Y. Kerr, and the SMOS Team
The 4 phases of a project

• The concept
  – Expression of needs
  – Theoretical solution
  – Practical solution

• The selling
  – Proposal writing
  – Concept fine tuning
  – Get the approval and funding (i.e., … support, help appreciated)
  – Keep it alive…

• The making (help also appreciated)

• The use, demonstration of usefulness etc… (help will be appreciated)

• The next generation
Background

• Initiated more than 20 years ago
  – Water and energy budget/ water resources management in Western Africa
• After testing many approaches
  – Vis NIR
  – Thermal infra red
  – Thermal inertia
  – Scatterometer and radar
• To no avail
The solution?

- Passive microwaves at Low frequency
  - L Band
- Collaborations with E Njoku and T Schmugge, D. Le Vine and C. Ruf
  - interferometry
- And with radioastronomers and antenna specialists
  - 2D Interferometry
Walk through
Rationale

- Changing climate
- Extreme events (floods, droughts, storms…)
- Increase skills of weather forecasts
- Water management
- Adequacy of crops and cultural practices to forcings

⇒ requires better forecasting and decision making tools
- need for SSS and SM frequent and global fields
Why measuring Soil moisture?

*Scientific Objectives:* Improve our understanding of the land component of the global hydrologic cycle, of the spatial and temporal evolution of the water storage, and of the soil atmosphere interactions so as to improve global water resources management - globally.
Multi-Model Consensus of Regions Where Soil Moisture Impacts Seasonal Precipitation

Scientific objectives: to increase the knowledge on the ocean component of the global water cycle, large scale circulation, and ocean’s role on the climate system.
Science Objectives for SMOS: Salinity

Ocean salinity rationale

- Thermohaline overturning circulation.
  How can climate variations induce changes in the global ocean circulation?
- Air-sea freshwater budget.
  How are global precipitation, evaporation, and the cycling of water changing?
- Tropical ocean and climate feedback

Lagerloef et al., 2001
Ocean Salinity and Climate

Salinity links the climatic variations of the global water cycle and ocean circulation

- Salinity is required to determine seawater density, which in turn governs ocean circulation.
- Salinity variations are governed by freshwater fluxes due to precipitation, evaporation, runoff and the freezing and melting of ice.

Air-Sea Water Flux accounts for
- 86% of global evaporation
- 78% of global precipitation

Importance
- Climate prediction
- El Niño forecasts
- Global Water budget

From J. Font et al. 2007
Salinity and Ocean Circulation

The ocean conveyor is sustained by elevated salinity in the Atlantic

The Atlantic Thermohaline Circulation
- A key Element of the Global Oceanic Circulation -

Schematic diagram of the global ocean circulation pathways, the 'conveyor' belt (after W. Broecker, modified by E. Maier-Reimer).

From J Font et al 2007
Science Objectives for SMOS: The SMOS Mission

SMOS is the second Earth Explorer opportunity mission (1st round)
An ESA/CNES/CDTI project
Selected in 1999, initiated in 2000
Phase B finished, C/D Started in January 2004 for a launch in 2009
A new technique (2D interferometry) to provide global measurements from space of key variables (SSS and SM) for the first time.

Pellarin et al
Le Traon et al
HOW?

- Passive microwaves
- L Band
- Antenna size → Two concepts
  - Aquarius/SMAP
  - SMOS
Interferometry

- angular resolution provided by **distant** antennas
- correlation products \( s(1) \times s(2) \rightarrow \text{visibility functions } V(D/\lambda) \)
- Inverse F.T. on \( V \rightarrow T_B(\theta) \)

Space sampling requirement: **every** \( \lambda/2 \) **value at least one time**; hence "**thinning**" possibilities.
Each integration time, (2.4 s) a full scene is acquired (dual or full pol)
• Average resolution 43 km, global coverage
• A given point of the surface is thus seen with several angles
• Maximum time (equator) between two acquisitions 3 days
L1c DATA

Making full use of angular measurements
High temporal sampling
The satellite
<table>
<thead>
<tr>
<th>System Parameter</th>
<th>Specified Value</th>
<th>SAT-PDR (actual value)</th>
<th>SAT-QR (IVT and RACT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systematic Error</td>
<td>1.5 K RMS (0°)</td>
<td>Not Available</td>
<td>0.9 K RMS in alias-free FoV</td>
</tr>
<tr>
<td></td>
<td>2.5 K RMS (32°)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level-1 SM</td>
<td>3.5 K RMS (0°)</td>
<td>2.43 K RMS</td>
<td>2.23 K RMS</td>
</tr>
<tr>
<td>Radiometric</td>
<td>5.8 K RMS (32°)</td>
<td>3.98 K RMS</td>
<td>3.95 K RMS</td>
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<tr>
<td>Sensitivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(220 K)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level-1 OS</td>
<td>2.5 K RMS (0°)</td>
<td>1.99 K RMS</td>
<td>1.88 K RMS</td>
</tr>
<tr>
<td>Radiometric</td>
<td>4.1 K RMS (32°)</td>
<td>3.26 K RMS</td>
<td>3.32 K RMS</td>
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<tr>
<td>Sensitivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(150 K)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td>4.1 K RMS (&lt;32°) during 10 days inside EMC chamber</td>
<td>Not Available</td>
<td>4.03 K RMS</td>
</tr>
<tr>
<td>(1.2 s integration)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td>0.03 K</td>
<td>Not Available</td>
<td>&lt; 0.02 K</td>
</tr>
<tr>
<td>(long integration)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A few dates

• March 17 → GOCE launch
• November 2\textsuperscript{nd} SMOS launch
• November 18 SODAP
• Start of data flow a few days after (piecewise) → calibration tests
• First image December 6th
• Around mid December starting full data acquisition (1 week DP-1 week FP etc)
• Cal val Activities
• Early May 2010 end of commissioning phase, routine operations
Launch Campaign
Products
ESA products

• Level 1
  – 1b snapshots --> possible to make pixels
  – 1c angular signature
  – Browse (42.5 deg, SMAP?)

• Level 2
  – 2 SM, Tau
  – 2 SSS
  – 2 Tb
Or simulated data

Products – L1C
End to End
### Models and mixed pixels

#### Aggregated fractions $F_M$ and $F_M$

<table>
<thead>
<tr>
<th>FM0 class</th>
<th>Aggregated land cover</th>
<th>FM class</th>
<th>Complementarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>FNO</td>
<td>Vegetated soil + sand</td>
<td>FNO</td>
<td></td>
</tr>
<tr>
<td>FFO</td>
<td>Forest</td>
<td>FFO</td>
<td></td>
</tr>
<tr>
<td>FWL</td>
<td>Wetlands</td>
<td>FWL</td>
<td></td>
</tr>
<tr>
<td>FWP</td>
<td>Open fresh water</td>
<td>FWP</td>
<td></td>
</tr>
<tr>
<td>FWS</td>
<td>Open saline water</td>
<td>FWS</td>
<td></td>
</tr>
<tr>
<td>FWO</td>
<td>Open water</td>
<td>FOW</td>
<td></td>
</tr>
<tr>
<td>FEB</td>
<td>Barren</td>
<td>FEB</td>
<td></td>
</tr>
<tr>
<td>FTI</td>
<td>Total Ice fraction</td>
<td>FTI</td>
<td></td>
</tr>
<tr>
<td>FEI</td>
<td>Ice &amp; permanent snow</td>
<td>FEI</td>
<td></td>
</tr>
<tr>
<td>FSI</td>
<td>Sea Ice</td>
<td>FSI</td>
<td></td>
</tr>
<tr>
<td>FUL</td>
<td>Low urban coverage</td>
<td>FUL</td>
<td></td>
</tr>
<tr>
<td>FUM</td>
<td>Moderate urban coverage</td>
<td>FUM</td>
<td></td>
</tr>
<tr>
<td>FTS</td>
<td>Strong topography</td>
<td>FTS</td>
<td></td>
</tr>
<tr>
<td>FTM</td>
<td>Moderate topography</td>
<td>FTM</td>
<td></td>
</tr>
<tr>
<td>FRZ</td>
<td>Frost</td>
<td>FRZ</td>
<td>Compementary</td>
</tr>
<tr>
<td>FSN</td>
<td>Non permanent dry snow</td>
<td>FSN</td>
<td>Suplementary</td>
</tr>
<tr>
<td></td>
<td>Non permanent wet snow</td>
<td>FSN</td>
<td>Suplementary</td>
</tr>
<tr>
<td></td>
<td>Non permanent mixed snow</td>
<td>FSN</td>
<td>Suplementary</td>
</tr>
</tbody>
</table>

- **Complementarity:** Sum of complementary fractions equals unity.
- **Supplementary:** Supplementary fractions are super-imposed.

#### Set of models for each surface type
End to End

- Performances for Soil Moisture level2
Retrieval characteristics

• Over part of the pixel
• Pixel content taken into account
• Antenna gain taken into account
• « pseudo » dielectric constant
• Temporal aspects (vegetation contribution)

• Extensive Algorithm validation
• Comparison with existing satellite data
• Needs now actual data
Higher levels

- CNES products
- L3 SM and OS
  - Spatially aggregated SSS
  - Buoys assimilated SSS
  - Multiorbit inversion (both)
  - Event detection
- L4 SM
  - Disaggregation
  - Root zone soil moisture
  - Risks detection
  - Multi sensor approach
  - Coastal areas
- Facilities to test your own: snow, texture, sea ice..
Sites strategy

- Taklamakhan, Dome C, Ocean
- Danube and VAS
- Moisture Map – Australia
- Northern Europe Siberia
- Southern Europe (SW France, Salamanca), USA, Canada
- Western Africa (Mali Benin) South Africa…
- Other SM sites from ISMWG initiative?
Interpolating atmospheric forcing with “actual” varying surface characteristics
Soil moisture simulated with ISBA and LMEB: Comparison with in situ measurements

RMSE = 0.0240
R² = 0.9096
And comparison with satellite data

![Graph showing soil moisture and polarisation ratio over time]

- Normalised soil moisture AMSR-E (~2 cm)
- Normalised polarisation ratio 6.7 GHz AMSR-E
- Normalised soil moisture mean SURFEX (2 cm)
- LAI MODIS 2005

Date range: 1/1/2005 to 11/1/2005

Yhk—nov 09
ECMWF-GLASS Workshop
Reading November 9-12/2009
S Juglea et al
And comparison with satellite data
Next steps SM Algo

• Keep simulators and prototype up to date.
• Analyse commissioning rehearsal data: make use of ground campaign in Germany, Spain, Australia and France.
• Fully validate/correct during commissioning phase
• Feed back to level 1
• Inter-comparison exercises
• Start working on statistical approaches.
• Synergies ==> AMSR-SCAT, etc…
Issues

- RFI
- Variable water bodies
- Snow ice (partial)
- Water routing
- Algo improvements
- …
Next steps

• SMOS FO?
  – same as SMOS almost
  – But for 15 years (3 off)

• SMOS NEXT
  – Water resources management
  – All specs kept but for spatial resolution (10 times better)
  – Or sensitivity (100 times better)
  – Or any combination of the two
Conclusion

• First two phases are over
• Now we must validate
• Disseminated
• And do research with the data
• NOTE
  – SM and Vegetation opacity
  – Spatial resolution!

• In other words still loads to do!
Thank you for your attention
Any questions?

http://www.cesbio.ups-tlse.fr/us/indexsmos.html