All-sky imagery: Observations and Simulations with the Local Analysis and Prediction System (LAPS)

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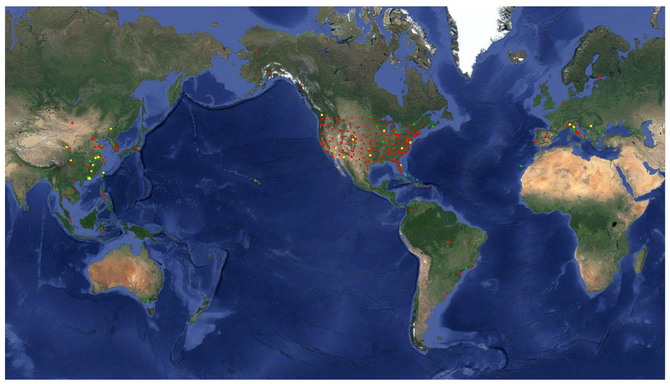
Introduction

- Local Analysis and Prediction System (LAPS) is used for data assimilation, nowcasting, and model initialization / post-processing
- High Resolution and Rapid Update
- Blends a wide variety of in-situ and remotely sensed data sets (e.g. METARs, mesonets, radar, satellite)
- About 150 group and individual users worldwide
- Federal, state agencies (e.g. NWS, USAF, California Dept. Water Resources)
- Private Sector (e.g. Greenpower Labs)
- Academia (e.g. University of North Dakota)
- International (e.g. Taiwan CWB, FMI, CMA, KMA)
- **System can be used to analyze and forecast clouds and related sky conditions**



Sites around the world where LAPS is being used

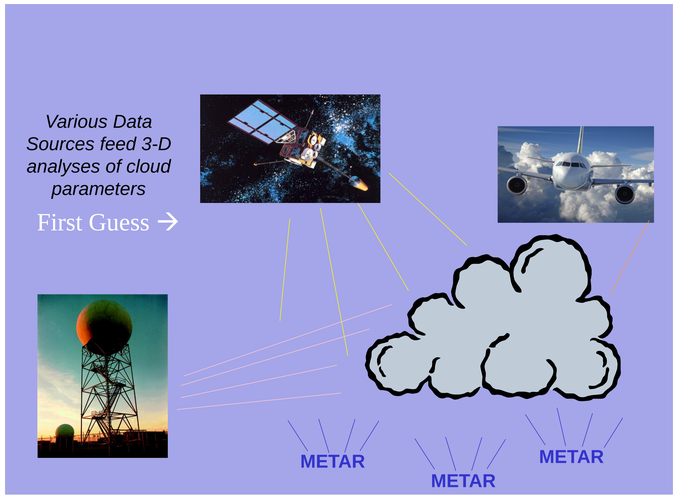
LAPS Attributes

- Analysis has variational and "traditional" options
- LAPS analyses (**with active clouds**) are used to initialize a meso-scale forecast model (e.g. WRF)
- Highly portable and efficient software with adjustable resolution
- **Utilizes 1km, 15min visible satellite imagery along with IR for rapid updating**
- **More info: http://laps.noaa.gov** (steve.albers@noaa.gov)

All-sky Simulation Purpose

- Helps communicate capabilities of high-resolution LAPS model, literally "peering inside"
- Display output for scientific and lay audiences
- Sensitive Independent validation
  - cloud microphysics, aerosols, land surface
- Visual display conveys a lot of information
- Helps guide improvements in cloud, etc. analyses and model initialization
- Cameras represent a potential data source for model data assimilation (radiances / cloud mask)

Three-Dimensional Cloud Analysis



Simulation Ingredients

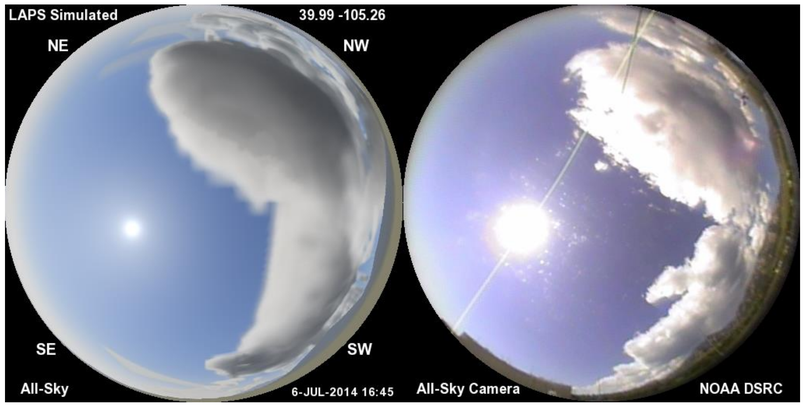
- 3-D LAPS 500m Resolution Gridded Cloud Analyses (cloud liquid, ice, rain, snow)
- Specification of Aerosols (optical depth, scale height)
- Atmospheric Pressure (for gas component)
- Vantage point from same location as camera (ground level or any altitude from 0-2000km)
- Location of Sun and other light sources (moon, planets, stars, sfc lights)

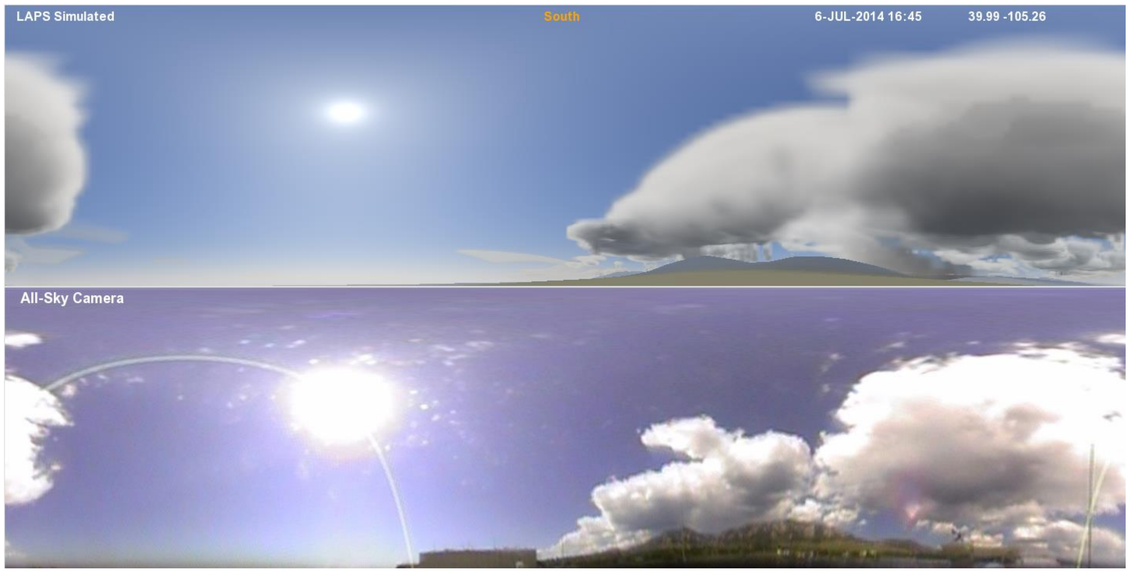
Polar "Fish-eye" lens view

Left is LAPS analysis simulation, right is camera image (Moonglow All-sky Camera)

Cylindrical Panoramic View

Top is reprojected LAPS analysis simulation, bottom is camera image





Visualization Technique

- Illumination of clouds, air, and terrain pre-computed
  - Simplified 3-D radiative transfer - 3 visible wavelengths
- Sky brightness based on sun and other light sources
- Ray Tracing from vantage point to each sky location
- Scattering by intervening clouds, aerosols, gas (via effective particle radius and optical thickness)
- Terrain shown when along the line of sight
- Physically and empirically based for best efficiency
- Compare with RTMs (CRTM, RRTMG, etc.)?

Clear Air (Gas/Aerosol) Sky Brightness

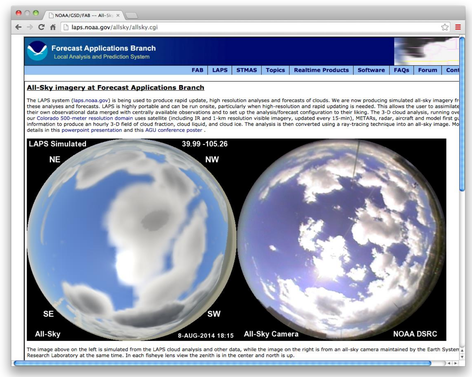
- Source can be sun or moon
- Rayleigh Scattering by N_2,O_2 Molecules (blue sky)
  - Minimum brightness 90 degrees from light source
- Ozone (O_3) absorption
  - Contributes to blue zenithal sky with low sun or twilight
- Mie Scattering by Aerosols
  - Multi-parameter (e.g. Henyey-Greenstein) phase functions
- Cloud/Terrain shadows can show crepuscular rays
- Night-time sky brightness from other light sources
  - Planets, stars, airglow, surface lighting
- Earth shadow geometry considered during twilight
  - Secondary scattering reduces contrast
- Ongoing work – improve spectral radiance handling

Cloud / Precip Scattering

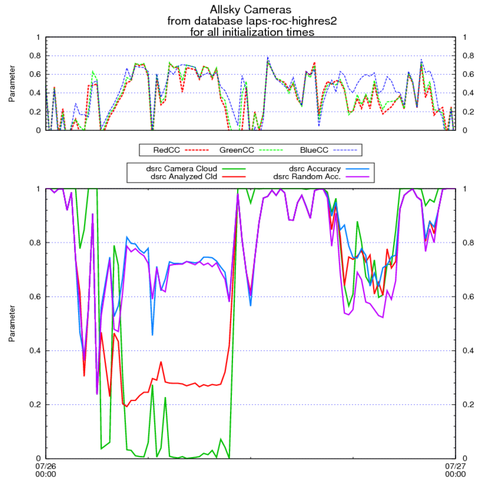
- Mie scattering phase function means thin clouds are brighter near the sun (with "silver lining")
- Thick clouds are the opposite, being lit up better when opposite the sun
- Phase function peaks in forward direction with single scattering - flattens with multiple scattering
- Rayleigh scattering by clear air can redden distant clouds
- Rainbows included in scattering phase function

All-Sky Web Page

- **Real-time Qualitative Comparison (5 camera sites)**



- **Quantitative Verification**



Results

- Fit is reasonable for a 500m analysis resolution
- Cloud placement better than random statistic
- Shading of clouds correlates with camera images

Variational Cloud Assimilation

- Development underway with variational cloud analysis and hot-start
- Satellite testing with CRTM (radiances), or NESDIS Cloud Optical Depth (with simpler forward model)
- Hot-start constrained more consistent clouds and water vapor, temperature, etc.
- Ensure analysis / model consistency with microphysics, radiation, & dynamics
- Use cameras as input data?