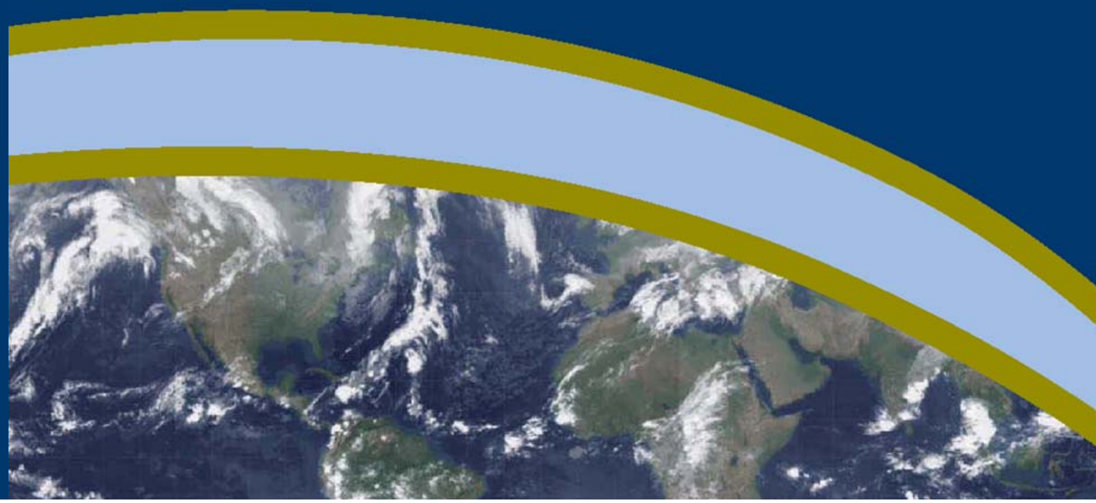
THORPEX
A World Weather Research Programme

TARGETED OBSERVATIONS FOR IMPROVING NUMERICAL WEATHER PREDICTION: AN OVERVIEW



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http://www.wmo.ch/pages/prog/arep/wwrp/new/documents/THORPEX_No_15.pdf

LIST OF CONTRIBUTORS

Sharanya J. Majumdar*, RSMAS, University of Miami, Miami, FL, USA

Sim D. Aberson, Hurricane Research Division, NOAA/AOML, Miami, FL, USA

Craig H. Bishop, Naval Research Laboratory, Monterey, CA, USA

Carla Cardinali, European Centre for Medium-Range Weather Forecasts, Reading, UK

Jim Caughey, World Meteorological Organization, Geneva, Switzerland

Alexis Doerenbecher, CNRM/GAME (Météo-France and CNRS), Toulouse, France

Pierre Gauthier, UQAM, Montreal, QC, Canada

Ronald Gelaro, NASA Goddard Space Flight Center, Greenbelt, MD, USA

Thomas M. Hamill, Physical Sciences Division, NOAA/ESRL, Boulder, CO, USA

Rolf H. Langland, Naval Research Laboratory, Monterey, CA, USA

Andrew C. Lorenc, United Kingdom Meteorological Office, Exeter, United Kingdom

Tetsuo Nakazawa, World Meteorological Organization, Geneva, Switzerland

Florence Rabier, CNRM/GAME (Météo-France and CNRS), Toulouse, France

Carolyn A. Reynolds, Naval Research Laboratory, Monterey, CA, USA

Roger Saunders, United Kingdom Meteorological Office, Exeter, United Kingdom

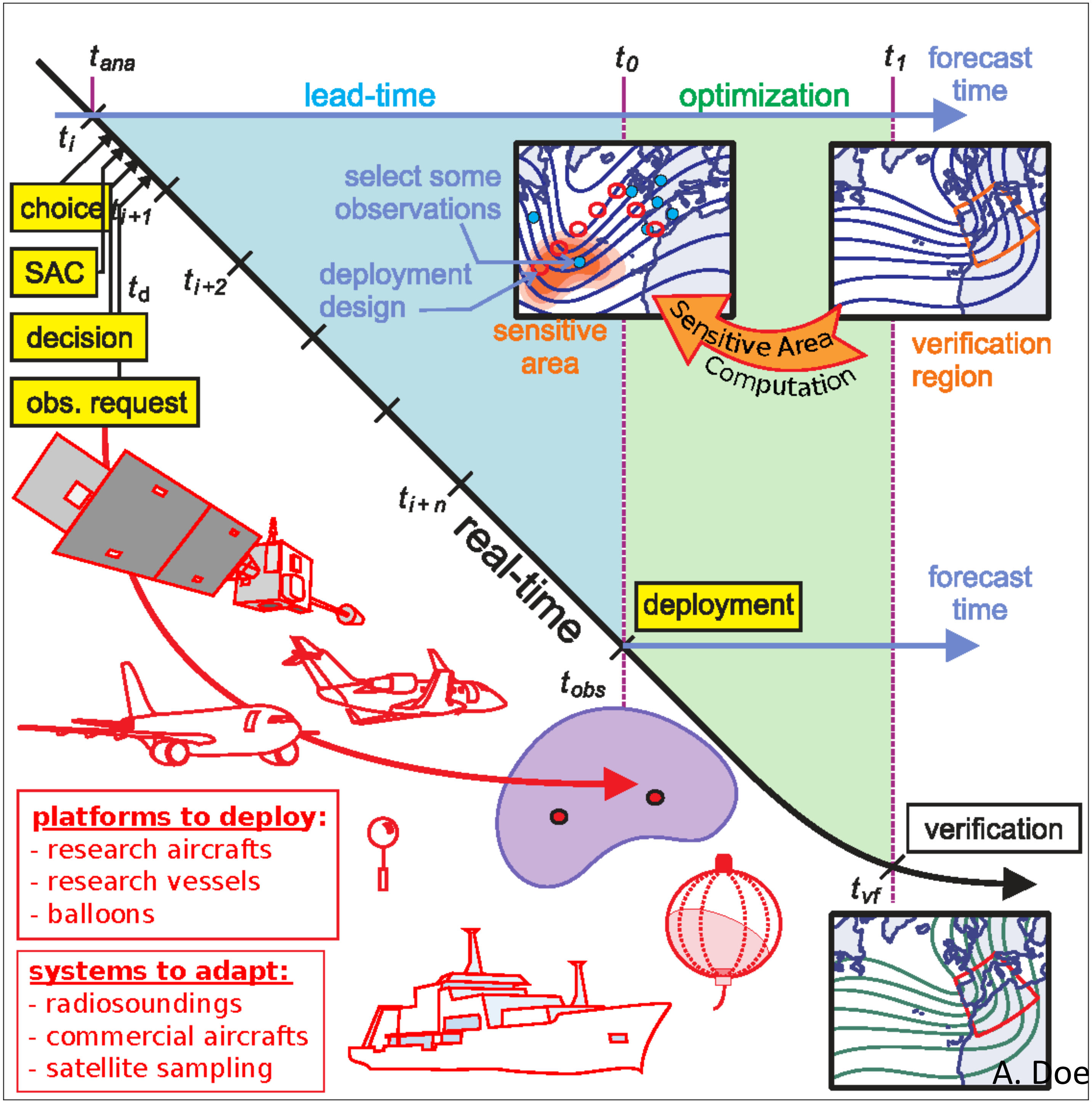
Yucheng Song, Environmental Modeling Center, NOAA/NCEP, Camp Springs, MD, USA

Zoltan Toth, Global Systems Division, NOAA/ESRL, Boulder, CO, USA

Christopher Velden, CIMSS / University of Wisconsin, Madison, WI, USA

Martin Weissmann, Meteorologisches Institut, Ludwig-Maximilians-Universität, Munich, Germany

Chun-Chieh Wu, National Taiwan University, Taipei, Taiwan



A. Doerenbecher

Pre-THORPEX and Independent Field Campaigns

Winter storms and tropical cyclones

Experiment	Period and Sample	Cases of Interest	Techniques used	Targeted Observations
NOAA Synoptic Flow	1982-1996. 21 expts	Tropical cyclone track	None	NOAA P-3 aircraft
NOAA Hurricane Synoptic Surveillance	1997 – pres. 214 cases up to and including 2010.	12-60 h forecasts of tropical cyclone track, mostly in Atlantic Basin.	Subjective; Ensemble variance of 850-200 hPa layer mean wind.	NOAA G-IV and USAF C-130 aircraft.
Fronts and Atlantic Storm Track Experiment (FASTEX)	Jan-Feb 1997. 19 intensive observing periods.	Life cycle of mid-latitude cyclones. Targeting 1-3 day forecasts.	Adjoint, Singular Vectors, Ensemble Transform.	Aircraft based in Ireland and North America, ships, soundings, surface and satellite.
North Pacific Experiment (NORPEX-98)	Jan-Feb 1998. 27 days; 38 missions	1-3 day forecasts of Pacific winter storms over Canada, United States & Mexico.	Ensemble Transform; Singular Vectors.	~700 dropwindsondes. Winds from geostationary satellites.
California Land-Falling Jets Experiment (CALJET)	Jan-Mar 1998.	0-12 h forecasts of winter storms.	Ensemble Transform; Singular Vectors.	NOAA P-3 aircraft.
NOAA Winter Storm Reconnaissance (WSR)	Jan-Mar, 1999-pres. 20-30 cases per year.	1-5 day forecasts of winter weather over North America.	Ensemble Transform Kalman Filter (ETKF)	NOAA G-IV aircraft and USAF C-130s based on Alaska and Hawaii. Since 2009, G-IV stationed in Japan.
Dropwindsonde Observations for Typhoon Surveillance near the Taiwan Region (DOTSTAR)	Annual, 2003 – present. 51 cases up to 2010.	1-4 day forecasts of tropical cyclone track in the western north Pacific basin.	Subjective sampling & ensemble variance, ETKF, and ADSSV	ASTRA aircraft stationed in Taiwan. 13-20 dropwindsondes per mission.

Field campaigns related to THORPEX (2003-)

Experiment	Period	Cases of Interest	Techniques	Targeted Observations
A-TReC	Oct-Dec 2003.	1-3 day forecasts of high-impact weather.	Energy and Hessian SVs, Adjoint, ETKF	Dropwindsondes; rawinsondes, drifting buoys, AMDAR, airborne Doppler Wind Lidar, rapid-scan AMVs.
AMMA (THORPEX component)	August 2006.	1-3 day forecasts of African weather, AEWs.	Adjoint, ETKF	Rawinsondes over Africa. Dropwindsondes launched from driftsonde gondolas for validation.
COPS/E-TReC	Jun – Aug 2007.	24-36 h forecasts of warm season precipitation.	Adjoint, SVs, ETKF	DWL, water vapor lidar, dropwindsondes. EUCOS rawinsondes and enhanced AMDAR.
GFDEx	Feb – Mar 2007.	1-2 day forecasts over northwest Europe.	SVs, ETKF	Additional rawinsondes, dropwindsondes from aircraft around southern Greenland and Iceland.
Eurorisk-PREVIEW	Feb – Dec 2008.	1-3 day forecasts over Europe.	SVs, ETKF	1402 Land Stations. 226 E-ASAP. 224 E-AMDAR.
International Polar Year / THORPEX	Spring 2008	1-2 day forecasts over Scandinavia, polar lows.	SVs, ETKF	Dropwindsondes released from aircraft.

Polar, mesoscale, rainfall, tropical weather …

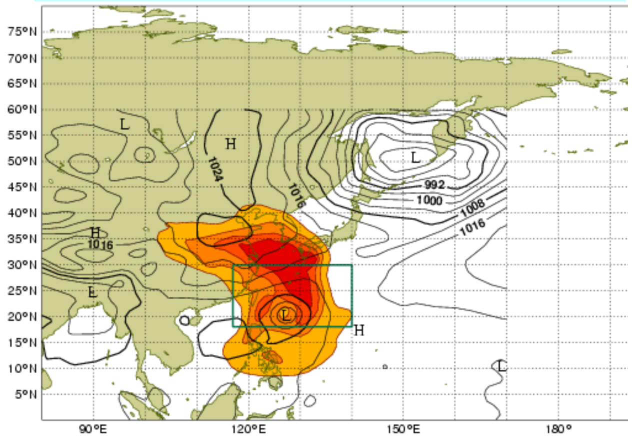
Field campaigns related to THORPEX (2003-)

T-PARC (Summer)	Aug-Sep 2008	1-4 day forecasts of TCs and their ET in the western North Pacific; a few non-TCs.	SVs, adjoint, ETKF, ADSSV, ensemble sensitivity	>1500 dropwindsondes. DWL and water vapor lidar. Rawinsondes, observations on research vessels, driftsondes, rapid-scan AMVs from geostationary satellite.
T-PARC (Winter)	Jan-Mar 2009	1-5 day forecasts of winter storms over N. America.	ETKF	Dropwindsondes from NOAA G-IV and USAF C-130 aircraft; extra rawinsondes over Russia; AMDAR.
DTS-MEDEX-2008	Sep – Dec 2008.	High-impact weather over Mediterranean.	Singular Vectors, ETKF	AMDAR, ~300 additional rawinsondes in Europe.
DTS-MEDEX-2009	Oct – Dec 2009.	High-impact weather over Mediterranean.	SVs, ETKF, KF Sensitivity	484 additional rawinsondes in Europe and Algeria; AMDAR.
Concordiasi	2010	Validate use of satellite sounder data over Antarctic.	Singular Vectors	640 dropwindsondes launched from 13 driftsondes, 25% being targeted. Single level data from 19 stratospheric balloons.

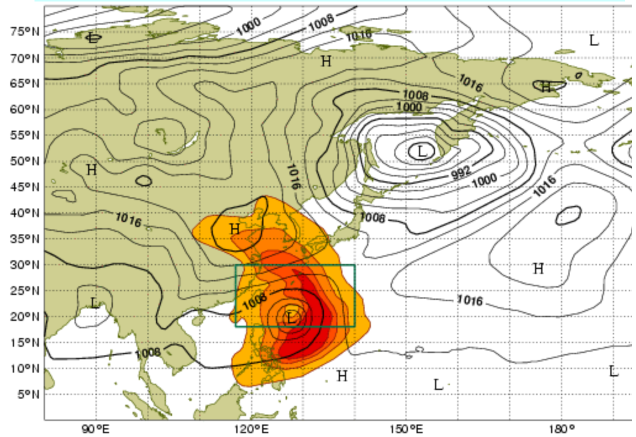
Polar, mesoscale, rainfall, tropical weather …

Targeted observing guidance (Typhoon Sinlaku, 2008)

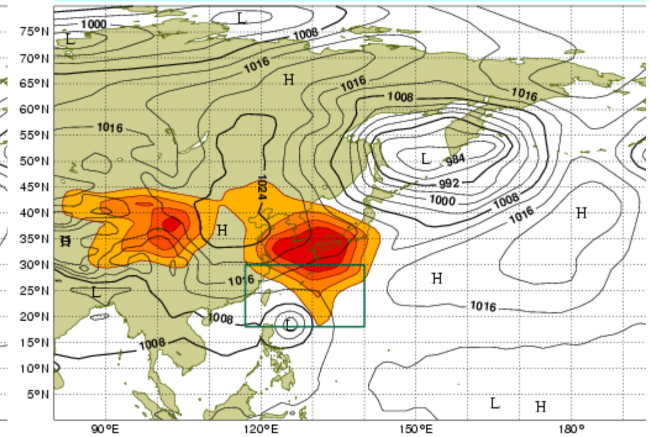
UYonsei MM5SV



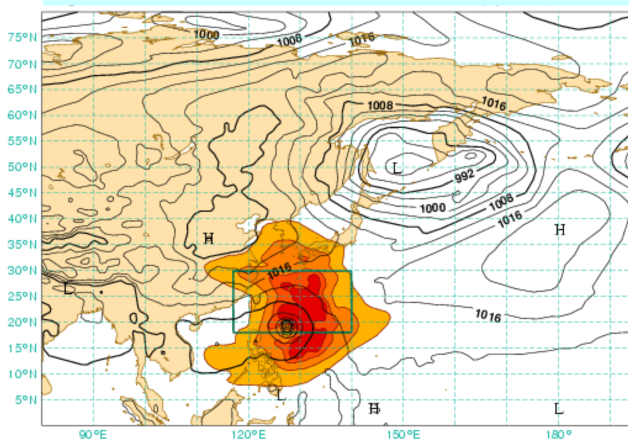
NRL SV



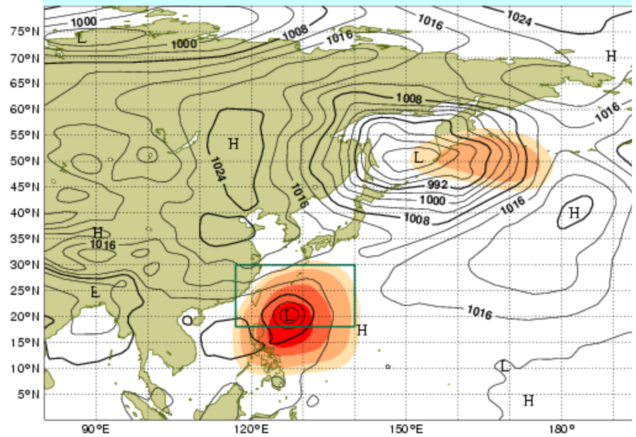
JMA SV



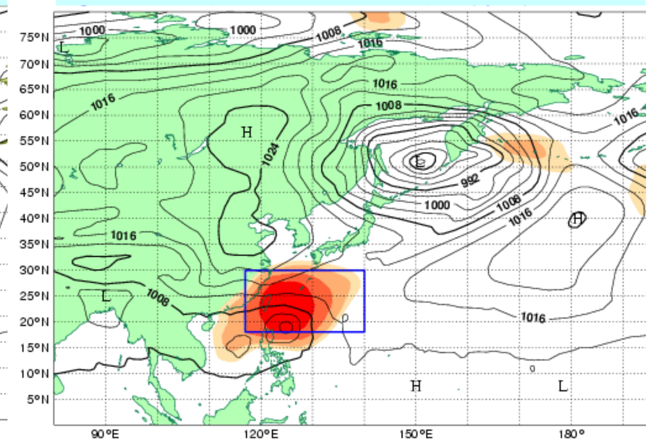
ECMWF SV

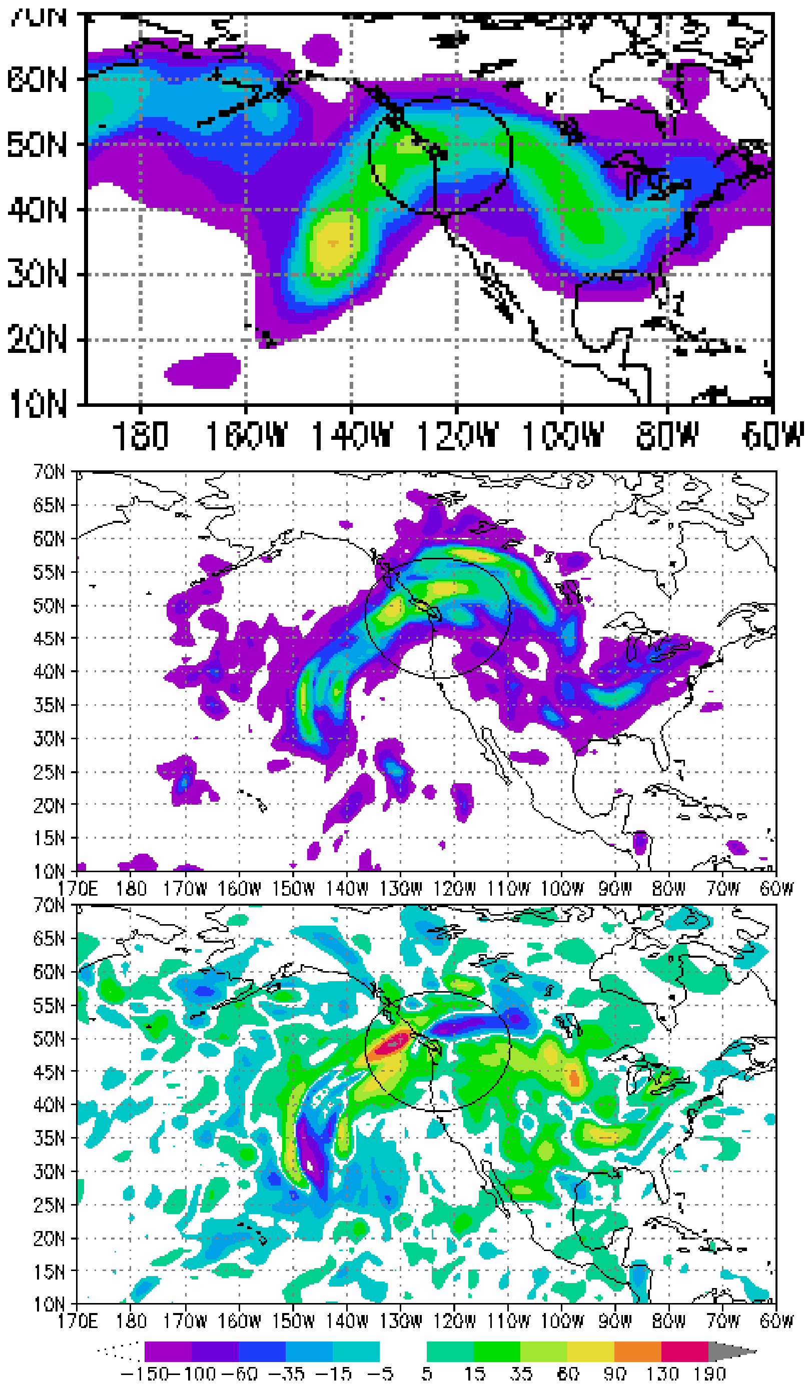


UMiami-NCEP ETKF



UKMO ETKF





ETKF predicted signal variance

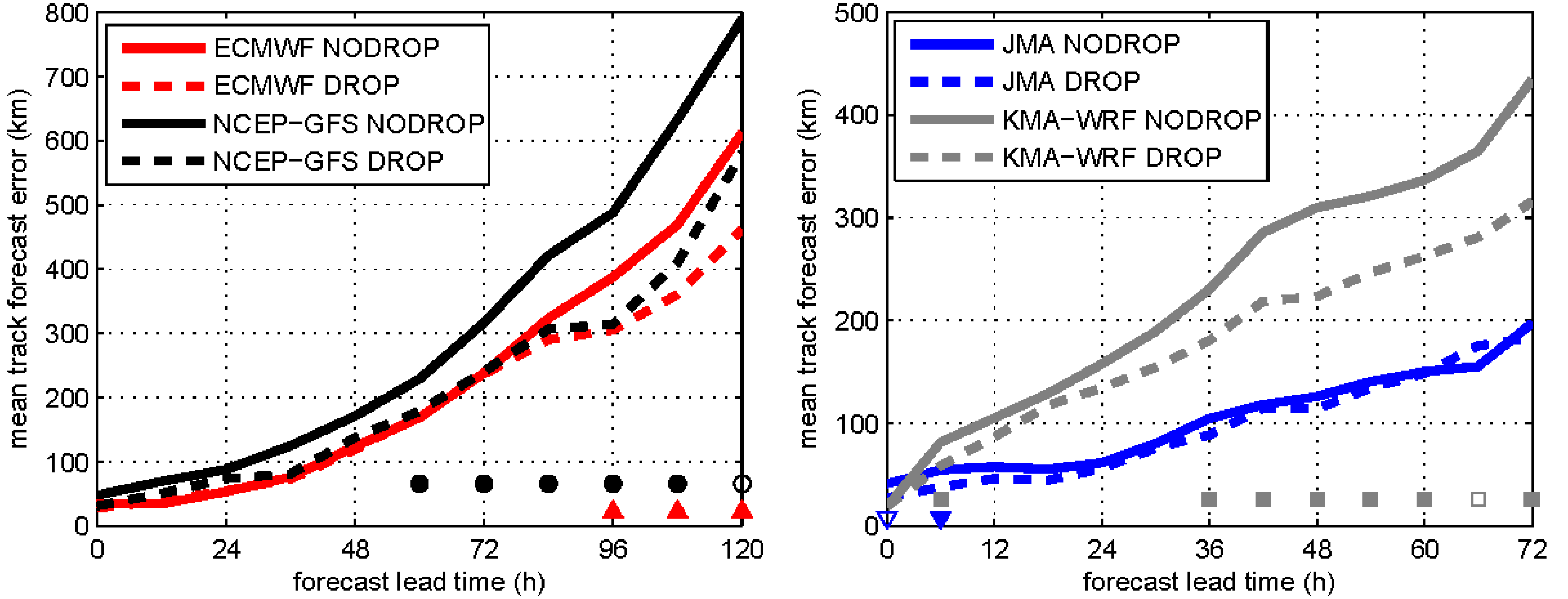
NCEP signal from targeted dropwindsondes

Forecast improvement

Majumdar et al. (2001)

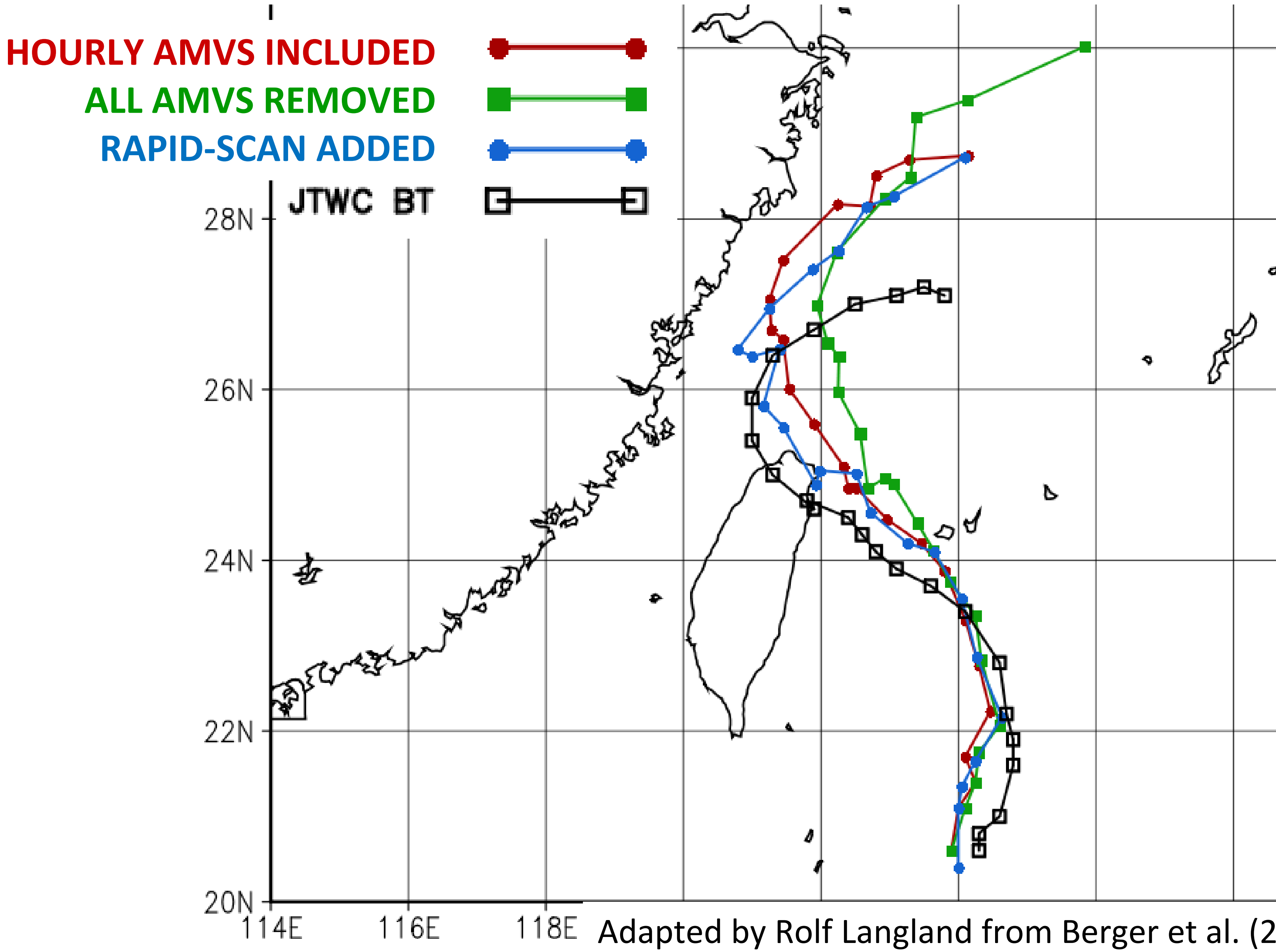
Evaluations

T-PARC Summer Phase (2008): Overall impact of dropwindsondes on TC track



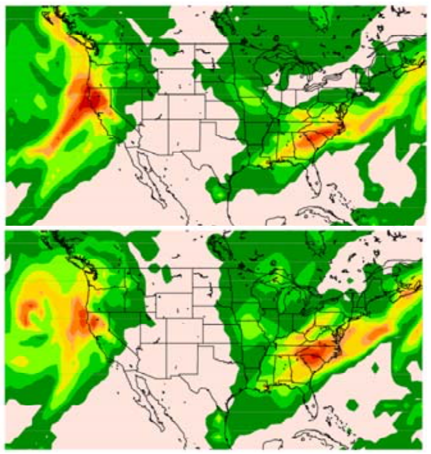
Weissmann et al. (2011)

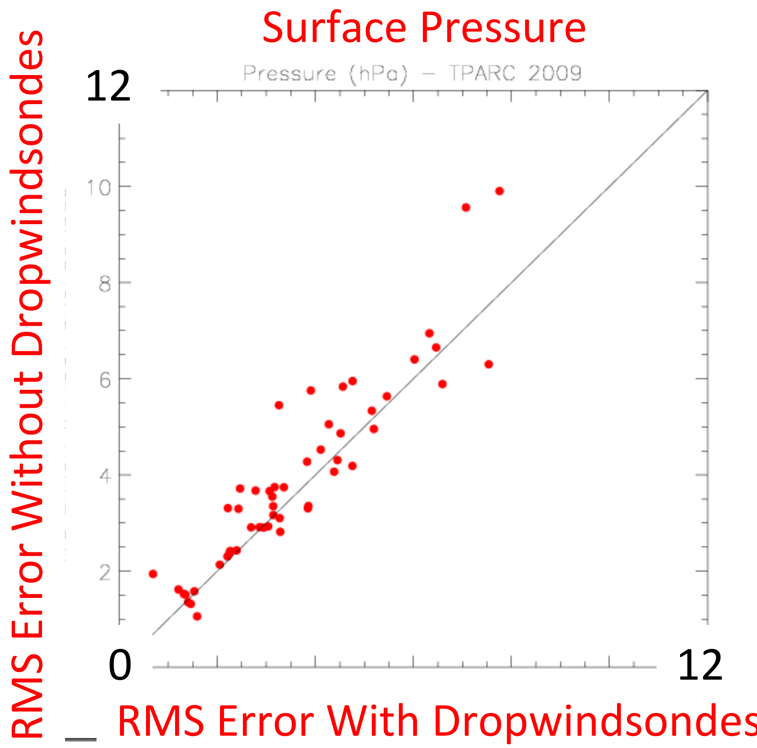
Typhoon Sinlaku(2008): Satellite AMVs



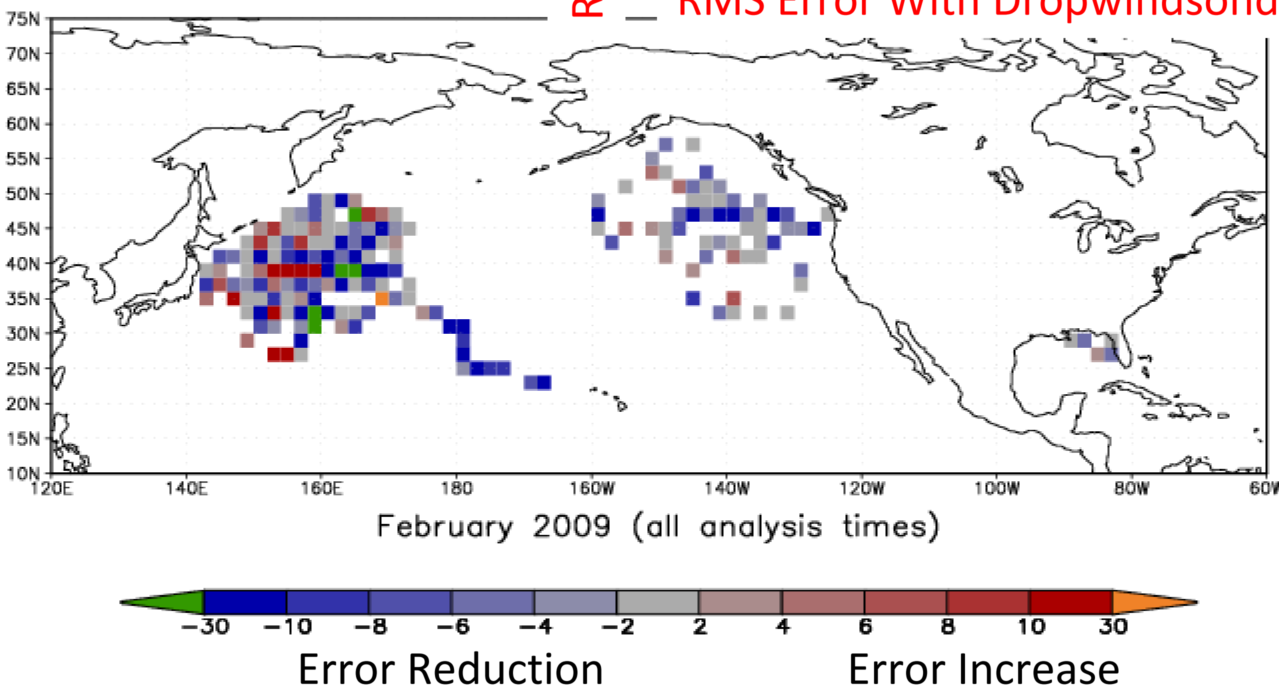
Adapted by Rolf Langland from Berger et al. (2011)

T-PARC Winter Phase (2009)





i. Observing Systems Experiments (OSEs)



ii. Adjoint-based impact of dropwind-sondes

i. Yucheng Song;
ii. Rolf Langland

Main results: Pre-THORPEX / Independent campaigns

Experiment	Main Results
NOAA Synoptic Flow	Mean errors in 12-60 h track forecasts in NOAA models reduced by 16-30%. Sample of 18 experiments in 11 Atlantic tropical cyclones.
Hurricane Synoptic Surveillance	10-15% average improvement in NCEP GFS track forecasts through to 60 h. Negligible improvements beyond 72 h. Minimal impact on GFDL forecasts. Sample of 176 missions, 1997-2006.
DOTSTAR	>14% average improvement in NCEP GFS, NOGAPS and JMA 1-3 day forecast track errors (10 cases in 2004). 10-20% average improvement in NCEP GFS 1-5 day track forecasts, with 60% of all cases improved (42 cases in 2003-9). Minor improvements and degradations in ECMWF.
FASTEX	Positive impact over Atlantic and Western Europe in short range (2 days or less). Around 10-15% for most modeling and assimilation systems.
NORPEX-98	Improved 2-day NOGAPS forecasts by 10% on average. Relatively small improvement in ECMWF.
WSR	RMS surface pressure errors during 1999 and 2000 reduced by 10-25% in low-resolution NCEP GFS. Approximately 70% of cases have been improved on average through the past decade of WSR programs.

Main results: THORPEX studies and campaigns

A-TReC	Small positive impact over large domains. Overall improvement in 32% of 38 forecasts using UKMO system. In ECMWF, forecasts of mean sea level pressure were improved (by at least 10%) in 24% of all cases. NOGAPS observation sensitivity showed the highest impact per observation to dropwindsondes.
AMMA-THORPEX	Large impact on analysis fields over Africa, and improvement of the precipitation in the first day of the forecast over central Sahel (with local degradation where the model is biased and observations are not many). Positive downstream impact over Europe at the 2-3 day range.
ECMWF studies	Removing SV-targeted observations over Pacific (Atlantic) reduces 2-day forecast errors of 500 hPa Z by 4.0% (2.0%). Increasing the radiance data density in SV-sensitive areas twice-daily improved forecasts at all levels, for forecasts up to 3-4 days in the southern hemisphere summer.
T-PARC (Summer)	20-40% improvement to NCEP GFS and KMA WRF track forecasts. Modest improvements to forecasts up to 3 days in ECMWF and JMA.
T-PARC (Winter)	75% of the 52 forecast cases of 1-5 days were improved. Magnitude of improvement to be determined.
Concordiasi	Reduction of error from dropsondes ~ that from Antarctica radiosondes.

Conclusions I

- Observations primarily targeted to attempt to improve short-range (1-3 day) forecasts.
- From OSEs:
  - Extratropics: value of targeted data small but positive on average, needs further evaluation
  - Tropical cyclones: track forecasts mostly beneficial statistically
- Benefit differs from model to model.
- Range of aircraft a limiting constraint.
- Targeted satellite data shows promise.

Conclusions II

- Adjoint-based evaluations
  - Only 50-54% of observations (targeted or otherwise) specifically act to improve the forecast
  - Large numbers of observations with relatively small individual impact provide a larger cumulative benefit than small numbers of obs
- Impact of any group of observations depends on (a) errors in prior forecast, (b) errors in observations, (c) DA and forecast methods.

Conclusions III

- Sensitivity methods
  - Extratropics: Observations in sensitive areas are more valuable than those deployed randomly.
  - Tropical Cyclones: not yet determined.

- *Recognize that forecast skill is improving due to improved resolution, observations, DA, physics. Hence, the average marginal impact of an individual observing system is decreasing.*

- Open question: **what is the overall cost-effectiveness of targeted observations?**

Recommendations

1. Explore utility for targeting existing observations (e.g. selected satellite data)
2. Improve understanding and quantification of the socio-economic value of observations.
3. More emphasis on science of targeting.
4. Improve basis for quantitatively predicting forecast error variance reduction. Current techniques have a linear inference.
5. Keep evaluating regular field programs in multiple NWP systems.

Thoughts for the future

- Global observational network design
  - Use targeting strategies to adaptively select / thin satellite data for assimilation?
- Regional targeted observations
  - Potential with rapidly adaptable observational resources, quick response time necessary.
  - Need rapidly updated models and ensembles, more continuous, serial targeting than has been done on synoptic scales?