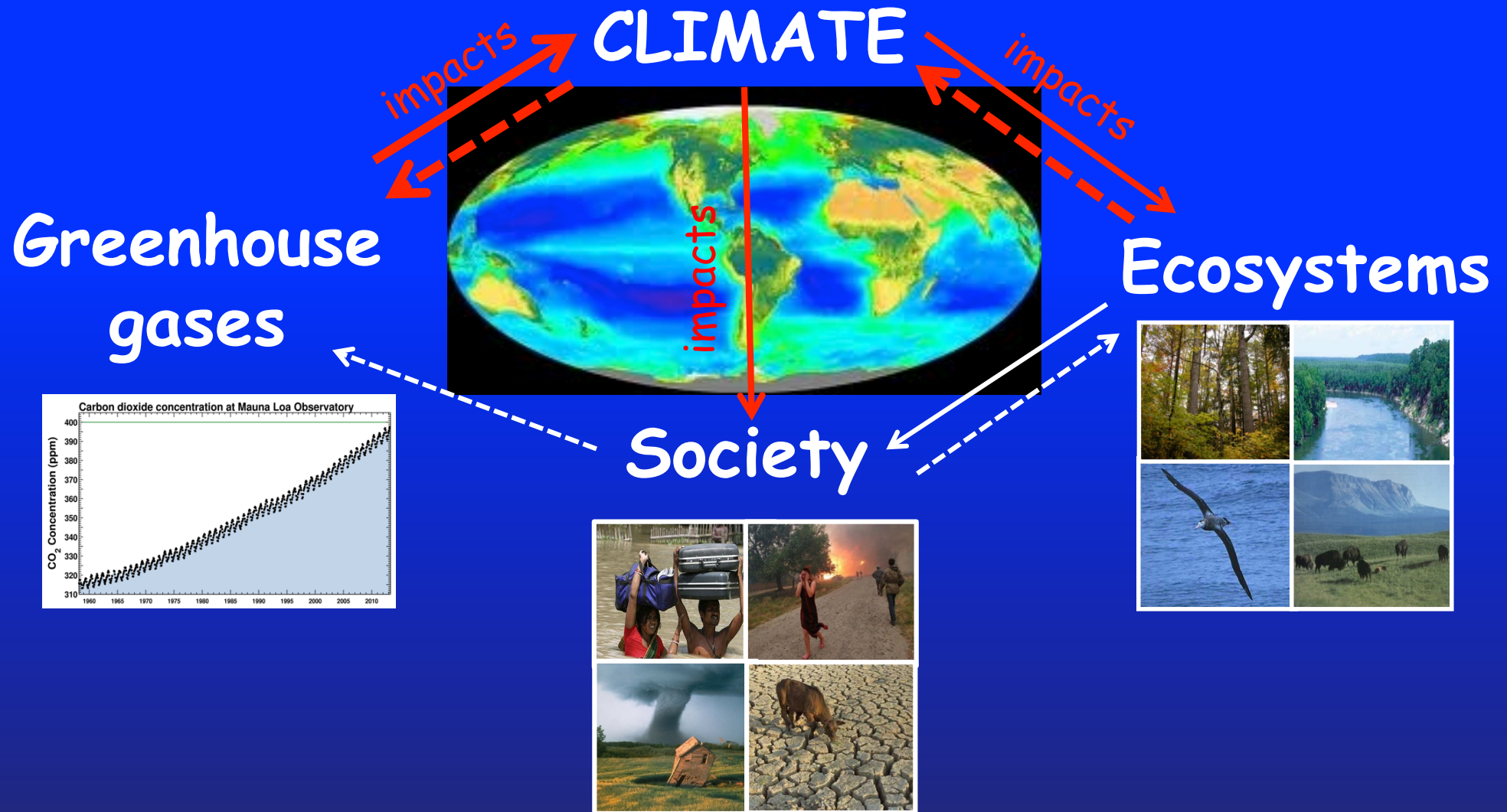


Climate Extremes



Extremes matter

- Extremes may or may not be rare
- They often break records: values outside of previous experience
- Things break (thresholds crossed)
- High impact events, high costs, loss of life and limb.



The straw that
breaks the
camel's back



Many types of weather and climate extremes, different space/time scales

- ❑ Drought (year to decade or longer, continental)
- ❑ Major flood (days to month, over large region)
- ❑ Heat wave (days, over large region)
- ❑ Ice storm (day, over small region)
- ❑ Tornadoes (minutes and several kilometers)
- ❑ Marine storms (hours to days and thousand kilometers)



False assumptions create vulnerability

"Let's put a science station here -- the ice NEVER melts out too soon,"

"Let's put a once-through cooling power plant on this river -- there will ALWAYS be plenty of water to cool it",

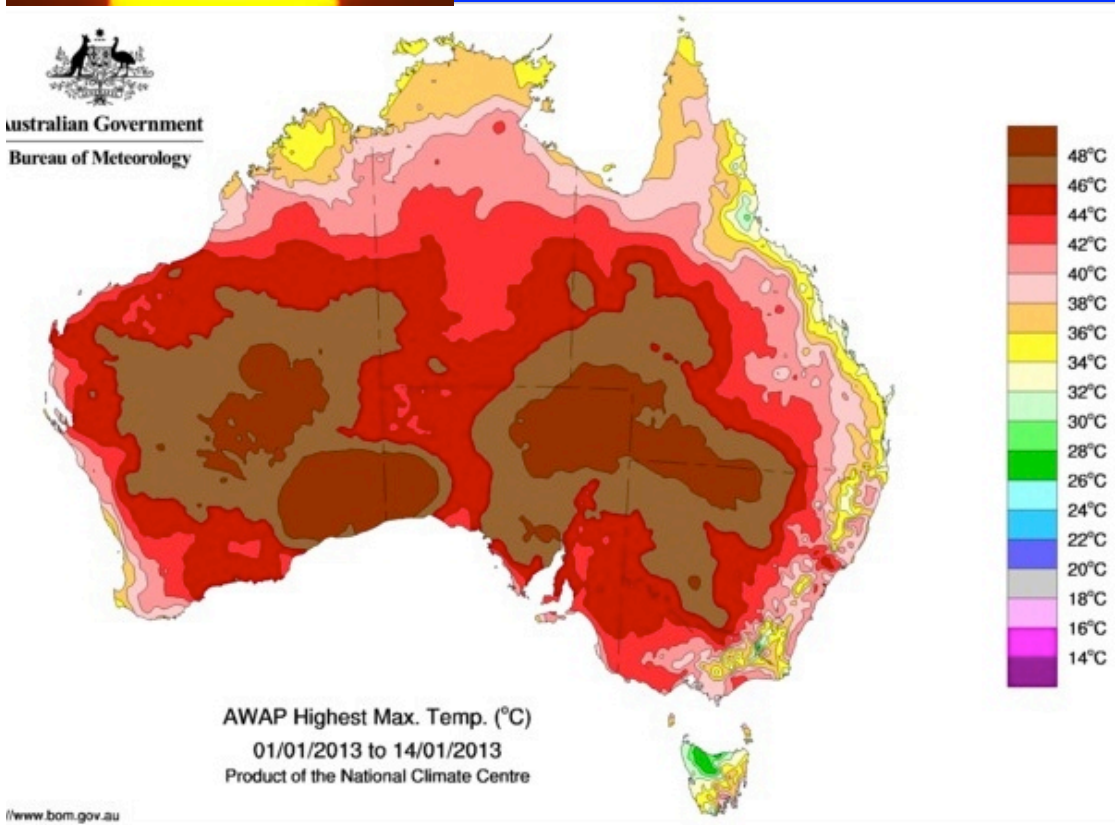
"Let's build a city here at the water's edge -- even bad storms NEVER flood this high" ...



May 23, 2013: Russia has ordered an "urgent" evacuation of its drifting ice station known as North Pole-40 that sits on top Arctic sea ice, because of disintegrating sea ice that is posing dangerous conditions

**Some 2013 climate
extremes**

Oz bushfires and heat: January 2013



Sydney record high 18 Jan 2013:
45.8°C (114.4°F) Observatory Hill
46.5 °C (115.7°F) Penrith
Hobart 8 Jan 2013: 41.8°C (107.2°F)
>80 structures lost Tasmania

April "showers" in Argentina

1 April 2013: Torrential rain Buenos Aires. Over night, rainfall records broken, >6 inches in less than two hours; flooding, killing eight people and leaving hundreds displaced.

Buenos Aires Central Observatory.

3 April 2013: Next storm
11 to 16 inches in some spots
In La Plata basin.

Damage: >\$500Million



"Since the early '80s, the frequency of extreme weather events dumping over 100 millimeters of water has tripled," Canziani

The "extremes" Grand Challenge

- GEWEX Science Question #3: GEWEX SSG and community
- CLIVAR Tiger Team: S. Gulev and X. Zhang (co-Leads), G. Hegerl, S. Schubert, A. Klein Tank, F. Zwiers, S. Woodruff, E. Harrison, V. Swail, X. Wang, K. Horsburgh
- Drought Interest Group
- ETCCDI
- IDAG
- Many national interests and activities

Climate extremes

At GEWEX SSG in October 2012

- David Karoly came and we had good interactions
- Plan made to get latest version of white paper to everyone.
- It never happened.
- We had planned for a workshop in Europe in 2014.
- David resigned 26 November 2012 (also from JSC)

March 25, 2013:

Xueben Zhang and Gabi Hegerl invited to form a task team for the Grand Challenge on Extremes

- Tasked to review and update white paper
- Identify ongoing and planned events and activities
- Recommend how best to interact/participate with the existing activities, what concrete steps WCRP can take to build on the ongoing activities or initiate new ones
- How WCRP should facilitate cooperation

Climate extremes and impacts

Global warming is changing our weather

The white paper was written by David Karoly but never finalized and not signed off on by anyone.

The title is listed as:

Science Underpinning the Prediction and Attribution of Extreme Events

vs GSQ 3: "Changes in extremes".

White paper must be redone.

New task team being formed:

Gabi and Xuebin have invited:
Francis Zwiers, Ron Stewart and Sonia Seneviratne, and are looking into invite four more people on board (event attribution, decadal prediction, monsoons, and cyclones).

Developing the white paper.

Proposed:

Judith Perlwitz, Rowan Sutton, Krishna Kumar Kanikicharia, Tom Knutson

Some background:

WCRP-UNESCO (GEWEX/CLIVAR/IHP) Workshop on metrics and methodologies of estimation of extreme climate events (September 2010, Paris)

The IPCC WGI and WG-II Special Report on “Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation” (SREX)

WCRP Open Science Conference

Need to address:

The nature of extremes

Scaling of extremes

Predictability of extremes in future climate

Problem areas and challenges identified at Paris Workshop

Why gaps in understanding still exist?

- **Insufficient quality and sampling of observational data**
- **Inadequate resolution of model simulations**
- **The same methods applied to the data of different resolutions require different approaches**

Advanced statistical methodologies for estimation of extremes themselves have not yet been exploited to the full extent

- **Spatial aspects of extremes and trouble in overcoming "scaling" problems**
- **"Compound events": unclear what kinds of pre-conditions lead to extreme outcomes**

We will not be able to fully understand what metrics and methodologies we should develop unless we understand the physical processes of the extremes

Recommendations from Paris Workshop

- enhance efforts to develop improved **high temporal resolution** (sub-daily) datasets that can be used to assess changes in extreme rainfall, drought, heat waves, floods, and storms
- include in the agenda of model evaluation the focus on the **model's ability to replicate extremes** and to better compare model output with observations
- a high priority on determining the main **phenomena** responsible for extremes and improving understanding of the relevant physical **processes**
- development of robust **statistical methods** for assessing extremes and their uncertainties and on making these tools available for wide-spread use.
- plan and launch an activity on analysis of extremes utilizing **CMIP5** data in the near future



GEWEX Science Question 3

How does a warming world affect climate extremes, and especially droughts, floods and heat waves, and how do land area processes, in particular, contribute?

A warming world is expected to alter the occurrence and magnitude of **extremes** from droughts to rainfall intensity, and the geographic distribution of rain and snow.

Such changes are related to an acceleration of the hydrologic cycle and circulation changes as well as to the direct impact of warmer conditions on atmospheric water vapor amounts, rainfall intensity, and snow-to-rain occurrence.

How well are models able to handle extremes and how can we improve their capability?

continued...

Some science questions

- How does a warming world affect climate extremes, and especially droughts, floods and heat waves?

A warming world alters the occurrence and magnitude of extremes from heat waves and droughts to rainfall intensity, and the geographic distribution of rain and snow: related to an acceleration of the hydrologic cycle and circulation changes plus the direct impact of warmer conditions on atmospheric water vapor amounts, rainfall intensity, and snow-to-rain occurrence.

- How well are models able to handle extremes and how can we improve their capability?
- How well do models simulate the characteristics (distribution, amount, intensity, frequency, duration, type) of precipitation – with particular emphasis on extremes of droughts and floods?
- How can the phenomena responsible for extremes be better simulated in models?

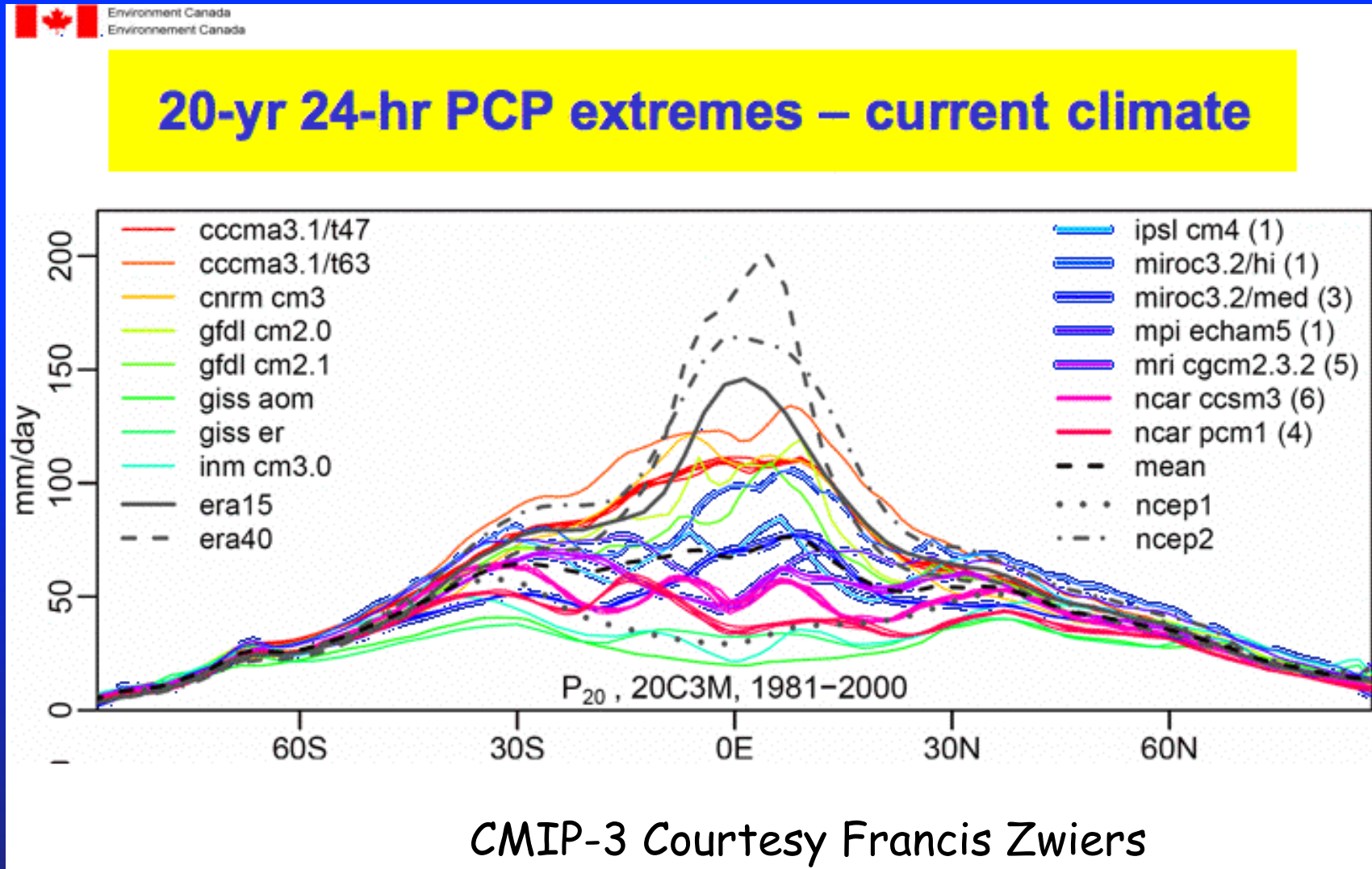
Capabilities on Extremes?

- They are not well analyzed (inadequate datasets)
- They are even less well simulated in models
- Attribution is an issue
- Can they be predicted?
- Informing adaptation strategy?

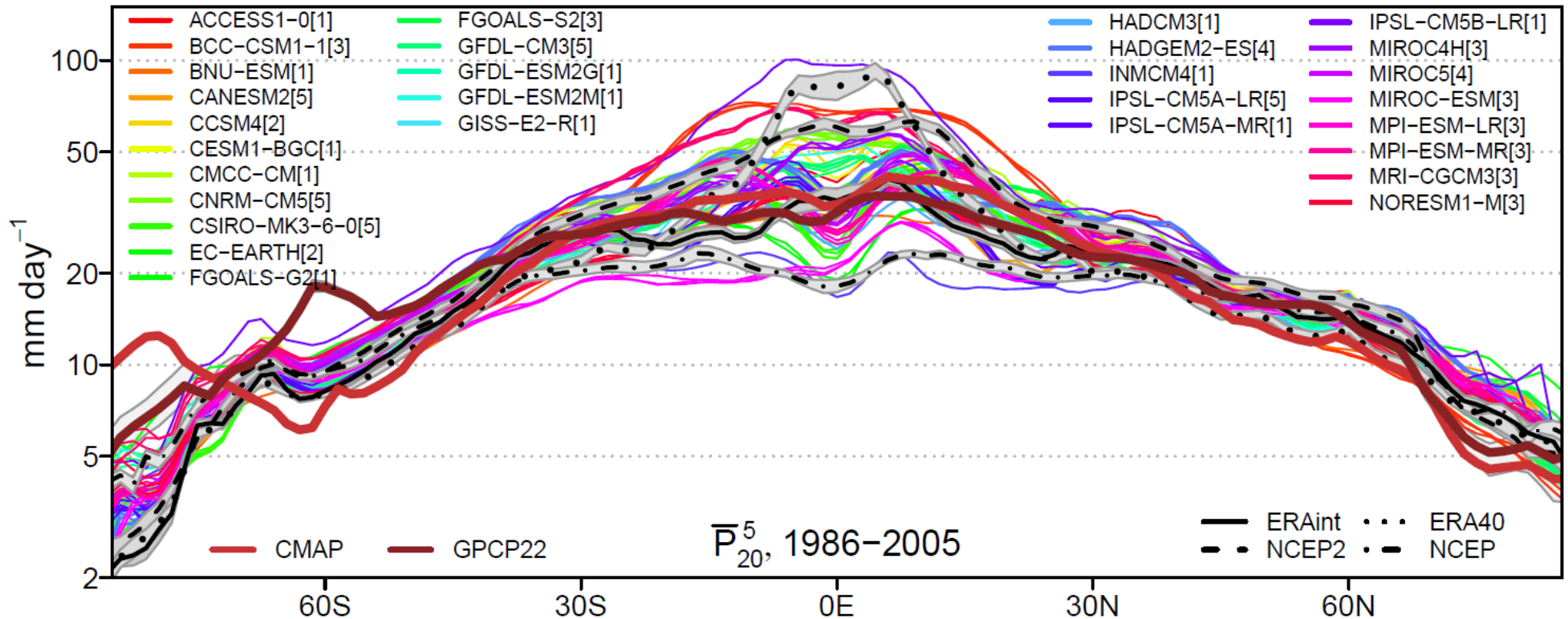
They pose major challenges!

All models are wrong, some are useful!

Models are demonstrably poor at extremes



Zonal means of 20-yr 5-day events



- Median model (not shown) compares quite well with GPCP and CMAP
- Models compare reasonably well with reanalyses at mid-latitudes
- Question of whether models reproduce precip correctly on resolved scales remains open

Changes in Extremes

-GSQ 3

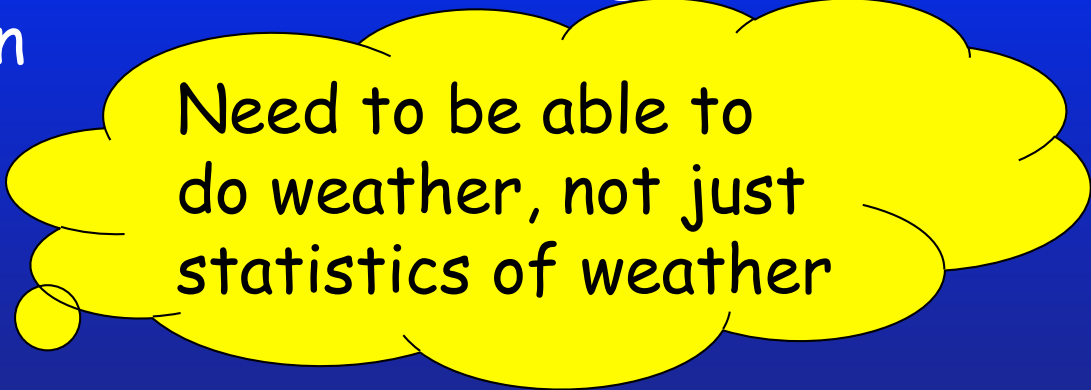
- What are the short-term, mid-term and strategic requirements for the existing observing systems and datasets, and which **observations** are needed to accurately quantify trends in the intensity and frequency of **extremes** on different space/time scales?
- How can **models** be improved in their simulation and predictions or projections of the magnitude and frequency of extremes?
- How can the **phenomena** responsible for extremes be better simulated in models?
- How can we promote development of **applications** for improved tracking and warning systems arising from extremes?

Some relevant phenomena

- Monsoons
- Blocking
- Mesoscale Convective Systems
- Tropical storms
- Tornadoes
- Hail
- Heat waves
- Sea level rise
- High sea temperatures: Coral bleaching
- Ocean acidification
- ENSO
- Teleconnections
- Snow storms
- Rain storms



Most poorly simulated!



Need to be able to do weather, not just statistics of weather



GEWEX Science Questions

How well are models able to handle extremes and how can we improve their capability?

- **Datasets** at high frequency (e.g., hourly)
- Characterize precipitation etc and allow for assessment against comparable **model datasets**.
- Promote **analyses** and how to improve **prediction**.
- **Confront models** with new observationally-based products
- **New metrics** of performance;
- Highlight shortcomings and developmental needs: focus field programs, process studies, numerical experimentation, and model development.
- **Applications** will be developed for improved tracking and warning systems, and assessing changes in risk of drought, floods, river flow, storms, coastal sea level surges, and ocean waves.
- In most cases, such applications will be done by GEWEX with CLIVAR and CliC.

Some Key Questions

- From **climate service** perspective: Can we predict the location, intensity and frequency of various types of extremes in the near term and in the future?
- From **science perspective**, ocean variability plays important role in the variability of extremes:
 - which aspects of extremes related to ocean variability are we most likely to advance over the next five years?
 - what improvements in physical understanding are required to make those advances?
- Ocean focused **CLIVAR**
 - Large scale ocean variability key to understanding long-term variations in the likelihood of extremes (e.g. ocean variability on droughts and monsoon variability)
 - Local/regional scale ocean influences directly affect tropical cyclogenesis, air-sea feedback processes affect tropical cyclone development, storm surge in tropical and extratropical regions

Key Science Challenges

- What **data** are needed (and how to obtain them) for properly characterizing extremes of different time and space scales and their changes, for characterizing the state of the oceans that are most relevant to extremes, and for the validation of models?
- What are the **causes** of changes in extremes both internal and external to climate system? How much of the changes can be attributed to forcing external to climate system and to factors such as modes of variability?
- What is the relative importance of **large-scale vs local** processes affecting extremes (e.g., circulation including ocean-atmosphere and external drivers vs ; local conditions such as land use and local feedbacks)?
- What can we learn about underlying **processes** and physical mechanisms of rare events through event attribution?
- Can **models** adequately represent these processes and how to improve models capability in simulating them?
- What is **predictability** of statistical properties of extremes at annual and decadal scale
- If and how will **modes** of variability change in the future? What are the resulting changes in extremes?

Major themes

- **Improved observational data.** New/Key initiatives are needed to improve the quality and availability of both historical and real-time in-situ **observations** for better characterization and quantification of weather and climate extremes and for better quantification of ocean states that influence weather and climate extremes. These include development of new and improvement of ongoing **reanalyses**, and continued homogenization and **data rescue** for in situ data, as well as development of new high resolution data sets that blend in-situ and remotely sensed data and spurring the advances in both.
-

Major themes

- **Quantification of long-term changes in extremes and understanding the causes:**
This includes continued improved understanding of causes both internal and external to climate system of changes in extremes, understanding causes of very rare events (such as extended heat wave and flooding) through event attribution to gain better understanding of physical mechanisms and processes underlying these events
-

Major themes

- **Processes and physical mechanisms** through which modes of variability and air-ocean interactions and feedbacks influence the **frequency and magnitude of extremes**: these include identification and characterization of these processes and mechanisms, evaluating model's capability in simulating such processes and improving model's representation of these processes, understanding if and how these modes of variability will change in the future and resulting changes in weather and climate extremes
-

Major themes

- **Extending operational **seasonal prediction** capabilities:**
There exists potentially useful skill in predicting modes of ocean/atmosphere variability at seasonal and perhaps longer time scales, it is important to explore potential use of such predictions in forecasting the frequency and magnitude of extreme events
 - **Harnessing advances in climate model development and initialization for **decadal** and long-term predictions for the **prediction** of changes in the likelihood of future extremes:** These include the development of best practices for the prediction or projection of frequency and magnitudes of extremes in the near term and in the future to address societal climate change adaptation needs.
-

Readiness

- **Event attribution** to gain better understanding of physical mechanisms and processes underlying very rare events:
 - **Detection and attribution** to gain better understanding of causes (ETCCDI)
 - Seasonal to decadal **prediction** of likelihood of frequency of extreme events
 - **Ocean variability** on drought
 - Extra-tropical and tropical storms
-

Attribution wrt storms

Global warming is "unequivocal" and "very likely" caused by human activities (IPCC 2007).

So shouldn't the null hypothesis be that there is a human influence?

Key difference: the uncertainties fall on the other side!

2 Effects:

- 1) Direct radiative forcing (small 1-2%)
- 2) Cumulative effects of past radiative forcing
 - Increased ocean temperatures and ice melt
 - Increased moisture
 - Land: in drought
 - 5-10% effect on precipitation.

The environment in which all storms form has changed owing to human activities.

Global warming has increased temperatures, and directly related to that, is an increase in the water holding of the atmosphere.

Over the ocean, where there are no water limitations, observations confirm that the amount of water vapor in the atmosphere has increased by about 4%, consistent with a 0.6°C warming of sea surface temperatures (SSTs) since about the 1950s.

Implementation strategies

- Maintain **international collaboration and coordination** for the development of data set and for building capacity in needy regions
- Make use of **existing meetings** as far as possible to build consensus and address questions, and use focused workshops, theme sessions at international meetings, to address one or more questions as needed
- Virtual institutes and **web based** meetings
- Maintain close **links** among WCRP projects, among panels and working groups of WCRP projects, and between observation and modeling community for effective coordination and timely exchange of data, information, new advances in science
- Work with other WCRP projects to build a **cross-cutting** implementation plan to guide funding agencies
- Establish a close link with **user** community (e.g. re-insurance and water management industries)

Links to WCRP GCs and other Project Science Questions

- All WCRP GCs and particularly the GC on Prediction and Attribution of Extreme Events.
- **CLIVAR** Research Opportunities: intraseasonal, seasonal and interannual variability and predictability of monsoon systems, decadal variability and predictability of ocean and climate variability, dynamics or regional sea level variability
- **GEWEX** Science questions: Observations and predictions of precipitation, changes in extremes, water and energy cycles and processes
- **SPARC** theme: Stratosphere-troposphere dynamical coupling
- **CLIC**: What will be the impacts of changes in cryosphere on atmospheric and ocean circulation

GEWEX RHPs and Extremes-Related Phenomena

Draft summary

	Heavy Precipitation	Floods	Winter Storms	Drought	Heat Waves	Fires
AMMA	•			•		
BALTEX	•	•	•	•		
CPPA	•	•		•	•	
HyMeX	•	•	•	•	•	
LBA	•	•		•		
LBP	•	•		•		
MAHASRI	•	•		•		
MDB	•	•		•	•	•
NEESPI	•	•		•		•
SRB	•	•	•	•	•	•

Drought Interest Group (DIG)

Open group; Formed in 2008 to:

- Identify and leverage current drought research activities already underway within WCRP
- Assess the missing links in drought research and coordinate drought research at an international level

Currently over 40 DIG members

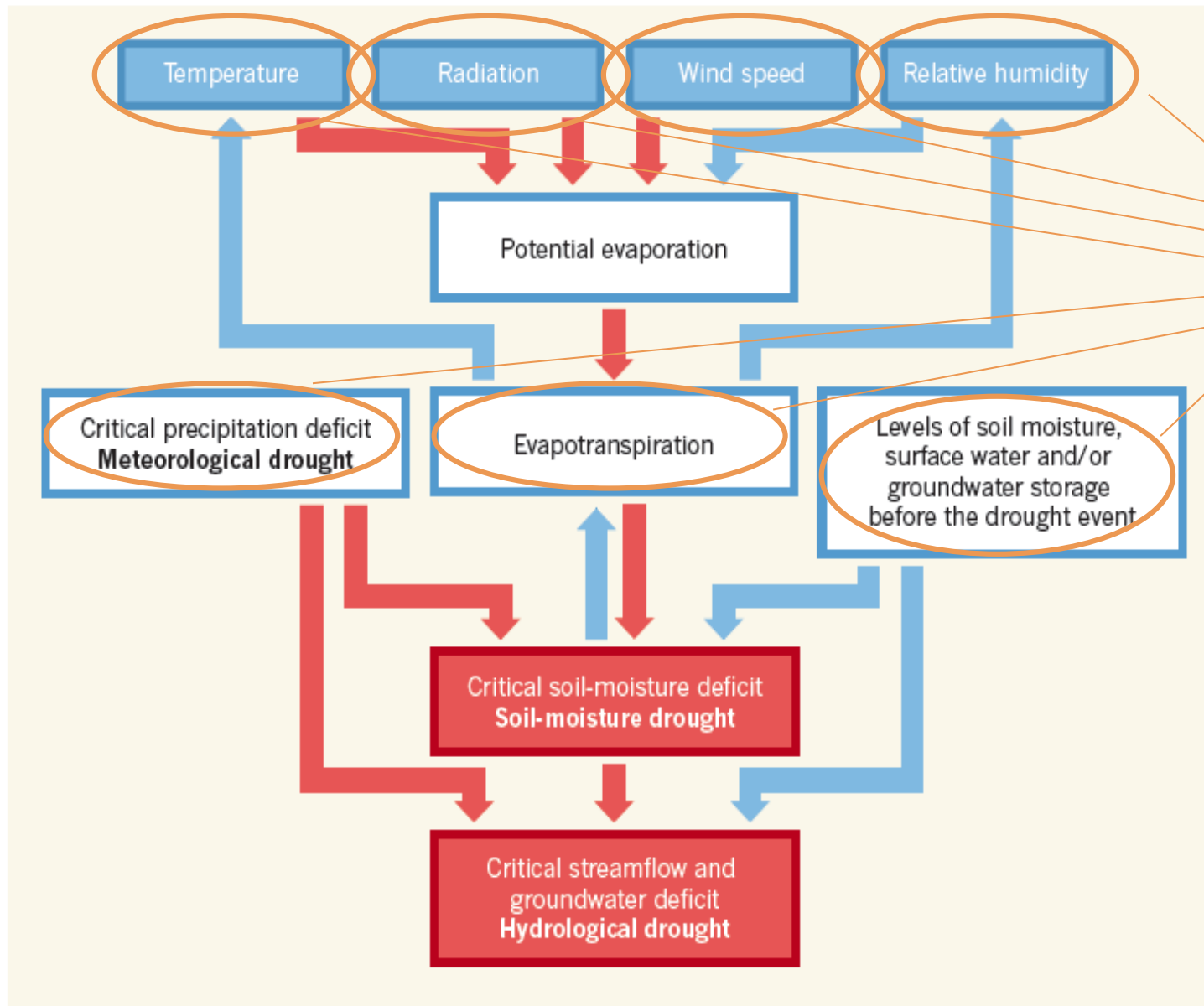
Consult with a much wider community:

2011 white paper on:

Drought Predictability and Prediction in a Changing Climate: Assessing Current Predictive Knowledge and Capabilities, User Requirements and Research Priorities



Drought drivers



ALL of these drivers are both affected by changes in global circulation patterns AND land surface conditions

(Seneviratne 2012, Nature)

Possible projects

How well are models able to handle extremes and how can we improve their capability?

- Datasets at high frequency (e.g., hourly)
- Promote analyses of data: Characterize precipitation etc and allow for assessment against comparable model datasets.
- Understanding processes and phenomena
- Confront models with new observationally-based products
- New metrics of performance;
- Highlight shortcomings and developmental needs: focus field programs, process studies, numerical experimentation, and model development.
- Develop applications for improved tracking and warning systems, information for users, assessing changes in risk of drought, floods, river flow, storms, coastal sea level surges, ocean waves...

There are multiple benefits and the results are important for society

- Improved information
- Improved models => improved predictions => reduced impacts
- All time scales, monthly, seasonal, decadal, centennial
- All space scales: regional to global
- Quantified uncertainties
- Information for water managers, decision makers, users
- Drought Information System
- Better interactions between research and users