Near Real-time Cloud Classification, Mesoscale Winds, and Convective Initiation Fields from MSG Data

Wayne Feltz*, J. Mecikalski, and K. Bedka*

Cooperative Institute of Meteorological Satellite Studies (CIMSS)

University of Wisconsin, Madison, WI, USA*

University of Alabama, Huntsville, AL, USA#

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OVERVIEW

- Heritage
- Proposed MSG Applications
- COPS as a Satellite Validation Resource
- Conclusion

HERITAGE

- UW-CIMSS Satellite-based Nowcasting and Aviation Applications (SNAAP)
- Primarily NASA funded through Advanced Satellite Aviation-weather Products (ASAP) initiative working with Federal Aviation Administration and National Center for Atmospheric Research USA
- 4th Year of Existence with UW-CIMSS Research Focus
  - **Convection,** Volcanic Ash, Turbulence
- Team continues to explore satellite- based aviation weather applications with emphasis on the 0-3 hour forecast problem
- Successfully proposed to apply GOES imager convective initiation algorithm on SEVIRI imager (August 2006) for future GOES-R Risk Reduction

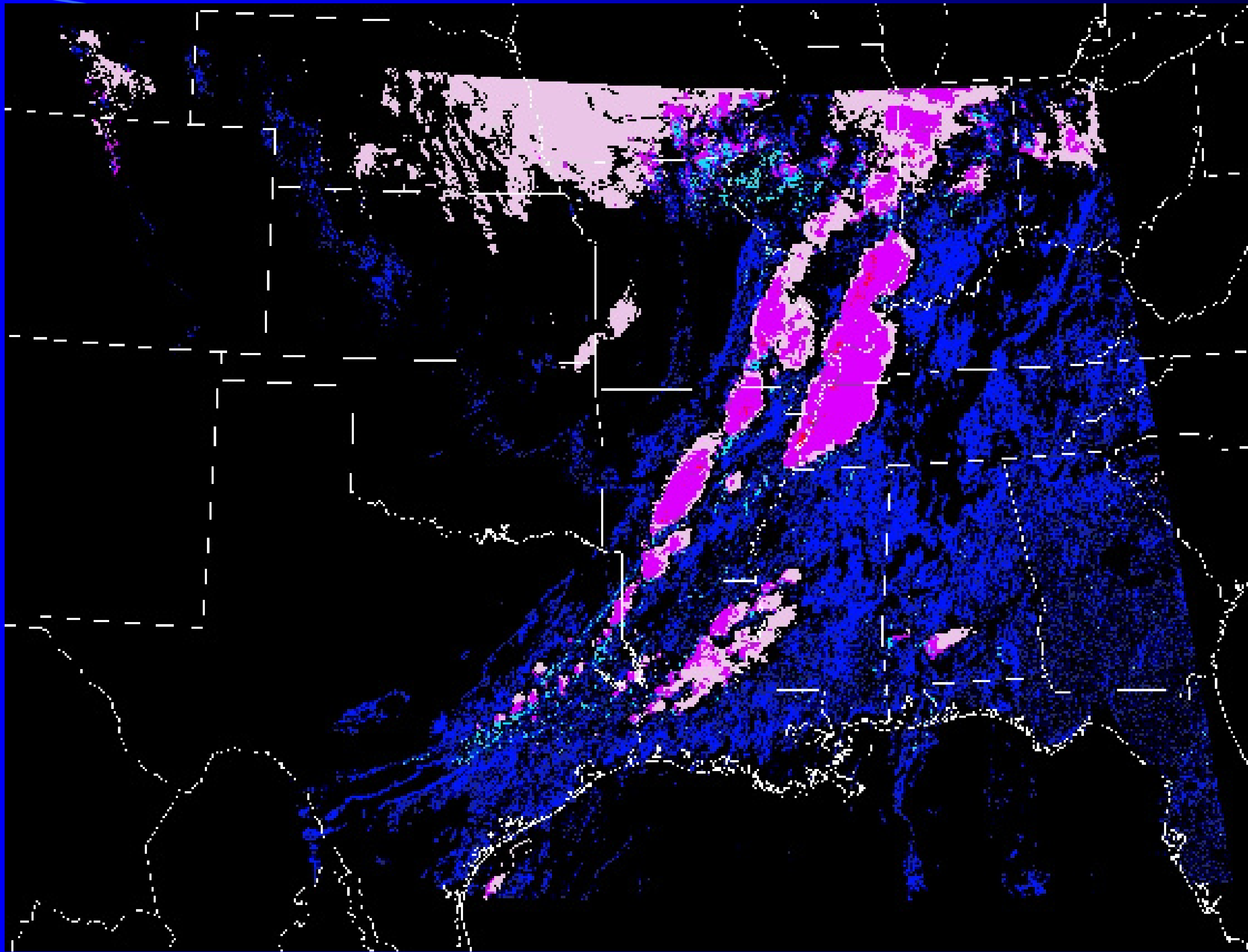
Why satellite-based nowcasting/aviation applications?

- Aviation/nowcasting community demands high temporal and spatial resolution at specified levels in the atmosphere
- Aviation weather hazard information is diagnostically driven and are only relevant on very short aviation time scales (0-3 hours for icing, convective initiation, turbulence, volcanic ash)
- Satellite data provides the primary information over data sparse oceanic, polar, and high terrain regions where commercial and general aviation aircraft operate
- While above points single out aviation the same can points can be made for nowcasting problem in general

Satellite-derived Convective Nowcasting and Aviation Applications

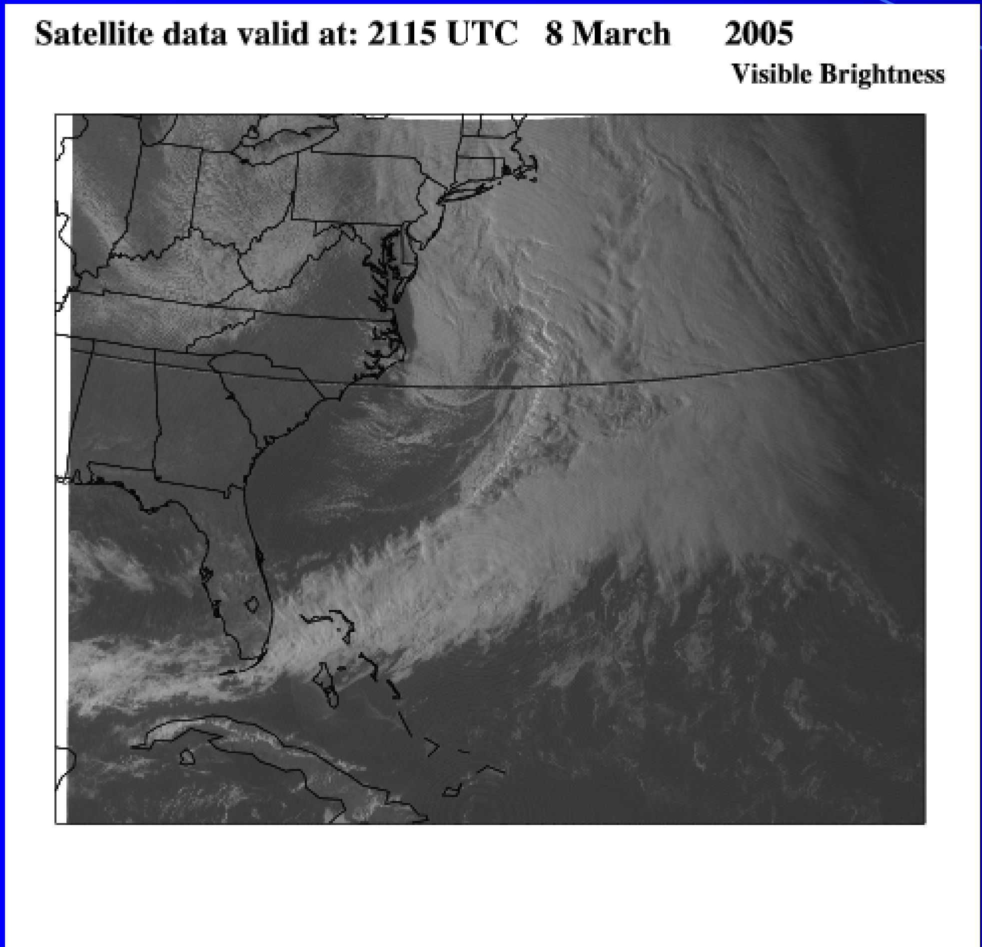
Satellite Convective Product Descriptions

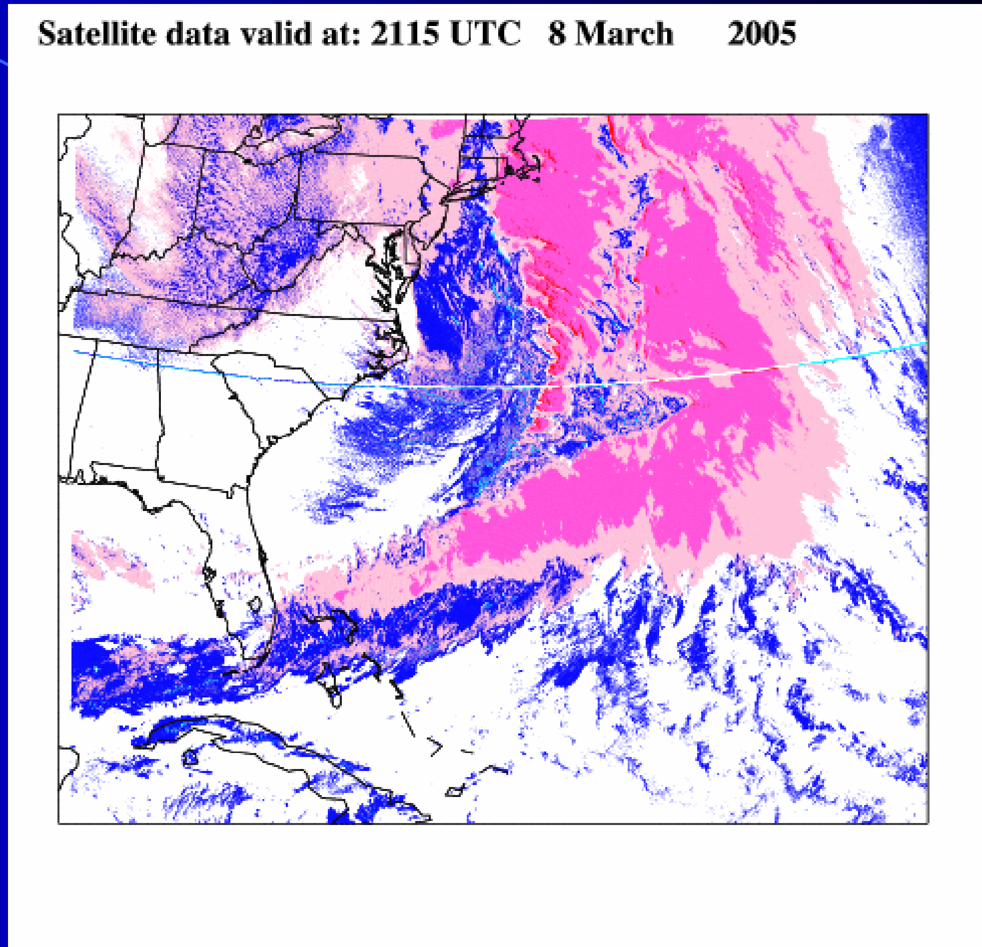
- Uses GOES 1 km VIS and 4-8 km multispectral IR imagery every 15-30 mins
- Convectively-induced clouds are objectively identified at a 1 km resolution
  - "Fair-weather" cumulus, cumulus congestus, deep overshooting cumulus tops, and thick/thin anvil cirrus are identified
  - Cloud-top temperatures and multi-spectral band differences are analyzed to identiy clouds in a pre-CI state
- Very high density "mesoscale" satellite winds are used to track cumulus over a 30-min period to identify persistent rapid growth
- Cumulus in a pre-CI state that exhibit rapid vertical growth are flagged as having good potential for future thunderstorm development



UAH/CIMSS Convective Cloud Mask Developed to Discriminate Between Cirrus Anvil (pink), Mature Cu (Pink, purple), mid-level Cu (light blue) and Cumulus (dark blue) Satellite CI Nowcasting Algorithm

Oceanic Cloud Classification



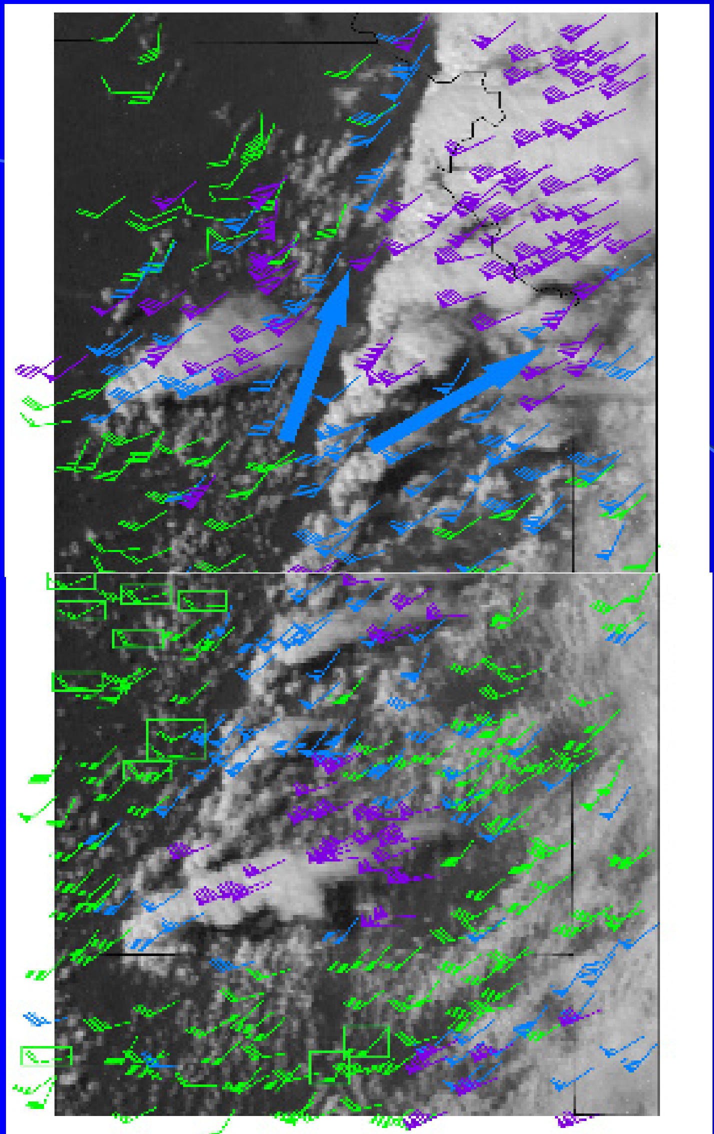


- Multi-spectral GOES-12 data for can be used to classify the various cloud features present within a scene

- Features highlighted here represent 1) small, immature cumulus 2) mid-level cumulus 3) deep convection 4) thick cirrus anvil 5) thin clouds

ASAP Satellite-Derived Wind Validation Studies

Kristopher Bedka, Wayne Feltz, Ralph Petersen, and Christopher Velden



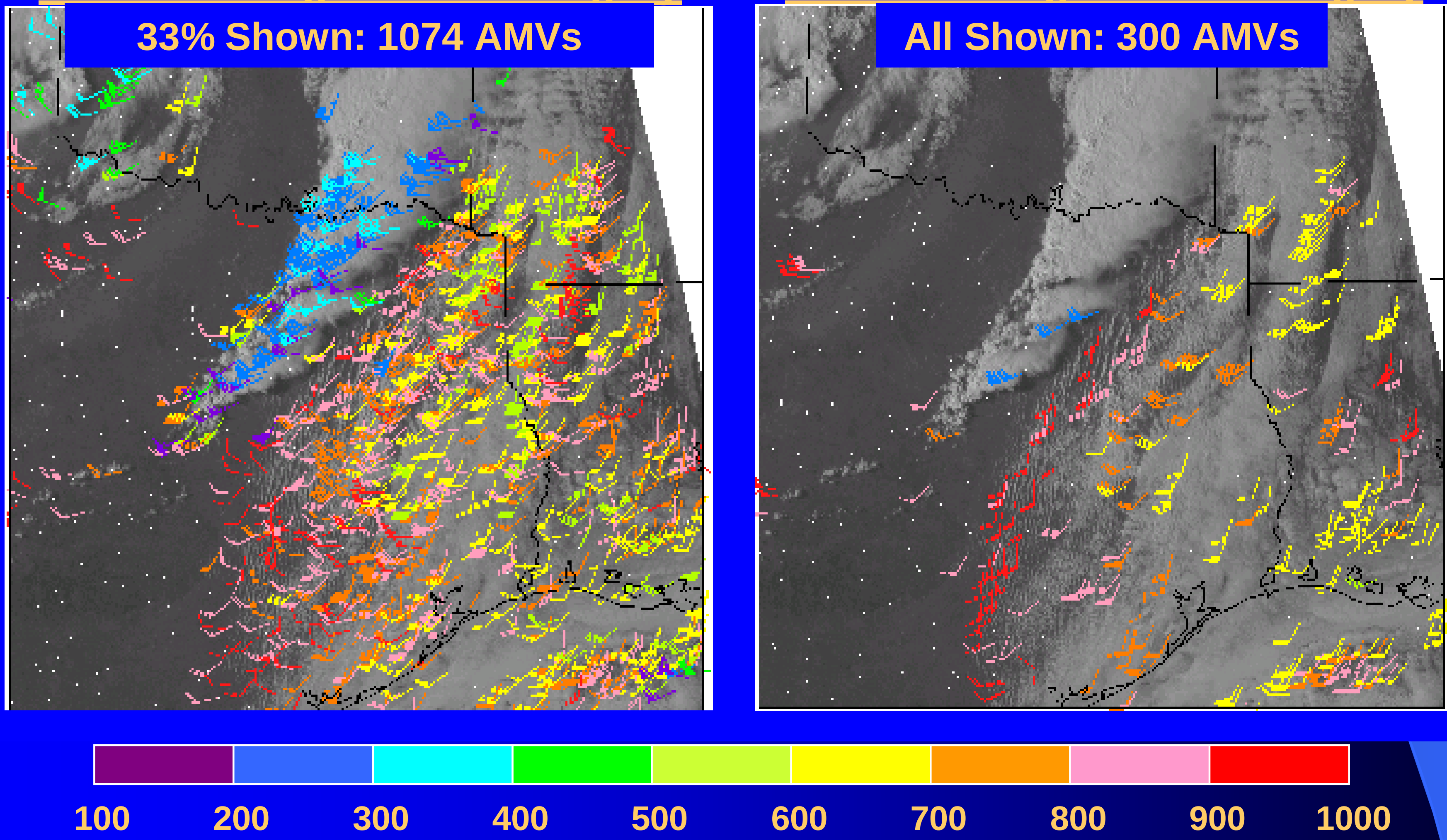
Mesoscale GOES-12 winds at 2002 UTC on 4 May 2003 over Eastern KS. 1000-700, 700-400, 400-100 hPa vector heights are overlaid upon GOES-12 1 km Visible imagery. From Bedka and Mecikalski (*J. Appl. Metor.*, 2005)

Product Description and Objectives

- High-density "mesoscale" satellite winds are obtained through adjustments in the feature tracking scheme, and relaxation of quality control and the NWP model "first-guess" constraints within the UW-CIMSS satellite wind algorithm
- These adjustments allow recognition of highly detailed atmospheric flow patterns in near real-time
- GOES-12 VIS, IR, and WV mesoscale winds are currently used to estimate thunderstorm growth rates in GOES imagery, but may also be applied to aviation flight planning and data assimilation applications
- Little published information exists describing the agreement of satellite-derived winds with reliable ground-based and in situ wind observations
- ***We are challenged to understand the limitations of current generation satellite wind algorithms in preparation for future satellite instrumentation, as there will be an increasing demand for high density flow information derived from GOES-R ABI***

Mesoscale vs Operational Satellite Derived Winds

MESO Settings 15 Min Imagery | **OPER Settings 15 Min Imagery**



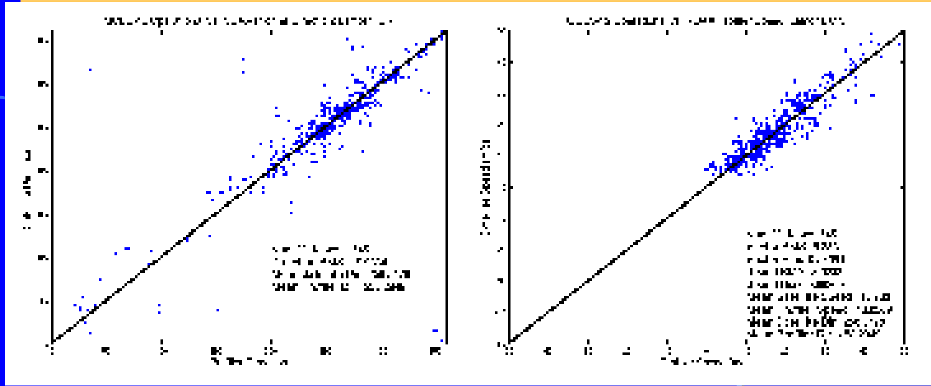
- 5 min resolution imagery will allow for better retrieval of mesoscale flows because the shape of cloud/WV features does not evolve much over short time scales

- 15 min resolution imagery includes movement components from both individual cloud elements and the broad scale cloud field, which are combined within a satellite wind

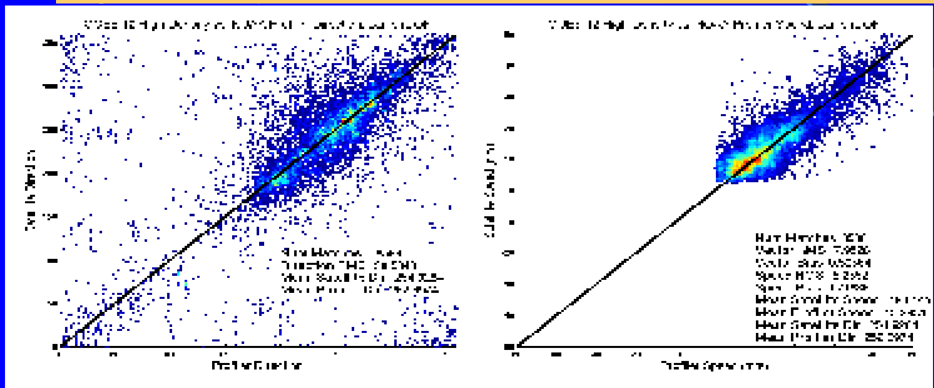
ASAP Satellite Motion Vector Validation

Kristopher Bedka, Wayne Feltz, Ralph Petersen, and Christopher Velden

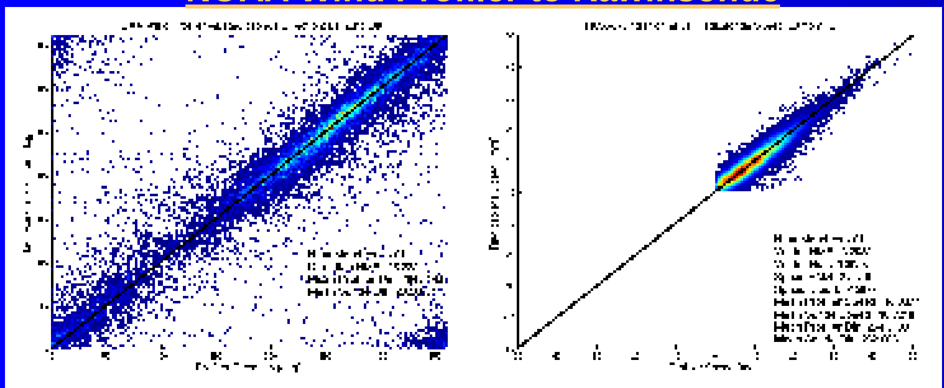
NOAA NESDIS Operational AMV to NOAA Wind Profiler



High-Density Mesoscale AMV to NOAA Wind Profiler



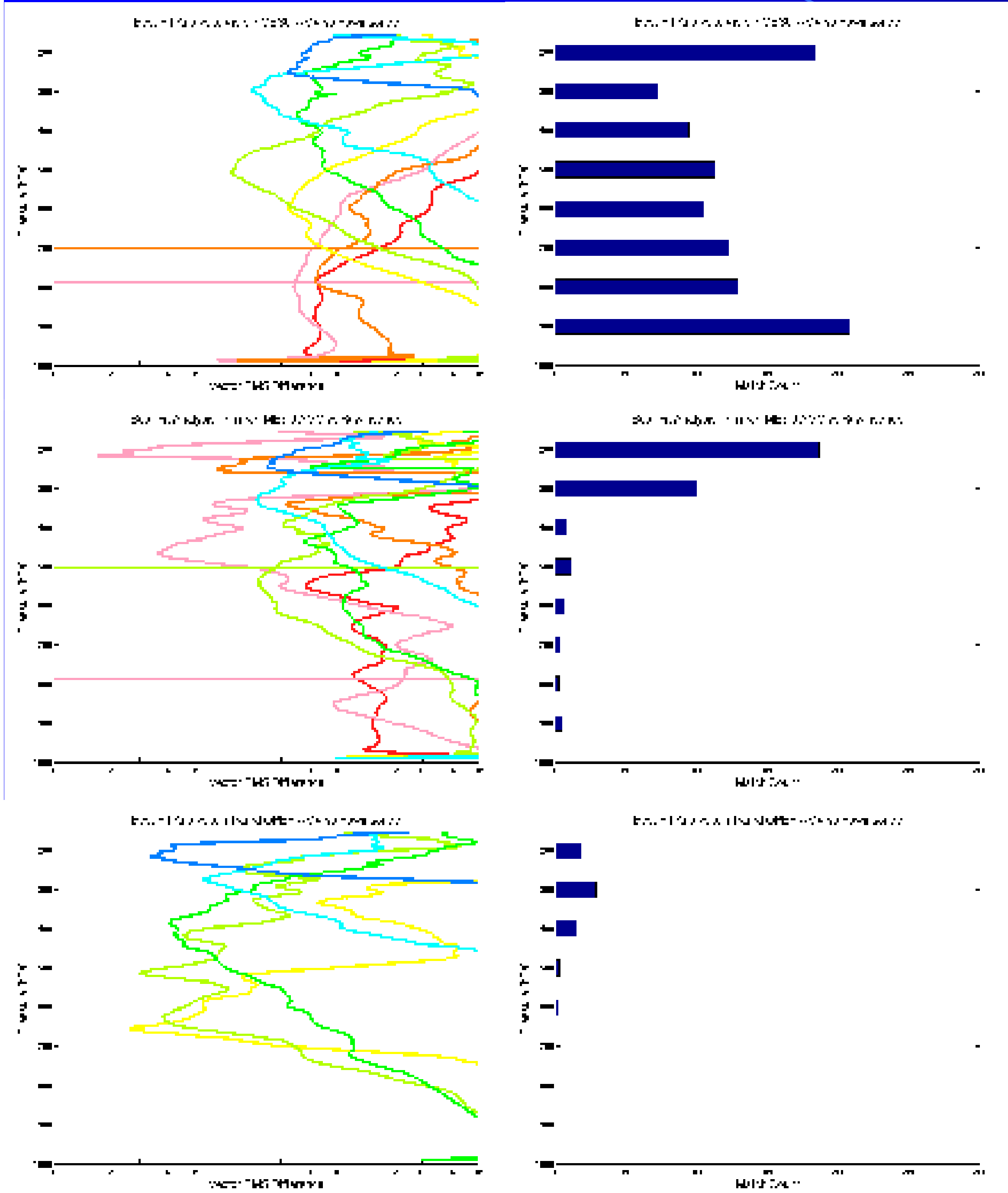
NOAA Wind Profiler to Rawinsonde



- GOES-12 VIS, IR, and WV high-density "mesoscale" motion vectors (MESO AMVs) are currently used to estimate thunderstorm growth rates in GOES imagery
- To use these motion vectors toward aviation turbulence identification and flight planning, we must understand their accuracy relative to robust wind measurements
- MESO and NOAA NESDIS operational (OPER) satellite motion estimates are compared here to 6-min NOAA Wind Profiler and rawinsonde data from the ARM SGP Central Facility
- From Apr. 12 to Nov. 31, 2005, there were 8588 MESO and 545 OPER AMV matches with QC'ed Profiler observations
- 81% (95%) of MESO (OPER) AMVs had vector RMS difference values below 10 m/s
- One must evaluate whether greater flow detail (MESO method) or better relative accuracy (OPER method) will better suit his/her particular satellite wind application

Satellite Motion Vector Best Fit Analysis

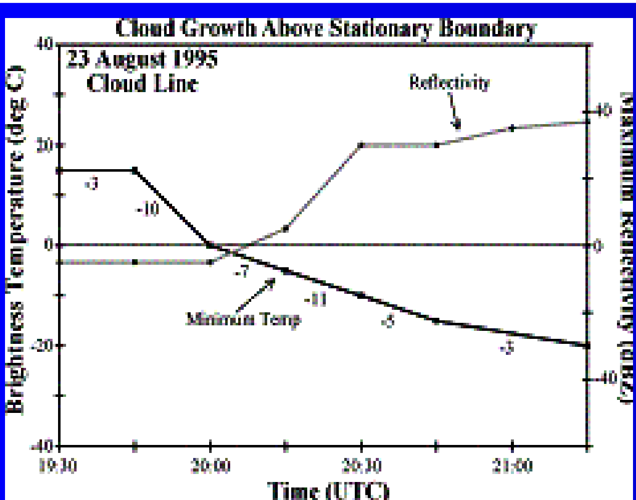
AMV Level of Best Fit **Height of AMV-Rawinsonde Matches**



- MESO and OPER AMVs are compared to a 381 level subset of radiosonde data to find the height where a given set of AMVs has the minimum vector RMS difference value (i.e. the "level of best fit")
- If the min RMS falls below the horizontal line, the vectors were assigned a height that was too high, and vice-versa
- Height assignments for VIS MESO vectors (IR window technique) and upper tropospheric IR MESO/OPER vectors was generally good
- "Perfect" height assignment would have reduced RMS differences by 10 to 15%
- Lower tropospheric IR vectors were assigned heights too low, yet more matches are needed to fully evaluate this
- Remaining AMV "error" is likely produced by feature tracking problems within the AMV algorithm, atmospheric variability between sonde and AMV, or that satellite feature motion simply does not perfectly match the true flow

Infrared Interest Fields for CI Nowcasting

CI Interest Field	Critical Value
10.7 µm T_B (1 score)	< 0° C
10.7 µm T_B Time Trend (2 scores)	< -4° C/15 mins ΔT_B/30 mins > ΔT_B/15 mins
Timing of 10.7 µm T_B drop below 0° C (1 score)	Within prior 30 mins
6.5 - 10.7 µm difference (1 score)	-35° C to -10° C
13.3 - 10.7 µm difference (1 score)	-25° C to -5° C
6.5 - 10.7 µm Time Trend (1 score)	> 3° C/15 mins
13.3 - 10.7 µm Time Trend (1 score)	> 3° C/15 mins

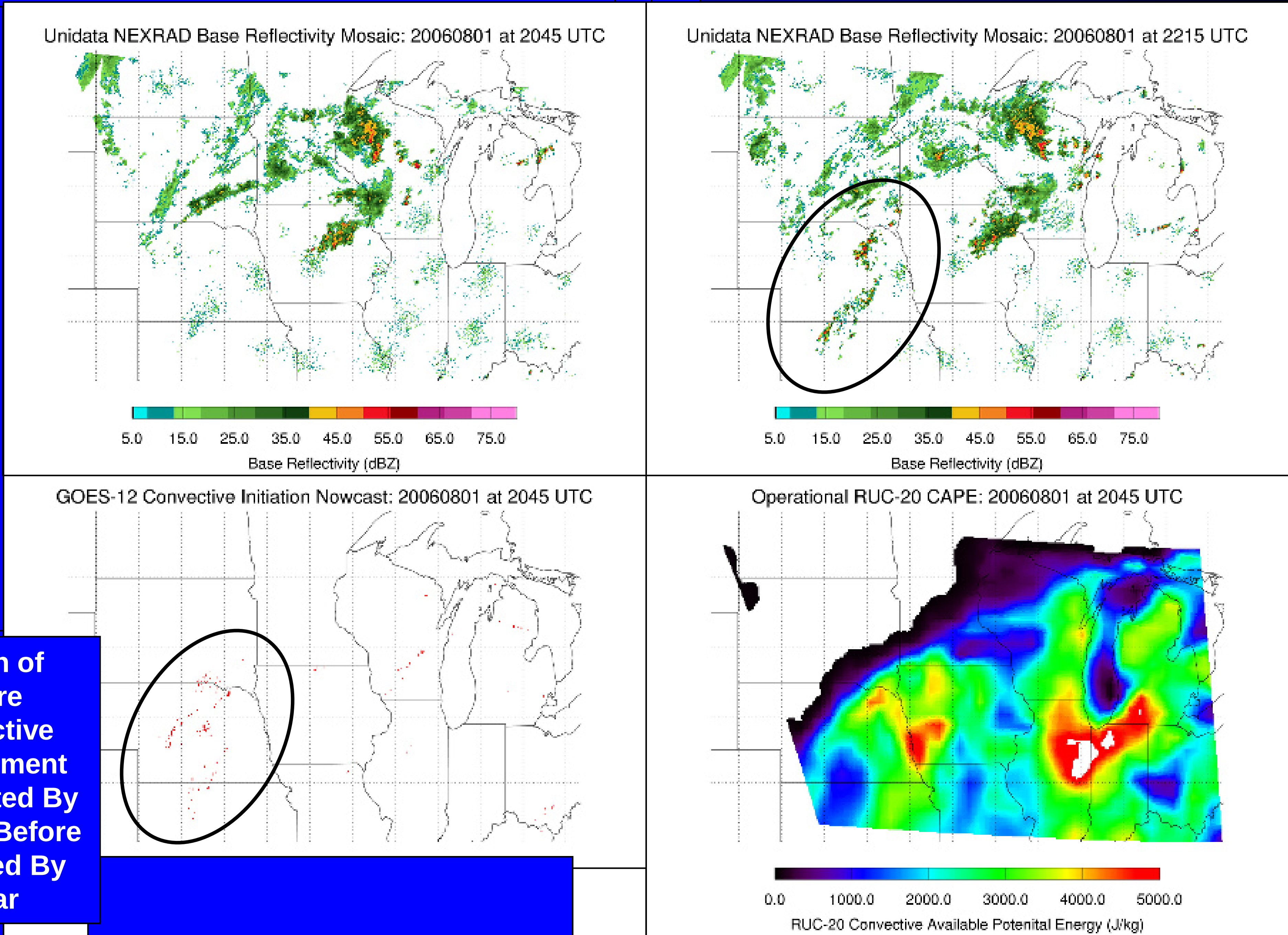


Roberts and Rutledge (WF, 2003) show the relationship between IR cloud top cooling and radar reflectivity change

When a cumulus cloud pixel IR T_B rapidly drops to the 0 to -20 °C range, radar reflectivity increases and CI occurs

SATCAST Product Examples

Convective Initiation Nowcasting



Region of Future Convective Development Highlighted By Satellite Before Observed By Radar

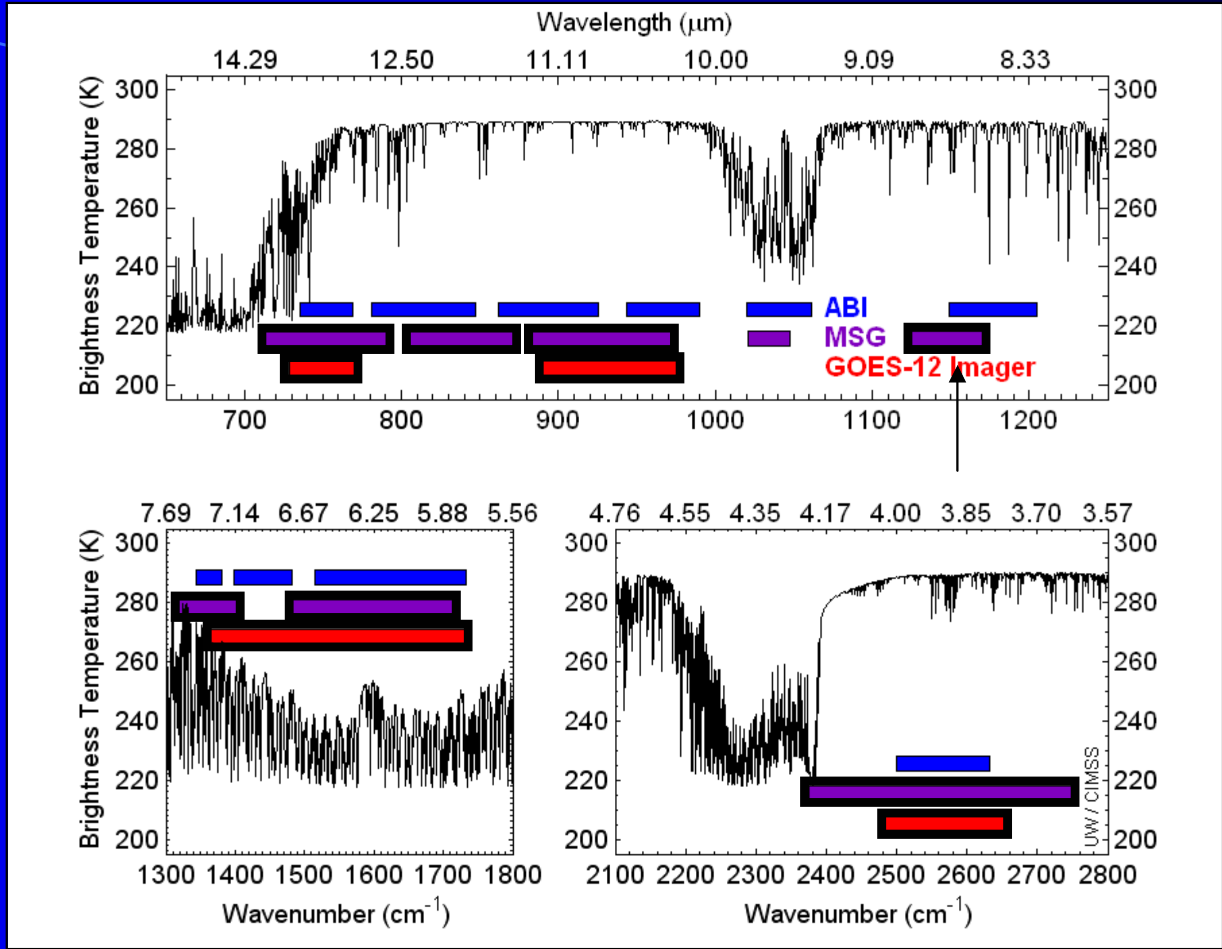
Geostationary Imager CI Nowcast Benefits

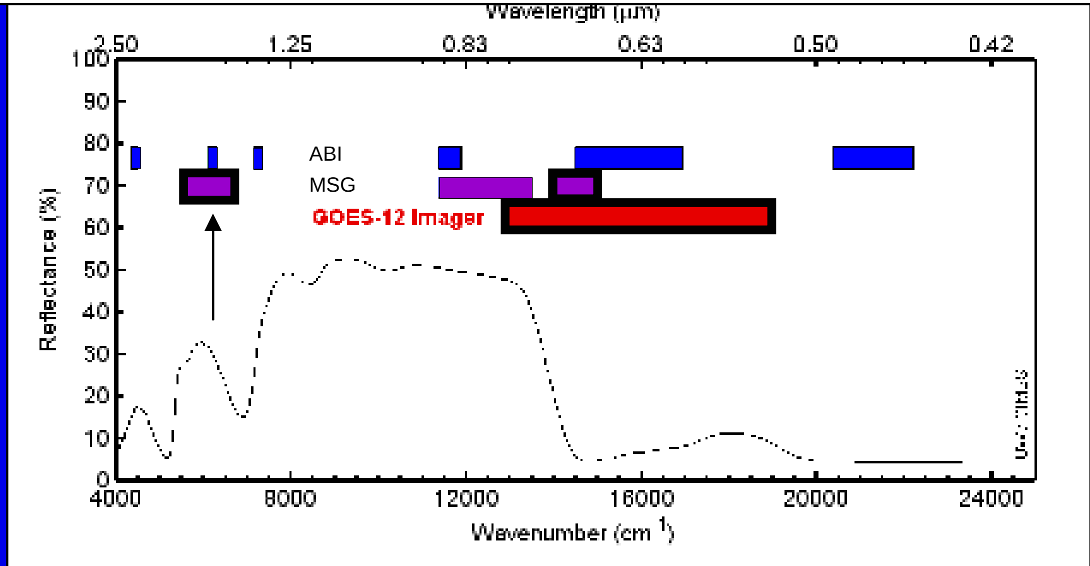
- All satellite inputs (winds, convective mask, and radiance tests all satellite derived)
- Takes advantage of temporal change of brightness temperature change, currently on of the few geostationary applications truly taking advantage of geostationary data temporally
- Provides ~45 minute lead-time for CI once cumulus clouds are present before 35 DBz radar reflectivity occurs (technical radar definition for convective initiation) of interest to many convective nowcasting efforts

Proposed GOES-R Risk Reduction Research (NOAA)

- Adapt current GOES imager software to MSG SEVIRI radiance inputs
- Optimize convective initiation, mesoscale AMV, cloud type classification
- Use the COPS ground-based instrument suite to validate products
- Provide optimal ABI convective initiation algorithm based on most advanced imager currently in operation
- Pave way for automated GOES-R ABI nowcast algorithm (~2012)

Channels Used in Convective Nowcasting

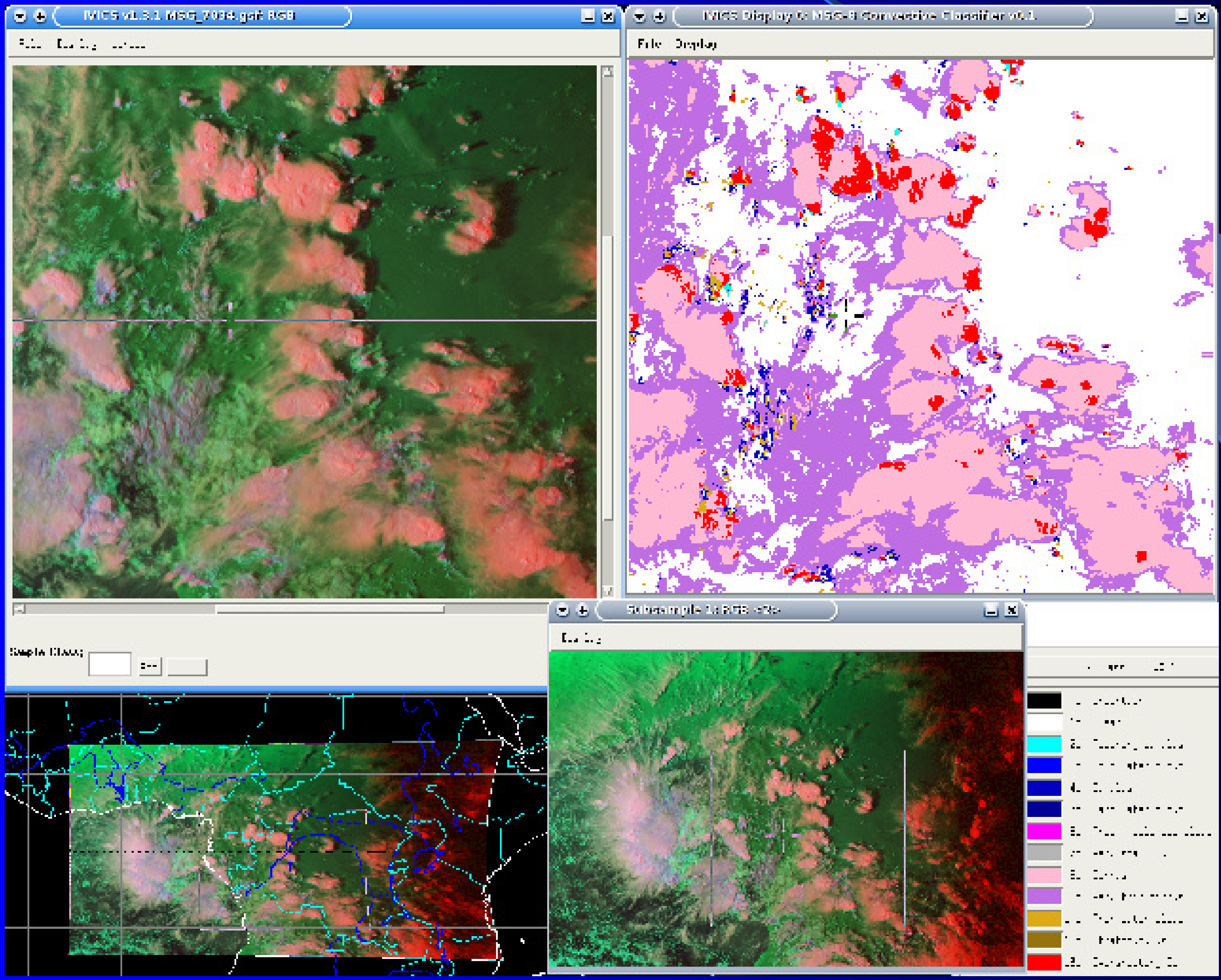


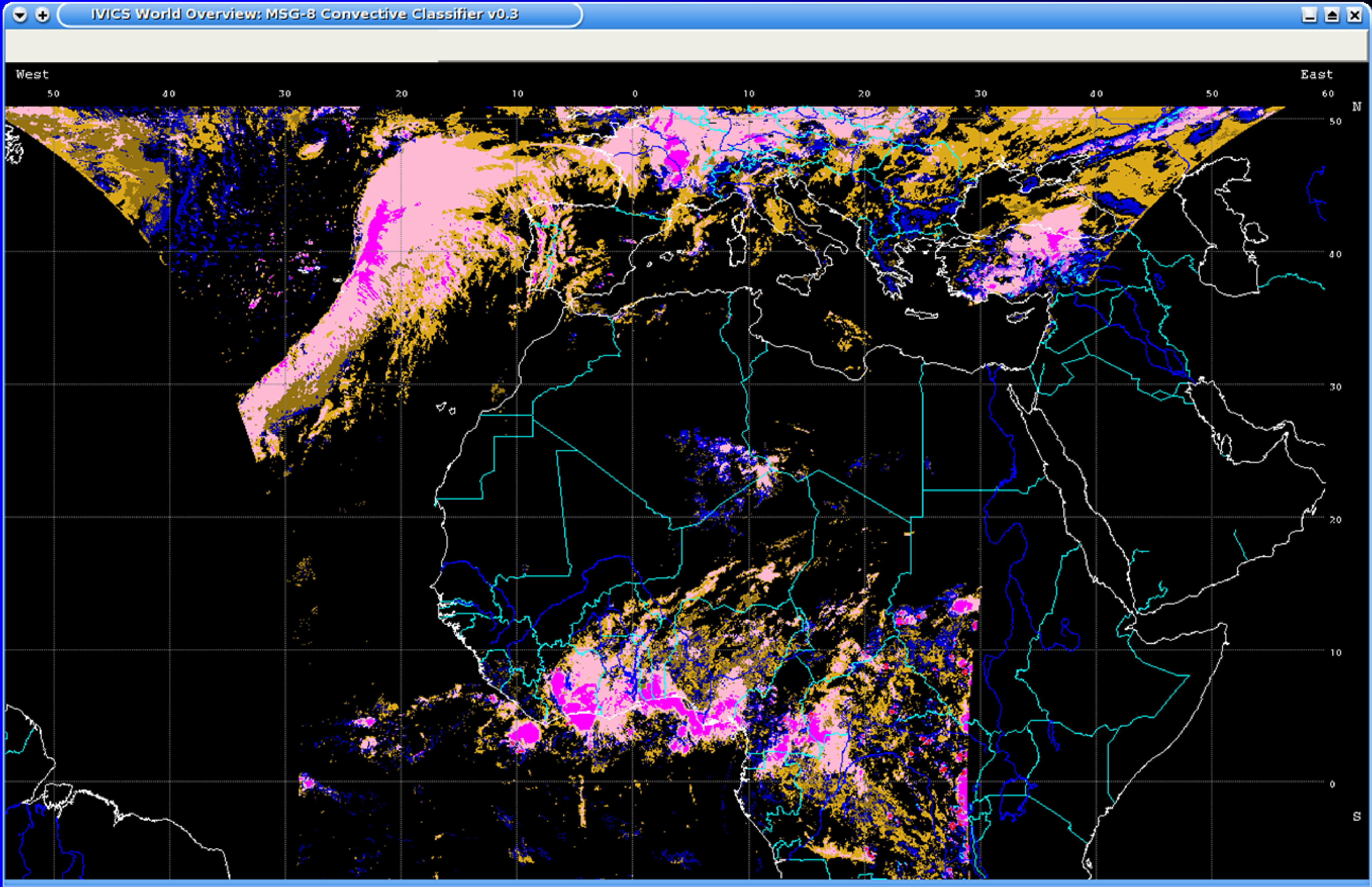


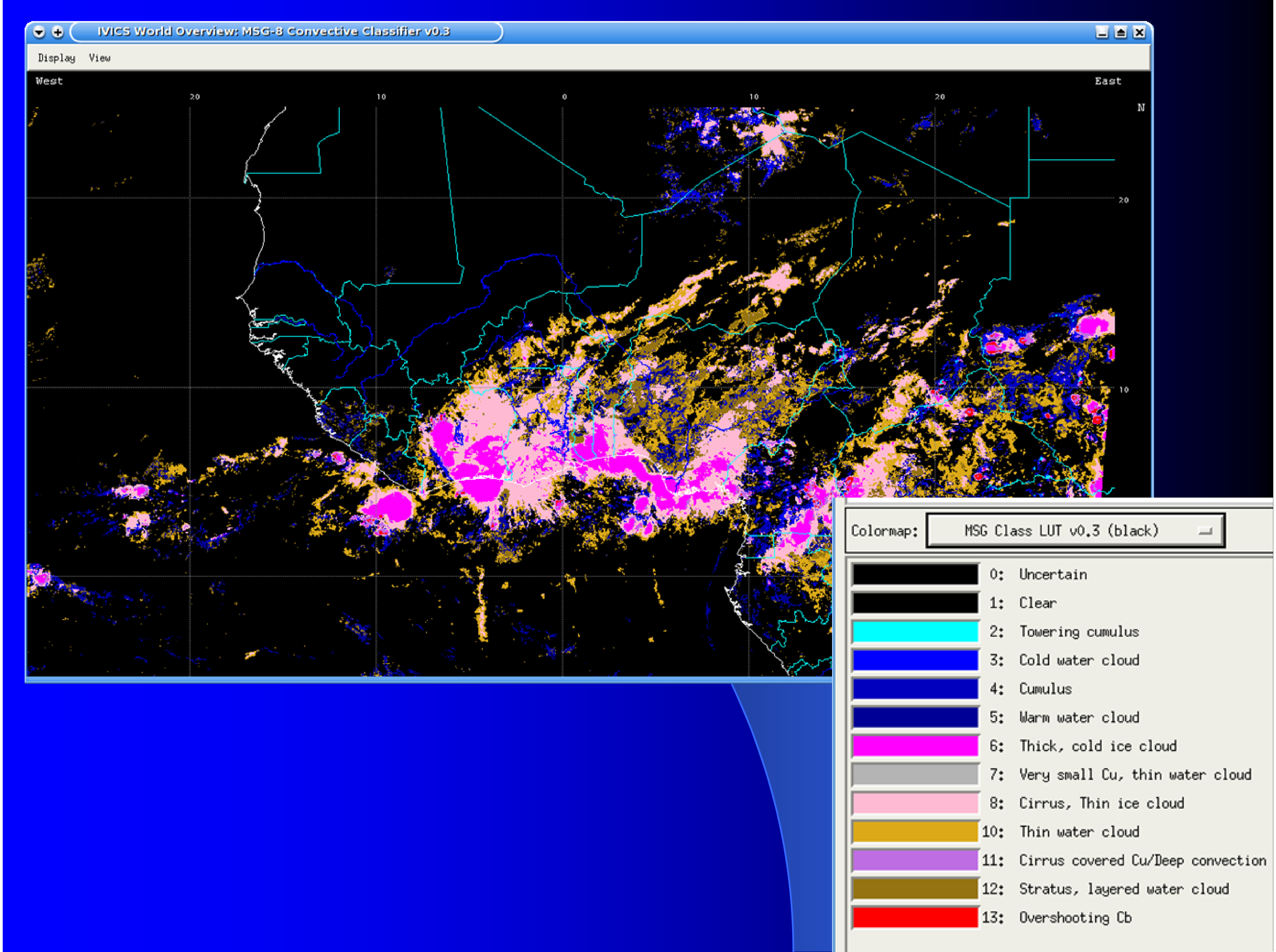
Objective Convective Cloud Classification from MSG SEVIRI

- SEVIRI has comparable spectral coverage to GOES-R ABI, which will allow us to evaluate the potential capability of ABI for monitoring and predicting the evolution and severity of convective storms

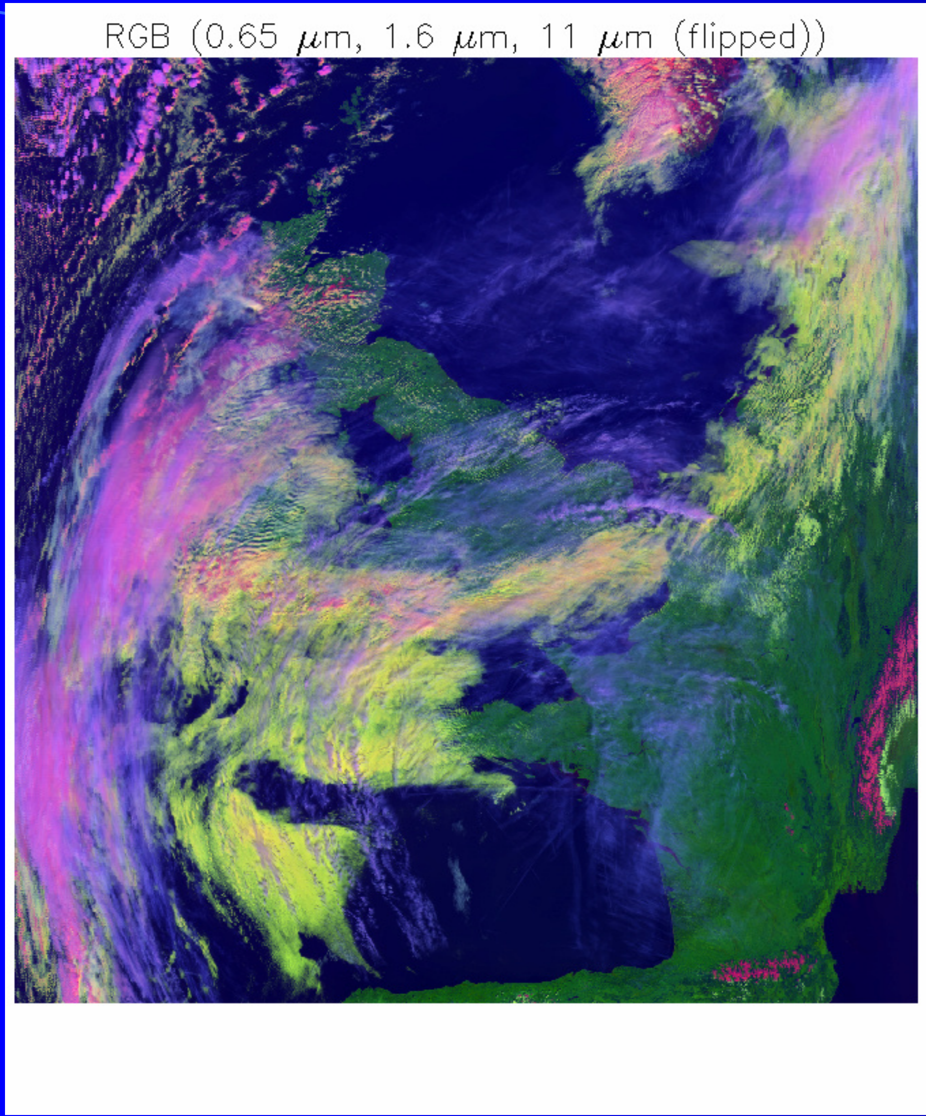
SEVIRI Convective Cloud Classifier over Central Africa

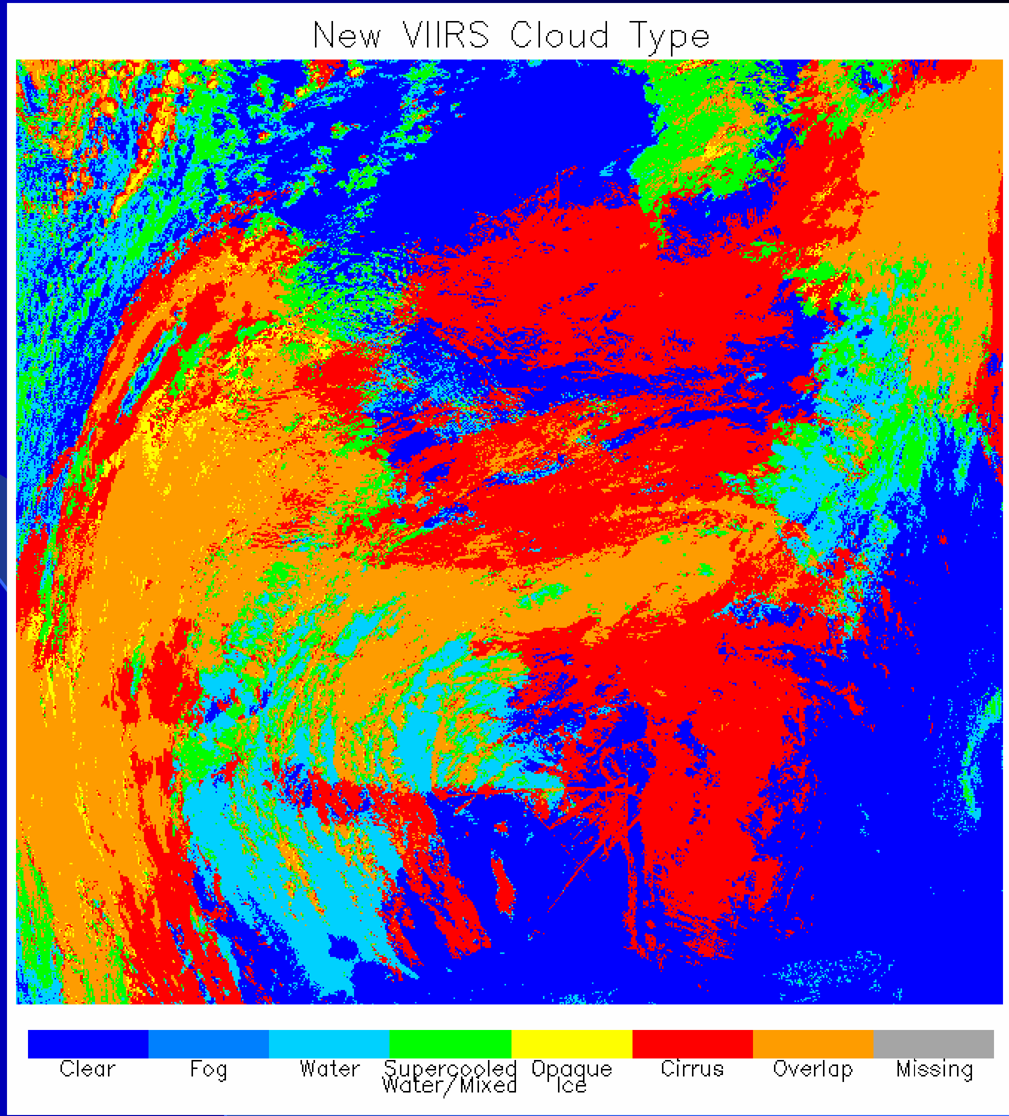



IVICS World Overview: MSG-8 Convective Classifier v0.3
West
East
50
40
30
20
10
0
10
20
30
40
50
60
N
S


IVICS World Overview: MSG-8 Convective Classifier v0.3
Display View
West
East
N
20
10
0
10
20
20
10
Colormap:
MSG Class LUT v0.3 (black)
0: Uncertain
1: Clear
2: Towering cumulus
3: Cold water cloud
4: Cumulus
5: Warm water cloud
6: Thick, cold ice cloud
7: Very small Cu, thin water cloud
8: Cirrus, Thin ice cloud
10: Thin water cloud
11: Cirrus covered Cu/Deep convection
12: Stratus, layered water cloud
13: Overshooting Cb

Test Water Phase Temporal Transitioning??
Cloud Phase Detection (Physical)
(Heidinger and Pavolonis technique)



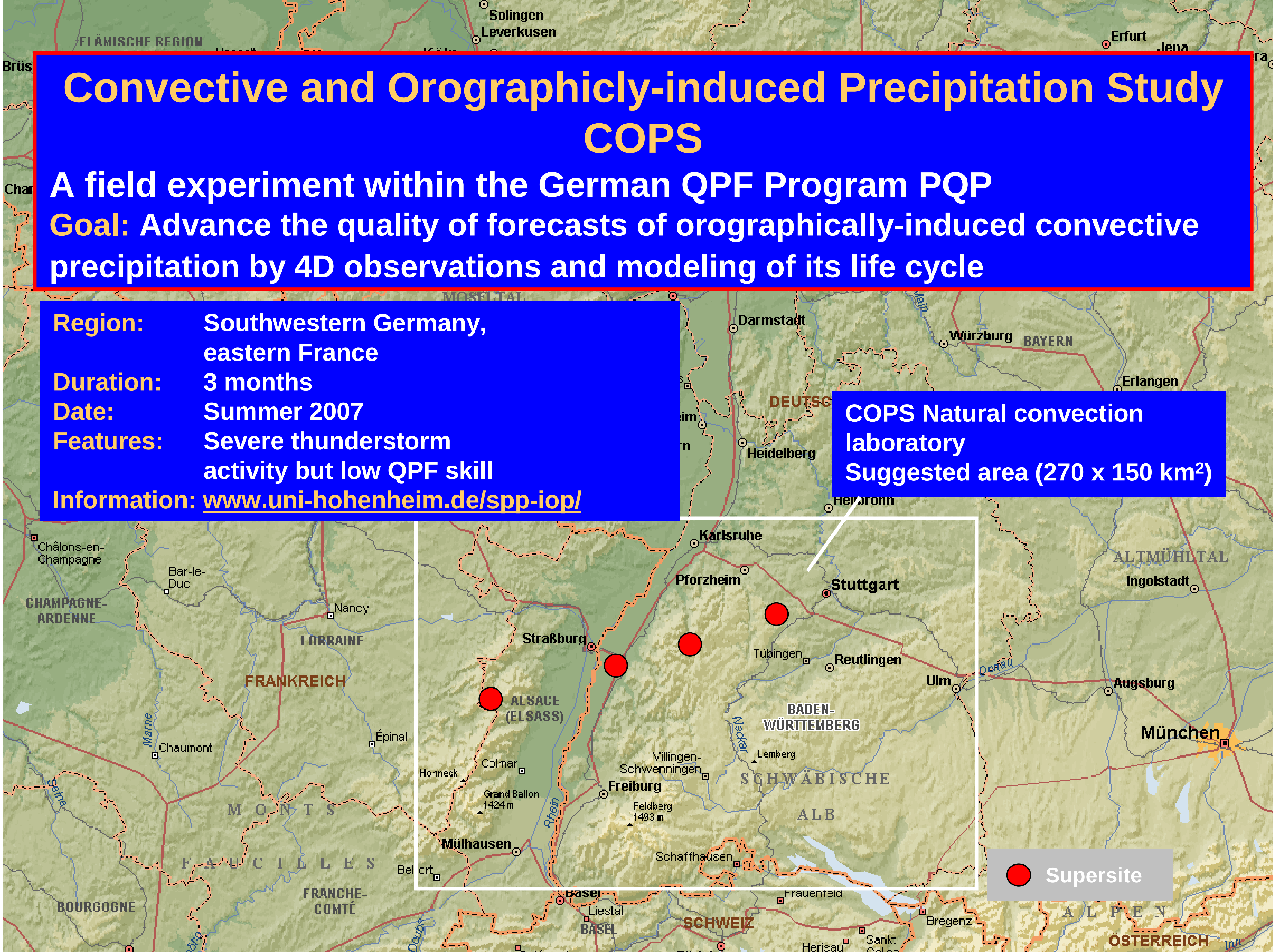


Convective and Orographicly-induced Precipitation Study COPS

A field experiment within the German QPF Program PQP

Goal: Advance the quality of forecasts of orographically-induced convective precipitation by 4D observations and modeling of its life cycle

Region: Southwestern Germany, eastern France
Duration: 3 months
Date: Summer 2007
Features: Severe thunderstorm activity but low QPF skill
Information: www.uni-hohenheim.de/spp-iop/



Supersites

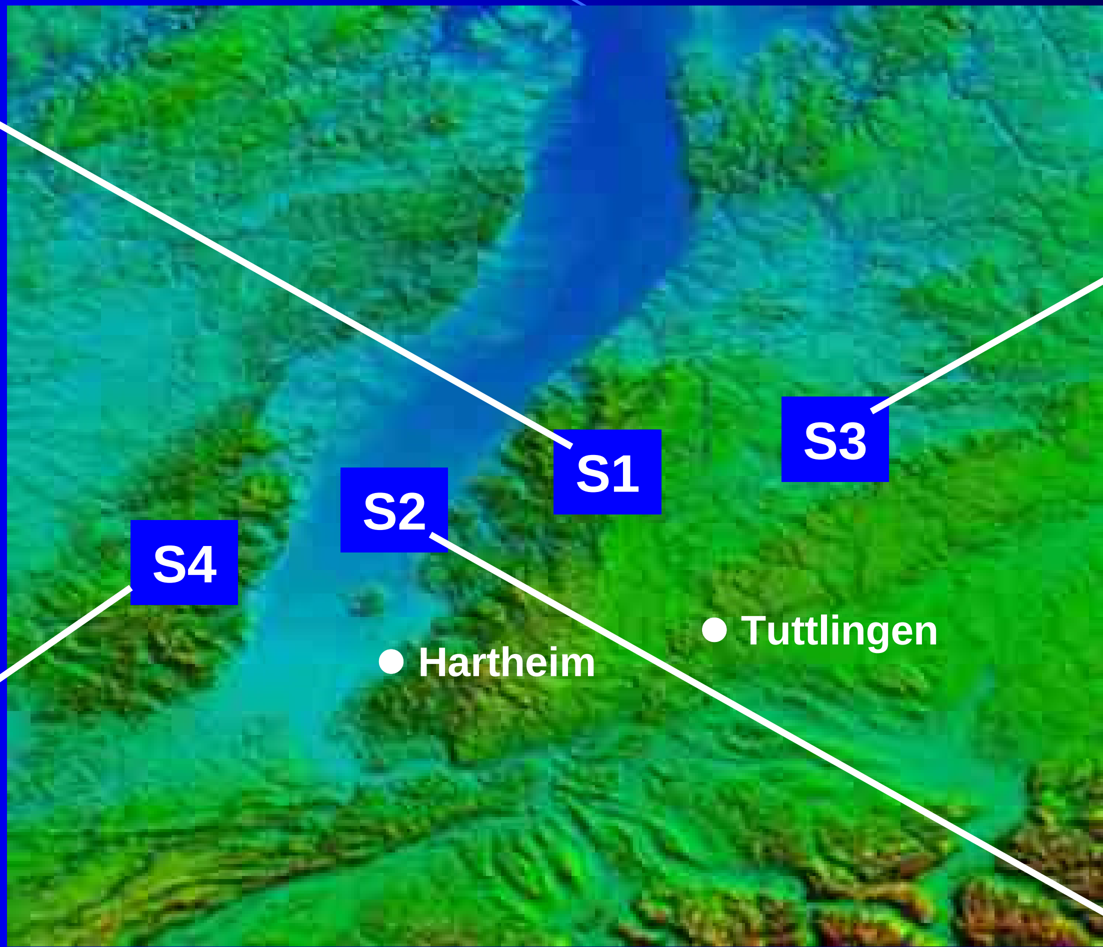
Lidars
Cloud radars
Precip. radars
Radiometers

S1

- AMF

WV DIAL
- RR Lidar
- WindTracer
- MWL & WiLi
- HATPRO

FZK Cloud Radar
UHOH X



S3

- CNR Raman Lidar
- CNR Radiometer
- UHH Cloud Radar
- WTR
- Sodar/RASS

Rhine valley

- RS Station (mobile)
- DOW

Between S1 and S3

- RS Station (mobile)
- DOW

S4

- CNRS Raman lidar
- CNRS Doppler lidar
- ASMUWARA
- Cloud radar

Black-Forrest valley entrances

- 2 FZK Sodars
- UF Sodar

S2

- UNIBAS Raman lidar
- UK Doppler lidar
- UK Ozone an Aerosol Lidar
- MICCY ·TARA

COPS Coordination

- MSG cloud, wind, and convective initiation research and algorithm transitions are currently ongoing
- Product quicklooks will be implemented at UW-CIMSS with EUMETSAT coordination
- Products will be available for in field evaluation
- MSG nowcasting application location for COPS still to be determined (UW-CIMSS, EUMETSAT, COPS …) using McIDAS or other software??
- MSG applications will be tested and working prior to COPS field experiment initiation so some maturity acquired before field use
- Time latency??

SUMMARY

- Proposed research focuses specifically on transitioning current GOES imager SATCAST algorithm for use with SEVIRI imager (more bands available) and then improving algorithm with additional channels
- Cloud classification algorithm is already in test mode for SEVIRI, mesoscale winds, and CI in transition
- The European COPS field experiment will be used as an DOE ARM-like validation resource to evaluate integrity of winds, cloud-type classification, and convective nowcast
- We are collaborating with Volker Gaertner, Marianne Koenig, and Johannes Schmetz at EUMETSAT to allow use in post-COPS era

References

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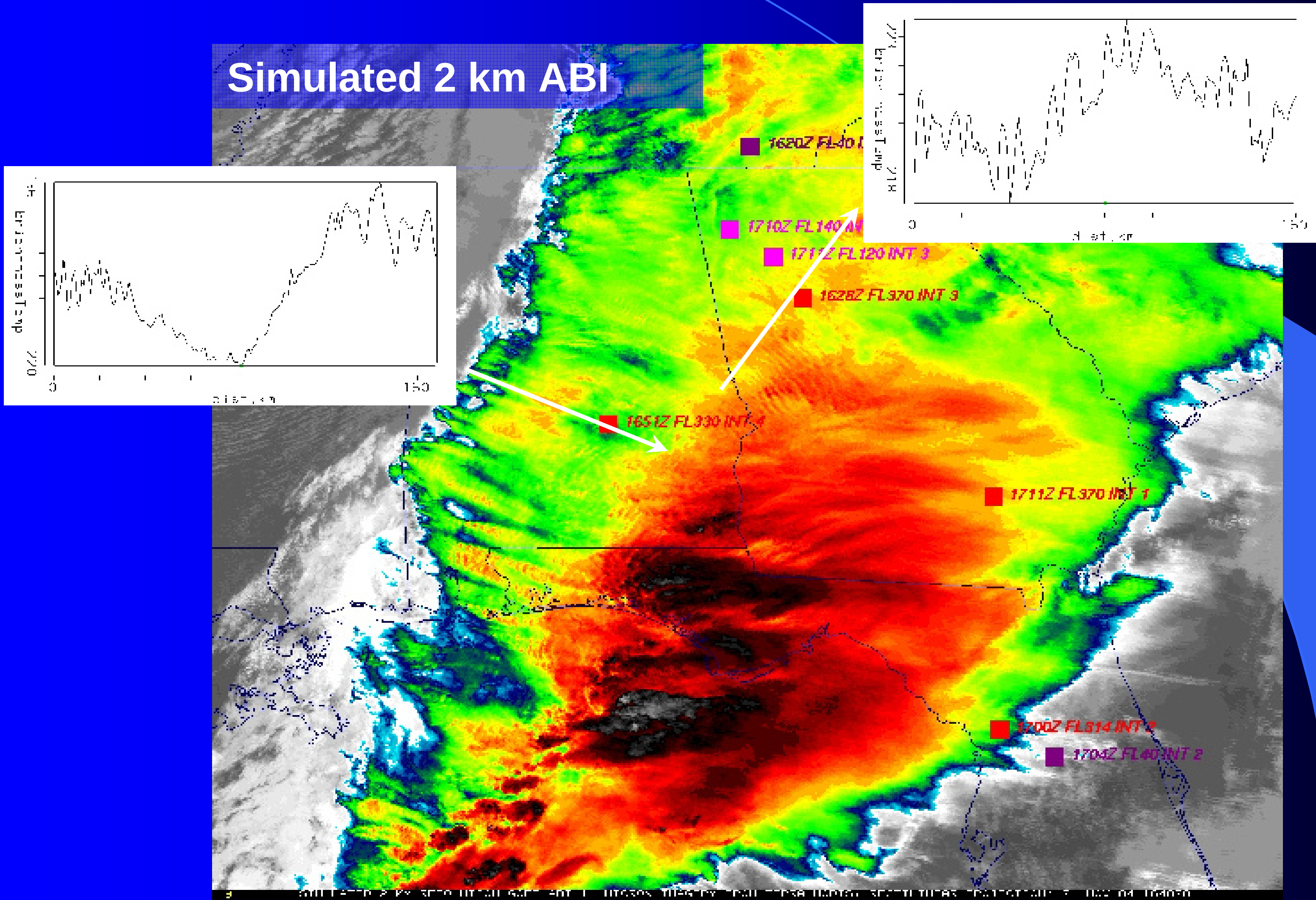
UW-CIMSS Satellite-based Nowcasting and Aviation Applications (SNAAP) Team Highlights

- Successful testing of GOES CI algorithm by FAA Convective Research Team
- Strong collaboration with worldwide Volcanic Ash Advisory Centers with regard to automated satellite-based volcanic ash detection and cloud height estimate
- New collaborations with NCAR Turbulence experts and satellite-based pathway for integration into NCAR Graphical Turbulence Guidance product
- These external ASAP collaborations have lead to new research/funding opportunities (NASA CAN, NASA ROSES, NOAA)
- CIMSS NASA Aviation Safety and Security Program Award for outstanding contributions to aviation weather research and development towards ASAP and TAMDAR programs
- 7 peer-reviewed papers, 17 conference presentations, and two MS Degrees

Convectively Induced Turbulence from ABI

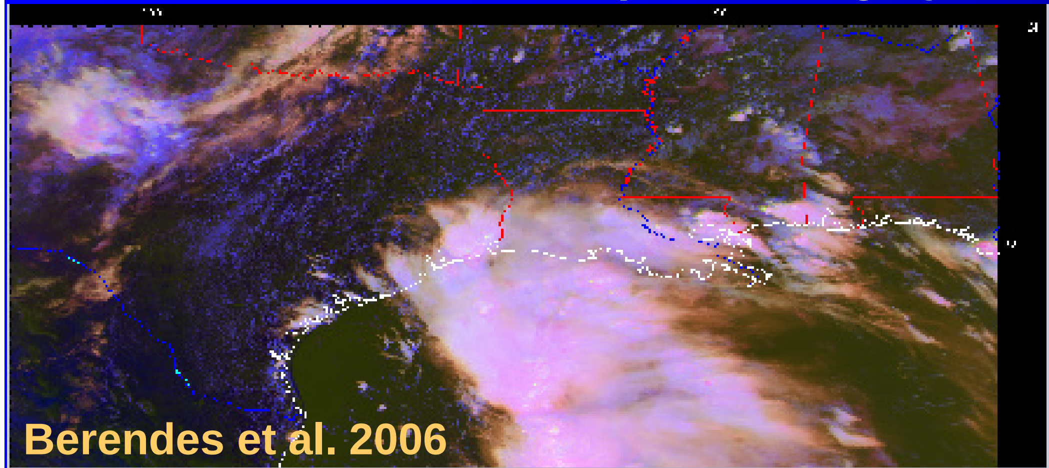
- High spatial resolution ABI imagery will allow us to observe the evolution of convectively-induced gravity waves, which can produce severe turbulence for aircraft



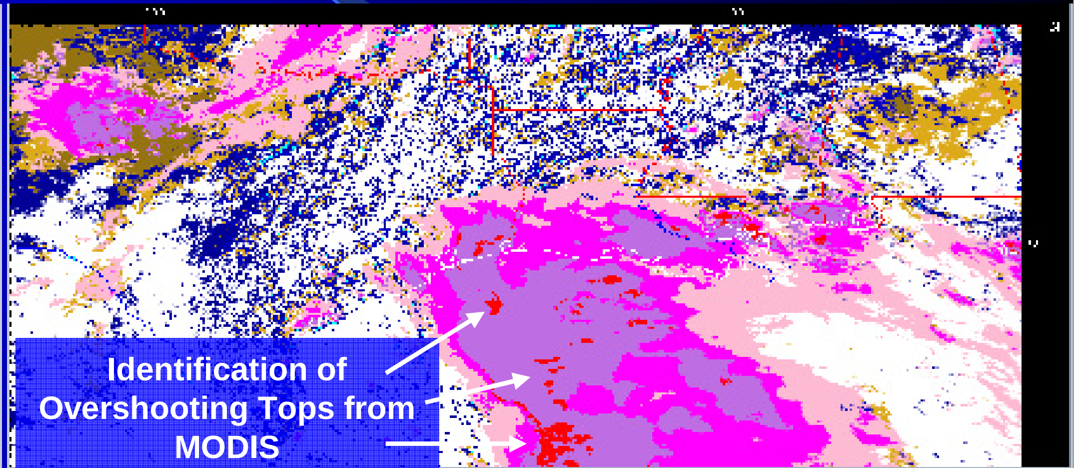
Objective Convective Cloud Classification from MODIS

- Increased spatial resolution and spectral coverage from MODIS allows for better depiction of hazardous convection over both land and ocean

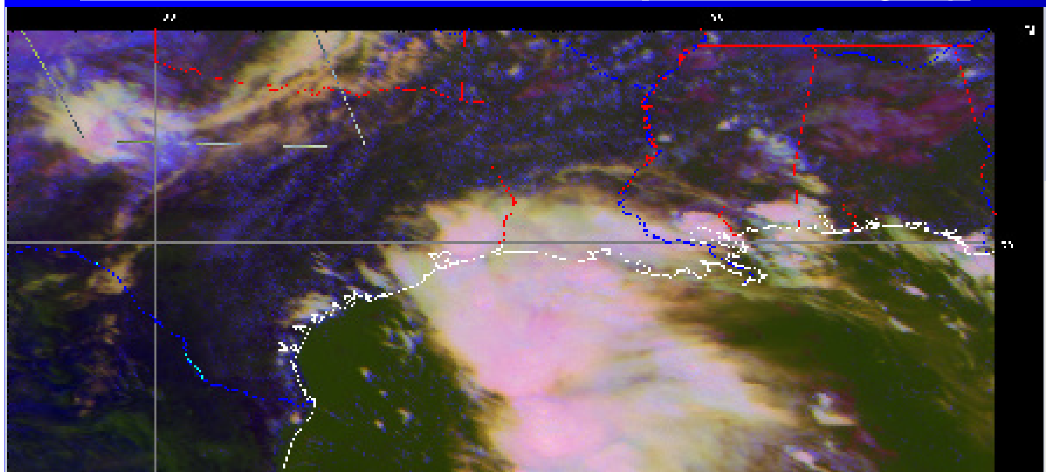
MODIS 3 Channel Composite Imagery



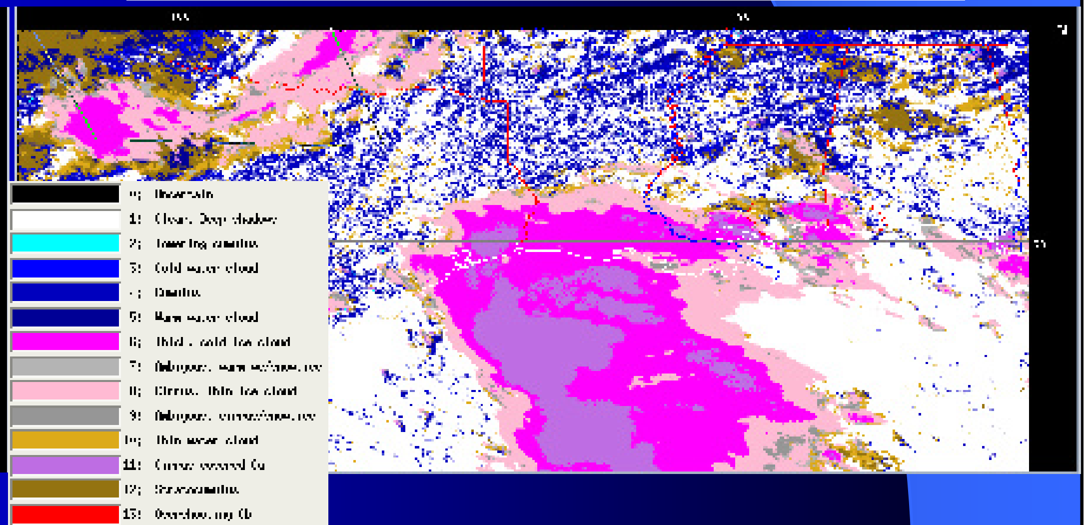
MODIS Convective Cloud Classifier



GOES-12 3 Channel Composite Imagery



GOES-12 Convective Cloud Classifier



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