Global analysis of Surface Skin Temperature Diurnal Cycle Over Land

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General problem

- The International Satellite Cloud Climatology Project (Rossow and Schiffer, BAMS, 1999) provides Ts estimates from NOAA/AVHRR and geostationary (Meteosat, Goes E and W, GMS) thermal infrared observations (~12 μm)

- *Limitations:* clear-sky only, at a 3-hourly resolution

- *Question:* how do we increase the time resolution, and how do we fill the missing data to obtain the full diurnal cycle?

→ design of a time-interpolation scheme

Previous works

From polar orbitor estimates

Reconstructed from models (Jin, JGR, 1999, 2000)

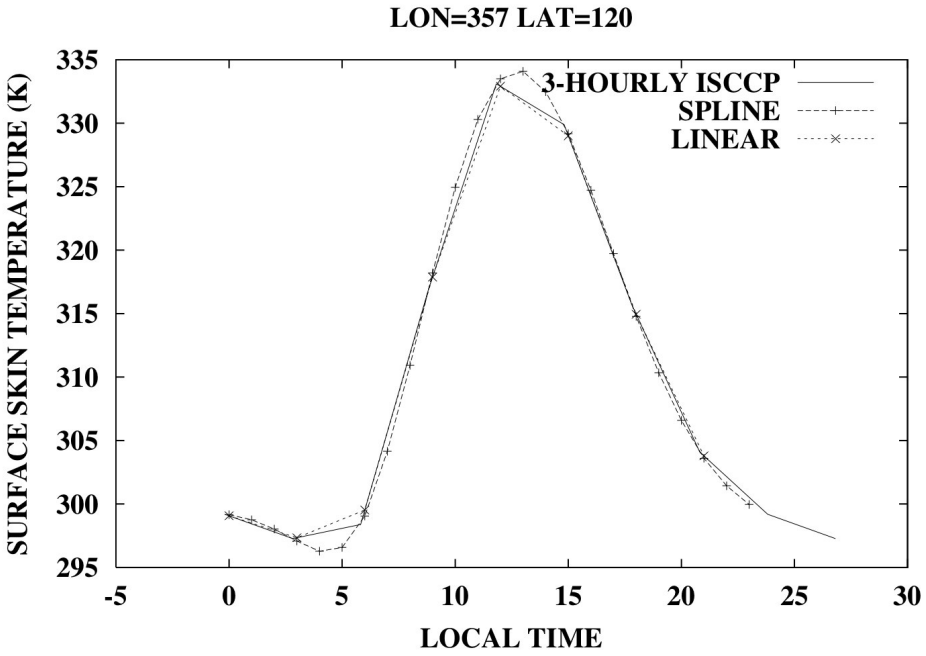
From geostationary satellite

High temporal resolution, but not global

From a combination of geostationary and polar orbitor satellite

Global and independent from models (Ignatov and Gutman, JC, 1999)

Linear & spline interpolation (example)



Spline interpolation reduces the damping of the diurnal amplitude of the cycle, spline allows curvature and works better.

Number of missing hours in the monthly diurnal cycle	Percentage of pixels for ocean	Percentage of pixels for land
0	60.55	58.05
1	5.12	9.48
2	15.25	20.90
3	10.45	8.60
4	4.53	2.47
5	1.97	0.38
6	1.30	0.07
7	0.72	0.03

Exemple from the ISCCP data base (3 hourly) over a month : even the monthly-mean cycles have missing hours

→ However, this type of method cannot work when too much data are Missing (especially when extrema are not well represented) an **PCA/iterative** scheme implemented to improve previous methods

Outline of the presentation

- PCA analysis of the Ts diurnal cycle
- A PCA/iterative interpolation scheme for Ts diurnal cycle
- Applications:
  - A dataset of Ts diurnal cycle amplitudes
  - Synthetic analysis for MW cloudy-sky sampling of the diurnal cycle
  - Soil moisture
  - Land flux

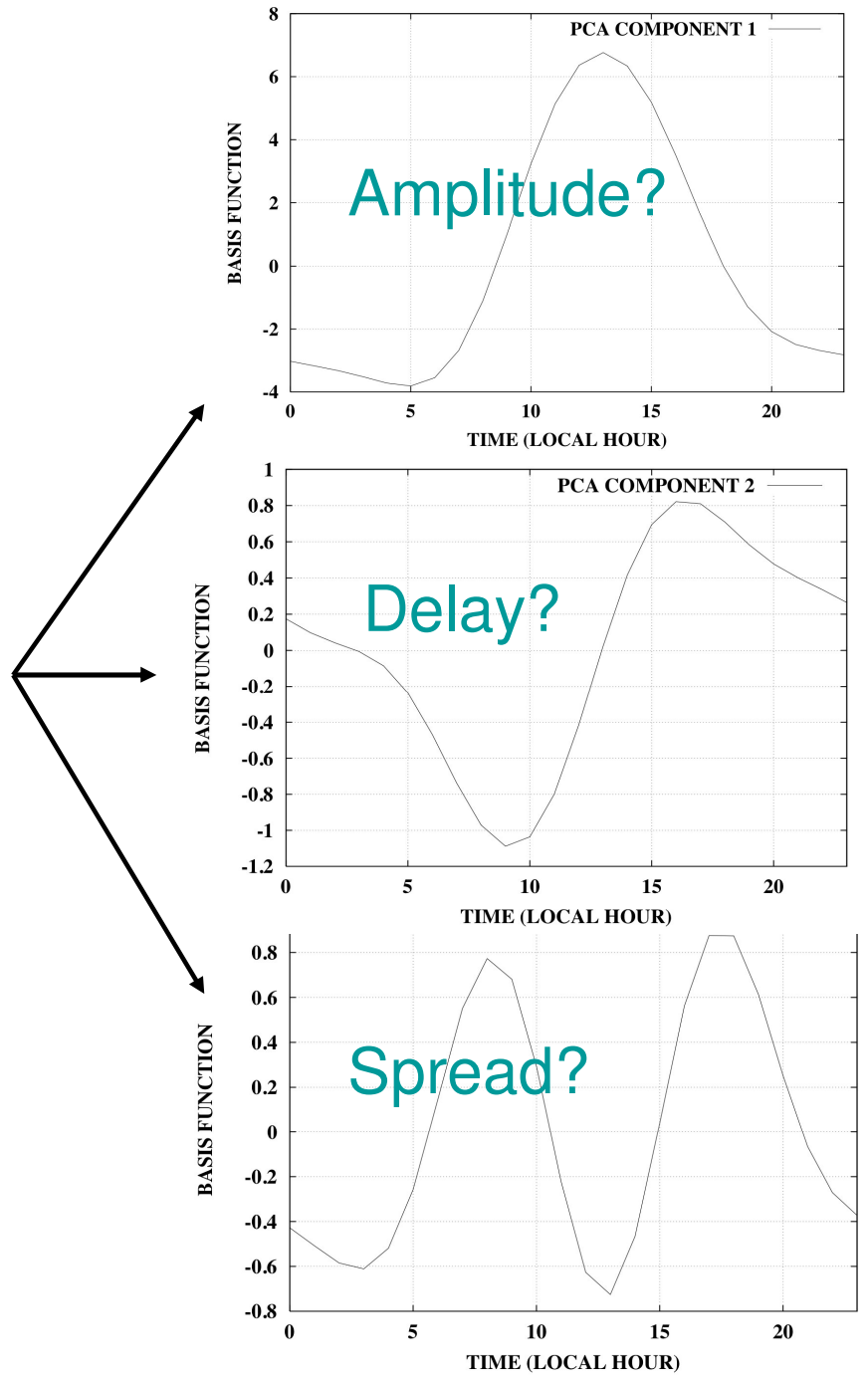
PCA analysis of the diurnal cycle

- We use a dataset of diurnal cycles for each location, globally, to perform a PCA analysis. We obtain specific diurnal shapes for each location. These 3 EOFs explain more than 97% of the cycles (92.83%, 2.36%, and 1.90% resp.).

- The diurnal cycles are represented with these 3 degrees of freedom:

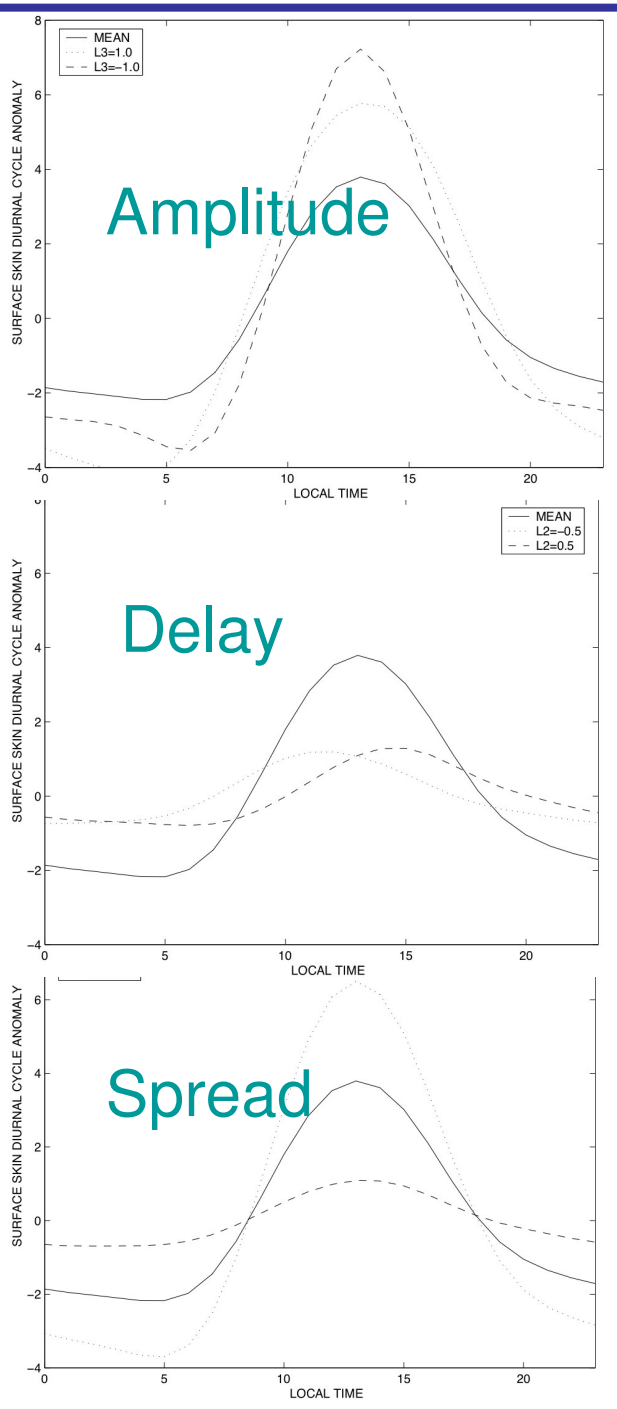
$$Ts = Tmean + \lambda_1 T_1 + \lambda_2 T_2 + \lambda_3 T_3.$$

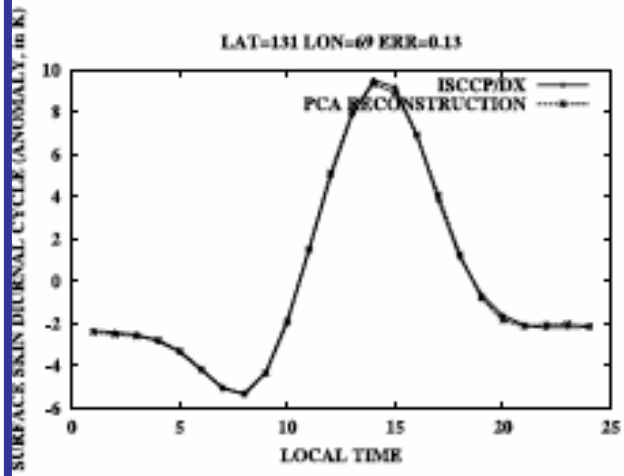
- No surface modeling involved.

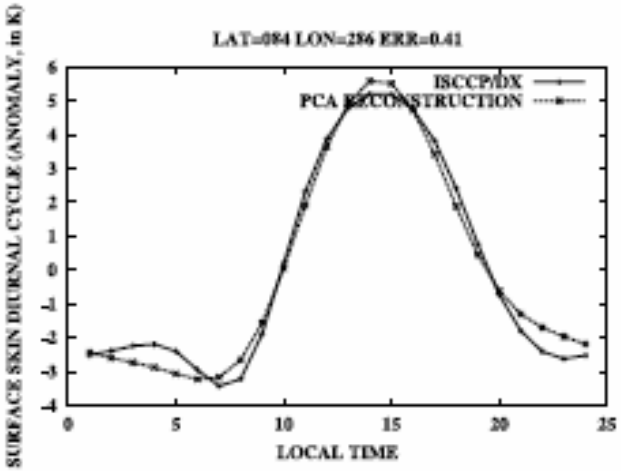


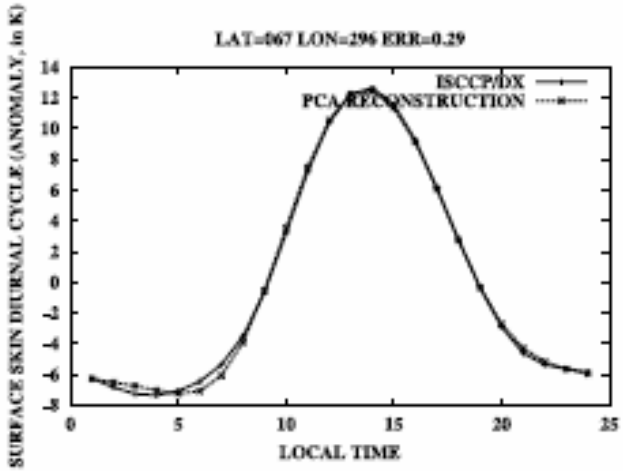
- Interpreting the PCA representation

For a particular location, varying the amplitude of these components (λ_1,λ_2,λ_3) modifies the general characteristics of the diurnal cycle.

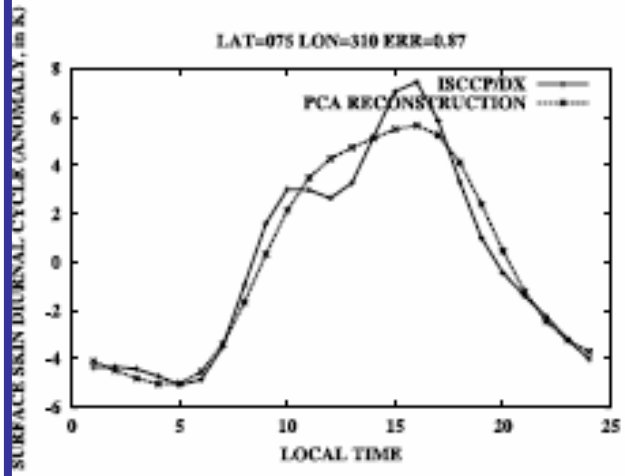


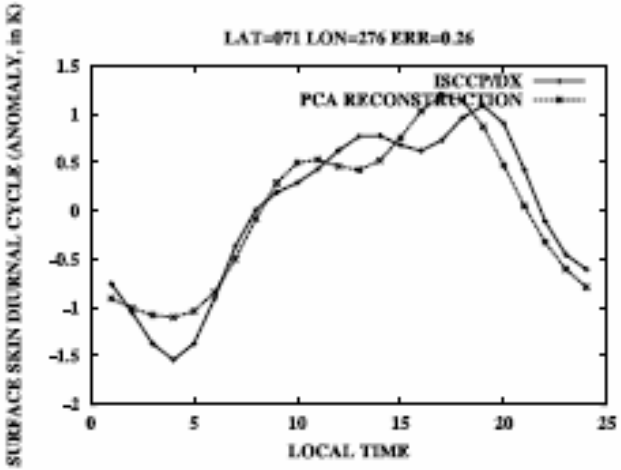


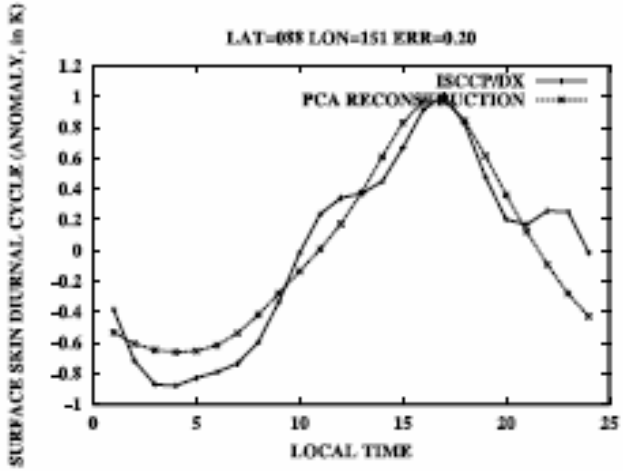




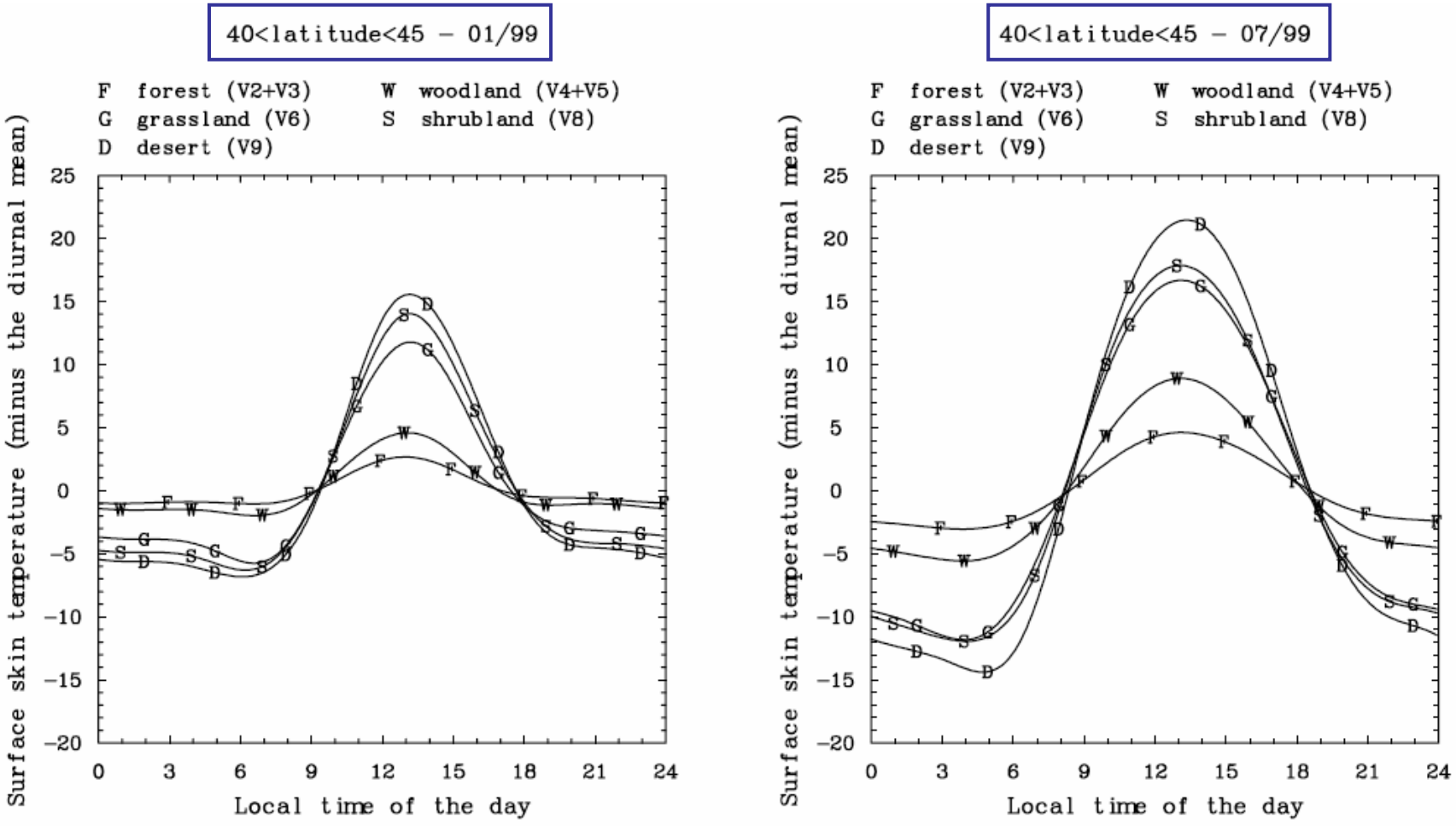
- 6 examples of PCA reconstruction using the first 3 components





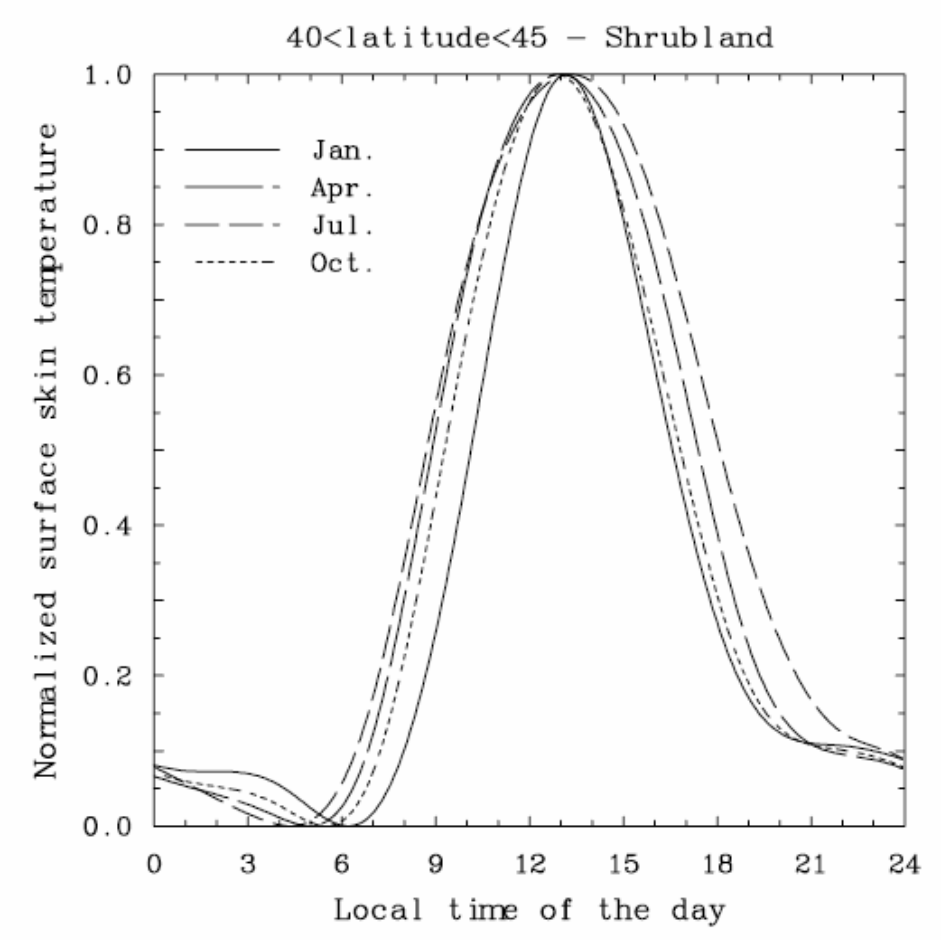


- Relationship with the vegetation type: realistic diurnal cycles

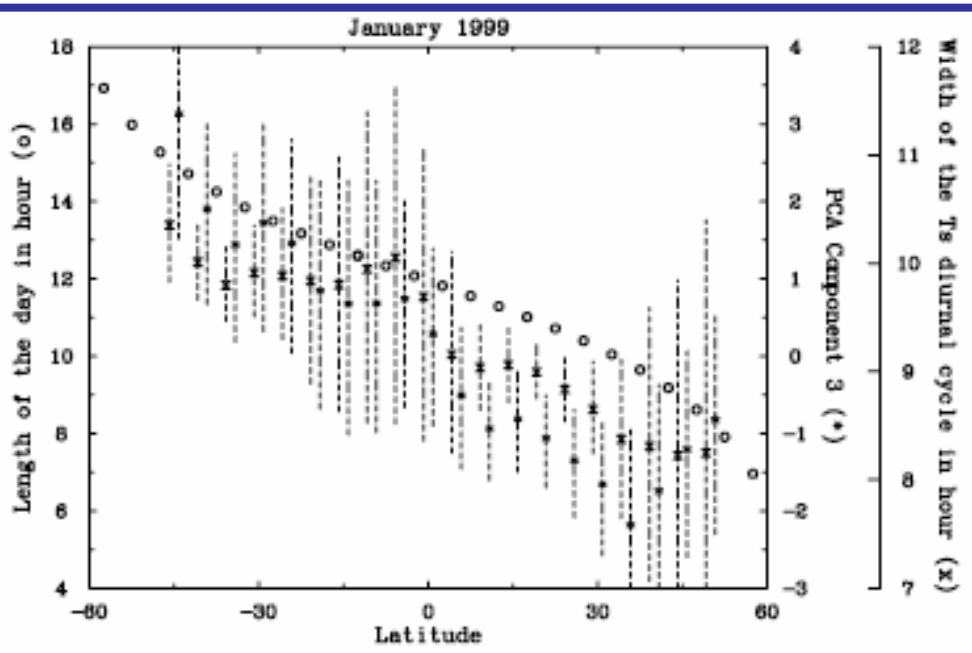


Ts cycles for 5 surface types

- Relationship with the season: realistic diurnal cycles

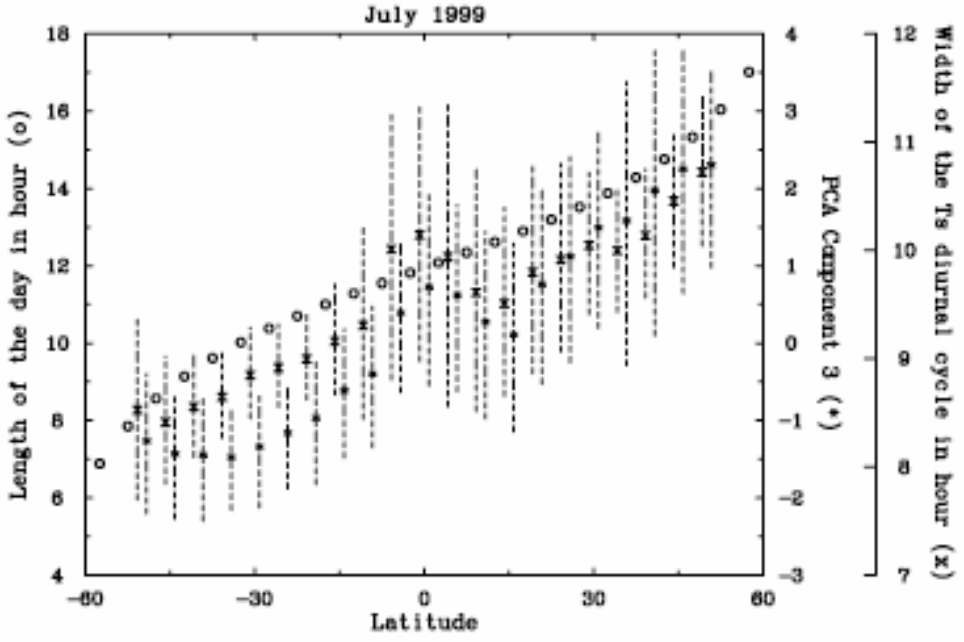


Ts cycle for different seasons over a given vegetation type (shrubland)



- Length of the day

Jan 1999

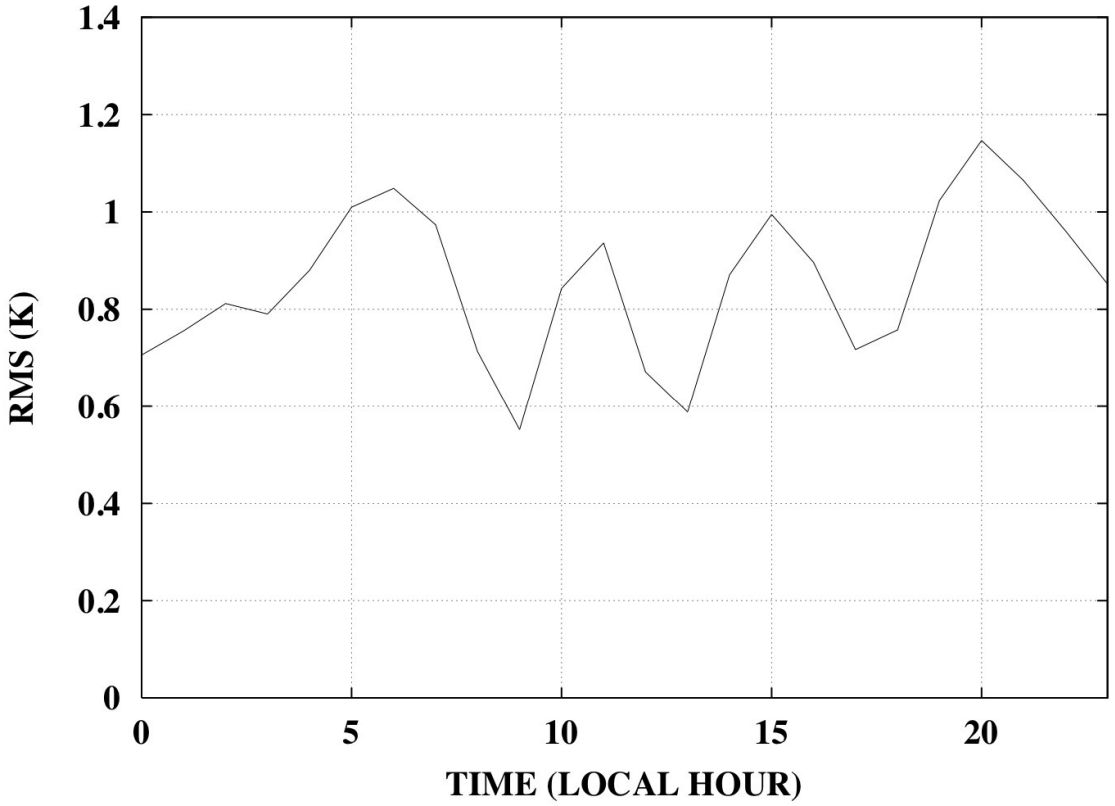


Jul 1999

Width of the diurnal cycle related to the length of the day but also modulated by the vegetation/soil moisture.

PCA / Iterative interpolation scheme

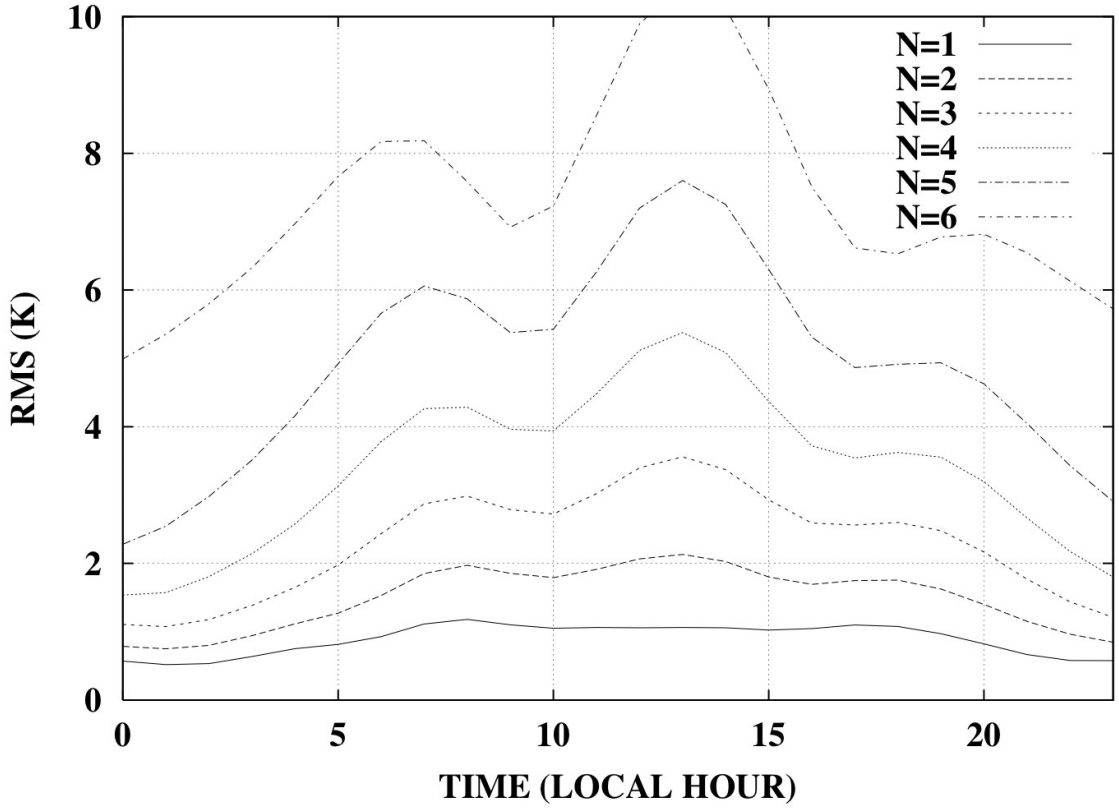
- RMS error between the 1-hourly cycle and its PCA-representation [no missing data]



This is the best estimate we can get with our « model » of the diurnal cycle.

The error is uniformly distributed in the cycle, RMS below ~ 1 K

• RMS error of the Ts cycle and its spline/PCA-interpolation [missing data]



Missing data is chosen here randomly in the cycle.

Extrema are the most important piece of information.

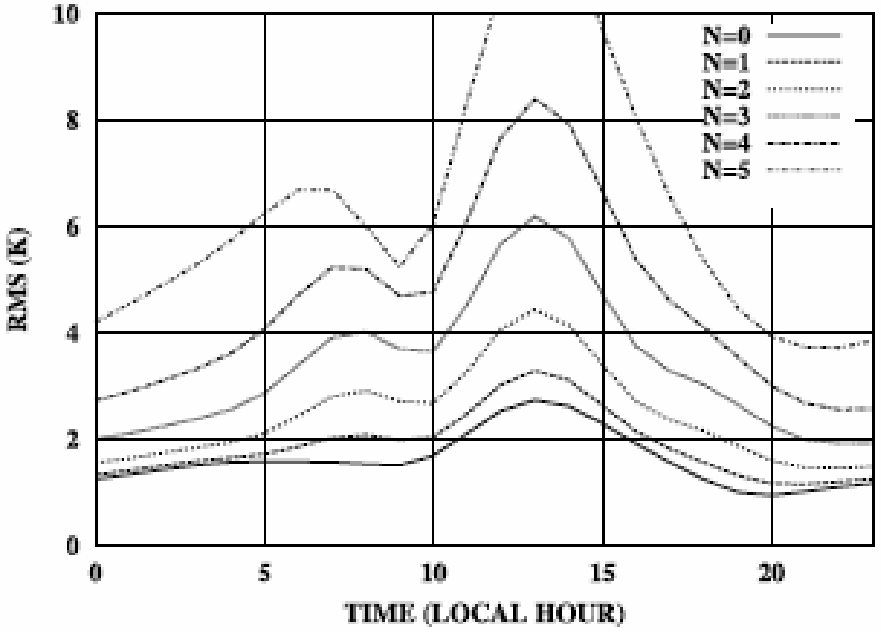
- PCA / Iterative interpolation scheme□

- An iterative algorithm is used to optimize the components (λ_1,λ_2,λ_3) so that the PCA-represented diurnal cycle gets closer to the incomplete Ts measurements. Once the optimization is complete, the PCA-representation interpolates the cycle at any time-resolution.

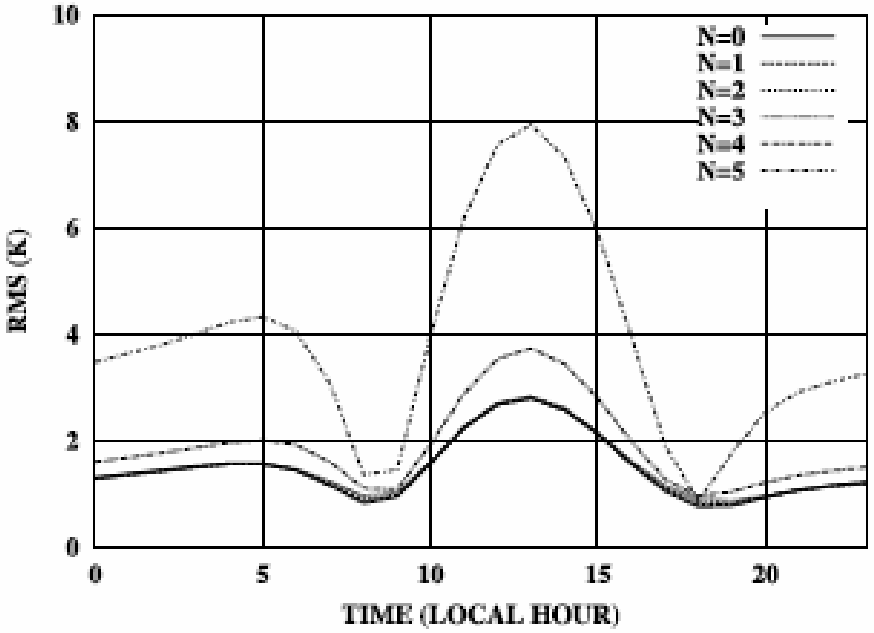
- Details at:

Aires, F., C. Prigent, and W. Rossow, Temporal interpolation of global surface skin temperature diurnal cycle over land under clear and cloudy conditions, J. Geophys. Res., 109, D04313, doi:10.1029/2003JD003527, 2004.830

- RMS error for spline/PCA PCA/iterative representation when missing data



With spline / PCA interpolation

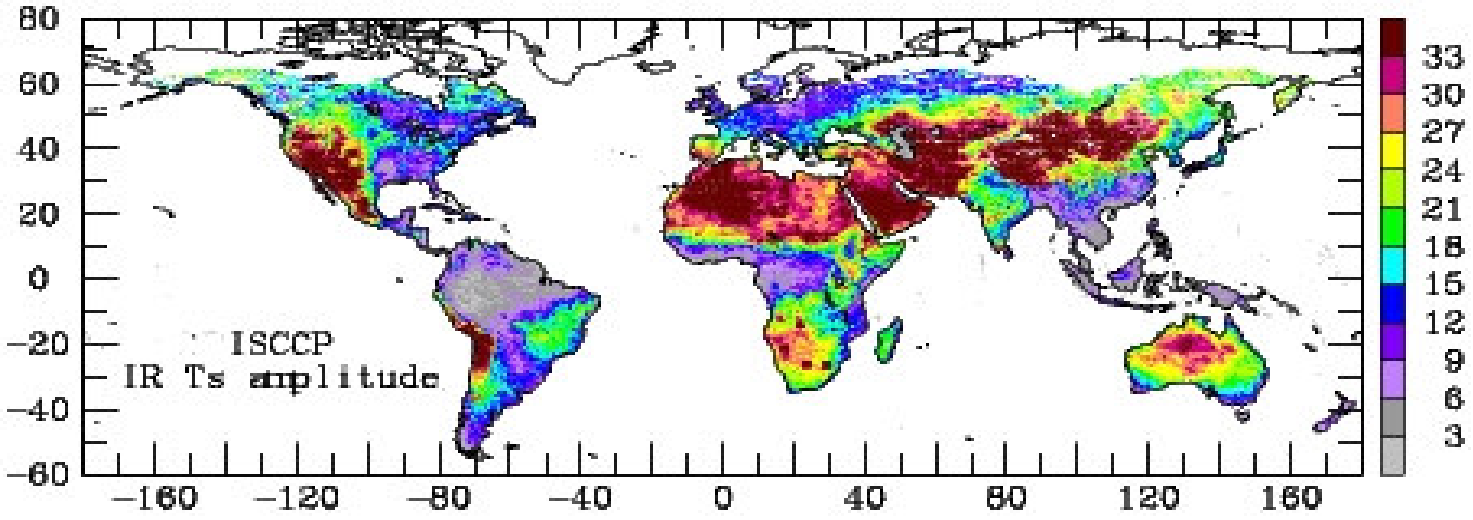


With iterative interpolation

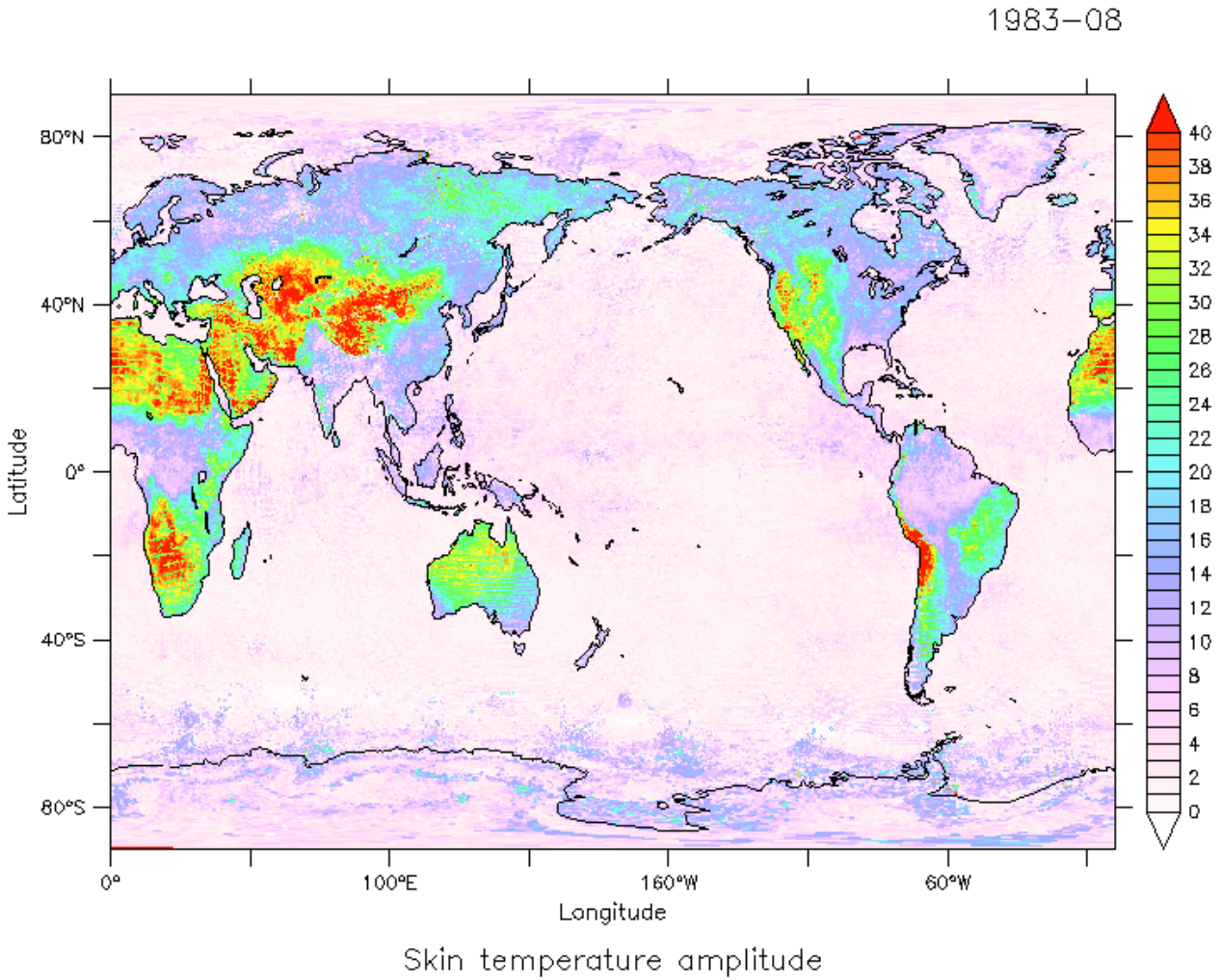
With the interative interpolation scheme, the errors increase much less with the number of missing data

Applications

Application 1: diurnal cycle amplitude



A monthly-mean dataset of clear sky full diurnal cycle and its amplitude from 1983 to 2005. Processing completed, starting to analyze and validate the data.



e.g. monthly means of the diurnal cycle amplitudes 1983-1988

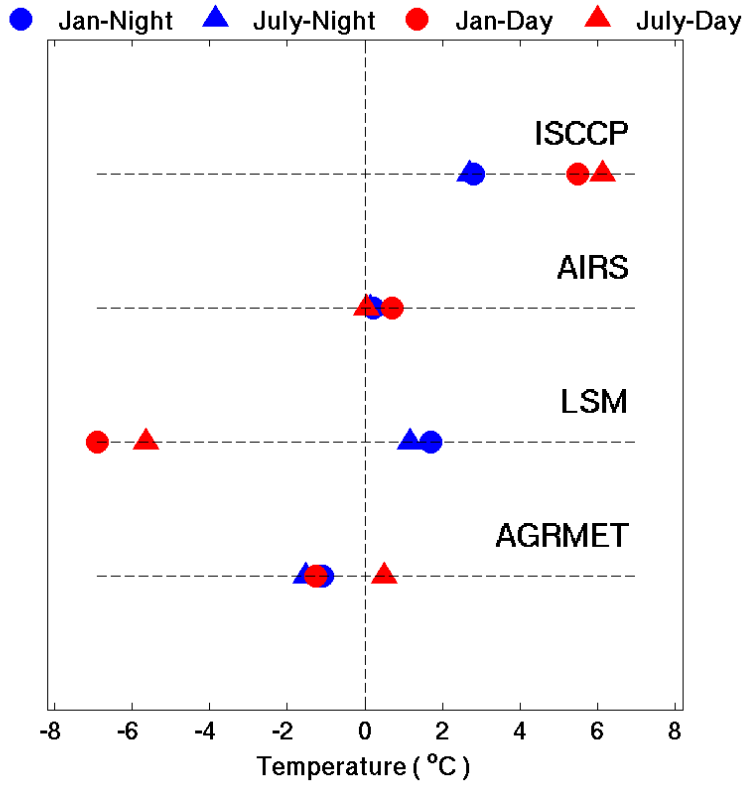


Fig. 1. Monthly mean biases between ISCCP, AIRS, AGRMET, NOAH-LSM and MODIS (reference) for Jan and July 2003. The top left panel gives the global biases for night (~1.30 am) and day (~1.30 pm) time. The bottom panels show global map of the monthly differences for night (left panels) and day-time (right panels) for July 2003.

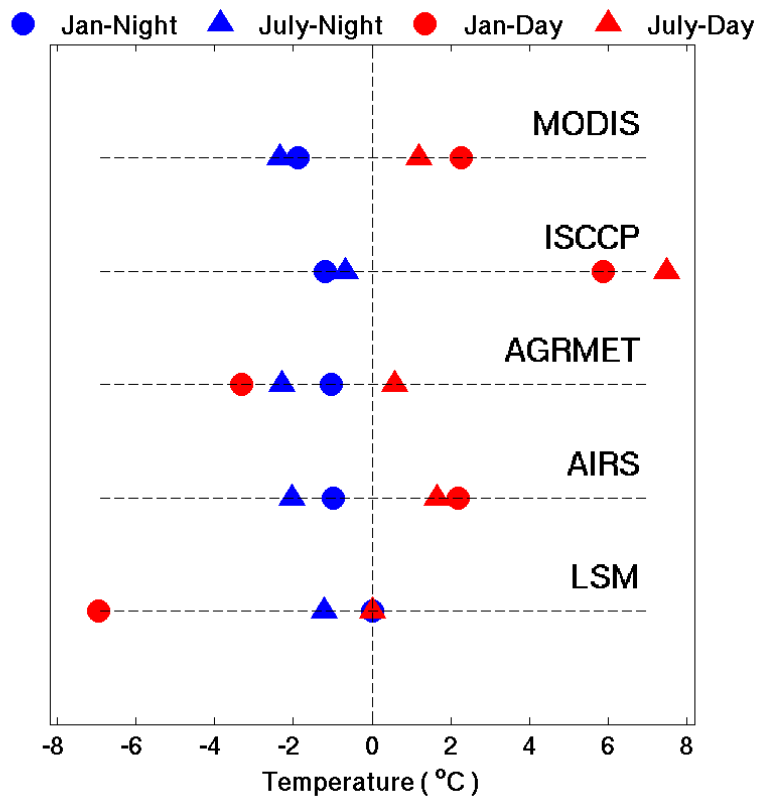


Fig. 5. Monthly mean biases between MODIS, ISCCP, AIRS, AGRMET, NOAH-LSM and CEOP in situ Ts (7 sites = 16 stations) for Jan and July 2003 night (~1.30 am) and day (~1.30 pm) times.

comparing ISCCP Ts with other estimates (see poster in following session)

comparing diurnal cycles (work with MSG Ts)

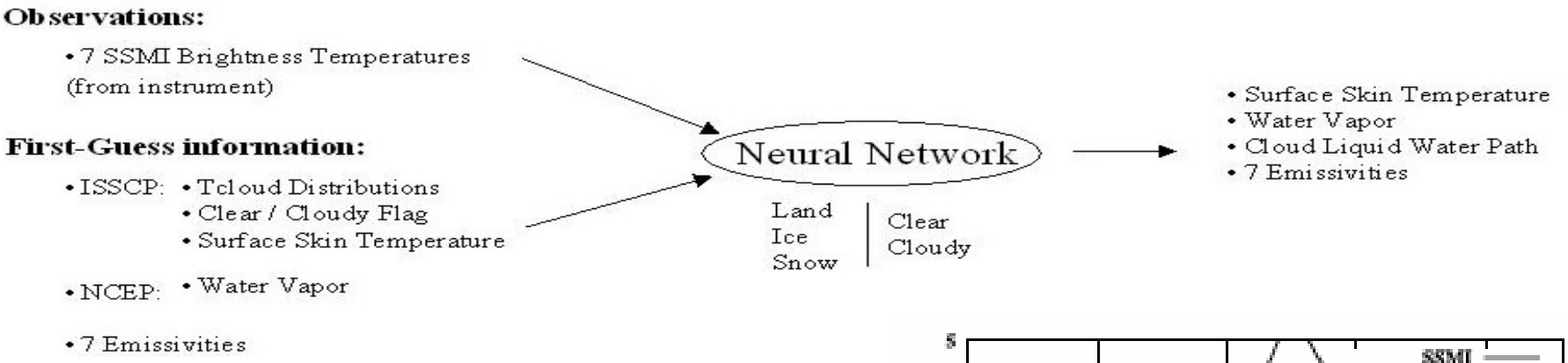
- ISCCP Ts for 2005+ should be processed soon.

- As the SEVIRI IR channels around ~12 um should be incorporated into the ISCCP compilation, it would be very interesting to compare the Ts and diurnal cycles from the LSA-SAF operational product and the ISCCP estimates.

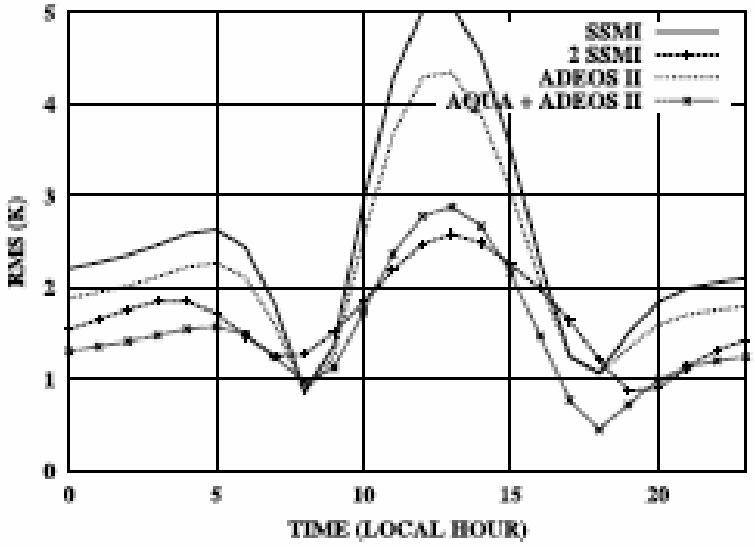
- The comparison of the LSA-SAF Ts over different biomes and seasons will be of great help to evaluate the 20+ years ISCCP series even if the comparison is limited in time.

Application 2: MW cloudy-sky Ts retrieval

Development of a method to retrieve Ts under clouds using combined SSM/I microwave and IR satellite measurements (Aires et al., JGR, 2001; Prigent et al., JAM, 2003)



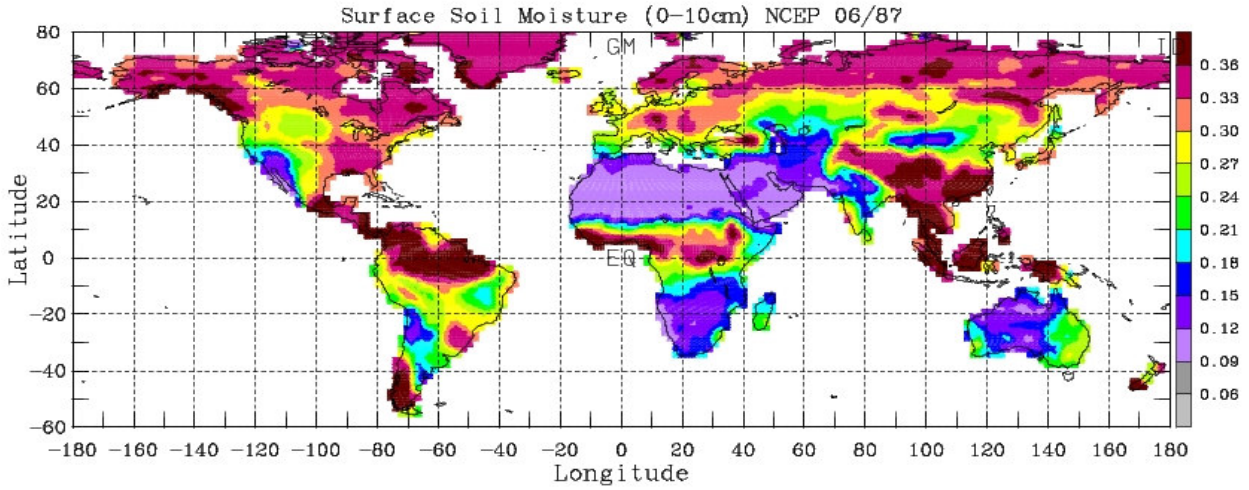
We use our interpolation scheme in synthetic data to measure the errors in the reconstruction of the diurnal cycle when using MW Ts retrievals.



RMS error of the interpolation scheme of the Ts diurnal cycle

Application 3: Soil moisture

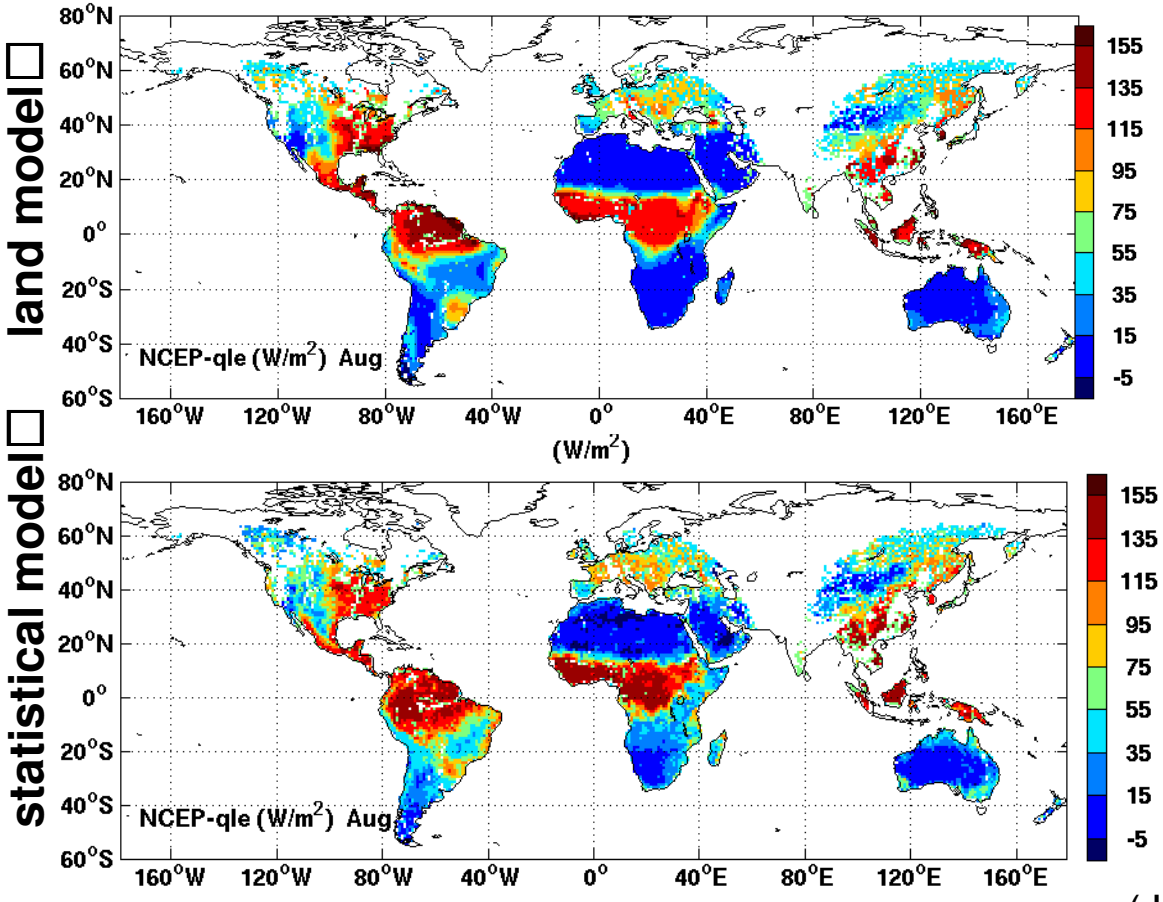
A new technique combining multiple satellite observations and the amplitude of the Ts diurnal cycle has been developed to evaluate the soil moisture in models.



(Prigent et al., JGR, 2005;
Aires et al., JGR, 2005)

Application 4: Land Fluxes

A statistical model is used to reproduce the global relationships between a suite of satellite observations (including the Ts diurnal cycle amplitude) and the fluxes from a given land surface model. The satellite data can then be used then to predict the fluxes.



Example of NCEP original (land model) and predicted (statistical model) monthly mean latent fluxes for Aug 1993.

(Jimenez et al., 2008, under review)

Conclusions

• General methodology to interpolate the diurnal cycle, based on a PCA technique, independent of models.

• A dataset of 20 years of monthly mean diurnal cycles for clear sky-only based on ISCCP estimates

• Ts retrieval from MW under cloudy-conditions: the interpolation sheme allows for the combination of both Ts retrievals (IR/MW) for a better cycle description. With more and more MW instruments on board missions, better sampling of the diurnal cycle.

• Ts amplitude dataset to be used in a variety of applications: (soil moisture, vegetation, surface fluxes …)

Conclusions

•□ Aires, F., C. Prigent, and W. Rossow, Temporal interpolation of global surface skin temperature diurnal cycle over land under clear and cloudy conditions, J. Geophys. Res., 109, D04313, doi:10.1029/2003JD003527, 2004.830