Contribution of HyspIRI measurements to improving the quality of satellite-derived Climate Data Records

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Outline

• Scales of variability in the ocean and atmosphere
• Potential of higher spatial resolution measurements
• Current limitations on CDRs imposed by medium resolution data
• Overcoming the combined geophysical and instrumental effects in CDRs
Turbulent Energy Cascade

• Energy is input to the climate system on large spatial scales and “cascades” through a sequence of turbulent processes to microscales.

• Satellite remote sensing offers a unique perspective of these processes: prime example is mesoscale oceanic variability.

• “Big whorls have little whorls that feed on their velocity, and little whorls have smaller whorls and so on to viscosity.” - L.F. Richardson.
Scales of atmospheric variability

Scales Figure 1. Scale definitions and different processes with characteristic time and horizontal scales. (Adapted from Orlanski, 1975, and Oke, 1987.)
Sub-mesoscale variability is not limited to shelf and estuarine processes.

SST images reveal mesoscale variability.
Ocean Color

2010 HyspIRI Science Workshop
24-26 August 2010 Pasadena
Clouds
How is progress made?

• In recent decades, progress in oceanic and atmospheric science has often followed the measurements of improved instrumentation:
  – Swallow floats & satellite images of oceanic mesoscale features.
  – Radars, aircraft and satellite measurements of cloud processes.

• But now, modeling has moved beyond measurement capabilities.
From below

Domain dimensions: 25x25 km
Blue: a density interface surface near the ocean surface
Orange: buoyant plume

From above

Courtesy: Tamay Ö zgökmen, RSMAS - MPO
Simulations of ocean mixing

Domain dimensions: 10x10 km
A density interface surface intersecting the ocean surface.

Courtesy: Tamay Özgökmen,
RSMAS - MPO
Grid size: 700m

Courtesy:
Dr Laurent Cherubin,
RSMAS-MPO
Nested grid resolutions: 2km $\rightarrow$ 690m $\rightarrow$ 230m

Courtesy: Dr Laurent Cherubin, RSMAS-MPO
How to measure sub-mesoscale variability?

- Ship-based: cannot provide synoptic sampling, even using multiple ships; traditional instruments are good for vertical sections, but not for horizontal.
- Tracers: difficult to capture by ship tracking; airborne laser tracking is promising and under development. Overall, total tracer amount is too small and too short-lived to provide insight.
- Gliders: these are in vogue, but expensive (so not too many), and have major post-processing challenges due to aliasing by time along the path.
- Drifters: feasible, but need O(100) in a concentrated deployment, which is large enough to create environmental concerns.
- VHF radar: good, but limited to coastal zones.
- High resolution satellite imagers (SARs, VIS, IR) – a very feasible option.
## Essential Climate Variables

The Essential Climate Variables (ECVs) are required to support the work of the UNFCCC and the IPCC. All ECVs are technically and economically feasible for systematic observation. It is these variables for which international exchange is required for both current and historical observations. Additional variables required for research purposes are not included in this table. It is emphasized that the ordering within the table is simply for convenience and is not an indicator of relative priority. Currently, there are 44 ECVs plus soil moisture recognized as an emerging ECV.

<table>
<thead>
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<th>Domain</th>
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</tr>
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<tbody>
<tr>
<td><strong>Atmospheric</strong></td>
<td><strong>Surface:</strong> Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour.</td>
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<td><strong>Upper-air:</strong> Earth radiation budget (including solar irradiance), Upper-air temperature (including MSU radiances), Wind speed and direction, Water vapour, Cloud properties.</td>
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<td><strong>Composition:</strong> Carbon dioxide, Methane, Ozone, Other long-lived greenhouse gases, Aerosol properties.</td>
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<td><strong>Oceanic</strong></td>
<td><strong>Surface:</strong> Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure.</td>
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<td><strong>Sub-surface:</strong> Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton.</td>
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<td><strong>Terrestrial</strong></td>
<td><strong>River discharge,</strong> Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (APAR), Leaf area index (LAI), Biomass, Fire disturbance, Soil moisture.</td>
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### GCOS Essential Climate Variables

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### Sea-surface temperature

### Sea ice

### River discharge

### Ocean colour (for biological activity)
Satellite-derived CDRs

- National Academy of Sciences Report (NRC, 2000): “a data set designed to enable study and assessment of long-term climate change, with ‘long-term’ meaning year-to-year and decade-to-decade change. Climate research often involves the detection of small changes against a background of intense, short-term variations.”

- “Calibration and validation should be considered as a process that encompasses the entire system, from the sensor performance to the derivation of the data products. The process can be considered to consist of five steps:
  - instrument characterization,
  - sensor calibration,
  - calibration verification,
  - data quality assessment, and
  - data product validation.”
Desired SST CDR uncertainties

• The useful application of all satellite-derived variables depends on a confident determination of uncertainties.

• CDRs of SSTs require most stringent knowledge of the uncertainties:
Sources of uncertainty in satellite-derived SSTs

Many sources of retrieval algorithm errors (green box) and geophysical and model errors (orange box) are dependent on the spatial resolution of the satellite data.
SST retrievals: identifying clouds

Many threshold values are scale dependent, and dependent on types of clouds present, and therefore dependent on time of day.
Why worry about sub-pixel variability?

Mixture modeling of radiances should give sub-pixel information:

\[ R = \sum_{i=1}^{c} r_i a_i + e \]

Beware……

Beware of per-pixel characterization of land cover

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and K. YANG
Science Systems and Applications, Inc., Code 922, NASA-GSFC, Greenbelt MD 20771, USA

Failure to account for the MTF (Modulation Transfer Function) can lead to >10% errors in classifications
Pixel spatial response function

- Instantaneous spatial responses of detectors are not uniform.
- This compounds the MTF effect and increases errors in retrievals at the pixel scale.

HyspIRI spatial resolution

Contours of actual directional response (dark is 100%)

Boresight

Nominal field of view (dashed)
Summary

- Natural variability covers a very wide range of scales, and is not truncated at the ~1km resolution of conventional oceanic and atmospheric imagers.
- High-resolution HyspIRI data over the oceans will provide new insight into oceanic and atmospheric processes relevant to climate studies.
- Many CDRs are derived from moderate-resolution data; high-resolution HyspIRI data can provide unique data with which to test, improve, and establish the limitations on accuracies imposed by sub-pixel variability. This would guide reprocessing algorithms to improve the accuracy of CDRs.
- Improved CDRs provide a better basis for decision-makers to make hard choices... and to justify them.
Global HyspIRI mission can make a unique contribution to the climate monitoring and climate research communities.
Acknowledgements

• Colleagues at RSMAS and elsewhere
• Support from NASA PO program, Dr Eric Lindstrom
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