Identifying and Characterizing Biocrusts Using Spectroscopy and Remote Sensing

Offer Rozenstein

Ben-Gurion University of the Negev, Israel

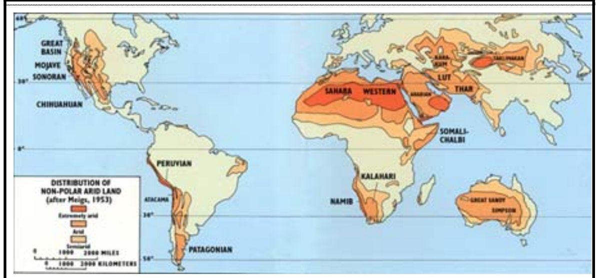
The Jacob Blaustein Institutes for Desert Research

Bio-GeoSpatial Technologies Lunch Seminar

McGill

The Albert Katz International School for Desert Studies

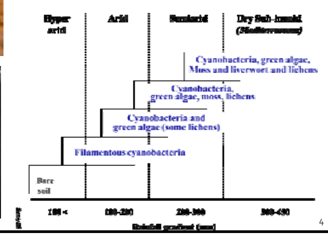
Global Distribution of Deserts



Drylands cover ~ 41% of the global land area

Biocrusts

- Biocrusts are critical components of desert ecosystems, significantly modifying the surfaces they occupy.



Biocrusts Ecological Functions

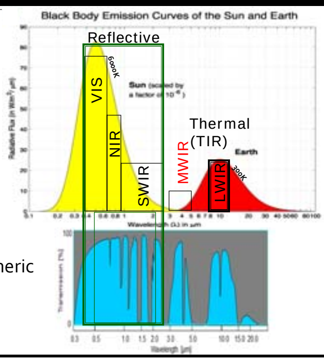
- Stabilizing the soil surface.
- Protecting the soil surface from erosion.
- Fixing carbon and nitrogen to the soil.
- Decrease water infiltration.
- Generate surface runoff.
- Complex interactions with flora and fauna.

Spectroscopy

- Benefits of spectroscopy for biocrust research:
  - Non destructive
  - Bypasses the traditional “wet” laboratory analyses
  - Applicable for both field & lab
  - Remote sensing

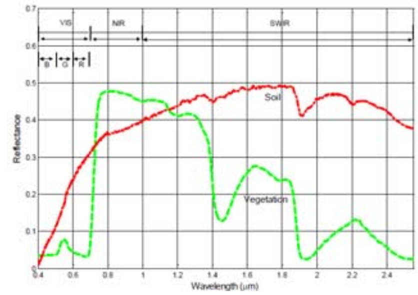
Remote Sensing

- **Physical Background**

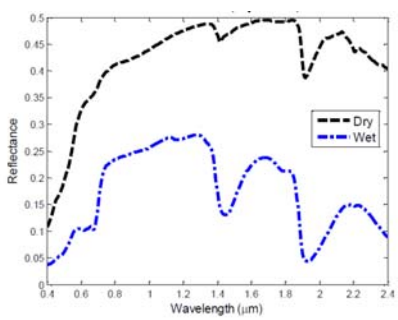


Atmospheric window

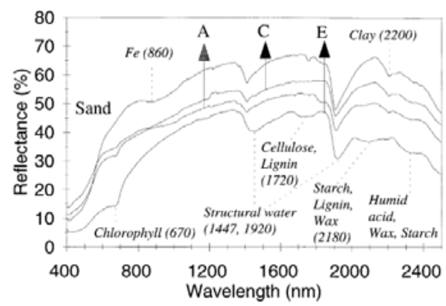
VIS-NIR-SWIR



Biocrust VIS-NIR-SWIR Reflectance



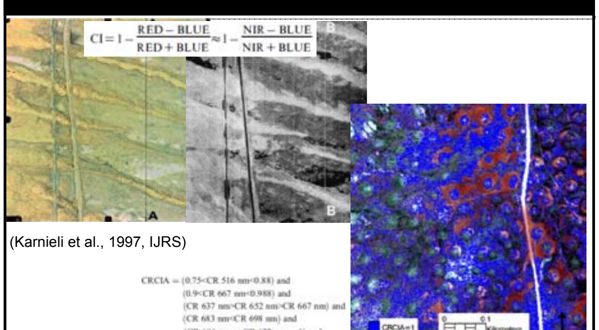
Chromophores in Biocrusts



(Karnieli et al., 1999, RSE)

Biocrusts Spectral Indices

$$CI = 1 - \frac{RED - BLUE}{RED + BLUE} \approx 1 - \frac{NIR - BLUE}{NIR + BLUE}$$



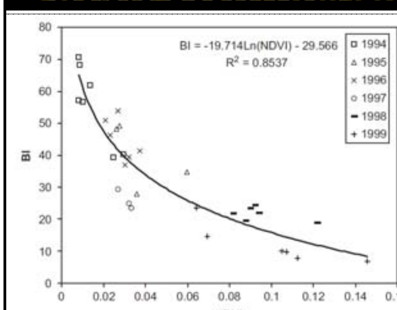
(Karnieli et al., 1997, IJRS)

CRCIA = (0.75<CR 516 nm<0.88) and
(0.9<CR 667 nm<0.988) and
(CR 637 nm>CR 652 nm>CR 667 nm) and
(CR 683 nm<CR 698 nm) and
(CR 606 nm or CR 622 nm = 1) and
((CR 652 nm − CR 667 nm)
<(CR 698 nm − CR 682 nm))

Weber et al., 2008

Field Spectroscopy for Assessing Biocrusts Successional Trends

(Zaady et al., 2007, JAE)



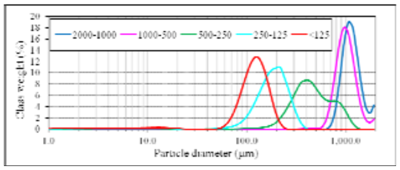
$$NDVI = \frac{NIR - RED}{NIR + RED}$$

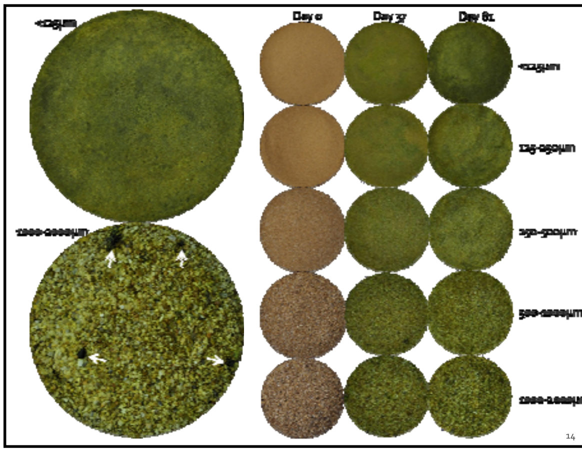
$$BI = \sqrt{GREEN^2 + RED^2 + NIR^2}$$

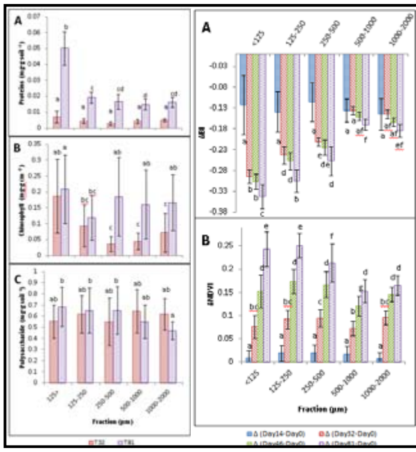
The Effect of Sand Grain Sizes on the Formation of Biocrusts

Offer Rozenstein, Eli Zaady, Itzhak Katra, Arnon Karnieli, Jan Adamowski, Hezi Yizhaq
(*Aeolian Research*, 2014)

- Rate of dispersal
- Dispersal patterns







$$BI = \sqrt{GREEN^2 + RED^2 + NIR^2}$$

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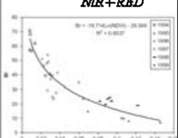
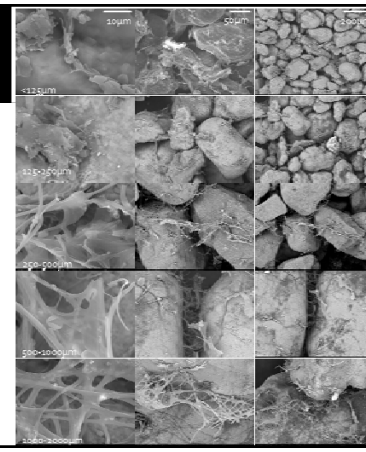


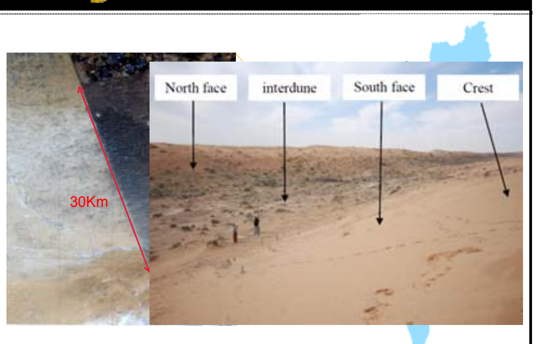
(Zaady et al., 2007, JAE)

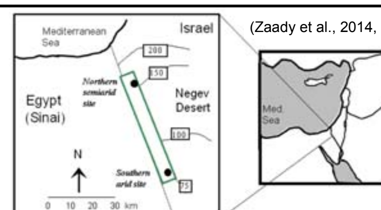
SEM Images

- Dispersal patterns
- Suggested filament's spreading mechanism
- Moisture effect?

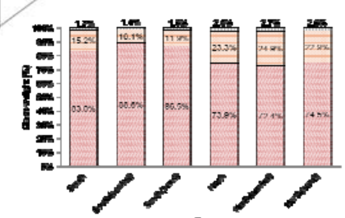


The Negev-Sinai Dune Field





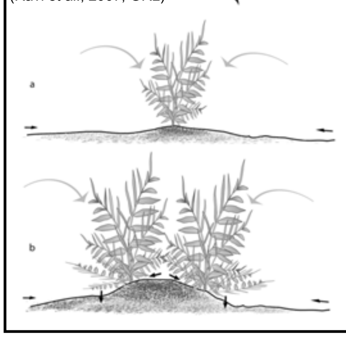
(Zaady et al., 2014, Aeolian Research)

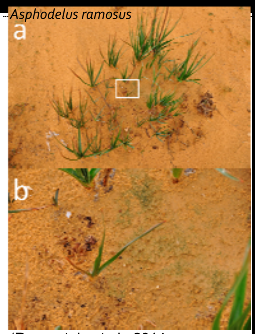


(Rozenstein et al., 2014, Aeolian Research)

Vegetation Ring Formation

(Ravi et al., 2007, GRL)



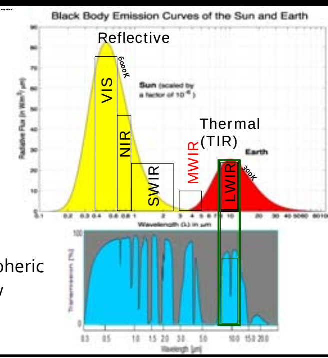


(Rozenstein et al., 2014, Aeolian Res.)

Remote Sensing

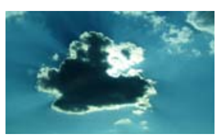
- Physical Background

Atmospheric window



LWIR Remote Sensing

- A significant advantage of RS in the LWIR is that sensors that operate within this region are not constrained by solar illumination.
- Enables:
  - RS at night
  - RS under smoke or clouds
  - Temperature measurements.



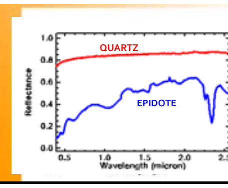
LWIR Remote Sensing

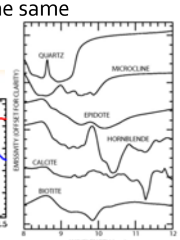
- The **emissivity** of a material (ε) is the relative ability of its surface to emit energy by radiation. It is the ratio of energy radiated by a particular material to energy radiated by a black body at the same temperature.

$\varepsilon = W_r/W_b$

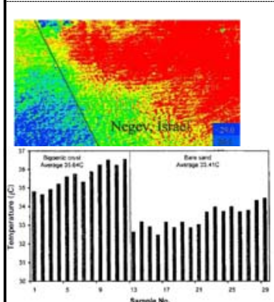
$W_b = \sigma T^4$

$W_r = \varepsilon\sigma T^4$

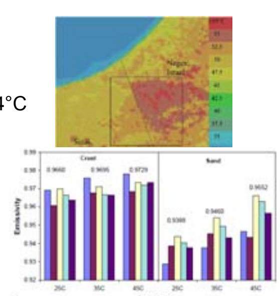




LWIR Remote Sensing of Biocrusts



Δ4°C

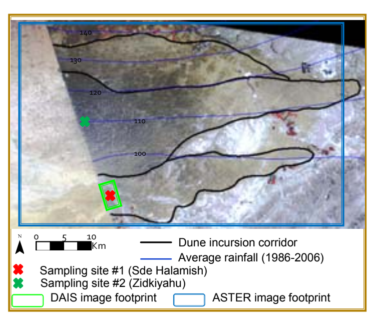


(Qin et al., 2001, IJRS)

(Qin et al., 2005, JAE)

Identification and characterization of biological soil crusts in a sand dune desert environment across Israel-Egypt border using LWIR emittance spectroscopy

Offer Rozenstein and Arnon Karnieli (*Journal of Arid Environments*, 2015)

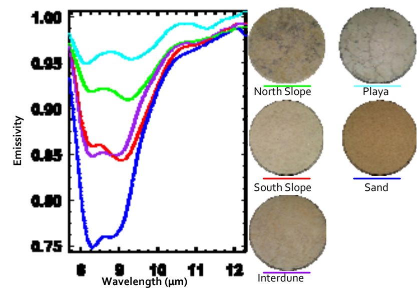


CI SR-5000 Radiometer

Spectral characterization of different BSCs using emission spectroscopy in the TIR region, with respect to dune sand.

(Rozenstein & Karnieli, 2014, J. Arid. Environ.)

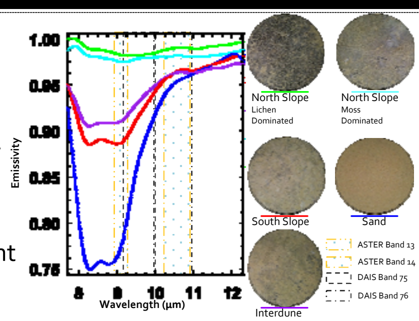
Laboratory Spectroscopy



(Rozenstein & Karnieli, 2014, J. Arid. Environ.)

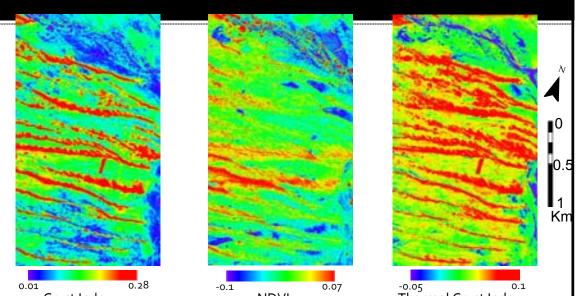
Laboratory Spectroscopy

- Good spectral separation between Biocrusts of different levels of development and sand.



(Rozenstein & Karnieli, 2014, J. Arid. Environ.)

Results: DAIS



Crust Index= $\dfrac{DN_{(0.65\mu m)} - DN_{(0.5\mu m)}}{DN_{(0.65\mu m)} + DN_{(0.5\mu m)}}$

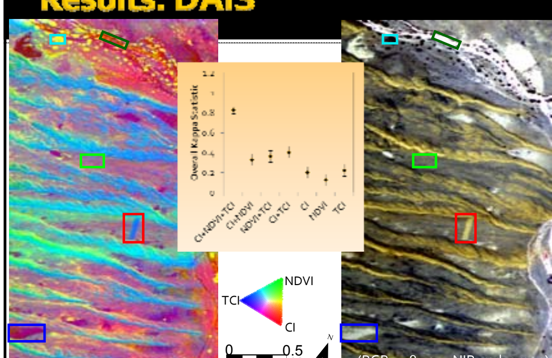
(Karnieli, 1997, IJRS)

NDVI= $\dfrac{DN_{NIR(0.79\mu m)} - DN_{R(0.65\mu m)}}{DN_{NIR(0.79\mu m)} + DN_{R(0.65\mu m)}}$

Thermal Crust Index= $\dfrac{DN_{(10.48\mu m)} - DN_{(9.64\mu m)}}{DN_{(10.48\mu m)} + DN_{(9.64\mu m)}}$

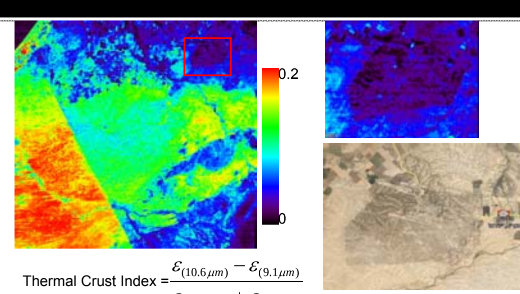
(Rozenstein & Karnieli, 2014, JAE)

Results: DAIS



(Rozenstein & Karnieli, 2014, J. Arid. Environ.)

ASTER

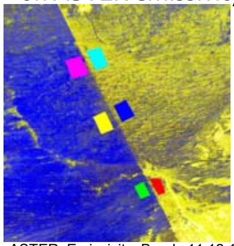


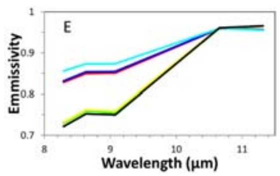
Thermal Crust Index = $\dfrac{\varepsilon_{(10.6\mu m)} - \varepsilon_{(9.1\mu m)}}{\varepsilon_{(10.6\mu m)} + \varepsilon_{(9.1\mu m)}}$

ASTER 23-Oct-2004, **Day**

ASTER

- Different emissivity for Sinai and the Negev on ASTER emissivity product

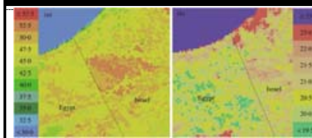




ASTER: Emissivity, Bands 11,12,14
23-Oct-2004, **Day**

(Rozenstein & Karnieli, 2014, J. Arid. Environ.)

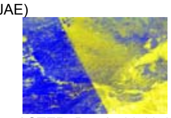
Day vs. Night



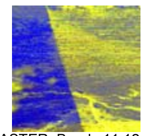
Day **Night**
NOAA-AVHRR LST 18-Jul-1998
(Qin et al., 2002, JAE)

Temperature contrast subsides

Emissivity contrast remains



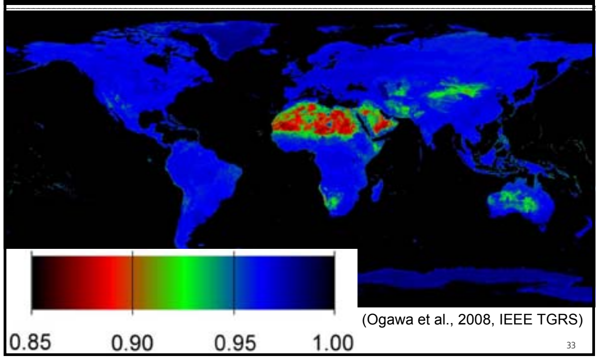
ASTER: Bands 11,12,14
09-Nov-2010, **Day**



ASTER: Bands 11,12,14
20-Sep-2005, **Night**

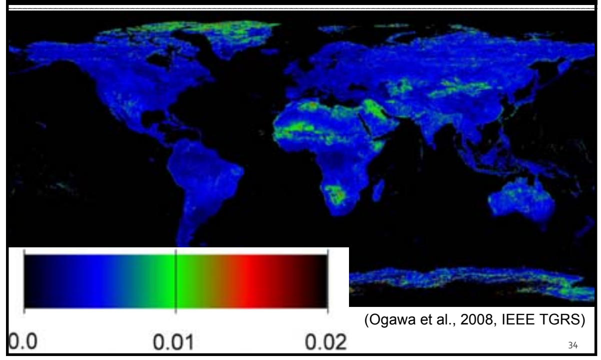
(Rozenstein & Karnieli, 2014, J. Arid. Environ.)

Global Emissivity (8-13.5µm)



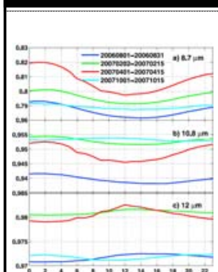
(Ogawa et al., 2008, IEEE TGRS)

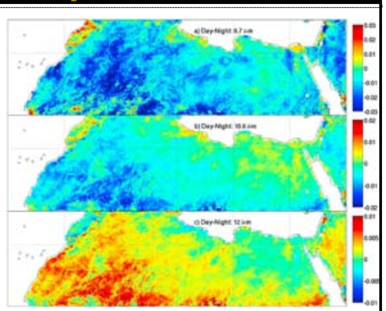
SD of Global Emissivity (8-13.5µm)



(Ogawa et al., 2008, IEEE TGRS)

SEVIRI Observations: Diurnal Emissivity Variations

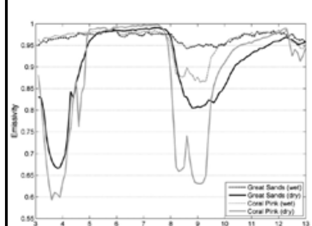




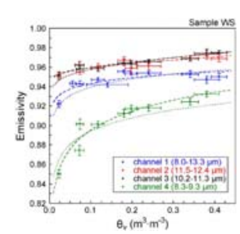
(Li et al., 2012, JGR)

Soil Moisture Changes Affect the Land Surface Emissivity

- ⬆soil moisture = ⬆emissivity



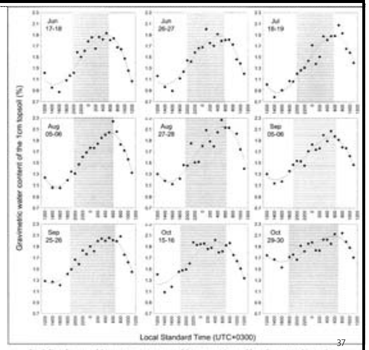
(Hulley, 2010, RSE)



(Mira et al., 2007, JGR)

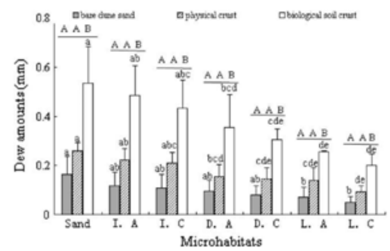
Diurnal Changes in Soil Moisture

- Dew formation at the surface
- Direct adsorption of water vapors



(Agam & Berliner,
J. Hydrometeorol.,2004)

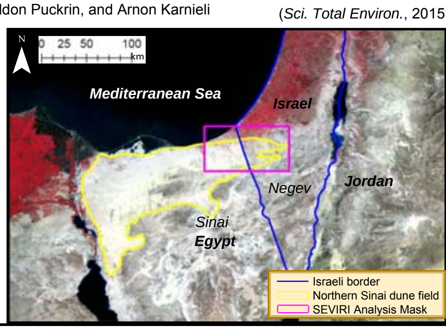
Biocrusts Absorb More Dew Than Sand Does



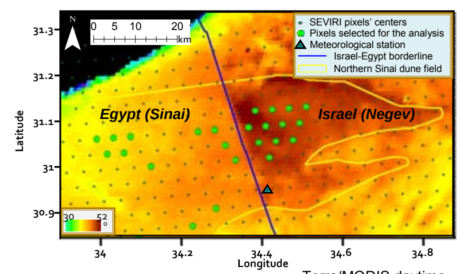
(Pan et al., 2010, J. Hydrol.)

Diurnal Emissivity Dynamics in Bare vs. Biocrusted Sand Dunes

Offer Rozenstein, Nurit Agam, Carmine Serio, Guido Masiello, Sara Venafra, Stephen Achal, Eldon Puckrin, and Arnon Karnieli (*Sci. Total Environ.*, 2015)



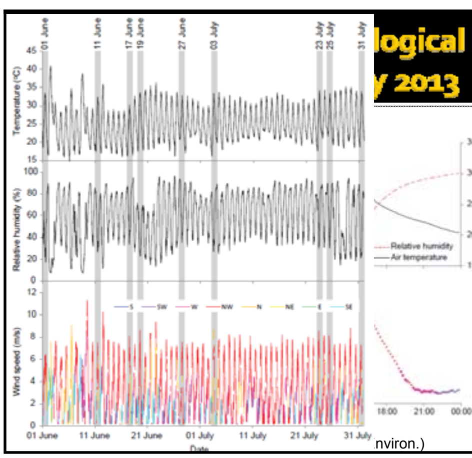
Selected Pixels



Terra/MODIS daytime land surface temperature 3-June-2013

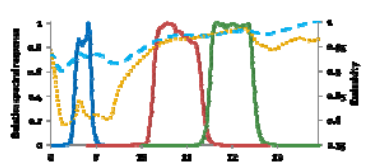
(Rozenstein et al., 2015, Sci. Total Environ.)

logical
y 2013



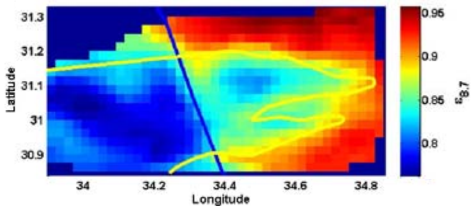
nviron.)

SEVIRI Channels and Field Spectra



(Rozenstein et al., 2015, Sci. Total Environ.)

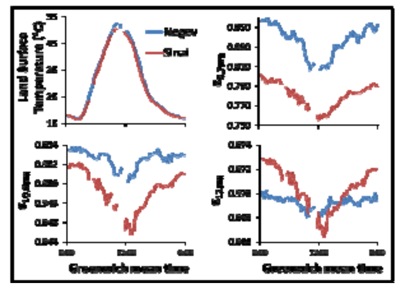
Average emissivity in the 8.7 µm SEVIRI channel for June-July 2013



(Rozenstein et al., 2015, Sci. Total Environ.)

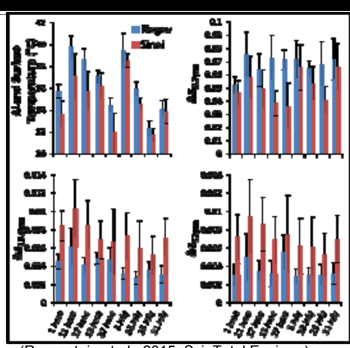
Diurnal Dynamics of Temperature and Emissivity

1-June-2013



(Rozenstein et al., 2015, Sci. Total Environ.)

Diurnal Variations on Selected Days

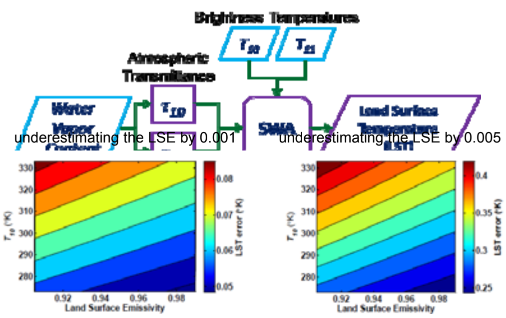


(Rozenstein et al., 2015, Sci. Total Environ.)

Possible Bias in LST Estimations

underestimating the LSE by 0.001

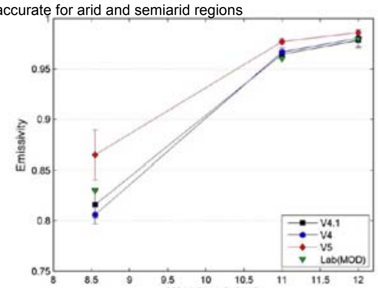
underestimating the LSE by 0.005



(Rozenstein et al., 2014, *Sensors*)

MODIS LSE is Overestimated and LST is Underestimated in all Bands

MOD11 – inaccurate for arid and semiarid regions



(Hulley & Hook., RSE, 2009)

Conclusions

- Biocrusts establish themselves more quickly and more homogenously on fine sand compared to coarse sand.
- Biocrusts have different spectral signatures than silicate sand in the LWIR spectral region.
- Different levels of biocrust development can be distinguished using LWIR spectroscopy.
- LWIR+VNIR fusion has great potential for land cover mapping.
- Diurnal emissivity variations caused by water vapor adsorption and evaporation were greater in biocrusted than bare sands.

Acknowledgments

This work was supported by:

- The Israeli Ministry of Science, Technology and Space
- The Pratt foundation.

Special thanks to:

- Arnon Karnieli

- Eli Zaady, Hezi Izhaq, Izhak Katra, Jan Adamowski, Nurit Agam, Carmine Serio, Guido Masiello, Sara Venafra, Eldon Puckrin, Stephen Achal, Zhihao Qin, and Yevgeny Derimian.

- Alexander Goldberg, Hiam Abu Glion, Erez Schmerler , Nitzan Swet, Gila Notesco, Amir Gil, Vered Ben-Yaacov, Tal Katz, and Yosef Ashkenazy

- My fellow students and colleagues at the remote sensing laboratory and BIDR.

Thank you.
Questions?