Introduction to the Kinematics Tool

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Aim Included Files Background Exercise 1 - Using the Kinematics Tool Exercise 2 - Looking at relative and absolute motion

Aim

This tutorial is designed to introduce the user to the features of the Kinematics Tool and teach the user how to compare absolute and relative plate kinematics.

Included Files

<u>Click here</u> to download the data bundle for this tutorial.

The tutorial dataset (2.7-Kinematics_Tool.zip) includes the following files:

Rotation file: Seton_etal_ESR2012_2012.1.rot

Coastline file: Seton_etal_ESR2012_Coastlines_2012.1_Polyline.gpmlz

Background

Kinematics describes the motion of objects and in a GPlates context, we can look at the kinematics of various features to understand their magnitude and direction of motion over time. In GPlates, the Kinematics Tool renders 2D plots of velocity (and velocity-related quantities) over time.

Exercise 1 - Using the Kinematics Tool

Introduction to the features of the Kinematics Tool and learn how to export data

- 1. Open GPlates and load the following files using Open Feature Collection.
 - Seton_etal_ESR2012_2012.1.rot
 - Seton_etal_ESR2012_Coastlines_2012.1_Polyline.gpmlz

2. Rotate the globe so that it is centred on **India** and select it using the Feature Inspection tool (Figure 1)



Figure 1: View of India (Step 2)

3. Utilities > Open Kinematics Tool... (or Ctrl+Shift+K)

A new window will open (Figure 2), however you will notice that it is blank (Figure 2)



Figure 2: Kinematics Tool Window

4. Click the 'Use focussed feature' button in the top left corner of the box. Data should now appear in the window that corresponds to the focussed feature (Figure 3).

se focussed feature	Time (Ma)	Lat	Lon	V mag (cm/yr)	V azimuth (*)	V colat (omv/yr)	V lon (cm/yr)	Ang V (*/Ma)	
se animation values	200	-26.2795	57.2831	3.2957	335.8197	-3.0065	-1.3499	-0.5067	
	190	-23.5325	56.0677	3.9089	197.3686	3.7307	-1.1669	-0.5173	
	180	-26.8411	54.7699	1.6177	163.9464	1.5545	0.4473	0.2858	
	170	-28.2277	55,2599	0.7009	72.1390	-0.2150	0.6671	0.2476	
	160	-28.0205	55.9340	5.6629	138.7247	4.2559	3.7357	-0.5132	
	150	-31.7663	59.9057	5.1867	154.7060	4.6895	2.2161	-0.4802	
Update	140	-35.9341	62,4149	4.9765	26.0225	-4.4720	2.1833	0.4585	
Export table	130	-31.8780	64.6807	6.7849	351.0018	-6.7014	-1.0612	0.9662	
Longitude Velocity magnitude Velocity aamuth Velocity colatitude Velocity longitude Angular velocity	Latitude								
	200			150	100		50		

Figure 3: Kinematics Tool describing the motions of the Indian Craton (Plate ID 501)

Note that this tool specifies the Latitude, Longitude and Plate ID of a point on the feature in focus (Figure 4). In this example, we note that the point we are calculating kinematics for has a Plate ID of 501, which corresponds to the Indian craton. Note that the Anchor Plate ID is set at 0. This means that we are calculating the absolute motion of this point. If we want to compute relative motion, we need to specify the plate we want to calculate relative motion with respect to (we will do this in Exercise 2).

If there is a specific point you wish to calculate kinematics for, you can manually type in the Latitude, Longitude and corresponding Plate ID into these fields and click Update. This is an alternate method of specifying the point you wish to calculate kinematics for, rather than using the focussed feature method.

25.8229 C Lon 74	7783 (2) Plate ID	501	Anchor Plate ID 0	5		Begin 2	00.00 Ma 🔃 End: 0.00 Ma	Step 10.00 My	
se focussed feature	Time (Ma)	Let	Len	V mag (cm/yr)	V azimuth (*)	V colat (cm/yr)	V lon (cm/yr)	Ang V (*/Ma)	4
ise animation values	200	-26-2795	57,2831	3.2957	335.8197	-3.0065	-1.3499	-0.5067	
	190	-23.5325	56.0677	3.9089	197.3686	3.7307	-1.1669	-0.5173	
	180	-26.8411	54.7699	1.6177	163.9464	1.5546	0.4473	0.2858	
	170	-28.2277	55.2599	0.7009	72.1390	-0.2150	0.6671	0.2476	
	160	-28.0205	55.9340	5.6629	138.7247	4.2559	3.7357	-0.5132	
	150	-31.7663	59:9057	5.1867	154.7060	4.6895	2.2361	-0.4802	
Update	140	-35.9341	62,4149	4.9765	26.0225	-4.4720	2.1833	0.4585	
Export table	130	-31.8790	64.6807	6.7849	351.0018	-6.7014	-1.0612	0.9662	
Longitude Welocity magnitude Welocity azimuth Welocity collatitude Welocity longitude Angular velocity	k c k								
	200	<u>8</u>		150	100 Time (Ma)		50		

Figure 4: Kinematics Tool highlighting Latitude, Longitude and Plate ID specifications

The table in the top half of this window describes a variety of parameters over a specified time period with specific time steps, as defined in the top right corner of the window (Figure 5). In this example, kinematics have been calculated between 200-0 Ma in steps of 10 My.

ise focussed feature	Time (Ma)	Let	Lon	V mag (cm/yr)	V azimuth (*)	V colat (cm/yr)	V Ion (cm/yr)	Ang V ("/Ma)	1
be animation values	200	-26.2795	57,2831	3.2957	335.8197	-3.0065	-1.3499	-0.5067	
	190	-23.5325	56.0677	3.9089	197,3686	3.7307	-1.1669	-0.5173	
	180	-26.8411	54.7699	1.6177	163.9464	1.5546	0.4473	0.2858	
	170	-28-2277	55.2599	0.7009	72.1390	-0.2150	0.6671	0.2476	
	160	-28.0205	55,9340	5.6629	138.7247	4.2559	3.7357	-0.5132	
	150	-31.7663	59.9057	5.1867	154.7060	4.6895	2.2161	-0.4802	
Update	140	-35.9341	62.4149	4.9765	26.0225	-4.4720	2.1833	0.4585	
Export table	130	-31.8780	64.6807	6.7849	351.0018	-6.7014	-1.0612	0.9662	
Longitude Velocity magnitude Velocity azmuth Velocity colatitude Velocity longitude Angular velocity	Latitude 8 0 5								
	200	8		150	100		50		

Figure 5: Kinematics Window highlighting calculation specifications

The Begin, End and Step fields can also be determined by how your animation is configured. To calculate kinematics for the same time period and timesteps as the animation, click the 'Use animation values' option (Figure 6). Unless you have already specified values, GPlates will use the default Begin, End and Step values.

se focussed feature	Time (Ma)	Let	Lon	V mag (cm/yr)	V asimuth (*)	V colat (cm/yr)	V lon (cm/yr)	Ang V (*/Ma)	
te animation values	200	-26.2795	57.2831	3.2957	335.8197	-3.0065	-1.3499	-0.5067	
	190	-23.5325	56.0677	3.9089	197.3686	3.7307	-1.1669	-0.5173	
	180	-26.8411	54,7699	1.6177	163.9464	1.5546	0.4473	0.2858	
	170	-28.2277	55.2599	0.7009	72.1390	-0.2150	0.6671	0.2476	
	160	-28.0205	55.9340	5.6629	138.7247	4.2559	3.7357	-0.5132	
	150	-31.7663	59.9057	5.1867	154.7060	4.6895	2.2161	-0.4802	
Update	140	-35.9341	62.4149	4.9765	26.0225	-4.4720	2.1833	0.4585	
Export table	130	-31.8780	64.6807	6.7549	351.0018	-6.7014	-1.0612	0.9662	
Longitude Velocity magnitude Velocity azmuth Velocity colatitude Velocity longitude Angular velocity	Latitude 6 0 05								
	200			150	100		50	· · ·]	

Figure 6: Kinematics Tool window highlighting the 'Use animation values' button

If you want to configure the animation values, go Reconstruction > Configure Animation... and specify values here (Figure 7).

	Animate from:	200.00		Ma	Use Main Window	
	to:	0.00	×	Ма	Use Main Window	
	with an increment of:	10.00	A V	м	per frame.	
	Reverse the Animatic	n by swa	pping <mark>t</mark>	he st	tart and end times.	
 Finish anir Loop Close this 	nation exactly on end time dialog when animation star	ts				

Figure 7: Configure Animation window

The data in this table is displayed as a graph in the bottom half of the window, however only one variable is displayed at a time. To change the variable that is displayed, we can use the buttons to the left of the graph (Figure 8). At the moment, we can see how latitude has changed from 200-0 Ma.

itse focussed feature	Tirre (Ma)	Let	Lon	V mag (cm/yr)	V azimuth (*)	V colat (cm/yr)	V len (cm/yr)	Ang V (*/Ma)
Use animation values	200	-26,2795	57,2831	3.2957	335.8197	-3.0065	-1.3499	-0.5067
	190	-23.5325	56.0677	3.9089	197.3686	3.7307	-1.1669	-0.5173
	180	-26.8411	54.7699	1.6177	163.9464	1.5546	0.4473	0.2858
	170	-28.2277	55.2599	0.7009	72.1390	-0.2150	0.6671	0.2476
	160	-28.0205	55.9340	5.6629	138.7247	4.2559	3.7357	-0.5132
	150	-31.7663	59.9057	5.1867	154,7960	4.6895	2.2563	-0.4802
Update	140	-35.9341	62.4149	4.9765	26.0225	-4,4720	2.3833	0.4585
Export table	130	-31.8780	64.6807	6.7849	351.0018	-6.7014	-1.0612	0.9662
Langtude Welocity magnitude Welocity azmuth Welocity colatitude Welocity iongitude Welocity iongitude	Latitude							
	1 200			150	100		50	

Figure 8: Kinematics Tool with Display panel highlighted

5. Change the graph so that it displays Longitude vs time.

The y-axis of the graph (Longitude) shows all values, which compresses the graph a little and makes it difficult to detect changes in motion. We can use the tools to the right of the graph (Figure 9) to zoom in and out to see more detailed longitudinal changes.

be animation values	200							
	11.00	-26.2795	57,2831	3.2957	375.8197	-3.0065	-1.3499	-0.5067
	190	-23.5325	56.0677	3.9089	197.3686	3.7307	-1.1669	-0.5173
	180	-26.8411	54,7099	1.6177	163.9464	1.5546	0.4473	0.2858
	170	-28.2277	55,2599	0.7009	72.1.390	-0.2150	0.6671	0.2476
	260	-28.0205	55.9340	5.6629	138.7247	4.2559	3.7357	-0.5132
	150	-31.7663	59.9057	5.1867	154.7060	4.6895	2.2161	-0.4802
Update	140	-35.9341	62.4149	4.9765	26.0225	-4.4720	2.5833	0.4585
Export table	130	-31.8790	64.6807	6.7549	351.0018	-6.7014	-1.0612	0.9662
Longitude Velocity magnitude Velocity colatitude Velocity longitude Angular velocity	Longitude 100 % o % 0 % 1 100 minuteraturaturaturaturaturaturaturaturaturatu				· · 1		1	

Figure 9: Kinematics Tool with view controls highlighted

The 4 controls can be used to change the way the graph is presented as follows:



Autoscale y-axis: automatically scales to the extent of the y-axis - useful for detecting minor changes in motion.



Stretch y-axis: zooming in



Compress y-axis: zooming out



Flip horizontal axis: flips time axis (x-axis) - useful to see motion backwards from present day or motion forwards from the specified time.

6. Have a play around with these tools to see how they change the presentation of the graph so it is easier to see how the longitude changed over time (Figure 10).

Note: when you have finished using the 'Autoscale y-axis' tool, you must deselect it to make the other tools available



	Time (Ma)	Lat	Lon	V mag (cm/yr)	V azimuth (*)	V colat (cmv/yr)	V lon (cm/yr)	Ang V (*/Ma)
Use animation values	200	-26.2795	57.2831	3.2957	335.8197	-3.0065	-1.3499	-0.5067
	190	-23.5325	56.0677	3.9089	197.3686	3.7307	-1.3669	-0.5173
	180	-26.8411	54,7699	1.6177	163.9464	1.5546	0.4473	0.2858
	170	-28.2277	55,2599	0.7009	72.1390	-0.2150	0.6671	0.2476
	160	-28.0205	55.9340	5.6629	138.7247	4.2559	3.7357	-0.5132
	150	-31.7663	59.9057	5.1867	154.7060	4.6895	2.2161	-0.4802
Update	140	-35.9341	62.4149	4.9765	26.0225	-4.4720	2.1833	0.4585
Export table	130	-31.8780	64.6807	6.7849	351.0018	-6.7014	-1.0612	0.9662
in Local de								
Eonglude Ielocity magnitude Ielocity namyti Ielocity namyti Ielocity colatitude Ielocity ionglude Angular velocity	8 2 2 2 2 2	-	-					

Figure 10: Longitude vs time with: **a)** 'Autoscale y-axis' **b)** 'Autoscale y-axis' and 'Flip horizontal axis'

7. Change the graph so that it displays Velocity magnitude vs time (Figure 11).

See that at 0 Ma (present day), it says that the velocity is 0 cm/yr (Figure 9). This implies that the point we are looking at is stationary, yet we know that this is not true.

e focussed feature	Time (Ma)	Lat	Lon	V mag (cm/yr)	V azimuth (*)	V colat (cm/yr)	V lan (cm/yr)	Ang V (*/Ma)
se animation values	200	-26.2795	57,2831	3,2957	335.8197	-3.0065	-1.3499	-0.5067
	190	-23.5325	56.0677	3.9089	197.3686	3.7307	-1.1669	-0.5173
	180	-26.8411	54,7699	1.61.77	163.9464	1.5545	0.4473	0.2858
	170	-28.2277	55,2599	0.7009	72.1390	-0.2150	0.6671	0.2476
	160	-28.0205	55.9340	5.6629	138.7247	4.2559	3.7357	-0.5132
	150	-31.7663	59.9057	5.1867	154.7060	4.6895	2.2161	-0.4802
Update	140	-35.9341	62.4149	4.9765	26.0225	-4.4720	2.1833	0.4585
Export table	130	-31.8780	64.6807	6.7849	351.0018	-6.7014	-1.0612	0.9662
Longitude Valority manufade	E 15					\wedge		1

Figure 11: Kinematic Tool

8. To fix this, click 'Settings' in the bottom left corner, which will open up a new window. Choose the second velocity option "(T + dt) to T" and change the Yellow velocity warning to 15cm/yr (Figure 12).

This will highlight the row of any timestep that has a velocity greater than 15cm/yr in yellow. Similarly, the row of any timestep with a velocity greater than 30cm/yr will be highlighted in red. These velocity warnings can be changed to any values you choose and are particularly useful to determine when plate motion reaches and/or exceeds a particular velocity threshold.

	-	
Velocity time step dt:	10.00 Ma	×
Velocity method		
🔘 T to (T - dt)		
Velocity method ○ T to (T - dt) ◎ (T + dt) to T ○ (T + dt/2) to (T - dt/2)		
(T + $dt/2$) to (T - $dt/2$)		
0 (1 1 3 4 2) 3 (1 3 4 2)		
Yellow velocity warning	15.00 cm/yr	

Figure 12: Configure Velocity Calculations (Step 8)

9. Click 'Apply', then 'Close' and click 'Update' in the main Kinematic Tool window.

Notice that now we have one of the rows highlighted in red (200 Ma). Are there any rows highlighted in yellow? Hint: scroll down in the table or use the graph to help you (Figure 13).



Figure 13: Kinematics tool after velocity has been updated **a)** Velocity warning for 200 Ma when velocity was greater than 30cm/yr **b)** Velocity warning for 50 Ma when velocity was greater than 15cm/yr

The values calculated in the table can be saved and exported for later use as a csv file.

10. In the main kinematic Tool window, click 'Export Table' (Figure 14). Navigate to where you would like to save your file and click 'Save'.

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Use roculated rearbure	Time (Ma)	Call Print	Lon	v mag (cmvyr)	V ADHILIDI (*)	v cout (cmvyr)	w ton (cmcys)	Ang V (7Ma)	ï
Use animation values	100	.22.5255	54.0672	3 3967	340.4444	31056	4 5521	-0.5967	٦
	180	-36.6411	54 2600	19099	201.7209	16011	-1.44%	4.5077	
	130	-20-2012	55,2500	1.6177	141.2582	1.5219	0.5198	0.3958	
	160	-38.0355	55.0340	0.2009	69.4366	-0.2463	0.6562	0.3426	
	150	-31,7663	59.9057	5.6629	136.0625	4.0778	1.9294	-0.5132	
Ubdate	140	-25.9342	62,4149	5,1867	1521462	4.5858	2.4233	-0.4002	
F. contraction	110	-11.8790	64.6807	4.0765	23,7390	-4.5555	2,0034	0.4585	
Velocity magnitude Velocity asmuth Velocity colatitude Velocity longitude Angular velocity	Velocity (cm/yr)						~		
	200		100	150	100 Time (Ma)		50		

Figure 14: Kinematics Tool showing 'Export table' option (Step 10).

Exporting these values can be useful if you wish to plot the motion of different points on the same graph. GPlates only allows you to plot the motion of one point at a time, however if you export this data to another program (eg. Excel), you can then plot the kinematics of multiple points eg. to compare the motion of a single point in different reconstruction models.

Exercise 2 - Looking at relative and absolute motion

Compare the absolute kinematics of Australia with its kinematics relative to Antarctica.

In Exercise 1, we looked at the absolute motion of a point over time. We can also use the Kinematics Tool to investigate the motion of a point relative to another plate. This can be useful to determine when different plates are moving as one and when they start to move independently. In this exercise, we will investigate both the absolute motion of Australia over the past 200 Ma and also its motion relative to the Antarctic plate.

- 1. Make sure the rotation and coastlines files are loaded in GPlates
- Seton_etal_ESR2012_2012.1.rot
- Seton_etal_ESR2012_Coastlines_2012.1_Polyline.gpmlz
- 2. Rotate the globe so that Australia and Antarctica are in view (Figure 15)



Figure 15: View of Australia and Antarctica (Step 2)

3. Using the Feature Inspection Tool, select Australia

4. Utilities > Open Kinematics Tool... (or Ctrl+Shift+K)

5. Select 'Use focussed feature'. Notice that this option gives us a point on the eastern edge of the Australian continent (Figure 16)

Since we will be looking at the motion of Australia relative to Antarctica, we want to choose a point closer to Antarctica, ideally somewhere along the southern coast (Figure 16).



Figure 16: Automatically selected point for kinematic calculations in yellow, manually selected point in red

6. Manually change the Latitude and Longitude in the top left corner of the Kinematics Tool window to -32.0295, 132.1987. Make sure the Plate ID is 801 (Australian Plate) and the Anchored Plate ID is 0. We will also change the Begin and End times to 190 Ma and 0 Ma respectively. We keep 10 My timesteps. Then press 'Update'.

7. Change the display of the graph and look at the absolute Latitude, Longitude, Velocity Magnitude and Velocity Azimuth of Australia over time (Figure 17)





Figure 17: Absolute kinematics for a point on the southern Australian coastline

We now want to compute the motion of this same point relative to Antarctica

8. In the Kinematics Tool window, specify the Anchor Plate ID as 802 (Antarctica) and click 'Update'

9. Change the display of the graph and look at the absolute Latitude, Longitude, Velocity Magnitude and Velocity Azimuth of Australia over time (Figure 18).





Figure 18: Kinematics for a point on the southern Australian coastline, relative to the Antarctic plate.

Notice that for a period between 190-130 Ma, the four parameters we are looking at do not change. This indicates that there is no relative motion between Australia and Antarctica at this time, but this does not mean that the point is stationary. Rather, this indicates that Australia and Antarctica were moving as one during this period, and when the graphs begin to show changes in these parameters, Australia and Antarctica are starting to move independently.

If we were to look at the absolute motion of a corresponding point in Antarctica, we would expect identical kinematics during 190-130 Ma, as indicated by the lack of relative motion. We can also check this by playing the animation in the main GPlates window.

Note: Be careful when comparing graphs if you have used the 'Autoscale y-axis' tool - some changes will be magnified so they appear greater than they are. The y-axis extents of of different graphs may also differ and become a problem when comparing Latitude and Longitude.