24th EVGA Working Meeting 2019

Scheduling of twin telescopes and its impact on troposphere and UT1 estimation

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Axel Nothnagel[2],
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Jan-Henrik Haunert [2]

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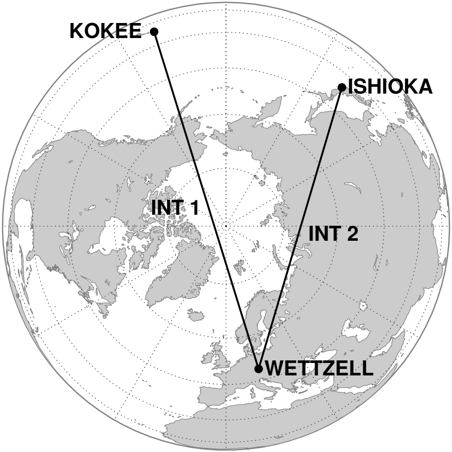
2) University of Bonn, Germany

CHALMERS
UNIVERSITY OF TECHNOLOGY

18 March 2019

Motivation



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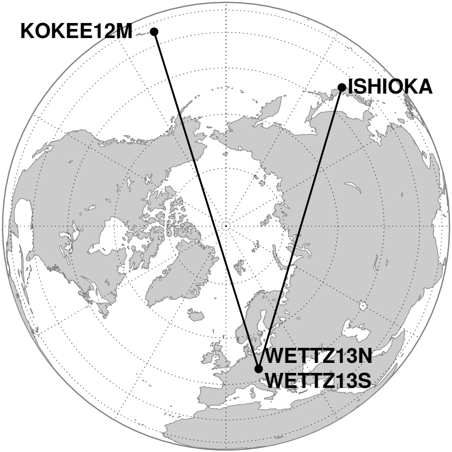

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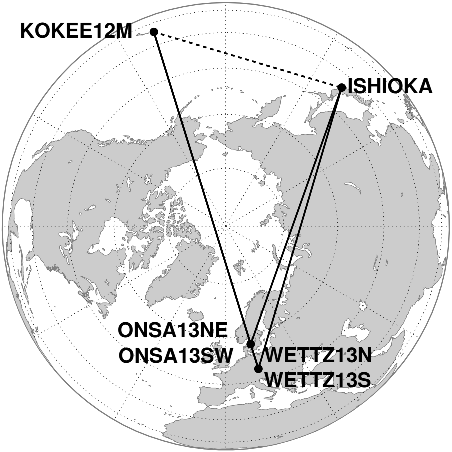
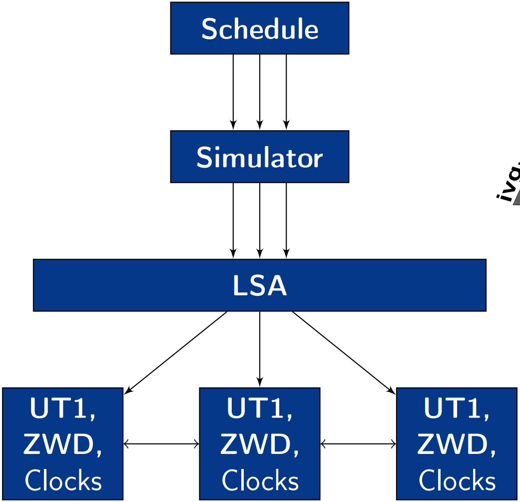


Overview



ivg::ASt

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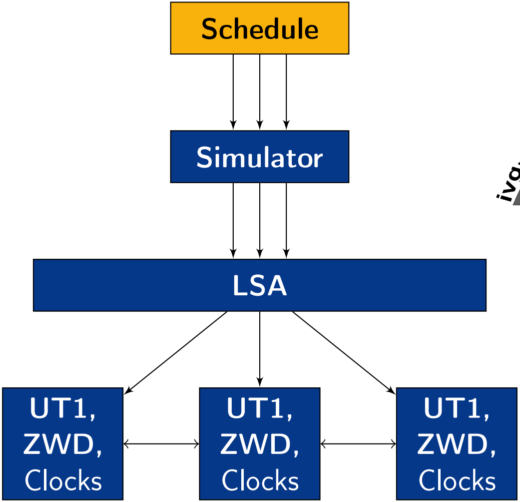
Schedule
Simulator
LSA
UT1, ZWD, Clocks
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Scheduling

Strategy

- regular observations: *one observation per minute*
- **optimal** sky coverage

Observations

- duration: 30 s
- minimum SNR: 20

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- 32 channels @ 32MHz
- 1-bit sampling

Twins

- twins never observe the same source together
- spherical distance $> 60^\circ$

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Integer Linear Programming

$$\max \Phi(\boldsymbol{x}) = \boldsymbol{a}^{\mathsf{T}}\boldsymbol{x}$$

subject to linear inequality constraints

$$\boldsymbol{C}\boldsymbol{x} \leq \boldsymbol{b}$$

with $\boldsymbol{x} \in \{0, 1\}$

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subject to linear inequality constraints

$$\boxed{\boldsymbol{C}\boldsymbol{x} \leq \boldsymbol{b}} \longleftarrow \begin{array}{c}\text{modelling}\\ \text{scheduling problem}\end{array}$$

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one baseline

$$\boxed{\boldsymbol{C}\boldsymbol{x} \leq \boldsymbol{b}} \longleftarrow \begin{array}{l} \boldsymbol{C} \in \mathbb{R}^{61409 \times 7089} \\ \boldsymbol{x} \in \{0,1\}^{7089} \\ \boldsymbol{b} \in \mathbb{R}^{61409} \end{array}$$

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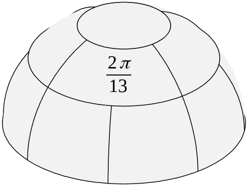
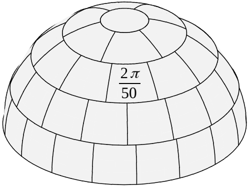
Sky Coverage Score

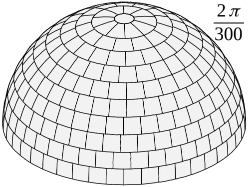
- **multiple partitions** of hemisphere into cells of **equal size** and similar shape
- evaluation period: 20 minutes
- period shift: 5 minutes



partition 1
(13 cells)



partition 2
(50 cells)



partition 3
(300 cells)

Sky Coverage Score

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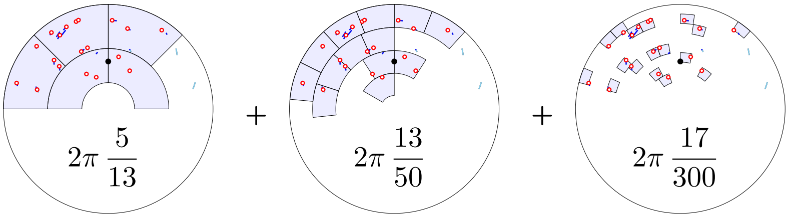
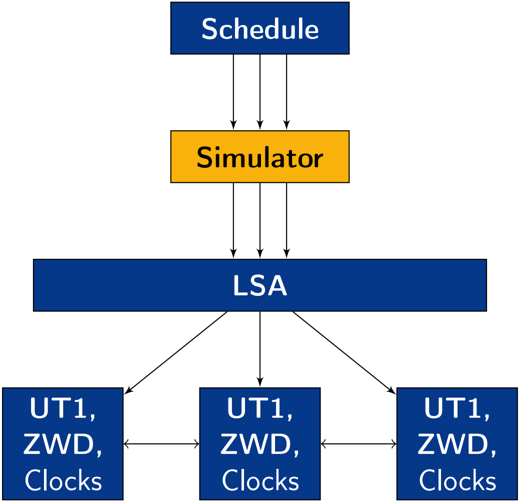


partition 1 (13 cells) | partition 2 (50 cells) | partition 3 (300 cells)

Simulation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Simulation

$$\tau_{\mathsf{sim}} = \tau_g + \mathsf{clock}_2 - \mathsf{clock}_1 + Mf(\epsilon_2) \cdot \mathsf{ZWD}_2 - Mf(\epsilon_1) \cdot \mathsf{ZWD}_1 + \mathsf{wn}$$

geometric delay

- IERS conventions
- ITRF2014, ICRF2
- polar motion and nutation: IERS C04
- UT1: BKG eopi

Simulation

$$\tau_{\text{sim}} = \tau_g + \underbrace{\text{clock}_2 - \text{clock}_1}_{\text{Allan std.: } 10^{-14} \text{ s @ 50 min}} + Mf(\epsilon_2) \cdot \text{ZWD}_2 - Mf(\epsilon_1) \cdot \text{ZWD}_1 + \text{wn}$$

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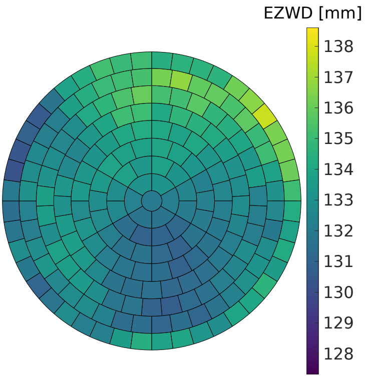
partitioning

- spatial: 209 cells of equal size
- temporal: 1 minute steps

turbulence model

- Nilsson & Haas (2010)
- Parameters: Petrachenko et al. (2009)
- inital ZWD = 450 ps / 135 mm
- VMF1
  - ▷



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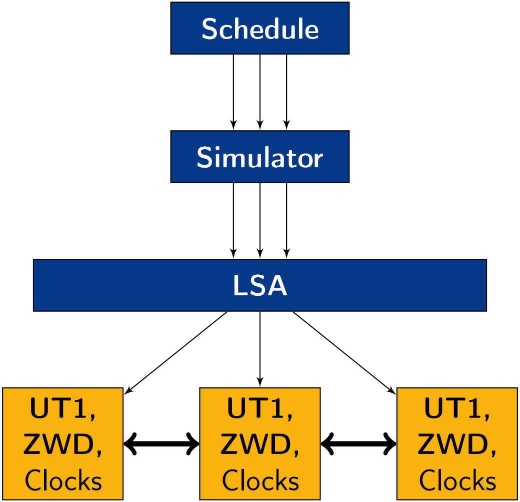
20 ps white noise

Results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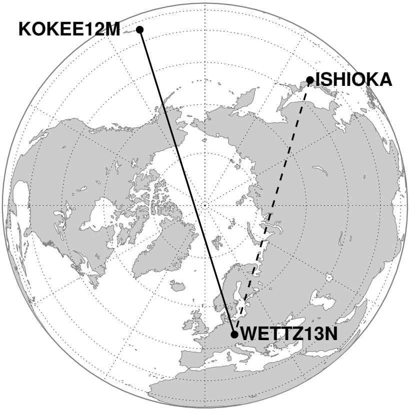
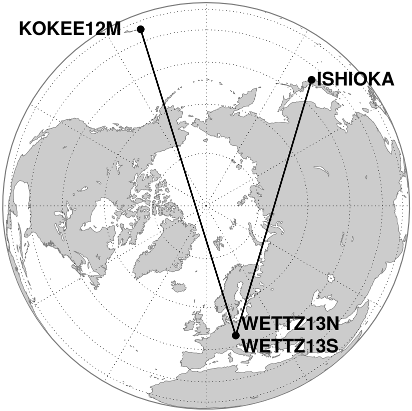
VGOS Intensive Network



name	station
0 twin	Wn Is (K2)
1 twin	Wn Ws Is K2
2 twin	Ow Oe Wn Ws Is K2

VGOS Intensive Network



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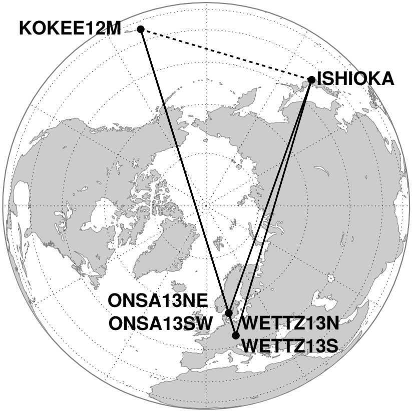

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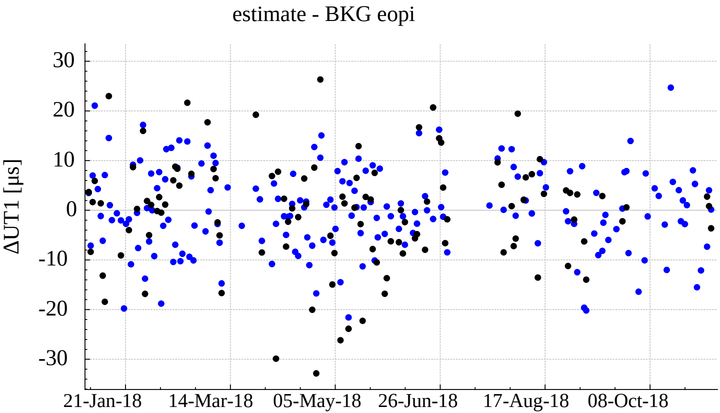
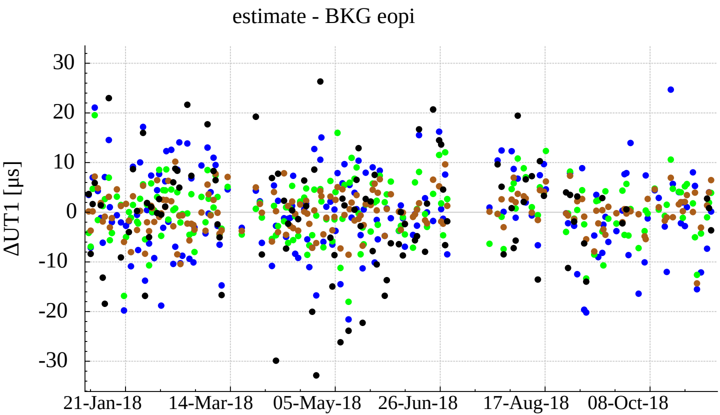
Simulation Results: UT1



solution	mean (μs)	WRMS(μs)
• original schedule (S/X)	-0.5	11
• 0 twins	0.1	8

Simulation Results: UT1



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• 0 twins	0.1	8
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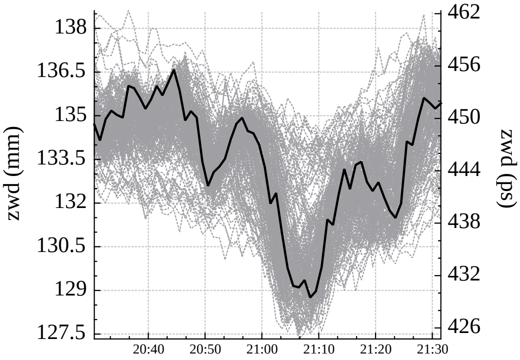
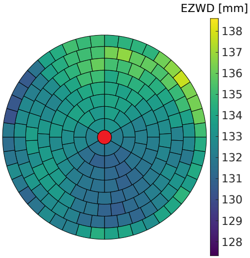
• 2 twins	0.2	4

Exemplary ZWD time series



– simulated (true) ZWD



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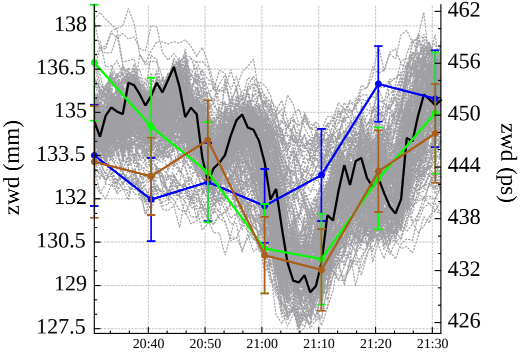

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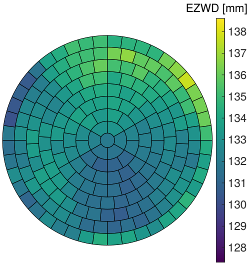

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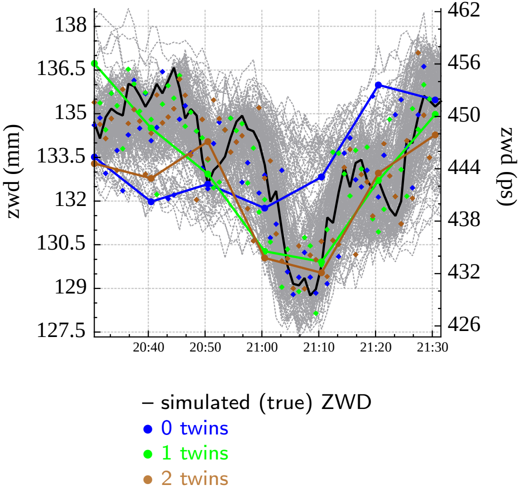

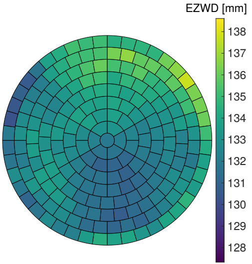

Simulation Results: ZWD

Average difference true - estimated ZWD (ps)

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<tr><td>Cn $\times 10^{-7}\mathrm{m}^{-\frac{1}{3}}$</td><td colspan="2">0.94</td><td>2.30</td><td>1.46</td><td colspan="2">0.72</td><td></td></tr>
</table>

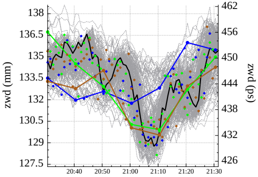
Conclusion

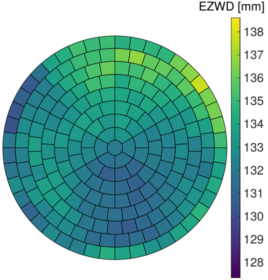
Twin Telescopes in intensive sessions

- twin stations improve UT1 estimations
  - more observations
  - more baselines with large east-west component
- ZWD only slightly improved
  - troposphere is not rotational symmetric
  - mapping functions can not model turbulence adequately

Thank you for your attention!

armin.corbin@chalmers.se





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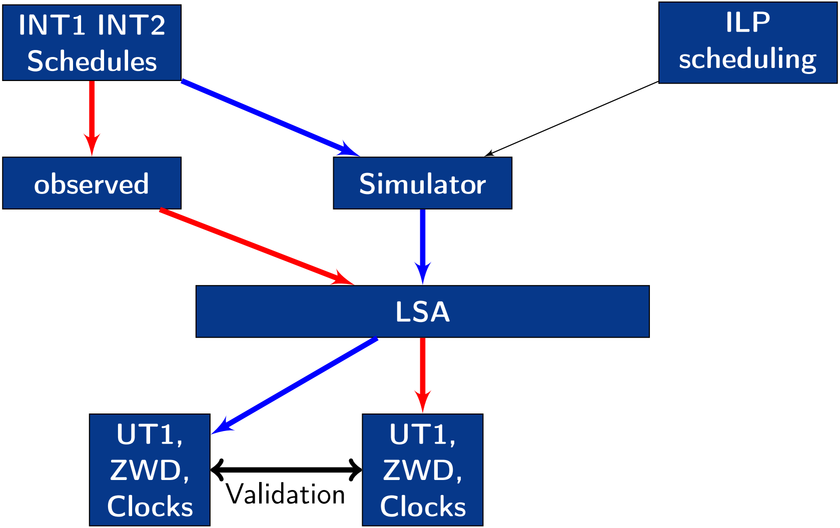
Rutman, J. (1978), 'Characterization of phase and frequency instabilities in precision frequency sources: Fifteen years of progress', *Proceedings of the IEEE* **66**(9), 1048–1075.

Validation of Simulation



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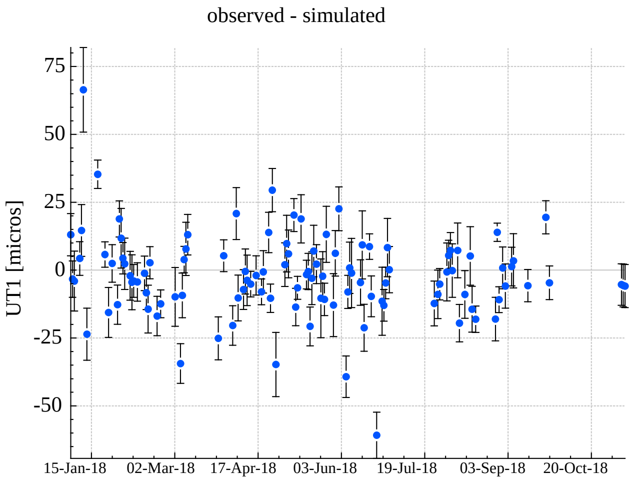
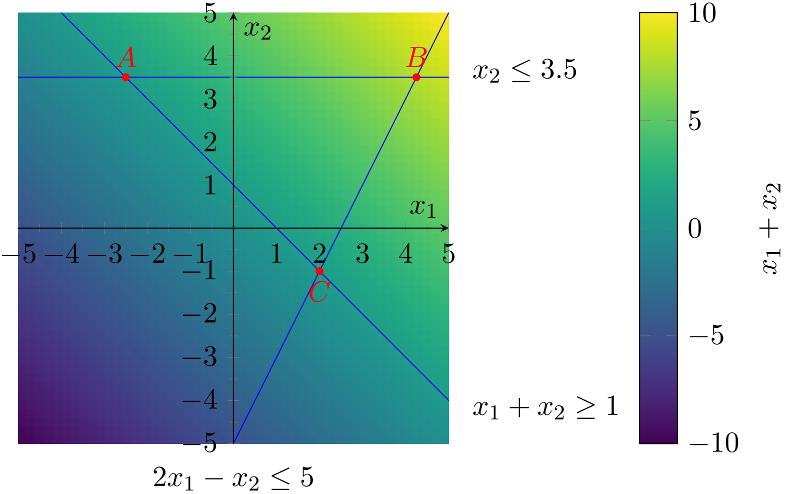


WRMS 14 μs Median: -3 μs

ILP 2D-Example



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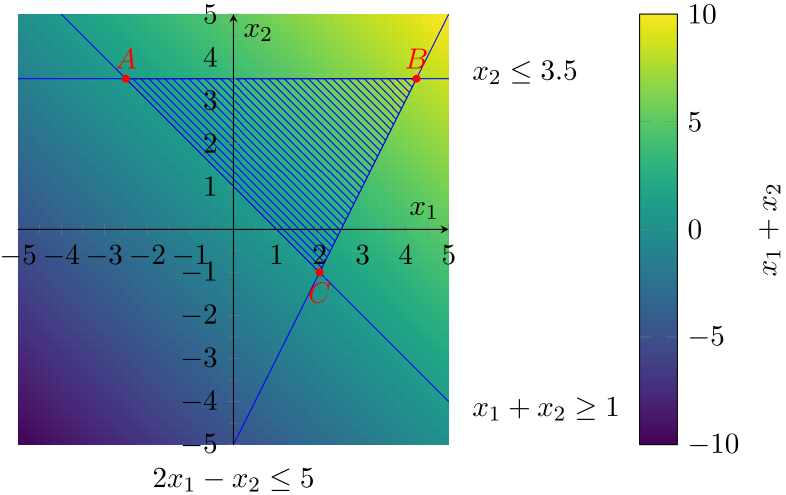

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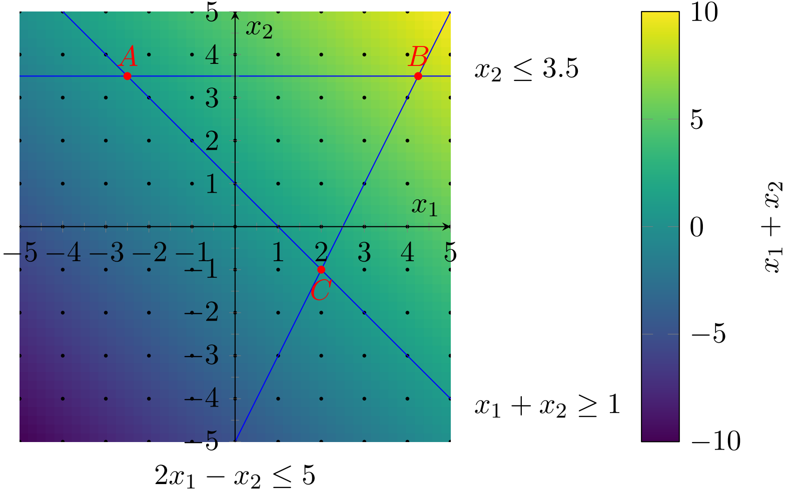
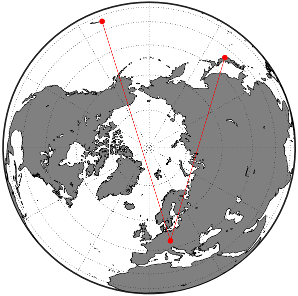
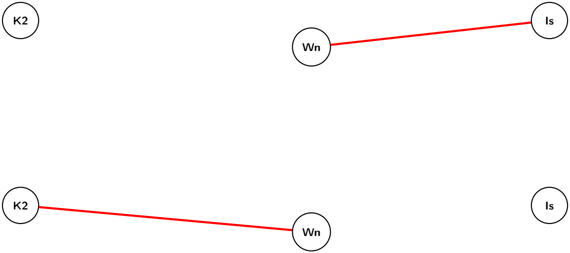


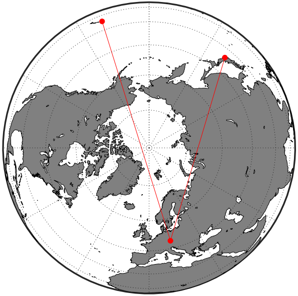
Detail Networks

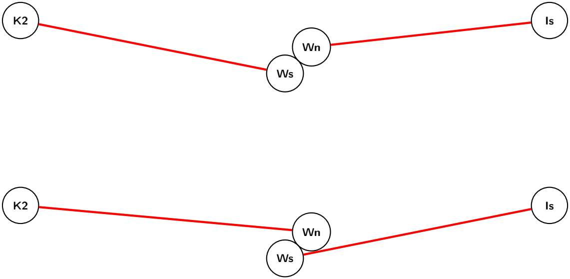
0 twins





Detail Networks
1 twins





Detail Networks
2 twins