VOG Chemistry Transport and Deposition

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Some Basic Questions

- What is its composition?
- What processes occur in the plume?
- What processes result in exposure to vog components
- How does the current Big Island situation compare with other volcanic environments?

What is its composition?

Not a simple answer:

It starts out as a mixture of gases (and solids) that include H_2O, CO_2, SO_2, SO_3, N_2, H_2, HCl, HF, inert gases, volatile metal salts, plus ash and spatter

The heavy stuff falls out first: rock fragments, Pele's hair/tears

Then the gases condense and begin to react with the atmosphere

Some of the gases are strongly hygroscopic:

HCl gas + H_2O -> HCl Acid aerosol

HF gas + H_2O -> HF Acid aerosol

SO_3 gas + H_2O -> H_2SO_4 Acid aerosol

These processes begin almost instantly – as soon as the plume exits the vent and begins to cool and mix with air

Some of the gases react with O_2:

$SO_2 + O_2 \rightarrow SO_3 + H_2O \rightarrow H_2SO_4$

The oxidation of sulfur dioxide is a relatively rapid reaction occurring with a half-life of a few hours or less depending on sunlight, composition of the plume, and particulate loading in the plume

As the plume is carried by the prevailing winds, the acid gases and aerosols react with other atmospheric gases.

One of the most important reactions is that with ammonia:

$$H_2SO_4 + NH_3 \rightarrow (NH_4)_2SO_4$$

$$HCl + NH_3 \rightarrow NH_4Cl$$

The source of the ammonia is from the moist tropical soils

The final process during transport is deposition and removal from the atmosphere:

Dry deposition – gravitational settling of the solid and liquid aerosols present in the plume

Condensation and removal in rainfall

The processes occurring in the plume have several implications for the potentially exposed communities

1) The compositions of the vog will be different for each community that is exposed:

In Volcano Village the primary compounds are:

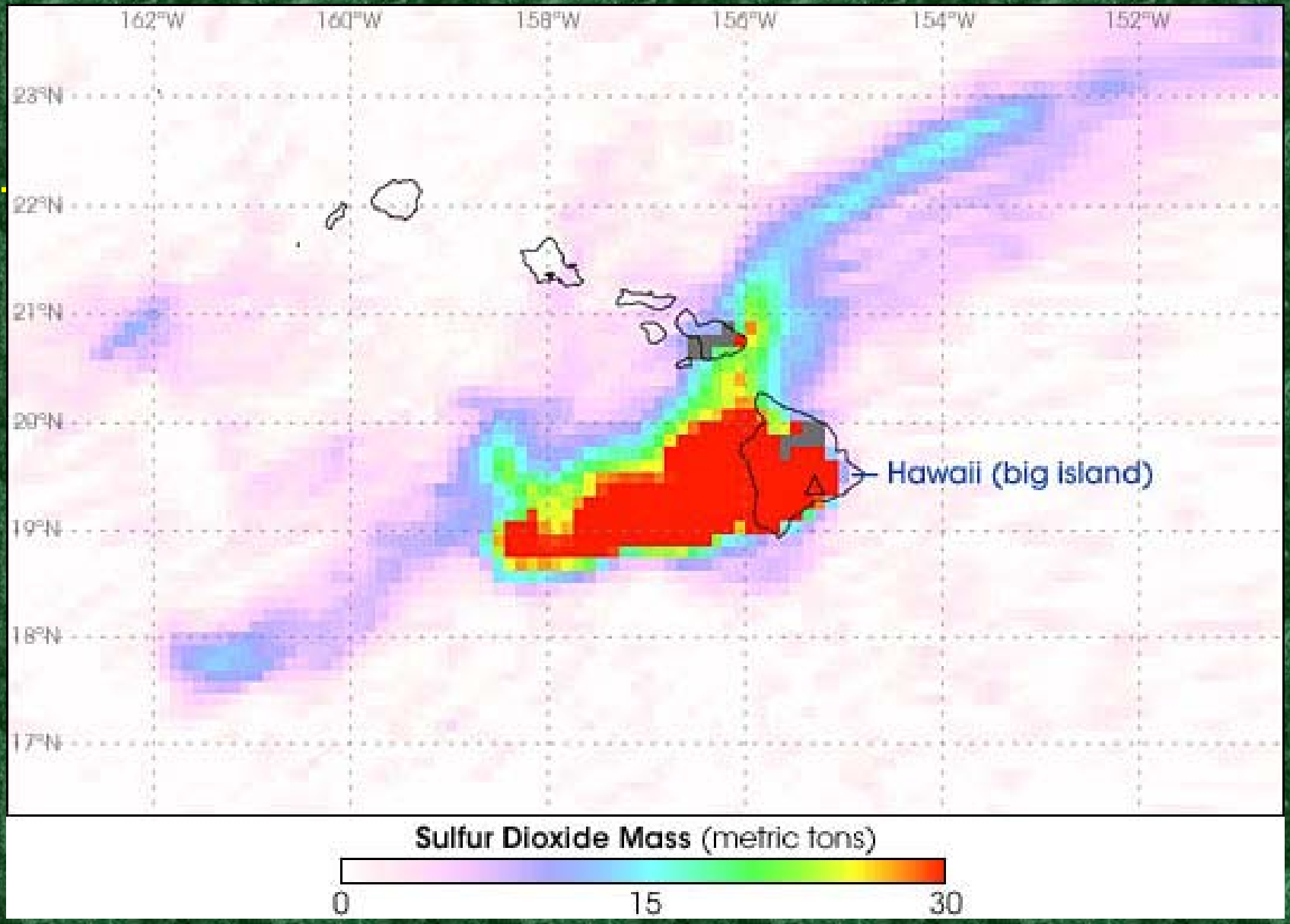
SO_2, H_2SO_4 (AA), and HCl (AA)

In Pahala the vog is likely to be:

H_2SO_4 (AA), SO_2, $(NH_4)_2SO_4$, NH_4Cl, and HCl (AA)

In Kona the vog is mostly:

$(NH_4)_2SO_4$, NH_4Cl, and H_2SO_4 (AA)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17°N
Hawaii (big island)
Sulfur Dioxide Mass (metric tons)
0
15
30

2) There are multiple modes of exposure to the vog constituents:

Direct exposure to the gases and suspended aerosols

Dry deposition of the liquid and dry aerosols onto surfaces

“Wet” deposition in rainfall

3) There may be secondary effects from the dry and wet deposition:

Acidification of catchments and mobilization of potentially toxic elements that are insoluble under pH neutral conditions

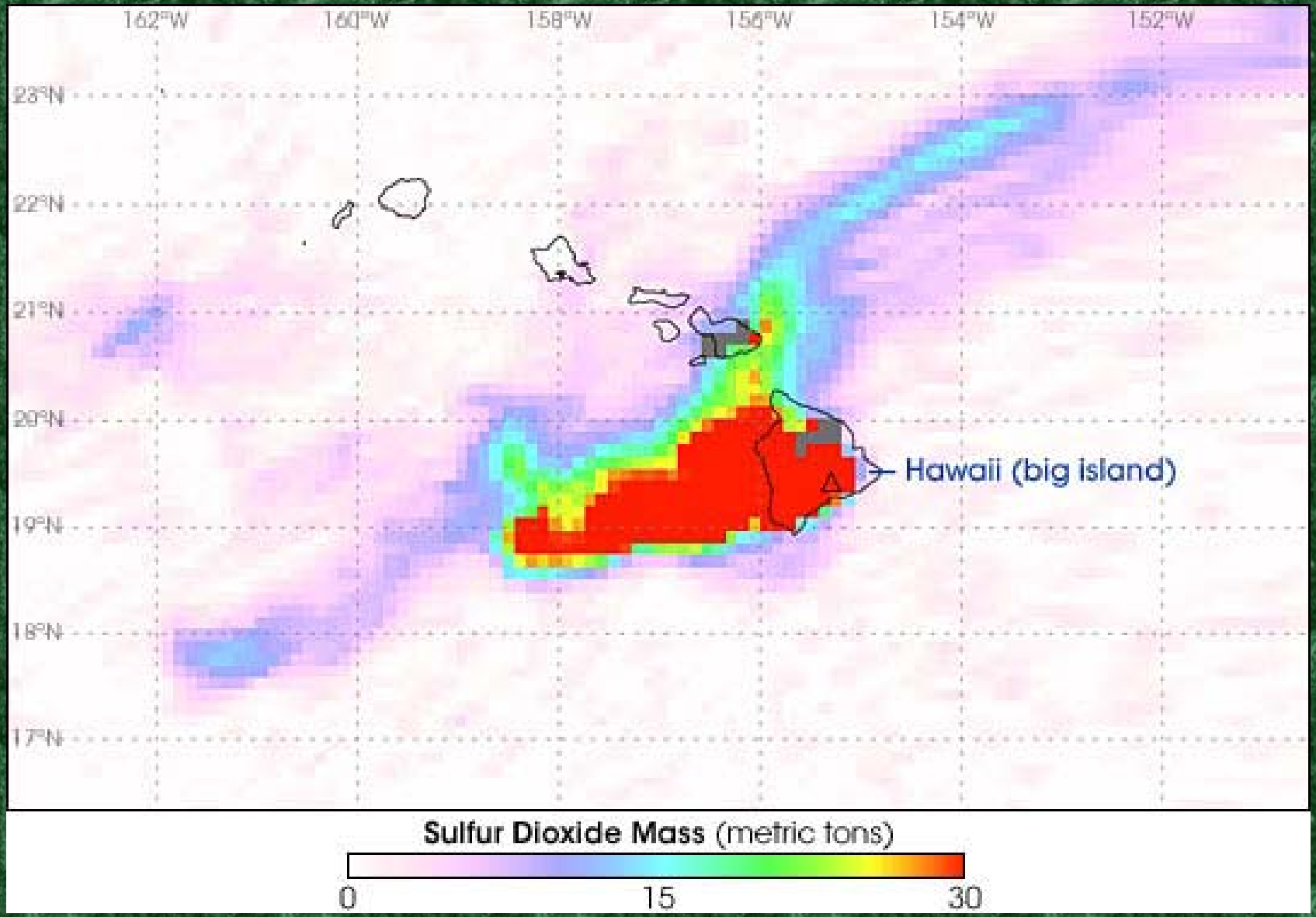
Accumulation of potentially toxic compounds on forage crops during extended dry climatic conditions

Uptake and bio-accumulation of potentially toxic compounds into the food chain

Secondary Effects (cont.)

There has been conjecture that high rates of atmospheric loading by aerosols may also bring about a reduction of rainfall due to an overabundance of condensation nuclei in the atmosphere


N
Kaho'olawe
Maui
Mauna Loa
Mauna Kea
a
b
c
Kilauea plumes
Hawai'i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Comparison with Other Volcanic Systems

There are few analogues to the Big Island conditions:

Continental (e.g. Central and South America, Philippines, Indonesia) volcanoes have much different chemistry of magma and gases. Often more explosive, and have higher HCl/HF contents and lower SO_2

With these systems, communities are impacted by long term exposure to the gases; there are problems with livestock and agriculture due to ash accumulation and Fluoride uptake by both animals and humans.

Likewise, acid rains can cause serious crop damage.

- Masaya Volcano in Nicaragua produduces ~2000 t/d of SO_2 but ~86 t/d of HF
- Miyakijima, at it's peak, was producing ~54,000 t/d SO_2 on an island of only ~21 square miles in area.
- Etna, on the island of Sicily, produces ~6000 t/d but at an elevation of ~10,000'

Conclusions

- Kilauea's plume contains a variety of elements and compounds of possible concern
- The intensity of exposure to gases and aerosols from Kilauea will be highly variable (depending on distance and wind trajectories) around the Big Island
- Assessing exposures will require a carefully designed sampling/ monitoring program