Developing a Long Term Data Record of Land Surface Temperature

MODIS Land Collection 5/LTDR Workshop
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Jeffrey L. Privette[1], Ana C. Pinheiro[1], Yunyue Yu[2]

[1]Remote Sensing And Applications Division
NOAA/NESDIS National Climatic Data Center
Asheville, North Carolina

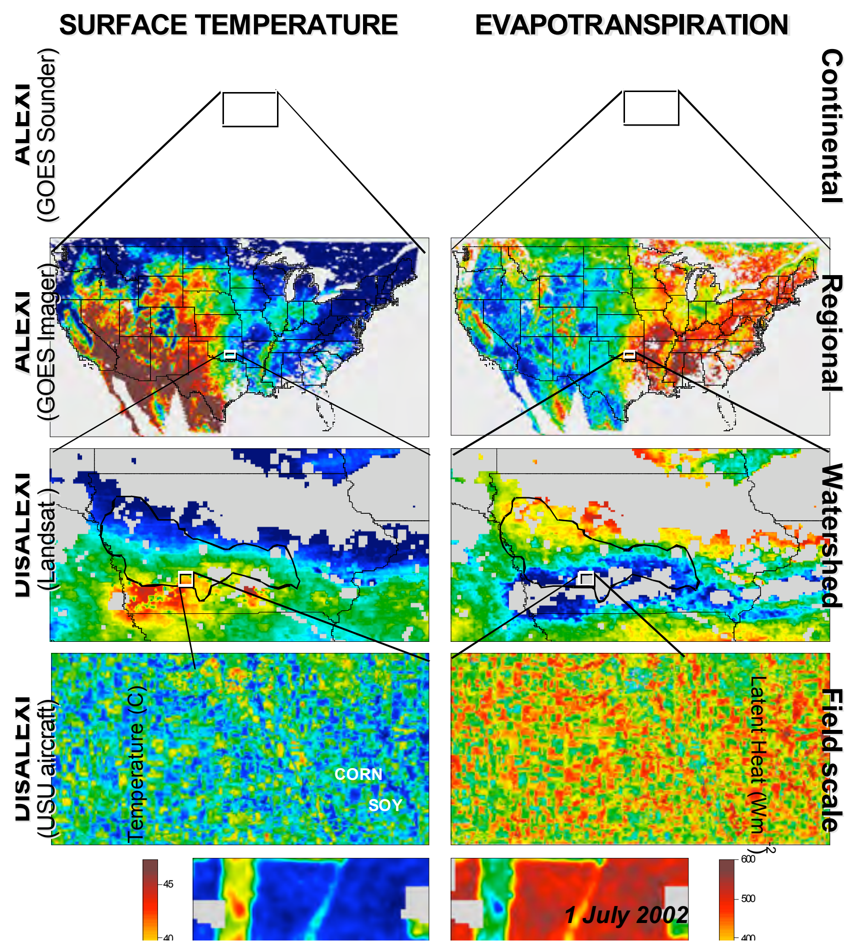
[2]Center for Satellite Application and Research
NOAA NESDIS
Camp Springs, Maryland

Outline

- Motivation for LST LTDR
- Framing the LST Challenges
- Preliminary Work
- 2007 Plans and Schedule

LST Named An <u>Essential Climate Variable</u> by CCSP, GCOS & EOS*

- Mapping drought / crop stress
- Boundary conditions for weather, energy budget and climate models
- Wildfire risk assessment, detection and burnt area mapping
- Urban heat flux mapping
- Insect breeding areas and vector-borne illness potential
- others



(Images from M.C. Anderson)

Climate Change Science Program Strategic Plan Chapter 12. Observing and Monitoring the Climate System, published by the U.S. Climate Change Science Program, Washington, DC 20006

The *Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC*, GCOS-82, April 2003 (WMO/TD No. 1143).

M. D. King, , *EOS Science Plan: The State of Science in the EOS*, ED. 1999.

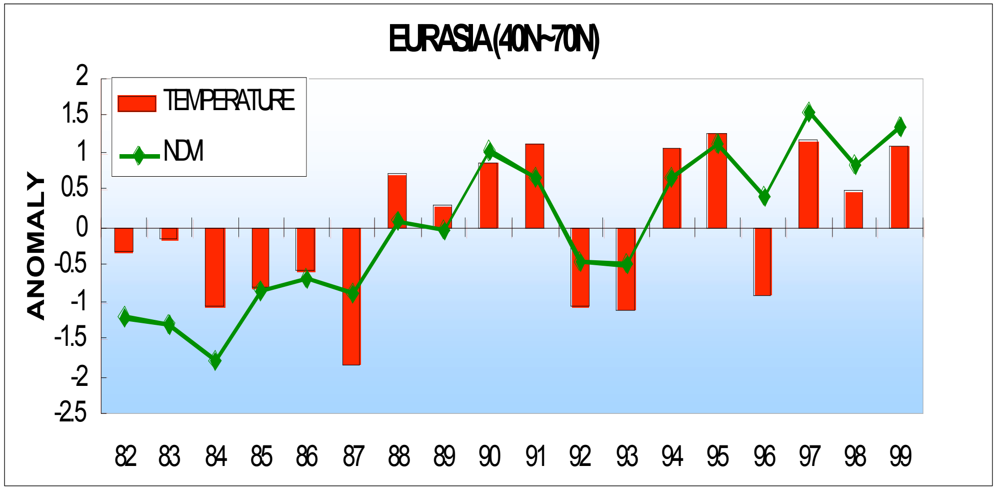
Climate Change Detection Using Preliminary AVHRR LTDR

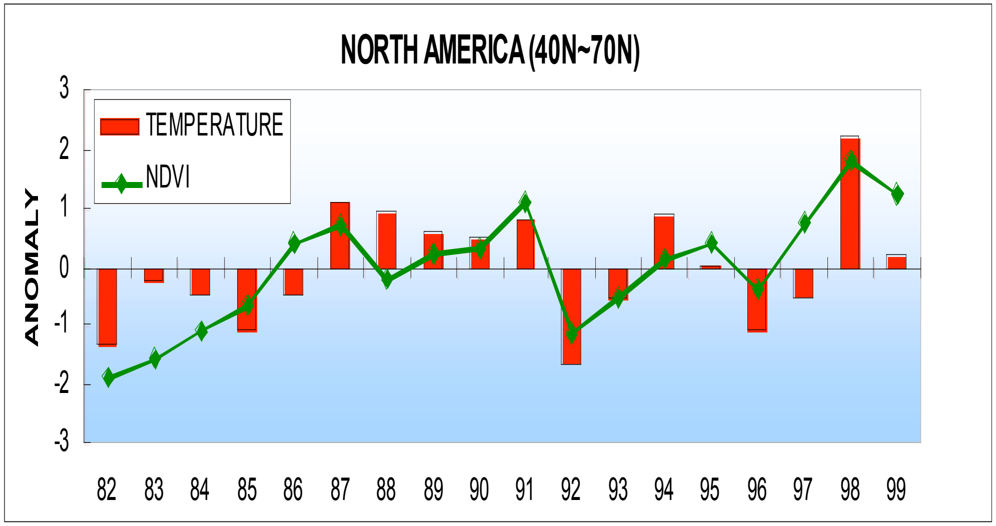
Example

Northern latitude "greening" found from AVHRR vegetation index

Culprit: Longer growing seasons due to warming temperatures

► "Anomaly" is determined relative to reference climate information (statistics) derived from long time series of well-calibrated products

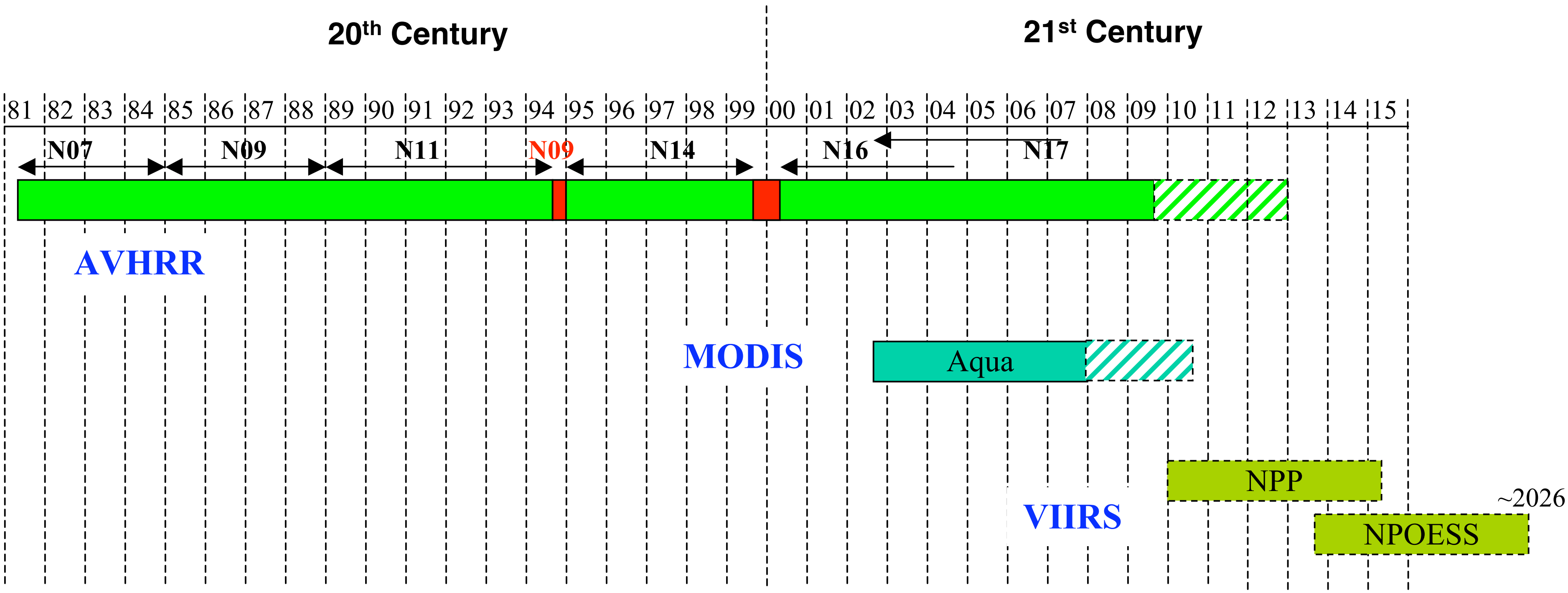




Courtesy Ranga Myneni

Source Data For LTDR LST

13:30 orbit



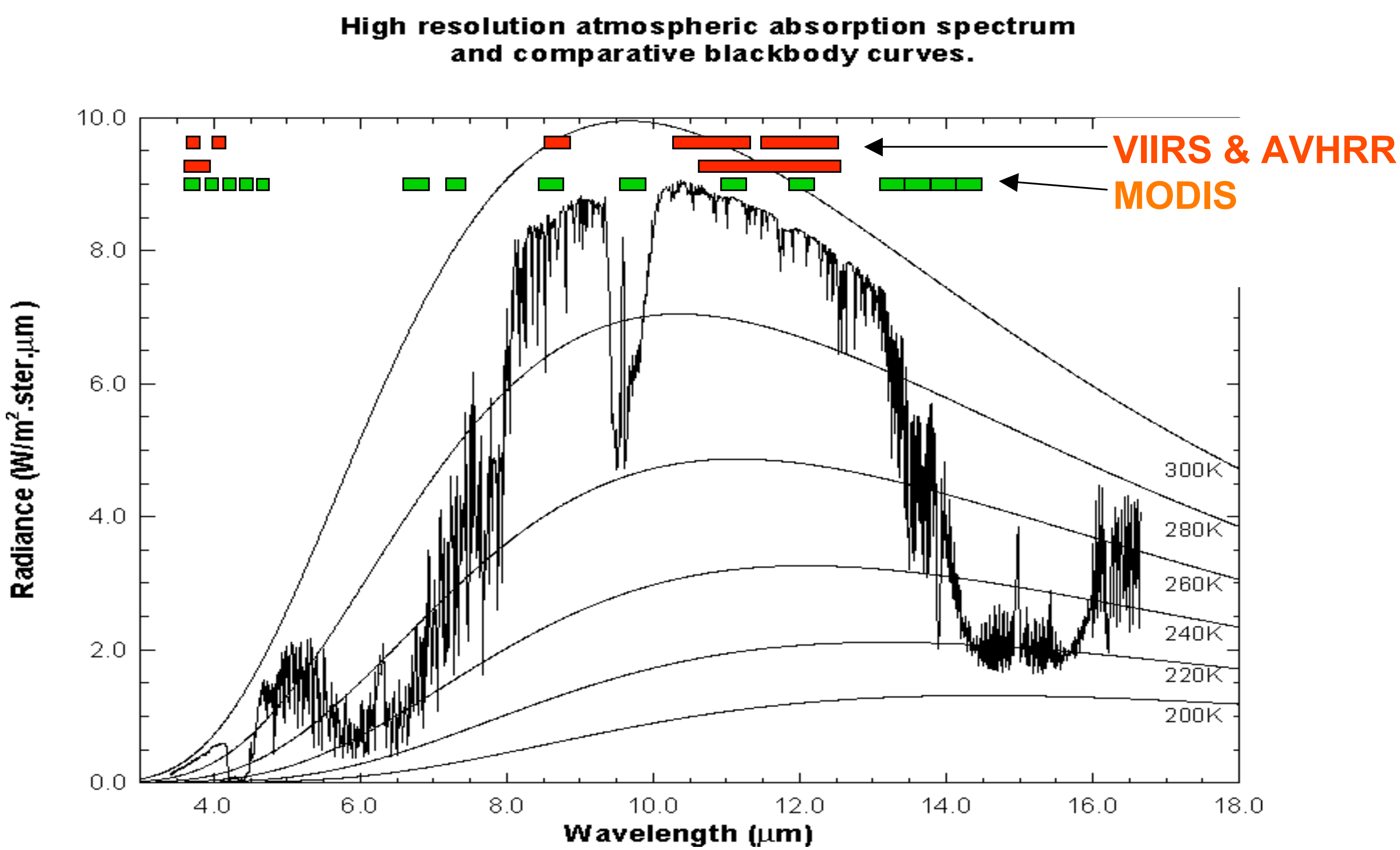
45-year Record From Just 3 Sensor Designs

Observatory Differences Provide Unique Challenges for Diurnally-Changing Variables

Satellite Sensor Characteristics	AVHRR	MODIS	VIIRS
Platform/System	*NOAA/POES*	*EOS Terra and Aqua*	*NPP/NPOESS***
Data Period	*1981-present*	*2000 (Terra) to present 2002 (Aqua) to present*	*Planned: ~2009 (NPP) to ~2026 (NPOESS)*
Spatial Resolution (Nadir) [km]	*1.1 (LAC) ~4 (GAC*)*	*1*	*0.75*
Pixel Growth Across Scan	*Unconstrained*	*Unconstrained*	*Constrained*
Overpass Time (nominal)	*13:40-14:30 (NOAA pm orbit drifts); (METOP will also provide 09:30 data from 2007+)*	*10:30 (Terra) 13:30 (Aqua)*	*13:30*
Temporal Resolution	*At least twice daily*	*At least twice daily*	*At least twice daily*
Radiometric Resolution	*10 bits*	*12 bits*	*12 bits*
Swath	*2800 km (±55°off nadir)*	*2330 km (±55°off nadir)*	*3040 km (±56°off nadir)*
Mid-IR bands (number)	*1*	*4*	*2*
TIR bands (number)	*2*	*3*	*3*

All are nominally sun-syncronous, polar-orbiting

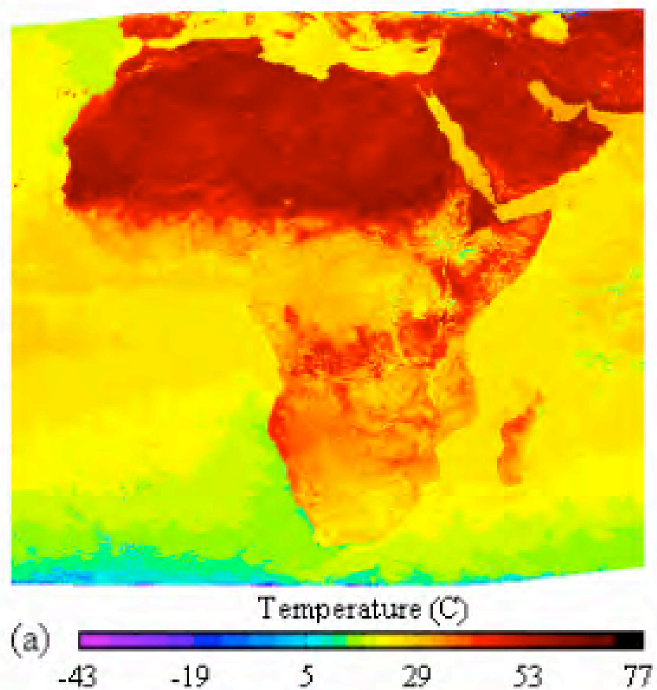
Spectral Differences Add To Emissivity and Water Vapor Uncertainties



Orbital Drift of NOAA Satellites

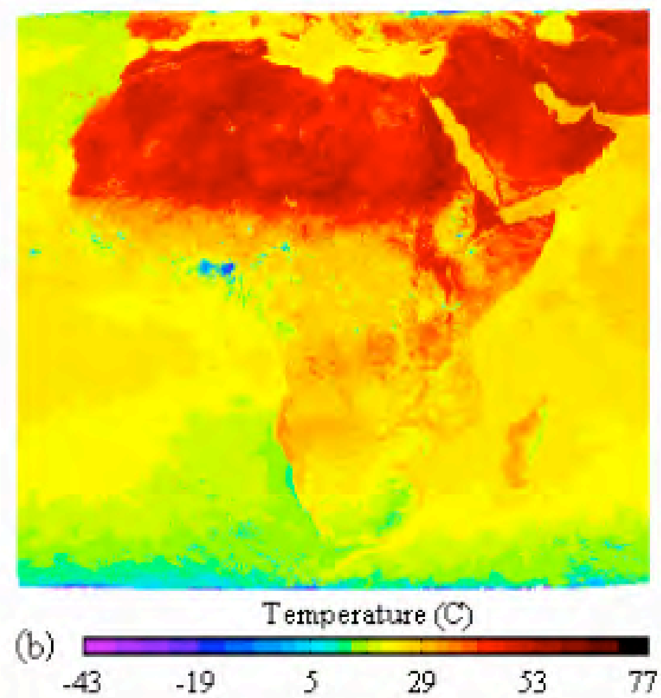
Is Africa’s Surface Cooling?

LST in July 1996



NOAA-14’s First Year: Overpass Time: ~13:30

LST in July 2000



NOAA-14’s Fifth Year: Overpass Time: ~16:00

➔ LST Time Series require temporal “normalization” for intercomparison

From *Pinheiro et al., Remote Sensing of Environment, 103 (2006)*

Team's Recent LST LTDR Preparatory Efforts/Findings

• Yu, Y., J.L. Privette and AC Pinheiro (2006), Evaluation of split window land surface temperature algorithms for generating climate data records. *IEEE Trans. Geophys. Remote Sens*., submitted.

• Pinheiro, ACT, R Mahoney, JL Privette and CJ Tucker (2005), A daily long term record of NOAA-14 AVHRR land surface temperature over Africa, *Remote Sens. Environ.,* 103 (2):153-164.

• Pinheiro, A.C.T., J. Descloitres, J.L. Privette, J. Susskind, L. Iredell, and J. Schmaltz (2006), Near-real time retrievals of land surface temperature within the MODIS rapid response system. *Remote Sensing of Environ.* doi:10.1016/j.rse.2006.09.006

• Yu, Y, JL Privette and AC Pinheiro (2005), Analysis of the NPOESS VIIRS land surface temperature algorithm using MODIS data, *IEEE Trans. Geophys. Remote Sens*., 43(10), doi:10.1109/TGRS.2005.856114.

• Pinheiro, A.C., J.L. Privette and P. Guillevic (2005), Modeling the angular anisotropy of land surface temperature in a savanna, *IEEE Trans. Geophys. Remote Sens.,* 44(4):1036-1047. doi. 10.1109/TGRS.2005.863827

• Pinheiro, A.C., J.L. Privette, R. Mahoney and C.J. Tucker (2004), Directional biases in a 5-year Daily AVHRR Land Surface Temperature Product over Africa, *IEEE Trans. Geophys. Remote Sens*., 42(9):1941-1954. doi:10.1109/TGRS.2004.831886

• Yu, Y., A.C. Pinheiro, and J.L. Privette (2006), Correcting land surface temperature measurements for directional emissivity over 3-D structured vegetation. *Remote Sensing and Modeling of Ecosystems for Sustainability III, 2006, Proceedings, SPIE*, San Diego, CA, 13-17 August 2006, v. 6298, 310-320.

• Yu, Y., J.L. Privette, and A.C. Pinheiro (2006), Improved correction of atmospheric absorption by split window surface temperature algorithms. *Second Recent Advances in Quantitative Remote Sensing*. Ed. José A. Sobrino. Servicio de Publicaciones. Universitat de Valencia. Valencia, Spain, 2006, 77-83. ISBN of book: 84-370-6533-X; 978-84-370-6533-5.

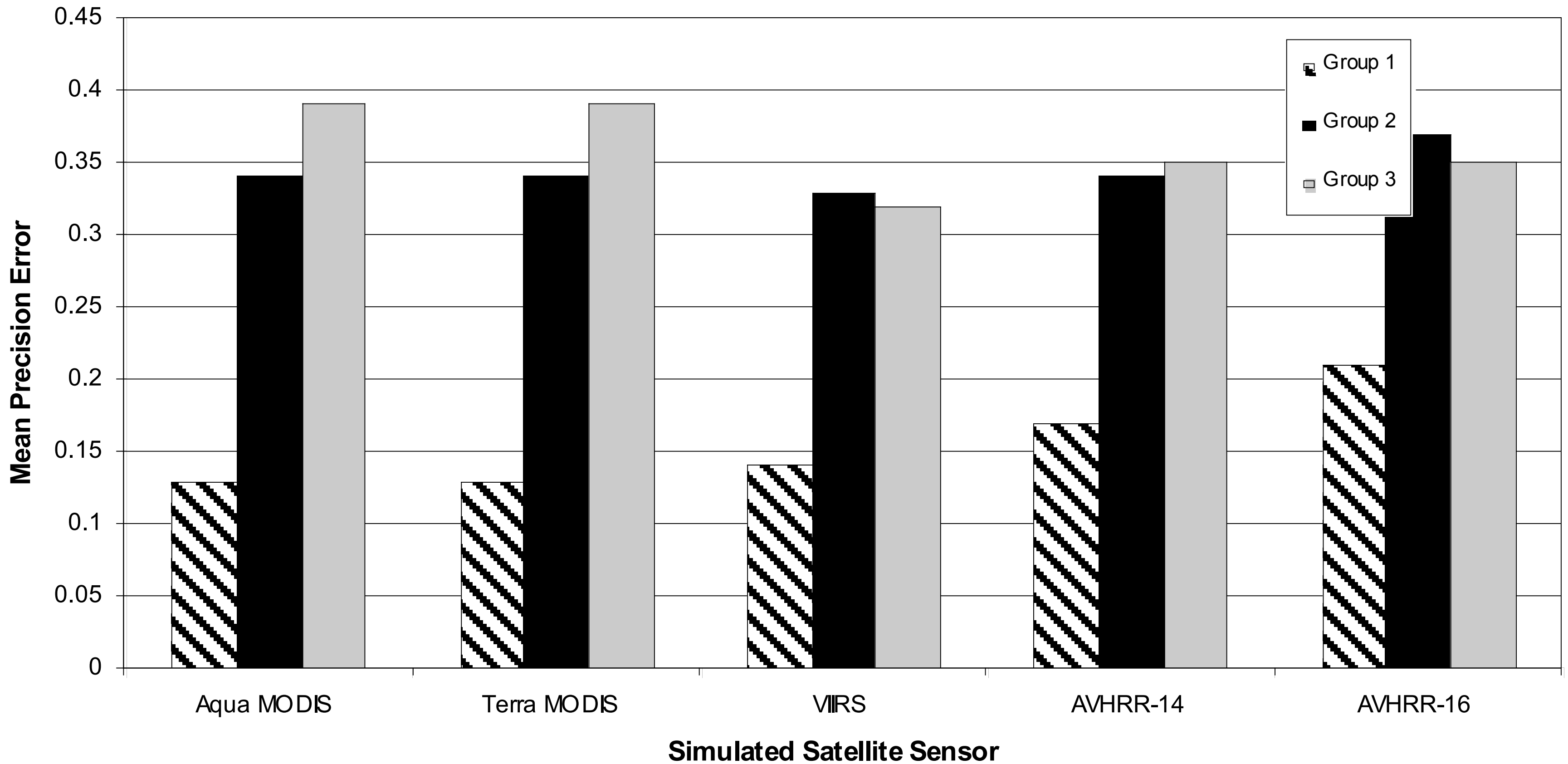
• Privette, J., A.C. Pinheiro, and Y. Yu (2006), Developing a multi-decadal climate data record of land surface temperature: a research agenda. *Second Recent Advances in Quantitative Remote Sensing*. Ed. José A. Sobrino. Servicio de Publicaciones. Universitat de Valencia. Valencia, Spain, 2006, 295-301. ISBN of book: 84-370-6533-X; 978-84-370-6533-5.

Intercomparison of Heritage Algorithms

No	Formula#	Reference
1	$T_s = C + (A_1 + A_2 \frac{1-\varepsilon}{\varepsilon} + A_3 \frac{\Delta\varepsilon}{\varepsilon^2})(T_{11} + T_{12}) + (B_1 + B_2 \frac{1-\varepsilon}{\varepsilon} + B_3 \frac{\Delta\varepsilon}{\varepsilon^2})(T_{11} - T_{12}) + D(T_{11} - T_{12})(\sec\theta - 1)$	Wan *et al.* [1];
2	$T_s = C + A_1 \frac{T_{11}}{\varepsilon} + A_2 \frac{T_{12}}{\varepsilon} + A_3 \frac{1-\varepsilon}{\varepsilon} + D(T_{11} - T_{12})(\sec\theta - 1)$	Prata & Platt [2]; Caselles *et al.* [3]
3	$T_s = C + A_1 T_{11} + A_2(T_{11} - T_{12}) + A_3(1-\varepsilon_{11}) + A_4 \Delta\varepsilon + D(T_{11} - T_{12})(\sec\theta - 1)$	Ulivieri *et al.* [4]; Sobrino *et al.* [5]
4	$T_s = C + A_1 T_{11} + A_2(T_{11} - T_{12}) + A_3 \frac{1-\varepsilon}{\varepsilon} + A_4 \frac{\Delta\varepsilon}{\varepsilon^2} + D(T_{11} - T_{12})(\sec\theta - 1)$	Becker & Li [6]; Sobrino *et al.* [5]
5	$T_s = C + A_1 T_{11} + A_2(T_{11} - T_{12}) + A_3(T_{11} - T_{12})(1-\varepsilon_{11}) + A_4 T_{12} \Delta\varepsilon + D(T_{11} - T_{12})(\sec\theta - 1)$	Price [8]; Sobrino *et al.* [5]
6	$T_s = C + A_1 T_{11} + A_2(T_{11} - T_{12}) + A_3 \varepsilon + D(T_{11} - T_{12})(\sec\theta - 1)$	Uliveri *et al.* [9]
7	$T_s = C + A_1 T_{11} + A_2(T_{11} - T_{12}) + A_3 \varepsilon + A_4 \frac{\Delta\varepsilon}{\varepsilon} + D(T_{11} - T_{12})(\sec\theta - 1)$	Vidal [10]
8	$T_s = C + A_1 T_{11} + A_2(T_{11} - T_{12}) + A_3(1-\varepsilon) + A_4 \Delta\varepsilon + D(T_{11} - T_{12})(\sec\theta - 1)$	Coll *et al.* [11]
9	$T_s = C + A_1 T_{11} + A_2(T_{11} - T_{12}) + A_3(T_{11} - T_{12})(T_{11} - T_{12}) + A_4(1-\varepsilon_{11}) + A_5 \Delta\varepsilon + D(T_{11} - T_{12})(\sec\theta - 1)$	Sobrino *et al.* [12]

Most Algorithms Are Minimally Sensitive to Sensor Bandpass Differences

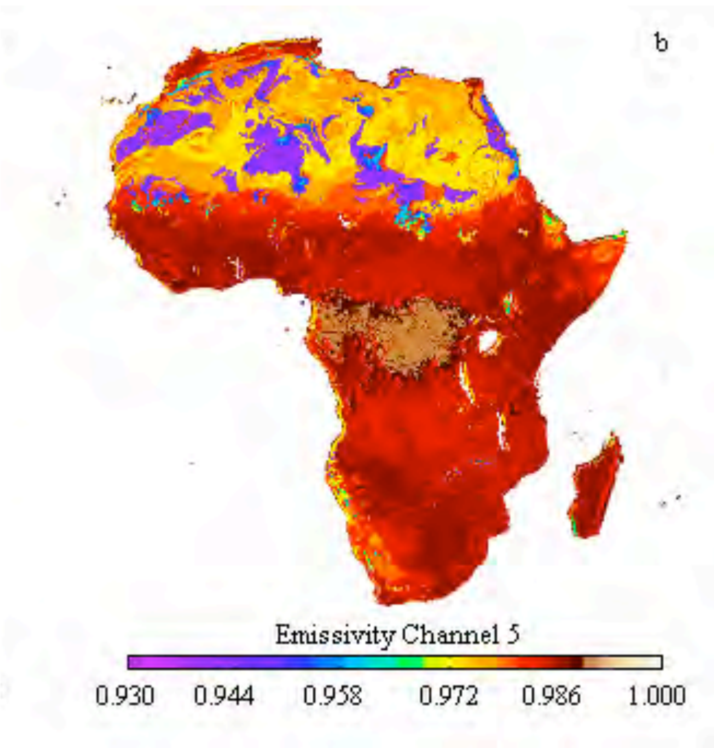
Heritage algorithms are grouped by similarity in results

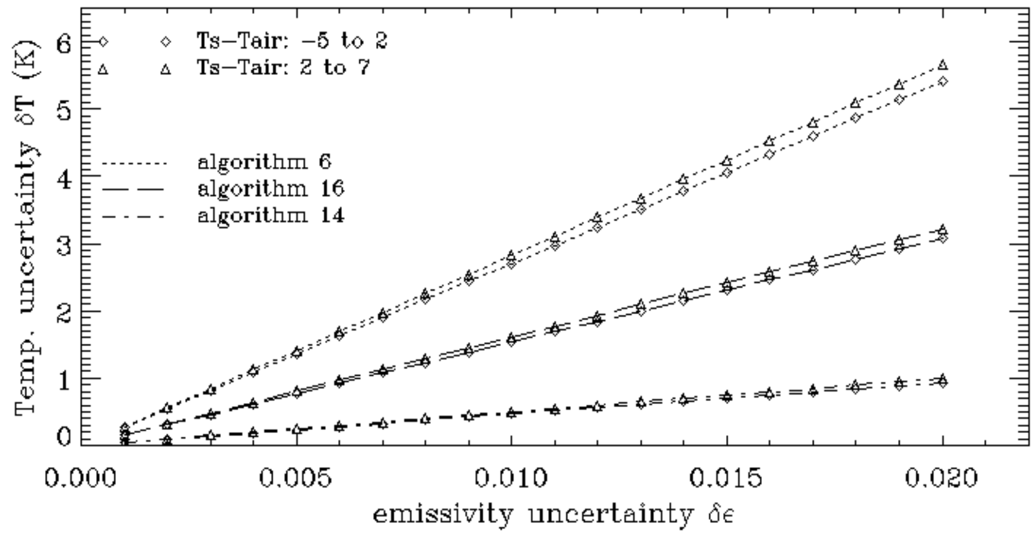


Encouraging!

From Yu et al., *IEEE*, forthcoming

Sensitivity to Emissivity Uncertainties Varies Significantly





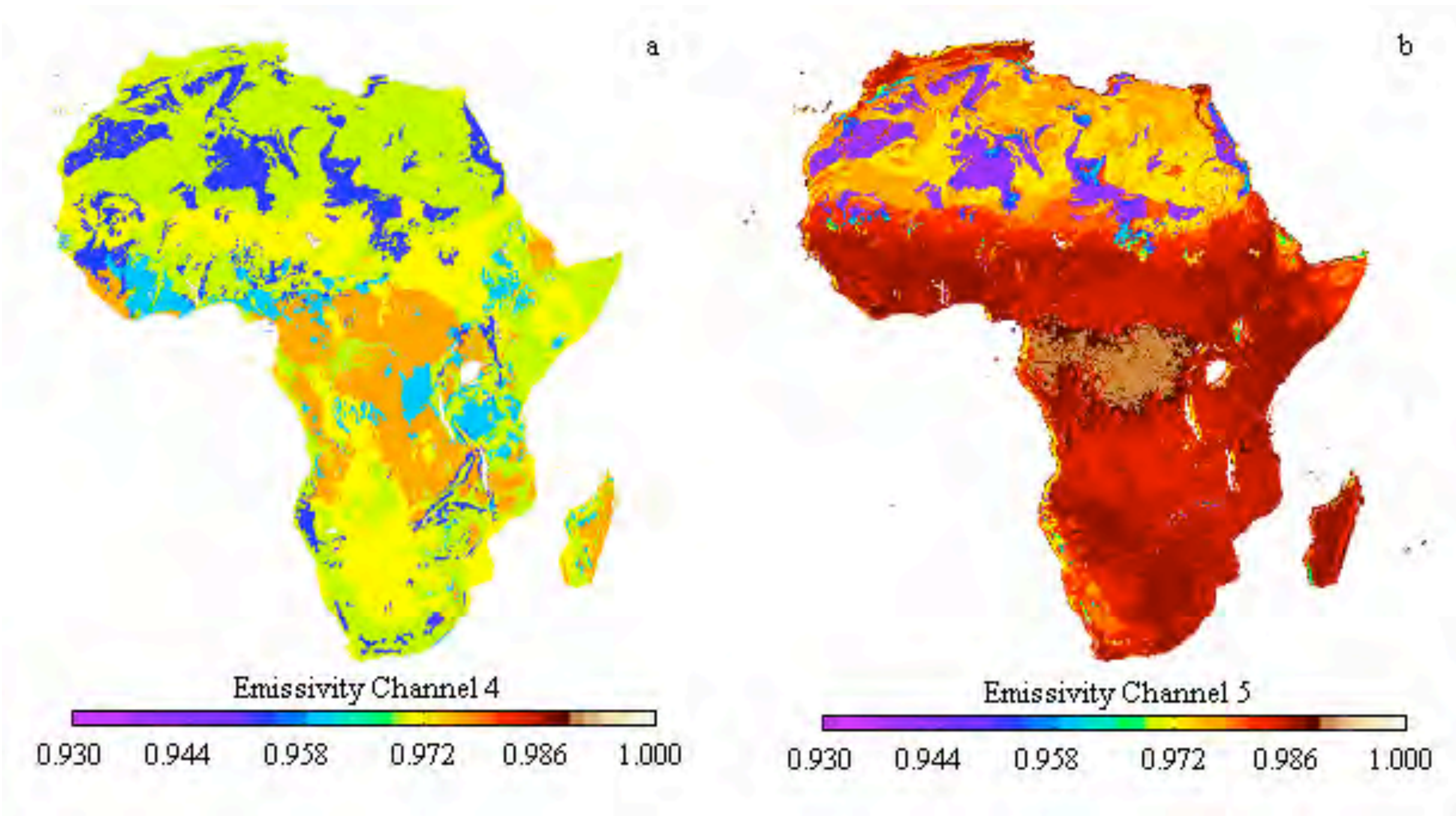
Warm atmospheric condition
Mean emissivity=0.97
Spectral emissivity difference=0.005

➔ Land-cover-based ε maps are likely not sufficient.

From Yu et al., *IEEE*, forthcoming

Towards Spatially Continuous Emissivity Maps

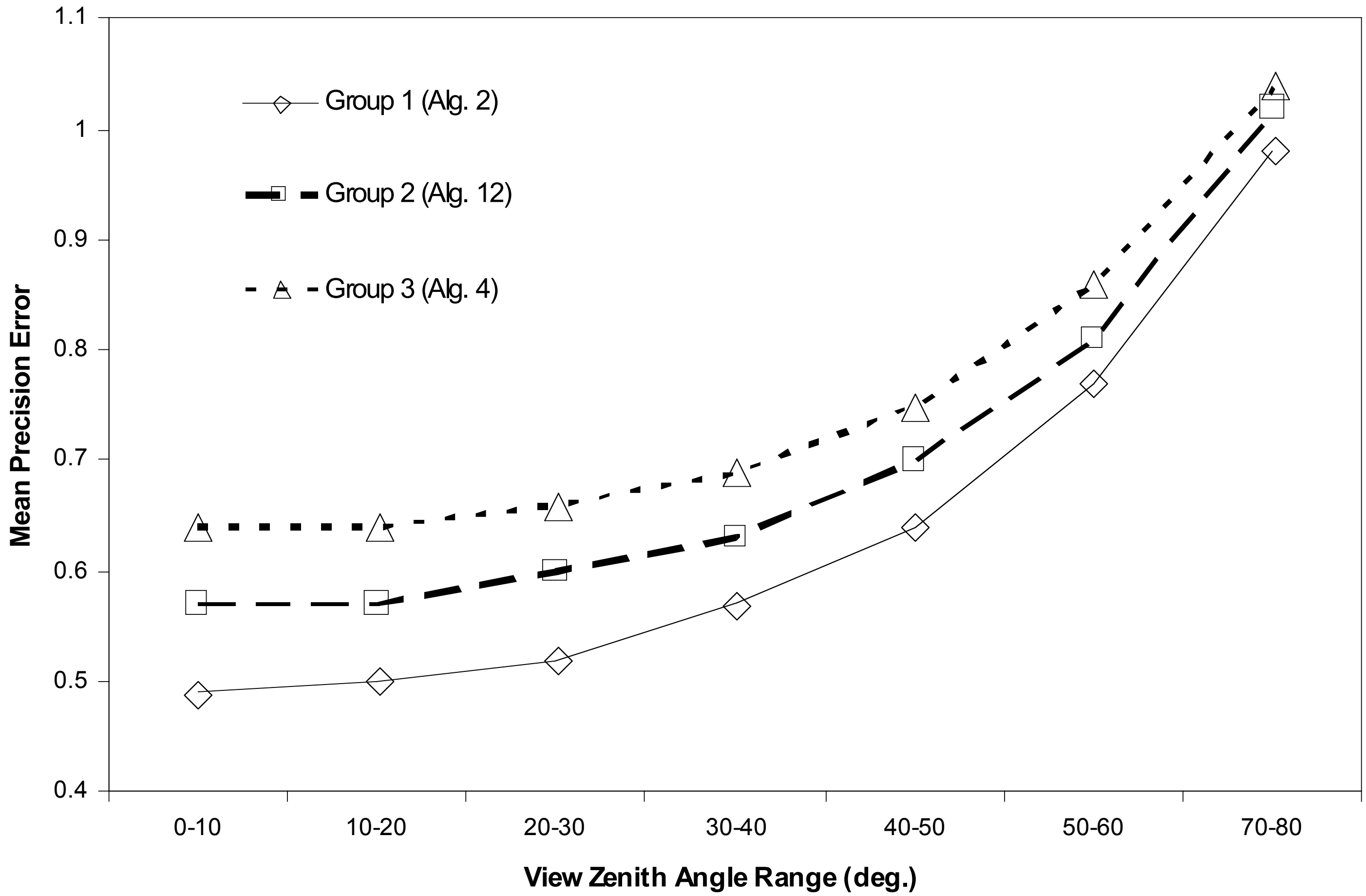
From Pinheiro et al., *RSE, 2006*



ε= ε(MODIS IGBP Land Cover Type, Soil Type, <barren, herbaceous, tree fractional cover>, laboratory emissivity

➔Pros: Inter- and intra land cover class spatial variability, pixel-wise “spatially continuous” per reality
➔Cons: Fractional emissivity summed linearly (no cavity), Not temporarly or angularly varying, Not validated

Atmospheric Path Length Effects Can Be Reduced With One Additional Term

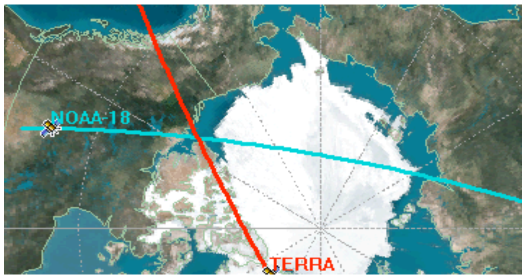


➔ "Angularly-tuned" split window algorithms still "break down" at high view angles

From Yu et al., *IEEE*, forthcoming

Validation Approaches

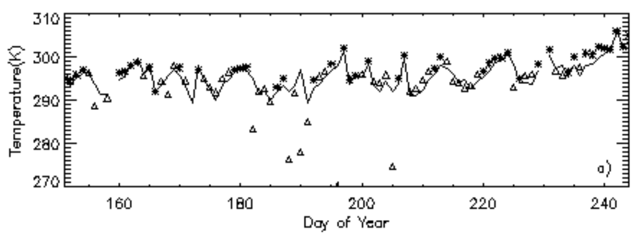
1.



"Simultaneous Nadir Overpass": Polar-orbiting satellites with different altitudes regularly cross orbital intersections within seconds of each other in polar regions

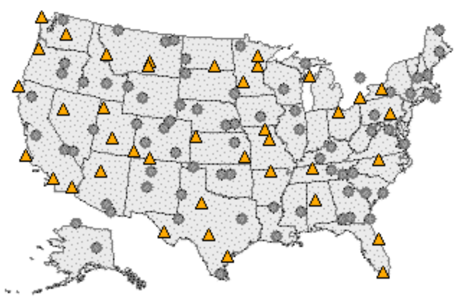
From *F. Weng., IGARSS, (2005)*

2. Field campaigns provide rigorous but limited data (e.g., Validation of AVHRR 14 LST in South Africa (Y2000).



From *Pinheiro et al., Remote Sensing of Environment, 103 (2006)*

3.



Continuous field observations from NOAA's Climate Reference Network and SurfRad are archived in near real time at the National Climatic Data Center (NCDC). Approximately 100 sites.

2007 Plans

Tasks for Pilot LST Product

- Acquire 1 yr. TOA B(T) from Project
- Generate global “continuous fields” emissivity maps
  - AVHRR already developed for Africa
  - Extendable to MODIS, VIIRS, global
- Finalize algorithm choice (Yu recent work)
- Develop QA/QC method/format
- Generate global LST test product
- Validation/evaluation with field / ASTER / MODIS products
- *Orbital Drift to be addressed if time allows*

Task Schedule for 2007

Task	Planned Completion
Acquire 1 yr. TOA B(T) from Project	January
Finalize algorithm choice	March
Generate global “continuous fields” emissivity maps	May
Develop QA/QC method/format	May
Generate global LST test product	July
Validation/evaluation with field/ASTER/MOD11	December

Questions?

Thanks!