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Automated Cloud Detection with the GOES-R Advanced Baseline Imager

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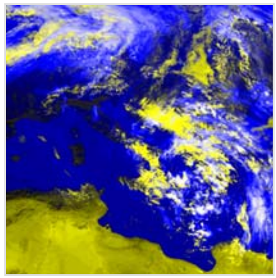
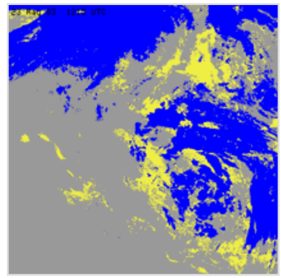
- Goal: Identify clouds using automated multispectral algorithms and retrieve their spatial, radiative, and microphysical properties
- Step 1: Invoke automated cloud-detection algorithm to find clouds and determine their phase (ice, water)
- Step 2: Retrieve the wavelength-invariant properties cloud-top temperature (spatial) and IWP (microphysical)
- Step 3: Microphysical properties: estimate effective particle size, IWP/LWP, and mass-median particle size
- Step 4: Spatial properties: using a spatial-context algorithm, estimate cloud top/base heights and cloud effective pressure
- Step 5: Radiative properties: infer visible extinction optical thickness and TIR emissivity

Automated Cloud Detection

Series of single-channel and multispectral cloud tests that detect clouds and discriminate between water and ice (see www.aer.com/cloud) - d'Entremont and Gustafson, 2003: **Analysis of Geostationary Satellite Imagery Using a Temporal-Differencing Technique.** *Earth Interactions*, **7**, Paper 3.



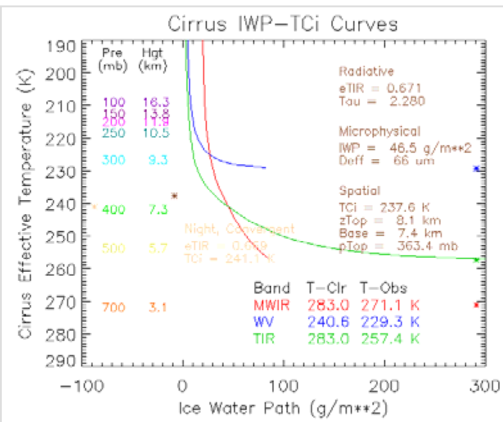
Visible-TIR Composite

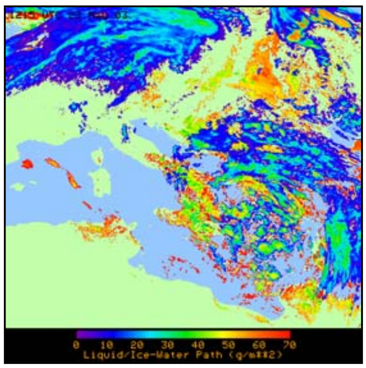


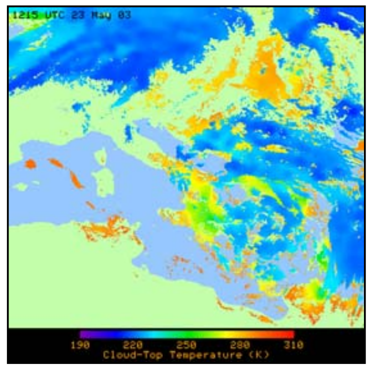
Cloud Mask:
Yellow = Water Blue = Ice

Retrieving Fundamental Cirrus Attributes

Multispectral approach that simultaneously solves two equations in two unknowns: cirrus ice-water path and effective temperature (effective particle size is parameterized using cirrus environmental temperature, so that $D_{eff} = D_{eff}(T_{Ci})$). Our retrieval's numerical recipe is illustrated graphically below:

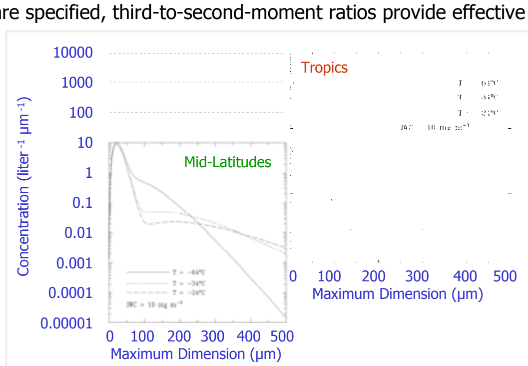






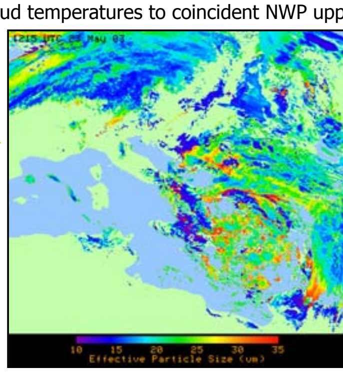
Cirrus Microphysics

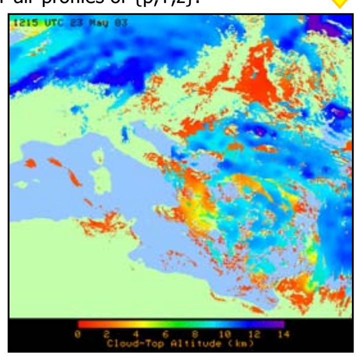
We use aircraft-data observations of ice-particle habits (size distributions, crystal shapes) compiled as a function of cirrus environmental temperature and atmosphere type (mid-latitude, tropics), as compiled by cloud physicists at the Desert Research Institute in Reno NV. Once the size distributions are specified, third-to-second-moment ratios provide effective diameter.

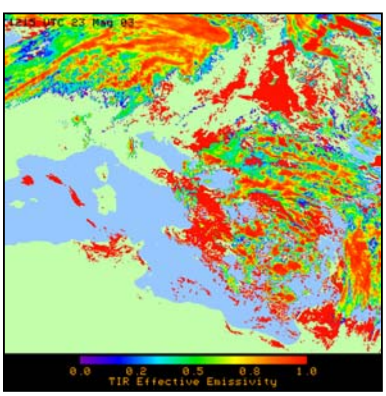


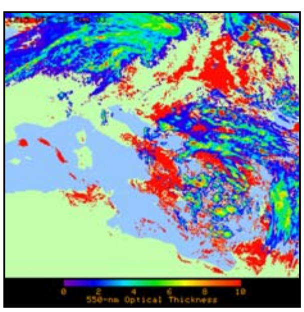
Cirrus Spatial Attributes

Cloud-top pressure and height are obtained simply by comparing the retrieved cloud temperatures to coincident NWP upper-air profiles of {p,T,z}.









Estimating Radiative Properties

Relationships between bulk cirrus emissivity ε, ice-particle effective diameter D_{eff}, IWP, and visible extinction optical thickness τ_{ext} (properties in red are "knowns" after the first retrieval iteration; others can be solved for):

$$\varepsilon = 1 - \exp[-3\,IWP\,Q_{abs} / (2\,\rho_{ice}\,D_{eff})]$$

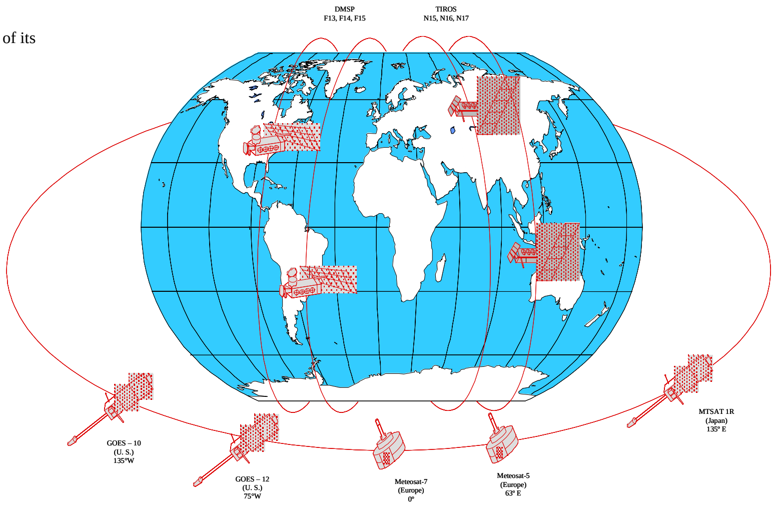
$$\tau_{ext} = 3\,IWP / (\rho_{ice}\,D_{eff}\cos\theta_{sat})$$

Operational Cloud Analysis Using Combined GEO and Polar Sensors

Cloud Depiction and Forecast System (CDFS)

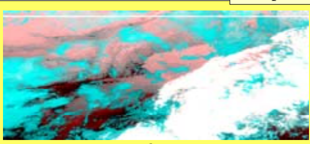
- The Air Force Weather Agency (AFWA) completed a major upgraded of its operational global satellite-based cloud analysis/forecast capability
  - Operational in June 2002
  - Hourly analysis/forecast at 24 km horizontal resolution
  - AER-developed algorithms for cloud amount, height, type
- Expands analysis capability from previous DMSP only
  - DMSP/OLS (2 channel)
  - TIROS/AVHRR (5/6 channel)
  - GOES imager (5 channel)
  - Meteosat MVIRI (3 channel) and SEVIRI (12 channel)
  - MTSAT (5 channel)
- Continuation of 30+ year history of operational global analysis
  - New algorithms developed specifically for CDFS II

Addition of geostationary satellites significantly improved coverage in the tropics and mid latitudes

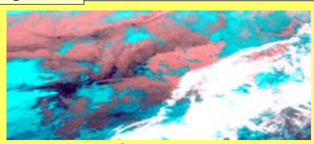


Current Satellite Constellation

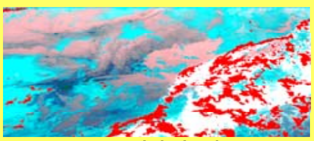
Temporal Signatures



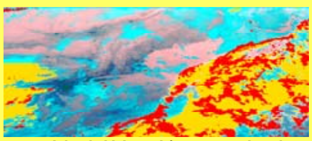
Initial Image



Subsequent Image



Temporal Cloud Mask

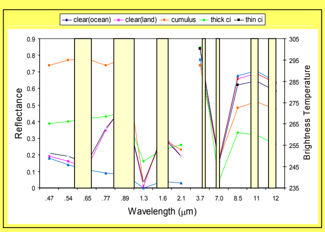


Local threshold derived from temporal mask

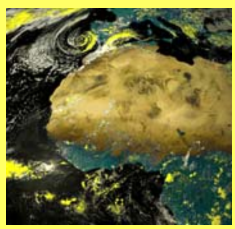
Temporal and Spectral Processing

- Temporal processing uses time change information to define local dynamic cloud thresholds
  - Useful for detecting early convection
- Multispectral analysis used to discriminate clouds from reflective/cold backgrounds
  - Desert, sun glint, snow/ice
  - Cloud phase discrimination
  - Operational in June 2002

Multispectral Signatures

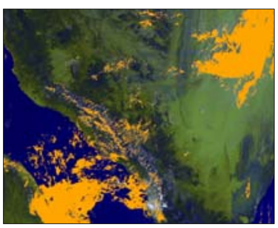


Multispectral techniques provide enhanced ability to discriminate cloud from backgrounds

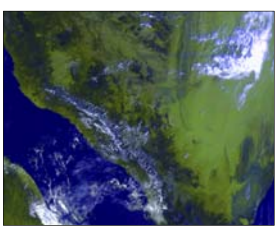


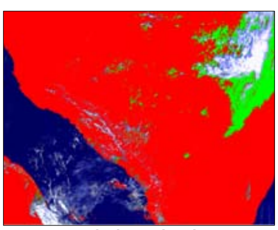
Cloud phase and background type

Desert Backgrounds



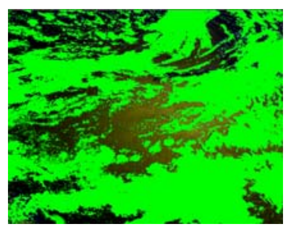
Cloud Mask



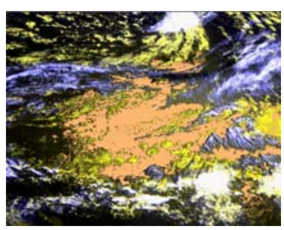


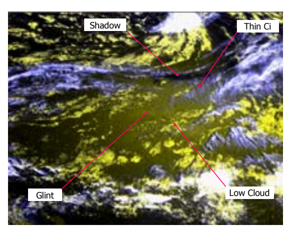
Desert background mask

Sun Glint Backgrounds



Cloud Mask

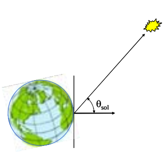




Sun Glint Mask

Day/Night Terminator

- Transition from reflectance to emittance tests
  - Can result in abrupt artificial cloud boundaries
- Introduce solar-zenith angle dependence to cloud tests



$$T_{MWIR} - T_{TIR} > \begin{cases} \theta_{sol} \le \theta_{day} & : Th_{day} \\ \theta_{day} < \theta_{sol} < \theta_{night} & : Th_{day} + \Delta Th_{day\text{-}night} \left(\dfrac{\theta_{sol} - \theta_{day}}{\Delta\theta_{day\text{-}night}} \right) \\ \theta_{sol} \ge \theta_{night} & : Th_{night} \end{cases}$$

Terminator Performance/Consistency