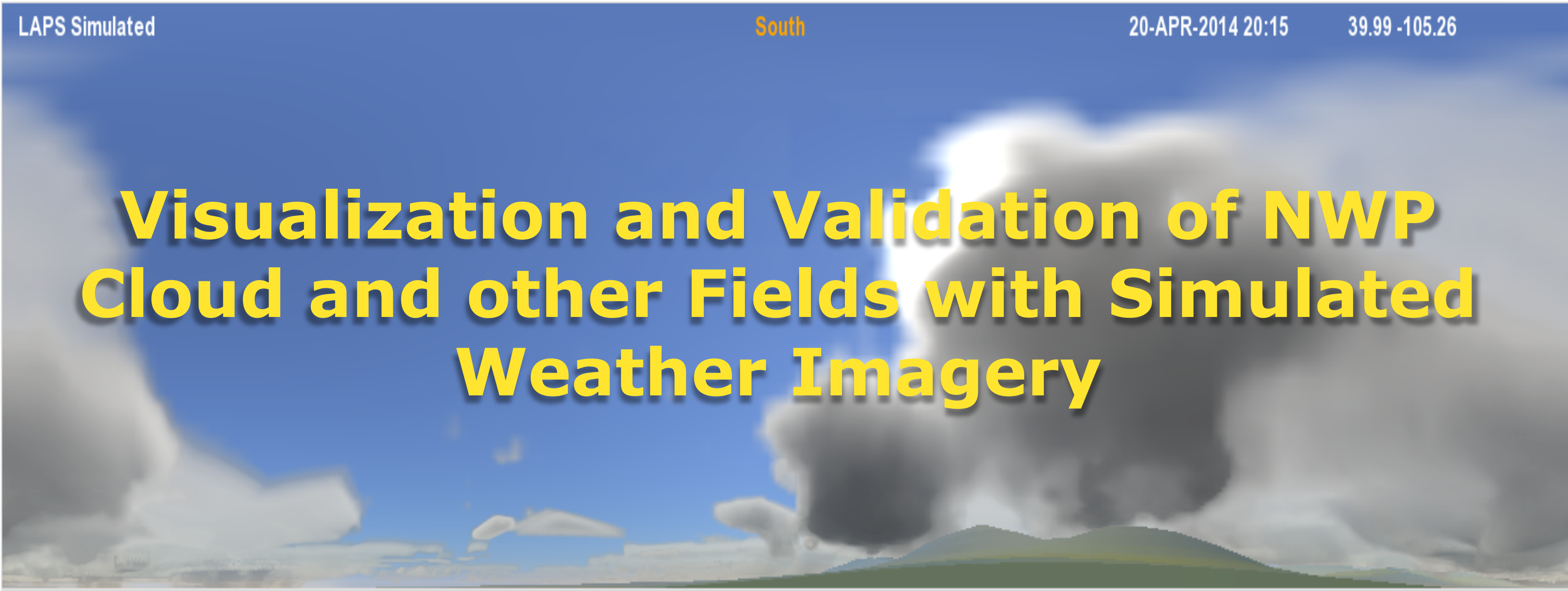
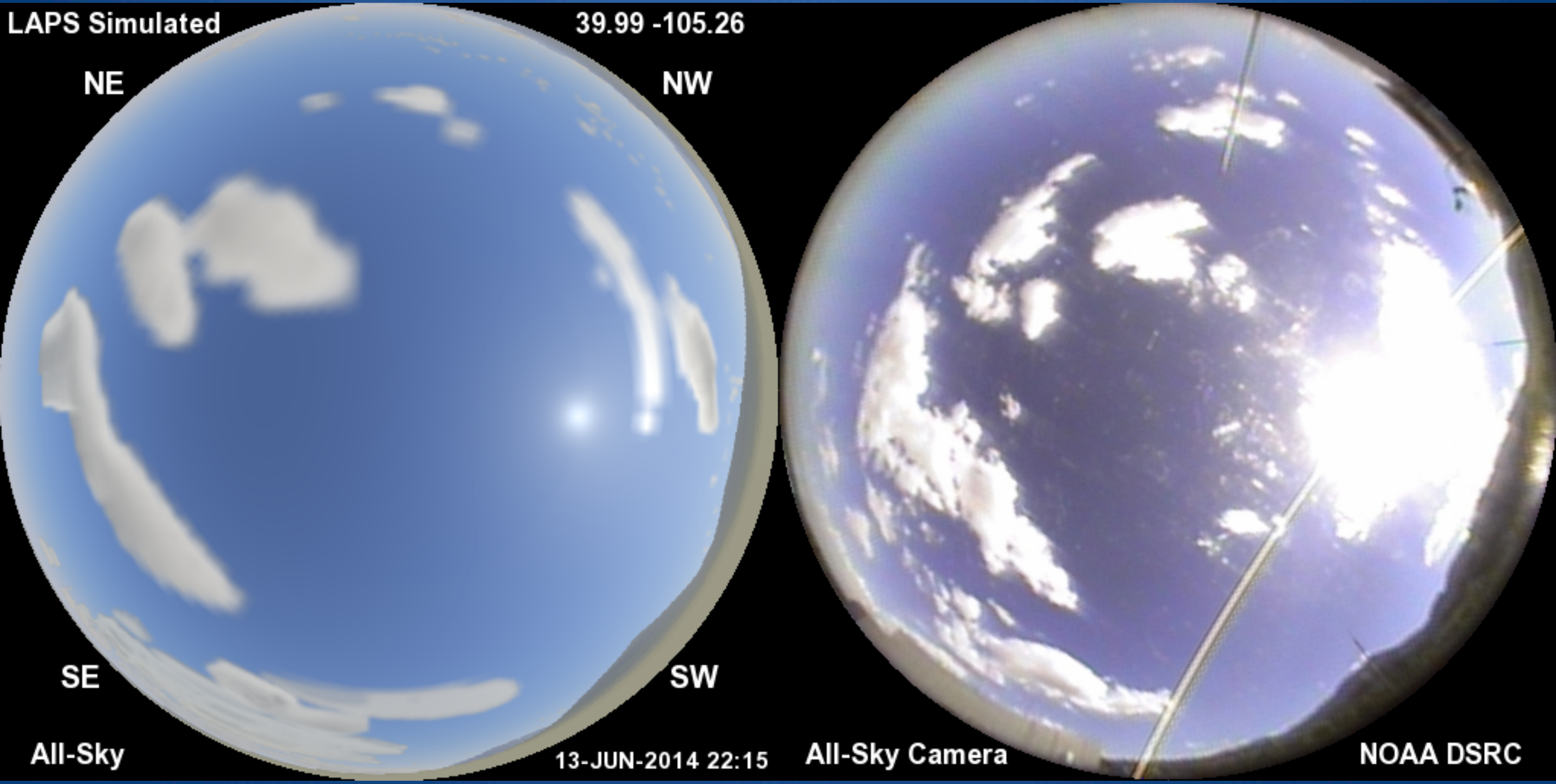


Visualization and Validation of NWP Cloud and other Fields with Simulated Weather Imagery

Steve Albers, Kirk Holub, Yuanfu Xie, Zoltan Toth (NOAA/ESRL/GSD)

Simulated All-Sky Image (left) Compared with All-Sky Camera (right)



A way to peer into the model analysis (or forecast)

All-sky Simulation Purpose

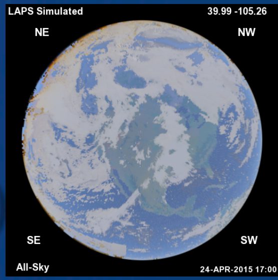
- Helps communicate capabilities of high-resolution real-time model, literally "peering inside"
  - Real-time Analyses
  - Forecasts
- Visual display conveys a lot of information
  - Clouds, Precipitation, Aerosols, Land Surface
- Display output for scientific and lay audiences
  - Connect weather phenomena with what can be seen in the sky (bringing science and art together)
- Helps guide improvements in cloud, etc. analyses and model initialization
  - Sensitive independent validation of both model fields and visualization package
- Potential use as an input for model data assimilation
  - Variational forward model (e.g. GSI or vLAPS)

All-sky Simulation Context

- Unique combination of analysis (or forecast) system with all-sky images having these elements
  - Real-time model data (clouds, precip, aerosols, gas, land surface)
  - Vantage point can be inside the atmosphere
  - Visually realistic (e.g. light scattering effects)
  - Works day and night
  - High resolution (including sub-kilometer)
  - Rapid update (e.g. 15 min)
  - Other visualizations we've seen have just some of these elements
- Coupling of 3-D model with camera imagery provides opportunities for improved, more detailed cloud and solar radiation forecasts
- Techniques are applicable to other visualization packages (e.g. TerraViz), and various models

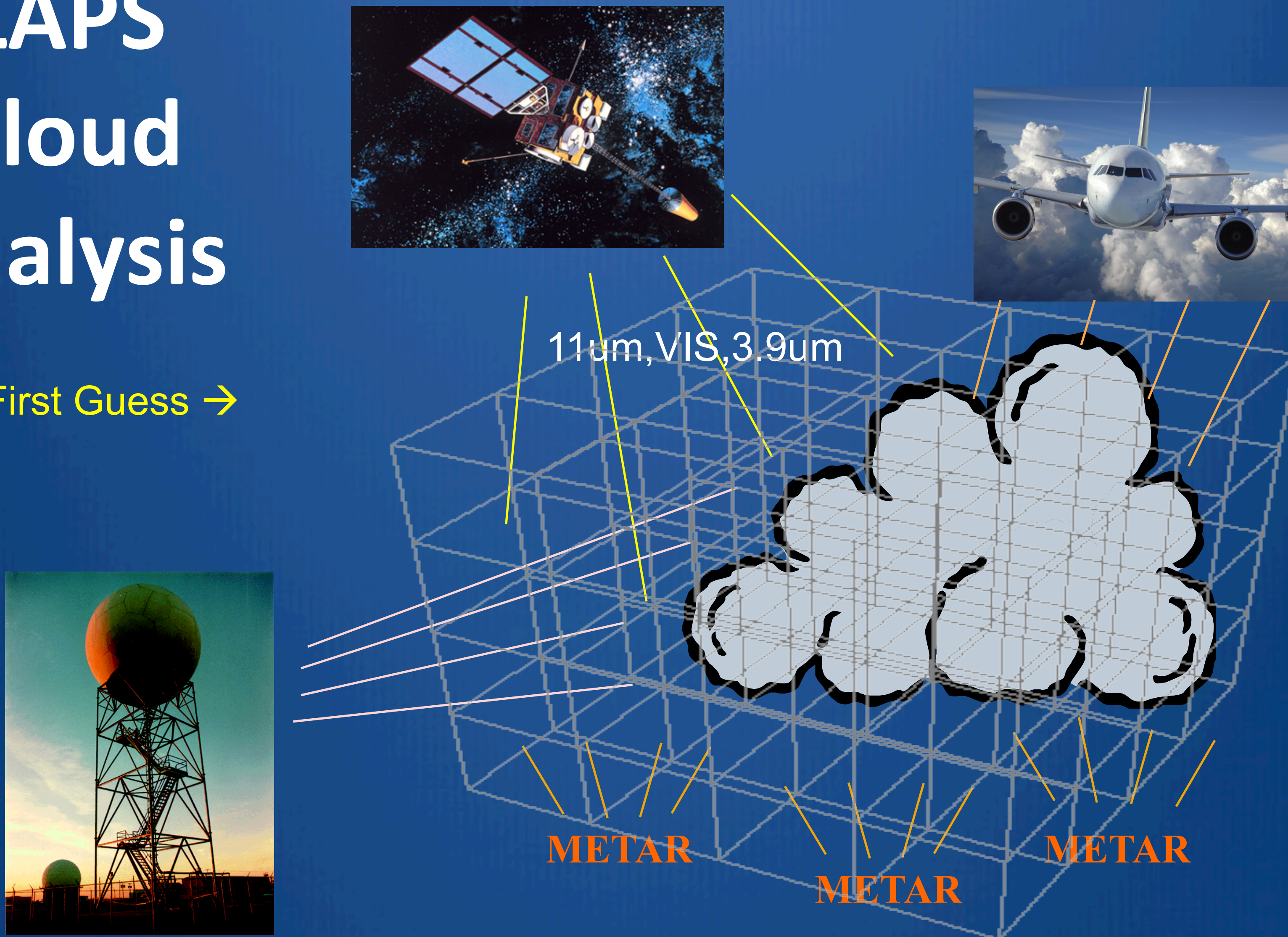
Sky & Weather Simulation Ingredients

- 3-D cloud / hydrometeor analyses (or forecasts)
  - Cloud liquid / ice, rain, snow, graupel
  - LAPS system developed at ESRL/GSD (for example)
  - Typical grid resolution = 500m
- Land Surface (3-color spectral reflectance - including snow cover)
- Locations of sun, moon, planets, stars
- Aerosol parameters
  - Optical depth (~.03-.30)
  - Scale height (~750-3000m)
  - Size distribution
- Nighttime city lights, airglow
- Specify vantage point – easily movable
  - Latitude, longitude, elevation / altitude (surface to 40000km)
  - Viewing window up to full 360° sphere (virtual reality)



LAPS Cloud analysis

First Guess →



(Albers et. al. 1996)

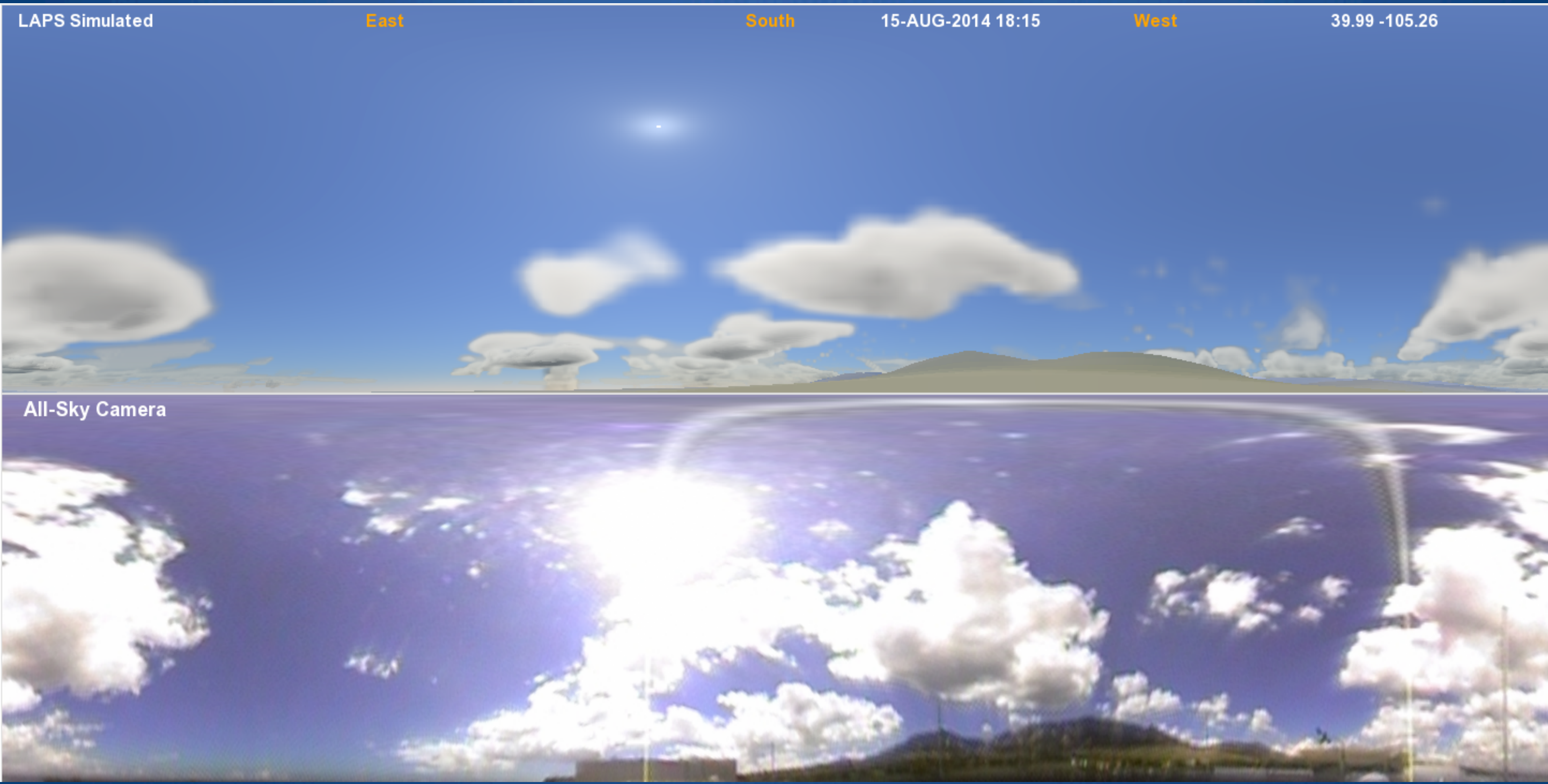
DSRC Rooftop
“Moonglow” Camera

Other cameras:

- Mt. Evans webcam
  (Meyer-Womble Observatory
  Univ. of Denver)
- Longmont Astronomical Society
- 300m BAO Tower (Erie, CO)

Cylindrical Panorama Comparison

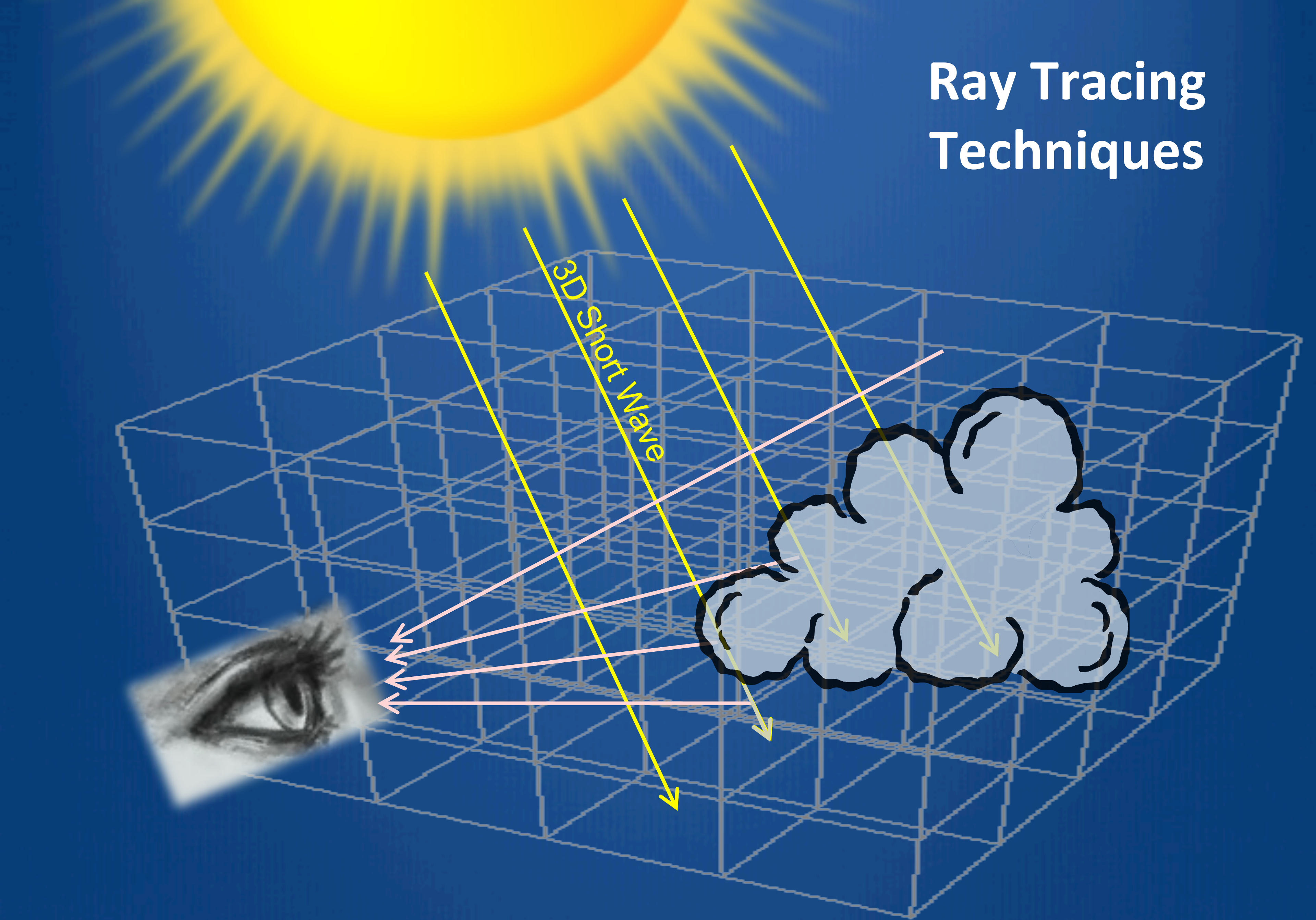
(1/4 degree resolution)



Top: simulated sky via LAPS analysis

Bottom: observed sky ("Moonglow" camera atop ESRL)

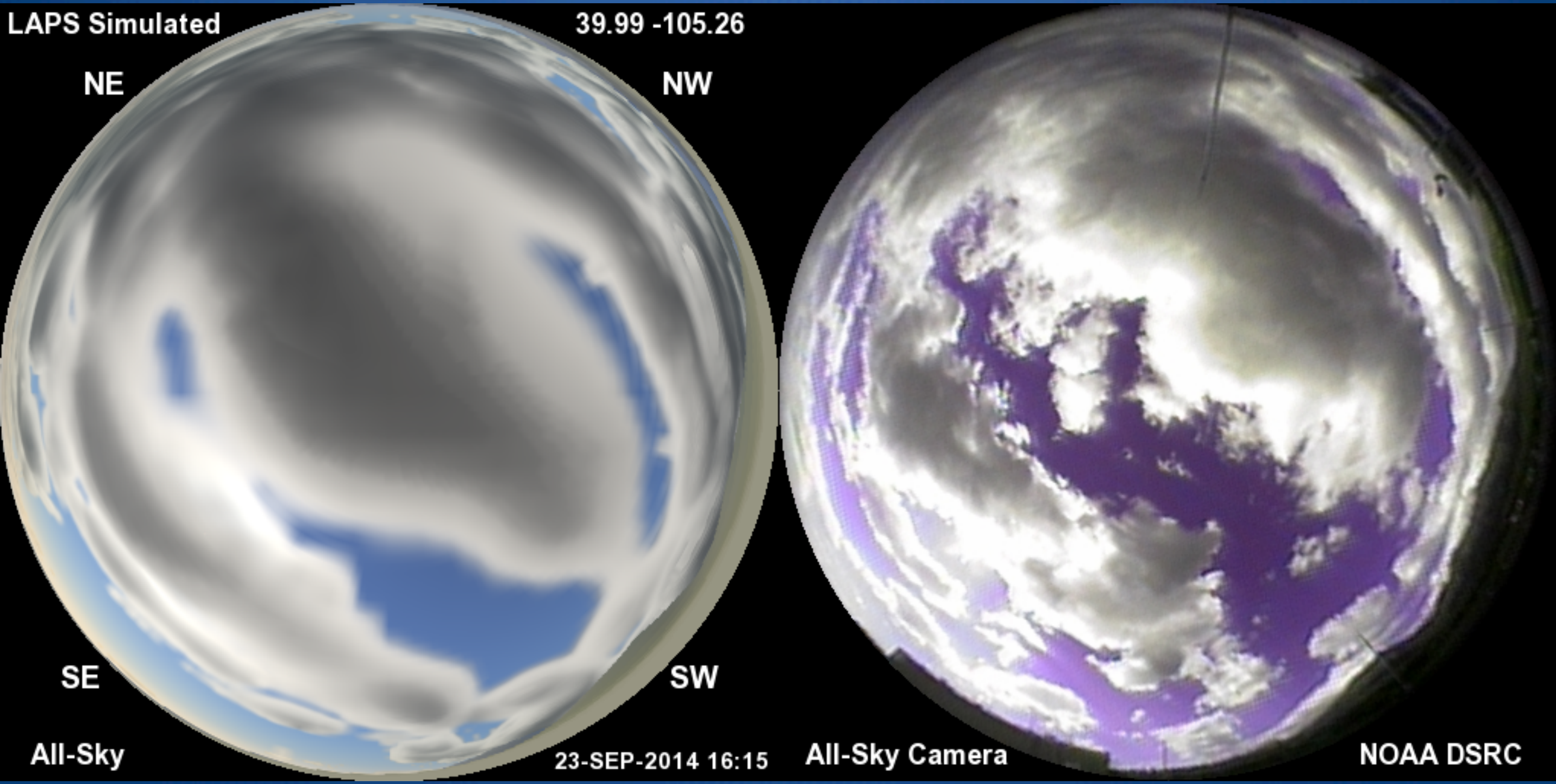
Ray Tracing Techniques



Ray Tracing Techniques

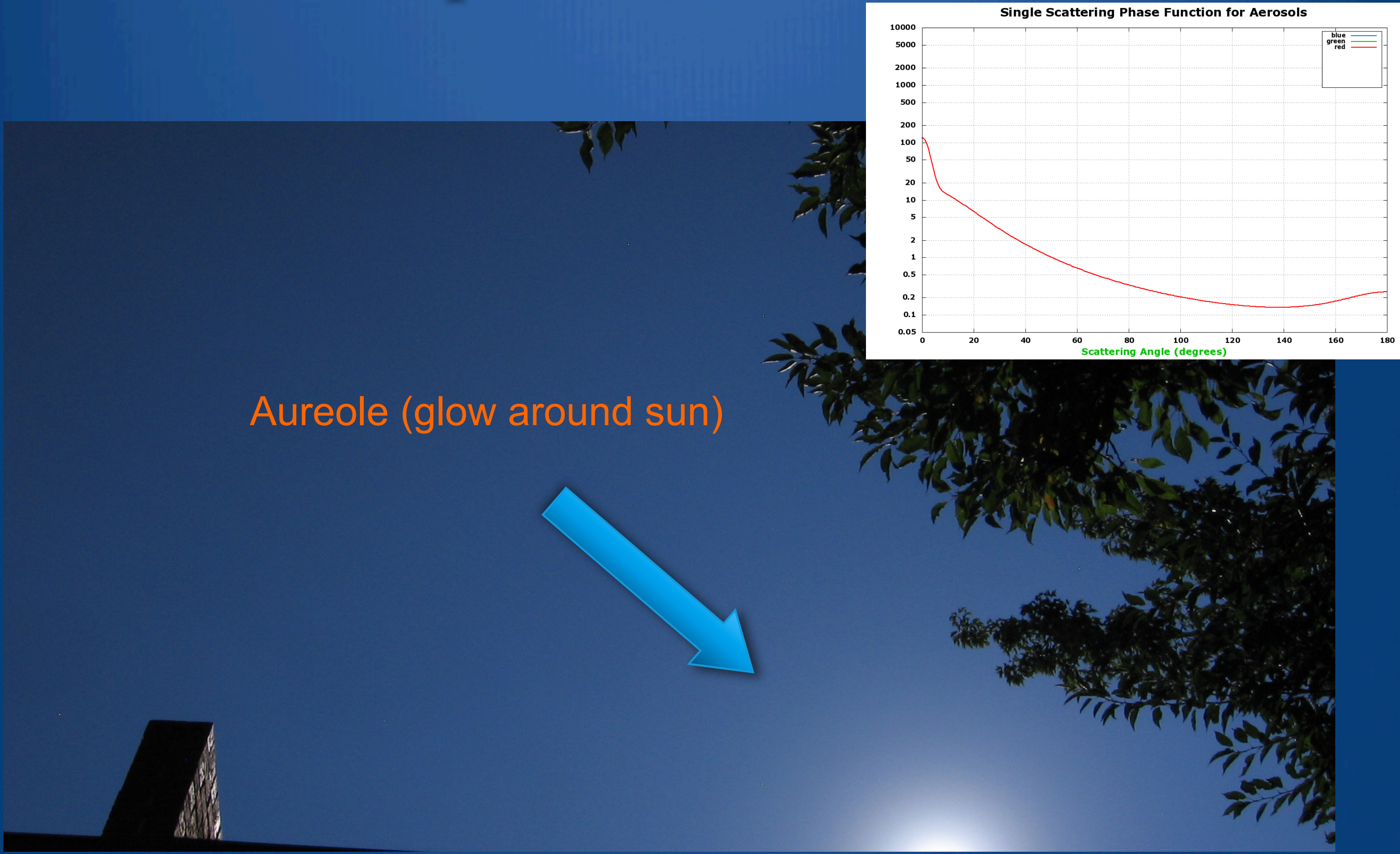
- Determine 3-D short wave radiation field
- Light scattering by hydrometeors, aerosols, gases
  - Cloud liquid / ice, rain, snow, graupel
  - Determine optical thickness along light ray paths
  - Rayleigh and Mie scattering
  - Single / Multiple scattering phase functions
  - Calculated using 3 colors
  - Shadowing effects and terrain
- Light scattering by land / water / snow surface
  - Spectral albedo and reflectance (BRDF) used
  - Spectral Solar Irradiance fields (GHI, DNI) - Renewable Energy Link
  - Terrain slope considered

Cloud Illumination (and scattering)



Thicker central regions of wave clouds are darker

Closeup of Solar Aureole

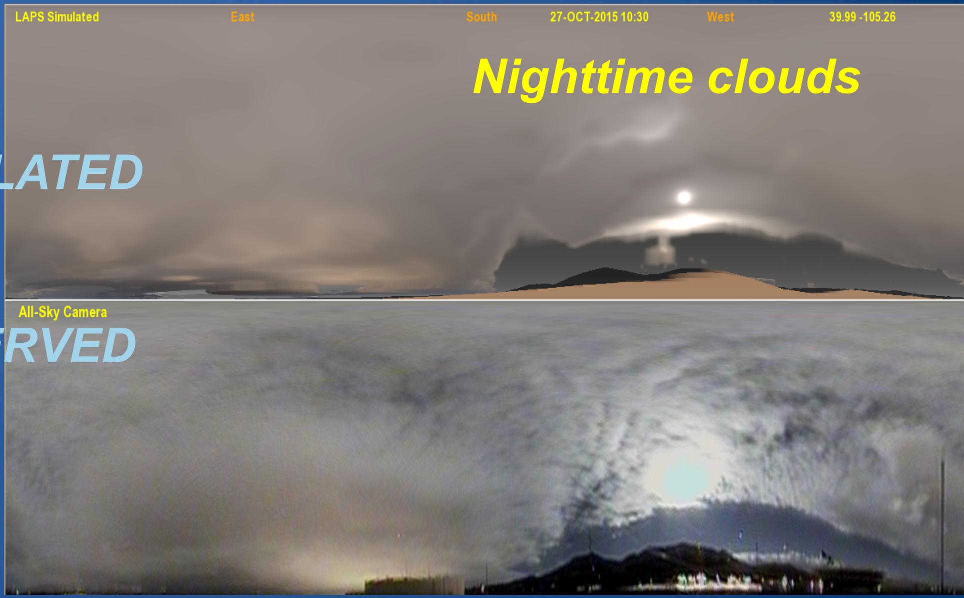


Aerosols modeled with vertical extinction coefficient profile and scattering phase function. Phase function and Angstrom exponent depend on size distribution

Cylindrical Panoramic Analysis Comparison

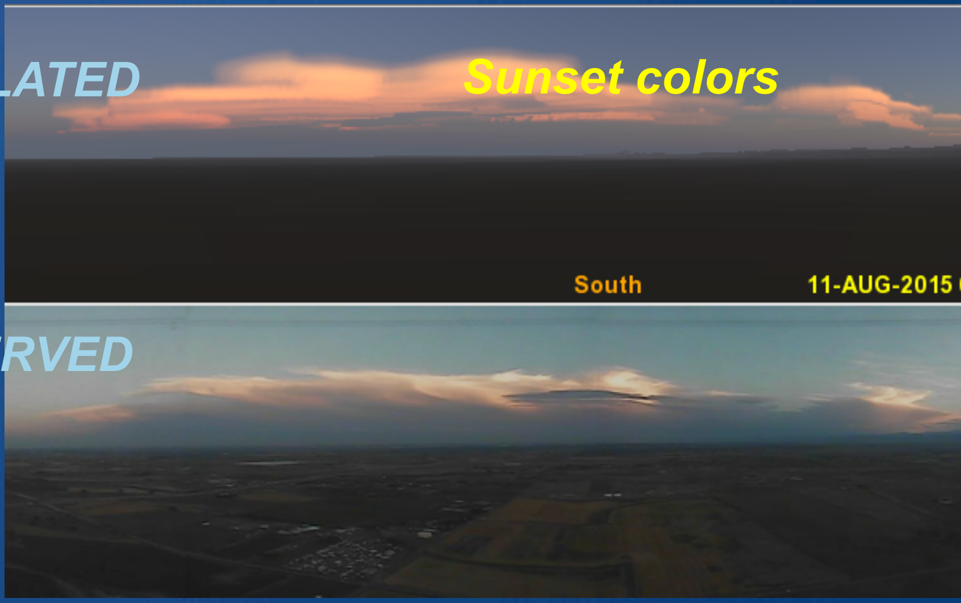
(500m grid - 1/4 degree angular resolution - animation)

FOUR SIMULATED vs OBSERVED COMPARISONS



SIMULATED

OBSERVED

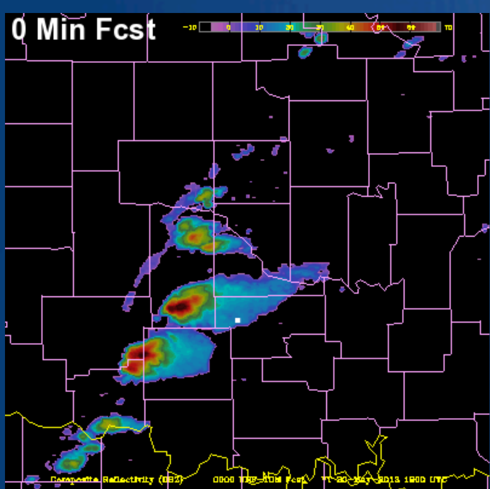


SIMULATED

OBSERVED

LAPS / WRF Forecast Animation

(1km grid - 1/4 degree angular resolution)



"▪" is observer position

Moore tornado storm - May 20, 2013

Initialized 1900 UTC / Valid times 1900-2020 UTC

Moving storm perspective at 1-min intervals

- **"Chaser Cam"**

Good hot-start continuity

Recent Cloud Analysis Improvements
(*aided by all-sky comparisons*)

- Improved consistency of cloud albedo and microphysical variables
- Improved consistency between visible, IR, METARs and model first guess
- Better thin cirrus detection
- Satellite navigation
  - Parallax offset using various techniques
  - Systematic satellite navigation error correction

Variational Cloud Analysis

- Variational cloud analysis currently under development
  - based on existing LAPS and GSI cloud analyses
- Simultaneous solution with all types of data + constraints
- Use satellite radiance (e.g. CRTM) or algorithms (e.g. DCOMP/NCOMP)
  - radiances may blend more naturally with other types of data, helping to fill in clouds missed by satellite
- Radars used for precipitating hydrometeors
- Appropriate forward models and constraints
  - constraints between state variables and hydrometeor fields
- Will use all-sky cameras as input data

Future Directions

- Improve ray-tracing techniques
  - Radiation calculations
  - Monte Carlo methods?
  - Beyond Clouds: Aerosols + Land surface (Earth System)
- Improve scattering phase functions
- Connect with microphysics packages and chemistry models
  - Details on hydrometeor & aerosol species
  - Both for validation and for DA
- IR cameras
  - ASIVA IR camera used by ARM
- Add polarization?
- Use TerraViz / Game Engines for fast visualization

Future Directions - II

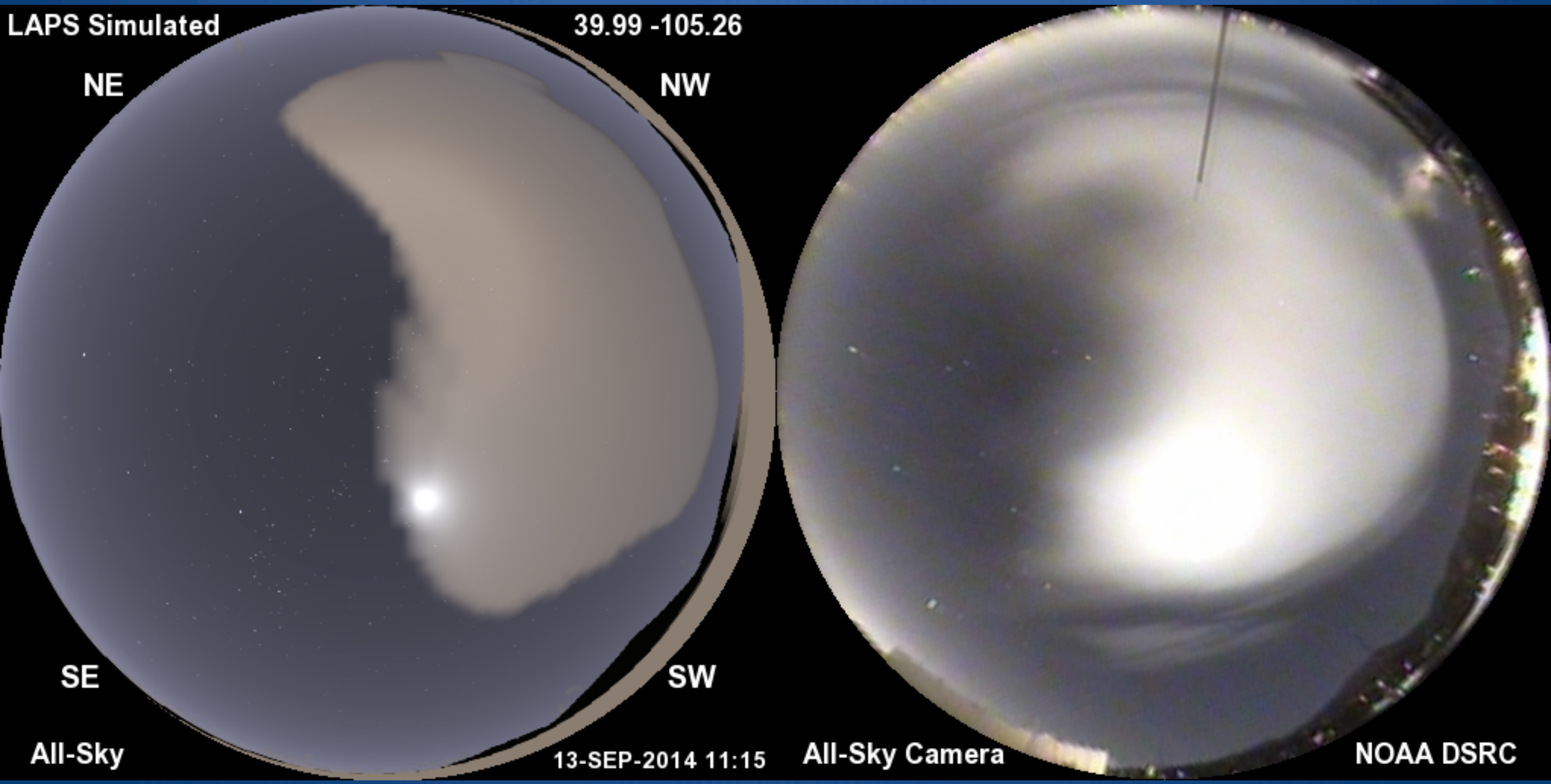
- More cameras, via NOAA's observing systems?
  - Add to ASOS?
  - FAA camera networks (e.g. Alaska)
  - Airborne cameras?
  - CSTAR / AWIPS
- Data assimilation with variational cloud and GSI analysis
  - Efforts underway to use GSI cloud/hydrometeor analysis (used in HRRR/RAP) with all-sky forward model for nowcasting.
  - Use derived METAR, cloud mask, image correlation, or spectral radiances
  - Check applicabilty of available RTMs

“Launch” into the stratosphere (40km up), 360^{o} spherical view

More at laps.noaa.gov/allsky/allsky.cgi

Backup Slides

Nighttime Clouds (and stars)



Illumination by moonlight and artificial surface lighting

Rainbow Case Analysis Comparison

August 28 2014   01:15UTC (DSRC site)


LAPS Simulated
South
20-APR-2014 20:15
39.99 -105.26
The sky is the limit!
All-Sky Camera
More at laps.noaa.gov/allsky/allsky.cgi