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Weather & Climate Impacts on Energy Planning, Operations and Maintenance

Alberto Troccoli (CSIRO)

APEC Climate Symposium

Honolulu, Hawaii, 17-19 October 2011

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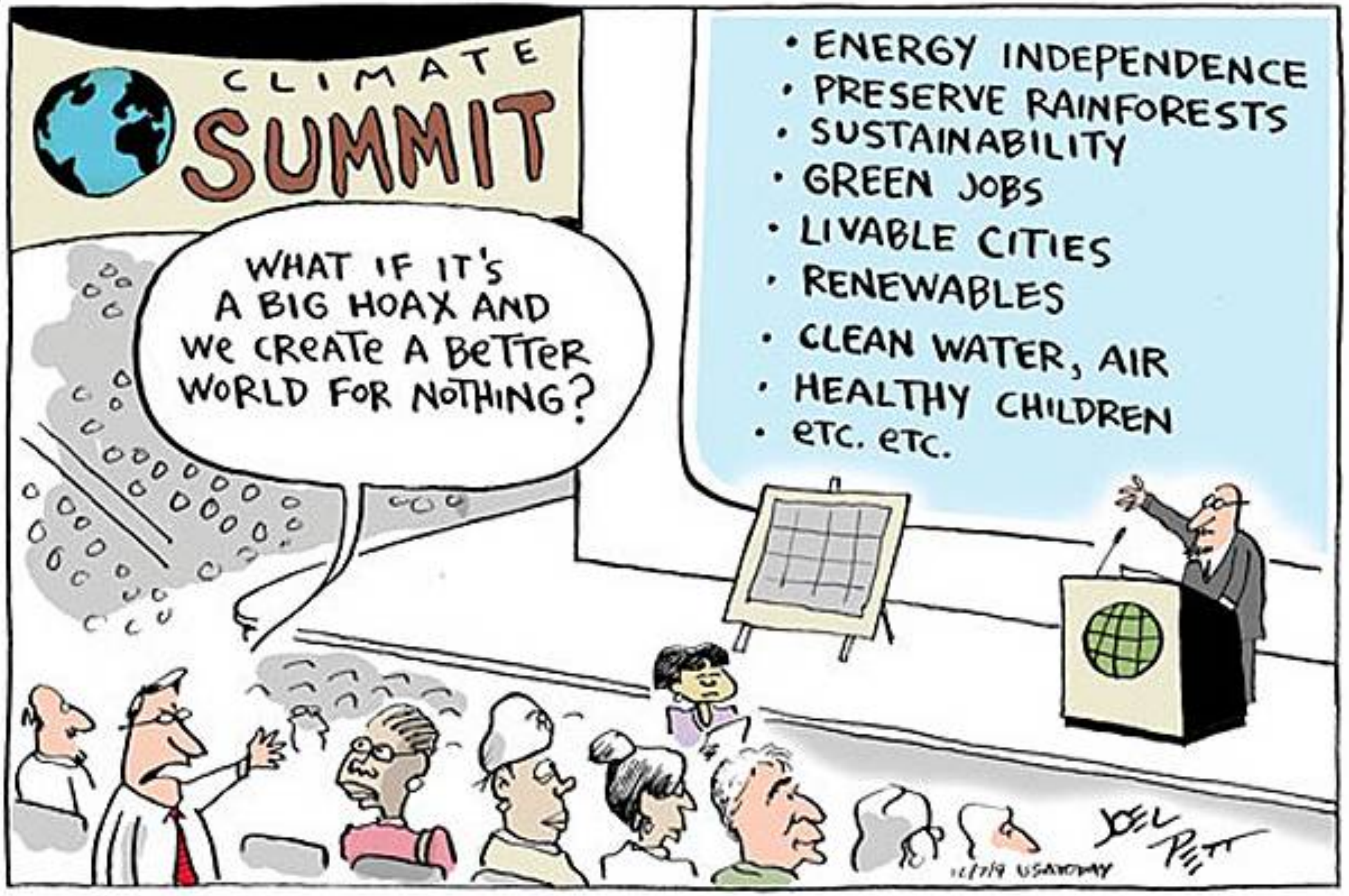
Outcomes of Climate & Energy interaction: not all about impact of emissions on climate



Outline

1. Projected climate and energy demand changes
2. Current climate variability & changes impacts on energy industry
3. Tools for climate risk management for the energy industry
4. Summary NATO Workshop on Climate & Energy and next steps

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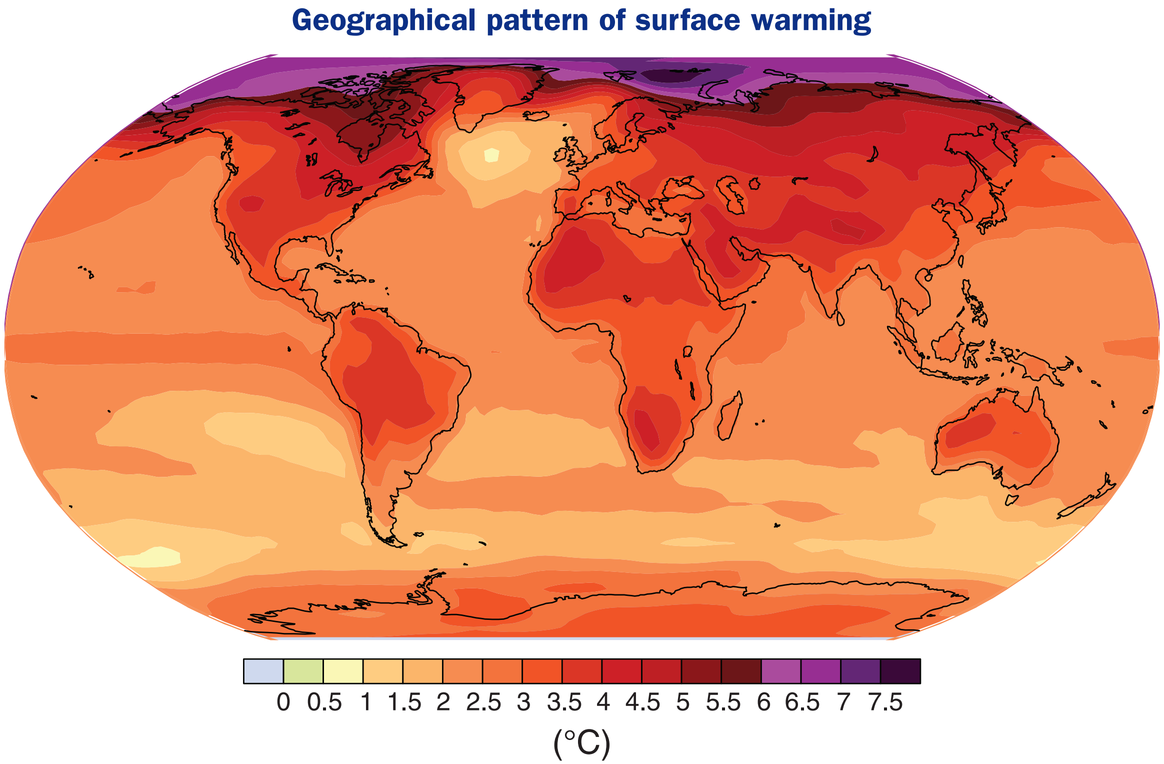
Main message

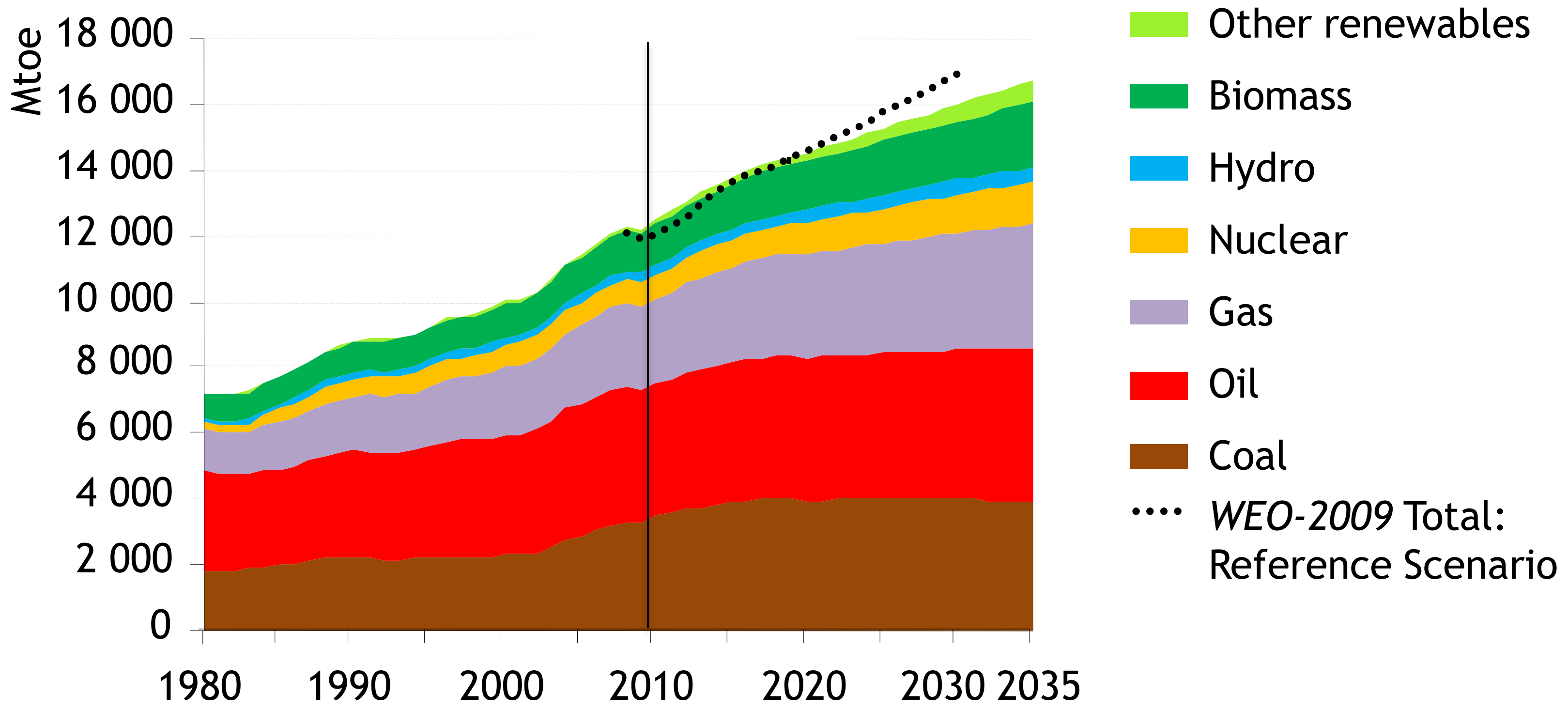
Not only is the energy sector at risk from future climate changes but it is also at risk from current hydro-meteorological climate variability & change. However, there are tools to tackle these risks.

Projected surface temperature changes



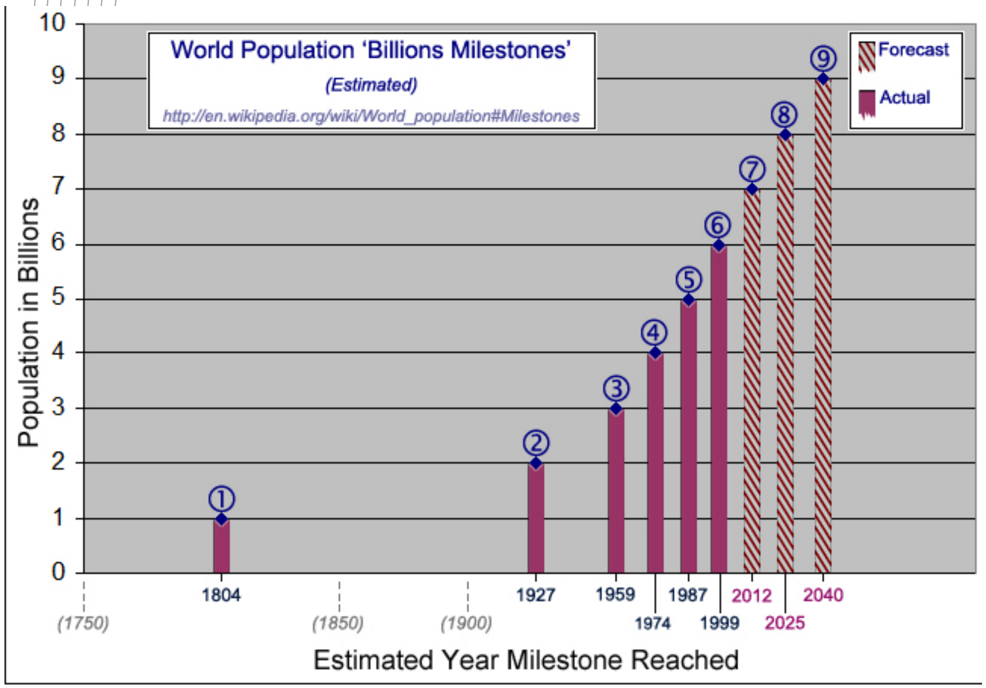
Projected surface temperature changes for (2090-2099) relative to (1980-1999). The map shows the multi-AOGCM average projection for the A1B SRES scenario (IPCC 2007).

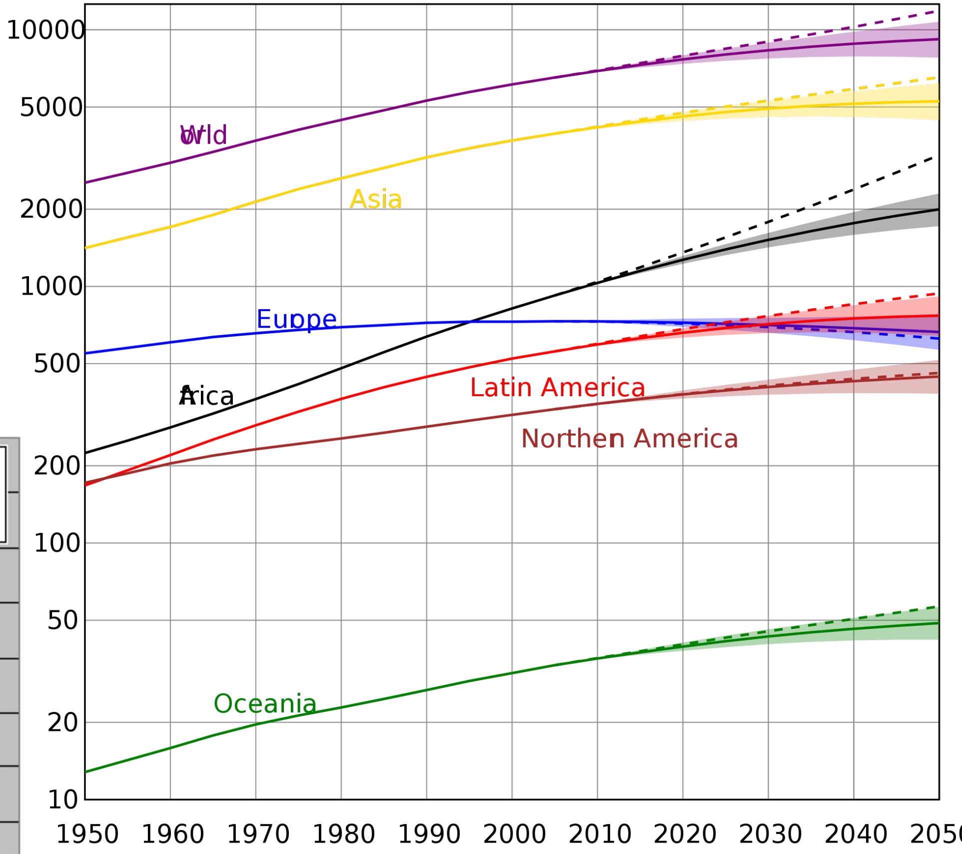
Historical and projected changes in Energy Demand



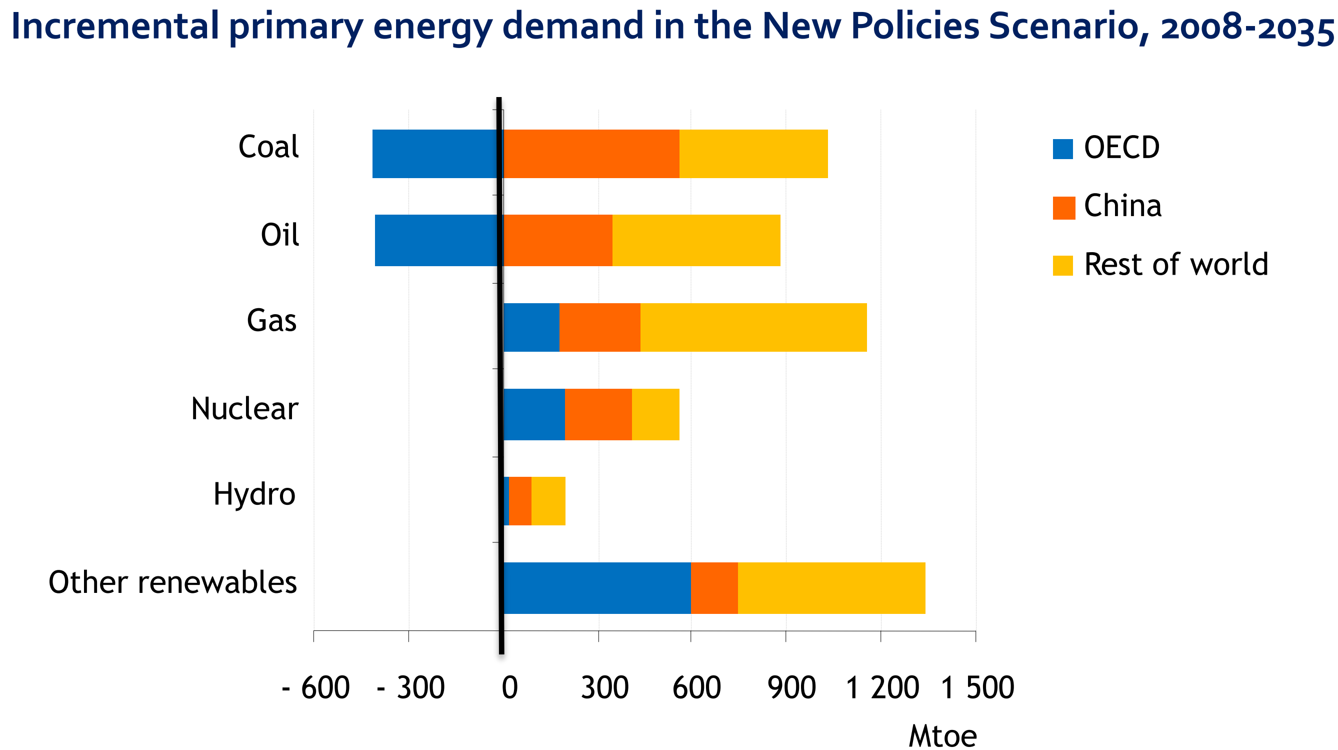
Fossil fuels projected to maintain a central role in the primary energy mix but their share declines from 81% in 2008 to 74% in 2035 (International Energy Agency [IEA], World Energy Outlook 2010)

Historical and projected trends in Population





Projected changes in Incremental Energy Demand



Demand for all types of energy increases in non-OECD countries, while demand for coal & oil declines in the OECD (IEA, World Energy Outlook 2010)

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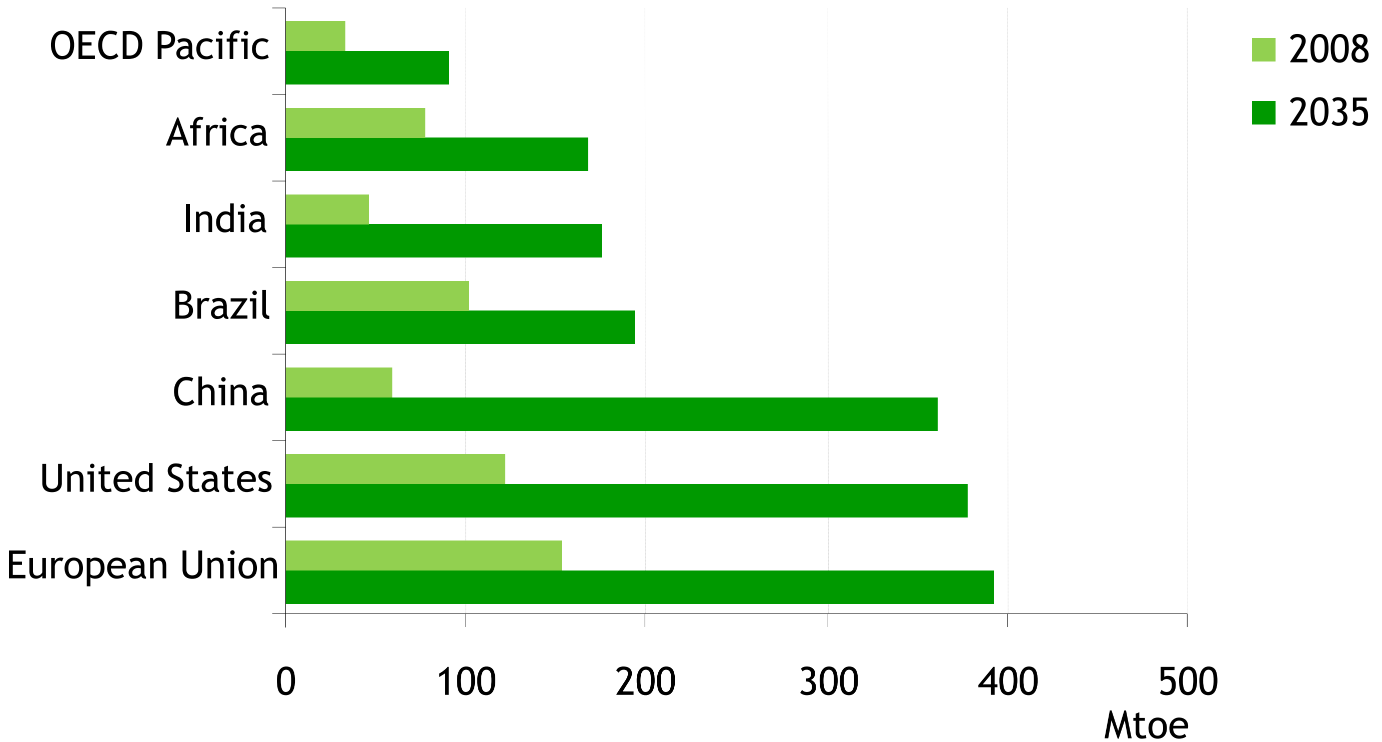
Projected changes in Renewable Energy Demand



The use of renewable energy triples between 2008 & 2035, driven by the power sector where their share in electricity supply rises from 19% in 2008 to 32% in 2035 (IEA, World Energy Outlook 2010)

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Energy Services Will Be Increasingly Affected By Climate Change but …

… the best available (global) baseline over which to assess future climate changes is the observed climate in the recent past.

Various hydro-meteorological and climate factors have the potential to affect the energy sector

Ebinger and Vergara, World Bank (2011)
See also: Williamson et al., Helio International (2009)
Urban and Mitchell, IDS (2011)

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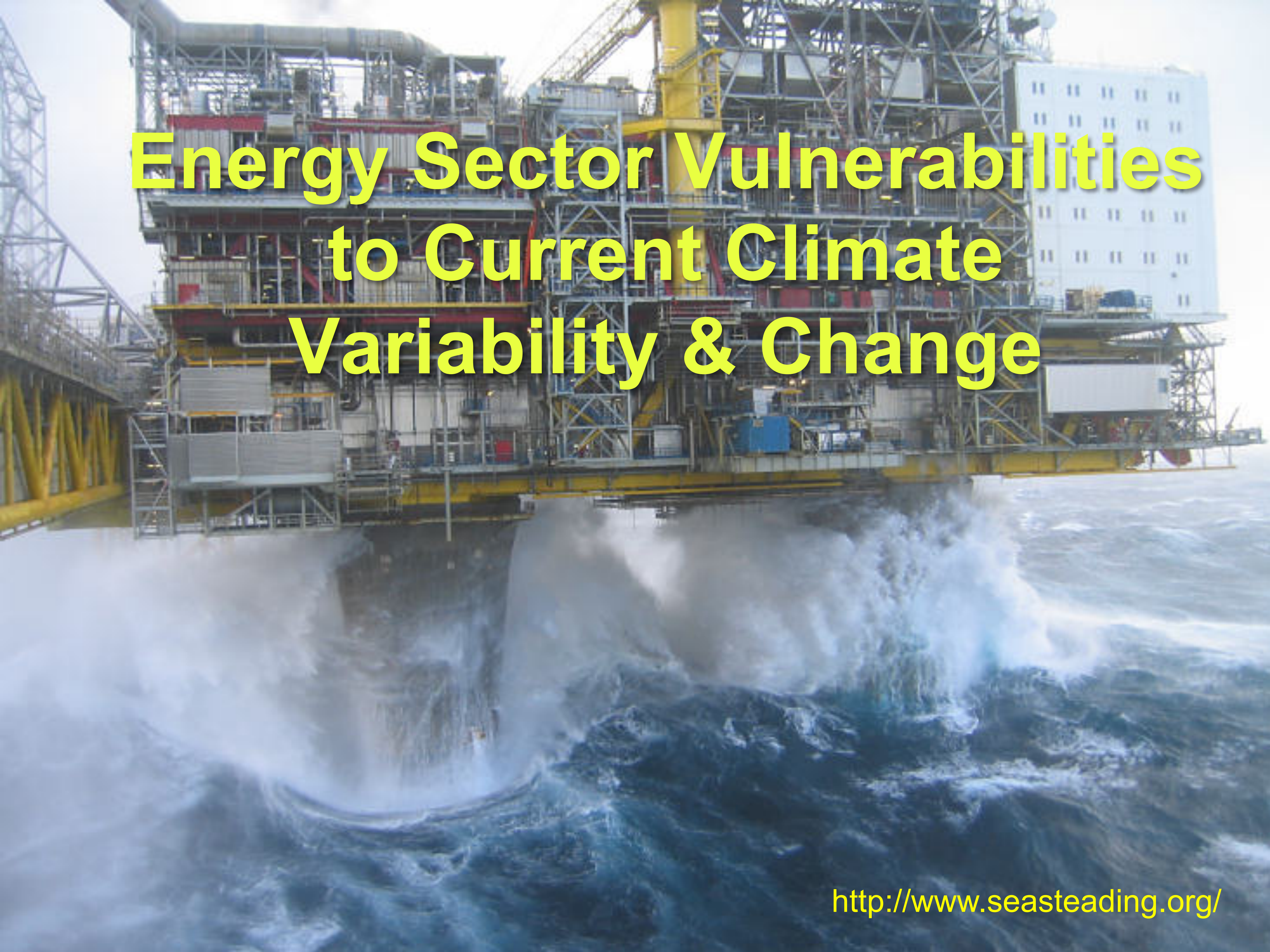
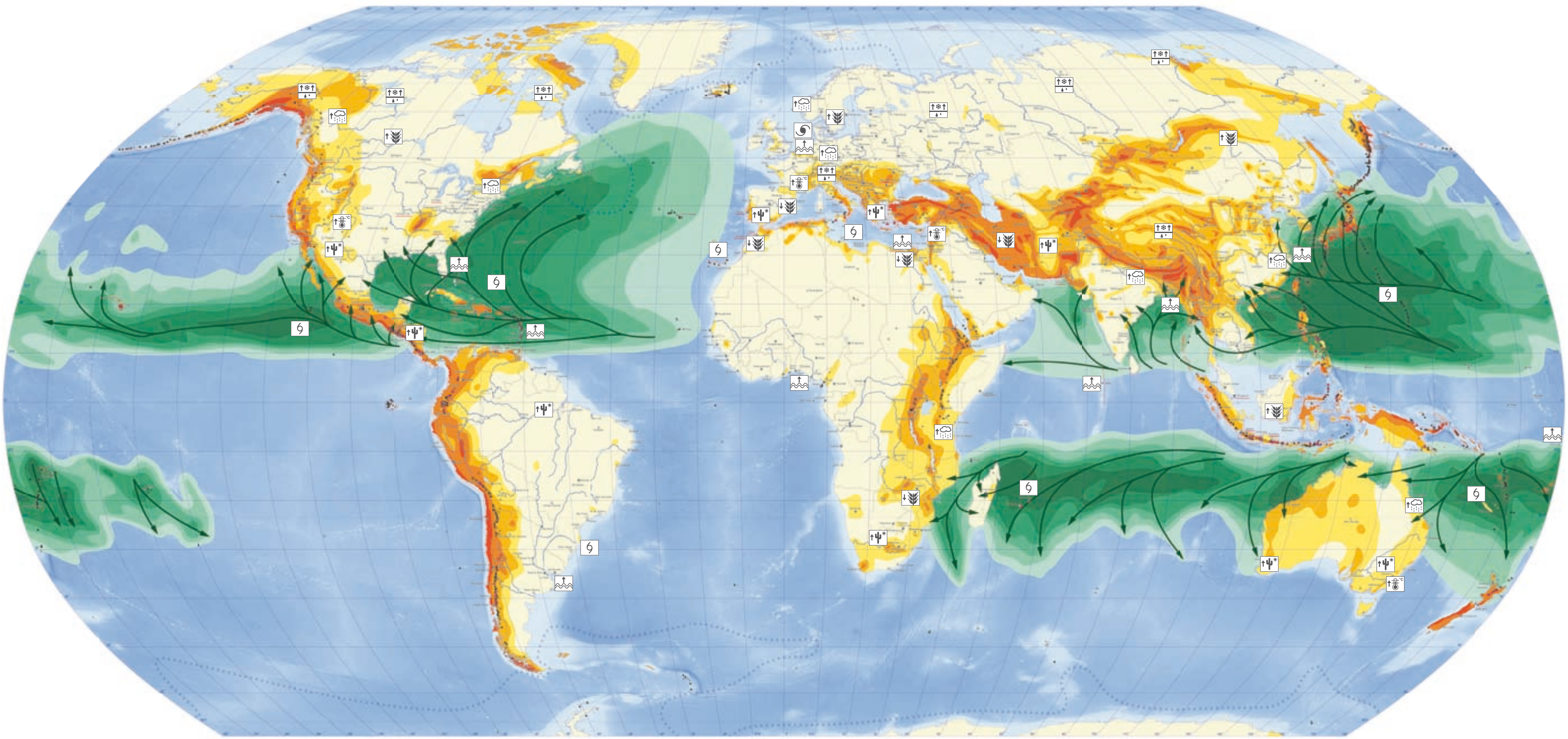

Energy Sector Vulnerabilities
to Current Climate
Variability & Change
http://www.seasteading.org/

NATHAN WORLD MAP OF NATURAL HAZARDS



EARTHQUAKES

- Zone 0: MM V and below
- Zone 1: MM VI
- Zone 2: MM VII
- Zone 3: MM VIII
- Zone 4: MM IX and above

Probable maximum intensity (MM: Modified Mercalli scale) with an exceedance probability of 10% in 50 years (equivalent to a "return period" of 475 years) for medium subsoil conditions.

Osaka Large city with "Mexico City effect"

TROPICAL CYCLONES

Peak wind speeds (in km/h)*

- Zone 0: 76–141
- Zone 1: 142–184
- Zone 2: 185–212
- Zone 3: 213–251
- Zone 4: 252–299
- Zone 5: ≥300

* Probable maximum intensity with an exceedance probability of 10% in 10 years (equivalent to a "return period" of 100 years).

Typical track directions

VOLCANOES

- Last eruption before 1800 AD
- Last eruption after 1800 AD
- Particularly hazardous volcanoes

TSUNAMIS AND STORM SURGES

- Tsunami hazard (seismic sea wave)
- Storm surge hazard
- Tsunami and storm surge hazard

ICEBERG DRIFTS

Extent of observed iceberg drifts

CLIMATE IMPACTS

Main impacts of climate change already observed and/or expected to increase in the future

- Change in tropical cyclone activity
- Intensification of extratropical storms
- Increase in heavy rain
- Increase in heatwaves
- Increase in droughts
- Threat of sea level rise
- Permafrost thaw
- Improved agricultural conditions
- Unfavourable agricutural conditions

POLITICAL BORDERS

- State border
- State border controversial (political borders not binding)

CITIES

- Denver >1 million inhabitants
- San Juan 100,000 to 1 million inhabitants
- Maun <100,000 inhabitants
- Berlin Capital city

Data resources

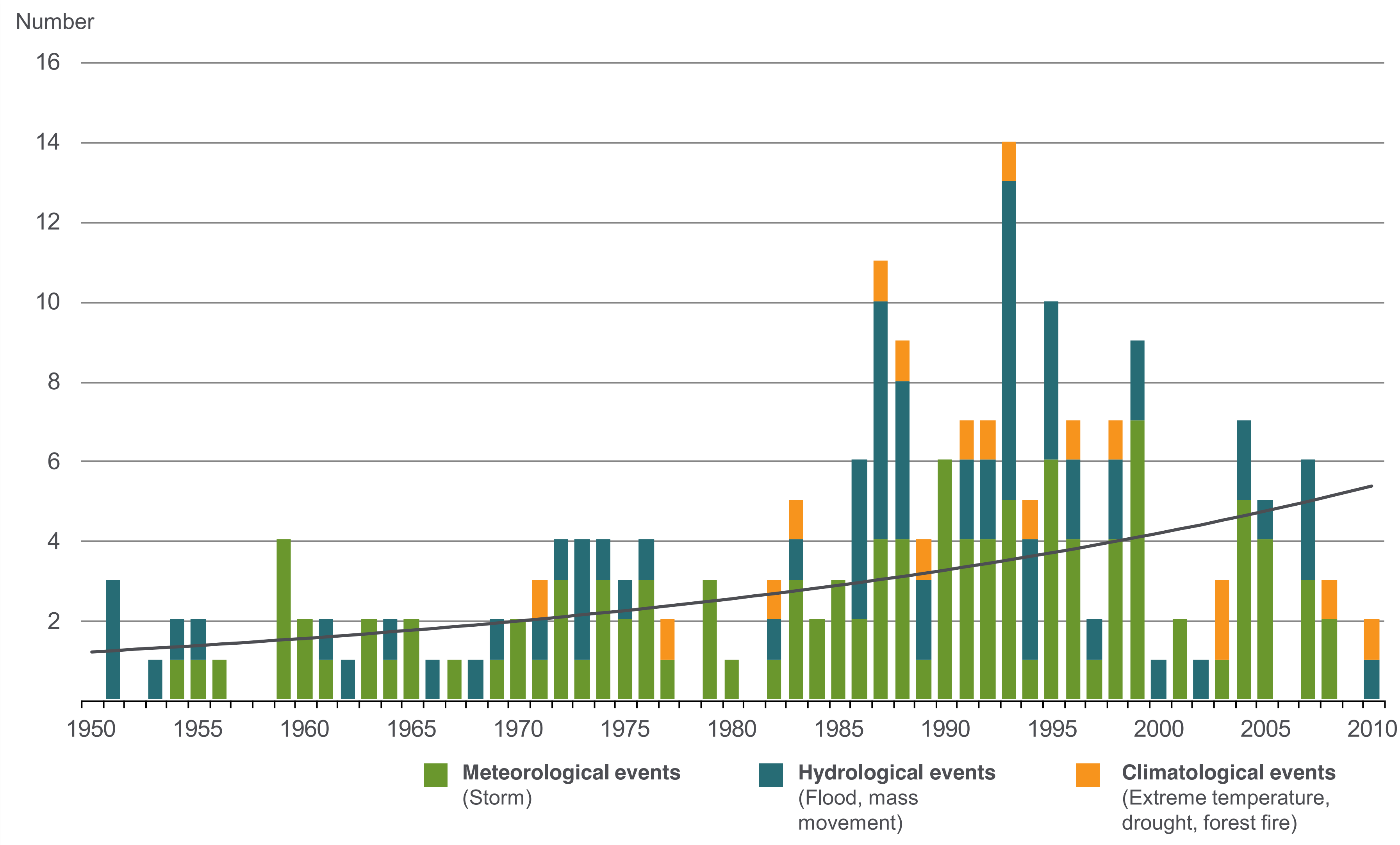
Bathymetry: Amante, C. and B. W. Eakins, ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis, National Geophysical Data Center, NESDIS, NOAA, U.S. Department of Commerce, Boulder, CO, August 2008. **Extratropical storms:** KNMI (Royal Netherlands Meteorological Institute). **Temperature/Precipitation 1978–2007:** Climatic Research Unit, University of East Anglia, Norwich.

Munich Re (2011)

NatCatSERVICE

Great weather catastrophes worldwide 1950 – 2010

Number of events with trend



Hydro-meteorological and climate variables of relevance to energy industry

Humidity

Cloudiness

Temperature

Rainfall

Wind speed and/or direction

Snowfall and ice accretion

Short-wave radiation

Sea level

Wave height

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Direct and Indirect Impacts of Weather & Climate on Energy Industry

- **Weather and climate can have direct effects on all aspects of the energy systems life cycle**
  - Energy resource endowment and infrastructure
  - Energy design and planning
  - Energy supply and operations
  - Energy transmission, distribution, and transfers
  - Energy demand
- **But also indirect effects through other economic sectors**
  - Agriculture: use of land for biofuels or coal seams gas
  - Water resources: extensive use of water for electricity generation, oil refining and irrigation of energy crops

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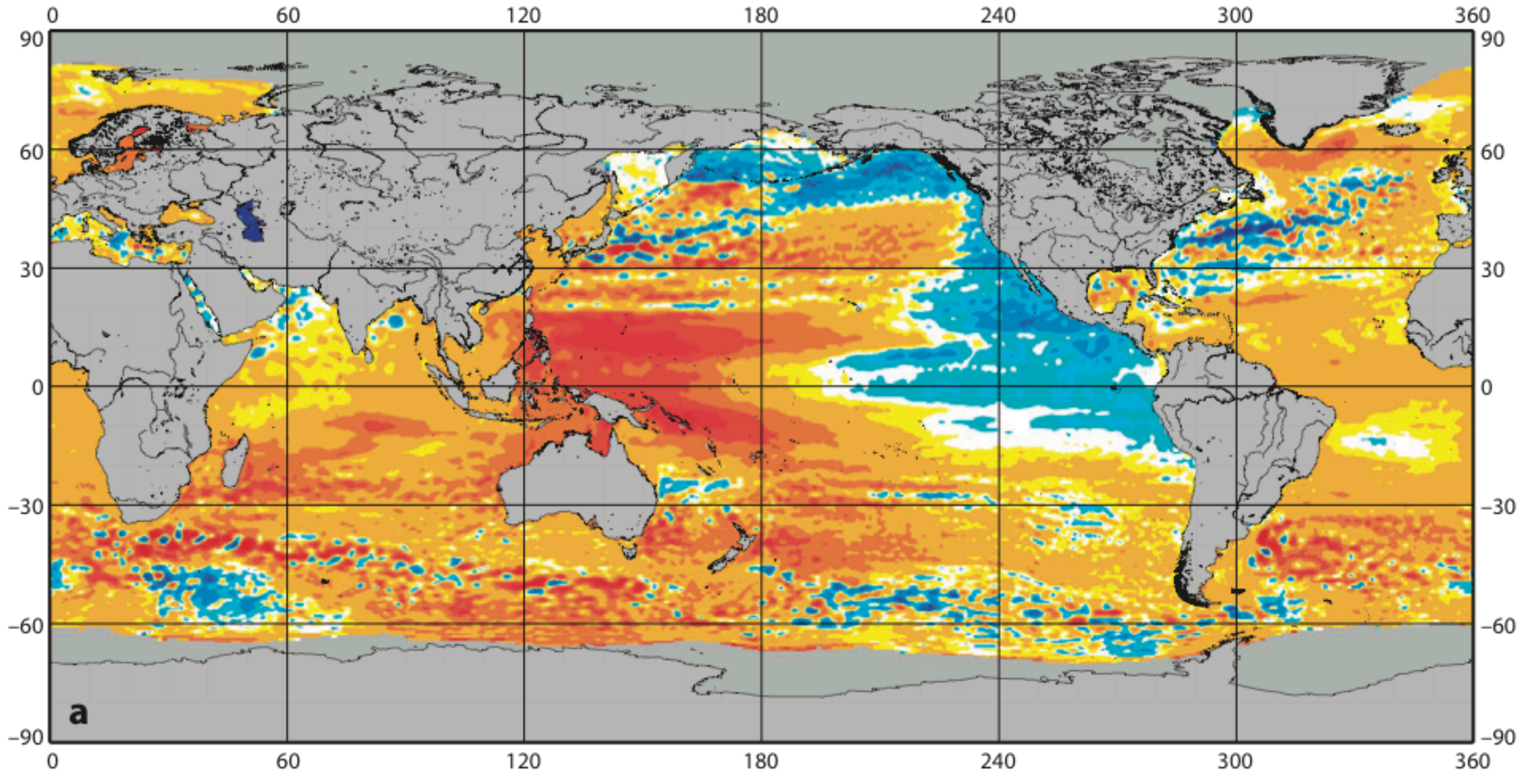
Observed changes in sea level (mm yr^{-1})



Map of spatial trend patterns of observed sea level between January 1993 and December 2008 (Cazenave and Llovel, 2010).

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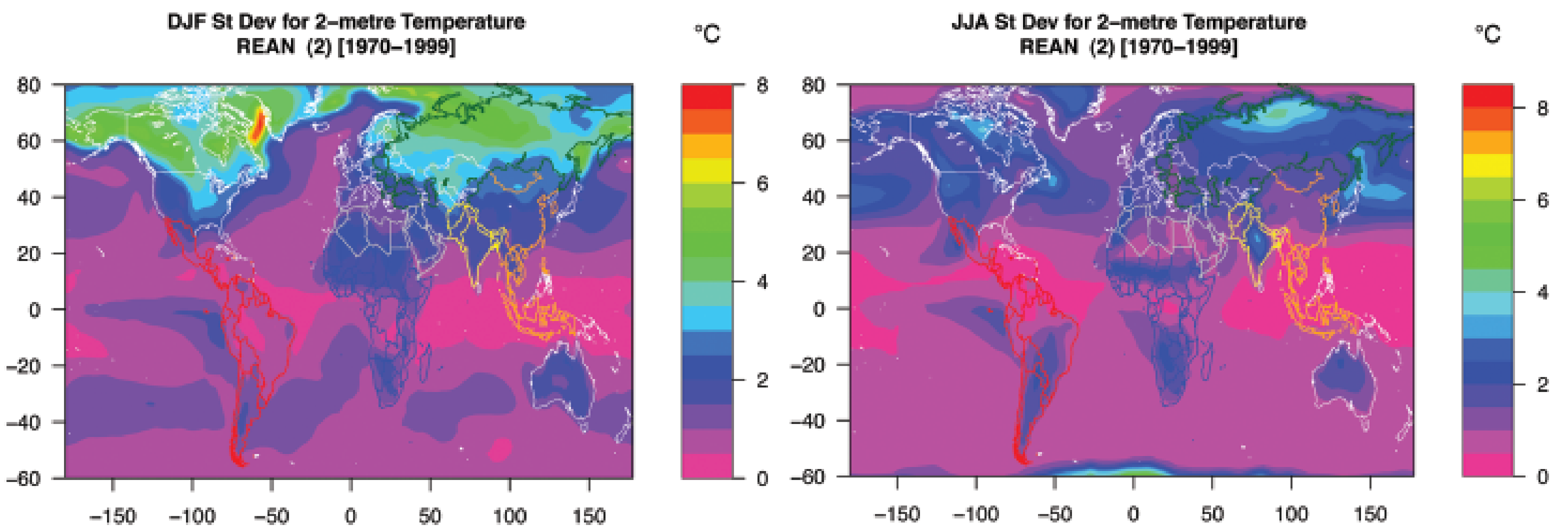
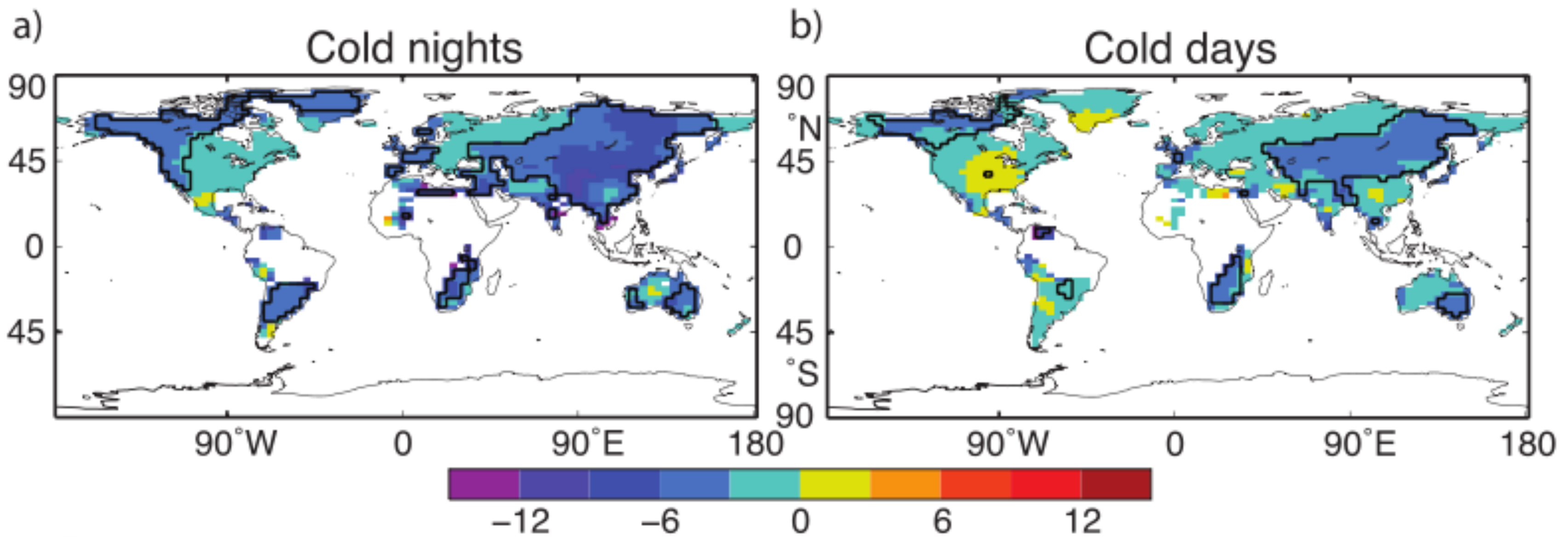
Observed variability in surface temperature

Figure 2.2. Seasonal Standard Deviation of Two-Meter Temperature for DJF (Left) and JJA (Right) as an Average of the Two ERA-40 and NCEP/NCAR Re-analyses



Large deviations of in excess of 4°C are present particularly over Siberia, a region where permafrost is prevalent (Ebinger and Vergara, WB, 2011)

Observed changes in cold nights and days



Observed trends (days per decade) for 1951 to 2003 in the frequency of extreme temperatures, defined based on 1961 to 1990 values, as maps for the 10th percentile: (a) cold nights and (b) cold days (IPCC 2007).

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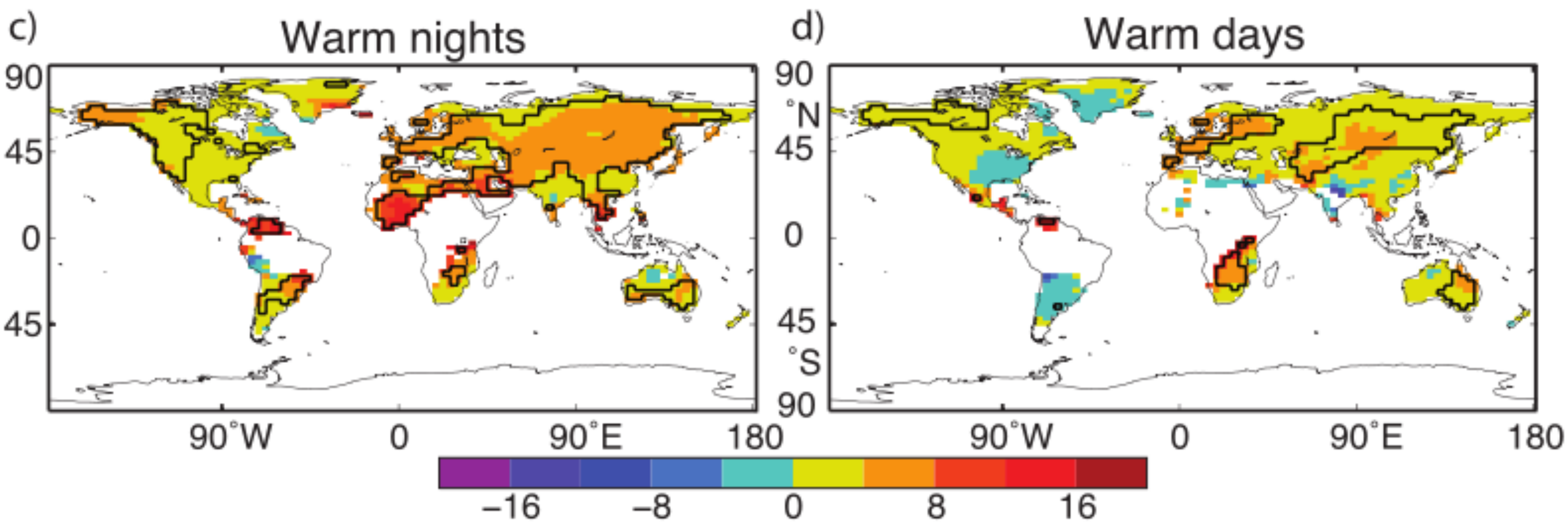
Observed changes in warm nights and days



Observed trends (days per decade) for 1951 to 2003 in the frequency of extreme temperatures, defined based on 1961 to 1990 values, as maps for the and 90th percentile: (c) warm nights and (d) warm days (IPCC 2007).

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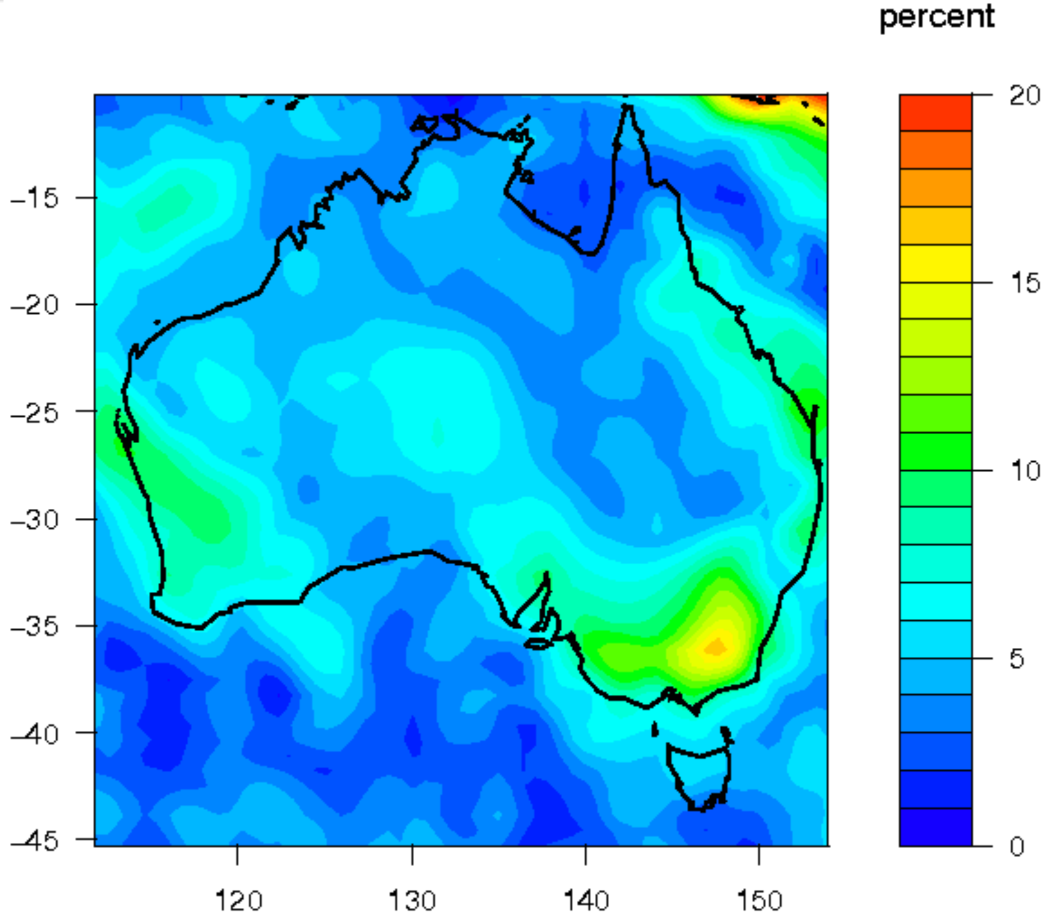
Observed inter-El Niño variability



Range of winter mean global solar horizontal exposure in El Niño years as a percentage of the overall mean (Davy and Troccoli 2011)

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Weather/Climate and Energy interaction: Ex. 1 – Mining industry and flooding

Effect of floods on coal mines

• Widespread disruption at the open-cut coal mine in Queensland, Australia in 2010-2011 during one of the strongest La Niña events

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Weather/Climate and Energy interaction: Ex. 2 – Oil industry and storms

Effect of hurricanes on oil platforms

- Widespread disruption to the oil industry during strong hurricanes like Katrina (2005) and Ike (2008)

Weather/Climate and Energy interaction: Ex. 3 – Nuclear energy and heatwaves

Effect of high water temperature on nuclear reactors

- France was forced to import electricity from Britain due to heatwave in 2009 that put a third of its nuclear power stations out of action
- During heatwave of 2003, nuclear plants drained an excess of hot water into rivers, leading to considerable damage to flora and fauna

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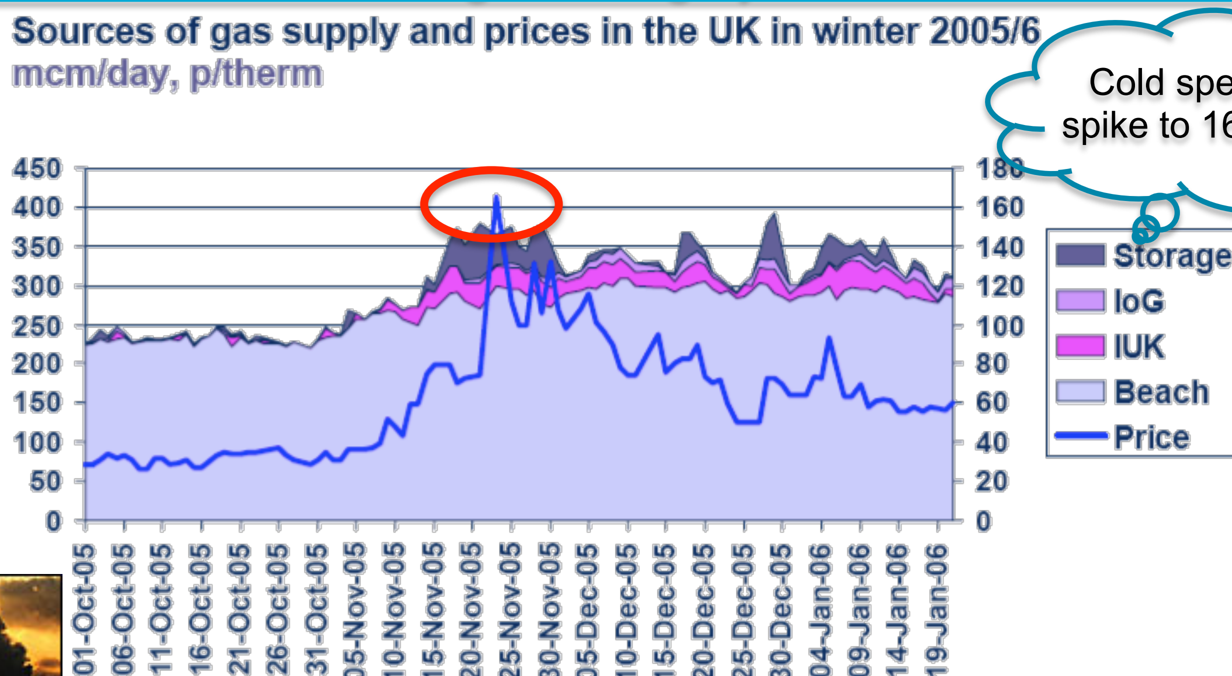
Weather/Climate and Energy interaction: Ex. 4 – Gas demand and market response

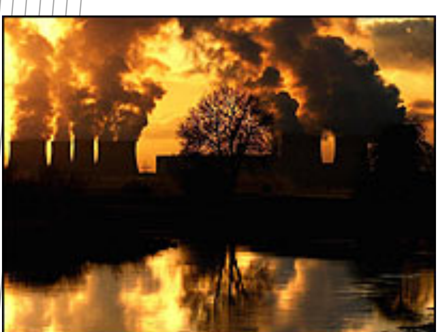
Effect of temperature on energy prices

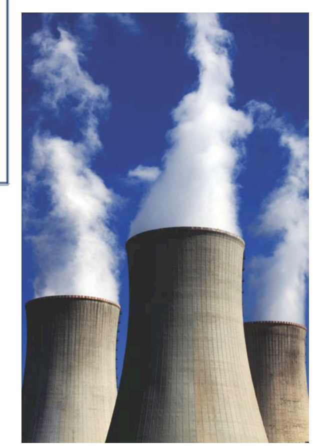
- Sudden changes in temperature can have a large impact on gas price (e.g. via supply shortages, speculations)
- Importance of forecasting/warning system

25 Oct 2005



Cold spell: prices spike to 160 p/therm





Source: Department Trade and Industry (UK)

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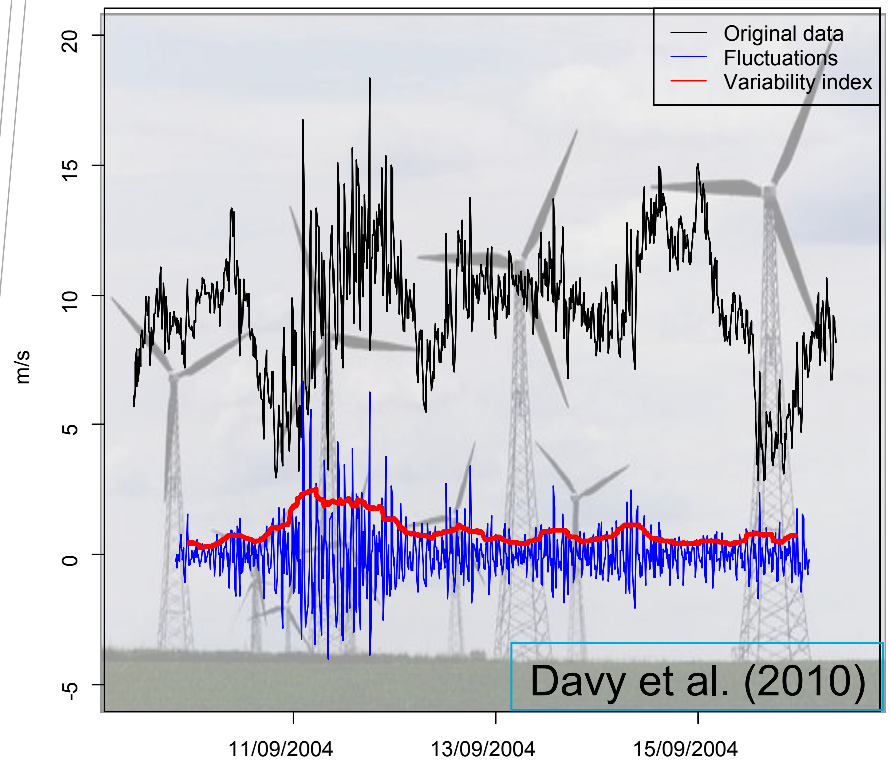
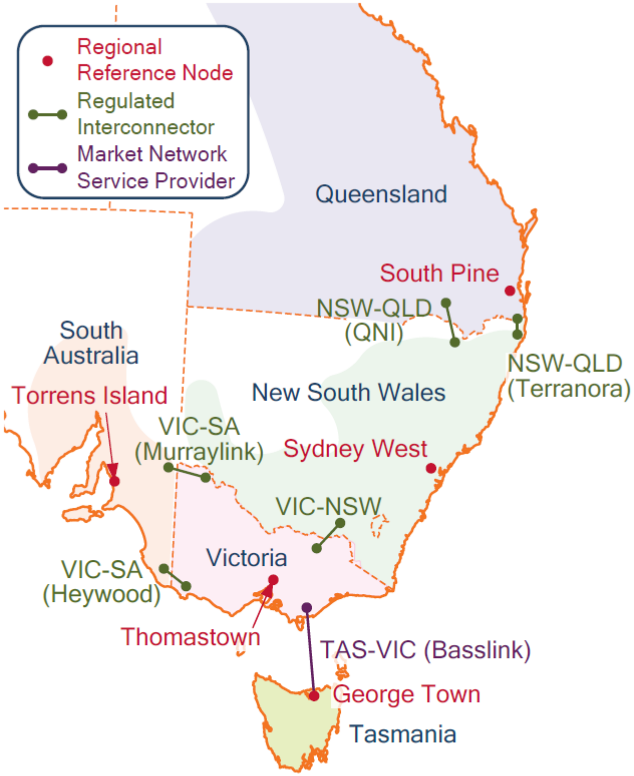
Weather/Climate and Energy interaction: Ex. 5 – Wind energy grid integration

Predicting highly variable wind conditions

- Excessive ramp rates may lead to curtailment (grid capacity limits)
- Essential for grid system operation – alarming system
- Complementary approach is to store energy using e.g. batteries





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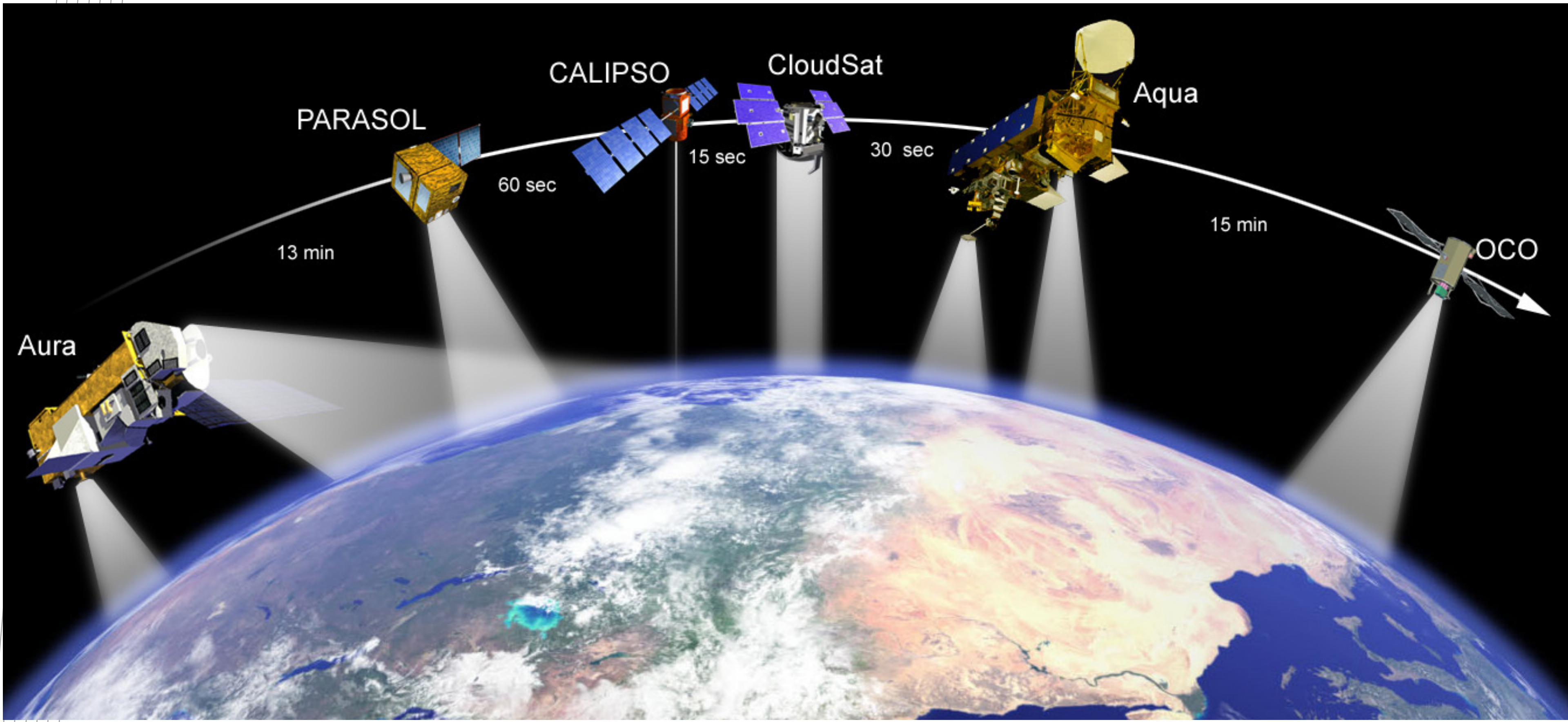
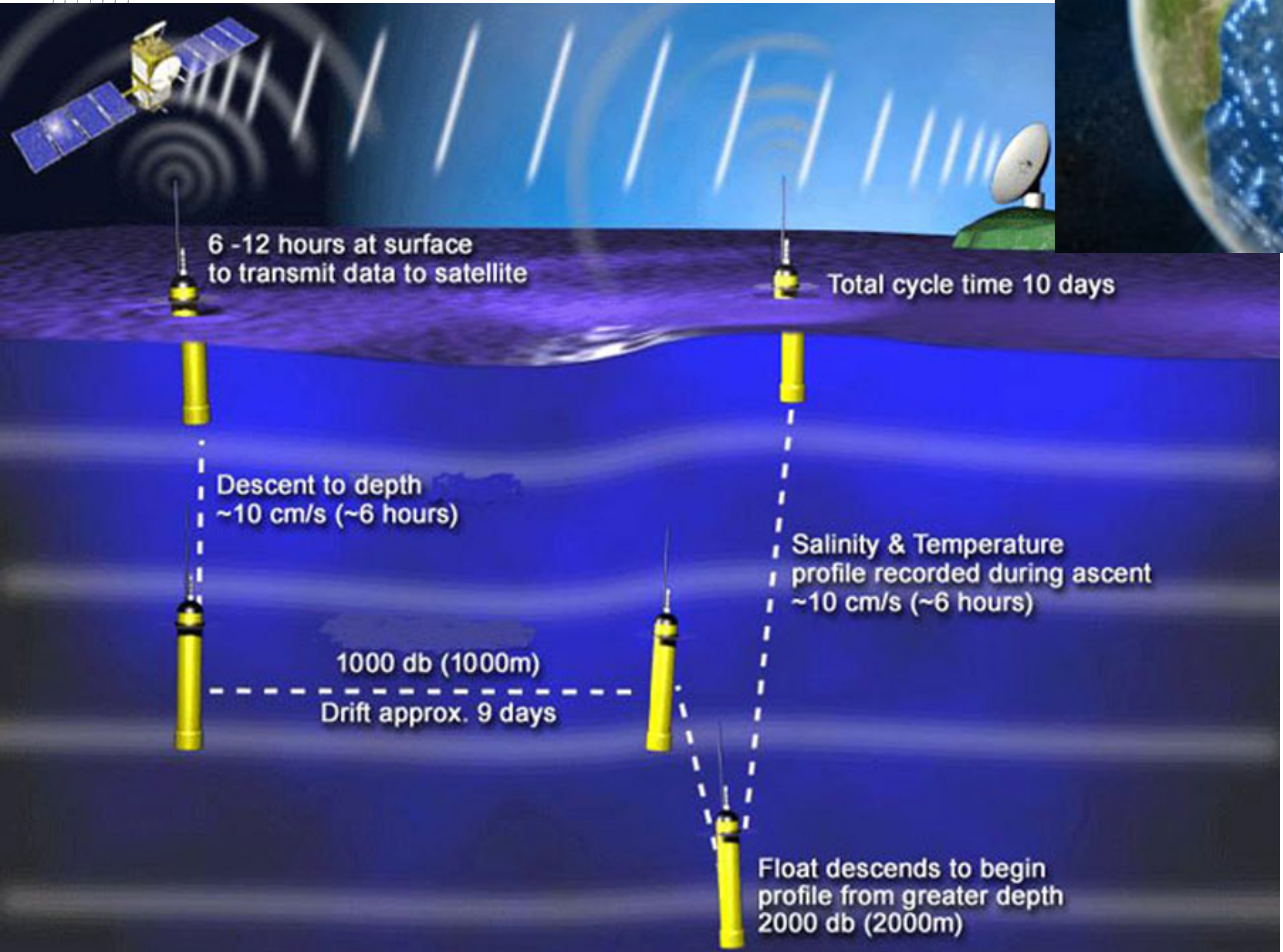
Tools for Weather/Climate Risk Management for the Energy Industry

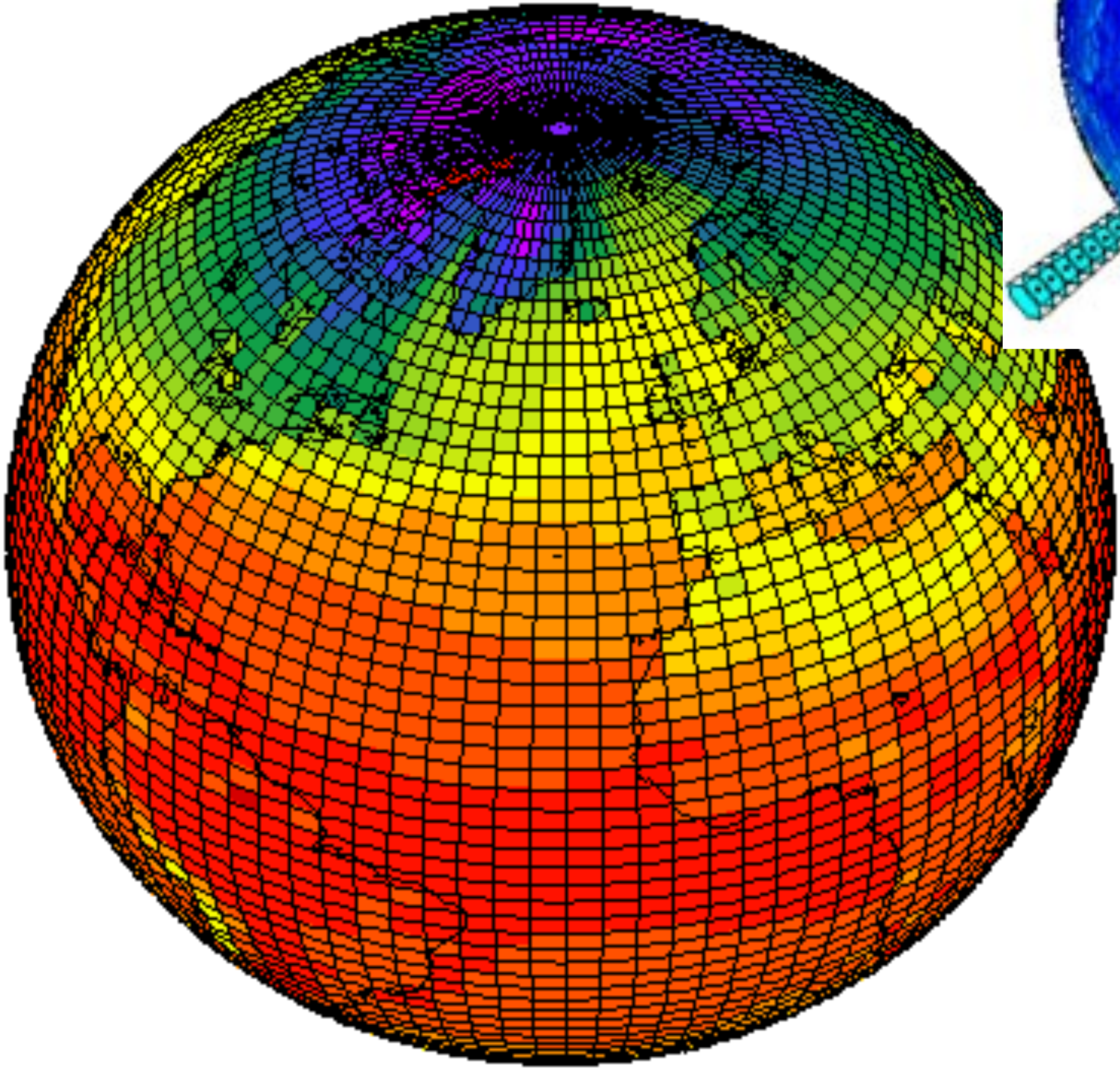
Monitoring the weather from space

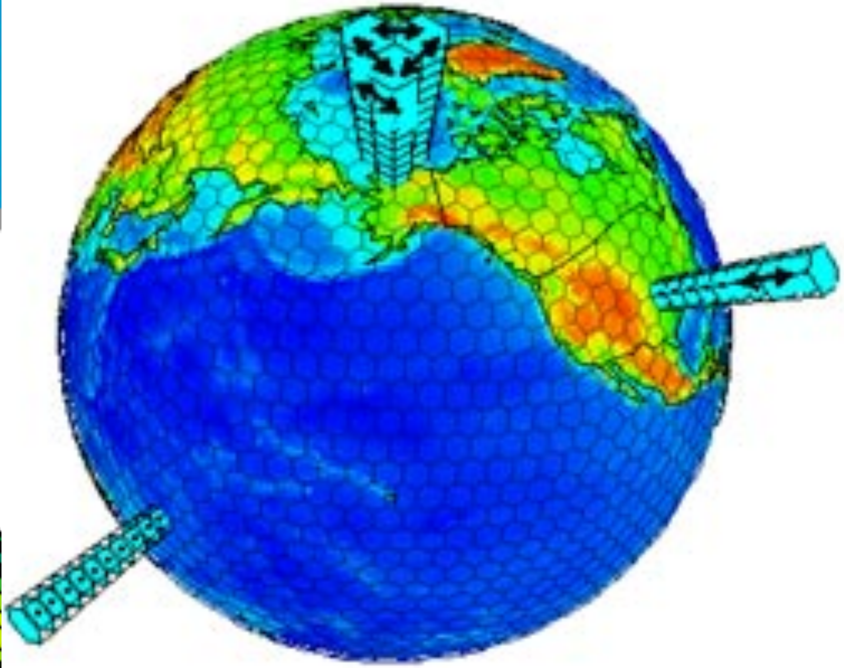


Monitoring the oceans



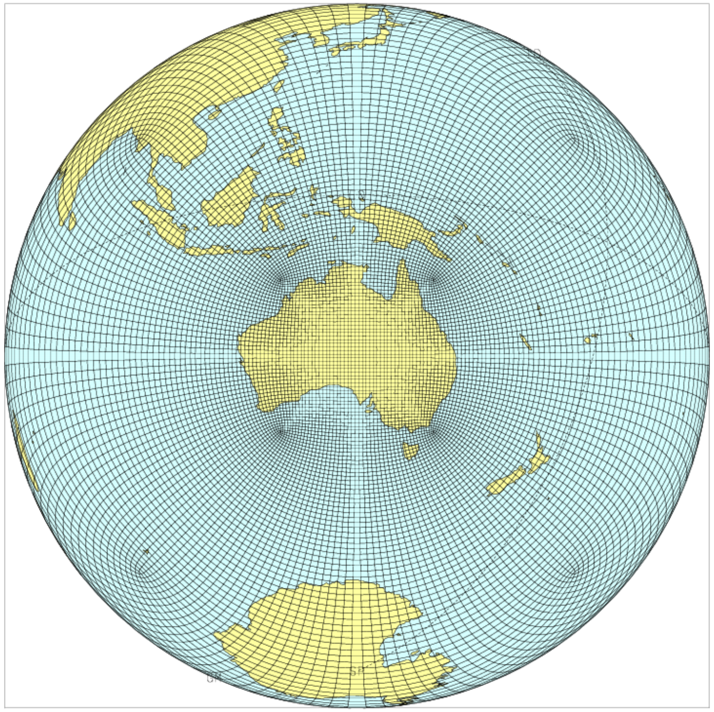
Computer Models to Simulate Climate





A dynamical model approach at the base of our developments

- CMAR maintains a meso-scale model, CCAM, a flexible tool that can provide dynamical high resolution local features
- Advantages are:
  - No singular points (e.g., the north or south pole).
  - No hard boundaries – CCAM is a global model.
  - The grid can be stretched for high resolution simulations (e.g., 10km).
  - The stretched grid can be repositioned anywhere in the world.



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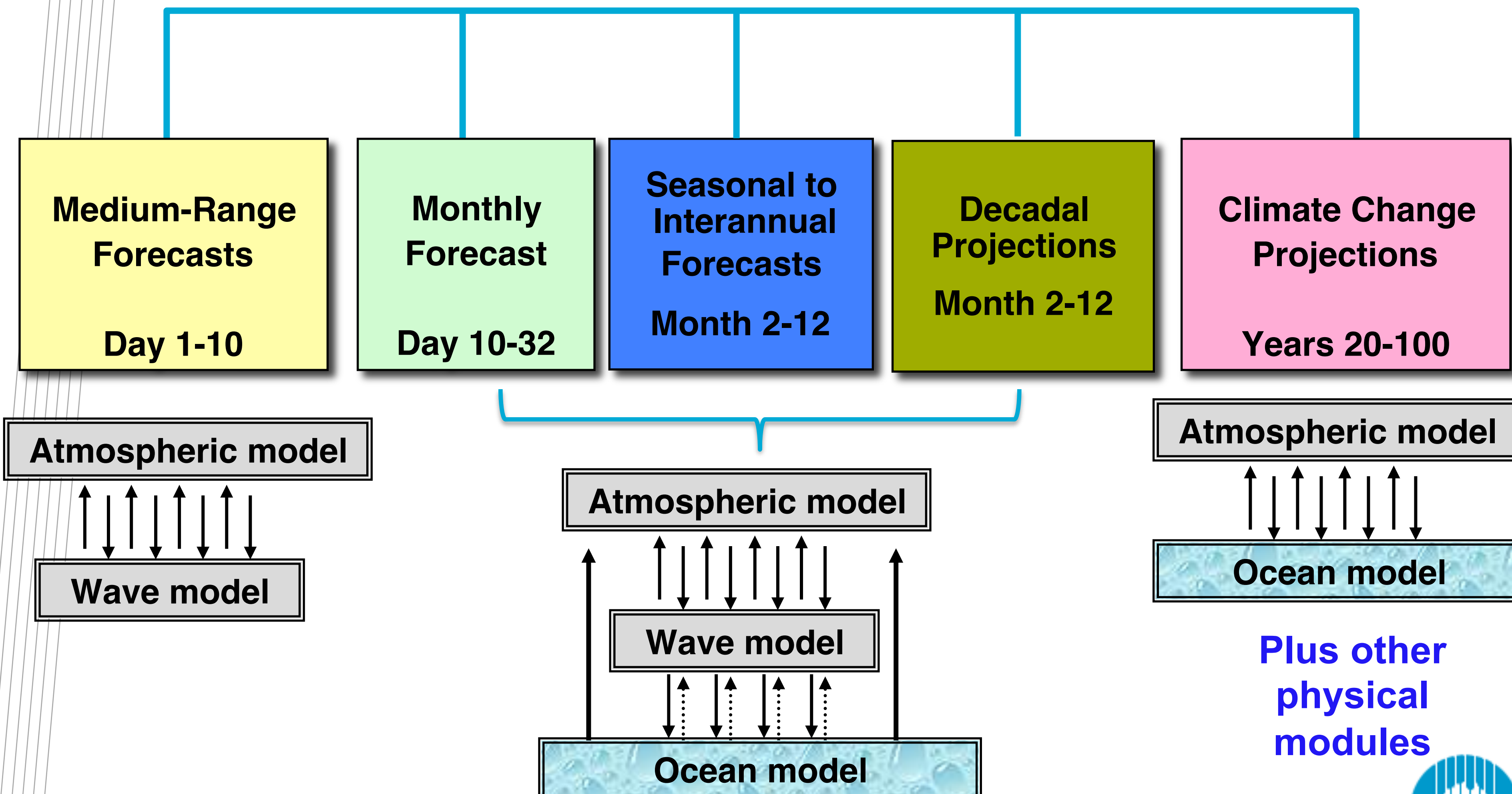
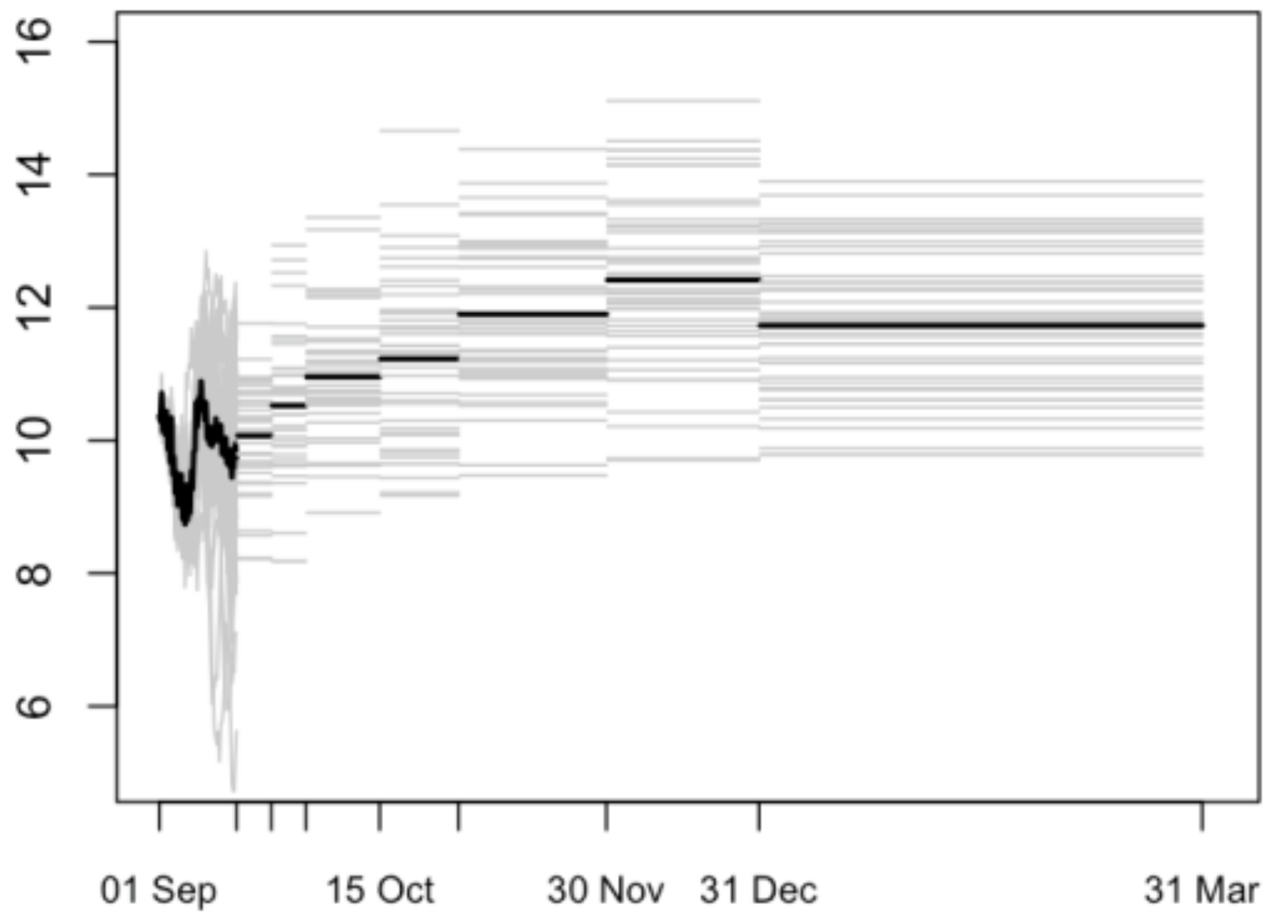
Weather and Climate Dynamical Forecasts

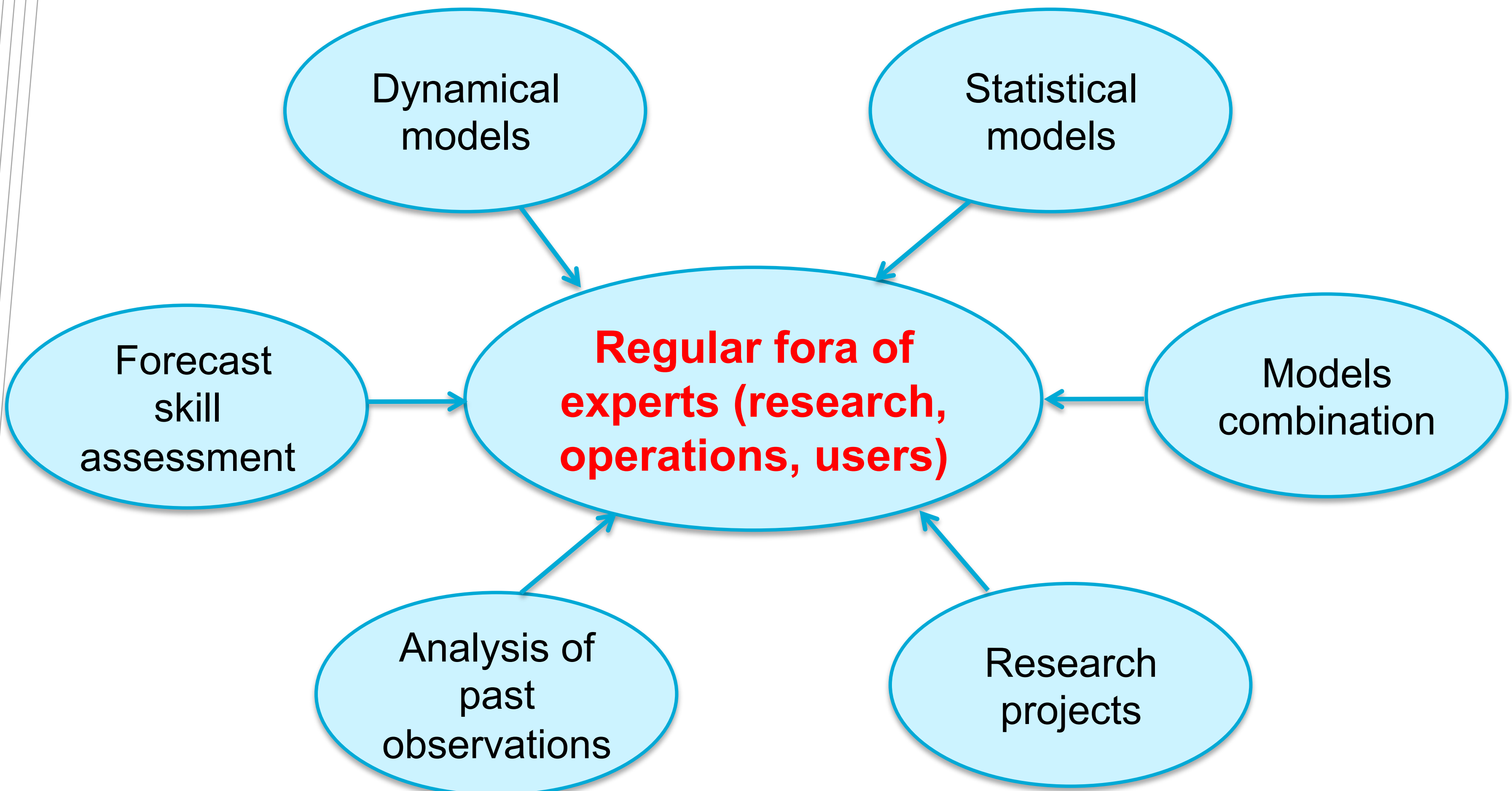


Time averaging for a generic forecast



Troccoli (2010)

Combining the available tools



Characteristics of wind speed observations and their long-term trends

Characteristics of wind speed observations

Long-term linear trends of wind speed provide a useful indicator for circulation changes in the atmosphere and are invaluable for the planning and financing of sectors such as wind energy

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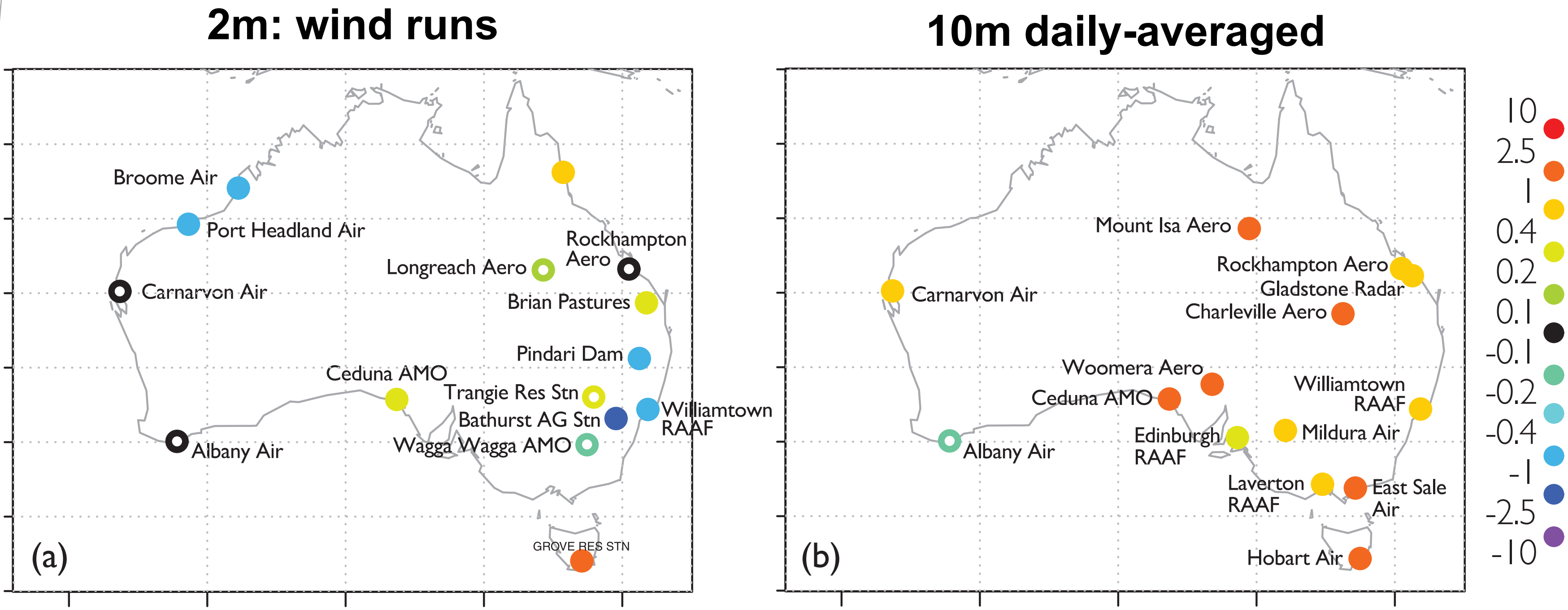
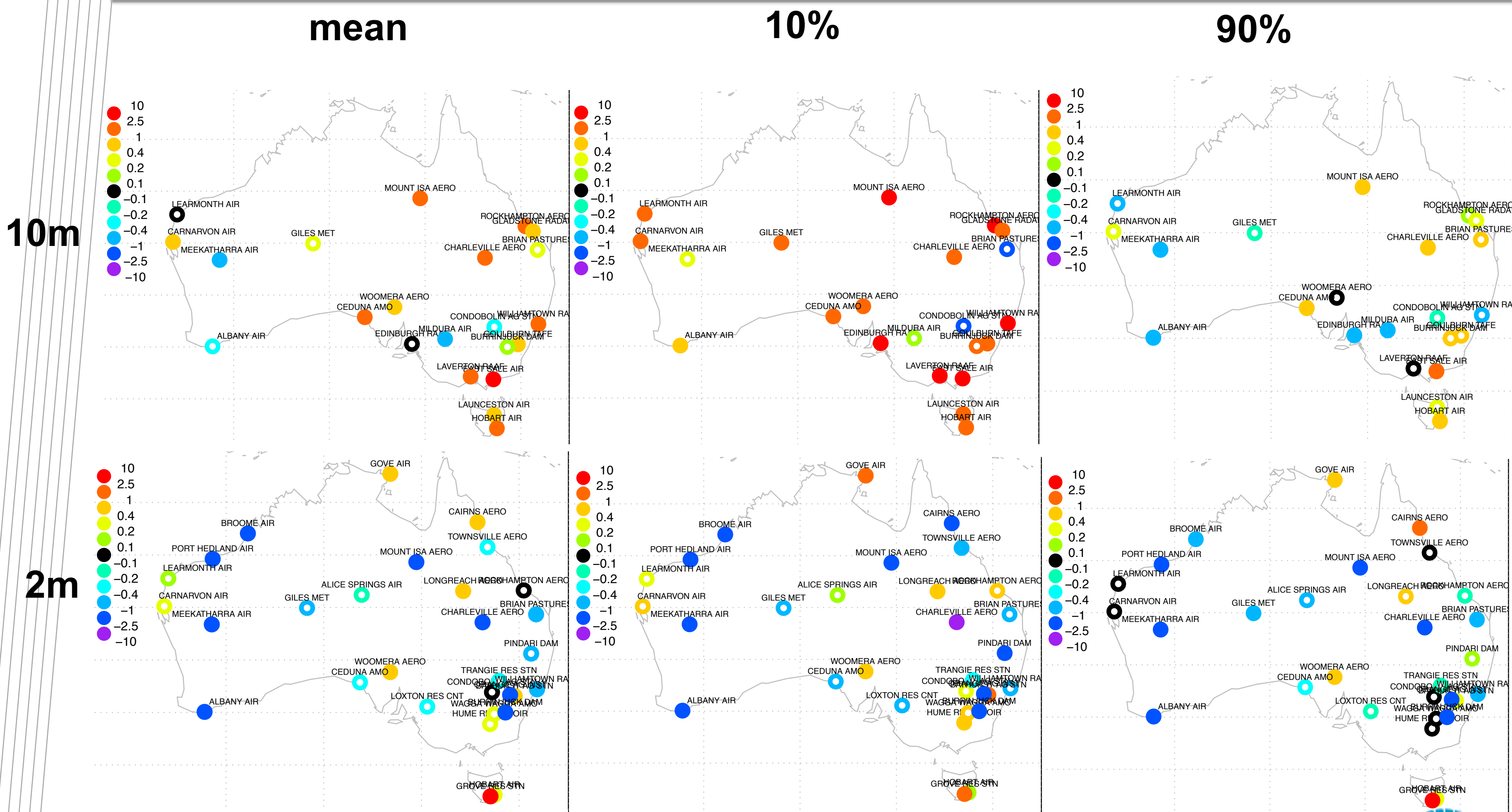
Wind speed trends 1975-2006 (in % a^{-1})



Trends at **2-m** height are mostly **negative** whereas at **10-m** height are mostly **positive** (Troccoli et al. 2011)

Wind speed trends 1989-2006 (in % a^{-1})



Troccoli et al. (2011)

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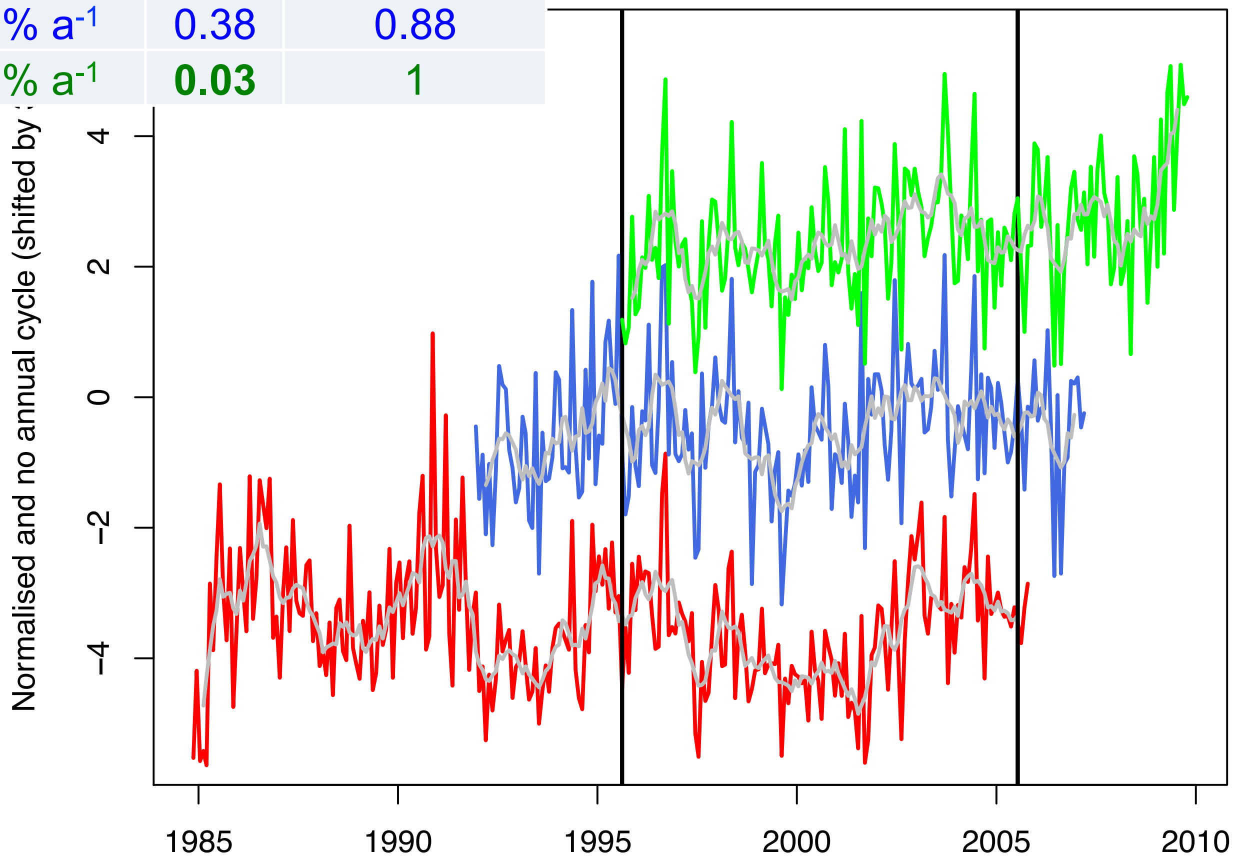
2m, 10m & 40m wind speed comparison

Wind data	Linear trend	p-val	Corr Tower
Windrun 2m	0.23 % a^{-1}	0.85	0.57
AWS 10m	0.54 % a^{-1}	0.38	0.88
Tower 40m	**0.55** % a^{-1}	**0.03**	1



Troccoli et al. (2011)

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Water Dam Management
using Climate Forecasts

Manantali dam water management using seasonal forecasting information

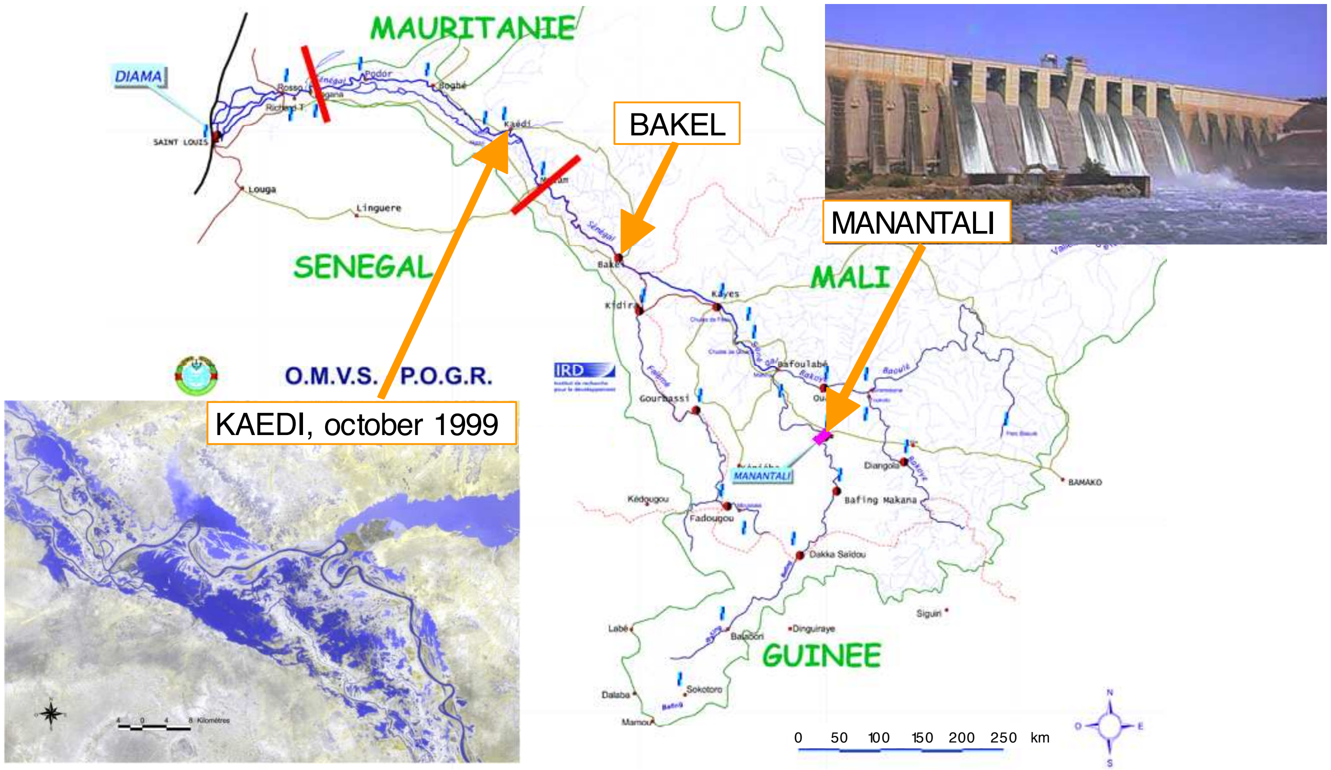

Figure 1 : catchment of the Senegal river, with red bars delinating the zone where the recession crops are evaluated

Bader et al. (2005)

Manantali dam water management using seasonal forecasting information

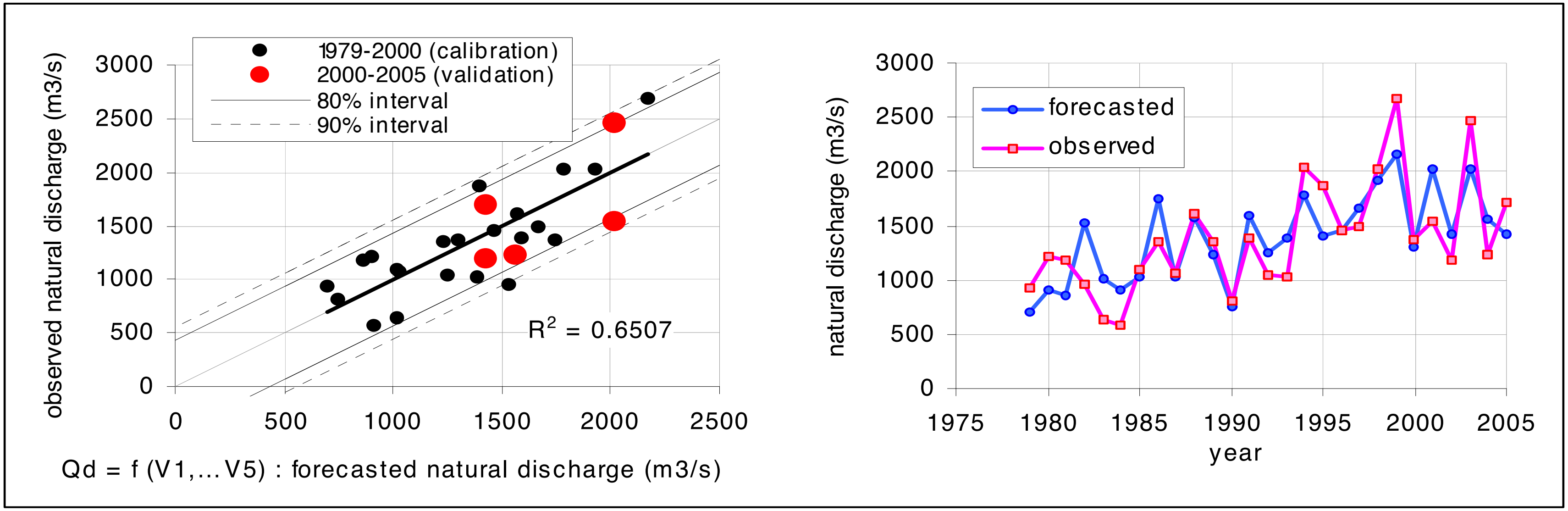

Figure 7 : Natural discharge of the Senegal river at Bakel in september-october : observed values and forecasted values calculated with the 5 first PCs of ARPEGE results (zone J2)

Bader et al. (2005)

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Main message

Not only is the energy sector at risk from future climate changes but it is also at risk from current hydro-meteorological climate variability & change. However, there are tools to tackle these risks.

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The International Conference Energy & Meteorology 2011 will be held from **8 – 11 November 2011** at the Surfers Paradise Marriott Resort & Spa, **Gold Coast**, Australia

For more details about the programme, keynote speakers' bios, social events and/or to register, please visit http://www.icem2011.org

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Thank you for your attention

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