Space Technology and Earth System Science

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Technology Development Drivers as we thought!!

Government investments have been leading to Commercialization

- Space Travel
- Space Exploration
- Communication
- Computational
- Remote Sensing

So what is driving it now – science or economic market??

Is public interest slowing down??

And Tax payers/legislatures want technology development must have specific end users i.e., beneficiaries
Science – Astrophysics from L2

*Science will still offer major breakthroughs*
Our Challenge in this century will be learning and adapting to Climate Change

Earth System Science
…..and will be dealing with multiple societal issues
The concentration of CO$_2$ in the atmosphere has reached a record high.
Aqua Mid-Tropospheric CO$_2$ Product

(Animation from Mous Chahine, the AIRS Science Team, and the NASA GSFC Scientific Visualization Studio [SVS])
Five Year Average Temperature Anomalies 1880-2005

Warming trend in Northern Hemisphere

Ref: NASA GISS Simulation
What influences our Climate System?

• The Solar Variability ... *Sun*

• Atmospheric Gases ... *Trace Gases*

• Anthropogenic Activity

• Natural Earth Orbital Perturbations

• Ocean Circulation

• Atmospheric Feedbacks
Earth’s Energy Budget

- Reflected solar radiation: 107 W m⁻²
- Incoming solar radiation: 342 W m⁻²
- Outgoing longwave radiation: 235 W m⁻²

- Reflected by clouds, aerosol and atmosphere: 77 W m⁻²
- Reflected by the surface: 30 W m⁻²
- Absorbed by the surface: 168 W m⁻²
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- Latent heat: 78 W m⁻²
- Evapotranspiration: 78 W m⁻²
- Thermals: 24 W m⁻²

- Emitted by the atmosphere: 165 W m⁻²
- Atmospheric window: 40 W m⁻²

- Greenhouse gases:
  - 40 W m⁻²

- Back radiation: 324 W m⁻²
- Surface radiation: 390 W m⁻²
### Earth’s Atmosphere and Trace Gasses

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Chemical Formula</th>
<th>Concentration by Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>$N_2$</td>
<td>78.08%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>$O_2$</td>
<td>20.95%</td>
</tr>
<tr>
<td>Argon</td>
<td>$Ar$</td>
<td>0.93%</td>
</tr>
<tr>
<td>Neon</td>
<td>$Ne$</td>
<td>18.2 ppmv</td>
</tr>
<tr>
<td>Helium</td>
<td>$He$</td>
<td>5.2 ppmv</td>
</tr>
<tr>
<td>Krypton</td>
<td>$Kr$</td>
<td>1.1 ppmv</td>
</tr>
<tr>
<td>Xenon</td>
<td>$Xe$</td>
<td>100.0 ppbv</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>$H_2$</td>
<td>50.0 ppbv</td>
</tr>
<tr>
<td>Water Vapor</td>
<td>$H_2O$</td>
<td>3.0% at the equator</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.2% near the poles</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>$CO_2$</td>
<td>364.0 ppmv</td>
</tr>
<tr>
<td>Methane</td>
<td>$CH_4$</td>
<td>1.7 ppmv</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>$N_2O$</td>
<td>310.0 ppbv</td>
</tr>
<tr>
<td>Ozone</td>
<td>$O_3$</td>
<td>&gt;100.0 ppbv in stratosphere</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-100.0 ppbv in troposphere</td>
</tr>
<tr>
<td>Chlorofluorocarbons (CFCs)</td>
<td>Various</td>
<td>600-800.0 pptv</td>
</tr>
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</table>

*ppmv = parts per million by volume*
*ppbv = parts per billion by volume*
*pptv = parts per trillion by volume*
Ocean Thermohaline Circulation - The Great Conveyor Belt
Orbital variations are producing changes in the seasonal and latitudinal distribution of incoming solar radiation at the top of the atmosphere.

Slow variations of the Earth’s orbit are induced by gravitational torque by other planets, mainly Jupiter, Saturn, and Venus.
Sea ice is reduced
Wet snow
Melting ice

Reduced surface albedo
More energy absorbed

Temperature increases

More sea ice reduction

Temperature increases

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Overarching Questions

How does the Earth work?

How is the Earth changing?

Are human activities altering the chemical composition of the planet?

How does our changing environment affect life on Earth?

Forces acting on the Earth system → Earth system responses → IMPACTS → Feedbacks

Earth System
Climate Modeling Research

Earth System integrated analyses, monitoring and predictions
What Earth Science can Contribute

• **Understand and Develop**: Study the past, observe the present, and predict the future

• **Technology**: Develop technology by defining new measurement requirements to address unknowns

• **Utilize**: Apply results to address societal needs
Addressing societal issues

- Agriculture
- Disasters
- Air Quality
- Health
- Oceans
- Water Resources
- Weather
Flood Mapping and Modeling
Once again, the year 2010 showed the world the devastating impact that natural disasters can have on human lives and livelihoods. After the relatively moderate year of 2009, natural disaster impact took a turn for the worse in 2010 with more than 297,000 fatalities. One must note that trends and patterns in disaster statistics are often greatly altered by single extreme events causing excessive damage. For instance, the devastating earthquake and tsunami in Japan. Over the last four decades, the mortality figures of 2010 were only surpassed in 1970, when a tropical cyclone affected the African continent and caused 450,000 deaths.

In 2010, 42 more disasters were reported than in 2009. The number of reported disasters (385) approximated the average yearly disaster occurrence from 2000 to 2009 (387). Although the total number of reported disasters in 2010 approached the 2000 annual average of disaster occurrence, a slight change was seen in the distribution between disaster subgroups. Mostly, hydrological disaster occurrence increased whereas meteorological disaster occurrence decreased, hereby enlarging the share of hydrological disasters in 2010.

The number of victims increased from 198.7 million in 2009 to 217.3 million in 2010 but remained below the annual average number of victims of 227.5 million for the period 2000 to 2009. The number of victims from hydrological disasters increased by 98.9% compared to the yearly average of the last decade. In contrast, climatological, meteorological and to a lesser extent geophysical disasters showed a decrease.

Figure 7: Natural disaster impacts by disaster subgroup: 2010 versus 2000-2009 annual average

Source: http://www.emdat.be/
Global mosaiced/ subsetted Surface Reflectance and Cloud Mask products within approx. 2.5 hours of observation

Orbit: 705km, 10:30am, descending node (Terra) and 1:30pm ascending node (Aqua), sun-synchronous

Spatial resolution:
- 250m (Bands 1-2)
- 500m (Bands 3-7)
- 1000m (Bands 8-36)

Terra Launch date, December 18, 1999
Aqua Launch date, May 4, 2002

LANCE
Land Atmosphere Near Real Time Capability of EOS (Earth Observing Systems)

- LANCE provides access to near-real time (NRT) data products from the MODIS (Terra and Aqua), AMSR-E (Aqua), AIRS (Aqua), MLS (Aura), and OMI (Aura) instruments in less than 3 hours of the observation time.
Daily NRT Global Flood Mapping

Formats Currently Available:
- PNG
- KML
- Shape Files

Public access: http://floodobservatory.colorado.edu/LanceModis.html
Shuttle Radar Topography Mission - (SRTM)

Measurements: gridded elevation data of 80% of the Earth's surface with 30m – 90m resolution

Most land surfaces between 60 degrees north latitude and 54 degrees south latitude.
### NASA Near Real Time Rainfall Measurements

**Near Global Precipitation Data Every 3 Hours**

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Instrument</th>
<th>Spectral Freq./Wavelength</th>
<th>Measurement type/algorithm</th>
<th>Temporal Coverage</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRMM</td>
<td>TRMM Combined Instrument (2B31)</td>
<td>n/a</td>
<td>retrieval based on TMI and PR</td>
<td>1998-present</td>
<td>4 km</td>
</tr>
<tr>
<td>TRMM</td>
<td>TMI (2A12)</td>
<td>10, 19, 23, 37, 85* GHz; dual-polarized except 23 is V</td>
<td>microwave imager/ GPROF</td>
<td>1998-present</td>
<td>5x8 km</td>
</tr>
<tr>
<td>Aqua</td>
<td>AMSR-E</td>
<td>6, 10, 18, 23, 36, 89* GHz; dual-polarized except 23 is V</td>
<td>microwave imager/ GPROF</td>
<td>April 2004-present</td>
<td>5x8 km</td>
</tr>
<tr>
<td>DMSP series</td>
<td>SSMI</td>
<td>19, 22, 37, 85* GHz; dual-polarized except 22 is V</td>
<td>microwave imager/ GPROF</td>
<td>1998-November 2009</td>
<td>12.5x15 km</td>
</tr>
<tr>
<td>NOAA series</td>
<td>AMSU</td>
<td>53, 89, 150, 183 GHz</td>
<td>microwave sounder/ NESDIS algorithm</td>
<td>2000-2010</td>
<td>16 km (nadir) – 25x50 km (limb)</td>
</tr>
<tr>
<td>NOAA series and METOP-A</td>
<td>MHS</td>
<td>53, 89 GHz</td>
<td>microwave sounder/ NESDIS algorithm</td>
<td>2011-present</td>
<td>16 km (nadir) – 25x50 km (limb)</td>
</tr>
<tr>
<td>Geosynchronous (GOES, METEOSAT, GMS, MTSAT series)</td>
<td>Imager</td>
<td>11 micron</td>
<td>thermal infrared/ VAR</td>
<td>1998-present</td>
<td>4 km (nadir) – 8x12 km (limb)</td>
</tr>
<tr>
<td>GPCC Monitoring Analysis</td>
<td>Surface precipitation gauges</td>
<td>n/a</td>
<td>monthly precipitation gauge analysis</td>
<td>1998-April 2005</td>
<td>1°</td>
</tr>
<tr>
<td>Climate Assessment and Monitoring System</td>
<td>Surface precipitation gauges</td>
<td>n/a</td>
<td>monthly precipitation gauge analysis</td>
<td>May 2005-present</td>
<td>0.5°</td>
</tr>
</tbody>
</table>

* TRMM used to calibrated all other satellites

**Near Real-Time TRMM Multi-Satellite Precipitation (TMPA-RT) 3-hourly product**

Huffman/NASA GSFC
65° inclination, non sun-synchronous orbit, mean altitude of 407 km
- Precipitation physics observatory
- Reference standard for inter-satellite calibration of constellation sensors

Radar: 1.26 GHz
Radiometer: 1.4 GHz
Antenna swath: 1,000 km
Resolution: 40 km radiometer and 3 km radar
Real-time global estimation of flood areas using satellite-based rainfall and a hydrological model running globally, every three hours at 0.25°.

http://trmm.gsfc.nasa.gov

Adler/Policelli UMD/NASA GSFC
Flood Modeling in Lake Victoria Basin

Flood potential for Lake Victoria Region (Kenya, Tanzania and Uganda) – home to 30 million people and over 175,000 are effected due to devastating floods

Using 1KM DEM
Water as a sustainable resource

[Diagram showing the distribution of water sources: Oceans (97%), Groundwater (22%), Frozen (77%), Lakes, Rivers, and Streams (1%).]
HKH Region with Major River Basins

HKH Map with major river basins
Enhance the decision making capacity of ICIMOD and its member countries for management of water resources (floods and irrigation) in the short (snow, rainfall) and the long-term (glaciers).

Integrate snow and glaciers outflow to primary river basins (Ganges, Indus and Brahmaputra)

- Provide a methodology that allows the snow extent with glacier maps to determine water outflow from melting glaciers using mass balance equations.

Explore the impact of climate change scenarios on water resources in the Himalayan region using hydrological models.

Benefits

- Provide an integrated decision support capability incorporating snow, glacier and ice melt water in stream flow models for hydrological managers.

- Develop understanding of glacier physics.
Himalayan Glacier Mapping

- 118 new scenes acquired in over the Himalayas
- total Himalayan scenes in the GLIMS database: 4830

The line or zone on glacier’s surface where a year’s ablation balances year’s accumulation. It is determined at the end of the ablation season, and commonly occurs at the boundary between superimposed ice and glacier ice.
GRACE Reveals Massive Depletion of Groundwater in NW India

The water table is declining at an average rate of 33 cm/yr

GRACE is unique among Earth observing missions in its ability to monitor variations in all water stored on land, down to the deepest aquifers.

During the study period, 2002-08, 109 km$^3$ of groundwater was lost from the states of Rajasthan, Punjab, and Haryana; triple the capacity of Lake Mead.
• NASA is partnering with USAID to develop a Land Data Assimilation System for the MENA, which will provide regional water balance assessments to address:
  – water availability, 1/8 degree resolution
  – water and agriculture variability
  – aquifer monitoring

• World Bank has approved a Global Environment Fund (GEF) Regional Grant under the Mediterranean Sustainable Development Program to extend the MENA LDAS to multiple regionally-focused NASA based water data platforms strategically located through the MENA.
  – Negotiations are underway to engage NASA and USAID in this process

Precipitation (mm/month) for July 2007 at 0.04° resolution, from the UC Irvine PERSIANN-GCCS system. Hourly, near-real time data from PERSIANN will be a primary input to the MENA LDAS.

Mean evapotranspiration rate (mm/day) from the MENA LDAS for April, 2006.

Rodell, Bolten, Toll, Habib /GSFC, Kumar, Engman GSFC/SAIC,), Ozdogan/UW, Zaitchik/JHU
Summary

• Significant advances have been made by several nations in space technology for exploration, sciences and travel
• Now, the era has begun to commercialize space travel.
  – Space orbital debris will continue to be a big challenge
• Science must continue to drive the technology development
• Partnering and Data Sharing among nations is very important to maximize the cost benefits of such investments
• Climate changes and adaptability will be a big challenge for the next several decades
  – Natural disasters frequency and locations
  – Economic and social impact can be global
  – Water resources and management