Potentials in improving predictability of multiscale tropical weather systems evaluated through ensemble assimilation of simulated satellite-based observations

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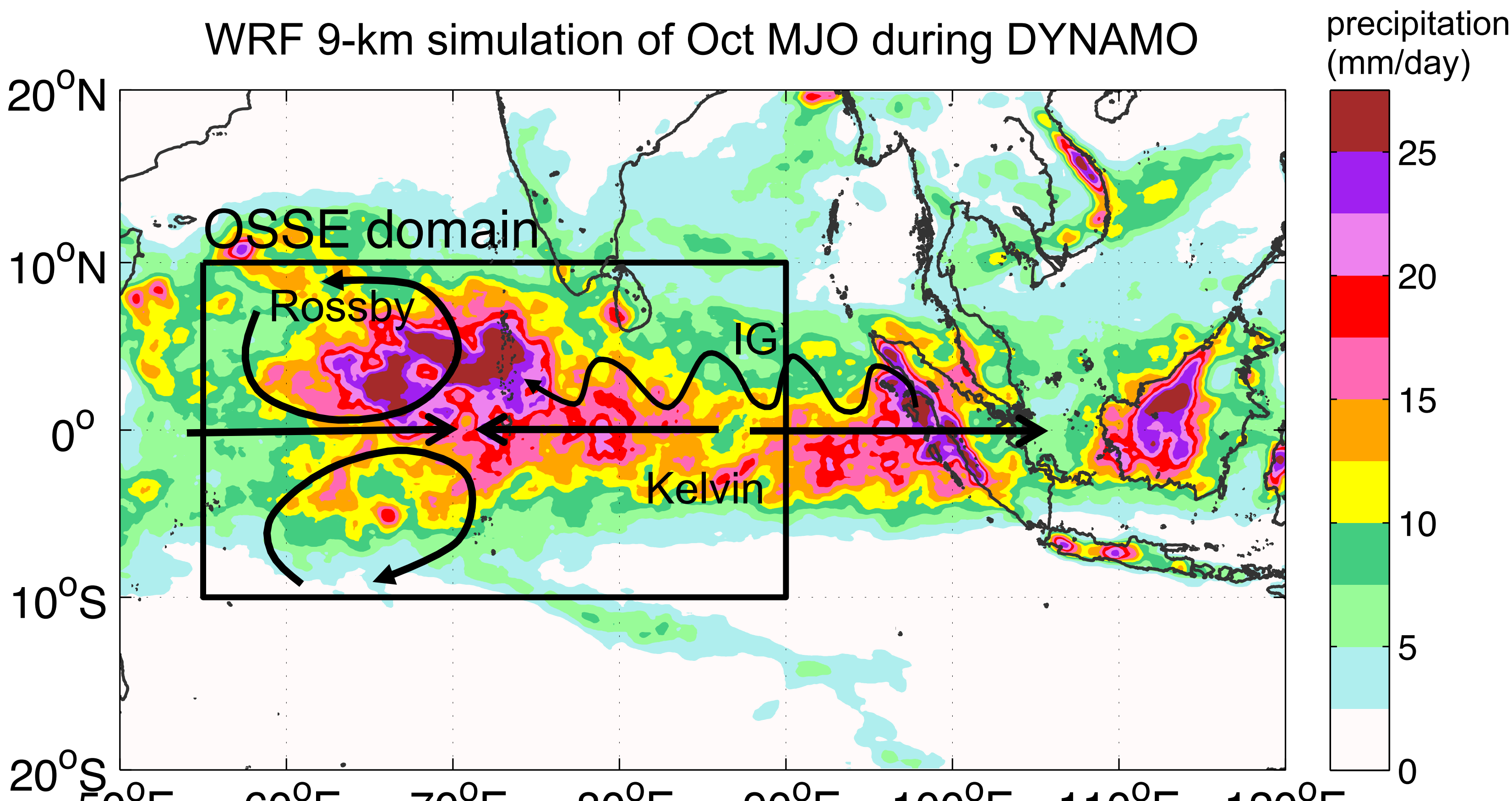
Background and Motivation

Multiscale tropical weather systems: important component of the global circulation

Can current/future satellite observations help improve their (practical) predictability?
→ Run an Observing System Simulation Experiment (OSSE) to find out!

WRF 9-km simulation of Oct MJO during DYNAMO

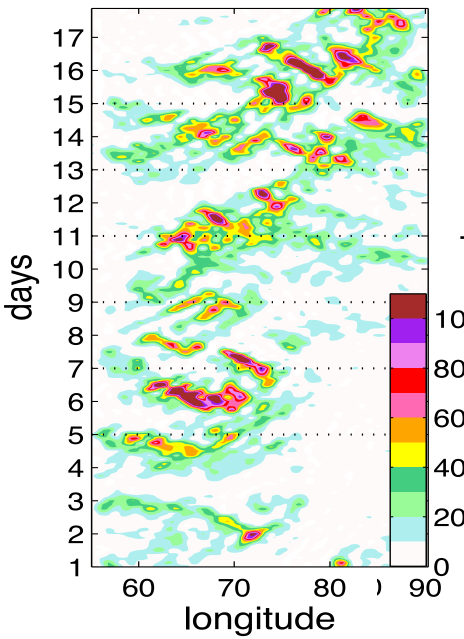


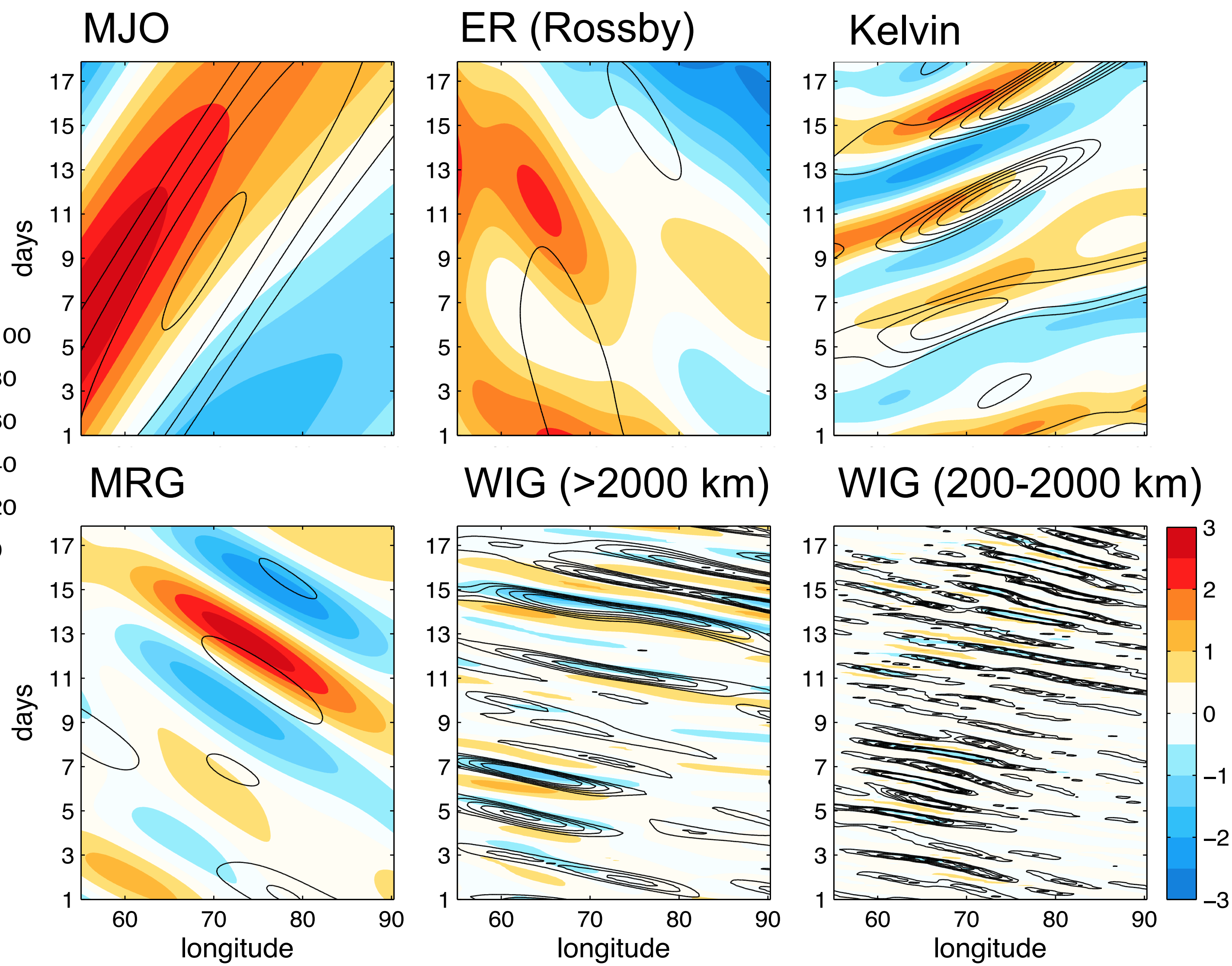
animation

Multiscale tropical weather systems

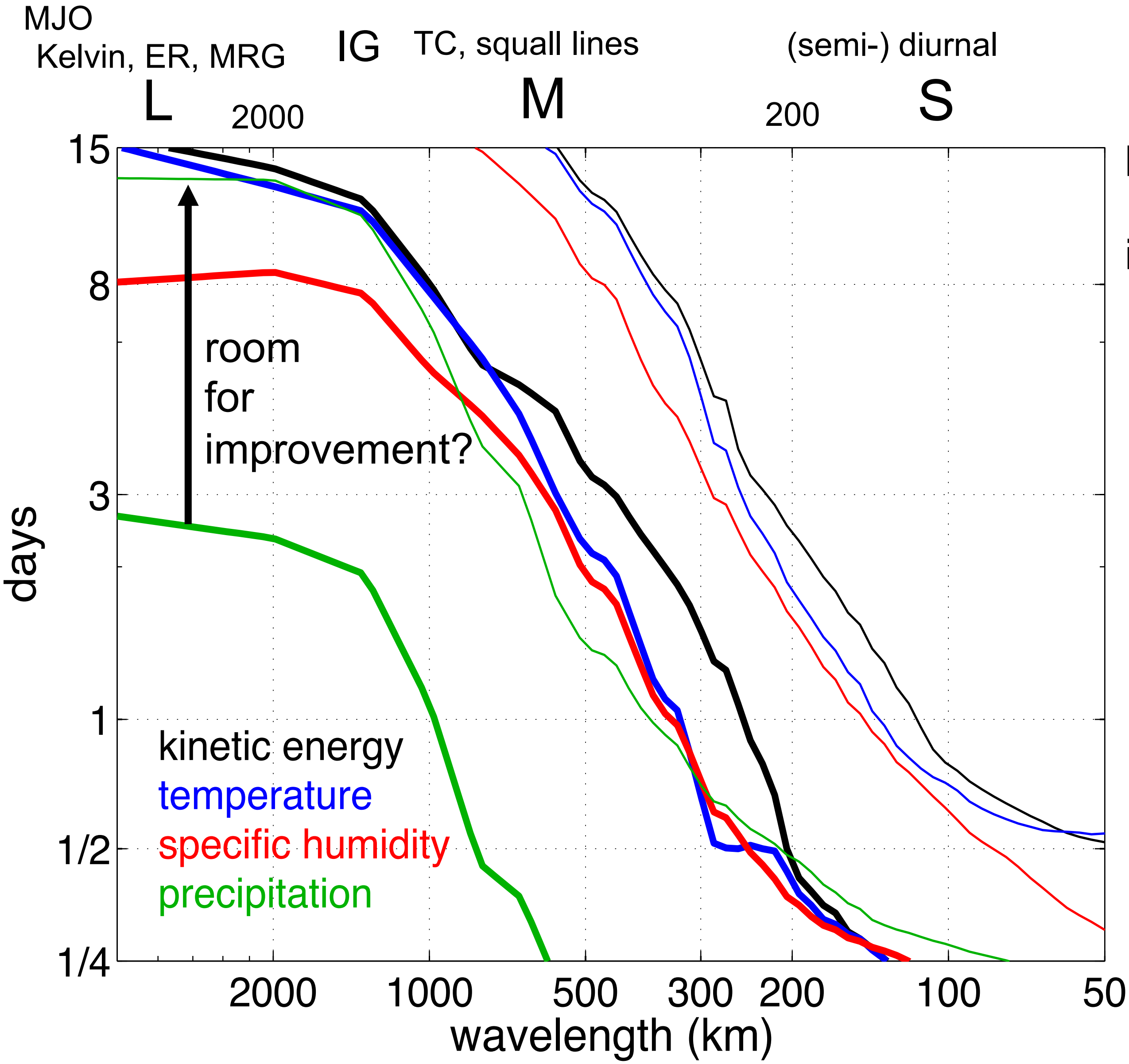
Hovmoller diagrams of precipitation (contour) and 850-mb U (color) filtered with Wheeler-Kiladis (1999) space-time windows

unfiltered precipitation





Practical versus intrinsic predictability



practical predictability (thick)

intrinsic predictability (thin)

predictability limit:
time at which error grows to a level as large as the signal itself

scale dependency!

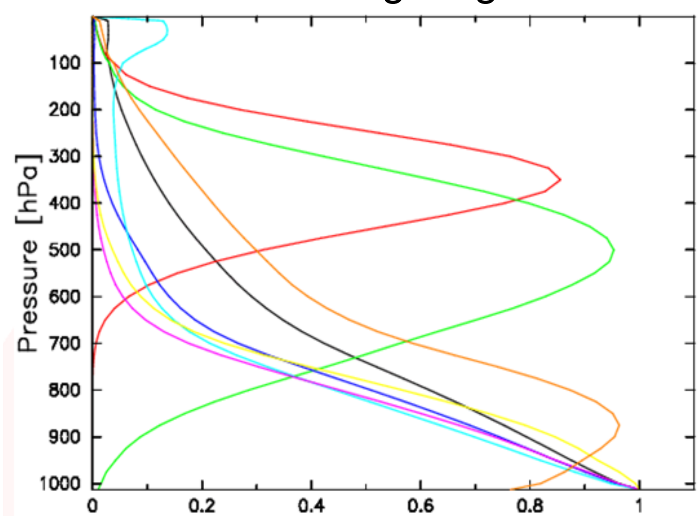
(Ying and Zhang 2017, JAS)

Satellite-based observing networks: temperature and humidity

Polar-orbiting:
ATOVS radiance (AMSU-A/B, HIRS)
- T and Q retrieval assimilated every 3 h

Geostationary:
Meteosat-7 with higher temporal/ horizontal resolution than ATOVS
- channel-3 Tb directly assimilated

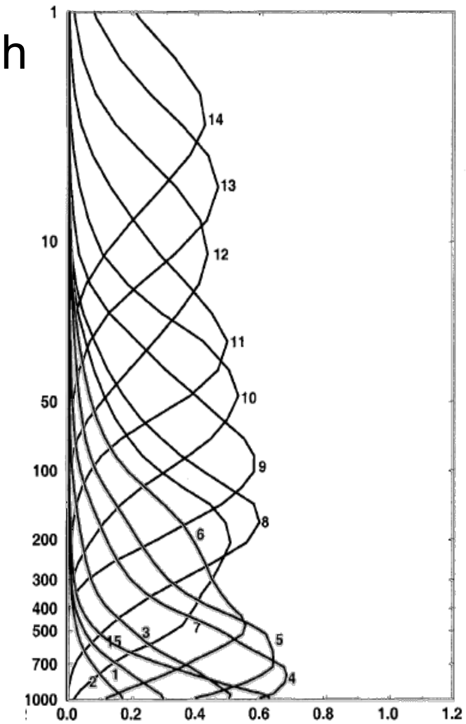
Meteosat-8 weighting functions



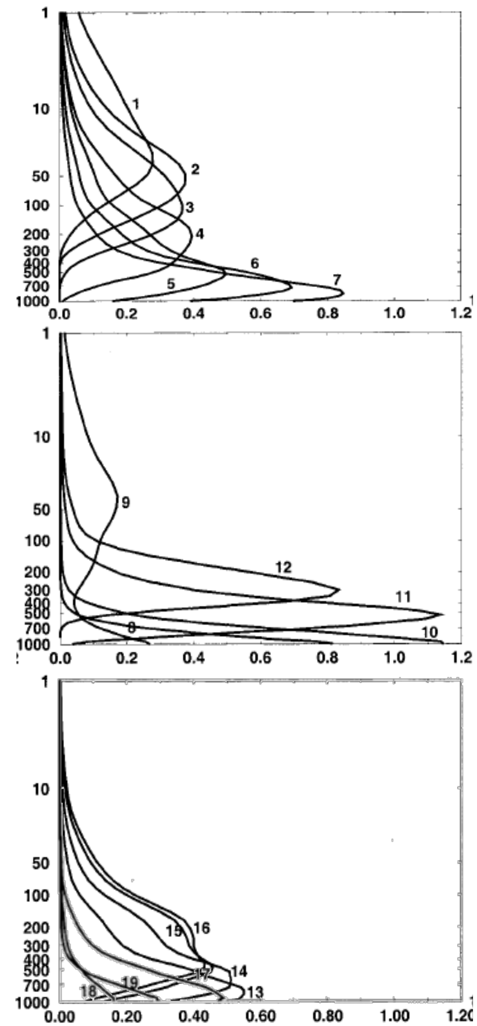
(EUMETSAT)

weighting functions

AMSU-A



HIRS/3

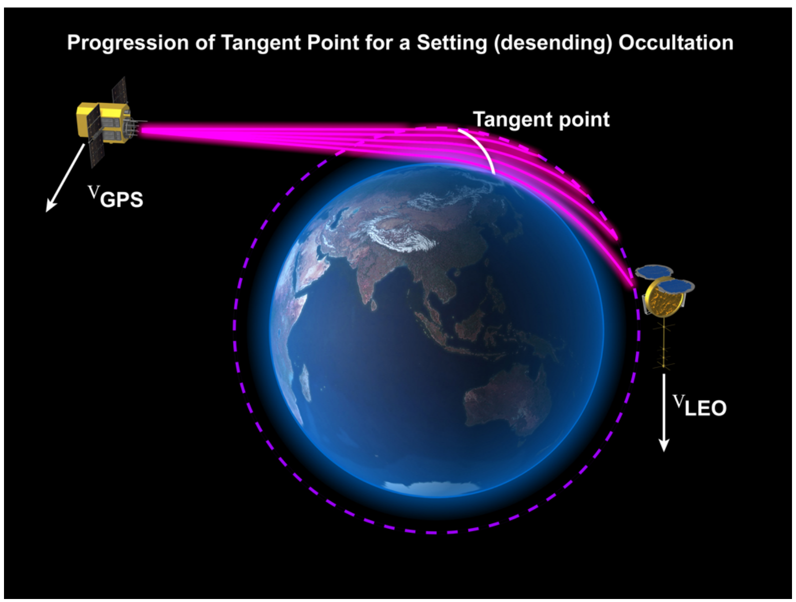


(Li et al. 2000)

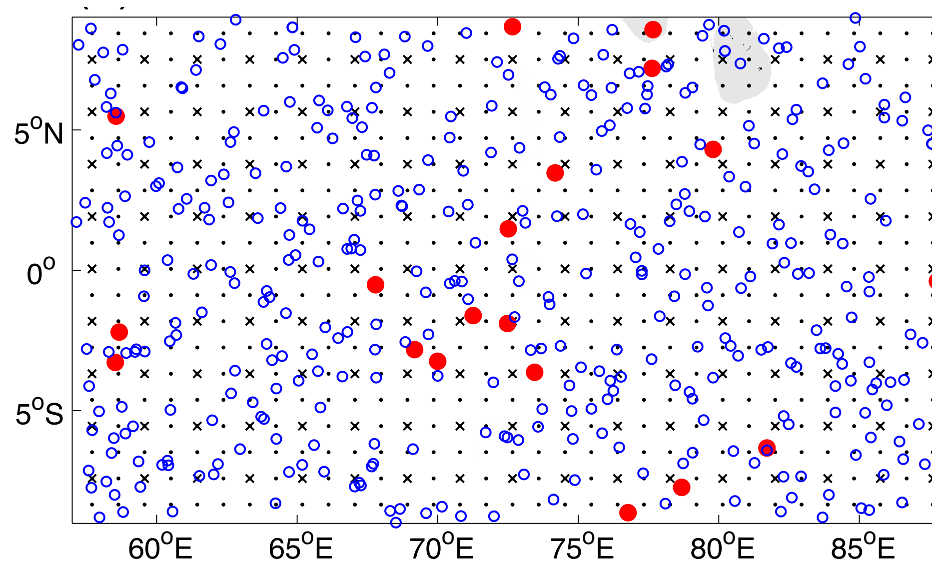
Satellite-based observing networks: temperature and humidity

GPS radio occultation (GPSRO)
- limb-sounding provides better vertical resolution than nadir-sounding
- currently lower horizontal resolution than ATOVS

COSMIC2 mission – 12 LEO satellites providing ~8000 profiles globally every 3 h

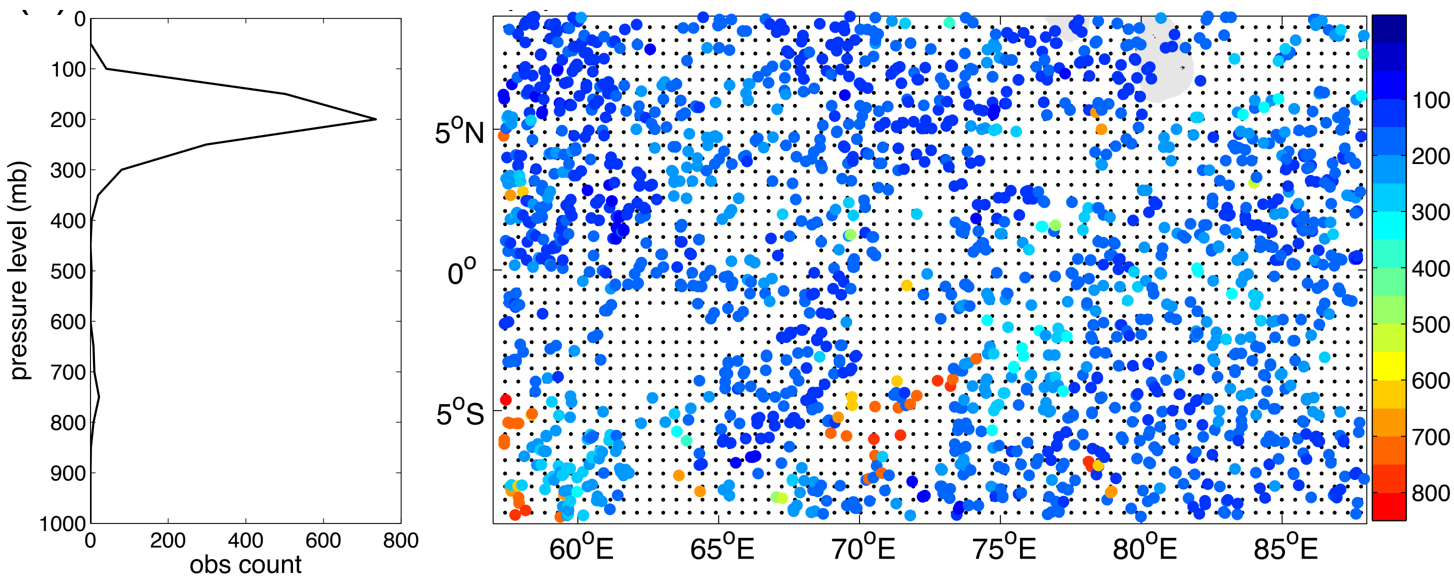


red dot: COSMIC2 resolution
blue circle: CubeSat resolution



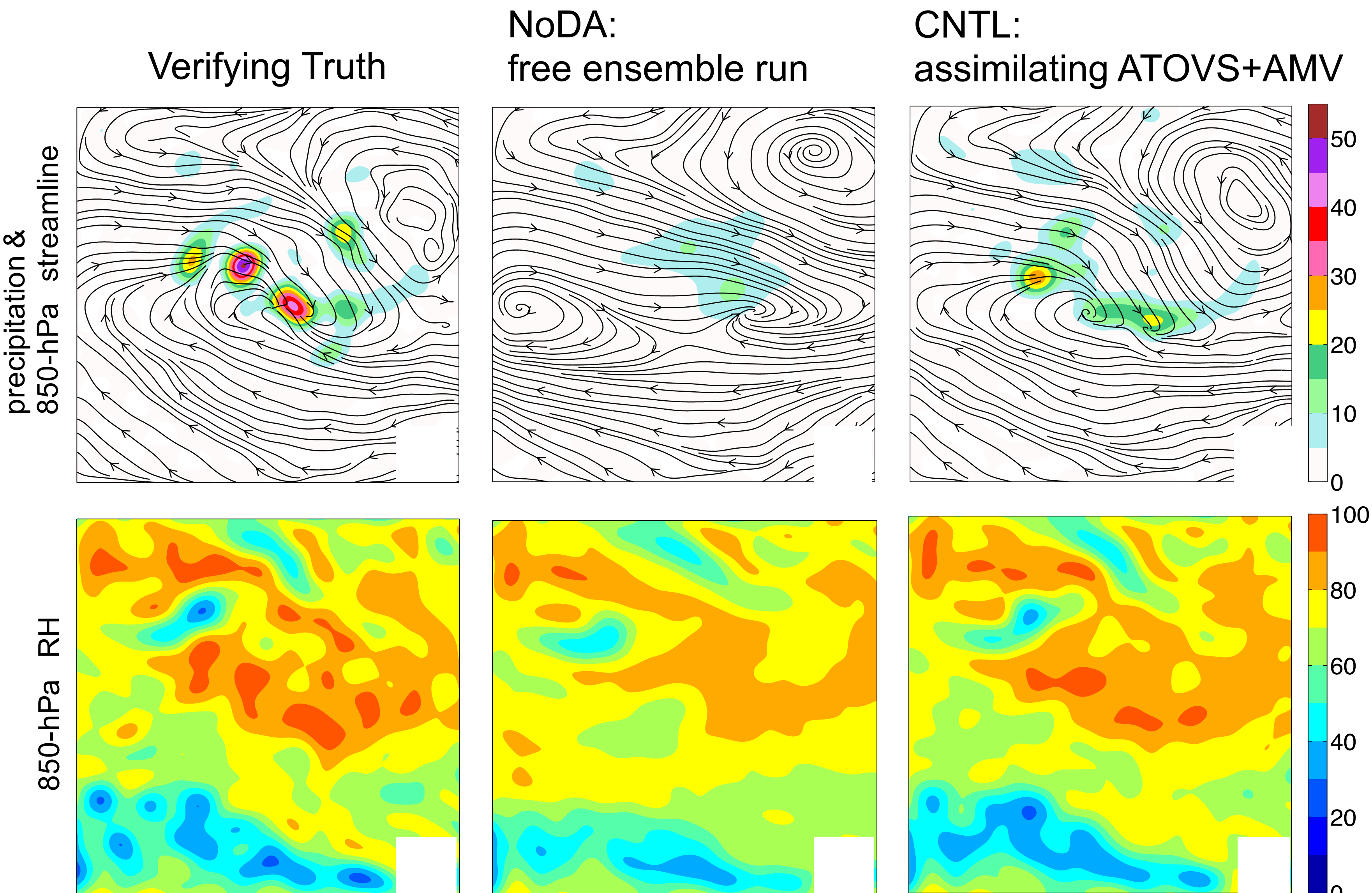
Satellite-based observing networks: wind

Atmospheric Motion Vector (AMV)
- tracing cloud features
- mostly available at upper levels



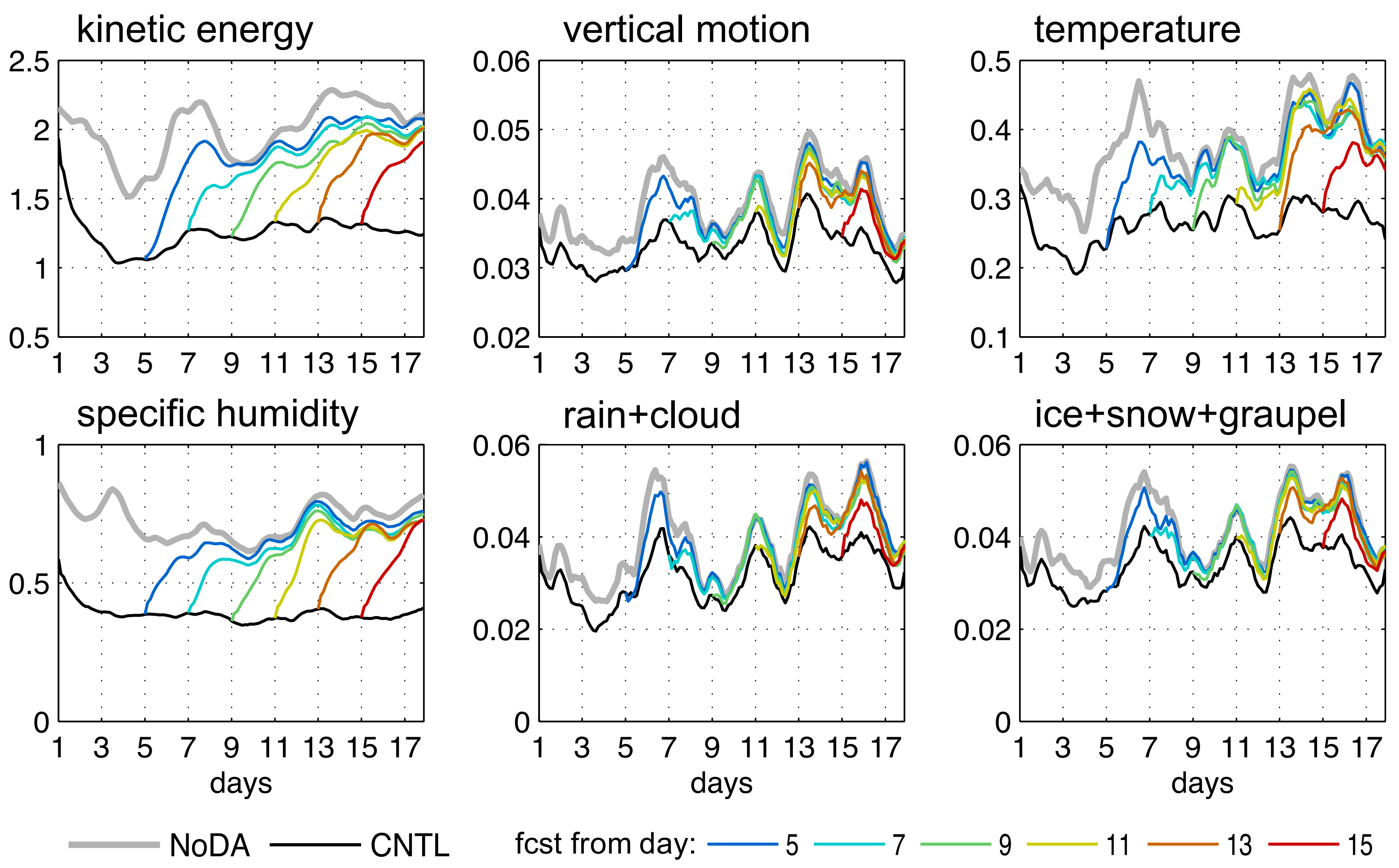
Cyclone Global Navigation Satellite System (CYGNSS)
- retrieves surface wind speed through ocean roughness
- supplements low-level wind information

Performance of a benchmark case



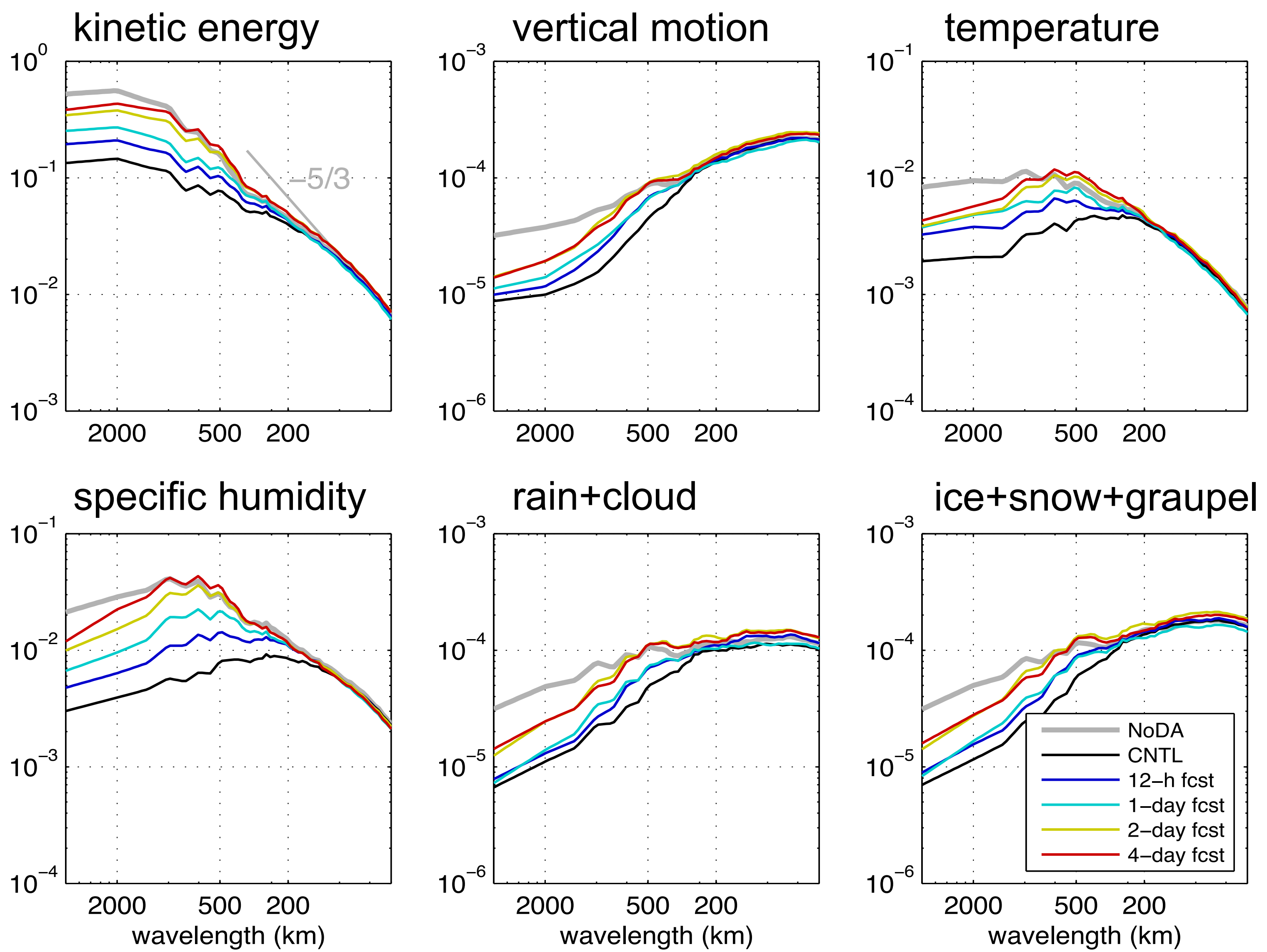
Performance of a benchmark case

time series of domain-averaged errors (RMSE)



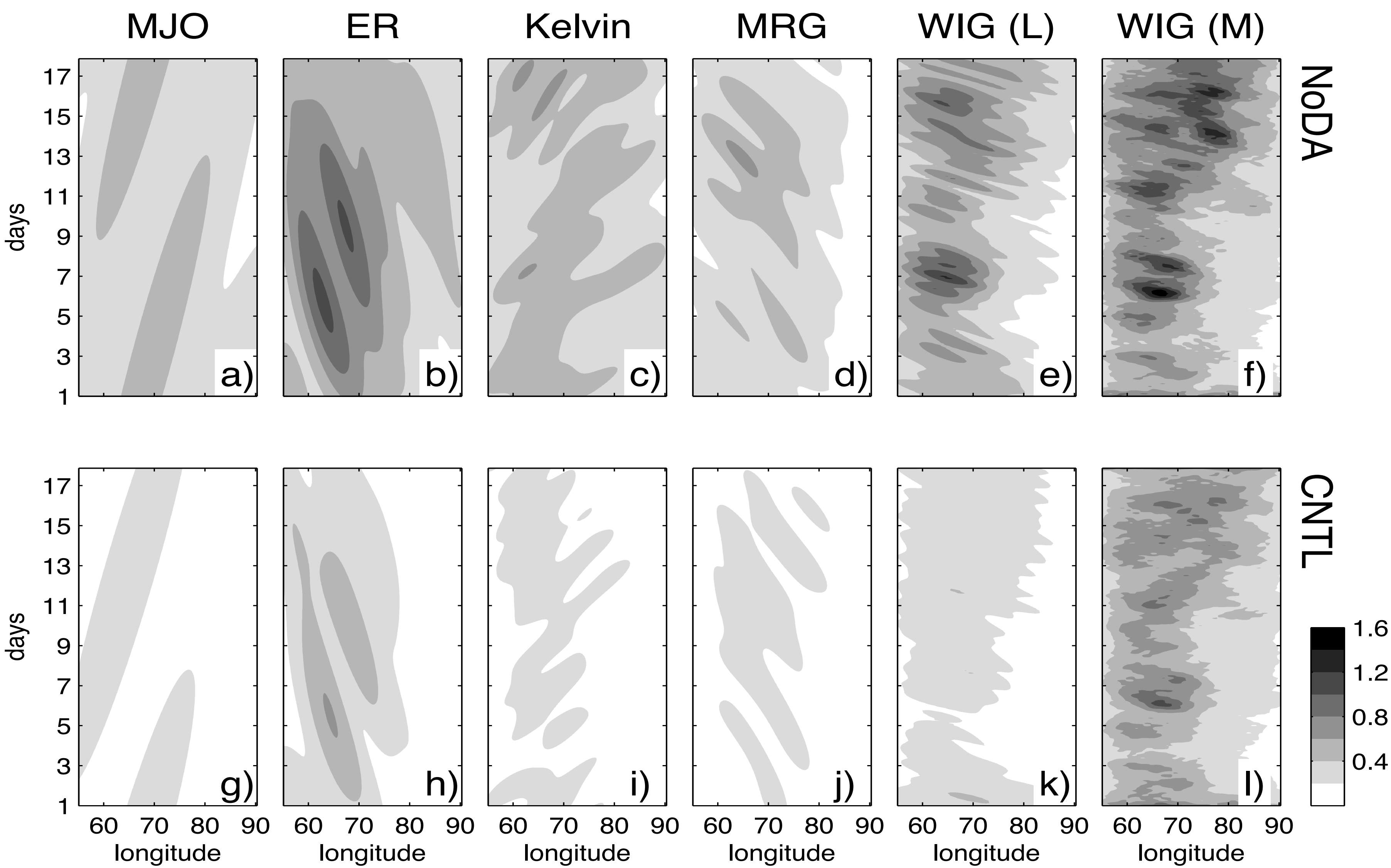
Performance of a benchmark case

time-averaged 2D power spectra of errors



Observation impact for each wave mode

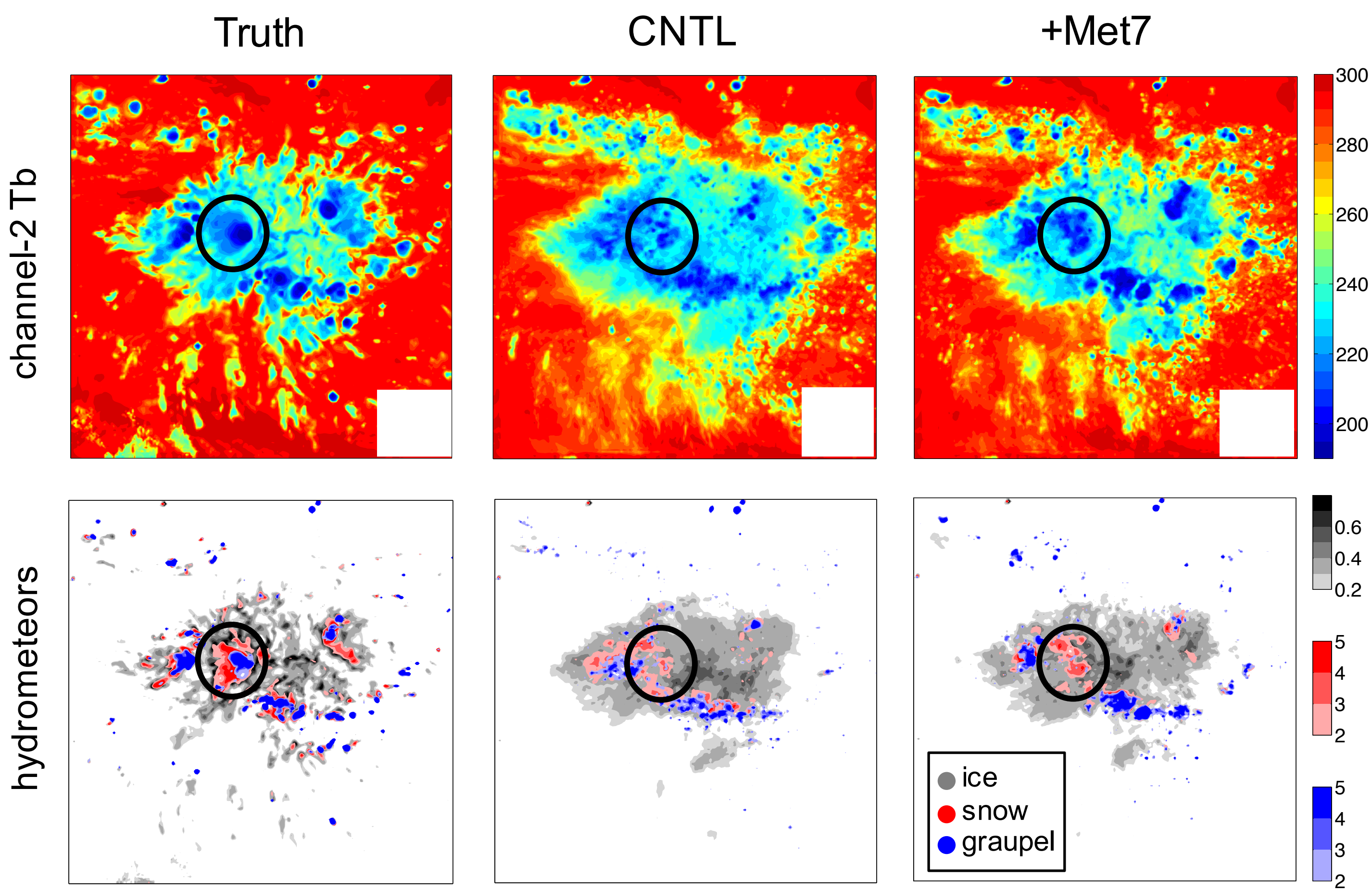
room-mean difference total energy $0.5(u'^2+v'^2+kT'^2)$, Hovmoller diagrams



Impact from Meteosat-7 IR Tb

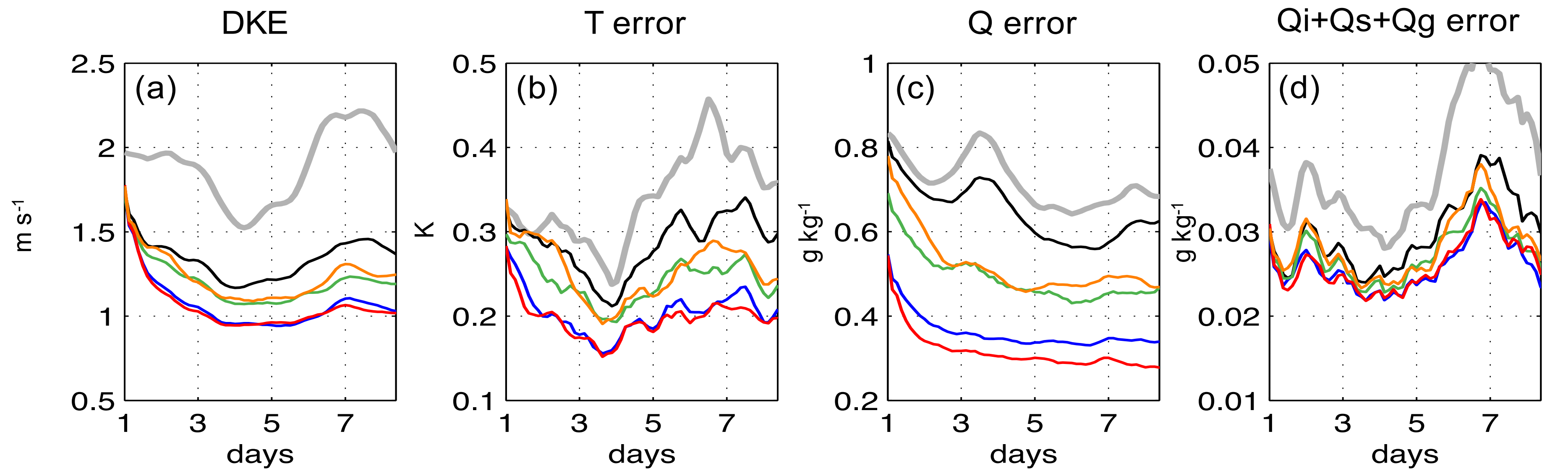
further reduce errors in hydrometeors (ice, snow, graupel) at smaller scales

channel-3 Tb is only sensitive to cloud top, more impact on snow than graupel



Influence from observation resolution

time series of domain-averaged analysis errors



NoProfile: AMV+Met7+CYGNSS

+ATOVS: NoProfile + ATOVS at current resolution

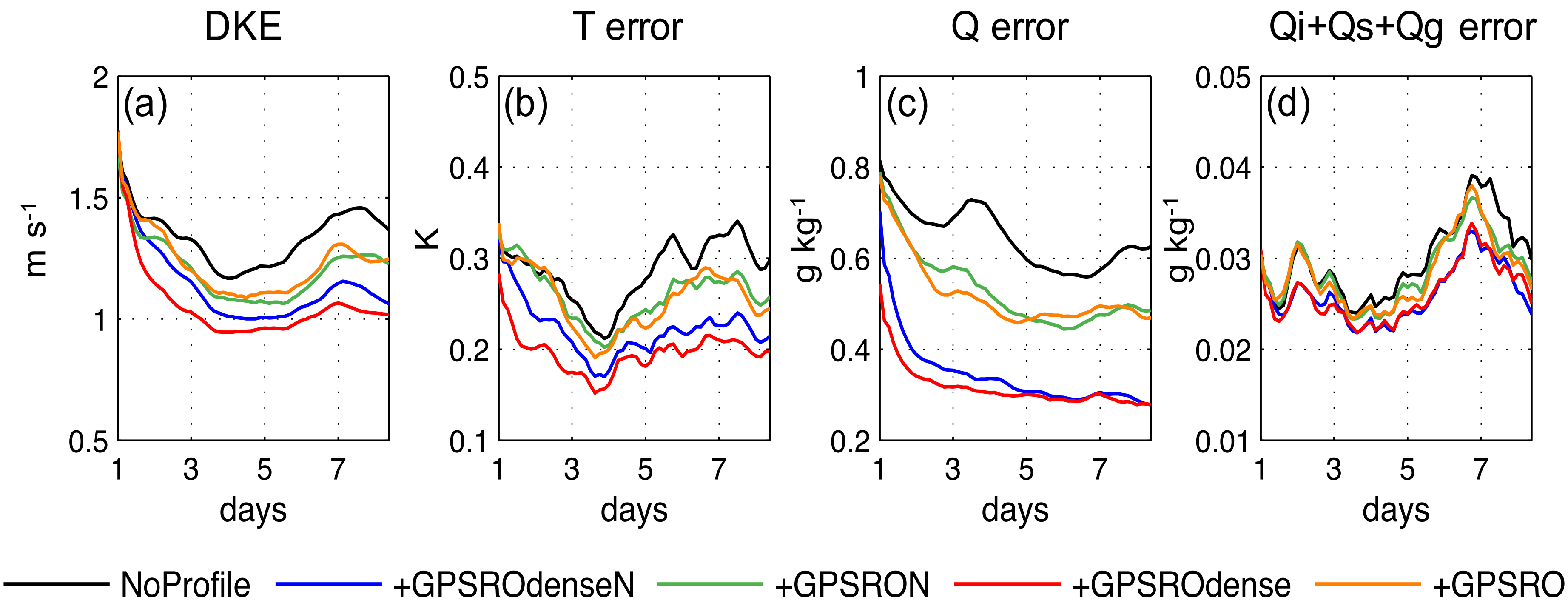
+ATOVScoarse: NoProfile + ATOVS with horizontal and temporal resolution reduced by half

+GPSRO: NoProfile + GPSRO at COSMIC2 resolution

+GPSROdense: NoProfile + GPSRO at CubeSat resolution (25 times more data)

Direct assimilation versus assimilating retrievals

time series of domain-averaged analysis errors



+GPSRON: same as +GPSRO but assimilating refractivity (N) directly

$N = 77.6\ p/T + 3.73 \times 10^5\ e/T^2$

assimilating retrievals outperforms direct assimilation, likely due to not accounting for errors in retrieval process.

Summary

Current/future satellite observations can improve the practical predictability of tropical weather systems at scales larger than 200 km.

Large-scale wave modes (MJO, Kelvin, Rossby, MRG, 2-day waves) can have predictability horizon extended more than 4 days.

Fine-resolution observation is essential for intermediate-scale systems (IG waves), such observations currently include ATOVS retrieved profiles and Meteosat radiances.

Current GPS radio occultation (COSMIC2) can bring an impact approaching ATOVS at half resolution; CubeSat constellation will bring comparable impact.