All-sky imagery – observations and simulations with the Local Analysis and Prediction System (LAPS)

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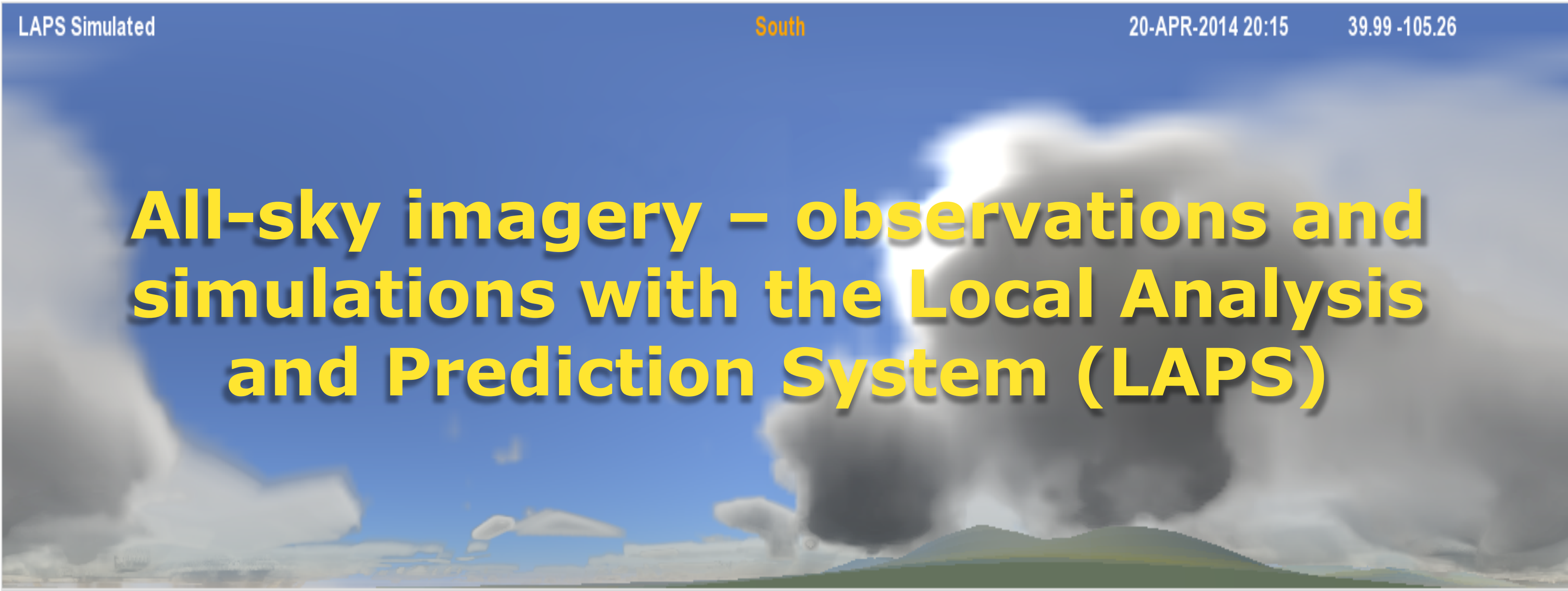
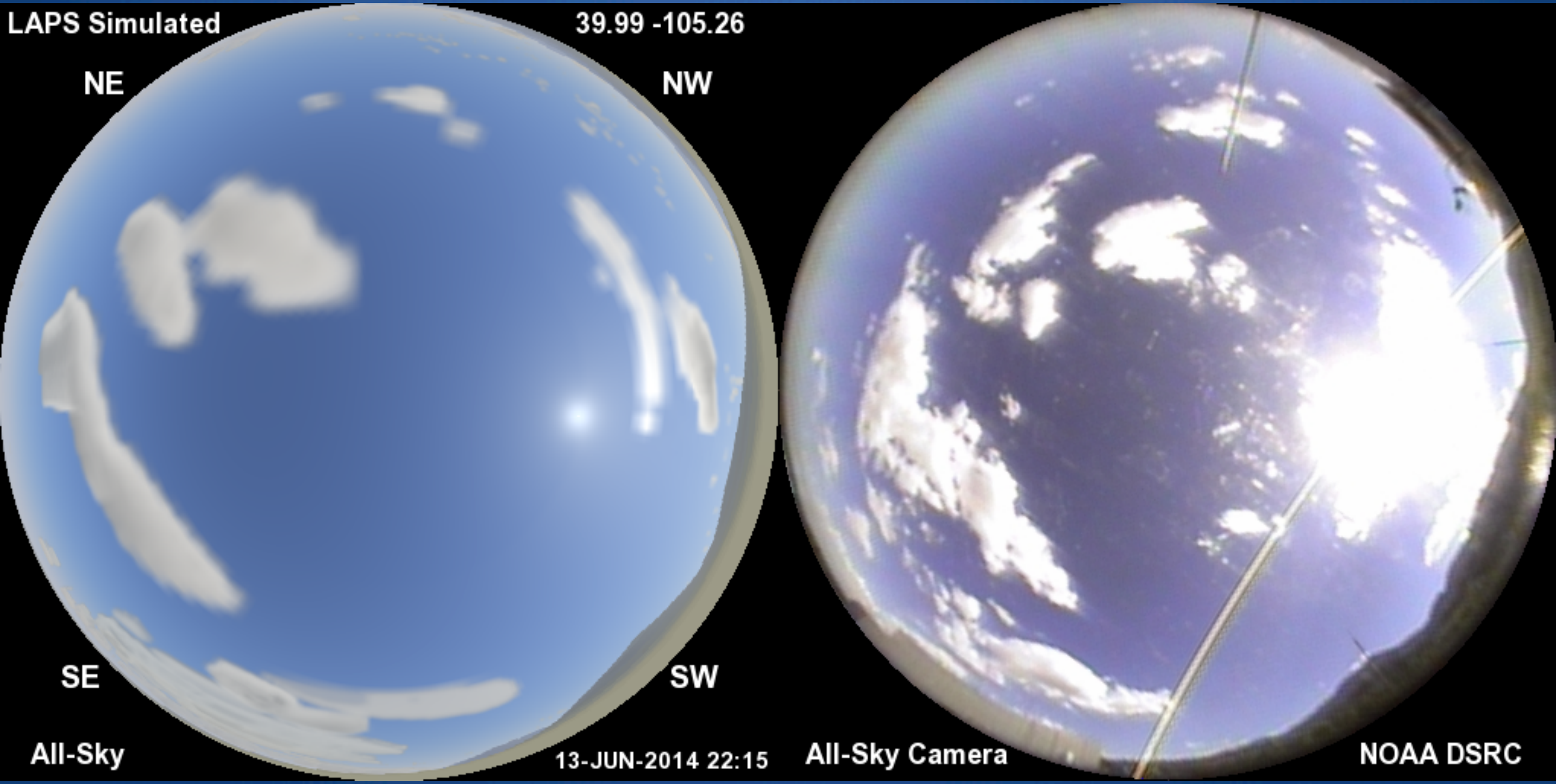
(NOAA/ESRL/GSD)



Updated 6/22/2015 1830UTC

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



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

All-sky Simulation Purpose

- Helps communicate capabilities of high-resolution real-time model, literally "peering inside"
  - Real-time Analyses
  - Forecasts
- Display output for scientific and lay audiences
  - Connect weather phenomena with what can be seen in the sky (bringing science and art together)
- Visual display conveys a lot of information
  - Clouds, Precipitation, Aerosols, Land Surface
- 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 (for vLAPS & GSI)

All-sky Simulation Context

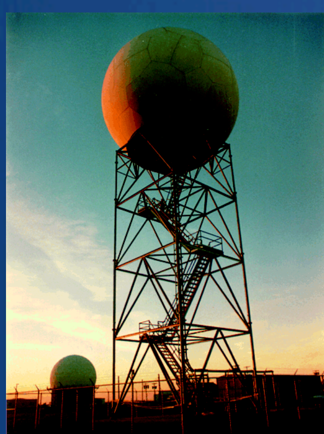
- Unique combination of analysis (or forecast) system with all-sky images having these elements
  - Real-time model data (clouds, precip, aerosols, gas, land surface)
  - Vantage point inside the atmosphere
  - Visually realistic (e.g. light scattering effects)
  - Works day and night
  - High resolution (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

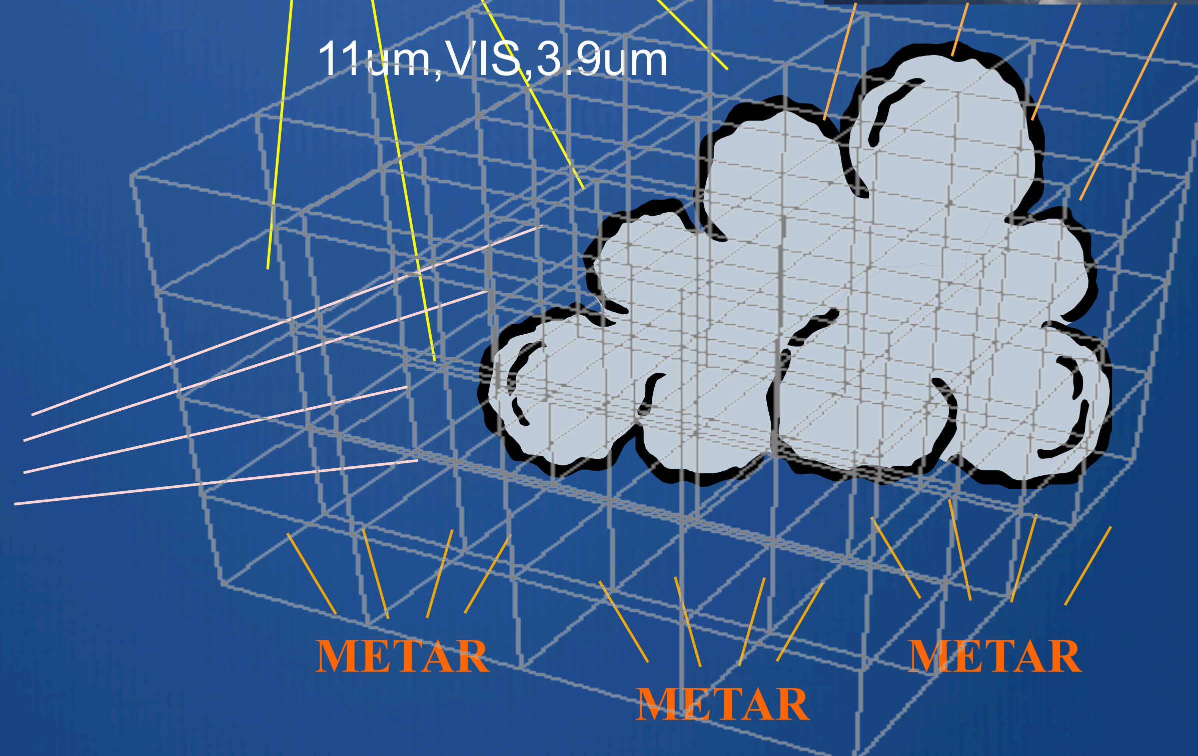
All-sky Simulation Ingredients

- 3-D LAPS cloud analyses (or forecasts)
  - Cloud liquid, ice, rain, snow, graupel
  - LAPS model developed at ESRL/GSD
  - Typical grid resolution = 500m
- Land Surface info (3-color surface albedo, including snow cover)
- Locations of sun, moon, planets, stars
- Specification of Aerosols
  - Optical depth (~.03-.30)
  - Scale height (~1500-2000m)
  - 3-D extinction coefficient derived from above two quantities
- Specification of nighttime city lights
- Specify vantage point – easily movable
  - Latitude, longitude, elevation

LAPS Cloud analysis

First Guess →





(Albers et. al. 1996)

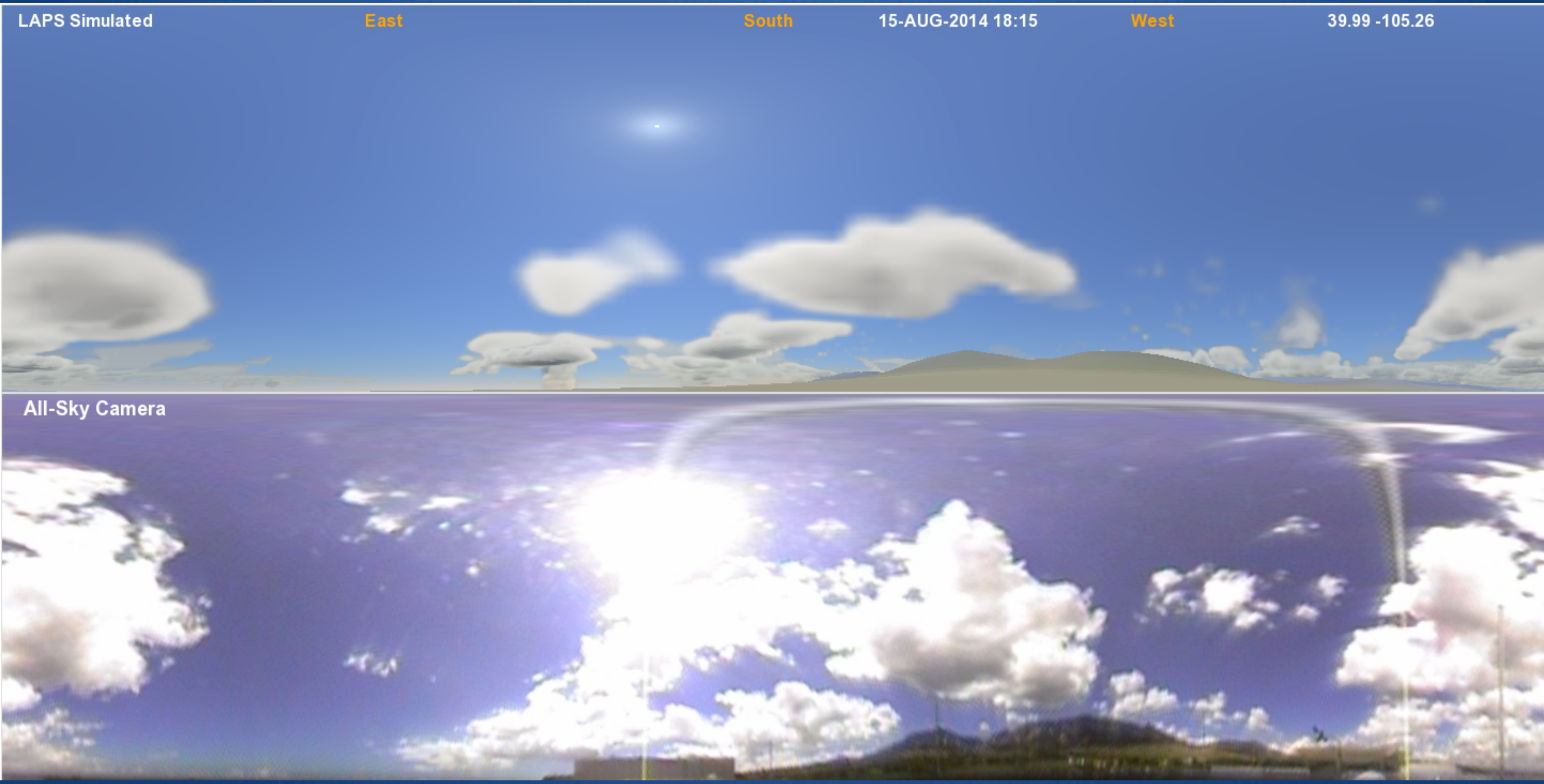
DSRC Rooftop
“Moonglow” Camera

Other cameras:

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

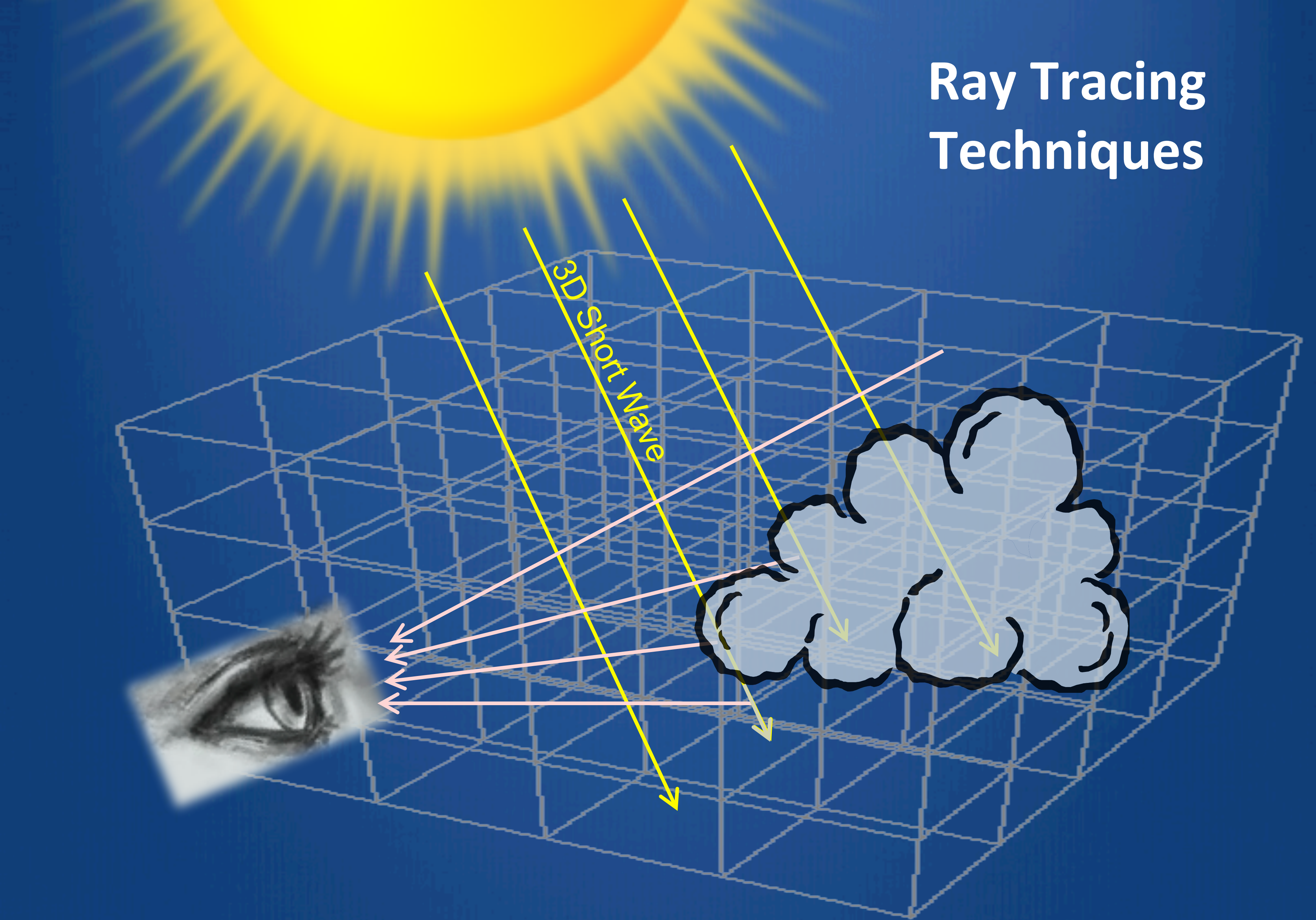
Cylindrical Panoramic View

(1/4 degree resolution)



Top is LAPS analysis simulation
Bottom is camera image ("Moonglow" camera atop DSRC)

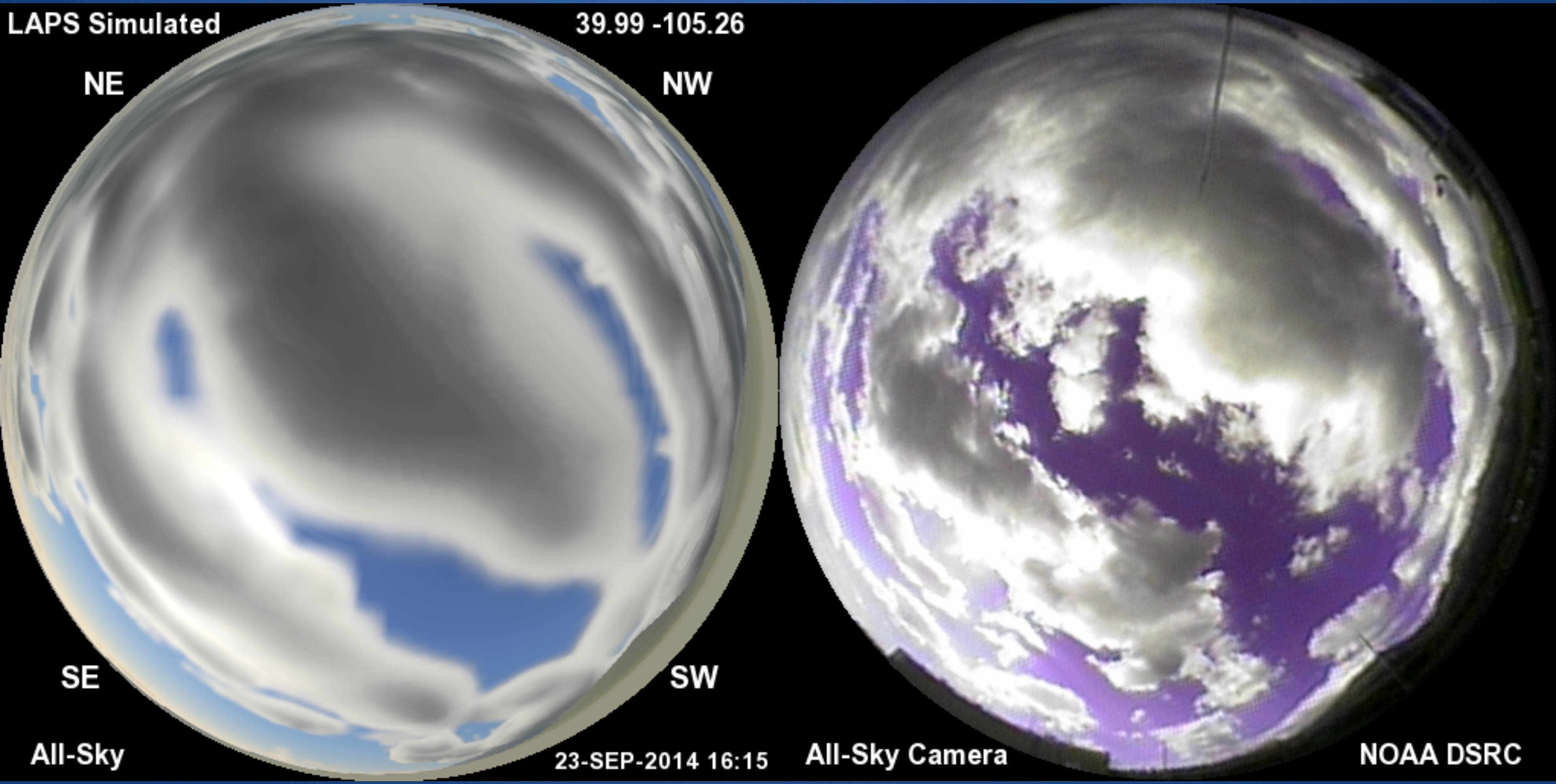
Ray Tracing Techniques



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
- Further details on web site
    - laps.noaa.gov/allsky/allsky.cgi

Cloud Illumination (and scattering)

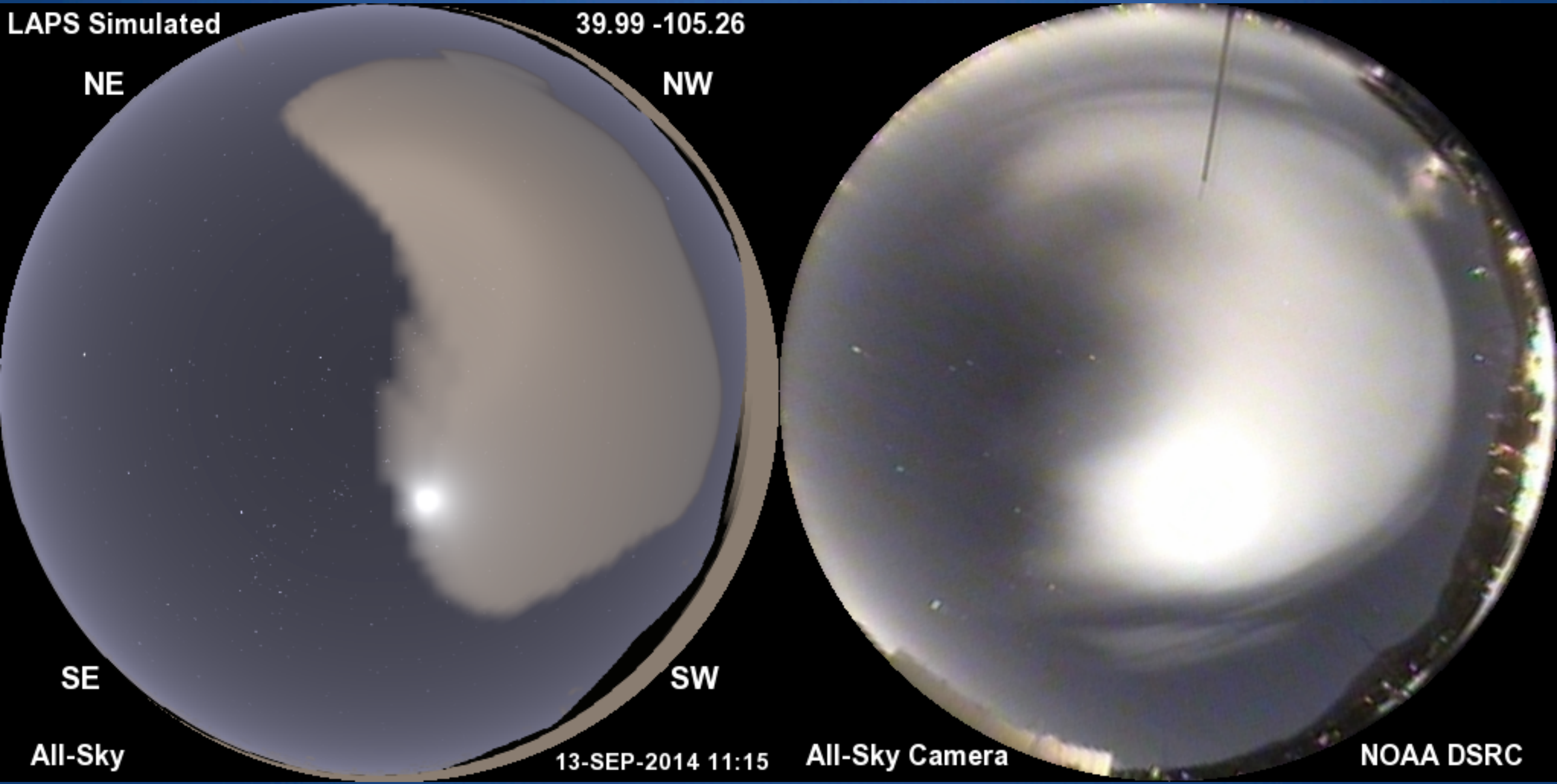


Thicker central regions of wave clouds are darker

Closeup photo of Solar Aureole

Aerosols modeled with appropriate scattering phase function

Nighttime Clouds (and stars)



Illumination by moonlight and artificial surface lighting

Cylindrical Panoramic Analysis Comparison

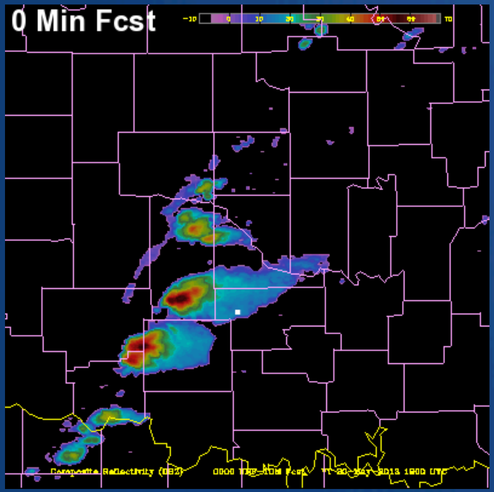
(500m grid - 1/4 degree angular resolution - loop)

Rainbow Case Analysis Comparison

August 28 2014 01:15UTC (DSRC site)

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
  - Applying parallax offset using various techniques
  - Systematic satellite navigation error correction

Variational Cloud Analysis

- "vLAPS" currently under development
  - based originally on traditional LAPS cloud
- Simultaneous solution with all types of data
- 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
- Appropriate forward models and constraints
  - constraints between satellite and other data types
- Will use all-sky cameras as input data

Future Directions

- Improve ray-tracing techniques
  - e.g. low sun angles
  - Monte Carlo methods?
- Improve scattering phase functions
- Connect to microphysics packages and chemistry models
  - Both for validation and for DA
- Add IR cameras and visualizations
  - ASIVA IR camera used by ARM
- Add polarization

Future Directions - II

- Incorporate into NOAA's observing systems?
  - Add to ASOS?
  - FAA camera networks (e.g. Alaska)
- Data assimilation with "vLAPS" and GSI
  - Planning underway to use GSI cloud/hydrometeor analysis (used in HRRR/RAP) with all-sky forward model for nowcasting.
  - Use derived METAR, cloud mask, or actual radiances
  - Check applicabilty of available RTMs


LAPS Simulated
South
20-APR-2014 20:15
39.99 -105.26
The sky is the limit!
All-Sky Camera
Updated 11/13/2014 xxxxUTC