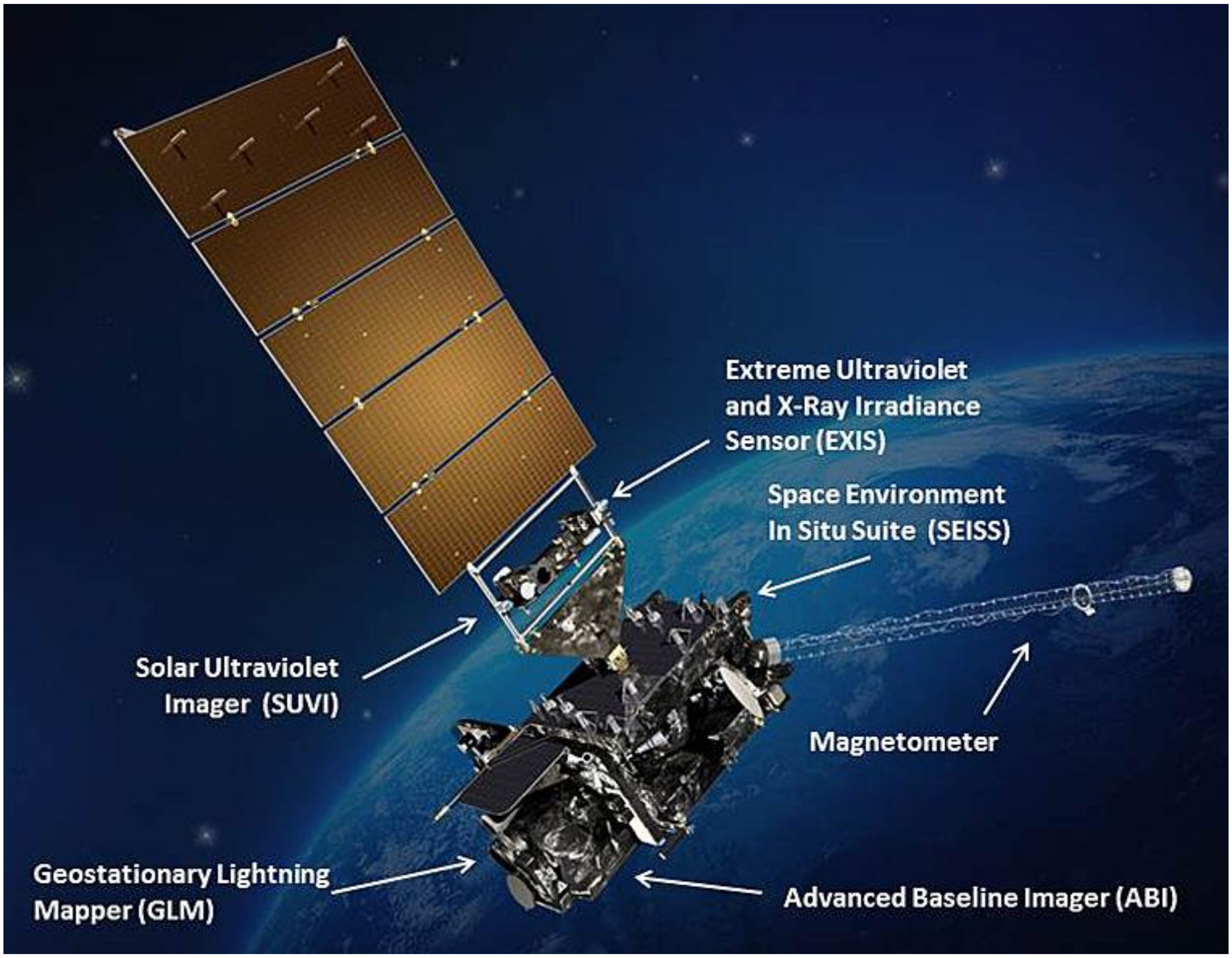
Satellite Training Advisory Team Report



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Executive Summary

The Satellite Training Advisory Team (STAT), comprised of Science and Operations Officers (SOOs) and satellite liaisons, met to review the current breadth of training related to geostationary satellite meteorology in developing new foundational training tracks for National Weather Service (NWS) operational meteorologists. The STAT proposes and recommends training in five primary track areas: Geostationary Operational Environmental Satellite R-Series (GOES-R) Introduction and Satellite Meteorology Background, Geostationary Lightning Mapper (GLM), Mesoscale/Convection, Synoptic Scale, and Numerical Weather Prediction (NWP) Data Assimilation.

The STAT recommends a curriculum of foundational training that includes self-paced lessons incorporating intra-lesson interactivity. The interactivity will include updated and condensed modules and web applications that enable “hands on” interrogation of operationally-relevant examples. Content will be sufficiently modular to support tailorable curricula on the Learning Management System (LMS) by the SOO or designee. These examples will draw from domestic and international satellites, including Himawari-8, GOES-14, and Suomi National Polar-orbiting Partnership (SNPP).

The STAT recommends training on Advanced Baseline Imager (ABI) imagery and baseline products, including multi-spectral approaches, feature identification, and NWP data assimilation. Additional training includes an introduction to the GLM as well as basic implications of the lightning imagery. The capstone exercises are Weather Event Simulator (WES) simulations that encompass topics from the synoptic- and meso-scale tracks.

The STAT encourages exceptionally close interaction among the Office of Science and Technology Infusion, the Office of Central Processing (Advanced Weather Interactive Processing System [AWIPS] Program) and Office of Observations to assure that examples of imagery and products used in training match what appears in AWIPS II.

The goal of this training plan is to provide guidance to the training development community to assure operationally relevant training materials and curricula are available immediately after GOES-R launch.

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Document Information/General Recommendations

- How to read the document:
    - The outline contains the topic and subtopic areas the team felt was important to cover for operations.
    - The gray text in the Tracks section indicates the recommendations from the team on what training is currently available and could be used with appropriate modification, and what gaps we have found.

- While the team reviewed a LARGE number of existing training materials, we did not go through everything, due to either time or access constraints. The team recognizes that there may be other sources of information not specifically mentioned in the document that could be used by the training developers, such as training development in progress and not yet released, or training that exists but was not readily available from other sources (i.e., JAXA, JMA, EUMETSAT, and WMO).

- It is very important that each of the learning objects have some type of interaction associated to test the material beyond a simple quiz. This interactivity reinforces the learning. Interactivity could be provided in different forms, but should not require a substantial load time that interrupts the flow of learning content. For example, there are web applications in current COMET modules and available online from CIMSS that would be useful in order to allow trainees to explore the imagery, products, and affirm their understanding of how GOES-R is useful for assessing atmospheric features.

- Content will be sufficiently modular to support tailorable curricula on the LMS by the SOO or designee.

- A clear understanding is needed of what GOES-R imagery, baseline products (ABI and GLM), and multi-spectral applications will be available for forecasters to use in AWIPS immediately after launch. This includes details about the bit depth, spatial resolution, and temporal frequency. Training developers will need to engage continuously with the GOES-R Program and AWIPS Program Office throughout the training development process. If the GOES-R training effectiveness is to be maximized, what is seen during the training should match what can be seen by the trainee in their AWIPS workstations as closely as possible (e.g., color maps), both in terms of available products and how they look. Additionally, the STAT emphasizes the importance of having the imagery and products in AWIPS II as soon as the GOES-R data flow begins during the post-launch testing for effective training.

- It is encouraged to incorporate data from existing satellites in the approximate following order of preference, depending on application: Himawari-8 (spectral bands), GOES-14 (SRSOR), simulated imagery, VIIRS imagery, and MSG into this training effort as GOES-R data will not be available until after the foundational training is released.

Document Information/General Recommendations (cont.)

- The amount of time listed for each section is just an estimate for planning purposes. They are not listed as specific criteria. They are, instead, meant to guide the training developers in understanding the relative importance of each of the sections. The main emphasis is on creating relatively small chunks of training (mostly 10-20 minutes) that can be tailored into LMS curricula depending on the needs of the office.

- Other reference material (such as fact sheets, quick guides, etc.) were not specifically covered in this document. While those are important reference material for operational forecasters (especially through the coming on-demand reference tool being developed for AWIPS II), they are not tracked for completion. Instead, they are seen as critical supplemental information.

Methodology

- The STAT started with guidance from the document, “Evaluation of Existing GOES Training modules at: COMET, VISIT (CIRA, CIMSS) & SPoRT” compiled by Jim Gurka (completed August 12, 2015) which assessed existing training as it relates to objectives identified in the 2014 Satellite User Readiness Training (SURT) Team Report document.

- The STAT then identified current training material that could be incorporated into new, focused, satellite training that will satisfy the foundational and cross-program objectives. In addition, the STAT identified existing material that needs updated or modified with additional content, as well as training gaps that need to be considered.

- Recommendations on training (style) delivery are provided.

Training Outline

GOES-R Introduction and SatMet Background Track (240 minutes)

- Basic principles of radiation (15 minutes)
- Basic operation of the GOES-R satellites (15 minutes)
    - Scan strategies and temporal refresh
    - Bands overview - Why do we need 16 channels? How bands capture atmosphere in three dimensions
    - Spatial resolution, parallax
    - Bit depth (change from 8 to 12 and 14) and improved color enhancements
    - Operation of GOES-R and current GOES simultaneously
- Spectral bands (90 minutes). This training should cover meteorological feature identification through radiative science (i.e., how to identify a meteorological feature with that spectral band and how features appear at varying spectral wavelengths).
    - Visible (10 minutes)
        - Bands 1, 2
    - Near-infrared (20 minutes)
        - Bands 3, 4, 5, 6
    - Infrared, excluding water vapor (30 minutes)
        - Bands 7, 11, 12, 13, 14, 15, 16
    - Water vapor (30 minutes)
        - Bands 8, 9, 10
- Multi-channel interpretation approaches (30 minutes)
    - RGBs
    - Band differences (use examples of 11-3.9 fog product and cloud phase) and other arithmetic manipulations
    - Coordinate with what will be available in AWIPS
- Baseline products (80 minutes)
    - Cover all baseline products available, including strengths and limitations of:
        - Aerosol (10 minutes)
        - Clouds and microphysics (20 minutes)
        - Fire characterization including land surface (10 minutes)
        - Hurricane intensity estimate (10 minutes)
            - Regionally specific (tropical only)
        - Rainfall and precipitation (10 minutes)
        - Stability indices and legacy profiles (10 minutes)
        - Derived motion winds (10 minutes)
        - Volcanic ash (10 minutes)

Training Outline (cont.)

Geostationary Lightning Mapper Track (40 minutes)

- COMET: Introduction to GLM (30 minutes)
    - What is Total Lightning?
    - How GOES-R detects total lightning
- Using GLM in AWIPS (10 minutes)

Mesoscale/Convection Track (120 minutes)

- Introduction to individual modules (10 minutes)
- Specific examples (Including an example and an interactive exercise for each)
    - Pre-convective environment
        - Surface conditioning (differential heating from moist and dry soils) (10 minutes)
        - Elevated mixed layers (10 minutes)
    - Features
        - Pre-convective cloud features (stable wave, open cellular, etc) and undular bores (10 minutes)
        - Boundary-forced convection (boundary identification, fronts, outflow, sea/lake breeze, etc.) (10 minutes)
        - Mountain waves and orographic enhancement (10 minutes)
        - Fog/low clouds formation and dissipation (10 minutes)
        - Mesolows (10 minutes)
    - Convective evolution
        - Cumulus congestus/growth (cu fields, TCUs, orphan anvils, feeder clouds) (10 minutes)
        - Discrete storms (cooling rate to overshooting tops to decay or upscale growth), including enhanced V (20 minutes)
        - Mesoscale convective systems, including transverse banding to Mesoscale convective vortices (10+ minutes)

Synoptic Features Track (80 minutes)

- Cyclogenesis (40+ minutes total) (update all items with AHI to show advantage of additional bands).
    - PV concept (10 minutes)
    - Life cycle (20 minutes)
    - TROWALs (10 minutes)
- Other jet features (10+ minutes)
- General Circulation Patterns (ridges, troughs, cols, etc.) (10 minutes)
- Atmospheric Rivers (Identify and Analyze) (10 minutes)
- Tropical to Extratropical Transition (10+ minutes)

Training Outline (cont.)

NWP/Data Assimilation Track (30 minutes)

- COMET: How Satellite Observations Impact NWP (with changes) (15 minutes)
- Impact of GOES-R on Satellite Data Assimilation (5 minutes)
- Comparing NWP Simulated Satellite Imagery to Observed Satellite Imagery (10 minutes)

Tracks

GOES-R Introduction and SatMet Background

Outline:

- Basic principles of radiation (15 minutes)
    - COMET: Basics of Visible and Infrared Remote Sensing (Core)
        - Contributes to: Basic principles of radiation
        - Keep: Chapters 2 and 3
        - Recommendation: Change into oral presentation format
- Basic operation of the GOES-R satellites (15 minutes)
    - Scan strategies and temporal refresh
        - Gap: Use material from ftp://ftp.ssec.wisc.edu/ABI/kansascity2015/Schmit_Gerth_ABI_27MAY2015.pptx Use Himawari examples where possible
    - Bands overview - Why do we need 16 channels? How bands capture atmosphere in three dimensions
        - Gap: Use material from ftp://ftp.ssec.wisc.edu/ABI/kansascity2015/Schmit_Gerth_ABI_27MAY2015.pptx Use Himawari examples where possible
    - Spatial resolution, parallax (plots from existing GOES-R introduction lectures (see ftp link below))
        - Gap: Use material from ftp://ftp.ssec.wisc.edu/ABI/kansascity2015/Schmit_Gerth_ABI_27MAY2015.pptx Use Himawari examples where possible
    - Bit depth (change from 8 to 12 and 14) and improved color enhancements
        - Gap: Use material from GOES-R color table WG.
    - Operation of GOES-R and current GOES simultaneously
        - Gap: How compositing will work, could use Himawari and GOES-15/West example, differences between GOES-R and GOES (they will be operating simultaneously during PLPT), what may look different?
        - Gap: Use material from ftp://ftp.ssec.wisc.edu/ABI/kansascity2015/Schmit_Gerth_ABI_27MAY2015.pptx to show changes for GOES-R compared to current GOES
        - Geographic distribution of better resolution (due to higher resolution of ABI, higher resolution will change compared to two current GOES imagers)

GOES-R Introduction and SatMet Background (cont.)

- Spectral bands (90 minutes). This training should cover meteorological feature identification through radiative science (i.e., how to identify a meteorological feature with that spectral band and how features appear at varying spectral wavelengths).
    - Parent objective: Understand how to use new data from GOES-R (RGB, new wavelengths, etc.
    - COMET: GOES Channel Selection V2
        - General: This format is good, but most content applies to current GOES.
        - Recommendation: Take content that pertains to GOES-R and incorporate into new channel selection for GOES-R module. Blend of radiative science and meteorological features is ideal.
    - COMET: GOES-R ABI: Next Generation Satellite Imaging
        - "Explore the ABI Spectrum" is good, but needs update to replace simulated imagery with real Himawari imagery if possible
    - Recommendation: Use content from quick information guides that are found at http://www.goes-r.gov/education/ABI-bands-quick-info.html
    - Visible (10 minutes)
        - Bands 1, 2
            - Gap: Use Himawari bands for this training.
    - Near-infrared (20 minutes)
        - Bands 3, 4, 5, 6
            - Gap: Use Himawari bands for this training.
            - No existing training for near-infrared bands.
                - Need examples of near-infrared bands under varying solar illumination, incorporate cloud microphysics from NWP, case studies of operational uses, hot spot detection.
    - Infrared, excluding water vapor (30 minutes)
        - Bands 7, 11, 12, 13, 14, 15, 16
        - Recommendation: Incorporate weighting functions
            - Gap: No existing training for the infrared bands, other than water vapor.
            - Need examples of the infrared bands for
                - Hot spot detection
                - Ozone concentration
                - Discerning low-level water vapor

GOES-R Introduction and SatMet Background (cont.)

- Water vapor (30 minutes)
  - Bands 8, 9, 10
  - Recommendation: Incorporate weighting functions
  - Recommendation: Stress three-dimensional representation of mid/upper troposphere
  - SHyMet for Forecasters: Water Vapor Channels (Core)
    - Contributes to: Spectral bands, Water vapor
    - Good example of level of content that should be provided for other bands
    - Increase emphasis on three-dimensional nature of water vapor
    - General: This is comprehensive introductory lesson that describes the many operational uses for water vapor imagery, including comparison to numerical weather prediction fields. The web-based version of this lesson is only around 30 minutes.
    - Keep: Training on features, references to NWP fields
    - Add: Specific examples to three water vapor bands from Himawari
    - Remove: AWIPS menus, different map projections, composite imagery, comparison to MODIS, etc.

- Multi-channel interpretation approaches (30 minutes)
  - RGBs
    - Recommendation: Simple examples (individual bands only, no differences)
    - Recommendation: Stay away from specific applications
  - Band differences (use examples of 11-3.9 fog product and cloud phase) and other arithmetic manipulations
  - Coordinate with what will be available in AWIPS
  - Gap: Assure new band manipulation approaches that are consistent with the new spectral channels
  - COMET: Multispectral Satellite Applications: RGB Products Explained (Core)
    - Contributes to: Multi-spectral channel interpretation approaches
    - General: The plan is to provide an introduction to how RGBs are formed with the intent that the baseline products training will compare the spectral bands to actual products through the use of RGBs
    - Keep: Explanation of how RGB composites are created and a few simple examples (nothing with band subtractions)
    - Add: Hands on exercise for RGB creation, such as http://cimss.ssec.wisc.edu/goes/webapps/satrgb/satrgb_flower1.html
    - Remove: References to other satellites

GOES-R Introduction and SatMet Background (cont.)

- Baseline products (80 minutes)
    - Gap: No existing training for baseline products.
    - Recommendation: Work with baseline product developers to create training for each baseline product.
    - Parent objective: Understand the limitations/strengths of satellite based winds.
    - Most baseline products should be available in AWIPS on "day one"
    - Integrate spectral bands into product discussion (check product-specific band list for accuracy)
        - Use simulated products and Himawari-8 examples where possible, otherwise polar-orbiting satellite examples
    - Cover all baseline products available over SBN, including strengths and limitations of:
        - Aerosol (10 minutes)
            - incorporate visible and near-IR bands (with bands 1 to 7) to discern extent of dust/haze/smoke
            - Covers Aerosol Detection, Aerosol Optical Depth
            - Example: http://cimss.ssec.wisc.edu/goes/blog/archives/19897
        - Clouds and microphysics (20 minutes)
            - with bands 2, 5, 6, 10, 14, 15, 16
            - Covers Clear Sky Mask, Cloud Optical Depth, Cloud Particle Size Distribution, Cloud Top Height, Cloud Top Phase, Cloud Top Temperature, Fog and Low Cloud (FLS training might be helpful here).
        - Fire characterization including land surface (10 minutes)
            - with bands 7, 14, 15
            - Covers Fire Hot Spot, Land Surface Temperature, Snow Cover
        - Hurricane intensity estimate (10 minutes)
            - Regionally specific (tropical only)
            - Make sure this will be available in AWIPS
        - Rainfall and precipitation (10 minutes)
            - with bands 10, 11, 14, 15
            - Covers Rainfall Rate/QPE, TPW, Vertical Moisture Profile
        - Stability indices and legacy profiles (10 minutes)
            - with bands 8 through 16
            - Covers Derived Stability Indices

GOES-R Introduction and SatMet Background (cont.)

        - Derived motion winds (10 minutes)
            - with bands 7, 8, 9, 10, 14
            - Covers Derived Motion Winds
        - Volcanic ash (10 minutes)
            - with bands 10, 11, 14, 15, 16
            - Covers Volcanic Ash (reference AWIPS offering)
- Geostationary Lightning Mapper
    - See GLM breakout

Considerations:

- Unify the default color enhancements in AWIPS and the ones used in the training.
- Work with AWIPS program to determine what exactly will be available on "day one".
- This is the approach taken by the 88-D radar products. The training should always go back to the base products. The training for baseline products should have heavy reliance on the spectral bands imagery.

Recommended delivery techniques:

- Self-paced training with audio
- Intra-lesson interactivity will consist of short exercises that encourage the meteorologist trainee to explore the channels, features, and/or concept previously discussed.
    - Examples: CIMSS webapps and SIFT tool for interactivity
    - May need to add baseline products to SIFT

Expected Time: 4 hours (240 minutes)

<u>GLM</u>

Outline:

- COMET: Introduction to GLM (30 minutes)
    - Keep: 1 (Introduction, GLM Benefits/Capabilities, condensed version of 1.3); condensed version of 2.2 (Lightning Flash Exploration), 2.4 (Producing GLM Flashes).
    - Remove/Condense:
        - Condense 1.3 (History of Lightning Detection from Space). Quick mention of history is appropriate, level of detail is not.
        - Condense 2.2 (Lightning Flash Exploration) section. (see Identified Gaps bullet)
    - Needs updating:
        - Oklahoma 1995 example (there are many more recent examples).
        - Update expected GLM field of view or make it clearer what will happen when GOES-R/S/etc. shift to east/west.
        - Also update the ground-based detection maps in 1.1.1. (ENTLN/NLDN/etc.) if possible to reflect updated changes.
- Using GLM in AWIPS (10 minutes)
    - AWIPS Differences in Space-Based Detection and Ground-Based Detection - there are multiple lightning menus in AWIPS. How is this any better than anything else? What is the difference? (This could be folded into the GLM module section 2.2.)
    - Gap: What will be delivered in AWIPS with GLM? How will this look? Training needs to get as close as possible here so forecasters know what to expect and interpret.

Not covered (this information belongs in applications training, not foundational):

- *Most applications sections in COMET: Introduction to GLM from 3.3 onward. This should be covered in Level 2/applications.*
- *All SPoRT Total Lightning Training (SPoRT Total Lightning 1, SPoRT Total Lightning Operational Uses -- General, Severe Weather, Additional Applications)*
    - *General: Generally good, but LMA-specific. This is too in depth in applications for the foundational training--recommend that this be included in "Level 2" or applications sections.*

Recommended Delivery Techniques:

- Self-paced training with audio
- A couple of interactions interspersed in the self-paced training

Mesoscale/Convection

Outline:

- Introduction to Curriculum (10 minutes introduction)
    - Gap: It would need to be created to introduce the format of the individual modules listed below. The concept to the individual modules is to introduce the topic, show an example with up-to-date satellite imagery (Himawari-8 or SRSOR as much as possible), then have an interactive section where the trainee identifies the features on their own. (see recommended delivery technique at bottom of page).
- Specific examples (Including an example and an interactive exercise for each)
    - Pre-convective environment
        - Surface Conditioning (differential heating from moist and dry soils) (10 minutes)
            - Need new presentation content for this, a few cases exist on CIMSS satellite blog
            - VISIT: Objective Satellite Based OT and Enhanced V Anvil Thermal Couplet Signature Detection, Slides 44-46 start to touch on this
            - Specific request to include event with previous rainfall that may have changed terrestrial temperatures
            - New infrared bands should contribute to low-level water vapor advection and and surface moisture
        - Elevated Mixed Layers (10 minutes)
            - VISIT: Tracking the Elevated Mixed Layer with a New GOES-R Water Vapor Band, use a single case only, update case with bands from GOES-R ABI, should be approximately half of current length
    - Features
        - Pre-Convective Cloud Features (stable wave, open cellular, etc) and undular bores (10 minutes)
            - VISIT: Basic Satellite Imagery Interpretation in the Tropics, Slides 3-8
            - VISIT: GOES Imagery for Forecasting Severe Weather, Slides 7-9, 14, prefer recent case, however
            - VISIT: Objective Satellite Based OT and Enhanced V Anvil Thermal Couplet Signature Detection, Slides 4-15

VISIT: One Minute Visible Satellite Imagery Applications for Severe Thunderstorms, 4:15-7:15 or so (in YouTube version). Prefer recent case, especially with SRSOR.

Mesoscale/Convection (cont.)

- Boundary-forced Convection (boundary identification, fronts, outflow, sea/lake breeze, etc.) (10 minutes)
  - VISIT: Satellite Interpretation for Coastal Effects, Slides 15,18 good example, but want SRSOR example.
  - Some examples from VISIT: One Minute Visible Satellite Imagery Applications for Severe Thunderstorms, VISIT: Basic Satellite Imagery Interpretation in the Tropics (e.g., slides 25 to 27)
  - Possible gap: example of outflow boundary interacting with a front
- Mountain Waves and Orographic Enhancement (10 minutes)
  - Some examples from VISIT: Objective Satellite Based OT and Enhanced V Anvil Thermal Couplet Signature Detection (e.g., Slide 30)
  - VISIT: Synthetic Imagery in Forecasting Orographic Cirrus, Slides 8 & 18 as an example of what is intended
  - Possible gap: viewing through new GOES-R Water Vapor bands (see fact sheet on ABI/AHI Band 10 for example http://www.goes-r.gov/education/docs/ABI-bands-FS/ABIBand10_LowerLevel_WV-IR_FINAL.pdf)
- Fog/Low Clouds Formation and Dissipation (10 minutes)
  - VISIT: Satellite Interpretation for Coastal Effects, Slides 24-25
  - VISIT: Forecaster Training for the GOES-R Fog/Low Stratus (FLS) Product, Slides 22-27 (stay away from regionally specific examples until level 2)
  - Need specific example using 10.4/11.2-3.9 (or other bands)
  - One-minute imagery of fog dissipation (one-minute visible imagery) would be a good idea (case from blog, such as http://cimss.ssec.wisc.edu/goes/blog/archives/16461)
  - RGBs that will be in AWIPS on “day one” should be incorporated
- Mesolows (10 minutes)
  - VISIT: Objective Satellite Based OT and Enhanced V Anvil Thermal Couplet Signature Detection, Slides 31-36
  - Visible imagery, maybe near-infrared?
  - Show loop, objectives are for forecasters to identify increased convergence with impacts on sensible weather (deep convection, cloud banks, precipitation chances/banding, etc.)

Mesoscale/Convection (cont.)

- Convective evolution
  - Cumulus congestus/growth (Cu fields, TCUs, orphan anvils, feeder clouds) (10 minutes)
    - VISIT: GOES Imagery for Forecasting Severe Weather, reduce to one case, preferably using an SRSOR case (OPG cases from June 2015).
    - Examples appear in VISIT: One Minute Visible Satellite Imagery Applications for Severe Thunderstorms that could be incorporated (that are not used above in boundary identification)
  - Discrete storms (cooling rate to overshooting tops to decay or upscale growth), including enhanced V (20 minutes)
    - Gap: Need a new module on discrete storms that use baseline products instead of existing PG products for cloud top cooling
    - VISIT: Objective Satellite Based OT and Enhanced V Anvil Thermal Couplet Signature Detection, remove references to overshooting top product (NOAT did not select overshooting tops in Pick 5 exercise because forecasters can identify with their eyes)
    - Gap: Incorporate GLM in terms of trends (not specifically jumps). The SPoRT total lightning modules do not specifically address these issues but come close (and only with ground-based LMAs). COMET: Introduction to GLM Section 3.2/Convection addresses this to some extent (would need to be more condensed/focused).
  - Mesoscale convective systems, including transverse banding to Mesoscale convective vortices (10+ minutes)
    - Gap: Need a new module on MCS formation and sustenance, including upstream environment and impact on MCS; also cloud top indicators indicative of MCS strengthening/weakening
    - VISIT has existing lesson from more than 10 years ago on MCVs (http://rammb.cira.colostate.edu/training/visit/training_sessions/mesoscale_convective_vortices/video/), needs to be significantly updated with GOES-R type imagery and condensed in time.
    - Gap: Incorporate GLM trends. SPoRT Total Lightning modules and COMET: Introduction to GLM do not address.

Expected Time: 2 hours (120 minutes)

Mesoscale/Convection (cont.)

Recommended Delivery Techniques:

- Begin topic with an introduction (10 minutes or less) on the layout of the individual interactive exercises.
- Interactive exercises for each topic that follow a basic three-part formula
    - Introduction to the topic and how GOES-R will aid the forecasters with identification, analysis, and tracking.
    - An example where the instructor walks through an example using GOES-R proxy data (Himawari-8, SRSOR from GOES-14) to show the main features identified in the topic.
    - An interactive exercise where the trainee is asked to identify the features for the specific topic.
- Simulation (e.g., WES) encompassing all of the individual module topics so forecasters can interact with the data in the AWIPS environment. (could be combined into other simulations for other tracks, doesn’t need to be separate).

Synoptic Features

Outline:

- Cyclogenesis (40 minutes total) (update all items with AHI to show new bands).
    - PV concept (10 minutes)
        - Revise: http://cimss.ssec.wisc.edu/goes/visit/wv_pv.html and make accessible via web without downloading VISIT lesson
        - Include examples from: http://cimss.ssec.wisc.edu/goes/blog/?s=potential+vorticity
        - Do not use ozone product in lesson; not a baseline product
    - Life cycle (Each slide from VISIT: Cyclogenesis: Analysis Using Geostationary Satellite Imagery is a bullet in this training module, 6 to 19; VISIT: Interpreting Satellite Signatures, slides 37 to 43) (20 minutes)
        - Slide 6 Baroclinic leaf phase - this pattern represents the beginning of the cyclogenesis process.
            - The term Warm Conveyor Belt (WCB) is introduced. Warm Conveyor Belt here as defined by Harrold (1973) as a flow of high theta-w air that ascends as it advances poleward ahead of the cold front. It often produces precipitation.
        - Slide 7 Baroclinic leaf phase (jet structure) - An S shaped area begins to develop in the WCB.
            - Upper level short wave interacts with surface front leading to surface pressure falls and increasing vertical motions. The result is increasing thermal advection, rising air and an expanding cloud shield ahead of the region of the developing surface low, and an increase the upper level wind speeds.
            - shows drier air at mid-upper levels to the southwest of the develop baroclinic leaf where subsidence is occurring. Warming is south of the inflection point. If this were not the case, cyclogenesis would most likely not occur. (Could also use info from SHy4, slide 28)
        - Slide 8 Incipient position of the surface low
        - Slide 9 Schematic accompanying description on previous slide
        - Slide 10 Development of warm and and cold conveyor belts - formal definitions
        - Slide 11 Warm and cold conveyor belts - schematic from Carlson 1980
        - Slide 12 Baroclinic leaf advanced phase.
        - Slide 13 Advanced leaf phase - described in previous 2 slides. Frame 2) Water vapor example of schematic
        - Slide 14 Evolution to the comma shape
        - Slide 15 Fully developed comma cloud
        - Slide 16 Emerging CCB in IR imagery as well as the developing cusp,
            - Water Vapor shows position of surface low at various stages as well as the WCB/CCB in mature system.
        - Slide 17 Occlusion begins - As system occludes cold and warm air begin to mix and sfc low begins to fill. Upper level wind speeds decrease poleward of the center.
        - Slide 18 Surface low begins to fill
        - Slide 19 Basic cyclogenesis

<u>Synoptic Features(cont.)</u>

- TROWALs (10 minutes)
  - Slides 44-45 of SHyMet for Forecasters: Water Vapor Channels
- Other jet features (10+ minutes)
  - Bent back occlusion (a.k.a. sting jet) possible example: http://cimss.ssec.wisc.edu/goes/blog/archives/9502
  - Possible bent back occlusion examples from Himawari? Better conceptual model would be useful
  - Gap: We need two examples that shows development of low-level jet ahead of extratropical cyclone: daytime case and nighttime case. Summer case might be ideal as winter cases are more dynamic.
  - MSC: Water Vapor Interpretation Short Course will also have some useful material: https://www.meted.ucar.edu/training_course.php?id=44
- General Circulation Patterns (ridges, troughs, cols, etc.) -- 10 minutes
  - Gap: Need additional training on identifying the features mentioned.
  - SHyMet for Forecasters: Water Vapor Channels (slides 18-19) show a good representation of the uses of WV images for large scale flow analysis (hemi or ocean basin merc). Needs to be updated with GOES-R type images/bands.
  - COMET: Introduction to Tropical Meteorology, Chapter 3, Use figure 3.4, section 3.1.4 to illustrate scales as a reminder.
  - COMET: Introduction to Tropical Meteorology, Chapter 3, Relate Fig3.14 of section 3.2.2 to http://www.ssec.wisc.edu/owl-lobby/loop.html, type “d”
  - MSC: Water Vapor Interpretation Short Course will also have some useful material: https://www.meted.ucar.edu/training_course.php?id=44
- Atmospheric Rivers (Identify and Analyze) -- 10 minutes
  - COMET: Satellite Feature Identification: Atmospheric Rivers Definition (Slides on definition of atmospheric river could be used).
  - Gap: Need to address how the additional WV channels on GOES-R support the identification and analysis of ARs? Need to mention the relationship between current GOES Sounder and GOES-R Band 10 (See GOES-R Fact Sheet).
- Tropical to Extratropical Transition -- 10+ minutes
  - COMET Introduction to Tropical Meteorology, Chapter 8, section 5.
  - The information in the section mentioned above is good, but needs to be condensed and turned into a module with updated AHI example.

Not covered (this information belongs in applications training, not foundational):

- *Precipitation other than relation to cloud features. The intent to exclude specifics and prepare an integrated module that encompasses multiple observing platforms. (This is a Level-2 topic and need not be addressed in the foundational training.)*

Synoptic Features(cont.)

Expected Time: 1 hour 20 minutes (80 minutes)

Recommended Delivery Techniques:

- Main cyclogenesis module (30 min.) completed first.
- Interactive exercises follow where trainees are asked to identify specific features at certain times.
- Simulation (e.g., WES) encompassing all of the individual module topics so forecasters can interact with the data in the AWIPS environment.

NWP Data Assimilation

Outline:

- COMET: How Satellite Observations Impact NWP (15 minutes)
    - Keep
        - Which Satellite Observations are Assimilated
        - Accepting Data from New Instruments (Flowchart)
        - Assimilating Satellite Observations and Retrievals (Flowchart)
        - Assimilating Satellite Observations
        - Assimilating Satellite Retrievals
    - Needs Updating
        - Graph of instrument contribution to forecast error reduction
        - Daily percentage of data ingested into NWP models (2005)
- Impact of GOES-R on Satellite Data Assimilation (5 minutes)
    - Gap: This is briefly discussed in the GLM module, but what does GOES-R offer that's different from previous GOES satellites that will affect NWP performance (e.g., new ABI channels, increased temporal resolution)? IF this is a GOES-R specific core, then this would appear to be the main concern--and something that is not addressed. (Could use Himawari data impacts as an example)
- Comparing NWP Simulated Satellite Imagery to Observed Satellite Imagery (10 minutes)
    - Gap: There hasn't been much emphasis placed on comparing forecast satellite imagery to observed satellite imagery except for the HWT training. Need to expand on this (in separate track). Some VISIT sessions on simulated reflectivity may be useful.

Not Covered (this information belongs in applications training, not foundational):

- *Impact of JPSS to the data assimilation process. (This is believed to be a separate module within JPSS training, and/or a separate update to the existing "How Satellite Observations Impact NWP" module.)*

Recommended Delivery Techniques:

- Self-paced training with audio

Interactive Exercises and Simulations

Intra-lesson Interactivity

Purpose: Provide an opportunity to view and interact with the GOES-R imagery and products to firmly establish understanding and interpretation.

Note: This interactivity is not intended to use supplemental meteorological information (i.e., stay specific to satellite meteorology, individual concept at hand) unless it contributes to the learning and understanding of the physical concepts.

It is envisioned that intra-lesson interactivity is handled outside of the Weather Event Simulator. Intra-lesson interactivity will consist of short exercises that encourage the meteorologist trainee to explore the channels, features, and/or concept previously discussed. Most lessons should have a period for exploration via trainee-driven exercises.

Requirements: The interactive tools should be easy to use without a significant interruption to the training process. They should run on the web, or easy to install on Windows.

Options for tools to accompany "hands on" exercises include the following:

- Web applications
  - http://cimss.ssec.wisc.edu/education/goesr/
    - Temporal, spectral, and spatial applications
  - http://cimss.ssec.wisc.edu/goes/webapps/satrgb/overview.html
- Other platform-independent visualization software that provides interrogation of individual channels and/or products
  - SIFT (CIMSS application developed for and used in Guam)

Post-lesson Simulations

Purpose: Provide an opportunity to view and interact with GOES-R-type data in an AWIPS-2 workstation-style environment at the end of the training sequence. Provide the SOO or designee with an opportunity to evaluate the forecasters' learning effectiveness.

Note: The simulations are intended to be different from the intra-lesson interactivity. They are also intended to focus on Level-1 activities (e.g., identification and analysis) with minimal Level-2 application (e.g., combinations, data fusion).

Requirements: Platform must mirror AWIPS-2, but does not necessarily have to use the WES-2 Bridge. AWIPS-2 visualizations and color curves will need to be finalized if this is to be successful.

Interactive Exercises and Simulations(cont.)

Two simulations:

1. Exploring the ABI Bands and synoptic features (including comparisons to NWP). (2 hours) - use the 2011 CIMSS case as a template, condensed and updated with new data if possible (Himawari in particular), include “day one” RGBs and products not covered in 2 (Mesoscale/Convection).
    a. 2011 ABI WES Guide (http://cimss.ssec.wisc.edu/goes/abi/loops/WES_for_GOES-R_ABI_2011_Version.pdf)
2. Mesoscale/Convection - subject-specific cases (potentially using SRSOR data), either regional SSD or local SOO selects at least one applicable for local/regional needs. (They are also intended to focus on Level-1 activities (e.g., identification and analysis) with minimal Level-2 application (e.g., combinations, data fusion)).

Examples:

i. Fog/Low Cloud Case
ii. Convection/GLM Case
iii. Tropical/Extratropical Transition Case
iv. Orographic Case

Appendix I -- Definitions

- Definitions of module codes and modules reviewed by this team.
    - The module codes in this document are references to the reviewed courses outlined in a separate document, linked here, by FDTD, and furthered reviewed by the STAT.
        - C: COMET
        - VIS: VISIT View (CIRA, CIMSS)
        - SP: NASA SPoRT
        - SHy: SHyMET for Forecasters
    - Although dozens of training courses and material were reviewed for this assessment and recommendations; it is really a subset of the total training that exists on various satellites, their uses and applications.

Appendix II -- Exceptions

- The training includes content relevant to a wide range of NWS meteorologists.

- However, some National Centers will require different training that focuses on their unique missions. National Centers requiring specialized training include the Space Weather Prediction Center (SWPC), Climate Prediction Center (CPC), and Environmental Modeling Center (EMC).

- Meteorologists and hydrologists at the River Forecast Centers and National Water Center can review abbreviated training, covering only the ABI, without completing the training tracks that focus on specific synoptic- and meso-scale features.

- This is only level 1 training (foundational). Additional efforts will be needed for proficiency training at levels 2 and 3 after GOES-R data and products are operationally available in AWIPS II.