UNIVERSITY OF TWENTE.

ATMOSPHERIC CORRECTION

DR. MARLOES PENNING DE VRIES

FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

INTRODUCTION

- Main topic: Atmospheric correction
- At the end of this lesson, you can:
  - Explain what clouds and aerosols are and how they affect radiative transfer
  - Describe the main modes of satellite remote sensing
  - Compare advantages and disadvantages of dark pixel correction, invariant pixel correction, radiometric correction, and correction using radiative transfer modeling
  - Identify the most suitable mode of atmospheric correction for a particular application
  - Perform simple dark pixel and invariant pixel corrections by hand
  - Explain the spectrally dependent effects of an absolute atmospheric correction
  - Perform simple statistical analyses of Level-1 and -2 satellite data

COURSE LEARNING OUTCOMES

- Explain the basic concepts in geo-information science relevant for the acquisition of geospatial data and for their entry and management in a database.
- Define spatial references, coordinate systems and projections for geospatial data and apply relevant transformations for data integration.
- Explain electromagnetic radiation and the main processes of its interaction with the Earth surface and atmosphere.
- Apply radiometric and atmospheric correction and image enhancement techniques to a remote sensing dataset.
- Explain visualization principles and apply these for the visualization of geospatial data products as input for interpretation and information sharing.

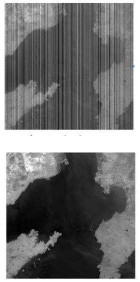
OUTLINE

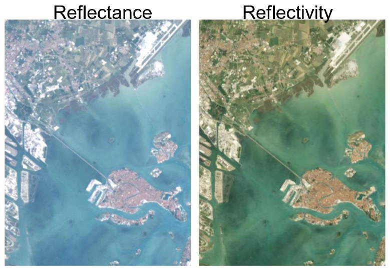
- Introduction
- Recap: Radiative transfer in the atmosphere
- Clouds and aerosols
- Modes of Earth Observation
- Atmospheric correction
  - Histograms
  - Light paths
  - Relative AC
  - Absolute AC
- Exercise

APPLICATIONS OF ATMOSPHERIC CORRECTION

- You need to do an AC to:
  - improve visualization (image enhancement)
  - correct sensor inaccuracies
  - correct surface, atmosphere, and geometrical factors

remote-sensing-portal.com

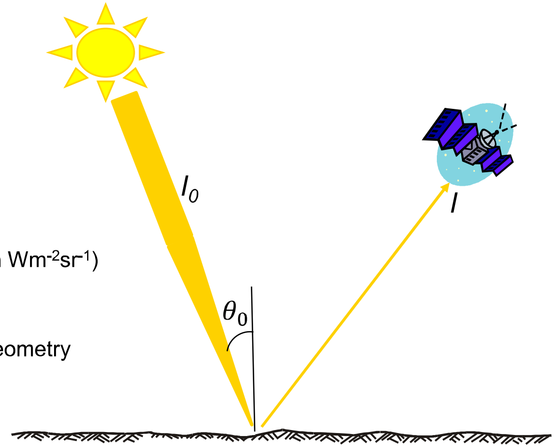

Chen et al., 2017



https://blog.mapbox.com/before-and-after-atmospheric-correction-97f55cb2b5d1

IRRADIANCE, RADIANCE AND REFLECTANCE

- Irradiance I_0:
  - Description of source strength
  - flux per unit area (in Wm^{-2})
- Radiance I:
  - Measured by satellite instrument
  - flux per unit area and solid angle (in $Wm^{-2}sr^{-1}$)
- Reflectance R:
  - Property of surface, atmosphere, geometry
  - $R = \frac{\pi I}{I_0 \cos \theta_0}$
  - NOT equivalent to reflectivity!



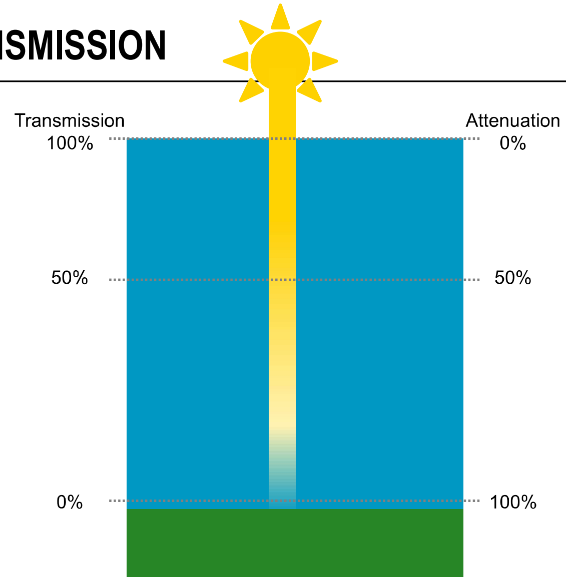
UNIVERSITY OF TWENTE.

RADIATIVE TRANSFER IN THE ATMOSPHERE

FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

ATTENUATION AND TRANSMISSION

- Radiation is either attenuated or transmitted by the atmosphere
- Radiation can be attenuated by scattering or absorption



ATTENUATION

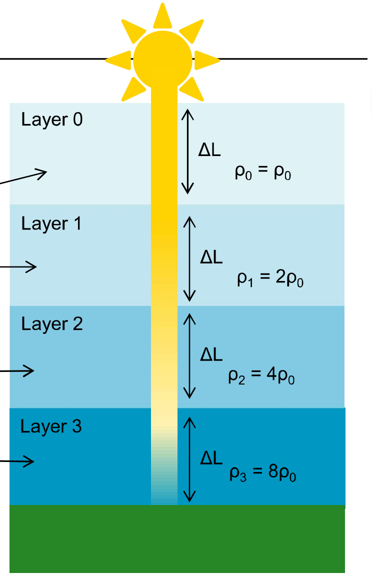
- Degree of attenuation (optical air mass *m*) depends on:
  - path length through medium (*L*) and
  - density of medium (ρ)
- But the atmosphere is layered...

$m_0 = \Delta L \rho_0$

$m_1 = \Delta L \rho_1 = 2\,\Delta L \rho_0 = 2m_0$

$m_2 = \Delta L \rho_2 = 4\,\Delta L \rho_0 = 4m_0$

$m_3 = \Delta L \rho_3 = 8\,\Delta L \rho_0 = 8m_0$

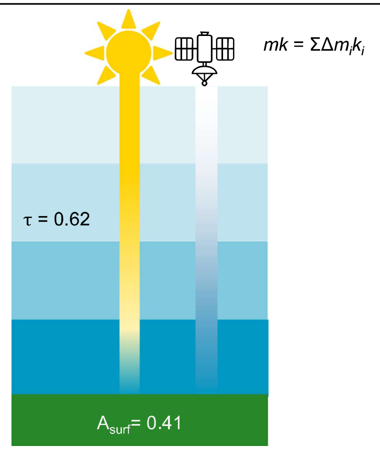


$m = m_0 + m_1 + m_2 + m_3 = \Sigma m_i = \Sigma \Delta L_i \rho_i$
$\rightarrow m = \int \delta L \rho_i$

SO HOW TO CALCULATE TRANSMISSION?

- Bouguer's law: transmission $\tau = e^{-mk}$
  - m = absolute air mass
  - k = extinction coefficient (probability)
- For medium with N layers: $mk = \sum_{i=0}^{i=N} m_i k_i$
- Hence: $\tau = e^{-\sum_{i=0}^{i=N} m_i k_i} = \prod_{i=0}^{i=N} e^{-m_i k_i}$
- So transmissions are multiplicative!

$$\tau_{\uparrow} = e^{-\int_{z=BOA}^{z=TOA} m(z)k(z)dz}$$

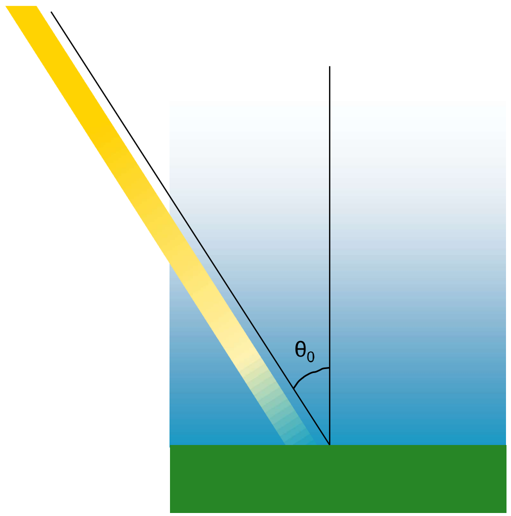


RELATIVE AIR MASS

- Slant paths are longer -> larger optical air mass
- Normalization using relative air mass, m_r

$$m_r = \frac{L_S \cdot \rho}{L \cdot \rho} = \frac{m_S}{m}$$

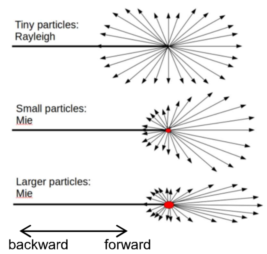
- Radiation from Sun to Target: $m_r = \cos\theta_0$
- So: $m = m_r \Sigma \Delta L \rho_i$



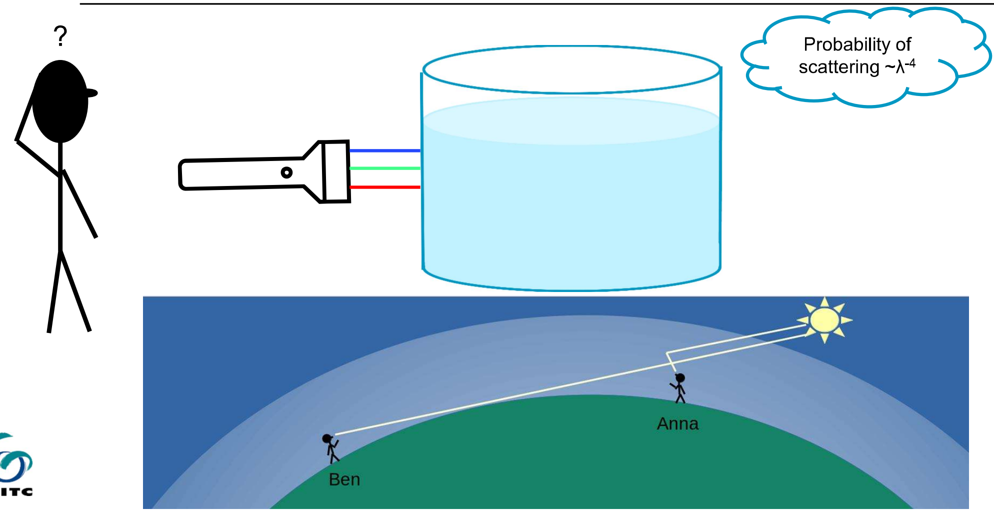
SCATTERING

- Interaction of radiation with large objects (>> wavelength)
  - Reflection
  - Absorption

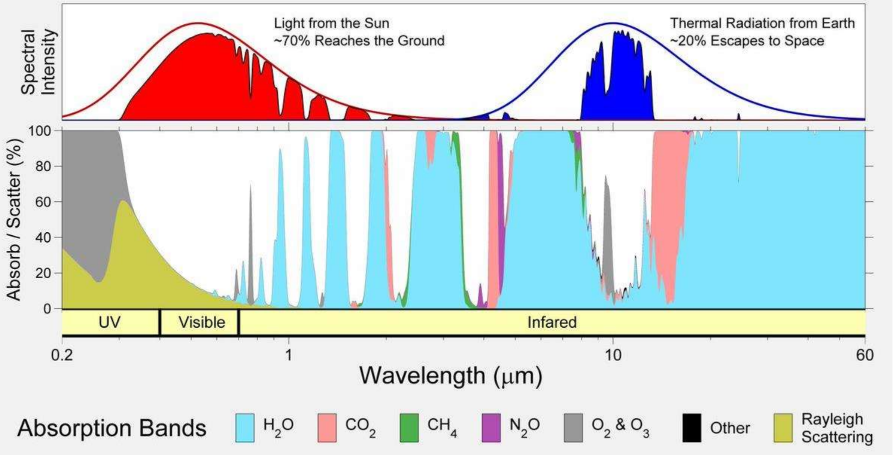
- Interaction of radiation with small objects (≤ wavelength)
- Absorption + (partial) re-emission
- Re-emission in all directions: scattering



REMEMBER THE EXPERIMENT?



ABSORPTION



UNIVERSITY OF TWENTE.

https://twitter.com/rarohde/status/1196761516051238912

LET'S DO THE COFFEE AND MILK EXPERIMENT

- Light is completely attenuated by both milk and coffee
- But what is the difference?

UNIVERSITY OF TWENTE.

UNIVERSITY OF TWENTE.

ATMOSPHERIC COMPOSITION

AEROSOLS AND CLOUDS

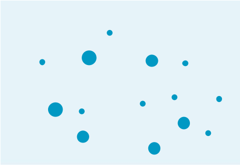
FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

AEROSOLS

- Small particles (0.1-10 µm) suspended in the atmosphere
- Scatter and absorb radiation
- Residence time: hours-days-months
- Separation into primary and secondary aerosols

AEROSOLS

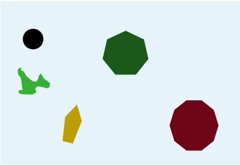
- Small particles (0.1-10 µm) suspended in the atmosphere
- Scatter and absorb radiation
- Residence time: hours-days-months
- Separation into primary and secondary aerosols
- Secondary aerosols
  - Form from gases in atmosphere
  - Small (0.1-0.5 µm), round droplets
  - Smog, vog, biogenic aerosols



Smog over a Polish city
Photo by Pogribow (Wikimedia)

PRIMARY AEROSOLS

- Primary aerosols
  - Directly emitted
  - Mostly natural sources
  - Medium-large size, various shapes



Straw residue burning in Punjab
Photo by IndiaToday

Dust storm in Afghanistan
Photo by Tonymapping (Wikimedia)

Eruption of Sarychev volcano
Photo from ISS – NASA

CLOUDS

- Blue planet?

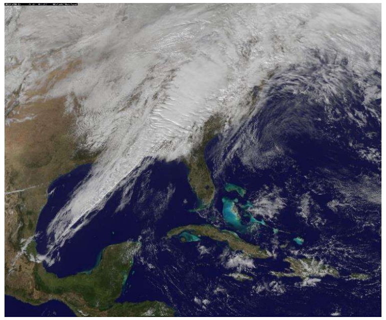
- 2/3 of planet covered by clouds!

CLOUDS

- Blue planet?

- 2/3 of planet covered by clouds!

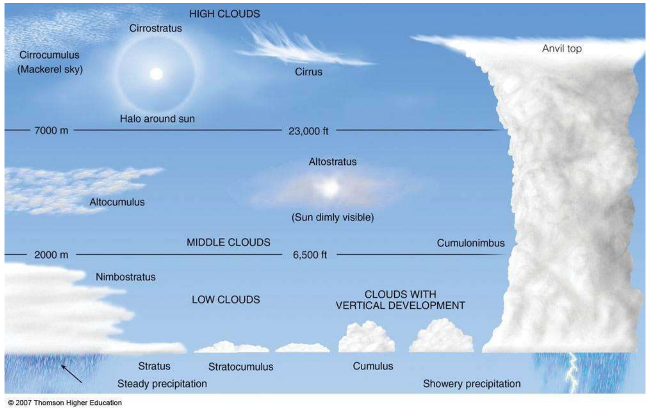
- Clouds dominate radiative transfer and block the surface from view
- Cloud-covered observations are removed



- Unless we're interested in clouds!

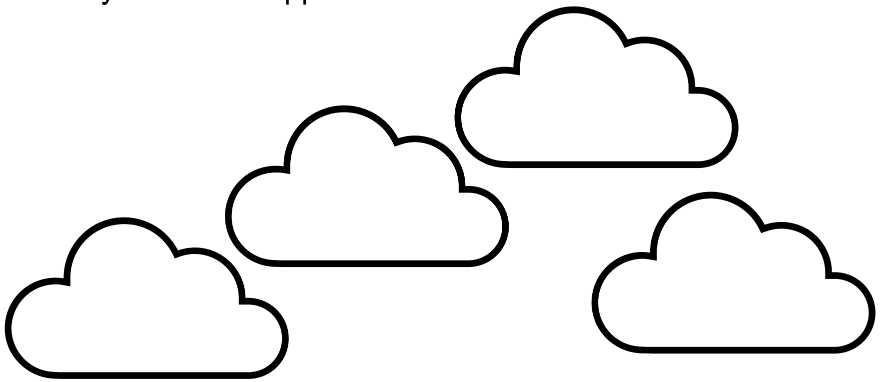
CLOUDS

- Nearly all clouds in troposphere
- No absorption of visible radiation
- Warm clouds: water droplets >10 μm
- Cold clouds: ice particles
- Radiative transfer complicated!



WAIT A MINUTE...

- Why do clouds appear white?



UNIVERSITY OF TWENTE.

ATMOSPHERIC COMPOSITION

GASES

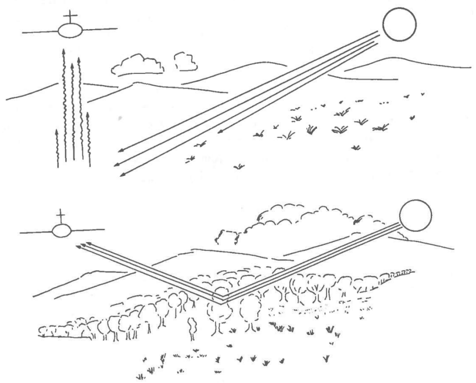
FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

UNIVERSITY OF TWENTE.

TYPES OF REMOTE SENSING FOR EO

ACTIVE & PASSIVE

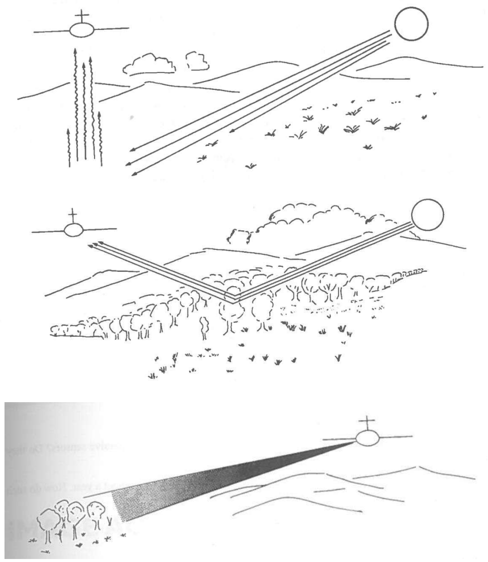
- Passive: receiver only
  - Reflected/scattered radiation from Sun, surface, atmosphere (UV-MW)
  - Emitted radiation from surface, atmosphere (IR and longer)



Campbell, chap. 2

ACTIVE & PASSIVE

- Passive: receiver only
  - Reflected/scattered radiation from Sun, surface, atmosphere (UV-MW)
  - Emitted radiation from surface, atmosphere (IR and longer)
- Active: sender and receiver
  - RaDAR (MW and longer)
  - LiDAR (visible)



Campbell, chap. 2

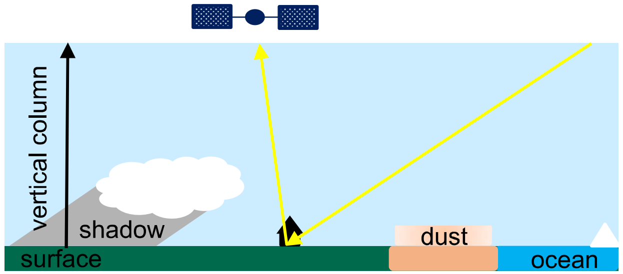
UNIVERSITY OF TWENTE.

ATMOSPHERIC CORRECTION

LIGHT PATHS

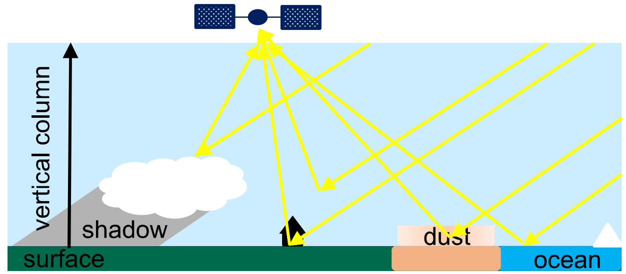
INTERACTION OF RADIATION WITH THE ATMOSPHERE: LIGHT PATHS

- Attenuation detected by the satellite is the attenuation along the light path



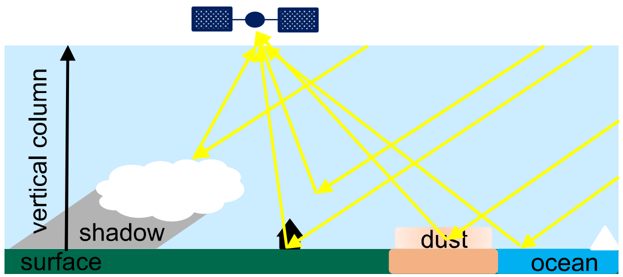
INTERACTION OF RADIATION WITH THE ATMOSPHERE: LIGHT PATHS

- Attenuation detected by the satellite is the attenuation along the light path… or rather along all light paths
- What effects do clouds, aerosols, surface, atmosphere have on the light paths?



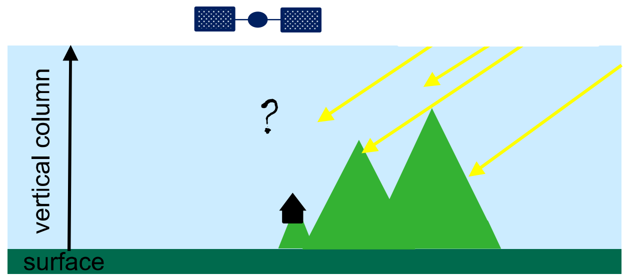
INTERACTION OF RADIATION WITH THE ATMOSPHERE: LIGHT PATHS

- Attenuation detected by the satellite is the attenuation along the light path… or rather along all light paths
- What effects do clouds, aerosols, surface, atmosphere have on the light paths?
- attenuation
- change of direction



DISCUSSION

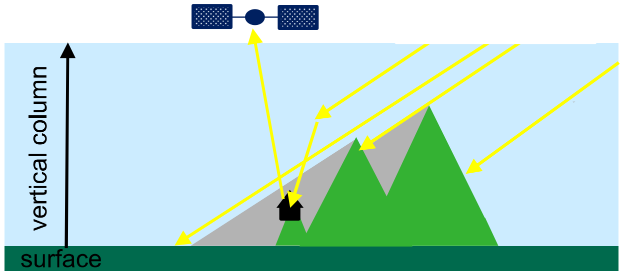
- What is the influence of topography on light paths?



DISCUSSION

- What is the influence of topography on light paths?

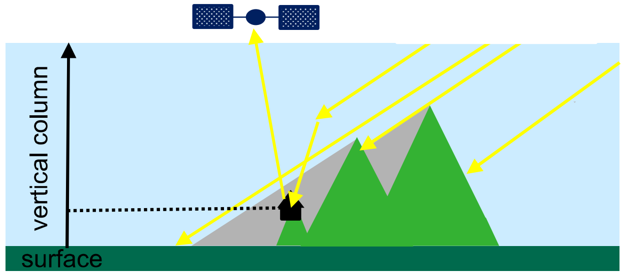
- Shadows
  - Only indirect radiation on target
  - Less information



DISCUSSION

- What is the influence of topography on light paths?

- Shadows
  - Only indirect radiation on target
  - Less information
- Less Rayleigh scatter
  - Atmosphere most dense near surface
  - Adapt AC



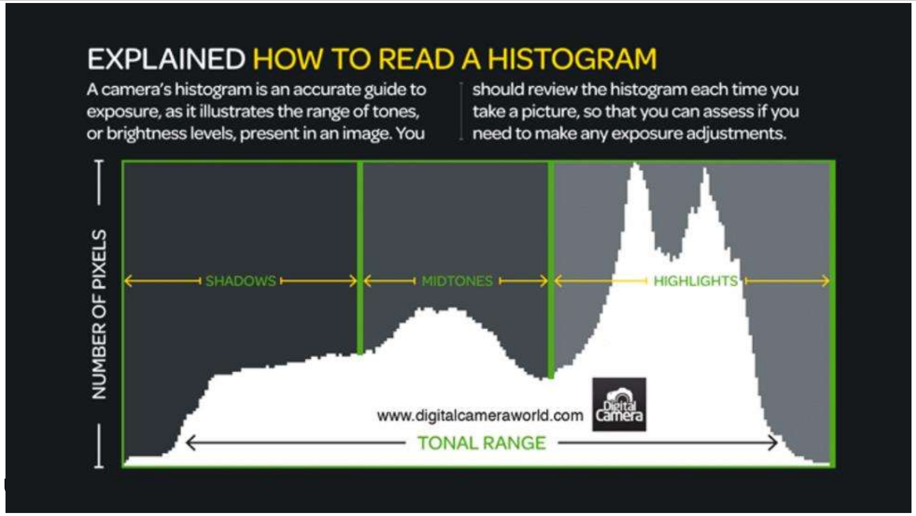
UNIVERSITY OF TWENTE.

ATMOSPHERIC CORRECTION

METHODS

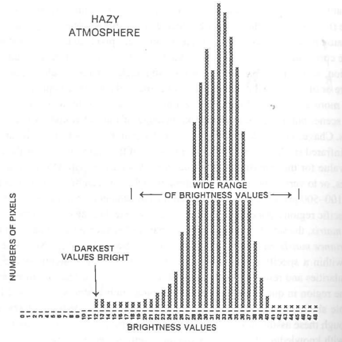
HISTOGRAMS

-



RELATIVE AC (1)

- Dark object subtraction
- Assume reflectance of dark target due to atmosphere only
- Subtract this value from all reflectances
  - Each channel separately!

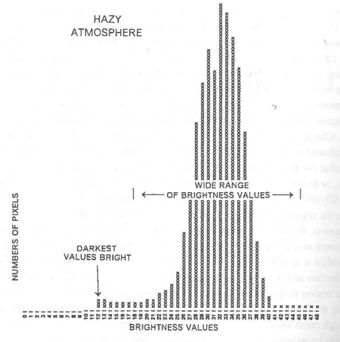


https://www.slideserve.com/vilmos/image-preprocessing

J.Campbell: Introduction to Remote Sensing, 2007

RELATIVE AC (1)

- Dark object subtraction
- Assume reflectance of dark target due to atmosphere only
- Subtract this value from all reflectances
  - Each channel separately!
- Simple, “cheap” method
- Universal applicability
  - if dark areas are present
- Approximation
- No absolute physical quantity

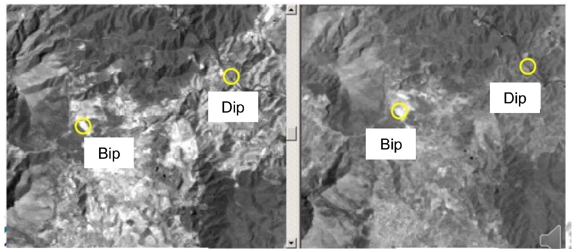


https://www.slideserve.com/vilmos/image-preprocessing

J.Campbell: Introduction to Remote Sensing, 2007

RELATIVE AC (2)

- Dark and bright reflective-invariant areas
- In a time series, assume that atmosphere is only cause of changes
- Calibrate slave images to master

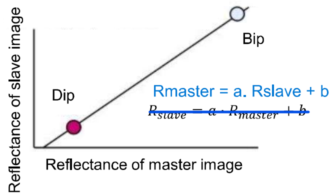


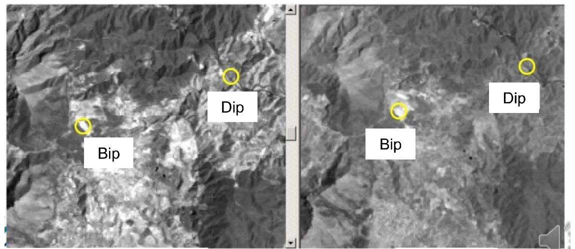
Master date A Slave date B

Figures from G. Parodi (https://www.slideshare.net/parodign/atmospheric-correction-albuferaweb)

RELATIVE AC (2)

- Dark and bright reflective-invariant areas
- In a time series, assume that atmosphere is only cause of changes
- Calibrate slave images to master





Master date A Slave date B

- Simple
- Approximate; no absolute physical quantity

Figures from G. Parodi (https://www.slideshare.net/parodign/atmospheric-correction-albuferaweb)

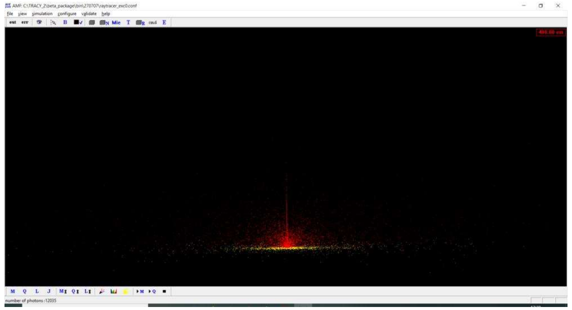
ABSOLUTE AC

- Known target
- Adjustment to radiances detected by calibrated instrument
- Simple, absolute physical quantities, not exact

ABSOLUTE AC

- Known target
- Adjustment to radiances detected by calibrated instrument
- Simple, absolute physical quantities, not exact

- Modelling of atmosphere
- Radiative Transfer Model (RTM)
- Exact
  - If input parameters are known
- Expensive



RADIATIVE TRANSFER MODELS

- RTMs calculate the signal observed at TOA
- What input do they need?

How to participate?

UNIVERSITY OF TWENTE.

1. Go to wooclap.com
2. Enter the event code in the top banner

Event code
EJHOUG

1. Send @EJHOUG to 0970 1420 2908
2. You can participate

UNIVERSITY OF TWENTE.

EXERCISE

FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

TODAY'S EXERCISE

- Supervised exercise:
  - Haidi Abdullah
  - Srinidhi Gadde
- 10:45 - 15:30
- Rooms 2405 and 2409
- At the end of this exercise, you will be able to:
  1. Perform simple dark pixel and invariant pixel corrections by hand
  2. Explain the spectrally dependent effects of an absolute atmospheric correction
  3. Perform simple statistical analyses of Level-1 and -2 satellite data

LITERATURE

- Core book
- Campbell
- Chen, Y., et al: "Stripe noise removal of remote sensing images by total variation regularization and group sparsity constraint", Remote Sens. 2017, 9(6), 559, https://doi.org/10.3390/rs9060559