Characterizing the Diurnal Cycle in a Global Analysis/Forecast System

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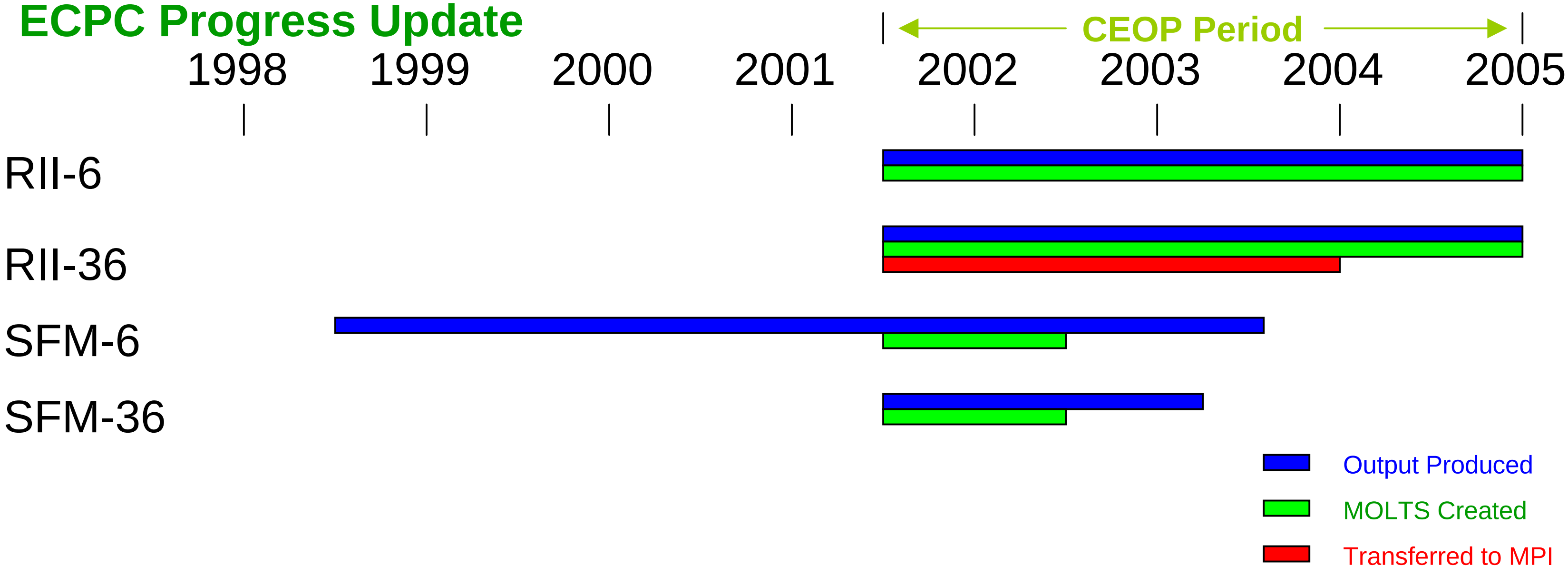
Outline

- ECPC's Participation in CEOP
- Preliminary Examinations of the Diurnal Cycle of Precipitation in the NCEP/DOE Reanalysis II Model
- Characteristics of Key Regions
- Future Work

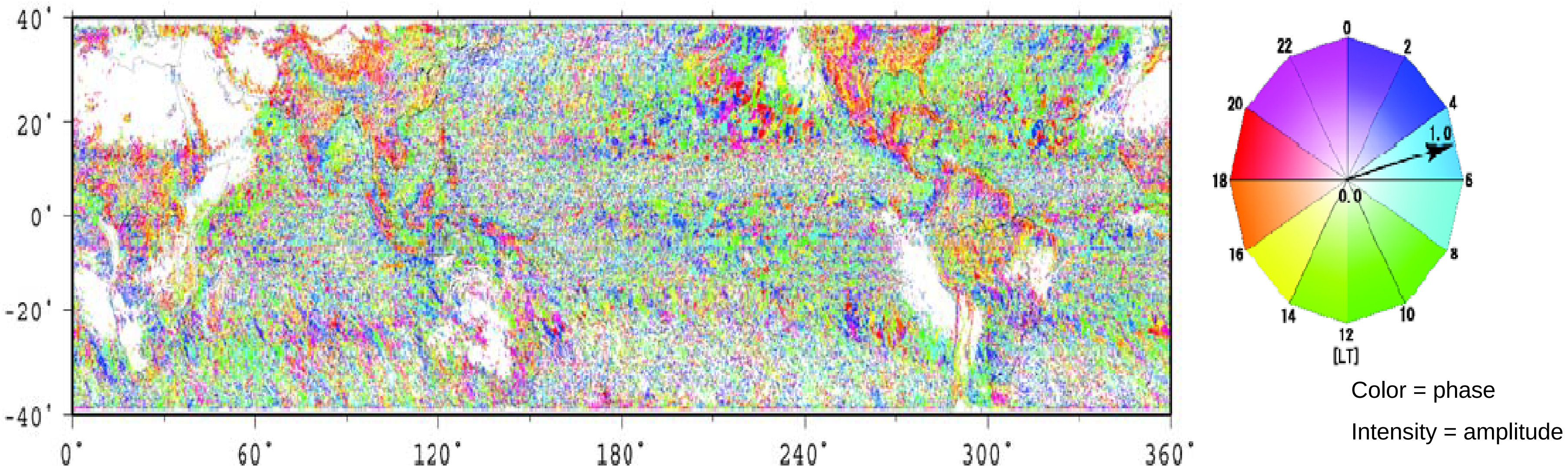
CEOP Participation

- The Coordinated Enhanced Observing Period (CEOP) presents a golden opportunity to evaluate the modeling and observation of the energy and hydrologic cycles
  - CEOP allows both global and regional applications with many components examined at high frequencies
- At the Experimental Climate Prediction Center (ECPC), we provide results from two atmospheric GCMs:
  - The NCEP/DOE Reanalysis II (Kanamitsu et al. 2002b)
  - ECPC's Seasonal Forecast Model (Kanamitsu et al. 2002a) Reanalysis
- In addition to an augmented 0-6 hour analysis, we are also contributing 36-hour forecasts initialized daily at 12UTC

ECPC Progress Update



Observed Diurnal Cycle of Precipitation



Source: Nakamura, May 2004 GEWEX Newsletter

- The Tropical Rainfall Measuring Mission (TRMM) shows a late afternoon peak over most land areas in June, July, and August from 1998-2002.
  - Some areas show regional characteristics, others break into smaller scale patterns
  - Also observed:
    - Morning peak over the oceans
    - Smaller-scale patterns over the oceans and Winter Hemisphere
    - Morning peak over the Southern Himalayas, later peak over Tibet
    - Later peak over the eastern slope of the Rockies than over the rest of the Continental United States
    - Small-amplitude diurnal cycles over arid regions and stratocumulus regions west of continents

- Global observations of the diurnal cycle are rare, particularly for other components of the hydrologic and energy cycles.

Method

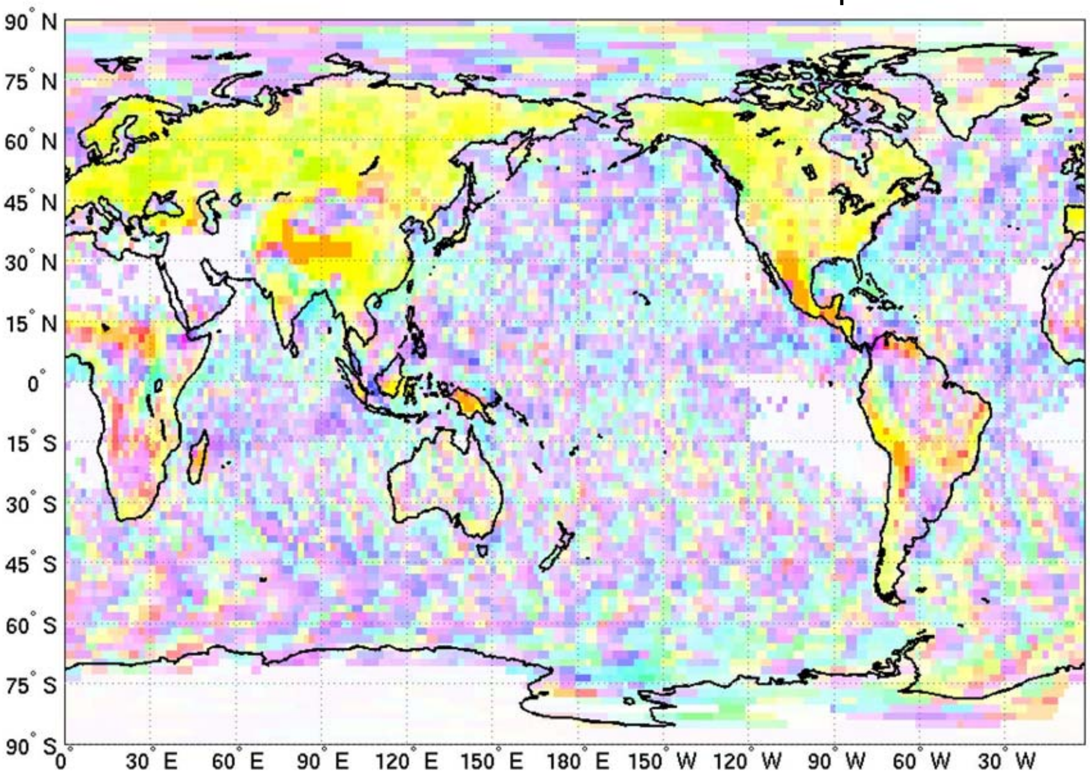
- Experiment using the Reanalysis II model (T62L28):
  - 36-hr forecasts initialized at 12UTC daily from July 1, 2001 - July 1, 2004
  - Output arranged into 3-hourly time series using the 15-36 hour forecasts (to eliminate some spin-up issues)

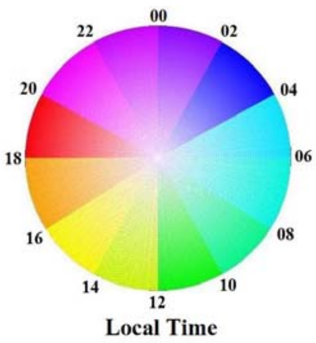
- We fit diurnal, semidiurnal, and seasonal harmonics to generate smooth diurnal cycles.
  - Phases are adjusted for local time (12=local solar noon)

- In order to separate noisy regions from areas featuring an organized diurnal cycle, we normalize the amplitude of the diurnal cycle by the time series' standard deviation

Modeled Diurnal Cycle of Precipitation

JAS 2001-2003 Diurnal Peak of Precipitation





Color = phase

Intensity = amplitude/standard deviation

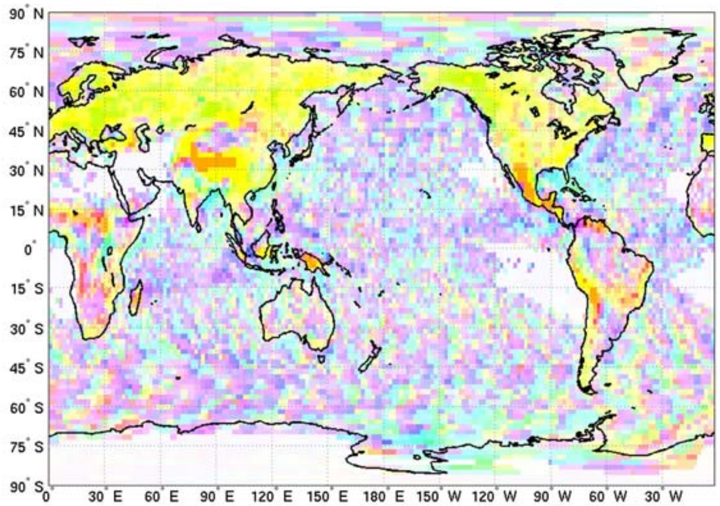
2001-2003 July, August, and September Diurnal Peak of Precipitation. Color signifies phase of the diurnal peak, intensity indicates the relative magnitude of the amplitude/standard deviation

- Preliminary examination shows general agreement with observations:
  - Mid-afternoon peak in precipitation over Northern Hemisphere continents
  - Morning peak over the oceans
  - Smaller-scale organization over oceans and Winter Hemisphere
  - Later peak in mountains
  - Areas of lower amplitude over stratocumulus regions and some arid regions

Precipitation expected to be among the most difficult components to reproduce, as it is highly sensitive to errors in the energy and hydrologic cycles

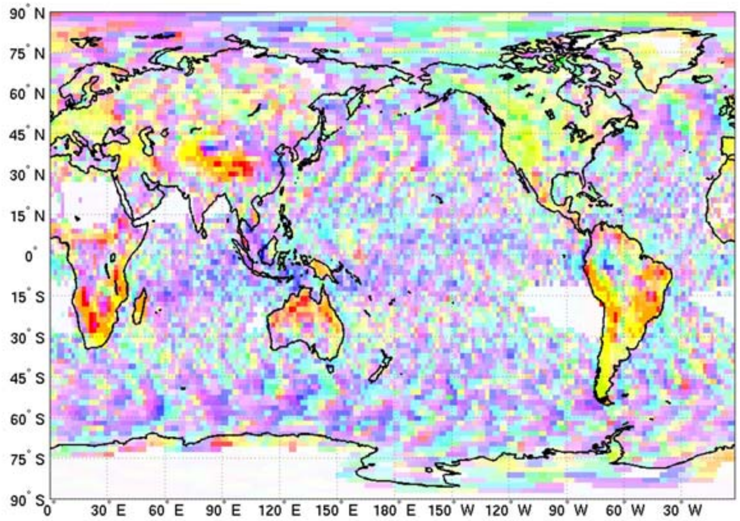
Seasonality of the Diurnal Cycle of Precipitation

JAS 2001-2003 Diurnal Peak of Precipitation



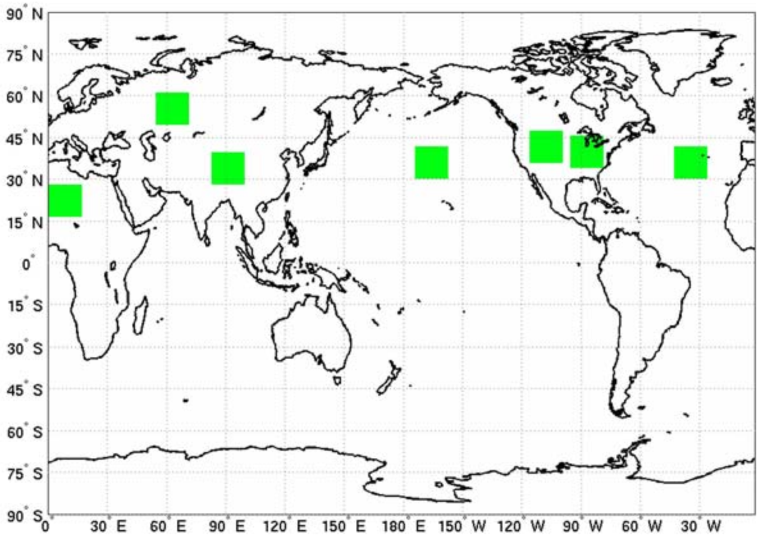
- Boreal Summer
  - Continental-scale mid-afternoon peaks over Northern Hemisphere Continents
  - Less regional character over Winter Hemisphere continents

JFM 2002-2004 Diurnal Peak of Precipitation



- Boreal Winter
  - Late-afternoon peaks over Southern Hemisphere continents
  - More pronounced regionality over Southern Hemisphere continents
  - Less regional character over Northern Hemisphere continents
  - Indicative of intensified Rossby waves in Wintertime

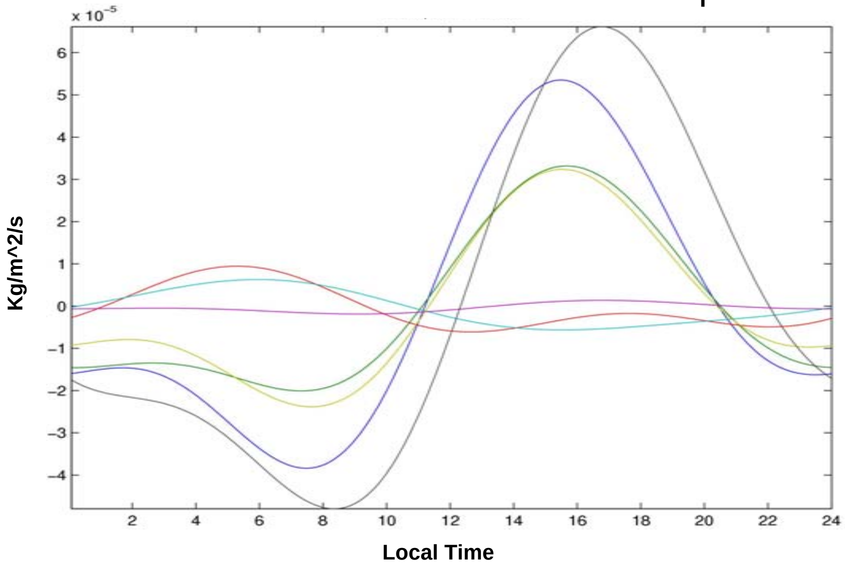
Uniqueness of Various Regions



7 Regions selected for uniqueness:

- Eastern USA - fairly flat, uniform, and wet
- Western Russia - fairly flat, uniform, and dry
- North Pacific - Ocean region
- North Atlantic - Ocean region
- Sahara - Arid region
- Rockies - High Elevation, fairly dry
- Himalayas - High Elevation

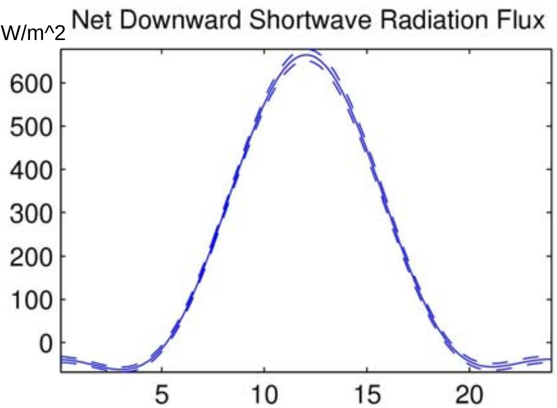
JAS 2001-2003 Diurnal Peak of Precipitation



Precipitation Variation:

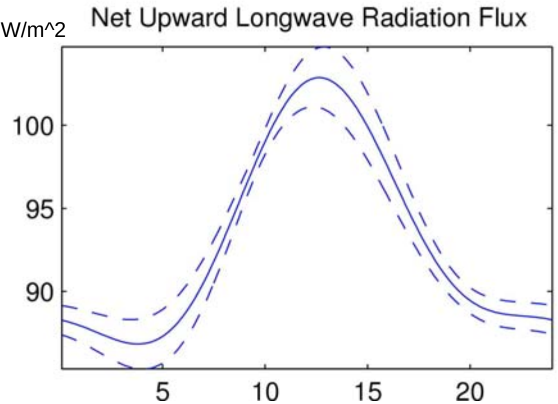
- Continental regions have afternoon peaks
- Ocean regions have morning peaks
- Wide variation of amplitude
- Semidiurnal contribution varies

Eastern USA Summertime Diurnal Cycle



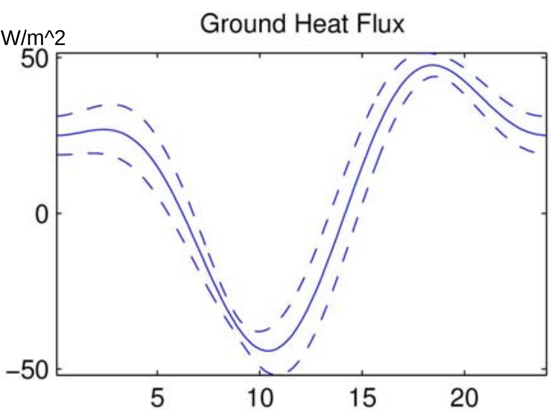
Net SW Radiation

- Strong diurnal cycle peaking at noon
- Little variation over region



Net LW Radiation

- Slight lag from solar noon
- Fast increase in morning, tapering off through the night

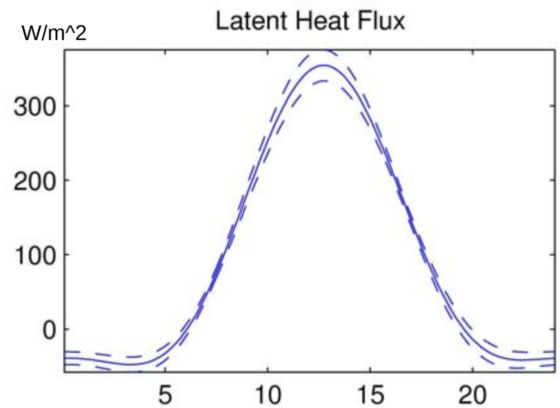


Ground Heat Flux

- Carries energy away from surface in morning
- Warms the surface during the nighttime

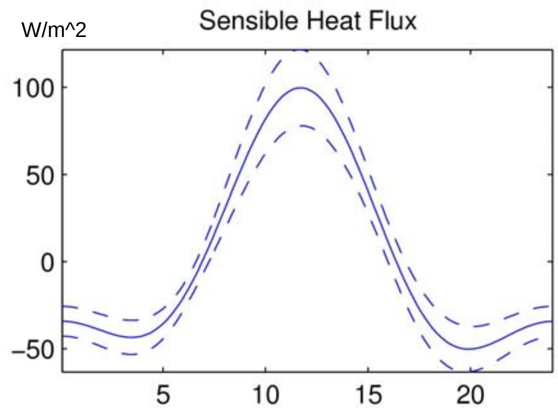
Latent Heat Flux

- Peaks in early afternoon
- Consistent throughout region with high amplitude



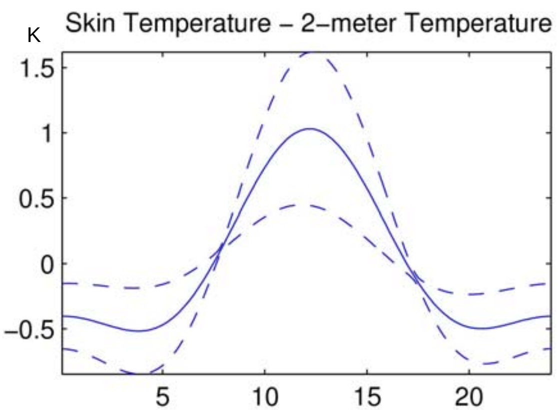
Sensible Heat Flux

- Peaks at solar noon
- Downward flux at nighttime

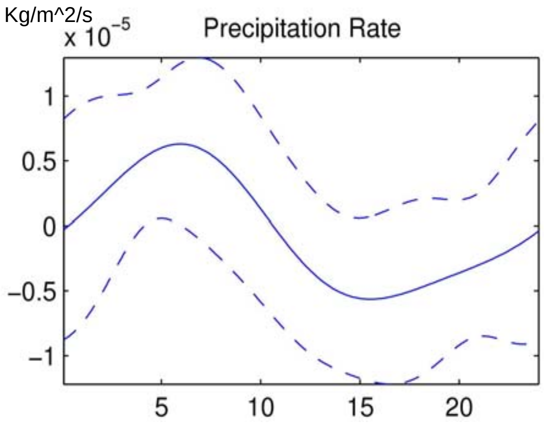


Surface Temperature Gradient

- Peaks just after solar noon
- Negative at night
- Low variability in region near sunrise and sunset

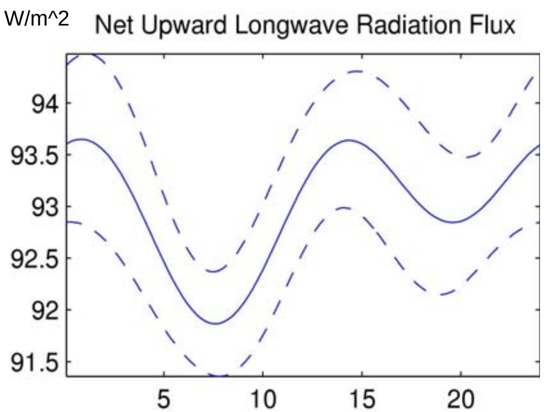


North Atlantic Summertime Diurnal Cycle



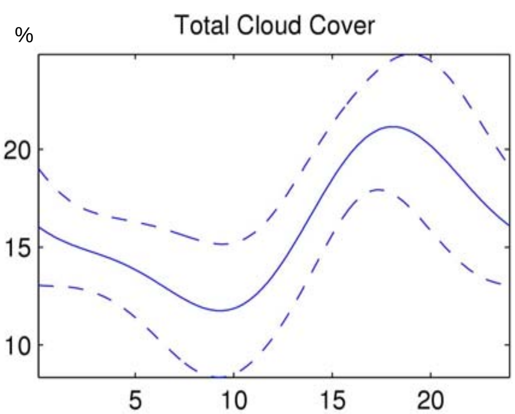
Precipitation Rate

- Peaks in early morning
- Strong variation over region



Net LW Radiation

- Strongly Semidiurnal
- Evening Minimum

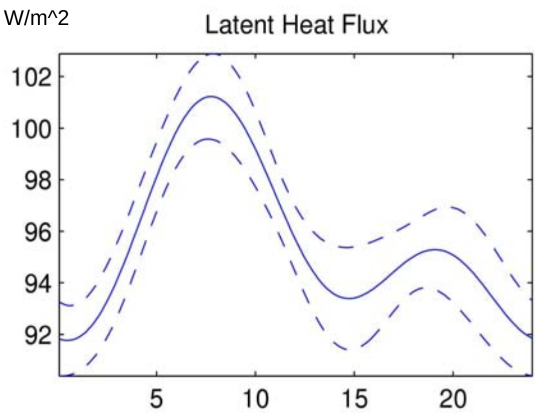


Total Cloud Cover

- Peaks in evening

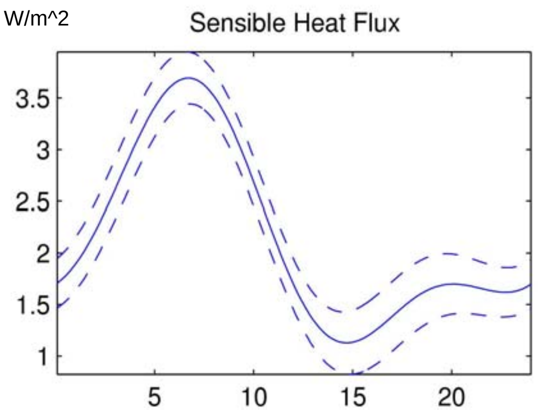
Latent Heat Flux

- Peaks in early morning
- Semidiurnal peak in evening



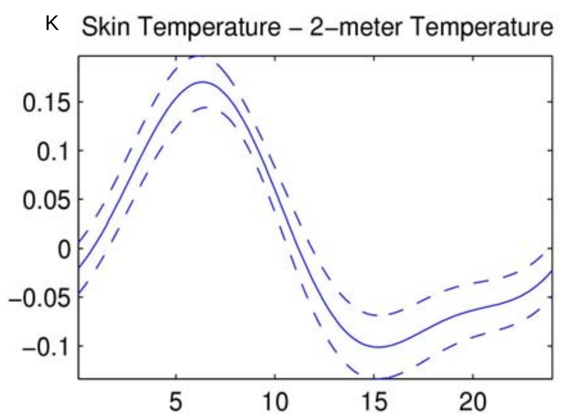
Sensible Heat Flux

- Peaks in early morning
- Much weaker than Latent Heat Flux (Low Bowen Ratio)



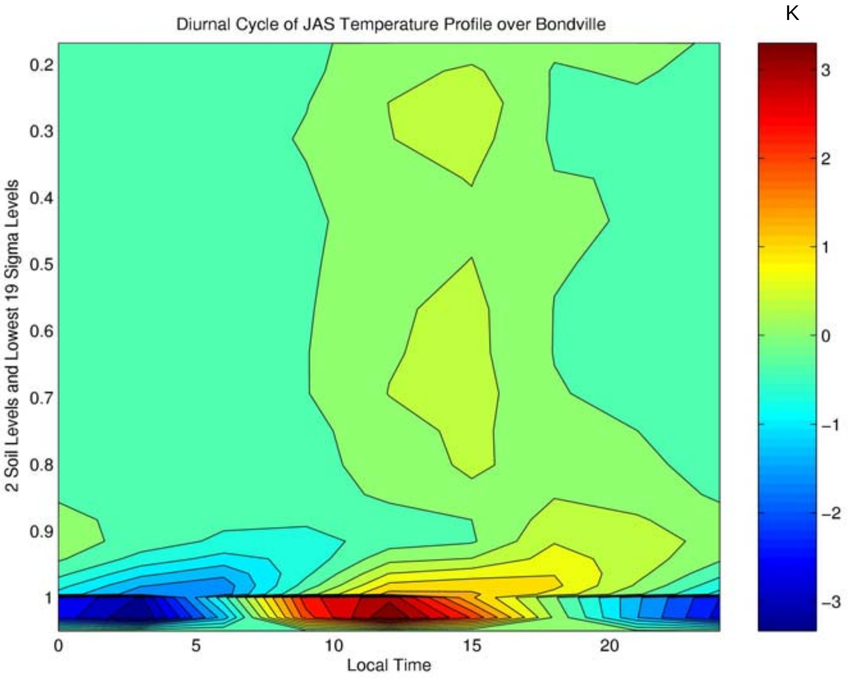
Surface Temperature Gradient

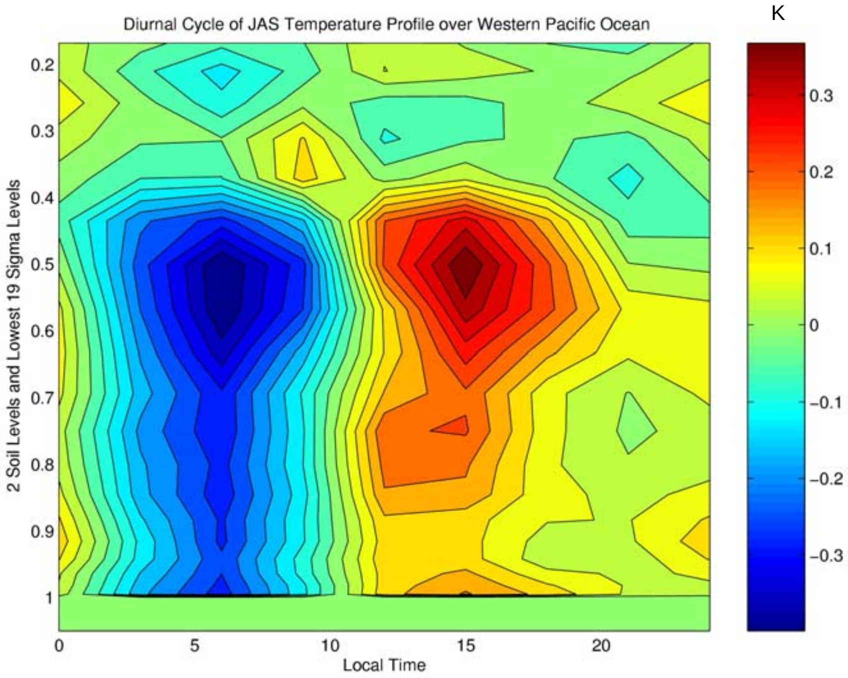
- Peaks in early morning
- Due to lack of diurnal cycle in SSTs



Regional Station Profiles

Can we follow vertical propagation of heat and moisture through diurnal cycle?





- Mid-Latitude Land Station:
  - Diurnal heat wave propagates away from surface (in both directions)
  - Surface layer contains bulk of diurnal cycle in soil
  - Dominated by radiation

- Tropical Ocean Station:
  - Dominated by rapid, near-barotropic signal in troposphere
  - Extends well beyond boundary layer
  - Convection?

Conclusions and Future Work

- The evaluation of the diurnal cycle provides a good tool to diagnose a model's handling of the energy and hydrologic cycles
- Preliminary examinations of the Reanalysis II model's diurnal cycle of precipitation show general agreement with observations
  - Ocean/continent characteristics
  - Summer/Winter Hemisphere contrasts
  - Elevated/lower region comparisons
- Variations in diurnal cycle characteristics across various regions shed light on dominant processes and biases in the model
- The vertical profiles offer a glimpse into the extent and effect of the diurnal cycle

- **Our future work:**
  - Extend current approach into water budget processes
    - Surface and Atmospheric balances of water and energy budgets
  - Use regional and/or coupled atmosphere/ocean models to better resolve the diurnal cycle
  - Compare RII results with SFM results

  - **Compare model results with CEOP observations**