EARTH SYSTEM SCIENCE ANALYSIS

Earth is a system of individual parts that work together as a complex whole. We call the four major parts of the earth system *spheres*. These parts include the lithosphere, hydrosphere, biosphere and atmosphere.

Changes continually occur within earth's four major spheres. We call such changes *events*. An event can cause changes to occur in one or more of the spheres. An event can also be the effect of changes in one or more of the spheres. An *interaction* is the two-way, cause and effect relationship between an event and a sphere. Earth System Science studies the interactions between and among events and the earth's spheres.

An Introduction to ESS Analysis

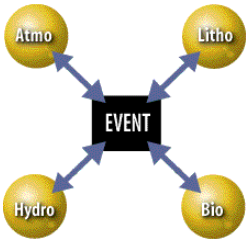
Earth System Science examines each event to sphere, sphere to event and sphere to sphere interaction. This is Earth System Science analysis, or ESS analysis.

An ESS analysis has four steps, which include looking at

- how the event affects each of the spheres,
- how each sphere affects the event,
- how the spheres affect each other, and
- connecting the interactions.

Step 1: Event > Sphere Interactions

How could an event affect each sphere? The answers to this question are the event > sphere impacts.



E > A

For example, fires can create tremendous heat and develop fast rising columns of heated air, which in turn can bring in more air at the base of the fire, drop the humidity in the area of the active fire to near zero and make dense smoke, which travels hundreds of miles.

E > H

Ash from fires falls into ponds, lakes and streams. What impacts might you expect this to cause in the hydrosphere? Is the effect of burning embers from the falling debris landing in the streams worth considering?

Don't worry about getting all the interactions … you probably won't be able to. Just focus on identifying a few impacts. And remember, the impacts on some spheres will be more numerous than on others. That's not a problem.

E > B

Fires burn and kill the plants and trees, as well as animals that cannot escape, in the area. How else do fires affect the biosphere? There are the obvious destructive effects on plant and animal life as well as on the habitat. You might also consider the beneficial effects of burning off accumulated debris on the forest floor and similar occurrences that might be advantages of burning.

E > L

Forest fires burn the parts of the soil where plants put down their roots. What effects might fires have on the lithosphere? Here, you might consider the effects on soils.

Step 2: Sphere > Event Interactions

How could each sphere affect an event? The answers to this question are the sphere > event impacts.

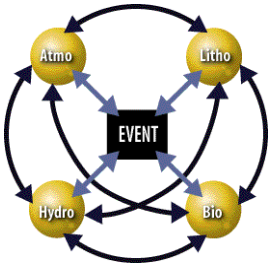
Take another look at the Earth System Diagram above. Notice that the arrows go not only from the event to each sphere but also from the spheres back to the event. Consider: if something happened to the biosphere because of fires, might that have an effect on the fires themselves? For example, if fires cause the forest floor debris (biosphere) to burn off, how might that change in the biosphere affect the fires? Clearly, the fires would be using up fuel necessary to keep them burning. So, a statement such as "The leaf litter was burned by the fires thus diminishing the amount of fuel available to keep the fires burning in that area" might be a valid B > E interaction.

Look at each set of possible changes fires might make on each sphere. If they occurred, how might these changes in turn affect the fires? Consider whether these changes have short-term or long-term effects.

Step 3: Sphere > Sphere Interactions

How can each sphere affect the other spheres? The answers to this question are the sphere > sphere impacts.

Now that you have an idea of how an event and the spheres can affect one another, it is time to introduce one more level of interaction. Take a look at the Earth System Diagram below. Notice the additional arrows going to and from each of the spheres. These additional arrows indicate another set of interrelationships influenced by an event.



If an event creates certain changes in one sphere, how might those changes lead to changes in the other spheres? For example, fires might burn the soil (lithosphere) to a depth of several inches or more in certain hot spots. What effect do you think that would have when it finally started raining and there was runoff to the streams (hydrosphere)? If there were burning embers in the atmosphere that eventually fell back into the streams (hydrosphere), how might that blackened debris affect any aquatic invertebrates and fish (biosphere) that survived the event?

Try to see what interactions you can find among the different spheres. Think about what changes might occur in each sphere as a result of fires. Add these effects to your ESS analysis.

If you find yourself thinking, "If the hydrosphere is damaged by the falling charred debris and that does major damage to the fish, then how does that affect the biosphere?" that's a good sign because it means you're beginning to look at the way the world works. It seems to be one great collection of interacting spheres and then along comes a new event and the process of balancing starts over again.

There isn't any right or complete answer for ESS analyses. You just need to be able to <u>explain and support why</u> you think something may have an impact.

Keep in mind as you list the interactions that it is important for you to offer scientific reasoning or explanations for why or how the interactions occur. Such reasoning and explanations display your understanding of the science behind the interactions. These explanations are valuable for you and others because they make your *why* and *how* thinking visible and they often help you to think about additional ESS interactions.

Some of the interactions also establish feedback loops. For example, as fires burn, they dry vegetation around them, thus creating more fuel for the fire. This <u>positive feedback loop</u> reinforces the burning of the fires. A <u>negative feedback loop</u> that lessens the intensity of the fires is established when ash from the fires is carried into the atmosphere and forms condensation particles for water vapor. These condensation particles eventually form clouds that release precipitation. The precipitation can put out the fires.

EVENT:

Fire in a sparsely wooded area with a narrow, slowly moving stream that runs through the center of the area and feeds into a small pond on the edge of the area.

LIST AS MANY EVENT > SPHERE INTERACTIONS AS YOU CAN.

LIST AS MANY SPHERE > EVENT INTERACTIONS AS YOU CAN.

LIST AS MANY SPHERE > SPHERE INTERACTIONS AS YOU CAN.

Step 4: Causal Chains

The interactions that occur within Earth's system actually occur as a series of chain reactions, which ripple through Earth's spheres like waves that spread out from a pebble tossed in a still pond. This means that an event often leads to a change in one sphere, which leads to a change in another sphere, which leads to a change in yet another sphere.

For example:

1. A forest fire destroys all the plants in an area (E > B).
2. The absence of plants leads to an increase in the erosion of the soil (B > L).
3. Increased amounts of soil enter streams leading to increased turbidity, or muddiness, of the water (L > H).
4. Increased turbidity of the water has a negative impact on the plants and animals living in the stream (H > B).

You can write the four interactions above as a causal chain that synthesizes the results of the ESS analysis and describes how the event can lead to a ripple of effects throughout the Earth system. Causal chains show the interdependence of Earth's spheres. I've summarized the causal chain outlined above in a narrative form below.

E > B > L > H > B

The fire consumed the vegetation. A decrease in vegetation resulted in increased soil erosion because there were fewer roots to hold the soil in place. Increased erosion of loose soil led to increased soil particles, or sediments, in streams. This would make stream water muddier. Sediments in the water clogged the gills of fish and other aquatic organisms and choked them.

The following are some simple causal chains.

A > B > E
More than 8 weeks of warm to hot, low humidity air masses drew moisture out of grasses and trees prior to the fires.

E > A > E
The intense fires created their own upward air movement, increasing the wind velocity and drawing in oxygen at the base of the flames to continue to feed the fire.

Notice in the case above the causal chain is from the event to a sphere and then back to the event. Causal chains don't always have to go just from an event to one sphere then another sphere. They can also lead back to the event.

Finally, the following is a more complex illustration of an ESS causal chain.

E > L > B > L > B > L > H > B
Heat from the fires can affect the topsoil. As an illustration, the fires baked out a lot of the nutrient-rich organic matter, humus. This may make it more difficult for many of the plants to start growing again. However, burned plant debris that did not blow away becomes part of the new soil and can provide some nutrients for pioneer plants, much as gardeners prepare soil with ashes from a fireplace. However, because soil moisture is extremely low due to the fires, surviving seeds of all types, plus windblown seeds and spores, cannot germinate until new rain falls in the area.

DEVELOP A CAUSAL CHAIN USING AS MANY AS POSSIBLE OF THE INTERACTIONS YOU PREVIOUSLY LISTED.

Step 5: Human impact

National Geographic
Earth Pulse Connections
http://www.nationalgeographic.com/earthpulse/connections-and-resources.html