COSMO model implementation used in IMWM-NRI

Andrzej Mazur, Grzegorz Duniec

Institute of Meteorology and Water Management - National Research Institute
Department for Numerical Weather Forecasts COSMO

Department of Numerical Weather Prediction COSMO

Department of Numerical Weather Forecasts COSMO

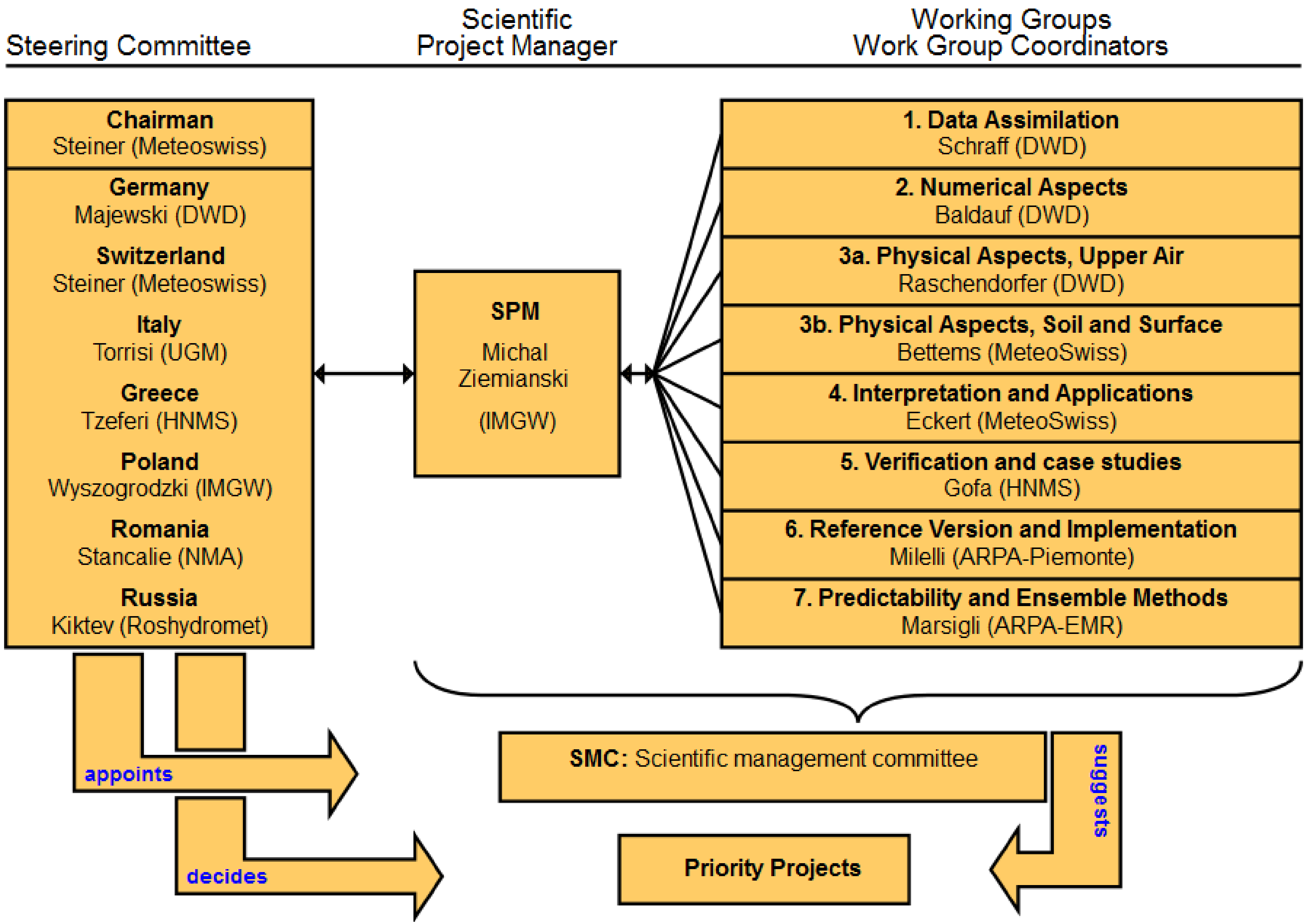
head: Dr. Andrzej Wyszogrodzki

Twelve full-time employees

- Development of Numerical Methods
  * 4 persons
- R&D of COSMO Physical Parameterizations
  * 4 persons
- Commercial and Operational Products
  *3 persons
- Verification and Quality Control
  * 3 persons
- Model Operators
  * 4 persons

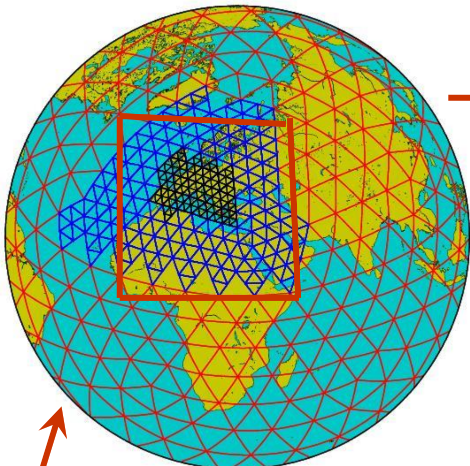
Consortium for Small – scale Modeling COSMO

http://cosmo-model.org/content/consortium/structure.htm



COSMO – deterministic forecasts

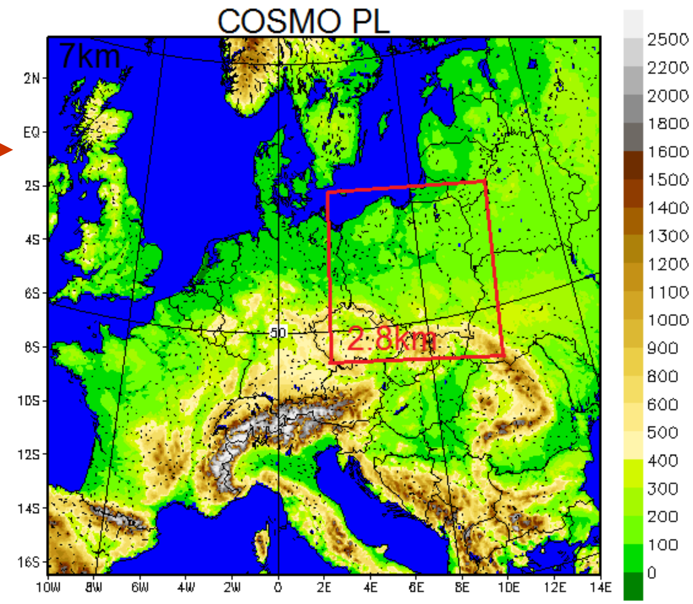
Global Model ICON



ICON forecast

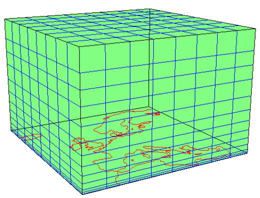
boundary and initial conditions

COSMO-14km,7km

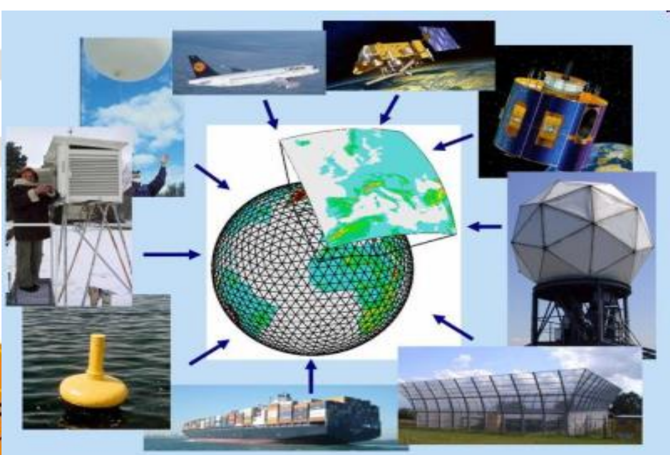


COSMO forecast

verification



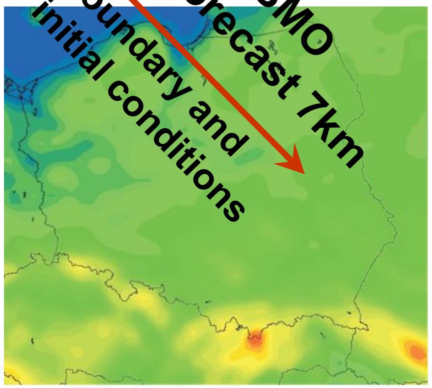
ICON Data Assimilation



COSMO Data Assimilation 7km

COSMO forecast 7km

boundary and initial conditions

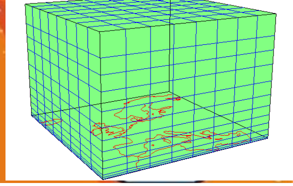


COSMO forecast

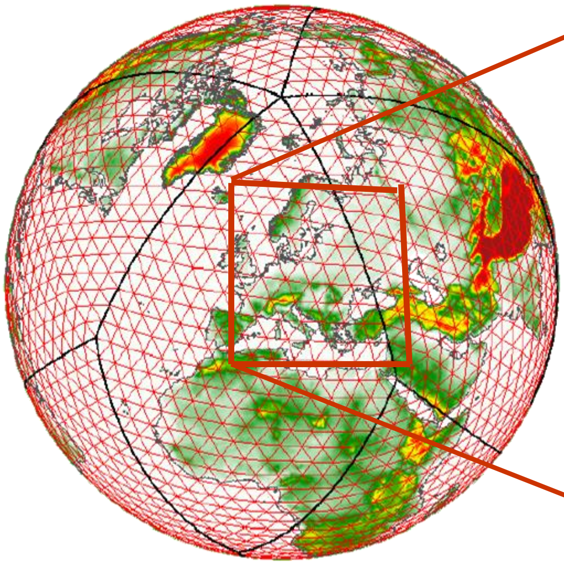
COSMO-2.8km

GTS (Global Telecommunication System) server

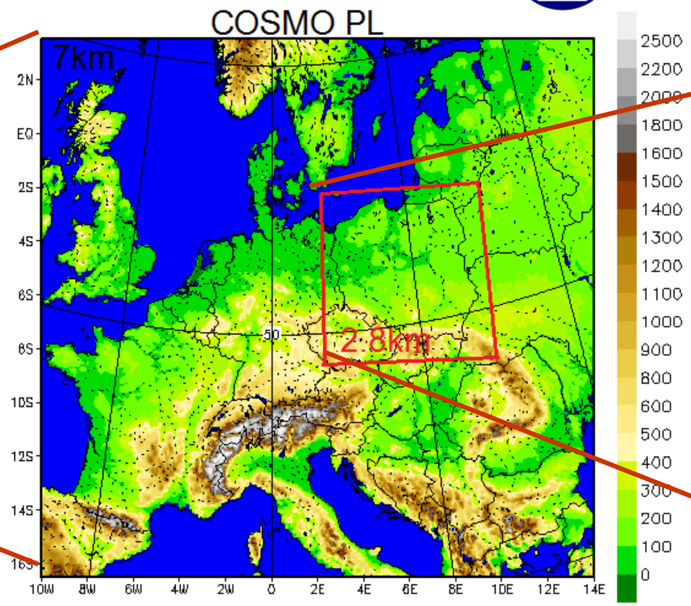
COSMO Operational Configuration



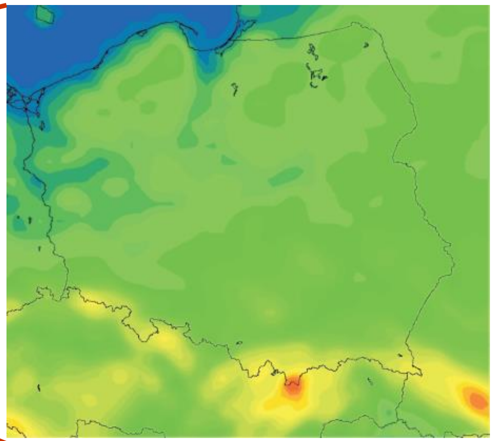
ICON



COSMO-7km



COSMO-2.8km



icosahedral-hexagonal grid

Non-hydrostatic Model
Convection parameterization: Bechthold
Δx = 13 km
2880x1441 * 90 punktów
T = 180 h (00,12 UTC)
78 h (06,18 UTC)

Non-hydrostatic Model
Convection parameterization: Tiedtke
Δx = 7 km,
2695 km x 2247 km
385 x 321 x 40 punktów
Δt = 40 sec., T = 78 h
Four runs per day:
00, 06, 12, 18 UTC

Non-hydrostatic Model
convection-permitting scale
Δx = 2.8 km,
798 km x 714 km
285 x 255 x 50 punktów
Δt = 30 sec., T = 36 h
Two runs per day:
00, 12 UTC

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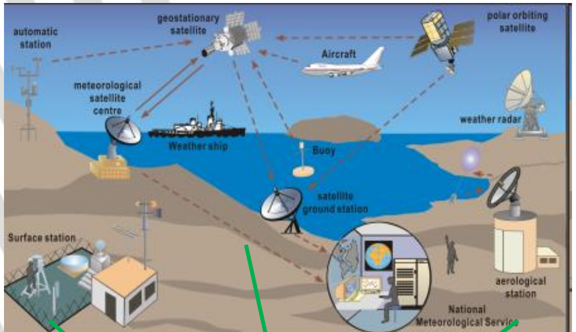
COSMO data assimilation scheme

Obserwations of IMWM / WMO: SYNOP, SHIP, TEMP, METAR, PILOT, AIREP, AMDAR, SATEM, SATOB



GTS Server
(Global Telecom. System)

Model Query
(for observations from given term)

Bash Shell scripts
(prepare queries ”xml” to Sky/GLObus system with observations’ type and time range)

Sky Klient
(sends ”xml” queries to Sky/GLObus system)

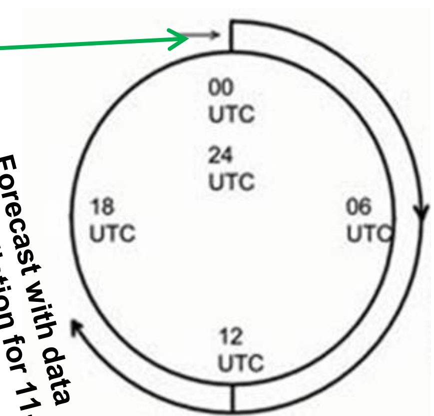
Sky/Globus System
Continuous archiving of data for one year range
Conversion from GTS to BUFR format
Delivery of data from selected time range and observation type

MODEL COSMO
(data assimilation)

Conversion bufr2netcdf
(conversion of files from BUFR to NetCDF format)

Input in NetCDF format
(input for DAAC mode)

Start of COSMO with assimilation, initial- and boundary conditions from ICON



Forecast with data assimilation for 11-15 UTC

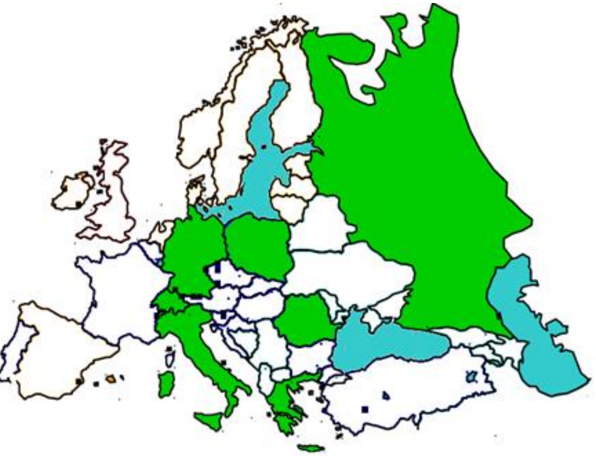
Forecast start. Initial conditions from analysis, assimilation between 23-11 UTC

The new infrastructure platform for COSMO model

Cluster „Aura" (COSMO).
- 2 blades c7000 (16 servers BL460c each)
- **ProLiant HP Bl460c G6 - 32 blades**
- **2 4-core processors Intel Xeon X5570 (256 total)**
- **2 management servers DL380G6**
- **InfiniBand 4xQDR**
- **speed: 2,5 TFlops**
- disk array MSA2324FC, 2 TB (+8TB) capacity
-**NetApp disks via the Fibre Channel protocol**

Cluster „Grad" (COSMO).
- 10 casette systems *c7000*
-**145 servers *BL460c Gen8***
***6 management nodes,* 2 8Core CPU**
***139 computation nodes ,* 2x10Core CPU,**
128GB RAM (increase ~10x)
- performance – HPLinpack test ~61 Tflops (speedup ~25x)
- disk array HP3PARStoreServ7400 ~70TB capacity.

COSMO model



- Fully compressible;
- Non-hydrostatic,
- Conservation rights-based

Hydro- and thermodynamic equations:

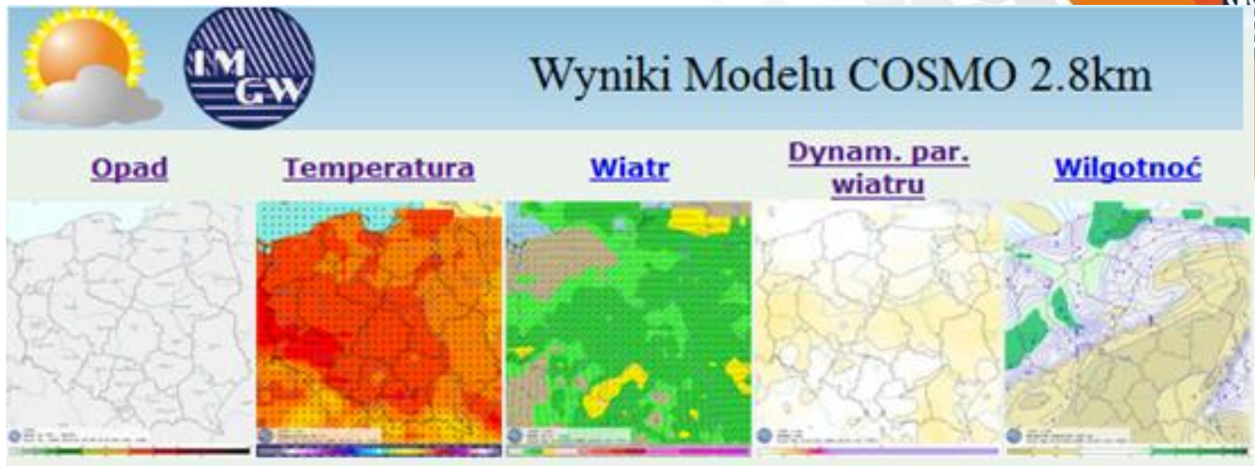
- Momentum conservation
- Mass conservation
- Energy conservation

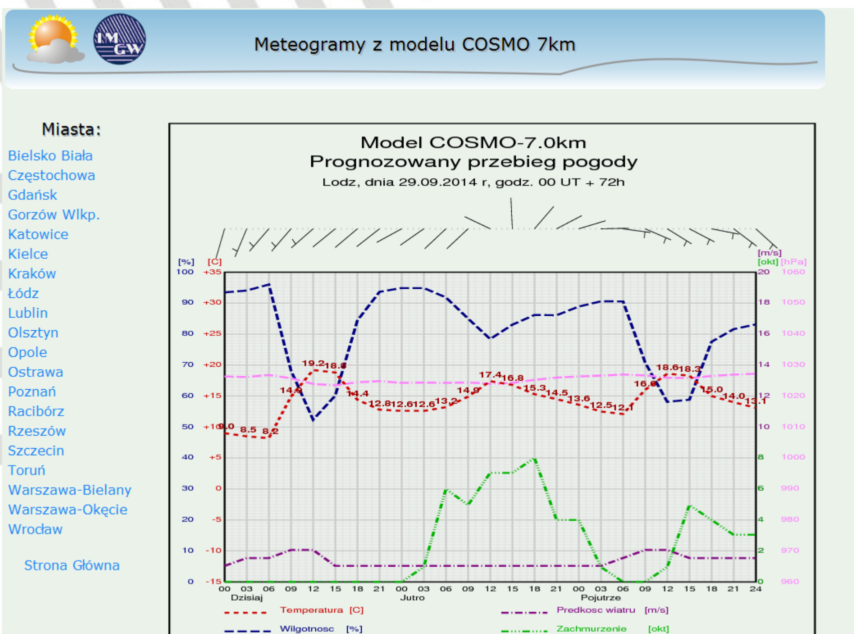
Parameterizations in COSMO model:

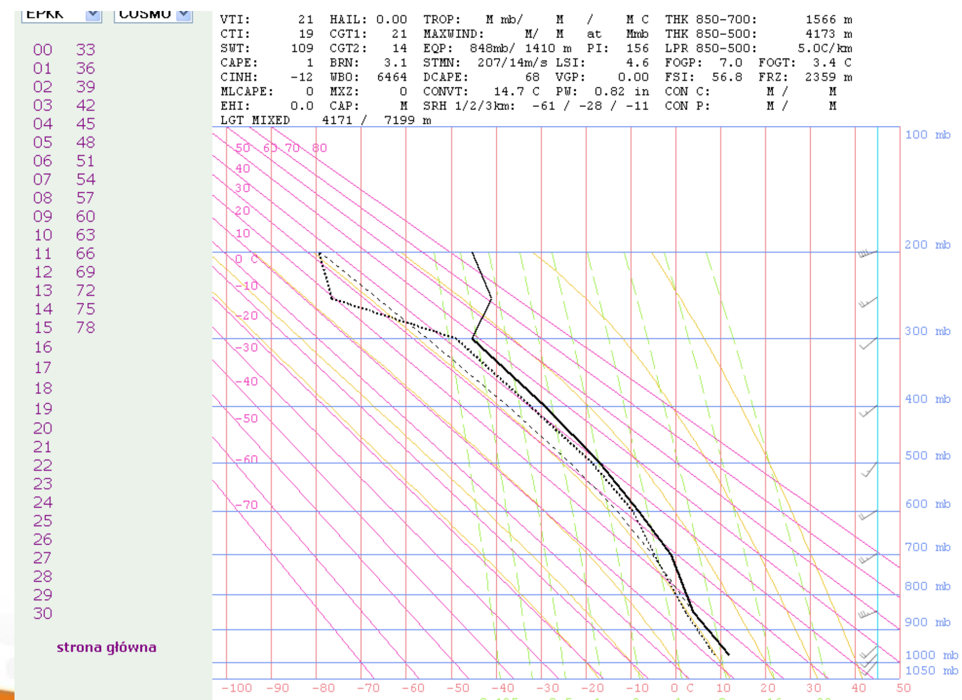
- Boundary-layer processes
- Physical and microphysical processes in clouds
- Convective processes
- (Tiedtke scheme: deep/shallow convection)
- Radiative processes
- Land Surface Model: TERRA/TERRA_ML

Standard Products

- Maps
- Meteograms
- Aerograms
- 3D Grib data

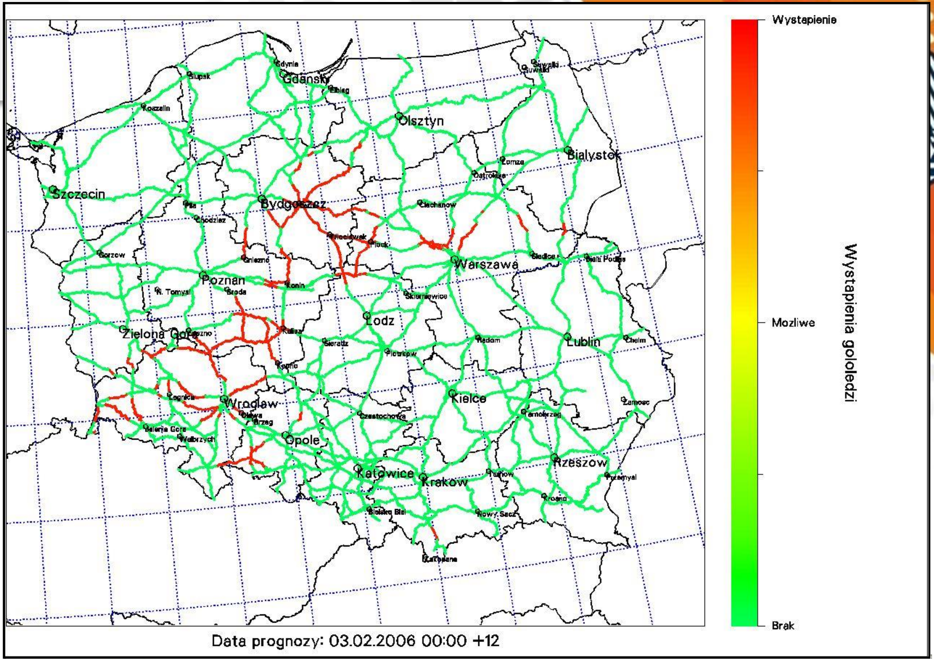


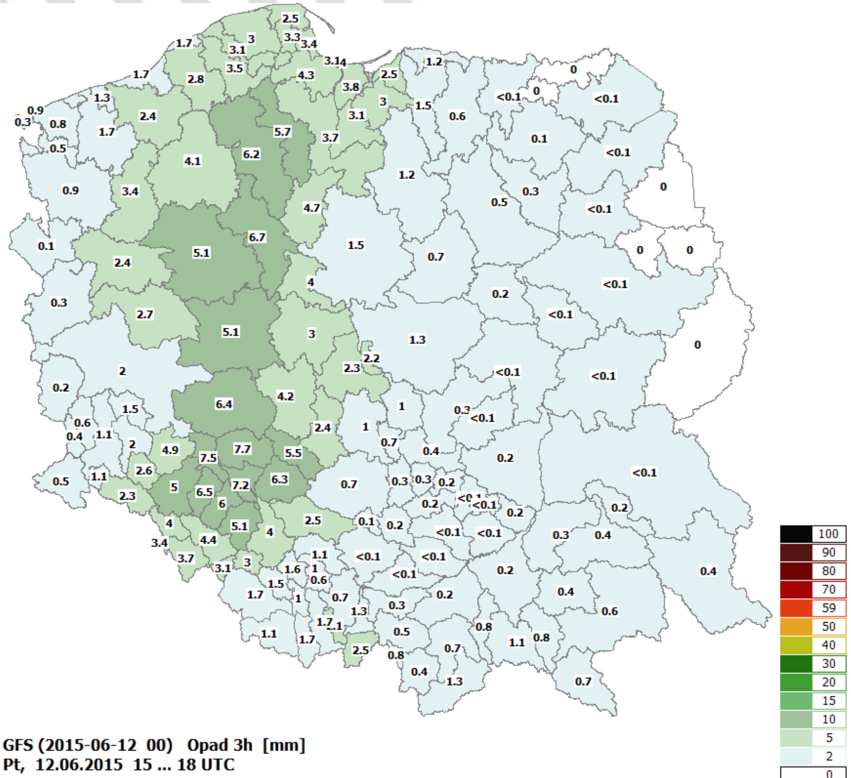




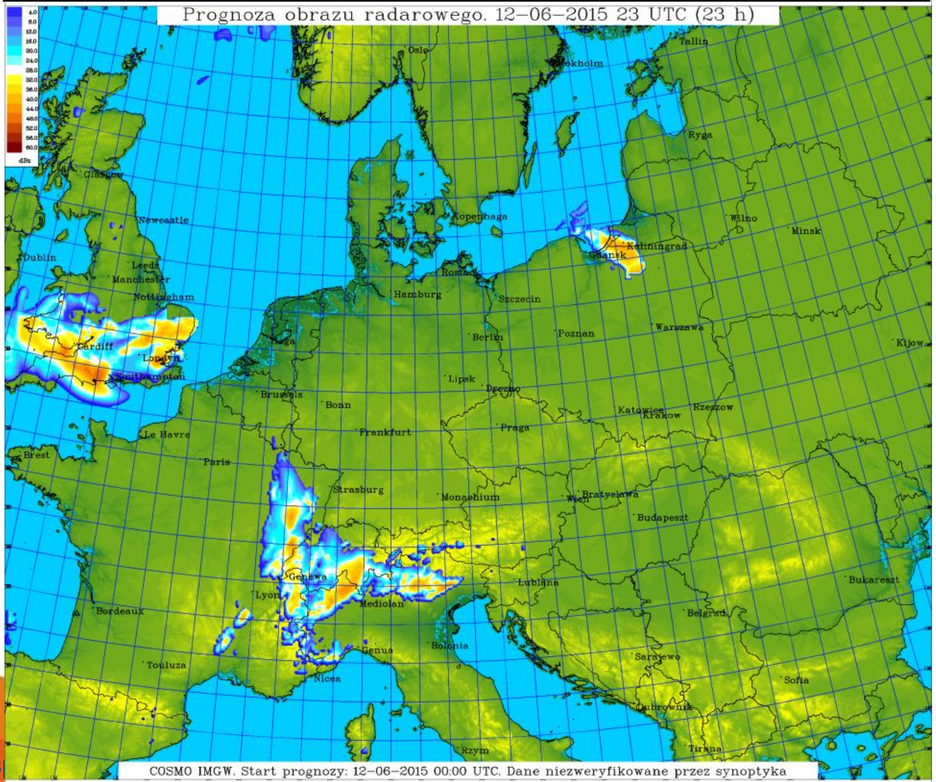
Dedicated Products

- **SOMD**
- **Hydrological model input**
- **Radar reflectivity**
- **WW3**





GFS (2015-06-12 00) Opad 3h [mm]
Pt, 12.06.2015 15 ... 18 UTC



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Section for R&D of COSMO Physical Parameterizations

* Studies in progress

Ensemble forecasts

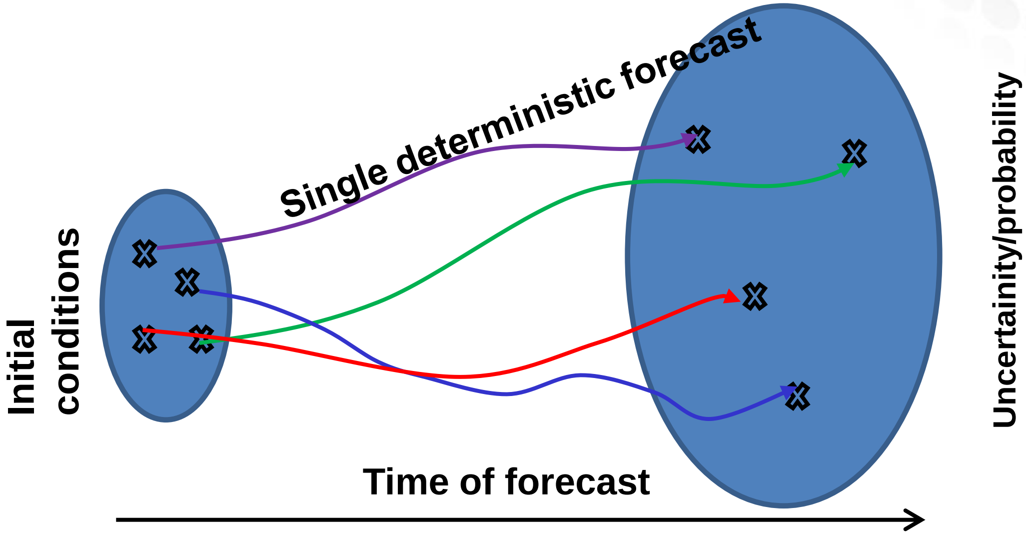
Parameterization of physical processes in soil

Parameterization of clouds' electricity

** planned*

Probalistic ensemble forecasts

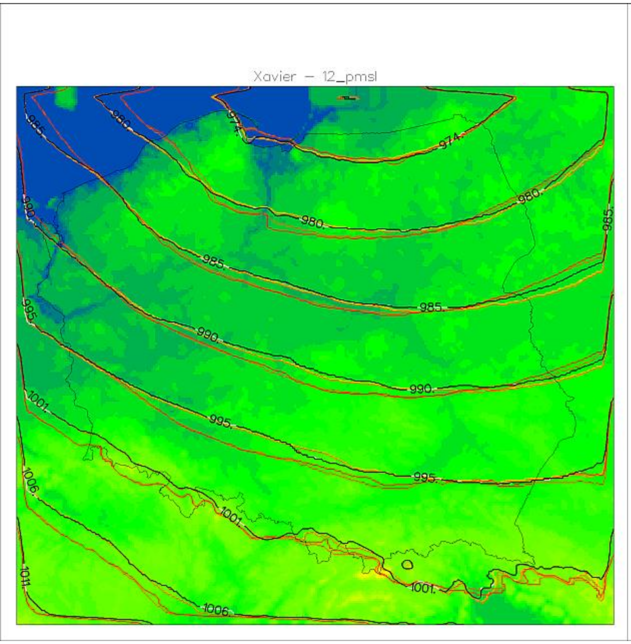
- ❑ Ensemble (set) of forecasts, each starts with various initial conditions, uses a different physics or model numerics.
- ❑ Ensemble mean are closer to reality (forecast skill) than single (deteministic) forecast.

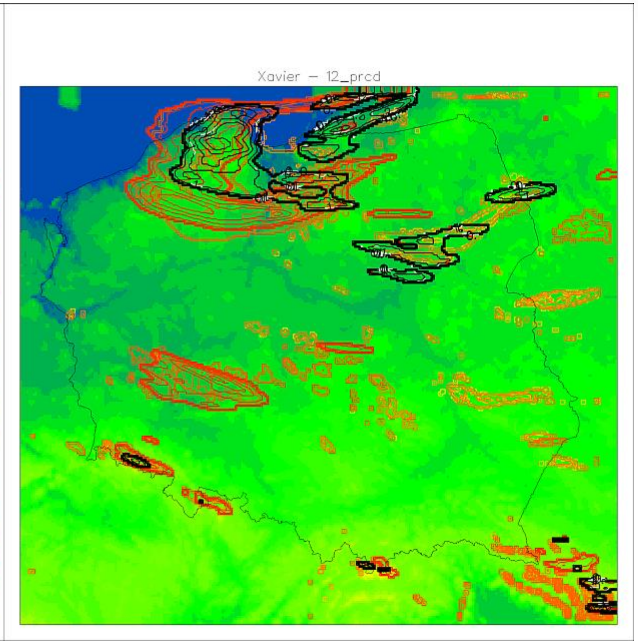


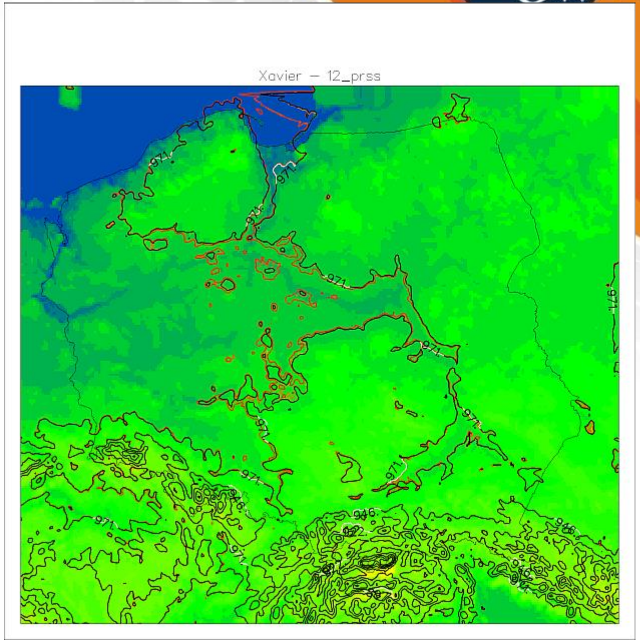
How to prepare an ensemble member(s)

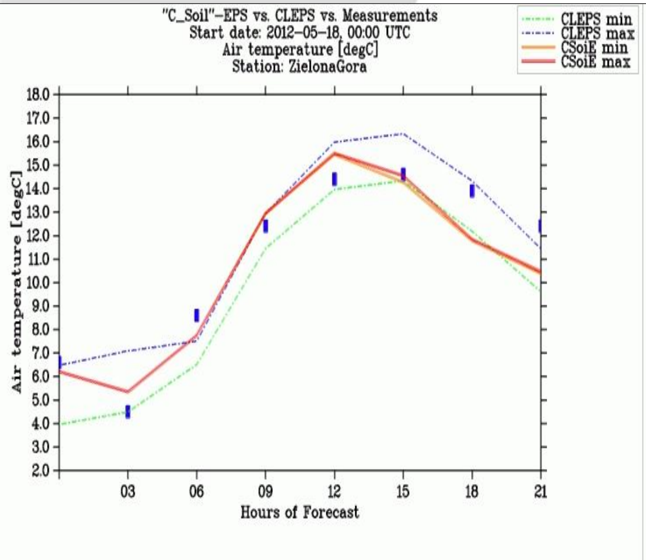
- **Model numerics:** different schemes (methods for solution of equation)
- **Model physics:** different parameterization schemes
- **Perturbation of initial conditions**

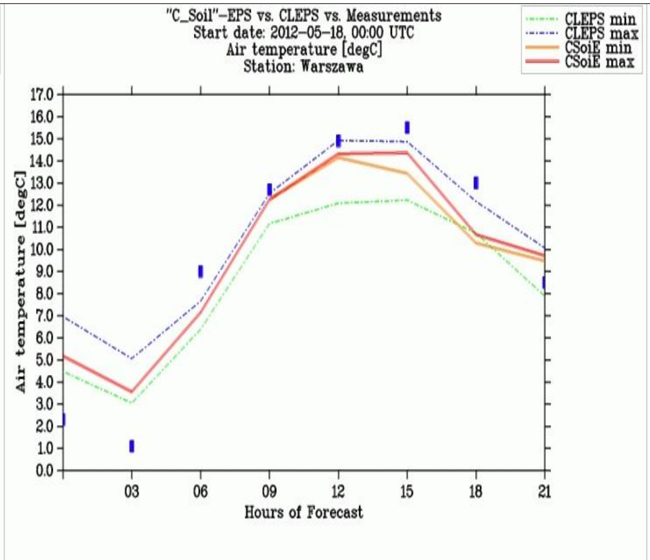
Examples

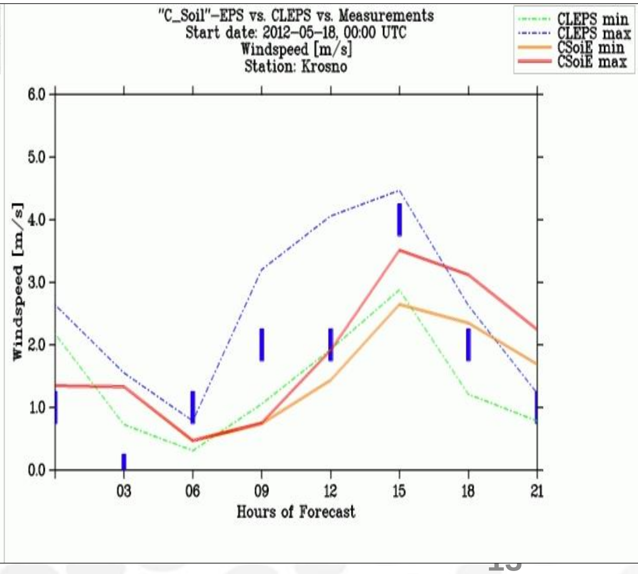

Xavier — 12_pmsl


Xavier — 12_prcd


Xavier — 12_prss


"C_Soil"–EPS vs. CLEPS vs. Measurements
Start date: 2012–05–18, 00:00 UTC
Air temperature [degC]
Station: ZielonaGora
CLEPS min
CLEPS max
CSoiE min
CSoiE max
Air temperature [degC]
Hours of Forecast


"C_Soil"–EPS vs. CLEPS vs. Measurements
Start date: 2012–05–18, 00:00 UTC
Air temperature [degC]
Station: Warszawa
CLEPS min
CLEPS max
CSoiE min
CSoiE max
Air temperature [degC]
Hours of Forecast


"C_Soil"–EPS vs. CLEPS vs. Measurements
Start date: 2012–05–18, 00:00 UTC
Windspeed [m/s]
Station: Krosno
CLEPS min
CLEPS max
CSoiE min
CSoiE max
Windspeed [m/s]
Hours of Forecast

Assimilation of GNSS*) Integrated Water Vapour in COSMO Model

(Anluf, Stephan, Schraff, Potthast, Eichner, 2009-2011, DWD)

- COSMO-DE is ready to read ZTD and IWV either from NetCDF or ASCII files (COST-716 format provided by GFZ Potsdam)
- Mostly Zenith Total Delay (ZTD) is measured
- Integrated Water Vapour (IWV) directly used if available
- Bias correction could be done optionally
- Threshold quality control is applied to the IWVob
- IWV less than 2 kg/m^2 is neglected

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*) Global Navigation Satellite Systems

Assimilation of GNSS Integrated Water Vapour in COSMO Model

- ZTD can be converted into IWV:

$$\Delta t_{\text{vap}} = \Delta t_{\text{tot}} - \frac{2,2765p}{1-\varepsilon} \qquad \text{IWV}_{\text{obs}} = \frac{\Delta t_{\text{vap}}}{R_{vap}\left(k_s + \dfrac{k_l}{70,2+0,72T}\right)}$$

- *p*- pressure at receiver;
- *T* – temperature at station;
- *ε* – constant depending on station height, latitude.

- IWV is converted into humidity by defining an "observed" specific humidity profile
- If result exceeds saturation, it is corrected

$$q_{v0} = q_{v_{gs}} \frac{\text{IWV}_{\text{ob}}^{\text{corr}}}{\text{IWV}_{\text{gs}}}$$

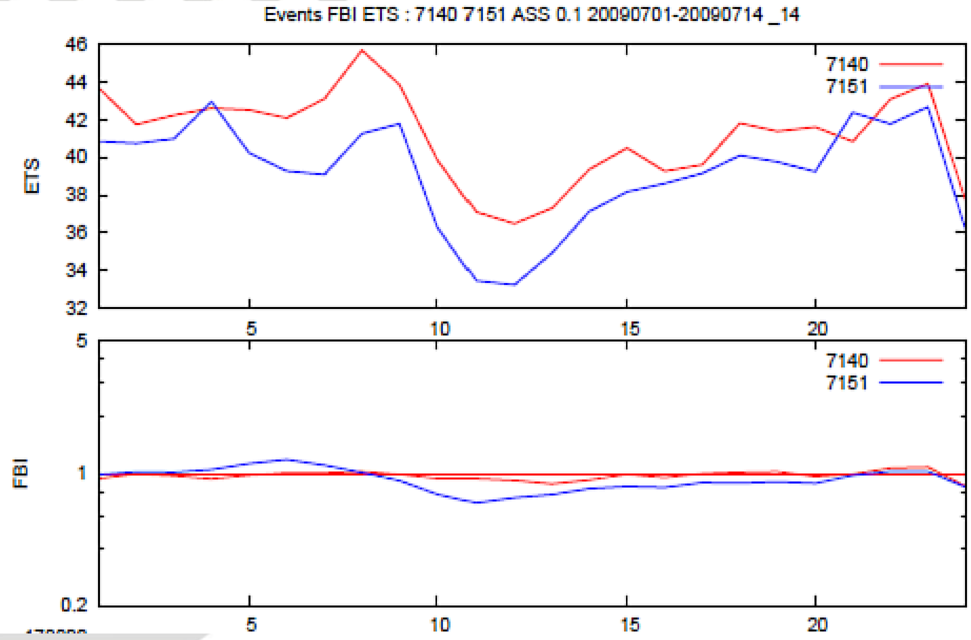
- Stop after 20 iterations or if deviation is smaller than 0.1%

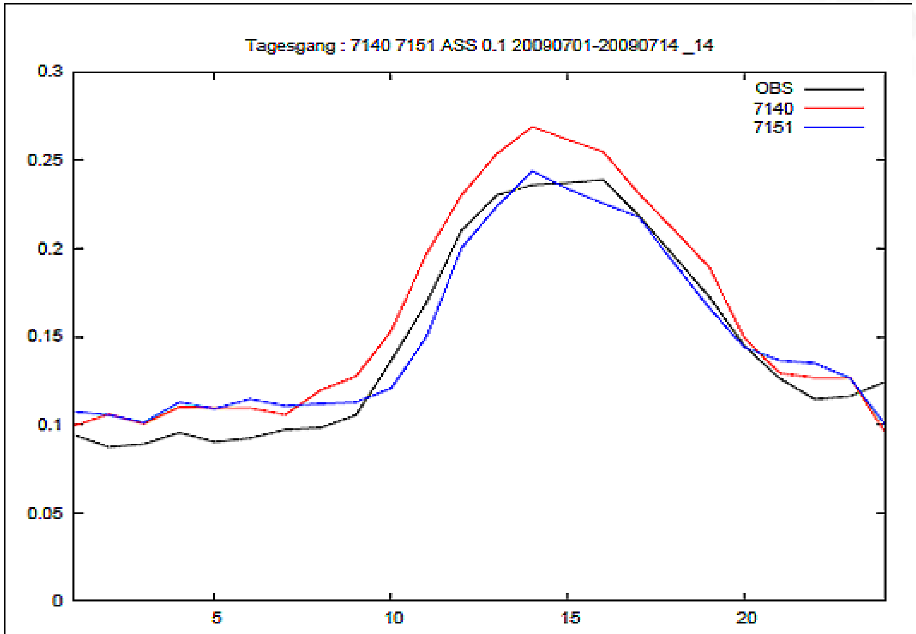
Adapted from: „Assimilation of GPS data: GPS Radio-Occultation and GNSS Integrated Water Vapor" Anluf, Stephan, Schraff, Potthast, 2011

„Assimilation of GNSS Integrated Water Vapour" Karolin Eichler, Klaus Stephan, Christoph Schraff, COSMO User Seminar, 2010

Assimilation of GNSS Integrated Water Vapour in COSMO Model

- General positive impact in assimilation
- Positive impact in forecast if enough data in nudgecast





Verification of precipitation (14-day-average, 21 hour starting at 00 UTC)

Blue = Control run without GNSS data
Red = Run with ‘operational‘ GNSS data

Adapted from: „Assimilation of GPS data: GPS Radio-Occultation and GNSS Integrated Water Vapor" Anluf, Stephan, Schraff, Potthast, 2011

„Assimilation of GNSS Integrated Water Vapour" Karolin Eichler, Klaus Stephan, Christoph Schraff, COSMO User Seminar, 2010

Assimilation of GNSS Integrated Water Vapour in COSMO Model

Goal: operational IWV assimilation

- Reduce biases, solve „cloud ice problem"
- Quality control (black-/whitelist)
- Get more data into the nudgecast

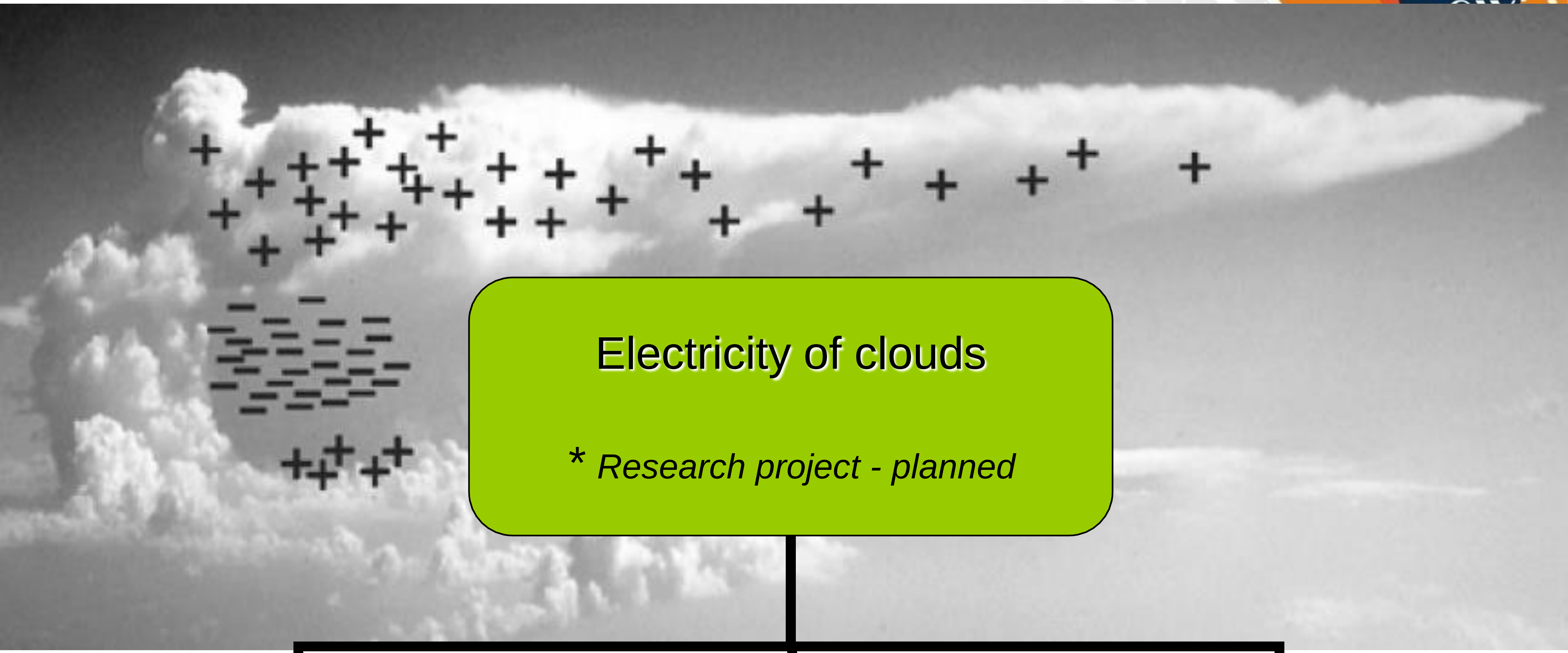
Long-term plans:

- Assimilation of GNSS data into ICON Worldwide network: USA, Japan, South-Korea, Australia, China, . . .
- GNSS slant delays

Adapted from: „Assimilation of GPS data: GPS Radio-Occultation and GNSS Integrated Water Vapor" Anluf, Stephan, Schraff, Potthast, 2011

„Assimilation of GNSS Integrated Water Vapour" Karolin Eichler, Klaus Stephan, Christoph Schraff, COSMO User Seminar, 2010

Parameterization of clouds electrification – project



Electricity of clouds

* *Research project - planned*

Climatological analysis

analysis of
physical phenomena
responsible
for
electricity of clouds

** In progress*

Preparation of
Parameterization
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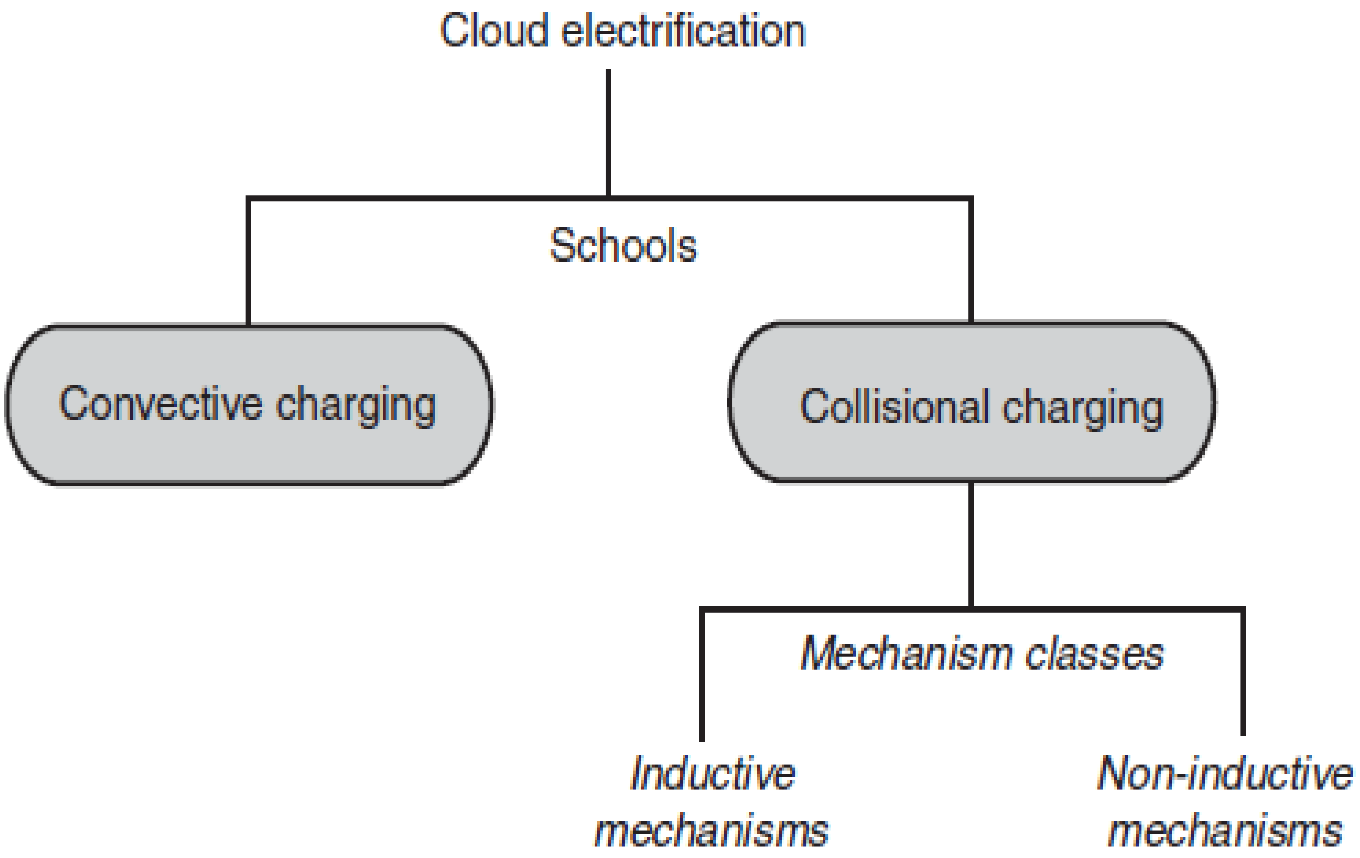
implementation

Tests

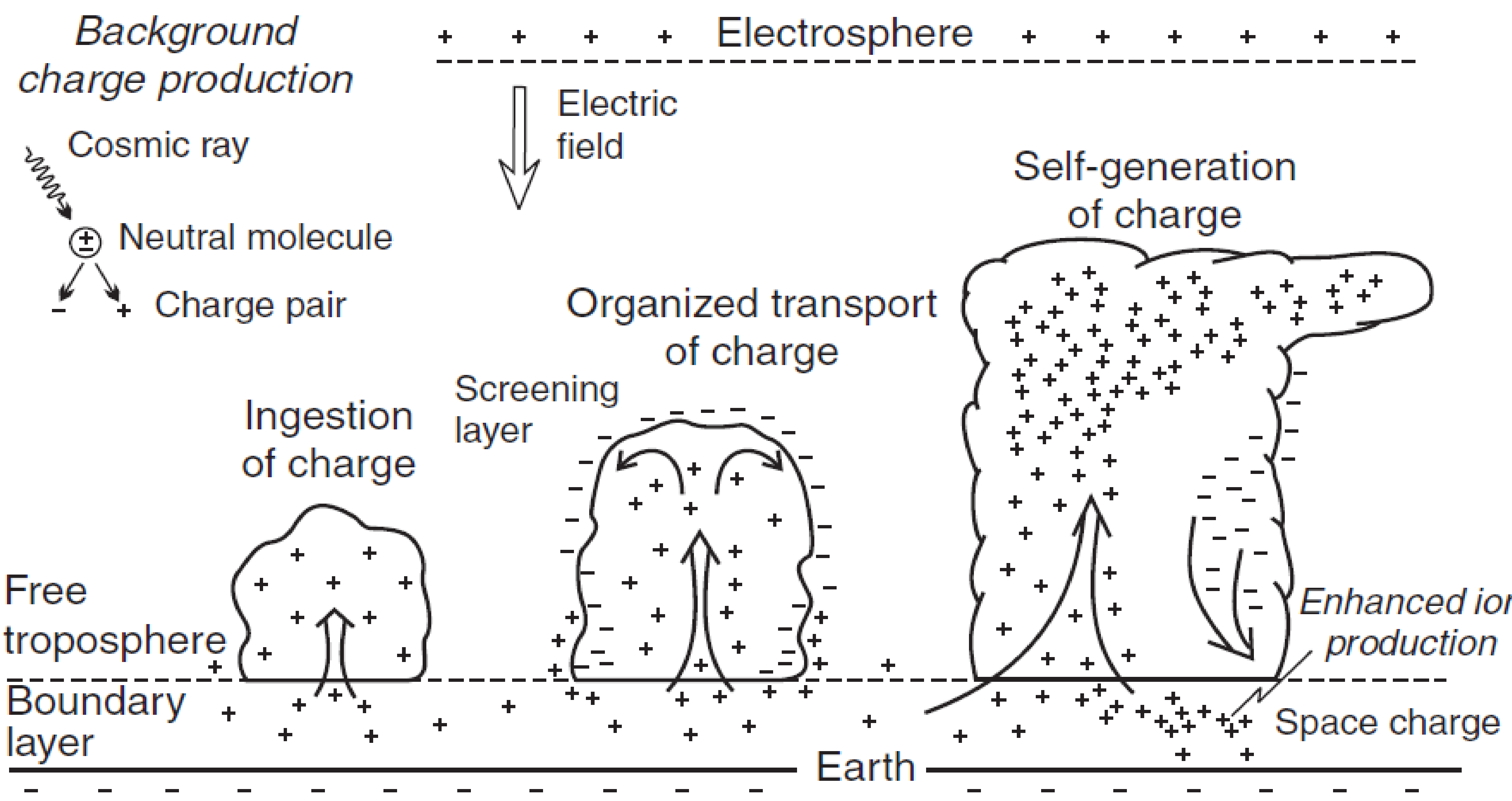
Adapted from „*Physics and Chemistry of Clouds*" D. Lamb, J. Verlinde, Cambridge University Press, 2011

Parameterization of clouds electrification – project



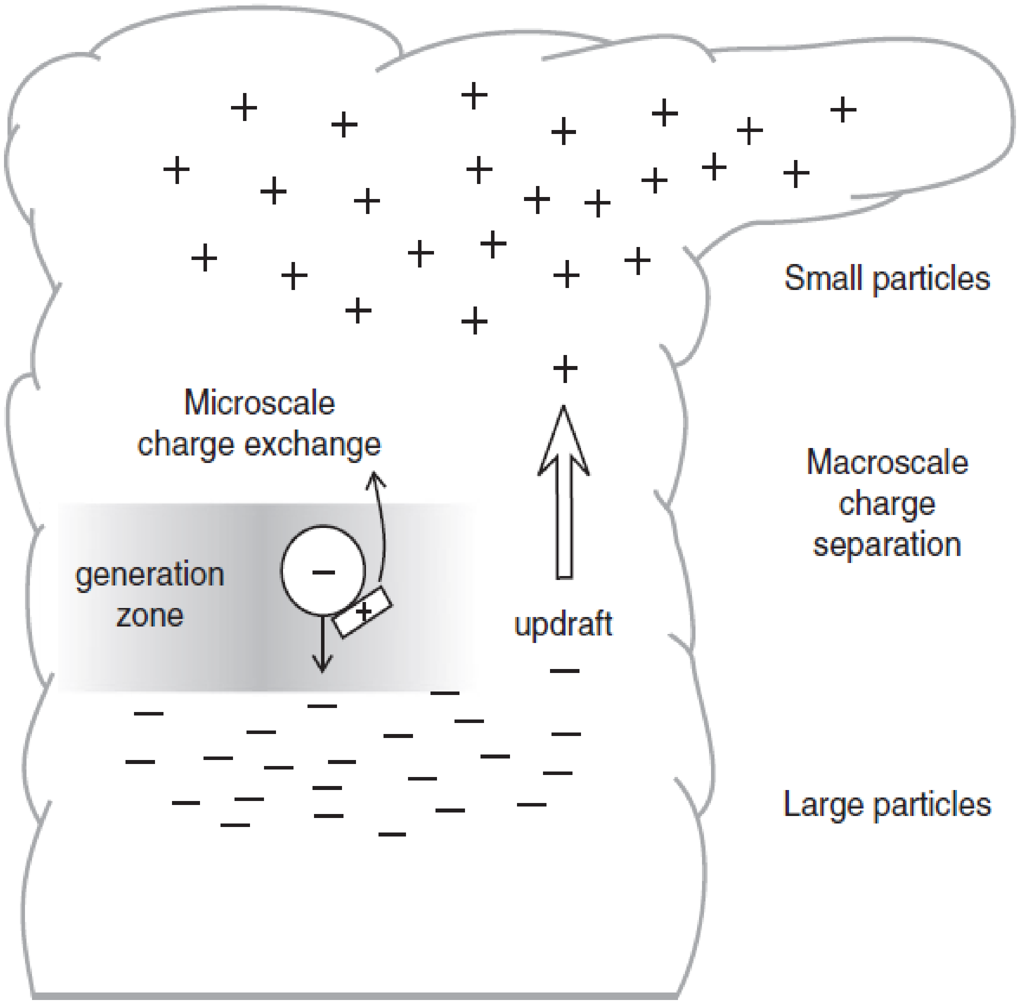
Adapted from „*Physics and Chemistry of Clouds*" D. Lamb, J. Verlinde, Cambridge University Press, 2011

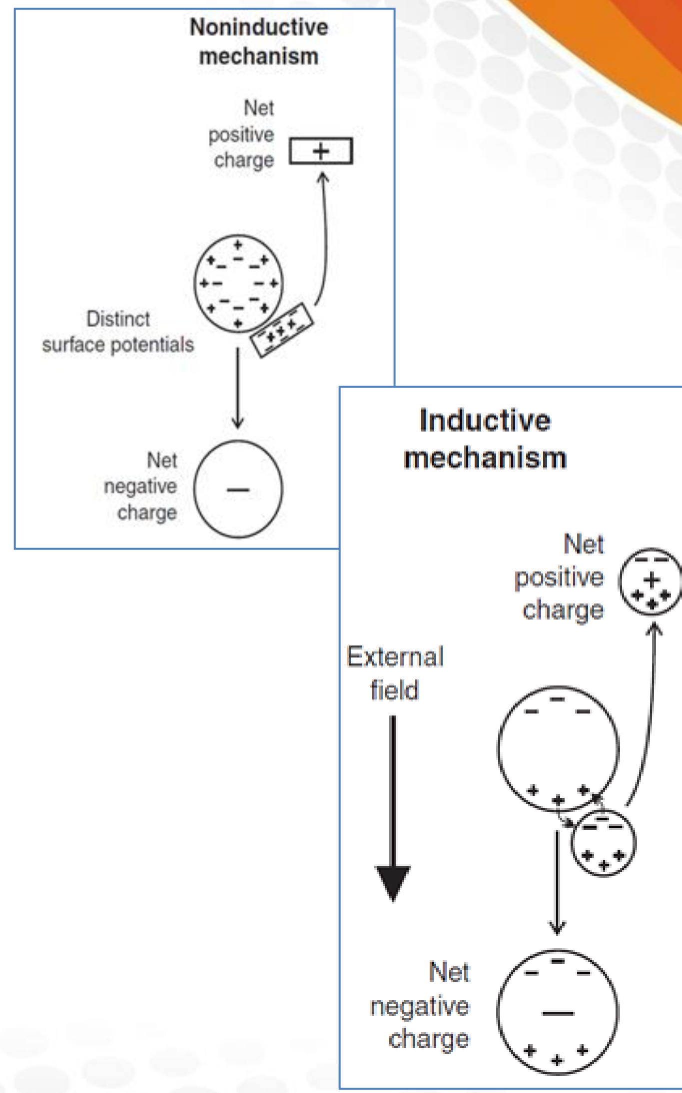
Convective charging



Adapted from „*Physics and Chemistry of Clouds*” D. Lamb, J. Verlinde, Cambridge University Press, 2011

Collision charging

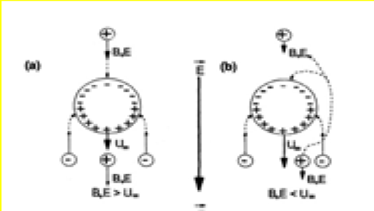




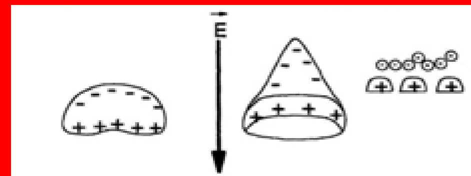
Adapted from „*Physics and Chemistry of Clouds*" D. Lamb, J. Verlinde, Cambridge University Press, 2011

charging mechanisms

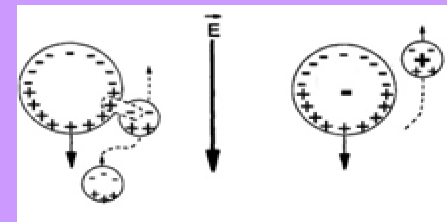
Inductive



Charging by selective ion capture

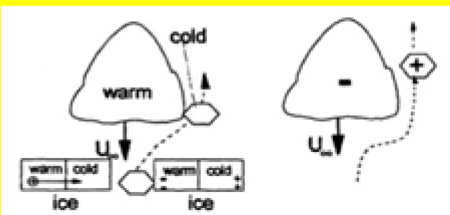


Drop breakup charging

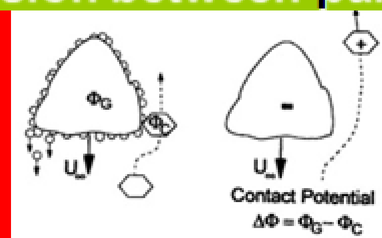


Particle rebound charging

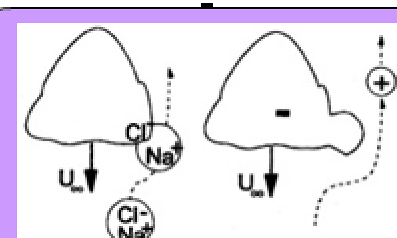
collision between particles



The thermo – electric effect



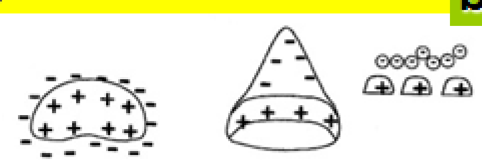
The contact potential effect



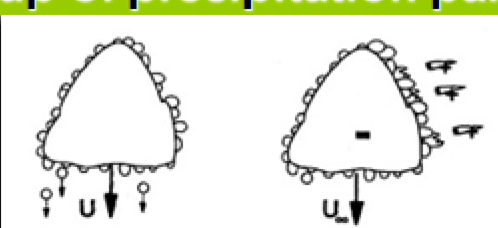
The Workman – Reynolds effect

Non – Inductive

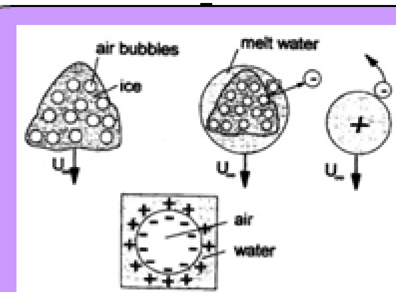
breakup of precipitation particles



breakup of a freezing drop & drop breakup



Splintering during riming



Graupel melting

Adapted from „*Microphysics of Clouds and Precipitation*" H. R. Pruppacher, J. D. Klett, Springer, 1996

Non – Inductive charging mechanisms - parameterization

- The non-inductive mechanism appears to be most effective when rimed graupel collides with cloud–ice particles or snow in a region that also has liquid water.

- The sign and magnitude of the charge that is transferred depends on ambient temperature, liquid water content and impact speed.

PARAMETERISATIONS:

Jayaratne & Gardiner: charge transferred to a rimed graupel/hail particle when it collides with a cloud-ice/snow particle

$$\delta q = k_q D_i^m \left(\Delta \upsilon_{gi}\right)^n \left(LWC - LWC_{crit}\right) f\left(\Delta T\right)$$

Saunders

$$\delta q = k_q D_i^m \left(\Delta \upsilon_{gi}\right)^n f\left(\Delta T, EW\right) \quad EW = LWC \cdot \varepsilon_{collect}$$

*EW*crit – value of **effective liquid water content** at which the polarity change

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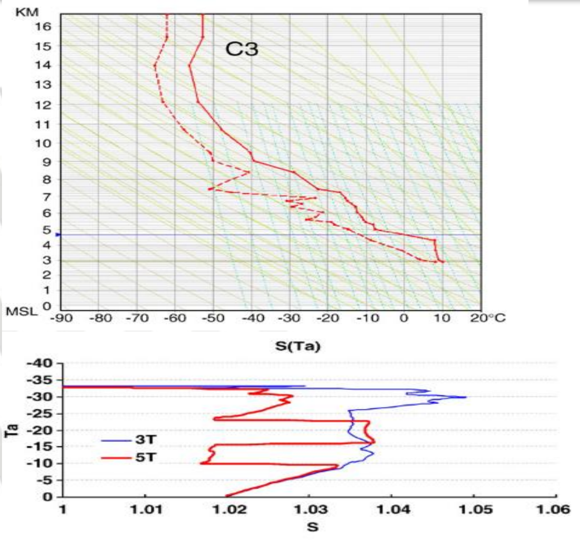
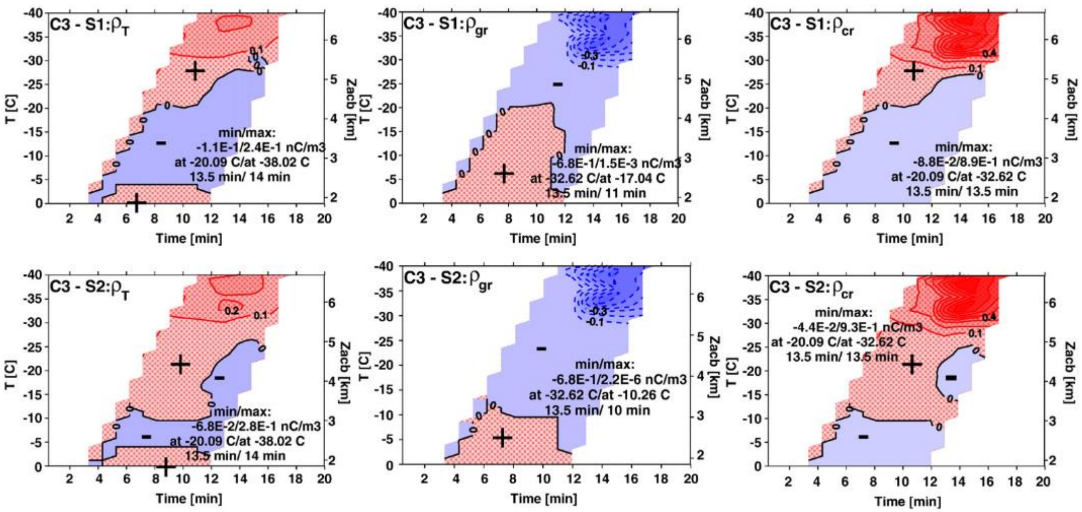
„*Measurement of initial potential gradient and particle charges in a Montana summer thunderstorm*", Gardiner, Lamb, Pitter, et al., J. Geophys. Res., 90, (1985), 6079-86.
„*The electrical nature of storms",* D. R. MacGorman, W. D. Rust, Oxford University Press, 1998.

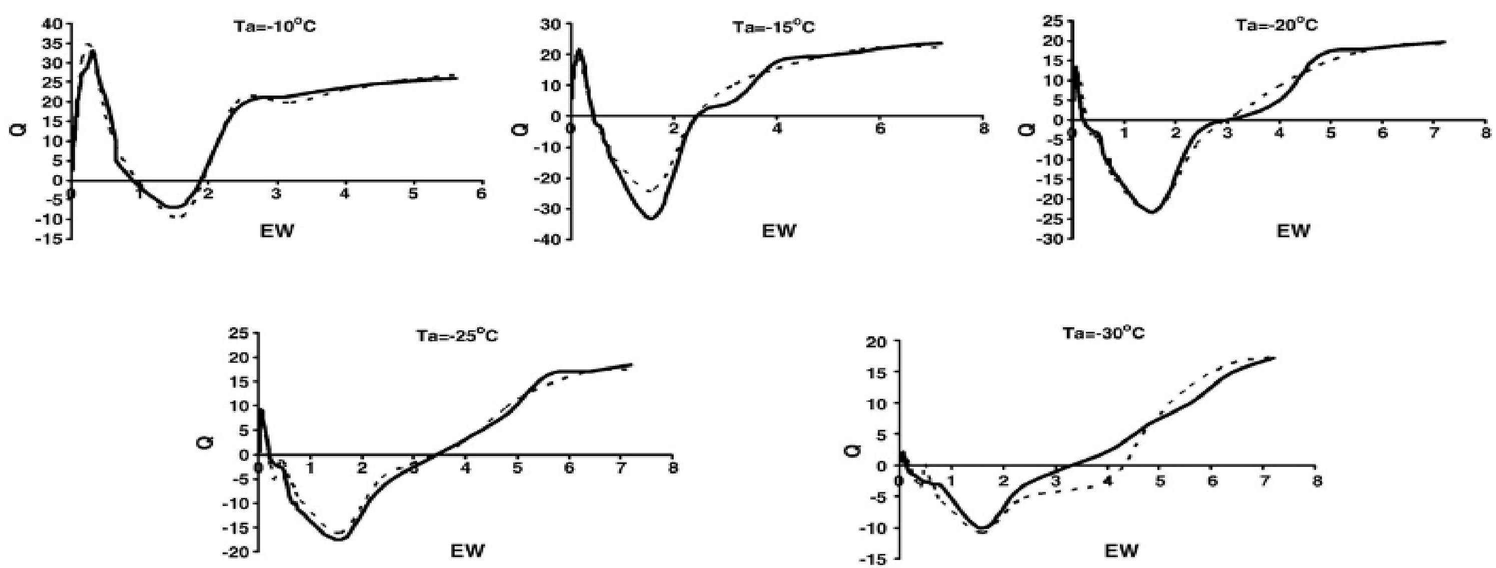
Non – Inductive charging mechanisms - parameterization



C3 Cloud: Saturation of the water vapor with respect to water (S) as a function of the cloud temperature Ta in the 3rd and 5th ascending thermals.



C3 cloud: Total charge density – ρ_T (left panel) and densities of the charge carried by graupel – ρ_{gr} (middle panel) and ice crystals – ρ_{cr} (right panel) with S1 and S2 parameterizations (including the saturation effect) as a function of the height (and cloud temperature T) and the model time. The negative charge is presented by dashed isolines on solid (blue) background and the positive charge by bold isolines on hatched (red) background. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



Charge as a function of effective water content EW at different temperatures Ta ≤ − 10 °C. Bold line — Takahashi's (1978) charge values; dashed line — charge values obtained by Eqs. (8), (9) and (10).

„Parameterization of thunderstorm charging including the cloud saturation effect", **Tsenowa, Mitzeva, Saunders, Atmospheric Research (2010), 356-365.**

Research plan

- **Operating activities:**

a) Assimilation GNSS data in COSMO model at IMWM.

- **Theoretical research (clouds physics):**

a) non–inductive charging mechanism parameterization ;

b) inductive charging mechanism and its parameterization;

c) implementation results in COSMO model and numerical tests.

Research plan - continued

- **The use of GNSS data:**

a) for verification current non–inductive charging mechanism parameterization;

b) to develop non–inductive charging mechanism parameterization;

c) for analysis of the validity of RAR index on the mechanism thunderstorm charging;

d) for parameterization of the saturation effect on the sign of charge transfer;

Research plan - continued

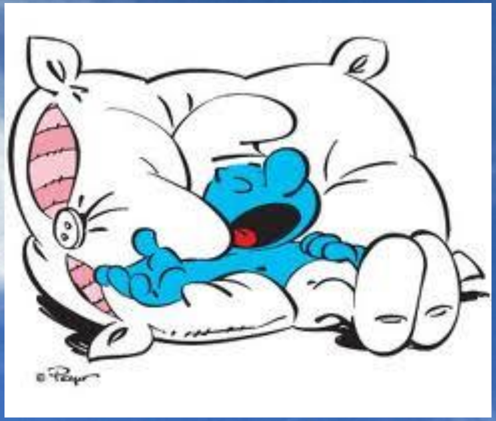
- **The use of GNSS data:**

e) for verification equations for the charge values at cloud temperatures:

- higher than -10˚C;
- lower than -10˚C;

f) for parameterization of thunderstorm charging taking into account other mechanisms;

Thank you for your attention



Andrzej Mazur, Grzegorz Duniec
Institute of Meteorology and Water Management
National Research Institute
Department for Numerical Weather Forecasts COSMO
PL-01-673 Warsaw, 61 Podleśna str.
+48 22 5694-134; +48 22 5694-130
andrzej.mazur@imgw.pl; grzegorz.duniec@imgw.pl
www.imgw.pl, www.pogodynka.pl