INTERNATIONAL WEATHER RESEARCH PROJECTS

Zoltan Toth - GSD

Acknowledgements: David Carlson, Louis Uccellini, Yuanfu Xie, Steve Albers, Chris MacDermaid, Cecelia DeLuca, Carolyn Reynolds, Sharan Majumdar, Deon Terblanche, Paolo Ruti, Brian Golding, Thomas Jung, Andrew Robertson, Robert Vitard, Yuejian Zhu, Andre Methot, Rolf Langland, Jeff Whitaker, Yucheng Song

OMSZ Seminar, 27 May 2015

OUTLINE / SUMMARY

- **THORPEX accomplishments** – Adaptive methods
  - Targeted observations
  - Ensemble-based background covariance
  - Ensemble-based probabilistic forecasts
- **New WWRP projects**
  - Polar Prediction Project (PPP)
  - Sub-Seasonal to Seasonal Prediction Project (S2S)
  - High Impact Weather Project (HIWeather)
- **US engagement**
  - Agencies – Community initiative
    - Weather Hazard Reduction in Changing Climate?
- **Enablers**
  - EarthCube
  - Announcements of Opportunities

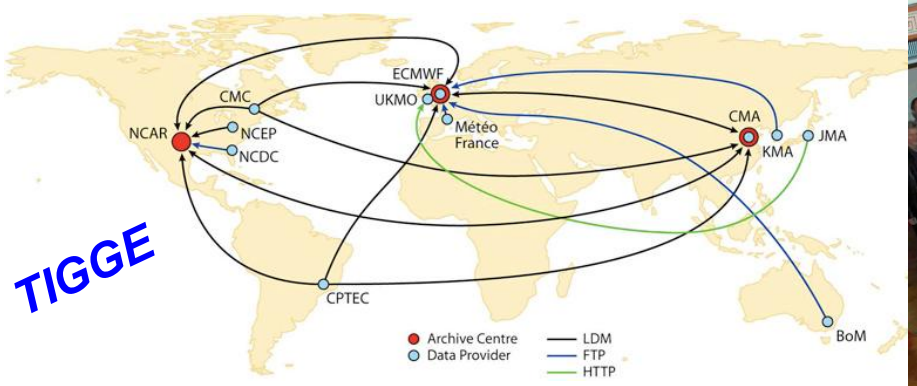
THORPEX 101 – 2005-2014

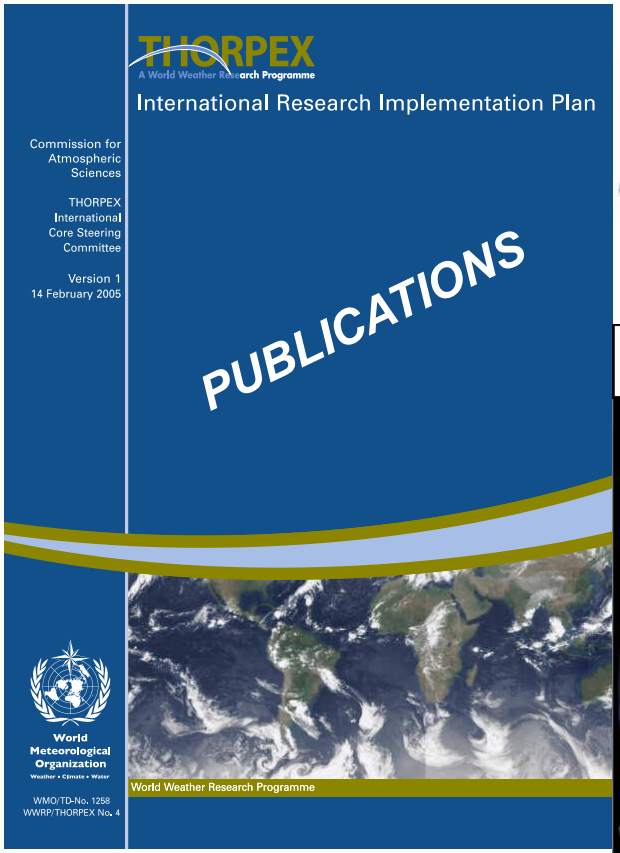
- **Objective**
  - Accelerate improvements in high impact weather forecasts
- **History**
  - WMO/WWRP sponsored program launched in 2004
- **Approach**
  - Modernize / optimize end-to-end forecast system
    - Observing, data assimilation, ensemble forecast, decision support systems
    - Allocate research resources to maximize overall economic impact
    - Adaptive & probabilistic approaches
      - Observations, covariances, physics, decision procedures
  - Coordination across
    - Components of forecast system
    - Nations & regions
    - Research & operational communities

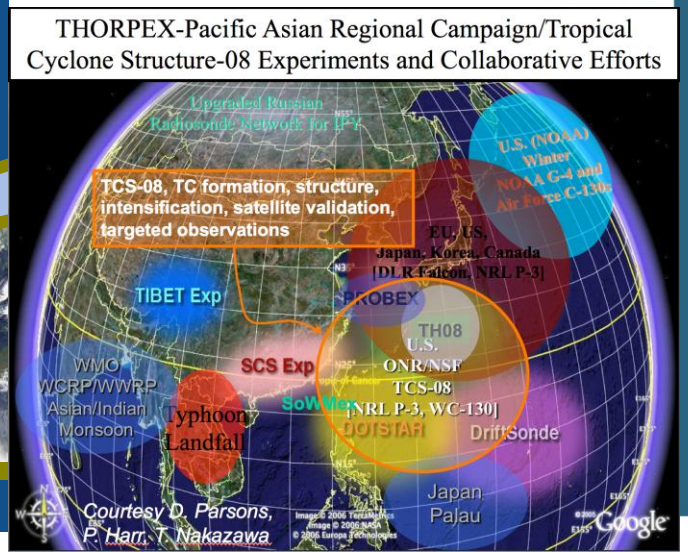
MAJOR INTL. ACCOMPLISHMENTS

- **More organized** weather community
  - Focus on weather forecast research
  - Science Symposia, workshops, Working Group meetings
- **Global engagement**
  - Field campaigns (T-PARC), GEO projects – incl. Africa health initiative
- **End-to-end forecast process**
  - Use of forecasts included – Societal and Economic Research Applications (SERA)
- **Dialogue between academia & operations**
  - R2O projects, training of forecasters, etc
- **TIGGE** – THORPEX Interactive Grand Global Ensemble
  - Archive of operational global ensemble forecasts
    - 10 providers, 3 archive centers

MAJOR INTL. ACCOMPLISHMENTS - 2







"ADAPTIVE" – APPEARS 26 TIMES IN TIP

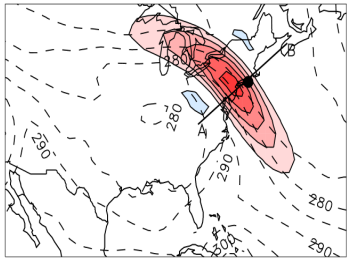
- Adaptive
  - "Case dependent modification of forecast procedures"
- Adaptive **reallocation of forecast resources**
  - Observations, DA, ensemble forecasting, products/services
- Adaptive observing systems
  - **Targeted observations** – *Winter Storm Reconnaissance*
- Adaptive use of voluminous observational datasets
  - (More)/less **data thinning** in (in)sensitive areas
- Adaptive **Quality Control**
  - Use ensemble-based variances
- Data assimilation
  - **Case dependent covariances** – e.g., *Hybrid GSI*
- Ensemble
  - Resolution vs membership **case dependent optimization**
  - Adaptive probability forecasts - *NAEFS*
- NWP system configuration
  - More resources for high impact areas / cases

MAJOR US ACCOMPLISHMENTS

- $ 20+M THORPEX-related investments by agencies
  - Field campaigns, AOs, archives, etc

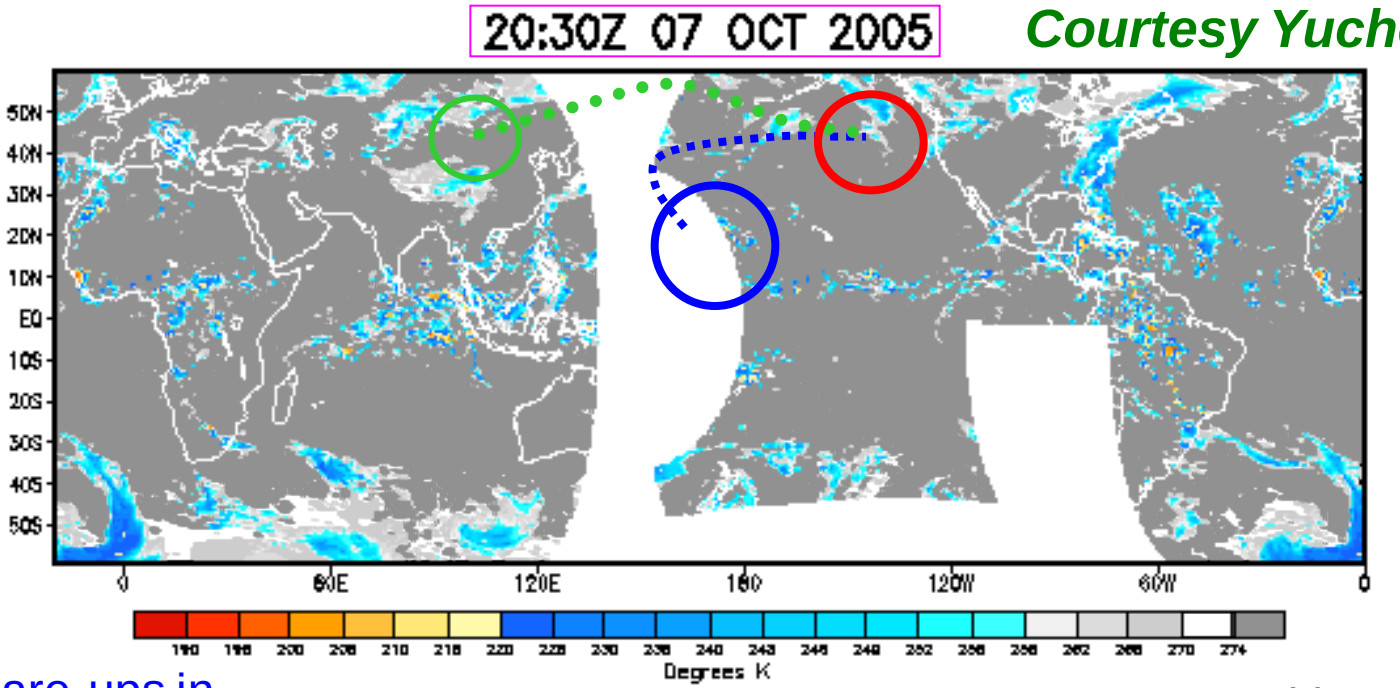
Developed, tested, & operationally implemented

- Adaptive observations
  - **Winter Storm Reconnaissance** (WSR) program
    - National Weather Service
- Ensemble based data assimilation
  - **Hybrid GSI-EnKF** - NCEP
- Multi-center ensemble forecasting
  - **North American Ensemble Forecast System** (NAEFS)
    - NCEP, Canada, Mexico
    - + FNMOC - National Unified Operational Prediction Capability



MAIN THEME OF WINTER T-PARC

Study the lifecycle of perturbations as they originate from the tropics, Asia, and/or the polar front, travel through the Pacific waveguide, and affect high impact wintertime weather events over North America and the Arctic

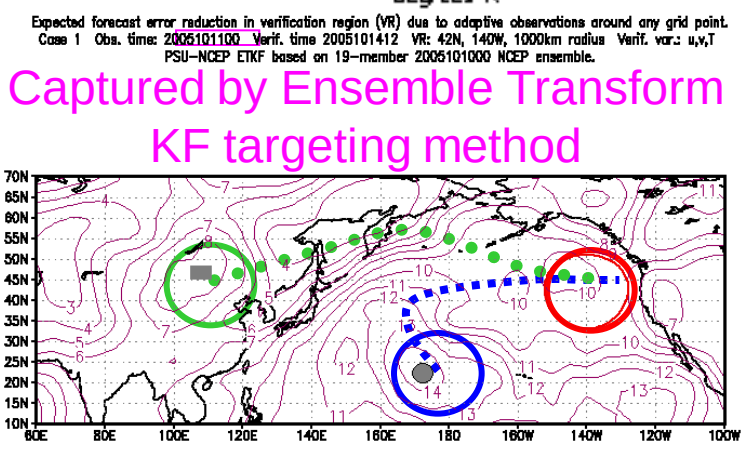


Courtesy Yucheng Song

Tropical flare-ups in western Pacific (IR) merge with

Waves on westerly flow to influence

Deep cyclogenesis in northeast Pacific



Captured by Ensemble Transform KF targeting method

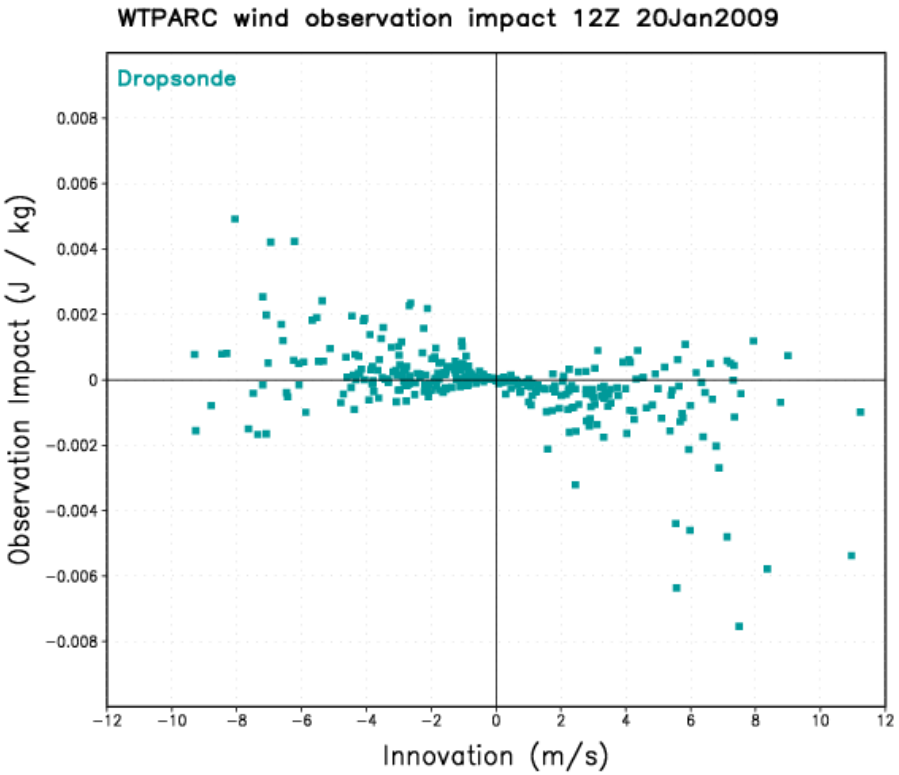
Sensitive area 1, 00UTC 11 Oct

Sensitive area 2, 00UTC 11 Oct

Verification region, 12UTC 14 Oct

WTPARC

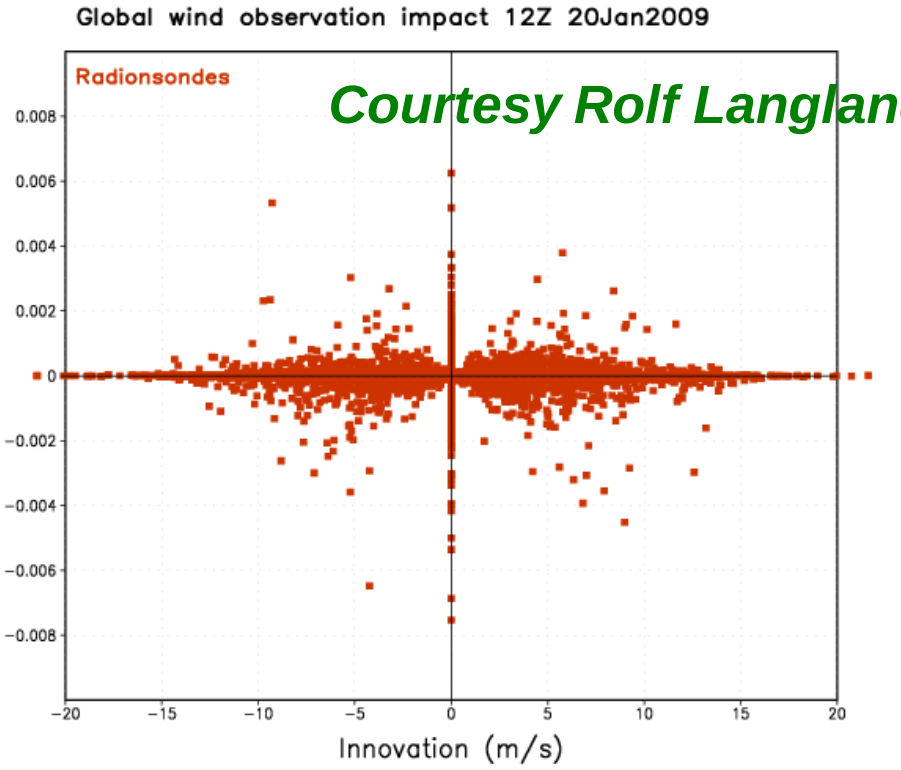
Dropsonde winds



Forecast error reduction
sum = -0.0399 J kg^{-1}
334 observations

Global

Radiosonde winds



Courtesy Rolf Langland

Forecast error reduction
sum = -0.4688 J kg^{-1}
59,112 observations

Impact per-ob = Sum of impact / #ob data

Raob impact per ob: -0.79 e-5 J/kg Drop impact per ob: -11.95 e-5 J/kg

Targeted observations have 15 times the impact of routinely taken observations

WSR Summary statistics for 2004-07

Variable	# cases improved	# cases neutral	#cases degraded
Surface pressure	21+20+13+25=79	0+1+0+0=1	14+9+14+12=49
Temperature	24+22+17+24=87	1+1+0+0=2	10+7+10+13=40
Vector Wind	23+19+21+27=90	1+0+0+0=1	11+11+6+10=38
Humidity	22+19+13+24=78	0+0+0+0=0	13+11+14+13=51

OVERALL EFFECT:

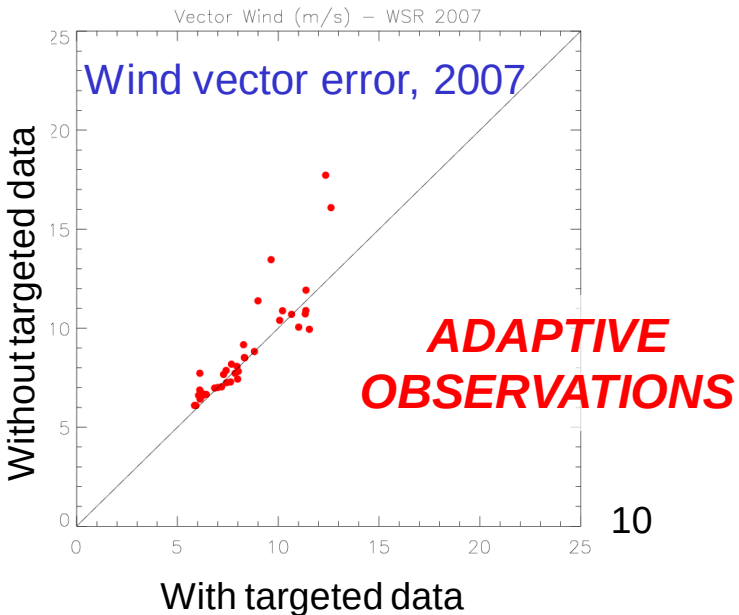
25+22+19+26 = 92 POSITIVE CASES

0+1+0 +0 = 1 NEUTRAL CASE

10+7+8 +11 = **36 NEGATIVE CASES**

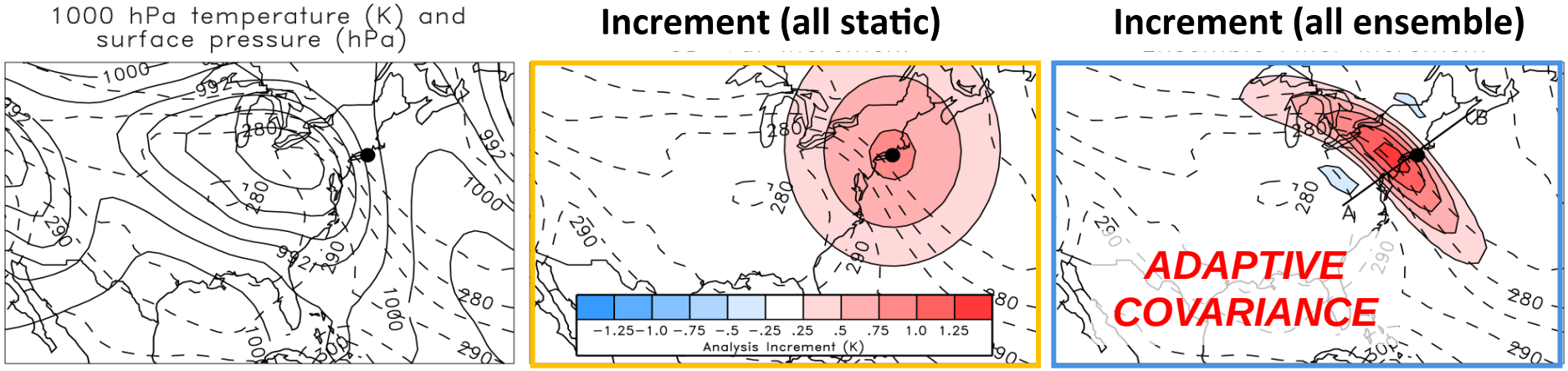
71.3% improved

27.9% degraded



HYBRID COVARIANCE

From Jeff Whitaker



- Incorporate ensemble perturbations directly into variational cost function through extended control variable
  - Lorenc (2003), Buehner (2005), Wang et. al. (2007), etc.
    - Preconditioning ignored for simplicity

From Daryl Kleist

$$J(x_f', a) = b_f \frac{1}{2}(x_f')^T B_f^{-1}(x_f') + b_e \frac{1}{2}\sum_{n=1}^{N}(a^n)^T L^{-1}(a^n) + \frac{1}{2}(Hx_t' - y')^T R^{-1}(Hx_t' - y')$$

β_f & β_e: weighting coefficients for fixed and ensemble covariance respectively

$\mathbf{x}_t'$: (total increment) sum of increment from fixed/static **B** ($\mathbf{x}_f'$) and ensemble **B**

α_k: extended control variable; :ensemble perturbations

$\mathbf{x}_k^e$ - analogous to the weights in the LETKF formulation

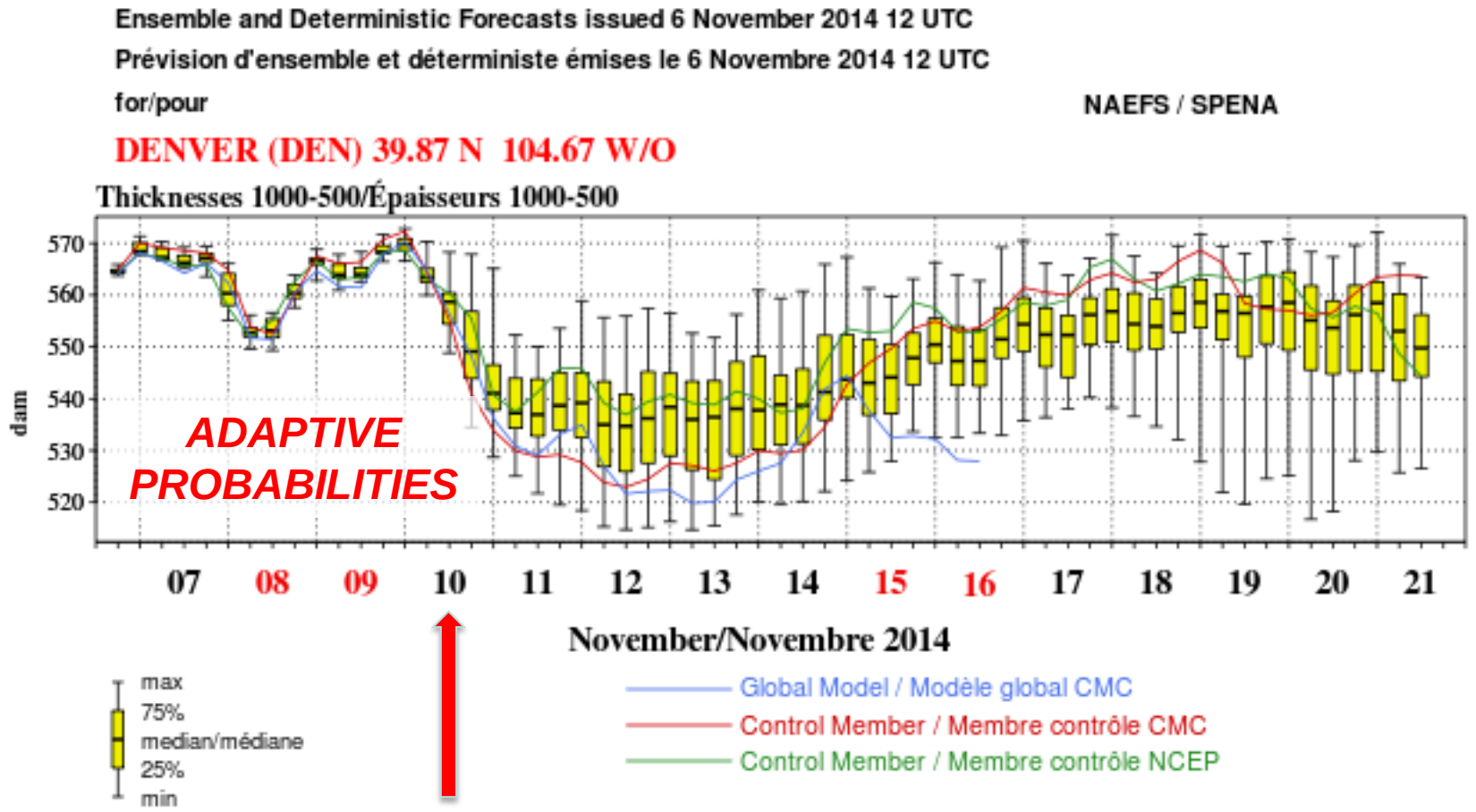
L: correlation matrix [effectively the localization of ensemble perturbations]

$$\mathbf{x}_t' = \mathbf{x}_f' + \sum_{n=1}^{N}\left(\alpha^n \circ \mathbf{x}_e^{\,n}\right)$$

6-DAY NAEFS FORECAST OF COLD SPELL

Environment Canada
Environnement Canada

NAEFS
SPENA

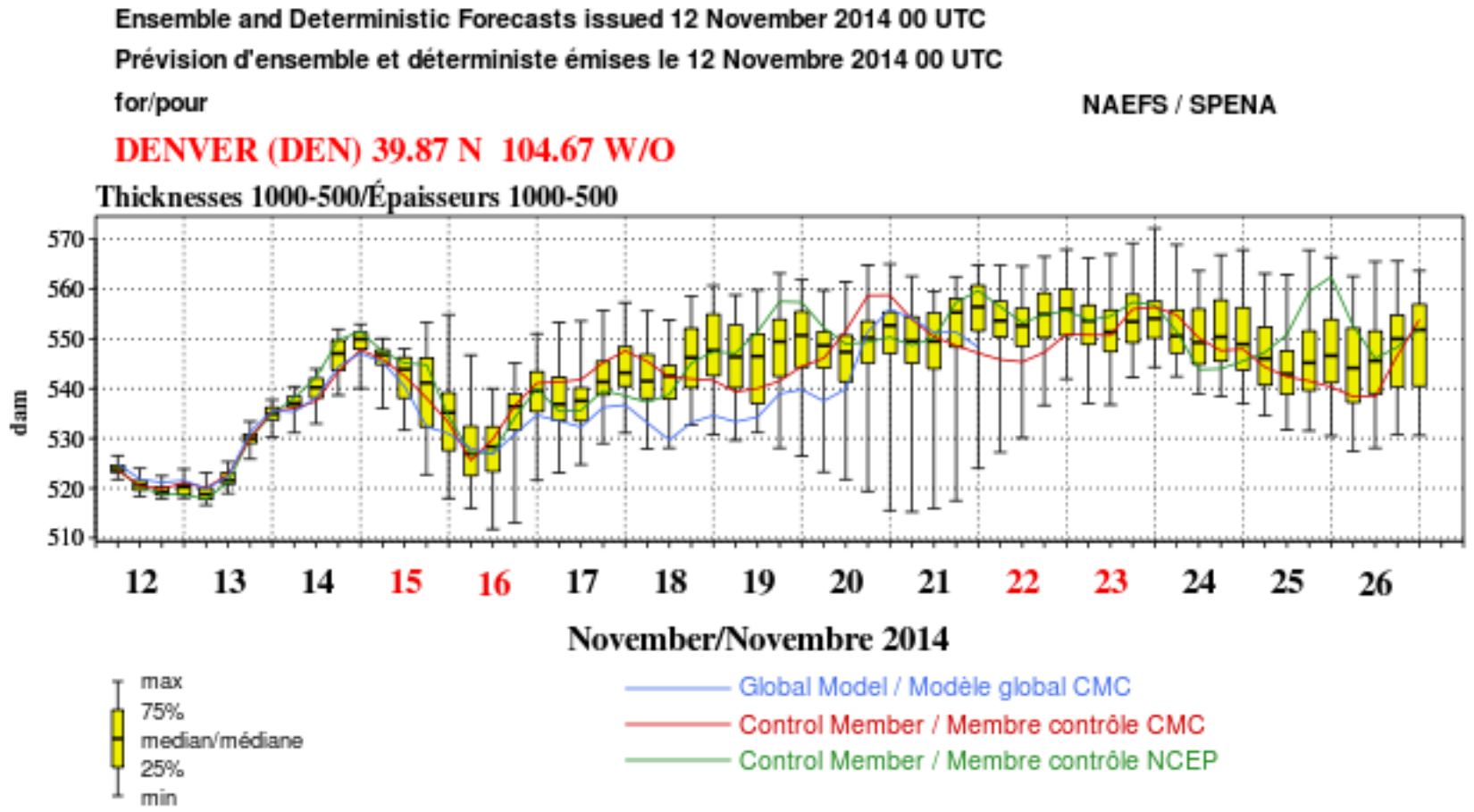


BIG PREDICTED CHANGE

DID IT HAPPEN?

Environment Canada
Environnement Canada

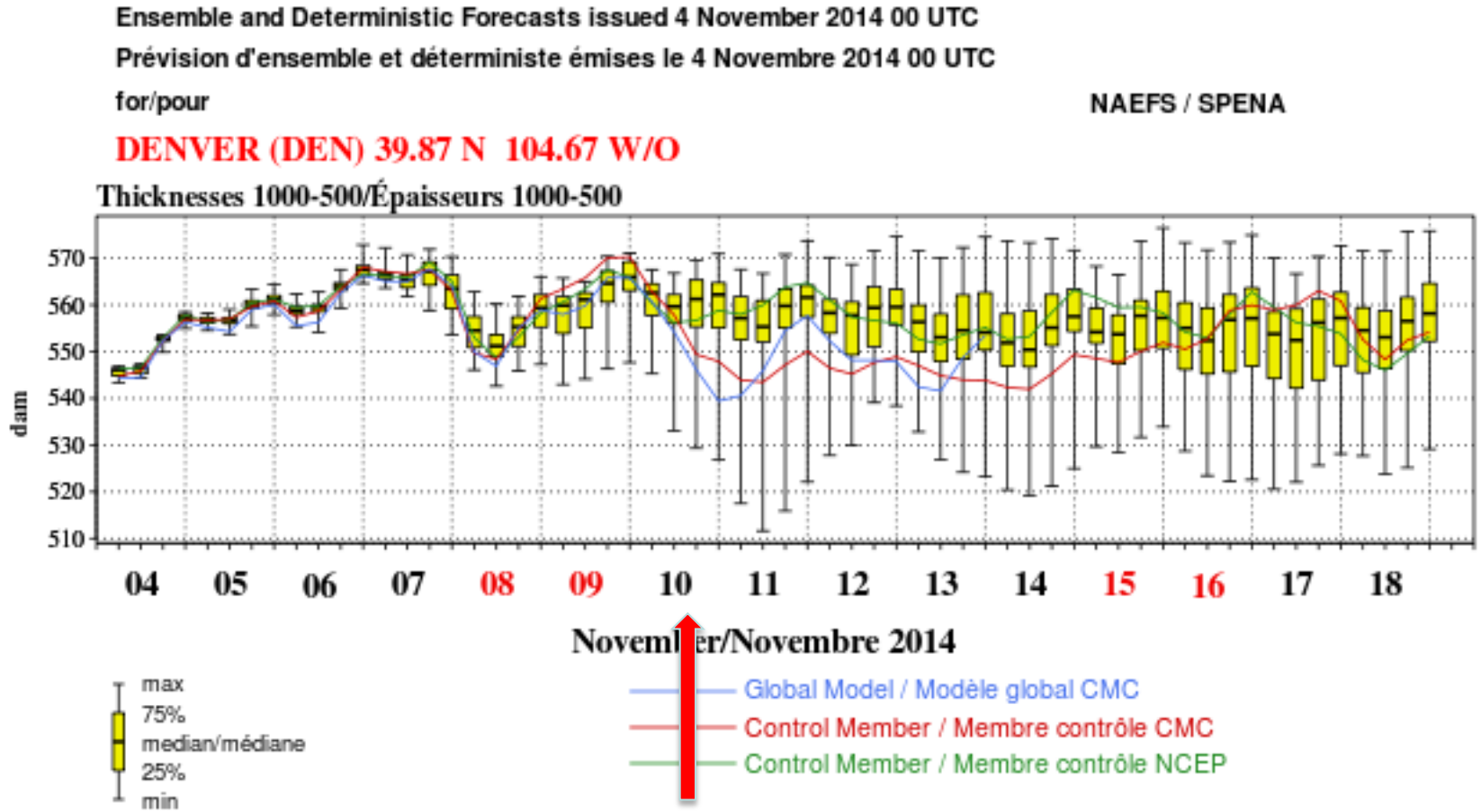
NAEFS
SPENA



NAEFS FORECAST AT LONGER LEAD

Environment Canada
Environnement Canada

NAEFS
SPENA



POTENTIAL FOR BIG CHANGE PREDICTED

How to use low probabilities? Why only small number of members show extreme cold?

FUTURE RESEARCH OPPORTUNITIES

- **Stakeholder engagement**
  - Objective assessment of costs/benefits of weather research
    - **Articulate societal need for / potential impact of weather research**

- **Optimal design of observing systems**
  - Use **OSSE** etc not only for evaluation but design

- **Global scale nowcasting**
  - **Cloud scale data assimilation** w remote observations
  - Non-hydrostatic Earth System **coupled forecasting**

- **Impact forecasting** using **multi-center ensembles**
  - Decision support based on quantified forecast uncertainty
    - Forecast **impact of weather** – not only weather

Polar Challenge – Rick Spinrad

Polar Prediction Project (PPP)

The Science Plan and Implementation Plan are available!

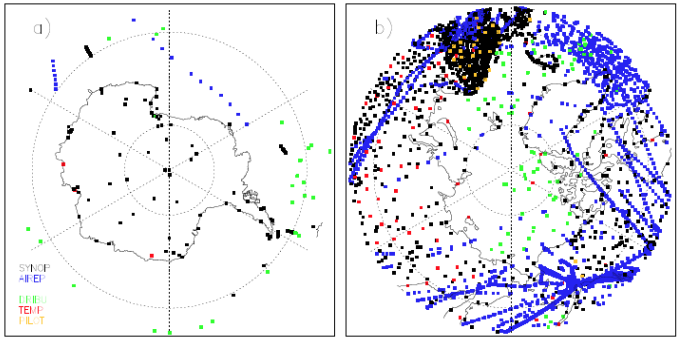
❑**Objective:** *Deon Terblanche, Thomas Jung*

- "Promote cooperative international **research enabling development of improved weather and environmental prediction services** for the polar regions, on time scales from **hourly to seasonal**" (contribution to WMO GIPPS)

❑**Research components**:

- observations, modeling, data assimilation, ensemble forecasting
- predictability, diagnostics, teleconnections
- societal and economic research applications, verification

❑**Implementation**: Year of Polar Prediction (YOPP) – period 2017-2018 – YOPP Summit, WMO, 13-15 July 2015



Courtesy T. Jung, AWI

❑**Synergies** with the WCRP Polar Climate Predictability Initiative (PCPI)

❑**Project Office**: AWI, Germany

❑**Trust fund**: from Canada, Norway and UK so far, further contributions welcome

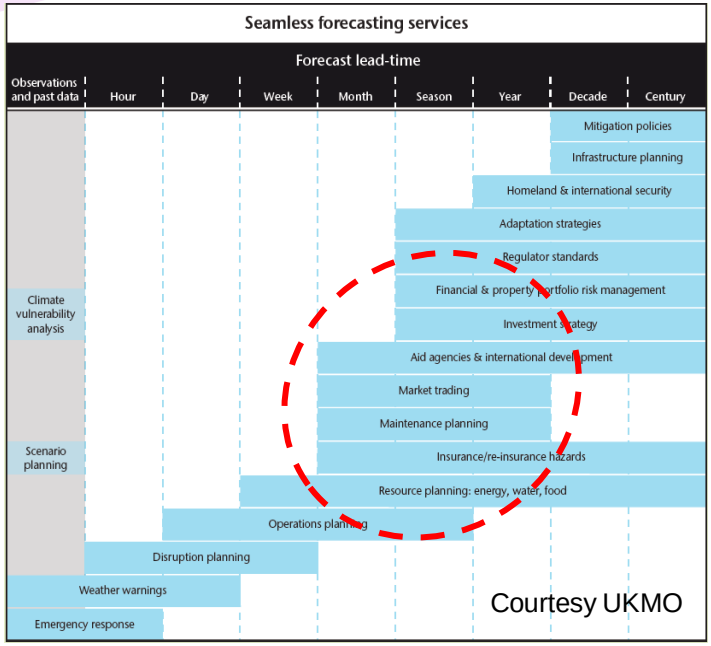
US participants: C. Fairall, D. Bromwich, M. Holland, D. Perovich

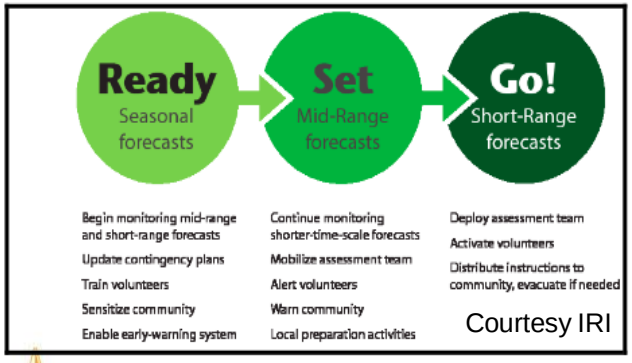
Mid-Range Forecasting Challenge – Rick Spinrad

Deon Terblanche, R. Vitard, A. Robertson

Subseasonal to Seasonal (S2S) Project

http://s2sprediction.net/





- **Objectives:**
  - To improve forecast skill and understanding on the S2S timescale with emphasis on **HIW – 2 wks – 2 mos**
  - To promote uptake by operational centres and exploitation by the applications community
  - To capitalize on the expertise of the weather and climate research communities to address GFCS priorities
- **Implementation underway**: TIGGE-like multi-model data base being established, 5 sub-projects
- **Demonstration projects on extreme events**(e.g. 2010 Russian heatwave, floods in Pakistan in 2010 and Australia in 2011, and 2012 European cold spell)
- **Project Office**: NIMR, KMA, Jeju, Korea (official ceremony at EC-65) – S2S session and workshop (monsoon focus) 22-26 June 2015
- **Trust fund**: from Australia, USA and UK so far, welcome further contributions from Members.

US Participants: A. Robertson, B. Kirtman, A. Kumar, D. Waliser, P. Dirmeyer

High Impact Weather (HIWeather) Project

Deon Terblanche, Brian Golding

MISSION

Promote Co-Operative International Research to achieve a Dramatic Increase in Resilience to High Impact Weather, worldwide, through Improving Forecasts for timescales of minutes to two weeks and Enhancing their Communication & Utility in Social, Economic & Environmental Applications

HIWeather

The WWRP High Impact Weather Project

World Meteorological Organization
Weather · Climate · Water

FOCUS ON SELECTED HAZARDS

Urban Flood: Reducing mortality, morbidity, damage and disruption from flood inundation by intense rain, out-of-bank river flow, coastal wave & surge overtopping and from consequent urban landslides.

Wildfire: Reducing mortality, morbidity, damage and disruption from wildfires &their smoke.

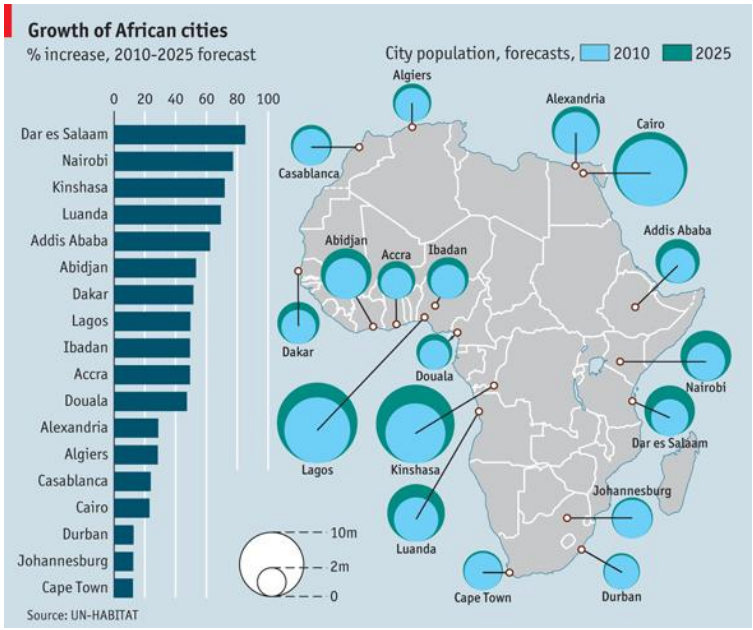
Extreme Local Wind: Reducing mortality, morbidity, damage and disruption from wind & wind blown debris in tropical & extra-tropical cyclones, downslope windstorms & convective storms, including tornadoes.

Disruptive Winter Weather: Reducing mortality, morbidity, damage and disruption from snow, ice and fog to transport, power & communications infrastructure.

Heat & Air Pollution in Megacities: Reducing mortality, morbidity and disruption from extreme heat & pollution in the megacities of the developing and newly developed world.

New possible RDPs

A. MacDonald – High Impact Challenge

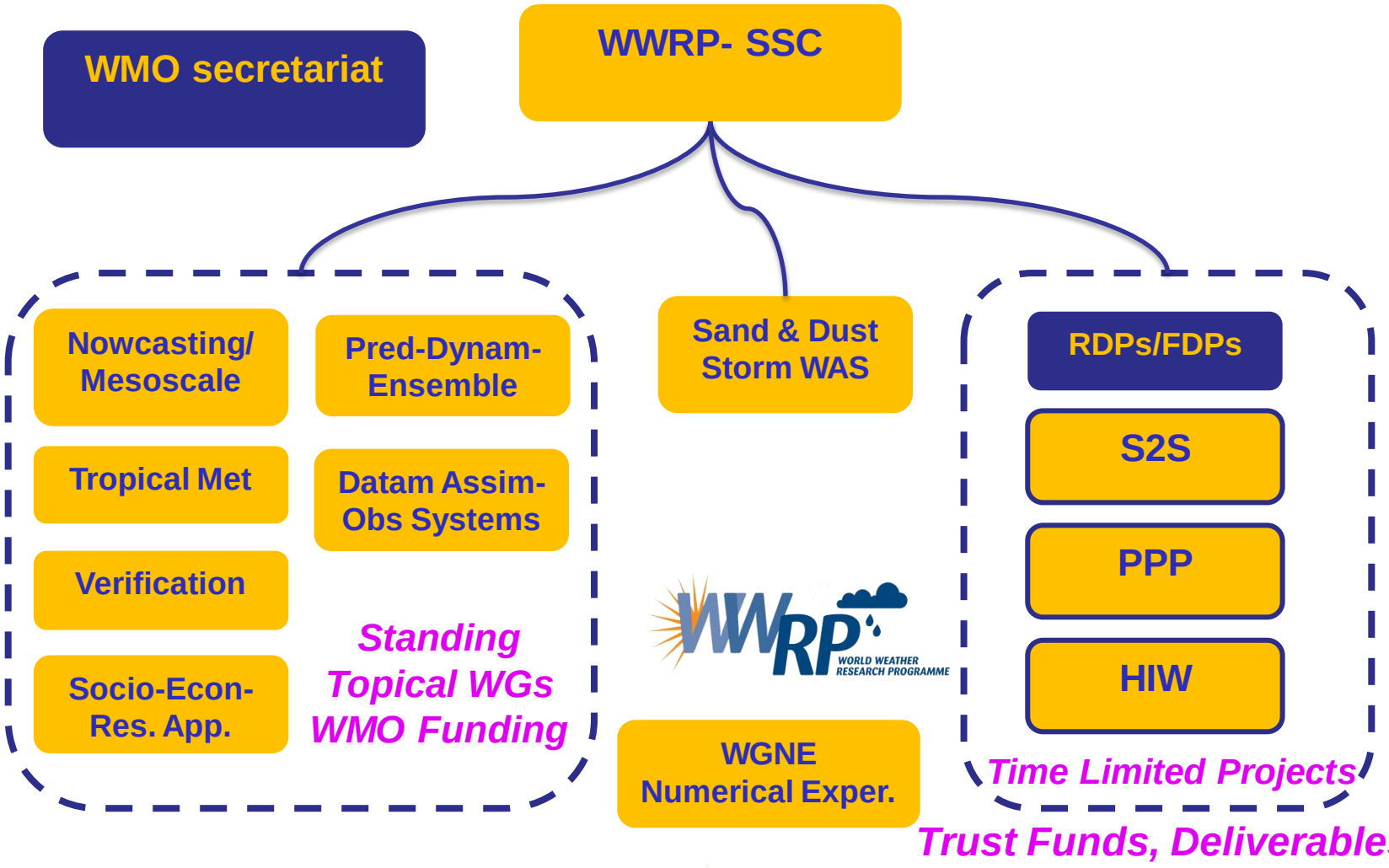


Lake Victoria RDP project – S. Goodman, S. Albers

US Participants: S. Majumdar, R. Morss

Weather · Climate · Water

WWRP Structure

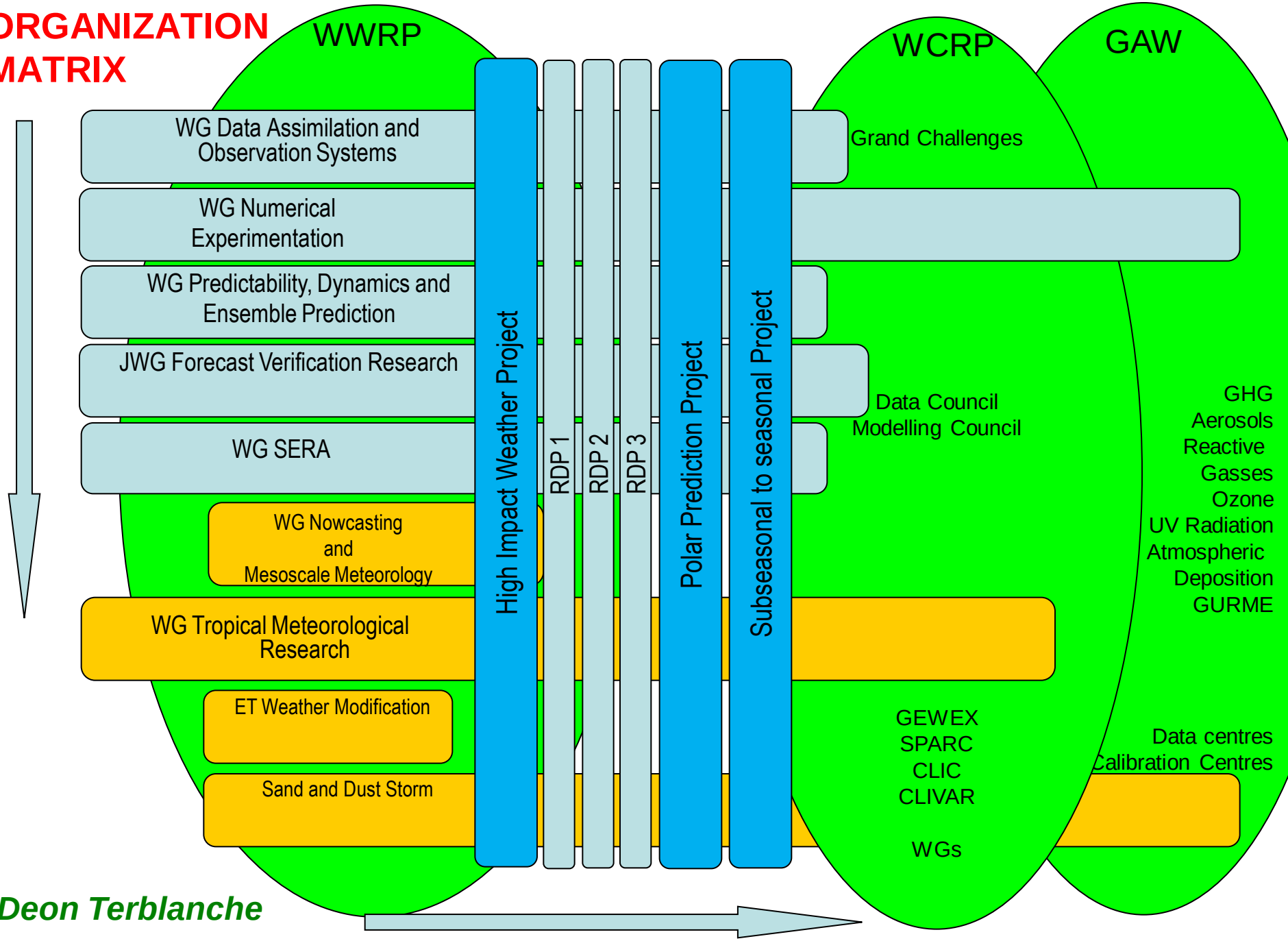


After Paolo Ruti

WCRP World Climate Research Programme

Weather · Climate · Water

WMO PROJECT ORGANIZATION MATRIX



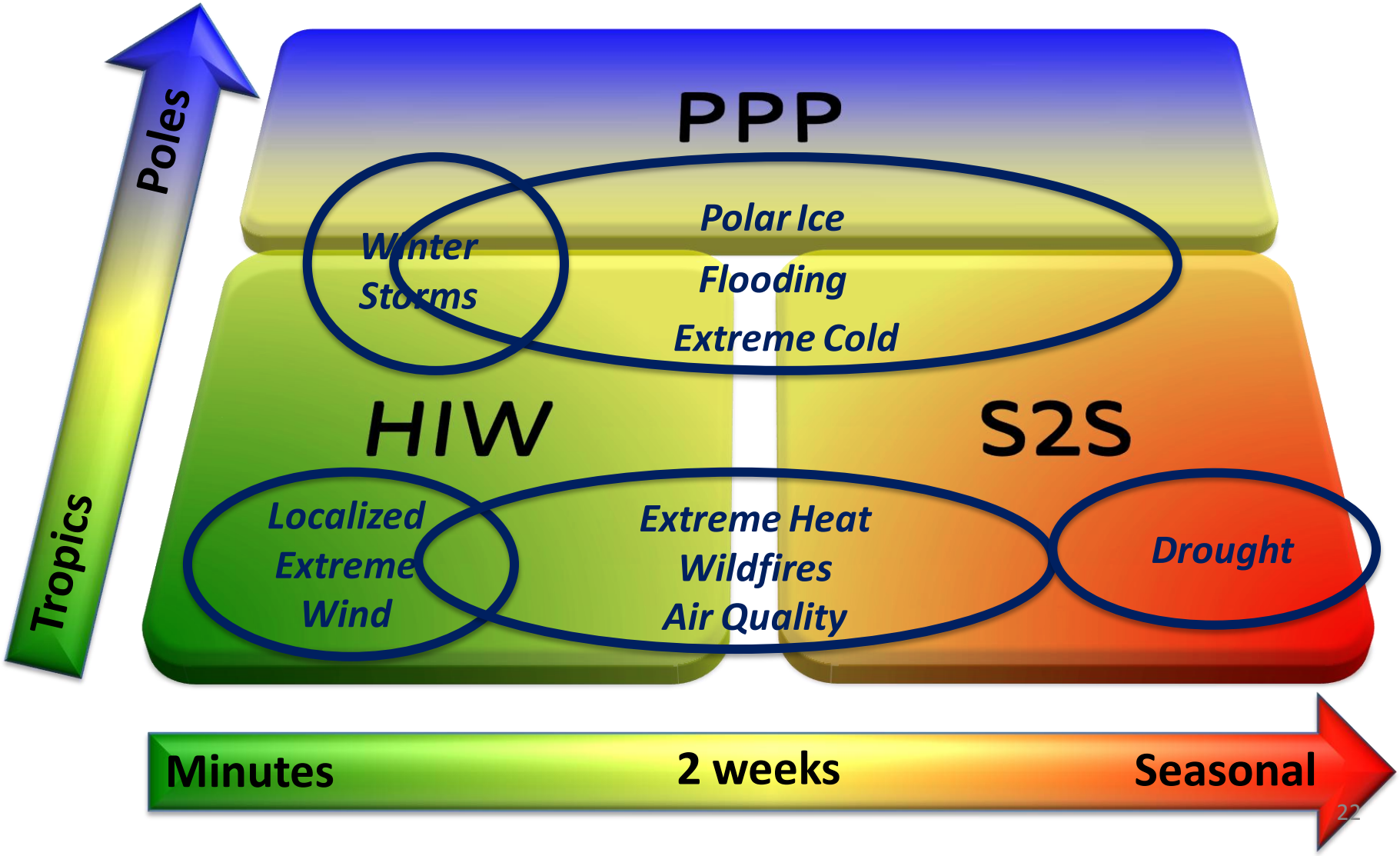
Deon Terblanche

US ORGANIZATION

- THORPEX ended Dec. 2014
  - Laura Furgione, US PR to WMO presented Certificates to contributors
- Transitional period in 2015
  - THORPEX Committees transform to
    - Interim Weather Research Committees
      - TORs developed for standing comm.
      - Membership established/expanded (FAA & DOE interest)
- US THORPEX Exec Comm. – NASA, NOAA, NSF, US Navy =>
  - Interagency Weather Research Coordination Committee (IWRCC)
    - T. Lee, J. Cortinas, B. Lapenta, P. Harr, M. Peng, D. Eleutero
    - Oversees CWRSC
- US THORPEX Science Steering Committee =>
  - Community Weather Research Steering Committee (CWRSC)
    - Develop Science Plan; Fall 2015 Workshop
      - Carolyn Reynolds & Sharan Majumdar, Co-Chairs

WMO/WWRP International Legacy Projects

Sharan Majumdar & Carolyn Reynolds



US OBJECTIVES - IWRCC

- **Coordinate** US participation in 3 legacy & other WWRP projects
- **Align agency programs** w national / international projects
- Leverage / **optimize use of national research infrastructure**
- **Foster Research to Operations** (R2O) transition
- Review progress / provide **oversight of national projects**
- Provide **guidance on international weather research** to US PR
- **Develop community initiatives**
  - High impact weather research
    - With high socio-economic relevance

MOTIVATION / CONTEXT FOR CHOICE OF PROJECT – 30k VIEW OF "PROGRESS"

"Humanity is like a brakeless car accelerating on a curvy downhill mountain road, its cheerful passengers oblivious of any problems ahead."

Paraphrased quote from Edward Plunkett (1878-1957)

- Have we lost the breaks?
  - Acceleration not sustainable
  - At which curve may we lose control?

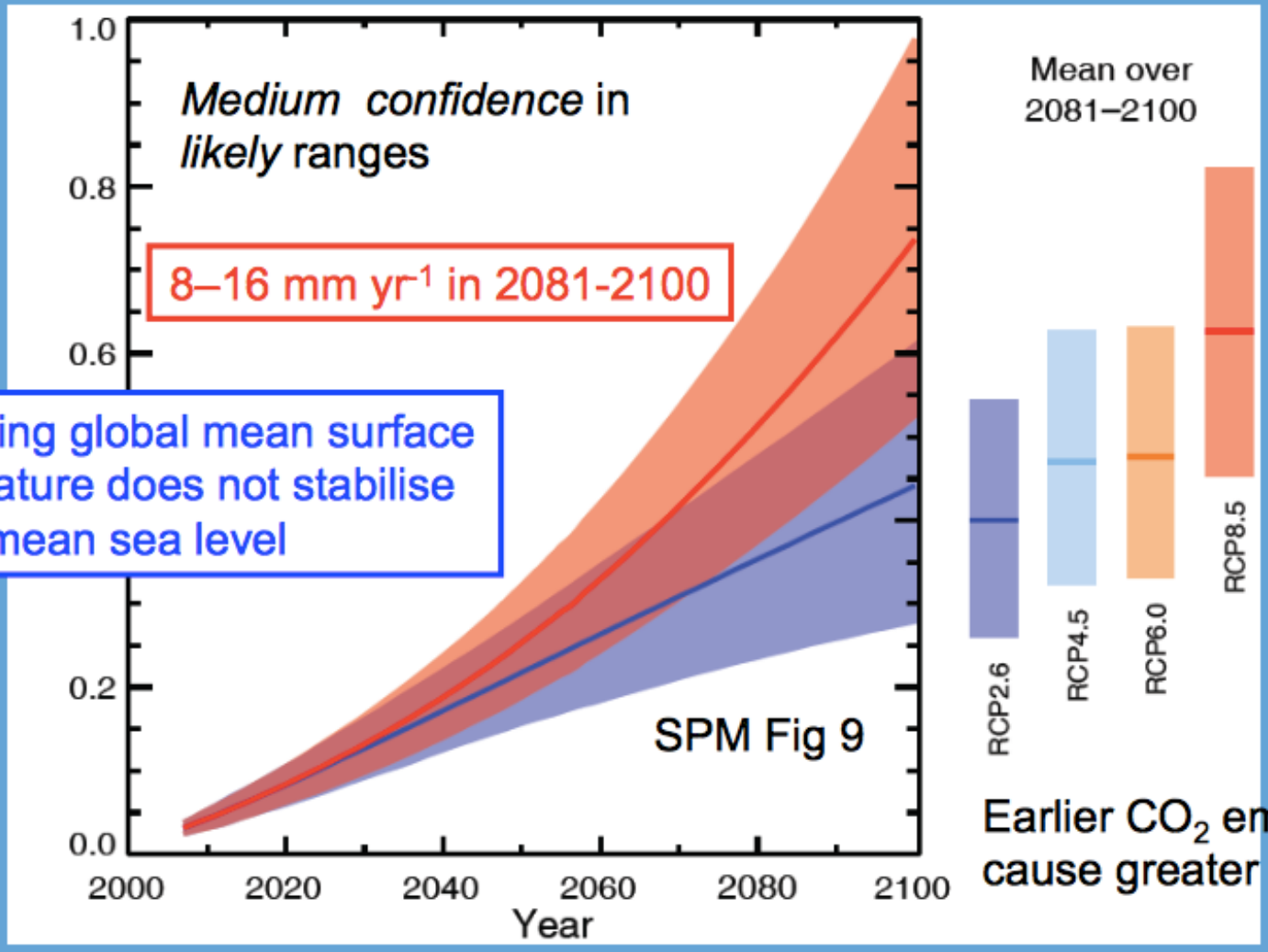
CURVES ON THE ROAD

- **Climate change**
  - Changing extreme weather / drought
  - Ice-free Arctic
  - Rising sea level
  - Ocean acidification
  - Ecosystem collapse
- **Population growth**
  - Water & food shortage
- **Growing gap between rich & poor**
- **Environmental pollution**
  - "External" – Fresh water, ocean, land, ecosystem pollution
    - Chemicals including medicines
      - Endocrine disruptors, carcinogens, antibiotics, etc
  - "Internal" – Incidental / deliberate ingestion from environment
    - Genetic impact – Declining fertility, etc

Growth as value? Is that sustainable?

Under all RCPs the rate of sea level rise will *very likely* exceed that observed during 1971–2010

Courtesy Gerald Meehl



Stabilising global mean surface temperature does not stabilise global mean sea level

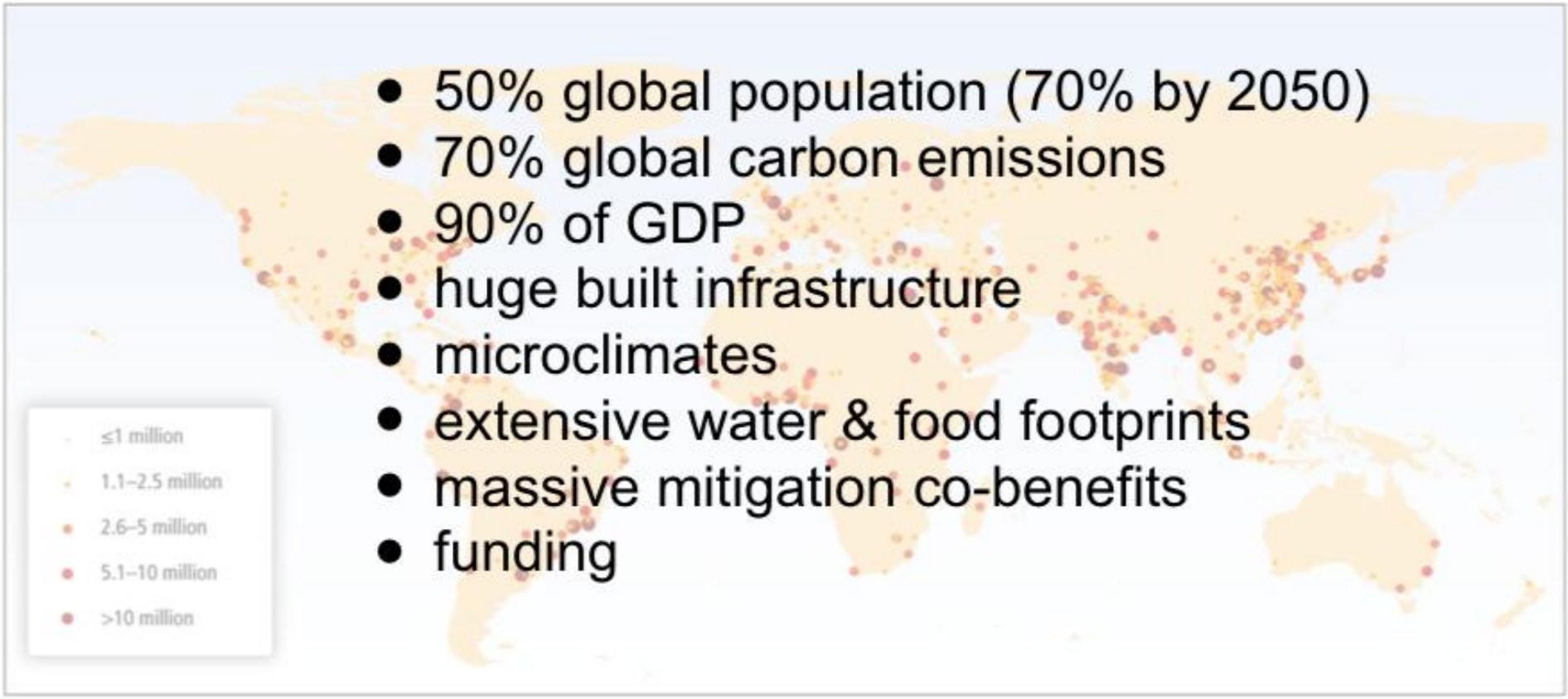
HOW SCIENCE CAN AFFECT CHANGE?

- Western sciences **good at analysis**, taking things apart
- **Less so with synthesis** / integration, putting things together
- **Work** seamlessly **across disciplines** to capture full reality
  - Weather & Climate - Ontologically one system
    - Dual perceptions due to different investigative methods
  - Nature & Society – Inseparable on global scale
    - Major human impact globally
- Only via **integration of natural laws & social policies** can we
  - Predict coupled Earth System (w prescribed or predicted *policies*)
  - Influence / shape future

For societal (and not only "scientific") relevance

WCRP
World Climate Research Programme

Proposed WCRP coastal megacities initiative

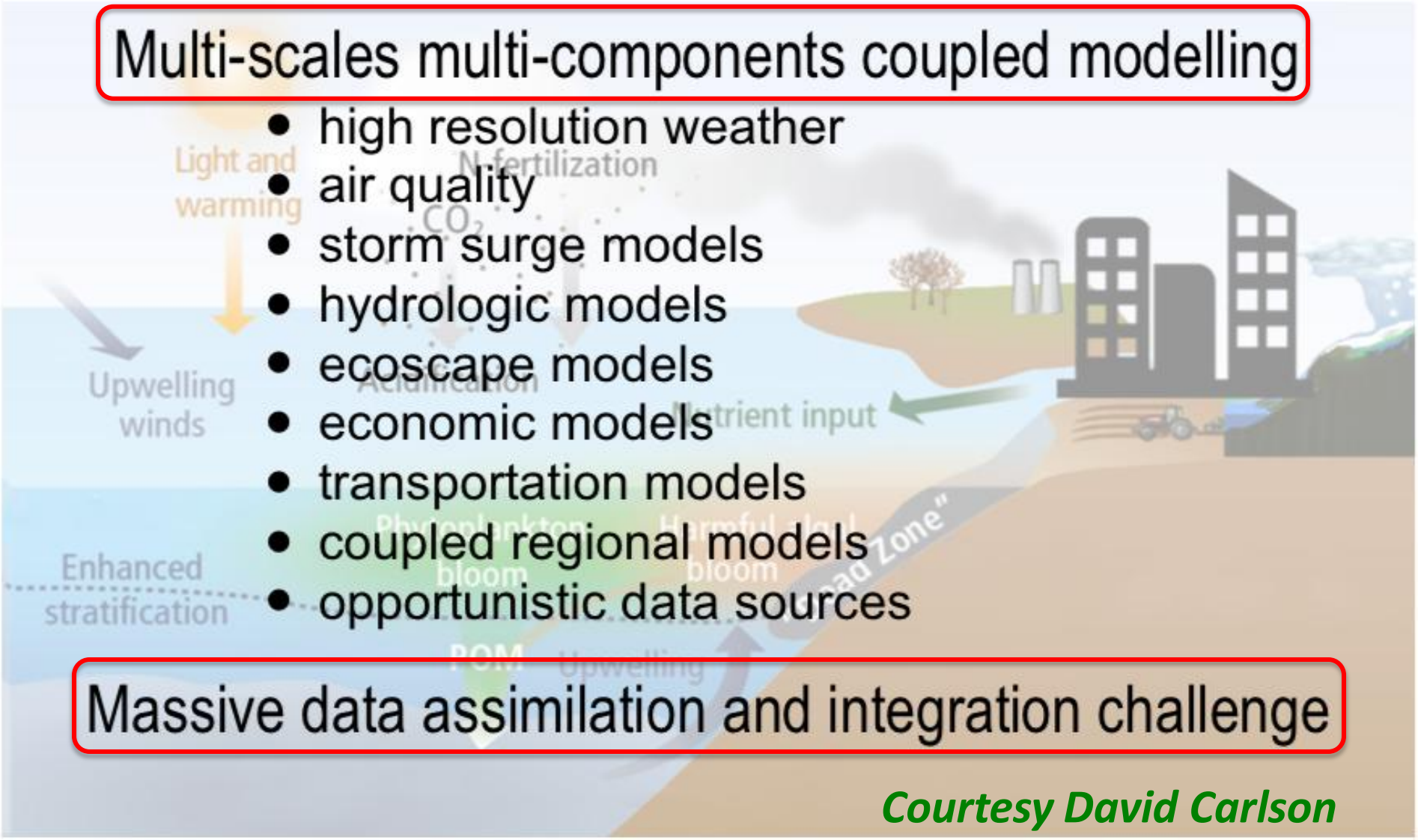


- 50% global population (70% by 2050)
- 70% global carbon emissions
- 90% of GDP
- huge built infrastructure
- microclimates
- extensive water & food footprints
- massive mitigation co-benefits
- funding

Courtesy David Carlson

Multi-scales multi-components coupled modelling

- high resolution weather
- air quality
- storm surge models
- hydrologic models
- ecoscape models
- economic models
- transportation models
- coupled regional models
- opportunistic data sources

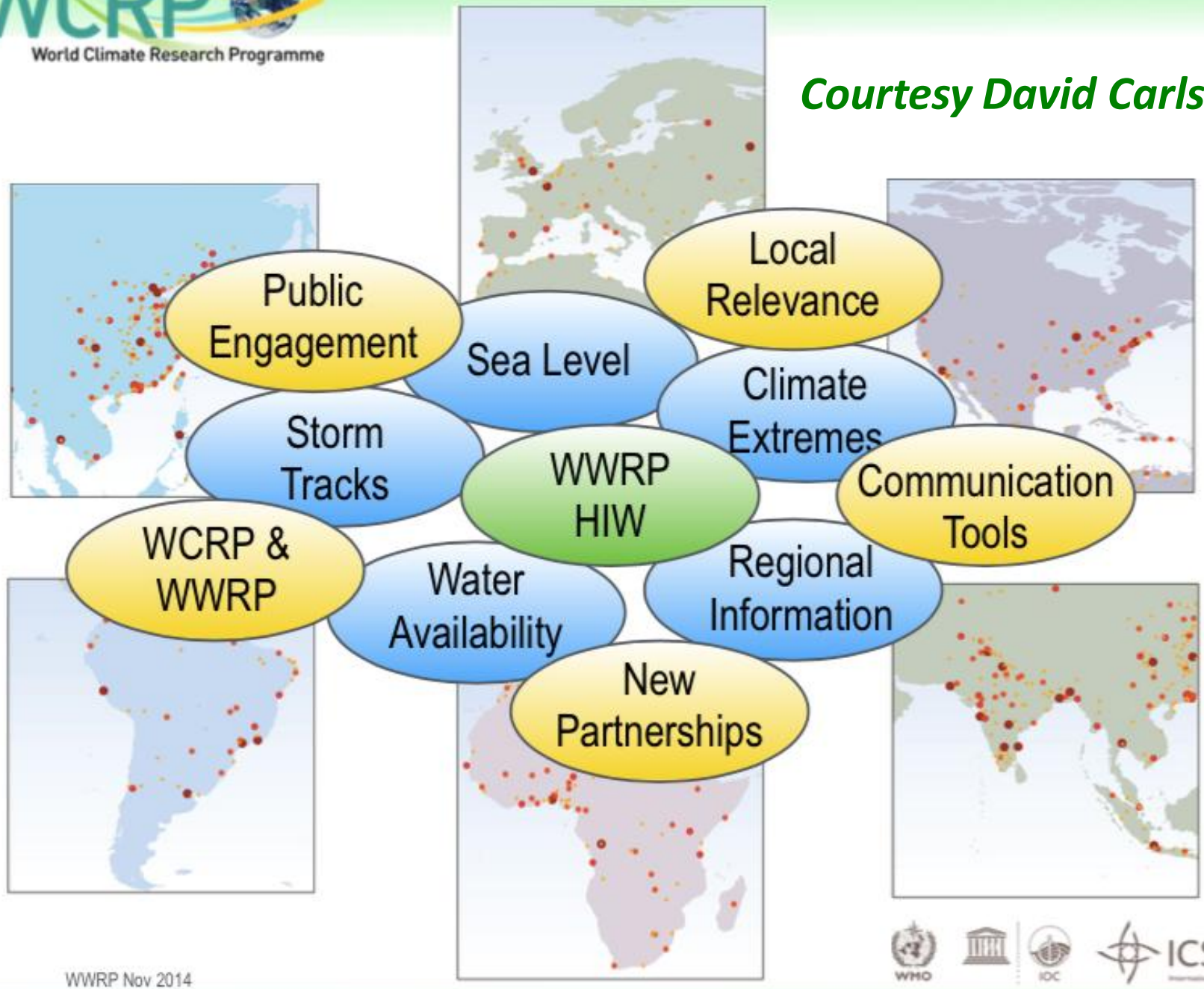


Massive data assimilation and integration challenge

Courtesy David Carlson

World Climate Research Programme

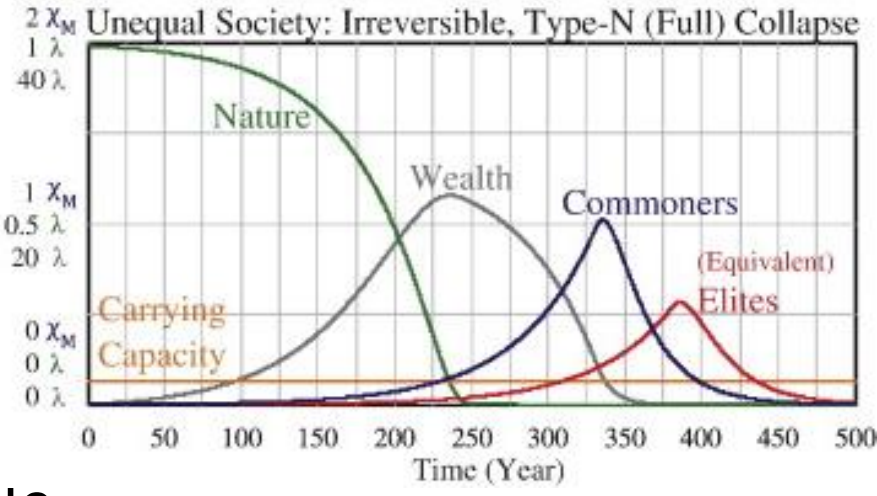
Courtesy David Carlson



HUMAN – NATURE DYNAMICS – HANDY

Ecological Economics, S. Motesharrei, J. Rivas, E. Kalnay 2014

- Conceptual **4-var. model**: Nature, Wealth, Poor, Rich
  - 10 parameters based on Predator – Prey model
    - E.g., "Carrying Capacity" – maximum Population Nature can sustain
  - One of very few "**quantitative**" analyses
- Study "**equilibrium**" btw human activities & nature
  - Long-term behavior, not short-term forecasting
- **Over-exploitation** of Poor or Nature results in **collapse**
- **Policies critical for staying in equilibrium space** where
  - Sustainable steady state possible

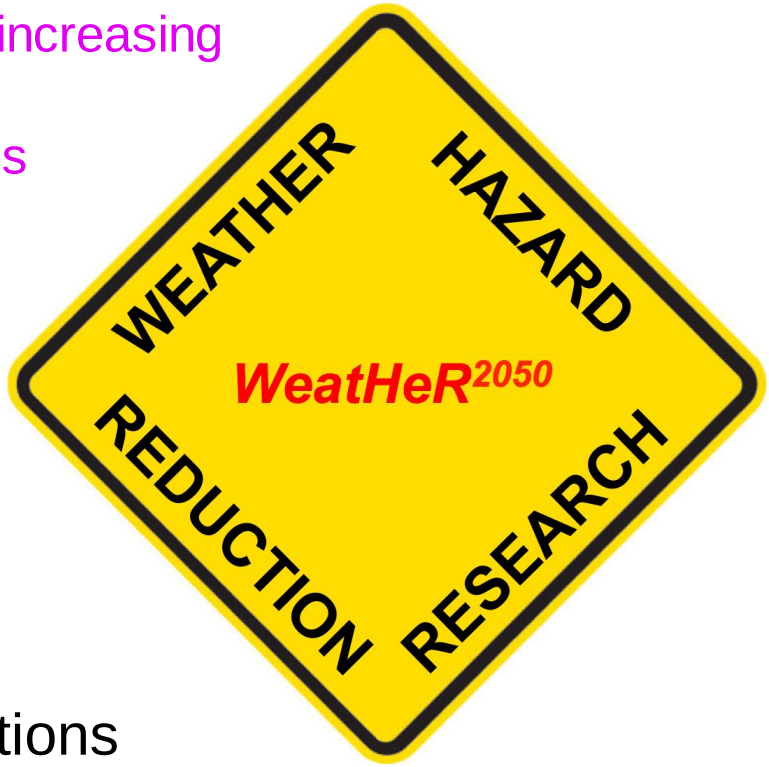


POTENTIAL RESEARCH PROJECT:

WEATHER HAZARD REDUCTION IN A CHANGING CLIMATE - 2050

Credits – David Carlson, Director, WCRP-WMO

- **Objective** - Develop & test new methods to
  - Predict and reduce multiple hazards amid increasing vulnerability due to changes in population, infrastructure, climate, and rising sea levels



- **Context** – Three major WWRP projects
  - Polar Prediction Project (PPP)
    - Polar – global interactions & predictability
  - Subseasobal to Seasonal (S2S) prediction
    - Extend predictability to weeks 3-4
  - High Impact Weather (HIWeather)
    - Impact (not only weather) forecasting
- **Approach** – Virtual experiment / simulations
  - Use global decadal prediction scenarios for ~ 2050
  - Downscale with regional / local models incl. hydrology/slosh etc models
  - Simulate weather, predictions, impact, Emergency Management / socioeconomic response

POTENTIAL RESEARCH PROJECT:

WEATHER HAZARD REDUCTION IN A CHANGING CLIMATE - 2050

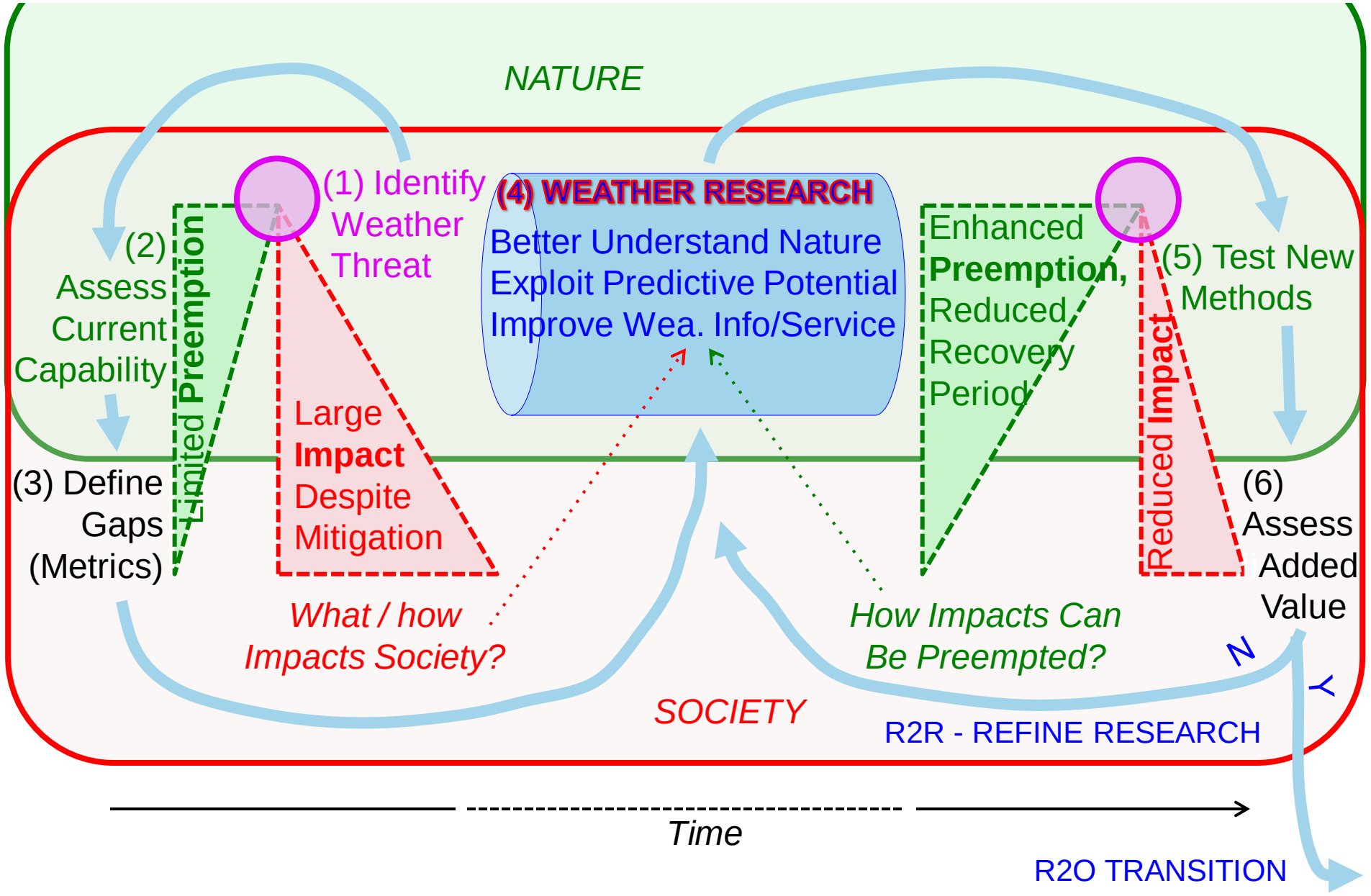
Credits – David Carlson, Director, WCRP-WMO

- **Implementation**
  - Choose vulnerable coastal megacity – eg, New York City (Hurricane Sandy)
    - Floods/inundation/water resource man., winds (aviation / RE), heat waves / AQ, winter storms, etc
  - Partner w climate change research
  - Engage & collaborate w regional stakeholders (public/private)
  - Move methods performing best in simulations into real operations
  - Measure impact of research both in simulated & real environment

- **Infrastructure** – Build on EarthCube cyberinfrastructure
  - General & modular design
- **Organization** – Joint WMO WWRP-CWRP Research Demo Project (RDP)
  - ESPC, CLIVAR, OSTP interests?
- **Outcome** – Research results *and* relocatable virtual lab system
  - Applicable in other US or international locales

PROJECT DESIGN – FROM RESPONSE TO PREEMPTION

SHIFT BALANCE FROM MITIGATION TO PREPARATION



WEATHER RESEARCH ENABLERS

- **Cyberinfrastructure** development
  - EarthCube – NSF community initiative
- **Community software approaches**
  - Code repositories, systems, environments, protocols, design
- **Opportunities**
  - R2O, USWRP, NASA, NSF, NRC, intl. engagement

EARTHCUBE

How to fit a sphere into a square?

- **Scope** - Develop / transform cyberinfrastrucure to
  - Better understand/predict the Earth system from Sun to center of Earth

- **Objective** - Data-enabled geosciences research
  - Interoperability across disciplines
  - Global data discovery and knowledge management
  - Data sharing & integration

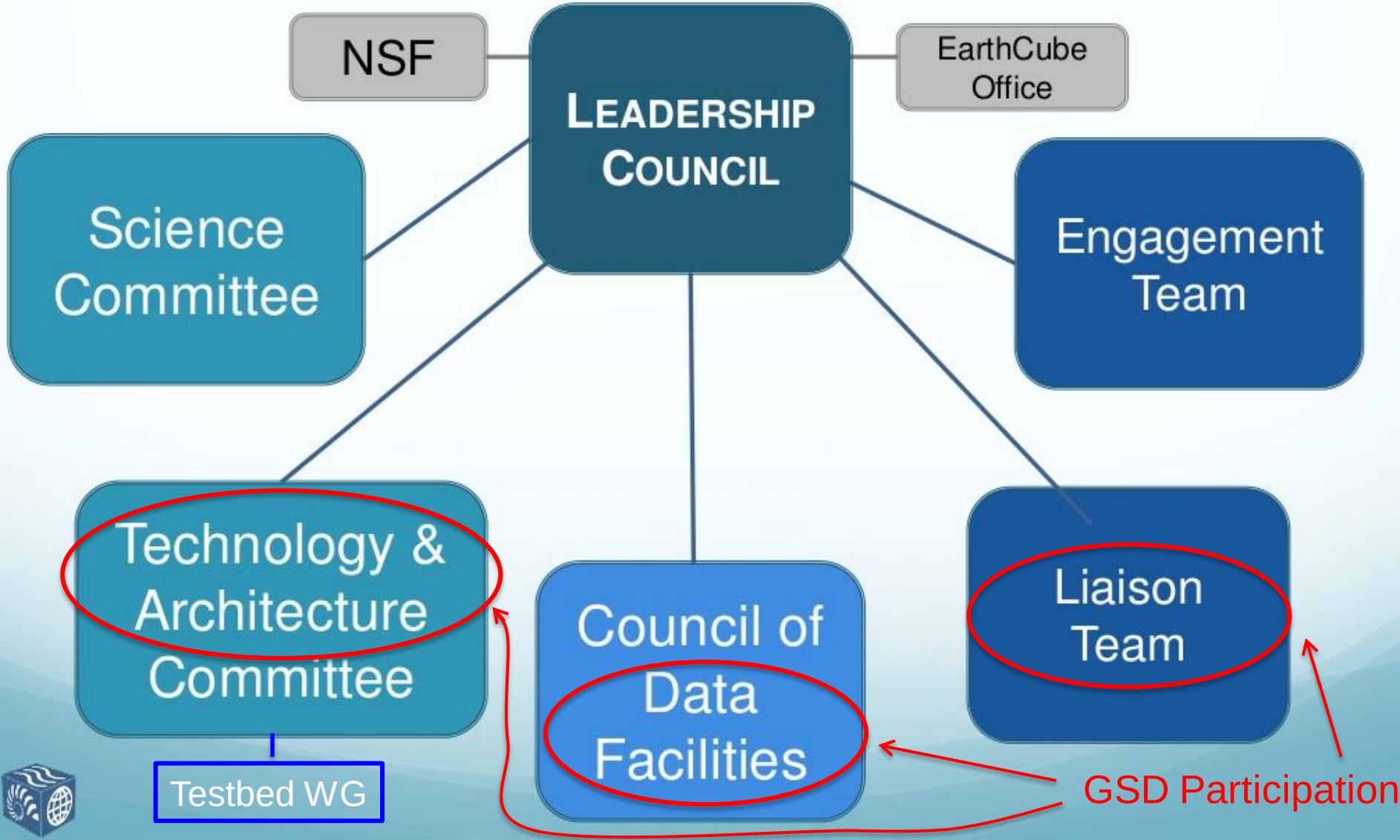
- **Approach** – 10-year NSF program started in 2011
  - Geosciences Directorate (GEO) & Division of Advanced Cyberinfrastructure (ACI)
  - Community of Earth, computer, & social scientists, educators, data managers

- **Accomplishments**
  - 25 domain workshops
  - Over 2,500 Community members
  - 27 funded projects
    - $25+ M project awards

Chris MacDermaid

EARTHCUBE ORGANIZATION

Chris MacDermaid



EARTHCUBE TESTBED

- **Objective** - Collaborative planning & testing of technologies

- **Approach** - Common ground for prototyping, testing & integration
  - Facilitate verification / validation of
    - Technologies, use cases, architecture design, components, scalability, interface specifications, & standards
  - Integrate separately funded EarthCube components / products

- **Outcome** - Demonstrate & showcase of EC technologies for
  - Science users, technologists, & broader geosciences community

Chris MacDermaid

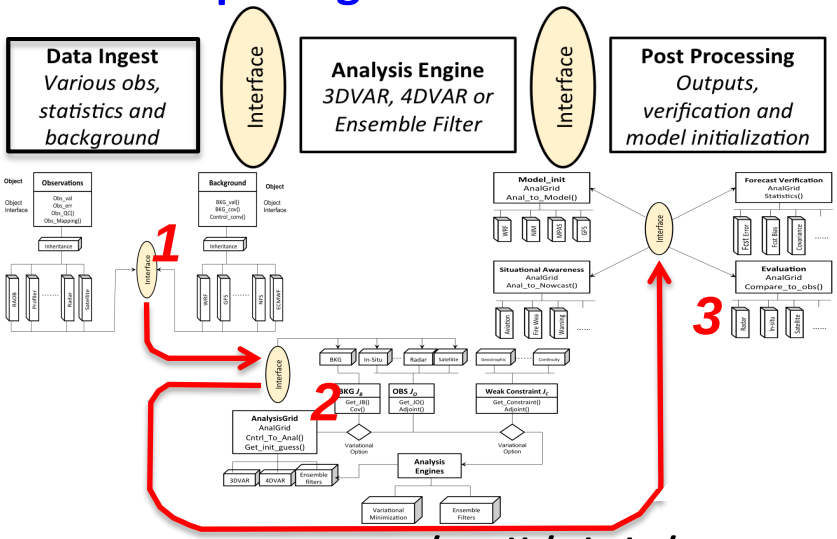
COMMUNITY SOFTWARE APPROACHES

- **Code repositories** – Easy access to software
  - WRF, HWRF, GSI, MET (Developmental Testbed Center)

- **Protocols for code development** – Connect diverse models / data
  - ESMF, NEMS, NUOPC, ESPS, Web Services, OpenMI, OpenClimateGIS

- **Community developed major systems**
  - Radiative transfer models
    - CRTM (JCSDA), RTTOV (Europe), RRTMG (WRF), G-SDSU (NASA)
    - Combine / modularize algorithms into **common package**?

- **Object Oriented Design** – Planned
  - OOPS (ECMWF), CDAR (US)

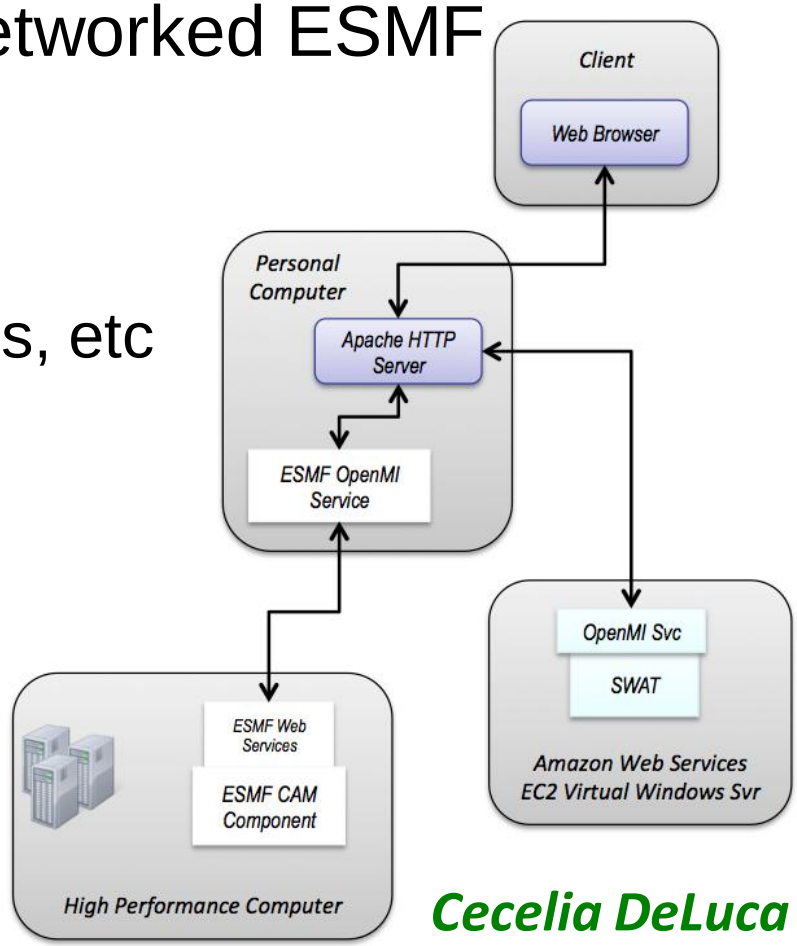


Yuanfu Xie

- **Collaboration environments**
  - Virtual Lab (VLab, NOAA) – http://www.nws.noaa.gov/mdl/vlab/
  - Earth System CoG (CU) - https://earthsystemcog.org/projects/cog/

CLOUD COMPUTING

- **Distributed models** / tools – Networked ESMF components
  - Physically / organizationally scattered
  - Widely different scales, disciplines, etc



- **Coupling via web services**
  - 1- or 2-way coupling of ESMF components

- **Applications** use network of models - NEMS
  - Atmosphere, land, hydrology run on their own grid
  - Web services invoke highly localized models
  - Link with EarthCube Testbed - Prototype by end of 2015

EARTH SYSTEM PREDICTION SUITE (ESPS)

- **Common modeling infrastructure**
  - U.S. weather, climate, & ocean modeling systems
    - ESMF compliant w NUOPC conventions

Cecelia DeLuca

- **Current components**
  - Coupled system
  - Atmosphere, ocean, wave, sea ice

Coupled Modeling Systems							
	NEMS	CFSv3	COAMPS / COAMPS-TC	NavGEM-HYCOM-CICE	GEOS-5	ModelE	CESM
					2015	2015	2015
Atmospheres							
GFS/GSM							
NMMB							
CAM							
FIM	2015						
GEOS-5 FV					2015		
ModelE Atm							
COAMPS Atm							
NavGEM							
NEPTUNE							
Oceans							
MOM5							
HYCOM						2015	
NCOM							
POP							
Ice							
CICE					2015	2015	
Wave							
WW3	2015		2015		2015		2015
SWAN							

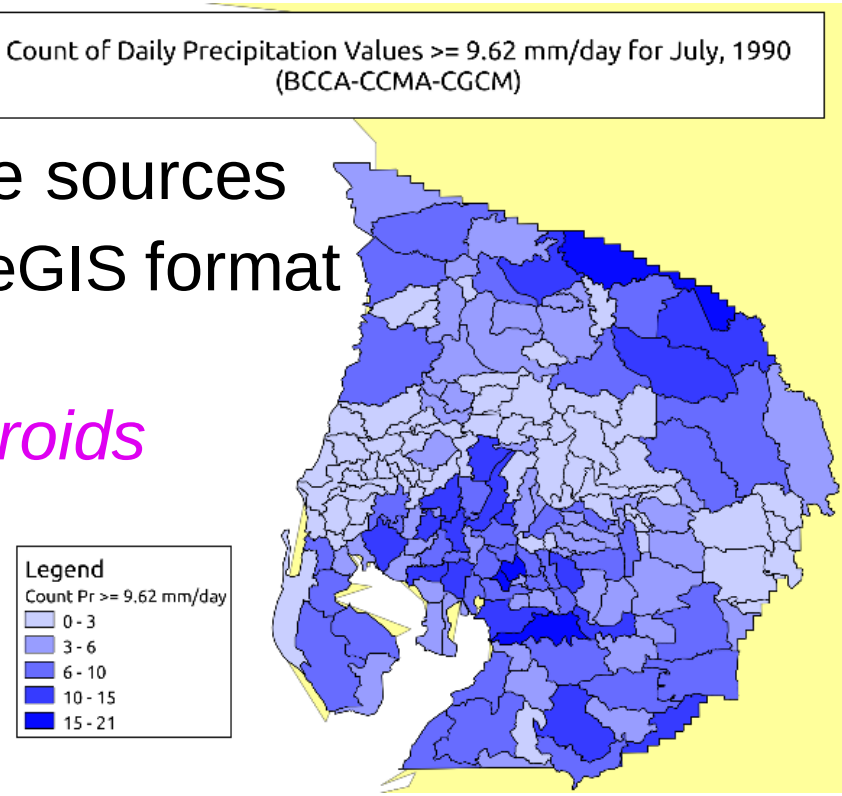
LEGEND: Compliant; (Completion date); In progress

- **Target systems**
  - NOAA - NEMS, CFSv3, MOM5
  - US Navy – NavGEM – HYCOM - CICE, COAMPS (- TC)
  - NASA - GOES-5, ModelIE

DATA ACCESS

- **Dynamic access** to
  - Multidiscipl. data from multiple sources
  - Convert native to OpenClimateGIS format
    - End-user analysis ready format

      Data manipulation on steroids
  - Being integrated into ESMF



- **Earth System Documentation** – ES-DOC
  - Metadata standard to describe Earth system models
    - For better understanding & use of output data
  - Customizable questionnaire creates documentation
  - View, search, compare models
  - International effort w NOAA participation

Cecelia DeLuca

OPPORTUNITIES

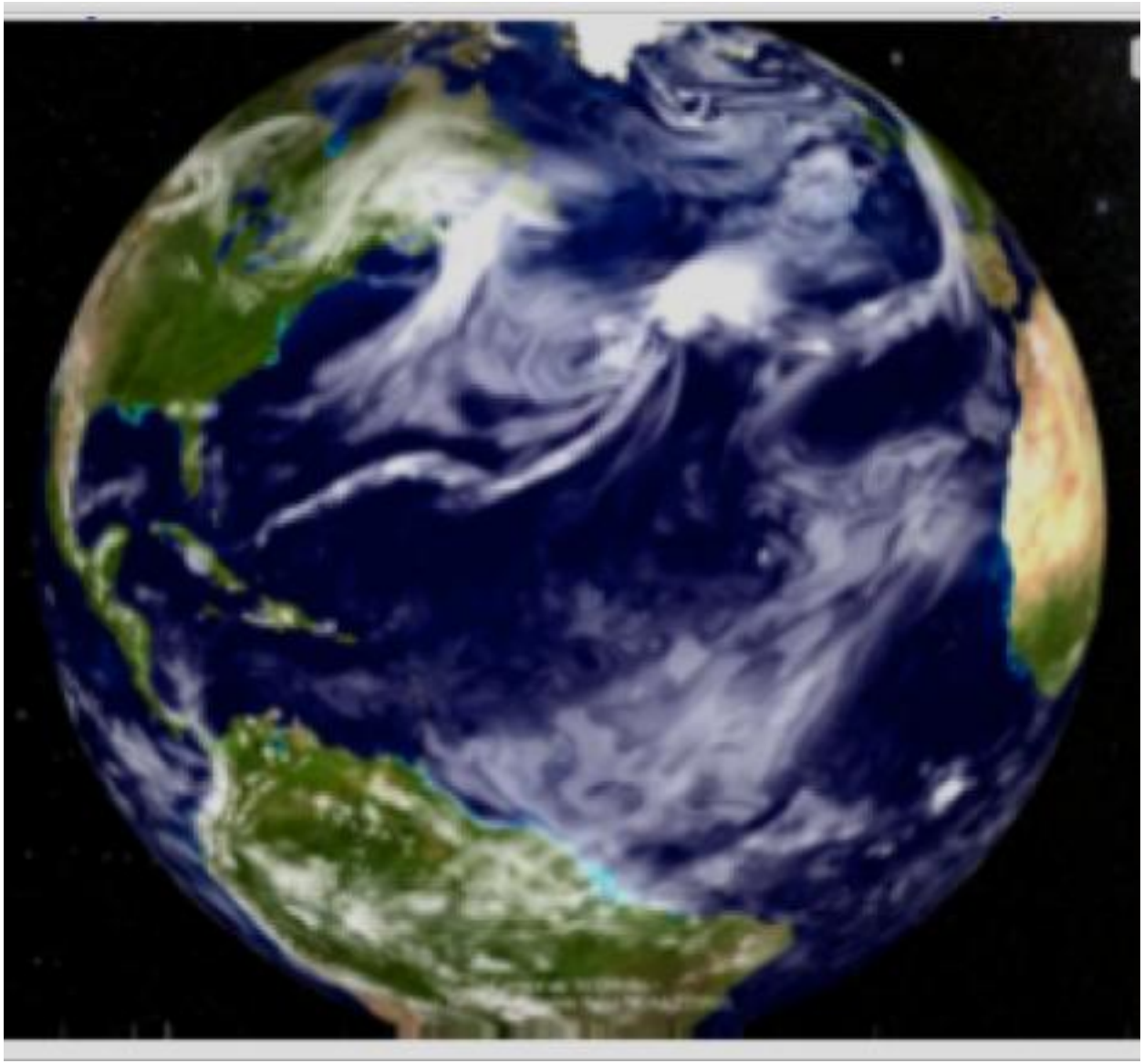
- **USWRP** – OAR, linked w NOAA Testbeds
- **R2O** – NWS, next generation operational systems
- **NASA Roses** – Remote sensing
- **NSF** – EarthCube, Earth sciences research
- **NRC Associateship**
  - Lab Program Rep (LPR) – Zoltan
  - Guidelines for Advisers:
    - http://sites.nationalacademies.org/PGA/RAP/PGA_056238
  - Adviser Information (special steps for CI advisors)
    - http://sites.nationalacademies.org/PGA/RAP/PGA_046588
- **International example** - Germany
  - Waves to Weather – Collaborative Research Center Proposal
    - Multiscale processes shaping local weather

OUTLINE / SUMMARY

- **THORPEX accomplishments** – Adaptive methods
  - Targeted observations
  - Ensemble-based background covariance
  - Ensemble-based probabilistic forecasts
- **New WWRP projects**
  - Polar Prediction Project (PPP)
  - Sub-Seasonal to Seasonal Prediction Project (S2S)
  - High Impact Weather Project (HIWeather)
- **US engagement**
  - Agencies – Community initiative
    - Weather Hazard Reduction in Changing Climate?
- **Enablers**
  - EarthCube
  - Announcements of Opportunities

~ 30,000 k NEIS VIEW OF PLANET EARTH

The fitting of a sphere into a square

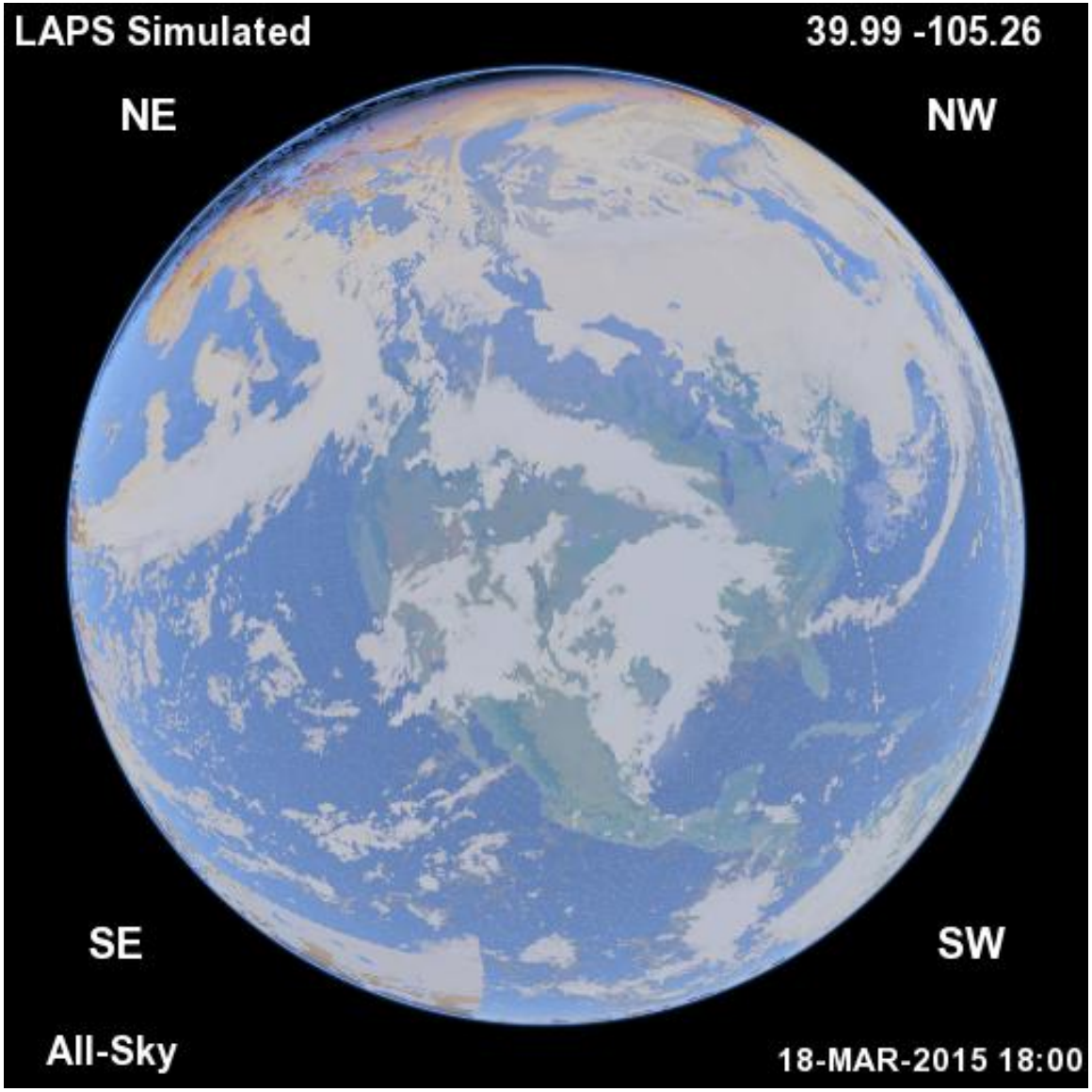


Courtesy
Stan Benjamin

BACKGROUND

~ 30,000 k SIMULATED VIEW OF PLANET EARTH THROUGH 3D GLOBAL CLOUD ANALYSIS

The fitting of a sphere into a square



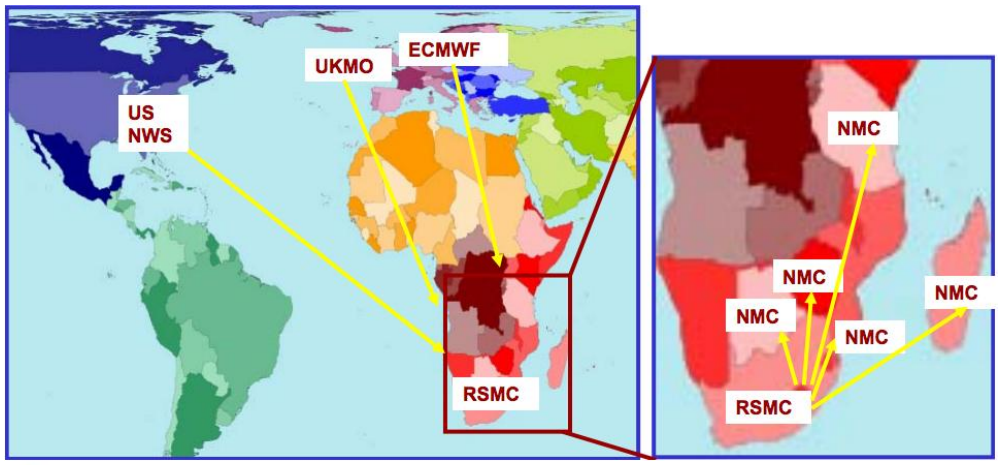
Simulation via Radiative Transfer Model developed at GSD

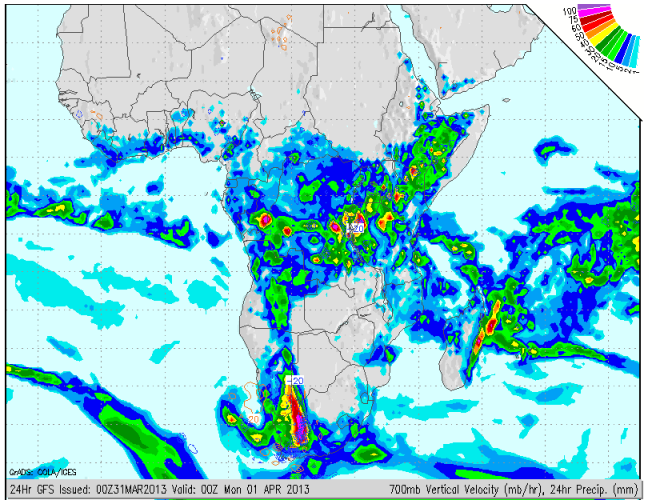
Courtesy
Steve Albers

Severe weather demonstration project

- Cascading forecasting process, from global to national level.
- Southeastern Africa, 5 countries involved, Regional Center in Pretoria
- Related research topics: nowcasting, mesoscale modeling, radar meteorology, assimilation in mesoscale models.

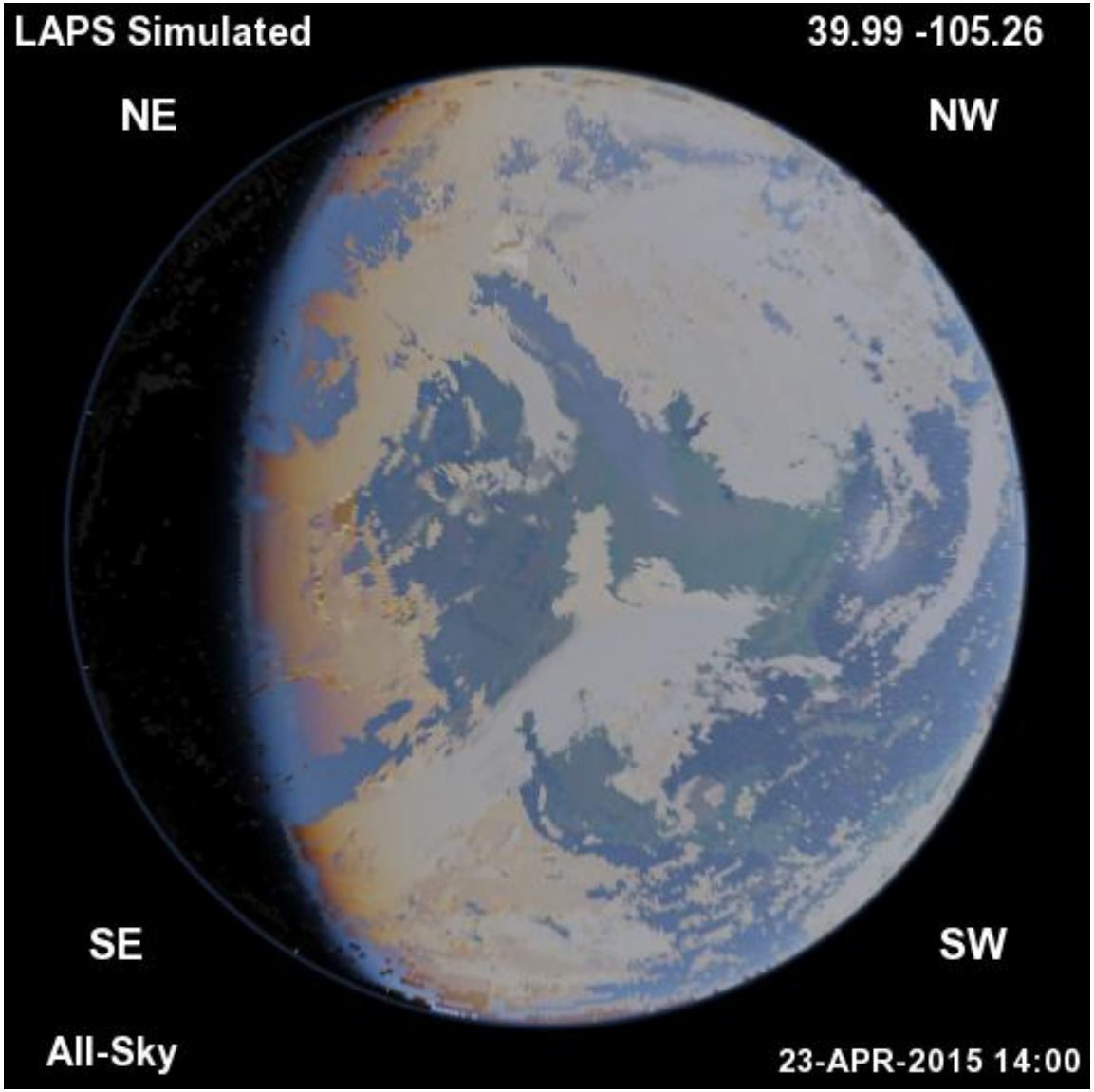
Recommendation: better coordination between national NHMCs and regional specialized centers in order to coordinate also research activities.





~ 30,000 k SIMULATED VIEW OF PLANET EARTH THROUGH 3D GLOBAL CLOUD ANALYSIS

The fitting of a sphere into a square

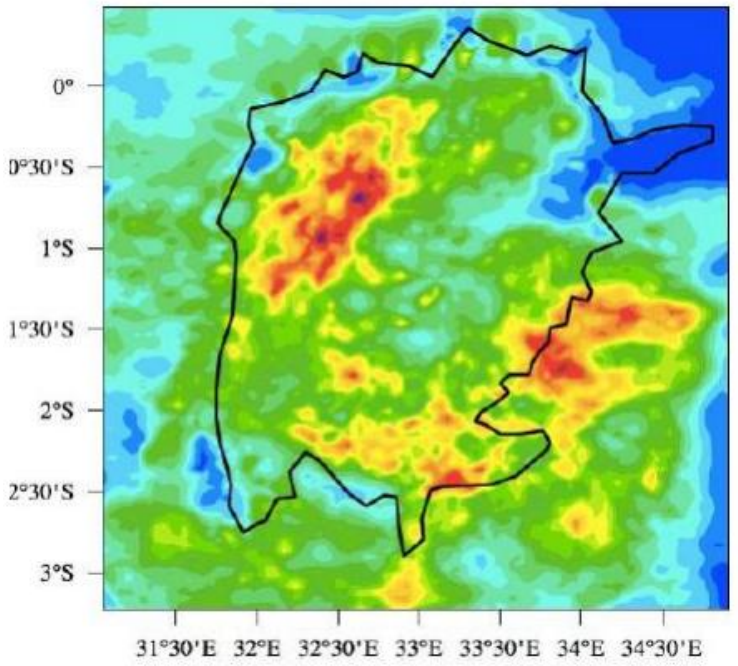


Simulation via Radiative Transfer Model developed at GSD

Courtesy
Steve Albers

Lake Victoria research priorities

- Develop a nowcasting system based on high-resolution modeling and satellite data
- Perform a case study for the Lake Victoria with a verification phase
- Prepare guidelines for operations



Recommendation:

- better collaboration between Universities and NMHSs must be established in the region
- partnership with the countries inside and outside of the region should be improved with higher responsibilities taken by RA I countries

COMMUNITY DATA ASSIMILATION

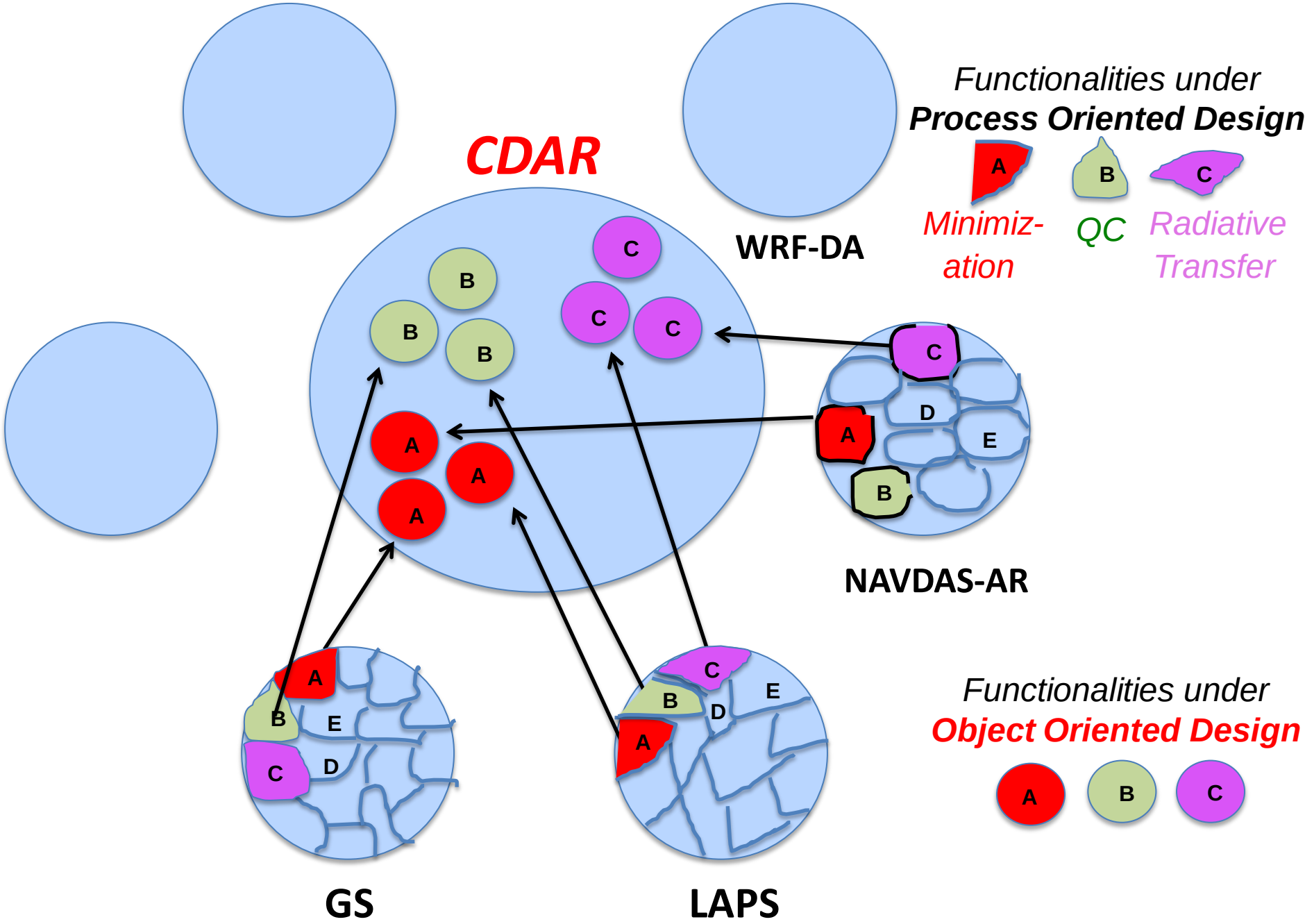
- Distinguish btw science algorithms vs software engineering – SE

- Handful of major systems – GSI, WRFDA, LAPS, DART, NAVDAS-AR, etc
  - Connected on algorithm level
  - Disjoint on software level – separate repositories
  - Major impediment for R&D, R2O, and Operations

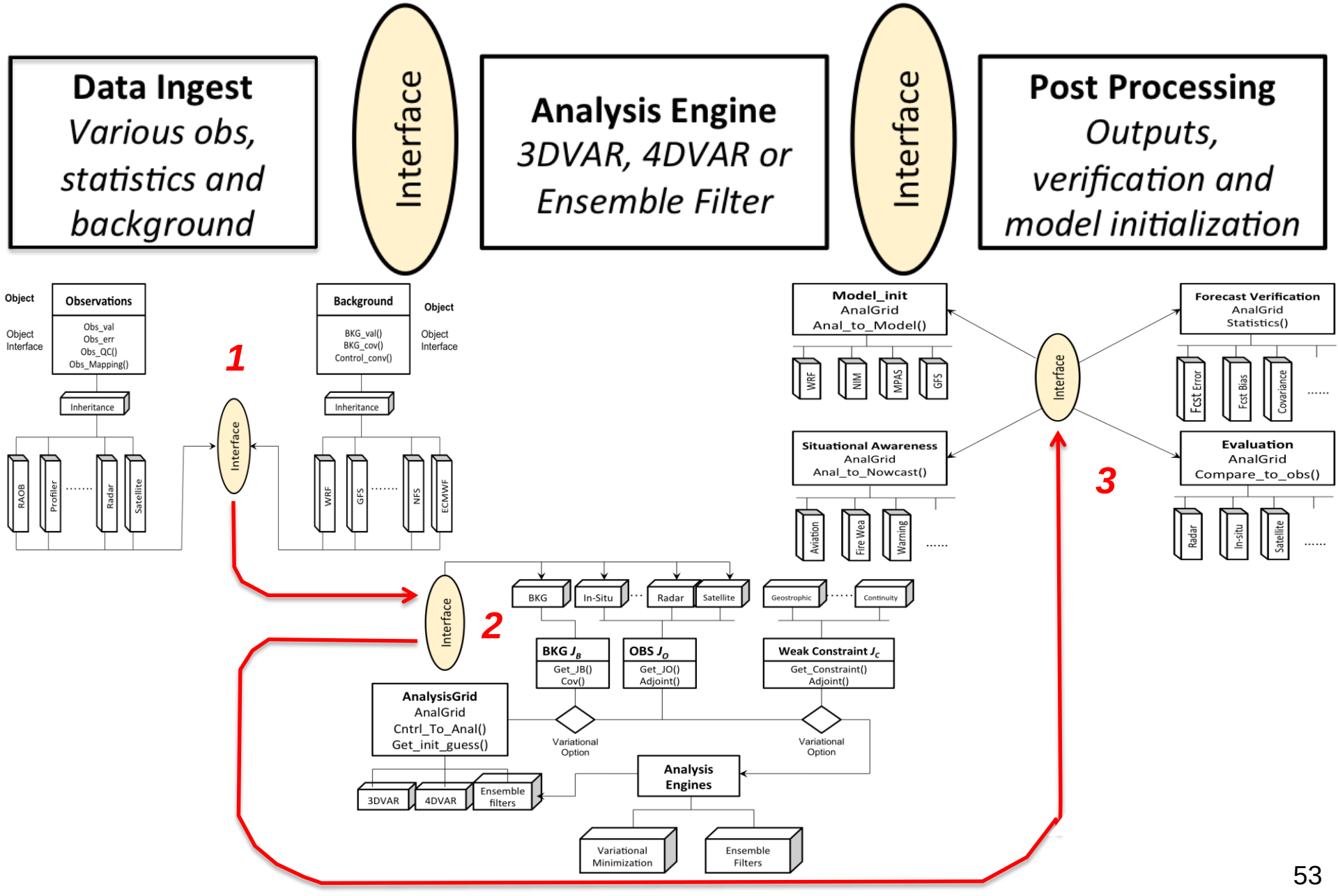
- Community Data Assimilation Repository – CDAR (BAMS ms)
  - Invite DA community to discuss & adopt Object Oriented Design

- Benefits
  - Software-level interactions among DA groups – faster R&D
  - More direct R2O
  - Much wider selection of algorithms to tailor to each
    - Application
    - Operational suite

COMMUNITY DATA ASSIMILATION REPOSITORY (CDAR)



DA - OBJECT ORIENTED DESIGN



RADIATIVE TRANSFER MODELS

For display, data assimilation, numerical modeling

- **LAPS** package – Albers 2015
  - Physically based
    - With empirical simplifications for speed
  - Vantage point / view
    - Looking in any direction from above, within, below atmosphere
  - Light source – Sun, Moon, stars, artificial light – Day & Night
  - Parallax correction – Important for fine scales

- **CRTM**
  - Strong on IR & Microwave, visible more recently added
  - Designed for Satellites and Aircraft looking downward

- **RRTMG** (in WRF)
  - Irradiance (integrated radiance) at gridpoints

- **Goddard Satellite Data Simulator Unit (G-SDSU)**
  - Easier to parallelize
  - Radar included
  - GOCART aerosol Microphysics included

- Combine / modularize algorithms into **common package**?
  - Ongoing discussion between CRTM – LAPS developers

30k VIEW

"Humanity is like … people packed in an automobile which is traveling downhill without lights at a terrific speed and driven by a four-year old child. The signposts along the way are all marked 'Progress'"

Lord Dunsany, quoted in "Diet for a New America" by John Robbins

- Have we lost the breaks?
  - Acceleration not sustainable
  - At which curve may we lose control?

WHERE WE FAILED

- **Stakeholder Panel** never formed
  - Low funding level, less than expected impact
- US **coordination sub-optimal**
  - International engagement less productive
- R&D misses
  - **Optimal design of observing systems**
    - Evaluation, instead of design of observing systems
  - **DA for moist / finer scale processes**
  - Global Interactive Forecast System (**GIFS**)
    - Truly international probabilistic forecast effort
  - SERA research
    - Lack of funding
    - **Cost – benefit analysis** of new observing/DA/ensemble systems

OPPORTUNITIES

- Objective assessment of costs/benefits of weather research
  - **Articulate societal need for / potential of weather research**
- Coordinated national initiative
  - **Broaden coalition** - Engage more agencies
- R&D needs / gaps
  - **Global nowcasting** system
    - Cloud DA w remote observations
    - Non-hydrostatic, Earth System coupled forecasting
  - Decision support based on quantified forecast uncertainty
    - Forecasting **expected impact of weather** – not only weather

WHAT WE ACCOMPLISHED

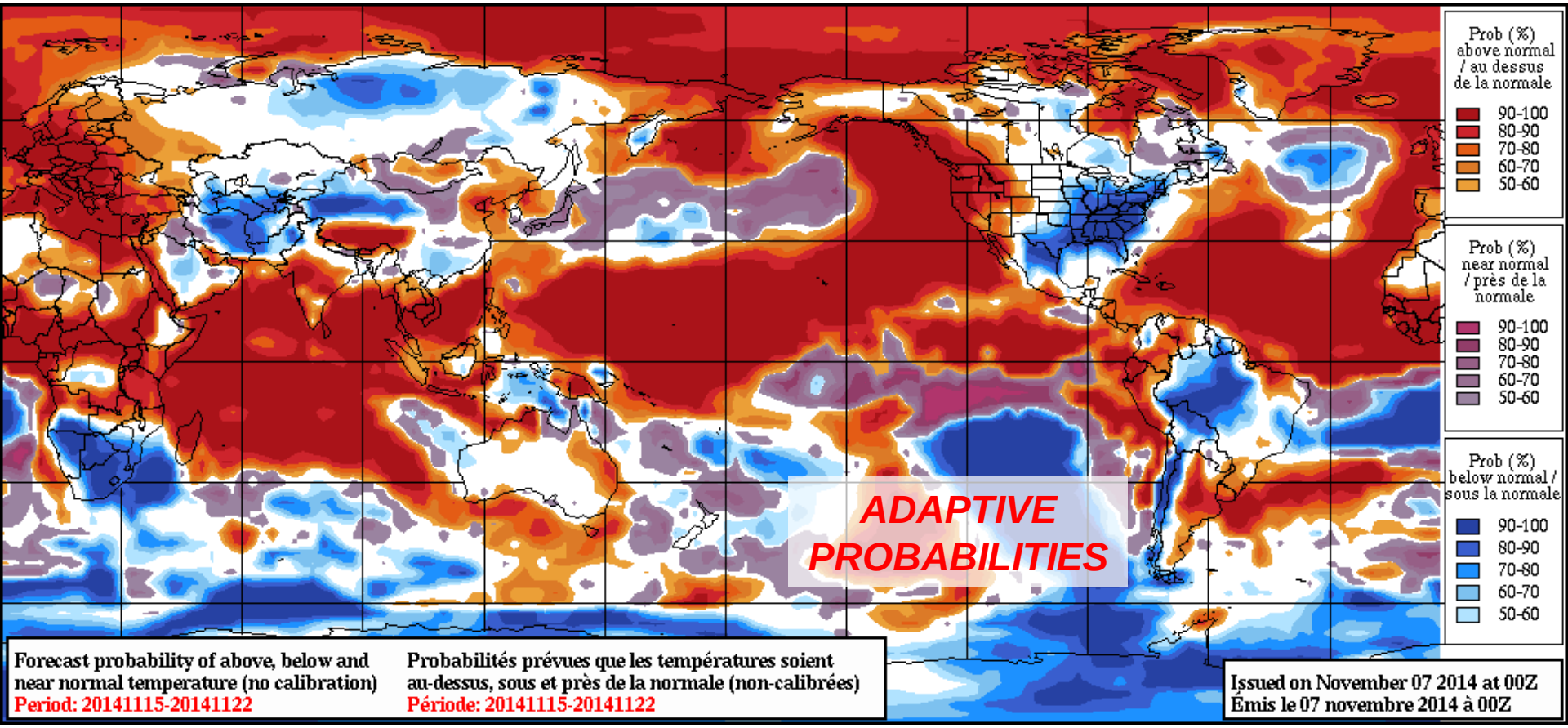
- Weather community became **more organized** / energetic
- **Dialogue between academia & operations**
- More attention to **use of forecasts**
- R&D & R2O accomplishments
  - Adaptive observational techniques
    - **Winter Storm Reconnaissance (WSR) program**
  - Ensemble-based DA / covariance in variational DA
    - **Hybrid GSI**
  - Multi-center ensemble system
    - **North American Ensemble Forecast System (NAEFS)**

US ENGAGEMENT IN INTERNATIONAL EFFORTS

- Major contributions to THORPEX
  - Leadership/membership in WGs
  - T-PARC, TIGGE, NAEFS, hybrid GSI, WSR

- Momentum maintained
  - Interim Interagency Weather Research Coordination Committee
    - NOAA, NSF, US Navy, with others invited (NASA, FAA, DOE, etc)
  - Interim Community Weather Research Planning Committee
    - Carolyn Reynolds & Sharan Majumdar as co-chairs

- Objectives of new initiative
  - Promote socio-economically relevant weather research
  - Coordinate US response to legacy & new international projects
  - Leverage by creating research infrastructure serving multiple needs


Prob (%) above normal / au dessus de la normale
90-100
80-90
70-80
60-70
50-60
Prob (%) near normal / près de la normale
90-100
80-90
70-80
60-70
50-60
Prob (%) below normal / sous la normale
90-100
80-90
70-80
60-70
50-60
ADAPTIVE PROBABILITIES
Forecast probability of above, below and near normal temperature (no calibration)
Period: 20141115-20141122
Probabilités prévues que les températures soient au-dessus, sous et près de la normale (non-calibrées)
Période: 20141115-20141122
Issued on November 07 2014 at 00Z
Émis le 07 novembre 2014 à 00Z


WEATHER
HAZARD
WeatHeR2050
REDUCTION
RESEARCH