# Surface radiation budget of the Baltic Sea from satellite data

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# *Outline*

- Satellite Monitoring of the Baltic Sea environment (**SatBałtyk**)
- ✓ www.satbaltyk.eu
- The possibility of applying satellite information and other alternative sources to estimate the net radiation fluxes for the Baltic Sea
- ✓ Components of the radiation budget
- ✓ Input data and format
- ✓ Algorithms and validation
- ✓ Products
- ✓ Summary

# Radiation budget at the sea surface

$$NET = SW\uparrow\downarrow + LW\uparrow\downarrow$$

Net shortwave radiation

$$SW\uparrow\downarrow = SW\downarrow - SW\uparrow$$

Net longwave radiation

$$LW\uparrow\downarrow = LW\uparrow - LW\downarrow$$

downward and upward shortwave irradiance

$$SW\downarrow = \int_{0.3\mu m}^{3\mu m} E_d(\lambda, z=0)\,d\lambda$$

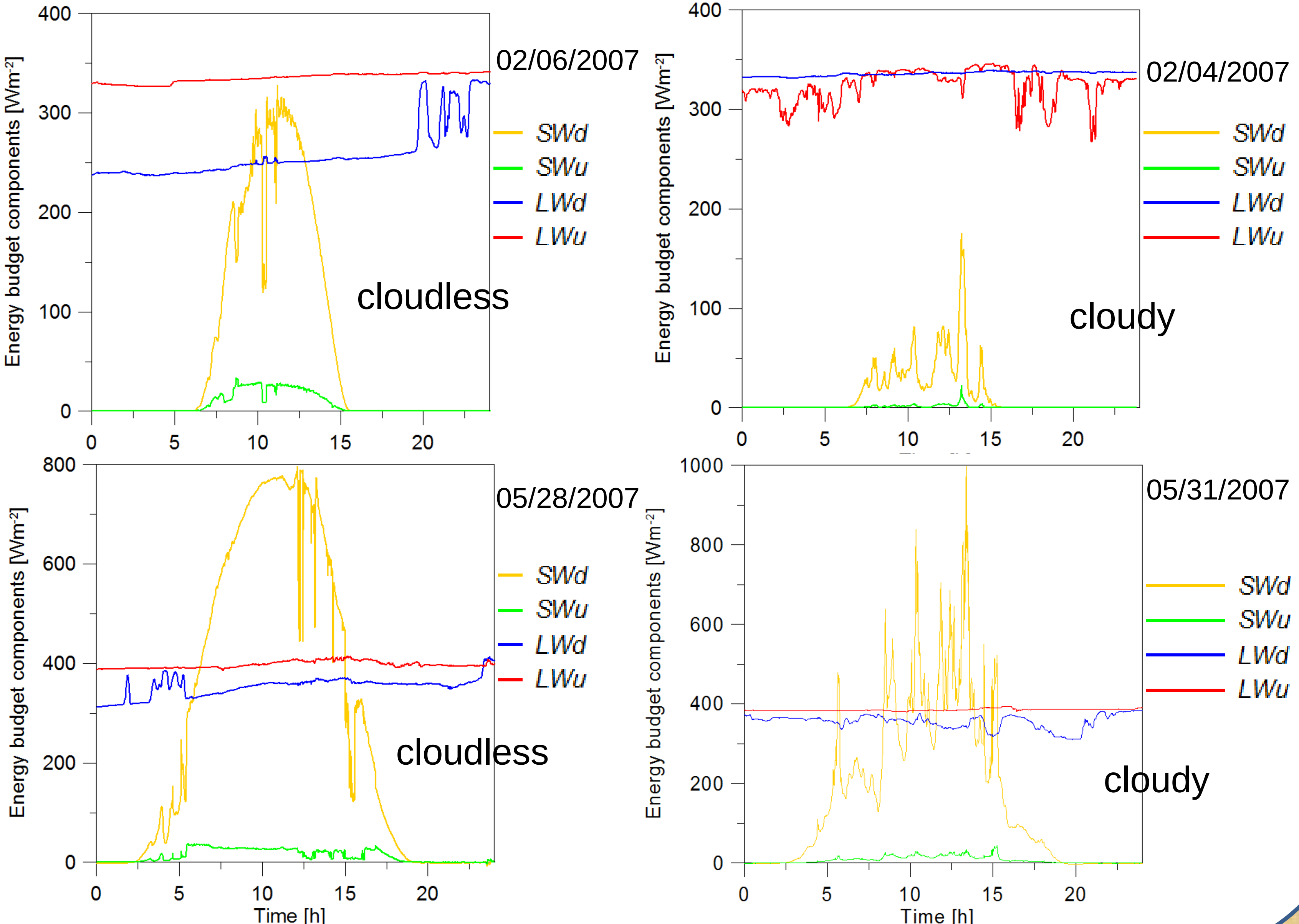
$$SW\uparrow = \int_{0.3\mu m}^{3\mu m} E_u(\lambda, z=0)\,d\lambda$$

downward and upward longwave irradiance

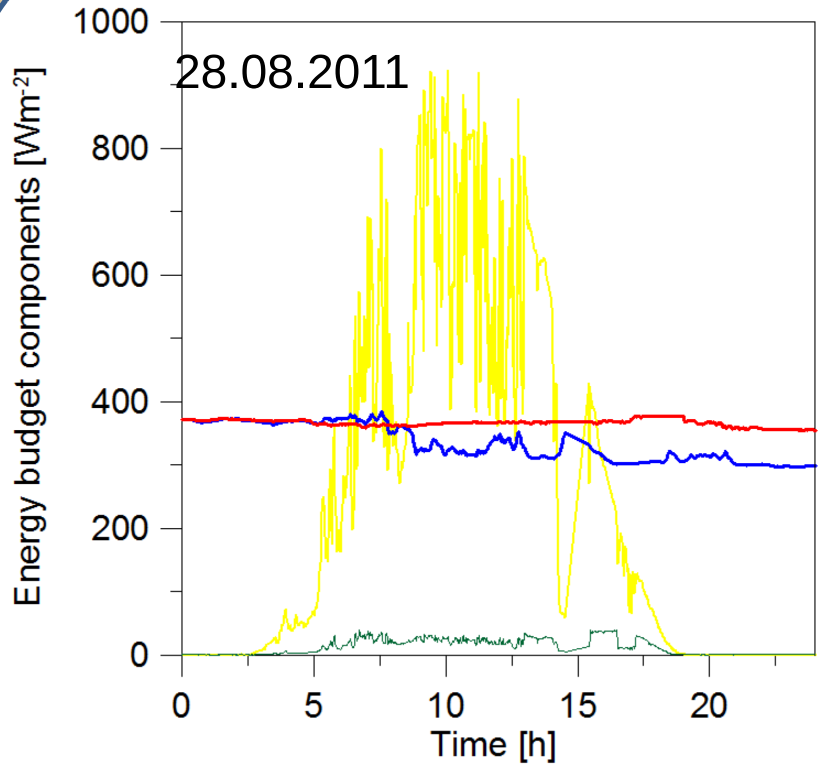
$$LW\downarrow = \int_{3\mu m}^{100\mu m} E_d(\lambda, z=0)\,d\lambda$$

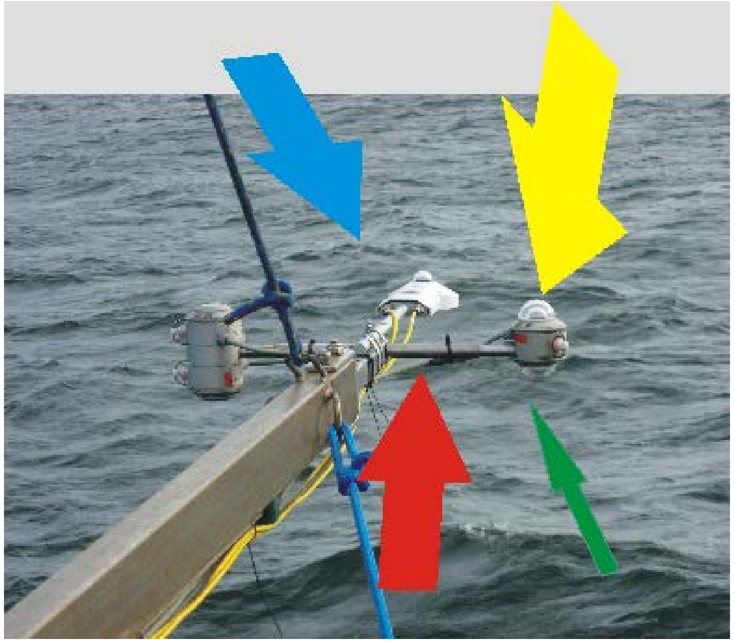
$$LW\uparrow = \int_{3\mu m}^{100\mu m} E_u(\lambda, z=0)\,d\lambda$$

# Radiation budget at the sea surface



# *Radiation budget at the sea surface*



Pyrgeometers and pyranometers s/y Oceania Baltic Sea

*SW*↓ - downward shortwave irradiance $SW_d$ *LW* ↓ - downward longwave irradiance $LW_d$

*SW*↑ - upward shortwave irradiance $SW_u$ *LW*↑ - upward longwave irradiance $LW_u$

# *The date used in the analyzes*

**Satellite**

- MSG/SEVIRI
  - ✓ Cloud mask
  - ✓ Cloudiness parameter
- AVHRR
  - ✓ Ozon content
  - ✓ AOT
  - ✓ Sea surface temperature

**Model M3D,UM**

- ✓ Sea surface temperature
- ✓ Air temperature
- ✓ Water vapour

**IN SITU**

- ✓ $SW_d$
- ✓ $SW_u$
- ✓ $LW_d$
- ✓ $LW_u$

Different formats!

# *Data format*

- Area: Baltic Sea
- Projection:

✓ Lambert_Azimutal_Equal_Area

- Resolution:

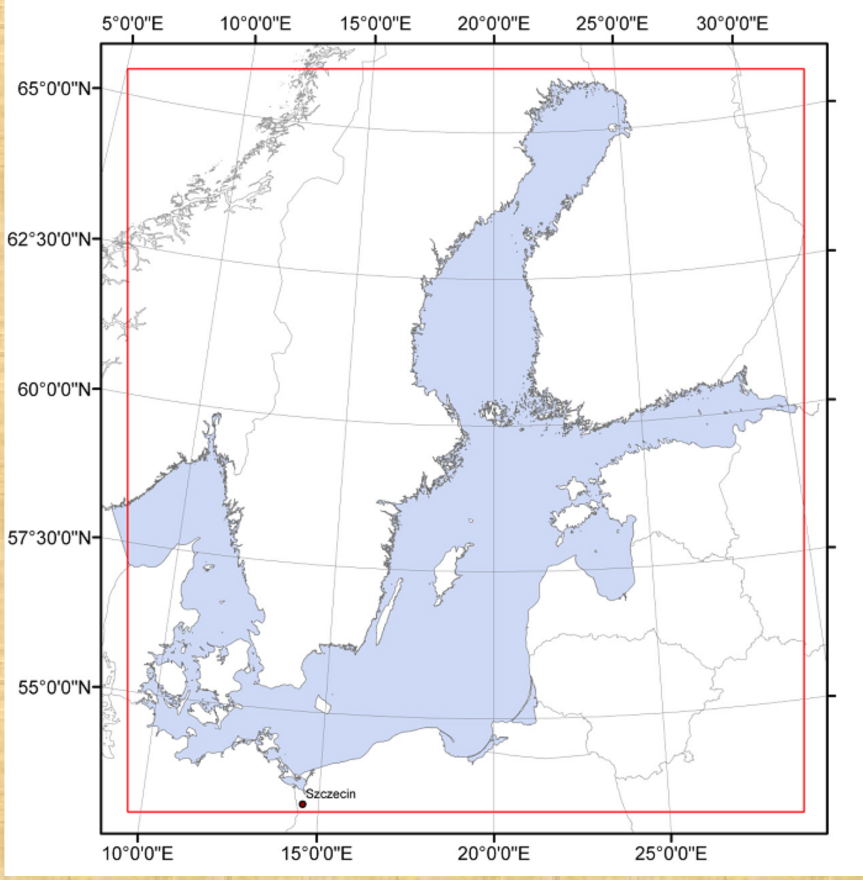
✓ 4 km (352X320 pixels)

- Generation frequency:

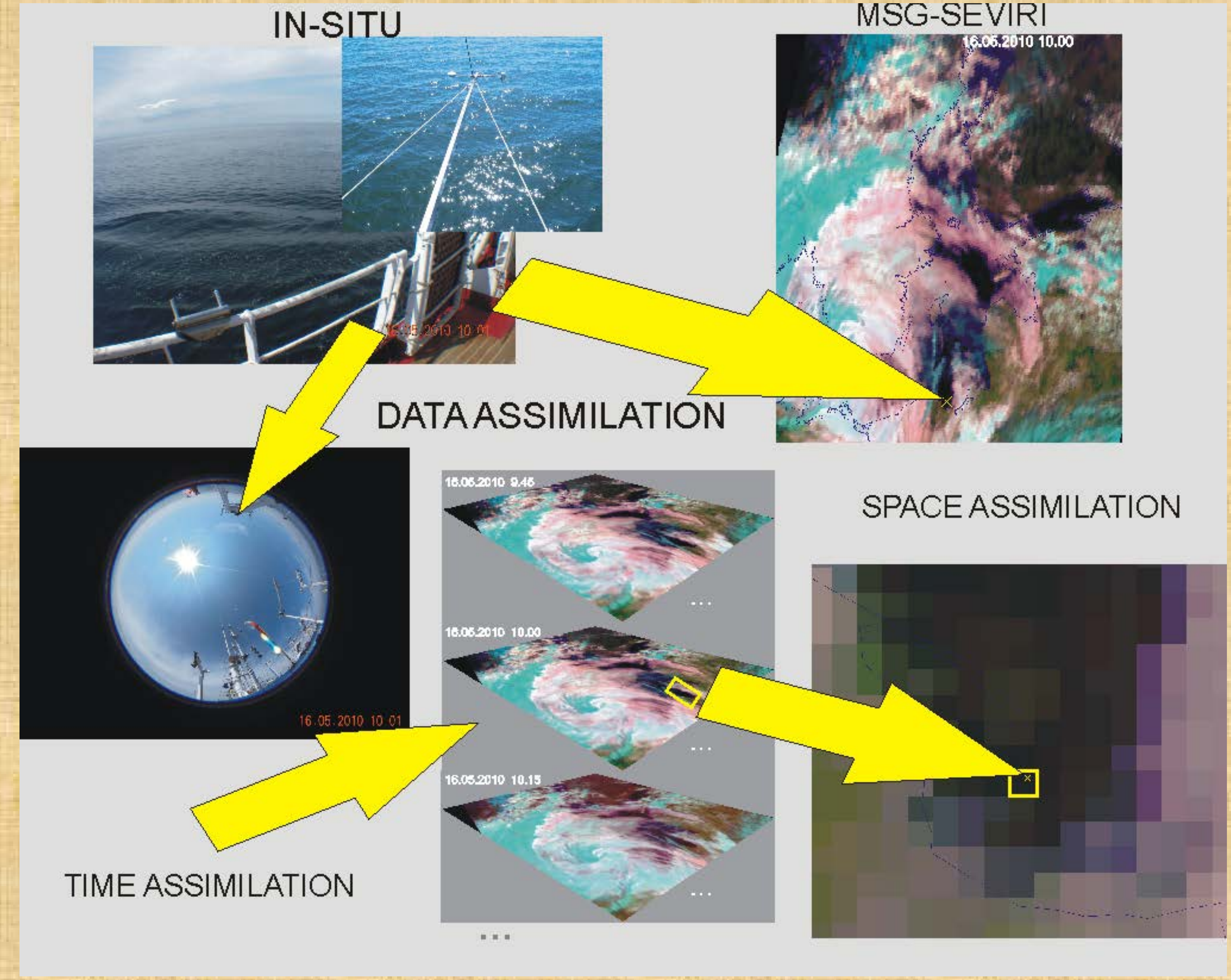
✓ SEVIRI – 15 min

✓ M3D, UM model – 60 min

- The basic grid for SatBałtyk 1 km



# *Comparison satellite and in situ data*




## In situ data

- ✓ Southern Baltic
- ✓ 2009-2013
- ✓ s/y Oceania
- ✓ 10 min time average
- ✓ Lat –long
- ✓ Pyranometer and pyrgeometer

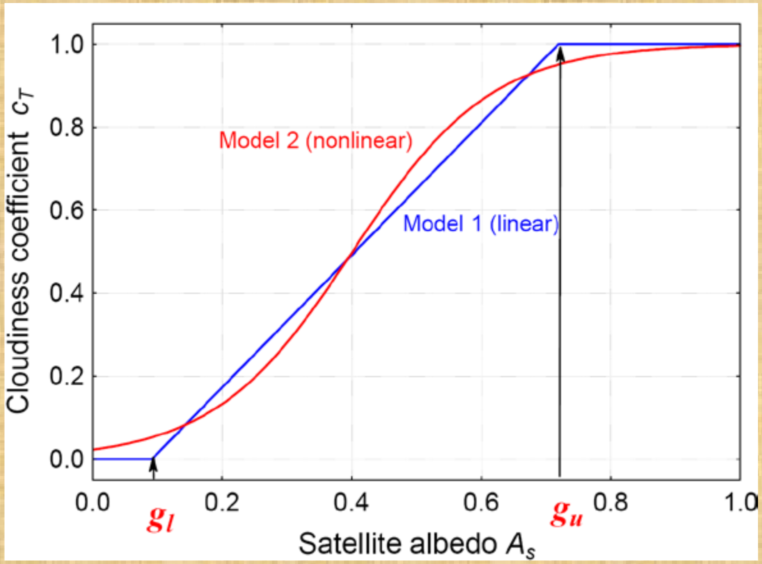
***Estimation of the radiation fluxes***

***Algorithms and validation***

# *Downward shortwave radiation flux $SW_d$*

- Algorithm (Krężel et  al. 2008 model SOLRAD)

$$SW_d = SW_{d,0} T_{cloud}$$



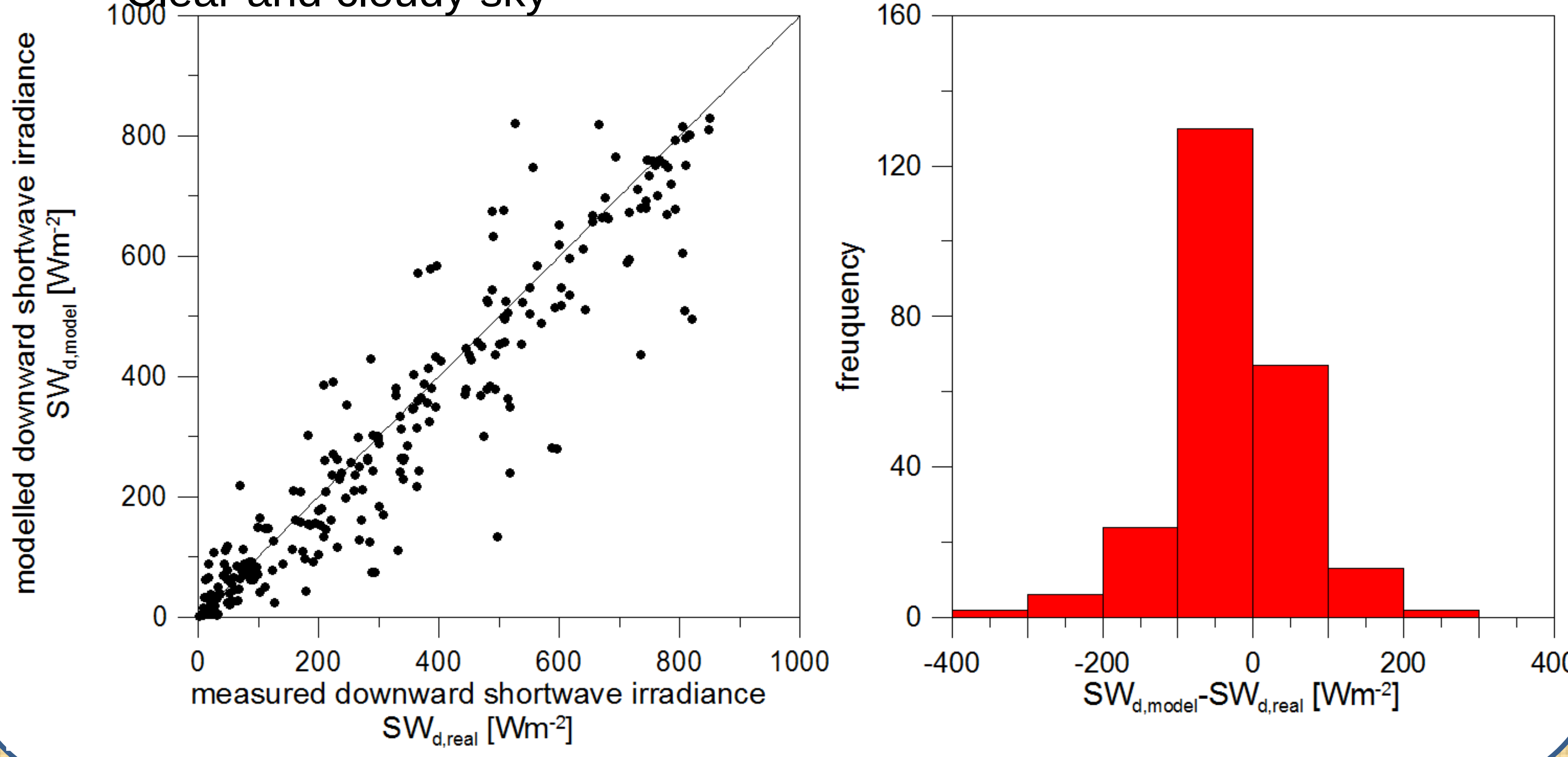

✓ *$T_{cloud}$ – cloud transmittance*
✓ *$SW_{d,0}$ - for clear sky*

- Input data

✓ MSG/SEVIRI (VIS channels) – **cloud mask**, **cloudiness coefficient**
✓ NOAA/AVHRR – Aerosol Optical Thickness (AOT), Ozon
✓ UM model – vapour pressure

# *Validation*

Clear and cloudy sky




bias : - 18 $Wm^{-2}$
stdev : 80 $Wm^{-2}$
R : 0.91

- In situ data $SW_d$ were measured during cruises on the southern Baltic Sea (2011- 2012)
- Problem with cloudy sky

# Upward shortwave radiation flux $SW_u$

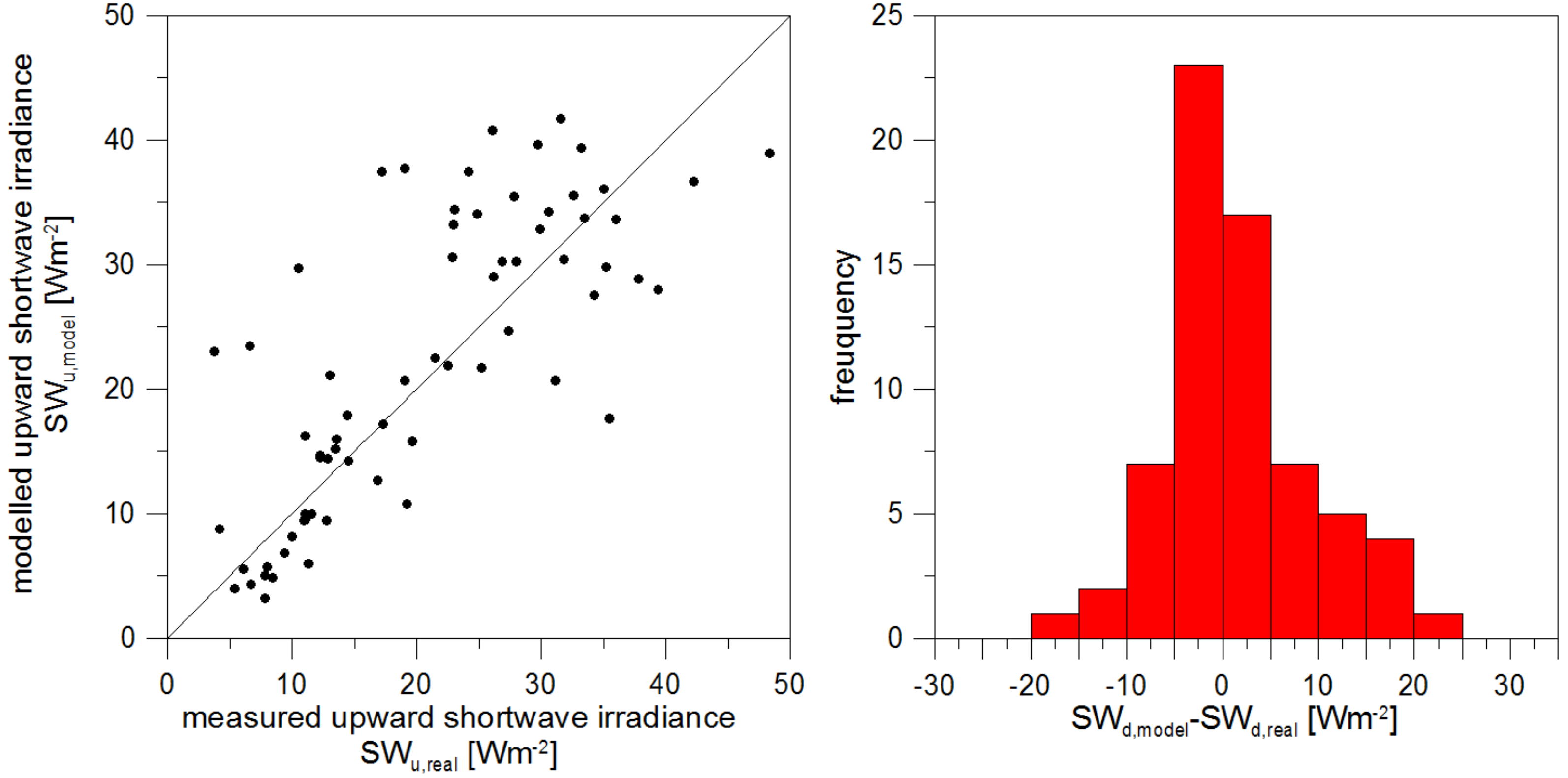
$$SW_u = SW_d A_s$$

$$A_s = aT + b + (1 + cT - d)\exp[-(90 - SZA)(e/T + f]$$

$$T = \frac{SW_d[h=0]}{SW_d[h=TOA]}$$

- $A_s$ – sea albedo ( Payne 1979 function adopted to Baltic Sea area, modified by Rozwadowska 1992)
- *SZA* – solar zenith angle
- $SW_d$ – as input data from algorithm SOLRAD
- *a,b,c,d,e,f* – modified empirical constants

# *Validation*




bias : 2 Wm$^{-2}$
stdev : 8 Wm$^{-2}$
R : 0.77

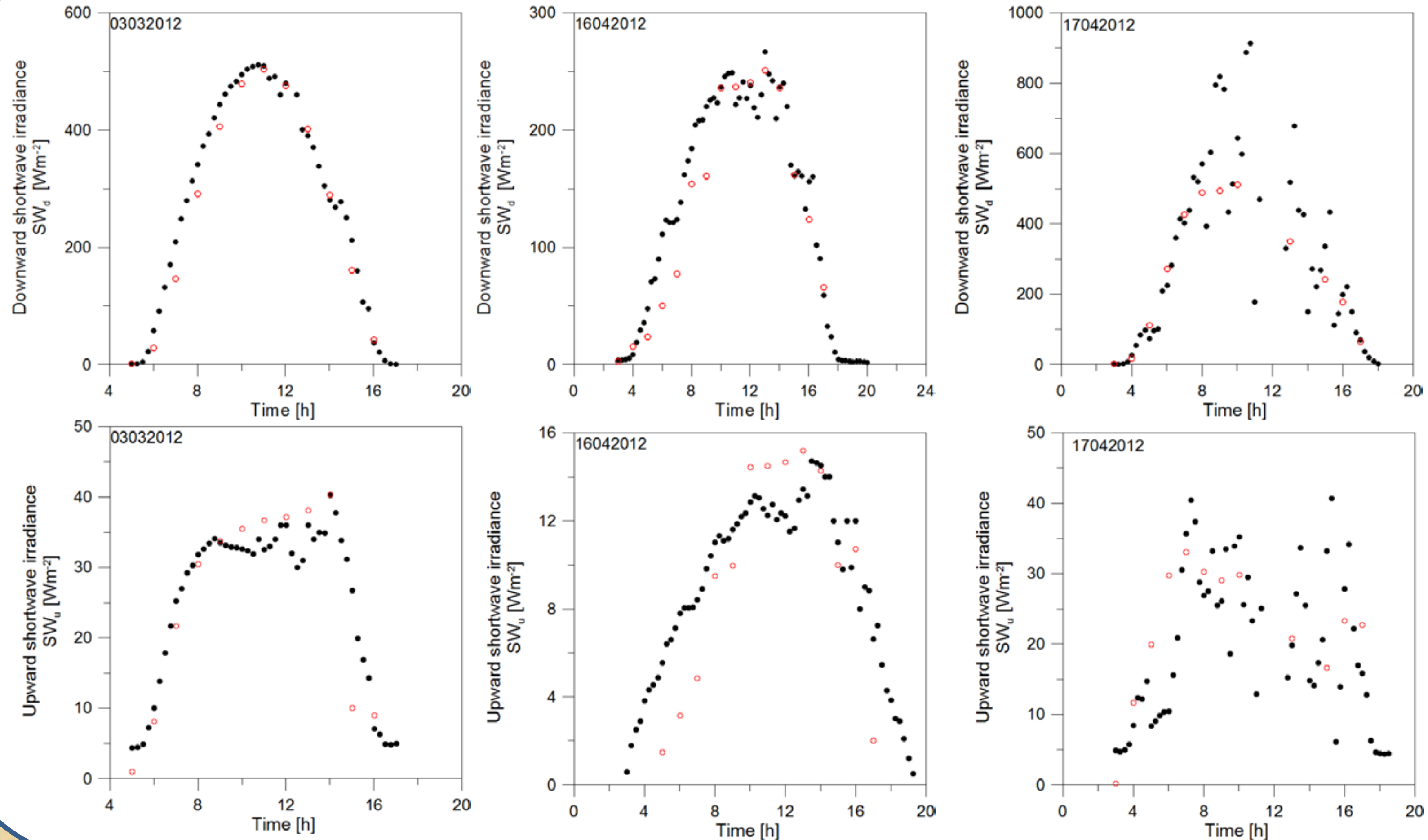
- In situ data $SW_d$ measured during cruises on the Southern Baltic Sea (2011- 2013)
- Problem for rough sea and low position of the sun

# *Validation*

cloudless

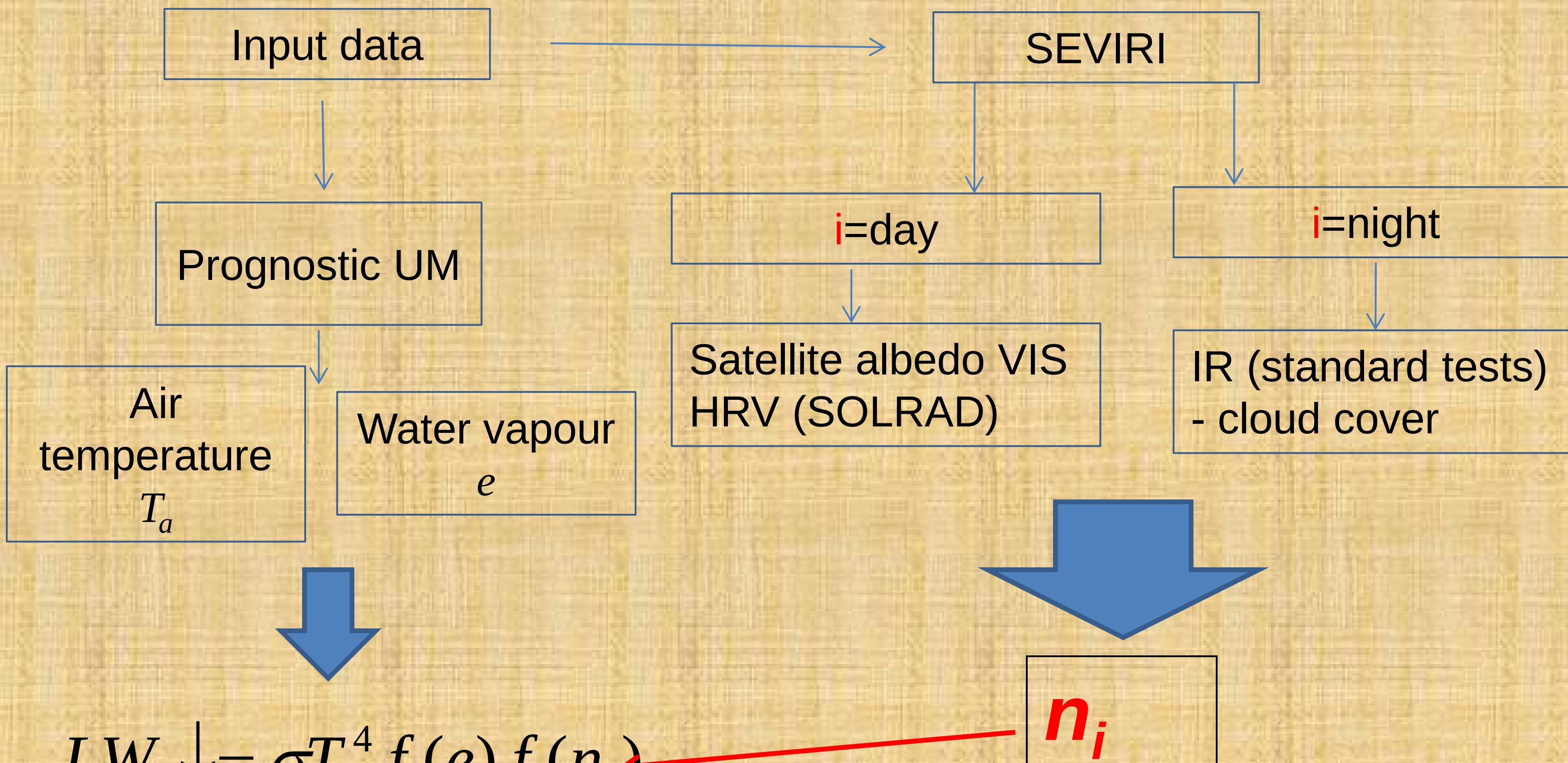
full cloud cover

fractional cloud




model - ●
real - ●

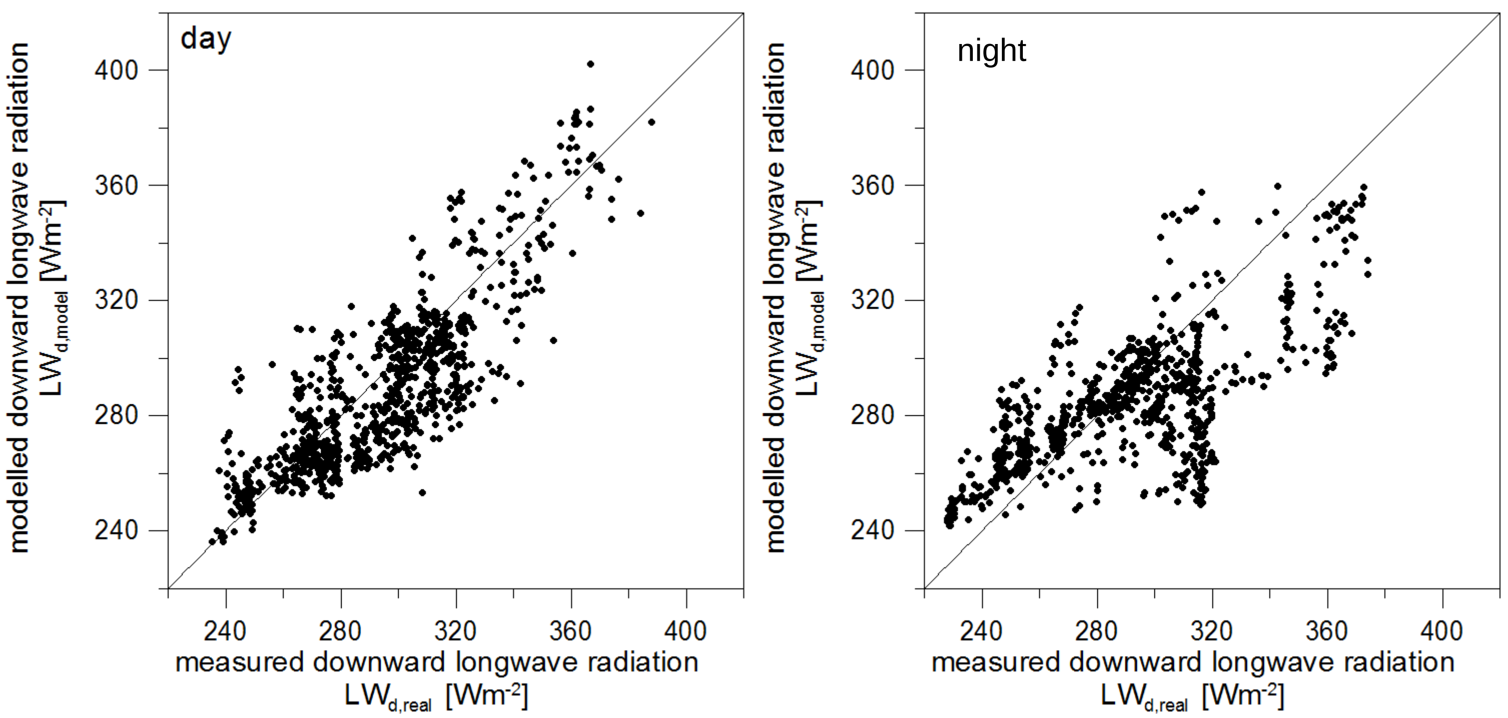
# Downward longwave radiation flux $LW_d$




$$LW\downarrow = \sigma T_a^4 f(e) f(n_i)$$

Zapadka et al. 2007, 2008

# *Validation*

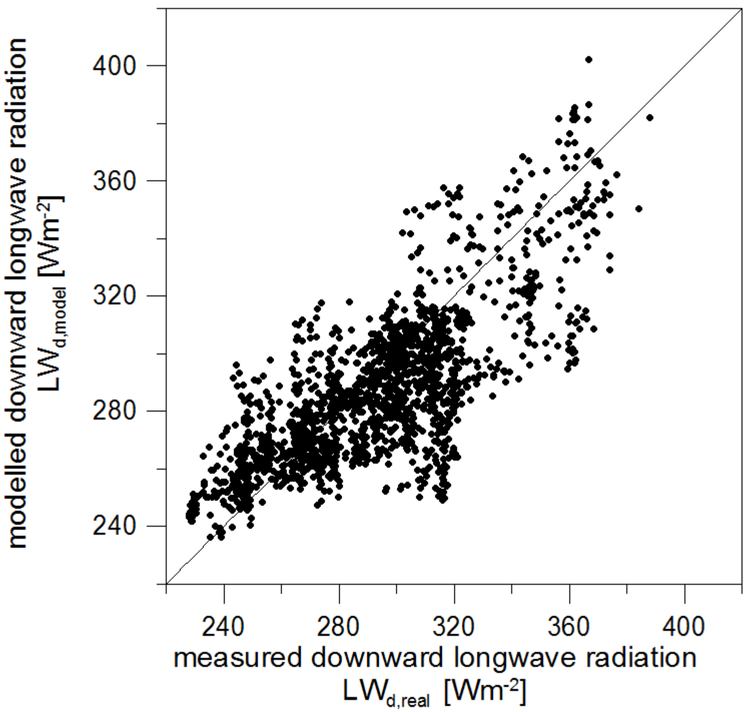


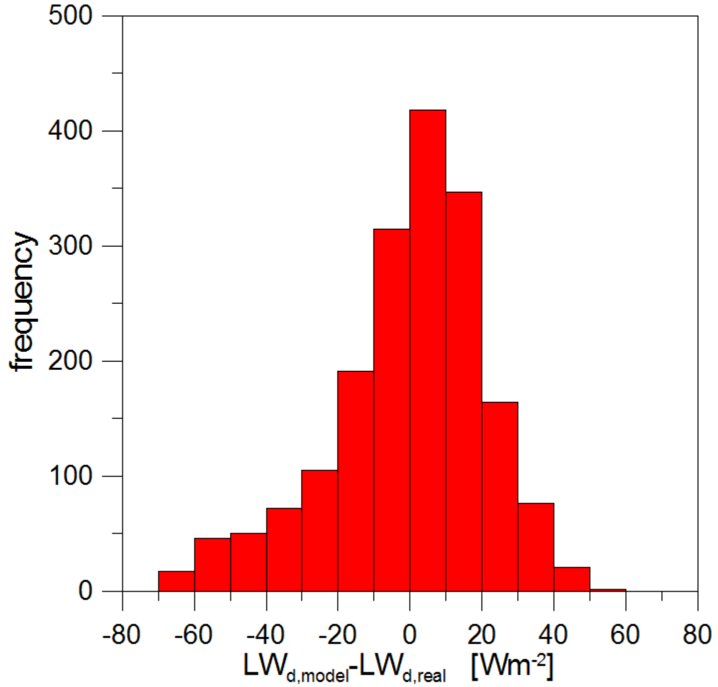

bias : - 5 Wm$^{-2}$
stdev : 17 Wm$^{-2}$
R : 0.84

bias : 5.2 Wm$^{-2}$
stdev : 28 Wm$^{-2}$
R : 0.71

# *Validation*

Day and night




bias : -0.2 $Wm^{-2}$
stdev : 23 $Wm^{-2}$
R : 0.77

Problems:
Cloud identification

# *Upward longwave radiation flux $LW_u$*

Cloud mask → Cloudy → Hydrodynamic model M3d

Cloud mask ↓ Clear ↓

AVHRR
(10.8 μm;12.0 μm)

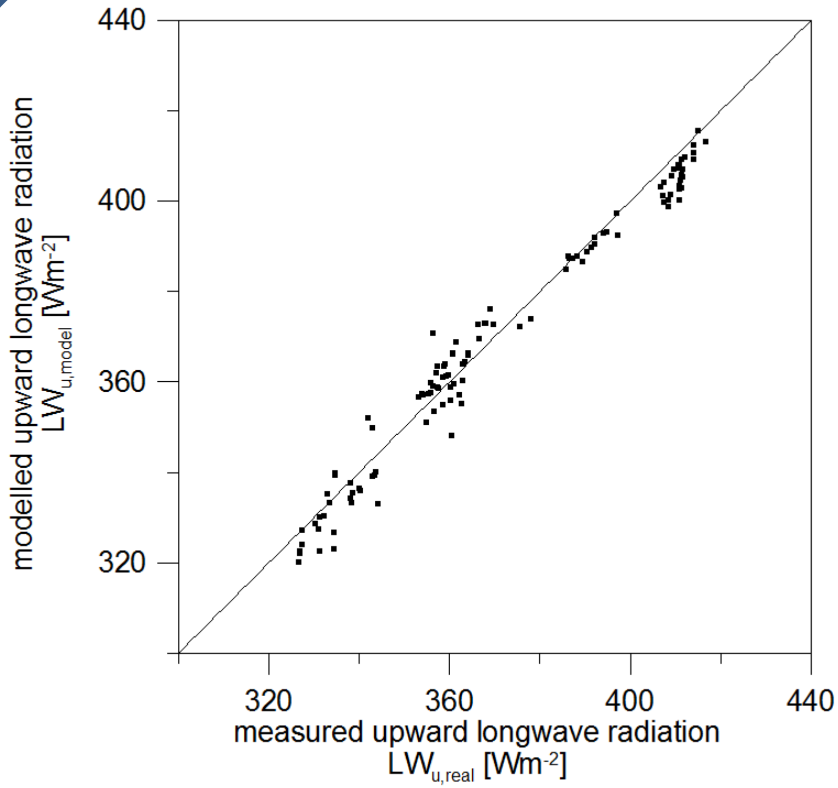
Algorithm:
sea surface
temperature $T_s$

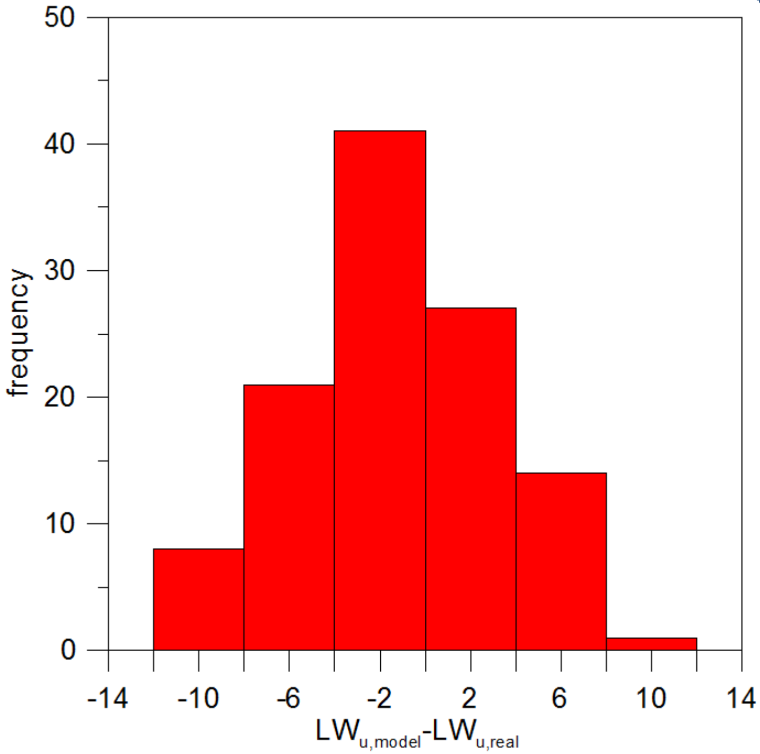
$$LW_u = \varepsilon \sigma T_s^4$$

*$T_s$ – sea surface temperature*
*$\varepsilon$ - sea surface emissivity*

- ✓ Cloudy conditions dominate the Baltic Sea during 2/3 of the year
- ✓ The temperature of the sea changes very slowly
- ✓ Cloud mask must be correct

# *Validation*
# *$LW_{u,real}$ versus $LW_{u,model}$ from AVHRR*



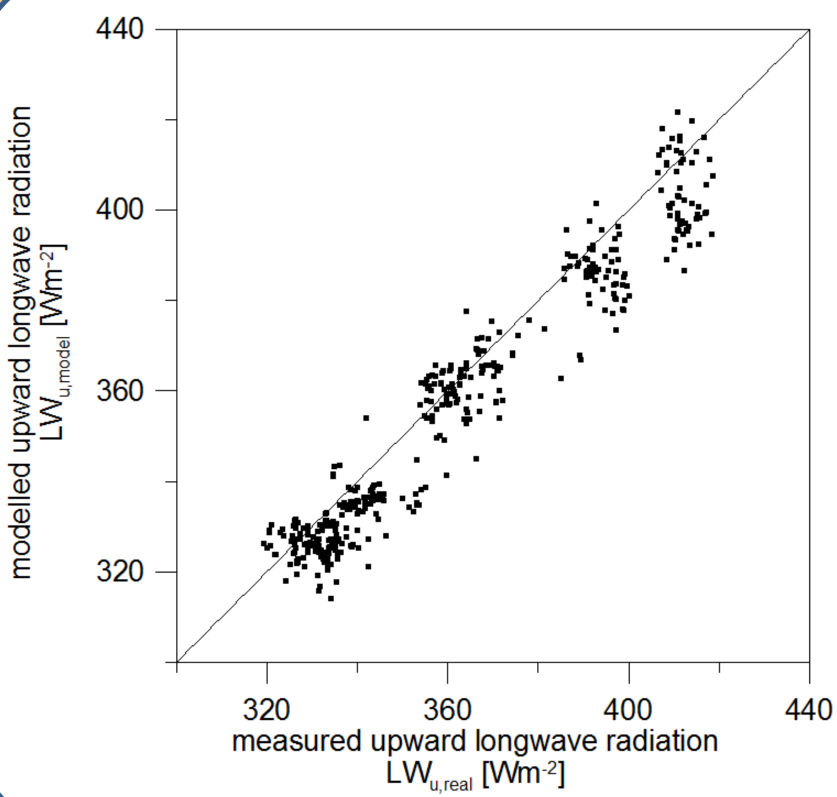



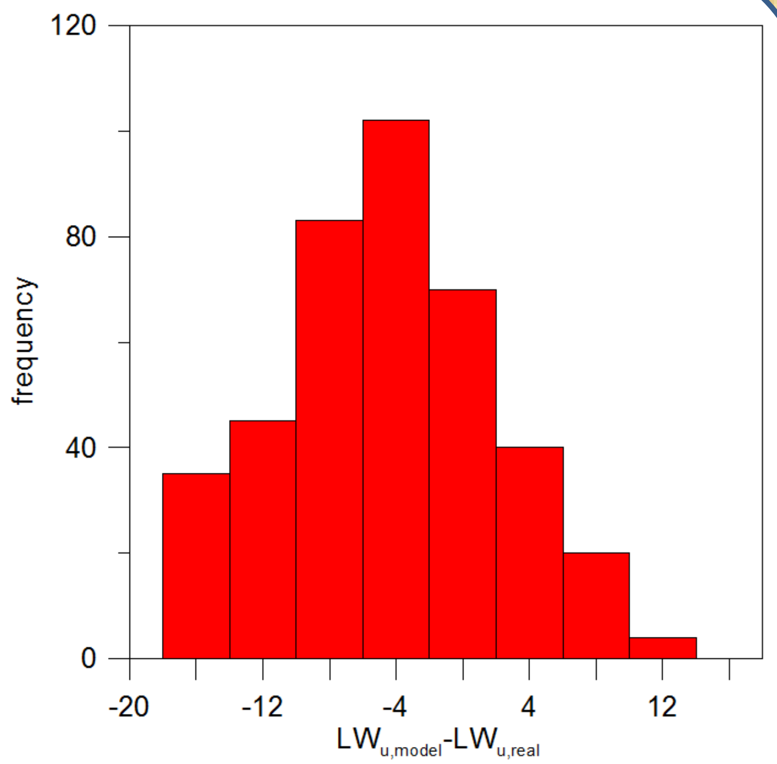

bias : -1.3 $Wm^{-2}$
stdev : 4.5 $Wm^{-2}$
R : 0.99

✓ For clear sky

# *Validation*

# *$LW_{u,real}$ versus $LW_{u,model}$ from M3D +AVHRR*




bias : -5.3 $Wm^{-2}$
stdev : 7.3 $Wm^{-2}$
R : 0.97

- ✓ The biggest errors for a coastal zone
- ✓ Pyrgeometer CGR 3

# *Products*

- Instantaneous maps

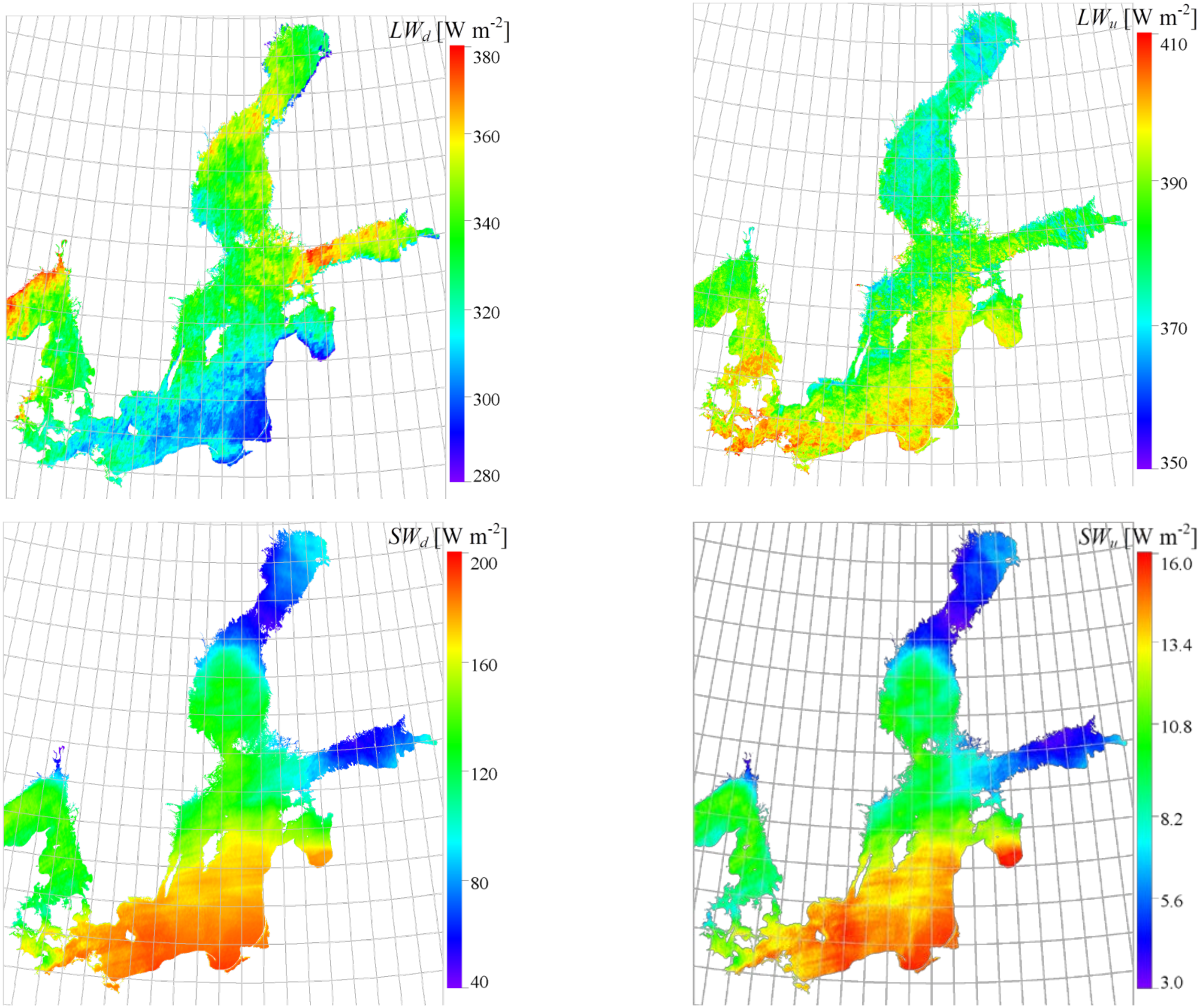
✓ $SW_d$ ; $SW_u$ - every 15 minutes for daytime

✓ $LW_u$- c. 8 maps per day

✓ $LW_d$- every 1 hour

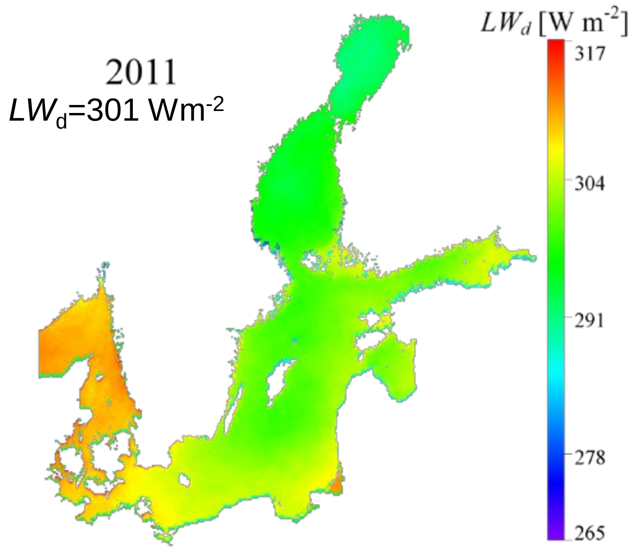
- Daily maps – the main product of SatBałtyk
- Monthly
- Annual

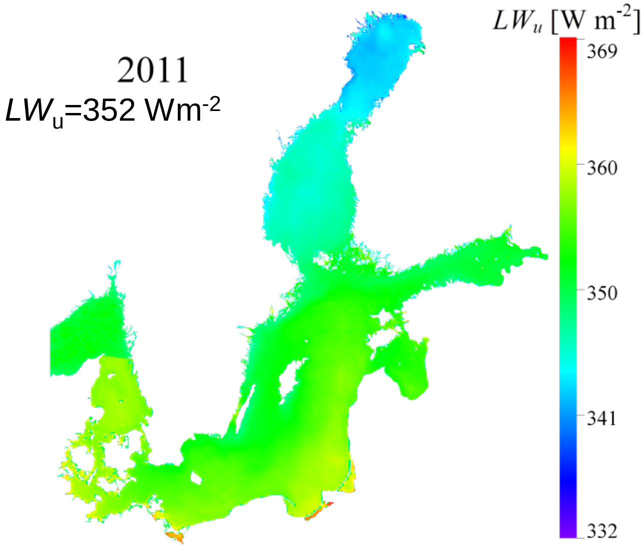
# Products – the average daily

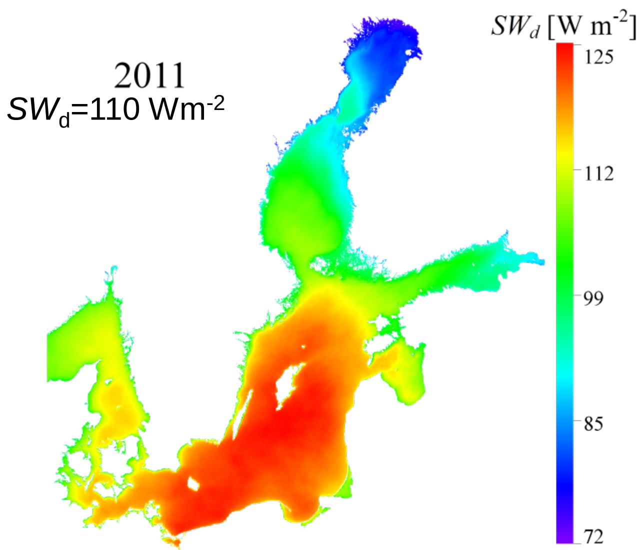


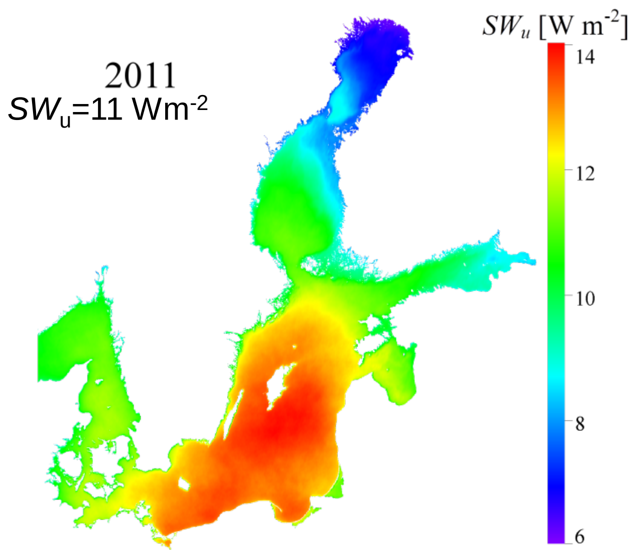

2012-09-10

# Products – the average annual

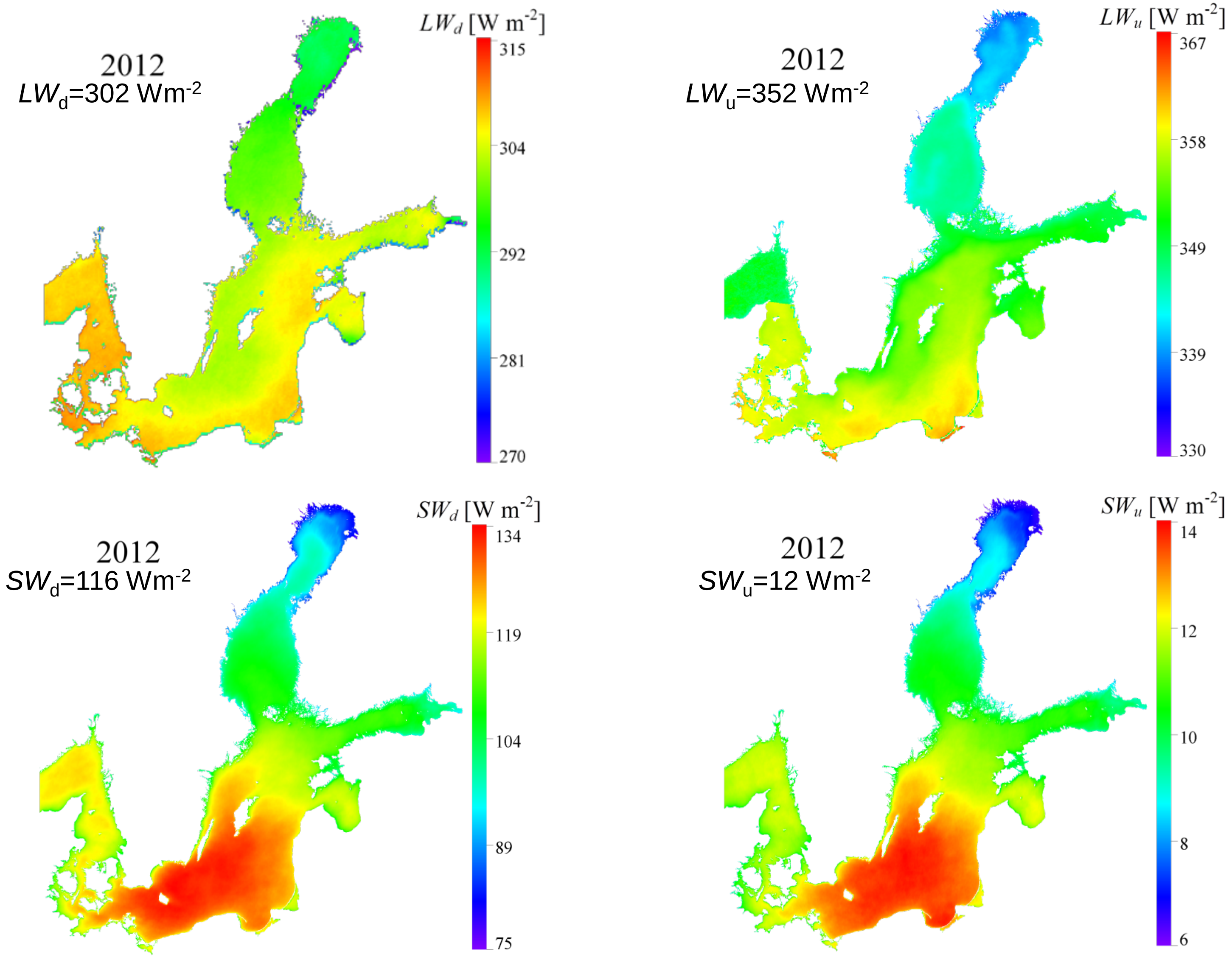


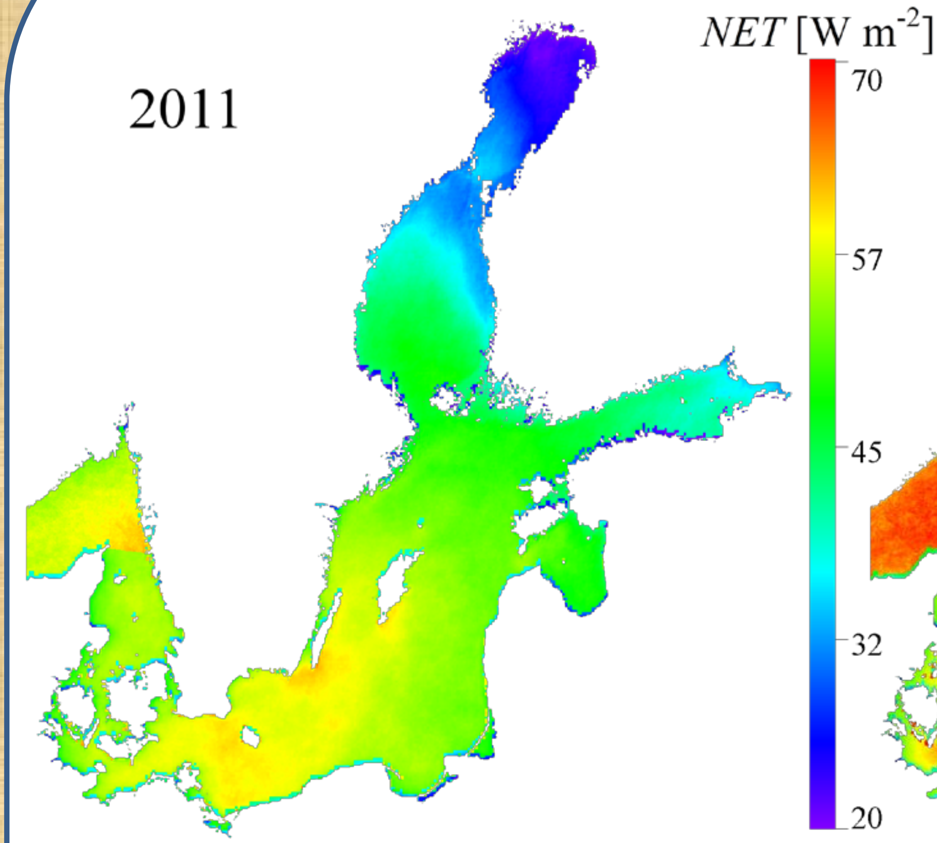



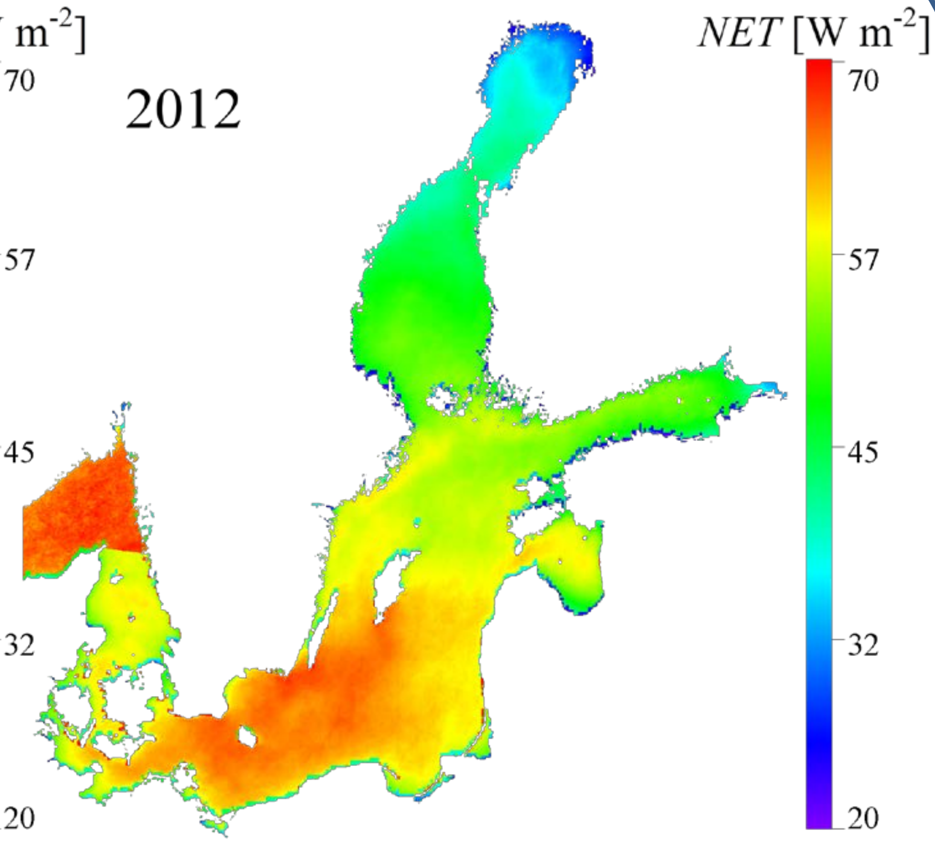



# Products – the avarage annual



# Products – the average annual




*NET*=48 Wm$^{-2}$

*NET*=54 Wm$^{-2}$

# Summary

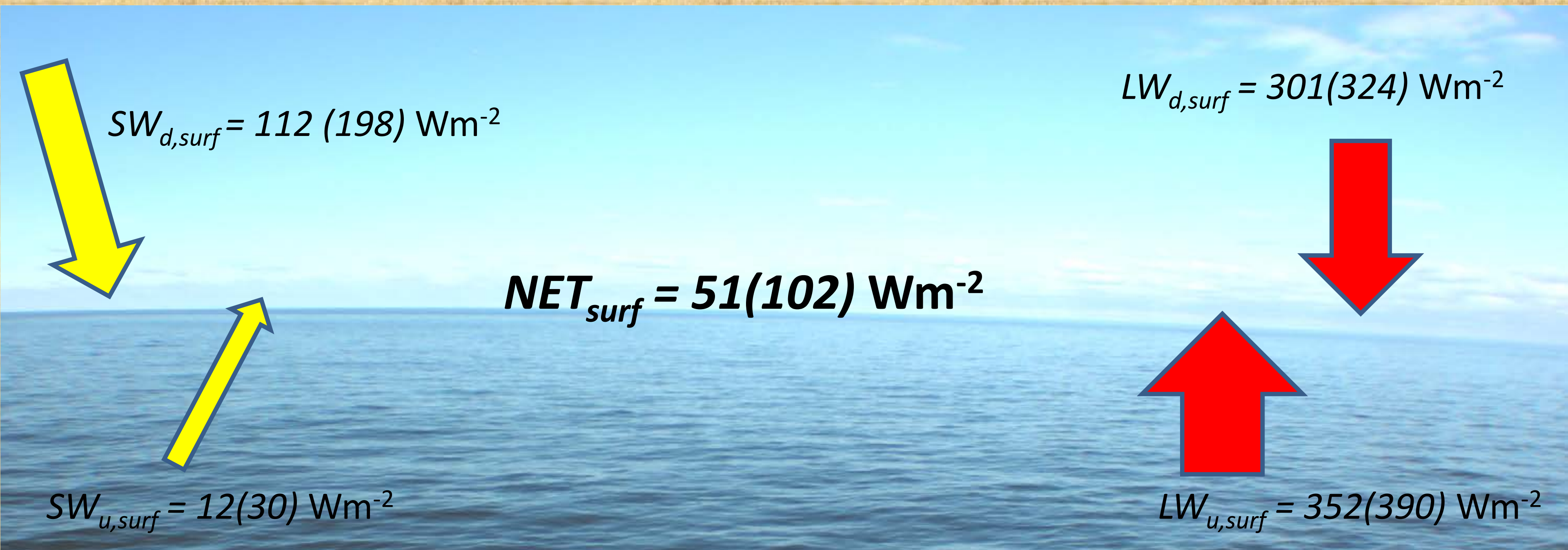
- ✓ Presented methods are appropriate to estimate shortwave and longwave radiation budget components
- ✓ the statistical errors and correlation coefficient are acceptable: for instantaneous data
  - ➢ $SW_d$ = 80 $Wm^{-2}$ R=0.91; $SW_u$ = 11 $Wm^{-2}$ R=0.87
  - ➢ $LW_d$ = 23 $Wm^{-2}$ R=0.77; $LW_u$ = 4.5 $Wm^{-2}$ R=0.97
- ✓ The average annual:

| | *NET* [$Wm^{-2}$] | $SW_d$ [$Wm^{-2}$] | $SW_u$ [$Wm^{-2}$] | $LW_d$ [$Wm^{-2}$] | $LW_u$ [$Wm^{-2}$] |
|---|---|---|---|---|---|
| 2011 | 48 | 110 | 11 | 301 | 352 |
| 2012 | 54 | 116 | 12 | 302 | 352 |

## *Major causes of errors*

- difficulty with determining cloudless pixels $T_s = T_{cloud}$ (algorithm identifies  the clouds as the sea or vice versa)
- problems with identification of clouds and mask cloud
- a few cloud levels not identifiable
- empirical measurements

# Thank you for your attention




**Dziękuję**

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

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