

Hyperspectral OLR for Improved Climate Applications

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Acknowledgements:

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Background

1) OLR is an important component of climate

- Outgoing longwave radiation (OLR) is a primary component of the global and regional energy budget and transfer
- Estimation of OLR made from satellite measurements has been widely used for nearly 40 years:
 - Quantifying energy budget of the earth system
 - documenting the state and variations of the atmospheric system;
 - *monitoring and assessments of climate variability*
 - *estimating precipitation over the tropical and sub-tropical regions*

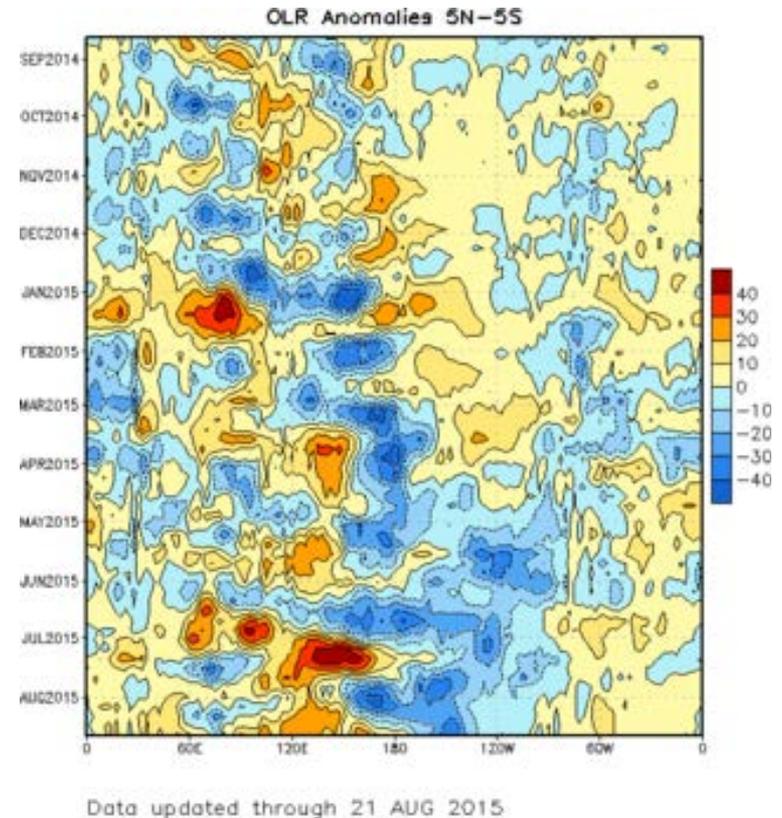


Figure 1: Time-longitude section of pentad OLR anomaly over the tropics (5°S-5°N), used by NOAA Climate Prediction Center for the monitoring of Madden – Julian Oscillation (MJO). (copied from NOAA/CPC Official Webpage: (<http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml>))

Background

2) Current CPC Operational OLR data has problems

- Poor estimation accuracy restricted by the narrow band observations from the AVHRR;
- Insufficient use of observations from all available satellites due to the strategy to use the OLR data only from the afternoon satellites to reduce the impacts of the OLR diurnal cycle to the definition of the daily mean;
- Artificial trends and discontinuities caused by orbit shifts of the NOAA polar satellites and the imperfect instrument inter-calibration (figure 2); and
- Coarse time and space resolution (monthly – pentad : 2.5°lat/lon) to resolve individual weather systems associated with MJO and other climate variability.

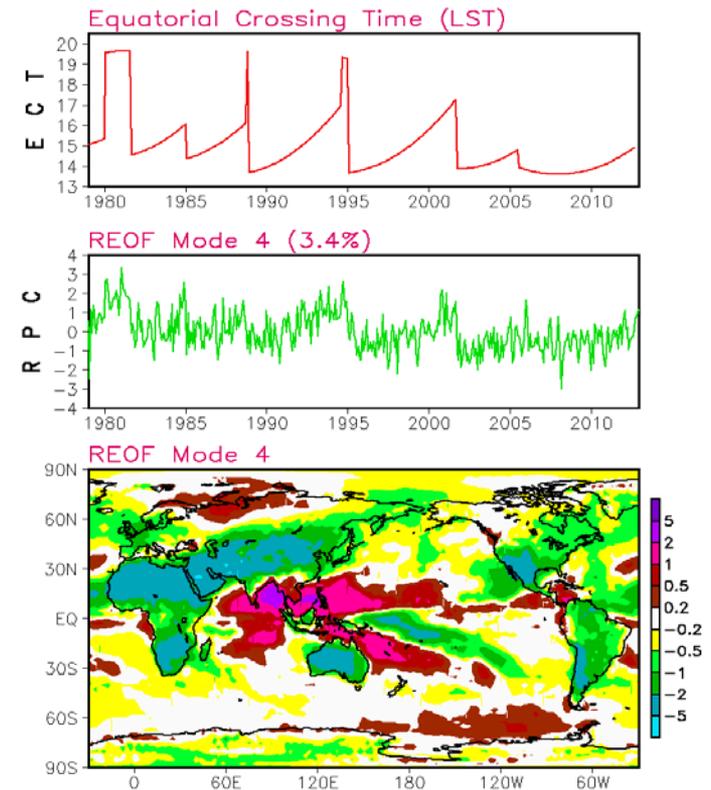


Figure 2: Time series (middle) of the principal component (PC) and the spatial loading (bottom) of the fourth mode of the rotated EOF analysis of the CPC AVHRR OLR monthly anomaly, together with (top) the time series of the equator crossing time (ECT) of the NOAA polar orbiting satellites from which the AVHRR data are utilized to construct the NOAA OLR. Correlation between the satellite ECT and the OLR time series, together with the land/ocean contrast in the EOF spatial loading, indicate that the ECT changes have produced artificial variability of OLR due to the sampling different phases of the diurnal cycle.

Background

3) *Hyperspectral OLR for improved climate monitoring*

- Broadband OLR not available on a real-time (<1day) basis
- Techniques developed to derive OLR from **the hyperspectral** measurements of infrared radiance from advanced sensors:
 - *The Atmospheric Infrared Sounder (AIRS)*
 - *The Infrared Atmospheric Sounding Interferometer (IASI), and*
 - *The Cross-track Infrared Sounder (CrIS)*
- NESDIS Operations has started the routine production of the level-2 OLR orbit data from the IASI hyperspectral measurements onboard the MetOp-A satellite

Goal and Objectives:

- **Long-term goal**

Developing next generation NOAA OLR data capitalizing the technology advances in the satellite OLR achieved in recent years

- *Combined use of OLR measurements from multi-platform / multi-sensors*
- *substantially improved quantitative accuracy*
- *refined spatial/ temporal resolution (at least 0.25°lat/lon; daily)*
- *reduced temporal in-homogeneities*
- *covering an extended period from 1979*
- *updated on a quasi real-time basis*

- **First step**

- *Examining strategy to transition the newly available high-resolution, high-quality **IASI OLR** for enhanced operational climate monitoring, climate analysis, and climate model verifications at CPC.*

IASI OLR

1) *What we have achieved*

- Reprocessing

Generated Level 2 hyperspectral OLR data from both the MetOp A and B satellites for the entire time periods

- Adjusting the IASI OLR against AVHRR climatology

The raw IASI OLR is adjusted against the AVHRR long-term climatology

- Real-time system

Established real-time processing system at CPC to receive the L1 data from NESDIS, generate L2 IASI OLR, adjust the IASI OLR against AVHRR and produce gridded fields for climate applications

IASI OLR

2) Comparison with operational AVHRR OLR

- Operational OLR (top)
 - The operational CPC OLR is derived from infrared window channel measurements of AVHRR using empirical relationships;
 - Only OLR data from one single satellite (afternoon satellite) are used;
 - Currently the AVHRR OLR is from NOAA 18, with an orbit time of ~03-04PM
- IASI OLR (middle)
 - Derived from hyperspectral measurements aboard a satellite with a different orbit time (~09AM);
- Their differences (bottom)
 - The differences are quite large, at 5-10 W/m²
 - Especially, large differences are observed over tropics and over oceanic dry zones (e.g. SE Pacific, SE Atlantic), water vapor over where *Is* detected by IASI but not the AVHRR;

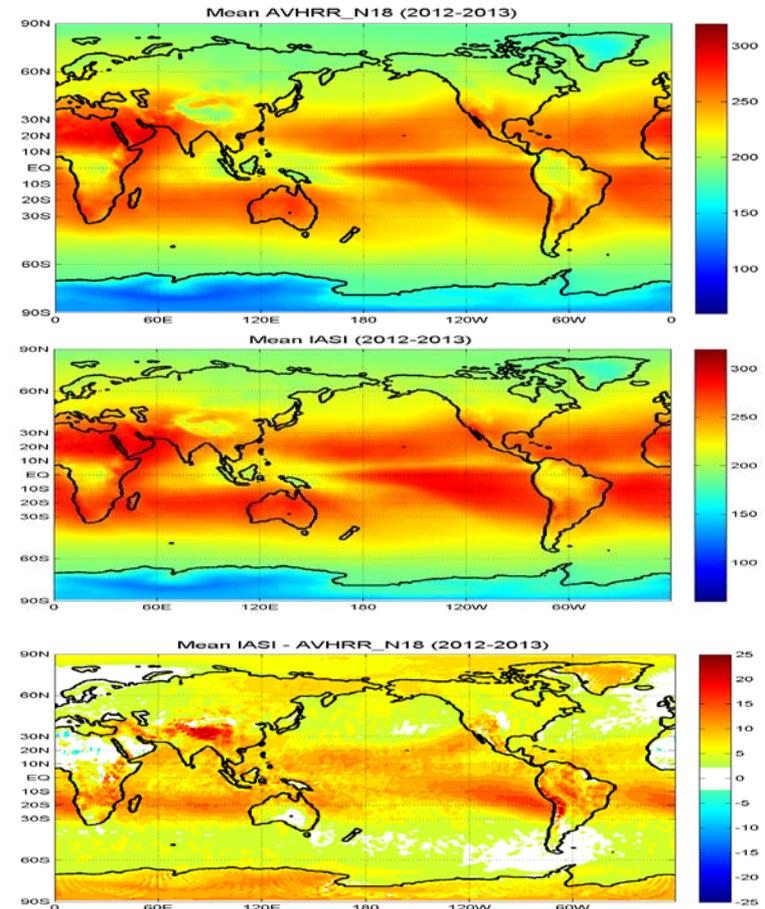


Figure 5: 2012-2013 annual mean OLR (W/m²) Derived from (top) AVHRR aboard NOAA18 and (middle) IASI aboard MetOP A, as well as (bottom) the differences between the two OLR data sets.

IASI OLR

3) *Attributions of the IASI/AVHRR OLR differences*

- Total OLR differences
 - *The differences shown in figure 5 are attributable to two factors: observation time and sensor/algorithm differences*
- Effects of different observation times (top)
 - Overall, quite small;
 - Relatively larger over tropics, especially over tropical land where diurnal cycle presents large magnitude
- Differences caused by different sensor /algorithm
 - *Dominating factor of the IASI/AVHRR OLR differences*
 - *Throughout the globe*
- ***Inter-calibration is needed between IASI and AVHRR OLR.***

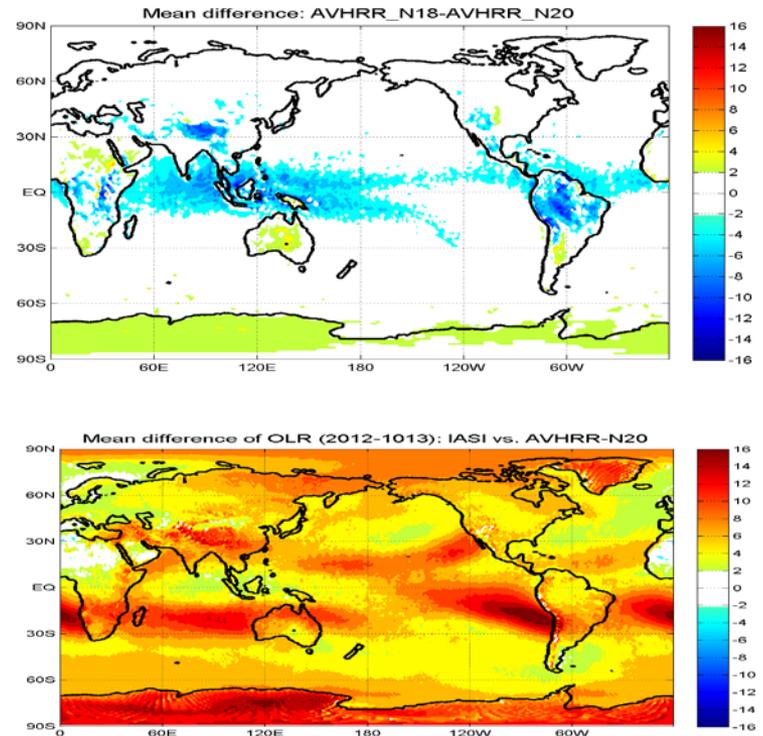


Figure 6: 2012-2013 mean OLR differences (W/m^2) between AVHRR OLR from NOAA 18 and MetOP A; and (bottom) AVHRR and IASI OLR from the same satellite (MetOP A).

IASI OLR

4) Inter-calibration between IASI and AVHRR OLR

- Differences between IASI and AVHRR OLR
- *Further inter-comparison between the IASI and AVHRR OLR shows the differences present regional / seasonal variations and perform as a function of OLR magnitude*
- Inter-calibration through PDF matching
- *A prototype algorithm is developed to perform inter-calibration between the IASI and AVHRR OLR through matching the probability density function (PDF) of the two OLR data sets;*
- *PDF tables are established for each grid box of 1°lat/lon and for each calendar month using the col-located IASI and AVHRR OLR data over 3-month sliding window centering at the target calendar month and over a 3°lat/lon square centering at the target grid box;*
- **The Differences in OLR are largely vanished after the PDF**

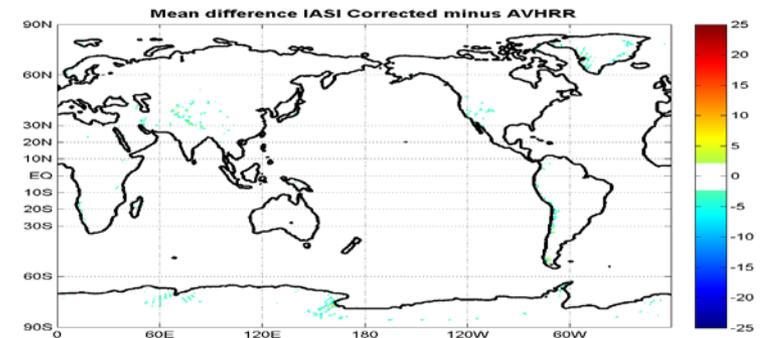
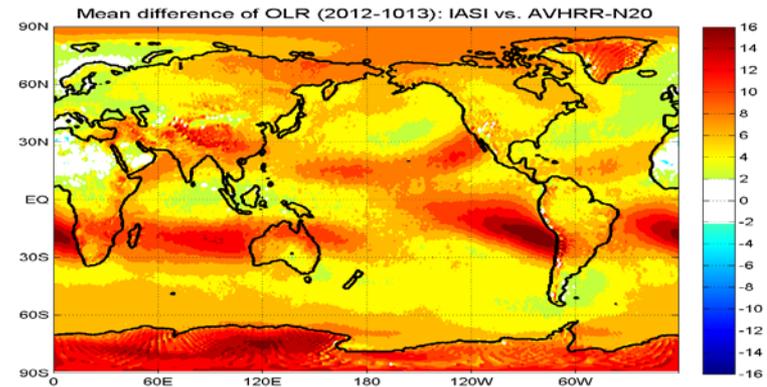


Figure 7: 2012-2013 mean OLR differences (W/m^2) between the IASI and AVHRR aboard MetOP A (top) before and (bottom) after the PDF calibration.

Applications of IASI OLR

1) Improved capacity to detect strong convection

- With a refined spatial resolution of 0.25°lat/lon , the IASI OLR is capable of quantifying the intensity of convection at a meso-scale cloud systems scale;
- Standard deviation of OLR inside a 1°lat/lon grid is very large, especially over ITCZ and land areas of strong convection where the standard deviation may reach 15W/m^2 or greater;
- Climate monitoring using OLR data on a 1°lat/lon grid, like the current operational AVHRR OLR, may substantially under-estimate the intensity of convective activities.

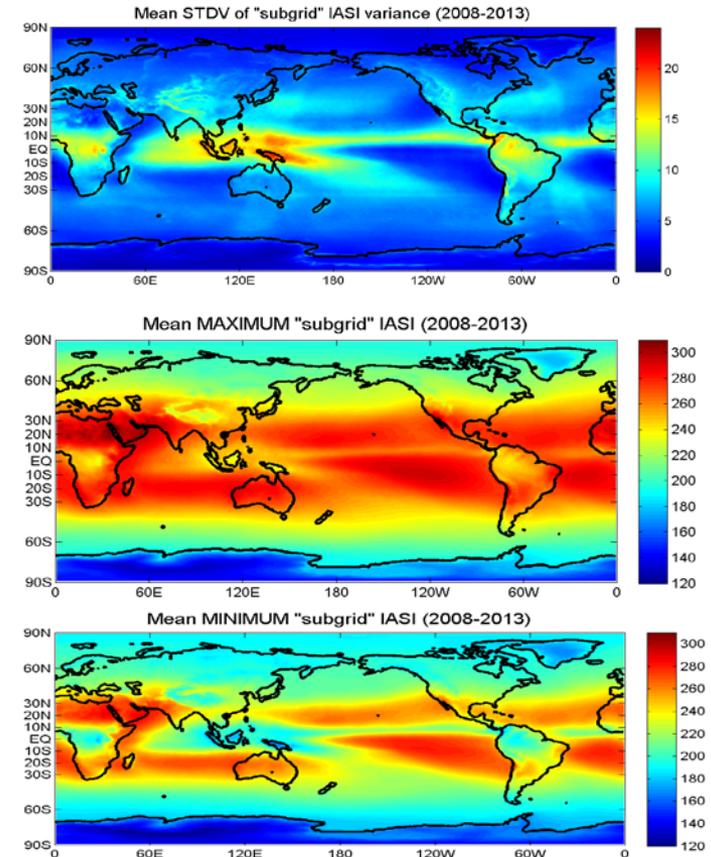


Figure 8: (Top) standard deviation, (middle) maximum, and (bottom) minimum of OLR values over 16 0.25°lat/lon grid boxes with a 1°lat/lon grid box. Statistics are averaged over 6 year period from 2008 to 2013. Units are all in W/m^2 .

Applications of IASI OLR

2) *Enhancing the tropical monitoring*

- With refined spatial resolution and improved capacity to detect strong convection, the IASI OLR provides a powerful mean to monitor tropical convection and its evolution;

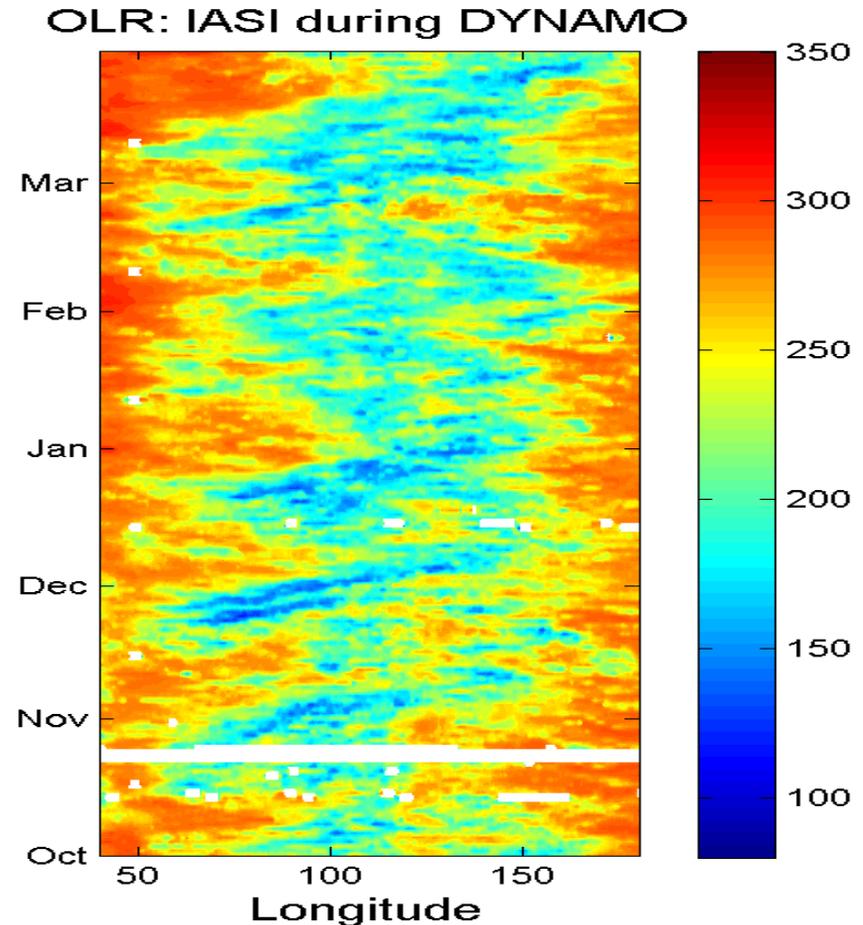


Figure 9: Time-longitude section of equatorial (5°S-5°N) mean IASI OLR during the DYNAMO experiment (Oct.2009 – Mar.2010).

Applications of IASI OLR

3) Accurate quantification on MJO evolution

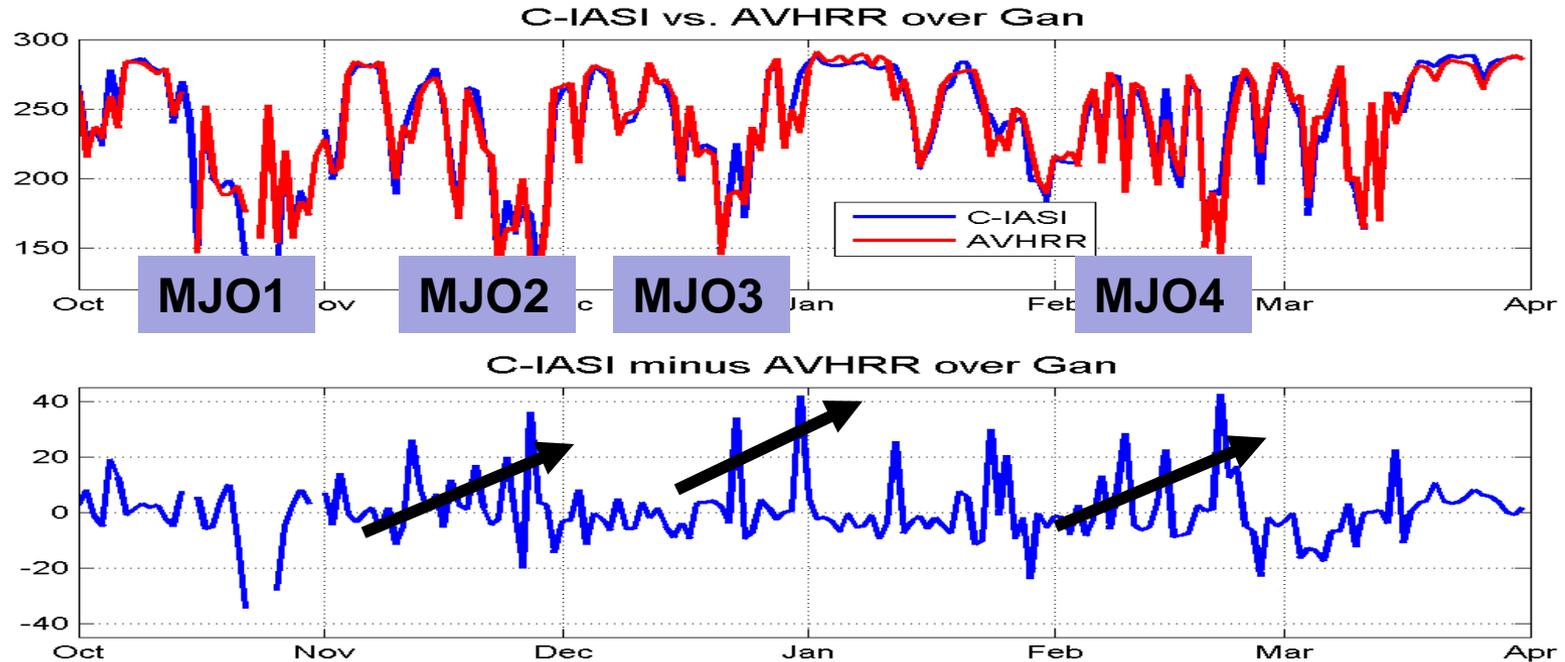


Figure 10: Time series of OLR derived from the operational AVHRR (top, red) and the calibrated IASI OLR (top, blue), as well as the difference between them (bottom), at a grid box over Gan Island during the DYNAMO field experiment period (Oct.2009 – Mar.2010).

- While both the IASI and AVHRR capture the MJO quite well, differences between them present a tendency in association with the evolution of MJO, suggesting possibility of aliased OLR quantification by the AVHRR OLR;
- Further work is underway to examine the causes of this difference and how we may improve the MJO monitoring taking advantage of the IASI OLR;

Applications of IASI OLR

4) Improved heat wave detection and quantification

- (top) Based on a 30+ year technology and derived from AVHRR infrared window channel measurements blind of water vapor variations, capacity of the operational OLR data to detect and quantify heat waves is compromised;
- (bottom) The IASI OLR presents better skills in capturing and quantifying the heat wave.

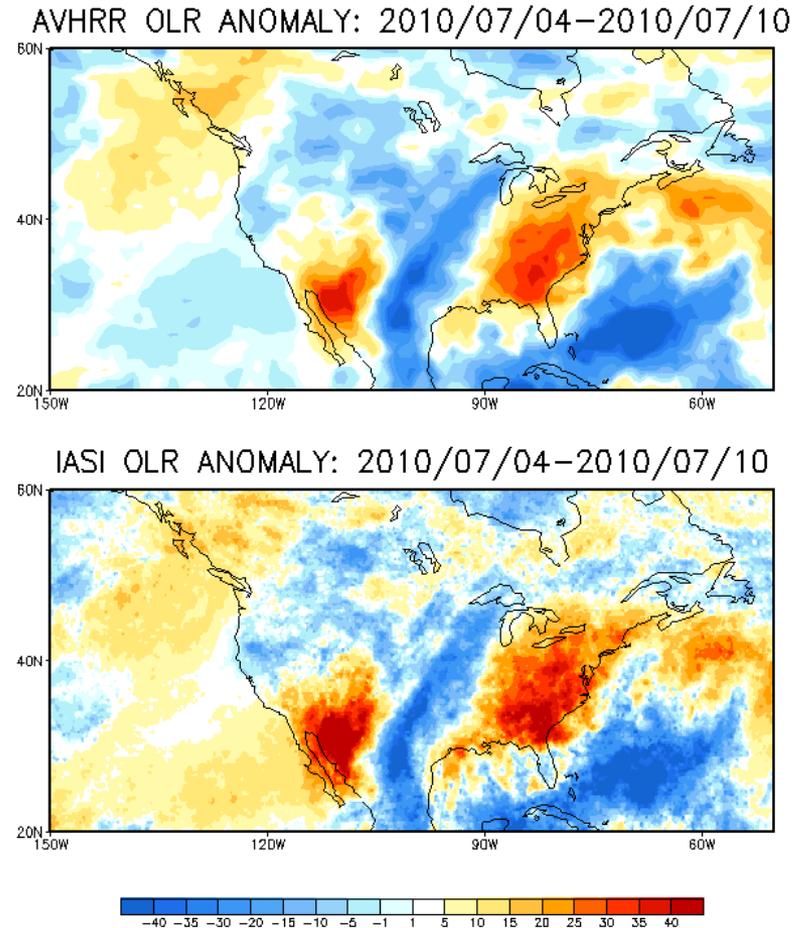


Figure 11: OLR anomaly (W/m²) associated with the heat wave of Jul. 4-10, 2010, derived from the operational AVHRR (top) and the IASI (bottom) data sets.

Summary and Future Work

- IASI OLR transition project show important improvements of the hyperspectral OLR for climate applications
- Further work is needed to repeat the work for hyperspectral OLR from other satellites and to combine the data from individual satellites into a consistent long-term time series
- We appreciate it very much JPSS's support for the reprocessing of hyperspectral OLR from CrIS and other sensors