Recent developments in physical parameterizations

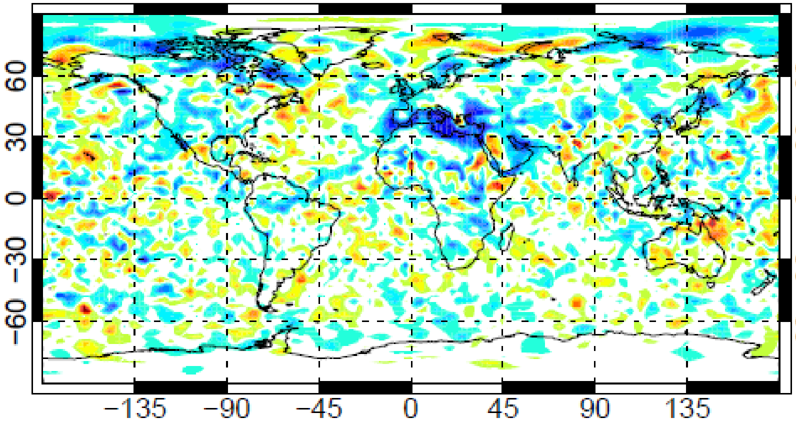
Part 2: ECMWF, JMA, NRL, DWD, MF

ECMWF

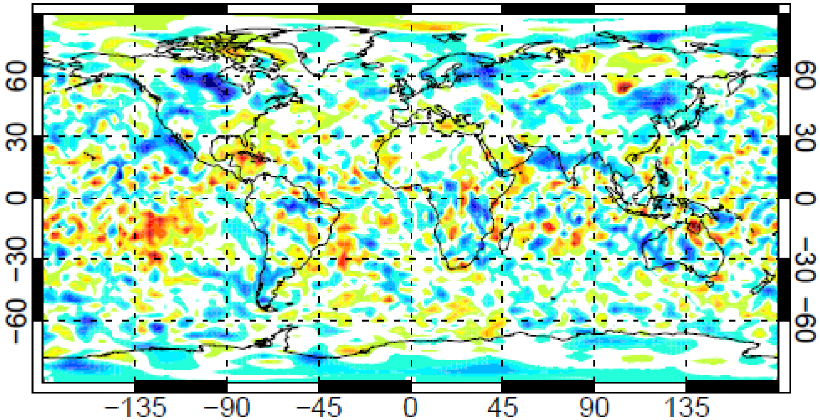
Introduction of subgrid lakes as 9th tile in land surface scheme (TESSEL) with lake model FLAKE for surface BC

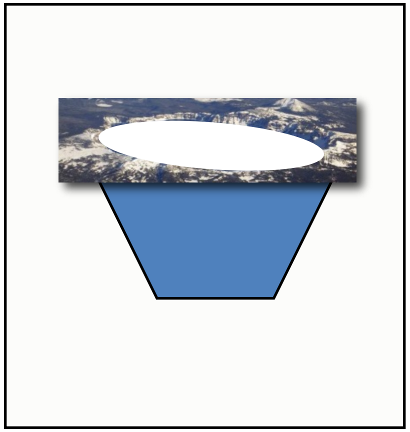
Reduction/increase of temperature RMS errors of T+48 hour forecasts against analysis at 1000 hPa due to introduction of fractional lakes

Summer experiment 15−Jun−2013 to 5−Jul−2013



Winter experiment 1−Dec−2013 to 31−Dec−2013





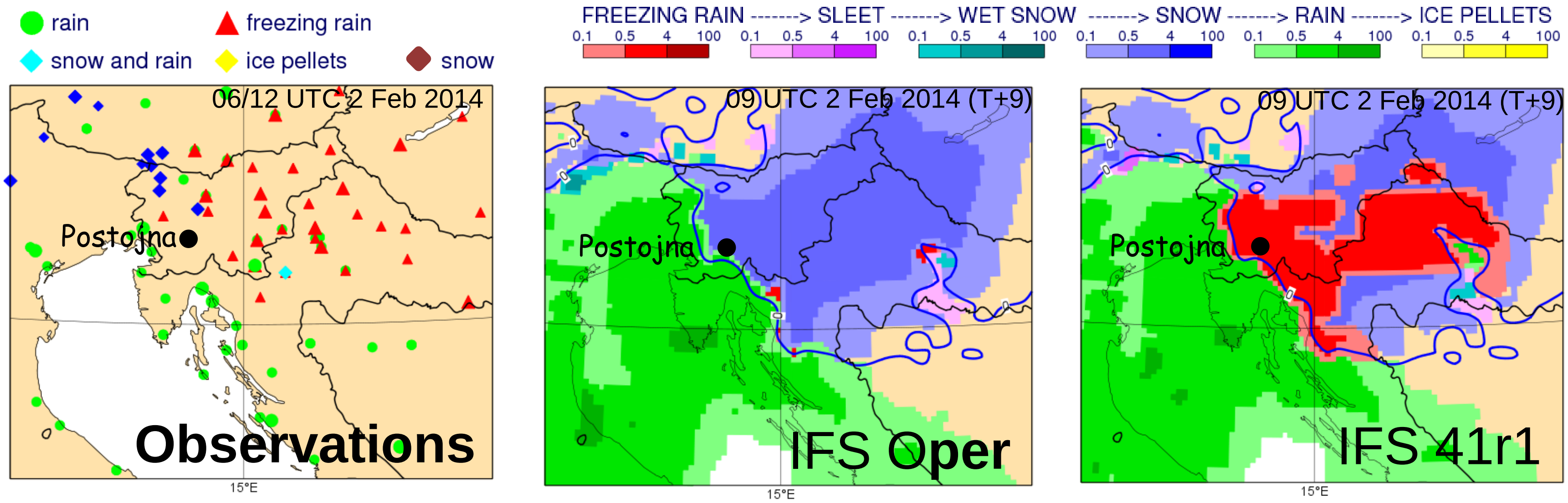
FLAKE

Forecast of 2m temperature are improved in proximity of lakes and coastal areas

Why also coastal areas? These are not lakes but points where land fraction > 50%. Before, these points were set to 100% land (through land/sea mask) and have now a water fraction.

Towards predicting high-impact freezing rain events (41r1)

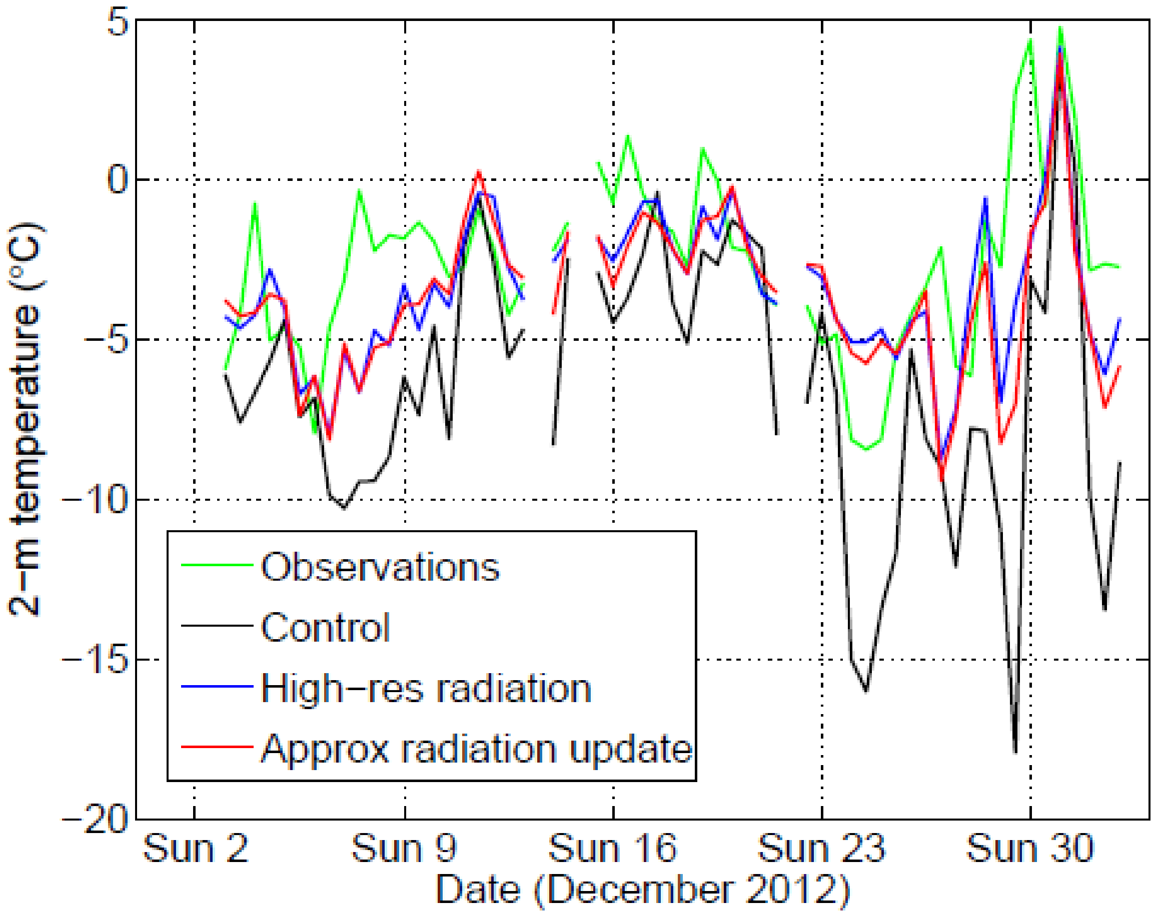
- Case Study: Slovenia/Croatia early Feb 2014
- Freezing rain caused severe disruption and damage, tranports/power/forests…
- Current IFS physics (40r1) not able to predict
- New physics in 41r1 allows prediction of freezing rain events
- Initial evaluation in HRES and ENS shows potential for useful forecasts
- Article in EC Newsletter Autumn 2014



Improved radiation at full resolution

- For computational efficiency, radiation computations are done at half the model resolution and 1-hourly for T1279 and 3-hourly for T639 (in the EPS).
- This leads to errors at coastal points (where land T and ocean temperatures are combined in the interpolation) and errors in the diurnal cycle.
- New scheme provides an approximated update of radiation at full resolution and every time step adjusting for local deviations in surface T and albedo.

Example:
2m T time series at Sortland, Norway (68.7N, 15.42E) from daily 24 and 36h forecasts,
verifying at noon and at midnight.



Experiments:
- **Control: T639 with radiation at half resolution every 3 hours.**
- **High-Res radiation: as control with radiation at full resolution and every time step.**
- **Approx radiation update: As control, but with new scheme.**

Hogan and Bozzo (2015) : Mitigating surface temperature errors using approximate radiation updates, ECMWF Tech Memo 746.

JMA

Update of physical processes (18 Mar. 2014)

1. Revising a stable boundary layer scheme
   →Improving wind fields and diurnal temperature variation in stable conditions
2. Revising albedo parameters in the desert areas
   →Reducing clear sky radiation biases
3. Introducing two-stream approximation for long wave radiation scheme
   →Accelerating radiation code and improving the middle atmosphere temperature structure
4. Introducing a non-orographic gravity wave forcing scheme
   →Improving the middle atmosphere climate and representation of long-term oscillation in the tropical lower stratosphere such as QBO
5. Changing the application criteria of energy correction terms in convective parameterization
   →Improving general circulation and global precipitation distribution
6. Applying 2nd-order linear horizontal diffusion in the divergence equation and adjusting 4th-order linear diffusion as a sponge layer around the model top region
   →Improving the middle atmosphere forecast accuracy

Update of cumulus convection and cloud scheme

- Under Development -

- Cumulus convection (Arakawa-Schubert)

1. Revising budget equation of moist static energy
   → Improving energy conservation
2. Revising estimation of static energy at cloud base
   - Entrainment rate based on Jakob and Siebesma (2003), adding static energy perturbation at cloud base

   → Improving convective heating profile
3. Revising snow melting process
   → Improving convective heating profile
4. Introducing fallout of precipitation between cloud base and cloud top
   - Iterative calculation to estimate entrainment rate

   → Improving convective heating profile

- Cloud (PDF-based parameterization (Smith 1990))

1. Removing increase of PDF width by cumulus effect
   → Reducing dry bias in the middle troposphere
2. Revising cloud ice falling process
   → Reducing time step dependency

JMA approach

Introducing a parameterization for convective initiation(PI) in kilometric scale model

- Based on the existing convective parameterization (Kain-Fritcsh, employed by JMA’s 5-km operational mesoscale model), but tendency from convective process is much smaller than the original one (assuming slower convective stabilization)
- At the initiation stage, if the dynamics does not produce updraft due to convection even with unstably stratified layer realized, the parameterization is activated and modifies layer stratification by weakly transporting heat and moisture vertically and releasing latent heat through phase transition of water, resulting in producing local low pressure area.
- Once such local low pressure area is generated, the dynamics of the model calculates convergence into the low pressure area and promotes development of convection.
- Because it acts very weakly, the parameterization just helps dynamics foster convective system.

NRL

NRL: Coupled Ocean/Atmosphere Prediction System

COAMPS-TC Tropical Cyclone Physics

Problem

Synoptic-scale at days 4-5 is not predicted adequately leading to track errors.
Rapid intensification & intensity of strongest storms (Haiyan) often not captured.

Solutions

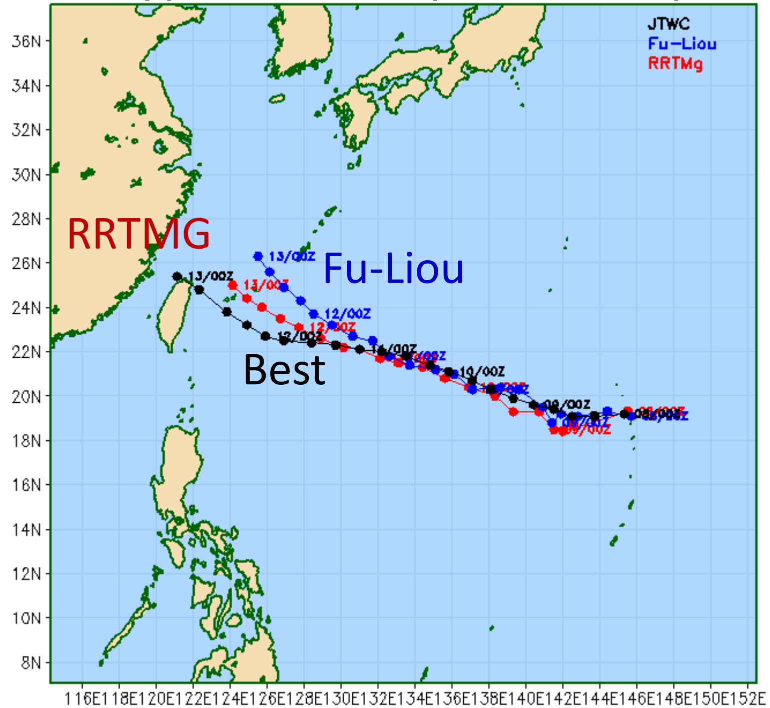
Improve the key TC physical parameterizations in COAMPS-TC.

RRTMG Radiation Findings

- Important interactions between radiation & microphysics that impact track, intensity.
  - ➢ Radiation top at 0.0001 hPa helps temp. bias
  - ➢ Snow-radiation interactions important

- **Upgrade COAMPS-TC physics for both inner-core and synoptic-scales**
- ➢ **RRTMG radiation**
- ➢ **New NRL & Thompson microphysics**
- ➢ **Shallow convection (UW, ED/MF)**
- ➢ **Upgrade to COAMPS-TC drag param.**

Typhoon Soulik (2013070800)



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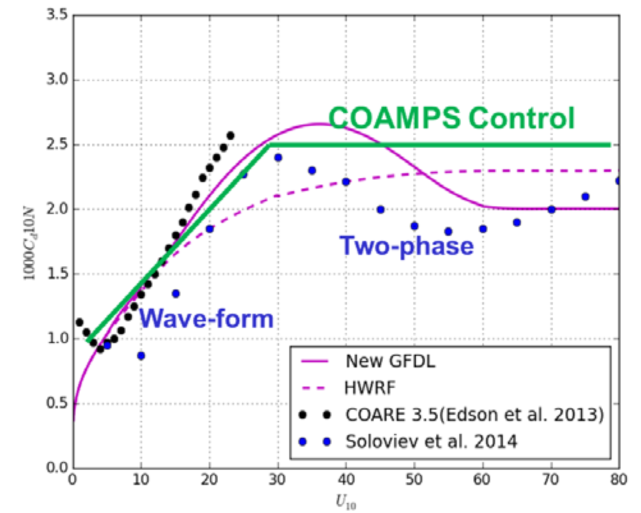
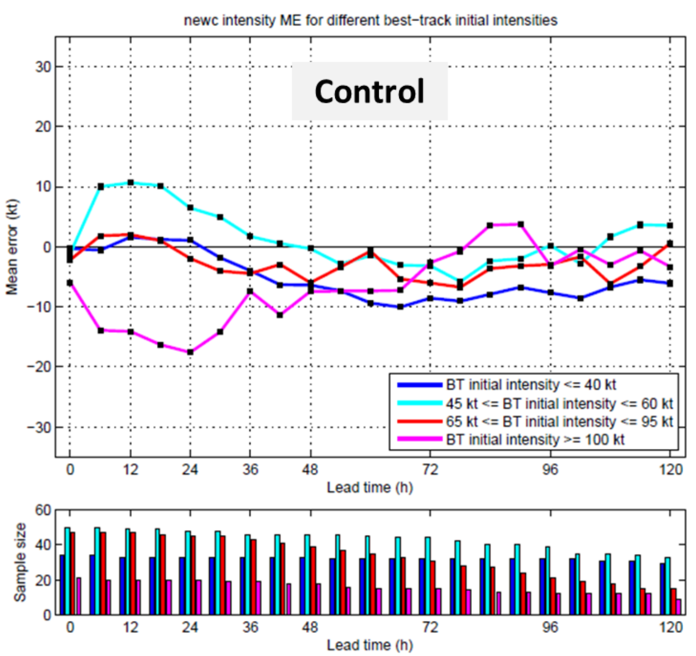
NRL: Coupled Ocean/Atmosphere Prediction System

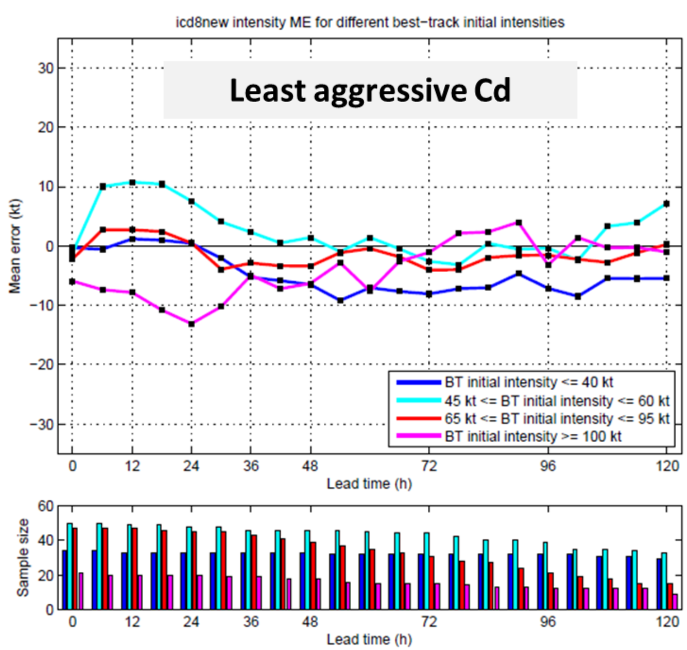
COAMPS-TC Surface Drag Coefficient Experiments

Soloviev et al. (2014) proposed a unified wave-form and two-phase parameterization for Cd:

- High wind regime: sea spray and bubbles form a two-phase interface with large density differences
- Aerodynamic property of sea surface is changed due to KH instability at the two-phase interface; local minimum of Cd occurs at ~60 ms^{-1}







- Negative intensity bias is reduced in magnitude
- Pressure-wind relation improved at high winds
- Cat. 4 & 5 intensities are attainable
- Model intensity ‘climate’ is more realistic

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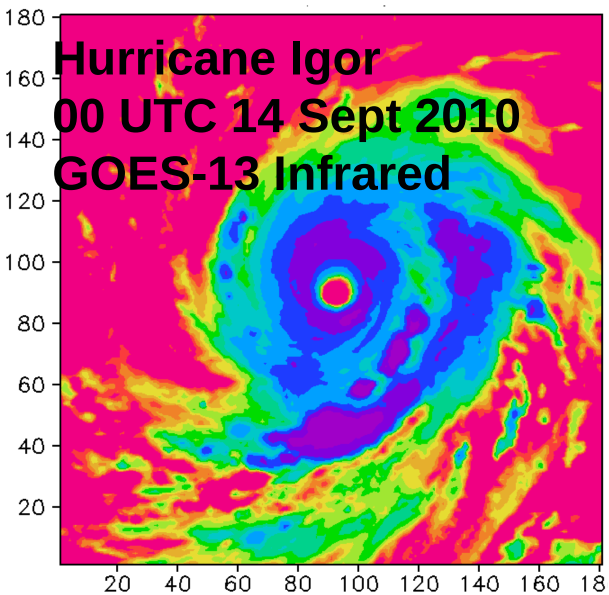
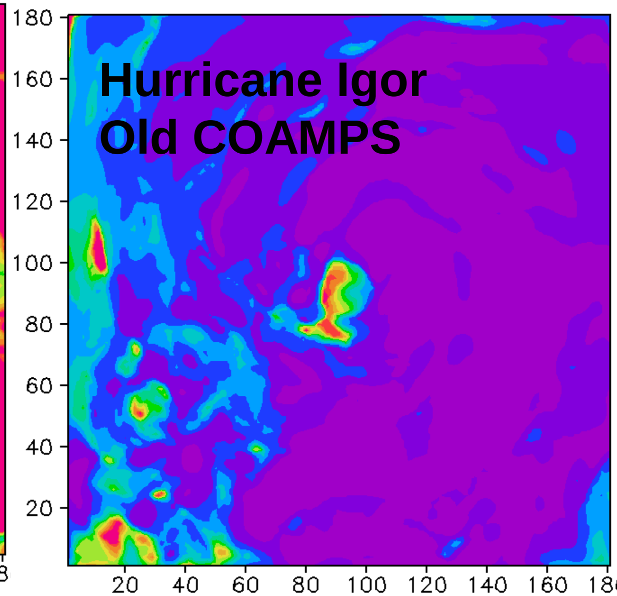
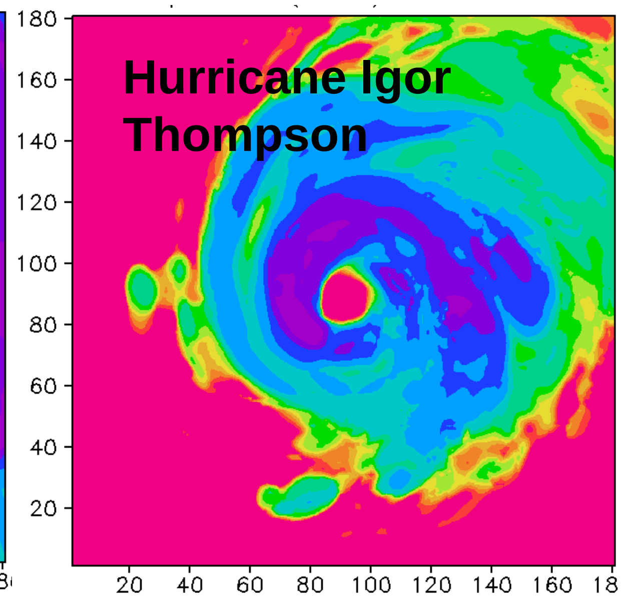
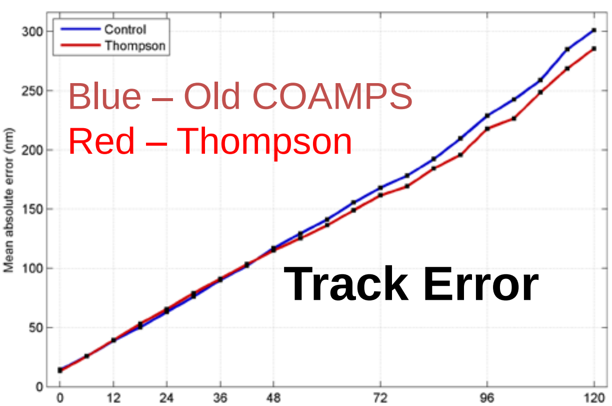
NRL: Coupled Ocean/Atmosphere Prediction System

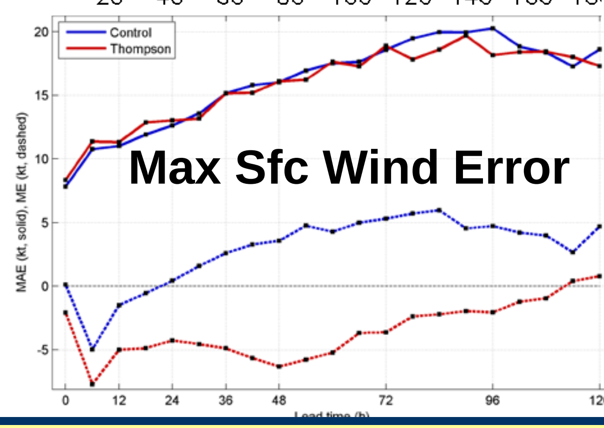
COAMPS-TC: Evaluation of Thompson Microphysics

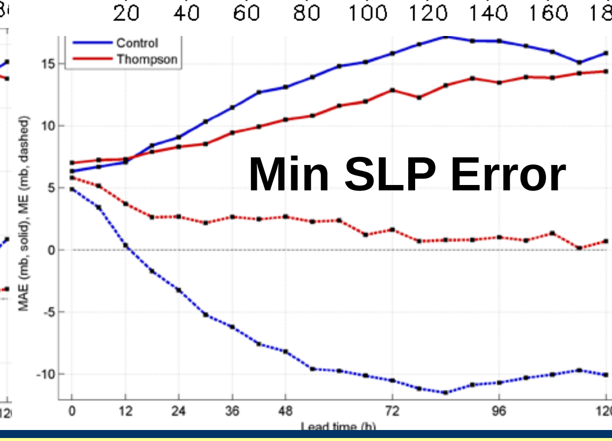












- **Synthetic imagery evaluation suggest Thompson captured general feature of TC inner core.**
- **The Thompson has similar track and intensity errors to the old scheme.**

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DWD

Revised cloud-radiation coupling

- ➔ RG92 radiation scheme includes only cloud drops and cloud ice. Other species (snow, graupel, rain, hail) translucent.
  - ➔ Include all grid scale species
- ➔ Extinction coeff. β, single scatt. albedo σ, asym. parameter g of hydrometeors only depending on their density, not their size (eff. radius R_e).
  - ➔ Switch to newer parametr. based on R_e:
    Hu & Stamnes (1993) – drops (D < 130 μm)
    Fu et al. (1996, 1998) – hex. needles (D < 140 μm)
    Spectral remapping to the 8 RG92 bands
  - ➔ Large-size-approx. for snow, graupel, rain, hail
  - ➔ R_e derived from mass density and particle size distribution assumptions from cloud microphysics
- ➔ Revision of effective factor for subgrid variability of gridscale clouds (previously: qx_rad = 0.5 qx !)
  - ➔ Theoretical analysis, new tuning parameters „radqc_fact“, „radqi_fact“ instead of fixed „0.5“
- ➔ Subgrid scale water/ice clouds in radiation scheme: qc, qi, R_e?
  - ➔ Revise formulation, add dependency on R_e
- ➔ Tuning of other uncertain parameters:
  - ➔ Number densities of cloud drops + cloud ice, needed for R_e in case of 1-moment microphysics
- ➔ Re-tuning of model system, using new Tegen aerosols
  - ➔ ongoing, but still long way to go!

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TKE-Scalar Variance (TKESV) Turbulence Scheme

- A TKE-Scalar Variance (TKESV) scheme is developed and successfully tested through single-column numerical experiments and through parallel experiments with the full-fledged COSMO model.
- Results from parallel experiments performed to date look favourable. Verification of results against observational data indicate improvements as to some scores, e.g. fractional cloud cover and 2m temperature and humidity.
- An outline of the TKESV scheme, including single-column tests and some details of the scheme implementation into COSMO, are given in Machulskaya and Mironov (2013, COSMO Newsletter No. 13).

from Dmitrii Mironov (DWD)

TKESV Scheme
“Baseline” Version for COSMO/ICON

- Prognostic equations for both $<u_i'^2>$ (TKE) and scalar variances and covariance, $<\theta_l'^2>$, $<q_t'^2>$ and $<\theta_l' q_t'>$ (TPE), including third-order transport
- Algebraic (diagnostic) formulations for scalar fluxes and Reynolds-stress components with due regard for anisotropy (via pressure scrambling terms parameterizations)
- Stability-dependent formulation for turbulence length (time) scale
- Statistical SGS cloud scheme, either Gaussian or skewed (ad hoc non-Gaussian correction, effect on both fractional cloud cover and buoyancy production of TKE)

from Dmitrii Mironov (DWD)

METEO-FRANCE

New convection scheme « PCMT »

"PCMT": Prognostic Condensates Microphysics and Transport

- 5 prognostic equations for convective hydrometeors (cloud droplets, ice crystals, rain, snow) and vertical velocity
- Grid-scale equations from the convection scheme separate microphysical processes and transport processes (Piriou et al., 2007)
- Same microphysics (Lopez, 2002) used for resolved and convective precipitations (called twice)
- Triggering condition, mass flux, entrainment based on buoyancy. CAPE relaxation time for closure (Gueremy, 2011)

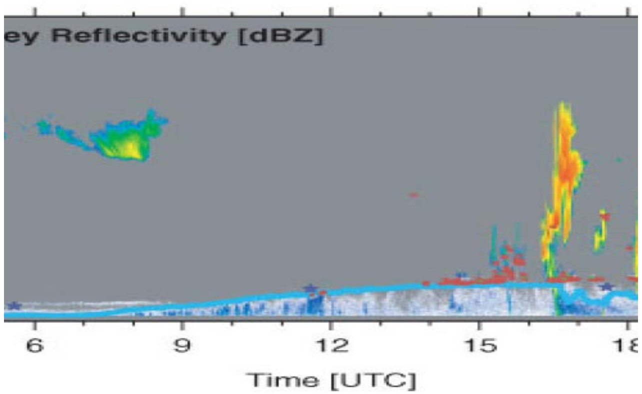
Piriou J.-M., J.-L. Redelsperger, J.-F. Geleyn, J.-P. Lafore and F. Guichard, 2007: An approach for convective parameterization with memory, in separating microphysics and transport in grid-scale equations , J. Atmos. Sci., Volume 64, Issue 11, pp. 4127–4139

Gueremy, J. F., 2011: A continuous buoyancy based convection scheme: one- and three-dimensional validation. Tellus A, 63: 687–706.

« PCMT » : 1D model evaluation

Evaluation of several 1D cases: ARM, BOMEX, EUROCS, LBA, AMMA, …

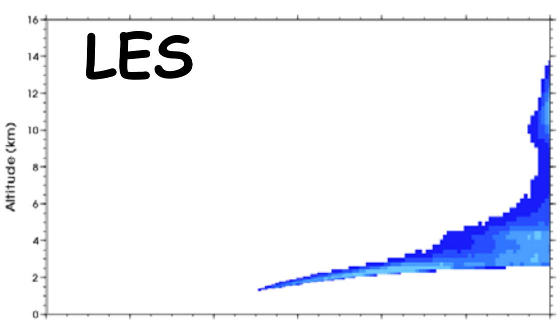
<u>EMBRACE FP7 project : Diurnal cycle of convection over the Sahel derived from the AMMA campaign (10th of July 2006 over Niamey)</u>

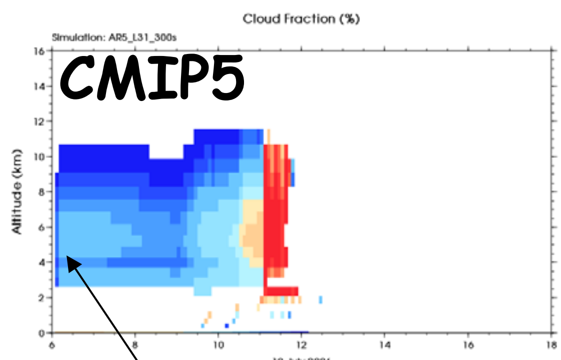


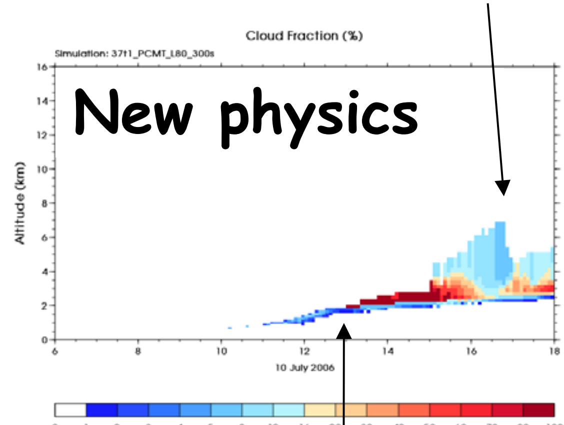
- Well documented case: Lothon et al. 2012
- Convection in a semi-arid environment
- Transition between shallow and deep convection
- Deep convection starts around 16h30

Deep convection underestimated

Cloud fraction







LES simulations
Couvreux et al. 2012

Triggering from the start of the simulation

Better representation of BL and shallow convection development

Microphysics developments

- ICE3: 1-moment microphysical scheme (operational in Arome)
  - Algorithmic developments to reduce time-step dependency
- LIMA: a 2-moment, mixed-phase microphysical scheme
  - Prognostic evolution of a realistic aerosol population
    - Multimodal (lognormal size distributions), 3D externally mixed aerosols
    - Distinction between several types of CCN / IFN / coated IFN
  - Explicit interactions between aerosols, clouds and precipitations
    - CCN activation extended from Cohard and Pinty 2000 -> cloud droplets
    - IFN nucleation following Phillips (2008,2013) -> ice crystals
    - Impaction scavenging of aerosols by rain
  - MACC (ECMWF) aerosol analyses provide initial and LB conditions

Revisiting Kalnay's "Rules for Physics Interoperability" 25 Years Later

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Towards Achieving Physics Interoperability

To address these new technical challenges, a multi-agency Physical Interoperability (PI) group has formed to modernize the Kalnay rules, as part of the National Unified Operational Prediction Capability (NUOPC).

1. We highlight some of the recommended modifications the PI group has made to the original 'Kalnay rules' in order to address some of the new computational and technical challenges.
2. We summarize a new software driver interface that will allow for the incorporation of physical parameterizations into operational and research NWP models in an efficient and standardized manner, much in line with the original vision of Kalnay et al. (1989).