Site name	Oldest Age (Ma)	Youngest Age (Ma)	MAT (°C)	Original Error (±°C)	Error this study (±°C)	Palaeolatitude	Palaeolongitude	Primary Reference	Notes
Porcupine River 90-1, Organic bed	15.3	15.1	8.00	1.17	8.00	68.199	-132.538	White and Ager, 1994	Pollen spores
Nenana Coal Fm	17	14	7.50	1.00	8.00	65.113	-140.196	Liu and Leopold, 1994	Pollen spores
Coal Creek	16	13	8.00	1.17	8.00	64.998	-140.17	Leopold and Liu, 1994; Grimaldi and Triplehorn, 2008	Pollen spores/insects
Purple Mountain	14.8	12.4	11.50	0.00	5.00	39.729	-113.792	Axelrod, 1995	Microflora assemblages
Tenachapi	15.5	11.8	18.50	18.50	9.50	35.303	-112.75	Axelrod, 1940	Microflora assemblages
Martha's Vineyard	16	11	14.30	5.00	5.00	39.728	-65.282	Frederiksen, 1984; Axelrod, 2000	Spores and pollen grains
West point island	15.97	5.33	12.00	1.00	5.00	-53.409	-53.643	Macphail and Cantrill, 2006	Pollen spores
Kreuzau	15.97	11.61	18.00	3.00	5.00	49.904	4.84	Ferguson et al., 1998	Pollen and plant assemblages
Engelsdorf	14.3	13.8	18.30	2.50	5.00	47.956	10.6	Böhme et al., 2007	Coexistence on fossil wood
Oberlenghart	14.3	13.8	18.30	2.50	5.00	47.958	10.666	Böhme et al., 2007	Coexistence on fossil woods
Malgersdorf 1	14.3	13.8	18.30	2.50	5.00	47.98	11.357	Böhme et al., 2007	Coexistence on fossil woods
Baden Sooss	14.7	14.2	18.50	2.50	5.00	47.516	14.805	Kováčová et al., 2009	Foraminifera
Nogradszakal	15	13.6	15.25	1.25	5.00	47.811	18.028	Erdei et al., 2007	Coexistence approach on flora
Tengelic-2	15.97	13.65	19.00	2.00	5.00	46.11	17.27	Jiménez-Moreno, 2006	Palynological analysis
Ternova	14	12.7	16.80	1.60	5.00	47.846	21.605	Syabryaj et al., 2007	fossil leaves/fruits and seeds
Deleina C-12	15	12.2	17.00	1.40	5.00	43.773	21.539	Ivanov et al., 2002	Coexistence of palynofloras
Makresh C-37	14.2	12.2	17.00	1.40	5.00	43.644	21.596	Ivanov et al., 2002	Pollen coexistence apporach
C-136A	14.9	11.61	15.40	1.80	5.00	43.427	27.041	Ivanov et al., 2007	Pollen coexistence approach
Bascayir	15.97	13.65	19.15	2.15	5.00	37.692	27.013	Akgün and Akyol, 1999; Akgün et al., 2007	Coexistence
Milas-Kultak	15.97	13.7	18.90	2.40	5.00	36.97	27.171	Kayseri and Akgün, 2010	Coexistence on palynofloras
Isakovka	15.97	11.61	9.00	2.00	5.00	57.08	72.062	Gnibidenko et al., 1999	Magnetostratigraphic and paleobotanical
1-OP	15.97	11.61	9.00	2.00	5.00	56.364	71.822	Gnibidenko et al., 1999	Magnetostratigraphic and paleobotanical
Chifeng	15.97	11.61	12.00	3.00	5.00	44.137	118.63	Tao, 1997	Paleofloristic
Shanwang	17	14	12.70	3.00	5.00	39.004	118.063	Liu and Leopold, 1994; Sun et al., 2002	Pollen and leaf flora
Yallourn	16	15	19.00	5.00	5.00	-45.558	145.768	Kershaw, 1997 (Real paper Sluiter 1995)	Bioclim estimate
Yallourn	16	11.61	19.00	5.00	5.00	-45.563	145.729	Holdgate et al., 2007 (Real paper Sluiter 1995)	Bioclim estimate
Sønder Vium	16	14	16.00	4.00	5.00	53.83	4.98	Larsson et al., 2011	Pollen analysis and coexistence approach
Leizhou	15	13	18.50	3.00	5.00	23.27	108.09	Yao et al., 2010	Pollen and leaf analysis and coexistence approach
Zhujiangkou	15	13	23.00	3.00	5.00	24.20	111.32	Yao et al., 2010	Pollen and leaf analysis and coexistence approach
Columbia River Gorge	15.8	15.3	17.00	5.00	5.00	46	116.5	Takeuchi et al., 2007	Paleosols
Columbia River Gorge	15.8	15.3	16.00	5.00	5.00	46.5	119.3	Takeuchi et al., 2007	Paleosols
Rhine	16	14	17.00	2.00	5.00	49.30	3.06	Utescher, 2000	Coexistence on megafloras(seeds, fruits, woods)
Kangaroo Well	17	14.5	17.00	5.00	5.00	-32	129.7	Megirian et al. (2004)	Sediment modelling and flora and fauna analogs
Potosi, Bolivia	17	14.5	21.60	2.50	5.00	-21.7	-62.8	Gregory-Wodzicki et al. (1998)	CLAMP/Wolfe foliar physiognomic method
Fejej, Ethiopia	15	15	26.00	2.50	5.00	3.06	33.06	Wiemann et al. (1999)	Wood
Latrobe Valley	17	14.5	19.00	0.00	5.00	-45	146	Sluiter et al. (1995)	Coal deposits (bioclimatic prediction)
Cape Blanco, North America	17	14.5	16.20	0.00	5.00	43.78	-120.67	Wolfe (1994b)	Clamp
Waeaverville, North America	17	14.5	16.20	0.00	5.00	41.62	-119.14	Wolfe (1994b)	Clamp
Lantian, China	17	14.5	18.50	2.30	5.00	35.57	105.83	Liu et al. (2011)	Coexistence
Dunhua, China	17	14.5	15.80	3.40	5.00	45.13	126.35	Liu et al. (2011)	Coexistence
Namling Basin	17	14.5	6.80	3.40	5.00	30.91	87.24	Spicer et al. (2003)	Clamp
Treubach	17	14.5	16.40	1.00	5.00	47.11	10.22	Imbrie and McIntyre, 2006	Coexistence
Popovac	17	14.5	17.85	3.45	5.00	43.11	18.40	Utescher et al. (2007)	Coexistence
Weisselster and Lausitz Basin	17	14.5	16.35	1.95	5.00	48.89	9.03	Mosbrugger et al. (2005)	Coexistence
Lower Rhine	17	14.5	17.20	1.95	5.00	49.68	3.61	Mosbrugger et al. (2005)	Coexistence
Bacchus Marsh, SE Australia	17	14.5	13.00	0.00	5.00	-45	144	Greenwood (1994)	LMA
Cook Inlet, North America	17	15	11.00	3.00	5.00	62	-142	Wolfe, 1994	Clamp
Mangdan	17	15	19.65	3.60	5.00	25.81	96.56	Sun et al., 2011	LMA
Jianchuan	17	15	18.20	3.60	5.00	28.22	97.60	Sun et al., 2011	LMA
Tengchong	17	15	20.03	3.60	5.00	25.84	96.54	Sun et al., 2011	LMA
Schrotzburg	17	15	15.50	1.75	5.00	46.43	5.91	Uhl et al., 2006	CA,LMA,CLAMP,ELPA

Table S1. Compilation of terrestrial proxy records from Pound et al., 2012, Herold et al., 2011, and others. GPLATES version 1.0.2 (http://www.gplates.org) was used to rotate back the proxy records from modern day to 15 Ma (Müller et al., 2008).

Site Name	Site Location	Age (Ma)	Paleo-lat	Paleo-lon	MAT SST (˚C)	Error (˚C)	Primary Reference	Notes
ODP 1170A	Pacific Ocean below Australia	14.2-13.8	-50	147	18	1.2	Shevenell et al., 2004	Mg/Ca of surface dwelling planktonic foraminifer
ODP 1171C	Pacific Ocean below Australia	14.2-13.8	-51	149	17	1.2	Shevenell et al., 2004	Mg/Ca of surface dwelling planktonic foraminifer
M9	Tanzania	12.2	7.37	36.70	27	2.0	Stewart et al., 2004	surface dwelling planktonic foraminfer
M11 and M12	Tanzania	11.55	7.37	36.70	29	2.0	Stewart et al.,2004	surface dwelling planktonic foraminfer
ODP 1010	Subtropical East Pacific	12	31.23	-114.77	27.5	1.5	LaRiviere et al., 2012	Alkenone SST
ODP 1021	Northeast Pacific	12	39.93	-124.08	23	1.5	LaRiviere et al., 2012	Alkenone SST
AND-2A	Ross Sea	15.7	-76.49	158.90	5.5	5.0	Warny et al., 2009	Fossil Cyst Dinoflagellate (Dinoflagellate Ecological Tolerance)
ODP 925	Western equatorial Atlantic Ocean	15.8	2.56	-40.85	28.10	1.7	Zhang et al., 2013	TEX86, SST calculated using the Kim et al., 2008 Calibration

Table S2. List of SST proxy records from MMCO (17-11.5 MA). Table includes site name, site location, age in million of years (Ma), paleoclimate latitude and longitude, global MAT, methodological error (˚C), analysis used to estimate SSTs, and reference.

Table S3. MODEL EQUILIBRIUM DIAGNOSTICS		
Simulation Name and Records	**Residual surface energy (W/m^2)**	**Residual top of atmosphere energy (W/m^2)**
MMCO Records	-	-
PI	0.17	0.15
PI400	0.20	0.20
MMCO	0.14	0.15
MMCO560	-0.10	-0.09
MMCO800	-0.07	-0.05
LOW AIS	0.06	0.07
EP	-0.37	-0.37
EP+ORB	-0.36	-0.33
CCSM3.0 T31 355 ppm CO_2	-0.11	-0.09
CCSM3.0 T31 560 ppm CO_2	-0.04	-0.06

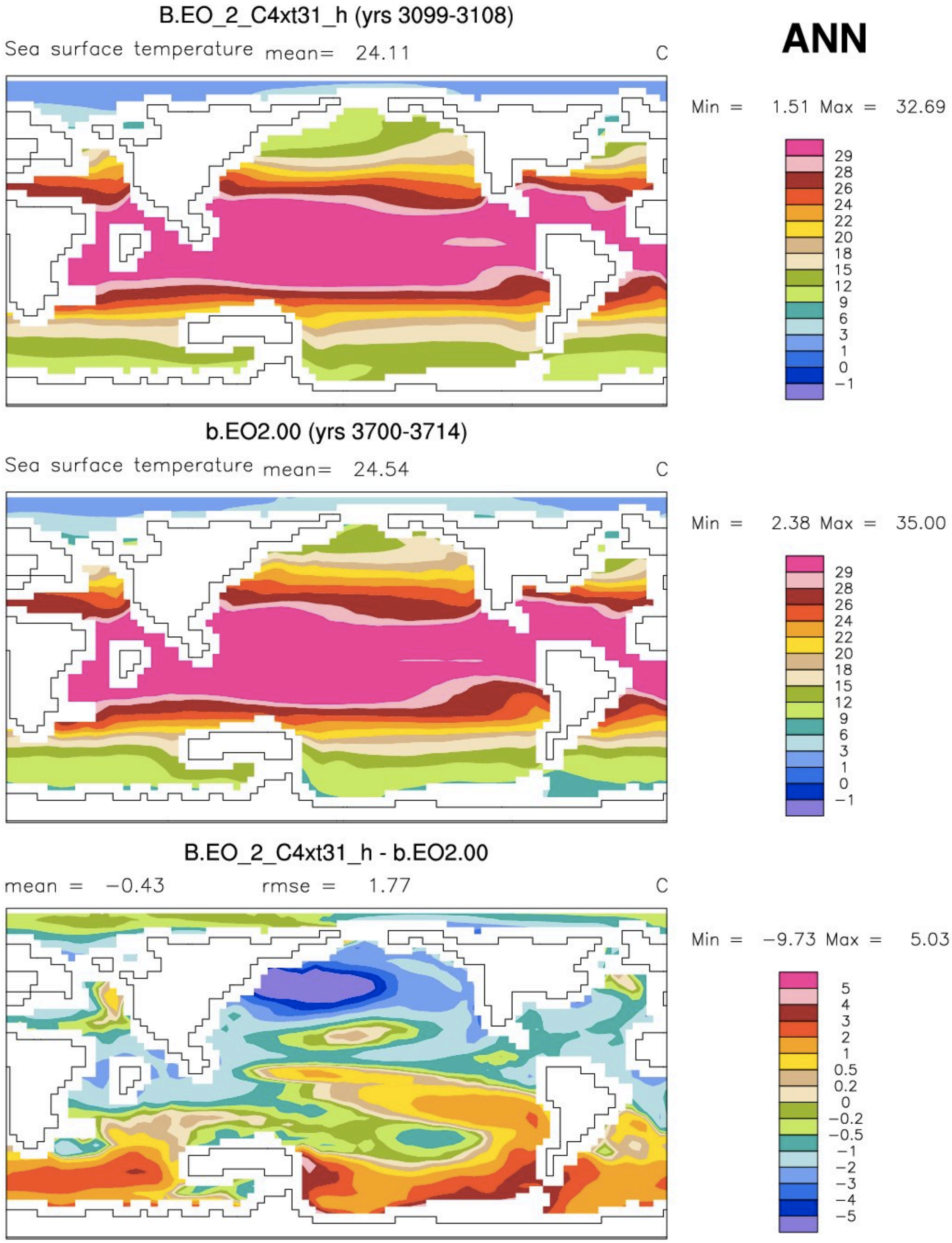

Figure S1. CESM1.0 and CCSM3.0 fully coupled atmosphere ocean Eocene simulations run at 1120 ppm CO_2 for over 3000 years. (a) CESM1.0 SST (˚C) distribution, (b) CCSM3.0 SST distribution, (c) and SST anomaly between CESM1.0 and CCSM3.0.

SM References:

Akgün F. and Akyol E.: Palynostratigraphy of the coal-bearingNeogene deposits in By k Menderes Graben, western Anatolia. Geobios, 32, 367–383, 1999.

Akgün, F., M.S. Kayseri, Akkiraz, M.S.: Palaeoclimatic evolution and vegetational changes during the Late Oligocene–Miocene period in Western and Central Anatolia (Turkey), Palaeogeography, Palaeoclimatology, Palaeoecology, 253, 56--90, 2007.

Axelrod, D.I., (1995), The Miocene Purple Mountain flora of western Nevada. University of California Publications in Geological, Sciences, 139, 1--62, 1995.

Axelrod, D.I.: A Miocene Flora from the western border of the Mojave Desert. Carnegie Institute of Washington, Publication 476, Washington, DC, USA, 1940.

Axelrod, D.I.: A Miocene (10--12 Ma) evergreen laurel–oak forest from Carmel Valley, California. Univ. Calif. Publ. Geol. Sci.145, 1--34, 2000.

Böhme, M. Bruch, A.A. Selmeier, A.: The reconstruction of Early and Middle Miocene climate and vegetation in Southern Germany as determined from the fossil wood flora. Palaeogeography, Palaeoclimatology, Palaeoecology, 253, 91–114 (this volume) doi:10.1016/j.palaeo.2007.03.035, 2007.

Donders, T.H. Weijers, J.W.H. Munsterman, D.K. Kloosterboer-van Hoeve, M.L. Buckles, L.K. Pancost, R.D. Schouten, S. Sinninghe Damsté, J.S. Brinkhuis, H.: Strong climate coupling of terrestrial and marine environments in the Miocene of northwest Europe. Earth and Planetary Science Letters, Volume 281, Issues 3–4, 15, 215--225, 2009.

Erdei, B., L. Hably, M. Kazmer, T. Utescher, and Bruch, A.A.: Neogene flora and vegetation development of the Pannonian domain in relation to palaeoclimate and palaeogeography. Palaeogeogr., Palaeoclimatol., Palaeoecol., 253, 131--156, 2007.

Ferguson DK, M. Pingen, R. Zetter, Hofmann, C.C.: Advances in our knowledge of the Miocene plant assemblage from Kreuzau, Germany. Rev Palaeobot Palynol, 101, 147–177, 1998.

Flower, B.P. and Kennett, J.P.: The Middle Miocene climatic transition: East Antarctic ice sheet development, deep ocean circulation and global carbon cycling. Palaeogeogr. Palaeoclimatol. Palaeoecol, 108, 537--555, 1994.

Frederiksen, N.O.: Stratigraphic, paleoclimatic, and paleobiogeographic significance of Tertiary sporomorphs from Massachusetts: U. S. Geological Survey Professional Paper, 1308, 25, 1984.

Gnibidenko, Z.N., V.A. Martynov, V.P. Nikitin, Semakov, N.N.: Magnetostratigraphic and paleobotanical description of the Miocene deposits in the Beshcheul Horizon of West Siberia. Russian Geology and Geophysics, 40, 1776--1788, 1999.

Grimaldi, D.A. and Triplehorn, D.M., 2008, Insects from the Upper Miocene Grubstake Formation of Alaska, American Museum Novitates Number 3612, p. 1-19,doi: http://dx.doi.org/10.1206/602.1.

Herold, N., Huber, M., and Müller, R. D.: Modeling the Miocene Climatic Optimum.Part I: Land and Atmosphere, J. Climate, 24, 6353–6372, doi:10.1029/2010PA002041, 2011.

Imbrie, J.D., McIntyre, A., 2006, SPECMAP time scale developed by Imbrie et al., 1984 based on normalized planktonic records (normalized O-18 vs time, specmap.017). doi:10.1594/PANGAEA.441706.

Ivanov, D.A., A.R. Ashraf, V. Mosbrugger, Palamarev, E.: Miocene microflora and palaeoclimate reconstructions from three sites in Bulgaria. PANGAEA. doi:10.1594/PANGAEA.596352, 2007.

Ivanov, D., A.R. Ashraf, V. Mosbrugger, Palamarev, E.: Palynological evidence for Miocene climate change in the Forecarpathian Basin (Central Paratethys, NW Bulgaria). Palaeogeography, Palaeoclimatology, 2002.

Jimenez-Moreno, G.: Progressive substitution of a subtropical forest for a temperate one during the middle Miocene climate cooling in Central Europe according to palynological data from cores Tengelic-2 and Hidas-53 (Pannonian Basin, Hungary). Review Palaeobotany and Palynology, 142, 1--14, 2006.

Kayseri M.S., and Akgün, F.: The Late Burdigalian–Langhian Time Interval in Turkey and the Palaeoenvironment and Palaeoclimatic Implications and Correlation of Europe and Turkey: Late

Burdigalian-Langhian Palynofloras and Palaeoclimatic properties of the Muğla–Milas (Kultak). Geological Bulletin of Turkey, 53, 1--44, 2010.

Kim, J. H., Schouten, S., Hopmans, E. C., Donner, B., and Sinninghe Damsté, J. S.: Global sediment core-top calibration of the TEX86 paleothermometer in the ocean. Geochimica et Cosmochimica Acta, *72*, 1154-1173, 2008.

Kováčová P., L. Emmanuel, N. Hudáčková, and M. Renard, M.: Central Paratethys paleoenvironment during the Badenian (Middle Miocene): evidence from foraminifera and sTable isotope (δ13C and δ18O) study in the Vienna Basin (Slovakia). Int. J. Earth Sci. 10.1007/s00531-008-0307-2, 2008.

Larsson L.M., V. Vajda, Dybkjær, K.: Vegetation and climate in the latest Oligocene–earliest Miocene in Jylland, Denmark. Rev. Palaeobot. Palynol., 159, 166-176, 2010.

LaRiviere, J. P., C.A. Ravelo, A. Crimmins, P.S. Dekens, H.L. Ford, M. Lyle, Wara, M.W.: Late Miocene decoupling of oceanic warmth and atmospheric carbon dioxide forcing Source: Nature, 486, 97--100, doi:10.1038/nature11200, 2012.

Liu, G. and Leopold, E.B.: Climatic comparison of Miocene pollen floras from northern East-China and south-central Alaska, USA,108,217, 10.1016/0031-0182(94)90235-6, 1994.

Leopold, E. B., and Liu, G.: A long pollen sequence of Neogene age, Alaska Range. Quaternary International, 22/23:103-140, 1994.

Liu, Y.S., T. Utescher, Z. Zhou, Sun, B.: The evolution of Miocene climates in North China: Preliminary results of quantitative reconstructions from plant fossil record. 304, 308--317, http://dx.doi.org.ezproxy.lib.purdue.edu/10.1016/j.palaeo.2010.07.004, 2011.

Macphail M., and Cantrill, D.J.: Age and implications of the Forest Bed, Falkland Islands, southwest Atlantic Ocean: Evidence from fossil pollen and spores. Palaeogeography, Palaeoclimatology, Palaeoecology, 240, 602--629, 2006.

Müller, R.D., Sdrolias, M., Gaina, C. and Roest, W.: Age, spreading rates and spreading asymmetry of the world's ocean crust, Geochemistry, Geophysics, Geosystems, 9, Q04006, doi: 10.1029/2007GC001743, 2008.

Pound, M., Haywood, A. M., Salzman, U., and Riding J. B.: Global vegetation dynamics and latitudinal temperature gradients during the Mid to LateMiocene (15.97–5.33Ma), Earth-Sci. Rev., 112, 1–22, doi:10.1016/j.earscirev.2012.02.005, 2012.

Royer D.L.: Climate reconstruction from leaf size and shape: new developments and challenges. In: Ivany LC, Huber BT (eds). Reconstructing Earth's Deep-Time Climate—The State of the Art in 2012. Paleontological Society Papers, 18, 195-212 (invited contribution), 2012.

Shevenell, A.E., J.P. Kennett, D.W. Lea, D.W.: Middle Miocene Southern Ocean cooling and Antarctic cryosphere expansion. Science, 305, 1766--1770, 2004.

Sluiter, I.R.K., A.P. Kershaw, G.R. Holdgate, and Bulman, D.: Biogeographic, ecological and stratigraphic relationships of the Miocene brown coal floras, Latrobe Valley, Victoria, Australia, *in* Demchuck, T.D., Shearer, J.C., and Moore, T.A., eds.. International Journal of Coal Geology, 28, 277--302, 1995.

Stewart, D.R.M., P.N. Pearson, P.W. Ditchfield, Singano, J.M.: Miocene tropical Indian Ocean temperatures: evidence from three exceptionally preserved foraminiferal assemblages from Tanzania. Journal of African Earth Sciences, 40, 173--190, 2004.

Sun, B-N et al., Neogene palaeoclimatic estimates based on eight fossil samples from South-West China. doi:10.1594/PANGAEA.761692, 2011.

Tao, J.J.: The paleofloristic and paleoclimatic changes during the Mid−Miocene in China. In: 1316 Jablonski, N.G. (Ed.), The changing face of East Asia during the Tertiary and Quaternary. The University of Hong Kong, Hong Kong, 1997.

Uhl, D., A.A. Bruch, C. Traiser, S. Klotz, S.: Palaeoclimate estimates for the Middle Miocene Schrotzburg flora (S-Germany). A multi-method approach. Internat. J. Earth Sci. 95, 1071--1085, 2006.

Utescher, T., Djordjevic-Milutinovic, D. Bruch, A. Angela, Mosbrugger, V.: Climate and vegetation changes in Serbia during the last 30 Ma. Palaeogeography, Palaeoclimatology, Palaeoecology, 253, 157--168, doi:10.1016/j.palaeo.2007.03.037, 2007.

Warny, S., R.A. Askin, M.J. Hannah, B.A.R. Mohr, J.I. Raine, D.M. Harwood, F. Florindo, Team, 1151 S.S.: Palynomorphs from a sediment core reveal a sudden remarkably warm Antarctica during the middle Miocene. Geology, 37, 955--958, 2009.

White, J. M., and Ager, T.A.: Palynology, paleoclimatology and correlation of Middle Miocene beds from Porcupine River (locality 90-1), Alaska. Quat. Int., 22--23, 43--77, 1994.

Yao, Y.F., A.A. Bruch, V. Mosbrugger, Li, C.S.: Quantitative reconstruction of Miocene climate patterns and evolution in Southern China based on plant fossils. Palaeogeography, Palaeoclimatology, Palaeoecology, 304, 291--307, http://dx.doi.org/10.1016/j.palaeo.2010.04.012, 2011.