CREST REMOTE SENSING OF CLIMATE GROUP

City College of New York

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SUMMARY OF PROJECTS

- International Satellite Cloud Climatology Project
  - Improvements (Calipso) & Re-processing
  - ISCCP “Research-to-Operations”

- CloudSat & Calipso
  - Level 3 Product Development
  - Global & Storm Cloud Vertical Structures

- Tropical Convection
  - Convective Processes & Mesoscale Dynamics
  - MJO, Monsoons, AEW & Hurricanes
SUMMARY OF PROJECTS

• Upper Troposphere – Stratosphere Water Vapor
  • Cirrus
  • Penetrating Convection

• Snow
  • Field Studies of Snow (and Ice)
  • Snow on Surface
  • Snowfall

• Land Surface Fluxes and Hydrology
  • Surface Turbulent Fluxes
  • Inundation

• Advanced Feedback Analysis
ISCCP CLIMATOLOGY 2009

CA=66.4%
PC=573mb
TAU=3.9
TC=261.6K
ISCCP MINUS CALIPSO TOTAL CLOUD AMOUNT
ISCCP PC - TAU histogram pattern and Map in Tropics over 21.5 years

Cluster Analysis + ISCCP D1 data

WS1: Deep cumulus clouds
WS2: Anvils clouds
WS3: Congestus clouds
WS4: Cirrus clouds
WS5: Shallow cumulus clouds
WS6: Stratocumulus clouds

Rossow et al., GRL, 2005
RFO of each cloud regime in 60E-180E region / 5S-5N latitude band
(MJO events in November-April periods from 1983 - 2004)
Composite of Annual Cycle of RFO (1984 - 2006)

Australia

WS1

WS2

WS3

WS4

WS5

WS6

WS7

WS8
Figure 7a: Frequency of occurrence of WS1 and 700-hPa meridional wind projected onto 2-10day filtered 700-hPa meridional wind at 12.5N, 30E. Anomalous WS1 frequencies are shaded every 0.5 and scaled by 30 (a value at a moderate strong convective event at the chosen basepoint; see also Kiladis et al 2009). Anomalous meridional winds are contoured every 0.1ms$^{-1}$ (positives solid and negatives dashed). The cross-sections are for 7.5-12.5N.
This figure is from a campaign in 1987 (Polarstern). It shows the ozone cross section, which indicates entrainment near ITCZ.

Ozone cross section is a good illustration of the Hadley Cell.
Cryospheric Processes Laboratory  
EAS Dept. and NOAA CREST

MAIN ACTIVITIES
- Remote sensing of the cryosphere
- Cryosphere/climate interactions
- High latitude field measurements
  - Arctic climate change

MAJOR ONGOING PROJECTS:
- Maintenance and refinement of the NASA AMSR-E snow operational product (NASA)
- Combination of active/passive MW data for snow parameters retrieval (NASA)
- Surface mass balance of the Greenland ice sheet (NASA, NSF)
- Investigating glaciers with visible/NIR satellite data
- Investigating supraglacial lakes in Greenland (WWF, NSF)
- Melting in Antarctica and the Arctic and links to climate variability
Greenland melting anomaly in 2007

Tedesco, EOS, 2007 b
MICROWAVE EMISSIVITY VERSUS TEMPERATURE

- Emissivity 19V
- Emissivity 19V-19H
- Emissivity 19V-37V
- Emissivity 19V-85V
Snowfall Rate Estimation from Multi-Spectral Satellite Based Information

Student: Cecilia Hernández-Aldarondo, PhD

Study Areas & Data used

• Input data
  – AMSU-B channels: 89-, 150-, 183±1-, 183±3-, 183±7 – GHz

• Calibration and validation data
  – Ground-based snowfall rate observations
    • Quality Controlled Local Climatological Data (QCLCD) product from the National Climatic Data Center (NCDC)
Normalized Transfer Entropy (TE) estimates between Lorenz variables

$TE \in [0,1]$
ISCCP Improvements

• **Switch to B1U** – code re-write completed, now testing smaller-scale spatial contrast test & sliding time windows & revised thresholds

• **Polar Cloud Detection** – testing ideas from J. Key’s AVHRR algorithm: daytime TB45 test helps but nighttime TB45 test does not, old TB3 test may be dropped, increased TB4 threshold with alternate TB45 nighttime test may help

• **Surface skin temperature** – More realistic surface emissivities implemented

• **Planned VIS changes** -- better tau precision, better ice treatment (aspect ratio, correct error), included aerosol effects, better land surface reflectances

• **Possibilities** -- particle sizes
ISCCP MINUS CALIPSO TOTAL CLOUD AMOUNT

D2–Calipso max = 7.99 min = -30.68
Preparations for Re-Processing in 2010

- Code adapted to newer computers
- Code adapted to B1U
- Testing finer spatial test and sliding time window
- Testing new polar cloud detection
- IR retrieval code revised for better treatment of surface
- Starting on VIS retrieval code revisions
- Beginning tests of new products
CLOUDSAT L3 PRODUCT

Part A – Basic Cross-Sections

Twice-daily, Reduced Resolution (50 km - 500 m)

Merged, Averaged L2 Variables at Each Location
CLOUDSAT L3 PRODUCT

Part B -- Statistical Histograms

Reflectivity vs Particle Size

Optical Thickness vs Particle Size

Water Content vs Particle Size

Water Content vs Precipitation
CLOUDSAT L3 PRODUCT

PART C – Gridded Monthly Statistics
Gridded at 4.5° x 4.5° with Cloud Fraction
Cloud Layer (Type) Properties from Part A
Vertical Structure Statistics from Part A
Accumulated Histograms from Part B

Additional Histograms
Water Content—Particle Size—Temperature
Water Content—Particle Size—Relative Humidity
Cloudy Alpha & Beta Parameters
Clear Alpha & Beta Parameters
Frequency over PC for WS-1, Zone TR

0610 for Land + Ocean
Frequency over PC for WS-3, Zone TR

0610 for Land + Ocean

Centroid
CCH-C3
C&C

Frequency (%)

Bin of PC (hPa)

Centroid
CCH-C3
C&C
For ISCCP-DX MC, $\tau = [0.02, 1.27)$

$\gg 1M$

0610 for Land+Ocean, Global

For ISCCP-DX MC, $\tau = [1.27, 3.55)$

$\gg HL$

0610 for Land+Ocean, Global
8 Monsoon Sectors
Composite of Annual Cycle of WS1 RFO (1984 - 2006)

- a) Global
- b) Africa
- c) Indian Ocean
- d) West Pacific
- e) Central Pacific
- f) East Pacific
- g) South America
- h) Atlantic
Composite of Annual Cycle of WS3 RFO (1984 - 2006)

a) Global

b) Africa

c) Indian Ocean

d) West Pacific

e) Central Pacific

f) East Pacific

g) South America

h) Atlantic
Composite of Annual Cycle of RFO (1984 - 2006)

South Asia
Composite of Annual Cycle of RFO (1984 - 2006)
Fig. 7b: as in Fig. 7a but for WS3
MOZAIC FACTS:

1. Measuring RH, T, p, u, v, and O₃ (NOₓ and CO since 2000);
2. 1 min & 15 km;
3. Flight levels: ~ 300-200 hPa;
4. RH ~ 5% accuracy
5. O₃ ~ 2 ppb accuracy

Founded by the EU in 1993;

Five long-range commercial aircraft;

Operational since 08/94 with ~ 2500 flights/yr
NASA AMSR-E product

- PI – Tedesco (CUNY)
- co-PI – Kelly (U. Waterloo)
- co-I’s J. Foster (NASA)
- Collaborators: M. Hallikainen, C. Derksen
  - Support Specialist: J. Miller
• Planned field activities:

- GAPS10 - Idaho, February 2010
- Fieldwork in Vermont, January, April 2010
- Sodankyla, Finland, March 2010
- Greenland, June 2010
Preliminary Conclusions
Model Input

• AMSU-B
  – Snow product, 183±1, 183±3 GHz

• AMSU-A
  – ATs near 50 GHz (4, 5, 7, 8) and 89GHz
  – Products: Emis@50 GHz, Tsurf

• GOES @ 25 km
  – Mean @ 25 km: Band 3, Band 6
  – Min. - 25 km window: Band 3, Band 6
  – Std. dev – 25 km window: Band 6

• SNODAS @ 25 km – previous day
  – Snow water equivalent (SWE)
  – Snow depth (average)
  – Snow melt (average)
  – Maximum in 25 km window of Non-snow (liquid) precipitation
  – Snow pack sublimation std dev in the 25 km window

• RUC Data
  – TMP @ 675, 600, 575, 550, 525 mb
  – u wind @ 975, 850, 825, 725, 625, 600, 575, 500 mb
  – v wind @ 925 mb
  – Surface lifted index (LFTX) - sfc anl
  – Best lifted index (BLI - to 500 hPa) - sfc anl
  – Storm relative helicity (HLCY) - sfc anl
  – Pressure (PRES) isotherm
  – Geopotential height (HGT) isotherm
  – Temperature (TMP) - tropopause
**Information-Theoretic quantities to estimate information flow between different variables**

**Mutual information:** If we have some knowledge about one variable $X$, how much information do we also have about another variable $Y$ (amount of information shared between two variables)

\[
I(X;Y) = \sum_{x \in X} \sum_{y \in Y} p(x,y) \frac{p(x,y)}{p(x)q(y)}
\]

- Joint probability
- Kullback-Leibler divergence between $p(x,y)$ and $p(x)p(y)$: Measure of difference of Joint probability from the product of their marginals (thus measure of (in)dependency)

Note that $I(X;Y)=I(Y;X)$, i.e. symmetric. Only provides information shared between $X$ and $Y$. No information about the directionality: Does $X$ cause $Y$; or does $Y$ cause $X$?

**Solution:** Make use of the generalized Markov property: Test if future sample $X_{i+1}$ depends only on its past $k$ samples $(X_i^{(k)})$ but not on past $l$ samples of variable $Y (Y_j^{(l)})$: Measure the Kullback divergence between

\[
p\left(x_{i+1} | x_i^{(k)}, y_j^{(l)} \right) \quad \text{and} \quad p\left(x_{i+1} | x_i^{(k)} \right)
\]

\[
TE_{Y \rightarrow X} = T(X_{i+1} | X_i^{(k)}, Y_j^{(l)}) = \sum_{i=1}^{N} p(x_{i+1}, x_i^{(k)}, y_j^{(l)}) \log_2 \frac{p(x_{i+1} | x_i^{(k)}, y_j^{(l)})}{p(x_{i+1} | x_i^{(k)})}
\]

Similarly, in the other direction:

\[
TE_{X \rightarrow Y} = T(Y_{i+1} | X_i^{(k)}, Y_j^{(l)}) = \sum_{i=1}^{N} p(y_{i+1}, x_i^{(k)}, y_j^{(l)}) \log_2 \frac{p(y_{i+1} | x_i^{(k)}, y_j^{(l)})}{p(y_{i+1} | y_i^{(k)})}
\]

$x_i^{(k)} = \{x, ..., x_{i-k+1}\}$
**Application: Lorenz equations**

\[
\frac{dx}{dt} = \sigma(y - x)\\
\frac{dy}{dt} = -xz + rx - y\\
\frac{dz}{dt} = xy - bz
\]

**Parameters:** $\sigma = 10; \quad b = \frac{8}{3}; \quad r : Rayleigh\ number$  
**Initial conditions:** $x = 0, y = 1, z = 0$
FABRICE’S SLIDES
Dynamic of global surface water from multi-satellite observations (Papa, Rossow, Prigent)

Mean surface water extent (km²) at annual maximum

1993-2004, monthly surface water extent variations by latitude zones: decrease of ~6% in the Tropics

- SSM/I emis, ERS scatt, AVHRR
- Data mapped on equal-area grid with 0.25°x0.25° resolution at equator (773 km²)
  - Monthly resolution, soon daily
- Now for 1993-2004 and at least to be extended to 2012 and longer
Direct Applications:

- Understanding hydrological processes and floods dynamic
- Validation/ Improvement of hydrological models
- Surface waters are the largest natural sources of CH4: this data is used in CH4 models or to help separate the different contributions (anthropogenic, fire, wetlands...)

![Graph showing CH4 emissions from wetlands, biomass burning, and fossil fuels.]

Wetlands are the bigger contributors to the interannual variability in methane emissions.

CH4 emissions from wetlands estimated from multi-sat. method.

Since 1999, compensation between an increase in anthropogenic emission and a decrease in CH4 emissions from wetlands.

Combining this dataset with other observations:

- With radar altimetry and DEM, it provides land surface water volume change.
- Decomposition of water falling on land into the different components of the water balance equation.

\[
\text{GRACE (Total water storage)} = \text{Surface water storage} + \text{Soil Moisture} + \text{Groundwater}
\]

Contribution of terrestrial surface water to sea level change?

Impact of terrestrial hydrology to other climatic components:
Ex: Impact of river discharge on ocean circulation, sea surface salinity....:

Large impact of fresh water fluxes from rivers into the Bay of Bengal in terms of salinity and ocean stratification.

Impact on SST, cyclogenesis, monsoon variability.