Supporting Information for "Validation of a Neutral Density Model Using the SET HASDM Density Database"

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1. Figures S1 to S40

Introduction

This Supporting Information contains 40 additional figures that supplement the figures included in the main body of the paper. Figures S1–S20 show the mean densities at the given altitudes graphed as a function of time for the SET HASDM density data, and both the EXTEMPLAR and unmodified NRLMSIS models. Each plot corresponds to

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one complete year, from 2000 through 2019. Densities at altitudes of 800, 600, 400, 300, and 200 km are shown, from top to bottom. The plotted values are the base 10 logarithm of the mean values of the densities, in units of kg/m^3. The mean or average values at each time step are obtained by integration over a spherical surface. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue. All points are calculated at 3 h intervals. The red lines are drawn last and may obscure the others where they overlap.

Figures S21–S40 show two ratios graphed as a function of time. Each plot corresponds to one complete year, from 2000 through 2019. Ratios at altitudes of 800, 600, 400, 300, and 200 km are shown, from top to bottom. The plotted values are the base 10 logarithm of the ratio between the mean values of the densities derived by different methods. The ratio of the EXTEMPLAR and SET HASDM density database values are graphed with the red line, while the NRLMSIS and HASDM ratios are drawn in blue. All points are calculated at 3 h intervals.

HASDM , EXTEMPLAR , and NRLMSIS Mean Neutral Densities
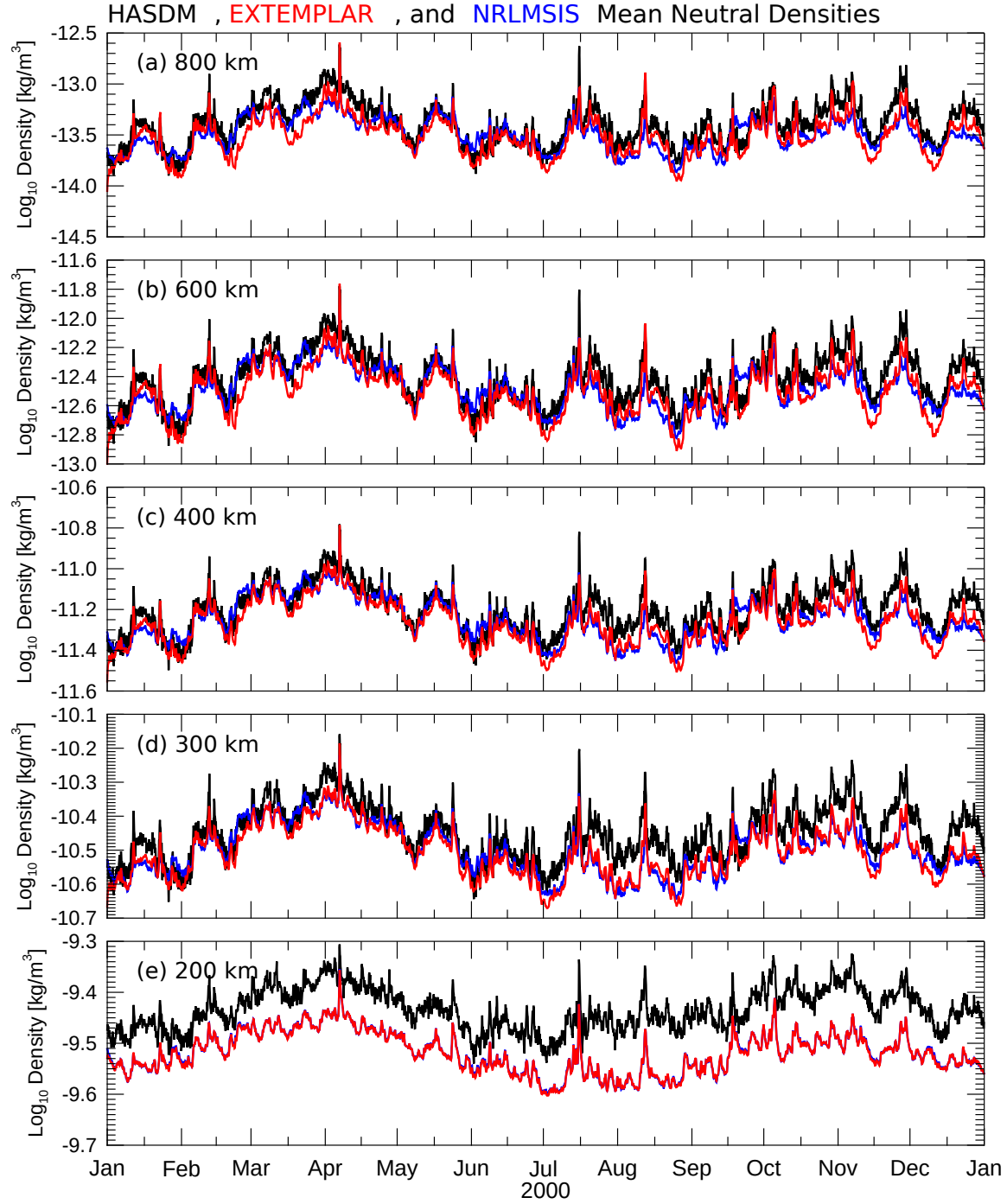
Figure S1. Mean densities graphed as a function of time, using a logarithmic scale, for the year 2000. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
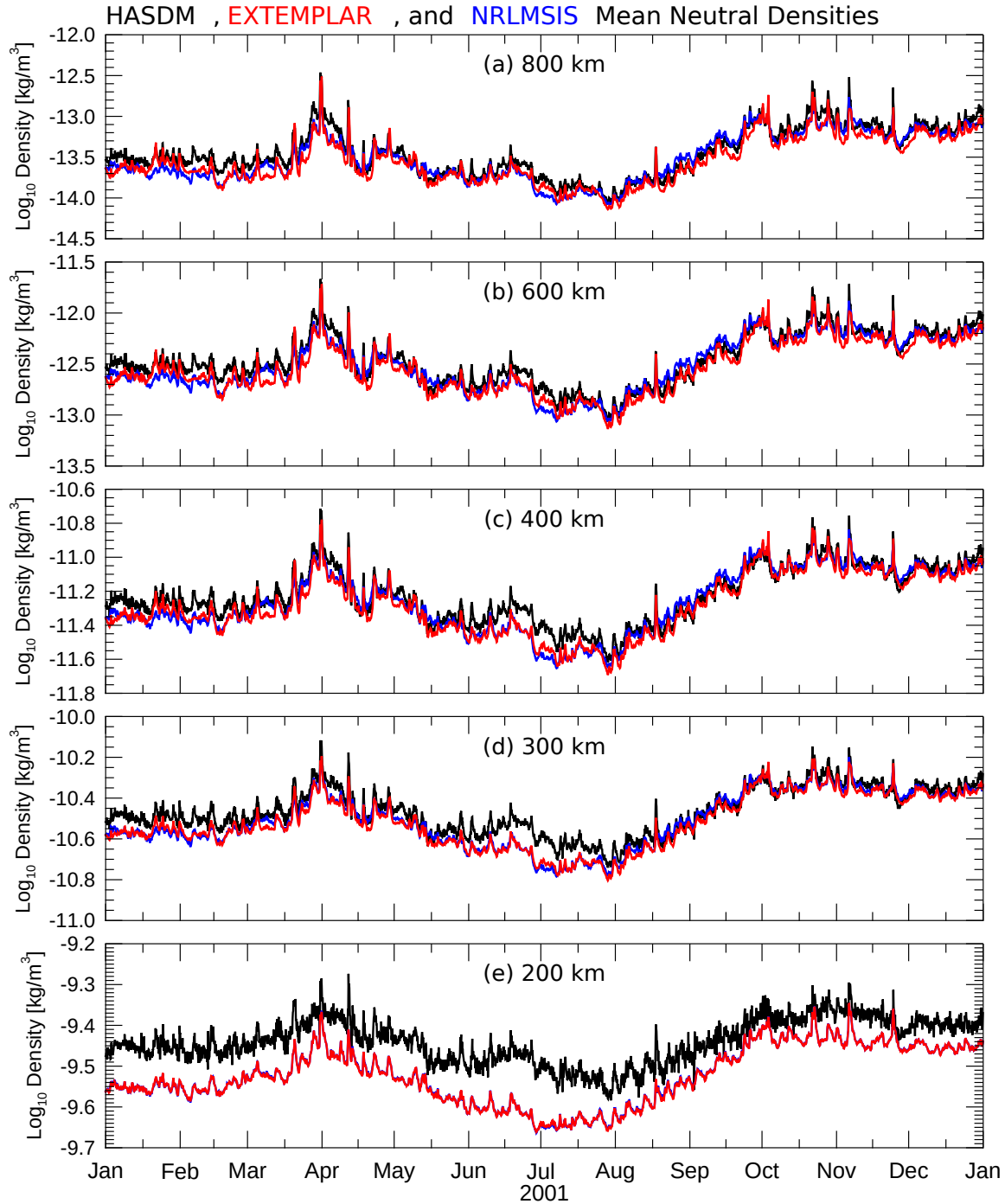
Figure S2. Mean densities graphed as a function of time, using a logarithmic scale, for the year 2001. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
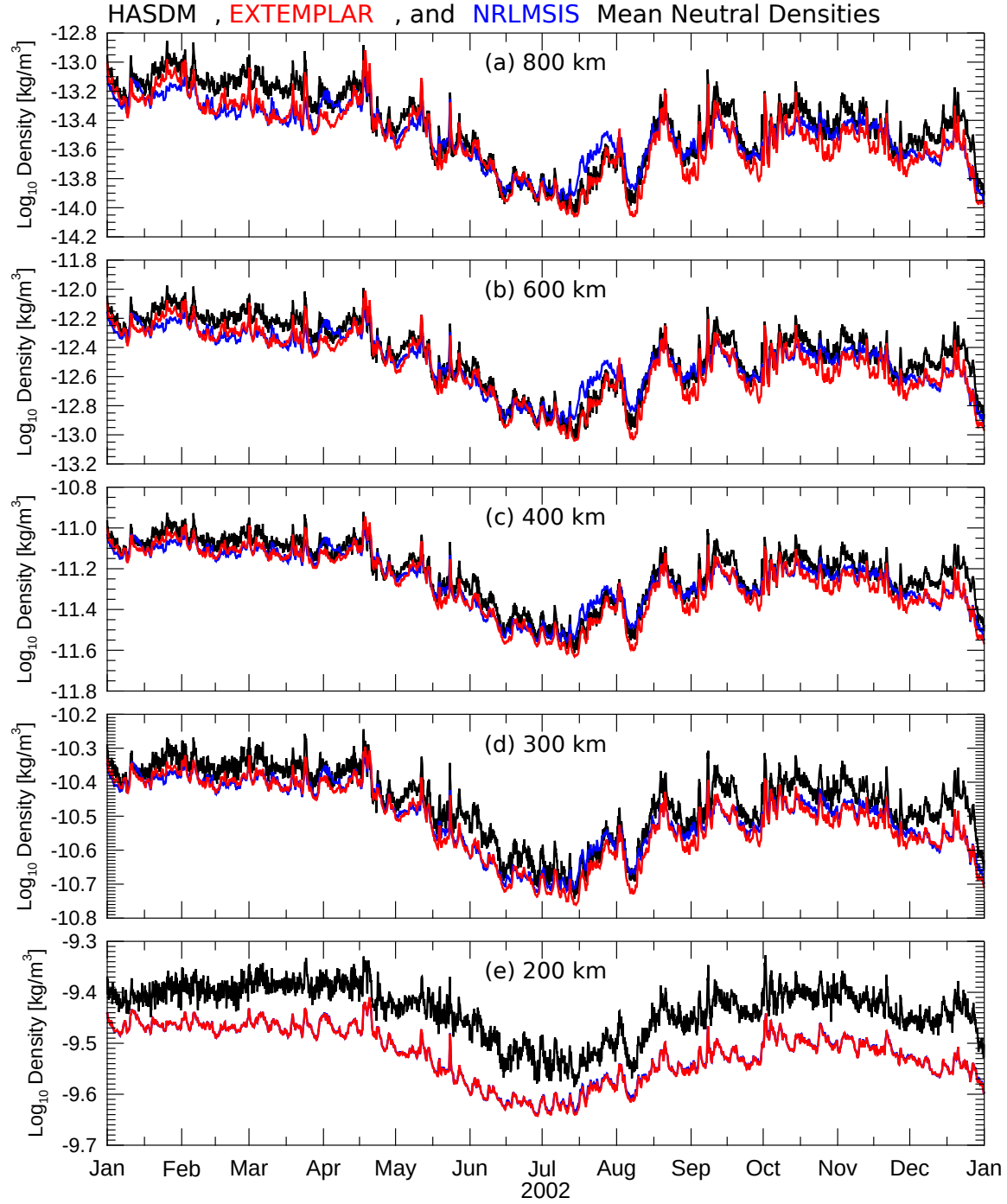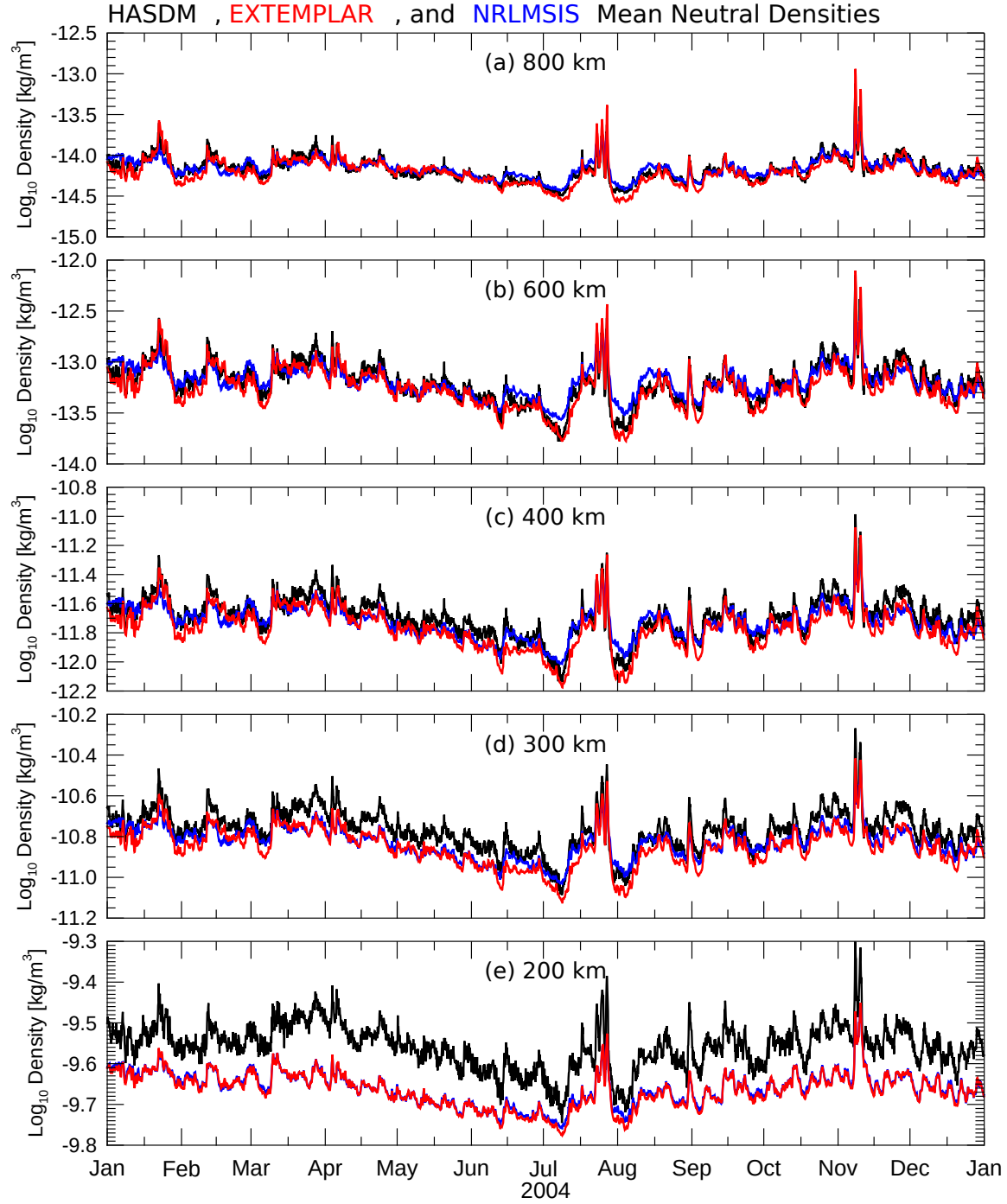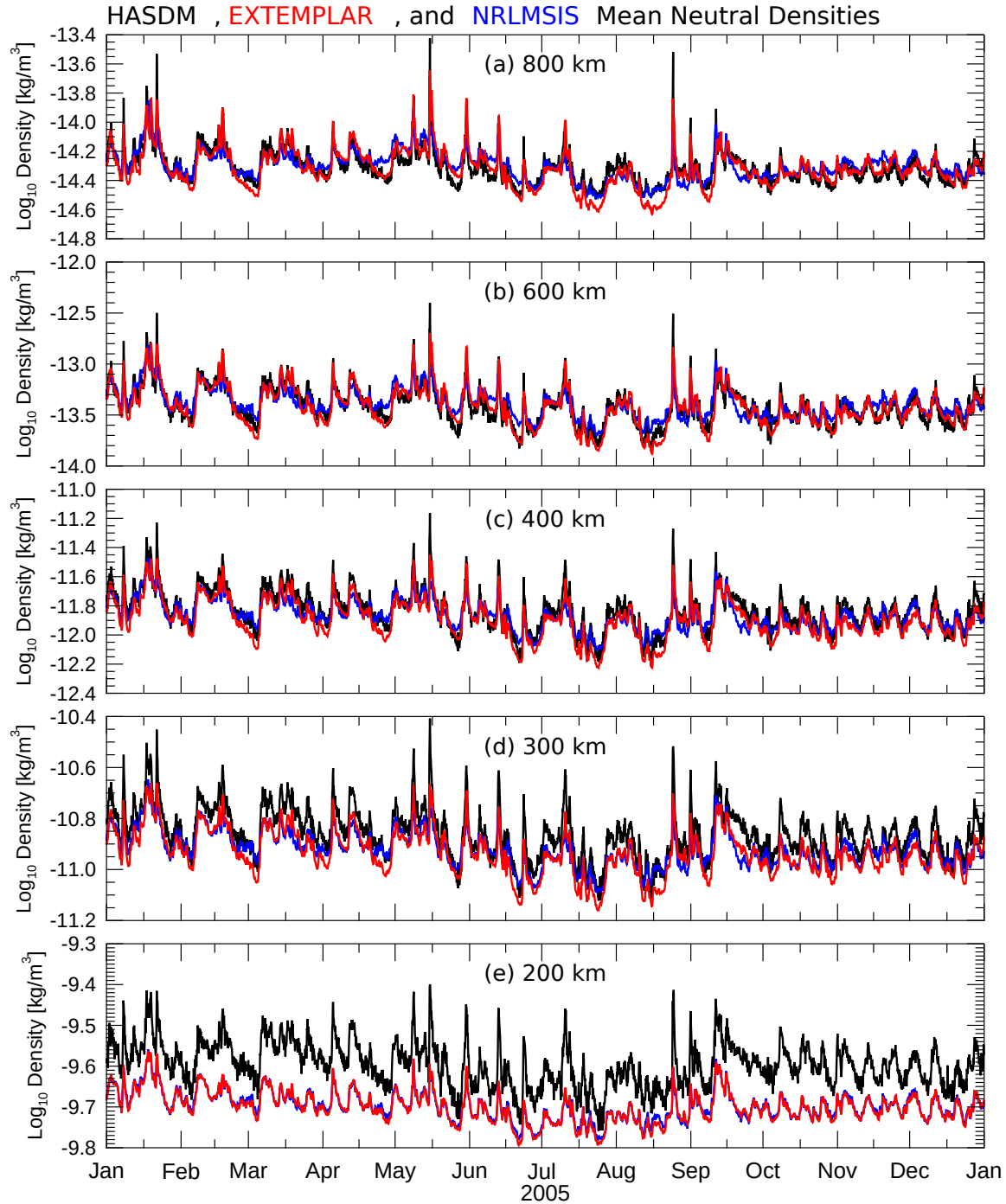
Figure S3. Mean densities graphed as a function of time, for the year 2002. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
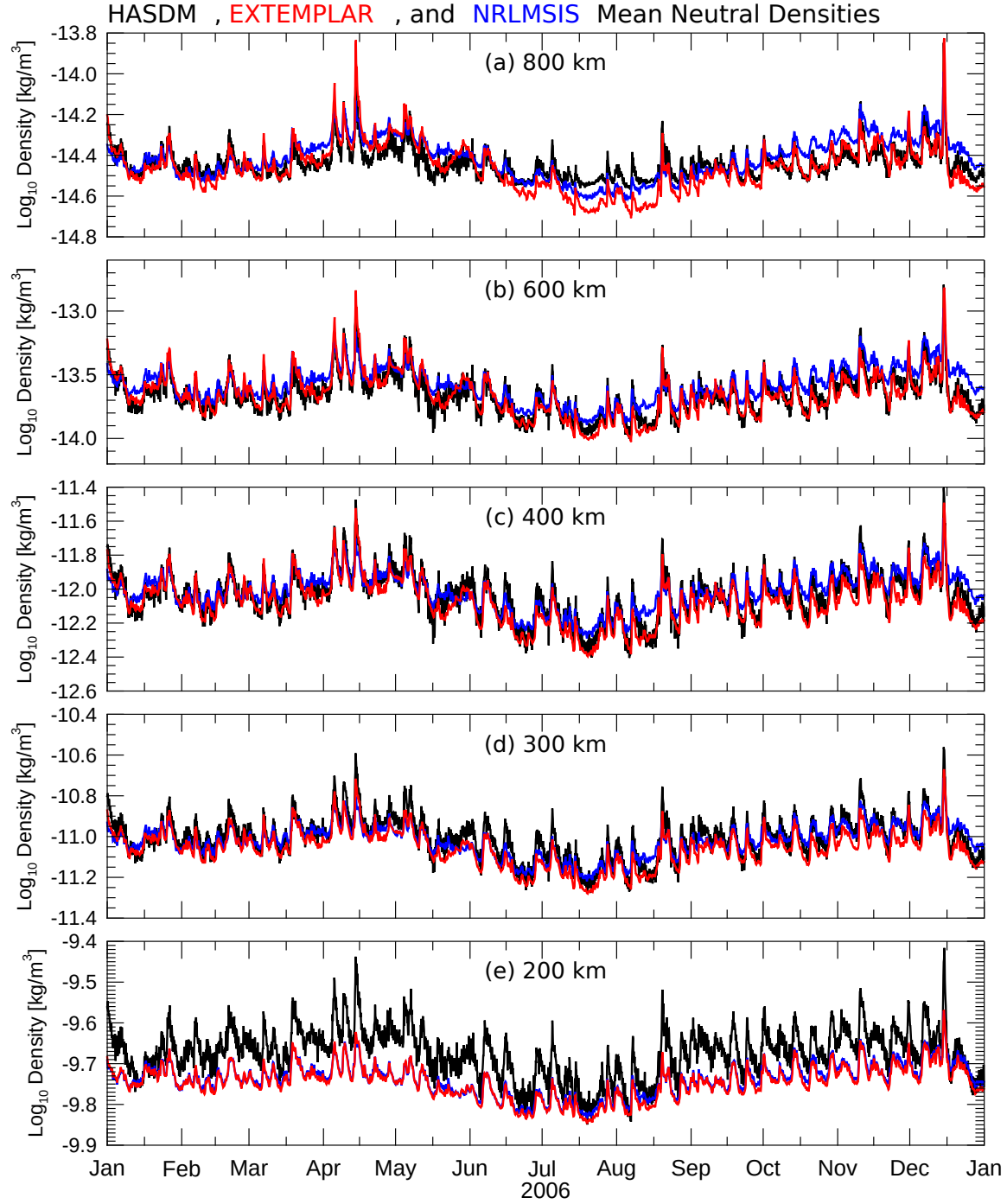
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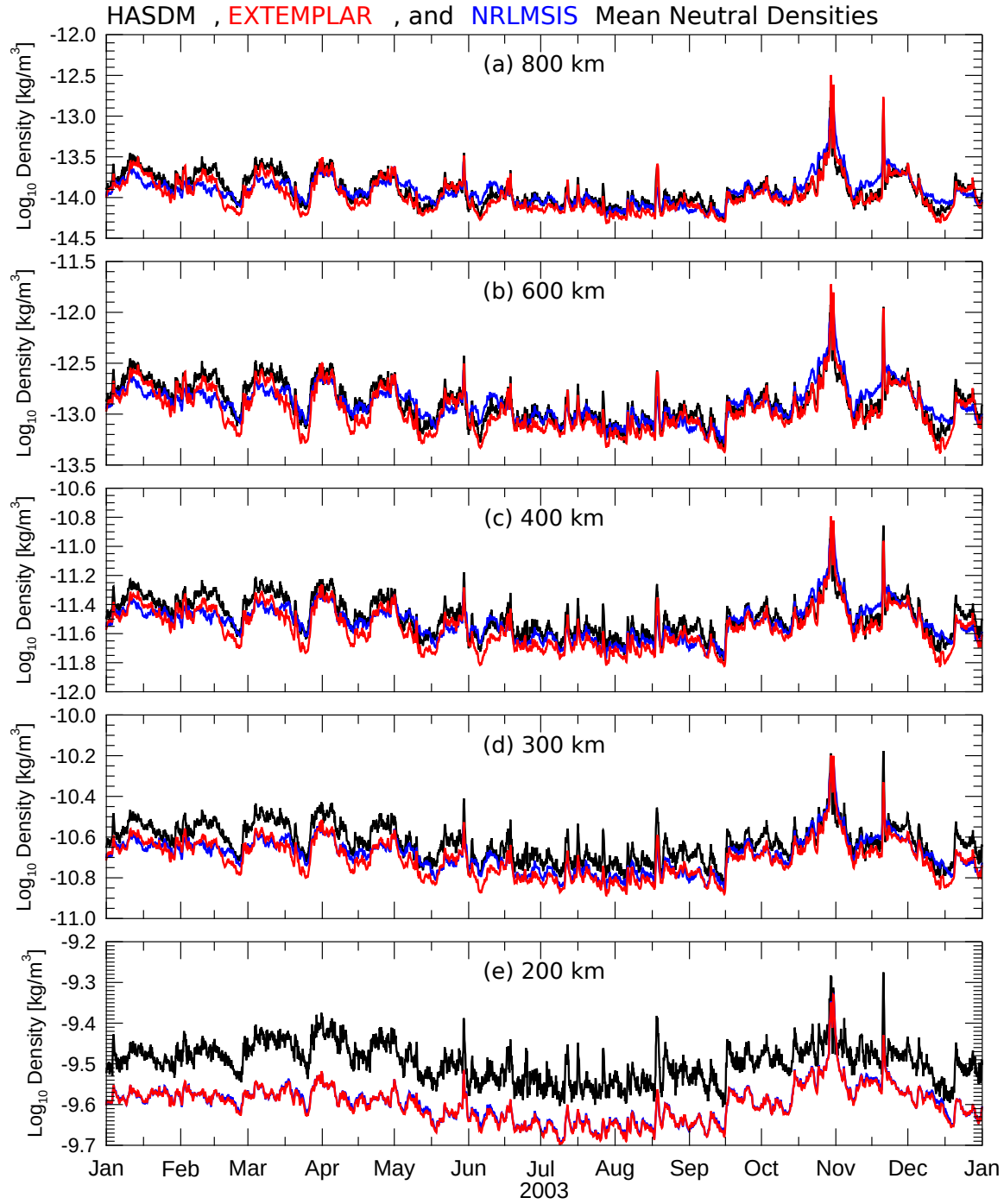
Figure S4. Mean densities graphed as a function of time, for the year 2003. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
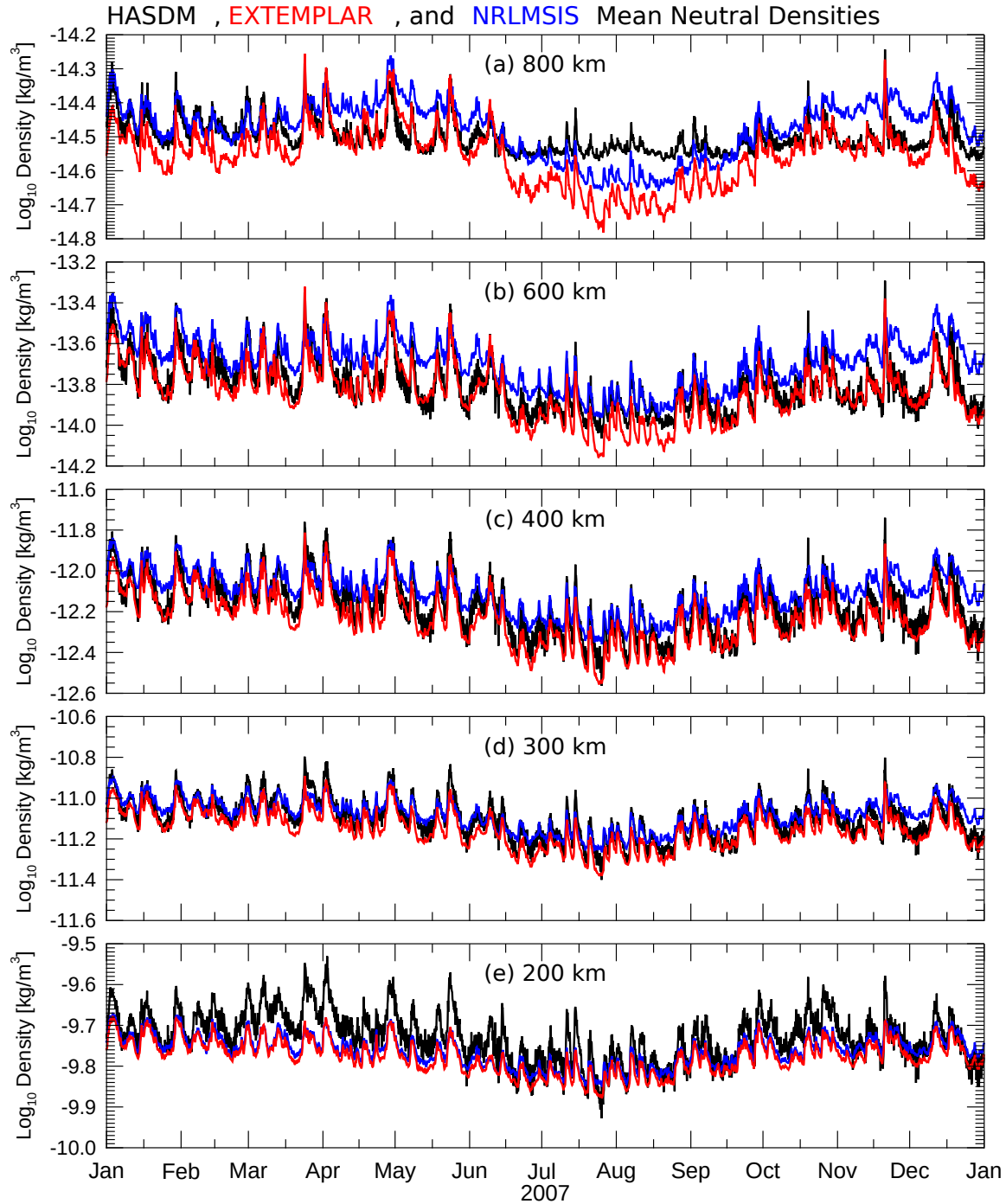
Figure S5. Mean densities graphed as a function of time, for the year 2004. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
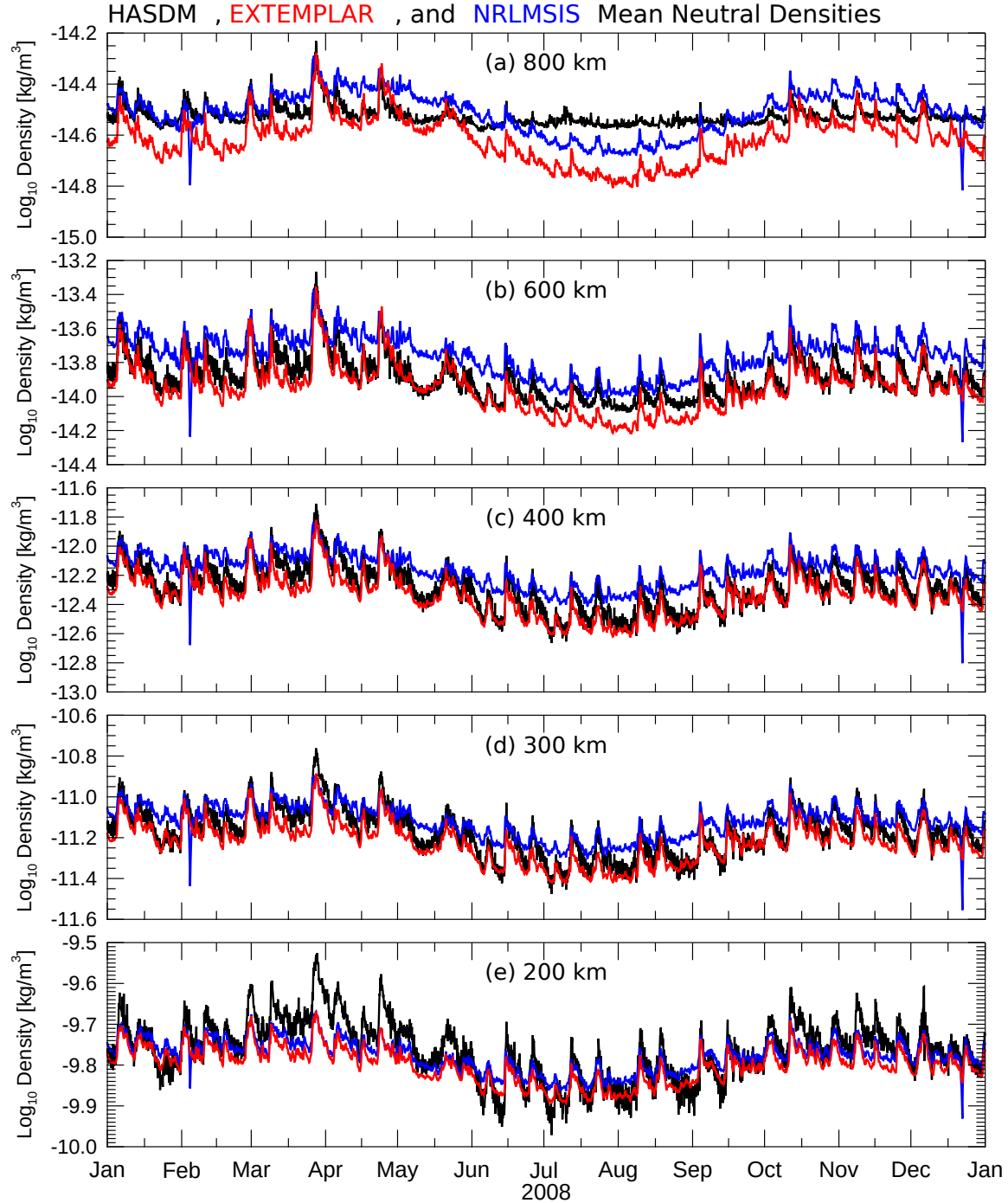
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Figure S6. Mean densities graphed as a function of time, for the year 2005. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.

Figure S7. Mean densities graphed as a function of time, for the year 2006. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
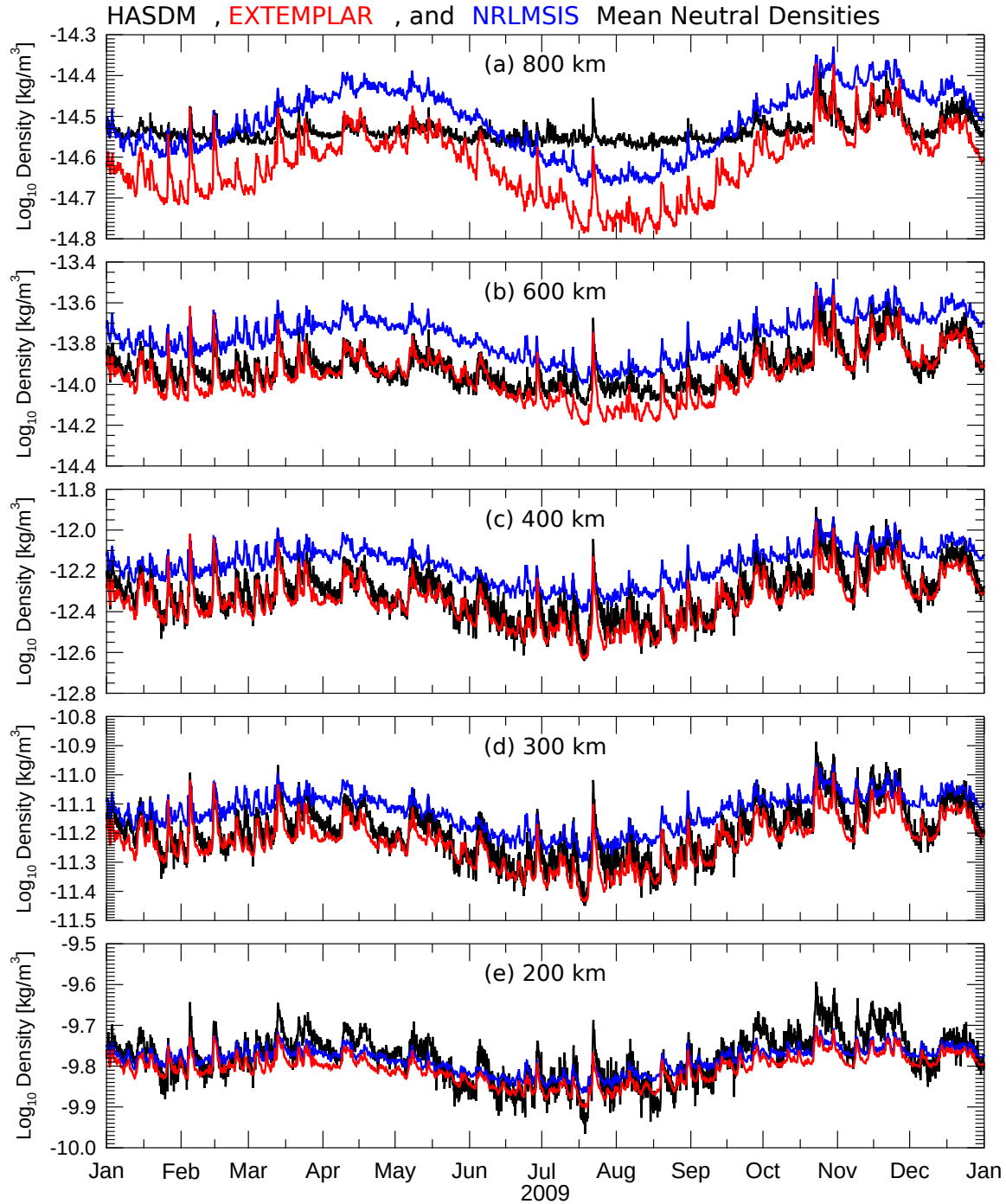
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Figure S8. Mean densities graphed as a function of time, for the year 2007. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.

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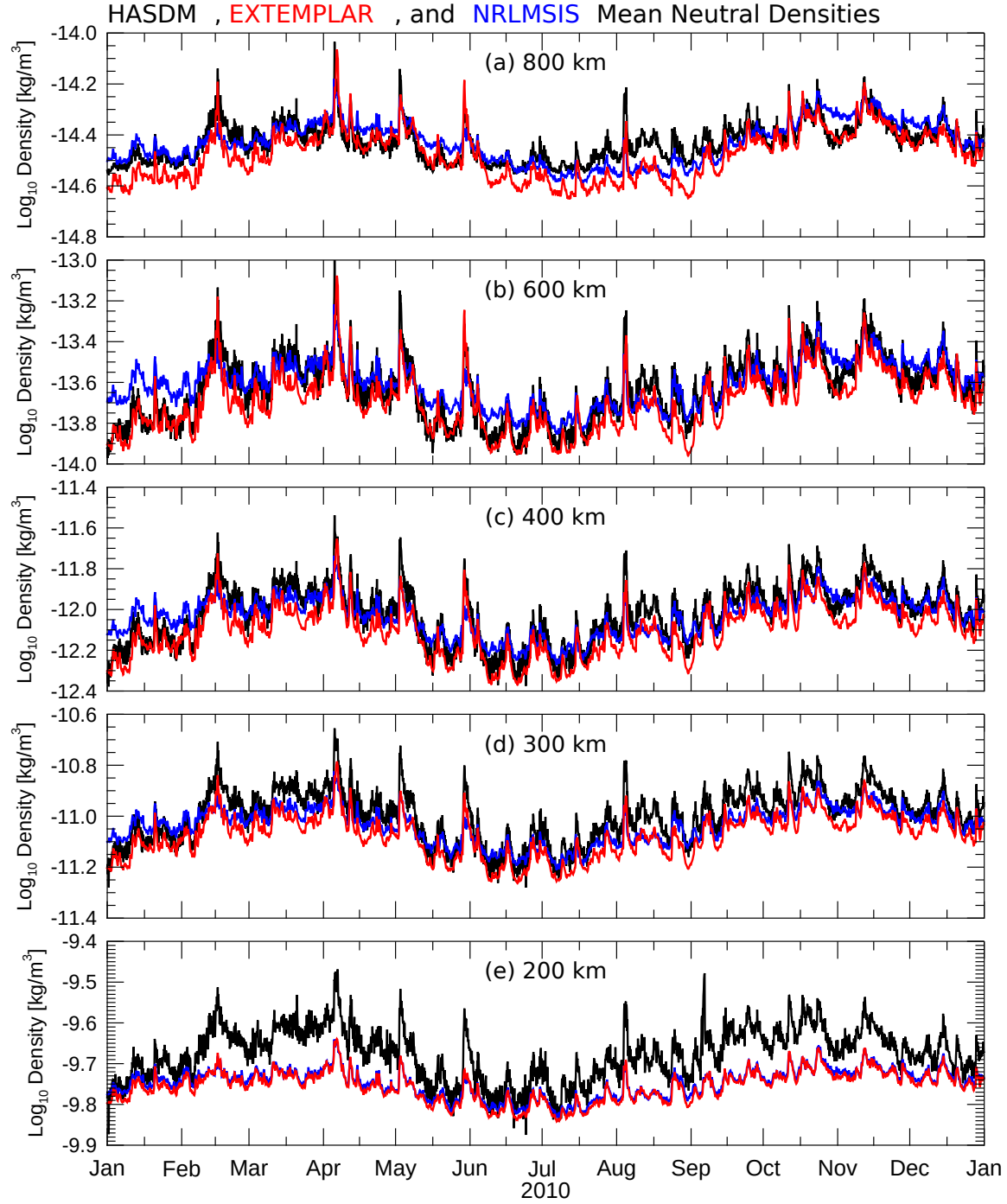HASDM , EXTEMPLAR , and NRLMSIS Mean Neutral Densities

Figure S9. Mean densities graphed as a function of time, for the year 2008. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
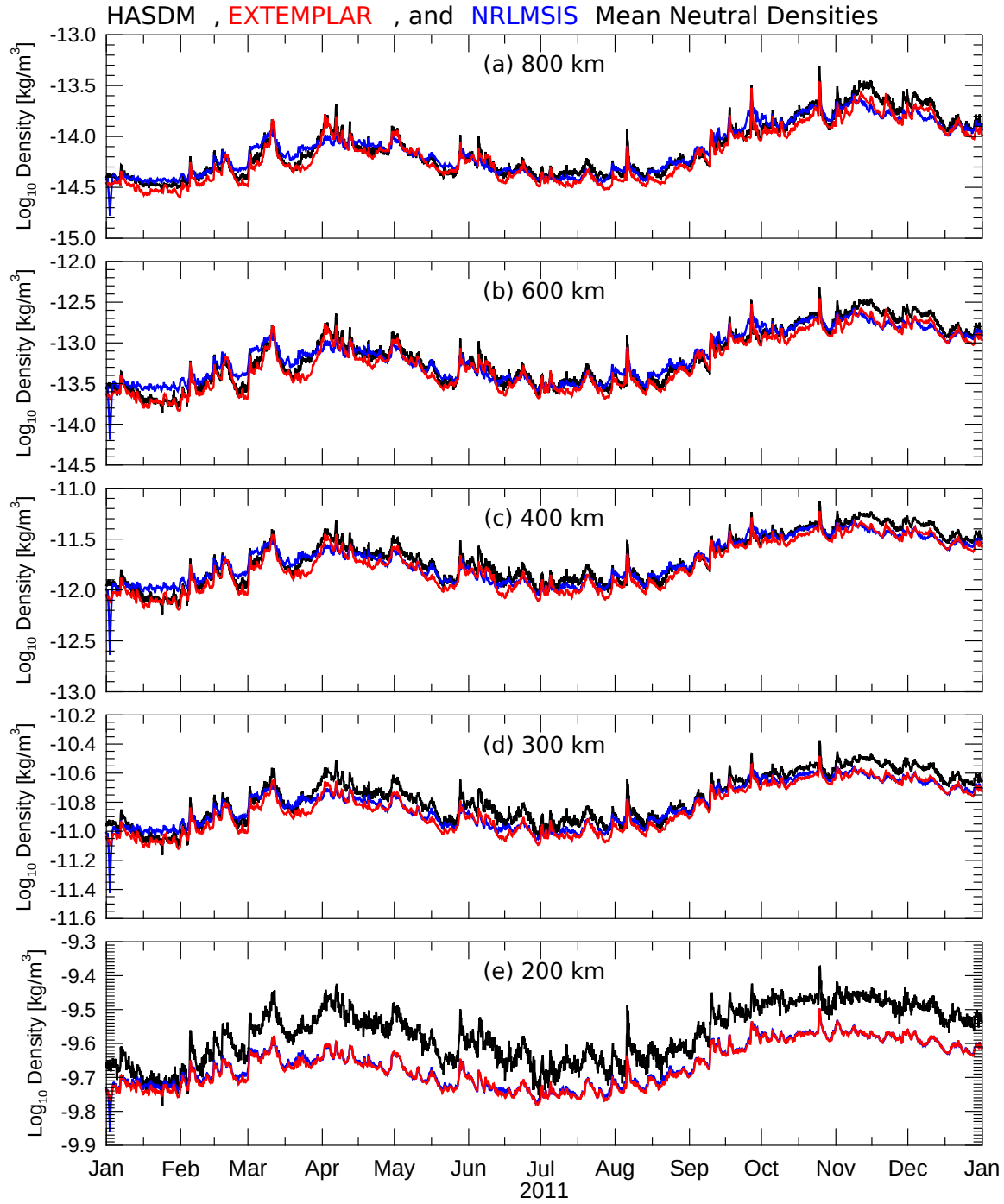
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Figure S10. Mean densities graphed as a function of time, for the year 2009. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.

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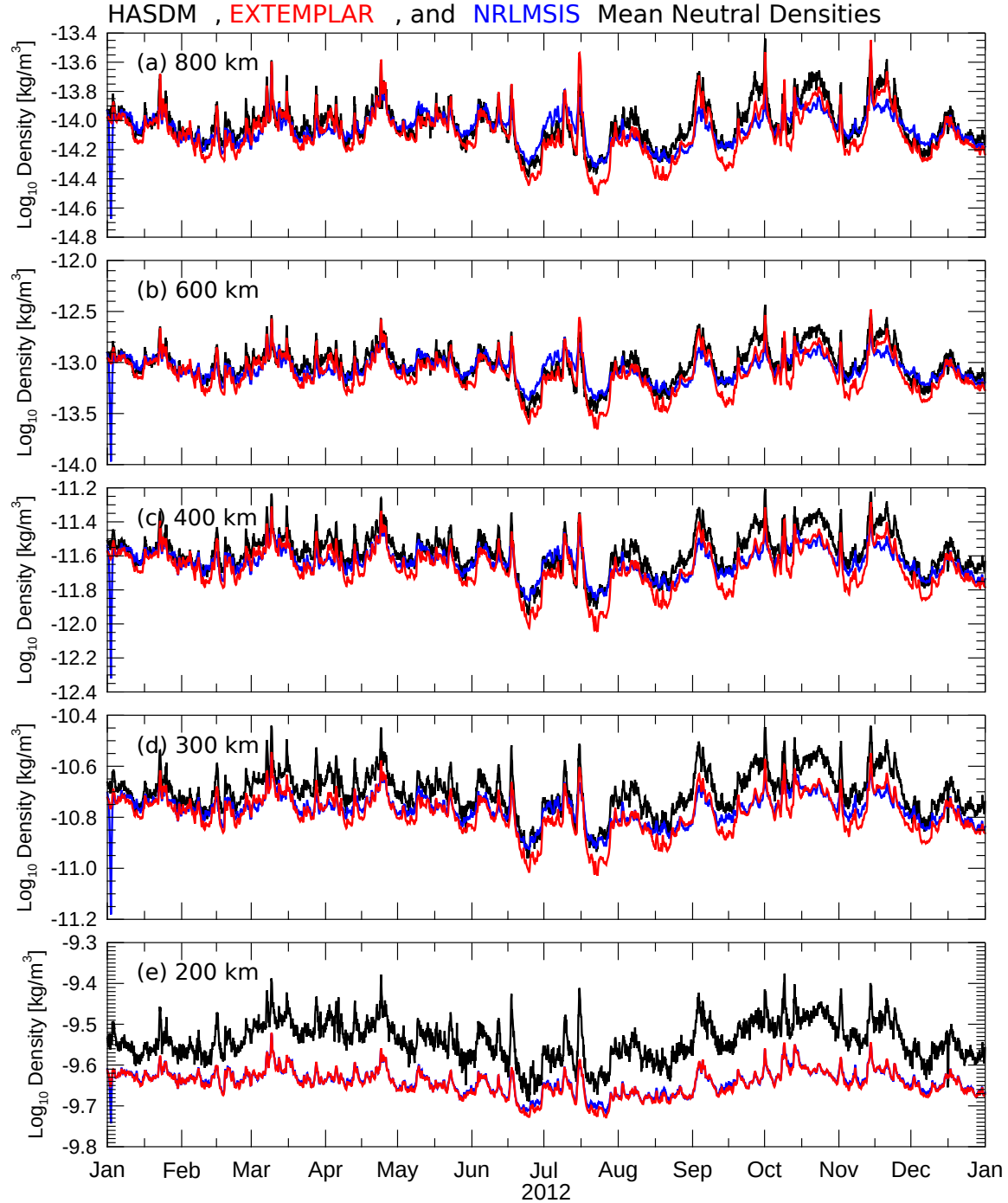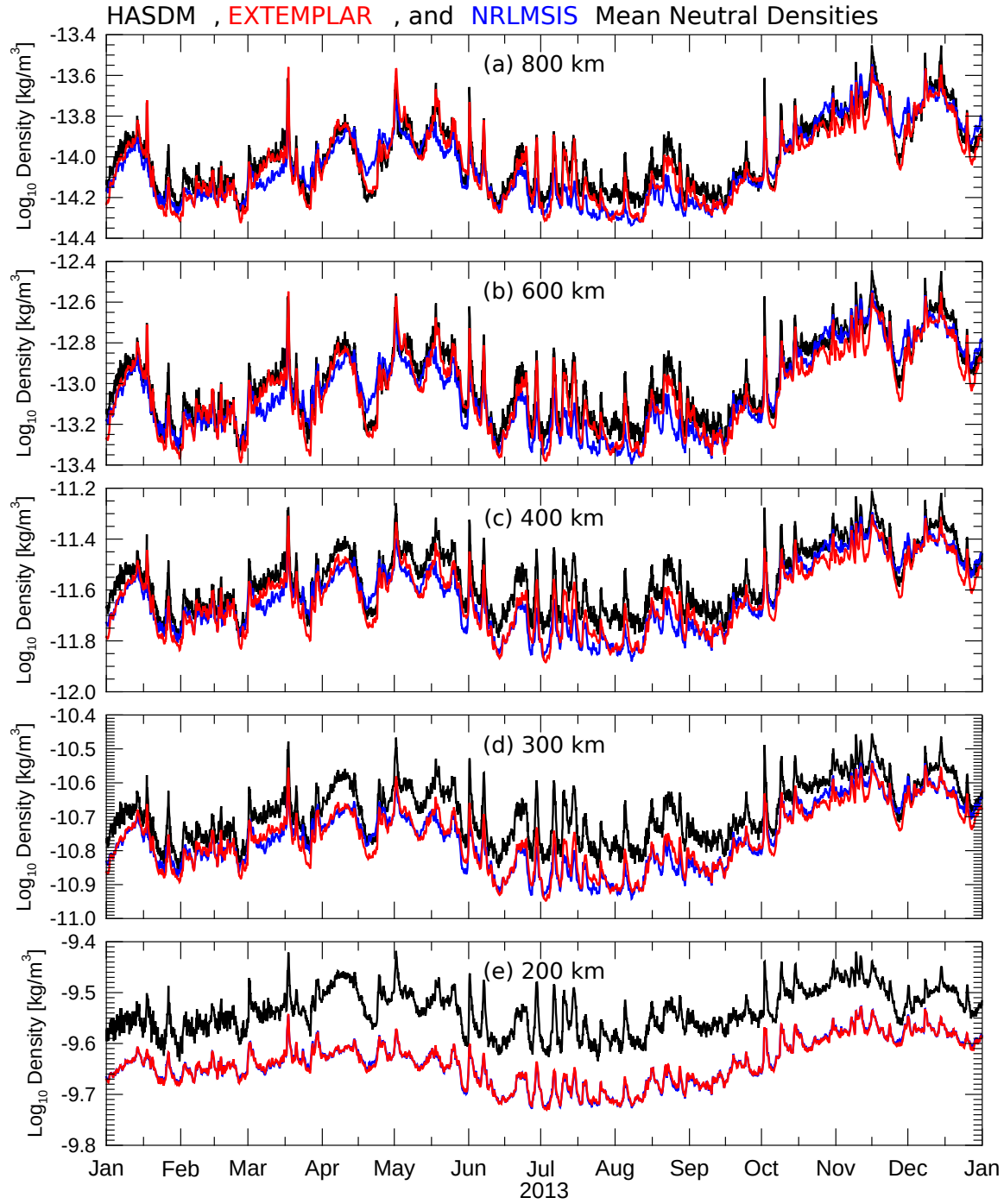HASDM , EXTEMPLAR , and NRLMSIS Mean Neutral Densities

Figure S11. Mean densities graphed as a function of time, for the year 2010. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
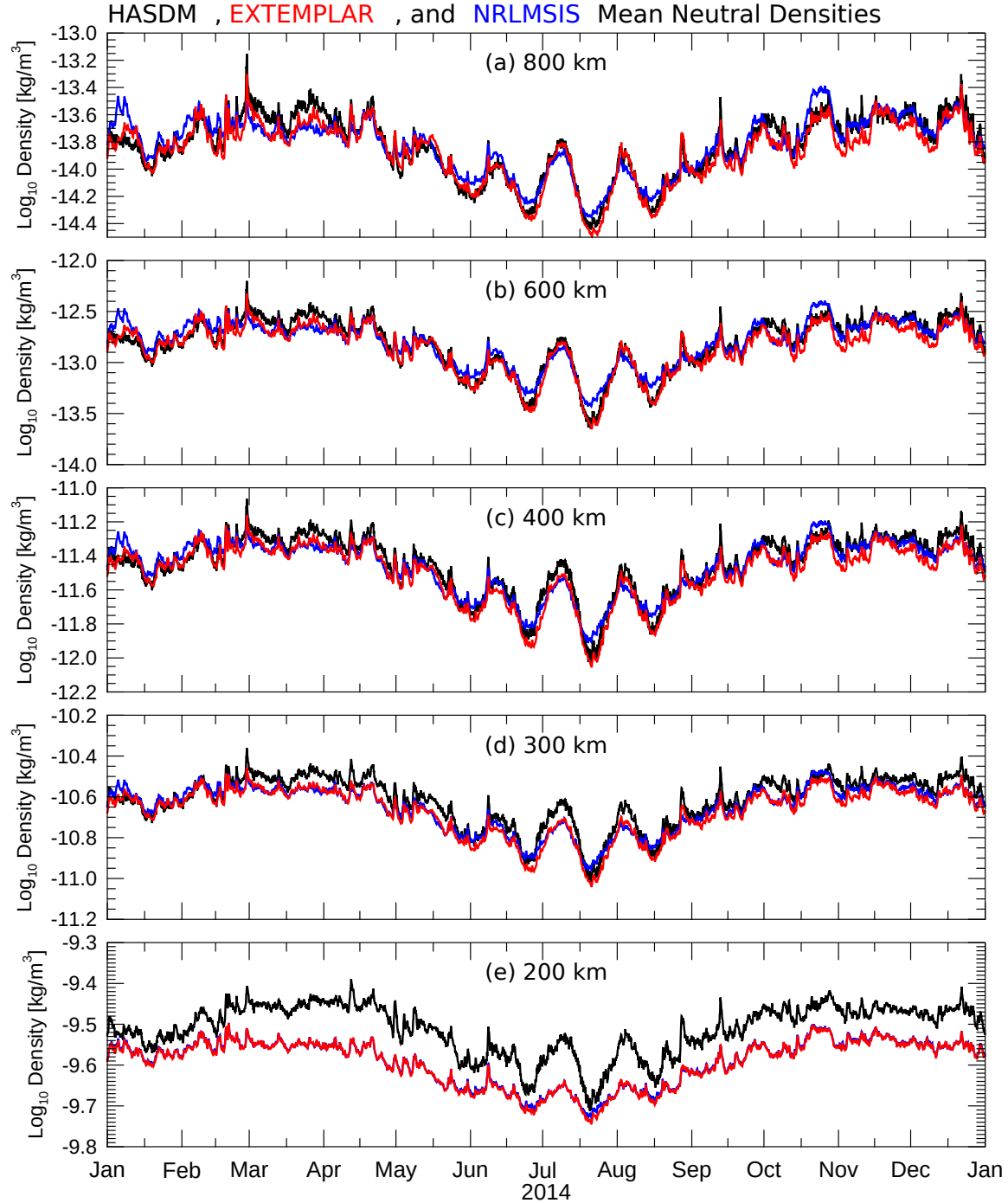
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Figure S12. Mean densities graphed as a function of time, for the year 2011. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
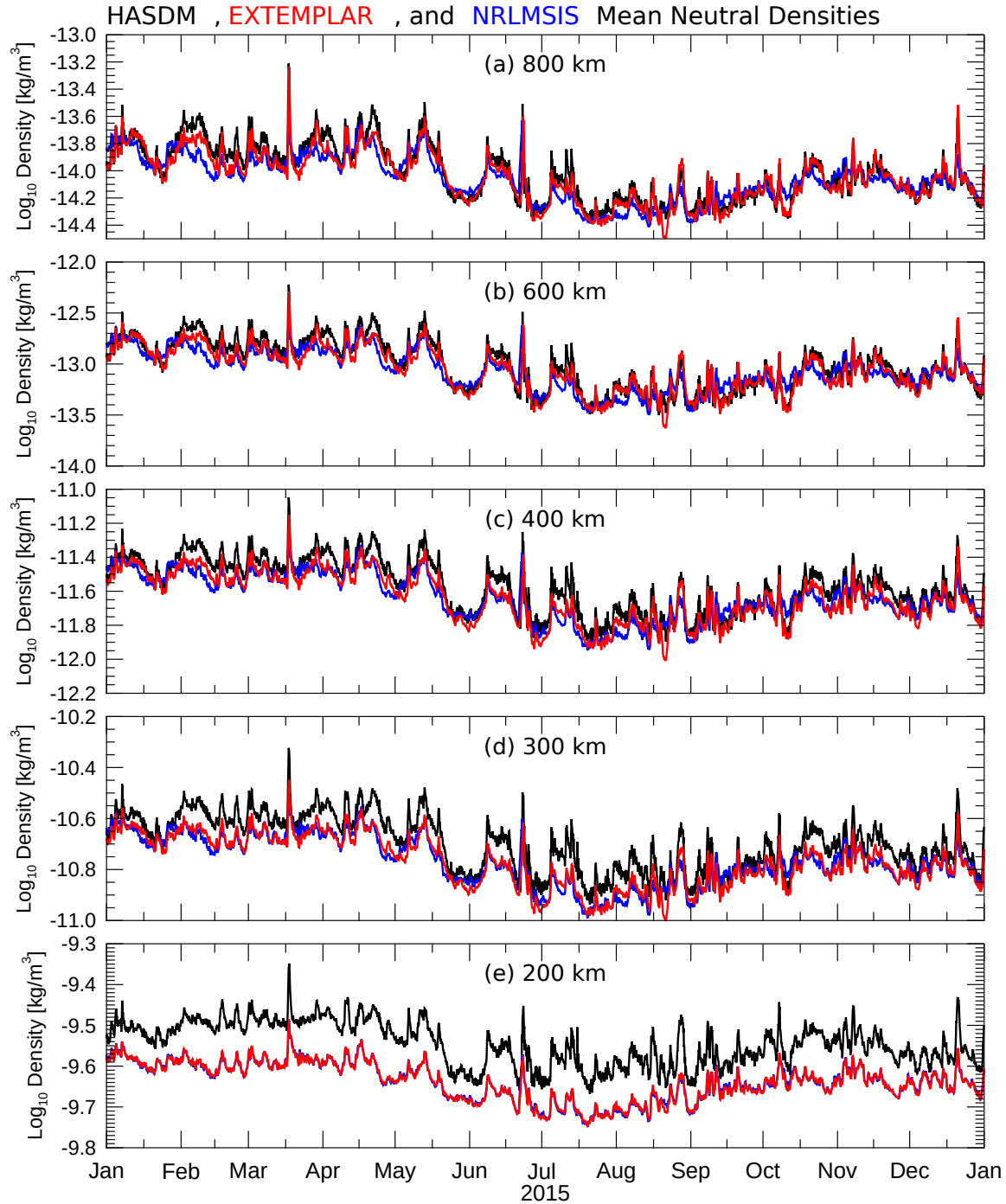
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Figure S14. Mean densities graphed as a function of time, for the year 2013. The SET

HASDM density database values are graphed with the black lines, EXTEMPLAR results in

red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to
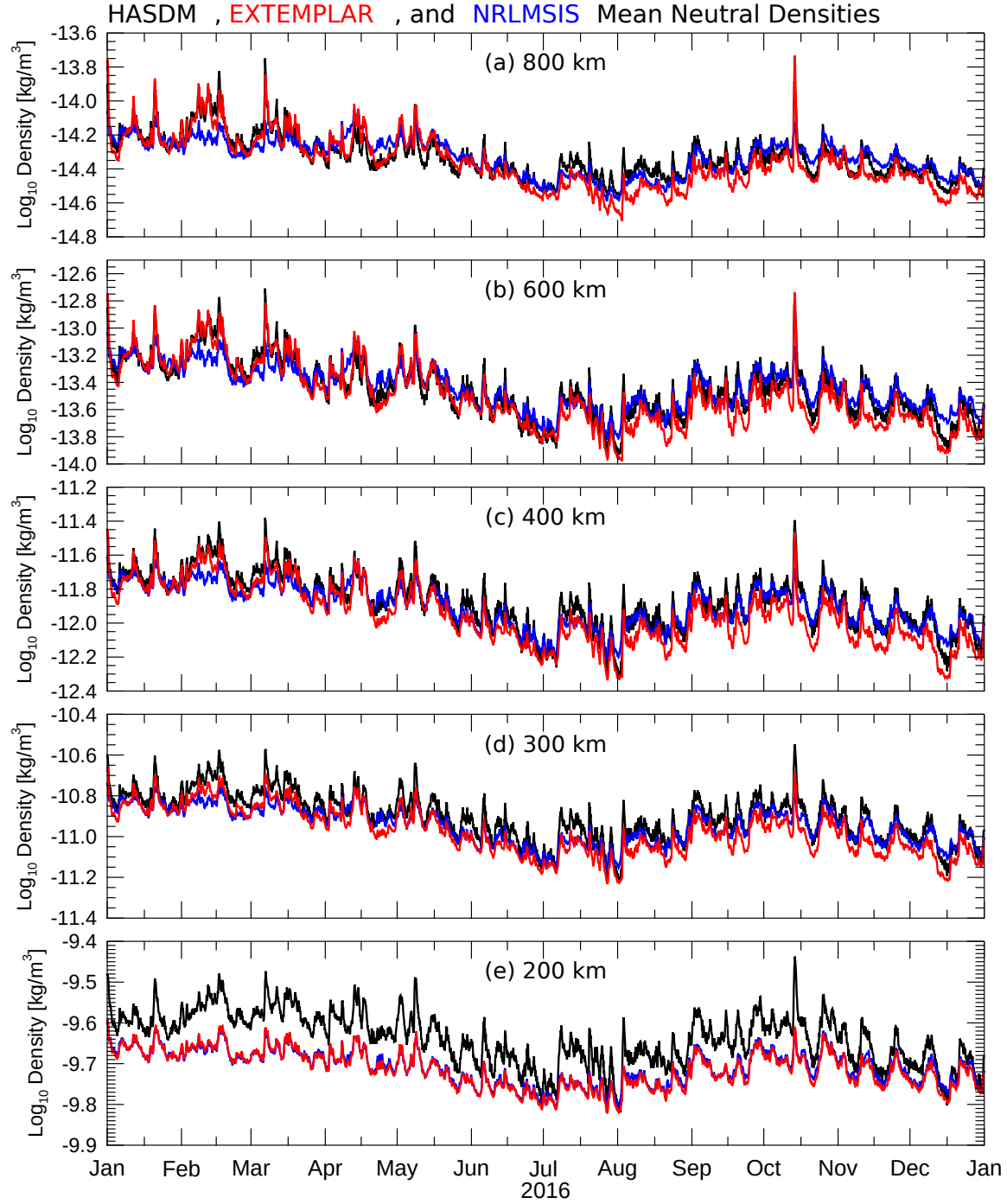
bottom). Units are kg/m^3.

Figure S15. Mean densities graphed as a function of time, for the year 2014. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
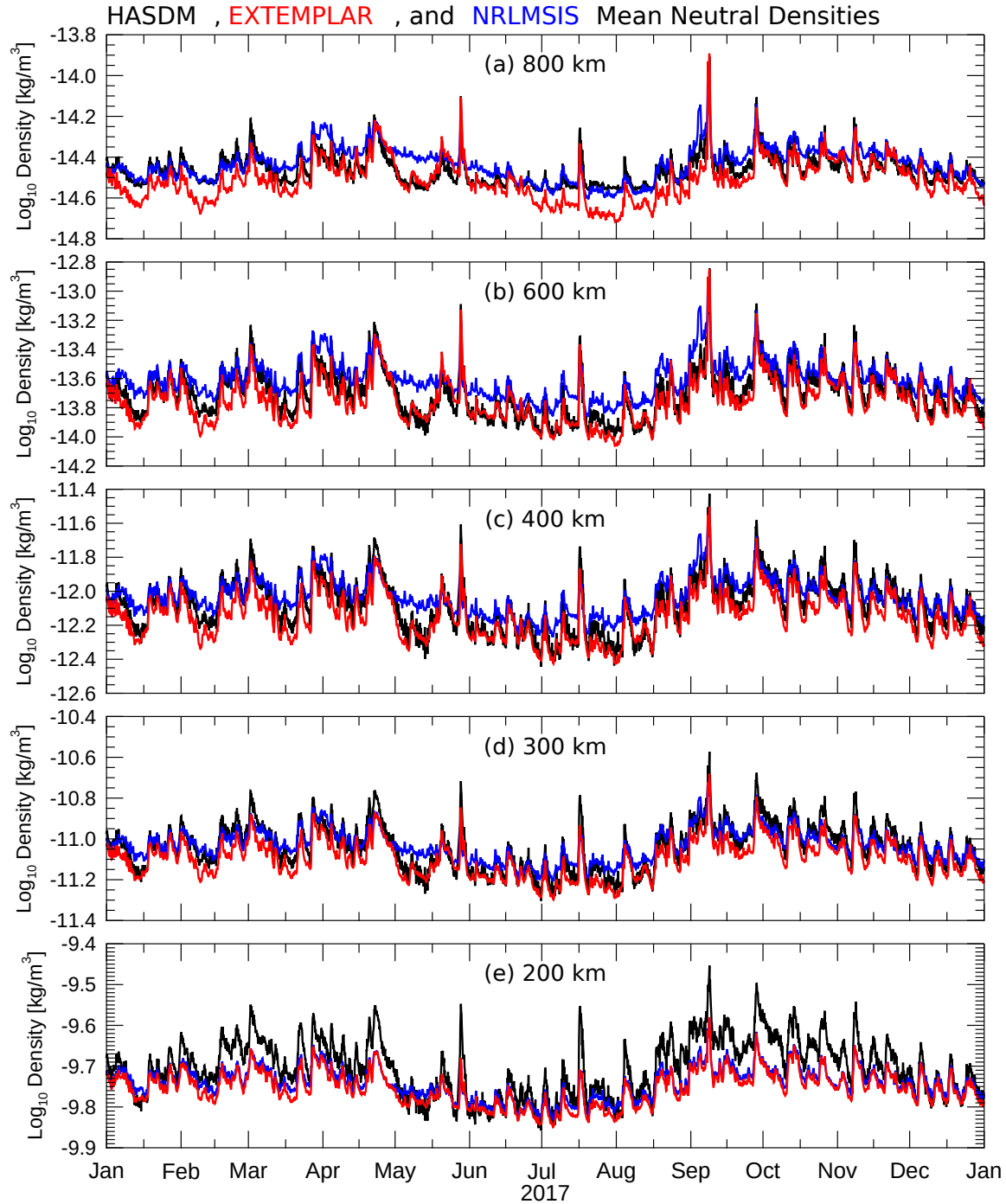
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Figure S17. Mean densities graphed as a function of time, for the year 2016. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
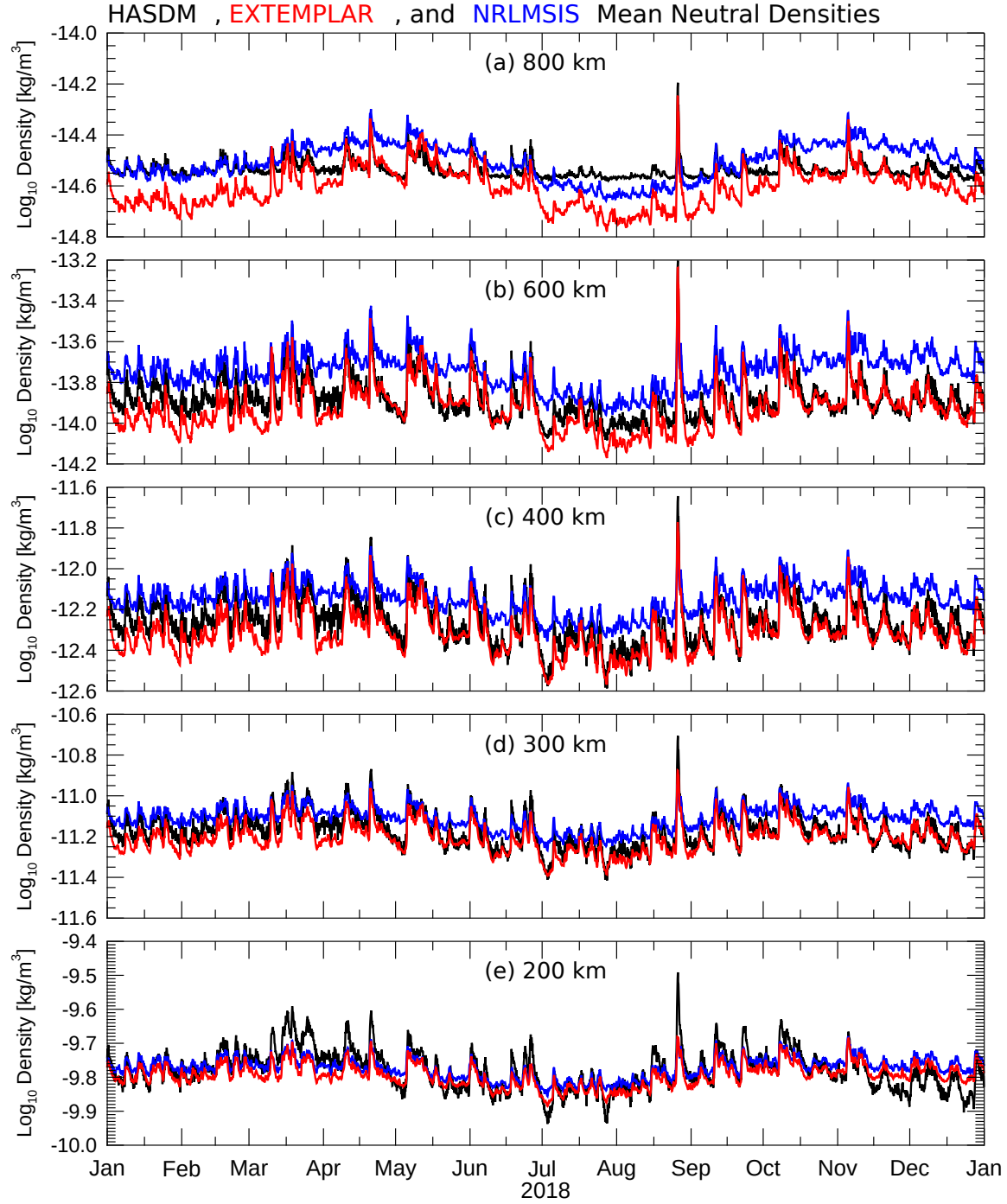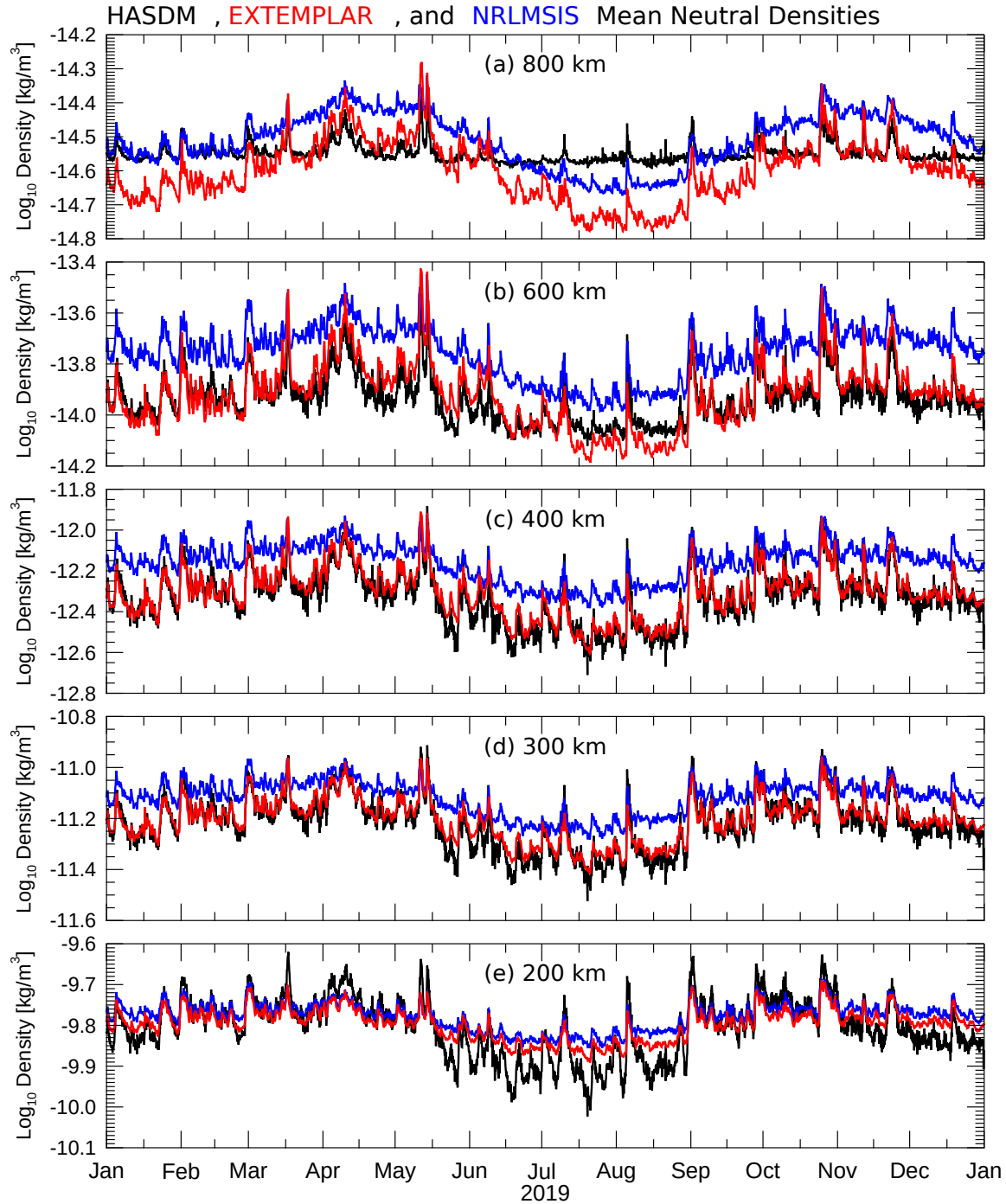
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HASDM , EXTEMPLAR , and NRLMSIS Mean Neutral Densities

(a) 800 km

(b) 600 km

(c) 400 km

(d) 300 km

(e) 200 km

Figure S19. Mean densities graphed as a function of time, for the year 2018. The SET HASDM density database values are graphed with the black lines, EXTEMPLAR results in red, and the NRLMSIS model values in blue, for altitudes of 800, 600, 400, and 300km (top to bottom). Units are kg/m^3.
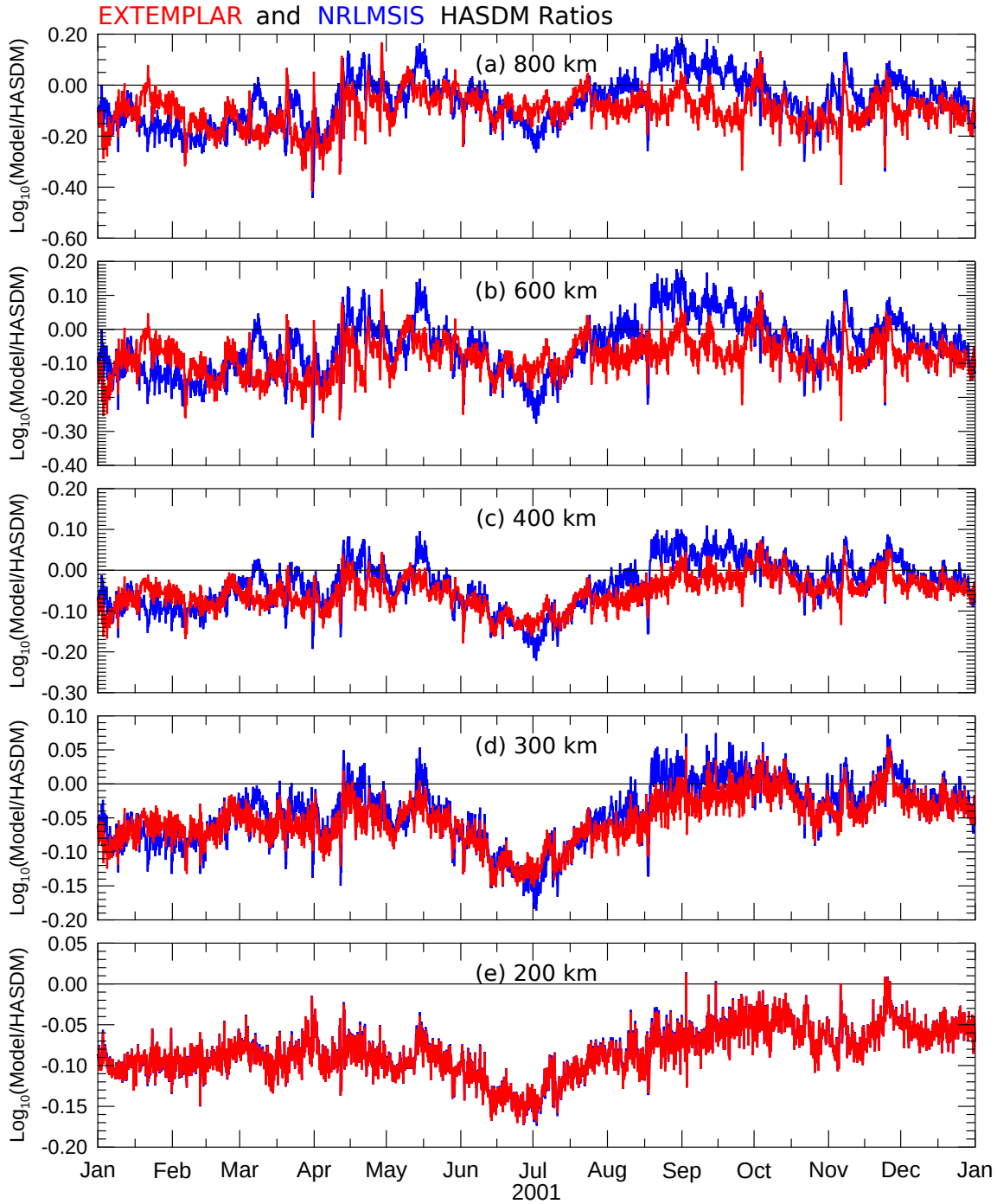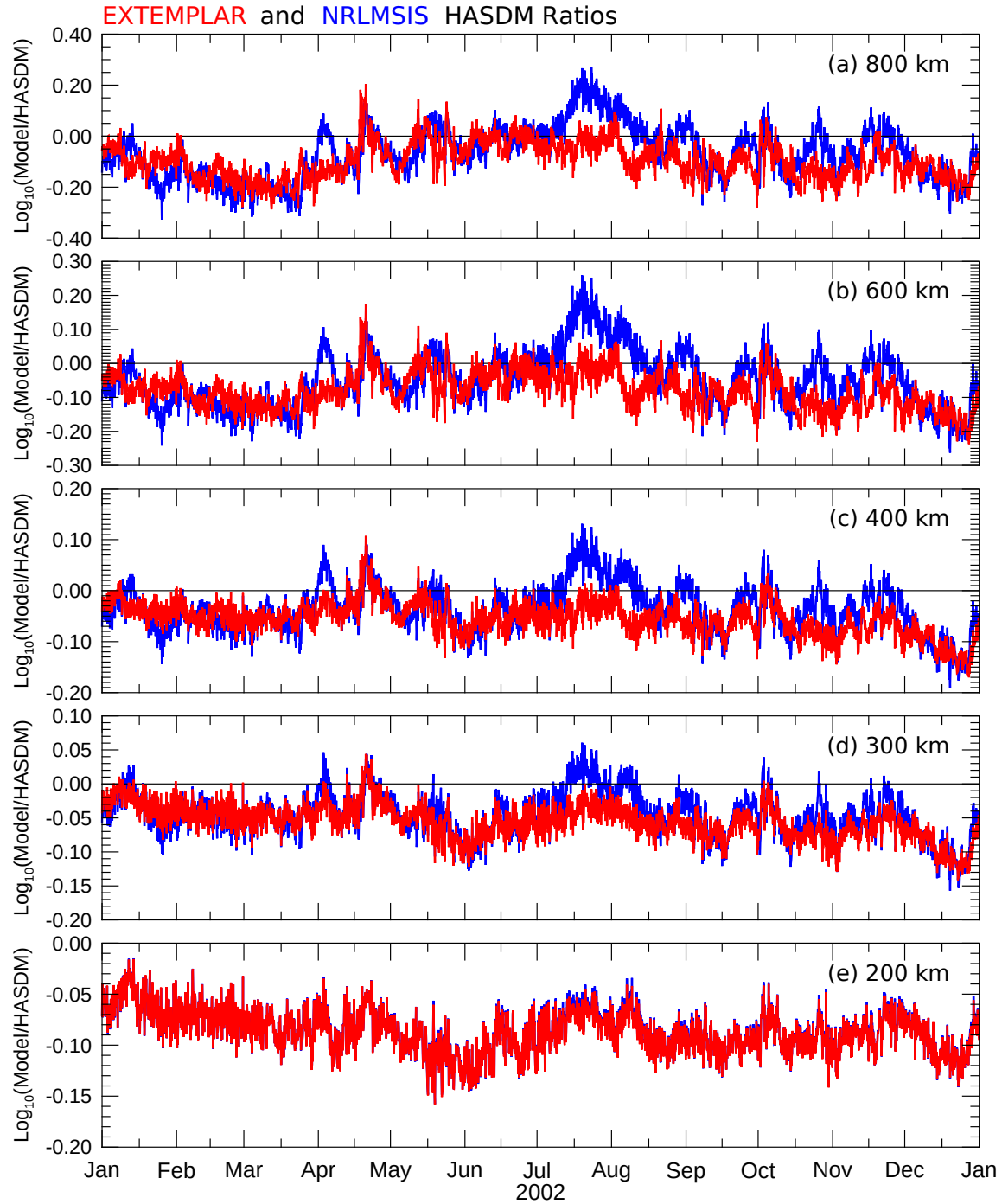
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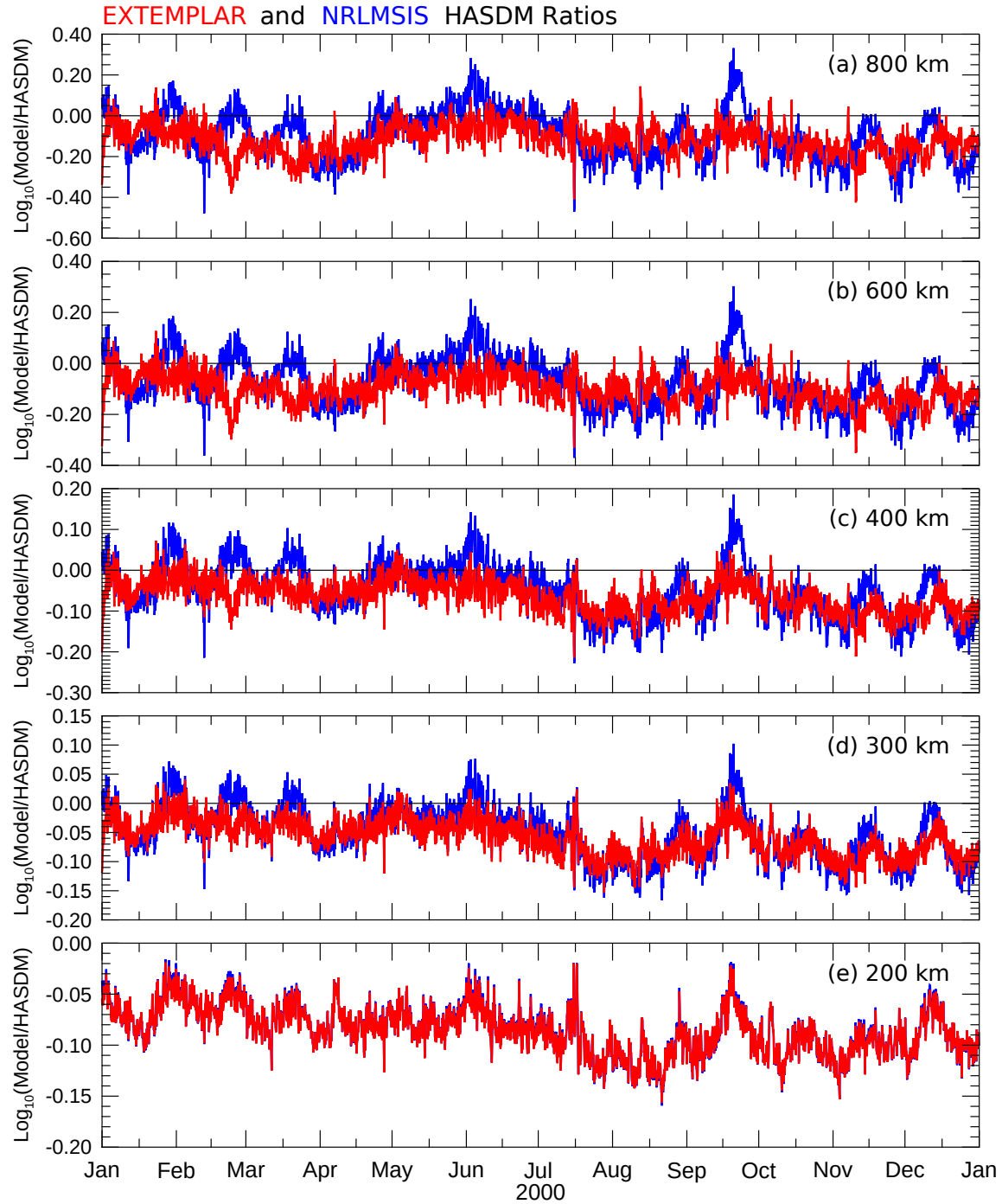
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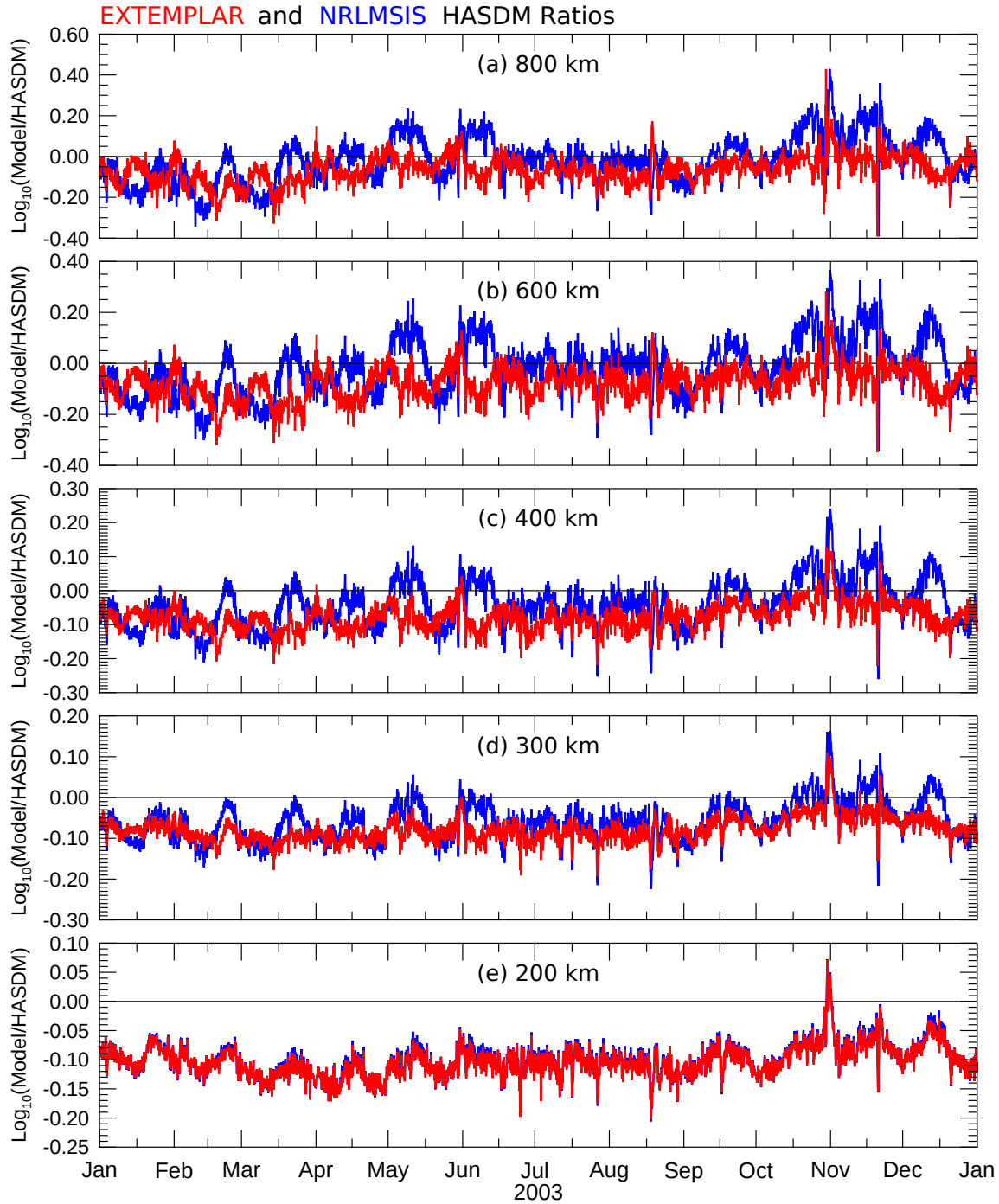
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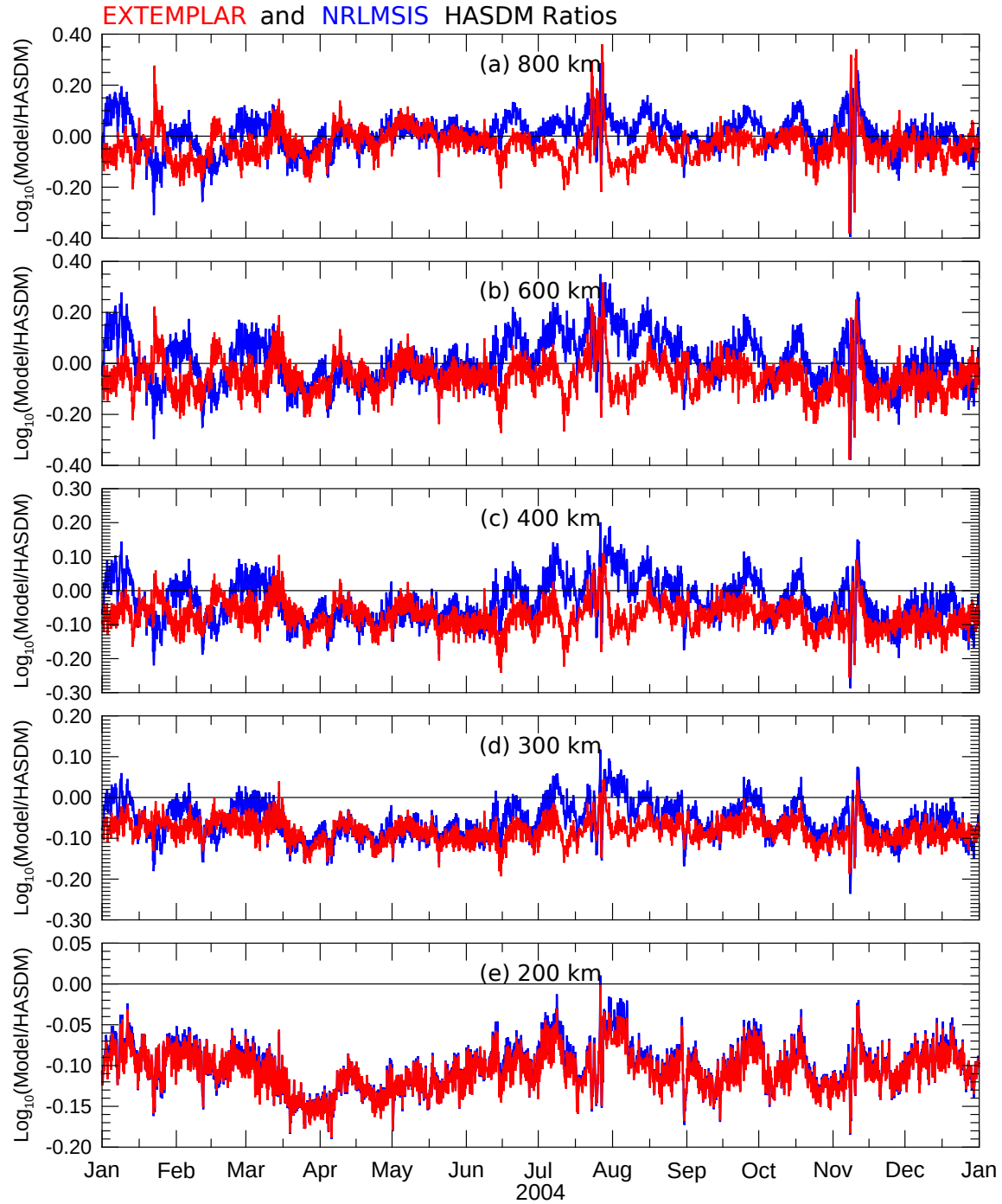
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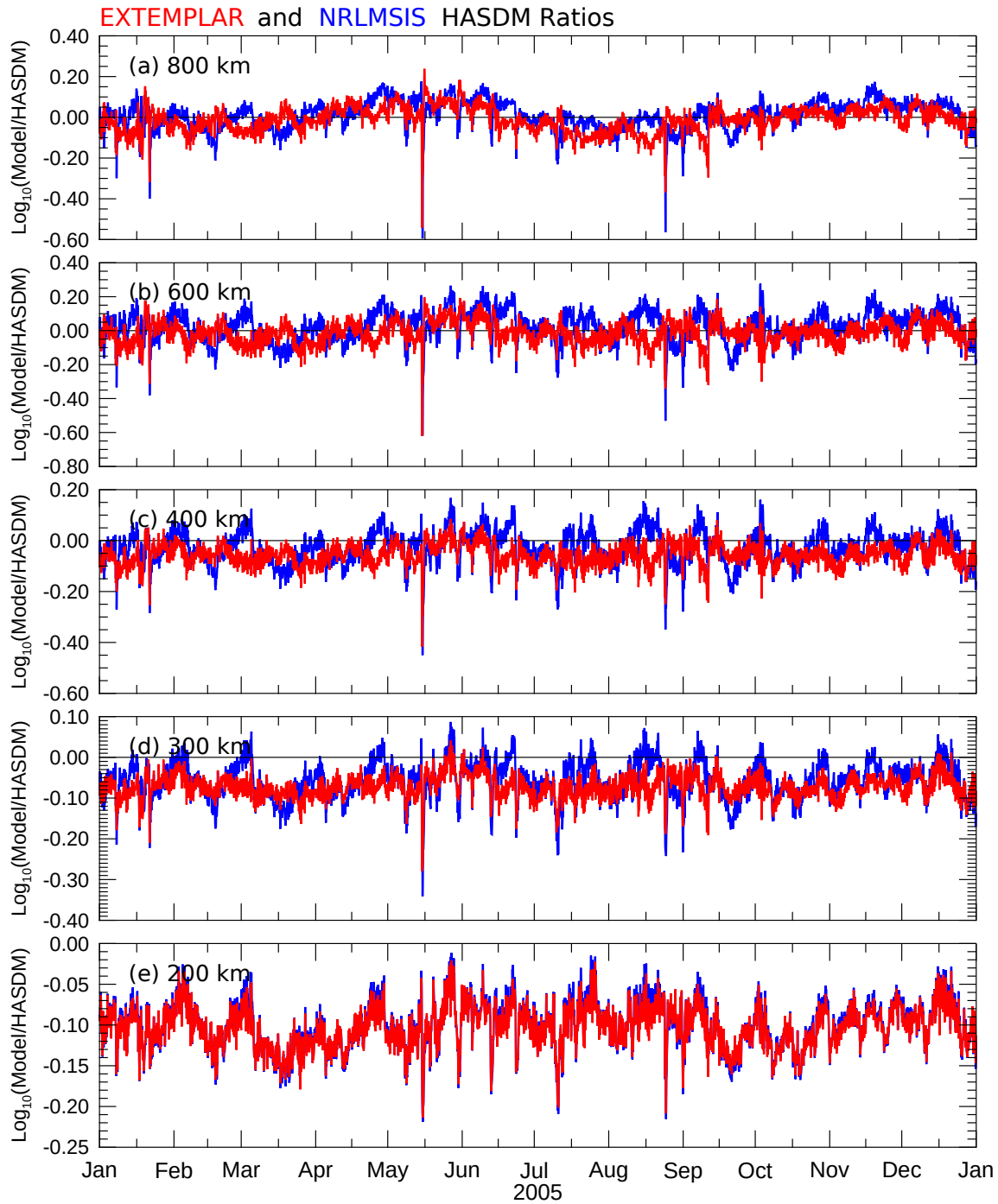
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Figure S25. Ratios of mean densities as a function of time, for the year 2004. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.
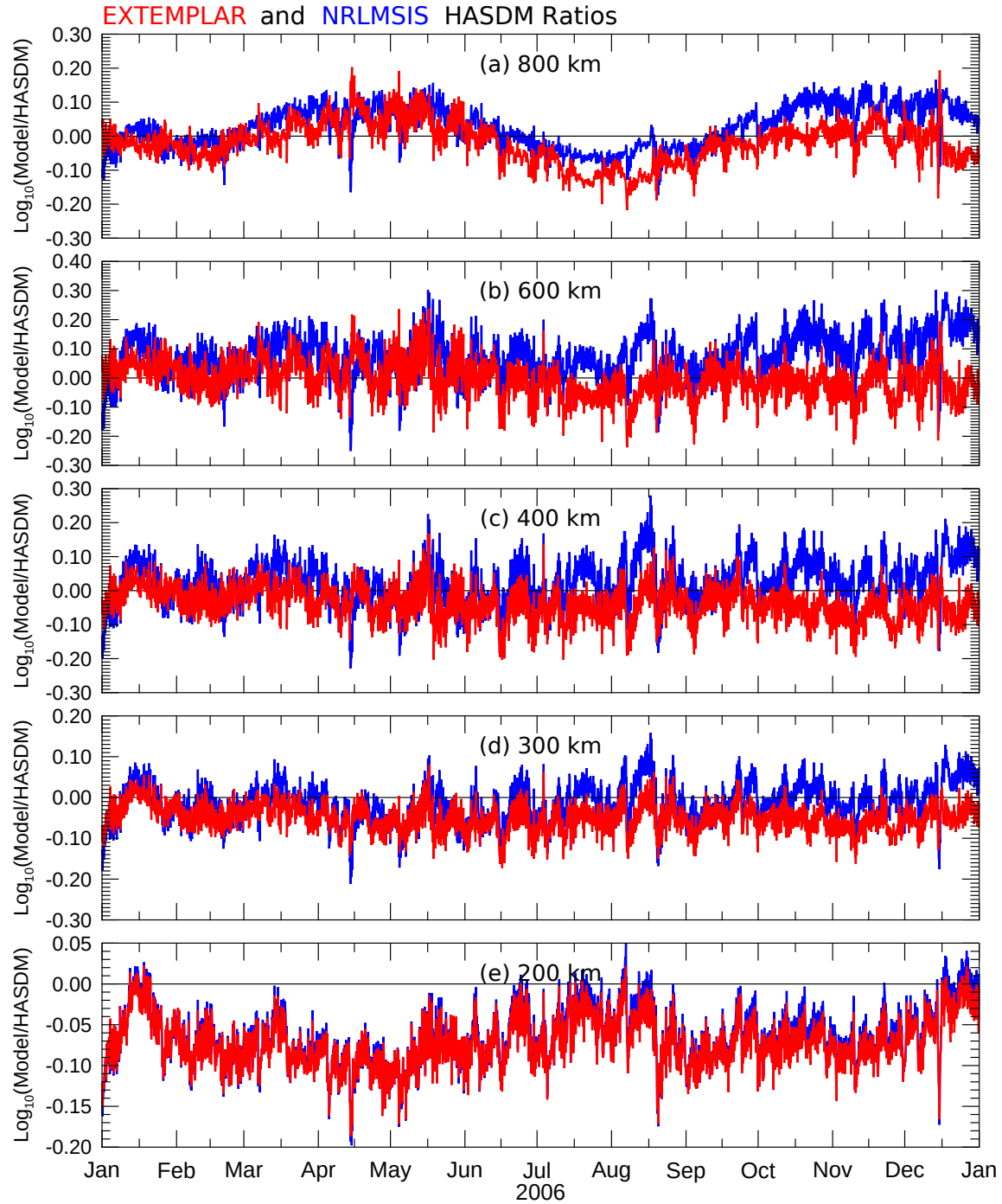
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Figure S26. Ratios of mean densities as a function of time, for the year 2005. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.
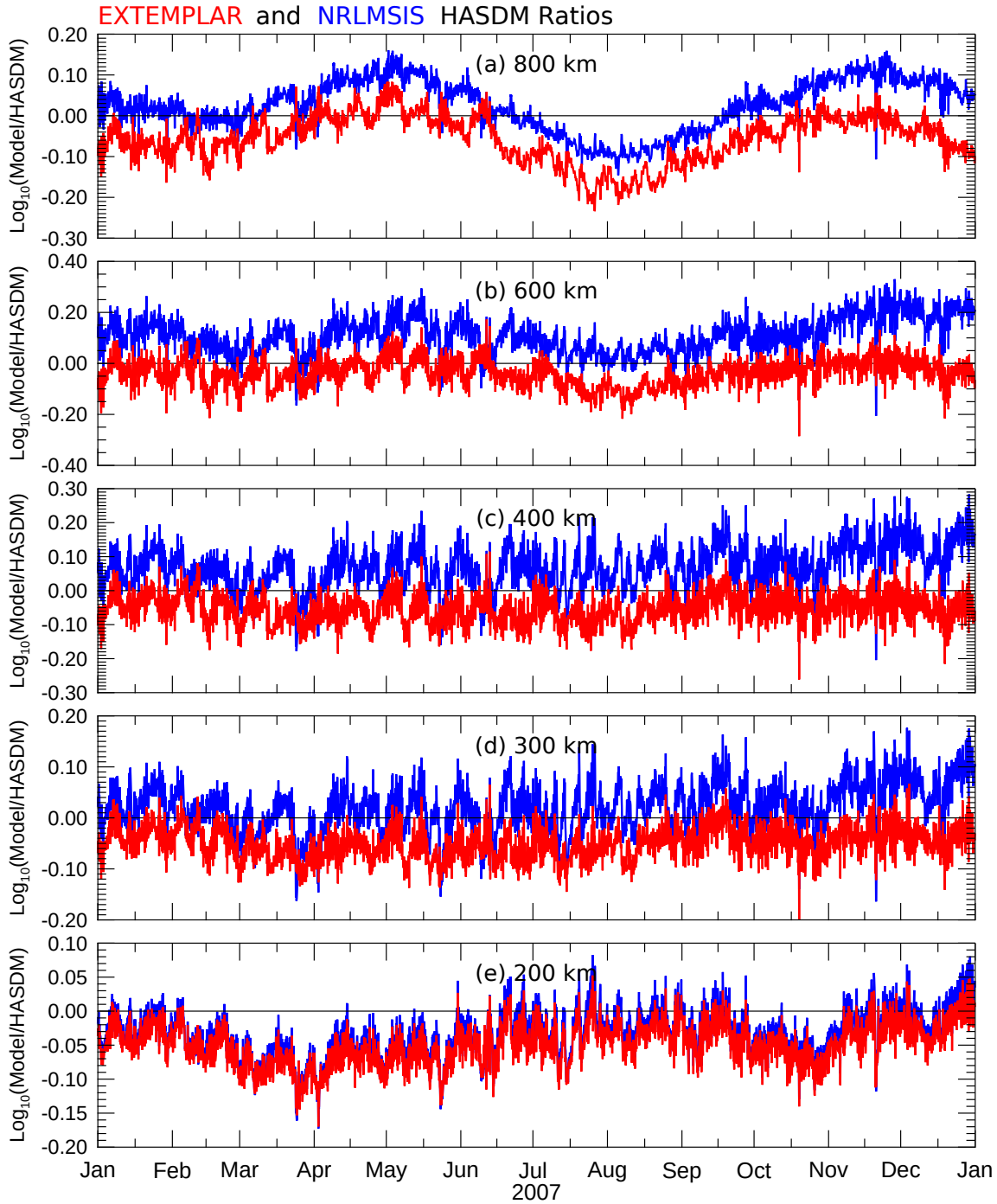
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Figure S27. Ratios of mean densities as a function of time, for the year 2006. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.
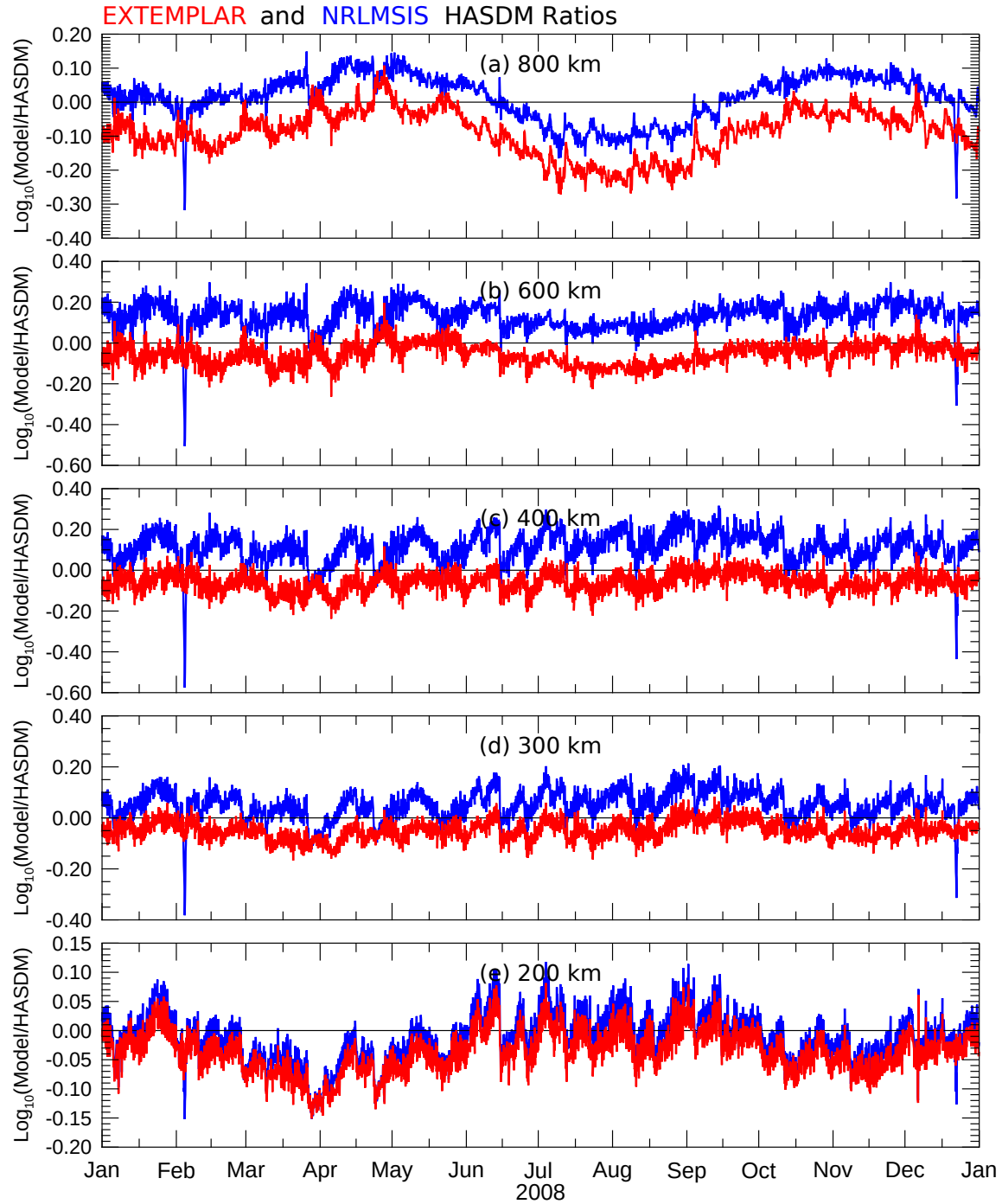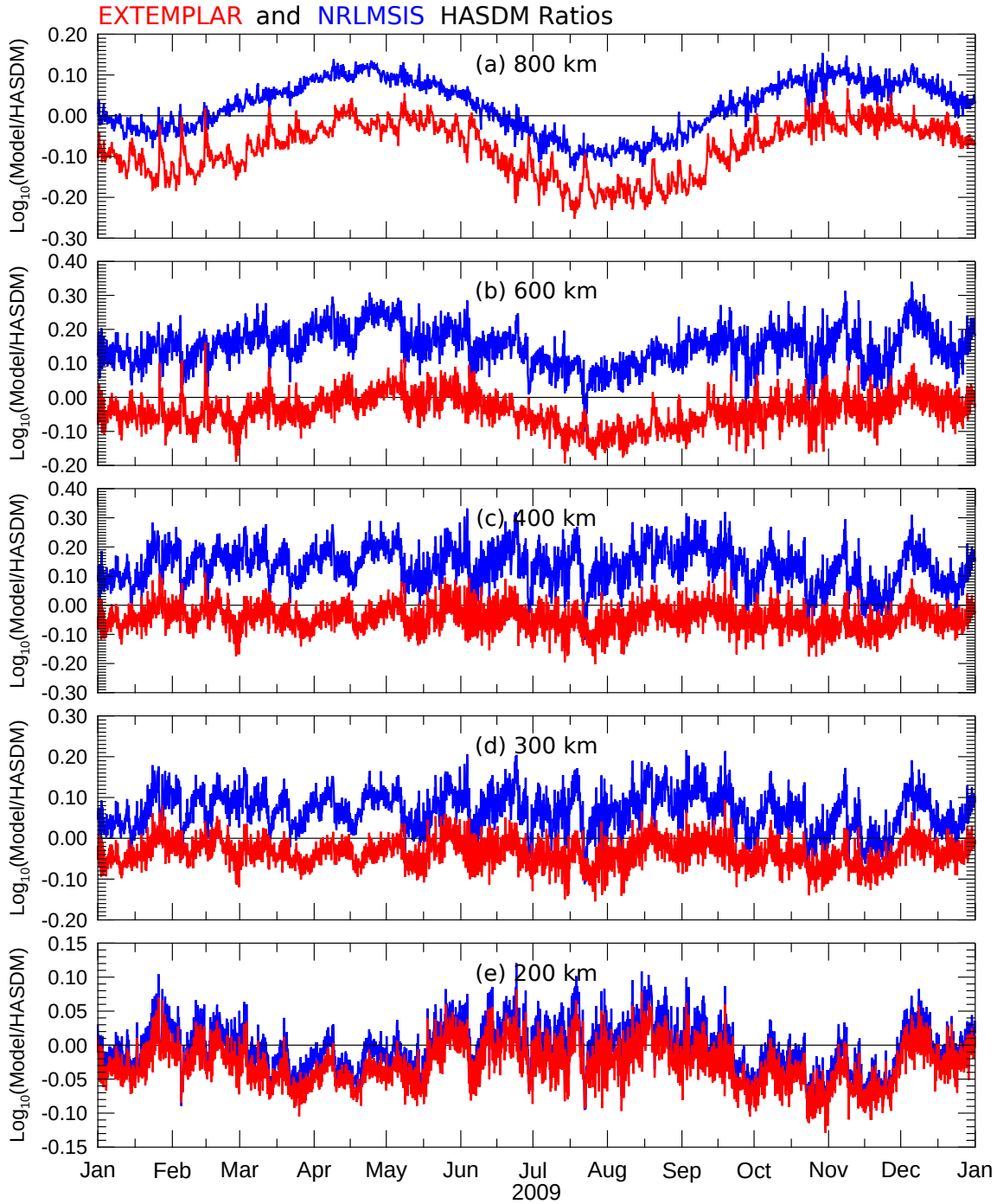
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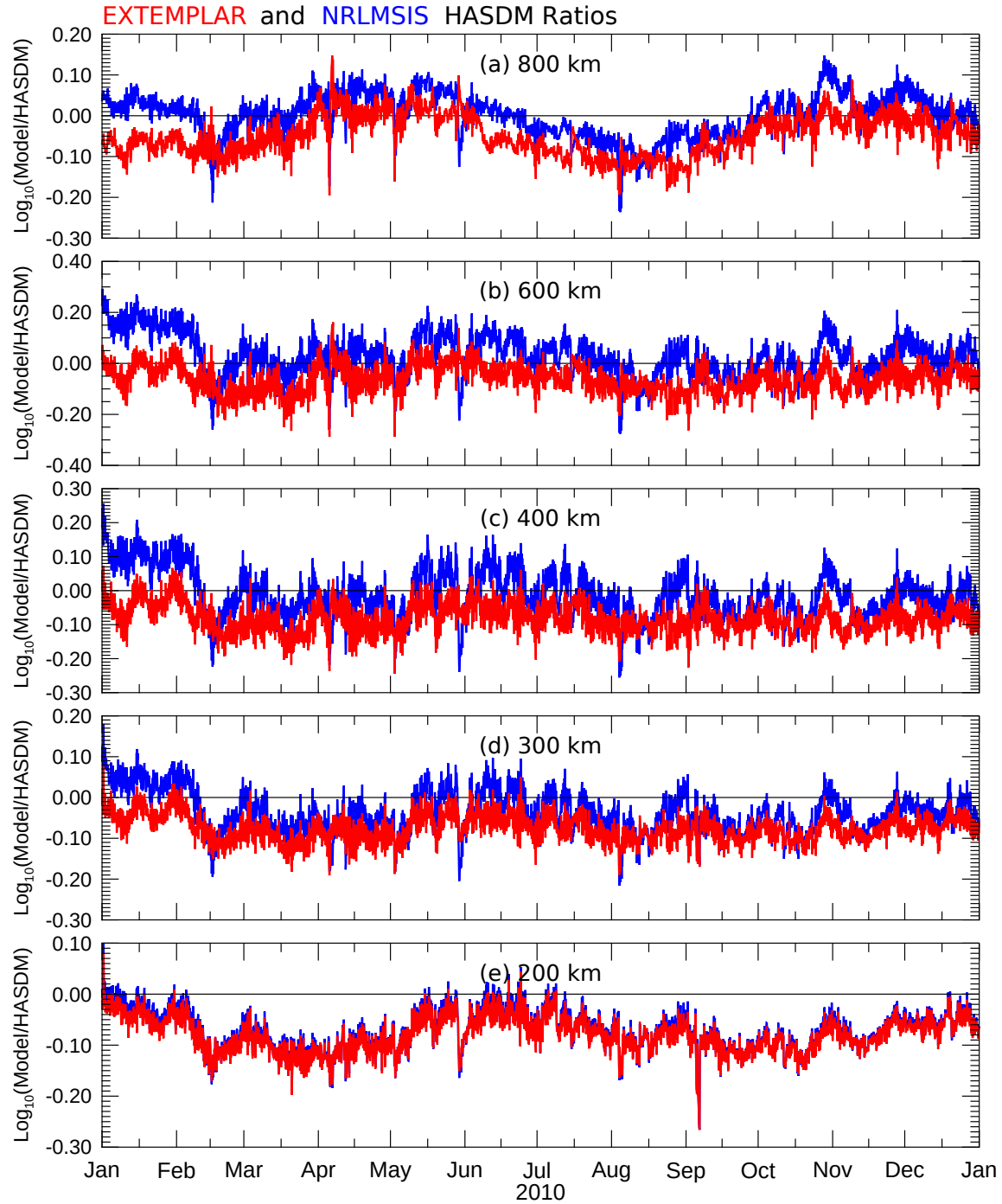
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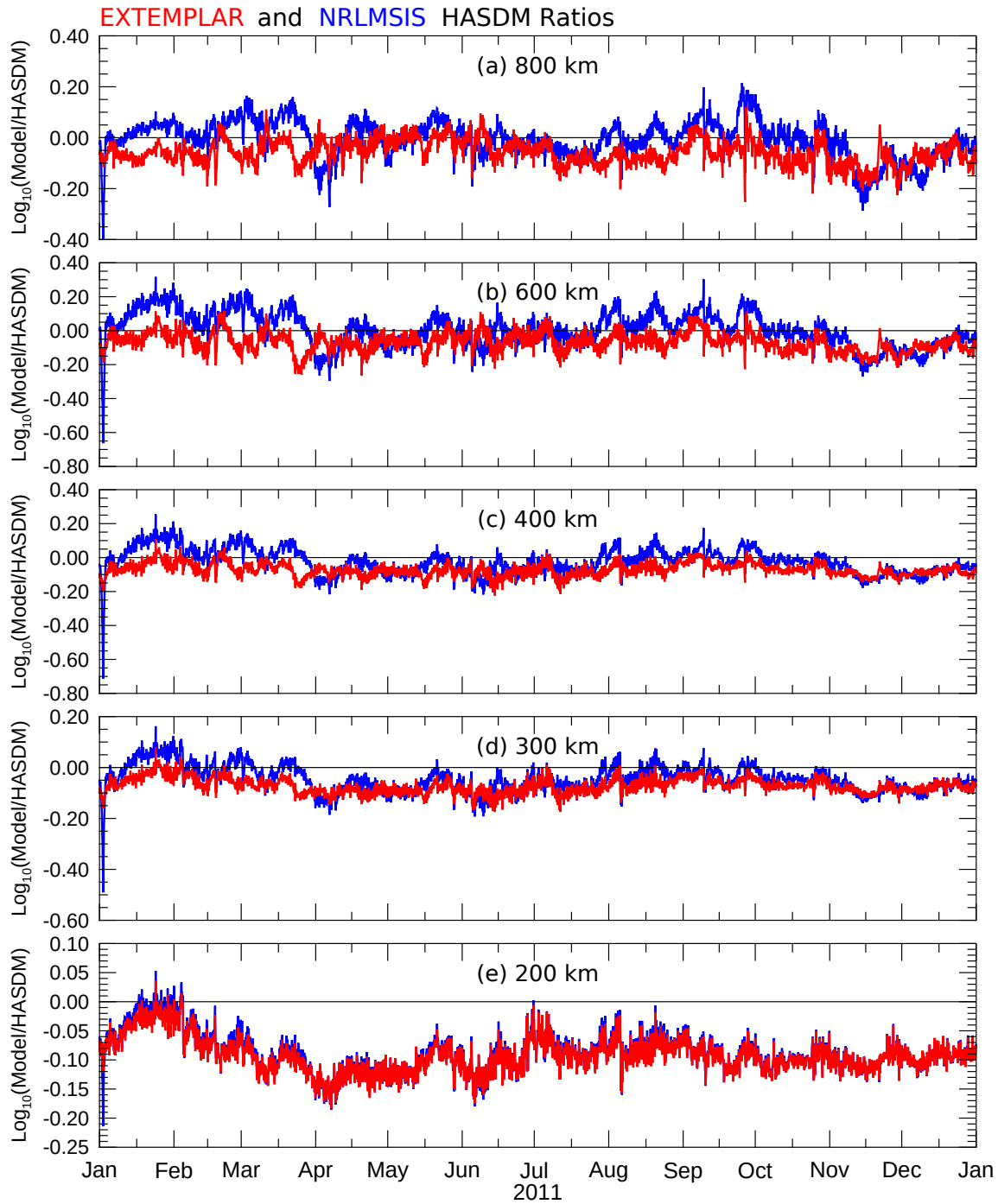
Figure S30.   Ratios of mean densities as a function of time, for the year 2009. The ratios

between the EXTEMPLAR results and SET HASDM density database values are drawn in red,

and the ratios between the NRLMSIS model values and the SET HASDM density database values

are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The

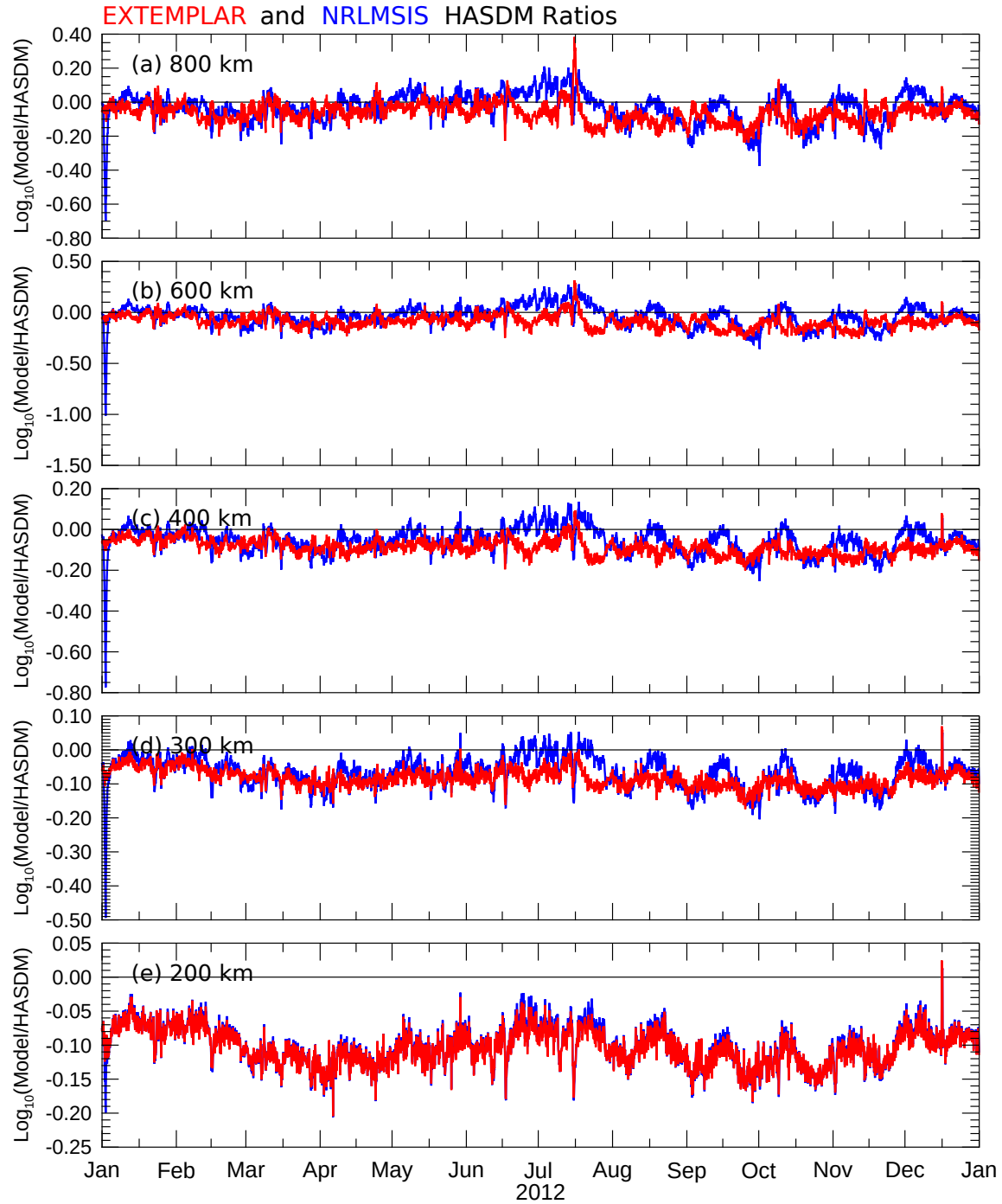base 10 logarithm of the ratios are shown.

Figure S31. Ratios of mean densities as a function of time, for the year 2010. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.
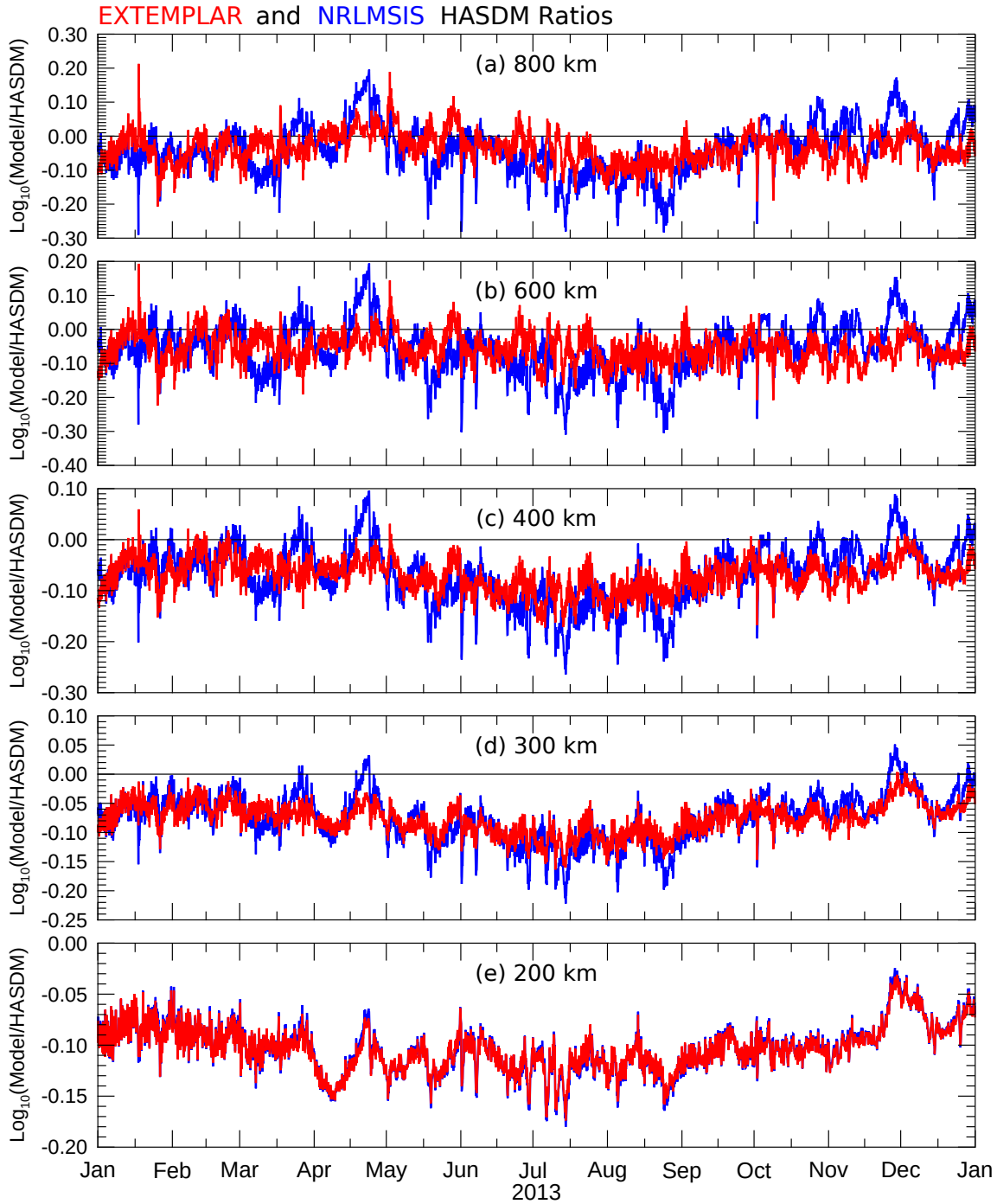
Figure S32. Ratios of mean densities as a function of time, for the year 2011. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.

Figure S33. Ratios of mean densities as a function of time, for the year 2012. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.
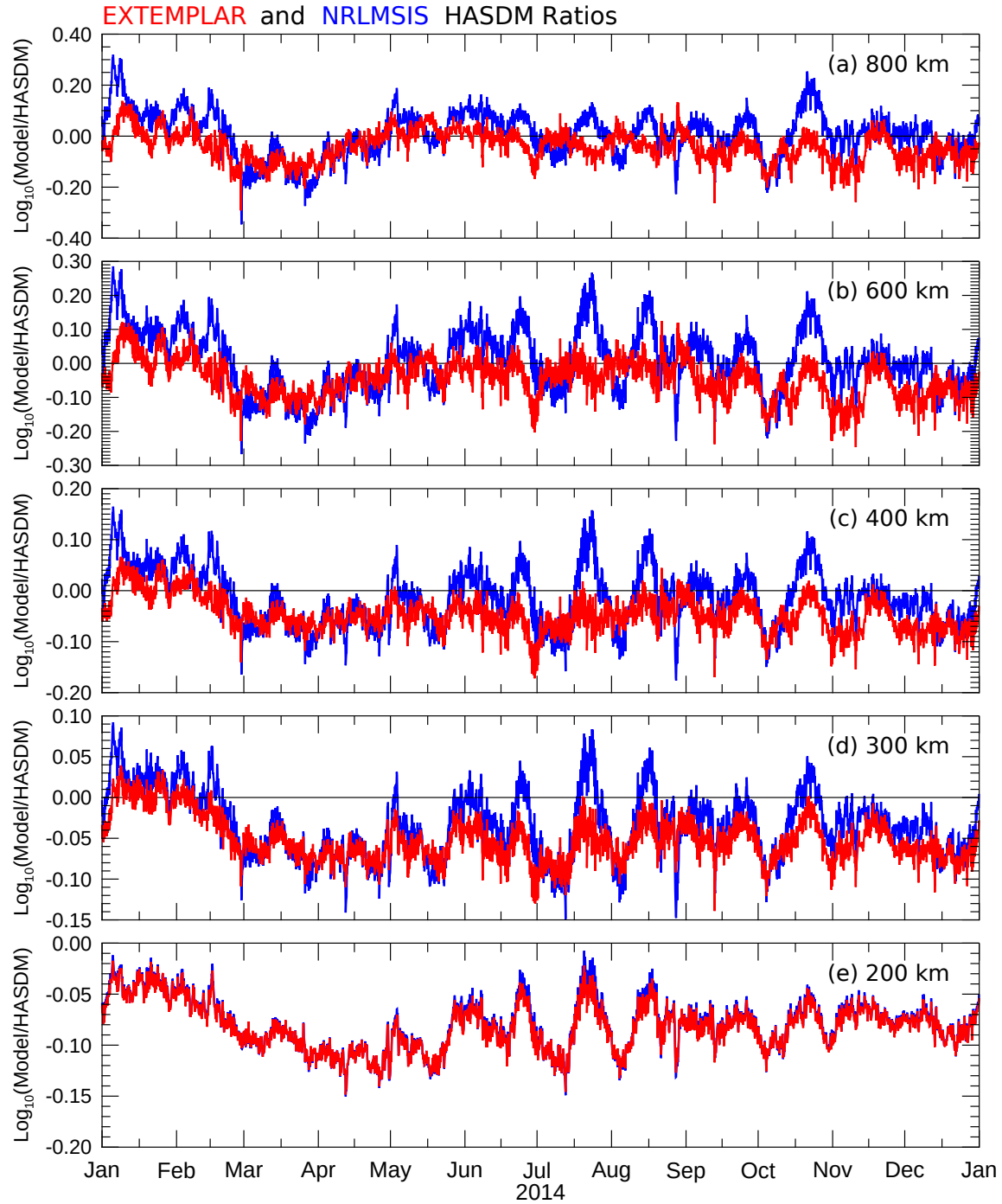
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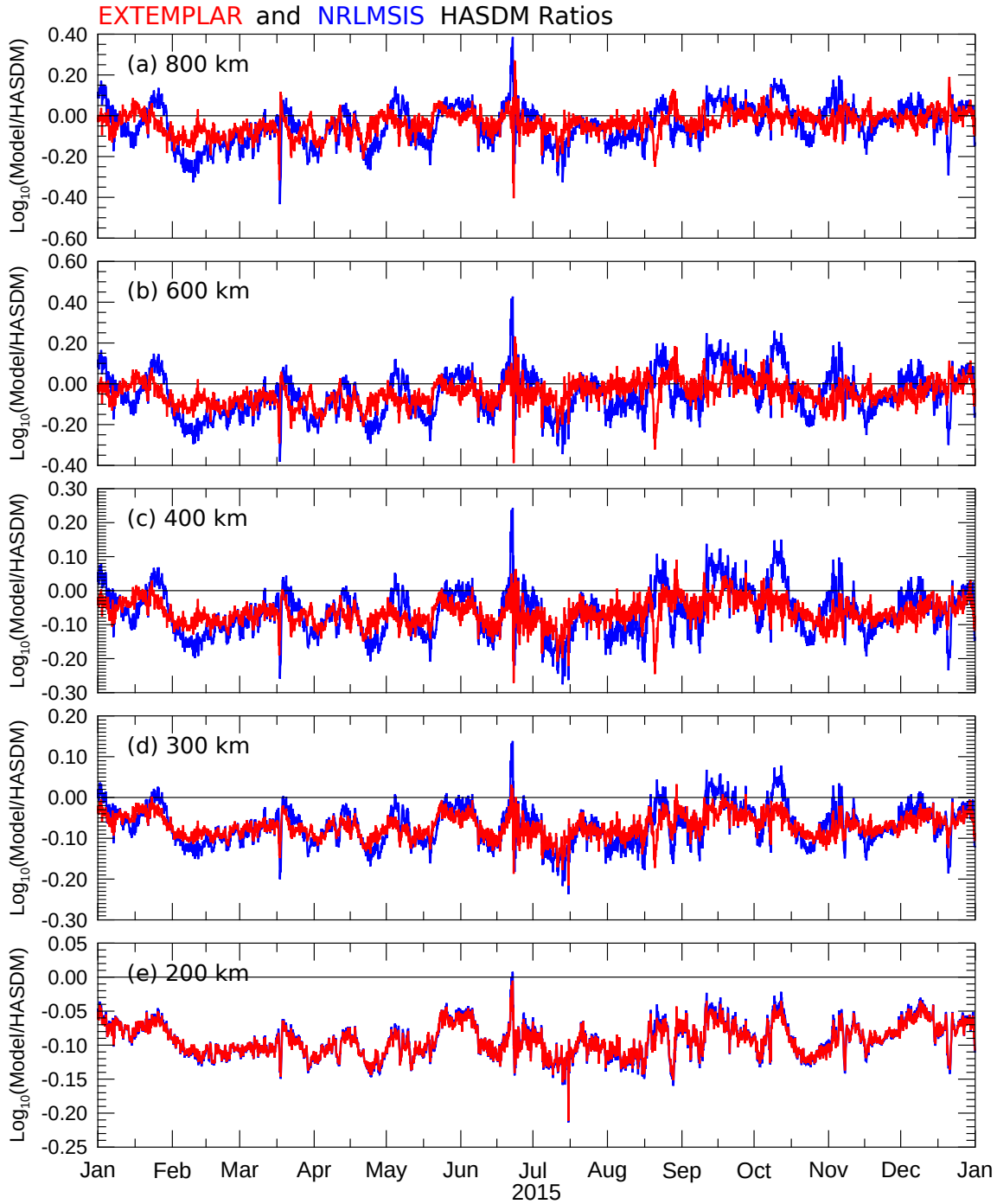
Figure S35. Ratios of mean densities as a function of time, for the year 2014. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.
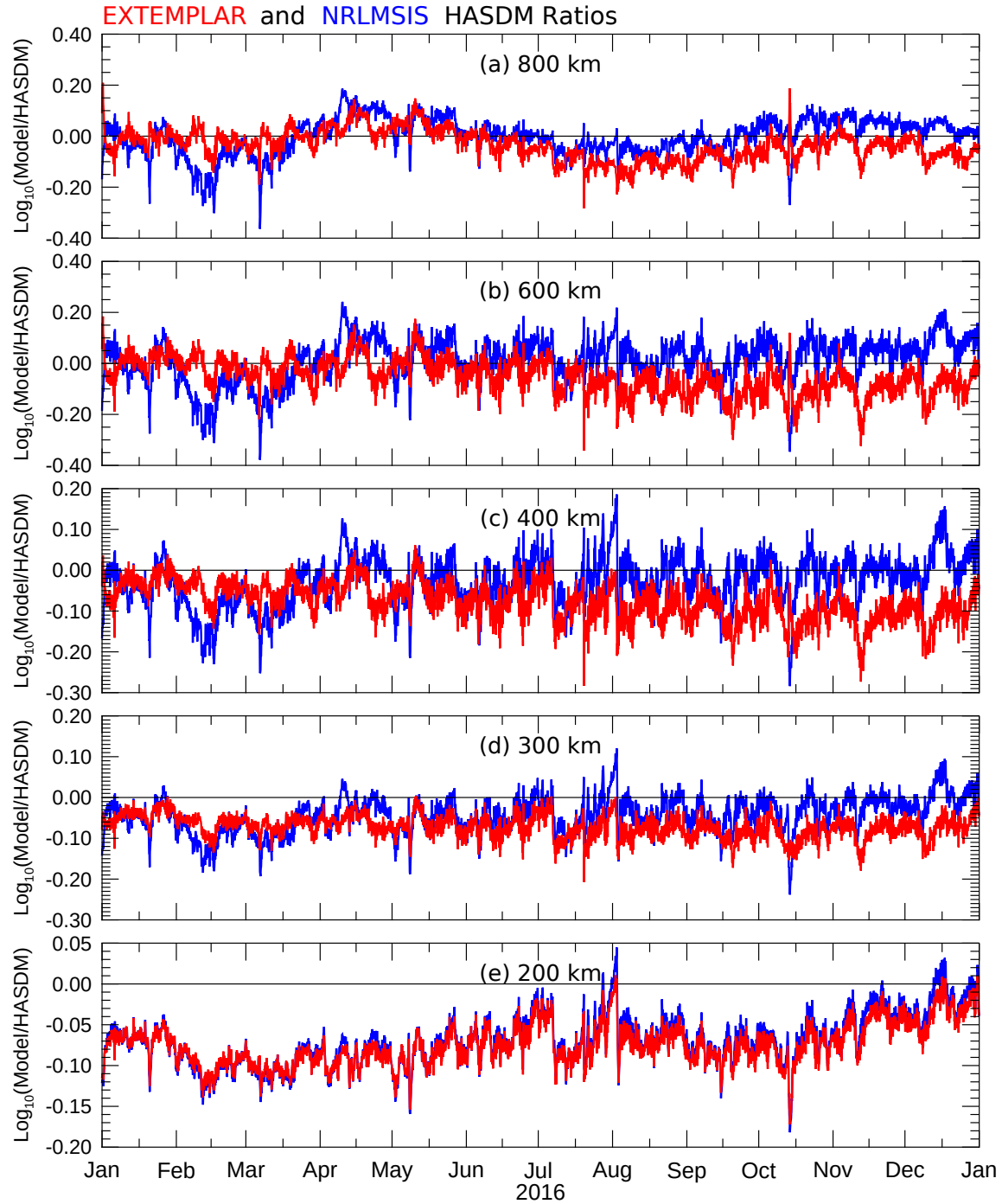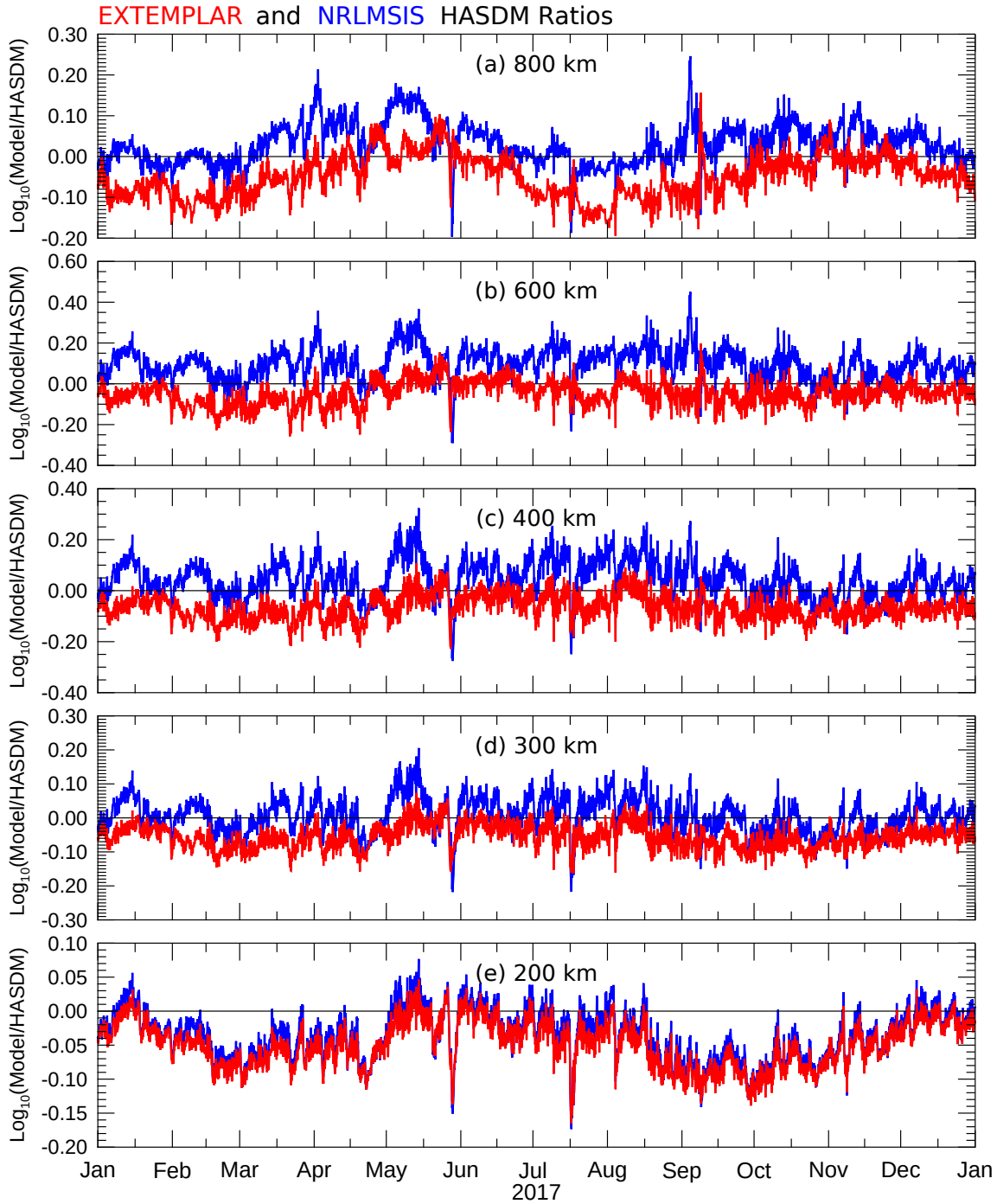
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Figure S36. Ratios of mean densities as a function of time, for the year 2015. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.
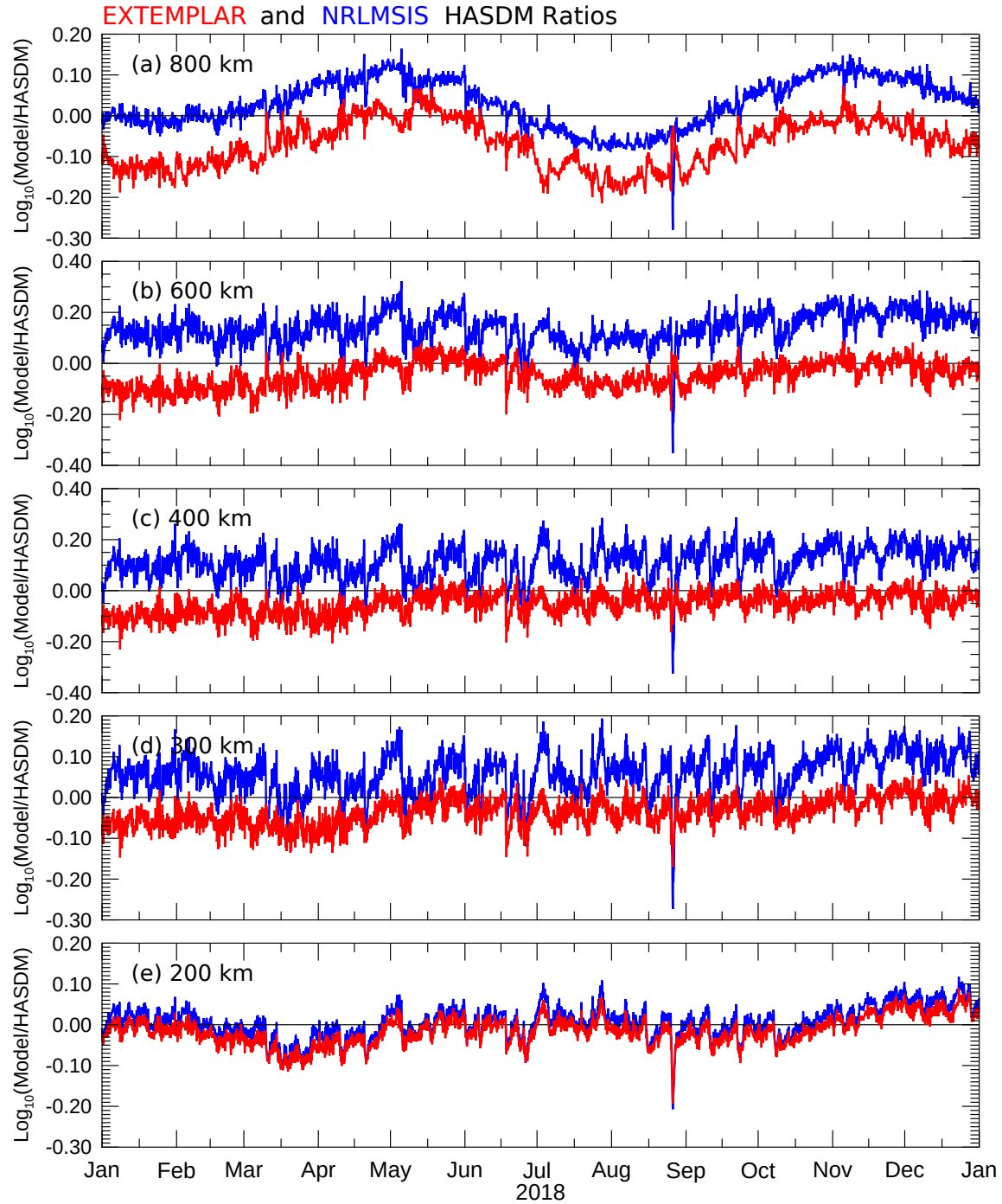
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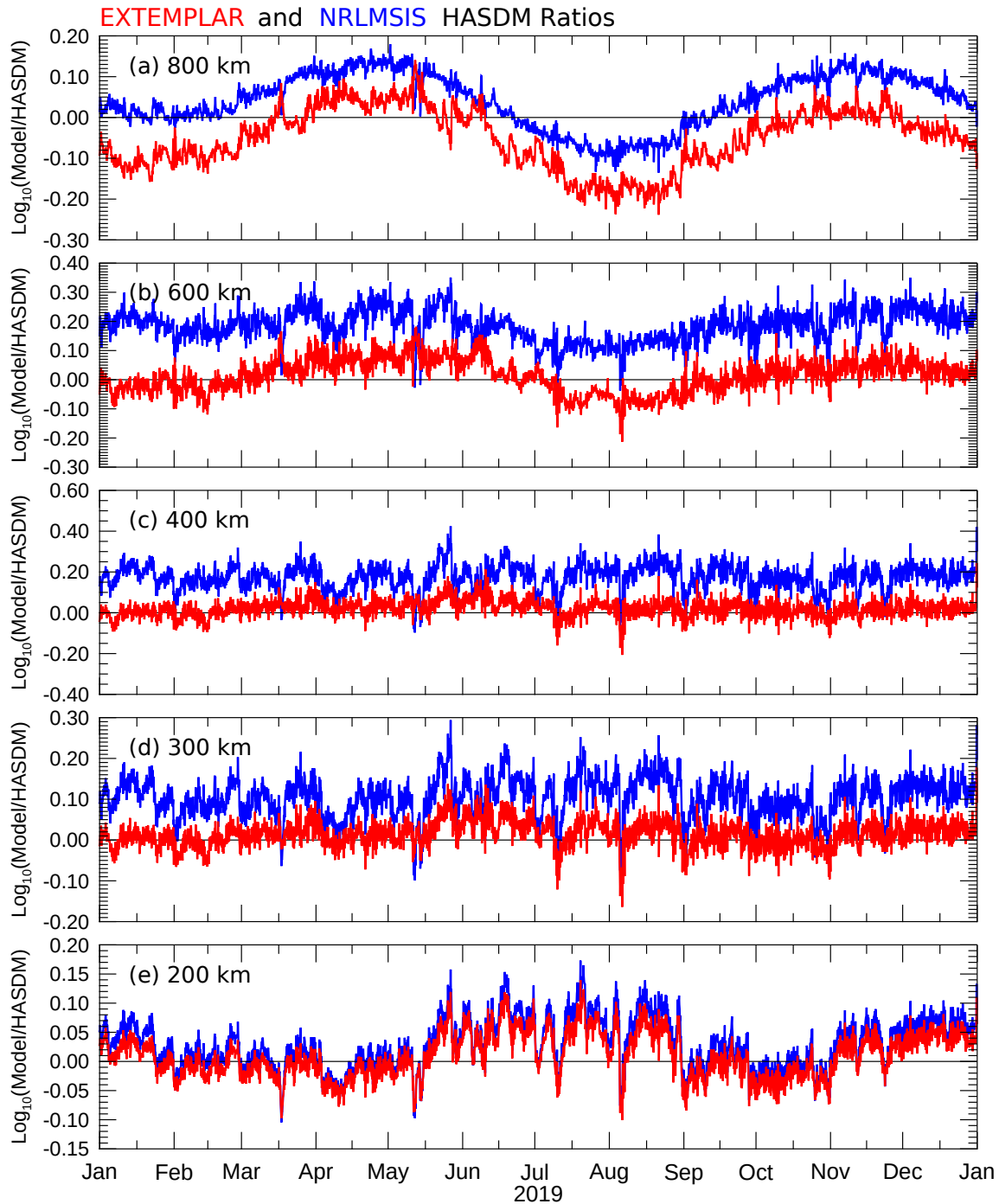
Figure S38. Ratios of mean densities as a function of time, for the year 2017. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.

Figure S39. Ratios of mean densities as a function of time, for the year 2018. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.

Figure S40. Ratios of mean densities as a function of time, for the year 2019. The ratios between the EXTEMPLAR results and SET HASDM density database values are drawn in red, and the ratios between the NRLMSIS model values and the SET HASDM density database values are drawn with the blue lines, for altitudes of 800, 600, 400, and 300km (top to bottom). The base 10 logarithm of the ratios are shown.