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PASSIVE REMOTE SENSING OF OCEANIC WHITECAPS: ALGORITHM DESCRIPTION

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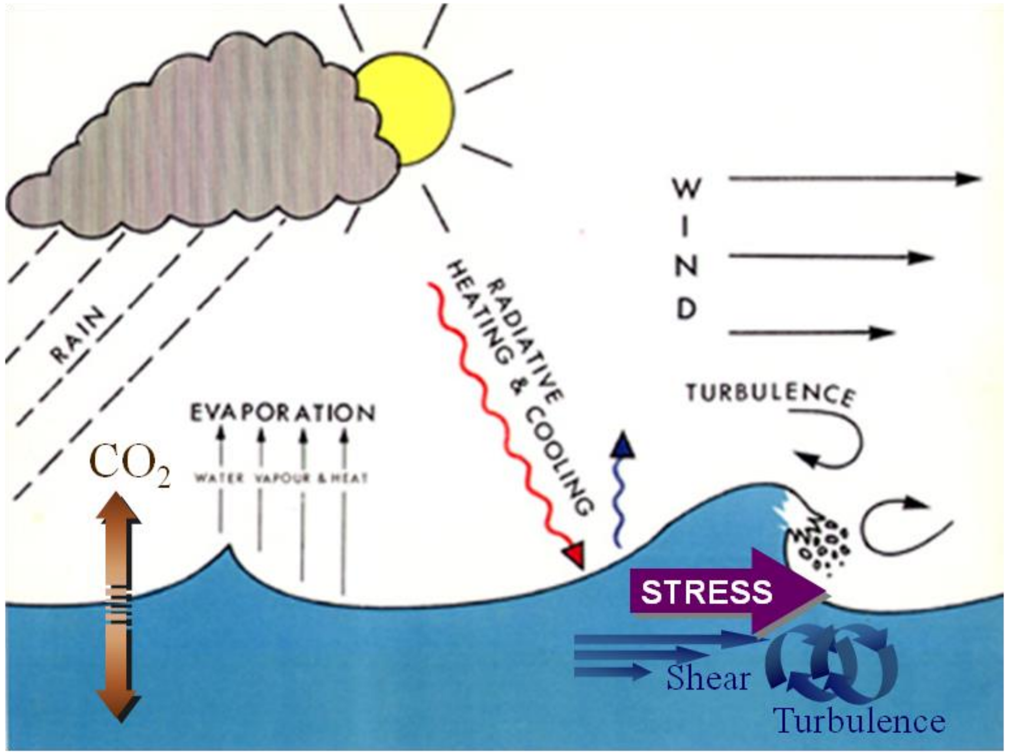
Session
Air-sea flux measurements, datasets, and applications
11 June 2018

Air-sea processes and surface fluxes



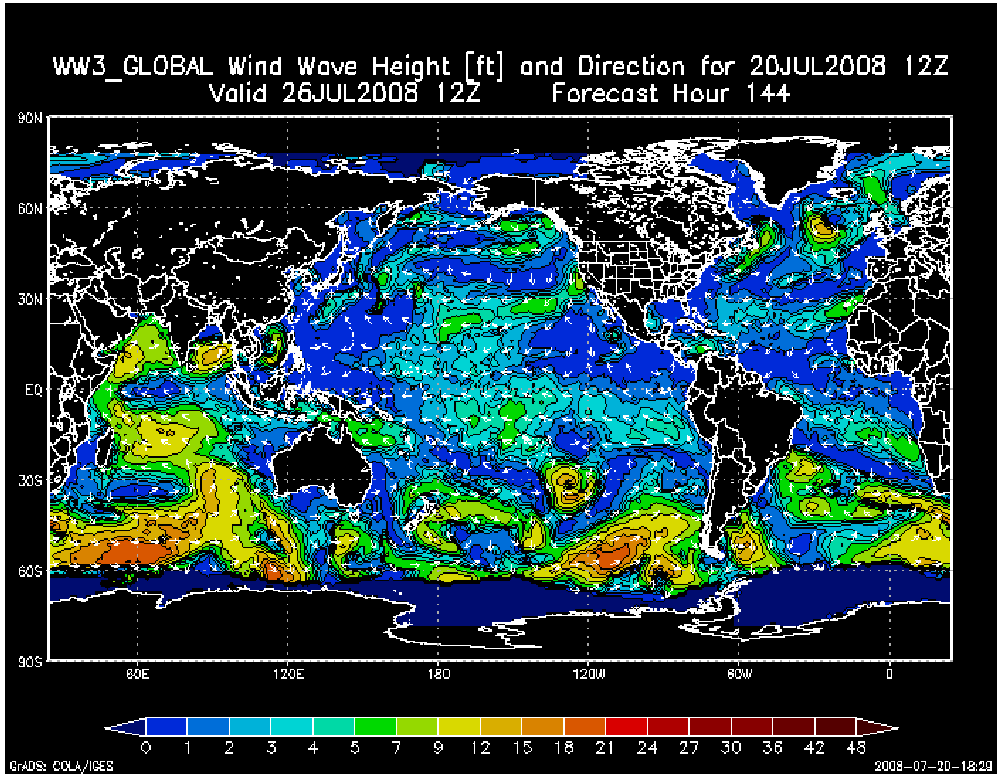
Mass
- ❑ Gas flux
- ❑ Sea spray flux

Heat
- ❑ Sensible heat flux
- ❑ Latent heat flux

Energy
- ❑ Momentum flux
- ❑ Turbulent dissipation

Surface fluxes and atmosphere-ocean coupling

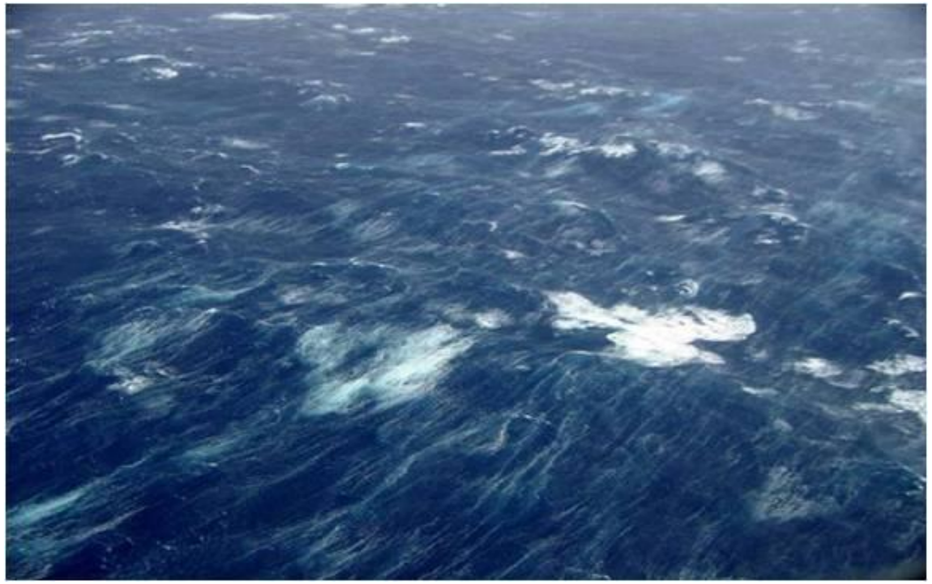
- ❑ Surface fluxes used for
  - ❖ Modeling ocean-atmosphere coupling
  - ❖ Boundary conditions in models
  - ❖ Understanding ocean dynamics



- ❑ Surface flux accuracy affects models for
  - ❖ Weather
  - ❖ Wave field
  - ❖ Visibility (aerosols)

Surface fluxes and whitecaps

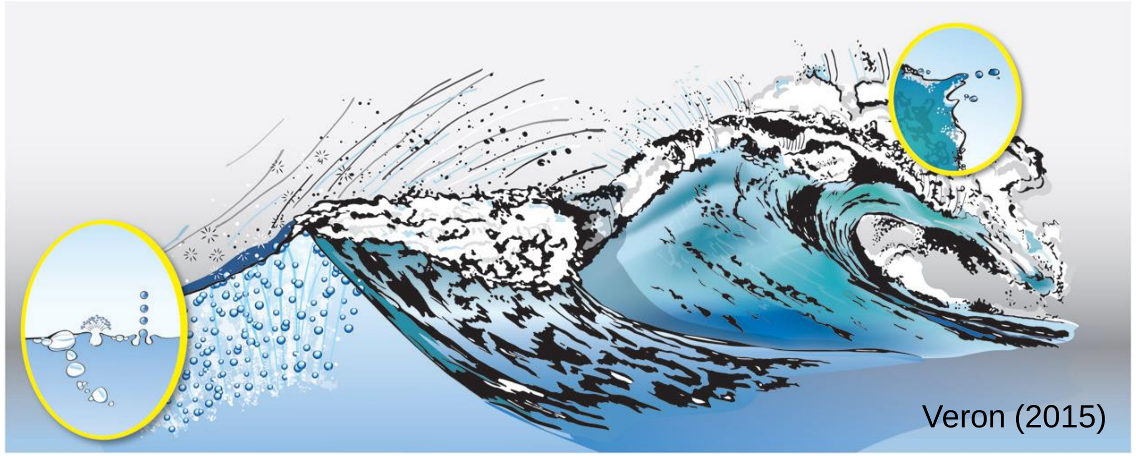
- Whitecap fraction W



- Sea spray source function

$$\frac{dF(r,U)}{dr} = f(r).f(U)$$

$$\frac{dF(r,U)}{dr} = f(r).W(U)$$

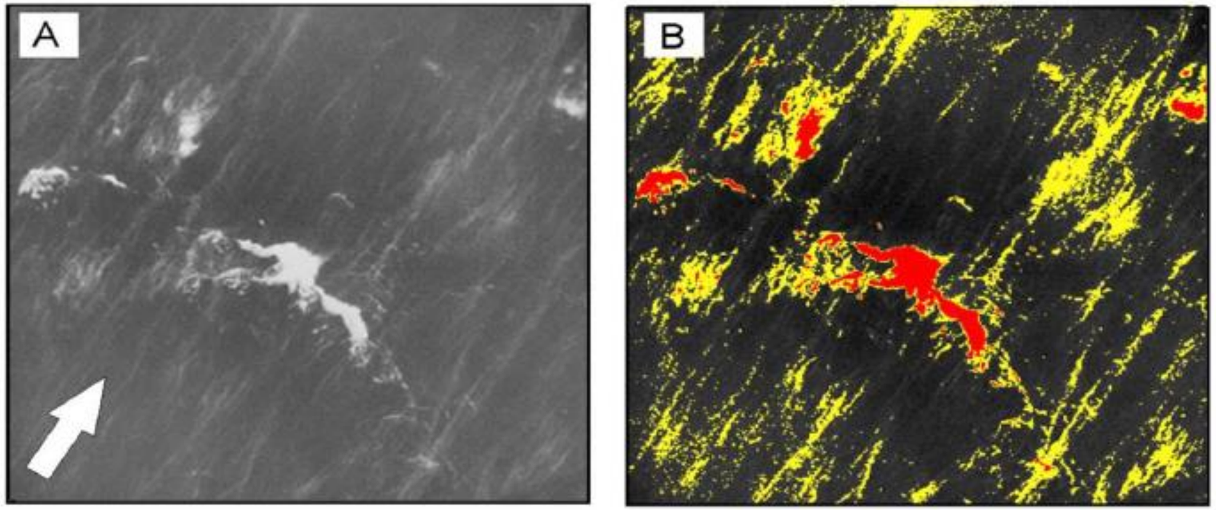


Veron (2015)

In situ measurements of whitecap fraction

- Photographic measurements
  - Intensity threshold
  - Wide variations

Holthuijsen et al., 2012



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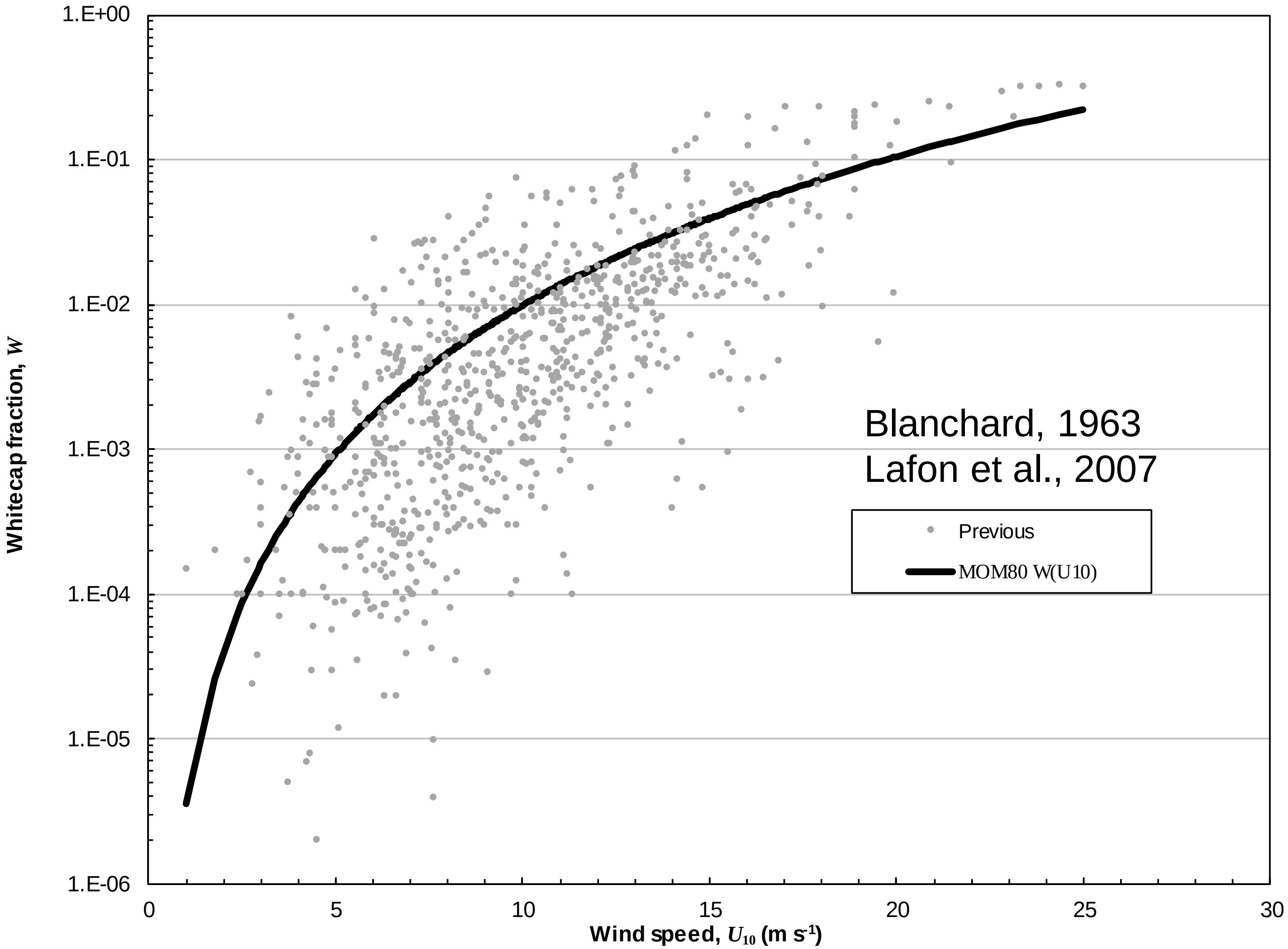
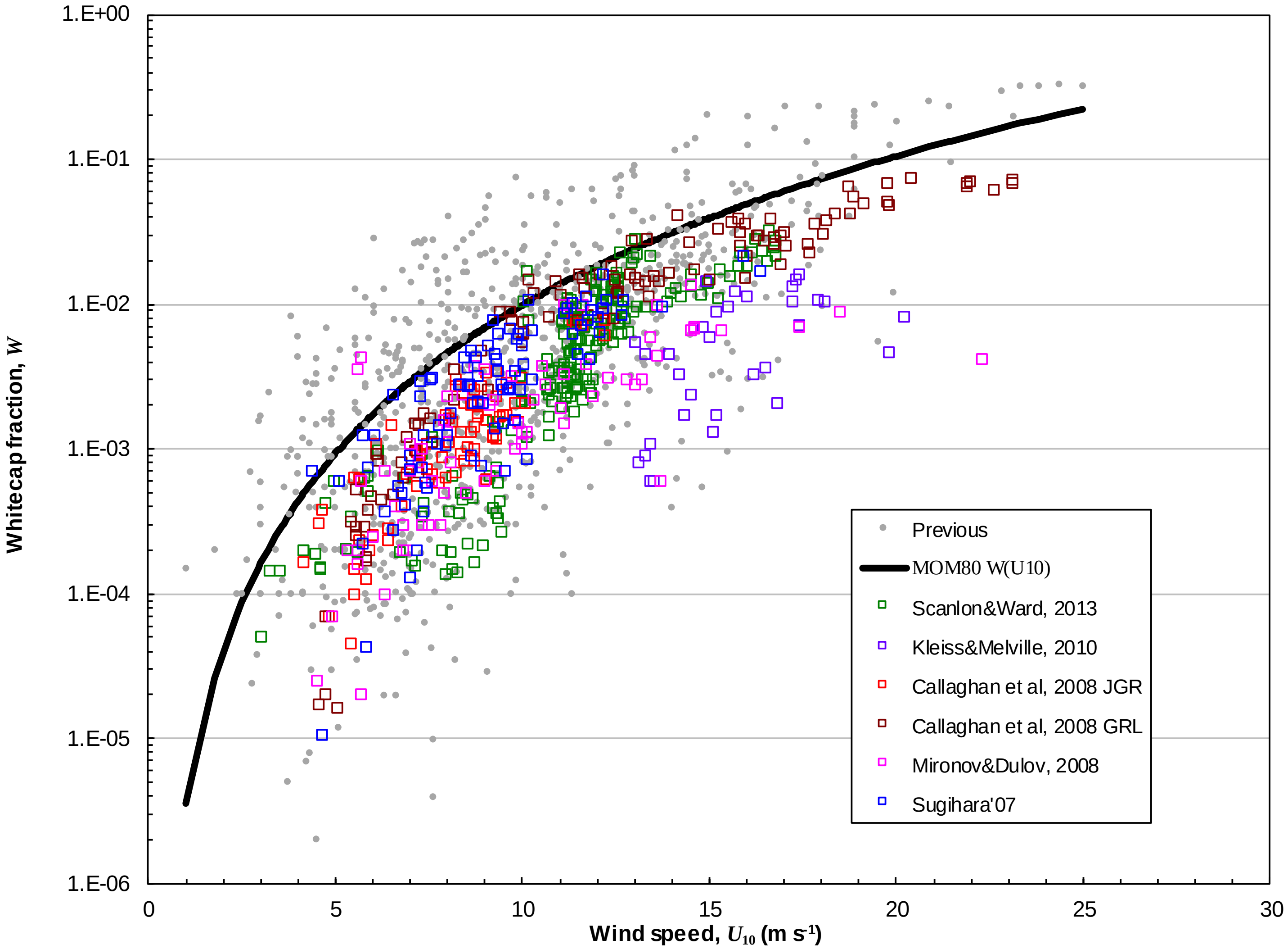


In situ measurements of whitecap fraction

- ❑ Photographic measurements
  - ❖ Intensity threshold
  - ❖ Wide variations
- ❑ Improvements
  - ❖ Digital photography
    - ➢ Data volume
  - ❖ Image processing algorithms
    - ➢ Consistency among groups



In situ measurements of whitecap fraction

- ❑ Photographic measurements
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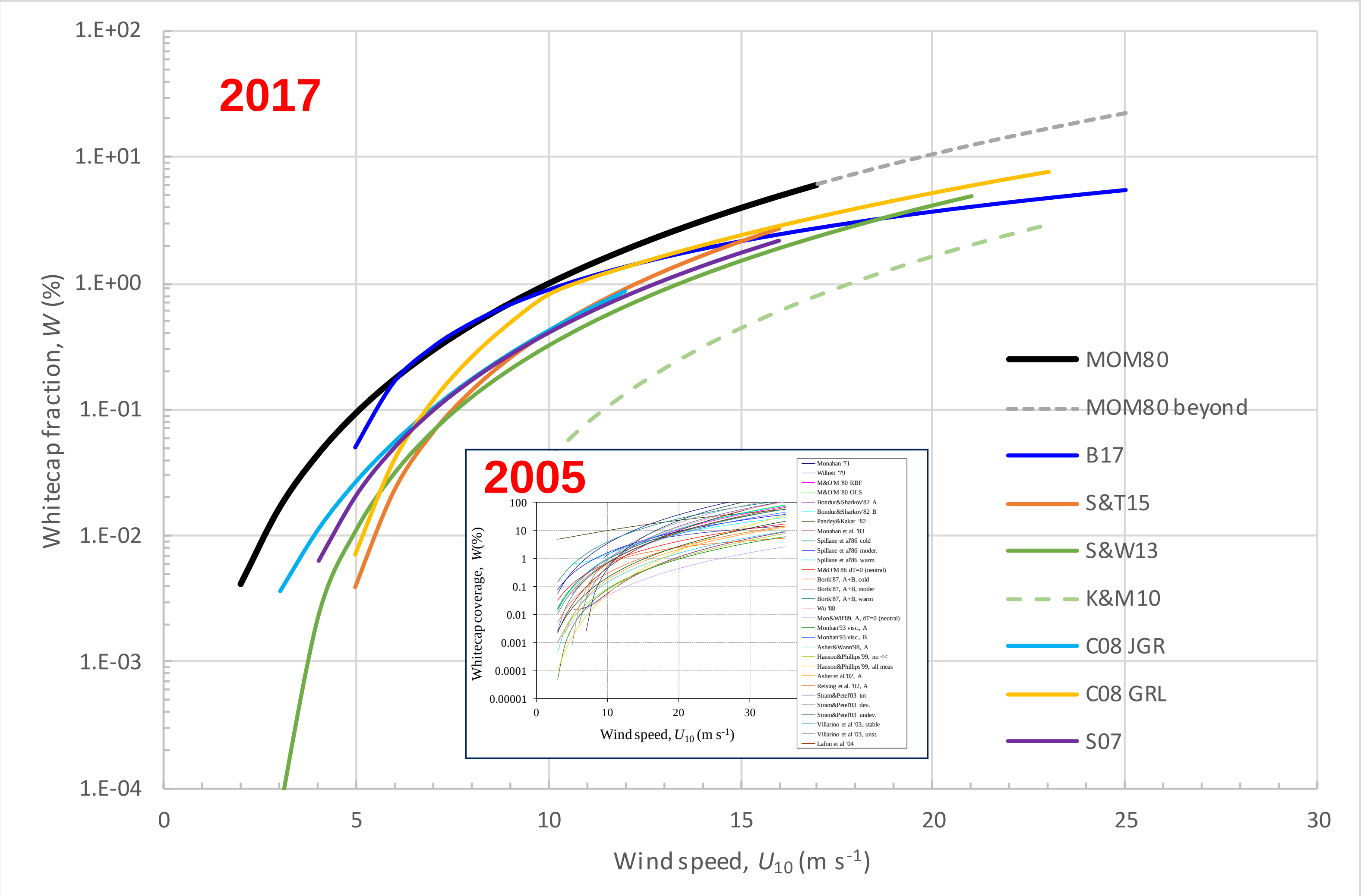
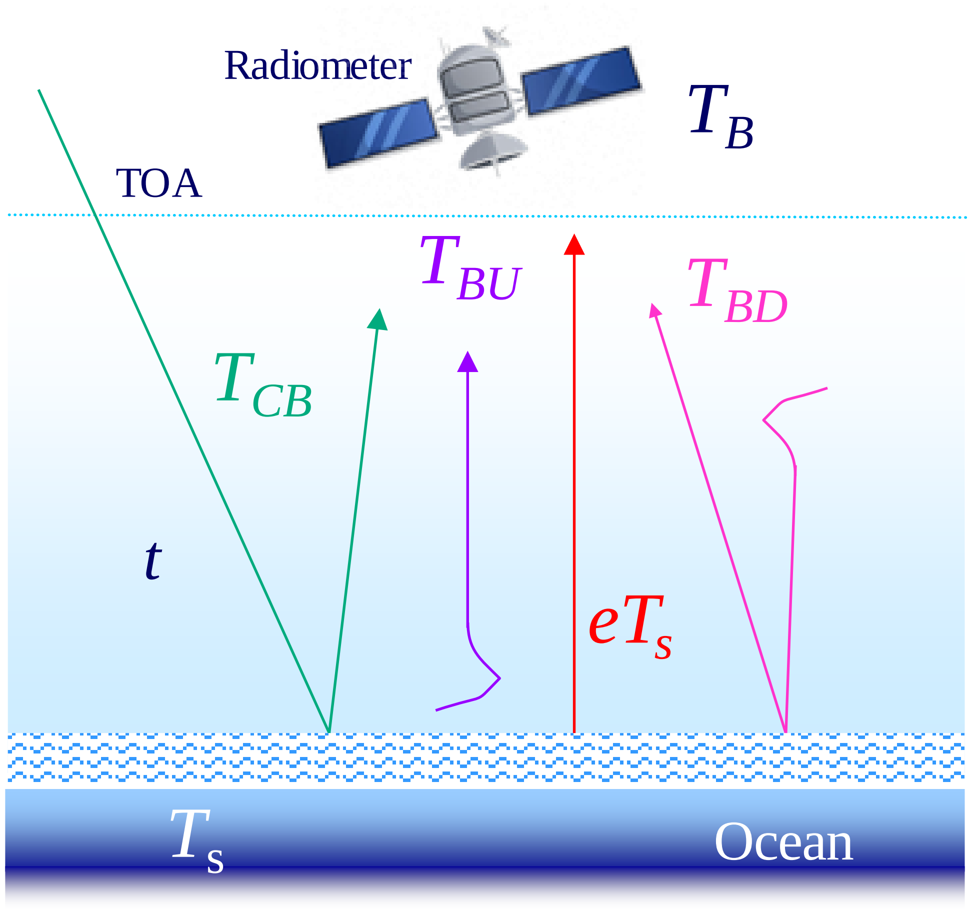
- ❑ Improvements
  - ❖ Digital photography
    - ➢ Data volume
  - ❖ Image processing algorithms
    - ➢ Consistency among groups
- ❑ Order of magnitude variability

$$W(U, H_s, \Delta T, T_s, S, C)$$

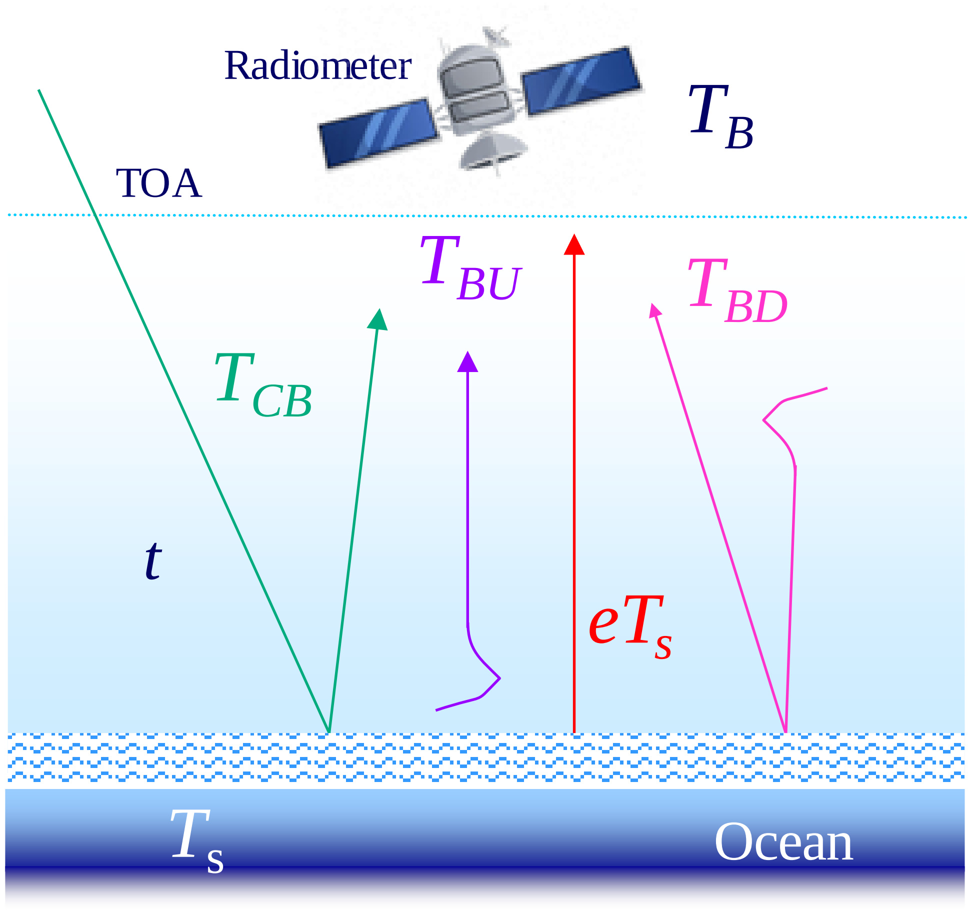


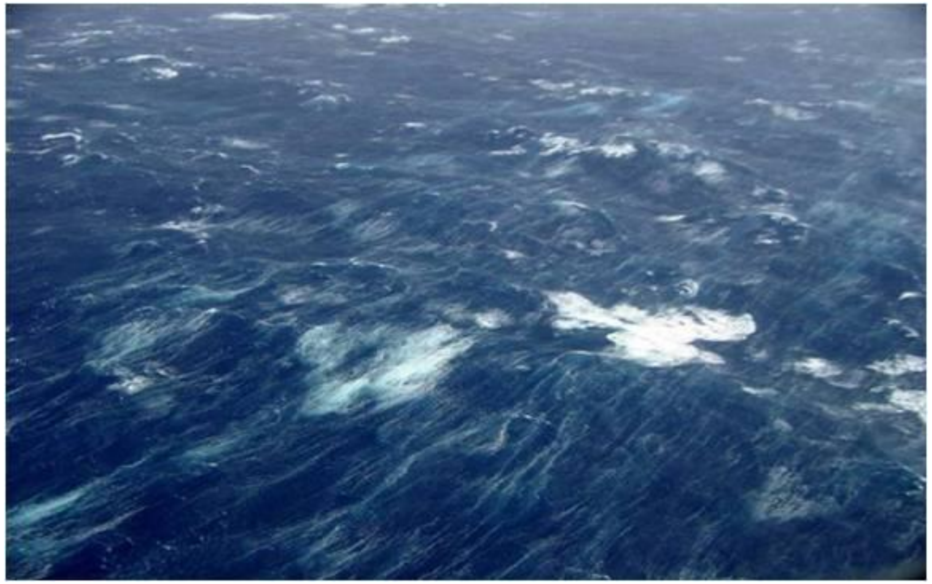
Ocean remote sensing: Radiative Transfer Model



$$T_B = teT_s + T_{BU} + trT_{BD} + t^2 rT_{CB}$$

Whitecaps observed with passive microwave radiometry





$$T_B = teT_s + T_{BU} + trT_{BD} + t^2 rT_{CB}$$

$$r = 1 - e$$

$$e = e_W + e_r = WE_f + (1 - W)E_r$$

Whitecaps observed with passive microwave radiometry

- Measure T_B
  - Satellite
  - Aircraft
  - Ship

- Model T_B contributions
  - Atmospheric model (t etc.)
  - Roughness model (e_r)
  - Foam model (E_f)

$$T_B = teT_s + T_{BU} + trT_{BD} + t^2 rT_{CB}$$

$$r = 1 - e$$

$$e = e_W + e_r = WE_f + (1 - W)E_r$$

Estimate whitecap fraction

- Measure T_B
  - Satellite
  - Aircraft
  - Ship

- Model T_B contributions
  - Atmospheric model (t etc.)
  - Roughness model (e_r)
  - Foam model (E_f)

$$W = \frac{e_W}{E_f} = \frac{e - e_r}{E_f}$$

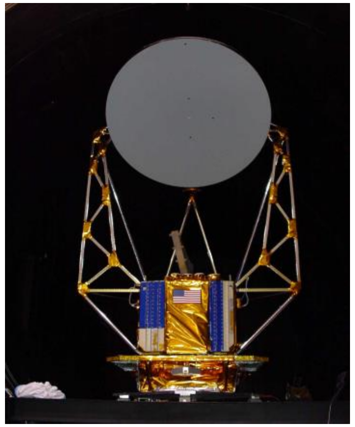
$$e_W \equiv WE_f = e - e_r$$

$$e = e_W + e_r = WE_f + (1 - W)E_r$$

Algorithm $W(T_B)$ at NRL

- Measure T_B
  - WindSat

Gaiser et al., 2004



Freq (GHz)
6.8
10.7
18.7
23.8
37.0

- Model T_B WindSat geophysical model (GMF)
  - Atmospheric model (t etc.)
  - Roughness model (e_r)
  - Foam model (E_f)

$$W = \frac{e_W}{E_f} = \frac{e - e_r}{E_f} = \frac{T_{B\,WS}^{TOA} - T_{Brmod}^{TOA}}{E_f A}$$

$$e_W \equiv W E_f = e - e_r$$

$$e = e_W + e_r = W E_f + (1 - W) E_r$$

Algorithm $W(T_B)$ versions

- ❑ Measure T_B
  - ❖ WindSat

- ❑ WindSat T_B data
- ❑ Versions/updates of GMF
- ❑ Input data for GMF

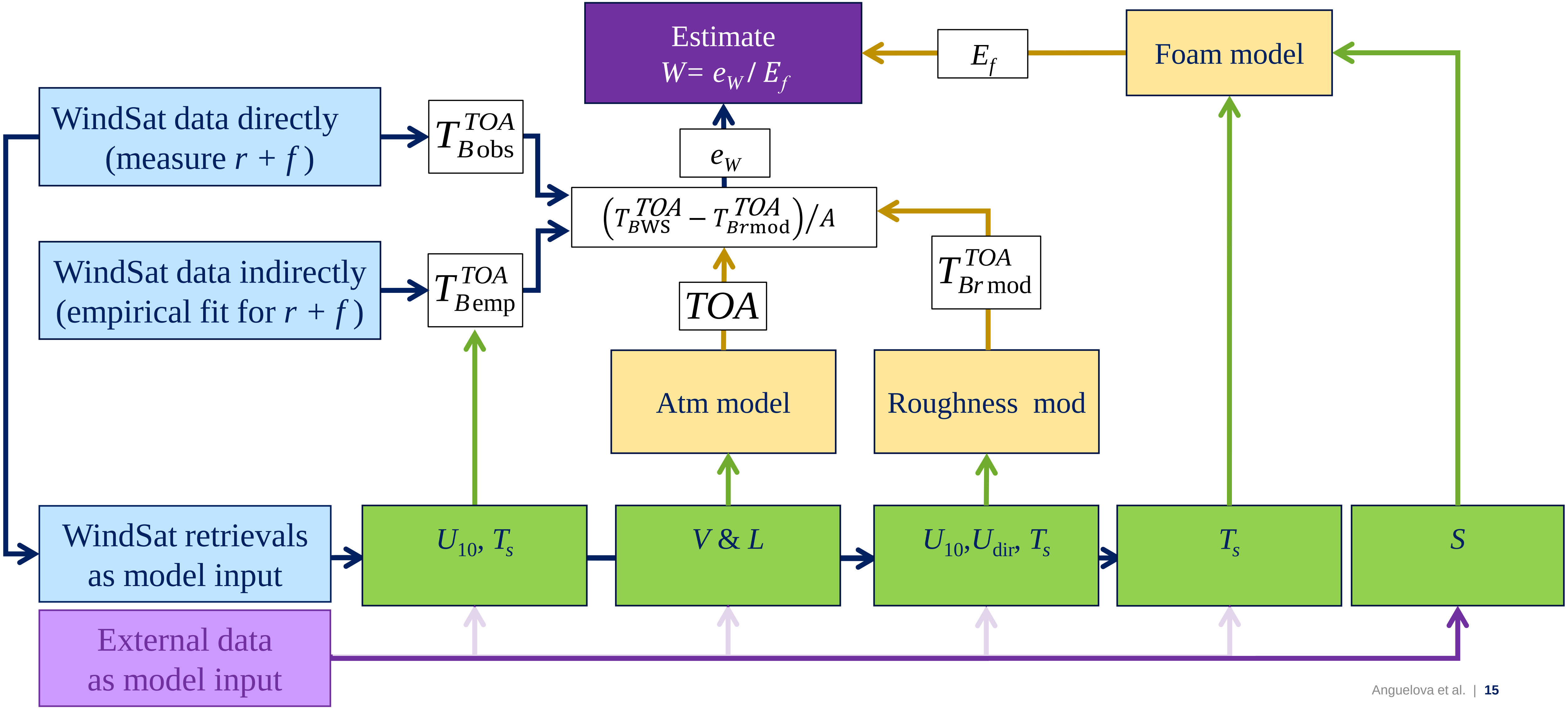
- ❑ Model T_B WindSat geophysical model (GMF)
  - ❖ Atmospheric model (t etc.)
  - ❖ Roughness model (e_r)
  - ❖ Foam model (E_f)

$$W = \frac{e_W}{E_f} = \frac{e - e_r}{E_f} = \frac{T_{BWS}^{TOA} - T_{Brmod}^{TOA}}{E_f A}$$

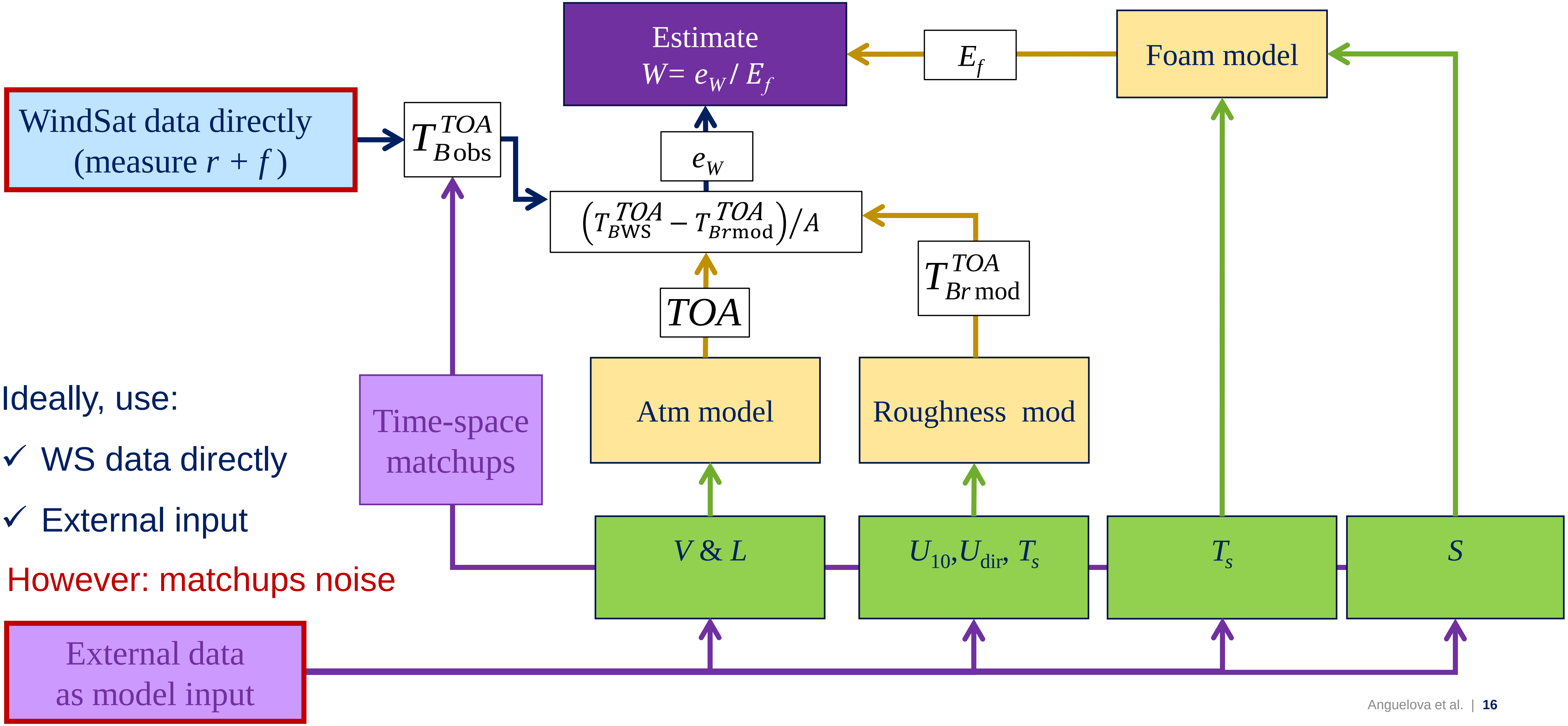
$$e_W \equiv WE_f = e - e_r$$

$$e = e_W + e_r = WE_f + (1 - W)E_r$$

Implementation approaches



Implementation ideally

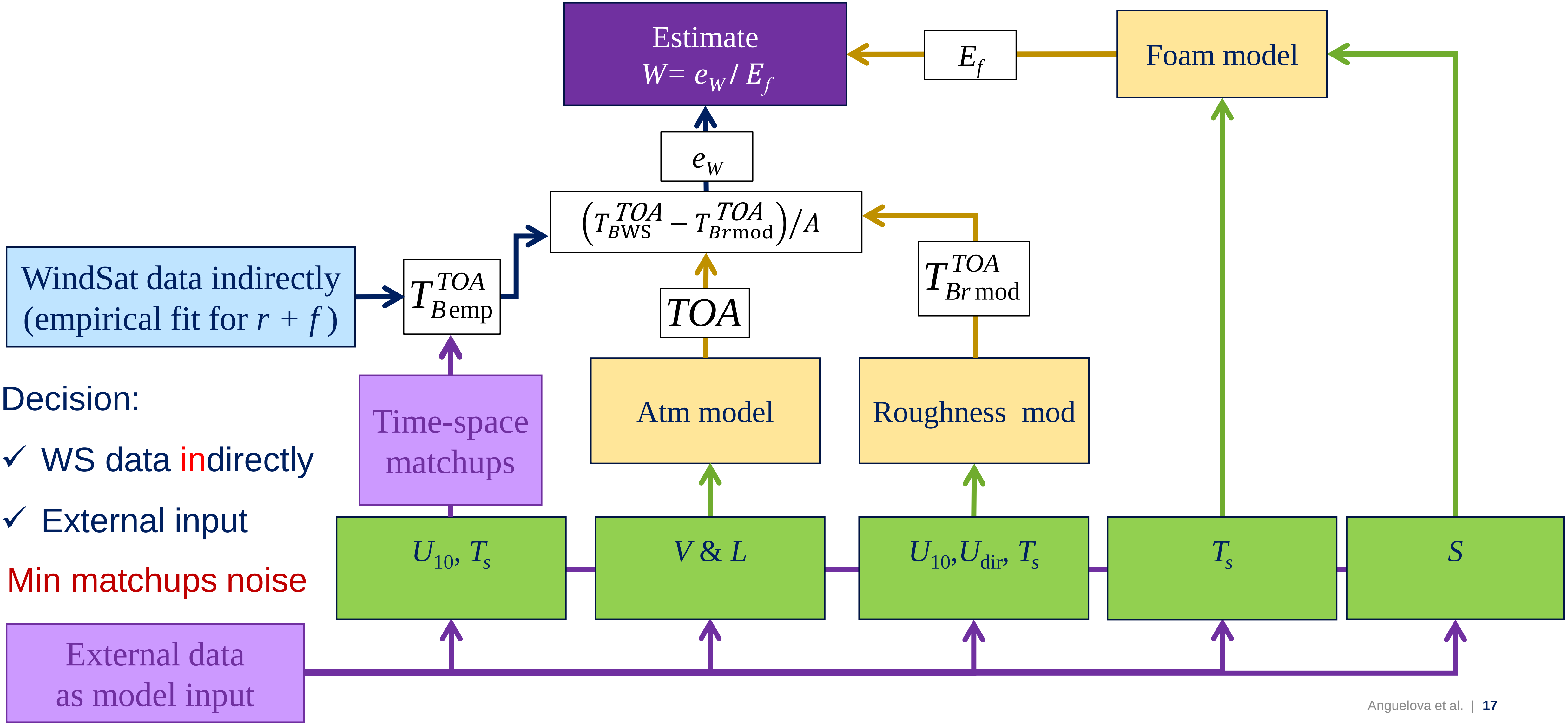


Ideally, use:

- ✓ WS data directly
- ✓ External input

However: matchups noise

Implementation used

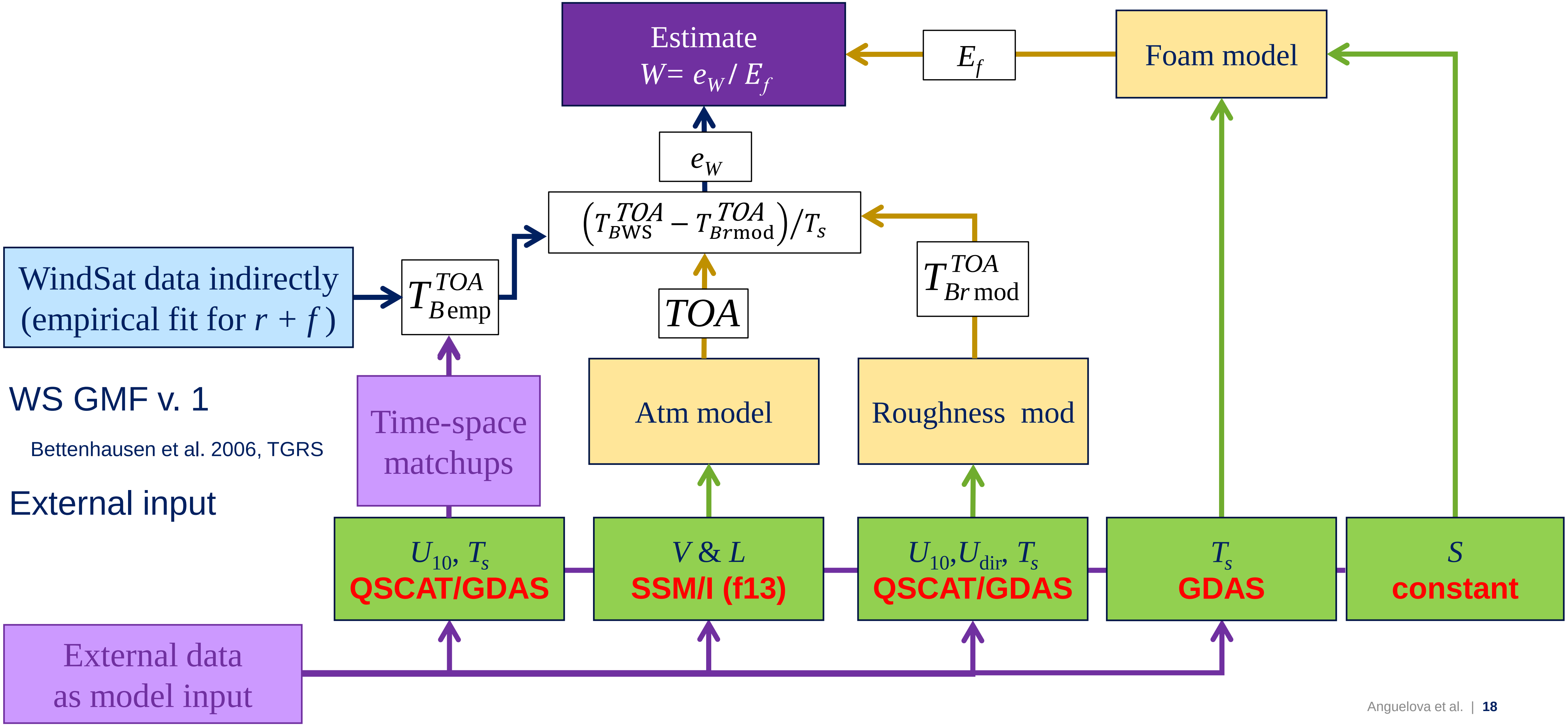


Decision:

- ✓ WS data indirectly
- ✓ External input

Min matchups noise

Algorithm $W(T_B)$ v. 1

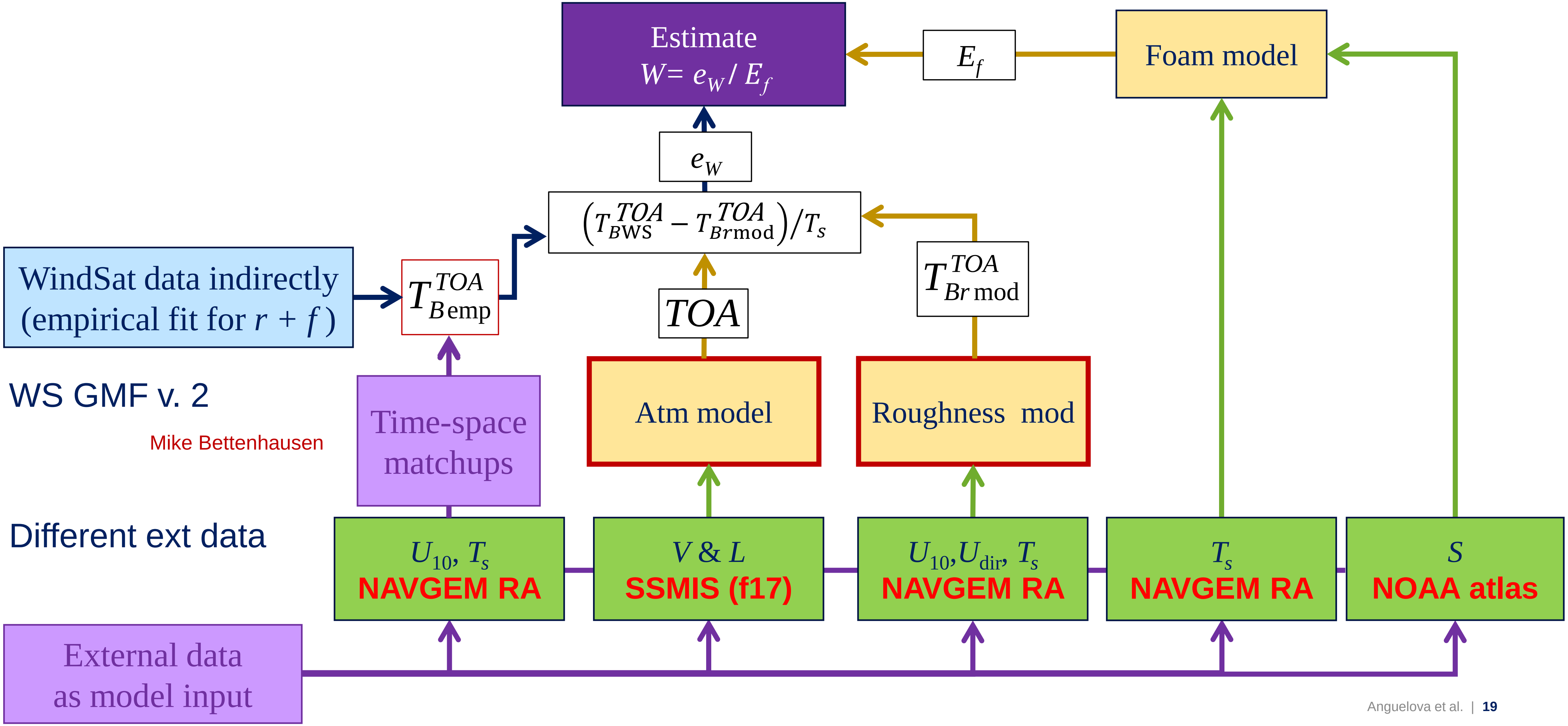


- ✓ WS GMF v. 1

  Bettenhausen et al. 2006, TGRS

- ✓ External input

Algorithm $W(T_B)$ v. 2

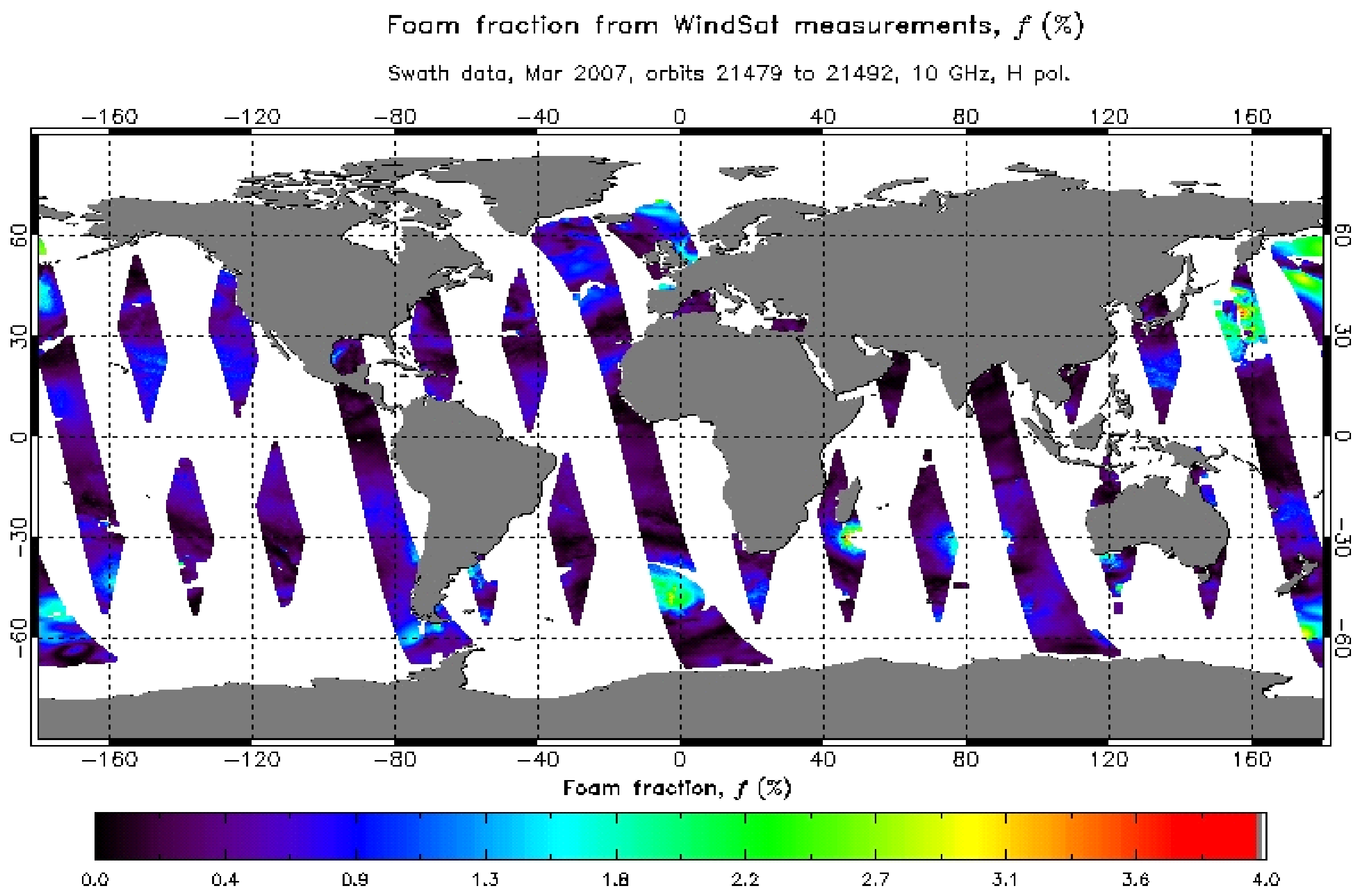


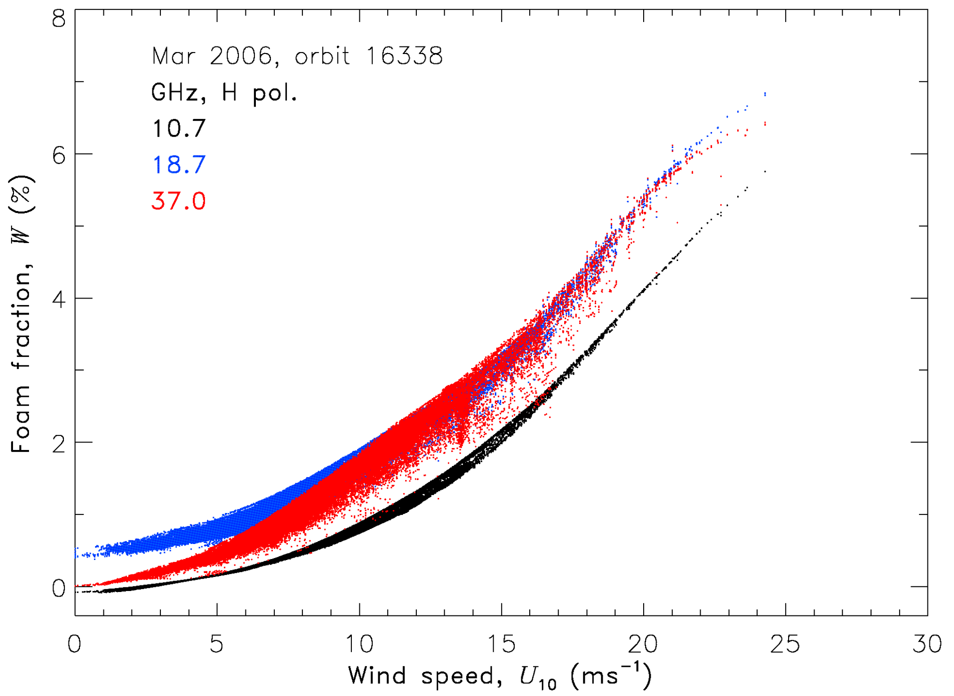
- ✓ WS GMF v. 2

Mike Bettenhausen

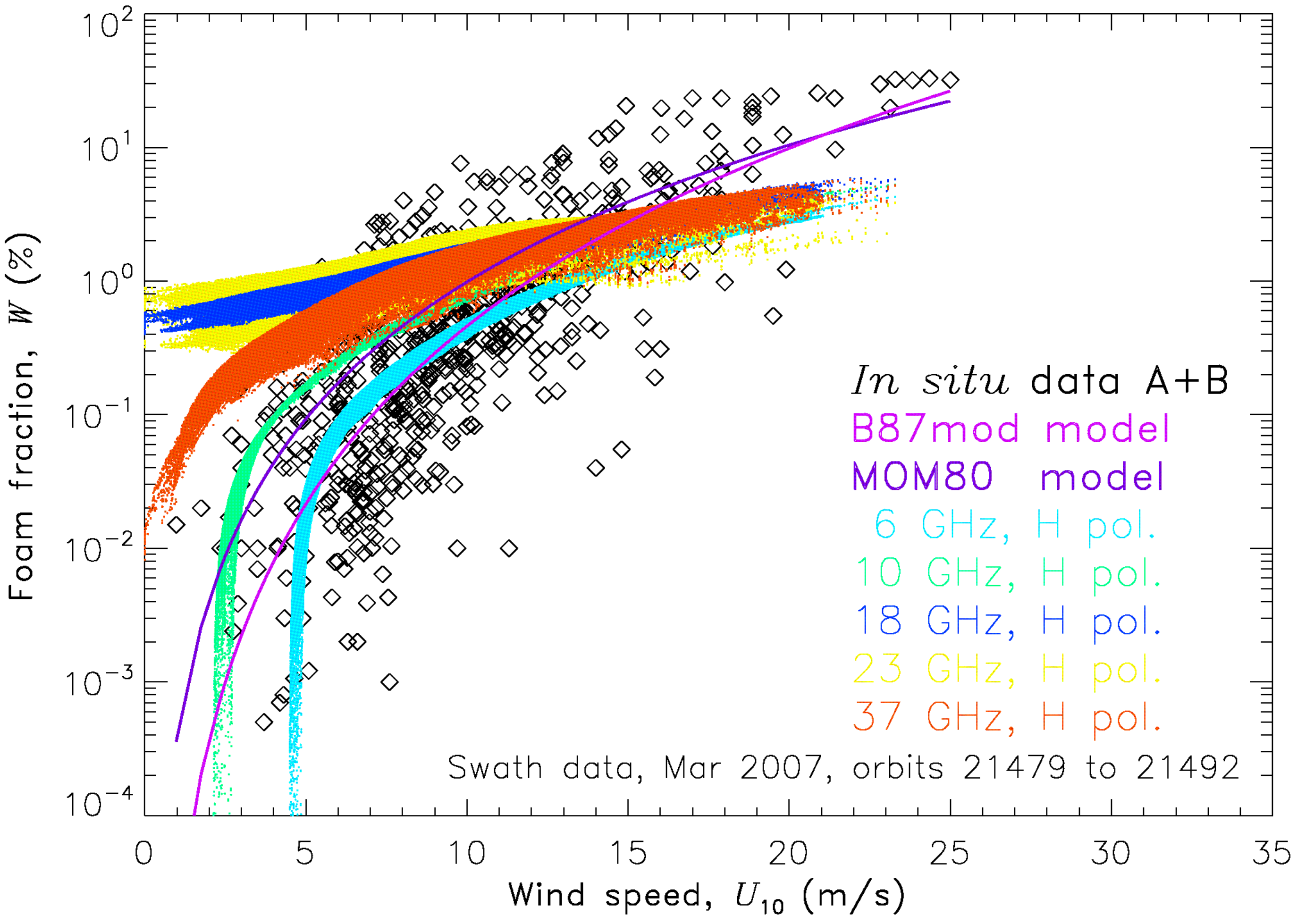
- ✓ Different ext data

Daily $W(T_B)$ data (v. 1)

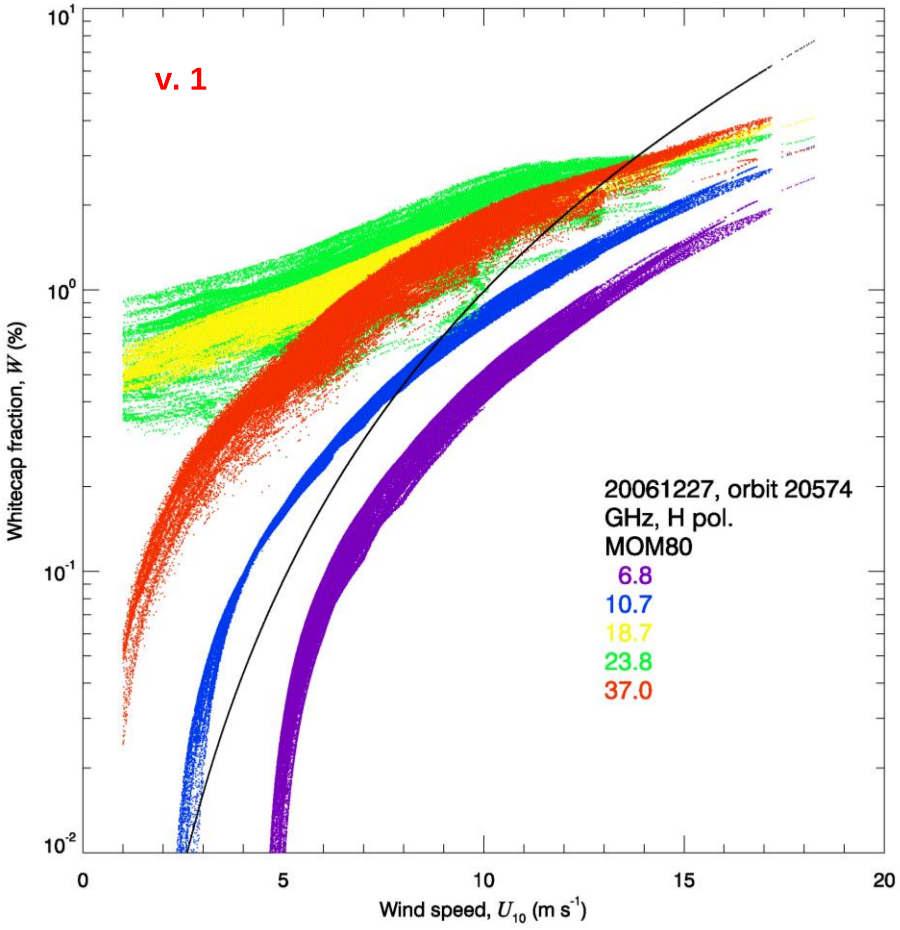


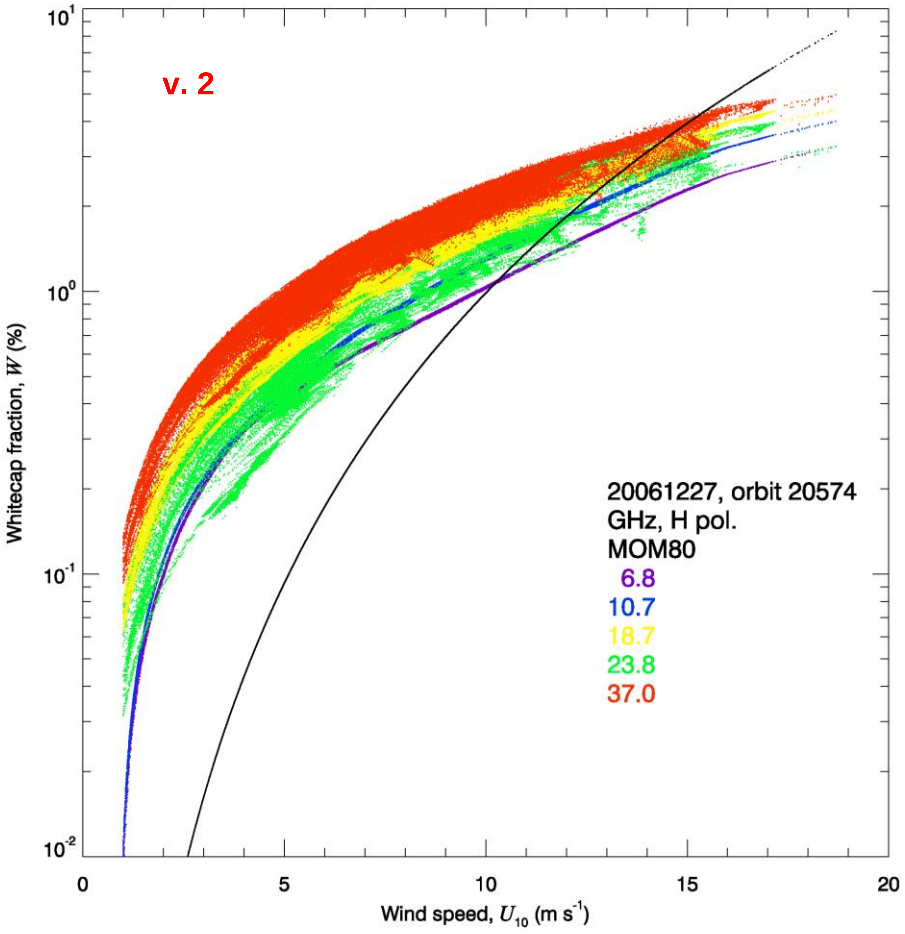


Compare to in situ data



Whitecap fraction from two versions





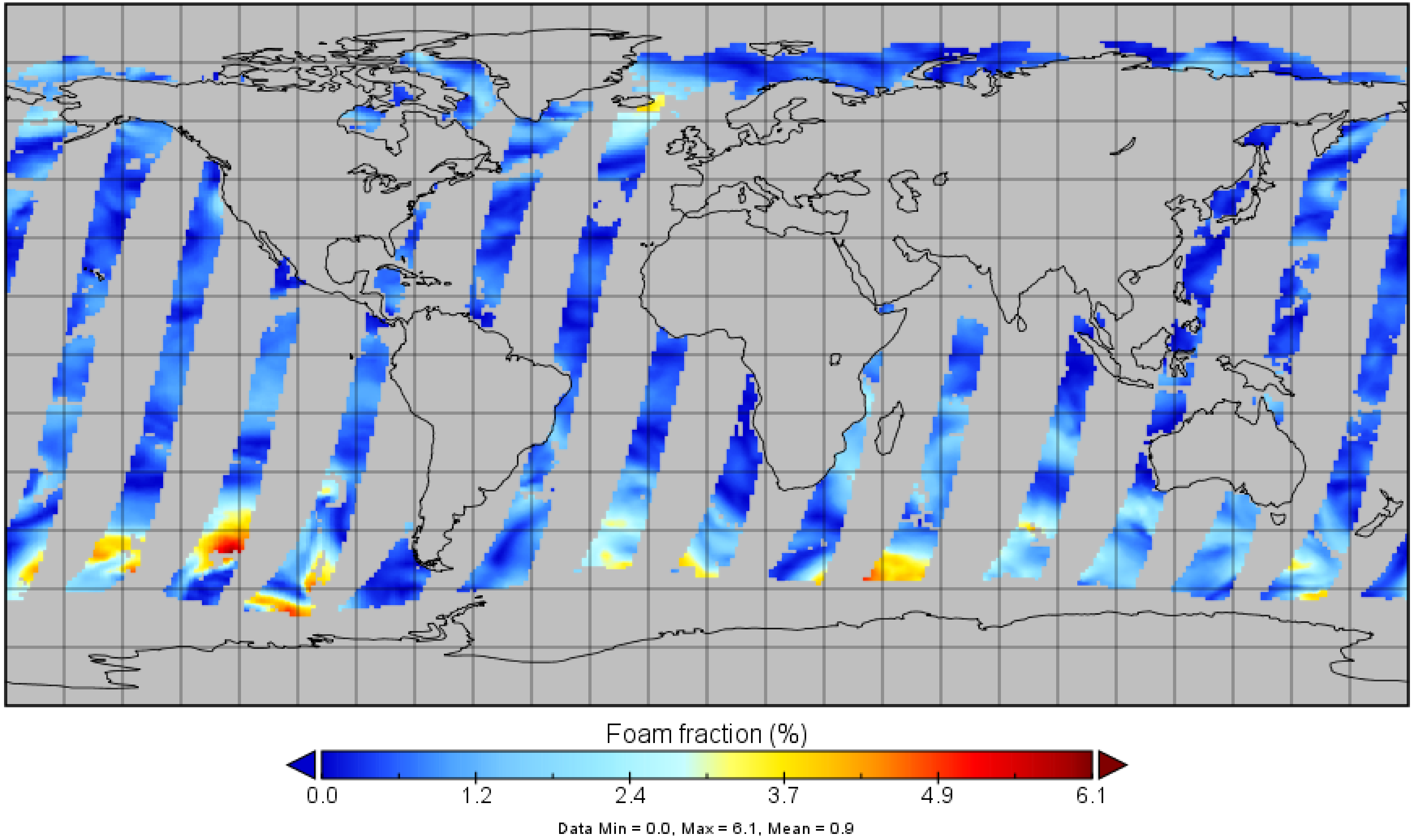
Updates *W* data, gridded

1 Sep 2014
10.7 GHz

Grid 1° x 1°

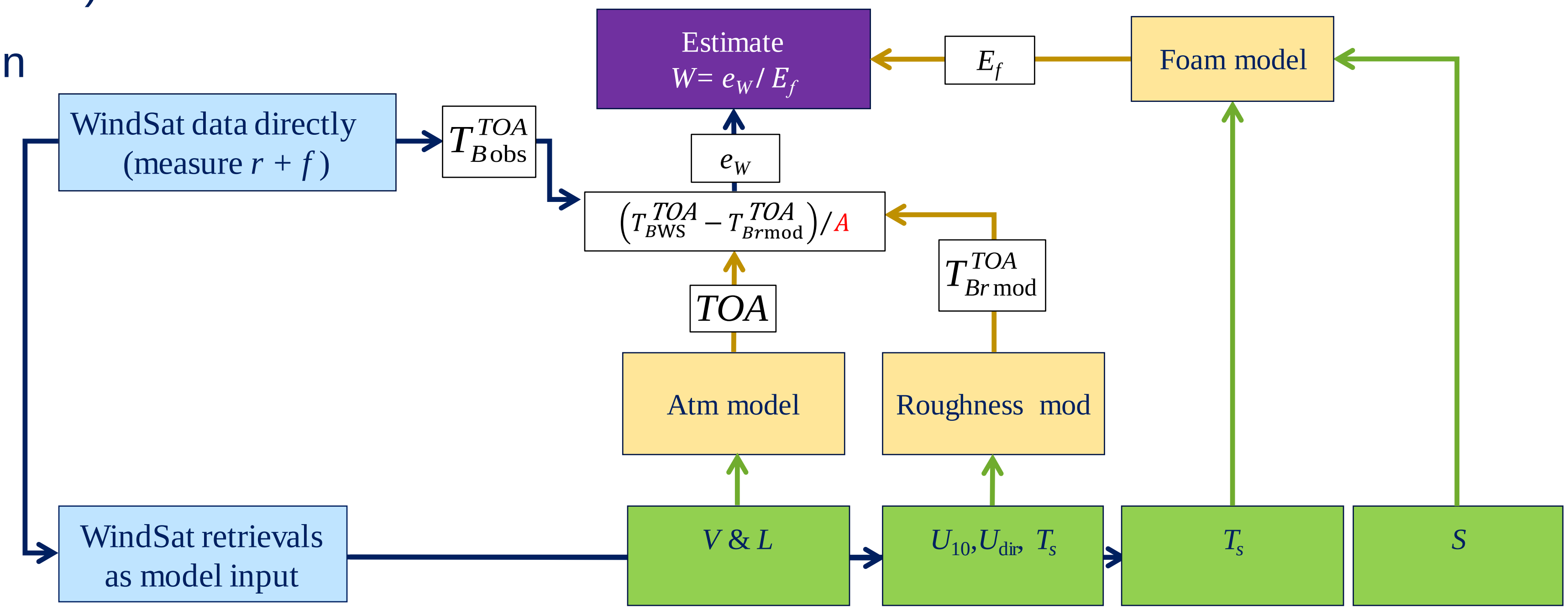
Full 2014
Daily maps
netCDF files

NAAPS (Navy aerosol model)



Future work on $W(T_B)$ algorithm

- Version with WindSat data as input for models
- Tune W by varying
  - Foam void fraction (upper limit)
  - Foam thickness distribution



Future work on $W(T_B)$ algorithm

- ❑ Version with WindSat data as input for models
- ❑ Tune *W* by varying
  - ❖ Foam void fraction (upper limit)
  - ❖ Foam thickness distribution

- ❑ Database with independent meteo data
- ❑ Parameterize effect of wave field

Thank you!