Values from Liu et al. (2009) used the calibration by Kim et al. (2008), while Douglas et al. (2014) used the $TEX^{L}_{86}$ calibration. If studies argued that $TEX^{L}_{86}$ calibration was better adapted to high latitudes (SST below 15°C), and $TEX^{H}_{86}$ for mid to low latitudes, Taylor et al. (2013) showed that was actually more suited for shallow water environments, independently of the SST estimated temperature. Uncertainties remain on this topic, as Ho and Laepple (2016) recently suggested that $TEX^{H}_{86}$ might actually reflect subsurface temperatures and therefore challenge the paleoclimatic interpretations based on the usually warm polar SST values measured for the Paleocene or the Eocene periods.

The paleolocation of the proxies was reconstructed using Gplates (www.portal.gplates.org). We differentiate terrestrial proxies results from coastal and low elevation locations from those which paleo-elevation have been estimated higher than 1000 m (when available). The interest of separating altitude records from other proxies is twofold: first, the coarse resolution of our model induces a smoothing of the elevation, hence a tendency to return higher temperature on the location of high altitude proxies ; second, as fossil material are usually found in basins, they represent the surrounding flora or fauna, whether it comes from the basin area itself or from higher elevation in the surroundings. A fossil assemblage can therefore induce a cold bias on the location of the proxy itself by representing the high altitude neighboring regions. As an elevation difference of 1000 m for a given latitude is susceptible to induce differences in temperatures of ~6.5°C, it is an important parameter to consider.

**Table 1: Late Eocene (38-34Ma) terrestrial proxy compilation**

| Site | Location (paleo) | altitude | references | MAT (°C) | MAT error |
|---|---|---|---|---|---|
| **ANTARCTICA** | | | | | |
| McMurdo | -77,7°N, 153,2°E | ? | Passchier et al. (2013) | 13 | 0 |
| King George | -66°N, -66,5°E | ? | Passchier et al. (2013) | 13 | 2 |
| ODP 1166 | -68°N, -66,5°E | ? | Passchier et al. (2013) | 12 | 0 |
| **SOUTH AMERICA** | | | | | |
| Ñirihuau (Chile) | -45°N, -61°E | ? | Hinojosa & Villagran (2005) | 18,4 | 0 |
| Gran Barranca (Argentina) | -50°N, -58°E | ? | Kohn et al. (2015) | 12,4 | 5 |
| **MYANMAR** | | | | | |
| Pondaung | 18,5°N, 90,6°E | ? | Licht et al. (2014) | 26 | 2 |
| **CHINA** | | | | | |
| ChangChang (Hainan Island) | 25°N,107°E | No | Spicer et al. (2017) | 22 | 3 |
| Liushagang I (Leizhou, Guangdong) | 24,6°N, 106,9°E | No | Zhang 1981 | 16 | 5 |
| Youganwo (Maoming Basin) | 25°N, 108°E | No | Yu & Wu 1983 | 17 | 1 |
| Youganwo (Maoming Basin) | | No | Spicer et al. (2017) | 20 | 3 |
| Yongning Gr U (Ningming, Guangxi) | 25,5°N, 104,2°E | No | Wang 2003 | 18 | 1 |
| Nadu (Baise, Guangxi) | 27,3°N, 103,6°E | No | Guo 1979, Liu & Yang 1999 | 16 | 0 |
| Pinghu (Donghai) | 29,7°N, 119,4°E | No | Sun 1989, Zhang 1990 | 17 | 1 |
| Linjiang L (Qingjiang) | 31,6°N,112,1°E | No | He & Sun 1977 | 18 | 1 |
| Dagzukha (Xigaze, Tibet) | 32°N,85,2°E | Yes | Li 2009 | 17 | 1 |
| Dingyuan V (Hefei Basin) | 35,5°N,114,4°E | No | Wang et al 1987 | 14 | 2 |
| Relu U (Shiqu, Sichuan) | 36,2°N,94,9°E | Yes | Chen 1983 | 15 | 0 |
| Sanduo U (Gaoyou, Jiangsu) | 36,5°N,116,6°E | No | Zhang & Qian 1992 | 18 | 3 |
| Wanbaogou Gr U (Kulun Pass, Qinghai) | 38,1°N,88,2°E | Yes | Zhu 1985 | 19 | 3 |
| Lanzhou, Gansu | 39,4°N,100,2°E | Yes | Ma 1995 | 14 | 2 |
| Xining Gr (Minhe, Qinghai) | 39,5°N,100°E | Yes | Yu 2003 | 16 | 5 |

| Site | Location (paleo) | altitude | references | MAT (°C) | MAT error |
|---|---|---|---|---|---|
| Honggou III, IV (Xining, Qinghai) | 39,73°N,98°E | Yes | Sun 1980 | 17 | 4 |
| Xining | 40,1°N, 98,7°E | Yes | Hoorn, Han | 19 | 10 |
| Xining | | Yes | Wang 1990 | | 0 |
| Bashibulake (Shache Basin, Xinjiang) | 41°N, 72°E | No | Zhao 1982 | 19 | 2 |
| Xiaganchaigou L (Mangya, Qinghai) | 41,1°N, 86,4°E | Yes | Zhu 1985 | 17 | 1 |
| Huoshaogou Qiaojia (Yumen, Gansu) | 43,4°N, 92,9°E | Yes | Miao 2008 | 16 | 6 |
| Shahejie II (Qinhuangdao, Hebei) | 43,6°N,116,7°E | No | APE & NIGP 1978 | 17 | 1 |
| Xiaokuzibai (Kuche Basin, Xinjiang) | 44,1°N, 78,1°E | Yes | Zhao 1982<br>Zhang & Zhan 1991 | 19 | 2 |
| Genjiajie (Fushun, Liaoning) | 45,5°N,121,2°E | No | Qu 1993 | 18 | 0 |
| Hunchun | 46°N,128°E | No | Liu 1987, Zhang 1987 | 18 | 0 |
| S Primory'e (Russia) | 47°N, 129°E | ? | Utescher 2015 | 20 | 2 |
| S Primory'e (Russia) | | ? | Utescher 2015 | 18 | 0 |
| **EUROPE** | | | | | |
| Stare Sedlo | 48°N, 6°E | ? | Uhl et al, (2007) | 25 | 4 |
| Weiße Elster | 49°N, 6°E | ? | Uhl et al, (2007) | 21 | 3 |
| Weiße Elster & Lausitz Basin (Knau gravel pit) | | ? | Utescher 2015 | 18 | 0 |
| Weiße Elster & Lausitz Basin (Haselbach) | | ? | Utescher 2015 | 19 | 2 |
| **NORTH AMERICA** | | | | | |
| Florissant CO | 39,25°N, -95°E | Yes (3800m) | Boyle et al, (2008) ; Wolfe et al. (1998) | 14 | 3 |
| Sevier (UT) | 40°N, -102,9°E | Yes (3600 +/- 700m) | Gregory-Wodzicki (1997) | 13 | 3 |
| Copper Basin (NV) | 43,2°N, -105,4°E | yes (2000m) | Wolfe et al, (1998) | 10 | 1 |
| Badger's Nose (CA) | 42,6°N, -109,7°E | ? | Prothero (2008) | 15 | 2 |
| Comstosk (OR) | 45,8°N, -112,3°E | No | Retallack et al, (2004) | 21 | 1 |
| Gray Butte (OR) | 45,6°N, -110,2°E | ? | Smith et al, (1998) | 14 | 5 |

| Site | Location (paleo) | altitude | references | MAT (°C) | MAT error |
|---|---|---|---|---|---|
| **NORTH ATLANTIC** | | | | | |
| ODP 913 MBT | 69°N, -12°E | ? | Schouten et al, (2008) | 12 | 4 |
| ODP 913 Pollen | | ? | Eldrett et al, (2009) | 13 | 3 |
| ODP 643 | 64°N, -15°E | ? | Eldrett et al, (2009) | 14 | 2 |

**Table 2: Late Eocene (38-34 Ma) SST proxy compilation**

| Site | Location (paleo) | reference | SST (°C) | SST error | Method |
|---|---|---|---|---|---|
| **Seymour Island** | -65.7°N, -58°E | Douglas et al, (2014) | 12,6 | 2,0 | $\Delta_{47}$ *Cucullaea* |
| **Seymour Island** | | Douglas et al, (2014) | 12,9 | 3,0 | $\Delta_{47}$ *Eurhomalea* |
| **Seymour Island** | | Douglas et al, (2014) | 9,6 | 4,0 | $TEX^{L}_{86}$ |
| **ODP 689 (Weddell Sea)** | -64.7°N, 1.2°E | Petersen and Schrag (2015) | 12,3 | 1,0 | Δ47 |
| **ODP 689 (Weddell Sea)** | | Petersen and Schrag (2015) | 22 | 1,5 | Δ47 |
| **ODP 1172 (Tasmania)** | -62.4°N, 152.8°E | Douglas et al, (2014) | 17 | 4,0 | $TEX^{L}_{86}$ |
| **DSDP 277** | -59.8°N, 179.3°E | Douglas et al, (2014) | 25 | 4,0 | $TEX^{L}_{86}$ |
| **DSDP 277** | | Liu et al, (2009) | 25 | 1,1 | $U^{K'}_{37}$ |
| **DSDP 511** | -54.9°N, -34.1°E | Douglas et al, (2014) | 15 | 4,0 | $TEX^{L}_{86}$ |
| **DSDP 511** | | Liu et al, (2009) | 19,6 | 1,1 | $U^{K'}_{37}$ |
| **Brown Creek, Aus** | -54°N, 132°E | Kamp et al, (1990) | 18,4 | 0,7 | $\delta^{18}O$ |
| **ODP 1090** | -47.8°N, 0.2°E | Liu et al, (2009) | 24,2 | 1,1 | $U^{K'}_{37}$ |
| **Tanzania** | -14.7°N, 33.9°E | Pearson et al, (2001) | 25,5 | 0,7 | $\delta^{18}O$ |
| **Tanzania** | | Evans et al, (2018) | 29,7 | 3,2 | Δ47 |
| **Tanzania Lindi** | -15.7°N, 34.3°E | Pearson et al, (2001) | 28,5 | 0,7 | $\delta^{18}O$ |
| **ODP 929** | -5.9°N, -43.5°E | Liu et al, (2009) | 27,9 | 2,5 | $TEX_{86}$ |
| **ODP 929** | | Liu et al, (2009) | 27 | 1,1 | $U^{K'}_{37}$ |
| **ODP 803** | -5.2°N, -172.8°E | Liu et al, (2009) | 26,5 | 2,5 | $TEX_{86}$ |
| **ODP 1218** | 4°N, -113.5°E | Liu et al, (2009) | 23 | 2,5 | $TEX_{86}$ |
| **ODP 925** | 4.2°N, -43.5°E | Liu et al, (2009) | 28,3 | 2,5 | $TEX_{86}$ |
| **ODP 998** | 18.1°N, -75°E | Liu et al, (2009) | 20,5 | 2,5 | $TEX_{86}$ |
| **ODP 628** | 23.4°N, -71.7°E | Liu et al, (2009) | 30,5 | 2,5 | $TEX_{86}$ |
| **ODP 1052** | 28°N, -67.9°E | Okafor et al, (2009) | 31 | 1,2 | Mg/Ca |
| **Gulf Coast, USA** | 28.4°N, -81.1°E | Kobashi et al, (2004) | 20 | | $\delta^{18}O$ |

| Site | Location (paleo) | reference | SST (°C) | SST error | Method |
|---|---|---|---|---|---|
| **St Stephens Quarry** | 31°N, -87.8°E | Wade et al, (2012) | 32,5 | 2,2 | Mg/Ca |
| **Alabama US** | 31.5°N, -88°E | Pearson et al, (2001) | 26,5 | 0,7 | $\delta^{18}O$ |
| **Tarim** | 40°N, 75°E | Bougeois et al. (2016) | 27,5 | 10 | $\delta^{18}O$ |
| **DSDP 336** | 59.1°N, -13.5°E | Liu et al, (2009) | 20,2 | 1,1 | $U^{K'}_{37}$ |
| **ODP 913** | 69°N, -5°E | Liu et al, (2009) | 18,3 | 1,1 | $U^{K'}_{37}$ |

**Table 3: Late middle Eocene (42-38Ma) terrestrial proxy compilation**

| Site | Location (paleo) | altitude | references | MAT (°C) | MAT error |
|---|---|---|---|---|---|
| **ANTARCTICA** | | | | | |
| McMurdo | -77,7°N, 153,2°E | ? | Passchier et al. (2013) | 13 | 0 |
| King George | -66°N, -66,5°E | ? | Passchier et al. (2013) | 13 | 2 |
| ODP 1166 | -68°N, -66,5°E | ? | Passchier et al. (2013) | 12 | 0 |
| **SOUTH AMERICA** | | | | | |
| Ñirihuau (Chile) | -45°N, -61°E | ? | Hinojosa & Villagran (2005) | 18,4 | 0 |
| Gran Barranca (Argentina) | -50°N, -58°E | ? | Kohn et al. (2015) | 12,4 | 5 |
| **MYANMAR** | | | | | |
| Pondaung | 18,5°N, 90,6°E | ? | Licht et al. (2014) | 26 | 2 |
| **ASIA** | | | | | |
| ChangChang (Hainan Island) | 25°N,107°E | No | Spicer et al. (2017) | 22 | 3 |
| Liushagang I (Leizhou, Guangdong) | 24,6°N, 106,9°E | No | Zhang 1981 | 16 | 5 |
| Youganwo (Maoming Basin) | 25°N, 108°E | No | Yu & Wu 1983 | 17 | 1 |
| Youganwo (Maoming Basin) | | No | Spicer et al. (2017) | 20 | 3 |
| Yongning Gr U (Ningming, Guangxi) | 25,5°N, 104,2°E | No | Wang 2003 | 18 | 1 |
| Nadu (Baise, Guangxi) | 27,3°N, 103,6°E | No | Guo 1979, Liu & Yang 1999 | 16 | 0 |
| Pinghu (Donghai) | 29,7°N, 119,4°E | No | Sun 1989, Zhang 1990 | 17 | 1 |
| Linjiang L (Qingjiang) | 31,6°N,112,1°E | No | He & Sun 1977 | 18 | 1 |
| Dagzukha (Xigaze, Tibet) | 32°N,85,2°E | Yes | Li 2009 | 17 | 1 |
| Jianghan Basin | 34°N, 111°E | ? | Ma 2012 | 20 | 2 |

| Site | Location (paleo) | altitude | references | MAT (°C) | MAT error |
|---|---|---|---|---|---|
| Dingyuan V (Hefei Basin) | 35,5°N,114,4°E | No | Wang et al 1987 | 14 | 2 |
| Cheshme | 36°N, 61°E | ? | Akhmetiev 2014 | | |
| Relu U (Shiqu, Sichuan) | 36,2°N,94,9°E | Yes | Chen 1983 | 15 | 0 |
| Sanduo U (Gaoyou, Jiangsu) | 36,5°N,116,6°E | No | Zhang & Qian 1992 | 18 | 3 |
| Wanbaogou Gr U (Kulun Pass, Qinghai) | 38,1°N,88,2°E | Yes | Zhu 1985 | 19 | 3 |
| Lanzhou, Gansu | 39,4°N,100,2°E | Yes | Ma 1995 | 14 | 2 |
| Xining Gr (Minhe, Qinghai) | 39,5°N,100°E | Yes | Yu 2003 | 16 | 5 |
| Honggou III, IV (Xining, Qinghai) | 39,73°N,98°E | Yes | Sun 1980 | 17 | 4 |
| Xining | 40,1°N, 98,7°E | Yes | Hoorn, Han | 19 | 10 |
| Bashibulake (Shache Basin, Xinjiang) | 41°N, 72°E | No | Zhao 1982 | 19 | 2 |
| Xiaganchaigou L (Mangya, Qinghai) | 41,1°N, 86,4°E | Yes | Zhu 1985 | 17 | 1 |
| Huoshaogou Qiaojia (Yumen, Gansu) | 43,4°N, 92,9°E | Yes | Miao 2008 | 16 | 6 |
| Shahejie II (Qinhuangdao, Hebei) | 43,6°N,116,7°E | No | APE & NIGP 1978 | 17 | 1 |
| Xiaokuzibai (Kuche Basin, Xinjiang) | 44,1°N, 78,1°E | Yes | Zhao 1982<br>Zhang & Zhan 1991 | 19 | 2 |
| Genjiajie (Fushun, Liaoning) | 45,5°N,121,2°E | No | Qu 1993 | 18 | 0 |
| Fushun, Liaoning | 45,5°N,121,2°E | No | Ma 2012 | 18 | 2 |
| Hunchun | 46°N,128°E | No | Liu 1987, Zhang 1987 | 18 | 0 |
| S Primorye (Russia) | 47°N, 129°E | ? | Utescher 2015 | 20 | 2 |
| S Primorye (Russia) | | ? | Utescher 2015 | 18 | 0 |
| S Primorye | | ? | Akhmetiev 2014 | | |
| Huadian Basin | 47,7°N, 124°E | No | Ma 2012 | 17 | 1 |
| Zaisan Basin | 48°N, 85°E | ? | Akhmetiev 2014 | | |
| Yilan-Yitong | 50.5°N, 126°E | ? | Ma 2012 | | |
| Turgai | 51°N, 57°E | ? | Akhmetiev 2014 | | |
| Pavlodar | 54°N, 70°E | ? | Akhmetiev 2014 | | |
| **EUROPE** | | | | | |

| Site | Location (paleo) | altitude | references | MAT (°C) | MAT error |
|---|---|---|---|---|---|
| Stare Sedlo | 48°N, 6°E | ? | Uhl et al, (2007) | 25 | 4 |
| Weiße Elster | 49°N, 6°E | ? | Uhl et al, (2007) | 21 | 3 |
| Weiße Elster & Lausitz Basin (Knau gravel pit) | | ? | Utescher 2015 | 18 | 0 |
| Weiße Elster & Lausitz Basin (Haselbach) | | ? | Utescher 2015 | 19 | 2 |
| **NORTH AMERICA** | | | | | |
| Florissant CO | 39,25°N, -95°E | Yes (3800m) | Boyle et al, (2008) ; Wolfe et al. (1998) | 14 | 3 |
| Sevier (UT) | 40°N, -102,9°E | Yes (3600 +/- 700m) | Gregory-Wodzicki (1997) | 13 | 3 |
| Copper Basin (NV) | 43,2°N, -105,4°E | yes (2000m) | Wolfe et al, (1998) | 10 | 1 |
| Badger's Nose (CA) | 42,6°N, -109,7°E | ? | Prothero (2008) | 15 | 2 |
| Comstosk (OR) | 45,8°N, -112,3°E | No | Retallack et al, (2004) | 21 | 1 |
| Gray Butte (OR) | 45,6°N, -110,2°E | ? | Smith et al, (1998) | 14 | 5 |
| **NORTH ATLANTIC** | | | | | |
| ODP 913 MBT | 69°N, -12°E | ? | Schouten et al, (2008) | 12 | 4 |
| ODP 913 Pollen | | ? | Eldrett et al, (2009) | 13 | 3 |
| ODP 643 | 64°N, -15°E | ? | Eldrett et al, (2009) | 14 | 2 |

**Table 4: Late Middle Eocene (42-38 Ma) SST proxy compilation**

| Site | Location (paleo) | reference | SST (°C) | SST error | Method |
|---|---|---|---|---|---|
| **Seymour Island** | -65.7°N, -58°E | Douglas et al. (2014) | 12,6 | 2,4 | $\Delta_{47}$ *Cucullaea* |
| **Seymour Island** | | Douglas et al. (2014) | 13,5 | 2,0 | $\Delta_{47}$ *Eurhomalea* |
| **Seymour Island** | | Douglas et al. (2014) | 13,4 | 4,0 | $TEX^{L}_{86}$ |
| **ODP 1172** | -62.4°N, 152.8°E | Bijl et al, (2009), values with $TEX^{L}_{86}$ calibration in Douglas et al. (2014) | 20 | 4,0 | $TEX^{L}_{86}$ |
| **DSDP 277** | -59.8°N, 179.3°E | Hines et al, (2017) | 26,6 | 1,7 | Mg/Ca |
| **New Zealand (Hampden)** | -51°N, -165°E | Hollis et al. (2012) | 16,8 | 4,0 | $TEX^{L}_{86}$ |
| **New Zealand (Mid Waipara)** | | Hollis et al. (2012) | 17,4 | 4,0 | $TEX^{L}_{86}$ |

| Site | Location (paleo) | reference | SST (°C) | SST error | Method |
|---|---|---|---|---|---|
| **Tanzania Lindi** | -15.7°N, 34.3°E | Pearson et al, (2001) | 32 | 0,7 | $\delta^{18}O$ |
| **Java KW01** | -0.4°N, 109.2°E | Evans et al, (2018) | 35 | 2,0 | $\Delta_{47}$ |
| **Java KW01** | | Evans et al, (2018) | 36,3 | 1,9 | $\Delta_{47}$ |
| **ODP 925** | 1.4°N, -151.4°E | Liu et al, (2009) | 28 | 1,1 | $U^{K'}_{37}$ |
| **ODP 925** | | Liu et al, (2009) | 29 | 2,5 | $TEX_{86}$ |
| **ODP 865** | 8.3°N, -151.4°E | Tripati et al, (2003) | 31 | 4,7 | Mg/Ca |
| **Gulf Coast, USA** | 28.4°N, -81.1°E | Kobashi et al, (2004) | 21 | 0,7 | $\delta^{18}O$ |
| **Istra More 5** | 39°N, 10°E | Pearson et al, (2001) | 24 | 0,7 | $\delta^{18}O$ |
| **Tarim** | 40°N, 77°E | Bougeois 2016 | 27,5 | 10 | $\delta^{18}O$ |
| **Hampshire Basin** | 48.4°N, -6.4°E | Evans et al, (2018) | 23,2 | 2,6 | $\Delta_{47}$ |
| **DSDP 336** | 59.1°N, -13.5°E | Liu et al, (2009) | 21,8 | 1,1 | $U^{K'}_{37}$ |
| **ODP 913** | 69°N, -5°E | Liu et al, (2009) | 25 | 1,1 | $U^{K'}_{37}$ |
| **ACEX** | 87.9°N,136.2°E | Weller and Stein 2007 | 8 | 1,1 | $U^{K'}_{37}$ |

**Table 5: Qualitative proxy compilation used in Figure 4a.**

| Site | Location (modern) | reference | main qualitative composition |
|---|---|---|---|
| **Yilan-Yitong (China)** | 46°N, 129°E | Ma et al. 2012 | forest |
| **Huadian (China)** | 43°N, 127°E | Ma et al. 2012 | forest |
| **Fushun (China)** | 42°N, 124°E | Ma et al. 2012 | forest |
| **Jiuquan (China)** | 40°N, 97°E | Ma et al. 2012 | shrub/grass |
| **Qaidam (China)** | 38°N, 91°E | Ma et al. 2012 | shrub/grass |
| **Dahonggou (China)** | 37°N, 95°E | Ma et al. 2012 | shrub/grass |
| **Xining (China)** | 37°N, 102°E | Hoorn et al. 2012 | shrub/grass |
| **Lushi (China)** | 34°N, 111°E | Ma et al. 2012 | grass |
| **Tantou (China)** | 34°N, 118°E | Ma et al. 2012 | forest |
| **Tailai (China)** | 36°N, 117°E | Ma et al. 2012 | forest |
| **Nanling (China)** | 31°N, 118°E | Ma et al. 2012 | forest |
| **Jianghan (China)** | 30°N, 113°E | Ma et al. 2012 | shrub/forest |
| **Baise (China)** | 22°N, 109°E | Ma et al. 2012 | forest |
| **Assam (India)** | 26°N, 92°E | Saxena and Trivedi 2009 | forest |
| **southern India** | 12°N, 79°E | Boucot et al. 2013 | forest |
| **Kashmir (India)** | 39°N, 75°E | Boucot et al. 2013 | forest |
| **Cambay (India)** | 22°N, 73°E | Boucot et al. 2013 | forest |

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|---|---|---|---|
| **Rajasthan (India)** | 27°N, 74°E | Boucot et al. 2013 | forest |
| **Pondaung (Myanmar)** | 21°N, 94°E | Licht et al. 2014 | forest |
| **Nanggulan and Walat (Java)** | 6°S, 107°E | Morley 2018 | forest |
| **Mangkalihat (Kalimantan)** | 1°N, 118°E | Morley 2018 | forest |
| **Turgai (Russia)** | 51°N, 57°E | Akhmetiev and Zaporozhets 2014 | forest |
| **Zaisan (Russia)** | 48°N, 85°E | Akhmetiev and Zaporozhets 2014 | forest |
| **Chesme (Turkmenistan)** | 36°N, 61°E | Akhmetiev and Zaporozhets 2014 | shrub |

**Figure 6 : JJA Air Temperature (in Kelvin) at 300 mb for Control (a) ERA 5 reanalysis (b) with contours overlaid each degree.**

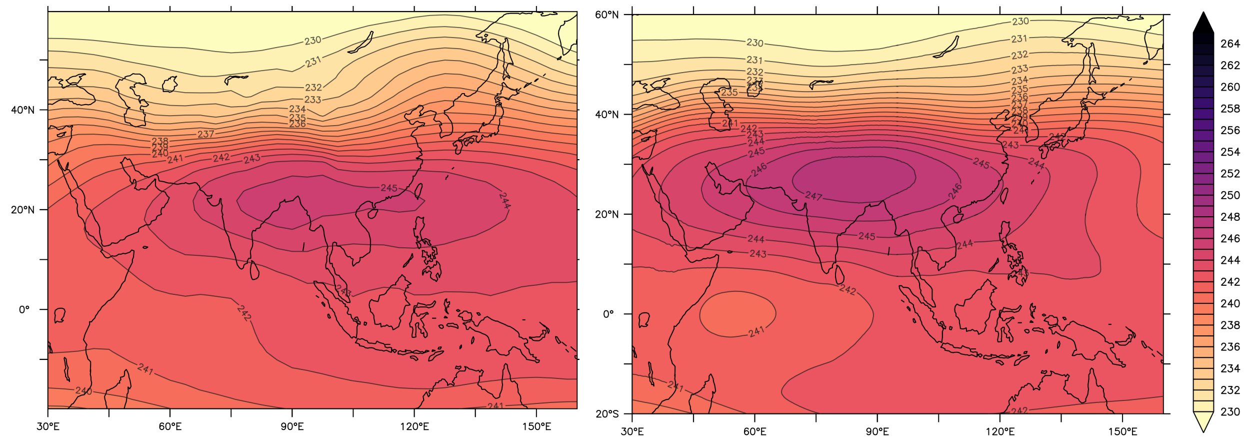
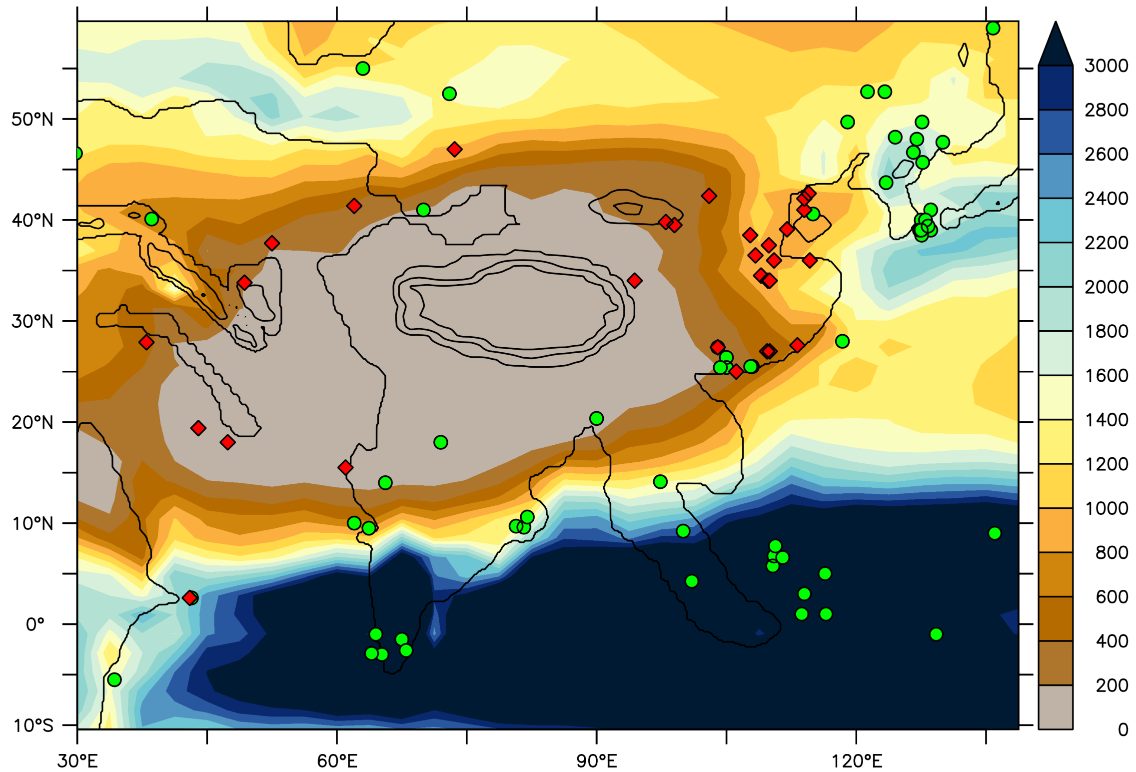


**Figure 7 : Late Eocene Mean Annual Precipitations are shaded (in mm/year) and compared to the occurrence of arid climate related evaporites deposits (red diamonds) and more ever-wet climate related coal deposits (green circles).**



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