Slide 1 – Title Page with Authors and Contributors

Slide 2 – Humor Page

Slide 3 - WHY are we doing this? Awareness for the mostly meteorological Forecaster. To show how complex and hard it can be. Again – to raise awareness! “Stay Frosty” – as they say in the movies.

Slide 4 – Humorous answer to WHY?

**Person answering the question – Our own Jeff Osiensky, ESSD Deputy Chief and volcano ash program manager for the National Weather Service.**

Slide 5 – Partial answer to the WHY Question – Why in the lower 48? Not if, but when!

Comparisons - Mount St. Helens to: Long Valley Caldera, Yellowstone Caldera, and Crater Lake Volcano eruptions. This is what could (will) happen.

Slide 6 – New Volcanic Ash Training – explain when idea started and who involved. (To start – Myself, Jeff Oseinsky, Carvin Scott, Bernie Connell – later, Kristine Nelson and Tony Hall.)

Slide 7 – Objectives of both sessions.

Slide 8 – Lead to VA Part 1

Slide 9 – **Example of volcano type**: Mount St Helens - May 18, 1980

**Composite (strato) Volcano**: Typically steep-sided, symmetrical cones of large dimension built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs and may rise as much as 8,000 feet above their bases. Some of the most conspicuous and beautiful mountains in the world are composite volcanoes, including Mount Fuji in Japan, Mount Cotopaxi in Ecuador, Mount Shasta in California, Mount Hood in Oregon, Mount St. Helens and Mount Rainier in Washington.

Slide 10 – **Example Ground Hazard**. Mayon Volcano, Philippines. Photograph by C.G. Newhall on September 23, 1984.

**Pyroclastic flow**: are high-density mixtures of hot, dry rock fragments and hot gases that move away from the vent that erupted them at high speeds. They may result from the explosive eruption of molten or solid rock fragments, or both.

How: Explosive volcanic eruptions can produce fast-moving (gravity) flows or currents of hot gas and rock (collectively known as tephra – which is really a plasma of sorts), which can travel away from the volcano at speeds generally as great as 700 km/h (450 mph). The gas can reach temperatures of around 1,000 deg C (1,830  deg F). These flows normally hug the ground as they accelerate downhill, spreading laterally (if the terrain is shaped appropriately) under gravity. Sort of the rocky analogy of a meteorological combination – the collapse of the ventilation column (collapse of a thunderstorm) due to the weight of the tephra (similar to a downburst) and then the acceleration downslope of the dense material (similarto a katabatic wind). Their speed depends upon the density of the current, the volcanic output rate, and the gradient of the slope. Obviously, inhaled ash particles from within a hot, dense pyroclastic flow will almost always result in death(from severe burns and/or asphyxiation).nhaled ash particles from within a hot, dense pyroclastic flow will almost always result in death(from severe burns

Slide 11 – **We also talk about just what volcanic ash is** (and show examples).

**Example if Hazard in the air (to aircraft in this case**). Ingestion of volcanic ash by engines may cause serious deterioration of engine performance due to erosion of moving parts and/or partial or complete blocking of fuel nozzles.

Volcanic ash contains particles, whose melting point is below engine internal temperature. In-flight, these particles will immediately melt if they go through an engine. Going through the turbine, the melted materials are rapidly cooled down, stick on the turbine vanes, and disturb the flow of high-pressure combustion gases. This disorder of the flow may stall the engine, in worst cases.

Slide 12 – **Remote Sensing and Observations.** Ash from Mt. Pinatubo blankets the region like snow – 11/27/1991. Why so important.

Weak eruptions, spreading (optical thinning) of the plume, or background non-volcanic clouds can significantly reduce the visible satellite signature, making it quite difficult to correctly discern the ash cloud. Wide variability in composition and structure of ash can also cause various detection problems. Ash cloud height can be a particularly tricky problem, especially when the plume is optically thin. Aircraft radar is ineffective in locating ash clouds.

Slide 13 – Lead in to **Satellite Observations, Data, Analysis and Products.** Image: Artist’s depiction of GOES N(13) – Allan Kung, for NASA NOAA – from: GOES N Fact Sheet (2006)

Slide 14 – **Example Visible imagery MODIS**. RGB Image From: Operational Significant Event Imagery (OSEI) – MODIS AQUA RGB (Band 1, 4, 3) – 4/19/2010@13Z - Eyjafjallajokull (ay-yah-FYAH'-plah-yer-kuh-duhl) volcano.

Slide 15 – **Example of 3.7 um imagery used to identify hotspots**. NOAA-19 AVHRR data – hotspots Eyjafjallajokull Volcano – 4/20/2010 – **3.7um.** Here, hotspots can be seen at the red arrows (green-blueish colored areas). Such hotspots can be identified through the use of a mid-infrared channels (e.g. AVRHH - 3.7 µm, GOES – 3.9 µm, etc.) since an increase of the temperature generally results in a high signal response in this spectral region. The intensification of the hotspots in this image indicate that Eyjafjallajokull potentially started to eject more lava and therefore less ash.

Slide 16 – **Example of Longwave differencing Product**. **Meteosat-9 Second Generation (MSG) 11-12 micron image (Longwave difference) -** Eyjafjallajokull VolcanoAsh Cloud **(Purple – i.e. negative values) -** May 7, 2010. This image demonstrates that a negative split window difference picks up more than just ash – particularly in arctic regions when viewing from geostationary satellites with a large viewing angle.  Those other areas in the high arctic that are roughly the same “color” are not ash, but represent regions of the top of (relatively moist) stable layers. How can we tell the difference? – Mostly in terms of “context and situational awareness” – (i.e. if we know that a volcano is going off in a certain area…).

Slide 17 - **Example of Meteostat Combined (Multispectral) Product for finding Ash and SO2**. April 20, 2010 0943Z – Meteosat-9: From German Aerospace Center (DLR). Eyjafjallajökull volcano in Iceland emitted large quantities of ash and sulfur dioxide into the atmosphere. Sulfur dioxide and ash particles differ in their radiative properties and through the use of suitable combinations of channels at 10.8 microns and 12 microns (longwave differencing) – you get ash (highlighted in yellow) and from the differencing of the 8.7 micron channel and the 12 micron channel – we get SO2 (marked in blue). The grey background represents brightness temperature at 10.8 microns. Ongoing dilution of the “plume” or overlying clouds makes detection quite difficult. Therefore, ash-free classified areas are not necessarily a safe airspace.

Slide 18 - **Poster Image – NOAA GOES-R – *Continuous Environmental Monitoring***

Slide 19 – **Example of Aircraft observation.** **Okmok 08/03/2008.** View of Okmok eruption, taken from NE bound Alaska Airlines flight at 35,000 ft above sea level on August 3, 2008 between 20:00 and 20:08. Plume tops estimated to ~ 7,000 ft above sea level using nearby Mount Vsevidof (elev. 7,051 ft / 2,149 m) for reference.Picture Date: August 03, 2008. **Image Photographer/Creator: Mees, Burke – Alaska Airlines.**

Airborne perspective. Great viewing distance and aspect. Can also use cameras. However, there is limited nighttime use. Also, water/ice cloud or other poor visibility can obscure volcanic cloud. Requires some local infrastructure and reliable communications. Limited nighttime use. \*\*\*Remember, most aircraft weather radar is not sensitive to volcanic ash. This is undergoing change, however.

Slide 20 – **Example of ground based radar observation.** From: “**Early Detection of the 5 April 2005 Anatahan Volcano Eruption using the Guam WSR-88D” -** Timothy P. Hendricks, National Weather Service Forecast Office, Guam. PGUA 0.5 degree reflectivity image for 1726 UTC 5 April 2005 - 50 to 55 dBZ observed at 9 km (30,000 ft) over Anatahan.

NEXRAD WSR88D Radar is especially good (if within 250nm) at early detection of volcanic eruptions – particularly in remote regions and at night. It also excels at getting good echo top measurement for plume height estimates. At the time of the image here…plume height was already above 30kt ft…with the 1.5 degree scan showing echoes to over 50kt ft!

Anatahan erupted at approximately 1610 UTC. Within minutes, the PGUA WSR-88D signaled the onset of another major eruption. Since Anatahan is located within the range of the PGUA WSR-88D, early detection of major eruptions of the volcano is not only possible, but is likely. The PGUA 0.5 degree reflectivity at 1616 UTC (six minutes after eruption began) shows a faint echo directly over Anatahan between 20 and 30 dBZ. – with the plume tops already at least 9 km (30,000 ft) AGL. Less than an 1.5 hrs later, echoes were being pick up by the 1.5 deg tilt, showing plume tops over 50,000 ft.

Slide 21 – **Things to remember**.

Slide 22 – **Modeling Examples** – Iceland, May 7, 2010

Slide 23 – **Modeling Hypotheticals**: What if scenarios. All 48hr runs – starting July 21 00Z.

Left – Mount Lassen

Right – Long Valley

Slide 24 – **Start VA Part 2 Examples**

Slide 25 **- Case (Jeff Oseinsky)** – Pre-eruption case (November 2008 – January 2009). Eruption March 15, 2009. Major eruption March 22, 2009.

Slide 26 – **Example of some of the Organizations Involved**.

Slide 27 – **Example of (original) goals.**

Slide 28 - **Volcano Observatories** are a very important resource for **pre-eruption, eruption and post eruption** monitoring. Monitoring and research at the five volcano observatories (in conjunction with the Menlo Science Center in Menlo Park) helps advance the understanding of active volcanism and allows the Volcano Hazards Program to provide warnings of impending eruptions in the United States. They monitor earthquake activity, ground deformation, gas chemistry, and other geophysical and hydrologic conditions before, during, and after eruptions. Observations are used to detect activity leading to an eruption, provide real-time emergency information about future and ongoing eruptions, identify hazardous areas around active and potentially active volcanoes, and improve our understanding of how volcanoes erupt and change our environment.

Slide 29 – **VAACs** - The International Civil Aviation Organization **(ICAO**) has designated 24/7 volcanic cloud monitoring duties to 9 Volcanic Ash Advisory Centers (VAACs) around the world. The VAAC's are responsible for issuing Volcanic Ash Advisories, which alert aviation interests to the presence of volcanic ash clouds. The National Weather Service (NWS) is responsible for operating the Anchorage, AK and the Washington, D.C. VAACs.

Volcanic Ash Advisory Centers (VAACs) monitor Volcanic Ash plumes with in their assigned airspace. Each VAAC is responsible for providing Volcanic Ash Advisories (VAA) whenever an volcanic event occurs in their area of responsibility.

Slide 30 – **The lines of communication.**

**Typical Lines of Communication within the USA**

VAAC - Volcanic Ash Advisory Center

VO – Volcano Observatory

MWO - Meteorological Watch Offices

NWS – National Weather Service

CWSU - Center Weather Service Unit

WFO - Weather Forecast Office

AWC - Aviation Weather Center

FAA - Federal Aviation Administration

ICAO - International Civil Aviation Authority

FEMA - Federal Emergency

DoD - Department of Defense

ATCC - Air Traffic Control Center

DHS - Dept. Homeland Security

Slide 31 – **Example of VAA and VAG issuance**

Slide 32 – **How Part 2 finishes up. Significance to final bullet: Synthetic Imagery**

Slide 33 – **Synthetic Imagery Motivation and Goals**. Collaboration with **Shobha Kondragunta**, AWG aerosol (NOAA/NESDIS)

Slide 34 – **Example of GOES-R Advanced Baseline Imager (ABI) bands** and bandwidths that will be exploited.

Slide 35 **– Example details creating synthetic imagery**. \*\*\*COAMPS microphysics similar.

Slide 36 – **More, creating synthetic imagery.**

Slide 37 – **Example of 2km run for May 8, 2003 severe weather case (10 different bands).**

Slide 38 - **Real – or Synthetic?** Actual Image – GOES 13, April 24, 2010 – 14Z

Slide 39 - **Real – or Synthetic?** Synthetic Image derived from NSSL WRF model. For April 24, 2010 14Z.

Slide 40 – **Combined comparison of both images (loop).** Left: GOES-R Sythetic. Right: GOES-13

Slide 41 – **Water vapor imagery example/comparison. From NSSL 4 km wrf-arw run (Jack Kain).** The synthetic imagery loops are available in real-time starting at 1330 UTC every day. In the example below, the 7.34 micron band is compared to the observed GOES-13 Sounder data at a similar central wavelength. Note how the simulated data is at a better resolution that the sounder data (4 km v/s 10 km; GOES-R ABI will be 2 km), but the largest advantage is that the synthetic loop was available for viewing in the morning, thus providing an excellent resource for forecasters.

Synthetic 7.34 micron imagery from 24 April 2010 at between 12 and 00 UTC, and the observed imagery from the GOES-13 Sounder at a similar wavelength. Click for a larger view. In this case, the model does a fairly good job with the timing of the convection forming in the southeast U.S., but appears to overdo the coverage. The brightness temperatures in the clear areas match well, but the model has a cold bias with the thin cirrus clouds in the Great Lakes region.

Slide 42 –**Synthetic NSSL WRF-ARW Imagery – How it is done.** This product is a combined effort between the National Severe Storms Laboratory (NSSL) in Norman, Oklahoma, and The Cooperative Institute for Research in the Atmosphere (CIRA) in Fort Collins, Colorado, together with the NOAA/NESDIS RAMM Branch.

Daily output from NSSL's 4-km WRF-ARW is provided to CIRA, who then generate synthetic satellite imagery, which is sent to the Storm Prediction Center (SPC) Every day at 00 UTC, NSSL runs their 4-km WRF-ARW. As soon as the 12-hour forecast is completed, several variables are extracted and scp'ed to CIRA. These variables include temperature, water vapor, and other physical and microphysical parameters which are needed for the next step. When all variables have been receieved at CIRA, an observational operator is run to generate the synthetic imagery for 4 GOES-R ABI bands (6.185, 6.95, 7.34, and 10.35 microns). The simulated imagery is then converted to McIDAS AREA format and made avaiable for the SPC, who then makes the output viewable on their NAWIPS system. Hourly output between 12-00 UTC is processed daily, providing four 13-hour synthetic satellite loops. The resolution of the output is 4-km to match the input resolution of the cloud model; the real GOES-R ABI bands will have 2-km resolution.

This product has two primary purposes: 1) Synthetic imagery from cloud model output can be used to evaluate each model run. For example, one might compare a simulated water vapor band to observed GOES imagery from 12-18 UTC to see how well the model is handling the timing and location of upper level features, such as shortwaves. 2) Since the simulated bands are based on the GOES-R ABI, looking at the imagery will prepare forecasters for how the actual GOES-R imagery will look when it becomes operational. For example, certain features may be visible at these wavelengths which are not viewable in the current GOES bands.

Advantages of the synthetic ABI imagery include: 1) Satellite imagery can be viewed before the simulated time actually occurs, so forecasters know what to expect, 2) three water vapor bands allow one to view different atmospheric levels since the weighting functions peak at different levels, and 3) forecasters can use this imagery to prepare themselves for what actual GOES-R ABI imagery will look like. The biggest limitation is that the forecast is only as good as the cloud model forecast; if the model does not initiate convection, for example, then the convection will also be absent from the synthetic imagery.

Slide 43 - Left - **MODIS Satellite Image True color - Satellite: Aqua - Pixel size: 1 km Date: 2007/10/23 (created by NASA).** Right – Synthetic **Smoke added to synthetic true color GOES-R image.** GOES-R ABI will have the ability to produce imagery at 0.47 µm (blue) and at 0.67 µm (red).  Although GOES-R will be unable to produce any images at 0.555 µm (green), color imagery can still be generated with certain techniques. These techniques can be tested through the use of synthetic GOES-R ABI imagery. Synthetic imagery refers to satellite imagery of numerical model output. Shown in the right figure is an example of synthetic GOES-R ABI color imagery over southern California for 23 October 2007. On this particular day, southern California was experiencing wildfires. As a result, smoke properties were used to include smoke in the synthetic imagery. Each of the above listed bands were reproduced followed by the RGB combination that led to the color image. Smoke detection with GOES-R ABI will exceed current GOES capabilities as thin smoke plumes are only visible during low sun angle periods, while GOES-R will be able to highlight these areas during the entire daylight period.  This is due to the inclusion of a band at 0.47 µm (blue).

Slide 44 -**Synthetic Volcanic Ash plume from hypothetical eruption near Yellowstone, WY for June 27, 2010 – 21Z.** (Date at bottom of image is not correct) **Remember**, although this is a visible RGB…the reason it is not as “clear” as those that we see from MODIS is that there has been no correction for Rayleigh scattering (as is routinely done for MODIS imagery) so we “see” the effect of “blue” in the atmosphere. This will be taken care of in later synthetic imagery and also in real imagery coming from GOES-R.

**\*\*\*Thanks to Mike Pavolonis for volcanic ash data (single scatter albedo, extinction efficiency, and asymmetry parameters) at several different (visible) wavelengths so that we could rush into first trials. It will be years before we are able to “realistically” model (human) visible wavelength imagery in the same fashion as we can for many of the near IR and longwave IR bands.**

Slide 45 – End slide. **Common sense humor.**

**(FYI – E15 last erupted from 1821 to 1823)**