Year of Tropical Convection (YOTC)

Tropical convection, its organization and its large-to-global scale interaction

Duane Waliser, JPL/Caltech
Mitch Moncrieff, NCAR
Co-chairs, YOTC Science Planning Group

A Contribution to Seamless Weather-Climate Prediction
A Stark Demonstration of the “Tropical Convection Problem”

Aqua-Planet Experiment

N Models => N Answers

Courtesy, Dave Williamson, NCAR
The tropical atmosphere-ocean-land systems have never been so well observed.

Our computational and modeling resources are rapidly improving.

We have yet to fully exploit these resources and apply them to the "tropical convection problem".

**How to address this problem?**

i.e. to simultaneously address the large-to-global scale and the scales of convective organization?

---

**New/Improved Resources**

- Satellite Observations (e.g., EOS)
- In-Situ Networks (ARM, CEOP)
- GOOS (e.g., TAO, PRADA, drifters)
- IOPs (e.g., VOCALS, T-PARC, AMY)
- High-Resolution Deterministic Forecast Models & Global Analyses
- Research Models [e.g., Regional and Global Cloud(-System) Resolving Models]
Develop a virtual "field Program" with existing resources with model, parameterization & forecast improvement as a chief objective.

New/Improved Resources

- Satellite Observations (e.g., EOS)
- In-Situ Networks (ARM, CEOP)
- GOOS (e.g., TAO, PRADA, drifters)
- IOPs (e.g., VOCALS, T-PARC, AMY)
- High-Resolution Deterministic Forecast Models & Global Analyses
- Research Models (e.g., Regional and Global Cloud(-System) Resolving Models)

Conceptual Framing

FGGE, GATE, TOGA COARE

= YOTC

Focus “Year” Virtual IOP
Focus Period
May ‘08 – Apr ’10

Focus Areas
MJO & CCEWs
Easterly Waves & TCs
Trop-ExtraTrop Interaction
Diurnal Cycle
Monsoons
The "Year" of Tropical Convection (May 2008 to April 2010):
Climate Variability and Weather Highlights

Many authors/contributions
BAMS Submission Expected in June

1 Introduction .................................................................................................................................
2 Background Conditions and Low-Frequency Climate Variability .............................................
3 Tropical Waves ...........................................................................................................................
   3.1 Madden-Julian Oscillation ....................................................................................................
   3.2 Convectively Coupled Equatorial Waves ...........................................................................
   3.3 Easterly Waves ....................................................................................................................
4 Tropical Cyclones ....................................................................................................................... 
5 Monsoons ....................................................................................................................................
   5.1 Indian .................................................................................................................................
   5.2 East Asian / Western North Pacific ....................................................................................
   5.3 Australian ............................................................................................................................
   5.4 N. American ....................................................................................................................... 
   5.5 S. American .........................................................................................................................
   5.6 African ................................................................................................................................
6 Tropical – Extratropical Interactions ...........................................................................................
   6.1 Tropical-Extratropical Transitions .....................................................................................
   6.2 Extratropical Influences on the Tropics ..............................................................................
   6.3 Atmospheric Rivers ............................................................................................................
7 Diurnal Cycle ................................................................................................................................
8 Summary .......................................................................................................................................
Background Conditions & Low Frequency SST

Tropical SSTs

- W. Indian
- E. Indian
- Nino 4
- Nino 3
- N. Atlantic
- S. Atlantic

Warm in Year 2
Mostly +DMI

Year 1 – Modest La Nina
Year 2 – Modest El Nino

Mostly Warm Atlantic
Tropical Cyclone Occurrence During YOTC

Boreal Summer

Julian Hemming

Nargis, landfall over Myanmar, huge storm surge, 100,000 lives

Parma-1.8 m Rainfall

El Nino Modulation

Rick, 2nd Strongest in E. Pacific Ever

Grace

Ike - Largest size & Marko - smallest TC ever in this basin.
Summer Monsoons During YOTC

India
BN Goswami

S. America
Jose Marengo

2008
“Normal”
98% AIR

Breaks influenced by ISV

2009
Very Large Drought
78% AIR

Wet-north
Dry-south

Dry-north/east
Wet-south
Extra-Tropical Impact on Tropical Convection

5 Significant DRY-Season Wet Episodes in W. Africa

Peter Knippertz
Andrea Fink

16–19 February 2009
Atmospheric Rivers During YOTC

Tropical-Extratropical Interactions

Bin Guan

MJO -> AR -> CA Precip

10-day lead

5/08-4/09

5/09-4/10
**YOTC: Progress & Plans**

- **Science Plan** – Completed, WMO Technical Document.

- **Program Support/Information Specialist** – (Part-time): US THORPEX Exec Committee funding via U.S. NSF, NOAA, NASA.

- **Web site**: [http://www.ucar.edu/yotc](http://www.ucar.edu/yotc)

- **Implementation Plan Drafted and Discussed/Approved at IP Meeting in Honolulu July 13-15, 2009.**

- **WCRP-WWRP/THORPEX YOTC MJO Task Force** – 12/2009

- **YOTC Science Sessions** – Fall AGU’08, AMS’09, Spring AGU’09, Fall AGU’09, WP-AGU’10, AGU of Americas 2010, Fall AGU’10,

- **MJO TF Meeting and MJO Workshop, Busan, June 2010.**

- **YOTC Science Workshop + WGNE Meeting, China, Spring 2011.**
YOTC: Analyses, Forecasts & Special Diagnostics

- High-resolution, global analysis and forecast data sets are being made available to the community from ECMWF, NCEP and GMAO/NASA. e.g. T799 = 25km ECMWF + diagnostic fields (as of Jan’10, T1279 = 16kms)

ECMWF-YOTC Replicated at NCAR in coming months.
• Key satellite data (e.g., NASA A-Train, TRMM, geostationary) have been identified and funding secured from NASA for the:
  • Giovanni-based dissemination framework – Now Available
  • Multi-sensor CloudSat-Centric A-Train Data Set.
Satellite Data Analysis & Dissemination

NASA Giovanni & A-Train Data Interfaces

AIRS
AMSR-E
CALIPSO
CERES
CloudSat
GPS
ISCCP
MLS
MODIS
PEHRRP
QuikSCAT
TRMM/TMI
YOTC: A-Train Data Co-Location for Studying & Modeling Cloud/Convection

- **CALIPSO**
  - Aerosol \((p)\)
  - Cloud \((p)\)
  - \(\tau < 3\)

- **CERES**
  - TOA and SFC radiative fluxes

- **AIRS**
  - \(q(p)\), \(T(p)\)

- **ECMWF**
  - \(\omega(p)\)
  - \(q(p), T(p)\)
  - \(u(p), v(p)\)

- **MODIS**
  - Aerosol Opt Depth
  - Cloud Top - Temperature, Pressure, Particle Size, etc

- **AMSR**
  - Precipitation
  - SST
  - Prec Water
  - LWP
  - Surf, Wind Speed

- **CloudSat**
  - \(q_i(p)\) & IWP
  - \(q_i(p)\) & LWP
  - Cloud Type \((p)\)
  - \(~\) Particle Size \((p)\)
  - Light Precip

- **MLS**
  - UTLS \(-T(p), q(p), q_i(p), CO(p), O_3(p), HNO_3(p)\)

- **Ready Mid 2010**
YOTC Satellite Data Application – Convective / Microphysics

Moistening/Drying

1 – month of A-Train & ECMWF Data

- AMSR – Rain Rate
- CloudSat – IWC and Cloud Class
- ECMWF – Rel Hum

-> Need to replace with AIRS

Cooling/moistening from cloud-top detrainment

Cumulus induced Subsidence
Drying/warming

Rain re-evaporation and moistening/cooling
Overlapping field programs (e.g., T-PARC, VOCALS, AMY) that benefit from and contribute to YOTC were discussed.

A number of synoptic periods of interest have been identified and agreed upon (e.g. late May 2008 – early July 2009). These pave the way for extended analysis on the observation data sets and frame many of the modeling experiments. A premise of YOTC is community focus along the lines that field programs provide.
YOTC Implementation: Collaborative research

Weather: initial-value problem (IVP) for climate (seamless prediction)

- Transpose-AMIP: 5-day hindcasts of YOTC period(s) by:
  1. DOE/PCMDI CAPT Program with NCAR CAM (and maybe GFDL).
  2. A number of CMIP5 Models as Proposed by WGNE/WGCM.
  3. Multiple GCMs via GEWEX/EUCLIPSE project -> CFMIP2/GCSS.
  4. NCAR CAM utilizing super-parameterization (SP-CAM).

ABOVE GREATLY FACILITATED VIA ECMWF YOTC CONTRIBUTION

MJO & Convectively-Coupled Equatorial Waves

- High Resolution (~5-20km) MJO/CCEW hindcasts: UK Cascade, NICAM, GMAO GEOS, GMAO HiRes, CMMAP and GSFC MMFs, Rave/WRF.
- MJO multi-model 20-year hindcast experiment in (CLIVAR AAMP and AMY) to address prediction skill & predictability – extra output for YOTC.
- WWRP-WCRP YOTC MJO Task Force Activities – more process-oriented simulation diagnostics, boreal summer forecast metrics, etc.
**MJO Case Study Experiments**

- **6 periods identified w/ help M. Wheeler**
- **~5 modeling groups committed**
- **Details TBD Busan Mtg**

---

**Real-time MJO filtering superimposed upon 70cm R21 OLR Anomalies**

<table>
<thead>
<tr>
<th>Target Periods (priority)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) 01MAY2008 - 30JUN2008 (4)</td>
<td>- fast propagation of MJO into Bay of Bengal. - caused strong modulation of eastern Pacific ITCZ, including embedded TCs.</td>
</tr>
<tr>
<td>b) 15AUG2008 - 01NOV2008 (5)</td>
<td>- MJO convective onset (in central IO) about Aug 15. - suppressed period in mid-Sept, the second convective onset in December. Ocean occurred around Oct 12.</td>
</tr>
<tr>
<td>c) 01JAN2009 - 28FEB2009 (3)</td>
<td>- Weak sequence of the MJO that started with a suppressed IO from about 10-20 Jan. - MJO convection onset then followed in the IO on 22 Feb; propagating into N Australia in early Feb; coincident with strong compensating descent to south exacerbated by temperature in NSW/Victoria that affected the wild fires; strong cyclones, i.e., association with severe weather (floods, fires, storms).</td>
</tr>
<tr>
<td>d) 01APR2009 - 31MAY2009 (2)</td>
<td>- strongest MJO in the YOTC period up to Hawaii. Confined to Indian Ocean and Tropical Western Pacific; - OLR propagation; convectively coupled Kelvin wave activity; - westerly anomalies in Pacific; basin-wide SST increase; trends for MJO between La Nina and El Nina; MJO possibly triggered.</td>
</tr>
<tr>
<td>e) 20OCT2009 - 20DEC2009 (1)</td>
<td>- strong MJO onset in Indian Ocean; propagation into E Pacific; El Nino conditions; effects on N-hemispheric weather seasons/cycle.</td>
</tr>
<tr>
<td>f) 20DEC2009 - 20FEB2009 (1)</td>
<td>- strong MJO onset in Indian Ocean; propagation into E Pacific; southward in mid-Pacific region.</td>
</tr>
</tbody>
</table>

---

**Miura et al. 2007**

**Dec 2006 MJO**
YOTC Implementation: Collaborative research

**GEWEX Cloud System Study (GCSS):**
- Extension of GEWEX Pacific Cross-section Intercomparison (GPCI) for June-August 2008 of YOTC: transition of stratocumulus, trade-cumulus, deep convection.

**Tropical-Extratropical interaction**
- Tropical – extratropical interaction studies (TPARC and TCS08) focusing on the life cycle and impacts of tropical convection on the prediction and predictability of mid-latitude weather (e.g., ET, storm tracks).

**Easterly Waves and Tropical Cyclones**
- Synergistic forecast and analysis study in the Atlantic sector of easterly waves, tropical cyclones and their modulation by intraseasonal variability. Cases during YOTC identified.

**NCAR Tropical Channel Model (TCM) simulations:**
- 4-km mesh, ECMWF T799 dataset for initial & meridional BCs.
- Maritime Continent ‘prediction barrier’: orographic, diurnal cycle, coastal effects on MJO
YOTC Implementation: Next Steps

• Move forward with collaborative research identified at the July 2008 YOTC Implementation Planning Workshop – a multi-year effort.
• YOTC synoptic description article(s) e.g., BAMS and/or special issue – drafts expected May 2010.
• Expand involvement of tropical interests in YOTC (e.g., Africa, China, India, Korea, S. America) -> WP AGU, S.A. AGU, WGNE + YOTC Science Workshop in China Sp’2011
• Planning first YOTC MJO Task Force meeting along with Monsoon ISV Workshop June 2010, APCC, Busan.
• Address multi-agency research funding for multi-year collaborative projects. Order of $2+M/yr for 3+ years. (MJO, TCs/EWs, monsoon, trop-extratrop, diurnal cycle)
• Help frame DYNAMO field campaign in 2011 focused on MJO onset in Indian Ocean.
Convective parameterization is based on assumptions that imply a gap between cumulus and resolved scales of motion (~1 km - 100 km).

But a scale-gap does not exist: mesoscale convective organization fills the gap.

Addressing this key problem is high on the YOTC research agenda (2006 ICTP Workshop).

For the first time, problem is tractable using existing models and observations (YOTC integrative strategy).

**Bridging the Scale Gap**

- **LES-CRM** (∆ ~100 m)
- **Global CRM** (∆~1 km)
- **Global NWP** (∆~10 km)
- Satellite, field measurements

**Climate models by 2020**
Tropical Convection-Wave Continuum

Diurnal Cycle
- Upscale organisation?
- MJO Suppressed Phase?
- Trigger

Upscale organisation?

Mesoscale systems
- 1-100 km
- Hours

Synoptic systems
- 100’s km
- Days

Modulates activity

Seasonal Cycle
- Monsoons
- Upscale organisation?
- Modulates activity

MJO
- 1000’s km
- Weeks

Extended Predictability

ENSO, Climate Change

2006 ICTP Workshop (Moncrieff et al. 2007)