Birthday Sunrises on a Chaco Canyon Horizon

"Chaco Canyon remains a very special place to us. Even though the ancestors of my people inhabited the area, I think the Canyon belongs to everyone now. Chaco visitors need to express their own personal reverence." - a descendant of the people who built and inhabited Chaco Canyon 1000 years ago

Activity Overview:

An astronomically aligned Great Kiva in Chaco Canyon, NM (**Fig. 1**) serves as a culturally enriching context for learning how the sunrise position on the eastern horizon changes over the course of a year and how this knowledge can be used to track time. The facilitator begins by introducing Chaco Canyon and the Kiva (see background info below). Next they use the winter & summer paths of the Sun to explain why sunrises occur at different points on the horizon. Then the facilitator leads inquiry into the often surprising cyclical nature of the sunrise positions and invites participants to use "Sun stickers" to mark their birthday sunrise. This activity has been tested in four modalities with diverse ages, families, and Chaco visitors. This Guide focuses on #4 below:

Venue(s)	**Table top station, interactive slide presentation, planetarium dome, on-site guided experience**
Ages	**8+ in small groups and families**
Materials	**Printables, downloadables**
Time for completion	**3-10 minutes per group of 3-4 for the tabletop version of the activity**
NGSS Standard	ESS1.A

1) live-facilitated with guided tour groups on site at the Great Kiva using **Fig. 2** (see #6 in **Materials**)
2) live-facilitated with larger audiences via a PowerPoint (PPT) slide of **Fig. 2** (see #6 in **Materials**)
3) live-facilitated in planetarium dome together with the seasonal paths of the Sun (see **Appendix B**)
4) **4)** self-directed or **facilitated tabletop activity** using a 4-foot long poster (See #2 & 6 in **Materials**)

Learning Goals:

1. To learn how the sunrise position on the eastern horizon changes over the course of a year and how this knowledge can be used to track time.
2. To be able to use a known "horizon calendar" to estimate the approximate position of the Sun at sunrise on their birthday

Time:

3-10 minutes per group of 3-4, depending on facilitation. The activity can work well in family groups of this size.

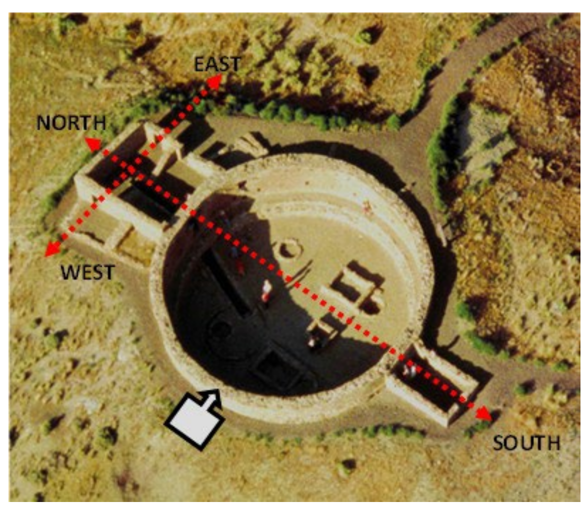

Fig. 1: Aerial view of a Great Kiva in Chaco Canyon. It is precisely aligned N-S-E-W. The kiva is more than 60 feet (~20 meters) across. People are no longer able to go into the kiva but the area around it is often open to the public. White box shows the viewing perspective to the eastern horizon.

Fig. 2: The view to the eastern horizon as seen from the western side of the Great Kiva (see white box with arrow in **Fig. 1**). A Chaco Ranger named G B (Gee Bee) dedicated himself to documenting sunrise positions at key seasonal times of year.

Materials for Tabletop Activity:

1. Activity Table (for a 3- or 4-foot long tabletop poster)
2. Printed laminated poster (see **Appendix A** for instructions)
3. Sticky notes, or 1- 2" diameter "Sun" stickers, or similar
4. Pens or thin-tipped markers (for writing on the stickers)
5. Tape (masking, painters, duct, or gaffers) for securing the 3- or 4-foot poster to the table or a wall
6. Slides for display or presentation to support facilitation
7. Means of showing seasonal paths of the Sun: Options include: **a.** Solar Motion Demonstrator. **b**. the diagram in **Fig. 5** (included in the Slides in #6 above). **c.** a dome simulation. **d.** full-bodied tracing of winter & summer paths while facing south in the local environment - see **Appendix B**)

Fig. 3: Before finding birthday sunrises on the horizon, Brownie Girl Scouts had faced to their right (to the south) and used their arms to trace the winter & summer paths of the Sun in the sky from sunrise to sunset. This helped to see why the low winter Sun rises so far south of east and the high summer sun rises so far north of east.

Setup for Tabletop Activity (Fig. 4):

1. Secure the large poster printout of the Chaco horizon to the tabletop [**NOTE: orient the table so that the participants are facing eastward as they engage with the long, tabletop poster**]
2. Cut or tear off individual "Sun" stickers so that the paper is still attached to the sticker. Each participant gets one sticker (or a sticky note) for writing their name (or initials) and birth date.

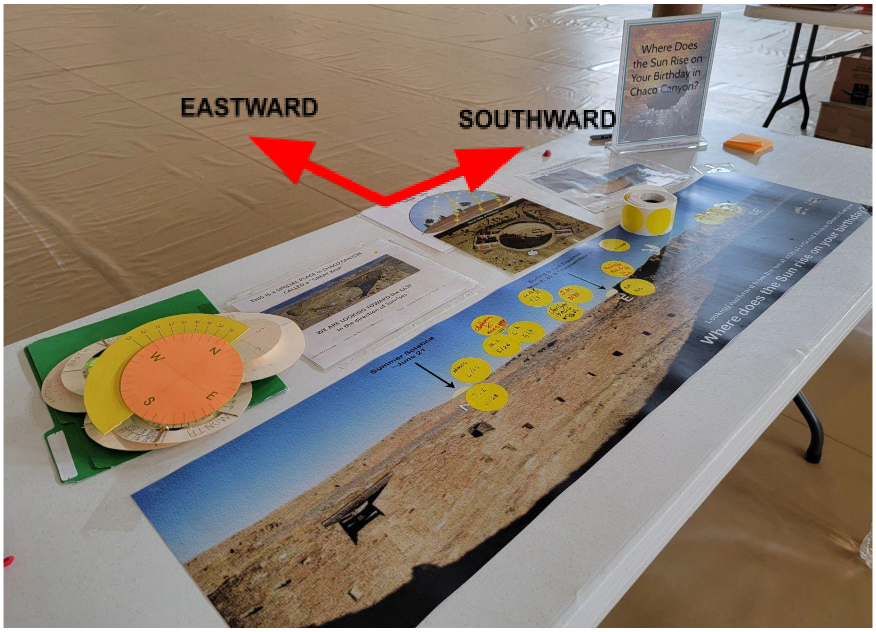

Fig. 4: Example Set-up with tabletop poster. Orient to the local cardinal directions.

Activity Steps:

1. Read the quote at the top of the first page aloud. Show **Fig. 1** and other slides from #6 of the **Materials** section to provide background about how special it is to view the sunrise from this Great Kiva in Chaco Canyon.
2. Hand out sticky notes or stickers and pens that work well on the sticker surface. Invite everyone to write their name (or initials) and their birth date.
3. Refer to the poster and explain the quest: "Now we'd like to determine where the Sun rises on your birthday along this *very* special horizon in a place called Chaco Canyon." Ask: "Have you heard of Chaco Canyon?"
4. Provide more background on Chaco and the Great Kiva [see Background below and slides in #6 of **Materials**.]
5. Ask while coordinating gestures on the poster: "Did you realize that the Sun rises at different places on an eastern horizon depending on the time of year?" [Pause]
6. While coordinating gestures on the poster: Joke: "I know…in school they told you that 'the Sun rises in the east and sets in the west', but it only does that *exactly* on two days of the year = Fall and Spring equinoxes. At other times of year the Sun rises at horizon positions that are more toward the north or more toward the south of the due east position."

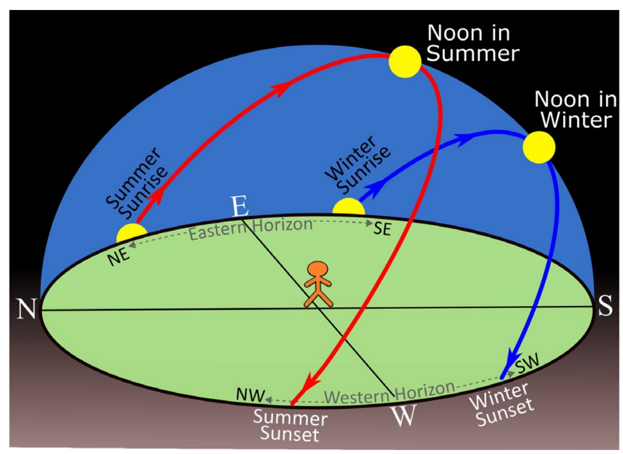

Fig. 5: Comparing the paths of the Sun through the sky in summer and winter. In summer the Sun's path (red line) is much higher in the sky, making more daylight hours. In winter the Sun's path (blue line) is much lower in the sky, making fewer daylight hours. Imagine that you are the orange person in the center. Trace the two paths with your fingers. Notice that in summer (red line), the Sun rises north of east (NE) and sets north of west (NW). And in winter (blue line) the Sun rises south of east (SE) and sets south of west (SW). Between Summer and Winter, the sun rises at positions in between. Thus you can learn to tell what time of year it is by where the Sun is rising on the eastern horizon!

7. Say: "Let's try to make sense of this." Refer to one of the following ways of showing the path of the Sun at different times of year (e.g. **Fig. 5** and caption, or choose from other options on the list in #7 of the **Materials** section above). NOTE: Younger learners make this connection MUCH more easily with an embodied approach using real directions in the local environment or in the planetarium dome. It is valuable for *all* learners to face east as they engage the horizon poster and to face south as they trace out the differences between the "sunrise to sunset" paths of the Sun in summer and winter using the real directions.
8. Return attention to the 4-foot poster and invite participants to: "Point to your guess of where you think the Sun rises on your birthday on this horizon."
9. Ask each learner: "What is your birthday and why do you think the Sun rises there?" This will help you, the facilitator, to quietly achieve a sense of what (if any) misunderstandings are afoot. Some **misunderstandings encountered during field testing are that…**
    a. … the sunrise position is always due east [Only on the Spring and Fall Equinoxes];
    b. … if there is not a labeled date for sunrise, then the Sun does not rise there;
    c. … there is a unique sunrise position for each day or month of the year in linear fashion;
    d. … January sunrises are after December, out to the right (farther south than Dec solstice);
    e. … July sunrises are after June, out to the left (farther north than the June solstice)
    f. … after the December solstice, the sunrise position loops back around to the June solstice. This is a conflation of a "horizon calendar" with Earth's orbital position around the Sun.
10. Without naming it, steps 9 and 10 demonstrate what it means to *interpolate*…in other words to help learners see that October and November birthday sunrises will occur at estimated and unlabeled positions between the September Equinox and the December Solstice sunrises. Start by pointing at the September Equinox sunrise position. Ask: "Which way should I go for a sunrise on an October birthday? Should I go toward December? Or toward June? [toward December].
11. Reply: "Right!" Then model the interpolation between September and December [Start by pointing at the September Equinox position and say, "September"...and in a rhythmic cadence….point to an intermediate position about one third of the way toward December and say, "October", then point to another intermediate position about two thirds of the way toward December and say, "November", and then point to the December solstice position and say, "December" .... then pull up your pointing finger and pause. **This is a key moment for learning how a horizon calendar works**.]
12. Ask: Hmmmm…. Where do you think January sunrise positions should be? [Usually some say farther to the south beyond the December solstice and others already understand that after the December solstice the sunrise positions begin to come back northward.]
13. Explain with coordinated gestures: "Ah but the sunrise position never goes outside of the solstice boundaries. It never rises farther south than the Winter Solstice position, when the Sun's path is at its lowest in the sky. And the Sun never rises farther north than the Summer Solstice position when the Sun's path is highest in the sky."
14. Ask: "So where would January sunrises have to be?" [It has to come back northward and so January sunrise positions are in about the same place as November sunrise positions.]
15. Ask: "What about February?" [Keeps coming back northward]

16. Say: " Here we are in the zone of March birthdays [which is labeled the same as September - aha!], but in March the sunrises are moving northward toward Summer, instead of southward toward Winter. And sunrise positions change much faster day-to-day near the Equinoxes and slower near the Solstices"
17. Ask: "Where are the April sunrise positions?" [point to one-third the way toward June solstice]
18. Ask: "Where are the May sunrise positions?" [point two-thirds the way toward June solstice]
19. Point to the June solstice and say, " Now here is the June solstice position - on about the 21st of June."
20. Ask: "Where would any June birthdays after the 21st be? Where would the July sunrise position be?" [Most will now say that you must return back southward toward the May sunrise position, but some may need reminding that sunrise positions do not go farther northward than the Summer solstice.]
21. Ask: "Where are the August sunrise positions?" [Point to this zone. One father-daughter pair delighted in realizing that the Sun would rise in almost the same place on their August and April birthdays!]
22. Say: "And now here we are back to the September zone of sunrises again."
23. Invite younger learners (3rd to 8th graders): "Let's all point together for each month of the year and say the month out loud as we go." [Start with September and track through all the months of the year, to get the interpolations between equinoxes and solstices and the cyclic reversals at the solstices into the bodies and gestures of the learners. ***Seriously, this works and has a basis in education research***.]
24. THEN say: "So now put your sticker near the position where the Sun rises on your birthday."
25. Check in with each learner individually about their birthday sunrise position while asking others to be attentive. Lead further inquiry if needed until everyone has their birthday sunrise position in approximately the right place, and especially in the right place relative to other participants.
26. Offer each learner a participation reward (a pin, a patch, or whatever) for their engagement and invite them to find their own Sun-watching place inside or outside their home. Tell them what they need:
    a. a clear view to an eastern horizon that has some varied features on it;
    b. willingness to observe safely and faithfully from the same place every time so you can track changes: One little girl observed out a window from the kitchen sink of her family's New York City apartment. She took a picture of the first moment of sunrise on the birthdays of friends and relatives and sent them the photo as a birthday card.

Background Q&A

How and why does the apparent motion of the Sun change throughout the year?

Observations of the Sun's apparent motion reveal a pattern that repeats every year (NGSS Standard ESS1.A, https://www.nextgenscience.org/pe/ms-ess1-1-earths-place-universe). It results from a combination of Earth's daily rotation, its yearly orbit around the Sun, and the tilt of Earth's rotation axis. This axis maintains a near constant direction as Earth orbits the Sun. Because the axis tilt remains constant, the geometric relationships that determine the Sun's apparent position in the sky change as Earth changes location in its orbit.

Each day, the Sun appears to rise in the east, move across the sky, and set in the west. It is a common misunderstanding that the Sun rises due east and sets due west each day. Instead, the direction where the Sun appears to rise and set along the horizon changes throughout the year in a predictable pattern (See Fig. 5).

On equinox dates, the Sun appears to rise directly east and set directly west. After the March equinox, the directions of sunrise and sunset along the horizon move a little more north each day. This continues until the June solstice. After the June solstice, the directions of sunrise and sunset move back toward the south, changing a little each day.

At the September equinox, the Sun again appears to rise directly east and set directly west. After the September equinox, the directions of the Sun at sunrise and sunset continue to move south. This southward movement stops on the December solstice. After the December solstice, the direction of sunrise and sunset moves back toward the north, a little each day. This pattern repeats every year.

What is Chaco Canyon?

One thousand years ago Chaco Canyon was the center of a vast multicultural network in the 4-Corners region of the United States (CO, NM, UT, AZ). Ancestral Puebloan people built monumental sandstone structures that are precisely aligned to directions that could only have been determined by careful observation of the Sun and Moon cycles. Today Chaco is a World Heritage site that is chock full of evidence for ancient skywatching of the kind that is still carried out by contemporary Puebloan peoples in the US Southwest. In addition to architectural alignments, such evidence includes the use of horizon calendars to track the time of the year and interactions of light & shadow with rock art and architecture. The building featured in this activity is the largest excavated kiva in the Chaco system. A **kiva** is a revered space used by Puebloans for ceremonial, social, and political purposes. It is no longer possible to go inside this Great Kiva called Casa Rinconada, but the area around it can be visited by the public. Consider going to see your own sunrise, especially at Equinoxes and June Solstice when special programs are offered at the site.

References:

1. Wiki article on Chaco https://en.wikipedia.org/wiki/Chaco_Culture_National_Historical_Park
2. Other photos of Casa Rinconada https://commons.wikimedia.org/wiki/Category:Casa_Rinconada

Fig 6a: Summer solstice sunrise from the Great Kiva in Chaco Canyon

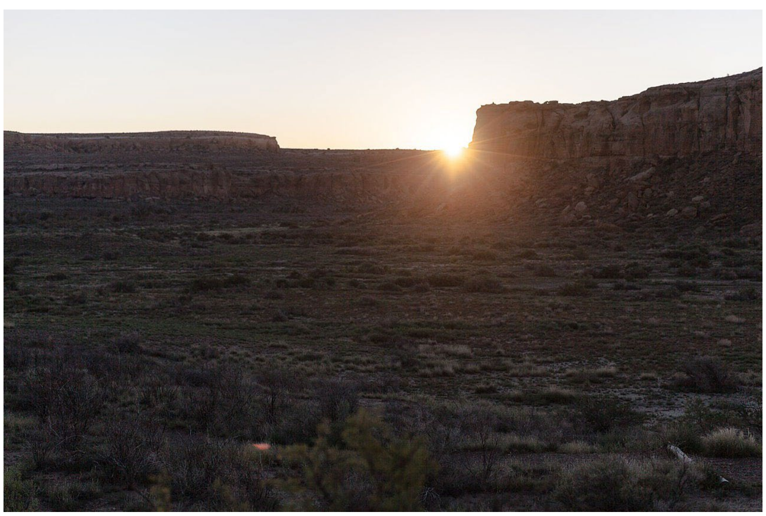

Fig. 6b: Equinox sunrise from the Great Kiva in Chaco Canyon

Appendix A: Printing the tabletop poster for Birthday Sunrises on a Chaco Canyon Horizon

Send your preferred size of Tabletop Poster file to a printing company of your choice. For best and most durable results, we recommend that it be laminated with a matte finish.

- Our Tabletop Poster (shown below) is available for download in two sizes on our website: https://punch.space.swri.edu/punch_outreach_birthday-sunrises.php

  36x12in PNG OR **48x16in PNG**

- Background Slides for Display or Presentation are also available **(PDF, 1 MB)**

Fig. 7: The 3 or 4-foot long poster (for use with the Tabletop version of the activity).

NOTE: Notice that the distance between the Equinox and Winter Solstice arrows is greater than the distance between the Equinox and Summer Solstice arrows. Why? The distance between the arrows depends on your latitude and the elevation of the local horizon. Chaco Canyon is at about 36 degrees North latitude. If the latitude were greater, the distance between the solstices would be greater and vice versa. On a flat horizon, the distances would be about the same on either side of the Equinox position. Locally, the sunrise positions are *also* dependent on the horizon elevation. In this case, the horizon is closer and higher in the southern portion of the horizon calendar (southward or right of the Equinox position) than in the northern portion (northward of the Equinox position). By the time the Sun clears the higher horizon in the southern portion, it appears farther south on its path.

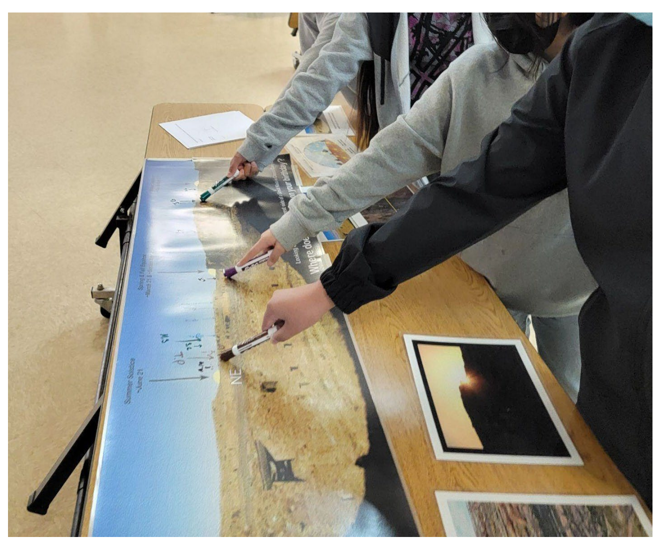

Fig. 8: 8th grade science students from the Pueblo of Acoma, NM are field testing the 4-foot long poster of the Great Kiva horizon. The ancestors of these students built and used the ancient structures and Sun-watching technologies in Chaco Canyon. Their contemporary culture still practices traditional Sun-watching while also collaborating on NASA projects like ours.

Appendix B:

Full-Bodied Tracing of the Winter and Summer Paths of the Sun

Fig. 9: Girl Scouts are following the facilitator (red top) in a full-bodied tracing of the eastward to westward paths of the Sun while facing south in the local environment and planetarium dome. The dome allows a concrete visualization of the Sun's path and an easy comparison among the paths at different times of year. This supports understanding of why there are more or less daylight hours and also how a horizon calendar works. Education research indicates that kinesthetic engagement with following the paths from sunrise to sunset significantly improves learning outcomes compared to passive viewing. Even without the planetarium dome the full-bodied tracing of the winter and solstice summer paths can be a powerful learning experience that helps to understand how the Sun rises at different places on the horizon at different times of year.