

Annex 1: Experimental Design Sheets - Core Experiments

Experiment *PI*

Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Ocean Input
Predicted	Local Pre-Industrial/Modern

Geographic Boundary Conditions

Land/Sea Mask	Topography	Ice Sheets	Vegetation
Local Modern	Local Modern	Local Modern	Pre-industrial prescribed

Greenhouse Gases*

CO ₂	N ₂ O	CH ₄	CFCs	O ₃
280 ppm	270 ppb	760 ppb	0	Local Modern

Solar Constant*

1365 W/m ²

Aerosols

Pre-industrial

Model Spin-up

Documented by individual groups

Orbital Parameters*

[ecc = 0.016724] - [obl = 23.446°] - [peri - 180° = 102.04°] Date of vernal equinox March 21 at noon (CMIP5/PMIP3 values as used in PlioMIP2)

*Modelling groups submitting CMIP7 experiments can set the solar constant, orbital parameters and atmospheric greenhouse gas levels in their PlioMIP3 pre-industrial experiment to be the same as in their CMIP7 DECK pre-industrial simulation.

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Experiment *LP*

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Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Deep Ocean Input		
Predicted	Previously spun up Pliocene simulation (e.g., Eoi400) or pre-industrial state		
Land/Sea Mask	Topography [‡]	Ice Mask	Vegetation
LP_LSM_v1.0.nc	LP_topo_v1.0.nc	LP_icemask_v1.0.nc	LP_mbiome_v1.0.nc

Greenhouse Gases

CO ₂	N ₂ O	CH ₄	CFCs	O ₃
400 ppm	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>

Solar ConstantAs Exp. *PI***Aerosols**As Exp. *PI***Model Spin-up**

Documented by individual groups – recommend starting from the end of an existing *LP*/Eoi400 experiment

Orbital ParametersAs Exp. *PI*

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[‡]Apply using the anomaly method (see Haywood et al. 2016 – Climate of the Past for additional details: <https://doi.org/10.5194/cp-12-663-2016>).

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Extension Experiments

Experiment *LP_min_LSM_change*

Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Deep Ocean Input
Predicted	Previously spun up Pliocene simulation (e.g., <i>LP/Eoi400</i>) or pre-industrial state

Land/Sea Mask	Topography [‡]	Ice Mask	Vegetation
LP_MinLSM_LSM_v1.0.nc	LP_MinLSM_topo_v1.0.nc	LP_MinLSM_icemask_v1.0.nc	LP_MinLSM_mbiome_v1.0.nc

Greenhouse Gases

CO ₂	N ₂ O*	CH ₄ *	CFCs*	O ₃ *
400 ppm	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>

Solar Constant*

As Exp. <i>PI</i>

Aerosols

As Exp. <i>PI</i>

Model Spin-up

Documented by individual groups – recommend starting from the end of an existing <i>LP/Eoi400</i> experiment
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Orbital Parameters*

As Exp. <i>PI</i>

[‡]Apply using the anomaly method (see Haywood et al. 2016 – Climate of the Past for additional details: <https://doi.org/10.5194/cp-12-663-2016>). *Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant, orbital parameters and atmospheric greenhouse gas levels in their PlioMIP3 *LP_min_LSM_change* experiment to be the same as in their CMIP7 DECK pre-industrial simulation.

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Experiment *EP*

Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Deep Ocean Input		
Predicted	Previously spun up Pliocene simulation (e.g., <i>LP/Eoi400</i>) or pre-industrial state		
Land/Sea Mask	Topography [‡]	Ice Mask	Vegetation
EP_LSM_v1.0.nc	EP_topo_v1.0.nc	EP_icemask_v1.0.nc	EP_mbiome_v1.0.nc

Greenhouse Gases

CO ₂	N ₂ O*	CH ₄ *	CFCs*	O ₃ *
490 ppm	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>

Solar Constant*

As Exp. <i>PI</i>

Aerosols

As Exp. <i>PI</i>

Model Spin-up

Documented by individual groups – recommend starting from the end of an existing <i>LP/Eoi400</i> experiment. Ensure that spin up methodology enables a direct/clean comparison of experiments <i>LP</i> , <i>EP</i> , <i>LP</i> ⁴⁹⁰ , <i>LP</i> ⁵⁶⁰ and <i>LP</i> ²⁸⁰

Orbital Parameters*

As Exp. <i>PI</i>

[‡]Near the CAS use the topography file. Elsewhere apply using the anomaly method (see Haywood et al. 2016 – Climate of the Past for additional details: <https://doi.org/10.5194/cp-12-663-2016>). *Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant, orbital parameters and atmospheric greenhouse gas levels in their PlioMIP3 *EP* experiment to be the same as in their CMIP7 DECK pre-industrial simulation.

Optional Experiments

Experiment *LP*⁴⁹⁰

Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Deep Ocean Input		
Predicted	Previously spun up Pliocene simulation (e.g., <i>LP/Eoi400</i>) or pre-industrial state		
Land/Sea Mask	Topography ^ψ	Ice Mask	Vegetation
LP_LSM_v1.0.nc	LP_topo_v1.0.nc	LP_icemask_v1.0.nc	LP_mbiome_v1.0.nc

Greenhouse Gases

CO ₂	N ₂ O*	CH ₄ *	CFCs*	O ₃ *
490 ppm	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>

Solar Constant*

As Exp. *PI*

Aerosols

As Exp. *PI*

Model Spin-up

Documented by individual groups – recommend starting from the end of an existing *LP/Eoi400* experiment. Ensure that spin up methodology enables a direct/clean comparison of experiments *LP*, *EP*, *LP*⁴⁹⁰, *LP*⁵⁶⁰ and *LP*²⁸⁰

Orbital Parameters*

As Exp. *PI*

^ψApply using the anomaly method (see Haywood et al. 2016 – Climate of the Past for additional details: <https://doi.org/10.5194/cp-12-663-2016>). *Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant, orbital parameters and atmospheric greenhouse gas levels in their PlioMIP3 *LP*⁴⁹⁰ experiment to be the same as in their CMIP7 DECK pre-industrial simulation.

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Experiment *LP*⁵⁶⁰

Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Deep Ocean Input		
Predicted	Previously spun up Pliocene simulation (e.g., <i>LP/Eoi400</i>) or pre-industrial state		
Land/Sea Mask	Topography [‡]	Ice Mask	Vegetation
LP_LSM_v1.0.nc	LP_topo_v1.0.nc	LP_icemask_v1.0.nc	LP_mbiome_v1.0.nc

Greenhouse Gases

CO ₂	N ₂ O*	CH ₄ *	CFCs*	O ₃ *
560 ppm	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>

Solar Constant*

As Exp. *PI*

Aerosols

As Exp. *PI*

Model Spin-up

Documented by individual groups – recommend starting from the end of an existing *LP/Eoi400* experiment. Ensure that spin up methodology enables a direct/clean comparison of experiments *LP*, *EP*, *LP*⁴⁹⁰, *LP*⁵⁶⁰ and *LP*²⁸⁰

Orbital Parameters*

As Exp. *PI*

[‡]Apply using the anomaly method (see Haywood et al. 2016 – Climate of the Past for additional details: <https://doi.org/10.5194/cp-12-663-2016>). *Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant, orbital parameters and atmospheric greenhouse gas levels in their PlioMIP3 *LP*⁵⁶⁰ experiment to be the same as in their CMIP7 DECK pre-industrial simulation.

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Experiment *LP*²⁸⁰

Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Deep Ocean Input		
Predicted	Previously spun up Pliocene simulation (e.g., <i>LP/Eoi400</i>) or pre-industrial state		
Land/Sea Mask	Topography [‡]	Ice Mask	Vegetation
LP_LSM_v1.0.nc	LP_topo_v1.0.nc	LP_icemask_v1.0.nc	LP_mbiome_v1.0.nc

Greenhouse Gases*

CO ₂	N ₂ O	CH ₄	CFCs	O ₃
As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>

Solar Constant*

As Exp. <i>PI</i>

Aerosols

As Exp. <i>PI</i>

Model Spin-up

Documented by individual groups – recommend starting from the end of an existing <i>LP/Eoi400</i> experiment. Ensure that spin up methodology enables a direct/clean comparison of experiments <i>LP</i> , <i>EP</i> , <i>LP</i> ⁴⁹⁰ , <i>LP</i> ⁵⁶⁰ and <i>LP</i> ²⁸⁰

Orbital Parameters*

As Exp. <i>PI</i>

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[‡]Apply using the anomaly method (see Haywood et al. 2016 – Climate of the Past for additional details: <https://doi.org/10.5194/cp-12-663-2016>). *Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant, orbital parameters and atmospheric greenhouse gas levels in their PlioMIP3 *LP*²⁸⁰ experiment to be the same as in their CMIP7 DECK pre-industrial simulation.

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Experiment *PI*⁴⁰⁰

Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Ocean Input
Predicted	Local Pre-Industrial/Modern

Geographic Boundary Conditions

Land/Sea Mask	Topography	Ice Sheets	Vegetation
Local Modern	Local Modern	Local Modern	Pre-industrial prescribed

Greenhouse Gases

CO ₂	N ₂ O*	CH ₄ *	CFCs*	O ₃ *
400 ppm	270 ppb	760 ppb	0	Local Modern

Solar Constant*

1365 W/m ²

Aerosols

Pre-industrial

Model Spin-up

Documented by individual groups. Ensure that spin up methodology enables a direct/clean comparison of experiments <i>PI</i> , <i>PI</i> ⁴⁰⁰ and <i>PI</i> ⁵⁶⁰

Orbital Parameters*

[ecc = 0.016724] - [obl = 23.446°] - [peri - 180° = 102.04°] Date of vernal equinox March 21 at noon

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*Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant, orbital parameters and atmospheric greenhouse gas levels in their PlioMIP3 experiment *PI*⁴⁰⁰ to be the same as in their CMIP7 DECK pre-industrial simulation.

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Experiment PI^{560}

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Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Ocean Input
Predicted	Local Pre-Industrial/Modern

Geographic Boundary Conditions

Land/Sea Mask	Topography	Ice Sheets	Vegetation
Local Modern	Local Modern	Local Modern	Pre-industrial prescribed

Greenhouse Gases

CO ₂	N ₂ O*	CH ₄ *	CFCs*	O ₃ *
Set to 560 ppm	270 ppb	760 ppb	0	Local Modern

Solar Constant*

1365 W/m ²

Aerosols

Pre-industrial

Model Spin-up

Documented by individual groups. Ensure that spin up methodology enables a direct/clean comparison of experiments PI , PI^{400} and PI^{560}
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Orbital Parameters*

[ecc = 0.016724] - [obl = 23.446°] - [peri - 180° = 102.04°] Date of vernal equinox March 21 at noon

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*Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant, orbital parameters and atmospheric greenhouse gas levels in their PlioMIP3 experiment PI^{560} to be the same as in their CMIP7 DECK pre-industrial simulation.

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Experiment *LP_highNH_lowSH_orbit*

Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Deep Ocean Input		
Predicted	Previously spun up Pliocene simulation (e.g., <i>LP/Eoi400</i>) or pre-industrial state		
Land/Sea Mask	Topography [‡]	Ice Mask	Vegetation
LP_LSM_v1.0.nc	LP_topo_v1.0.nc	LP_icemask_v1.0.nc	LP_mbiome_v1.0.nc

Greenhouse Gases

CO ₂	N ₂ O*	CH ₄ *	CFCs*	O ₃ *
400 ppm	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>

Solar Constant*

As Exp. <i>PI</i>

Aerosols

As Exp. <i>PI</i>

Model Spin-up

Documented by individual groups – recommend starting from the end of an existing <i>LP/Eoi400</i> experiment. Ensure that spin up methodology enables a direct/clean comparison of experiments <i>LP</i> , <i>LP_highNH_lowSH_orbit</i> and <i>LP_lowNH_highSH_orbit</i>
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Orbital Parameters

[ecc = 0.051086] - [obl = 23.6424] - [peri - 180° = 303.93] Date of vernal equinox: March 21 at noon

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[‡]Apply using the anomaly method (see Haywood et al. 2016 – Climate of the Past for additional details: <https://doi.org/10.5194/cp-12-663-2016>). *Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant and atmospheric greenhouse gas levels in their PlioMIP3 *LP_highNH_lowSH_orbit* experiment to be the same as in their CMIP7 DECK pre-industrial simulation.

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Experiment *LP_lowNH_highSH_orbit*

Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Deep Ocean Input			
Predicted	Previously spun up Pliocene simulation (e.g., <i>LP/Eoi400</i>) or pre-industrial state			
Land/Sea Mask	Topography [‡]	Ice Mask	Vegetation	
LP_LSM_v1.0.nc	LP_topo_v1.0.nc	LP_icemask_v1.0.nc	LP_mbiome_v1.0.nc	

Greenhouse Gases

CO ₂	N ₂ O*	CH ₄ *	CFCs*	O ₃ *
400 ppm	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>

Solar Constant*

As Exp. <i>PI</i>

Aerosols

As Exp. <i>PI</i>

Model Spin-up

Documented by individual groups – recommend starting from the end of an existing <i>LP/Eoi400</i> experiment. Ensure that spin up methodology enables a direct/clean comparison of experiments <i>LP</i> , <i>LP_highNH_lowSH_orbit</i> and <i>LP_lowNH_highSH_orbit</i>
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Orbital Parameters

[ecc = 0.054523] - [obl = 23.1432] - [peri - 180° = 107.3686] Date of vernal equinox: March 21 at noon

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[‡]Apply using the anomaly method (see Haywood et al. 2016 – Climate of the Past for additional details: <https://doi.org/10.5194/cp-12-663-2016>).*Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant and atmospheric greenhouse gas levels in their PlioMIP3 *LP_lowNH_highSH_orbit* experiment to be the same as in their CMIP7 DECK pre-industrial simulation.

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Experiment *PI_dyn_veg*

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Model Coupling

Atmosphere-Ocean-Vegetation

Integration Length

At least 500 years

Oceans

Ocean Mode	Ocean Input
Predicted	Local Pre-Industrial/Modern

Geographic Boundary Conditions

Land/Sea Mask	Topography	Ice Sheets	Vegetation
Local Modern	Local Modern	Local Modern	Predicted

Greenhouse Gases*

CO ₂	N ₂ O	CH ₄	CFCs	O ₃
280 ppm	270 ppb	760 ppb	0	Local Modern

Solar Constant*

1365 W/m ²

Aerosols

Pre-industrial

Model Spin-up

Documented by individual groups. Ensure that spin up methodology enables a direct/clean comparison of experiments <i>PI_dyn_veg</i> , <i>LP_dyn_veg</i> , <i>PI</i> and <i>LP</i>

Orbital Parameters*

[ecc = 0.016724] - [obl = 23.446°] - [peri - 180° = 102.04°] Date of vernal equinox March 21 at noon

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*Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant, orbital parameters and atmospheric greenhouse gas levels in their PlioMIP3 *PI_dyn_veg* experiment to be the same as in their CMIP7 DECK pre-industrial simulation.

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Experiment *LP_dyn_veg*

Model Coupling

Atmosphere-Ocean-Vegetation

Integration Length

At least 500 years

Oceans

Ocean Mode	Deep Ocean Input		
Predicted	Previously spun up Pliocene simulation (e.g., <i>LP/Eoi400</i>) or pre-industrial state		
Land/Sea Mask	Topography [‡]	Ice Mask	Vegetation
LP_LSM_v1.0.nc	LP_topo_v1.0.nc	LP_icemask_v1.0.nc	Predicted

Greenhouse Gases

CO ₂	N ₂ O*	CH ₄ *	CFCs*	O ₃ *
400 ppm	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>

Solar Constant*

As Exp. <i>PI</i>

Aerosols

As Exp. <i>PI</i>

Model Spin-up

Documented by individual groups – recommend starting from the end of an existing <i>LP/Eoi400</i> experiment. Ensure that spin up methodology enables a direct/clean comparison of experiments <i>PI_dyn_veg</i> , <i>LP_dyn_veg</i> , <i>PI</i> and <i>LP</i>
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Orbital Parameters*

As Exp. <i>PI</i>

277 [‡]Apply using the anomaly method (see Haywood et al. 2016 – Climate of the Past for additional
278 details: <https://doi.org/10.5194/cp-12-663-2016>).*Unless specified otherwise in the table, CMIP7
279 modelling groups should set the solar constant, orbital parameters and atmospheric greenhouse gas
280 levels in their PlioMIP3 *LP_dyn_veg* experiment to be the same as in their CMIP7 DECK pre-
281 industrial simulation.

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Experiment *LP_pi-EAIS*

Model Coupling

Atmosphere-Ocean

Integration Length

At least 500 years

Oceans

Ocean Mode	Deep Ocean Input
Predicted	Previously spun up Pliocene simulation (e.g., <i>LP/Eoi400</i>) or pre-industrial state

Land/Sea Mask	Topography [‡]	Ice Mask	Vegetation
LP_pi-EAIS_LSM_v1.0.nc	LP_pi-EAIS_topo_v1.0.nc	LP_pi-EAIS_icemask_v1.0.nc	LP_pi-EAIS_mbiome_v1.0.nc

Greenhouse Gases

CO ₂	N ₂ O*	CH ₄ *	CFCs*	O ₃ *
400 ppm	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>	As Exp. <i>PI</i>

Solar Constant*

As Exp. <i>PI</i>

Aerosols

As Exp. <i>PI</i>

Model Spin-up

Documented by individual groups – recommend starting from the end of an existing <i>LP/Eoi400</i> experiment. Ensure that spin up methodology enables a direct/clean comparison of experiments <i>LP</i> and <i>LP_pi-EAIS</i>
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Orbital Parameters*

As Exp. <i>PI</i>

[‡]Apply using the anomaly method (see Haywood et al. 2016 – Climate of the Past for additional details: <https://doi.org/10.5194/cp-12-663-2016>). *Unless specified otherwise in the table, CMIP7 modelling groups should set the solar constant, orbital parameters and atmospheric greenhouse gas levels in their PlioMIP3 *LP_pi-EAIS* experiment to be the same as in their CMIP7 DECK pre-industrial simulation.

Annex 2: Methodology to identify Late Pliocene orbital extremes and Early Pliocene modern-like orbits

Late Pliocene orbital extremes

Here we describe the methodology used to identify and calculate orbital configurations for the Late Pliocene orbital sensitivity experiments, *LP_highNH_lowSH_orbit* and *LP_lowNH_highSH_orbit*.

We use the orbital solution of Laskar et al., 2004 (LA04) to generate time-series of summer insolation at 65° N and 65° S at 1ky timeslices between 2.58 and 3.6 Ma. Here, summer insolation is defined as the mean top of atmosphere (TOA) insolation over 30° of Mean Longitude (ecliptic coordinate system; see Annex 3) of months 7 and 1 respectively (approx. 21 June - 20 July and 21 December - 20 January). For each experiment, we identify peaks and troughs in these timeseries that satisfy the experiment criteria (e.g., Highest NH summer insolation and lowest SH summer insolation) and then rank the 10 topmost peaks in each. For example, for *LP_highNH_lowSH_orbit* we identify 10 peaks with the highest 65° N insolation, and 10 peaks with the lowest 65° S insolation. From these two sets we identify peaks that optimise *both* criteria. For *LP_highNH_lowSH_orbit* we find a peak at 3.037 Ma BP (J2000; Julian years) which has the highest 65° N summer insolation and 5th lowest 65° S summer insolation in the 1ky timeslices between 2.58 – 3.6 Ma. For *LP_lowNH_highSH_orbit* a peak at 3.049 Ma has the lowest 65° N summer insolation and the highest 65° S summer insolation. These orbits have been used in Pliocene work previously (experiments Plio^{NHmax} and Plio^{NHmin} within Dolan et al., 2011; Salzmann et al., 2013).

The top of the atmosphere insolation, expressed as the anomaly against the modern, is shown within Figure A1 and the corresponding orbital configurations are shown within Figure A2, following the notation of Joussaume and Braconnot (1997). The 3.037 Ma orbit has an eccentricity of 0.051086, precession of -0.042388 radians, and obliquity of 23.6424°. The 3.049 Ma orbit has an eccentricity of 0.054523, precession of 0.052037 radians and obliquity of 23.1432°.

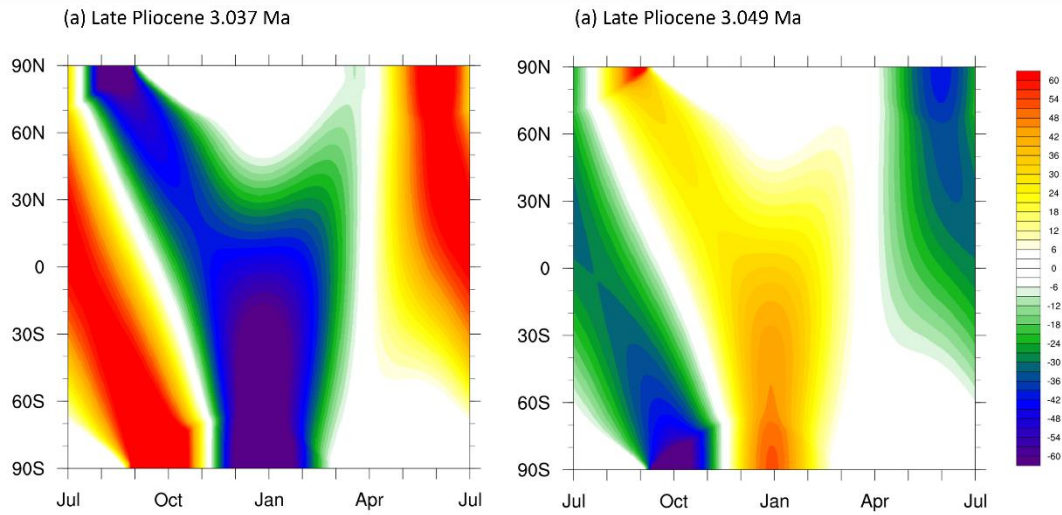


Figure A1. TOA insolation anomaly against the pre-industrial (Wm^{-2}), for (a) 3.037 Ma (experiment *LP_highNH_lowSH_orbit*) and (b) 3.049 Ma (*LP_lowNH_highSH_orbit*). Horizontal axis corresponds to 30° sweeps of Mean Longitude and approximate conventional dates of the months (e.g., 21st July).

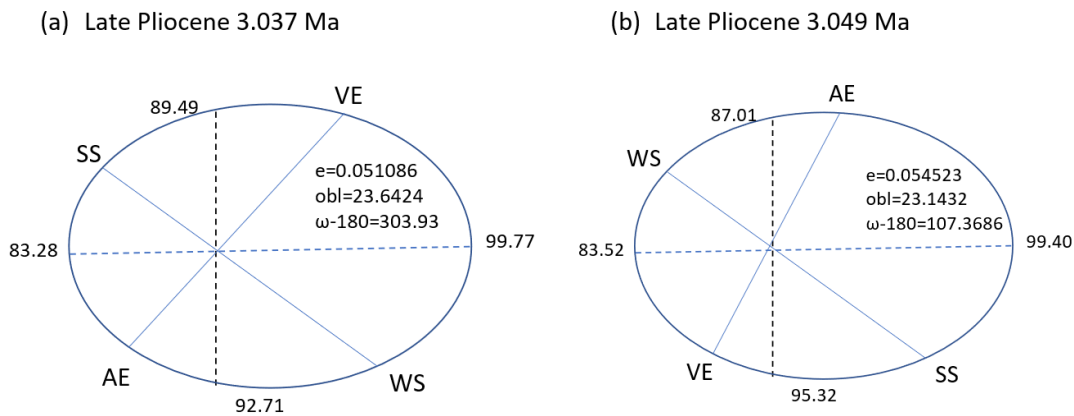


Figure A2. Orbital configuration for the (a) 3.037 and (b) 3.049 Ma orbits. Also shown are the number of days within the Northern Hemisphere summer (Summer Solstice to Autumnal Equinox), Autumn (Autumnal Equinox to Winter Solstice), Winter (Winter Solstice to Vernal Equinox), and Spring (Vernal Equinox to Summer Solstice). Season lengths are derived using the software of Kostadinov and Gilb (2014).

Early Pliocene modern-like orbit

The identification of modern-like orbits during the Early Pliocene allows the Early Pliocene experiment (EP) to use the *pre-industrial orbital configuration* in a way similar to the PlioMIP2 3.205 Ma time slice experiments.

We use the LA04 orbital solution to generate annual TOA insolation distributions (month vs. latitude) every 1 kyr between 3.6 and 5.322 Ma. We then compute the RMSE of the anomaly against the modern (J2000) and identify and rank peaks that maximise goodness of fit. We then compare these ranked peaks against the marine benthic oxygen isotope record of Lisiecki and Raymo 2005 (LR05) and the record of geomagnetic reversals (Gradstein et al., 2020). We identify two orbital configurations that coincide with negative excursions in LR05, and which lie close to geomagnetic reversals. Both peaks have RMSE anomalies from modern that are lower than the marine isotope stage (MIS) KM5c 3.205 Ma peak of PlioMIP2. The first peak at 4.474 Ma coincides with MIS N1 (4.487 to 4.457 Ma; LR05) situated in the Gilbert polarity chron within reverse subchron C3N.1r. The second peak at 4.870 Ma coincides with MIS Si5 (4.883 to 4.860 Ma; LR05) and is situated in the Gilbert Polarity Chron within normal subchron C3N.3n.

A comparison of these two Early Pliocene time slices against the pre-industrial configuration is shown within Figure A3 which compares the TOA insolation anomalies of the two peaks (Figures A3h and A3m) as well as for the PlioMIP2 3.205 Ma peak (Figure A3c). Considering temporal windows of 10 and 20 kyr around these two peaks we find insolation anomalies that are of similar magnitude to those observed for the temporal windows around the PlioMIP2 3.205 Ma peak.

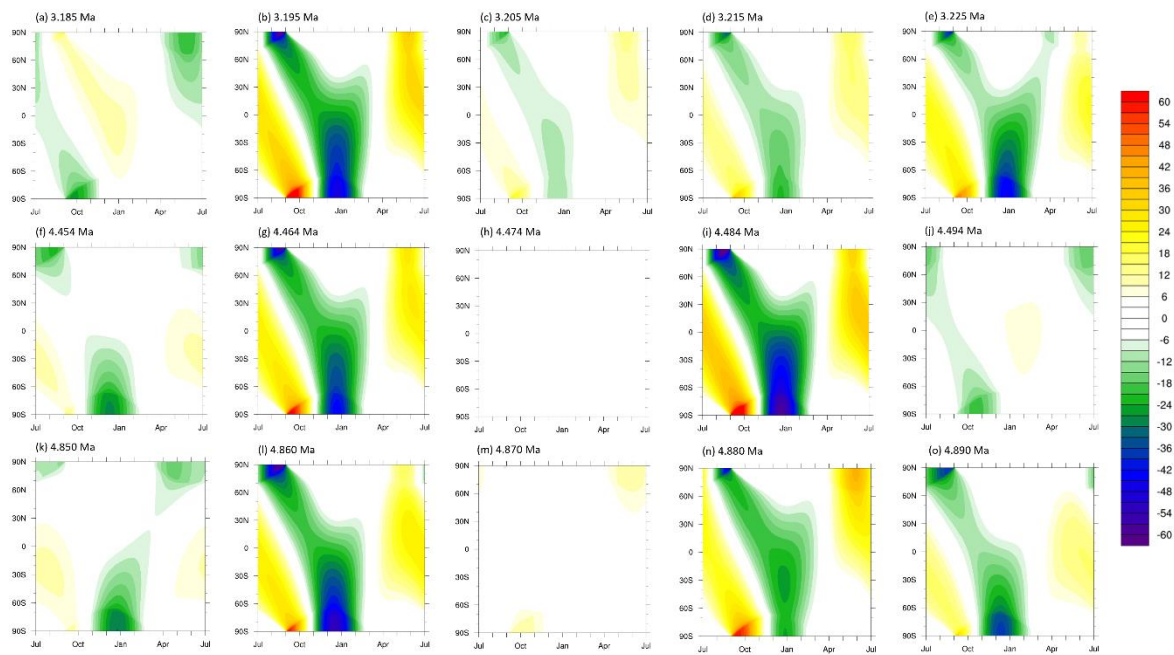


Figure A3. TOA insolation anomaly against the pre-industrial (Wm^{-2}) for (a-e) the 3.205 Ma PliomIP2 orbit and 10 and 20 kyr either side, and similarly for the two Early Pliocene time slices (f-j) 4.474 Ma and (k-o) 4.870 Ma. Note the colour scale is the same as for Figure A1.

Annex 3: Calendar correction for Late Pliocene orbital sensitivity experiments: Derivation of Monthly and Seasonal climatological means

The precession of Earth's axis and the changing orbital eccentricity modulate the length of Earth's seasons. Whilst fixing the vernal equinox (VE) to a reference value (e.g., March 21 at noon) ensures that different orbits are in phase at the VE, they cannot then be in phase at either the autumnal equinox (AE) or at the solstices. As climate models use fixed classical calendars which cannot capture changes in seasonal length (e.g., fixed 360-day, 365-day or Gregorian calendars), this impacts upon the comparison of climate model experiments of different orbits. To resolve this, one must move from the classical calendar to a celestial angular calendar in which each month is defined by a 30° sweep of Earth's celestial longitude. In this way, the solstices and equinoxes occur on the same date and changes in the insolation seasonal cycle are in phase. The transform from classical to celestial angular calendars

can be achieved either using a correction applied to climatological monthly means, or preferentially by regenerating corrected monthly means from daily model output.

The PlioMIP3 Late Pliocene orbital experiments (*LP_highNH_lowSH_orbit* and *LP_lowNH_highSH_orbit*, 3.037 and 3.059 Ma) have orbits that have shifted perihelion and significantly higher orbital eccentricity compared to the pre-industrial orbit. It follows that both experiments will exhibit phase shifting of the insolation seasonal cycle which may impact subsequent studies involving these experiments (e.g., those involving seasonal climate or comparison of specific monthly means). To enhance the utility of these orbital sensitivity experiments, groups that run them should provide key climatological fields as daily mean time-series fields (surface temperature, total precipitation rate and total evaporation rate; alongside monthly climatological means). If daily output is unfeasible, then modelling groups can provide standard climatological monthly means for these fields.

We will leave it to the discretion of subsequent researchers, rather than modelling groups, to apply the calendar correction to PlioMIP3 model output. Yet, if it is normal practice for a modelling group to transform (a subset of) climate model output to a celestial angular calendar, then this should be done alongside providing data on the native climate model calendar (Table A1). In this circumstance the netCDF time coordinate attributes can be used to record the *calendar* (e.g., time:calendar = “3049 ka”) and *month_lengths* (e.g., time:month_lengths = 27, 28, 29, 31, ...). The netCDF filename should also be differentiated from the standard classic calendar data. In terms of published methods to achieve a calendar correction we refer readers to Shi et al. (2022).

		3.037 Ma BP (<i>LP_highNH_lowSH_orbit</i>)		3.049 Ma BP (<i>LP_lowNH_highSH_orbit</i>)	
		First Day (day/month)	Month Length (days)	First Day (day/month)	Month Length (days)
1	January	23/12	34	7/1	27
2	February	26/1	33	3/2	28
3	March	28/2	32	3/3	29
4	April	1/4	31	1/4	31
5	May	2/5	29	2/5	32
6	June	31/5	28	3/6	34
7	July	28/6	28	7/7	34
8	August	26/7	28	10/8	33
9	September	23/8	28	12/9	32
10	October	20/9	30	14/10	30
11	November	20/10	31	13/11	28
12	December	20/11	33	11/12	27

Table A1: Angular calendar specified in terms of the first day (365-day classical calendar) and month length for 3.037 and 3.049 Ma orbits with the vernal equinox fixed to 21st March at noon. Values derived from the angular calendar conversion code described within Pollard and Reusch (2002); Pollard pers. comm., (2023).

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