Land Surface Thermal Infrared Emissivity Modeling for Operational Weather Prediction and Climate Models

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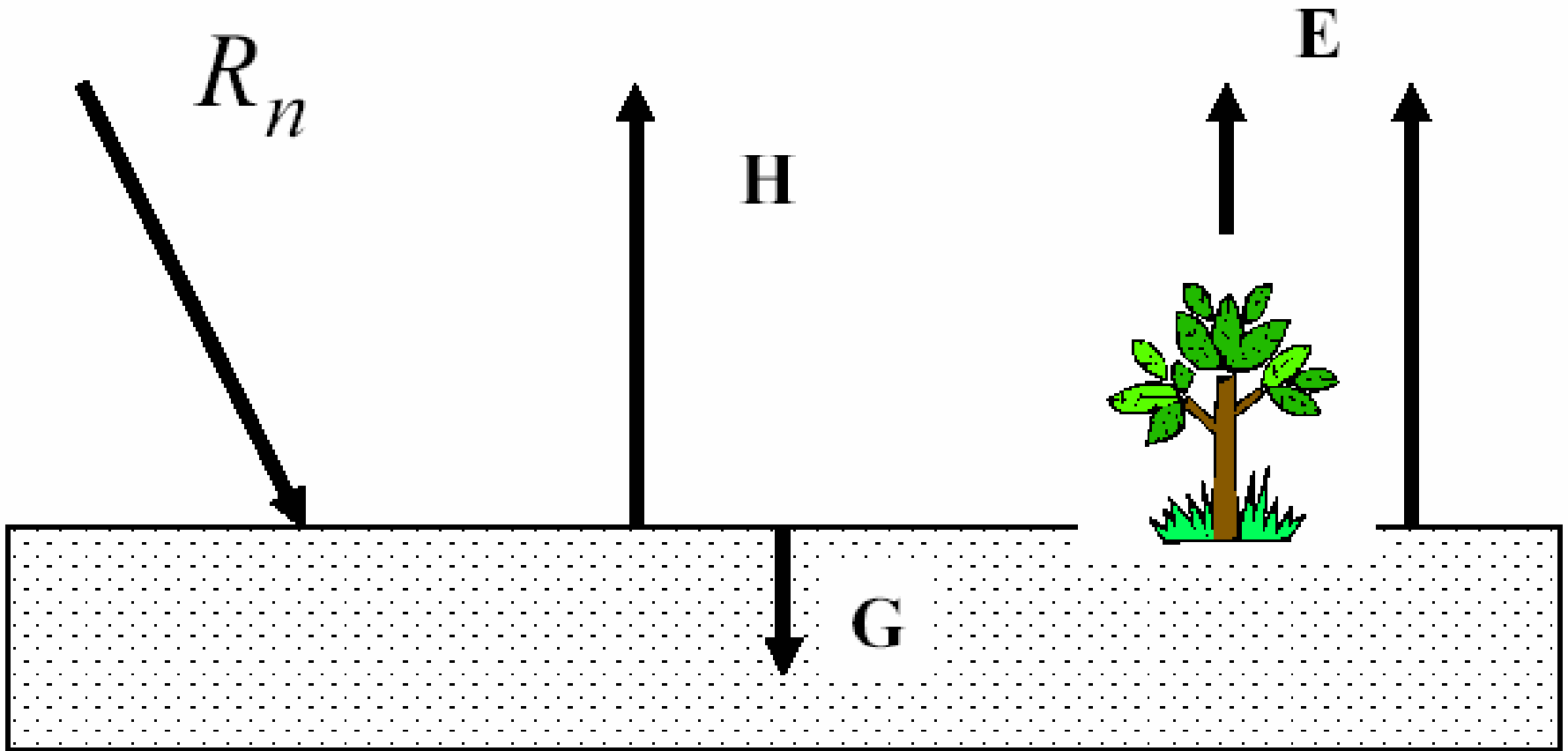
Surface energy balance equation

Surface radiation budget equation:

$$R_n = R_n^s + R_n^l = (1 - \alpha)F_d^s + \varepsilon F_d^l - \sigma \varepsilon T^4$$

albedo

Insolation

Emissivity

Longwave downward radiation

Skin temperature

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emissivity (ε) has only been handled very roughly so far

- ♣ the **R**adiative **T**ransfer for **TOV**S (RTTOV) code uses 0.98 for all land surfaces and 0.99 for sea ice;

- ♣ the ECMWF model also sets a constant for all land surfaces for the monitoring purpose;

- ♣ the Noah LSM sets emissivity as unity except for the presence of snowpack;

- ♣ the NCAR Community Land Model version 2 (CLM2) calculates canopy emissivity from LAI and sets soil and snow emissivities as 0.96 and 0.97.

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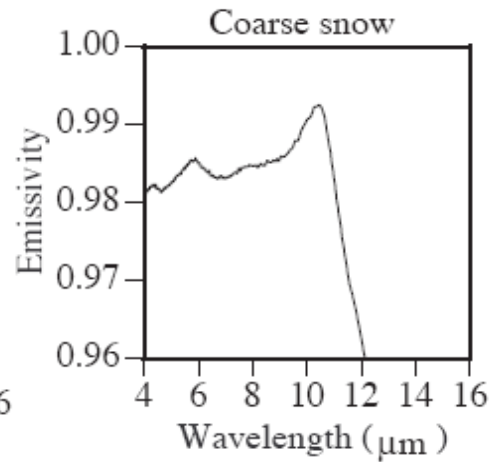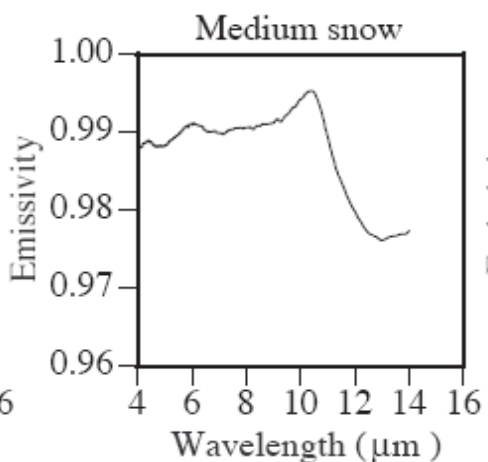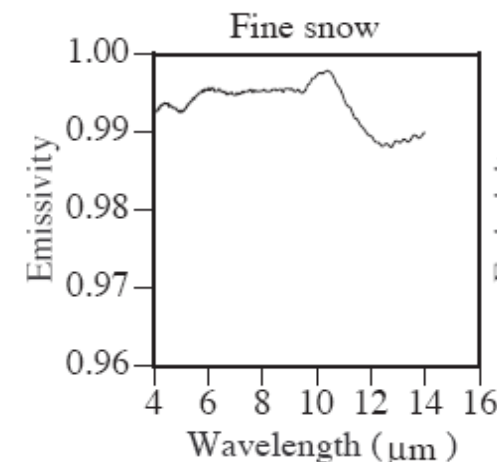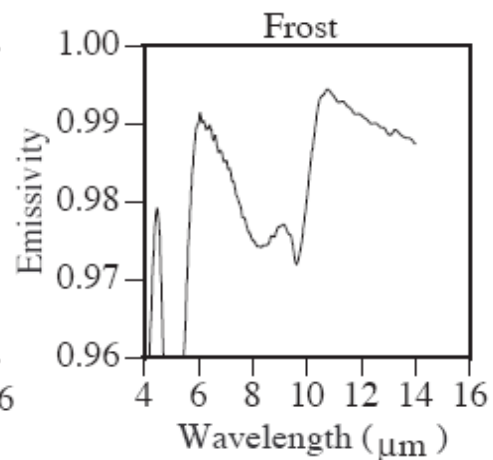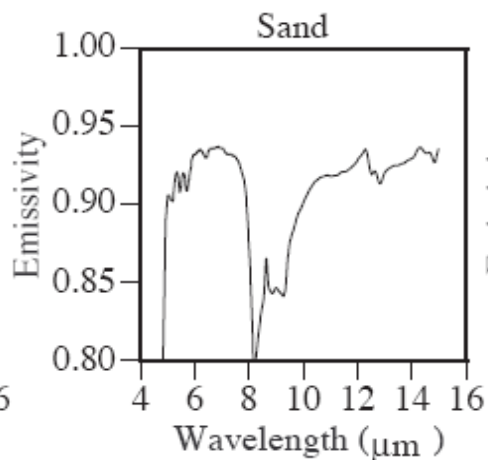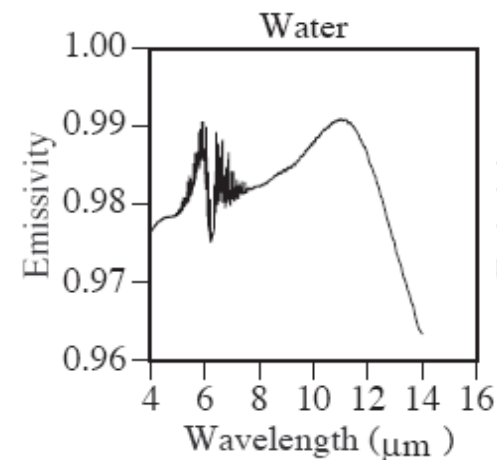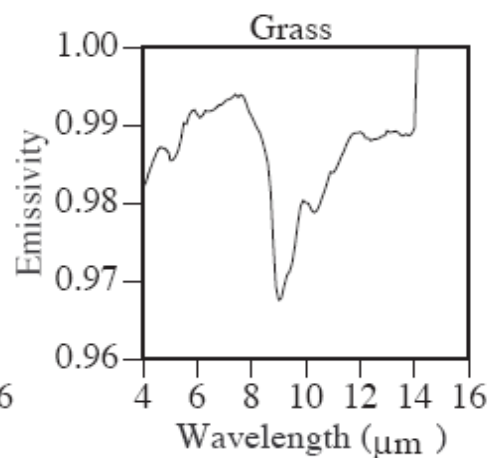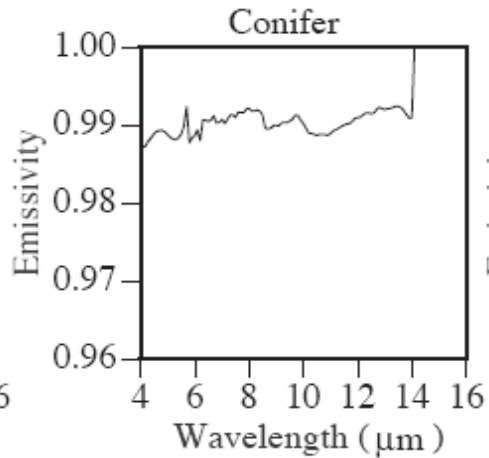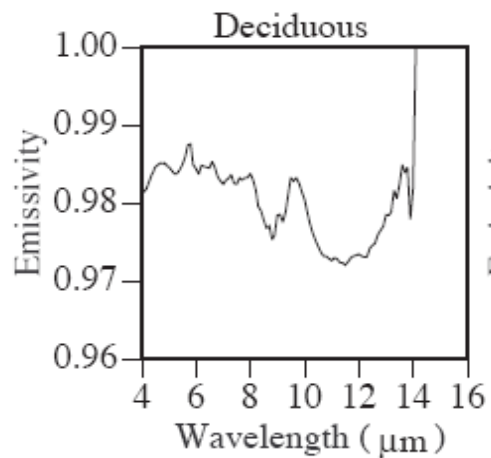
Measured emissivities in the Lab

Importance of surface thermal-IR emissivity

♣ Jin, M., and S. Liang, (2006), Impacts of the MODIS broadband emissivity on GCM simulation, *J. Climate*, 19:2867-2881.

➔ Developed narrowband to broadband emissivity conversion formulae

➔ Demonstrate the improvement of GCM simulation results using the actual emissivity values from MODIS

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Broadband emissivity from MODIS

Jan. 2003

July 2001

0.85 0.87 0.89 0.91 0.93 0.95 0.97
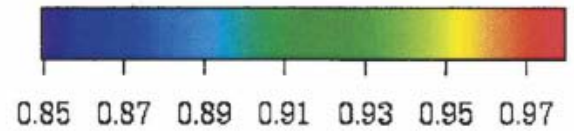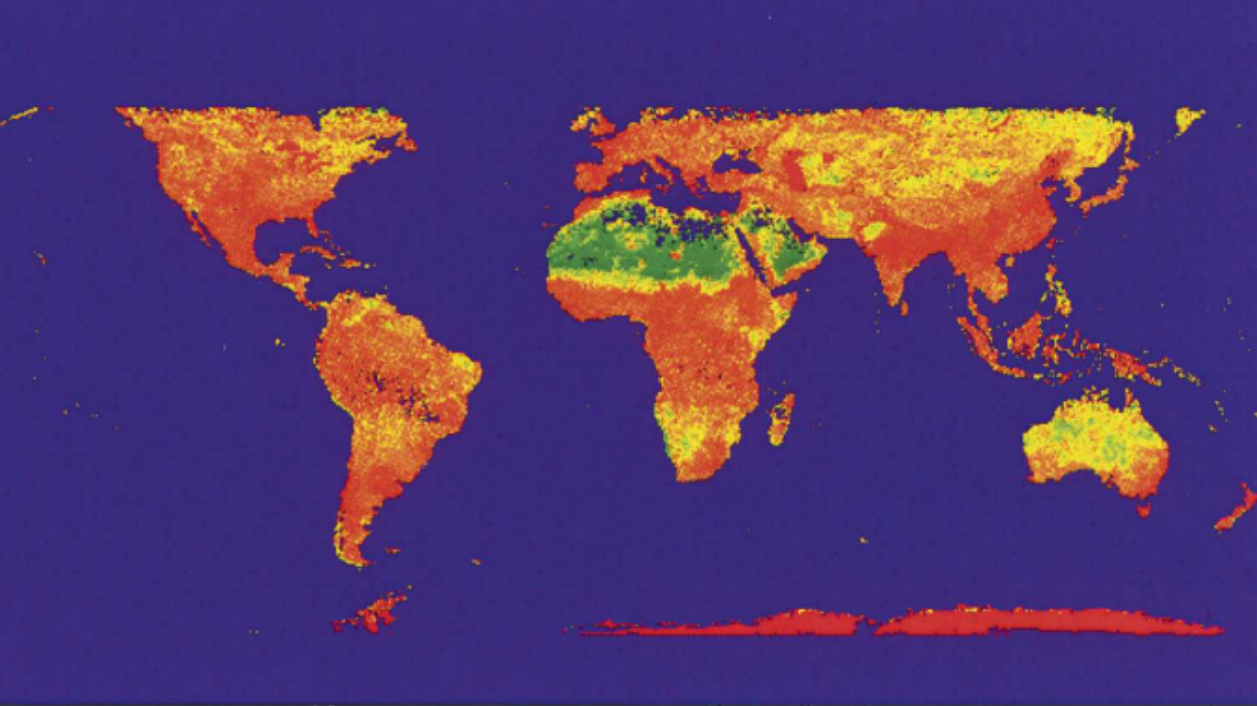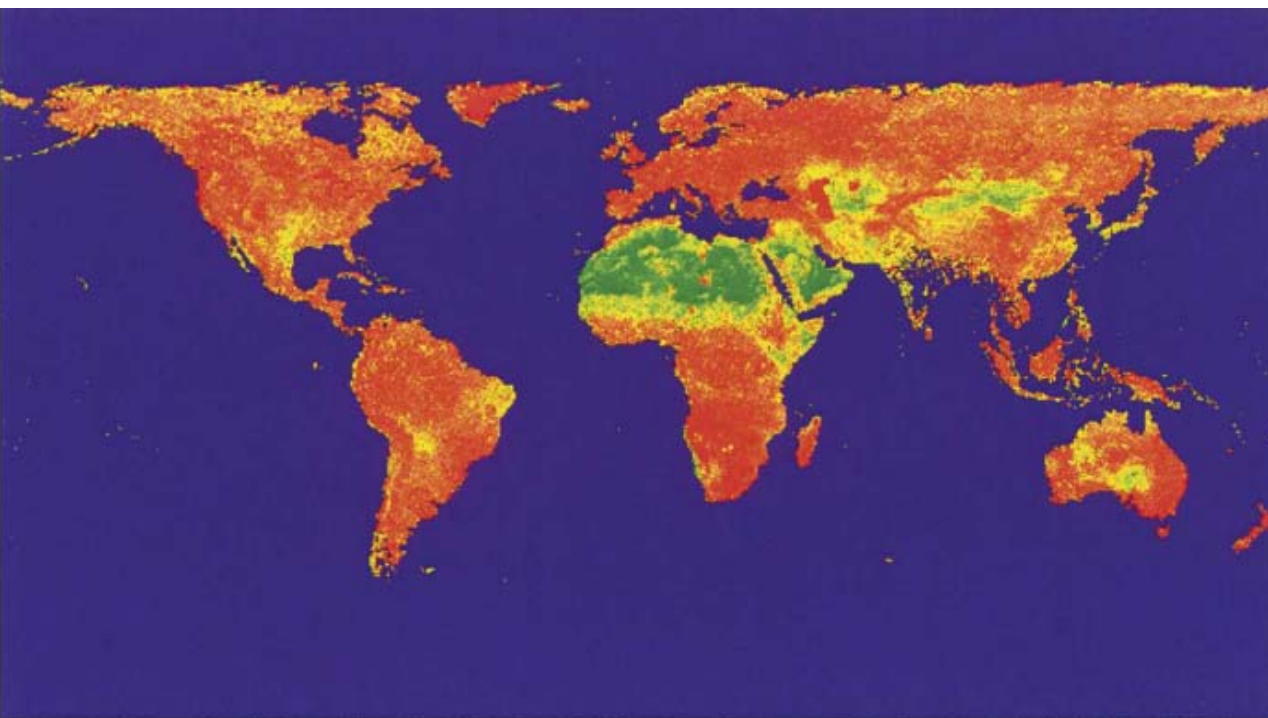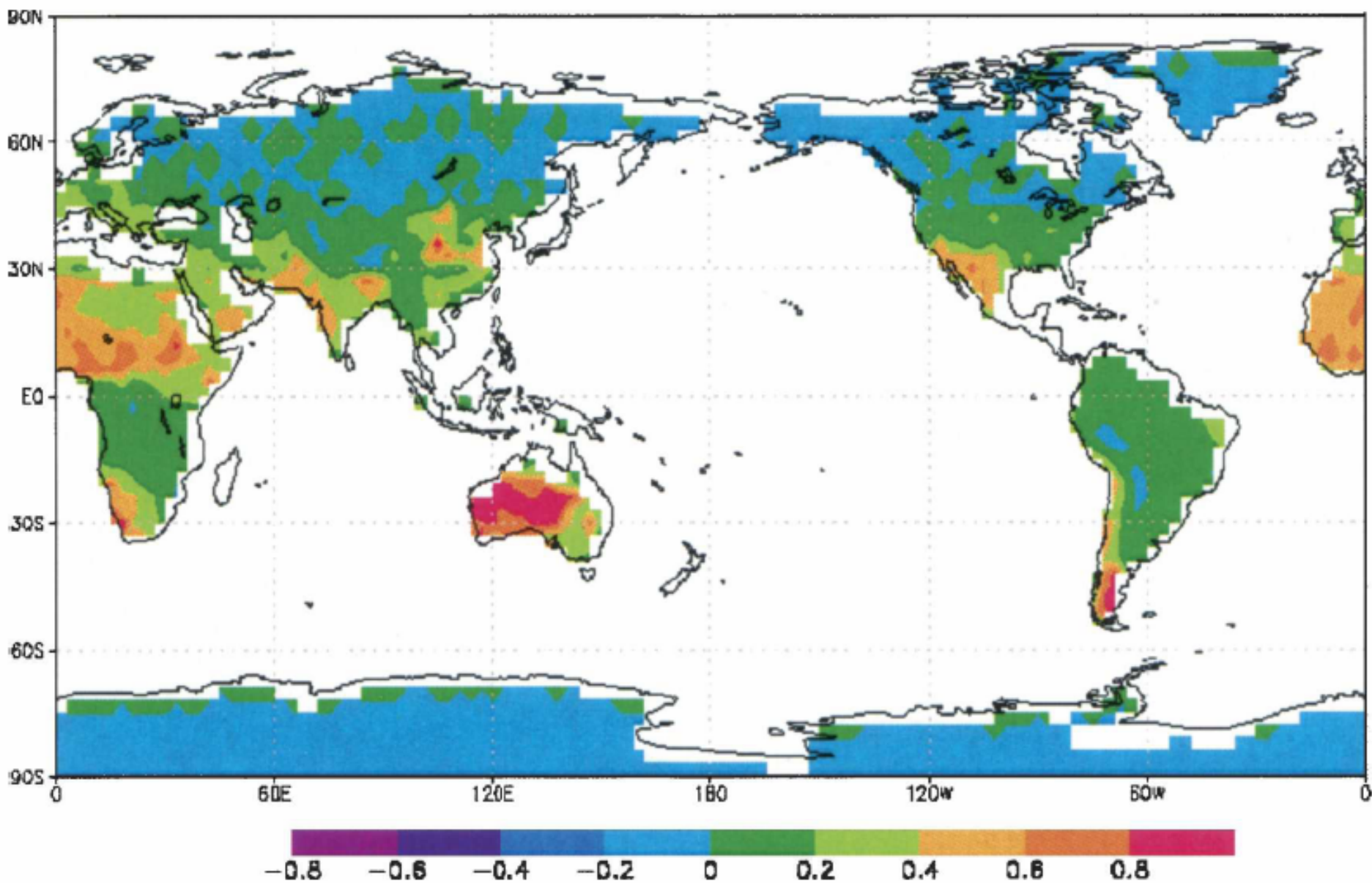
Offline CLM-simulated impact on the ground temperature (K) sensitivity run (0.90) minus the control run (0.96 as the default). The data are daily averages of January 1998.

Offline CLM-simulated impact on the sensible heat flux (WM-2) sensitivity run (0.90) minus the control run (0.96 as the default). The data are daily averages of January 1998.
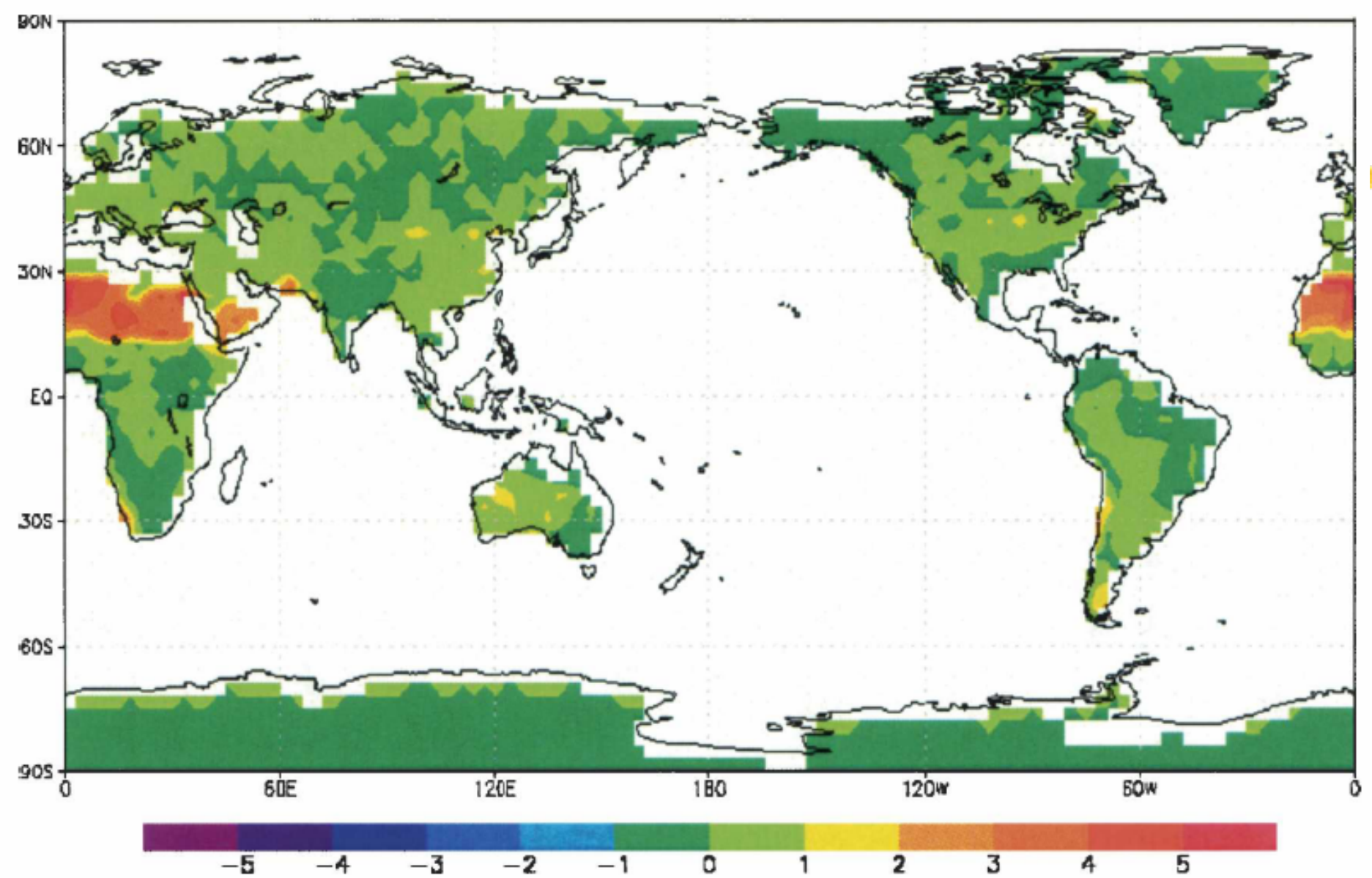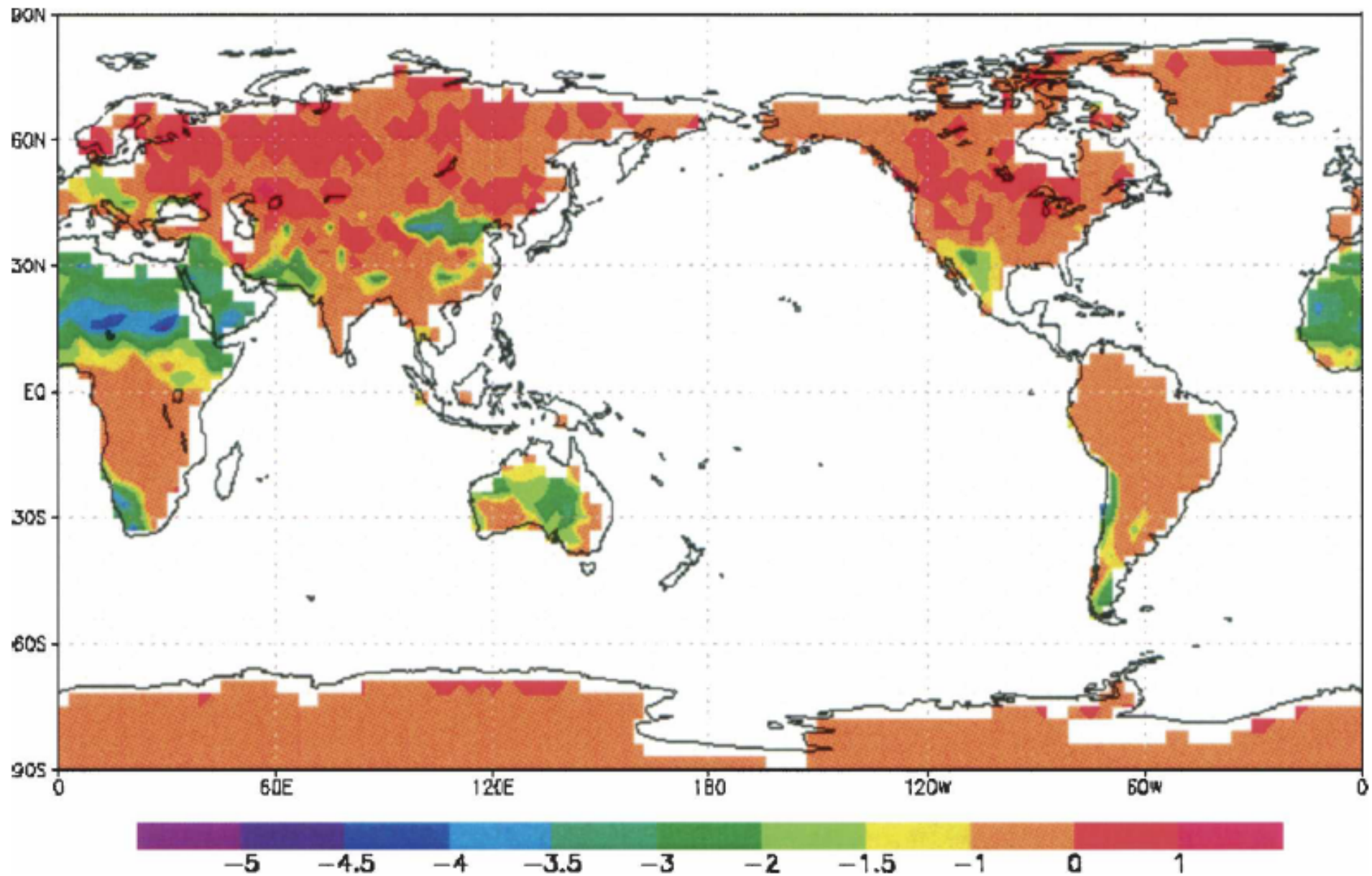
Offline CLM-simulated impact on the net longwave radiation (WM-2)
sensitivity run (0.90) minus the control run (0.96 as the default). The data are
daily averages of January 1998.

CAM2/CLM2, Daily average surface T, day1 0000-09-01
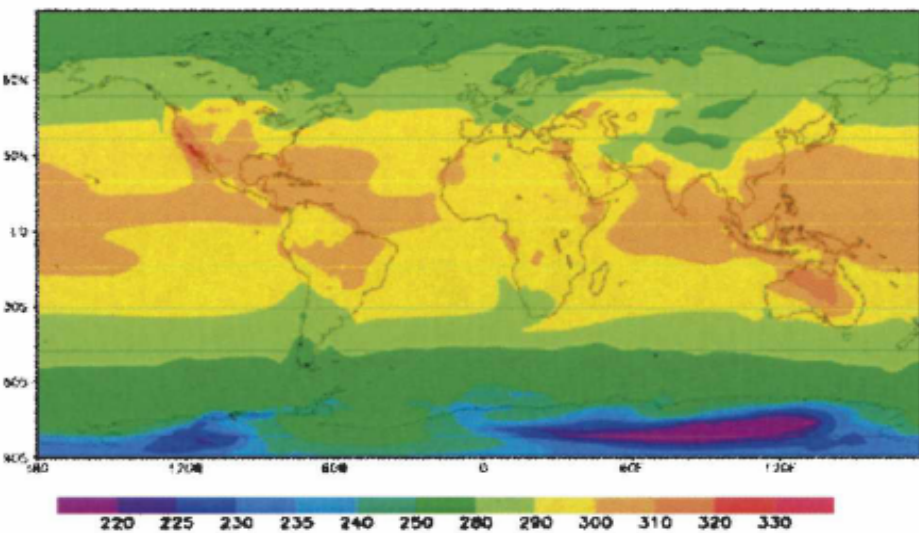
CAM2/CLM2, Daily average surface T, day2 0000-09-02

Emissivity effect, T for day1, emg=0.96 − emg=0.90
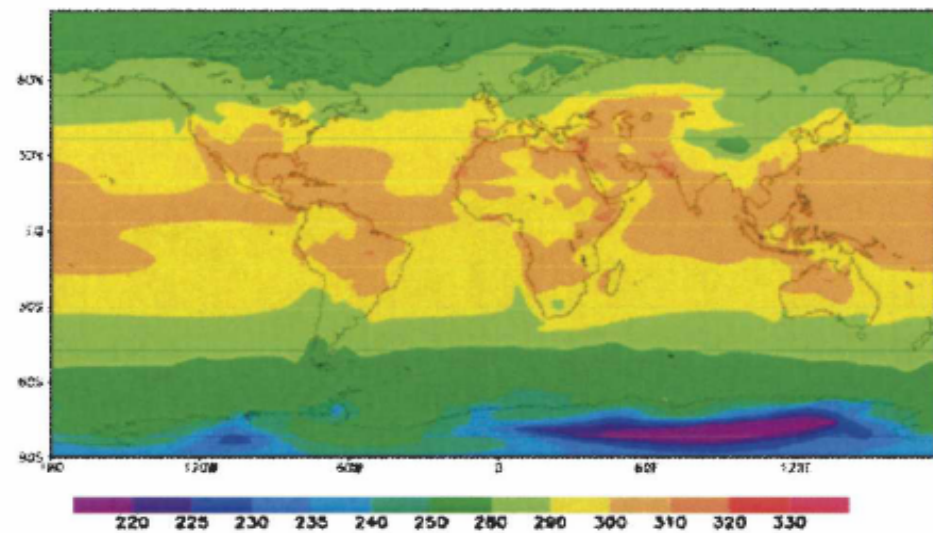
Emissivity effect, T for day2, emg=0.96 − emg=0.90
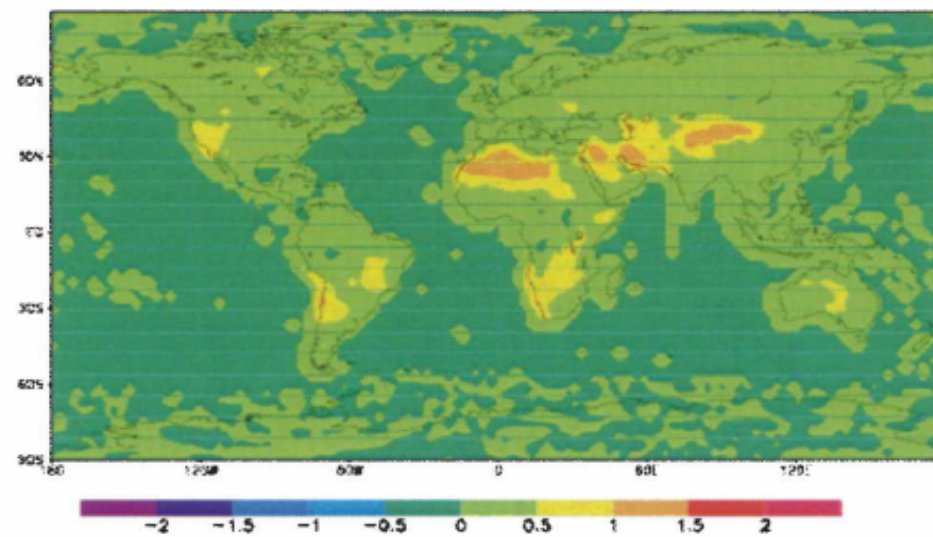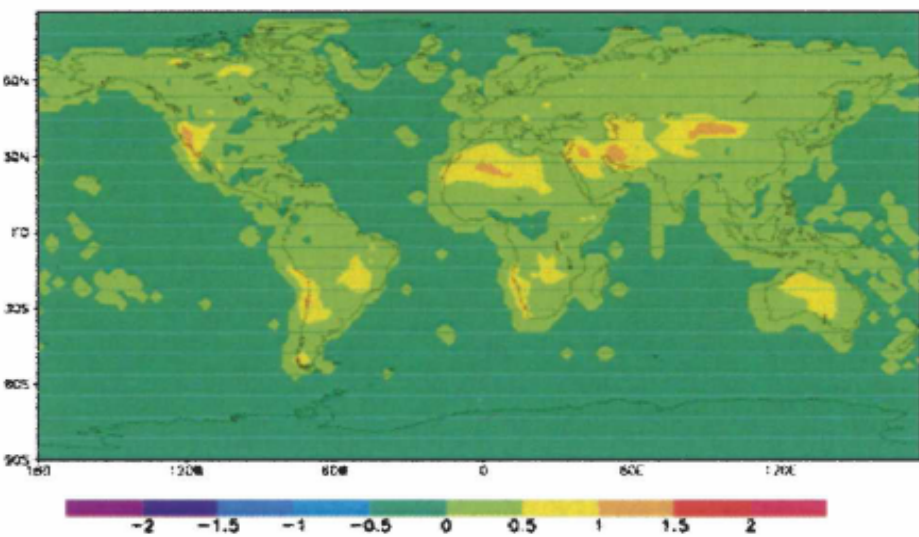
Emissivity impacts in the coupled model CAM2–CLM2: (a) & (c) control run of daily averaged surface air temperature; (b) & (d) the control run minus the sensitivity run;

Emissivity effect, T for day1, emg=0.96 − emg=T42
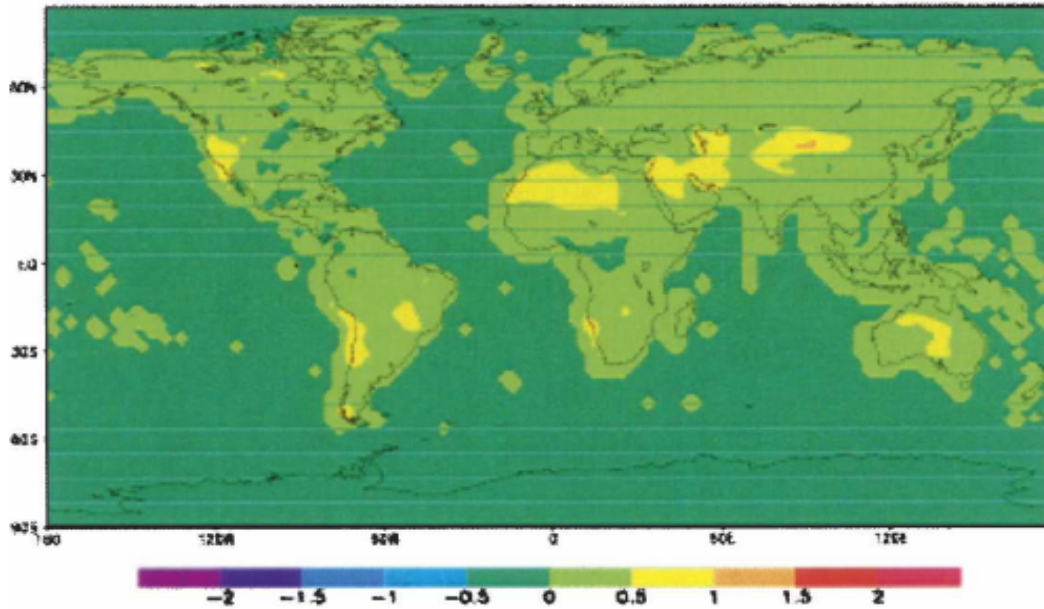
Emissivity effect, T for day2, emg=0.96 − emg=T42
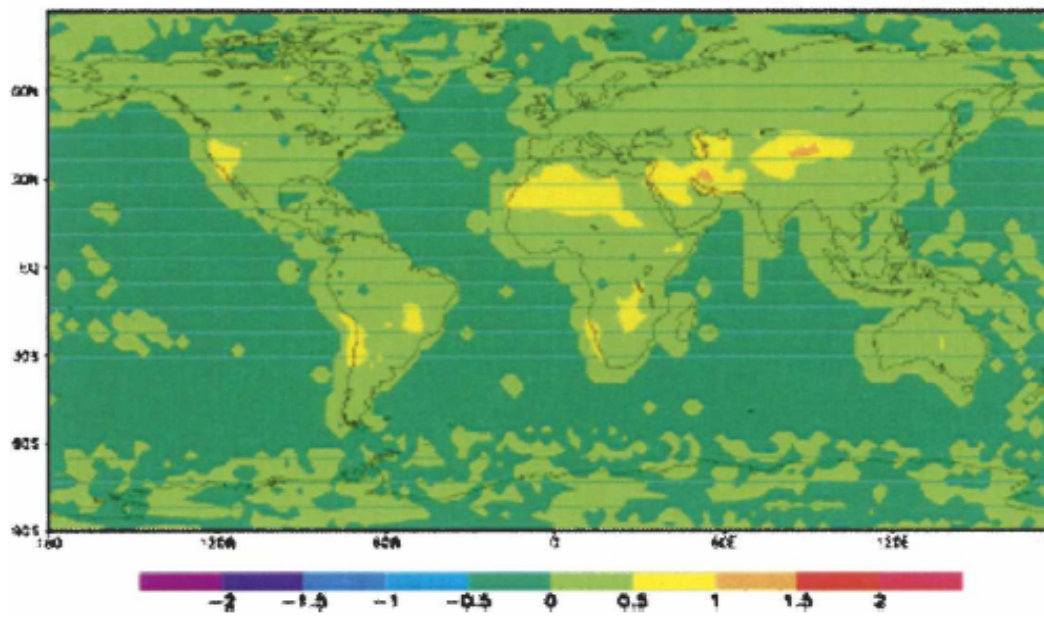
Coupled CAM2–CLM2 simulated emissivity impact on surface temperature (K) for two random days in September. The difference is the control run minus the sensitivity run. The control run uses CLM default soil emissivity (0.96), and sensitivity run uses satellite-observed emissivity at T42 resolution.

Objectives of this project

♣ **Our overall objective** is to develop forward land surface thermal-IR radiative transfer emissivity models for NWP and climate models

- ➔ generation of a high-resolution accurate emissivity database;
- ➔ empirical modeling of emissivity;
- ➔ physically-based modeling of emissivity.

Empirical relations

High-resolution emissivity database

Radiative transfer emissivity modeling

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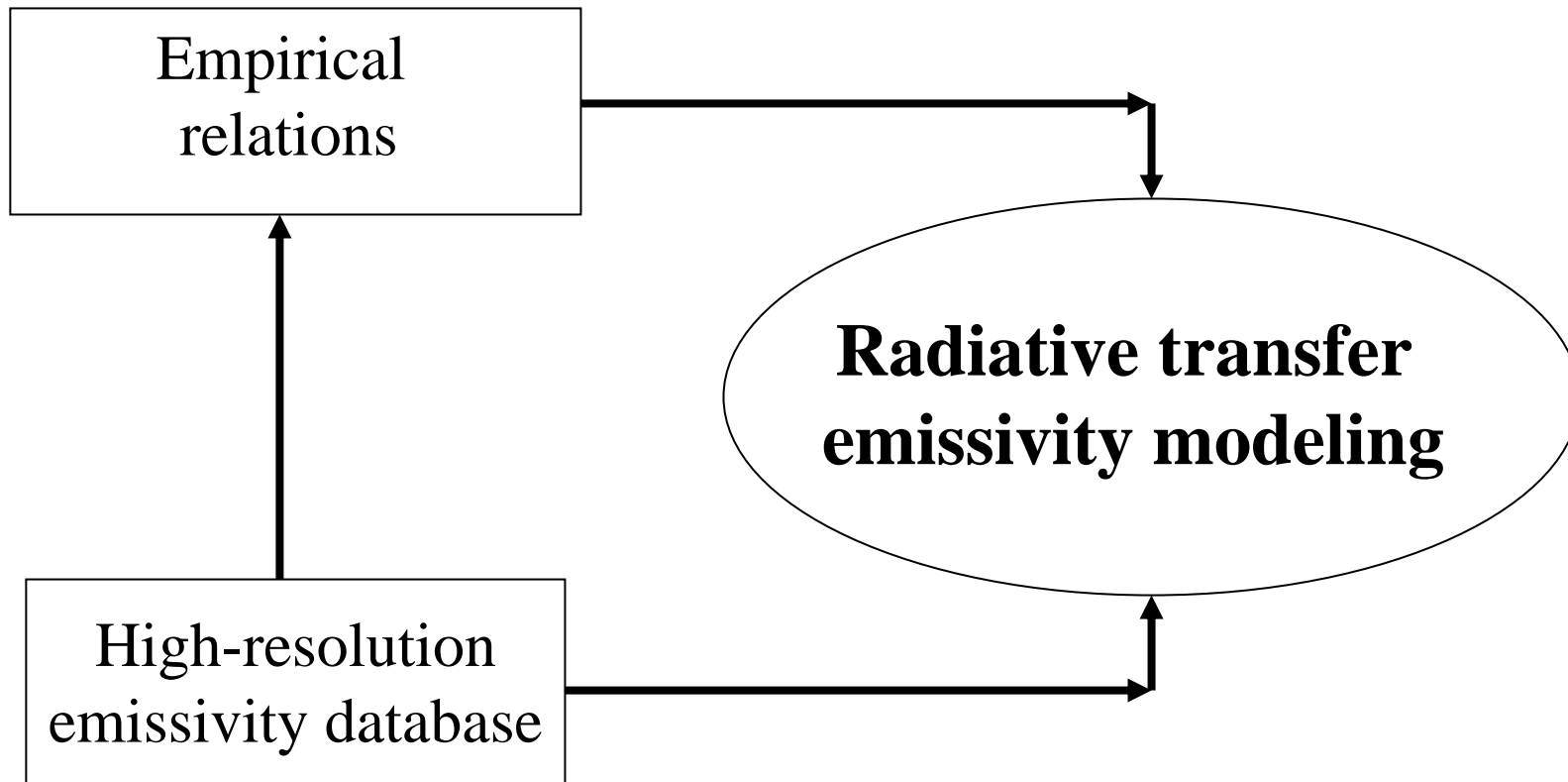
Generating an integrated high-resolution emissivity database

♣ CERES database

- ➢ an atlas in 1999 for broadband and window (8-12 µm) thermal-IR emissivity
- ➢ emissivity of each type is based on laboratory measurements
- ➢ 10' spatial resolution
- ➢ 18 IGBP land cover types
- ➢ invariant temporally except that snow and ice

♣ University of Wisconsin (UW) database

- ➢ data were derived using a procedure that fits monthly MODIS collection 4 day/night emissivity product
- ➢ This database has 0.05° grid size with a monthly temporal resolution for 10 wavelengths
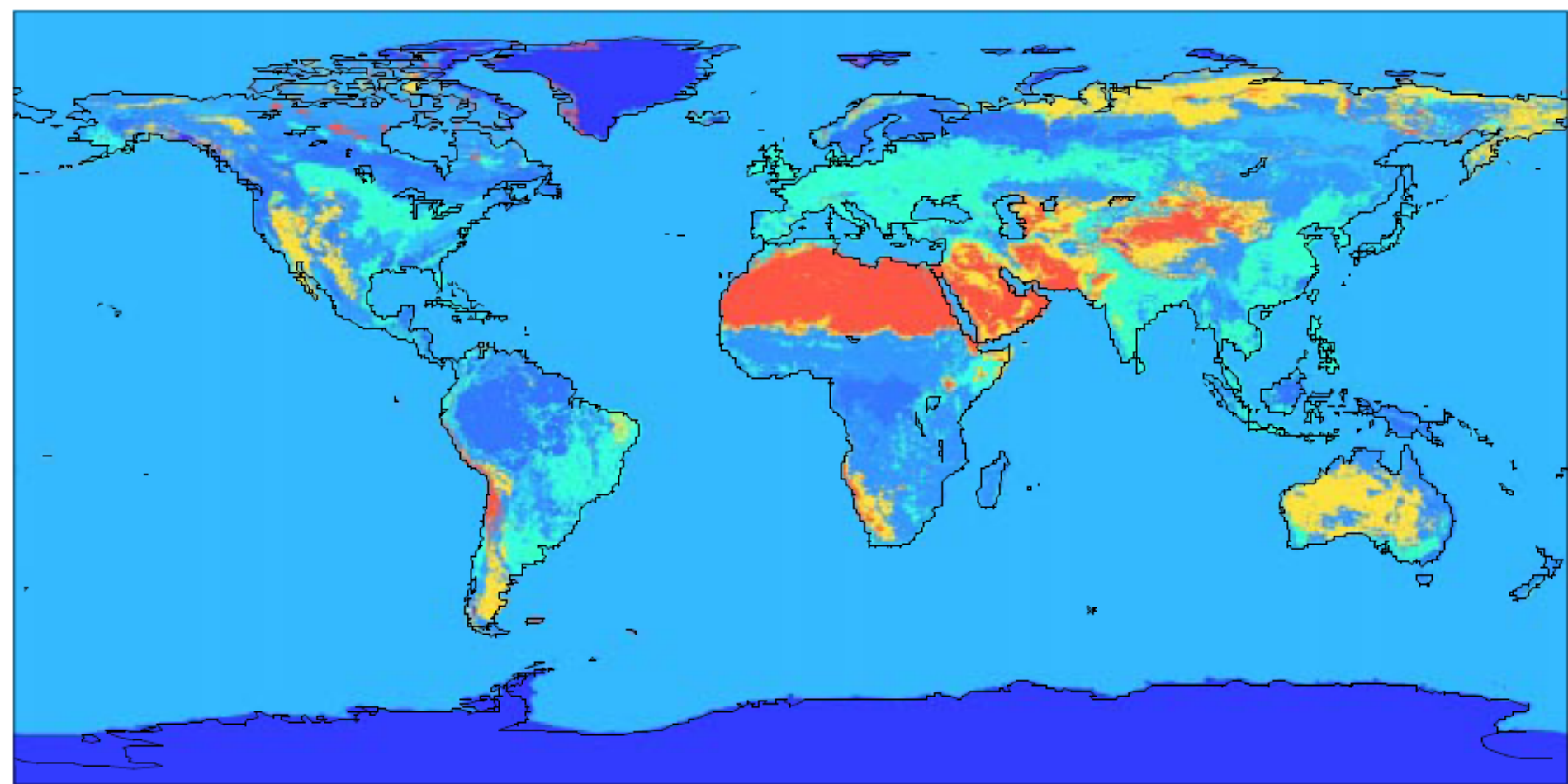
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CERES 10' broadband emissivity map
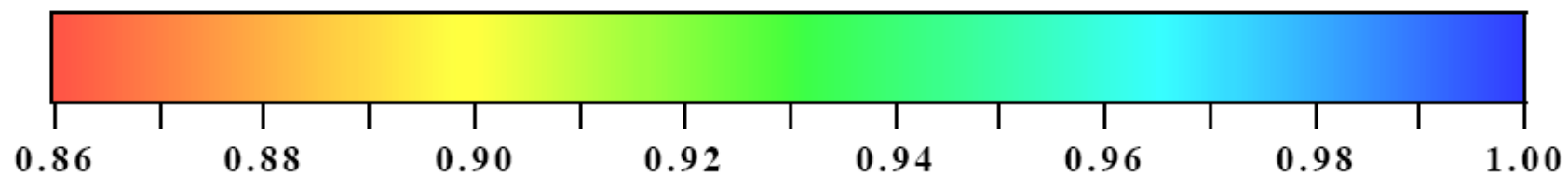
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CERES Window (8-12 μm) Surface Emissivity on 10' grid

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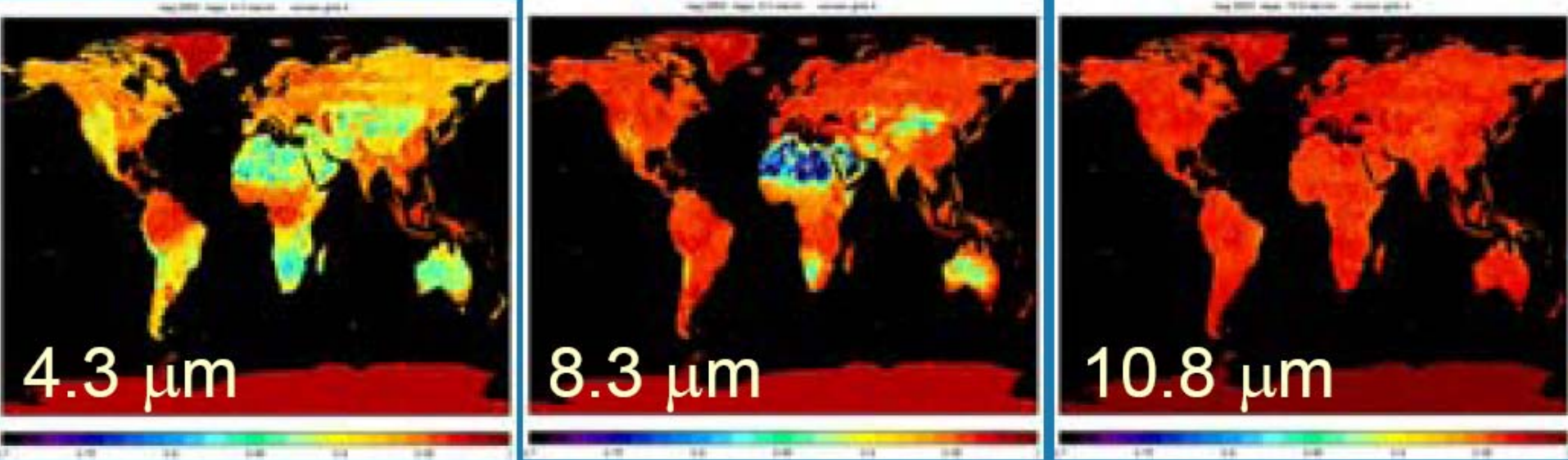
UW global maps of land surface emissivity derived with input from Aqua MODIS MYD11 Level 3 monthly data from August 2003

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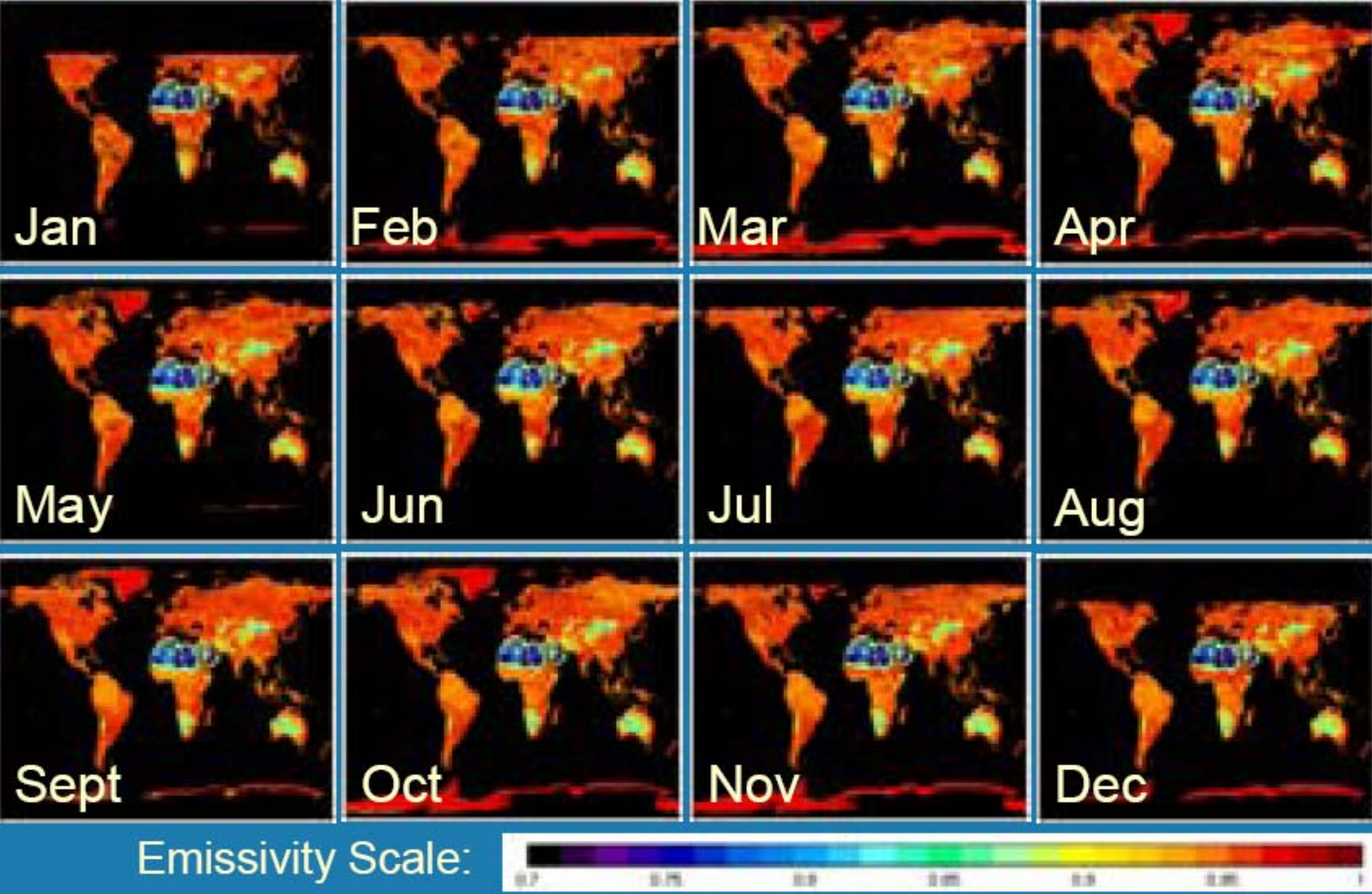
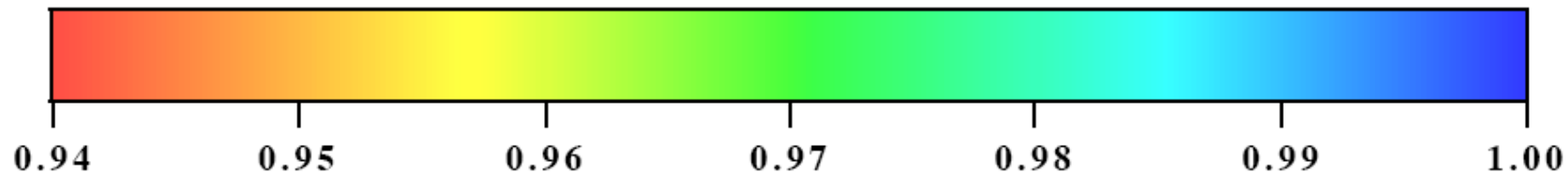UW global emissivity maps for 8.3mm derived for all 12 months of 2003.

Generating an integrated high-resolution emissivity database

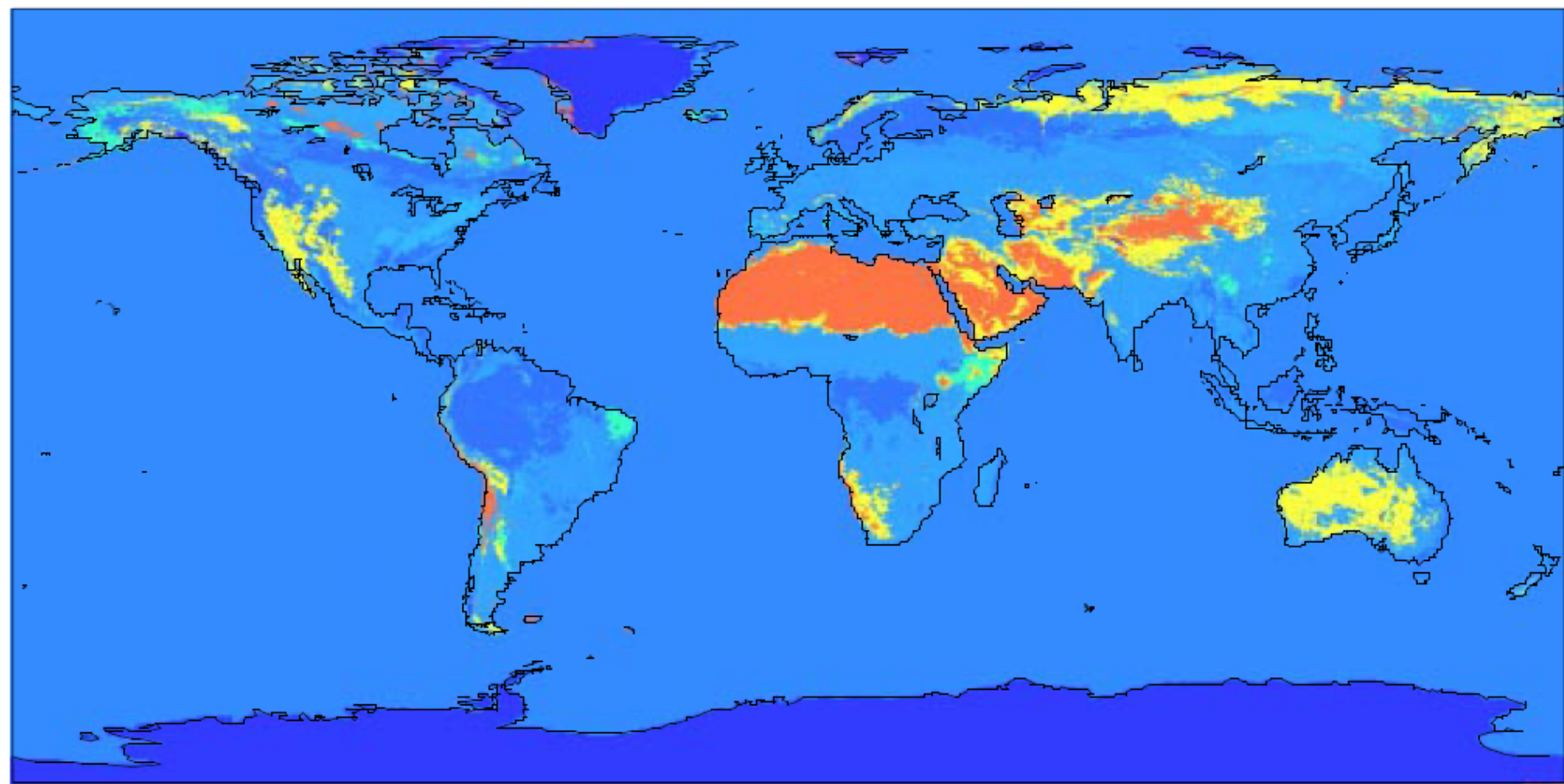- ♣ CERES and UW databases have the spatial and temporal resolutions too coarse to be used for generating empirical rules and calibrating and validating emissivity radiative transfer models

- ♣ We will combine emissivity values from multiple sources for each plant functional types using a data fusion method
  - ➔ MODIS look-up table values and day/night retrievals;
  - ➔ Estimated MODIS values using regression method
  - ➔ ASTER
  - ➔ SEVARI

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Empirical emissivity modeling

♣ Plant functional type (PFT) dependence

♣ Snow condition dependency (e.g., grain size)

♣ Dependence on land biogeophysical parameters (LAI, soil moisture, fractional vegetation coverage, shortwave albedo)

Radiative Transfer Emissivity Modeling

♣ **The first** will "calibrate" existing physical models that have been published in the literature or used.

  ➤ we can "calibrate" the model parameters so that the modeling behaviors can realistically match the actual emissivity values under different conditions since most of them are developed and calibrated at local scales.

♣ **The second** will compare and improve some of these models.

  ➤ there are multiple models for snow and soils

  ➤ we will compare different emissivity models mainly over sparsely vegetated surfaces and non-vegetated surfaces.

  ➤ help identify the best models and improve some of them if they do not perform well.

  ➤ The emphasis will be on modeling the heterogeneous landscapes

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Tasks	Year 1	Year 2	Year 3
Developing a high-resolution emissivity database	****	****	
Establishing empirical emissivity models		****	**- -
Assessing, calibrating and improving physical models		- -**	****

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Summary

♣ Ignoring emissivity may result in large errors in NWP and climate models;

♣ We aim to develop practical but accurate surface emissivity models ;

→ Developing high-resolution emissivity database;

→ Developing various empirical relations;

→ Testing and refining existing models and developing new models.

♣ Keep effective communications with the users

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Thank you !